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Rural Landscape Shaping Through the Introduction of Trees in Land Consolidation Projects in Poland

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Abstract. Land consolidation works carried out in Poland are mainly aimed at the improvement of spatial structure of plots in agricultural holdings. However, modern trends indicate the necessity of compliance with sustainable rural development policy. This implicates the inevitability of inclusion of the environmental, landscape, technical and organizational aspects in the land consolidation projects in Poland. One such operation is the introduction of trees and shrubs. The paper aims to investigate the scope of land consolidation design solutions concerning the introduction of trees and shrubs. The study was based on selected land consolidation projects from different regions of Poland. The paper also proposes the concept of implementation of the design solutions related to the introduction of trees and shrubs in the land consolidation projects.

Keywords: introduction of trees and shrubs, land consolidation project, rural areas in Poland.

Conference topic: Environmental protection.

Introduction

The basic function which is played by rural areas in Poland (about 90% of the area of Poland (GUS 2010)) is the function of production, including, first of all, the food production. Implementation of the idea of the multifunctional development in Poland stresses the demands for economic and social changes in rural areas, paying the attention to protection of the nature, in the context of responsibility for the natural environment (Bielska, Leń 2015). The idea of sustainable development of rural areas focuses, however, on issues related to protection of soils, waters, genetic resources of vegetation and animals and the agricultural landscape (Bielska, Leń 2015). It should be stressed that the agricultural landscape itself is a common good and, as such, it should be the subject of protection. The rural areas development programme considers the elements of the agricultural landscape. Legal provisions define *landscape values* – as the *area ecological, aesthetic or cultural value, as well as related terrain relief and natural components created by the nature or by humans* (Act 2004). Legal regulations (Act 2004) also stress that trees and shrubs are the special landscape form which may be created by humans. Article 5 item 27 of the (Act 2004) defines *woodlots* as – *trees and shrubs within the limits of a roadway, individual trees or shrubs or their groups which are not forests as understood by Art.3 of the Act of 28 September 1991 on forests* (Act 1991)*, including the area where they occur and other elements of the vegetation cover of that area, which meet the objectives of protection, production or social-and-cultural objectives.*

Therefore woodlots are all forms of the high vegetation, both created by humans and being the results of the natural vegetation succession. However, woodlots do not create independent ecosystems. In Poland the history of introducing woodlots has been continued since the 19th century. The first planned woodlots were introduced by Dezydery Chłapowski in his manor house at Turwia (the Wielkopolska province); he should be considered the precursor of the modern agricultural management (Raszeja 2010). The following forms which may be adopted by tree in the agricultural production space may be distinguished (Waszak 2002; Sobolewska-Mikulska, Pułecka 2007):

(i) individual trees – individual trees distributed independently in the landscape;
(ii) row – linearly distributed trees and shrubs (e.g. along roads);
(iii) belt – at least two-row belt of woodlots of the width up to 20 m (e.g. along a river);
(iv) group – groups of trees and shrubs of the size not exceeding 0.02 ha (e.g. on pastures);
(v) ait – groups of trees and shrubs of the size 0.02 – 0.10 ha (e.g. field bird or animal areas);
(vi) area – woodlots of the size bigger than 0.10 ha which are not forests due to ways of management.

Forms of woodlots and played functions in the agricultural production space are highly important for functioning of the entire agro-ecosystem (see Table 1).

Table 1. Functions and impact of trees and shrubs in rural areas (source: Sobolewska-Mikulska 2009)

Group of function	Function	Impact
Protection	Climate-forming	Containment of winds, modification of distribution of falls, the air and soil temperature, evaporation
	Soil protection	Belts of trees and shrubs across hillsides reduce water erosion; belts of trees perpendicular to wind directions reduce the wind erosion
	Water protection	Reduction of evaporation (e.g. within spring areas) and surface outflows, counteraction against chemical and biological pollution of waters
	Biocenotic	Creation of places for nesting and feeding of birds and insects, in particular wild Apidae, necessary to pollinate crop plants
	Sanitary-and-hygienic	Containment of dusts, toxic gases, unpleasant smells (e.g. from farms)
	Technical	Delimitation of property boundaries, covering the disfiguring places (e.g. refuse damps), protection actions (e.g. hedges of thorny bushes), fire protection actions, strengthening escarpments, signalling crossroads
Production	Timber production, production of woody elements	Delivery of various woody elements; delivery of edible fruits, products of bees, pharmaceutical raw materials, usable leaves
Social-and-cultural	Recreational	Creation of possibilities to rest, meeting aesthetical demands, contribution to mental and cultural human development

Considering the above aspects the current rules of land management in rural areas in Poland should take into account the possibilities to use lands for afforestation purposes within the frames of land consolidation works. Land consolidation project should consider location of woodlots in relation to arable lands (Kurowska et al. 2015). Contemporary land consolidation works which aim at improvement of the agricultural farming conditions through improvements in field expanse also allow to develop the afforestation project of transformed areas (Przegon et al. 2016). Land consolidation covers all fields which are located within the area of land consolidation; therefore location of woodlots should consider (Sobolewska-Mikulska 2015):

(i) arable lands – field, meadows, pastures, gardens;
(ii) areas close to waters – located close to surface waters, flowing and stagnant waters and around water infrastructure, such as melioration ditches and different hydrological constructions;
(iii) transportation areas – within the road belt, such as snow protecting hedges, within railroad areas and transportation routes, mainly as corridors leading and accompanying animals across highways;
(iv) industrial sites – around and within industrial sites, mainly as isolation of those areas from the agricultural production space;
(v) built-up areas in villages – round and inside settlements and farm facilities;
(vi) recreational facilities – places dedicated for tourists, including car parking places, camps etc.

Land consolidation works performed in Poland may be divided into the following types:

(i) conventional – aiming at development of more convenient farming conditions through elimination of inefficient patchwork of fields and improvements in shapes of farm expanse, as well as construction of the necessary technical infrastructure and multifunctional development of rural areas;
(ii) infrastructural – performed mainly with respect of disorganisation of the existing spatial structure of farms and villages and interfering into the existing agricultural road networks due to construction of highways, i.e. large linear investments;
(iii) performed in relation with implementation of flood protection investments – where land consolidation is one of methods of acquisition of real estates for the needs of construction of flood protection structures;
(iv) secondary – mainly caused by successive fragmentation of farms within areas which were covered by land consolidation works in the past.

The legal-and-technical procedures of implementation of all types of land consolidation works result from the act on land consolidation and exchange (Act 1982). Practical implementation of the concept of the multifunctional and sustainable development of rural areas requires that land consolidation has to be changed from a purely agricultural instrument to a multifunctional integral instrument, and the land consolidation project should consider the possibility of economic development of farms and create alternative sources of incomes, such as agro-tourism, services etc.; it should also support protection of the environment and development of the rural landscape (van Lier 2002). This also refers to projects concerning development of woodlots.

Data and Methodology

The objective of the research works is to analyse the scope of implementation of design solutions concerning the maintenance and introduction of trees and shrubs in land consolidation projects in Poland and to assess whether the issue is dealt with in a sufficient manner. The study was based on a representative sample of 15 selected land consolidation projects carried out in different regions of Poland and different time periods (see Fig. 1). The test objects were

chosen randomly. The total analysed area of land consolidation (13671 ha) equalled to 8.8% of the total area of lands covered by land consolidation works in Poland since the accession to the European Union, i.e. within the years 2004–2015 (154988 ha – Ministry of Agriculture and Rural Development data). Tests were performed on the basis of land consolidation documentation obtained from the Department of Management of Lands of the Ministry of Agriculture and Rural Development and from Voivodeship Bureaus of Geodesy and Rural Areas.

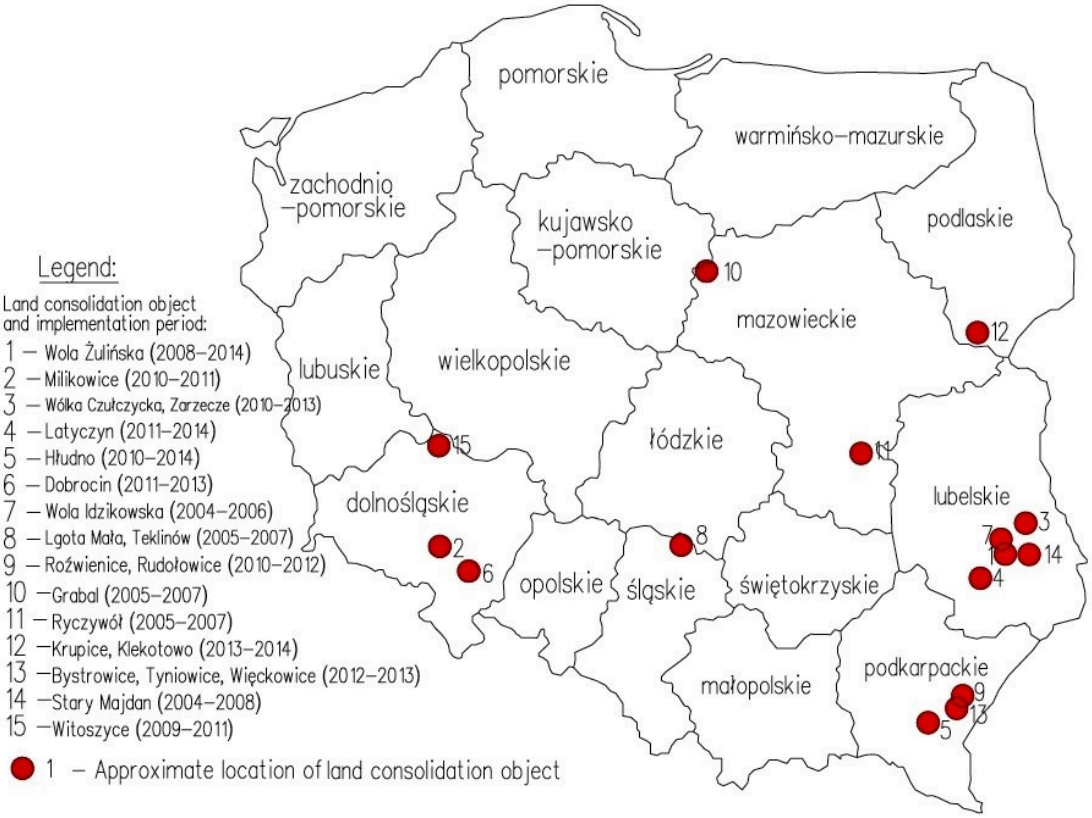

Fig. 1. Approximate locations of test objects in Poland.
(Source: Own elaboration)

Analysed actions related to the maintenance and introduction of trees and shrubs were grouped according to 6 types of design solutions that might be implemented in the land consolidation projects within the sustainable rural development (see Table 2).

Table 2. Analysed land consolidation design solutions related to the rural landscape shaping through the maintenance and introduction of trees and shrubs with assigned symbols (source: own elaboration)

Type of design solution	Assigned symbol
Maintenance of the high biodiversity and the high natural value areas of wooded land in natural conditions	M.HV.1.
Maintenance and protection of existing, inter-field trees	M.IF.2.
Introduction of trees and shrubs along transportation routes	I.TR.1.
Introduction of rows or belts of woodlots on balks, between neighbouring parcels or introduction of inter-field trees and woodlands	I.TB.2.
Introduction of trees or buffer zones along streams	I.BZ.3.
Introduction of trees and woodlands around and in the industrial areas, rural built-up areas or recreation and tourist facilities	I.OT.4

Results

The analysed scope of implementation of land consolidation design solutions related to the maintenance and introduction of trees and shrubs on the test objects is presented in tabular form (see Table 3).

Table 3. The scope of implementation of land consolidation design solutions concerning the maintenance and introduction of trees and shrubs (source: own elaboration)

Test object	Implementation of design solutions					
	M.HV.1.	M.IF.2.	I.TR.1.	I.TB.2.	I.BZ.3.	I.OT.4
1	+	+	–	–	–	–
2	+	+	+/–	–	+/–	–
3	+	+	–	–	–	–
4	+	+	–	–	–	–
5	+	+	–	–	–	–
6	+	+	+/–	–	–	–
7	+	+	+/–	–	–	–
8	+	+	–	–	–	–
9	+	+	–	–	–	–
10	+	+	–	–	–	–
11	+	+	–	–	–	–
12	+	+	–	–	–	–
13	+	+	–	–	–	–
14	+	+	–	–	–	–
15	+	+	+	–	–	–

Key: + implemented operation
– unimplemented operation
+/– operation not completed at the sufficient level

The research results indicate that environmental and landscape design solutions concerning the maintenance and introduction of trees and shrubs in Poland are only partially considered. Only actions related to the maintenance of existing wooded land are dealt with in a sufficient manner during land consolidation works (design solutions implemented on all test objects). In case of all test objects development of assumptions for the land consolidation project was preceded by a detailed field inventor and updating background maps with important land management elements which occur in the field – results of field inventory pointed to discrepancies between the real and reported land use ways. For example, in Dobrocin area the arable lands and green areas covered by the long, self-seeding processes, were considered (approx. 42 hectares of land covered with self-sown trees and shrubs and belts of trees in place of the former roads were marked). They were set aside areas with many years of highly developed vegetation succession; those lands were distinguished in the course of land consolidation works in the form of areas covered by trees and shrubs and they were remained with the existing land use ways. Attempts aiming at restoration of agricultural functions of those areas might have become ineffective and costly.

Operations aimed at the increased woodiness were performed only on 3 test objects and they were mainly located along transportation routes. New plantings along water reservoirs were planned only on "Milikowice" test object. There was no correlation between the forests and woodlands coverage rate on the test site and the scope of actions related to the introduction of new trees and shrubs (see Table 4). What is more, in the case of "Dobrocin" test site, the planned solutions were not fully implemented – only 1.8 km out of 4.5 km of planned roadside belts of trees were realized.

Table 4. Sizes of areas planned for introduction of new trees and shrubs in relation to the general characteristics of the land consolidation object (source: own elaboration)

Test object	Village area [ha]	Land consolidation area [ha]	Area of forests and woodlands in the village [ha]	Percentage share of forests and woodlands in the village area	Comments on implementation of design solutions related to introduction of new trees and shrubs	
					Allocated land area [ha]	Length of planned belts of trees and shrubs [km]
1	2	3	4	5	6	7
1	533.36	533.36	70.42	13.2%	–	–
2	947.42	947.42	21.54	2.3%	0.92	4.6
3	516.71	516.07	26.79	5.2%	–	–

End of Table 4

1	2	3	4	5	6	7
4	972.85	972.85	323.31	33.2%	–	–
5	1265.53	1224.70	236.99	18.7%	–	–
6	1349.11	1245.86	178.43	13.2%	0.90 – planned; 0.36 – realized	4.5 – planned; 1.8 – realized
7	550.86	550.86	2.41	0.5%	–	–
8	1057.10	1057.10	261.19	24.7%	–	–
9	1739.38	1492.53	254.42	14.6%	–	–
10	258.03	258.03	28.15	10.9%	–	–
11	774.04	301.00	194.95	25.2%	–	–
12	1863.07	1608.79	346.51	18.6%	–	–
13	1074.29	1074.29	6.25	0.6%	–	–
14	768.00	642.00	240.46	31.3%	–	–
15	1377.03	1245.95	199.18	14.5%	1.06	5.3

In all analysed cases, land consolidation process has not led to profound changes in the rural landscape. Nevertheless, landscape-and-environmental conditions were not deteriorated as a result of land consolidation proceedings either. What is more, some of the test sites (e.g. Krupice, Klekotowo) were characterised by a picturesque natural landscape and did not require major landscape creating operations – activities aimed at preservation and protection of existing state were required.

The proposal of a mathematical formula for regulation of the woodlands saturation in the rural landscape realized in the process of land consolidation

Areas of monoculture agricultural practices without biological-and-protection structures, such as individual trees, balks, bushes, are particularly predestined to introduce trees in the agricultural landscape. To maintain the natural balance of the rural landscape the most important are woodlots which are composed into the existing landscape structures, highly correlated with the complexity of spatial management of rural areas and implemented during land consolidation works. The discussed elements are mutually dependent and complement each other. Therefore the proposed idea concerning the arrangement of the rural landscape through woodlots assumes the necessity to introduce one of the following types of woodlots (besides individual trees): (i) row, (ii) belt, (iii) group, (iv) ait; (v) area. Therefore the total area of woodlots existing within the area of the land consolidation project A_{Qtot} is determined by the following formula:

$$A_{Qtot} = A_{Q1} + A_{Q2} + A_{Q3} + A_{Q4} + A_{Q5}, \quad (1)$$

where: A_{Qtot} – total area of woodlots within the geodesic rural precinct; A_{Q1} – area of the row woodlots; A_{Q2} – area of the belt woodlots; A_{Q3} – area of the group woodlots; A_{Q4} – area of the ait woodlots; A_{Q5} – area of the area woodlots.

Saturation of the agricultural landscape with woodlots assumed in the land consolidation project will depend on the existing landscape structures. The areas of: (i) lands under waters, (ii) built-up areas, (iii) transportation areas, mainly roads, (iv) ecological sites should be considered as the most important landscape structures *(LS)* in the agricultural space in relation to the introduction of new woodlots. The woodlots saturation should also correlate with the occurrence of forests. The coefficient of saturation of the agricultural landscape by woodlots within the area of the land consolidation project Q is determined by the following formula, according to cadastral data:

$$Q = \frac{A_{Fs} + A_{Qtot}}{A_V + \sum_{i=1}^{4} A_{LSi} \times (E_{LSi} - 1)} \times 100\%, \quad (2)$$

where: Q – the coefficient of saturation of the agricultural landscape by woodlots; A_{Fs} – area of forests within the geodesic rural precinct; A_{Qtot} – total area of woodlots within the geodesic rural precinct; A_V – total area of the geodesic rural precinct; A_{LSi} – the area of the ith type of landscape structure within the land consolidation project area (see Table 5); E_{LSi} – the coefficient of validation of landscape structures (see Table 5).

The values of the coefficient of validation of landscape structures E_{LSi} for the ith type of landscape structure within the land consolidation project area are presented in tabular form (see Table 5).

Table 5. The values of the coefficient of validation of landscape structures E_{LSi} for the ith type of landscape structure within the land consolidation project area (source: own elaboration)

The ith type of landscape structure within the land consolidation project area	Type of landscape structure LS_i	Values of the coefficient of validation of landscape structures E_{LSi}
i=1	LS_1 – lands under waters	$E_{LS1} = 3$
i=2	LS_2 – built-up areas	$E_{LS2} = 2$
i=3	LS_3 – transportation areas, mainly roads	$E_{LS3} = 3$
i=4	LS_4 – area of ecological sites	$E_{LS4} = 4$

The proposed formula may be applied at the stage of development of the land consolidation project for detailed calculations related to the saturation of the agricultural landscape by woodlots which increase the, so-called, "roughness" of the terrain. Such information may be also applied for designing location of woodlots in particular complexes of the project. The designing assumptions to be applied by the surveyor for the land consolidation project are presented in Table 6, depending on the obtained value of the coefficient of saturation of the agricultural landscape by woodlots. The above guidelines refer to complementing the agricultural landscape and they were assumed with the assumption that in Poland the forest coverage rate should reach 33% (with consideration of woodlots). This value was assumed as the target value which results from the National Forest Programme; it assumes that this value will be reached after the year 2050 (Sobolewska-Mikulska 2015).

Table 6. Proposed designing assumptions for the land consolidation project, depending on the obtained value of the coefficient of saturation of the agricultural landscape by woodlots Q (source: own elaboration)

Values of Q coefficient	Proposed designing assumptions
$Q < 33\%$	The necessity to introduce woodlots
$Q = 33\%$	Introduction of woodlots as a complement of the, so-called, "ecological routes" only
$Q > 33\%$	Introduction of woodlots not necessary

Conclusions

Woodlots and bushes play many functions in rural areas and they are an important element of the rural landscape. If adequately formed and spatially distributed, they may mitigate water deficit, soil erosion and crops' vulnerability to pests, as well as improve biodiversity, economic benefits and social life quality (Zajączkowski 2014). According to the idea of multifunctional and sustainable rural development, the land consolidation project should consider project solutions related to the maintenance and introduction of trees and shrubs in villages. The research results indicate that only the actions related to the maintenance of existing wooded land are dealt with in a sufficient manner during land consolidation works in Poland. Operations aimed at the introduction of new trees, shrubs and buffer zones are very seldom performed. Therefore the mathematical formula which regulates the saturation of the rural landscape with trees is proposed in the paper; it may be used by a surveyor to plan locations of trees when the land consolidation project is performed. The value Q=33%, corresponding to the assumed forestation index to be achieved in Poland after the year 2050, was considered as the satisfying coefficient of saturation of the rural landscape.

Disclosure statement

Authors declare they do not have any competing financial, professional, or personal interests from other parties.

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