

Use of Multi-Criteria Analysis for the Ranking of Land Consolidation Areas

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Key words: multi-criteria analysis, land consolidation, priority ranking

SUMMARY

In Croatia, as in other post-socialist countries, agricultural land is extremely fragmented. This significantly raises the costs of and impedes agricultural production. The land fragmentation manifests as a big number of relatively small cadastral parcels of each individual land owner. Additionally, the parcels are often very irregular in shape, which hinders an effective application of modern agricultural machinery. Land consolidation procedure, i.e., regrouping and merging partitioned agricultural land into bigger and more regular parcels, and simultaneously arranging road and canal networks, enables a significant improvement in the conditions of agricultural production. An analysis of Croatian official land administration data was made in order to determine land fragmentation and other agricultural indicators.

The basis for conducting land consolidation is the legal framework. Multi annual and annual plans are to specify priority areas for conducting consolidation. These plans should take into consideration the ratio between consolidation costs and benefits from improved conditions for agricultural producers. To ascertain that, it is necessary to determine areas suitable for consolidation and express their qualitative features in a quantitative manner. In this way it is possible to create a system for deciding on priority areas, based on a multi-criteria analysis of spatial data. Most of the necessary data on land and space can be found in the Land Administration System (LAS). However, some of the data was not available as an official, country-wide, data, and other sources of data were used. The base spatial unit for which assessment has been carried out for the whole territory of Republic of Croatia was cadastral municipality. The final result is a complete list of all cadastral municipalities, ranked accordingly to the suitability for agricultural land consolidation. The process of spatial unit's suitability ranking revealed some shortcoming of the existing Land Administration System, which will be further researched and considered within the Croatian Science Foundation Project named: Development of the Multipurpose Land Administration System, goal of which is improvement of efficiency and usability of LAS.

1. INTRODUCTION

Land is the essential limited natural resource. Among the other goods, land resources differ in that they are limited, it cannot be increased or decreased. It has a great importance for economic and social development. It is essential for economic and social activities of every person. It is an income source and therefore interesting for the individual and the state. The increase in the population, especially in recent decades, creates increasing pressure on land resources (Cetl and Prosen 2001). Land has been more and more intensively used and people to the land relations are becoming more complex. In order to use land more efficiently and sustainably its use must be carefully and efficiently governed (Zevenbergen et al. 2015).

Agricultural Land Consolidation is the agrarian-technical operation which aims to group and collect the segmented and fragmented holdings into one or more rounded whole in order to achieve a more rational agricultural production (Medić 1978, Van Dijk 2002, Vitikainen 2004). Land consolidation is a comprehensive procedure that requires careful planning in order to better utilize rural areas (UN FAO 2003, UN FAO 2004). Land consolidation on Croatian territory was carried out in the past, but for a long time there were no such projects. Start of the Land Consolidation procedures on a national level requires preparatory activities in order to determine the priority areas, i.e. areas for which it is assumed that redistribution of land is most needed and there are certain prerequisites for successful agricultural production together with the interests from people and state. This can be done by Land Consolidation Programme which should be done on the basis of measurable indicators, specific to a representative sample.

2. HISTORICAL OVERVIEW OF LAND CONSOLIDATION ON THE CROATIAN TERRITORY

In the Croatian areas, the first consolidation of the feudal estates emerged in the late 17th century as land arondation. Those regrouping was implemented by feudal lords, snatching land from the peasants and the lower nobility which continued into the 18th century. Karl VI prohibited this kind of enlargement of feudal arable land, which was followed by series of similar interventions made by Empress Maria Theresa. Urbarium (comprehensive register of farms) was made for three Counties in year 1756., and for additional three Counties were made by 1780. These registers regulated land distribution among individual peasant's family (Medić 1993).

In year 1902 a new law on land consolidation was introduced. The main features were: facilitated initiation of procedure, accelerated process, the performance of amelioration, Land Book correction, division of land communities and reduced implementation costs. To start a land consolidation it is sufficient to get a consent of the participants fifth who have in total half of the land, and, in exceptional cases, it is sufficient to have a consent of participants tenth and only a quarter of the land in total.

Land consolidation was typically covering the whole cadastral municipality undeveloped area with the possibility of inclusion of neighbouring municipalities' parts. As an advisory body in the process of land consolidation participated land consolidation committee with 4 to 12 members. Half of the members were elected by the participants, and the other half were nominated by the land consolidation authorities from the ranks of small, medium and large

landowners. Land valuation was performed as a land capability evaluation by a professional expert.

The Law on Land Consolidation from December 24, 1954, prescribes land consolidation at the request of interested parties, unless there is a larger hydro-technical, amelioration or road works, or other large objects of general interest. This law is significantly amended on April, 20th 1965 and on February, 23rd 1979. The main feature of this act is a planned approach: land consolidation is based on agricultural and urban documentation and it included re-organization of settlements in the extent necessary to achieve the purpose and objective of land consolidation.

From 1956 to 1980 land consolidation is performed on more than 650,000 hectares in 420 boulders. Most of the land consolidation works (Figure 1) refers to the area of Eastern Slavonia and Baranya (around 60% of total).

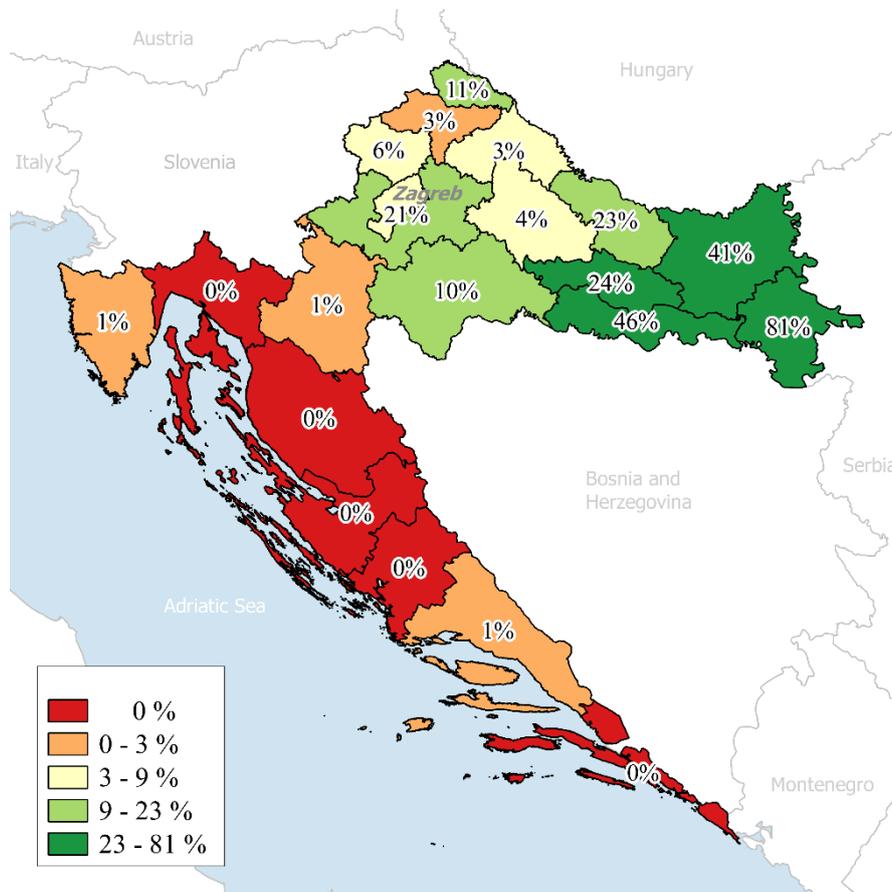


Figure 1. The percentage of land consolidated areas by Counties

3. CURRENT STATE OF CROATIAN LAND ADMINISTRATION SYSTEM

Croatia has approximately 14 million cadastral parcels (Figure 2) and total land area is 56,594 km². Many of these parcels records and ownership relations do not correspond to the situation on the field. Land consolidation is impossible to plan and to implement without a good and up-to-date land administration system and other spatial register's data.

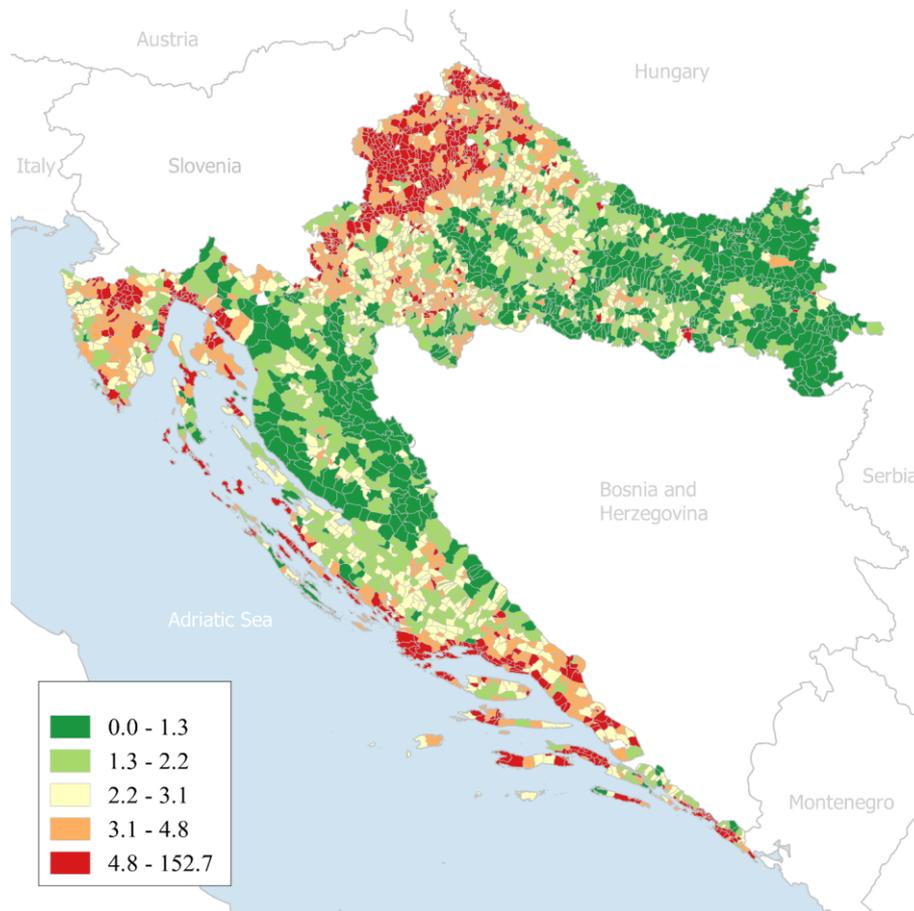


Figure 2. Average number of parcels/hectare

The Land Book is a public register of real and other rights to the property, regulated by the Law on property and other property rights. The fact that land registration is optional represents the biggest drawback because it calls into question completeness and accuracy of the registered data. Due to this, Land Book data cannot be used to determine land consolidation suitability index.

Total agricultural land is registered in the Cadastre. However, many years of lack of maintenance lack together with inappropriate classification makes use of these data questionable. In addition, cadastral records were not available in the form in which it would be possible to use them for suitability analysis. For this reason, for the purpose of priority areas valuation, data on current active agricultural land parcels was taken from Land Parcel Information System (LPIS, Croatian abbreviation: ARKOD).

ARKOD (LPIS) is the national system of agricultural parcels identification which register the agricultural use of land in the Republic of Croatia. The purpose of is to enable farmers to apply for subsidies in agriculture as well as their more transparent use. Agricultural parcels registered in ARKOD are the most reliable data on active agricultural land in Croatia. According to Corine Land Cover (CLC) project data from the year 2012, Croatia has total of 56% of agricultural land (31907 km²) (Figure 3). Of that total, only 33% of agricultural land is currently active (LPIS – ARKOD, 2015: 10679 km²).

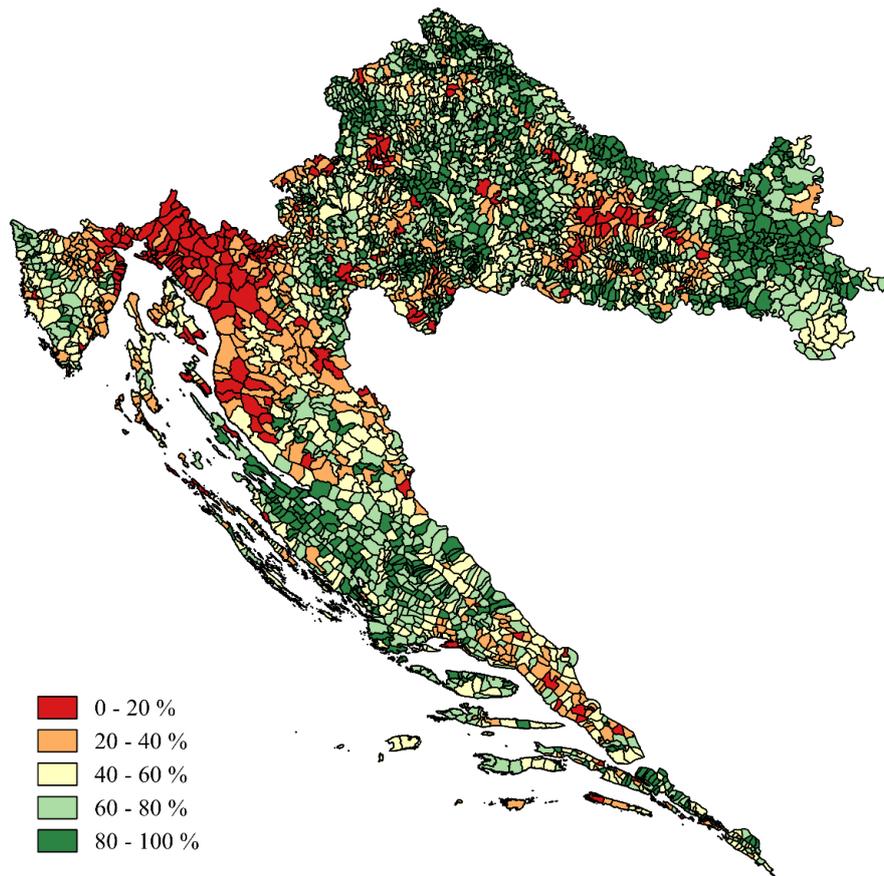


Figure 3. The share of agricultural land by cadastral municipalities according to CLC 2012

4. FACTORS AND METHODS OF PRIORITY AREAS RANKING

A prerequisite of the rural areas and agricultural land development is a rational approach to the ranking of the priority areas for the implementation of land consolidation. Priority areas can be ranked according to many factors. Transparent and rational method, together with the previously known criteria, will help avoid the doubts in impartial ranking of priority areas.

It is generally agreed that the factors of priority ranking in the purpose of agricultural land consolidation can be divided into three main groups:

- existing state of natural and anthropogenic characteristics
- demographic characteristics and social development
- economic feasibility requirements.

According to current Croatian regulations, land consolidation projects will be implemented accordingly to multi-year program adopted by Croatian Parliament, for a period of five years and annual programs approved by the Croatian Government (Official Gazette 51/2015). Based on Act of Land Consolidation, there is a need for analyses of all cadastral municipalities for the purpose of priority ranking.

Factors, for which data were available for all cadastral municipalities, were selected and used to calculate indicators values (Table 1) to form the final Land Consolidation Suitability Index.

Table 1. Indicators used to calculate land consolidation suitability index

Indicator number	Indicator name	Description	Datasource
1	Agricultural land share	Share of agricultural land in total area of cadastral municipality	ARKOD (LPIS)
2	Agricultural parcel size	Average size of agricultural parcel area	ARKOD (LPIS)
3	Agricultural parcel shape index	Average index of parcel shape fragmentation - measure of parcel shape irregularity	ARKOD (LPIS)
4	Agricultural holdings fragmentation index	Average index of agricultural holdings fragmentation	ARKOD (LPIS)
5	Share of state owned agricultural land	Share of state owned agricultural land parcels area in total cadastral municipality area	Agricultural Land Agency (ALA) database
6	Regional development index (RDI)	Composite indicator calculated as a weighted average of more fundamental socio-economic indicators	Ministry of Regional Development and EU Funds
7	Number of agricultural holdings	Number of agricultural holdings in cadastral municipality	ARKOD (LPIS)

For each indicator it was determined how they will be valued and weighed. Depending on the nature of each indicator, determining of their values can be a relatively simple task, but sometimes it can also involve a complex, time consuming spatial analysis, for which it is necessary to create automatic calculating procedures. One of the most challenging indicators to determine was Agricultural holdings fragmentation index (Indicator 4), which evaluate the form (compactness) of agricultural holdings (Figure 6) in each cadastral municipality. The analysis calculates this index as the average value (median was used) of each holding fragmentation index, which is calculated as ratio of minimum polygon area which covers all the agricultural parcels of one holding in one cadastral municipality (Figure 7), divided by total area of holding's agricultural parcels.

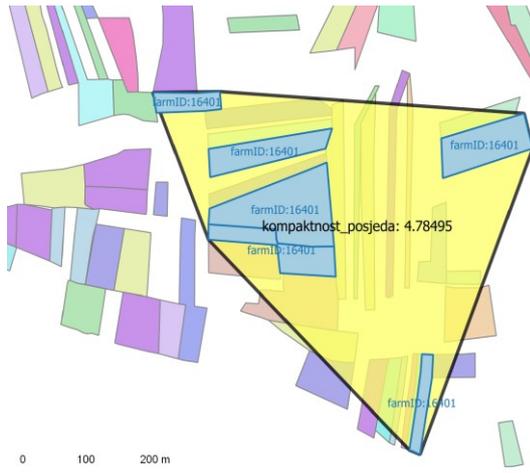


Figure 4. Example of Indicator 4 polygon area for one farm holding

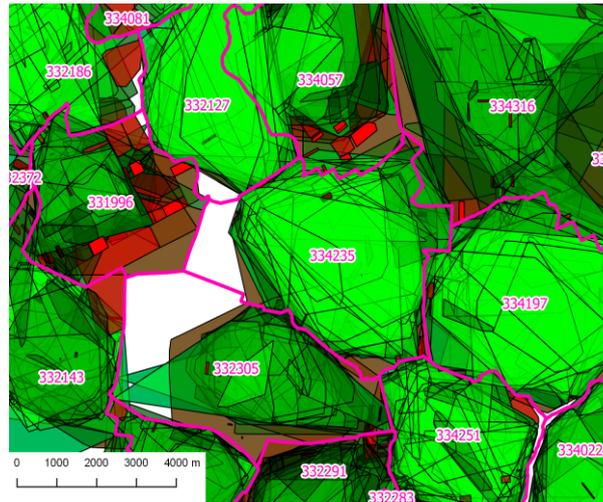


Figure 5. Farm holding polygons used to calculate Indicator 4 value

Based on all calculated indicator values, it is possible to determine the value of land consolidation suitability index – LCSi. The value of this index is determined in a way that all indicator ranges were normalized to range from 0 to 1 and then used to combine in order to calculate LCSi. The value of this index gives indexed measure of impact of all included indicators (Table 2). The higher value of LCSi means that the related cadastral municipality is more suitable for agricultural land consolidation (Figure 4).

Table 2. Final Rankings of Cadastral Municipalities

No.	CM_id	CM_name	LG_name	Indicator 1	Indicator 2	Indicator 3	Indicator 4	Indicator 5	Indicator 6	Indicator 7	LCSI
1	302775	Belica	Belica	0,799	0,181	0,902	1,000	0,068	0,750	0,527	4,227
2	308927	Krndija	Punitovci	1,000	1,000	0,155	0,027	1,000	0,750	0,023	3,955
3	334103	Grabovo	Vukovar	0,982	1,000	0,202	0,031	0,960	0,750	0,009	3,934
4	302996	Gardinovec	Belica	0,877	0,160	0,979	0,400	0,160	0,750	0,600	3,926
5	316849	Sesvete Ludbreške	Sveti Đurđ	0,919	0,156	0,693	0,508	0,205	0,750	0,673	3,903
...
3370	335266	Črnomerec	Zagreb	0,0000	0,0000	0,0000	0,0000	0,0005	0,0000	0,0000	0,0005

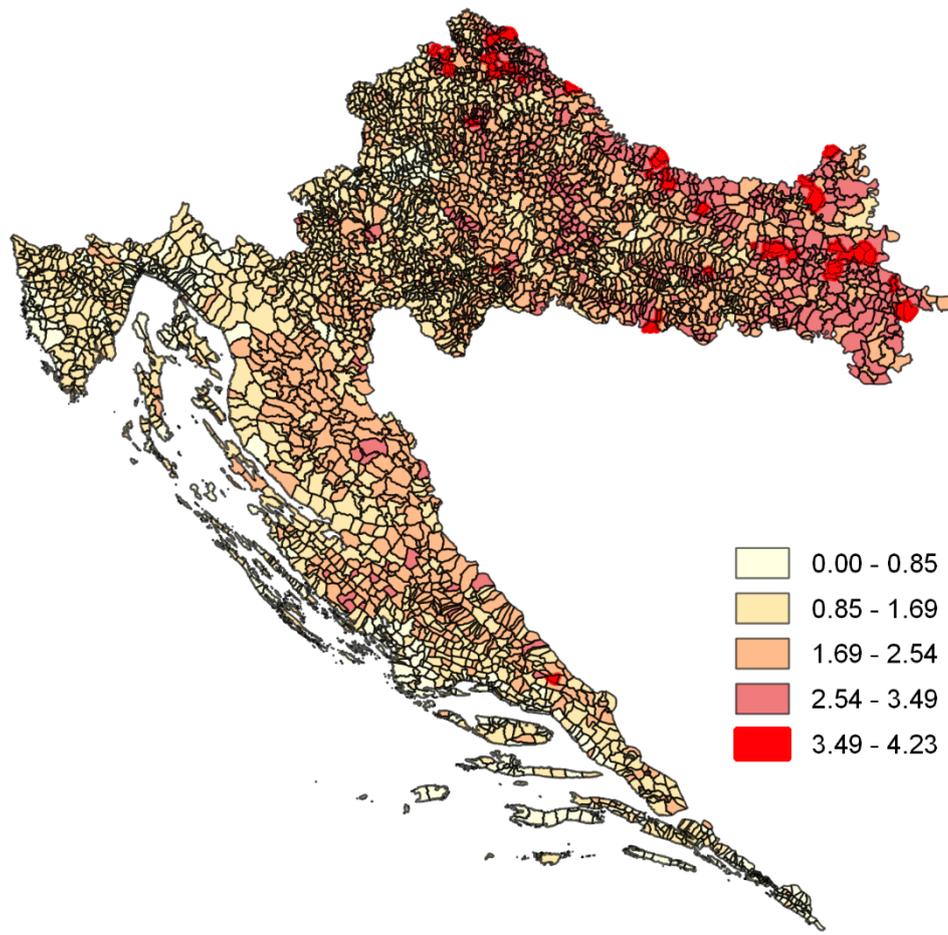


Figure 6. Thematic map of Cadastral municipalities LCSI values

For the needs of this project, normalized values of individual indicators were combined in a way that all the indicators values are simply summed (Figure 5 shows LCSI values distribution). Manual visual inspection was used to check the determined results and it showed that proposed ranking results are satisfactory and that they reflect the actual situation. However, for building of more complex combination and including weight impacts of each indicator it would be more suitable to use some of the currently available tools for multi-criteria analysis (some QGIS plugins were tested in project preparation phase). These tools allow easier and more effective setting of each individual indicators significance, thus changing the ranking results.

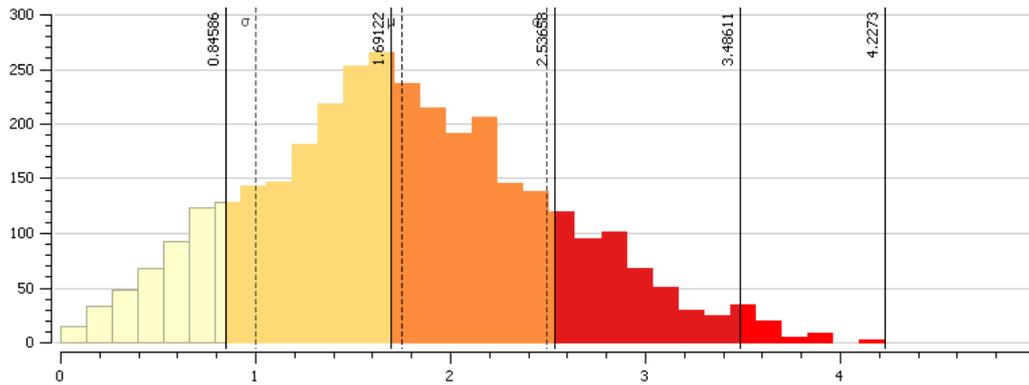


Figure 7. Cadastral municipality LCSI values distribution

5. CONCLUSION

In creation of a proposal for the cadastral municipalities priority ranking it is possible to use international experiences with respect to Croatian specifics.

The LCSI was calculated for each Cadastral Municipality based on selected individual indicators. These indicators included: share of agricultural land, size and shape of agricultural parcels, the distance between parcels of each holding, the number of possible land consolidation users, regional development index (RDI) and the share of state owned agricultural land.

Selection and calculation of used suitability indicators were strongly conditioned by the availability of the required data. Some of the important datasets were not available or were not available in a form suitable for automatic data processing. However, it is possible to evaluate that the set of available data was sufficient and representative to give a reliable priority ranking list. Of course, by including some additional data (e.g. accurate data on inactive agricultural parcels obtained from Cadastre) which have not been available, the result could be improved.

The proposed ranking contains the technical indicators and it is a good basis for the development of land consolidation program. Together with local community, from which it is possible to collect other indicators (e.g. interests for land consolidation...), sustainable agricultural land consolidation program can be made.

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Hrvoje Tomić works as an Assistant Professor at Department of Applied Geodesy, University of Zagreb, Croatia. In 2010 he received his Ph.D. from University of Zagreb for the thesis: “Geospatial Data Analysis in Purpose of Real Estate Valuation in Urban Areas”. His main research interests are GIS and DBMS technology in spatial data handling. Hrvoje Tomić has participated on several projects and has published several papers.

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