Pasakarnis, G, Maliene, V, Dixon-Gough, R and Malys, N

Decision support framework to rank and prioritise the potential land areas for comprehensive land consolidation

Decision support framework to rank and prioritise the potential land areas for comprehensive land consolidation

Giedrius Pašakarnis[1], Vida Maliene[1,2 *], Robert Dixon-Gough[3], Naglis Malys[4*]

[1]Institute of Land Management and Geomatics, Vytautas Magnus University Agriculture Academy, Studentu 11, Akademija, LT-53361, Kaunas distr., Lithuania
[2] Department of the Built Environment, Faculty of Engineering and Technology, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, United Kingdom
[3] Faculty of Environmental Engineering and Land Surveying, University of Agriculture in Kraków, 253c Balicka Street, Kraków 30-149, Poland
[4] School of Life Sciences, The University of Nottingham, University Park, Nottingham, NG7 2RD, United Kingdom

*Corresponding authors, E-mail addresses: v.maliene@ljmu.ac.uk (VM); naglis.malys@nottingham.ac.uk (NM)

Abstract
In Europe and often worldwide, national and local government authorities utilise different means to stimulate economic development and environmental protection of the land through the application of land consolidation. The direction of these efforts should take into consideration the fact that some administrative regions may have a higher potential for land consolidation than others. This is supported by the Food and Agriculture Organization of the United Nations (FAO) that advises on the identification of favourable regions for implementation of pilot land consolidation projects. In many European countries, especially those receiving European Union (EU) support for implementation land consolidation projects, the scrupulous allocation of funds to the best suitable regions is very important. The research in this paper identifies a key set of criteria and offers multiple-criteria analysis-based approach to rank and prioritise administrative regions for implementation of land consolidation. This methodology is applied in the case study identifying Klaipeda district as a municipality with the highest potential for land consolidations in the Western part of Lithuania. The proposed framework will enable national and local authorities to identify and prioritise regions for land consolidation in a transparent way ensuring efficient management of resources and fair allocation of financial support.

Keywords: land consolidation; decision support framework; multi-criteria decision analysis; ranking

1. Introduction

One of the historical drivers for land consolidation has been a partible inheritance, the division of inherited land leading to fragmentation and the gradual impoverishment of land holdings (Dixon-Gough, 2006; FAO, 2003; Thomas, 2006; Van Dijk, 2007, 2003a). In many countries, the land consolidation is carried out only in those cases where interested parties request for parcel reallocation aiming to improve economic efficiency of land use. More recently the catalyst for land consolidation has been the quest for the rationalisation of agriculture (Van Dijk, 2004) together with land restitution in some Central and Eastern European countries (Sklenicka, 2006; Van Dijk, 2003b). These drivers, combined with spatial developments, infrastructural projects, rural regeneration, and a growing awareness of the importance of environmentally sustainable land use have all led to increased interest in the optimisation of the processes and application of land consolidation (Pašakarnis and Malienė, 2010; Hartvigsen, 2014), which relies upon a delicate balance between public and private interests (Aleknavičius and Liaskovskaja, 2011; Dixon-Gough, 2006).

Land management instruments can no longer rely upon manual processes or traditional structures that had been developed to support former economic systems. To utilise systems that support individual processes and in which data and processes were maintained separately, such as land valuation and land titling, is no longer sustainable. They are being replaced by multipurpose land databanks in which information relating to resources, planning, land use, land value, land titles (including common property rights) can be integrated for a range of land administration and business purposes. Such land databanks (or multi-purpose cadastres) have a much broader and integrated vision than has been experienced in the past. The components of land registration, cadastral surveying, large-scale topographic mapping, soil fertility, spatial planning, and land valuation, together with their inter-relationships in the sphere of land markets, should be considered as an integrated system in which the common objective is the Global Goals for Sustainable Development as approved by the United Nations General Assembly (2015). One of the main advantages of such an integrated approach is that all rights, restrictions, and responsibilities (including both

two- and three-dimensional interests) relating to land must be considered in designing and implementing such a land administration system together with its integrated land databank. Such a system would be of immense value to the processes of land consolidation (from the early stages (highlighting territorial potential) until the very end of the project), which has the potential to make long-lasting effects upon the future lives of the participants.

Land consolidation requires difficult and conflicting decisions such as why and where, to satisfy the balance between the needs of ecology, the environment and agrarian efficiency (Lisec et al., 2005) in order to revitalize the declining countryside (Zhou et al., 2020). Traditionally these decisions have been made by groups of people, some linked to the area being consolidated and others from governmental departments, all of whom attempt to create the best possible decision. These decisions, whether about professional or private matters, or about the traditional responses to land consolidation are normally based upon experiential knowledge that can be intuitively changed according to particular situations. However, when researchers require a methodology capable of dealing with such conflicting criteria - such as economic, social and environmental factors, of both a quantitative and qualitative nature in a single evaluation process, Multi-Criteria Decision Analysis (MCDA) is often chosen (Mulliner et al.2013, 2016). MCDA is a discipline that encompasses mathematics, management, informatics, psychology, social science and economics etc., which is why researchers and commercial companies over the last decade have developed various software programs to help users structure and solve their decision problems (Ishizaka and Nemery, 2013). There is an opinion that cost benefit analysis is almost universal, but it is considered to be of limited use in complex situations, since all criteria must be measured in monetary terms (Hall and Tewdwr-Jones, 2011). According to Munda et al. (1998), multi-criteria evaluation techniques can help to provide more insight into the nature of conflicts and into ways to arrive at political compromises in the case of divergent preferences in a multi-group or committee system, thereby increasing the transparency of the choice process. Beinat (1997, p. 40) draws a fundamental statement about decision making by MCDA suggesting that the 'best' alternative can be interpreted only as 'better than' other alternatives involved in decision making. Ma zewski (1999) concluded that a decision problem which has a geographical reference component can be called a spatial decision problem. The core element is still the decision maker, although MCDA provides the possibility of exploring different spatial alternatives (Beinat and Nijkamp, 1998). MCDA for spatial decision making can be applied in many cases where issues related with land occurs, especially where a quick decisions are necessary, such as determining the land areas that after natural disasters need financial aid allocation first or identifying of the most sensitive hotspots (i.e. land conflicts areas) in developing countries most in need of advice concerning land rights security. All land consolidation experts agree that during a comprehensive land consolidation process there are various spatial 'conflicts' - not only between the parties, but also between objectives. Demetriou (2012) in his thesis reviewed various applications (for example environment, agriculture, transportation) where Spatial Decision Support Systems (SDSS) supports semi-structured spatial decision problems and, based on this discovered, how SDSS can be applied to the land consolidation process. Munnangi et al. (2020) argues that Geographic Information System (GIS) database with a decision support system will save time and bring more objectivity and transparency into the land consolidation process.

It may be observed that despite Western European countries (WEC) having traditions and practices extending for hundreds of years in organizing and implementing land consolidation projects (Jürgenson, 2016; Thomas, 2006; Zhou et al., 2020), they still undertake various marketing activities, information campaigns and use other methods to raise public awareness, regarding the results that are possible from land consolidation in all its forms, either singly or in conjunction with other instruments. One of the recent examples is the Dutch Kadaster, which in 2016 celebrating one hundred years practice in implementing land consolidation projects, has introduced a game for smart devices 'Move a Lot', where the player may 'play' at readjusting a land consolidation project area (Kadaster, 2016). It is highly likely that various proactive promotional activities influence the number of submitted applications from active farmers, which in turn generate the detailed investigations and analyses (pre-studies, feasibility studies etc.). Transparency and clear messages can assure the support of active local leaders - 'social activists' (Dudzińska et al., 2018) and about land consolidation benefits well informed land owners (Janus and Markuszewska, 2017) which are the main supporters and facilitators of land consolidation projects.

Since 2005, Lithuania has received support from the EU for the implementation of 53 land consolidation projects that have been completely free to the project participant, but despite that, applications for land consolidation are still quite rare. According to Janus and Markuszewska (2017) in Poland due to the improper method of selecting the re-parcelling projects during the EU financial period of 2007-2013 had an impact on the efficiency of land consolidation procedures. During a comprehensive literature analysis and interviews with land consolidation experts it was noted that certain countries (i.e. Finland, the Netherlands, Slovakia, Croatia and North Macedonia)

use country wide maps to identify potential regions for land consolidation (Figure 1). Recent research highlights the need for identification of most suitable and priority areas for land consolidation at various governing levels (Du et al., 2018; Janus and Markuszewska, 2017; Johansen et al., 2018; Mika et al., 2019; Munnangi et al., 2020; Wójcik-Leń et al., 2020). However, the scale and the criteria vary from country to country and are influenced by the national as well as regional policies and strategies.

The aim of this paper was to identify universally the most important criteria at different scales (municipal and project area) highlighting territorial potential for comprehensive land consolidation which could have a wide applicability. The study delivers decision making framework based on MCDA, which allows ranking and prioritising land areas for land consolidation. This methodology is applied in the case study in western part of Lithuania to rank municipalities with the highest potential for land consolidations in the Western part of Lithuania. The proposed framework can enable national and local authorities to prioritise their resources and manage land consolidation processes more efficiently.

2. Materials and methods

Research was organised by applying analysis of literature, performing survey questionnaire and in the course of case study. Figure 2 summarises the principal stages of this research. An abstraction of scientific articles, books, FAO reports were enriched with the experts' comments which revealed a variety of applied criteria for territorial potential identification and presently applied practices. International practices emphasized a rising demand for application of MCDA in ranking of potential areas for land consolidation.

For application of MCDA method, the weights of selected criteria were determined as described previously (Kao, 2010; Mulliner et al., 2013, 2016). The set of criteria showing the potential for comprehensive land consolidation and recognized by the international experts were verified within the case study with publicly available data. As one of the most widely used and best-proofed methods, the Weighted Sum Model or Simple Additive Weighting (WSM or SAW), developed by Fishburn (1967) and Triantaphyllou (2000), was used for MCDA analysis. The WSM method also contains same structure of data input and output, which is important when analysing spatial data with GIS (Geographic information system) software. The ArcGIS Desktop Standard v.10.4 software was used for data representation on the map at municipal (polygons) and project (points) levels.

Criteria weights and WSM score of the optimal alternative were calculated by applying following formulas:

Calculation of rank sum:

$$t_{sum,i} = \sum_{j=1}^{l} t_{ij}$$

Calculation of rank average:

$$t_{avg,i} = \frac{t_{sum,i}}{l}$$

Calculation of criterion importance:

$$g_i = \frac{t_{avg,i}}{\sum_{i=1}^{n} t_{avg,i}}$$

$$\underline{q_i} = 1 - g_i$$

$$q_i = \frac{\underline{q_i}}{\sum_{i=1}^{n} \underline{q_i}}$$

Criteria importance shows higher *q* values.

Calculation of criterion set of sum square:

$$S = \sum_{i=1}^{n} \left(\sum_{j=1}^{l} t_{ij} - \frac{1}{n} \times \sum_{i=1}^{n} \sum_{j=1}^{l} t_{ij} \right)^2$$

Estimation of Concordation coefficient (Kendall's W) – control of data normalization (W>0):

$$W = \frac{12 \times S}{l^2(n^3 - n)}$$

Applying Weighted Sum Model (Simple Additive Weighting) MCDA method matrix is normalized according these conditions:

If criterion is *Maximized*:

$$\underline{X}_{ij} = \frac{X_{ij}}{X_j^{max}}$$

If criterion is *Minimized*:

$$\underline{X}_{ij} = \frac{X_j^{min}}{X_{ij}}$$

where: X_{ij}– the value of the *i*-th criteria for the *j*-th alternative
X_j^{max}– the biggest value of the *i*-th criteria
X_j^{min}– the smallest value of the *i*-th criteria

The normalized matrix was developed by dividing each criterion value by the sum of its row. Following this, each criterion value is multiplied by its corresponding weight. Once values for all alternatives have been aggregated, the alternative with the highest value is selected as the best alternative.

The vector for weights (*w*) of attributes is $w = [w_1, w_2 \ldots w_n]$ wherein weights are normalized and sum of them is 1, that is:

$$\sum_{j=1}^{n} w_j = 1$$

WSM score of the optimal alternative is calculated as A* using following formula:

$$A^* = max_j \sum_{i=1}^{n} w_i a_{ij}$$

where a_{ij} are normalized values of decision matrix elements and w_i is the weight (importance) of the ith criterion.

3. European countries practice defining the potential areas for land consolidation

Haldrup and Hartvigsen (2005) emphasized that the selection of the best possible pilot site is a precondition for a good outcome of the land consolidation project. Importantly, FAO (2003) prepared recommendations as to what criteria have to be considered by land consolidation authorities when selecting a potential community for the implementation of pilot land consolidation projects. Accordingly, Finnish National Land Service has developed a map showing the 'Potential for Land Consolidation' by municipality using two main criteria to prepare the map: the size of land parcel, and the travel distance from the farmstead to the parcel (Hiironen and Ettanen, 2013; Konttinen, 2013). The Dutch Kadaster has developed an interactive webmap called the 'allotment barometer' that shows the potential for land consolidation. (Jansen, 2013). Such map facilitates a 'bottom-up' approach encouraging farmers to undertake actions if they want improvements. The improvement of the agrarian structure is of prime concern to farmers, whereas the realisation of other objectives related to the environment is often desired by society as a whole rather than by farmers alone. In order to draw the 'allotment barometer' the Kadaster has applied spatial MCDA to identify the quality of the agricultural parcel structure for more or less homogeneous areas based on four relative and absolute criteria:

- The average percentage of parcels with farm buildings (built-up areas, mainly farm centres which are the focus of activity for other parcels).
- The average percentage of parcels within a single ownership, which are distant from the farm centre. (It is especially important for dairy farmers).

- The average number of parcels which are far away from the farm centre taking into account all owned parcels (i.e. one large land parcel from six owned land parcels is far away from the farm centre which actually influences intensity of agricultural traffic and safety);
- The average size of parcels which are distant from the farm centre (i.e. distant parcels may be too small to have an economic benefit after bringing them near to the farm centre) (Jansen, 2013; Louwsma et al., 2014).

The Dutch 'allotment barometer' is not a detailed analysis as it is based only on a few parameters providing a good overview of the quality of the agricultural structure in an area. It serves as an indication of the possible savings for a farmer should this structure be improved whilst, at the same time, focussing discussion among citizens and authorities, as to whether it is reasonable to start projects, be they formal land consolidation or voluntary re-allotment (Louwsma et al., 2014). Recently, several Balkan countries (Croatia, North Macedonia) also expressed their interest in the identification of potential areas for land consolidation. For example Tomić et al. (2016) describes recent Croatian attempts in determining areas suitable for consolidation through applying MCDA by ranking of land consolidation areas. In 2017, North Macedonia with the support of FAO international experts applied MCDA to identify the potential cadastral municipalities suitable for land consolidation (Daugalienė, 2018; FAO, 2018).

The most recent efforts to develop criteria-based methodologies of ranking areas for land consolidation have been reported recently by Janus and Markuszewska (2017), Johansen et al. (2018), Mika et al. (2019), Muchová and Petrovič (2019), Wójcik-Leń et al. (2020). Such variety of criteria applied (natural and anthropogenic, land management and land administration, socio-economic, demographic, environmental characteristics etc.) across countries shows that every country makes its own choice relevant to the land consolidation approach, scale, data availability and reliability. Nevertheless the applied criteria reveals that the main focus stays on the agricultural improvements and it is easy to explain this fact in Van Huylenbroeck et al. (1996), Cay and Uyan (2013) words - the agriculture occupies most of the land in rural areas and remains the most important economic activity.

4. Defining the criteria showing the potential for comprehensive land consolidation

After analysing international practices, it was noticed that the variety of different criteria exists. In 2014 the questionnaire developed at Bristol Online Surveys platform was used to obtain opinions from international land management experts who had scientific and/or practical knowledge about land consolidation. Respondents were invited to indicate their opinion about the criteria showing the potential for comprehensive (also known as multi-purpose or integrated) land consolidation at different scales (Figure 3):

- to define potential areas (municipalities – LAU1/NUTS4 level) and
- to support decision making when selecting (ranking) project areas (project area level) for implementation.

Attention was focused on 39 European countries and the minimum expectation was to receive at least one opinion from each country. The survey was distributed via email to a total of 194 land management experts having knowledge about land consolidation, from which 69 responses were obtained from 37 European countries (response rate 36%). The survey was active for 2 months and 8 days (the period of 2nd of June to 10th of August, 2014). Invitation to participate in the survey was sent by email with covering letter and attached short instruction (describing the aim of the survey, providing some survey sample questions, and also a hyperlink to the survey). Three respondents from Lithuania were helped by the authors to fill in this survey as they had some difficulties with the English language. There were a few international respondents who dropped out during the process and failed to complete the questionnaire. Their responses were not considered as almost all questions were set as mandatory and Bristol Online Surveys platform does not allow for the submissions of partially filled questionnaires.

The online survey had 51 questions in total, the first three questions being for classification purposes only:

- The profile of respondents' expertise;
- The number of years of expertise in land consolidation; and
- The respondents' country of residence.

The survey results showed that most of the respondents assigned themselves as 'Scientists' (34.8%), whilst other respondents assigned themselves as 'Practitioners' (27.5 %), 'Both' (24.6%) and the remaining 13.0% as 'Other'. Experts who characterized themselves as 'Other' specified that they were policy makers, advisers, and lawyers.

Considering these clarifications and after performing a rigorous evaluation it would be possible to assign these 'Other' respondents to the 'Practitioners' as they have knowledge of how the land consolidation process is performed in their countries. The largest part of all respondents (24.6%) had '1 - 5 years' expertise in land consolidation, others represented '6 - 10 years' – (23.2%); 'More than 20 years' – (20.3%); '16 - 20 years' – (17.4%); '11 - 15 years' – (13.0%); and 'Less than 1 year' – (1.4 %). The type and experiential duration of the expertise of the survey respondents is detailed below in Table 1.

Table 1: Expertise characteristics of survey respondents

	Practitioner	Scientist	Both	Other	**Totals**
Less than 1 year	0	0	0	1	1
1 - 5 years	5	8	3	1	17
6 - 10 years	2	6	6	2	16
11 - 15 years	1	6	1	1	9
16 - 20 years	3	4	3	2	12
More than 20 years	8	0	4	2	14
Totals	19	24	17	9	**69**

Upon analysing the survey results it was determined that the most significant respondent group was 'Practitioner' having 'More than 20 years' experience in land consolidation.

The final question for classification purposes was regarding respondents' country of residence. Based on survey results a map was developed showing the number of international land consolidation experts from each country who had participated in the survey (Figure 4). Responses were obtained from all countries proposed in the survey with the exception of the Republic of Kosovo and Montenegro. The best results, when comparing the number of invitations (4) against responses received (4) was obtained from Lithuania as the authors were able to motivate respondents face-to-face or by phone to share their opinions on the survey. For other countries it was necessary to follow up multiple times in order to get their opinion.

Furthermore, a total of 20 criteria at municipal level and 26 criteria at project area level were provided for international land management experts having knowledge about land consolidation who were initially asked their opinion regarding each criterion regarding the importance of that particular criterion in the evaluation or whether it should be excluded (answers expressed in % **Error! Reference source not found.**2 and **Error! Reference source not found.**3). If the expert considered the criterion to be unimportant, that criterion would be excluded from the evaluation. If the expert decided that the criterion was important and that it indicated a potential for comprehensive land consolidation, then the expert was requested to state whether the value of this criterion should be higher (*Maximize* function) or lower (*Minimize* function). Exceptions may occur, for example the Land Fragmentation Index where the smaller the value shows the higher the degree of land fragmentation which mean that if decision maker prefers areas with higher land fragmentation function *Minimize* has to be used. Intentionally both of these levels (municipal and project area) had an optional text box space where experts were asked to suggest any additional important criteria (with preferred function) that they felt could be added to the list at particular levels which showed the potential for land consolidation.

Table 2: Criteria of importance at **municipal level** according to expert's opinion

	Municipality level				
No.	Criteria	Necessity, Yes/No	%	Function, Min/Max	%
1	Average land fragmentation index	Yes	89.9	Min	72.6
2	Average land parcel size	Yes	87.0	Min	53.3
3	Average distance from farmstead to the fields	Yes	87.0	Min	56.7
4	Number of ongoing infrastructure development projects	Yes	84.1	Max	69.0
5	Average agricultural holding size	Yes	81.2	Max	67.9
6	Average area owned by land fund/bank	Yes	81.2	Max	71.4
7	Number of areas foreseen for rural urbanization	Yes	79.7	Min	56.4

8	Number of prepared local development strategies	Yes	79.7	Max	69.1
9	Number of Local Action Groups	Yes	76.8	Max	58.5
10	Average abandoned land area	Yes	76.8	Max	50.9
11	Average land (soil) productivity score	Yes	72.5	Max	72.0
12	Average area for soil erosion prevention	Yes	72.5	Max	60.0
13	Number of employable people (20-64 age)	Yes	69.6	Max	79.2
14	Average area for natural resource conservation	Yes	69.6	Max	54.2
15	Average area with natural habitats	Yes	69.6	Min	56.2
16	Average area for re-naturalization	Yes	66.7	Max	52.2
17	Number of cultural heritage conservation objects	Yes	63.8	Max	65.9
18	Number of ongoing alternative energy projects	Yes	60.9	Min	52.4
19	Average area for afforestation	Yes	58.0	Min	52.5
20	Average area for re-cultivation	Yes	56.5	Max	74.4

Table 3: Criteria of importance at project area level according to expert's opinion

	Project area level				
No.	Criteria	Necessity, Yes/No	%	Function, Min/Max	%
1	Average parcel size	Yes	89.9	Min	61.3
2	Average land fragmentation index	Yes	88.4	Min	67.2
3	Area in bad drainage/ irrigation infrastructure condition	Yes	87.0	Max	80.0
4	Average distance from farmstead to the fields	Yes	82.6	Max	68.4
5	Area in bad road infrastructure condition	Yes	76.8	Max	73.6
6	Average number of prosperous farmers	Yes	76.8	Max	86.8
7	Number of land tenure constrains	Yes	76.8	Max	50.9
8	Average area owned by land fund/bank	Yes	76.8	Max	71.7
9	Average number of locals	Yes	73.9	Max	94.1
10	Number of objects foreseen for public needs	Yes	73.9	Max	68.6
11	Average agricultural holding size	Yes	72.5	Max	60.0
12	Area foreseen for rural urbanization	Yes	69.6	Min	54.2
13	Abandoned land	Yes	68.1	Max	59.6
14	Average area for soil erosion prevention	Yes	68.1	Max	66.0
15	Employable persons	Yes	66.7	Max	87.0
16	Average soil productivity score	Yes	65.2	Max	77.8
17	Number of eco-farms	No	65.2	-	-
18	Average area for natural resource conservation	Yes	65.2	Max	62.2
19	Average area for re-naturalization	Yes	62.3	Max	62.8
20	Number of land use constrains	Yes	60.9	Min	69.0
21	Average area with natural habitats	Yes	60.9	Max	61.9
22	Average area for re-cultivation	Yes	58.0	Max	67.5
23	Number of abandoned structures	Yes	55.1	Max	71.1
24	Average area for afforestation	Yes	52.2	Max	52.8
25	Number of countryside tourism objects	No	50.7	-	-
26	Number of ongoing/planned alternative energy projects	No	50.7	-	-

4.1. Criteria for selection of projects at municipal level

According to the majority of respondents' opinions all of the 'Criteria for selection of potential regions (municipalities) for comprehensive land consolidation' provided were important and showed the potential for comprehensive land consolidation (**Error! Reference source not found.**2). From the questionnaire results it is possible to identify the five most important criteria at municipal level, which are:

- **Average land fragmentation index**. 89.9% of respondents chose this criterion as the most important and 72.6% of these respondents indicated that a higher land fragmentation revealed a higher potential for land consolidation, which means that the lowest index value is preferred.
- **Average distance from farmstead to the fields**. 87.0% of experts chose this criterion as the second most important. 56.7% of experts suggested that a greater distance from farmstead to the fields shows a higher potential.
- **Average land parcel size**. 87.0% of respondents identified this criterion as the third most important. 53.3% of these experts thought that smaller land parcels showed a higher potential for land consolidation.
- **Number of ongoing infrastructure development projects**. 84.1% of respondents viewed this criterion as the fourth most important criterion. 69.0% of respondents said that municipalities having more ongoing infrastructure development projects have a higher potential for land consolidation than those who have fewer ongoing infrastructure development projects.
- **Average area owned by land fund/bank**. 81.2% of respondents considered that this criterion is an indicator of potential and 71.4% of these deem that a higher potential lies within those municipalities where a land fund/bank has more land. (Note: those countries which don't have land fund / bank but still have state owned agricultural land can play a very important role to increase land mobility and improve the outcome of the re-allotment planning).

It has to be highlighted here that criterion no 5 'Average agricultural holding size' received 81.2% of respondent's vote, but for its lower rate of values preference (67.9% of respondents thought that there was a higher potential for comprehensive land consolidation in those municipalities where the average agricultural holding size was higher) did not appear in the top five of the most important criteria.

The survey results have shown that the most questionable criterion showing the potential for comprehensive land consolidation at regional (municipal) level, according to experts, was concerned with environmental considerations: no 20 'Average area for re-cultivation' (56.5% of all respondents said that this criterion is important). By introducing this criterion, it was assumed that such choice could be done at least by a few transitional countries i.e. Slovakia having practice combining land consolidation together with land re-cultivation (Hudecova, 2015).

The respondents were given the opportunity to suggest that the authors consider the following factors when identifying 'criteria for selection of potential regions (municipalities) for comprehensive land consolidation':

- Although the high land fragmentation (**Error! Reference source not found.**2, criterion no 1) was accorded the highest priority for land consolidation, a minority of respondents (10.1%) chose to dissociate themselves from this conclusion in the open comment section of the survey. These respondents argued in support of using a cost/benefit ratio in that it can provide more predictive information as to what the project can add in improvement (added value) in relation to the added costs (labour + investments) in those improvements;
- It is possible to add as many relevant objectives as are needed although project feasibility may only be assured by including those objectives which provide added value, as some non-priority objectives can be better and faster realised separately from land consolidation;
- A detailed investigation of farmers' income sources and types of agricultural production has to be performed as, for example, dairy farms need more attention than farms focusing on annual crop production, or the production of fruits/berries, etc.;
- Comprehensive land consolidation projects can be very useful, but on the other hand they can be risky as well, since they could become too complicated and take too long to complete. That is why balancing in a tailor-made approach to each project has to be considered;
- A balance has to be struck between agricultural and environmental objectives, since as more nature development or afforestation objectives are added in a land consolidation project, the less interested the farmers become. In addition the enlargement of parcels decreases the perceived attractiveness of the traditional landscape for tourism;

- Land abandonment criteria are not applicable in many Western European countries, but such criteria might be important in other, especially transitional, countries.

One of the experts made a suggestion of using a 'whole area' indicator with many criteria instead of the 'average area', but such an indicator at municipal level does not assure equal rights for municipalities as some of them may be, for example, twice as large as some others. The same situation could apply at the project area level: one project could be dealing with 100 ha, others could exceed 1 000 ha.

Another expert offered the consideration that the average land fragmentation index differs between different countries. This is absolutely correct in that there are the Januszewki index, the Simmons index etc. and recently introduced by Demetriou (2012) the Global Land Fragmentation index, all of which take into account various parameters such as shape, size, ownership etc. These land fragmentation indices all are interpreted in the same manner; the smaller the index value, the higher the degree of land fragmentation. It is accepted that all types of possible land fragmentation index, however, and desires to obtain the experts' opinions as to whether higher or lower fragmentation shows more or less potential for comprehensive land consolidation.

Respondents participating in the survey suggested sixteen additional criteria, five of which were offered by more than one respondent (Table 44).

Table 4: Five supplementary criteria offered by respondents

No.	No. of respondents	Offered criteria	Offered function
1.	5	Percentage of land owners/farmers/communities/local authorities who are in favour of land consolidation.	Max
2.	2	Average area under demand for drainage (re-)construction.	Max
3.	2	Average farmland intensity consumption (ha) for agricultural production.	Max
4.	2	Land mobility/market index (average rate of transactions in the area).	Max
5.	2	Index of agricultural road network density (less density - more need for land consolidation).	Min

Only one notable criterion, revealing acceptance for land consolidation, was recommended by five (7%) respondents as an important factor to consider. A further four criteria, provided here above were offered by two experts, all the others being mentioned only once:

- The index for land consolidation possibilities (average number of parcels that one parcel can be merged with) – Max;
- The average area of the land cultivated by the farmer (without ownership limitation) – Max;
- The frequency of flooding episodes per time interval (i.e. one year) – Max;
- The average number of land owners having emotional bonds with land parcels (i.e. several generations were living in a certain place and that is the reason why the land owner, particularly if older, does not want to move to another place) – Min;
- The funds available for the objective realisation (physical improvements or investment in landscape / nature conservation) – Max;
- The number of linkages with other EU support programmes – Max;
- The average number of land owners who do not have valid land ownership documentation – Min;
- The index of agricultural intensity – Max;
- The concentrations of nitrates and pesticides in water (surface and underground) – Max;
- The average area envisaged in which to create buffer strips (i.e.. hedgerows) – Max;
- The proportion of established young farmers – Max;

4.2. Criteria for selection of project area level

Furthermore in the questionnaire some twenty six questions with possible 'criteria to choose (rank) projects for implementation from all applications for comprehensive land consolidation' were provided to the same experts. According to the questionnaire results (**Error! Reference source not found.**3), a majority of respondents identified 3 criteria as of no importance at all when defining potential at project area level:

- The number of countryside tourism objects;
- The number of eco-farms;
- The number of ongoing/planned alternative energy projects.

Following the analysis of the survey results it is possible to identify the five most important criteria at project area level:

- **Average land parcel size**. 89.9% of respondents identified this criterion as the most important. 61.3% of these experts think that smaller land parcels show higher potential for land consolidation;
- **Average land fragmentation index**. 88.4% of respondents chose this criterion as the second most important and 67.2% of these respondents said that higher land fragmentation shows higher potential for land consolidation, which means that lowest index values are preferred;
- **Area in bad drainage/ irrigation infrastructure condition.** 87.0% of experts chose this criterion as the third most important and 80.0% of these experts thought that larger areas in bad drainage/ irrigation infrastructure condition showed higher potential;
- **Average distance from farmstead to the fields**. 82.6% of experts chose this criterion as the fourth most important. 68.4% of them suggested that the further the distance from farmstead to the fields, the higher the potential;
- **Average number of prosperous farmers.** 76.8% of respondents defined this criterion as falling into the fifth position. Actually, there were three other criteria with the same score, but this criterion had a significant score (86.8%) among other respondents who thought that a higher number of prosperous farmers showed higher potential for comprehensive land consolidation.

Three other criteria, which received the same importance score (76.8%) after respondents' data analysis were:

- Area with poor conditions of road infrastructure (73.6% gave priority to larger areas);
- Average area owned by the land fund/ bank (71.7% gave priority to more land);
- Number of land tenure constraints (50.9% gave priority to more constraints).

The criterion 'Area in bad drainage/ irrigation infrastructure condition' appears in position no 3 in the list of the top five most important criteria at project area level. This confirms the importance of the FAO (2012) statement – that the restructuring of farms during land consolidation projects should be integrated with support programmes for farmers, such as the rehabilitation of irrigation systems and local roads.

The analysis of the survey data showed that, according to the experts, the most questionable criterion indicating the potential for comprehensive land consolidation at project area level was related to environmental considerations, 'Average area for afforestation' (with only 52.2% of all respondents agreeing that this criterion was important). In addition respondents used the opportunity to share their opinion with regard to elements to consider at project area level:

- When taking into account 'distance from farmstead to the fields' it is necessary to consider rural planning identity as Central and Eastern European (CEE) countries structure varies from Western European (WE) countries. In many CEE countries farmers live in villages which may be distant from the fields, whereas in many WE countries the farms tend to be located within or adjacent to the fields that they work;
- It is important to consider the existing drainage network when planning and building infrastructure and housing in order to assure the normal functioning of existing systems;
- It is necessary to consider other EU funded projects in the subject area in order to assure synergy between the realization of objectives;
- If farm sizes are very small, the land consolidation project might be ineffective because it can be a sign that people are already leaving the land. If farm sizes are too large the land consolidation project may also be ineffective because such farms can achieve their own land consolidation by economic means without any help from the land consolidation project.

The survey participants suggested that some of the criteria used at municipal level should be considered for use at project area level as well, namely those focused on 'the percentage of land owners/farmers/communities/local authorities who are in favour of land consolidation'. However, data of who is in favour is not available at the time when the MCDA is conducted, but only after the first phase of the land consolidation project actual implementation, when all landowners are interviewed (outcome of the feasibility study / first phase of the land consolidation project).

The criteria for municipality level could be reused for regions, counties, elderships or cadastral municipalities level. Identified criteria (municipal and project area level) are advisory in nature and can be changed or supplemented by necessary additional criteria and according to Haldrup and Hartvigsen (2005), the final selection of the project site(s) cannot be based on quantitative methods alone, but will have to be based on the 'best feeling' among the decision makers.

5. Ranking and prioritising of land consolidation areas by applying MCDA: a case study

In order to demonstrate the developed framework for raking and prioritising of potential areas for land consolidation, the case study was conducted. WSM method was used for MCDA as described in Materials and methods. Klaipeda region including seventeen district municipalities (Figure 5, Table 4) was selected for the analysis due to greatest demand for land consolidation projects at the national level. Despite a number of other criteria identified by international experts as important and used for developing general framework to rank and prioritise of areas for land consolidation at the municipal level, six criteria were applied in this case study. The selection of criteria was directly solicited by local authority of the district and following criteria were used for MCDA analysis: 1) average holding size, ha; 2) abandoned agricultural land, ha; 3) average soil fertility index; 4) number of employable people (20-64 age); 5) number of local action groups; 6) average land parcel size, ha (Table 4).

Table 4: Criteria and calculated weights at municipal level (selected municipalities)

Municipalities	**Average holding size, ha**	**Abandoned agricultural land, ha**	**Average soil fertility index**	**Number of employable people (20-64 age)**	**Number of Local Action Groups**	**Average land parcel size, ha**	**WSM score**
Klaipėda distr.	5.81	4.83	39.3	61.04	69	1.29	**0.805793703**
Telšiai distr.	20.47	6.21	38	58.16	31	3.12	**0.757652223**
Raseiniai distr.	13.99	2.96	42.4	57.42	61	2.66	**0.714786887**
Šiauliai distr.	9.78	3.36	45.3	59.32	60	2.6	**0.703836918**
Tauragė distr.	10.35	6.06	37.9	59.22	33	2.59	**0.690655351**
Kelmė distr.	11.26	4.32	37.5	56.94	45	3.07	**0.660445392**
Plungė distr.	9.48	6.27	35.3	58.24	24	2.74	**0.650977671**
Šilalė distr.	8.38	4.7	36.9	57.83	38	2.51	**0.645776212**
Pagėgiai distr.	19.44	3.38	34.4	58.7	20	3.3	**0.630587161**
Akmenė distr.	14.28	2.48	47.6	57.1	31	3.24	**0.630274534**
Mažeikiai distr.	8.85	2.78	43.5	61.13	36	2.56	**0.620500147**
Šakiai distr.	10.1	1.66	48.8	56.43	41	2.73	**0.61308229**
Šilutė distr.	8.19	3.12	35.2	59.01	43	2.78	**0.602499366**
Jurbarkas distr.	10.47	1.94	48.1	57.55	36	3.39	**0.595738232**
Kretinga distr.	8.38	2.03	39.6	58.73	33	2.07	**0.591017485**
Skuodas distr.	10.13	2.22	40.2	57.4	26	2.52	**0.572585106**
Rietavo distr.	10.28	4.91	36.3	58.09	12	3.99	**0.567965806**
Applied function	**MAX**	**MAX**	**MAX**	**MAX**	**MAX**	**MIN**	-
Weights	**0.172**	**0.17**	**0.158**	**0.152**	**0.172**	**0.175**	-
Sum of weights	**0.999**						-

Concordation coefficient W=0.01. Condition W > 0 approved

The MCDA analysis showed that Klaipėda district municipality has the highest potential for land consolidation (WSM score of 0.8058). Other district municipalities ranked in top five list were Telšiai, Raseiniai, Šiauliai and Tauragė.

Based on these ranking results the land management authorities will be able to initiate an active complain amongst landowners to stimulate their participation in land consolidation project.

Application of the decision making framework enabled to develop a map (Figure 5), which helps to provide further guidance for marketing campaign, planning and project screening. With the help of such maps, the local authorities will be equipped to make decisions on selection of the prospective project areas and funding allocations. In addition the comprehensive project site investigation might be performed since the success of the land consolidation project is directly related to the detailed examination of the project area as stipulated previously (Pašakarnis et al., 2013a; 2013b).

6. Conclusions

Land consolidation is of high political importance in most of the transitional countries and is under pressure of time (Dixon-Gough, 2006). To fulfil these demands, land consolidation must be achieved in the shortest possible time, and be economically feasible.

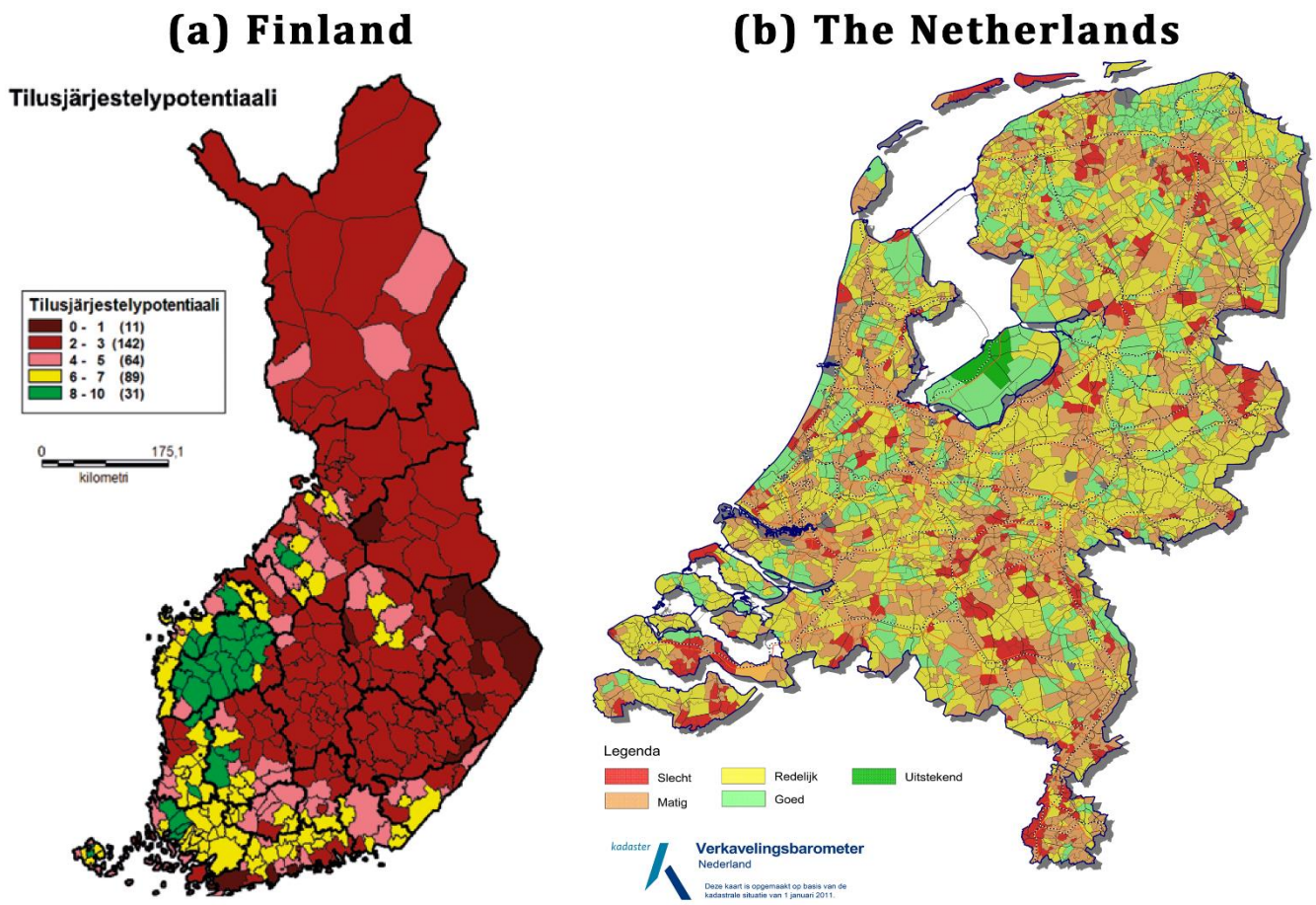
Land consolidation projects deal with many alternatives (for example the exchange of land parcels between participants, public facility allocation, land use suitability analysis etc.), in many different situations where MCDA could be applied very effectively. This should be applied even from the very start – at the project initiation stage. It was noted that the FAO has paid attention to selection of pilot land consolidation projects and has prepared recommendations with criteria identifying the potential areas for pilot projects implementation. The international practice, particularly in Finland and Netherlands, shows that the assistance with the identification of potential land consolidation areas is welcomed by both the authorities and land owners/users. It encourages the bottom-up approach in the decision making and initiating land consolidation projects. There are early attempts in the Balkan countries such as Croatia and North Macedonia to apply practices utilising MCDA methodologies to assist the land consolidation process.

Having a clear research problem (to identify territorial potential for comprehensive land consolidation) and spatial alternatives (municipalities/regions and project areas) a decision maker has to define precisely relevant criteria. A set of criteria showing the potential for comprehensive land consolidation at different scales were established using a combination of literature review and feedback from the international experts. The research has revealed that five most important criteria showing the potential for the comprehensive land consolidation at municipal level are: 1) the average land fragmentation index; 2) the average distance from farmstead to the fields; 3) the average land parcel size; 4) the number of ongoing infrastructure development projects; and 5) the average area owned by land fund/bank. According to the sixty-nine land management experts who have participated in the survey - the five most important criteria at project area level are: 1) the average land parcel size; 2) the average land fragmentation index; 3) the area in bad drainage/ irrigation infrastructure condition; 4) the average distance from farmstead to the fields; and 5) the average number of prosperous farmers.

The proposed decision making framework is applied in the case study at the municipal level enabling to rank and prioritise potential land consolidation areas in Klaipeda region. This demonstrated that developed methodology can assist land management authorities and political decision makers in their quest for a transparent procedure - efficient management of resources, feasibility evaluation, fair financial support allocation, areas for pilot projects identification etc. Cadastral enterprises, academia, research institutes, consultants in every country could work on Land Fragmentation Index, road network, slope index and other data (especially having spatial context) development. European countries, especially receiving EU support for land consolidation, should enrich their national land consolidation strategies with developed countrywide (at municipal or regional scale) maps showing the areas having the highest potential for land consolidation. Digital maps should be hosted and regularly updated at governmental land databanks and publicly accessible through OpenData portals in order to assure transparency, decision-making and influence bottom-up initiatives since consultants, academia, landowners, and all the involved public authorities will have access to the reliable spatial data.

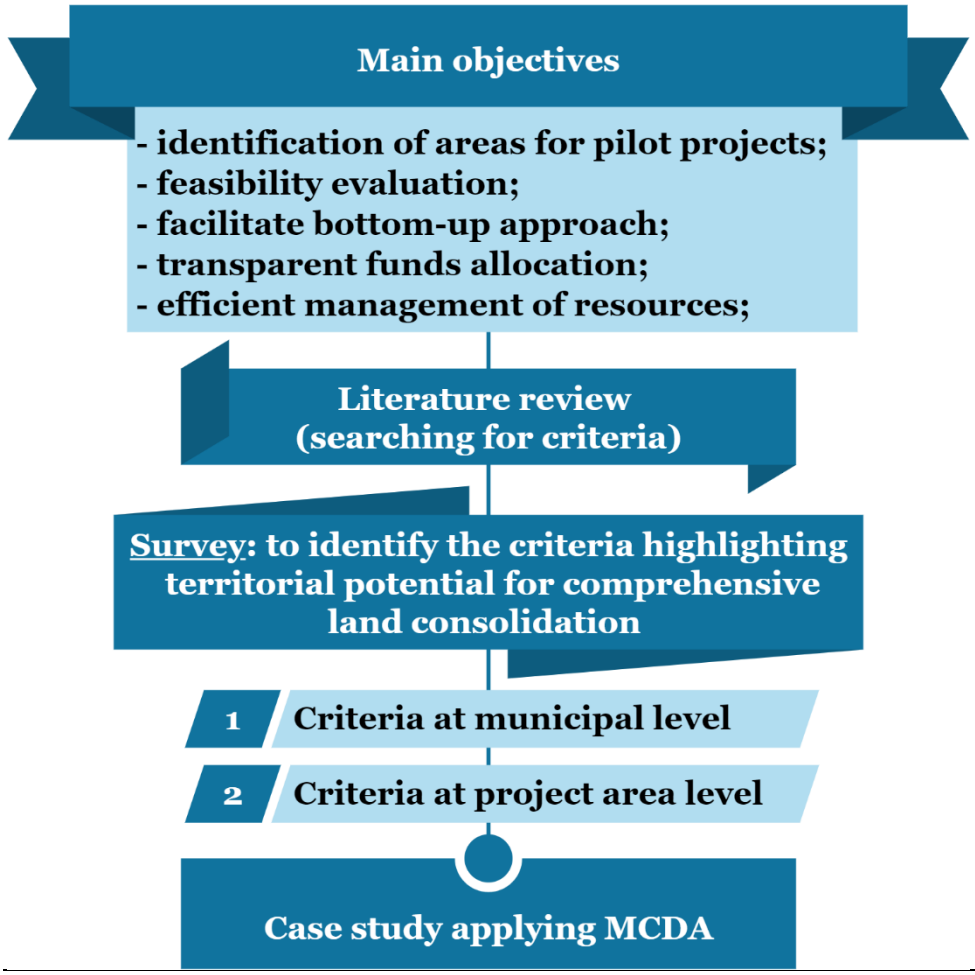
Figures

Figure 1: Country maps showing the potential for land consolidation



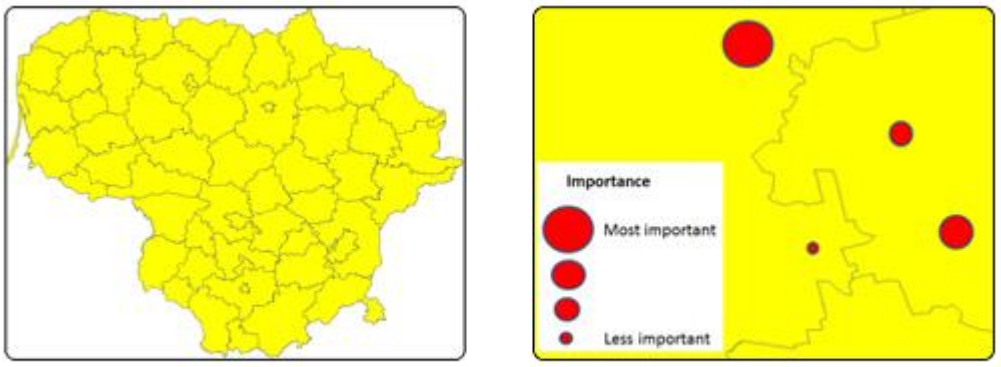
Source: (Hiironen and Ettanen, 2013, p. 29; Kadaster, 2011)

Figure 2: Principal stages of the research



Source: Self study

Figure 3: Structure of criteria significance

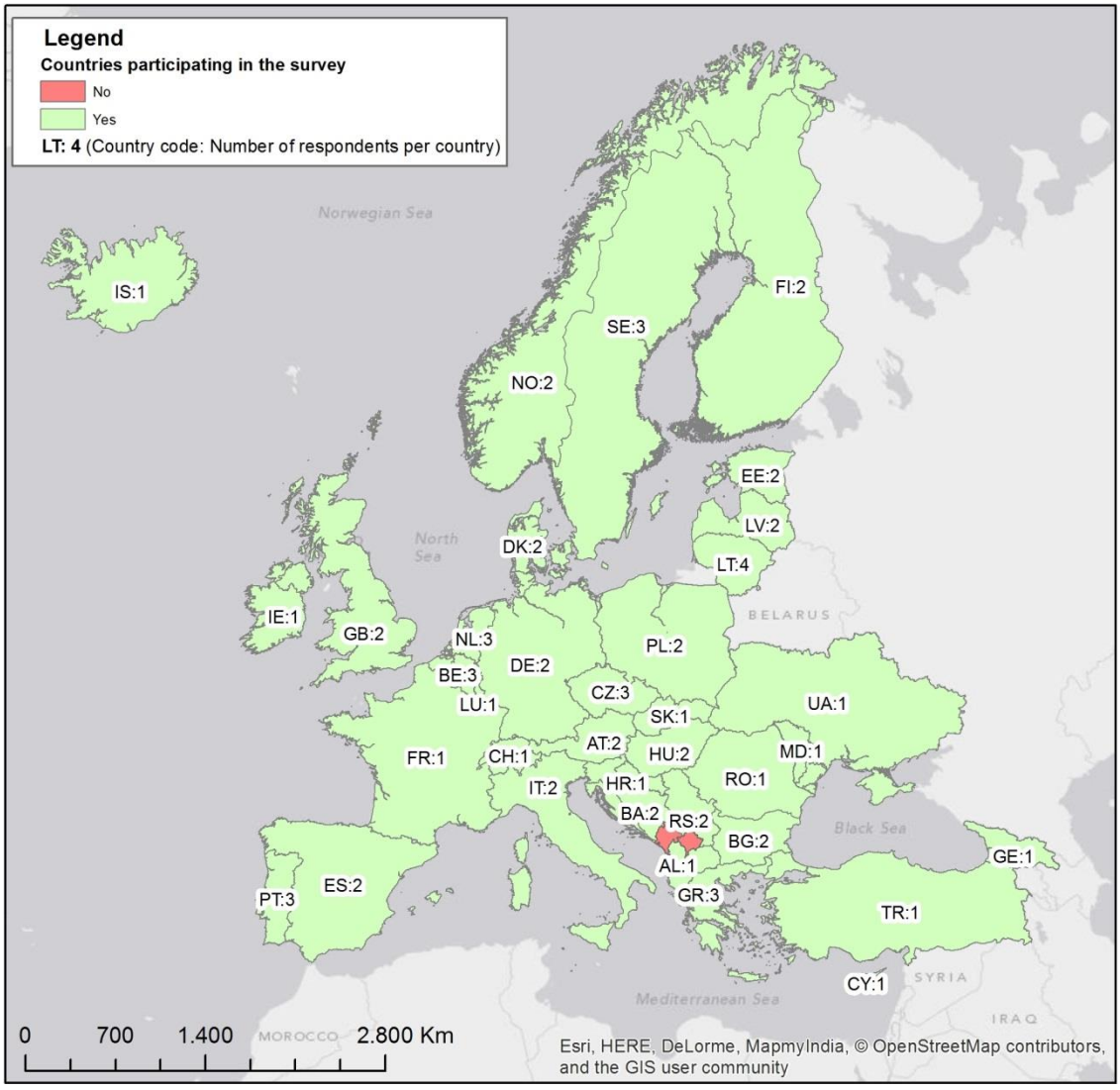


LAU1 (municipalities) level

Project area level

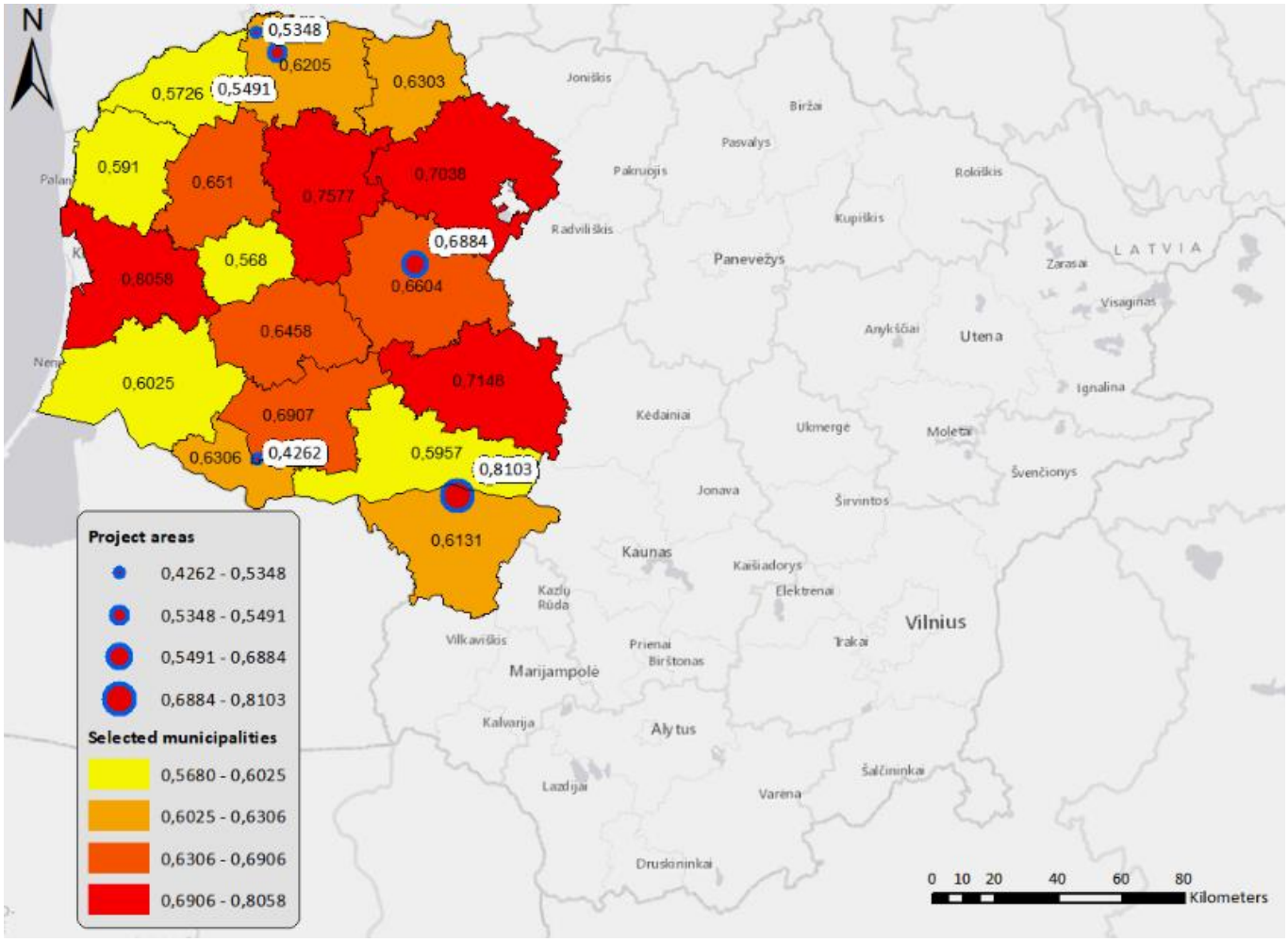
Source: Self study

Figure 4: Map showing country experts invited and who responded in the survey



Source: Self study

Figure 5: Map of Western part of Lithuania where district municipalities and project areas were ranked according to the selected criteria



Source: Self study

References

Aleknavičius, A., Liaskovskaja, J., 2011. Priorities of the public interest while executing the Land Reform during 1991-2008, in: Hepperle, E., Dixon-Gough, R., Kalbro, T., Mansberge, R., Meyer-Cech, K. (Eds.), Core Themes of Land Use Politics: Sustainability and Balance of Interests. vdf Hochschulverlag and der ETH Zurich, Zurich, pp. 121–134.

Beinat, E., 1997. Value Functions for Environmental Management, Environmen. ed. Springer-Science+Business Media, B.V.

Beinat, E., Nijkamp, P., 1998. Multicriteria analysis for land-use management, Environment & management. Springer Science & Business Media. https://doi.org/10.1007/978-94-015-9058-7

Cay, T., Uyan, M., 2013. Evaluation of reallocation criteria in land consolidation studies using the Analytic Hierarchy Process (AHP). Land use policy 30, 541–548. https://doi.org/10.1016/j.landusepol.2012.04.023

Daugalienė, V., 2018. Mainstreaming of the National Land Consolidation Programme (MAINLAND).

Demetriou, D., 2012. The Development of an Integrated Planning and Decision Support System (IPDSS) for Land Consolidation. University of Leeds.

Dixon-Gough, R., 2006. The Role of the State and Individual in Sustainable Land Management, in: Dixon-Gough, R., Bloch, P.C. (Eds.), The Role of the State and Individual in Sustainable Land Management. Ashgate Publishing, Ltd., Aldershot, pp. 159–176.

Du, X., Zhang, X., Jin, X., 2018. Assessing the effectiveness of land consolidation for improving agricultural productivity in China. Land use policy 70, 360–367. https://doi.org/10.1016/j.landusepol.2017.10.051

Dudzińska, M., Bacior, S., Prus, B., 2018. Considering the level of socio-economic development of rural areas in the context of infrastructural and traditional consolidations in Poland. Land use policy 79, 759–773. https://doi.org/10.1016/j.landusepol.2018.09.015

FAO, 2018. Twelve Macedonian sites selected for land consolidation [WWW Document]. URL http://www.fao.org/europe/news/detail-news/en/c/1106193/ (accessed 3.14.18).

FAO, 2012. Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security. Rome.

FAO, 2003. FAO LAND TENURE STUDIES 6. The Design of Land Consolidation Pilot Projects in Central and Eastern Europe. Rome.

Fishburn, P.C., 1967. Additive Utilities with Incomplete Product Set: Applications to Priorities and Assignments. Baltimore, U.S.A.

Haldrup, N.O., Hartvigsen, M., 2005. Getting Land Consolidation Pilot Projects going, in: Territorial Organization and Land Consolidation in the EU: The Way Ahead. Prague, p. 11.

Hall, P., Tewdwr-Jones, M., 2011. Urban and Regional Planning, 5th Editio. ed. Routledge, Oxon.

Hartvigsen, M., 2014. Land reform and land fragmentation in Central and Eastern Europe. Land use policy 36, 330–341. https://doi.org/http://dx.doi.org/10.1016/j.landusepol.2013.08.016

Hiironen, J., Ettanen, S., 2013. Peltoalueiden tilusrakenne ja sen parantamismahdollisuudet. Helsinki.

Hudecova, L., 2015. The Effectiveness of Land Consolidation in Slovakia, in: FIG Working Week 2015. FIG, Sofia, Bulgaria, p. 13.

Ishizaka, A., Nemery, P., 2013. Multi-criteria Decision Analysis: Methods and Software. John Wiley & Sons, Ltd.

Jansen, J.M.L., 2013. Explanatory email.

Janus, J., Markuszewska, I., 2017. Land consolidation – A great need to improve effectiveness. A case study from Poland. Land use policy 65, 143–153. https://doi.org/10.1016/j.landusepol.2017.03.028

Johansen, P.H., Ejrnæs, R., Kronvang, B., Olsen, J.V., Præstholm, S., Schou, J.S., 2018. Pursuing collective impact: A novel indicator-based approach to assessment of shared measurements when planning for multifunctional land consolidation. Land use policy 73, 102–114. https://doi.org/10.1016/j.landusepol.2018.01.040

Jürgenson, E., 2016. Land reform, land fragmentation and perspectives for future land consolidation in Estonia. Land use policy 57, 34–43. https://doi.org/10.1016/j.landusepol.2016.04.030

Kadaster, 2016. Can you solve our spatial problems? Play Move a lot! [WWW Document]. URL https://www.kadaster.com/-/can-you-solve-our-spatial-problems-play-move-a-lot- (accessed 12.20.16).

Kadaster, 2011. Verkavelingsbarometer.

Kao, C., 2010. Weight determination for consistently ranking alternatives in multiple criteria decision analysis. Appl. Math. Model. 34, 1779–1787. https://doi.org/10.1016/j.apm.2009.09.022

Keeney, R.L., Raiffa, H., 1976. Decisions with multiple objectives: Preferences and value tradeoffs. Wiley, New York.

Konttinen, K., 2013. Explanatory email.

Kučas, A., 2010. Location prioritization by means of multicriteria spatial decision support systems: A case study of forest fragmentation based ranking of forest administrative areas. J. Environ. Eng. Landsc. Manag. 18, 312–320. https://doi.org/10.3846/jeelm.2010.36

Lisec, A., Cerjak, M., Pintar, M., 2005. The influence of the land consolidation on the ecological elements in the rural landscape, in: Cygas, D., Froehner, K.D. (Eds.), The 6th International Conference “Environmental Engineering.” Vilnius Gediminas Technical University Press “Technika,” Vilnius, pp. 164–170.

Louwsma, M., van Beek, M., Hoeve, B., 2014. A New Approach: Participatory Land Consolidation, in: FIG Congress 2014. Engaging the Challenges - Enhancing the Relevance. Kuala Lumpur, pp. 1–10.

Malczewski, J., 1999. GIS and Multicriteria Decision Analysis. John Wiley & Sons.

Mika, M., Leń, P., Oleniacz, G., Kurowska, K., 2019. Study of the effects of applying a new algorithm for the comprehensive programming of the hierarchization of land consolidation and exchange works in Poland. Land use policy 88, 1–8. https://doi.org/10.1016/j.landusepol.2019.104182

Muchová, Z., Petrovič, F., 2019. Prioritization and Evaluation of Land Consolidation Projects—Žitava River Basin in a Slovakian Case. Sustainability 11, 2041. https://doi.org/10.3390/su11072041

Mulliner, E., Malys, N., Maliene, V., 2016. Comparative analysis of MCDM methods for the assessment of sustainable housing affordability. Omega 59, 146–156. https://doi.org/http://doi.org/10.1016/j.omega.2015.05.013

Munda, G., Parruccini, M., Rossi, G., 1998. Multicriteria evaluation methods in renewable resource management: integrated water management under drought conditions, in: Beinat, E., Nijkamp, P. (Eds.), Multicriteria Analysis for Land-Use Management. Springer Science & Business Media, pp. 79–93. https://doi.org/10.1007/978-94-015-9058-7

Munnangi, A.K., Lohani, B., Misra, S.C., 2020. A review of land consolidation in the state of Uttar Pradesh, India: Qualitative

approach. Land use policy 90, 1–12. https://doi.org/10.1016/j.landusepol.2019.104309

Pašakarnis, G., Malienė, V., 2010. Towards sustainable rural development in Central and Eastern Europe: applying land consolidation. Land Use Policy 27, 545-549.

Pašakarnis, G., Morley, D., Malienė, V., 2013a. Rural development and challenges establishing sustainable land use in Eastern European countries. Land Use Policy 30, 703-710.

Pašakarnis, G., Morley, D., Malienė, V., 2013b. Factors Influencing Land Consolidation Success: Lessons Learned in Lithuania, in: Hepperle, E., Dixon-Gough, R., Malienė, V., Mansberger, R., Paulsson, J., Pödör, A. (Eds.), 1st International and Interdisciplinary Symposium "Sustainability:Focus on Urban and Peri-Urban Development." vdf Hochschulverlag, Liverpool, pp. 121–131. https://doi.org/10.3218/3480-6

Sklenicka, P., 2006. Applying evaluation criteria for the land consolidation effect to three contrasting study areas in the Czech Republic. Land use policy 23, 502–510. https://doi.org/10.1016/j.landusepol.2005.03.001

Thomas, J., 2006. Property rights, land fragmentation and the emerging structure of agriculture in Central and Eastern European countries. J. Agric. Dev. Econ. 3, 225–275.

Tomić, H., Roić, M., Siniša, M.I., Mičević, B., Jurakić, G., 2016. Use of Multi-Criteria Analysis for the Ranking of Land Consolidation Areas, in: The Symposium on Land Consolidation and Land Readjustment for Sustainable Development. Apeldoorn, p. 12.

Triantaphyllou, E., 2000. Multi-Criteria Decision Making Methods: A Comparative Study, Volume 44. ed. Springer Science + Business Media B.V. https://doi.org/10.1007/978-1-4757-3157-6

United Nations General Assembly, 2015. Transforming our world: the 2030 Agenda for Sustainable Development.

Van Dijk, T., 2007. Complications for traditional land consolidation in Central Europe. Geoforum 38, 505–511. https://doi.org/10.1016/j.geoforum.2006.11.010

Van Dijk, T., 2004. Wanted: alternatives for program-driven land consolidation, in: Symposium on Modern Land Consolidation. Volvic (Clermont-Ferrand).

Van Dijk, T., 2003a. Dealing with Central European Land Fragmentation: A Critical Assessment on the Use of Western instruments, Land Use Policy. Eburon, Delft. https://doi.org/10.1016/S0264-8377(02)00082-0

Van Dijk, T., 2003b. Scenarios of Central European land fragmentation. Land use policy 20, 149–158.

Van Huylenbroeck, G., Coelho, J.C., Pinto, P.A., 1996. Evaluation Of Land Consolidation Projects (LCPs): A Multidisciplinary Approach. J. Rural Stud. 12, 297–310. https://doi.org/10.1016/0743-0167(96)00024-1

Wójcik-Leń, J., Postek, P., Stręk, Ż., Leń, P., 2020. Proposed algorithm for the identification of land for consolidation with regard to spatial variability of soil quality. Land use policy 94, 1–6. https://doi.org/https://doi.org/10.1016/j.landusepol.2020.104570

Zeleny, M., 1982. Multiple Criteria Decision Making. McGraw-Hill, New York.

Zhou, Y., Li, Y., Xu, C., 2020. Land consolidation and rural revitalization in China: Mechanisms and paths. Land use policy 91, 1–13. https://doi.org/10.1016/j.landusepol.2019.104379