The use of orthophotomaps to verify the network of agricultural transport roads in the land consolidation project

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Key words: road network, land consolidation, cadastral plot, orthophotomap, Poland.

SUMMARY

The number of cadastral plots is systematically growing in Poland. Currently, there are about 37.36 million. Over the past 12 years, the number of cadastral parcels has increased by over 3 million. In addition, the fragmentation in south-eastern Poland worsens the condition of the spatial structure. Comprehensive land consolidation works are improving this structure. Unfortunately, land consolidation is not performed on an appropriate scale. Only 18% of the country's territory was consolidated in Poland. In order to increase the number of land consolidations, EU co-financing was introduced - RDP, which allows to finance the consolidation process and land management after consolidation. EUR 2,000/1 ha of merged land was allocated for land management after consolidation. RDP funds are allocated to the agricultural transport routes designed in the integration project or modernized within the integrated area. Each newly separated cadastral parcel must have access to a public road. Therefore, based on the land and building register map (EGIB), we design the network of agricultural transport roads in the consolidation project. The EGIB map of the merged precinct does not always reflect the actual state of land use. Research shows [Balawejder et al. 2018] that there are actually more agricultural transport roads than in the EGIB base.

Therefore, the aim of this research is to use the current orthophotomap to verify the network of agricultural transport roads in the land consolidation project. The orthophotomap available at www.geoportal.gov.pl can be used by downloading raster files or via the WMS service. The above data sets are open archives containing image data for the entire territory of Poland, in different spatial resolution and from different dates. The scope of the research covered rural areas in the Podkarpackie Province, where land consolidation was carried out.

Based on the orthophotomap and the EGIB map superimposed on it, the density of the road network in the structure (before consolidation) G_1 and G_2 (after consolidation) was calculated. Based on the density of the road network in the G_1 facility and the density of the road network in the G_2 facility, the percentage index of the road network density in the W_4 merged area was calculated. The following results were obtained. Overall, the density of the agricultural transport road network has increased. Before consolidation, the road network density was 5.13 km/100 ha GR. After consolidation, the road network density was 6.01 km/100 ha GR. On the other hand, the road network index (W_4) in the examined objects is + 14.7%.

The use of an orthophotomap to verify the network of agricultural transport roads in the land consolidation project contributed to the achievement of a number of benefits. Agricultural transport routes have been located and designed to secure the access of each cadastral plot to a public road. Thanks to an otophotomap and a small study in the office (a study of existing and

planned roads and a study of plots without access), the time and costs of the study were reduced. There is no longer a need for a field survey of geodesists to assess the actual state of the agricultural transport road network for the land consolidation project, it can be done in the office using the current orthophotomap.

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1. INTRODUCTION

Almost 100 years of development of land consolidation that took place in Poland shows the multi-criteria nature of this procedure. EU funding helps to improve, among others the area structure of agricultural land in the European Union (EU) countries [Pawlikowska et al., 2017; Bieda, et al., 2014]. Agricultural area in the EU countries covers most of the land of the whole country [Klimach et al., 2020].

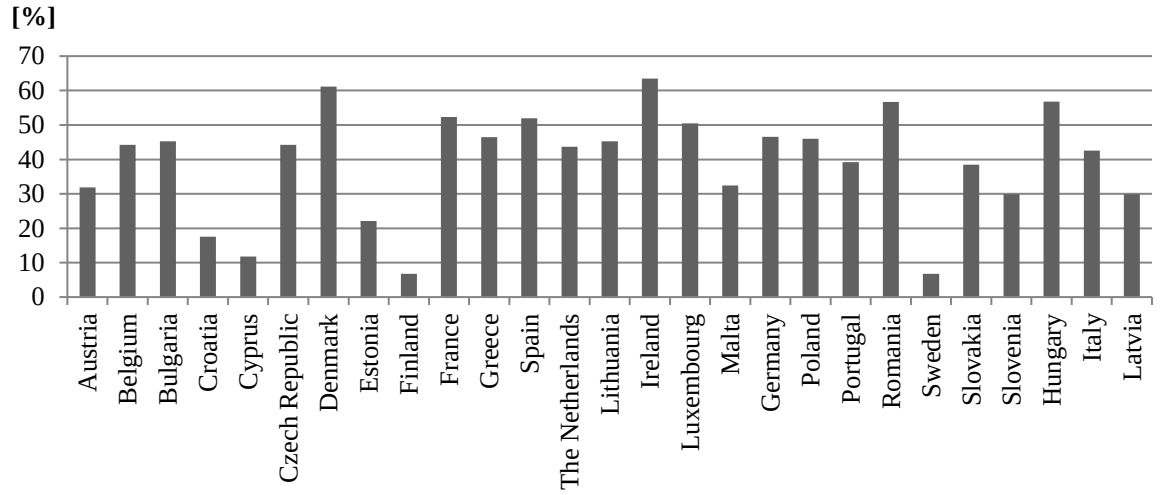

Fig. 1. Agricultural areas in individual EU countries.
Source: [Balawejder et al., 2021] based on data from FAO Estimate, 2016, [http://www.fao.org/countryprofiles/index/en/?lang=en&iso3=POL, date: 20.02.2021].

Figure 1 shows the agricultural area in individual EU countries. The agricultural area is the area that may be included in land consolidation works. Poland takes 9th place out of 27 EU member states, where 1st place is the largest percentage of agricultural area in relation to the country's area. Additionally, the very large fragmentation of the agricultural area in Poland makes us one of the leading countries that urgently need land consolidation [Stręk & Noga, 2019; Janus & Taszakowski, 2018; Noga et al., 2017; Balawejder & Leń, 2016]. The problem of excessive fragmentation of land concerns, among others: Bulgaria [Di Falco et al., 2010; Moteva, 2020], Cyprus [Demetriou, 2018], Czech Republic [Sklenicka, 2016], Estonia [Jürgenson, 2016], Finland [Vitikainen, 2014], Hungary [Cegielska et al., 2018], Latvia [Jankava et al., 2014], Lithuania [Pašakarnis & Maliene, 2010], Slovakia [Muchová & Petrovic, 2019], Spain [Crecente et al., 2002], The Netherlands [Louwsma et al., 2020; Stańczuk-Gałwiaczek et al., 2018].

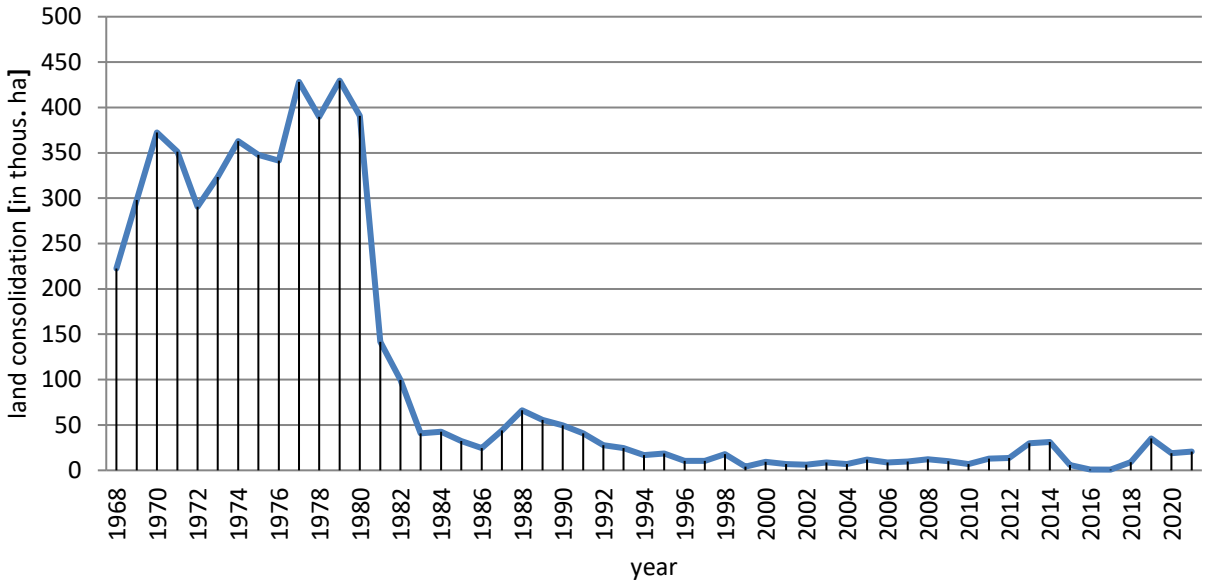

Fig. 2. Scope of land consolidation in Poland in 1968–2021.
Source: own research based on data from Ministry of Agriculture and Rural Development.

Since 1968, only 5,592,126 ha in Poland has been consolidated in Poland, which is 17.9% of the administrative area of Poland. As shown in Figure 2, most land consolidation was carried out in the 1970s. Later, the area of land consolidation decreased and increased slightly in the years 2013–2014 at the end of the RDP 2007–2013 program and in 2019, the RDP 2014–2020 program. According to Woch et al. [2018], the demand for consolidation works is very high. The greatest demand for over 50% of the area of communes occurs in south-eastern Poland [Basista & Balawejder, 2020; Basista, 2020], including in the Podkarpackie voivodeship [Balawejder & Noga, 2016].
In Poland, since 2008, the number of cadastral plots has been systematically increasing, which is illustrated in Figure 3. Based on the statistics collected at the Central Office of Geodesy and Cartography (GUGiK), a systematic increase in the number of cadastral plots can be observed in Poland. Over the past 12 years, the number of cadastral plots has increased by over 3 million. The number of cadastral plots is systematically increasing as a result of dividing real estate mainly related to the development of construction and road infrastructure in Poland, therefore the fragmentation of land in Poland is systematically growing. We can eliminate the fragmentation of land by comprehensive land consolidation. The areas with the highest fragmentation index are south-eastern Poland.

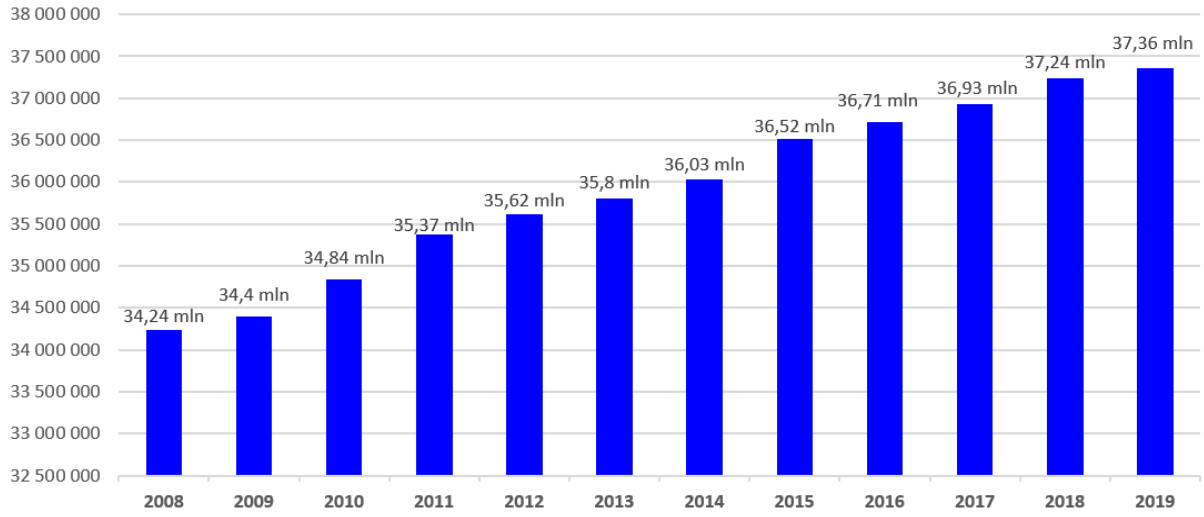

Fig. 3. Number of cadastral plots in Poland.
Source: GUGiK.

2. SPECIFIC STUDIES DATA ANALYSIS

Detailed research covered the areas of the Podkarpackie voivodeship, which are located in the south-eastern part of Poland. As shown in Table 1, in the Podkarpackie voivodeship, agricultural land that may be subject to consolidation covers 54.4% of the area of the Podkarpackie voivodeship. If we analyze the potential participants of consolidation, the land of natural persons in the Podkarpackie voivodeship covers 55.2% of the land area of the entire voivodeship.

Table 1. Summary for Poland with the division into the voivodeships discussed.

	Surface		Agricultural land		Private land		Population
Research area	ha	%	ha	%	ha	%	inhabitants/km^2
Podkarpackie voivodeship	1,784,576	5.7	971,434	54.4	984,509	55.2	119
Poland	31,270,627	100.0	19,177,780	100.0	18,181,348	100.0	123

Source: own research based on data from the EGiB.

The road analysis in the area of the Podkarpackie voivodeship was made on the basis of database records of land and buildings register from the Starost's Office (ODGIK) and on the basis of orthophotomap and aerial laser scanning data, made available by the Central Geodetic and Cartographic Documentation Center (CODGIK).

3.1 Land and buildings register

Geodetic and cartographic law defines land and buildings register (real estate cadastre) as an information system ensuring the collection, updating and land information sharing, to be interpreted uniformly (in terms of location, boundaries, area, and land type), also referring to

buildings and premises, their owners and other entities in possession of land, having right to its managing [Act 1989]. Creating, maintaining and sharing a database of these records for the district area in accordance with this Act is the task of the Starost's. In this study, a vectorised map was used for the land and buildings analysis, as well as a registration plot database together with land contours records.

3.2 Orthophotomap

An orthophotomap is a raster, cartometric area image, created as a result of orthogonal aerial photographs or satellite scenes processing. The orthophotomap is the result of differential rectification, during which the distortions resulting from the photograph inclination and terrain denivelation are removed [www.geoportal.gov.pl]. It is generated in the desired scale. Creating, maintaining and sharing an orthophotomap data in accordance with the Geodetic and Cartographic Law Act [Act 1989] belongs to the duties of Chief Surveyor of the Country. These resources are collected at the central, geodetic and cartographic resources level. In accordance with the Regulation on aerial and satellite imagery database and the orthophotomap and digital terrain model [Regulation 2020], such base is a collection covering orthophotomap data resulted from combining images together with metadata describing orthophotomap datasets. The orthophotomaps stored in GUGiK are made in the PL-1992 or PL-2000 rectangular coordinate system, in real colours (RGB) or false colors with the near infrared (CIR) channel. Continuous sensor development reduces the orthophotomaps' GSD (Ground Sampling Distance). The orthophotomaps collected in GUGiK have a different GSD: 0.25 m, 0.10 m, 0.05-0.07 m and under 0.05 m (the smallest GSD is 0.03 m). Most of them are from last 3 intervals, so equal or better than 0.10m. Orthophotomap data from GUGiK can be browsed using WMS (Web Map Service) and WMTS (Web Map Tile Service) in one of two services. Standard orthophotomap with GSD 0.25 m or high-resolution orthophotomap with GSD 0.10 m. Keeping the data up-to-date is very important. Plan of the GUGiK is to collect whole aea of Poland at least every 3 years. The coverage of the Poland in the context of year of acquisition is showed on the Fig. 4. Whole country have data sets from 2018 or earlier. Parts from 2019 are in yellow colour, from 2020 in blue and in green from 2021.

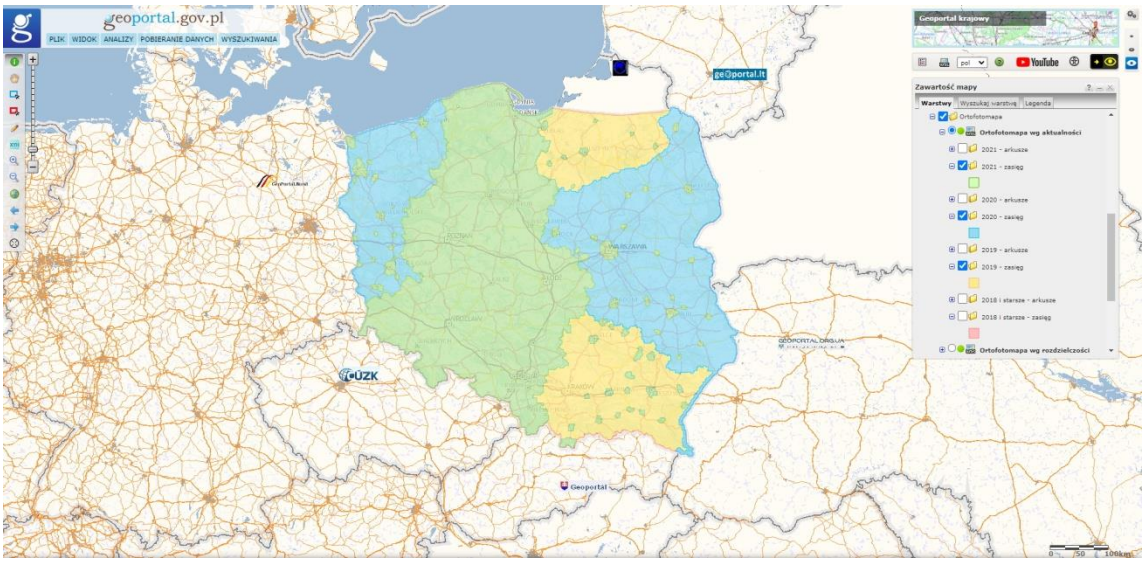

Fig. 4. Orthophotomap colour by years: 2019 - yellow, 2020 – blue; 2021 - green. *Source:* [www.geoportal.gov.pl].

3. ROAD INFRASTRUCTURE IN THE LAND CONSOLIDATION PROJECT

Each newly separated cadastral plot must have access to a road [Ustawa 1997]. Consequently, the road infrastructure in a land consolidation project is extremely important. A public road under the Act [Act 1985] can be called a road included under one of the road categories specified, which may be used by everyone, according to its purpose, with limitations and exceptions specified in the Act or other special regulations [Act 1985]. Public roads, due to their functions in the road network, are divided into categories:

- national roads - A (highway), S (expressway)
- voivodeship roads,
- district roads,
- communal roads.

On the other hand, private roads are divided into:

- internal roads,
- easement roads.

On the other hand, agricultural transport roads in the modernization or construction of new roads in the land consolidation project should take into account the sequence consistent with the functional class:

- main roads,
- collecting roads,
- auxiliary roads.

For the purposes of analysis, the collected information and materials regarding the road infrastructure in the assumptions for the land consolidation project should be presented in the form of tables and in a descriptive and graphic form as:

- Study of existing and planned roads,
- Study of plots without access.

The number of cadastral plots without access should also be provided, with the separation of forest plots and wooded plots. The following data is required for the analysis:

- Area of agricultural land in [ha],
- Length of agricultural transport roads in [km] in the research facility before and after consolidation,
- The length of agricultural transport roads per 100 ha of agricultural land in [km / 100 ha],
- Share of agricultural transport roads in communal roads in [%].

As shown by the research [Balawejder et al. 2018; Balawejder, Wójciak 2017] the land and building register database does not always reflect the actual state of use on the land. Therefore, there is a need to use an orthophotomap to verify the real state. In this way, we obtain the length of agricultural transport roads in kilometers in the research facility before land consolidation. On the basis of the data from the land and building records and the data determined on the orthophotomap, in many cases discrepancies were detected in the objects in question. Which were removed with these databases available for comparison. With the actual data at hand, the road network density index in the area of consolidation was successively calculated, successively calculating:

1. Based on the length of roads and the area of agricultural land in the facility before land consolidation, the density of the road network in the G_1 facility was calculated (1):
   G_1 =length A_[km]/100* GR_[ha] (1)
   where:
   – length A – road length measured in kilometers in the research facility before land consolidation;
   – GR – area of agricultural land in [ha].
2. Based on the length of roads and the area of agricultural land in the facility after land consolidation, the density of the road network in the G_2 facility was calculated (2):
   G_2 =length. B_[km]/100* GR_[ha] (2)
   where:
   – length B – road length measured in kilometers in the research facility after land consolidation;
   – GR – area of agricultural land in [ha].
3. Based on the density of the road network in the G_1 facility and the density of the road network in the G_2 facility, the percentage index of the road network density in the area of land consolidation W_4 was calculated:
   $W_4 = (G_2 - G_1)/G_2 * 100\%$ (3)
   where:
   G_1 – road network density in the research facility before land consolidation;
   G_2 – road network density in the research facility after land consolidation.

4. RESULTS

In total, the detailed research covered 16 precincts from the Podkarpackie voivodeship (from south-eastern Poland). In these precincts, land consolidation has been completed.

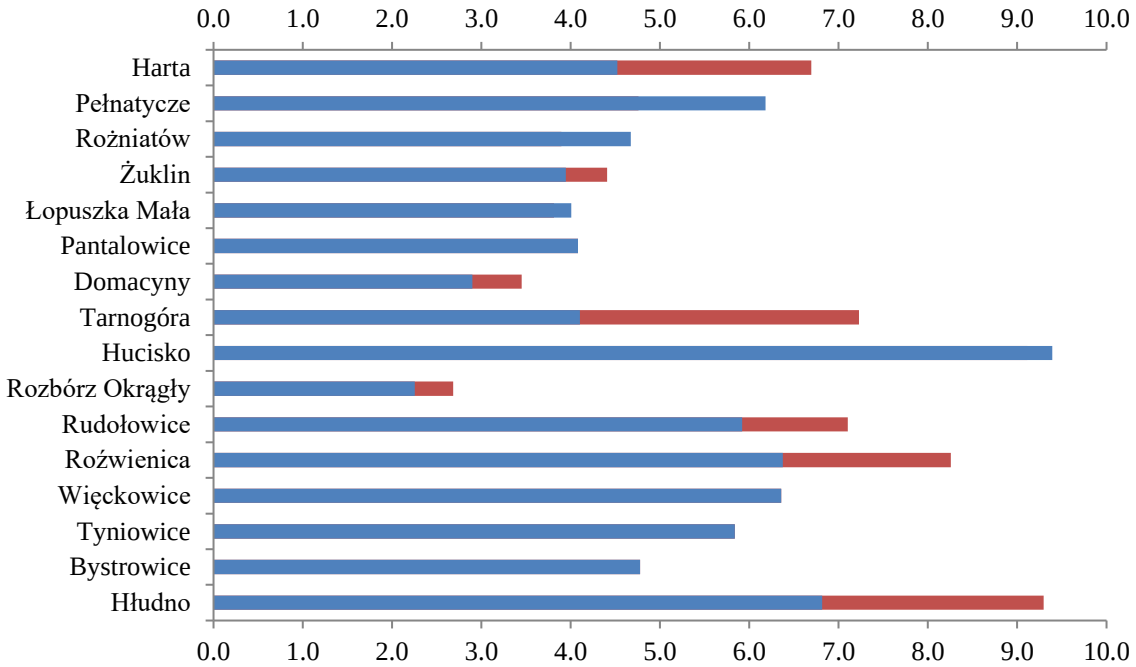

Fig. 5. Road network density before land consolidation (blue) and after land consolidation (red) in the analyzed 16 precincts. *Source:* own study.

By analyzing the density of the road network, we can say that it increased after the land consolidation project in the area under study. Detailed data is presented in Figure 5. Before consolidation, the road network density was 5.13 km / 100 ha GR. After consolidation, the road network density was 6.01 km / 100 ha GR. However, the road network index is + 14.7%. It ranges from + 32.4% in the village of Harta to -29.9% in the village of Pełnatycze, where the density of the road network has decreased. In villages where the road network index is negative, we observe the phenomenon of liquidation of unnecessary roads, which made it difficult for farmers to manage rationally. These are villages where the average area of an individual farm is about 3 ha. In the villages of Bystrowice, Tyniowice, Więckowice and Pantalowice, the indicator is 0%, which means that the density of the road network has not changed as a result of consolidation. Overall, this is a satisfactory result.

5. CONCLUSIONS

The present research was aiming at analyzing the road network and demonstrating the discrepancies between public roads indication in the land and buildings register and the actual usage of the area. The study was carried out with the use of modern geomatic tools. As a result of the analysis, it was stated:

1. The land and buildings records often contain data that is out of date and inconsistent with the actual use. Current EGiB data is the base for many surveying activities.
2. Modern digital techniques and geomatic tools enable to carry out in a short time accurate and reliable area analyses depending on the thematic context, they are very helpful in undertaking all the project duties of land consolidation.

3. The cost of land consolidation under RDP 2014-2020 for land in south-eastern Poland is:
    - Carrying out consolidation works 800 EUR / 1 ha of land
    - Post-merger management 2000 EUR / 1ha [Regulation 2015].
      These are high amounts, therefore it is even more necessary to thoroughly prepare the data for the design of the agricultural transport road network in the land consolidation project. The effect is shown in Figure 6.

Fig 6. An example of post-merger management - reconstruction of an agricultural transport road. On the left, the state before land consolidation, on the right, the state after land consolidation. *Source:* [Ministry of Agriculture and Rural Development 2018].

The rational shaping of the agricultural transport road network and the improvement of their technical condition contribute to the achievement of a number of benefits:

- The easement roads have been liquidated and the agricultural transport roads have been constructed, securing the access of each agricultural plot to the public road;
- Saving time, people, equipment and cargo transportation thanks to increased driving speed,
- Savings on transport costs resulting from the use of the nominal load capacity of vehicles;
- Reducing crop losses by eliminating permanent or temporary detours impassable roads;
- Increasing the intensity of agricultural production in hard-to-reach areas [Noga et al., 2017].

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