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A method of determination of economic results of land consolidation

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Abstract: The paper presents a new method of determination of economic benefits of land consolidation of farms, which result from reduction of land parcels' number. A model method and a logical method have been applied. The discussed economic benefits have been determined by means of comparing economic evaluation of a model farm's land configuration before and after land consolidation.

As a result of analysis, a mathematical formula that describes an economic benefit of land consolidation, resulting from the reduction of land parcels number, has been derived. The economic benefit is a function of the differences between the numbers of arable fields and the differences between the area of an arable lands and green lands of a farm, before and after land consolidation, as well as constant parameters and slope of linear regression equations for the models of such fields. The benefit does not depend on the area of farms.

Keywords: Land consolidation, agricultural engineering, agricultural economy

1. Introduction

One of the basic objectives of land consolidation of farms is rationalised distribution of land configuration (Act, 1982), which may be achieved by reducing the number of land parcels. Improvement of land configuration, resulting from reduction of the number of parcels, as well as modification of shapes of land parcels, allows for reducing expenditures for agricultural activities as well as reducing yield losses.

A farm's land configuration and an arable field's land configuration are distinguished in literature. The standard (Sectoral standard, 2002) defines the land configuration as follows. It is a system of lands of an agricultural farm (a company), with respect to the production or a farm centre. The land configuration is characterised by the distance of lands from the settlement, the number of parcels, size and shape of the farm etc.

Harasimowicz (2000) understands the arable field's land configuration as a field size and its spatial arrangement. The arable field's land configuration is characterised by size, length, width, elongation, regularity of borders, natural obstacles, which occur in the field, slope etc.

The land configuration of the arable field affects the level of production as well as selected costs of agricultural activity (Harasimowicz, 2000). Changes of the field's land configuration are connected with modifications in profits obtained. Factors limiting the profits due to arrangement of the land configuration (Harasimowicz, 2000) include the decrease of production and increase of some costs of agricultural activity. The decrease of the production level results from yield loss next to the field borders along its long and short sides. The increase of costs of agricultural activity, caused by the land configuration, is influenced by the costs of turning back at the field edges, costs of final passing related to completion of works, costs of empty passing and costs of additional loading and unloading related to transport of goods, as well as with management of the zone of turning back, which includes additional work load and additional sowing, distribution of fertilisers etc.

The discussed costs and yield losses are considered as costs related to the land configuration (Harasimowicz, 2000). In other words, they are the costs, which value changes with changes in spatial parameters of the arable field. Costs related to the field's land configuration are considered in the paper as the economic measure of the quality of the land configuration. The higher the costs related to the land configuration for a given area, the poorer is the quality of the land configuration.

Measurable effects of land consolidation related to land configuration might be reduced to one factor, i.e. to limitation of costs related to the land configuration of farms. Reduction of costs related to the farm's land configuration obtained in the land consolidation process, is possible as a result of arranging the land parcels closer to the settlement, designing parcels of appropriate size and limiting the number of parcels. Basing on those effects, economic benefits of land consolidation may be specified, resulting from: arranging land parcels closer to the settlement, appropriate arrangement of land parcels (arable field) and from limitation of the number of land parcels. The author focuses his attention of the latter benefit.

A method of determination of costs related to the land configuration of a model farm was already developed (Mielewczyk, 2000b). From the economical point of view, a model farm differs with the costs related to its land configuration before and after the land consolidation. Costs related to the farm's land configuration are expressed in corn units. Therefore, benefits of land consolidation for a farm, being the subject of the analysis, is also expressed in those units. The quantitative benefits may be expressed in value, i.e. in Polish Zlotys. This allows for using the result of research for economic evaluation of land consolidation results.

The discussion on the benefits resulting from the reduction of the number of land parcels only is missed in the literature concerning economic evaluation of land consolidation works. Many researchers have pointed the lacks in evaluation of farm's land configuration. For example, Harasimowicz states, that "in spite of many works concerning impacts of changes of a field, it is very far to cover the complete issues and it lacks in the range of methods of determination of basic parameters, that describe relations between the spatial features of fields with costs of cultivation or generated incomes" (Harasimowicz, 2000). The author has attempted to fill those gaps. He has earlier introduced the term "a standard parcel", which is now being modified with the correct term "a standard arable field".

The objective of this work is to determine economic benefits of land consolidation of farms, which result from the reduced number of land parcels. In further sections of this paper the farm is understood as an agricultural farm, a parcel – as a cadastral parcel and a field is understood as an arable field, including a standard field understood as a standard arable field.

2. Methodology of research

It has been assumed that a model farm consists of one settlement parcel and of n^{w} standard arable lands and k^{w} standard green lands (Mielewczyk, 2000b). In other words, it consists of one settlement parcel and cadastral parcels that are created of standard fields of both types, i.e. arable and green lands. The standard field, both, the arable and green land (Mielewczyk, 1998; 1999), is understood as a rectangular field characterised by the minimum costs related to its land configuration and by the area, and which is equal to the area of a field, for which the discussed field is a standard. The author uses a model field, i.e. the standard field instead of a really existing field. Use of the standard field has contributed to elimination of the impact of the field shape on the results of research. Such a model farm has a disadvantage. It results from the fact that it has too large number of standard arable lands and standard green lands.

The use of a model method and a logical method has been investigated. An access to a road only on one side of standard fields of both lands use types was assumed. Comparative analysis of economic evaluation of land configuration of standard fields for considered lands, before and after land consolidation, is the basis for determination of economic benefits of that operation. In the analysis of a model farm, costs related to its land configuration have been determined twice, i.e. before and after land consolidation operations. Difference of costs related to the land configuration of the model farm before and after the land consolidation works reflects the benefit that results from reduction of the parcels' number.

Benefits of land consolidation, resulting from the reduction of the number of parcels, were considered for two cases. In the first one, areas of investigated arable fields in a farm are the same before and after land consolidation. In the second case, the area of arable fields has been modified in the land consolidation process. Analysis of economic benefits of land consolidation, resulting from the reduction of the number of land parcels, was the basis for formulation of conclusions.

The research method developed, allowed for determining economic benefits of land consolidation of farm, resulting form decreasing of number of parcels.

3. Discussion of selected bibliography items

A method that specifies the economic evaluation of land configuration, i.e. which expresses the mathematical relation between costs related to land configuration and its geometric parameters and parameters used for calculation was described in literature (Banat and Harasimowicz, 1993; Harasimowicz and Kubowicz, 1993; Harasimowicz, 1996; 2000).

Used in calculation parameters that describe the influence of land configuration on costs related to land configuration are based on methods applied in Switzerland (Harasimowicz and Kubowicz, 1991a; 1991b). They refer to well-organised agriculture, fully mechanised, based on medium-power tractors and reaching high production effects, i.e. approximately 5×10^3 kg/ha. In Polish conditions, costs related to land configuration, calculated using those parameters, do not relate to the existing situation; they relate to the future. The work (Harasimowicz et al., 1995) presents the software for calculating economic evaluation of land configuration of a farm.

Using the results of the discussed method (Banat and Harasimowicz, 1993; Harasimowicz and Kubowicz, 1991b; 1993; Harasimowicz, 1996; 2000) the author has developed a way of determination of costs related to land configuration of a field of an arable land (Mielewczyk, 1999). Costs Kro related to a field of an arable land (in corn units [c.u.]), of one-sides access to a road, have been determined using the formula (Mielewczyk, 1999)

$$K_r^o = k_n^o B^o + s_b^o O^o + k_j n_n + k_{pn} d_{pn} + 0.5 k_t^o l_p^o P^o \tag{1}$$

where k_n^o – costs of returns on an arable land, for one hectometre of its width B^o (3.04 [c.u./hm]); B^o – width of a field of an arable land (in [hm]). The field width is understood as a dimension perpendicular to the direction of cultivation; s_b^o – edge losses on a field of an arable land, for a length of one hectometre of circumference (0.25 [c.u./hm]); O^o – length of field borders (circumference) of a field of an arable land (in [hm]); k_j – costs of management of one strip of returns of a field of an arable land (0.42 [c.u.]); n_n – the number of return strips on a field of an arable land; k_{pn} – costs of management of a strip of returns of a field of an arable land of the length of one hectometre (0.60 [c.u./hm]); d_{pn} – length of strips of return of a field of an arable land (in [hm]); k_t^o – costs of transport within a field of an arable land, for one hectometre of the field length, calculated for one hectar of the field area (1.17 [c.u./(hm × ha)]); l_p^o – calculation length of a field of arable land (ratio of the field area of an arable land to its width) (in [ha]); P^o – area of an arable land (in [ha]).

The way of determination of costs related to a land configuration of green land has been developed basing on results of research performed by other authors (Banat and Harasimowicz, 1993; Harasimowicz and Kubowicz, 1993; Harasimowicz, 1996; 2000), similarly to methods applied for an arable land. Costs K_r^{uz} related to land configuration of a green land, with one-sided access to a road, are determined (in [c.u.]) from the following formula (Mielewczyk, 1998; 2000a)

$$K_r^{uz} = k_n^{uz} B^{uz} + s_b^{uz} O^{uz} + 0.5 k_t^{uz} l_p^{uz} P^{uz} \tag{2}$$

where k_n^{uz} – costs of returns per one hectometre of a field of green land width (2.80 [c.u./hm]); B^{uz} – width of a field of a green land (in [hm]); s_b^{uz} – edge losses in a field of a green land, per one hectometre of circumference (0.09 [c.u./hm]); O^{uz} – length of a green land (in [hm]); k_t^{uz} – costs of transport within a green land, in c.u. per one hectometre of length and one hectare of the field area (1.21 [c.u./(hm × ha)]); l_p^{uz} – calculation length of a field of a green land (a ratio of the field area of a green land to its width) (in [hm]); P^{uz} – area of a green land (in [ha]).

Costs related to the land configuration of an arable land (1), as well as a green land (2), are the functions of features of land configuration of fields and calculation parameters. Values of calculation costs parameters, specified in brackets, related to land configuration of field, concern the agriculture of high productivity and full mechanisation of cultivation, based on medium-power tractors (Banat and Harasimowicz, 1993; Harasimowicz and Kubowicz, 1993; Harasimowicz, 1996; 2000). Costs k_t^o of transport within an arable land and within a green land k_t^{uz}, have been determined by the author (Mielewczyk, 1999) as an average considering three levels of mechanisation, i.e. for 55, 65 and 85 horsepowers tractors and the following types of rotation of crops: cereals, root crops and fodder crops (neglecting the mixed rotation of crops) (Harasimowicz and Ostrągowska, 1996).

It should be noted that the parameters used for calculation of costs related to land configuration for both arable and green land are constant, i.e. they do not depend on land classification and its area.

In author's works (Mielewczyk, 1998; 1999; 2000a) a model of an arable field, i.e. the standard arable land and the standard green land has been assumed. It has also been assumed that every standard arable field has the following features: it is a rectangle with minimum costs related to its land configuration; its area is equal to the field, for which it is the standard.

To meet the first assumption, it has been considered in formulae (1) and (2) that those fields are rectangular. The following relations have thus been assumed

a) for a field of an arable land: $P^o = l^o B^o$, where l^o – the length of a side parallel to the cultivation direction for a field of an arable land (in [hm]). A circumference O^o of a rectangular arable land is calculated from the relation: $O^o = 2B^o + 2l^o = 2B^o + 2P^o/B^o$; the number of strips of returns $n_n = 2$.

b) for a field of a green land: $P^{uz} = l^{uz} B^{uz}$, where l^{uz} – the length of a side parallel to the cultivation direction for a green land (in [hm]). A circumference O^{uz} of a rectangular green land is calculated from the relation: $O^{uz} = 2\,B^{uz} + 2\,l^{uz} = 2\,B^{uz} + 2\,P^{uz}/B^{uz}$. Besides, the calculation length of an arable and a green land has been assumed equal to the length of a side parallel to the cultivation direction, i.e. $l_p^o = l^o$ and $l_p^{uz} = l^{uz}$.

Therefore, the costs $K_r^{o,pr}$ and $K_r^{uz,pr}$ (in [c.u.]) related to land configuration of rectangular arable (Mielewczyk, 1999) and green (Mielewczyk, 1998; 2000a) land, respectively are expressed as follows

$$K_r^{o,pr} = k_n^o B^o + 2\,s_b^o B^o + 2\,s_b^o P^o/B^o + 2\,k_j + 2\,k_{pn} B^o + 0.5\,k_t^o (P^o)^2/B^o \tag{3}$$

$$K_r^{uz,pr} = k_n^{uz} B^{uz} + 2\,s_b^{uz} B^{uz} + 2\,s_b^{uz} P^{uz}/B^{uz} + 0.5\,k_t^{uz} (P^{uz})^2/B^{uz} \tag{4}$$

Then the minima of functions (3) and (4), i.e. minima of costs related to land configuration of rectangular fields of arable or green lands were determined. First derivatives of those functions with respect to the width (B^o, B^{uz}) were calculated and constrained to zero; second derivatives were supposed to be positive. In this way widths of field of arable land and green land were determined.

The widths B_w^o and B_w^{uz} of an arable land field and a field of a green land (in [hm]), respectively are expressed as follows

$$B_w^o = \{[2\, s_b^o\, P^o + 0.5\, k_t^o\, (P^o)^2]/[k_n^o + 2\, s_b^o + 2\, k_{pn}]\}^{1/2} \tag{5}$$

$$B_w^{uz} = \{[2\, s_b^{uz}\, P^{uz} + 0.5\, k_t^{uz}\, (P^{uz})^2]/[k_n^{uz} + 2\, s_b^{uz}]\}^{1/2} \tag{6}$$

Substituting the values of calculation parameters of costs related to land configuration of arable lands given in (1) and (2) to (5) and (6) the widths B_w^o and B_w^{uz} of rectangular arable field (Mielewczyk, 1999) and a green field (Mielewczyk, 2000a) become

$$B_w^o = 0.325\, [P^o\, (1 + 1.17\, P^o)]^{1/2} \tag{7}$$

$$B_w^{uz} = 0.246\, [P^{uz}\, (1 + 3.36\, P^{uz})]^{1/2} \tag{8}$$

Then, from (3) using (5) and from (4) using (6) and applying the values of calculation parameters of costs related to the land configuration given in (1) and (2), the costs related to the land configuration of the standard arable land K_w^o (Mielewczyk, 1999) and green land K_w^{uz} (Mielewczyk, 2000a) (in [c.u.]), respectively are obtained

$$K_w^o = 0.84 + [9.48\, P^o\, (1 + 1.17\, P^o)]^{1/2} \tag{9}$$

$$K_w^{uz} = 1.46\, [P^{uz}\, (1 + 3.36\, P^{uz})]^{1/2} \tag{10}$$

where P^o, P^{uz} – area of the standard arable and green land, respectively (in [ha]).

Formulae (9) and (10) may be replaced by corresponding equations of linear regression (Mielewczyk, 2000b):

$$K_w^o = a^o + b^o\, P^o \tag{11}$$

$$K_w^{uz} = a^{uz} + b^{uz}\, P^{uz} \tag{12}$$

where a^o, a^{uz} – the constant parameter of the linear regression for the standard arable and green land, respectively (the shift of a regression line along the ordinate axis) (in [c.u.]); b^o, b^{uz} – the inclination coefficient of a linear regression equation for the standard arable and green land, respectively, to the abscissa axis (in [c.u./ha]).

Analysis of the formulae (9) and (10) indicates that only one such model may be assigned to each real field of a given area, i.e. only one standard arable field of a given area corresponds to all arable lands of that area. Similar situation occurs for green green lands. It should be noted that such standard arable or green lands are considered as flat figures.

Shape of fields as well as the fact that the standard fields have the minimum costs related to land configuration, differ the standard fields from the real fields. Standard fields of both types have thus the dimensions (length and width) that ensure the minimum costs related to the land configuration.

The costs K_{gw} (in [c.u.]) related to the land configuration of a model farm, which consists of one settlement parcel, n^w standard arable lands, and k^w standard green lands may be expressed as follows (Mielewczyk, 2000b)

$$K_{gw} = a^o\, n^w + a^{uz}\, k^w + b^o\, P^o_g + b^{uz}\, P^{uz}_g \tag{13}$$

where n^w, k^w – the number of standard arable and green lands, respectively, in a model farm; P^o_g, P^{uz}_g – the total area of standard arable and green lands, respectively, in a model farm (in [ha]).

Values of constant parameters (a^o, a^{uz}) and coefficients (b^o, b^{uz}) of linear regression equations of standard arable fields depend on a area interval, for which they have been determined, e.g. for the area interval between 0.10 ha and 25.00 ha they are as follows a^o = 2.13 c.u., b^o = 3.34 c.u./ha, a^{uz} = 0.38 c.u., b^{uz} = 2.69 c.u./ha.

Determined values of parameters of linear regression equations relate to fully mechanised agriculture and high efficiency from one hectare, i.e. approximately 5×10^3 kg/ha. It should be stressed that the costs related to the land configuration of a model farm (13) consider only the sum of costs related to the land configuration of standard arable and green land (Mielewczyk, 2000b). They do not consider the distance between the settlement parcel and the standard fields, as well as their shape or the terrain relief.

It turns out from (13) that the costs related to the land configuration of a model farm are the function of the number of standard arable land and standard green land, their areas and constant parameters as well as inclination coefficients of linear regression equations of those standards.

The formula (13) was derived (Mielewczyk, 2000b) under the assumption that a model farm consists of one settlement parcel, n^w standard arable land and k^w standard green land. This assumption eliminated the influence of shapes of field on costs related to the land farm configuration. The value of costs related to the model land farm configuration expressed by (13) does not depend on the arable land quality since computational parameters of costs related to land configuration of fields – were determined for fields of high efficiency from a hectare (Banat and Harasimowicz, 1993; Harasimowicz and Kubowicz, 1993; Harasimowicz, 1996; 2000).

4. Formulation of the economic benefits of land consolidation of farms, resulting from the reduction of cadastral parcels

In the process of land consolidation, the number of parcels and the number of fields are reduced. The costs related to the land configuration of a model farm, before and after land consolidation, can be calculated using (13). In general, the costs related to the land configuration of a model farm before the land consolidation, are higher than the costs after the land consolidation. The difference in costs related to the land configuration (before and after land consolidation) is the economic benefit E resulting from the reduction of the number of parcels. The benefit (in [c.u.]) may be expressed as follows

$$E = K^p_g - K^s_g \tag{14}$$

where K^p_g, K^s_g – costs related to the land configuration of a model farm, before land consolidation and after land consolidation (in [c.u.]).

The first case discussed concerns the situation when the area of fields of particular land use types does not change during the land consolidation. Taking into account a number of standard fields, the economic benefit E_1 (in [c.u.]) is obtained from (14) using (11) and (12) as

$$E_1 = a^o\,(n^{w,p} - n^{w,s}) + a^{uz}\,(k^{w,p} - k^{w,s}) \tag{15}$$

where $n^{w,p}$, $n^{w,s}$ – the number of standard arable land fields in a model farm, before and after land consolidation, respectively; $k^{w,p}$, $k^{w,s}$ – the number of standard green land fields in a model farm, before and after land consolidation, respectively.

In the case discussed the economic benefit of land consolidation of a model farm, resulting from the reduction of the number of parcels, is the function of the increment of the number of standard fields of both land use types (before and after land consolidation), as well as the constant parameters of linear regression equations for the standard fields.

The second case considered concerns the situation, when the area of analysed fields has been changed during the land consolidation process. The economic benefit $E_{\Delta P}$ (in [c.u.]) of land consolidation of a model farm, resulting from the reduction of the number of parcels and areas of lands is then expressed by

$$E_{\Delta P} = a^o\,(n^{w,p} - n^{w,s}) + a^{uz}\,(k^{w,p} - k^{w,s}) + b^o\,(P_g^{o,p} - P_g^{o,s}) + b^{uz}\,(P_g^{uz,p} - P_g^{uz,s}) \tag{16}$$

where $P_g^{o,p}$, $P_g^{o,s}$ – the total area of standard arable land in a model farm before and after land consolidation, respectively (in [ha]); $P_g^{uz,p}$, $P_g^{uz,s}$ – the total area of standard green land in a model farm before and after land consolidation, respectively (in [ha]).

Total area of standard fields, both, the arable or the green land, before and after land consolidation, is understood as the total area of those lands in a model farm, under the process of land consolidation. Remaining areas of a farm, i.e. areas, which are not covered by the land consolidation, are not considered, however in these investigations. Denoting with Δ the difference in the number of standard fields, as well as in the area of field in (16), the following formula is obtained

$$E_{\Delta P} = a^o\,\Delta n^w + a^{uz}\,\Delta k^w + b^o\,\Delta P_g^o + b^{uz}\,\Delta P_g^{uz} \tag{17}$$

where Δn^w, Δk^w – the difference between the number of standard arable and green land, respectively, in a model farms, before and after land consolidation; ΔP_g^o, ΔP_g^{uz} – the difference between the total area of the standard arable and green land, respectively, in a model farm, before and after land consolidation (in [ha]).

The benefits expressed by (15), (16) and (17) are the so-called economic annual benefits that result from the reduction of the number of parcels. They relate to one agricultural production cycle. Such benefits will occur for many years until the conditions are changed.

Neither the standard arable lands nor the standard green lands frequently occur in practice. A standard field may be assigned to every existing field. In (15), (16) and (17) the numbers of standard arable fields before and after the land consolidation of a model farm occur. Therefore it may be assumed that the number of standard arable fields in a model farm, before and after land consolidation, is equal to the number of fields existing in the given farm, before and after this process. Thus, maintaining rigorousness of (15), (16) and (17), the numbers of standard arable field may be replaced there with the numbers of fields existing in the given farm.

If so, the economic benefit of land consolidation of a model farm, resulting from the reduction of the number of parcels, may be referred to the existing farms. Thus, it may be assumed in (15) and (16) $n^{w,p} = n^p$; $n^{w,s} = n^s$; $k^{w,p} = k^p$; $k^{w,s} = k^s$; and in (17) $\Delta n^w = \Delta n$; $\Delta k^w = \Delta k$; where n^p, n^s – the numbers of arable lands in a farm, before and after land consolidation; k^p, k^s – the numbers green lands in a farm, before and after land consolidation; Δn – the difference between the numbers of arable lands in a farm, before and after land consolidation; Δk – the difference between the numbers of green lands in a farm, before and after land consolidation. Therefore, the results of the analysis will refer to both, to a model farm as well as to a farm, which exists in practice.

The economic benefit of land consolidation of a farm, resulting from the reduction of the number of parcels, is expressed in c.u. – the quantitative approach; it may also be expressed in the Polish Zlotys – the value approach. The discussed benefit may thus be expressed as

$$E_{\Delta P}^{zl} = E_{\Delta P}\, w \tag{18}$$

where $E_{\Delta P}^{zl}$ – economic annual benefit of land consolidation of a farm, resulting from the reduction of the number of parcels, according to the value approach, i.e. in Polish Zlotys; w – the value of a c.u., expressed in Polish Zlotys.

The range of possible use of the developed formulae (15), (16) and (17) depends on the area interval, for which constant parameters (a^o, a^{uz}) and coefficients (b^o, b^{uz}) of the linear regression equations have been determined for standard fields, and on the required accuracy of determination of the benefits resulting from land consolidation.

Let the maximum discrepancy of the value of costs related to the land configuration of a standard arable field, calculated using linear regression equations (11) and (12) and their corresponding functions (9) and (10) for a given area ranging from 0.10 ha to 25.00 ha, be smaller than 0.10 c.u. For a green land and for a standard arable land with specified values a^{uz} and b^{uz} this condition is fulfilled for areas ranging from 0.20 ha to 25.00 ha, and from 1.00 ha to 25,00 ha, respectively. Area ranges from 0.20 ha to 1.50 ha and from 1.50 ha to 25.00 ha were used to determine the parameters linear regression equations (11) for a standard arable land. Their estimates are $a_1^o = 1.74$ c.u.; $b_1^o = 3.57$ c.u./ha and $a_2^o = 2.18$ c.u.; $b_2^o = 3.33$ c.u./ha, respectively. Considering the area intervals, the formula (16) becomes

$$E_{\Delta P1,2} = a_1^o\,(n_1^p - n_1^s) + a_2^o\,(n_2^p - n_2^s) + a^{uz}\,(k^p - k^s)$$

$$+\, b_1^o\,(P_{g1}^{o,p} - P_{g1}^{o,s}) + b_2^o\,(P_{g2}^{o,p} - P_{g2}^{o,s}) + b^{uz}\,(P_g^{uz,p} - P_g^{uz,s}) \tag{19}$$

where $E_{\Delta P1,2}$ – economic annual benefit of land consolidation of a farm, resulting from the reduction of the number of parcels, in such situation when the area of arable fields has been changed during the land consolidation process and after considering two area intervals:

(0.20 ha, 1.50 ha) and (1.50 ha, 25,00 ha) (in [c.u.]); a_1^o, a_2^o – the constant parameter of the linear regression equation for a standard arable land, for the area interval (0.20 ha, 1.50 ha) and (1.50 ha, 25,00 ha), respectively (in [c.u.]); b_1^o, b_2^o – the coefficient of inclination of the linear regression equation for a standard arable land for the area interval (0.20 ha, 1.50 ha) and (1.50 ha, 25,00 ha), respectively (in [c.u/ha]); n_1^p, n_1^s – the number of arable lands' fields in a farm, before and after land consolidation, respectively, which area falls within the interval (0.20 ha, 1.50 ha); n_2^p, n_2^s – the number of arable fields in a farm, before and after land consolidation, respectively, which area falls within the interval (1.50 ha, 25,00 ha); k^p, k^s – the number of green lands' fields, before and after land consolidation, respectively, which area falls within (0.20 ha, 25.00 ha); $P_{g1}^{o,p}$, $P_{g1}^{o,s}$ – the total area of arable lands' fields in a farm, which area falls within (0.20 ha, 1.50 ha), before and after land consolidation, respectively; $P_{g2}^{o,p}$, $P_{g2}^{o,s}$ – the total area of arable lands in a farm, which area ranges from 1.50 ha to 25.00 ha, before and after land consolidation, respectively.

In (19) the attention was paid that the discrepancy in estimated costs related to the land configuration, calculated for one standard field, caused by replacement of (9) and (10) with linear regression equations (11) and (12), is below 0.1 c.u. The formula (19) relates to both situations: when the areas of arable fields in a farm were modified during the land consolidation process, as well as to the situation, when they were left unchanged, and the numbers of arable lands and green lands were changed.

For field areas smaller than 0.20 ha two ways costs estimation may be applied. It was either obtained from (19) using calculated constant parameters (a_2^o and a^{uz}_2) and the coefficients of inclination of linear regression equations (b_2^o and b_2^{uz}), or as a difference of the costs related to land configuration calculated before and after the land consolidation, according to (9) and (10).

Considering both area intervals the formula (19) may thus be applied for the area interval (0.20 ha, 46.40 ha) when the assumed discrepancy is kept smaller than 0.1 c.u..

5. Analysis of economic benefits of land consolidation, resulting from the reduction of the number of parcels

Constant parameters of linear regression equations for the area interval between 0.10 ha and 25.00 ha in (15), (16) and (17) has been assumed to simplify further analysis. Analysis of (15) indicates that the reduction of an arable land by one field during the land consolidation results in the increase of benefits by approximately 2.13 c.u.. On the other hand, the decrease of the green lands by one field during the same operations results in the increase of benefits by 0.38 c.u.. The a^o to a^{uz} ratio equals to 5.6. This means that the benefit resulting from the land consolidation is about 5.6 times higher, when the arable land is decreased by one field, than when the reduction concerns the green lands.

From (19) it turns out that, depending on the area interval, the decrease of an arable land by one field, results in the benefits of approx. 1.74 c.u. for fields of the area (0.20 ha, 1.50 ha) and approx. 2.18 c.u. for fields of the area ranging from 1.50 ha to 46,40 ha. Ratios of a_1^o to a^{uz} and a_2^o to a^{uz} equal to 4.6 and 5.7, respectively. Dominating factor of the economic benefits of land consolidation of arable lands over land consolidation of green lands depends thus on the area interval and equals to 4.6 for the first interval, and to 5.7 for the second interval. Further analysis of (19) requires the separate discussion.

From the analysis of (15) it may be concluded that economic benefit of the farm's land consolidation, resulting from the reduction of the number of parcels, does not depend on the area of a farm.

The analysis of the formula (16) indicates that the increment of the economic benefit resulting from the decrease of arable lands by one field is equivalent to the loss of area of 0.64 ha of those lands. Similar relation occurs for green lands. Decrease of green lands by one field during the land consolidation results in the increment of benefits, equivalent to the loss of 0.14 ha of those lands.

Two parts in (17) may be distinguished. The first part results from the decrease of the number of arable fields ($a^{o}\,\Delta n + a^{uz}\,\Delta k$), which corresponds to (15), and the second part reflects the change of a farm area ($b^{o}\,\Delta P_{g}^{o} + b^{uz}\,\Delta P_{g}^{uz}$) during the land consolidation process. The effect of the first part of (17) will be positive, if the number of parcels is reduced. The effect of the second part will be positive for farms, which decrease the area of arable lands and negative for farms, which increase the area of arable fields.

Designing of new parcels is usually performed according to point values of arable fields, which were assigned to a farm before land consolidation but after consideration of reductions. It is assumed that the point value of farm remains unchanged during the land consolidation process. In (17) the point value is not considered, however the farm area is taken into account. If, after land consolidation, a farm receives poorer lands than before, its area will be increased. Increase of the area of analysed lands in a farm will result in the decrease of the discussed benefits.

If a farmer receives lands of higher quality than before land consolidation, the situation will be different. A farm will have smaller area of arable fields. The loss of area of arable fields in a farm, which occurs as a result of land consolidation, will result in the increase of the economic benefit comparing to the situation when the farm area remains unchanged (17). It leads to the well-known truth that during land consolidation a farmer prefers to obtain less area of arable fields of higher quality than a larger area of the poorer quality land.

Analysis of (17) indicates that the benefits of land consolidation resulting from the reduction of the number of parcels do not depend on the quality of lands. However, when the land consolidation is calculated with respect to values, the quality of arable fields, before and after land consolidation, affects the benefits in farms.

Let us consider determination of economic benefits of land consolidation resulting from the reduction of the number of parcels, for a cadastral district. Let the area of arable lands and green lands, before and after land consolidation, be constant for that cadastral district. During land consolidation process, some farms within a cadastral district may decrease and other farms may increase the area of arable fields (this is permitted by Art. 8.3 of the act (Act, 1982)). Total area of parcels, within one cadastral district of farms, which decrease the area of some farms, is equal to the total area of parcels taken over those lands by others farms. If it happens like this, it may be proved that for the cadastral district the benefit of land consolidation of farms resulting from the reduction of the number of parcels and caused by changes in the area (the second part of (17)) is equal to zero. This means that for the cadastral district the discussed benefit of land consolidation does not depend on the area of the arable lands and on the area of green lands, being the subject of land consolidation.

Thus, the annual economic benefit E_{obr} (in [c.u.]) of land consolidation within the cadastral district, resulting from the reduction of the number of fields, when the area of arable fields did not change during the land consolidation process may be calculated as follows (similarly to (15))

$$E_{obr} = a^{o} (n_{obr}^{p} - n_{obr}^{s}) + a^{uz} (k_{obr}^{p} - k_{obr}^{s}) \tag{20}$$

where n_{obr}^{p}, n_{obr}^{s} – the number of arable lands within the cadastral district, before and after land consolidation, respectively; k_{obr}^{p}, k_{obr}^{s} – the number of green lands within the cadastral district, before and after land consolidation.

It turns out from the formula (20) that the economic annual benefits of land consolidation, for a specified cadastral district, depends only on the reduction of the number of fields and on the constant parameters of linear regression equations for standard fields of both types. This benefit does not depend on the area of fields and on the quality of analysed fields, being the subject of land consolidation.

The second case for the cadastral district concerns the situation when the area of arable fields of farms is changed during the land consolidation process. Such change may be the result of transformation of discussed lands, elimination of balks, destination of lands for roads etc. It affects the benefits of land consolidation, resulting from the reduction of the number of parcels. Similarly to (16) the economic annual benefit $E_{obr,\Delta P}$ (in [c.u.]) of land consolidation within a cadastral district, resulting from the reduction of the number of parcels, when the area of arable fields have been changed during that process, may be calculated using the formula

$$E_{obr,\Delta P} = a^{o} (n_{obr}^{p} - n_{obr}^{s}) + a^{uz} (k_{obr}^{p} - k_{obr}^{s})$$

$$+ b^{o} (P_{obr}^{o,p} - P_{obr}^{o,s}) + b^{uz} (P_{obr}^{uz,p} - P_{obr}^{uz,s}) \tag{21}$$

where $P_{obr}^{o,p}$, $P_{obr}^{o,s}$ – the total area of arable lands within a cadastral district, before and after land consolidation, respectively (in [ha]); $P_{obr}^{uz,p}$, $P_{obr}^{uz,s}$ – the total area of green lands within a cadastral district, before and after land consolidation, respectively (in [ha]).

As it turns out from analysis of (21), the increase of areas of farms during the land consolidation process influences on the decrease of the benefits resulting from the reduction of the number of parcels. The reverse situation occurs when areas of farms are decreased during the land consolidation process.

The results obtained in this work can be applied in practice. The developed formulae (15), (16), (17), (19), (20) and (21), which allow for calculation of the value of economic benefits of land consolidation, resulting from reduction of the number of parcels, are related to fully mechanised agriculture with the high productivity per one hectare. Therefore, the constant parameters a^{o}, a^{uz} and coefficients of inclination of linear regression equations of standard fields of both lands use types may not correspond to the conditions that occur in the Polish agriculture. They may relate to the future. Those values depend on computational parameters of costs related to the land configuration (Banat and Harasimowicz, 1993; Harasimowicz and Kubowicz, 1993; Harasimowicz, 2000). Determination of the latter parameters for the Polish agriculture will allow for calculation of adequate benefits of land consolidation resulting from the reduction of the number of parcels.

6. Numerical example

Let us consider the benefit of land consolidation, resulting from the reduction of the number of parcels for three farms marked as *A, B* and *C*. Let all farms, before and after land consolidation, consist respectively of 30 and 5 arable lands and 20 and 4 green lands. The area of the farm *A* has not been changed during the land consolidation process. The area of the farm *B* has been decreased by 2.50 ha of green lands, and the area of the farm *C* has been increased by 2.50 ha of arable lands.

The benefit of land consolidation of farms, resulting from the decrease of the number of parcels will be calculated for the farm *A* using (15), while for the remaining farms – using (16). The benefits calculated for the discussed farms equal to 59.4 c.u., 66.1 c.u., and 51.1 c.u., for *A, B* and *C* farms, respectively. The highest value of benefits occurs in the farm *B* while the lowest – in the farm *C*.

In analysed farms, the decrease of the number of fields by 25 for the arable lands and by 16 for the green lands resulted in the increase of benefits by 53.3 c.u. and 6.1 c.u., respectively. The total value of benefits resulting from the reduction of the number of parcels only, for all farms, was thus equal to 59.4 c.u. In the farm *B*, in which the area of green lands was decreased, the benefits were raised by 6.7 c.u. In the farm *C*, in which the area of arable lands was increased by 2.50 ha, the benefits were decreased by 8.3 c.u.

As it turns out from this example, if the annual economic benefit of land consolidation is to be calculated, the number of arable lands, the number of green lands and the area increment, before and after land consolidation must be known.

From the agricultural economy point of view as well as from the farmer's point of view the number of fields is important. One or more arable fields may be included in an arable parcel. The shape of arable fields and wastelands within a parcel may influence creation of many fields. In the particular case the number of parcels is reduced as a result of land consolidation, but the number of fields is increased. In such situation the use of a parcel without consideration of the number of fields is unreasonable. Therefore, consideration of the areas and number of analysed fields for determination of economic benefits of land consolidation resulting from the reduction of the number of parcels was appropriate.

Conclusions

The following conclusions may be drawn basing on the presented analysis.

1. The applied model method allowed for development of the formula that determines annual economic benefits of land consolidation of farms, resulting from the reduction of the number of parcels.
2. The annual economic benefit of land consolidation of a farm, resulting from the reduction of the number of parcels, is a function of differences of the number of fields

and differences of areas of arable lands and green lands, before and after land consolidation, and parameters of linear regression equations for standard fields of analysed land use types.

3. The annual economic benefit of land consolidation of farms, resulting from the reduction of the number of parcels, occurs for a number of years, until the current situation is modified.
4. The increase of a farm area during the land consolidation process, results in the decrease of the value of economic benefits resulting from the reduction of the number of fields.
5. The decrease of a farm area during the land consolidation results in the increase of the value of annual economic benefit, resulting from the reduction of the number of parcels.
6. The analysis has confirmed that in the result of land consolidation a farmer prefers to get less lands of the higher quality after the land consolidation and as a result of calculation of the farm value, than it was in possession of that farmer before this process.
7. The increment of the annual economic benefit of land consolidation, caused by the decrease of the area of arable lands by one field is equivalent to the loss of its area by approximately 0.64 ha. The decrease of the area of green lands by one field is equivalent to the loss of its area by approximately 0.14 ha.
8. The annual economic benefit of land consolidation of a farm, resulting from the reduction of the number of parcels, in which the area of arable lands have not been changed during the land consolidation process, is characterised by the following features.
   a) It does not depend on the area of a farm being on the process of land consolidation;
   b) It does not depend on the lands quality;
   c) It depends on the values of differences of the number of fields of both lands use types, before and after land consolidation and on the value of constant parameters of linear regression equations of standard fields;
   d) The increment of values of benefits for arable lands, which is caused by the decrease of those lands by one fields, is constant for the following area intervals: a) for fields of the area (0.20 ha to 1.50 ha) it equals to approx. 1.7 c.u.; b) for field which area ranges from 1.50 ha to 46.40 ha it equals to approx. 2.2 c.u.;
   e) The increment of the value of the economic benefit, resulting from the decrease of green lands by one field, is constant. It equals to approx. 0.38 c.u. for green fields of the area (0.20 ha to 46.40 ha);
   f) The value of benefits resulting from land consolidation of arable lands is higher than in the case of green lands by a factor 4.6 for the areas (0.20 ha to 1.50 ha) and 5.7 for the areas ranging from 1.50 ha to 46.40 ha.
9. For a cadastral district the annual economic benefit of land consolidation, resulting from the reduction of the number of parcels, is characterised by the following features.
   a) It does not depend on the area of the cadastral district being the subject of the land consolidation process;
   b) It does not depend on the lands quality;

c) It depends on the reduction of the number of fields and on constant parameters of the linear regression equations of standard fields. That property occurs only when the area of arable lands and green lands have not been changed during the land consolidation process;
d) The increment of the values of benefits is equal to zero, when the increase of area of selected farms occurs whilst the area of other fields is decreased when transformation of arable fields does not occur and when the number of fields was not changed before and after the land consolidation process;
e) The increment of the value of the benefit is smaller when – during the land consolidation process – areas of farms are increased, as a result, e.g. of elimination of balks. When the areas of farms are decreased, e.g. as a result of using lands for a road, the opposite situation occurs;
f) Conclusions specified in item 8, 9 d, e and f also relate to a cadastral district.

10. The advantages of the proposed method include
    a) A simple formula used for calculation of benefits of land consolidation of farms and low input of works when fields correspond to parcels;
    b) Measurable results, i.e. the result obtained in c.u. may be expressed using values specified in currency;
    c) The universal application possibility, i.e. for calculation of economic benefits, resulting from the reduction of the number of parcels, for farms or for a cadastral district.
11. There is a need to determine appropriate values of computational parameters of costs related to land consolidation for the Polish conditions, in order to specify the values of parameters of linear regression equations for standard fields. Therefore, the continuation of investigations concerning those issues is recommended.

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Metoda określania efektów ekonomicznych scalenia gruntów

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Streszczenie

W pracy przedstawiono nową metodę wyznaczenia ekonomicznej korzyści scalenia gruntów gospodarstw rolnych, wynikającej ze zmniejszenia liczby działek ewidencyjnych. Zastosowano metodę modelową i logiczną. Podstawą wyznaczenia tej korzyści była analiza porównawcza ekonomicznej oceny rozłogu modelowego gospodarstwa rolnego, przed i po scaleniu gruntów.

W wyniku analizy wyprowadzono formułę matematyczną, opisującą ekonomiczną korzyść scalenia gruntów gospodarstw rolnych, wynikającą ze zmniejszenia liczby działek ewidencyjnych. Korzyść ta jest funkcją różnic liczb pól uprawnych i różnic powierzchni gruntu ornego i użytku zielonego gospodarstwa rolnego, przed i po scaleniu gruntów, oraz stałych parametrów i współczynników nachylenia równań regresji prostoliniowej modeli tych użytków. Nie zależy ona od rozmiaru powierzchni gospodarstw.