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Measuring the effectiveness of land consolidation: An economic approach based on selected case studies from Poland

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ABSTRACT

Land consolidation projects (LCP) are the most effective method for quick amendment of poor land fragmentation parameters. At the same time, they are costly due to both a long time horizon and auxiliary projects, in particular, road construction and improvement of field drainage or irrigation systems. The range of changes in parcel arrangement after consolidation varies, as does the economic efficiency of LCPs related to the changes. The paper proposes a approach to the assessment of LCPs that takes into account the production and income effects, which influence the income of farmers participating in consolidation processes, and potential benefits, such as the increased value of farmland and the effect of improved quality of cadastral documentation. Static and dynamic economic feasibility indices were calculated. In the latter case, a thirty-year life of the project and a 2.5 % discount rate were assumed. The study involved six projects completed in Poland under the European Union Rural Development Programme 2007–2013. The effectiveness of the investments was found to vary significantly. The calculated payback period was most often a few to several dozen years, depending on the project, index, and scope of considered effects. It has been demonstrated that if potential economic rents are included, the estimated payback period for an LCP can be reduced several times. It was further concluded that it is necessary to develop a method for the valuation of non-production effects of LCPs such as social, environmental, and landscape benefits.

1. Introduction

The spatial distribution of parcels significantly affects the economics of agricultural holdings (Blarel et al., 1992). This is particularly true for distances that have to be covered within holdings (Tan et al., 2010), but also the number of cultivated parcels, their areas, and shapes (Gónzalez et al., 2007; Janus et al., 2016). In the long perspective, low profitability of agricultural production leads to migration, changes in the land structure of holdings, and abandonment of land resulting in afforestation or natural forest succession (Wojewodzic, 2017; Janus and Bozek, 2018; Sroka et al., 2019). The impact of land fragmentation parameters on the functioning of agricultural holdings has been investigated by multiple researchers (del Corral et al., 2011; Manjunatha et al., 2013; Satola et al., 2018; Latruffe and Piet, 2014). The numerous arguments for the reduced number of parcels include shorter transport time, less losses on boundaries, facilitation of large production investment projects, and easier surveillance over the work (Monchuk et al., 2010). Improved land fragmentation parameters reduce the total production costs of the specific agricultural segment (Tan et al., 2008). Another critical aspect of reduced land fragmentation is the increased value of agricultural land (Kocur-Bera, 2016) and lower labour-intensity of agriculture, which can release significant human resources for other industries (Lu et al., 2019).

The effect of land fragmentation may vary depending on the methods, units, investigated area, dominant agricultural segment, and the level of detail of calculations (Looga et al., 2018). Note that land fragmentation itself is not considered a strictly negative situation. Many studies indicate its advantages such as facilitated labour smoothing and risk diversification (Tan et al., 2008) or improved crop diversity (Di Falco et al., 2010). For the same reason, land fragmentation can help with food security at the household level and climate change vulnerability (Ntihinyurwa et al., 2019).

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Although there are many methods for measuring land fragmentation available, the need to search for better methods of assessing the phenomenon (Demetriou et al., 2013) and better ways of expressing effects of changes in agricultural economics remains relevant. The available studies that attempted to link production effectiveness with the value of land fragmentation parameters or changes in land fragmentation resulting from land consolidation projects took into account the selected type of agricultural holdings (Manjunatha et al., 2013), selected type of production: rice (Tan et al., 2008; Rahman and Rahman, 2009) or milk (del Corral et al., 2011), and the division into agricultural production segments (Hiironen and Riekkinen, 2016).

Despite the large number of features that affect agricultural productivity, only some of them are significantly modified by any intervention measures (Looga et al., 2018), with land consolidation as the dominant one. Land consolidation project (LCP) is primary tool for making significant changes in the arrangement of plot boundaries and improving land fragmentation parameters (Munnangi et al., 2020; Muchová, 2019; Markuszewska, 2013). It, therefore, impacts many operational aspects of the relevant area. Apart from reducing the operational farming costs, it improves the landscape, environmental conditions, and helps the place grow in other domains as well (Sosnowski, 2018; Stańczuk-Gałwiaczek et al., 2018; Li et al., 2018; He, 2019; Shan et al., 2019; Kupidura et al., 2014). Non-agricultural effects stem mainly from new parcels of land with parameters suitable for development (Dudzińska et al., 2018), improved legal status of the land, upgrade of cadastral documentation (Hanus et al., 2018; Noszczyk and Hernik, 2019), or design and construction of new transport systems (Bacior and Prus, 2018; Wójcik-Leń et al., 2018). Furthermore, it limits the willingness to abandon the land and facilitates the potential sale of parcels, which are more attractive thanks to increased area and access to good quality roads (Krupowicz et al., 2017). This, in turn, contributes to the increase in the average area of consolidated holdings.

Beyond any doubt, LCPs improve the operational environment of agricultural holdings. Still, they are costly endeavours. High costs of LCPs stem mainly from the necessity to implement a number of road investments to render the new system of parcels usable (Pijanowski, 2019). The critical item in LCP estimates is the construction of new roads and upgrade – usually widening and paving – of the existing ones. The other critical intervention is changes or improvement of field drainage or irrigation systems.

The assessment of LCP effectiveness is a challenge also because today, land consolidation is not only about improvement of land fragmentation parameters. It is also – sometimes mainly – a tool for improving agricultural production, employment, taxation policy, infrastructure, public facilities, housing, and the protection of natural resources (Li et al., 2018). To answer the question of the effectiveness of LCPs, one has to define the method for the assessment. The most common approach is to calculate a number of land fragmentation indices for the parcel system before and after land consolidation (Ertunç, 2020; Stańczuk-Gałwiaczek, 2017; Janus and Markuszewska, 2017; Akkaya Aslan et al., 2007; Demetriou et al., 2013). This way, one can determine precisely the scope of change in the number of plots in each holding, their areas, shapes, and spatial dispersion.

When the diversity of land fragmentation parameters after LCPs is significant and their costs per unit area are similar, the question arises whether such projects are cost-effective. Regardless of the mechanisms of LF calculation, it can hardly ever unambiguously estimate the profitability of land consolidation projects (LCPs) (Luo and Timothy, 2017; Hiironen and Riekkinen, 2016; Djanibekov and Finger, 2018; Nguyen and Warr, 2020).

The economic approach to the assessment of the effectiveness of LCPs has been widely investigated. A detailed study on Finnish projects (Hiironen and Riekkinen, 2016) has demonstrated that the payback period for projects was from 12 to 31 years at the plot number reduction from 38 to 63 %. The accuracy of an economic approach to the assessment of LCP profitability depends on many factors. The first one is the selection of the group of parcel or holding features to valuate their changes as a result of the project. The second one is how changes in the features (such as the distance from plots to farm buildings and their area) are expressed directly in monetary units (Hiironen and Riekkinen, 2016) or in such a way that they can be quickly converted into such units (Harasimowicz et al., 2017). Another factor is the determination of the period over which one analyses the positive effects of LCPs. It can be estimated for several decades (Janus and Markuszewska, 2019), but the actual period can be shorter or much longer. It depends on how fast parcels are divided after land consolidation. In this regard, one can note significant differences between countries both in terms of law on land division and completely different trends for demographic changes in agricultural areas: from a quick growth of population to intensive depopulation and unfavourable changes in the age structure. Another factor affecting results of long-term economic analyses is the assumed value of the discount used for calculating dynamic indices. The reference parameter recommended by the European Commission for estimating the alternative long-term cost of capital was the 5 % rate. The European Commission allowed the use of values other than 5%, as long as they were justified by particular macroeconomics of a member state.

In an attempt to bridge the research gap regarding the principles of economic assessment of the effectiveness of LCPs, the authors proposed a methodology for evaluating the feasibility of such projects, taking into account both many factors that affect project costs and a broad range of benefits. Its practical application helps to answer the question of the profitability of the investment project, which an LCP is beyond any doubt. The proposed methodology has been applied to a broad set of LCPs carried out in Poland from 2007 to 2013. Their costs have been specified in detail and the effects of the boundary changes have been identified. An additional profit from the research was the answer to the question of the degree to which the economic approach to the assessment of the profitability works for a group of LCPs that is diversified in terms of holding size, location, and dominant agricultural method.

2. Methodological framework

Today's LCPs are, first and foremost, investment projects with strict schedules and budgets. Therefore, an assessment of their effectiveness needs to employ methods used for investment profitability evaluation. The biggest challenge is the appropriate selection of LCP effects to be considered and their proper valuation. As characteristics and primary objectives of LCPs vary significantly, so may the list of potential effects to be considered. The European Commission recommends the following metrics to analyse and assess investment projects: the payback period, undiscounted benefit and cost indices, discounted benefit and cost indices, the net present value, and the internal rate of return. First, the economic indices will be discussed. The proposed method for adapting them to the specific nature of LCPs taking into account cost and benefit categories specific to them will be tackled next.

2.1. Economic aspects of LCP assessment

Economic assessment of investment projects usually focuses on two groups of methods, static and dynamic. Static methods do not take into account the value of money changing over time. Their structure is relatively simple, but the results they offer grow less and less precise as the time horizon for the analysis expands. Static indices include the Simple PayBack Time (SPBT), a product of investment expenditures and the sum of benefits. It is the time it takes for aggregate benefits from a completed project to reach the costs of the project.

Analyses with a longer time horizon are better performed using dynamic methods, which employ a discount rate. Such analyses include the investigation of the effectiveness of LCPs the impact of which is planned for decades (Janus and Markuszewska, 2019). When dynamic indices are employed, it is necessary to assume a specific number of years to discount the effects. In light of the long-lasting nature of the

positive effects of LCPs, their effectiveness can be assessed using the following dynamic indices:

The Discounted PayBack Period (DPBP) for identifying the period when the effects discounted with a percentage rate will cover investment expenditure.

$$\mathrm{DPBT} = \log_{(r+1)}\left(\frac{I}{I - E^{*}r}\right) \quad (1)$$

where:

r – the percentage rate

E – annual effects of the investment

I – the investment expenditure or balance of the expenditure, costs related to the project, and those benefits that are not to be discounted.

The next index is the Net Present Value (NPV) employed when costs occur over several years, and results are expected later. It can be defined with the following equation: (2):

$$NPV = \sum_{t=1}^{n}\left(\frac{E}{(1+r)^{t}}\right) - \sum_{t=1}^{m}\left(\frac{I}{(1+r)^{t}}\right) \quad (2)$$

where:

n – the operational life of the investment; in this case, it is the assumed impact period of the LCP,

m – the time when investment costs occur,

E – effects of the investment per annum over n years,

I – the investment expenditure per annum over m years,

t – individual years of the assumed operational life of the project and costs.

For this method, discounted amounts are aggregated in consecutive n years of the operational life of the project. The net present value, which is the difference between discounted annual benefits and discounted investment expenditure, constitutes an unambiguous indicator of the economic effectiveness of the investment. The NPV provides simple economic arguments regarding investment decisions. An investment is acceptable when the NPV ≥ 0 and should be rejected from the point of view of costs and benefits when the NPV < 0.

The next potential index is the Internal Rate of Return (IRR) (Eq. (3)). It specifies the value of the discount rate (r) for which the net present value (NPV) is zero. As the discount rate increases for an investment project, the NPV declines, which affects the assessment of the investment and the decision whether or not to pursue it.

$$IRR = i_1 + \frac{NPV_1{}^{*}(i_2 - i_1)}{NPV_1 + |NPV_2|} \quad (3)$$

where:

i_1 – the required rate of return for which the NPV is positive (still close to zero),

i_2 – the required rate of return for which the NPV is negative (still close to zero),

NPV_1 – the NPV for i_1,

NPV_2 – the NPV for i_2.

The Profitability Index (PI) is advisable for the additional prioritising of investment projects by their attractiveness. It is the quotient of the sum of discounted positive cash flows in a given period and the sum of discounted negative cash flows. The PI represents the effect as relative values in relation to investment expenditures. The PI Eq. (4) is:

$$PI = \frac{\sum_{t=1}^{n}\left[\frac{E}{(1+r)^{t}}\right]}{\sum_{t=1}^{m}\left[\frac{I}{(1+r)^{t}}\right]} \quad (4)$$

where: E – effects of the investment per annum over n years (the sum of production and income effects or production, income, and potential effects), I – the investment expenditure per annum over m years (costs of the consolidation project and costs of post-consolidation development), t – individual years of the assumed operational life of the project and costs, r – the discount rate.

Table 1
A diagram of costs and profits of an LCP with a time frame used in the model.

Categories of costs and benefits of LCPs	LCP year							
	1	2	3	4[a]	5	6	…	n
Cost of LCP		X	X					
Cost of post-consolidation development			X	X				
Production and income benefits				X	X	X	X	X
Negative effects of organisational setback	X	X	X	X				
Cadastral rent				X				
Potential increase in land value					X			

[a] the first year the parcels are used under a new spatial and transport arrangements.

2.2. Estimating the costs and profits (benefits) of an LCP

For the net present value (NPV) to be employed in the assessment of the economic effectiveness of land consolidation processes, it first needs to be adapted to suit the consolidation process character. Note that both costs can be incurred in stages and effects can fall into different categories with various time frames. Table 1 presents a simplified diagram with a list of included components and their periods of influence. The presented model involves the following assumptions:

- the project life is 30 years following a public funding agreement, while its production and income effects first occur after the project is completed. In its guidelines for the methodology of cost and profit analysis, the European Commission's Directorate General for Regional and Urban Policy indicates that the project life differs depending on its nature. Reference intervals recommended by the commission are divided into sectors. The period for road projects is 25–30 years and for natural environment projects, 30 years. In light of the above, the authors concluded that the period for considering effects of land consolidation projects financed by EU funds should not be longer than 30 years (this value was used in further calculations);
- investment expenditure occurs in three consecutive years. It can be assigned to two primary stages: The first one includes costs of land surveyor's design, where new boundaries of parcels are set, and cadastral files are drafted and then approved. The other stage includes costs of auxiliary projects facilitating the use of the new parcels;
- organisational setback occurs in the year the decision to carry out an LCP is made or in the year the project work commences. It is assumed to reduce the farming income over several consecutive years (four years in the model). It is a result of uncertainty regarding the final effects of the project, such as the location of future parcels, which limits fertilisation possibilities and investment processes in a holding until a new arrangement of boundaries is legally approved. The assumption of the 4-year period of organizational setback was based on relevant research available in the literature. The agricultural income can be estimated to be reduced by 10–15 % a year for 3 or 4 consecutive years (Suchta, 1984; Kusmierz-Gozdalik, 2000; Woch et al., 2011). The reduction starts to be evident at least a year before the land is consolidated.
- the potential effect of the changed value of agricultural land occurs in the first year after the project is completed. While the change of agricultural land value due to increased unit areas of parcels, improved geometry, and access to a modern road network is rather apparent, if hinging on several local conditions, its actual, tangible effect occurs not sooner than when the land is sold, mortgaged, or used as an in-kind contribution. It should, therefore, be considered a potential effect.
- the potential effect of cadastral rent occurs in the year the LCP is completed. This effect is related to the savings farmers and the

authority keeping cadastral databases achieve through the ordering of real estate boundaries. Cadastral records for agricultural areas are very frequently outdated or based on old surveys. They require costly effort, most often outsourced under public tender procedures, to bring them up to appropriate technical and legal standards. LCPs eliminate the need to take such actions. The saving is considered a potential benefit as well.

Costs of LCPs today can be identified precisely because of the strict requirements of public funding for the relevant reporting schemes and their later settlement. The LCPs in Poland in 2007–2013 funded by the European Union involved two levels of costs: 500 euros per 1 ha of consolidated land in the Lubelskie, Podkarpackie, Małopolskie, Śląskie, and Świętokrzyskie voivodeships and EUR 350 per 1 ha in other parts of Poland.

The differentiation was mainly a result of differences in starting parameters of land fragmentation, which is an important factor affecting the time and cost of LCPs in Poland (a), particular as regards land surveying. Additionally, projects that facilitated the use of plots resulting from consolidation could be assigned an equivalent of 900 euros per ha. The facilities were mainly new and upgraded roads, upgrade of surface drainage, or restoration operations, to a lesser extent.

In order to assess the economic effectiveness of an investment project, one has to assume an appropriate discount rate. In the period of the investigated LCPs (2007–2013), the reference parameter recommended by the European Commission for estimating the alternative long-term cost of capital was the 5% rate. The European Commission allowed the use of values other than 5% as long as they were justified by particular macroeconomics of a member state, the type of project owner (in public-private partnerships, for example) and the sector. The present study assumed the discount rate of 2.5 %. It was because LCPs are not-for-profit public investments and inflation in 2007–2018 was relatively low (–0.9. to 4.3 %).

Dynamic methods for assessing investments are burdened with the issue of the length of the analysed period when investment effects occur. In its guidelines for the methodology of cost and profit analysis, the European Commission's Directorate General for Regional and Urban Policy indicates that the project life differs depending on its nature. Reference intervals recommended by the commission are divided into sectors. The period for road projects is 25–30 years and for natural environment projects, 30 years (Guidelines…). Both the expenditure and effects are distributed over time in the case of the present work. The first year of the life of a project is the year the public funding agreement is signed. Hence, effects for production were analysed from year 5–30, which is 26 years after it was completed.

Land consolidation benefits should be felt and assessed in various domains. Generally, the main focus is the improvement of farming processes, which should significantly affect holding's financial results. The Equations above (1, 2, 3, and 4) have the E variable, which is the effects of the specific LCP. Depending on the type of the selected index and the scope of benefit assessment, the value of E can be determined differently. In the proposed approach, the effects can be of production and income type (actual results E_1) as in Eq. (5), or they can include effects of the cadastral rent (R_g) and the probable growth of land value from the completed LCP, L_v (combined actual and potential effects E_2 calculated with Eq. (6)).

$$E_1 = (\Delta D_r + \Delta K_t + D_b - D_o) \tag{5}$$

$$E_2 = (\Delta D_r + \Delta K_t + D_b - D_o) + R_g + L_v \tag{6}$$

where: ΔD_r – the increase in land productivity,

ΔK_t – the reduction of costs of transport to fields (fuel and labour),

D_b – the income from cultivation of former border strips between fields,

D_o – the loss from the 'organisational setback',

R_g – benefits from improved cadastral records (cadastral rent),

L_v – the estimated increase in land value due to completion of the LCP.

Both equations present a way for calculating benefits that is appropriate for the structure of statistical indices. In the case of dynamic indices, each component of the equations is discounted for the period specified in Table 1 at the beginning of the project, which is year one in the assumed thirty-year period. Costs (Eq. (7)) are also discounted for dynamic indices as they are spread over time.

$$I_1 = KP + KZP \tag{7}$$

where:

KP – costs of preparation and completion of the LCP (the first row in Table 1),

KZP – costs of auxiliary projects, mainly construction of roads (the second row in Table 1).

The increase in land productivity in Eqs. (5) and (6), ΔD_r was calculated as shown below (Eq. (8)):

$$\Delta D_r = (LPI_{beforeLC} - LPI_{afterLC}) * V_{GU} * A \tag{8}$$

where:

A – the area of the analysed section in hectares,

$V_{GU.}$ – the value of grain unit calculated from the mean price of wheat, rye, and triticale in 2013–2016 according to data from the Polish Central Statistical Office, which was PLN 59.4 per GU (average exchange rate of the euro (EUR) to the Polish zloty (PLN) in $2017-2019 = 4.33$),

$K_{r\ beforeLC}$, $K_{r\ afterLC}$ – indices of reduced land productivity due to the area and shape of parcels (before and after land consolidation, respectively) (Janus et al., 2016; Harasimowicz et al., 2017). The value of the index (Eq. (9)) is expressed in grain units per ha of agricultural land for each parcel.

$$K_r = \sum_{k=1}^{i} \left(z_l * l + z_b * b + \frac{j_p * l}{4} \right) \tag{9}$$

where:

i – the number of parcels in the investigated area,

l – the length of the parcel in hm,

b – the width of the parcel in hm

z_l – the parameter determining costs related to parcel length,

z_b – the parameter determining costs related to parcel width,

j_p – the parameter determining costs related to transport within a parcel.

Thanks to the use of the grain unit, GU (Brandt and Schiller, 1953), which is equivalent to the protein energy in 1 dt of grain (Andreae and Gregor, 2013), the productivity of various agricultural areas and its changes in variable economic conditions can be compared regardless of the local prices and currency. At the same time, this approach facilitates expressing the value in grain units in any country for any date in a monetary form. The indices were assigned the following values: $z_l = 0.49$ $(GU \cdot hm^{-1} ha^{-1})$, $z_b = 4.19$ $(GU \cdot hm^{-1} ha^{-1})$, $j_p = 0.60$ $(GU \cdot hm^{-1} ha^{-1})$ (Janus et al., 2016; Harasimowicz et al., 2017). The authors decided not to make index values conditional on the type of land use because no reliable land-use information was available and because land use often changes after LCPs.

Another component of Eqs. (5) and (6), ΔK_t, which determines the reduction in costs of transport to fields was calculated with Eq. (10):

$$\Delta K_t = \Delta F * C_f + \Delta W * C_w \tag{10}$$

where:

ΔF – the change in fuel consumption (L),

C_f – the price of fuel (PLN/L),

ΔW – the change in workload (in h),

C_w – the unit cost of labour (in PLN/ha).

The analysis of changes in transport cost due to LCPs required a number of assumptions. First, the cost of labour in a holding was

assumed as the equivalent of the average employee remuneration in very small holdings in the FADN system from 2013 to 2016, which was PLN 9.2 per hour. The relative low value of the remuneration stems from the fact that farm labour is mainly seasonal and provided by poorly qualified people or foreigners, which accounts for low wages.

As regards the determination of the average number of trips to fields, the lack of details on the production structure and technology in the LCP area forced the authors to introduce certain simplifications to the analyses, which can be modified if more insight is available. According to both theory and practice, the number of trips to a field depends on the species of the cultivated plant, technology used, and the area of the crop (Jasińska and Kotecki, 2003; Starczewski, 2006). For the purpose of calculations in the paper and considering the farming conditions in fragmented areas in Poland, each plot is assumed to require not less than 10 trips a year (Wojciechowski, 2010). The average consumption of fuel of 20 L per 100 km was assumed. The average transport speed of 20 km/h and diesel fuel price of PLN 4.8 per litre as the average for the period from 2013 to 2016 according to data from the Polish Central Statistical Office.

The last parameter, D_B, which determines benefits resulting from the use of space available after border strip removal was calculated with the following equation:

$$D_b = \Delta B * I_B \quad (11)$$

where: ΔB – the area of removed border strips (ha), I_B – the agricultural income per unit area (PLN/ha)

The width of the eliminated border strip was assumed to be 0.4 m. The agricultural income from 1 ha of agricultural land was assumed as the mean value of income of very small holdings in the FADN system from 2013 to 2016, which was PLN 1118 per hectare. Whereas, the reduction of agricultural income due to the organisational setback, D_o can be estimated to about 10–15% a year for 3 or 4 consecutive years (Suchta, 1984, Kusmierz-Gozdalik, 2000, Woch et al., 2011). It occurs at least a year before land consolidation. The setback was assumed to amount to 10 % of the agricultural income.

Data on potential benefits of a completed LCP (rows five and six in Table 1) that were later used in Eqs. (6) and (9) were determined in the following way:

The authors performed an analysis of costs of LCPs in the Dolnośląskie Voivodeship to valuate the cadastral rent as it was not possible to have cost estimates for re-establishment of agricultural boundaries done for the investigated objects and the access to arm's-length costs of such work was very limited. It can be assumed with a high probability that the cost of re-establishment survey and marking of boundaries of plots before land consolidation would be higher than the sum of costs itemised in milestone payment reports for LCPs under items:

- analysis and assessment of land survey and map documentation with the view to their suitability for the land consolidation project;
- establishment of new real estate (cadastral parcel) boundaries;
- marking of new real estate (cadastral parcel) boundaries;

In light of the above, the value of the cadastral rent was set to 42 % of costs of preparation and completion of an LCP (excluding road investment projects).

The probable increase in land value resulting from LCPs was estimated using statistical methods and an analysis of data on real estate prices in agricultural areas in municipalities where the investigated LCPs were conducted. The source of data for the market research consisted of records of prices and values of real estate kept by locally competent district authority offices (second-tier administration in Poland). The analysis involved whole municipalities with the cadastral districts undergoing consolidation. The authors extracted data on transactions involving undeveloped agricultural real estate (single- and multi-use type) from 2018 to 2019 (total of 292 transactions). Each transaction was described with an additional set of features derived from cadastral maps and orthophotos. The following geometry specifications were added to the data from price registers: length, width, and perimeter of each parcel.

Additionally, the shape of each parcel, its precise position, neighbourhood, access to public roads, use barriers, agricultural condition of the land, and distance to the nearest habitats were assessed. The final sample size for the analysis following the verification comprised 203 observations. Note that the predictors of the value of agricultural land include area, aspect ratio, and access to a road. These features can potentially change as a result of an LCP. Statistical methods were used to calculate the aggregate value of agricultural parcels in the cadastral district before and after land consolidation. The difference was the L_v parameter (Eq. (6)). Its relative values (PLN/ha) are listed in Table 6.

3. Study area

The study of the effectiveness of LCPs involved a group of projects completed in Poland between 2007 and 2013 under the European Union Rural Development Programme (RDP). It is a recurrent programme, which has a seven-year project horizon. Today, LCPs are pursued under the RDP 2014–2020. The following aspects had to be considered when selecting land consolidation projects for the study: very diversified numbers of completed projects in voivodeships; very diversified project conditions (initial land fragmentation parameters, number of owners, size of holdings, arrangement of buildings), and limited access to full data on projects. They made the selection and acquisition of complete data more difficult. At the same time, the sample size could not be too large because of the extensive scope of analysis for each of them. Northern Poland was not considered for analysis as land consolidation projects are rare there. From among the remaining regions in Poland, the authors selected those that had the most diverse profiles. They are:

Biała Wielka village– a large-area project with a significant initial land fragmentation (before the project) where natural conditions promised excellent effects of land consolidation;

Koźlice village – a project for an area with a relatively low land fragmentation and dense developments;

Łętownia village – a project in difficult, mountainous conditions with poor soil quality and very dispersed developments;

Marysinek village – the only project from central Poland;

Świerkle village – a project where land consolidation was conducted due to the pending creation of a large-area agricultural holding as a result of the acquisition of land by its owners, which nevertheless, did not result in a compact land complex for the holding;

Wola Żulińska village – a project representing an area with high-quality soil and intensive agriculture combined with significant room for improvement through land consolidation.

The positions of the investigated objects against a map of Poland are shown in Fig. 1. The basic data for calculating economic indices are presented in Table 2 (benefits of LCPs) and Table 3 (costs of the projects).

The public aid for projects under the RDP 2007–2013 amounted up to 100 % of the eligible investment costs, while the required public aid of at least 25 % of eligible costs was covered by the state. The cost of each LCP was determined by the size of the area and potential public funding limits. As a result, the total eligible cost of an LCP could vary from several hundred euros (as in Świerkle) to several million euros (as in Biała Wielka). In each investigated object, the post-consolidation development works were significantly more costly than the preparation and completion of the LCP (Table 3).

4. Results

The data collected for each of the six investigated LCPs were analysed to determine the effects relevant to the increase in land

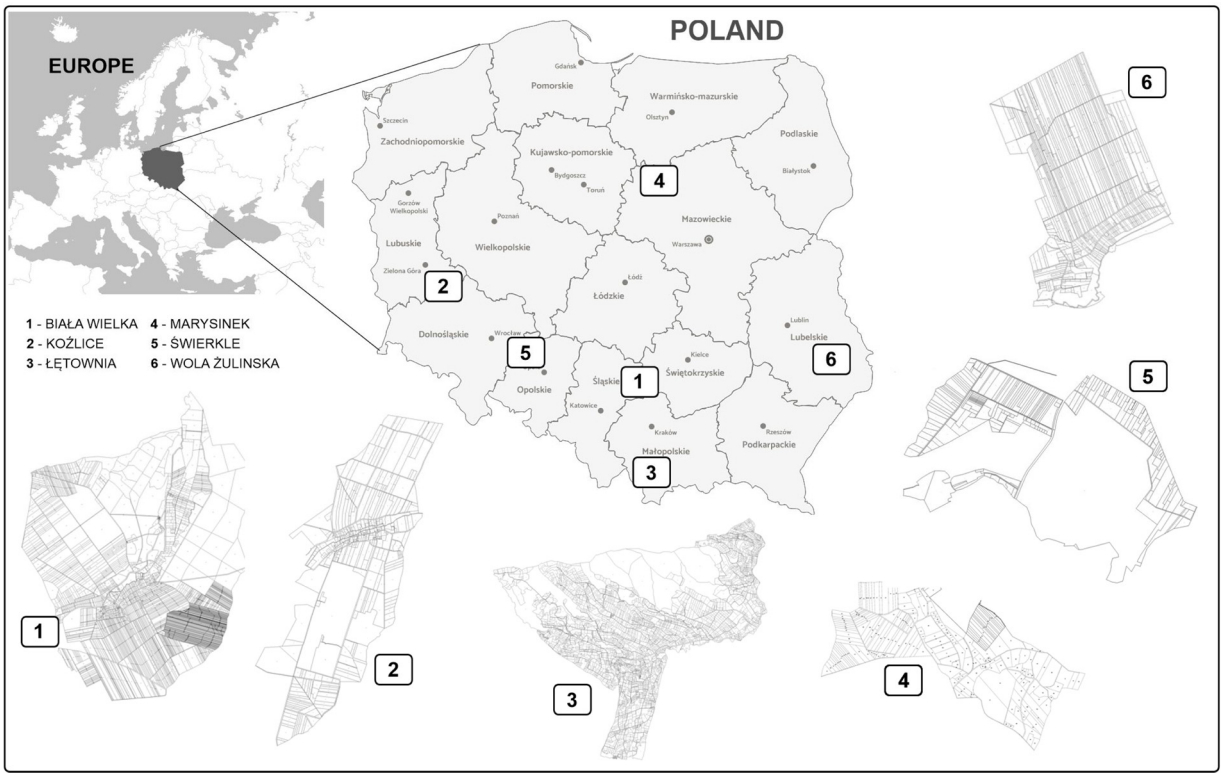

Fig. 1. Locations of the analysed group of LCPs.

productivity expressed in grain units per hectare of consolidated land, increase in areas recovered after removal of border strips, saved labour time, and saved fuel due to calculated reduction in the length of trips to fields (Table 4). Table 5 shows the valuation of the benefits as euro per hectare for each LCP.

The sum of benefits of the LCPs was juxtaposed with the valuation of their negative effects related to the organisational setback and potential positive effects – cadastral rent and potential increase in the value of land – are shown in Table 6 (data per hectare of consolidated land).

The last stage of the calculations was to determine the values of the five indices referred to above, SPBT, DPBT, NPV IRR, and PI (for the period of thirty years). The values were calculated for two options. The first one involved only actual benefits (Table 7), while the other also potential benefits of the cadastral rent and increased land value (Table 8).

5. Discussion

Economic effectiveness is measured by comparing results with costs. The results of the work indicate that LCPs should be considered investments with a long payback period. The significant variability of the effectiveness of such projects is evident already with a limited set of the six analysed objects, regardless of the index.

The payback period (considering all benefits, even potential ones) for the investigated group of projects is between 4–38 years for the SPBT and between 9 to over one hundred years for the DPBT (Table 8). If the cadastral rent and increase in the land value are removed from the analysis, the payback period grows longer from 21 to 51 years for the SPBT and from 33 years to never reaching the level of benefits that would offset the costs for the DPBT (as was the case for Marysinek).

The highest potential economic effectiveness of an LCP was identified for the village of Łętownia. It exhibited the highest level of land fragmentation before consolidation and a large number of plots without access to a public road. The payback period for this project was merely 4 years for the SPBT and 9 years for the dynamic DPBT. The optimistic periods were calculated, including additional potential effects. Should only actual effects be taken into consideration, the payback periods grow to 23 and 38 years, respectively. When only actual effects are taken into consideration, the most effective LCP is Wola Żulińska with payback periods of 18 and 26 years (for the SPBT and DPBT, respectively). The increase in productivity resulting from the removal of border strips, saved time, and saved fuel was the highest there: 356 PLN/ha/year (Table 5).

Some of the LCPs were not economically effective from the point of

Table 2
Basic data of the LCPs.

Name of the LCP (village)	Years completed	Area [ha]	Number of parcels		Parcel borders length [hm]		Average farm area [ha]	
			Before consolidation	After consolidation	Before consolidation	After consolidation	Before consolidation	After consolidation
Biała Wielka	2012	1713	3148	1861	4290	2772	2.41	2.38
Koźlice	2013	604	655	448	644	505	3.45	3.36
Łętownia	2012	981	5356	3096	3928	2779	1.55	1.42
Marysinek	2013	413	622	275	729	462	3.75	5.39
Świerkle	2011	240	446	246	708	229	1.74	1.89
Wola Żulińska	2013	533	1237	656	1817	1276	1.86	2.00

Table 3
Costs of the analysed LCPs.

Cadastral district	Eligible cost ('000 PLN)			Unit eligible cost (PLN/ha)		
	Land consolidation design	post-consolidation development	total	land consolidation design	post-consolidation development	total
Biała Wielka	3,740.6	6,754.8	10,495.4	2,181	3,946	6,127
Koźlice	868.4	2,015.0	2,883.4	1,478	3,430	4,908
Łętownia	2,128.7	3,416.2	5,544.9	2,170	3,488	5,658
Marysinek	489.8	1,112.9	1,602.7	1,186	2,695	3,881
Świerkle	217.3	557.3	774.6	1,534	3,935	5,469
Wola Żulińska	1,025.1	2,099.6	3,124.7	1,922	3,937	5,859

Table 4
Actual results of the LCP.

Project name	Increase in land productivity (GU)	Increase in crop area through the removal of border strips (ha)	Transport	
			fuel savings (litres/year)	labour time savings (h/year)
Biała Wielka	7,213.7	14.5	11,263	2,815.8
Koźlice	1,181.0	2.5	1,365	341.2
Łętownia	3,660.3	8.0	4,078	1,019.6
Marysinek	500.2	2.1	416	104.1
Świerkle	418.8	2.1	641	160.2
Wola Żulińska	2,661.1	4.5	3,784	946.1

view of the NPV index even with potential effects and a relatively low discount rate for cash flows (r = 2.5 %). For Marysinek and Koźlice, the current net value of the project was negative. This means the projects were not justified economically; effects would not offset costs in light of the variable value of money over 30 years.

The net present value (NPV) index was supplemented by discounted payback times (DPBT) estimated for the individual cadastral districts. This dynamic measure for assessing investment efficiency indicated that the effects of the LCP in Biała Wielka should be discounted over 24 years, in Koźlice, over 54 years, and in Marysinek, over more than a century considering the time preference expressed as rate r = 2.5 %.

The internal rate of return (IRR) determined the value of the discount rate (r) for which the net present value (NPV) of a project would be zero. The higher the IRR, the better the project score. Note that the project for Łętownia would have NPV = 0 (no gain nor loss) at a high discount rate of 15.65 %. The internal rate of return (IRR) was significantly higher than the discount rate also for Świerkle and Wola Żulińska (here, thirty-year effects of consolidation could be discounted with a 6.95 % and 5.90 % rate, respectively, which can be considered a good result as well). The IRR for Koźlice was near zero. No positive discount rate for Marysinek would allow thirty-year effects of consolidation to offset the costs.

The profitability index (PI) helped authors to sort the LCPs by the expected return per unit of expenses. The highest profitability was calculated for Łętownia, where each invested 100 euros yielded a thirty-year payback with a 66 euro surplus in increased farmer income, saved costs of boundary-related procedures, and increased land value. Świerkle could be expected to yield an over 40 % surplus over costs of consolidation. The value for Wola Żulińska and Biała Wielka approximated 20 %. The profitability for the other investigated objects was negative; the effects will never offset the costs.

The results show the diversity of economic effects within a group of LCPs completed at a similar points in time, under identical funding conditions, with almost identical costs per unit area, and in very similar legal and organisational conditions. The amount of cadastral rent is proportionate to the area of consolidated land. Project effectiveness is, therefore, determined mainly by the extent of changes in the area, shape of plots, reducing the distance from holdings to plots, and the scale of the estimated land value increase. These effects depend on many factors, which often reinforce or counter each other. They include the existing land arrangement of holdings, soil quality, settlement network, topography, or land fragmentation parameters before consolidation. Land in Poland has very diverse land fragmentation parameters The average area of agricultural holdings ranges from 3.98 ha to 30 ha depending on the region (Janus and Markuszewska, 2017). The average parcel area in the holdings fluctuates from 0.63 ha to 5.27 ha (Jędrejek et al., 2014). For this sole reason, the potential for improvement of land fragmentation parameters through LCPs varies a lot. The other reason is the diversity of goals of LCPs.

Both Polish regulations and expectations of the public indicate a preference for such projects that improve the local infrastructure, apart from just changing the spatial arrangement of parcels. Construction, alteration, or upgrade of the road system, improved surface drainage, and other auxiliary projects necessary to achieve project goals generate high costs. These projects constitute an integral part of LCPs even though they are considered separately in estimates and schedules. The separation is a result of the fact that Polish regulations require any projects based on a new arrangement of parcels to take place only after the administrative and legal process of approving the arrangement of boundaries of the parcels, which facilitates the auxiliary projects and update of cadastral databases and records in land and mortgage registers. By increasing the overall costs of an LCP, the auxiliary projects (mainly construction of roads) extend the time necessary for the effects to offset the expenses.

This applies in particular to goals important for the local community that initiated LCPs in the area. A very common reason for LCPs in Poland is the need to improve the access road network in the area in a comprehensive way or rectify cadastral records. Reduction in the number of parcels is a secondary goal in many cases. This may be caused by insignificant land fragmentation or abandonment of intensive

Table 5
Valuation of actual results of the LCP (PLN/year/ha).

Project name	Increase in land productivity	Income impact of removed border strips	Transport, fuel savings	Transport, labour savings	Total
Biała Wielka	249.8	9.4	31.5	15.1	305.9
Koźlice	119.5	4.8	11.2	5.3	140.8
Łętownia	221.6	9.1	20.0	9.6	260.3
Marysinek	71.9	5.8	4.8	2.4	85.0
Świerkle	175.8	16.2	21.9	10.6	223.8
Wola Żulińska	296.4	9.6	34.1	16.3	356.2

Table 6
Valuation of actual and potential effects of the LCPs.

Project name	Actual positive effects (PLN/year/ha)	Actual negative effects (organisational setback) (PLN/year/ha)	Cadastral rent (PLN/ha)	Potential increase in land value (PLN/ha)
Biała Wielka	305.9	62.3	905.1	613.9
Koźlice	140.8	106.7	611.6	704.7
Łętownia	260.3	87.1	899.1	3,971.5
Marysinek	85.0	111.6	490.7	598.7
Świerkle	223.8	189.2	634.4	3,300.1
Wola Żulińska	356.2	99.9	795.2	1,108.0

Table 7
Assessment of the economic effectiveness of the LCPs involving actual effects only.

Project name	SPBT (years)	DPBT (years)	NPV ('000 PLN)	IRR (%)	PI
Biała Wielka	21	33	–631.0	2.07	0.94
Koźlice	38	120	–1,406.5	NA	0.47
Łętownia	23	38	–842.2	1.39	0.84
Marysinek	51	NA	–1,021.1	NA	0.31
Świerkle	28	51	–242.9	0.24	0.66
Wola Żulińska	18	26	343.8	3.23	1.12

Table 8
Assessment of economic effectiveness of the LCPs involving actual and potential effects (i.e. increased land value and cadastral rent).

Project name	SPBT (years)	DPBT (years)	NPV ('000 PLN)	IRR (%)	PI
Biała Wielka	16	24	1,715.7	3.91	1.18
Koźlice	28	54	–711.9	0.02	0.73
Łętownia	4	9	3,389.8	15.65	1.66
Marysinek	38	134	–617.3	NA	0.58
Świerkle	10	16	251.2	6.95	1.35
Wola Żulińska	12	18	1,253.7	5.90	1.43

agricultural use of land because of low soil quality or unfavourable topography. In such cases, values of economic indices for results that are highly correlated with land fragmentation changes are low. At the same time, it is hard not to include such objects in analyses. It is because they are numerous and are subjected to the same selection and feasibility procedure as any other project.

In terms of invested funds, some of the investigated projects are uneconomic. It does not mean they were unnecessary. Costly subprojects carried out during land consolidation are based mostly on long-term consultations with the local community. Even though they reduce effectiveness indices, they contribute to a positive public reception of the project as a whole. An important conclusion of the research is that methods for assessing LCPs should vary depending on the type of area and goals of the projects even for those carried out at the same time in the same country under similar economic and legal conditions.

Still, the results do not point to the conclusion that land consolidation is not justified in areas where no payback of costs can be guaranteed over a specific period. When interpreting the results, one has to remember that the analysis involved only those factors that could be quantified to represent specific economic costs and gains. It did not involve, however, many observable and just as significant effects. These are social, environmental, or landscape results. How can protection of traditional cultural landscapes (Hernik et al., 2013), creation of ecological corridors (Liu and Xie, 2011), small-scale retention structures (Stańczuk-Gałwiaczek et al., 2018), or prevention of uncontrolled farmland abandonment (Janus and Bozek, 2018) be quantified?

Further research is, undoubtedly, necessary to determine the economic impact of LCPs on the improved functioning of whole localities and increased place attachment (Walker and Ryan, 2008), which may limit unfavourable demographic processes related to depopulation and the disturbed age structure of rural areas in the long term. Undoubtedly, areas after consolidation grow better not only in terms of agriculture and the actual effects last much longer than the 30 years assumed for the dynamic economic indices (Janus and Markuszewska, 2019). To tackle the problem of difficult valuation of some effects of LCPs and diversity of types of areas in need of consolidation, one may separate LCP funding cash flows into two categories. The first one would be set to maximise benefits in terms of minimisation of agricultural operating costs and the other one would be aimed at aiding the growth of rural areas, while certain low economic return-on-investment indices would be assumed and accepted a priori, to a certain extent. The question remains of whether one can approximate potential achievable results for a LCP at the planning stage. Although such attempts have been made (Colombo and Perujo-Villanueva, 2019), the problem calls for a further, much more in-depth investigation. This effort should be independent of analyses supporting the process of identifying objects to be consolidated employing several proposed approaches (Muchová and Petrovič, 2019; Wójcik-Leń et al., 2019; Leń, 2018; Janus and Taszakowski, 2018). To ensure a comprehensive assessment of the benefits of LCPs, it is necessary to develop methods for evaluating non-economic effects of the projects and expressing them in monetary terms.

6. Conclusions

The study identified a significant difference in payback periods between options with and without potential effects. Nevertheless, the effects of LCPs are better reflected from the perspective of both public administration responsible for cadastral databases and landowners whose land value increases significantly after consolidation if production and income effects, cadastral rent, and the potential increase in real estate value are included among the benefits. The payback period can be reduced by up to several hundred per cent in such a case.

The present study relatively extensively handled the problem of assessing the effectiveness of LCPs in economic terms. Note the universality of the research, since it can be relatively easily applied to virtually any LCP with information about plot geometry before and after consolidation, location of holdings, and road network system before and after consolidation. Nevertheless, local funding and agricultural land price variability conditions have to be considered to estimate costs of projects, and the range of benefits related to the cadastral rent and probable increase in land value.

The effectiveness of LCPs can be assessed using many indices, both simple and complex ones, that discount benefits over the life of the project. In the case of the latter, the payback periods are extended substantially. Land consolidation projects exhibit significant variability of effects, which entails a significant range of payback periods. They can, however, be reduced substantially if the benefits include improvement of cadastral documentation and an increase in land value.

The discussion indicates the need for the development of methods for assessing approximate effects of LCPs before they are commenced and a way of quantifying social, environmental, and landscape effects. The results facilitate the conclusion that the scope of estimated economic effects depends, to a large extent, on the index used to measure the effect. A significant result range can be even broader for dynamic

indices where the period during which the results are analysed and the value of the discount rate affect the results significantly.

CRediT authorship contribution statement

Tomasz Wojewodzic: Conceptualization, Methodology, Formal analysis. **Jaroslaw Janus:** Conceptualization, Methodology, Software, Writing - original draft, Writing - review & editing, Formal analysis. **Mariusz Dacko:** Formal analysis, Investigation, Validation. **Jacek Pijanowski:** Conceptualization, Resources, Project administration, Investigation. **Jaroslaw Taszakowski:** Resources, Investigation.

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Appendix A. Supplementary data

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