Ecological Indicators 93 (2018) 718–729

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

Spatial differentiation of indicators presenting selected barriers in the productivity of agricultural areas: A regional approach to setting land consolidation priorities

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ARTICLE INFO

Keywords:
Land fragmentation
Land consolidation
Rural areas
Poland
Multi-criteria analysis

ABSTRACT

Financial and organizational capabilities of implementing consolidation works are often considerably smaller than the requirements for them. The solutions enabling the identification of areas with the least favorable parameters of land spatial structure, where there is also a high probability of achieving significant positive effects of consolidation projects, become crucial. The article presents a method of solving this problem at the regional level. It was proposed to use the synthetic LCR_i indicator, which is a type of ranking of the urgency for implementing consolidation projects. Its construction is based on the weighted sum of six sub-indices, which describe the following factors: soil quality (SQ_i), land fragmentation (LF_i), parcel shape and area (PSA_i), farm structure (FS_i), roads accessibility (RA_i), and terrain difficulty (TD_i). The research area included one of the regions of Southern Poland named Malopolska. The attributes of approximately 4.5 million plots belonging to 1845 villages of the studied region with the total area of over 15 thousand km^2 were analyzed. Obtained results showing spatial variability of the values of sub-indices and the synthetic indicator were made available as thematic layers within the regional spatial information system. The final ranking is also used in the process of long-term planning of the location of consolidation projects, a task which in Poland is assigned to the local government at the regional level.

1. Introduction

The spatial structure of rural areas is one of the key factors affecting the level of income obtained from agricultural production. Excessive land fragmentation increases the operating costs of farms and limits yields (Latruffe and Piet, 2014; Harasimowicz et al., 2017). Both of these elements affect the direction of changes in areas used for agriculture (Jürgenson, 2016). They often lead to land degradation resulting from the abandonment of land cultivation (van der Zanden et al., 2017; Sklenicka, 2016; Bajocco et al., 2012; Prishchepov et al., 2013), leading to permanent social and cultural changes (Hernik et al., 2013). Parameters of spatial structure and their changes over time affect also gradual transformations of landscape (Nagendra et al., 2004; Kupidura et al., 2014). Land cultivation abandonment, associated with unfavorable agricultural conditions, has also its positive sides in the form of increasing biodiversity (Di Falco et al., 2010), expanding forested areas (Gutman and Radeloff, 2016) and improving carbon sequestration (Kuemmerle et al., 2015). In regions with satisfactory soil quality, good agriculture and a stable demographic situation, 'land abandonment' can be treated as a natural process of moving away from the agricultural use of areas with the most unfavorable environmental conditions. However, in areas with shortage of arable land and at the same time unfavorable parameters of land fragmentation, it is necessary to undertake actions leading to the improvement of the spatial structure of land. Their effect is the development of the economic situation of farms resulting from the reduction of the costs of their functioning, which at the same time reduces the phenomenon of permanent abandonment of land cultivation.

Noticeable changes in unfavorable land fragmentation parameters can be obtained as a result of land consolidation in a relatively short time (Niroula and Thapa, 2005; Wu et al., 2005). Its most important benefits include the increase in the area of parcels associated with the reduction of their number, bringing parcels closer to farm buildings, and the improvement of the quality and density of the transport network in a given area (Lisec et al., 2014). Land consolidation also affects landscape features (Moravcová et al., 2016), ecological aspects of consolidated areas (Wang et al., 2015), and also improves the quality of cadastral data (Hanus et al., 2018). Other methods solving the problem

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https://doi.org/10.1016/j.ecolind.2018.05.050
Received 14 January 2018; Received in revised form 17 May 2018; Accepted 22 May 2018

of land fragmentation, different than land consolidation alternatives, are rare. One that can be mentioned is the innovative approach used in Spain, described by (Ónega-López et al., 2010), which incorporates the integration of private and shared ownership of land for the purpose of its beneficial use.

Land consolidation is a tool commonly used in the world not only to improve the functioning of farms, but also as one of the elements of a comprehensive system of rural areas development (Hartvigsen, 2016; Muchová et al., 2016; Markuszewska, 2013; Sayılan, 2014). The history of the functioning and development of land consolidation is long, especially in Europe (Vitikainen, 2004; Pašakarnis and Maliene, 2010). Currently, these activities are implemented with varying intensity in many regions of the world, especially in China (Long, 2014; Luo and Timothy, 2017; Jin et al., 2017) and Central and Eastern Europe (Sky, 2015; Janus and Markuszewska, 2017; Muchová and Jusková, 2017).

High costs of the operation make universal implementation of land consolidation difficult. In the case of consolidation works financed with the European Union programs, the cost of the project in 2017–2013 in Poland ranged from 350 to 500 EUR/ha, while the costs limit for the implementation of post-consolidation land development was 900 EUR per hectare (Janus and Markuszewska, 2017). In the ongoing program for 2014–2020, the costs limit has been raised to 800 EUR per hectare for the project and up to 2000 EUR per hectare for the post-consolidation village development process. At such high costs, even seemingly large funds allocated for consolidation in Poland in the years 2017–2013, amounting to EUR 160 million, enabled the implementation of works in the area of about 93,000 ha, which is only 0.7% of the estimated most urgent needs for the implementation of these works in Poland (Jędrejek et al., 2014). It is very hard to compare the costs of land consolidation projects between different countries. The main reason is the differences in the scope of activities completed with land consolidation procedure, which may include the process of designing new boundaries as well as comprehensive activities ending with the construction of high-quality road network, essential drainage network and other elements of rural infrastructure improving the functioning of agriculture and the quality of life of the entire local community.

Land consolidation projects are realized mainly with public funds, although financial contribution of participants is also observed. Both of these sources can cover a small part of the needs signaled by the owners or resulting from the analysis of the needs of implementation of consolidation works. Therefore, the correct planning process of these works is a fundamental problem (Yan et al., 2015; Kwinta and Gniadek, 2017; Kong et al., 2014; Demetriou et al., 2012; Leń, 2018). They should be reduced to places where the improvement of the conditions for agriculture functioning is the most necessary, and at the same time the probability to obtain significant changes in the layout of property boundaries is sufficiently high.

1.1. Land consolidation planning

It is not possible to implement effective land consolidation process in any given area. The achievable result depends on many factors, such as: existing spatial structure parameters, terrain conditions hindering the process of creating new boundaries, local community attitude, existing legal conditions regulating the technical and legal aspects of a long-term procedure. Ignoring information indicating significant difficulties in the planned project process results in small observed effects of land consolidation despite incurred high costs of their implementation (Janus and Markuszewska, 2017). This problem may be solved by proper planning of consolidation work (Yan et al., 2015) based on a detailed analysis of prospective objects that may be the subject of these works. The ranking form of objects obtained in this way can be used both in centralized systems and in those in which the process of identifying villages suitable for consolidation takes place at the local level. In both cases, there is a need to choose objects for which the ratio of obtained benefits to the costs will be the most profitable.

Proper planning of land consolidation requires considering many factors and processing large data sets (Yan et al., 2015). The effects of such activities are satisfactory only when the analysis covers sufficiently large area. Most often it is the country level (in the case of a small area country), more often regional level or the level of individual communes. The importance of land consolidation planning as part of integrated rural development is emphasized in research conducted in China (Zhang et al., 2014). In this process, specialized IT solutions are used, as in the case of the 'ARTOP (Aslan and Arici, 2005) or LACONISS system (Demetriou et al., 2013a), supported by appropriate representation of spatial data (Kong et al., 2014). A comprehensive approach to land consolidation planning based on the ArcView environment is presented on the example of Longkou County in Shandong Province (Nie and Xu, 2006). The existing solutions are most often based on the assessment of parameters describing the spatial structure of land and its impact on agricultural use (Leń, 2018), analysis of road network access (Janus et al., 2017), use of the synthetic indicator for assessing the quality of the shape of parcels (Demetriou et al., 2013b), or analysis based on statistics of selected geometric features of parcels (Kwinta and Gniadek, 2017). Most often, highly accurate analyses concern relatively small areas, while studies at the regional level are based on data with a high degree of generalization.

In many works, the purposefulness of developing tools supporting selected stages of the consolidation process is indicated, starting with their planning (Li et al., 2009; Yan et al., 2015), computer simulation of the reallocation process (Aslan et al., 2018; Uyan et al., 2015), technical stages of boundary design (Tourino et al., 2003; Haklı et al., 2016) and evaluation of the effects of the entire project (Zhang et al., 2014; Jinhao et al., 2017). Needs in the design of tools useful in the planning process are noticed in different countries, as far apart as Estonia (Jürgenson, 2016) and China (Liu et al., 2014). Research in China is particularly interesting in this field, as consolidation works are being implemented there in an increasingly broader range. As noted in the research (Guanghui et al., 2015), management of the consolidation process has significant implications in the process of optimizing and organizing the agricultural space. Another solution presented on the example of Chinese experience suggests basing the strategic framework for planning land consolidation at the national level on the SWOT analysis (Yan et al., 2015).

The article presents the methodology used to assess the needs in the implementation of consolidation works applied in Poland at the regional level, for an area of about 15,000 km^2. The effects of the analysis were used by the self-government of the Malopolska Region as part of the policy pursued in the planning of consolidation works and used as an element of the regional spatial information system. The effects of the analysis made for such a large area may be valuable for the improvement of similar ongoing or designed activities in other regions of the world where the problem of large changes in the spatial structure of land is met with the lack of sufficient funds for their implementation. Despite the large research area, the individual components of the final assessment are based on partial assessments made at the level of individual cultivated parcels.

2. Study area

The Malopolska region with an area of over 15,000 km^2 is one of the 16 regions of Poland's administrative division. The region, excluding urban areas, consists of 168 communes and 1845 villages included in the analysis. Malopolska is a region that is very diverse in terms of conditions for agricultural activity. Largely diversified landforms and soil quality are noteworthy. The parameters of land fragmentation also have high variability, although the studied region should be included in areas with unfavorable parameters of land fragmentation (Janus et al., 2016). The average size of farms in 2015 was 3.98 ha (Janus and Markuszewska, 2017). Small- and medium-sized family farms predominate and large-scale farms are found only in a small number, only