



Decision Making in Water Resource Management from the Aspect of Land Consolidation Process [†]

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Abstract

Land consolidation is related to the agricultural land defragmentation and to improvement of agricultural production. The process of land consolidation encompasses a wide scale of changes including possibilities of irrigation system building and/or improvement. The process of competing land consolidation project (LCP) choice relates to adopting criteria and their values, and aiming to determine the LCP rank, i.e., its priority. In this research the influences of different criteria were investigated in combination with different approaches related to irrigation system building or risks they could cause. Four methods for decision making were applied (AHP, TOPSIS, VIKOR and SAW) when considering the simulated values of irrigation system and risk they could be burdened with.

Keywords: multicriteria decision making; AHP; TOPSIS; VIKOR; SAW; irrigation system

1. Introduction

Land consolidation projects (LCPs) are considered as costly rural development actions and often are questioned [1]. According to newer approaches land consolidation is moving in the directions of multi-objective and multi-functional transformation [2]. These statement shows that land consolidation projects should be chosen after very careful analysis, stressing their cost and complexity, which always raises the question: “Could we better invest the limited amount of money?” An additional complexity related to the LCPs is the fact that there are numerous stakeholders involved in LC projects, including authorities, landowners and investors. Furthermore, LCP must be realized under the legal framework. Those facts are considerably limiting the freedom in the LCP choice especially bearing in mind limited budgets, which implies the choice between LCPs involves competing for resources.

Considering the decision making in the situation of complexity related to LCP choice, it immediately follows that the criteria for LCP ranking should include a set of parameters which are fitted with the main goals of LCPs. Those parameters must be linked with the improvement of agricultural production: its efficiency, cost reduction, increasing yield and decrease the period of return on investment. The efficiency of agricultural production is related to increase in plot area, reduced costs of agricultural mechanization transportation (which could be achieved by adequate road network design) and improvement of irrigation systems.

The domain of water resource management is researched in relation with land consolidation. Among the main contributions of LCP realization considered are the flood



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protection measures, systemic design linked to hydrological and melioration systems facilitates for water retention and lag of the runoff [3]. According to Muchová et al., 2016, new options and strategies could be applied in the case of land consolidation applications to protect and develop the rural region and to highlight the chief problems in water management aiming to eliminate flood conditions [4]. Utilization of LCPs could reduce the negative effects of extreme rainfall [5]. Adequate implementation of LCPs in the domain of irrigation systems might help in optimal water availability calculation in the critical periods of water scarcity [6]. Concluding about the importance of water management in the process of LCP choice, it immediately follows that those criteria must be involved and properly evaluated.

Bearing in mind the multi-functionality and multi-objectivity of LCPs, it immediately follows that the evaluation of criteria in LCP ranking in the process of multicriteria decision making analysis (MCDMA) must be conducted very carefully and comprehensively. This means that the criteria must represent the main characteristics of the state of the art in the field, stakeholders must be included in the process of decision making and adequate decision-making methods should be applied.

2. Materials and Methods

Materials for this research are based on the data for cadastral municipalities belonging to the municipality of Bela Crkva located in the Vojvodina region, the Republic of Serbia. The criteria are chosen to fit the goals of this research, i.e., some criteria and values were adopted from previous research and additional criteria were introduced with randomly chosen values related to hydrological characteristics, hydrological risks and benefits associated. The method for data is based on previous research related to the LCP ranking methodology proposed in references [7–10].

Figure 1 shows the investigated area which encompasses the central east part of Vojvodina (Zrenjanin municipality). Approximate coordinates of the considered area (latitude and longitude) are: $\varphi = 45^{\circ}22'$; $\lambda = 20^{\circ}24'$.

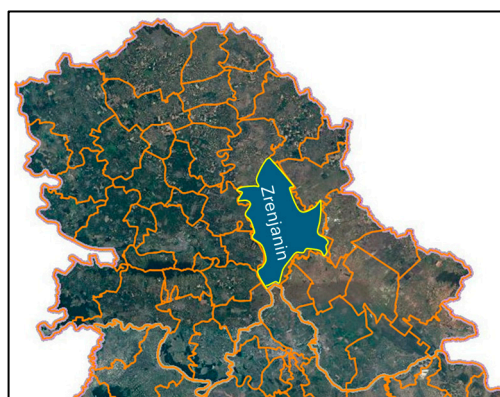


Figure 1. The area of investigation.

The active hierarchy process (AHP) [11–13] method was utilized for decision making in prioritizing the land consolidation projects when the existing hydrology is included in the set of criteria. The values of the first six criteria were adopted from the before-provided research [9] for the municipality of Zrenjanin but for the other four criteria the values were adopted approximately without in-depth research of their real values. This approach is provided with intention to determine the influence of irrigation systems in LCP Ranking. The analysis was provided by comparing the ranks with excluded hydrography criteria and with included hydrography criteria in the decision-making model. Firstly, the set of criteria without the hydrographical criteria were researched and after that the research with

included hydrographical criteria were provided. In this research the simulated set consists of 20 decision makers who weight the criteria randomly (actually, decision makers were simulated by random function).

The set without hydrographical criteria read as follows:

- (f1) The share of agricultural land in the total land consolidation area;
- (f2) The average surface area of the cadastral parcels for each land consolidation area;
- (f3) The average number of cadastral parcels per participant;
- (f4) The average surface area of each participant's property;
- (f5) The percentage of farmers owning property larger than 5 ha;
- (f6) The share of state property out of the total agricultural land;
- (f7) The active agricultural population;
- (f8) The cost of the land consolidation project;
- (f9) The state of surveying;
- (f10) The area of state property land leased (%—percentage of total area).

The set with hydrographical criteria read as follows:

- (f1) The share of agricultural land in the total land consolidation area;
- (f2) The average surface area of the cadastral parcels for each land consolidation area;
- (f3) The average number of cadastral parcels per participant;
- (f4) The average surface area of each participant's property;
- (f5) The percentage of farmers owning property larger than 5 ha;
- (f6) The share of state property out of the total agricultural land;
- (f7) The distance from nearest irrigation system;
- (f8) The cost of irrigation system per km length;
- (f9) Flood and drought risk reduction by irrigation system;
- (f10) Risks of irrigation system (nitrate leaching and pesticides).

3. Results and Discussions

In this research different scenarios were analyzed but only one is presented here. The presented scenario encompasses two cases: firstly, the set of criteria without hydrographical characteristics were considered and secondly, four criteria from the first set were excluded and four criteria related to hydrography were introduced. Table 1 contains the data for the first set and Table 2 contains the data for the second set of criteria.

Table 1. Criteria values for competing LCPs (without hydrology) ¹.

Criterion	f ₁	f ₂	f ₃	f ₄	f ₅	f ₆	f ₇	f ₈	f ₉	f ₁₀
Unit	%	ha/plot	plot/LN	ha/LN	%	%	%	e/ha	N.br.	%
Goal	Max	Min	Max	Max	Max	Max	Max	Min	Min	Max
800945	83.39	1.25	3.83	4.79	6.45	18.75	55.20	141.8	3	98.70
805548	82.43	1.06	2.22	2.36	2.37	46.08	45.54	133.1	1	59.04
805530	82.69	0.70	2.60	1.81	5.95	12.75	52.94	139.6	3	30.10
805556	64.39	0.73	5.22	3.79	8.19	41.12	77.61	138.2	3	46.52
805564	87.72	1.27	2.47	3.13	2.43	26.76	42.81	138.9	3	97.91
805599	90.33	1.78	3.25	5.78	3.32	36.69	51.05	135.6	3	97.93
805602	90.58	1.19	2.95	3.50	6.40	13.36	48.42	138.4	3	46.06
805645	91.70	0.97	2.73	2.65	8.47	27.69	81.24	133.8	3	85.02
802760	82.74	0.72	4.07	2.92	9.92	19.19	69.86	138.3	1	63.44
805696	50.86	0.62	5.24	3.24	4.12	51.49	60.07	135.7	3	60.31

Table 1. Cont.

Criterion	f ₁	f ₂	f ₃	f ₄	f ₅	f ₆	f ₇	f ₈	f ₉	f ₁₀
Unit	%	ha/plot	plot/LN	ha/LN	%	%	%	e/ha	N.br.	%
Goal	Max	Min	Max	Max	Max	Max	Max	Min	Min	Max
805491	63.02	0.69	4.32	2.96	5.43	38.36	56.93	142.0	3	44.84
805700	49.52	0.71	4.68	3.33	9.60	29.66	44.73	147.2	1	48.77
805718	75.81	1.53	2.27	3.47	5.54	36.18	55.73	137.5	3	58.89
805726	41.87	0.59	8.54	5.00	6.58	55.82	77.42	140.0	1	85.27
800643	74.28	0.84	4.44	3.74	11.63	26.74	74.44	139.7	1	33.69

¹ Data are obtained from the geodetic authority.

Table 2. Criteria values for competing LCPs (with hydrology) ¹.

Criterion	f ₁	f ₂	f ₃	f ₄	f ₅	f ₆	f ₇	f ₈	f ₉	f ₁₀
Unit	%	ha/plot	plot/LN	ha/LN	%	%	%	e/ha	N.br.	%
Goal	Max	Min	Max	Max	Max	Max	Max	Min	Min	Max
800945	83.39	1.25	3.83	4.79	6.45	18.75	2.00	0.80	0.30	0.71
805548	82.43	1.06	2.22	2.36	2.37	46.08	1.50	1.00	0.25	0.40
805530	82.69	0.70	2.60	1.81	5.95	12.75	3.20	0.60	0.15	0.92
805556	64.39	0.73	5.22	3.79	8.19	41.12	4.00	1.10	0.43	0.23
805564	87.72	1.27	2.47	3.13	2.43	26.76	2.50	0.90	0.18	0.07
805599	90.33	1.78	3.25	5.78	3.32	36.69	2.20	1.30	0.22	0.21
805602	90.58	1.19	2.95	3.50	6.40	13.36	5.00	0.70	0.31	1.00
805645	91.70	0.97	2.73	2.65	8.47	27.69	3.40	0.60	0.29	0.82
802760	82.74	0.72	4.07	2.92	9.92	19.19	4.80	0.75	0.36	0.29
805696	50.86	0.62	5.24	3.24	4.12	51.49	2.20	0.95	0.18	0.54
805491	63.02	0.69	4.32	2.96	5.43	38.36	7.30	0.60	0.10	0.81
805700	49.52	0.71	4.68	3.33	9.60	29.66	3.50	1.00	0.35	0.74
805718	75.81	1.53	2.27	3.47	5.54	36.18	1.30	0.90	0.25	0.57
805726	41.87	0.59	8.54	5.00	6.58	55.82	4.00	0.55	0.19	0.68
800643	74.28	0.84	4.44	3.74	11.63	26.74	1.80	1.00	0.21	0.45

¹ Data for the first six criteria (f₁–f₆) are adopted from the previous table and other four (f₇–f₁₀) were simulated. LN—certificate of title.

Applying the AHP method on given data in Tables 1 and 2, the following priority ranks of alternatives were obtained as given in Table 3. Statistical hypothesis testing relates to the equality of average ranks obtained by the 20 different decision makers in the cases when hydrology was excluded and included. Student's *t*-test was applied for testing equality of ranks with and without hydrology included (degrees of freedom equal 19 at the significance level $\alpha = 0.05$). The critical value for *t*-statistics equals to 2.0930.

The obtained results suggest that in most cases hydrology could significantly change the priorities of LCPs when hydrological parameters were included into the MCDM in the process of LCP prioritization. It is also noticeable that the root mean square deviations of ranks are significantly greater in the case when the set of hydrological criteria is included into the decision-making process.

These results imply that, in the process of decision making it is necessary to include all parameters which could affect the prioritization of available resources proper distribution. This result also implies that expertise is necessary in the process of criteria choice.

The limitation of this research is that simulated and real data were combined in the second case (when the hydrology is included). This means that, if the data were determined on the higher level of accuracy, obtained results could change. Furthermore,

the subjective approach of every decision maker (in phase of weights choice) could influence the LCPs' prioritization.

Table 3. LCP ranks (priority).

Case	Without Hydrology		With Hydrology		Average Rank		Statistics	H
Alternative	Rank	m_R	Rank	m_R	Rank	m_R	T	
800643	2.85	0.49	3.83	4.79	5.45	0.43	12.0019	H _a
800945	7.25	1.21	2.22	2.36	6.95	0.47	1.2632	H ₀
802760	2.35	0.67	2.60	1.81	2.25	0.23	0.8689	H ₀
805491	13.30	1.08	5.22	3.79	9.90	0.53	12.8994	H _a
805530	14.80	0.41	2.47	3.13	12.83	0.34	11.4784	H _a
805548	8.70	1.38	3.25	5.78	11.03	0.40	11.7349	H _a
805556	4.55	0.69	2.95	3.50	4.03	0.38	2.7368	H _a
805564	12.65	1.35	2.73	2.65	13.83	0.35	6.7494	H _a
805599	6.35	1.60	4.07	2.92	8.60	0.57	7.8734	H _a
805602	11.35	0.81	5.24	3.24	8.03	0.46	14.4036	H _a
805645	4.80	1.11	4.32	2.96	4.83	0.49	0.1011	H ₀
805696	8.20	1.24	4.68	3.33	9.65	0.41	6.9939	H _a
805700	9.35	1.69	2.27	3.47	8.60	0.58	2.5967	H _a
805718	12.50	1.32	8.54	5.00	12.95	0.38	2.3500	H _a
805726	1.00	0.00	4.44	3.74	1.10	0.14	1.4806	H ₀

Those limitations direct future research while determining the significance of criteria choice, accuracy of criteria values and subjective perception of certain criteria's importance.

4. Conclusions

Concluding on land consolidation's contribution, it is possible to state that it predominantly contributes significantly to agricultural production by including the hydrological benefits of balancing water flows. Irrigation systems produce a balance in flood circumstances and drought circumstances lowering the groundwater level. But this hypothesis requires additional parameters to be measured for additional refinement of the initial hypothesis. Further research is required to find out the possible effects of potentially high risks such as nitrate leaching, micropollutants and heavy metal accumulation. The proposed method used in this research could be the starting point for land consolidation analysis related to its improvements and risks by including irrigation systems into the LCPs prioritization.

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