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## **Conservation of natural ecosystems by land consolidation in the rural landscape**

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### **ABSTRACT**

Protecting the environment better livelihoods in rural communities have become increasingly important elements in land consolidation. The main objective of land consolidation is to improve the land holdings of farmers by concentrating their farms in as few plots as possible, and to support the farms with roads and infrastructure when needed. Experiences from the Western European countries and also from Slovenia show that land consolidation, which solely focuses on increase in productivity without taking into consideration the ecological aspects easily lead to negative effects. The fragmentation of natural ecosystems resulting from inappropriate land consolidation has been recognised as one of the major causes of the decline of biodiversity, the others being erosion, and the lowering of water table. In the areas of intensive agricultural production ecological structures, such as hedges, small areas of bushes, trees and water holes should be preserved. Because the efficiency of land utilisation increases after the implementation of land consolidation, the small land areas could be justified to ecological land use.

**Key words:** agricultural land consolidation, agricultural development, sustainable land planning, ecology, land management.

### **IZVLEČEK**

#### **OHRANJANJE NARAVNIH EKOSISTEMOV PRI ZLOŽBI ZEMLJIŠČ V KMETIJSKI KRAJINI**

Sonaravno urejanje kmetijskih zemljišč ob upoštevanju ekoloških meril predstavlja danes pomembno smernico pri izvajanju komasacij kmetijskih zemljišč. Osnovni namen komasacije kmetijskih zemljišč je izboljšanje posestne in zemljiške strukture in s tem posredno povečanje kmetijske pridelave, hkrati pa se nanaša na urejanje potrebnih dostopnih poti in druge infrastrukture v kmetijski krajini. Komasacije kmetijskih zemljišč v nekaterih zahodnoevropskih državah in tudi v Sloveniji, ki so bile osredotočene le na povečanje kmetijske proizvodnje,

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zanemarjeni pa so bili ekološki vidiki, so mnogokrat prinesle več škode kot koristi. Neprimeren pristop h komasacijam kmetijskih zemljišč in s tem povezano drobljenje in krčenje naravnih ekosistemov so lahko vzrok za povečanje občutljivosti zemljišč na erozijo rodovitnih tal, na sušna obdobja in za izginevanje številnih rastlinskih in živalskih vrst v kmetijski krajini. Na območjih z intenzivno kmetijsko pridelavo bi se morali ohranjati ekološki elementi, kot so obmejki, grmičevje, mlake ipd. S komasacijami kmetijskih zemljišč se uniči veliko takih ekoloških elementov, ki bi jih morali vsaj delno ohraniti, del pa nadomestiti z novimi ekološkimi površinami.

**Ključne besede:** komasacija kmetijskih zemljišč, kmetijski prostor, sonaravno urejanje, agrarne operacije, gospodarjenje z zemljišči.

## 1 INTRODUCTION

The history of land management goes back to the centuries when man settled permanently for the first time and began to cultivate land. The approach to cultivation of arable land has changed throughout history. The consequences of the past cultivation methods are reflected also in today's rural landscape. Today, land consolidation is one of the most important tools in rural development and can contribute to improvements in the productivity, efficiency, and competitiveness of the agricultural sector. Experiences from the past show that land consolidation, which focuses on increase in productivity without taking into consideration the ecological aspect, easily leads to a loss of biodiversity, erosion, sensitivity to drought, and destruction of the landscape. In some Western European countries intensive research is being done in terms of the influence of land consolidation on the rural landscape, where land consolidation without the ecological aspects was implemented (Knauer, 1991; Prosen, 1993). Experiences from the past are welcome in the sense of improving the approach to land consolidation in the future.

Arable land is part of the cultural landscape, the rural landscape that consists of: production area; cart tracks and agricultural roads as a connective element between the individual production unions; hedges and other boundary elements with the main function of protecting soil against water and wind erosion; ditches, brooks and rivers as water network; trees, groups of trees, small forests, bushes, pools, water holes, fallows and other landscape structures that are not set aside for the agriculture purpose; farms with outbuildings meant for preservation of agricultural produce (Knauer, 1991).

The main objective of land consolidation is to improve the land holdings of farmers by concentrating their farms in as few plots as possible, and to support the farms with roads and infrastructure, when needed. It leads to better land use planning and land management and if it is carried out in a comprehensive way it should support environmental protection and natural resource management. Otherwise, effects of land consolidation might be negative. Agricultural operations in general are marked as a degradation process of the landscape (Prosen, 1992). Simply a view of the agricultural landscape after land consolidation gives an impression of the negative effects of this process: new organisation of plots with straight roads and cart tracks without green frontier ecosystems, bushes and trees; open space with reduced amount of hedges, trees and other ecosystem patches; river banks with poor vegetation. There

are not only visual and psychological side effects of land consolidation in comparison with the natural landscape. Such a composition of landscape structures has resulted in land degradation, reduction of the natural ecosystems, sensitivity to natural disasters, etc. (Knauer, 1991; Prosen, 1993).

Land consolidation and land management in general have been more oriented to the needs of farmers and failed to follow the sustainable guidelines in the 2<sup>nd</sup> half of the 20<sup>th</sup> century throughout Europe. Such approach to land development and land use planning has created numerous phenomena of degradation of the natural and human environment. According to Knauer (1991) the following ecological structures are of significant importance for the conservation of biotopes along the agricultural plots and are on the other side strongly affected by the process of land consolidation (Borec, 1997):

- Hedges are strictly bounded areas that differ from the surroundings with the typical vegetation composition. Among others, they are important as habitat for predators of pests, and as habitat for other useful animals that are notable for the methods of new sustainable agriculture production. Hedges provide protection against evaporation and play an important role in wind and water erosion protection, and as an ecological network in the rural landscape. The variety of animal and plant species depends on age, width, microclimate and isolation from other ecological patches.
- Frontier ecosystems, such as narrow frontier landscape structures, appear above all as boundary areas between tilled grounds or between fields and roads (up to 1 m). In the process of land consolidation such frontier structures are removed or destructed later as a result of the intensive agricultural production. Some experts gave a special attention to the significance of such structures in the agricultural landscape where grass and herbs dominate (Knauer, 1991).
- Stream water with powerful or low stable current is an important structure in the rural landscape. Land consolidation influences the waterside vegetation and ecosystems along the riverbed that are because of the intensive agriculture production often partly or totally removed. The ecosystems along the river stream hold a significant importance in protecting the aquatic biota against the possible handicaps because of the chemical substances applied in the agricultural production.
- Ponds, pools and small water holes are known as landscape structures that are not set aside for agriculture production and are often destructed. Consequently, a specific ecosystem is destroyed.
- Trees in the landscape are usually autochthonous, landscape specific tree species that provide a habitat and an aesthetic role.
- Small tree groups, shrubbery and mixed structures hold a similar role to that of hedges with the difference of consisting of a nucleus that is well protected from the outside influences and is surrounded by shrubs and grass.

For the efficiency of the ecological functions, the above mentioned structures have to be connected through the ecosystems network. Such a network is also a condition for saving the biodiversity of the rural landscape. Increasing the probability of survival of species and sustaining the biodiversity in the landscape have become more and more important because of the integrated agricultural production that is based on the natural control of pests, acceleration of growth of advantageous insects and biotical reduction

of weeds. In Germany, as an example, the studies indicated that as a result of the former land consolidation about 18 % of bird species, 17 % of butterflies and over 100 plant species have disappeared from the agricultural landscape (Likar, 2000).

Among the others, the frontier ecosystems play an important role in the rural landscape (Knauer, 1991). The frontier between two plots is not an invisible line but a certain frontier structure with typical vegetation and composition. With the reduction of land fragmentation and the reduction of the number of plots, the sum of the boundaries of the plots is decreased, and consequently the area of the natural or semi-natural ecosystems is diminished. On the other side, the fragmented land is closely linked with roads. Pirc (1961) mentioned that the number and length of the supplying roads is proportional with the number of land plots. Furthermore, Pirc (1961) mentioned in his discussion about land consolidation and land management the importance of plot shape for the economical agricultural production and pointed out that the frontiers of the individual plots in a given area were also a significant surface acquisition for the agricultural production. In the 1960's the acquisition of arable land for agricultural production was emphasized. Thus the new structure of plots is an important contribution in agricultural productivity, and the additional areas could be determined for the ecological purpose.

In Slovenia, the most intensive period in the past century for land consolidation was between 1981 and 1990, when more than 50 000 ha of agricultural land were included in the process of land consolidation. In the last five years approximately 3 000 ha of agricultural land were consolidated (Cerjak and Prosen, 2001). By the comparison of plot areas and perimeters before and after implementing land consolidation for some land consolidated areas in Slovenia, an approximate estimation of what is happening with plot structures in the process of land consolidation is illustrated in the continuation. On the presumption that the frontier between two plots is a certain zone and not an invisible line, the area of those frontier ecosystems before and after land consolidation is determined.

## 2 MATERIAL AND METHOD

The analysis of changes of boundary lengths and field sizes due to agricultural land consolidation is based on the digital cadastral data for those areas in Slovenia where land consolidation was implemented within the last decade, except for the land consolidated areas Rosalnice (1988–1989) and Križevci (1989–1995). The main criterion for the selection of land consolidated areas was the possibility of getting the digital cadastral maps for the state of plot structures before and after the implementation of land consolidation. For the purpose of this research test areas of a total of 2 490 ha have been chosen, which represent almost 15 400 land plots before land consolidation. That includes the following land consolidated areas: Adrijanci, Dankovci, Križevci, Dravsko polje, Hodoš, Mlajtinci – Lukačevci, Moščanci, Nemška vas, Prigorica – Dolenja vas, Rosalnice, Šalovci. The majority of the test areas are from the north-east part of Slovenia, with the exceptions of land consolidated areas Nemška vas, Prigorica – Dolenja vas and Rosalnice from the south part of Slovenia. In the Pannonian Lowland and Drava lowland from the north-east part of Slovenia the agricultural production is an important segment in the economy, thus the majority of examples are from these regions.

The data of the old state of the plots were for some cadastral communities in analogue form, therefore the old cadastral maps had to be digitalised preliminarily. The structure of plots before land consolidation was compared with the structure of plots after land consolidation from the graphical part of the Digital Land Cadastre, where the plots of roads and areas of

water bodies were eliminated. For the determination of areas of frontier ecological elements in the rural landscape also the borders with roads and water areas were taken into account. The analysis of the areas and perimeters of land plots before and after land consolidation was done with GIS software ArcGIS 8, and was accomplished for all land plots in the test area. The average surface of the chosen land plots was estimated at 0.20 ha.

Thus the graphical cadastral data for the test areas were in different forms, and every land consolidated area was treated individually. Figure 1 shows the land consolidated area in the cadastre community Križevci (229 ha) as one of the test areas. Due to the limited space for the article the other test areas are not presented. At the end, some common statistics were done for all test areas with the purpose of getting some representative data for Slovenia.

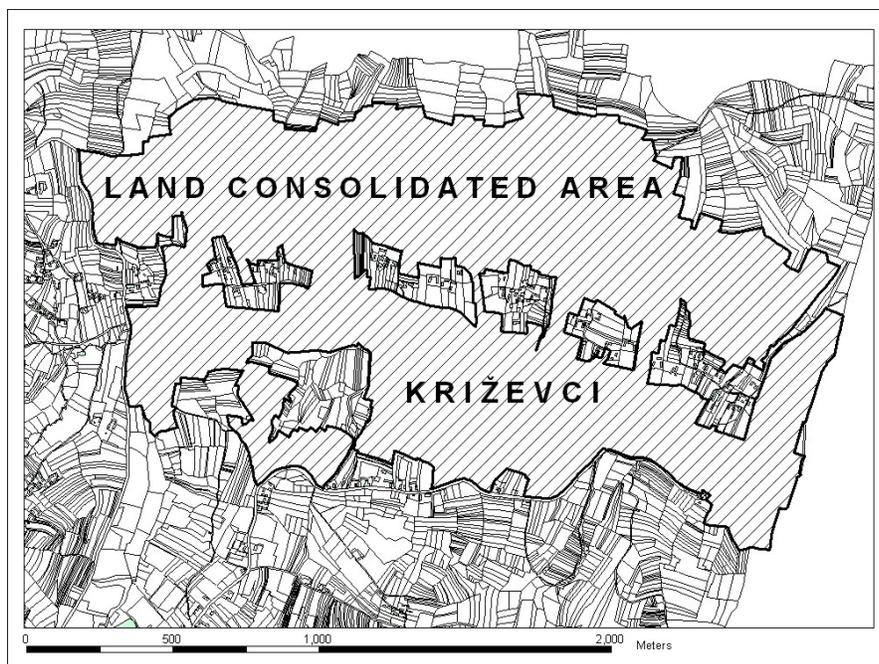


Figure 1: The land consolidated area in the cadastral community Križevci. (Source: Digital Land Cadastre of Cadastral Community Križevci. Digital Land Cadastre, 2003)

### 3 RESULTS AND DISCUSSION

When acknowledging that the plot boundary is a certain frontier ecological element in the rural landscape, the comparison of the old plot structure (before land consolidation) with the new one (after land consolidation) shows that the surface of different ecological patches along the plot boundaries is reduced in accordance with the reduction of plot boundaries.

According to Table 1, where some statistics about the plot areas before and after land consolidation were implemented, the number of plots has been reduced by 60 % on average. From the average area of the land plots before land consolidation – 0.20 ha, the average area has increased to 0.46 ha. The maximum area of plots increased significantly but, on the other hand, after land consolidation some small plots with an area of 0.01 ha remained as they were because of different reasons and specific spatial location.

Table 1: Areas of the plots before and after land consolidation for each land consolidated area (Digital Land Cadastre 2003, Digital Land Cadastre 2004a, Digital Land Cadastre 2004b).

Land consolidated area	Total area [ha]	Number of plots		Areas of the plots [ha]			
		before	after	$S_{max}$		$S_{aver}$	
				before	after	before	after
Adrijanci	265	2 221	882	1.20	3.45	0.11	0.28
Dankovci	87	426	205	1.22	2.25	0.19	0.34
Dravsko polje	503	1 098	424	3.53	9.17	0.47	1.15
Hodoš	224	1 005	436	4.74	6.58	0.21	0.46
Križevci	229	1 958	777	1.84	2.22	0.11	0.27
Mlajtinci/ Lukačevci	198	673	289	1.56	4.35	0.29	0.66
Moščanci	302	1 161	739	4.94	10.02	0.25	0.37
Nemška vas	40	480	144	0.34	0.87	0.08	0.27
Prigorica/ Dol. vas	398	5 190	1 082	1.44	12.70	0.07	0.33
Rosalnice	138	684	275	1.67	4.24	0.20	0.49
Šalovci	106	444	217	3.41	3.64	0.23	0.47
<b>TOTAL:</b>	<b>2 490</b>	<b>15 340</b>	<b>5 470</b>	<b>AVERAGE:</b>		<b>0.20</b>	<b>0.46</b>

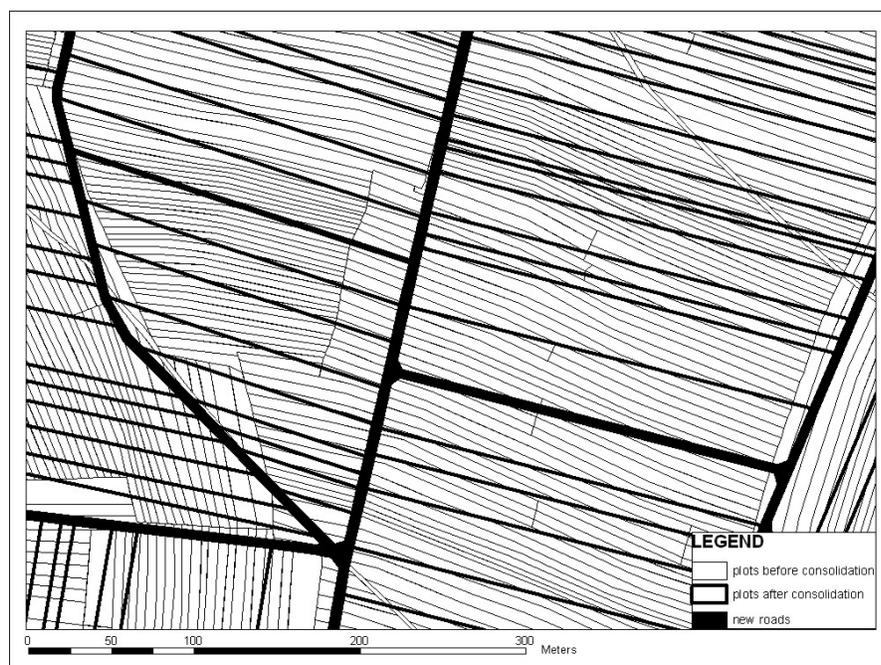


Figure 2: Comparison of plot structure before and after land consolidation has been implemented; consolidated area Prigorica – Dolenja vas. (Source: Digital Land Cadastre of Cadastral Community Dolenja vas. Digital Land Cadastre, 2004)

Additionally, in the process of land consolidation the shape of plots and access to the new plots play a significant role. Figure 2 shows the comparison of the old and new state of plot structure for the part of the land consolidated area Prigorica – Dolenja vas

in the cadastral community Dolenja vas, where the new road infrastructure is shown. The enlargement of the plot areas and the consecutive reduction of plot boundaries are shown as well.

After the implementation of land consolidation the shape of the plots changed and became more appropriate for economic agricultural production in general. This is being reflected in the coefficient – length of plot boundary/ plot area ( $k = d_{\text{boundary}}/S_{\text{plot}}$ ), which decreased as the consequence of the new, more advantageous shape of the plots. As it is illustrated in Table 2, the average value of the coefficient after the implementation of the land consolidation has been reduced by approximately 40 % in the test areas. On the other side, there are some remarkable maximum values of the coefficient after the land consolidation. The reason for these exceptions usually lies in some small left pieces of land close to the water stream and roads.

Table 2: Coefficient (k) length of the plot boundary ( $d_{\text{boundary}}$ ) / plot area ( $S_{\text{plot}}$ ) (Digital Land Cadastre 2003, Digital Land Cadastre 2004a, Digital Land Cadastre 2004b).

Land consolidated area	Total area [ha]	Coefficient $d_{\text{boundary}}/S_{\text{plot}}$ [ $\text{m}^{-1}$ ]					
		$k_{\text{min}}$		$k_{\text{max}}$		$k_{\text{aver}}$	
		before	after	before	after	before	after
Adrijanci	265	0.05	0.01	2.90	1.64	0.27	0.21
Dankovci	87	0.04	0.03	3.66	0.96	0.22	0.13
Dravsko polje	503	0.02	0.01	0.94	0.72	0.13	0.09
Hodoš	224	0.03	0.02	1.32	0.74	0.23	0.15
Križevci	229	0.04	0.03	2.19	1.93	0.27	0.20
Mlajtinci/ Lukačevci	198	0.04	0.03	3.29	1.67	0.24	0.15
Moščanci	302	0.02	0.02	1.76	1.12	0.17	0.16
Nemška vas	40	0.12	0.06	1.48	5.16	0.44	0.32
Prigorica/ Dol. vas	398	0.05	0.01	3.50	4.68	0.46	0.26
Rosalnice	138	0.04	0.03	0.99	2.26	0.19	0.14
Šalovci	106	0.02	0.02	0.86	1.01	0.21	0.16
<b>TOTAL:</b>	<b>2 490</b>			<b>AVERAGE:</b>		<b>0.26</b>	<b>0.18</b>

Thus, two factors influence the coefficient, shape of plots and length of the plot boundary, however, the coefficient itself might not be a suitable index for the study of the changes of the plot boundaries. In reality, the shape of plots is more or less geometrically irregular, therefore the influence of the form of the plot on the coefficient could be great. In the sense of conservation of natural and semi-natural ecosystems, more precisely the frontier ecosystems at the plot boundaries, the comparison of the length of plot boundaries before and after land consolidation is given in Table 3.

With land fragmentation and the number of plots, the sum of the plot boundaries increases. The total length of the plot boundaries in the land consolidated test areas before land consolidation was 2 218 km, and after land consolidation the sum of the length of the boundaries amounted to 1 182 km. With the reduction of the length normally some frontier ecological structures are disconnected and destroyed. As

known, a plot boundary is not an invisible line but a zone of specific vegetation that is important in the whole ecosystem of the rural landscape and should be handled carefully in land planning and land management.

Table 3: The length of plot boundaries (Digital Land Cadastre 2003, Digital Land Cadastre 2004a, Digital Land Cadastre 2004b).

Land consolidated area	Number of plots		Sum of the length of boundaries [km]		Difference $\Delta d$ [km]	Difference $\Delta d$ [%]
	before	after	before	After	Before	after
Adrijanci	2 221	882	244.9	139.9	105	43
Dankovci	426	205	57.5	41.0	16.5	29
Dravsko polje	1 098	424	261.4	170.6	90.8	35
Hodoš	1 005	436	137.9	96.0	41.9	30
Križevci	1 958	777	211.1	127	84.1	40
Mlajtinci/ Lukačevci	673	289	146.7	84.1	62.6	43
Moščanci	1 161	739	169.0	133.3	35.7	21
Nemška vas	480	144	81.1	34.5	46.6	57
Prigorica/ Dol. vas	5 190	1 082	734.7	234.6	500.1	68
Rosalnice	684	275	111.3	72.1	39.2	35
Šalovci	444	217	62.6	49.1	13.5	22
<b>TOTAL:</b>	<b>15 340</b>	<b>5 470</b>	<b>2 218</b>	<b>1 182</b>	<b>1 036</b>	

In the study case the total length of the plot boundaries has been reduced by approximately 1 036 km, which represents almost 50 % of the total length of the boundaries before land consolidation. Supposing that the average frontier width is half a meter, the area of the special frontier structures amounts to 52 ha, which is more than 2 % of the whole consolidated land. Furthermore, the plot structure after land consolidation is not in correspondence with the old state, which is also visible from Figure 2. Not only that the areas of different ecological patches along the plot boundaries are reduced in accordance with the reduction of plot boundaries, but also the boundaries of the new parcels are mostly new frontier structures in the rural landscape (Figure 2).

The Slovenian Forest Service carried out an investigation of the influence of land consolidation on hedges with a width of up to 10 meters. The areas of hedges before and after land consolidation were determined by digital capture of these areas on the basis of orthophoto maps. The investigation of impacts of agricultural operations between 1981 and 1991 on 3 031 ha of the arable land in the Vipava valley, West Slovenia, showed that the area of hedges has been reduced by three fifths. In the report it was mentioned that because of the intensive agricultural production also the isolated trees and frontier ecosystems along the individual plots, roads and artificial channels disappeared (Likar, 2000).

Since a given land consolidation, land use, could have important on-site and/or off-site environmental impacts (e.g. soil erosion, pasture degradation), such potential impacts should be assessed and subsequently considered in modifying the interim

process. A specific modification for mitigating the environmental impact may be the exclusion of certain areas from agricultural development.

#### **4 CONCLUSIONS**

From the ecological point of view, land consolidation should be planned together with the other sectors concerned with sustainable rural area development with the goal of conserving wildlife habitats and landscape features. Most ecological features depend on relatively small elements of the nature, expanding over the agricultural land that is usually managed extremely intensively. Sustainable land management that includes conservation and establishment of the ecological patches is one of the main priorities in terms of solving and mitigating the environmental problems in the rural areas.

Among the others, land consolidation has an influence on the plot frontier ecological elements, which was the topic of this study. According to the results of the study, almost 50 % of the frontier ecological elements along the plot boundaries disappeared in the test areas, considering that the plot boundary is a frontier ecological element in the rural landscape with a certain width. Besides this, the majority of plot boundaries after the implementation of land consolidation does not coincide with the old boundaries. Therefore the percentage of loss of the frontier ecosystems is even higher. The results of this investigation, based only on data from the cadastral maps, have also provided important information on how to argue when proposing a certain sum of surfaces for ecological purposes in the process of land consolidation. Through land consolidation the basic ecological structures should be preserved and, in the case of removing some of these structures, new ones should be established.

The elimination of the determined sum of areas from the agricultural land use for the purpose of conservation and establishment of natural habitats in the landscape is becoming more and more important in today's land planning and land management. The consequences of unsustainable land consolidation from the past and the results of this research could be treated as an example of how to explain and base the protection and establishment of the ecological structures in the rural landscape, when planning and implementing land consolidation in the future.

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## 6 REFERENCES

- Borec, A. 1997. Stanje in nadaljnji razvoj komasacij z vidika sonaravnega urejanja kmetijskega prostora ter zasnove sonaravne ureditve Spodnje Ščavniške doline. Magistrska naloga, Fakulteta za gradbeništvo in geodezijo, 105 p.
- Cerjak, M., Prosen, A. 2001. Komascija v zadnjem desetletju, razvoj agrarnih operacij in Evropska unija. Posestna sestava in kmetijska politika, XVI. tradicionalni posvet Kmetijske svetovalne službe Slovenije: 64-77.
- Knauer, N. 1991. Kmetijstvo in krajinska ekologija. Sodobno kmetijstvo, strokovna revija za kmetijstvo, živilstvo in gozdarstvo, 10: 417-440.
- Likar, V. 2000. Vpliv agrarnih operacij na geodetsko-katastrske evidence. Diplomaska naloga, Fakulteta za gradbeništvo in geodezijo; Ljubljana.
- Pirc, A. 1961. Urejanje kmetijskega prostora. Strokovne razprave, zvezek 4, I. del. Biotehniška fakulteta – Oddelek za agronomijo, 95 p.
- Prosen, A., 1992. Planiranje in urejanje podeželskega prostora. Pristop k razvoju podeželja, zbornik. Družba za razvoj podeželja, Ljubljana: 94-102.
- Prosen, A. 1993. Sonaravno urejanje podeželskega prostora. Fakulteta za arhitekturo, gradbeništvo in geodezijo, 180 p.
- Digital Land Cadastre 2003, Land Consolidation Area Križevci: Surveying and Mapping Authority of The Republic of Slovenia, Regional Geodetic Administration Murska Sobota, Branch Office Murska Sobota.
- Digital Land Cadastre 2004a. Land Consolidation Areas: Adrijanci, Hodoš, Mlajtinci – Lukačevci, Moščanci, Nemška vas, Prigorica – Dolenja vas, Rosalnice, Šalovci V: Geodetski Zavod Slovenije, Ljubljana.
- Digital Land Cadastre 2004b. Land Consolidation Areas: Dankovci, Dravsko polje: Geodetski Zavod Celje, Celje.