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A method to calculate economic key figures with regard to plot structure improvements

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Abstract: The aim of land consolidation projects is to improve the competitiveness of agriculture. Since land consolidation is subsidised by national and European means, the effectiveness of such measures must be determined. The following paper presents a method which makes it possible to calculate the direct economic effects of land consolidation. The calculations, considering labour demand, machinery costs and headland effects, compare the economic situation before and after land consolidation. The method was applied to four land-consolidation projects in Bavaria. It can be shown that, to a varying degree, land consolidation in the studied areas leads to a substantial decrease in labour demand and machinery costs.

Keywords: land consolidation, geographical information system, direct economic effects, labour demand, machinery costs

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A method to calculate economic key figures with regard to plot structure improvements

By MARTIN KAPFER, JOCHEN KANTELHARDT, Freising-Weihenstephan

1. Introduction

Huge parts of Europe are characterised by small-structured landscapes. Due to small plot sizes and a scattered plot structure, often coupled with an insufficient accessibility of plots, the agricultural usability of such regions is limited. In order to improve the competitiveness of agriculture in these regions, it is necessary to rearrange plot structures and adapt road networks. Such measures are costly, however, which raises the question whether it is worthwhile implementing them. In answer to this, the economic benefits of land consolidations need to be calculated.

This paper presents a calculation model which is based on geographical and farm-specific data and makes it possible to determine economic and socio-economic key figures in a spatially explicit way. The effects of land consolidation on labour demand and machinery costs are considered in this model, as well as yield effects, which arise due to a reduced importance of headlands.

The model is applied to four typical land consolidation projects in Bavaria. The selection of the projects is based mainly on agricultural criteria. Consequently, the projects reflect typical arable and grassland production situations. Both the Bavarian digital land register map, an internal database of the Bavarian land consolidation agency, and the IACS (the European Union's Integrated Administration and Control System) serve as spatial databases. In addition, a survey involving 80 local farmers is conducted.

2. Method and Database

From an agricultural point of view, land consolidation optimises size and form of agricultural plots and enhances the accessibility of these plots. The latter is done by consolidating plots in order to reduce driving times and by adapting the road network and improving the quality of roads. Thus, land consolidation affects the *driving time* farmers need to reach their plots and the *on-plot working time* farmers need to do their cultivation work on these plots.

The impact of these measures on the economic situation for agricultural enterprises depends greatly on the type of farming. In particular, farms which practise labour-intensive land cultivation and require frequent trips between farmstead and plots will benefit from land consolidation. Hence driving and on-plot working time calculations need to be related to the *farm-specific* situation. The various steps modelling the effects of land consolidation are presented in the following subchapters.

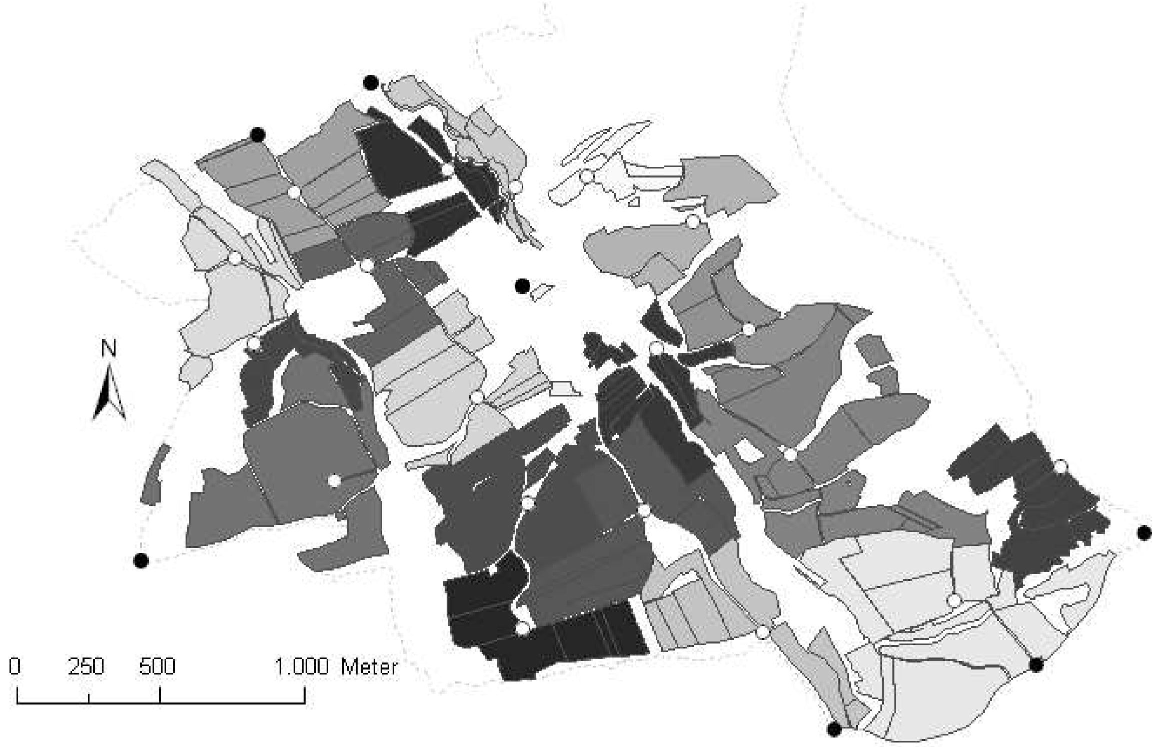
2.1 Modelling the impact of land consolidation on driving times

In order to carry out their cultivation work, farmers have to drive from their farmstead to the respective plots. Often it is also necessary to travel from plot to plot. The time required for these trips greatly depends on the distance between the plots of the respective farm (plot-to-plot distance) and the distance between farmstead and plots (farmstead-to-plot distance). In order to calculate the economic consequences of land consolidation, it is therefore necessary to determine the geographic location of plots and farmsteads and the distances between them.

In the present paper all distances calculated are specific to plot and farm. However, in order to minimise the calculation effort, the plots are clustered into sectors. A sector thereby comprises all plots which are in close proximity to each other and consequently have comparable accessibility. For each plot in such a sector, the same geographical location is assumed, expressed by a uniform geographical reference point. Farmsteads, in contrast, each receive an individual reference point. Where farmsteads are located outside a project area, a reference point is set at the point of entry into the project area.

Figure 1 visualises the reference points and the sector arrangement using the example of the land consolidation project *Obergessertshausen* (cf. chapter 3 for a brief description of this project region). Plot sectors are made up of plots of uniform colour, black dots signify the reference points of farmsteads and white dots signify the reference points of plot sectors.

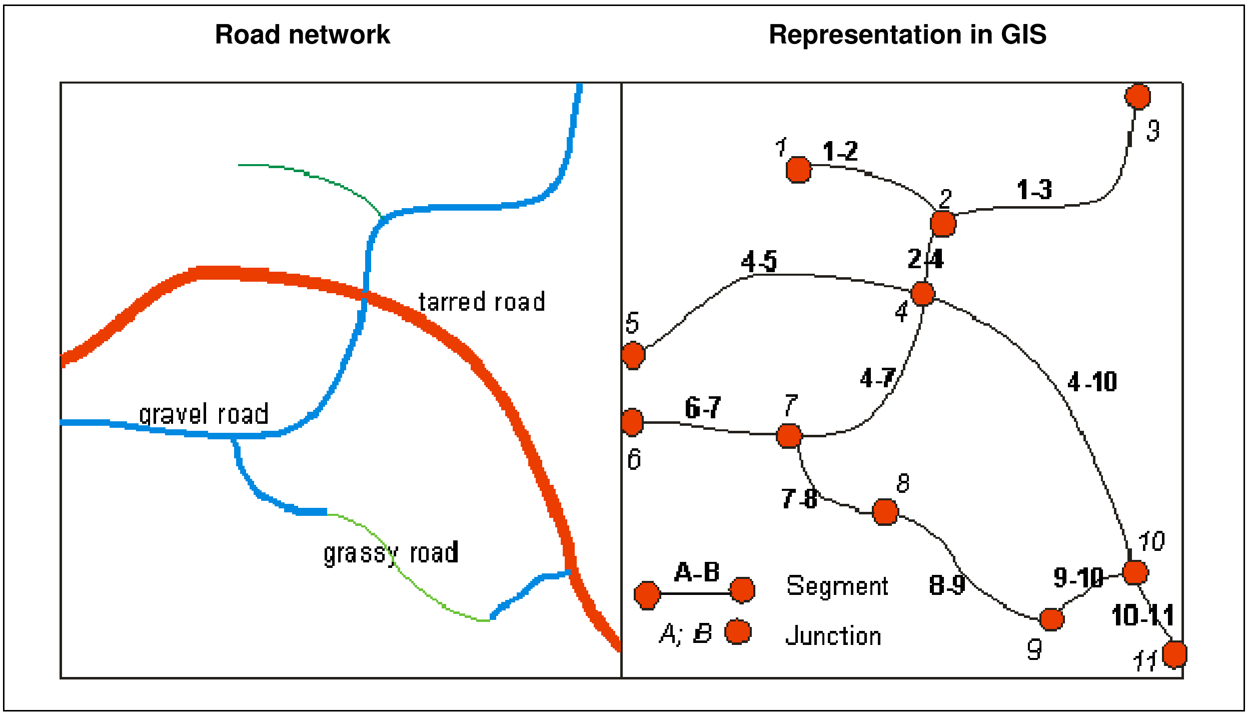
Figure 1: Sector arrangement in *Obergessertshausen* after land consolidation



Source: own illustration based on ICAS (2004) and AGLB-LE (2004)

It is necessary to capture and model the road network so that the driving times between plots and farmsteads can be calculated. In this model, the road network is expressed by a system of junction and road segments in-between these junctions (fig. 2). Junctions also comprise apart from road junctions the end points of roads as well as the reference points for plot sectors and farmsteads. A road segment starts and ends at a junction and is characterized by a uniform road quality. Altogether three road qualities are determined: tarred roads, gravel roads and grassy roads.

Figure 2: Schematic representation of road systems in GIS



Source: own illustration

In order to measure the plot-to-plot and the farmstead-to-plot distances, it is necessary to determine plausible travel routes between plots and farmsteads. This is done with the help of a GIS (Geographical Information System) based optimisation tool that determines the fastest route between the reference points. Plot-to-plot and farmstead-to-plot distances are calculated for each single plot within the four land-consolidation projects.

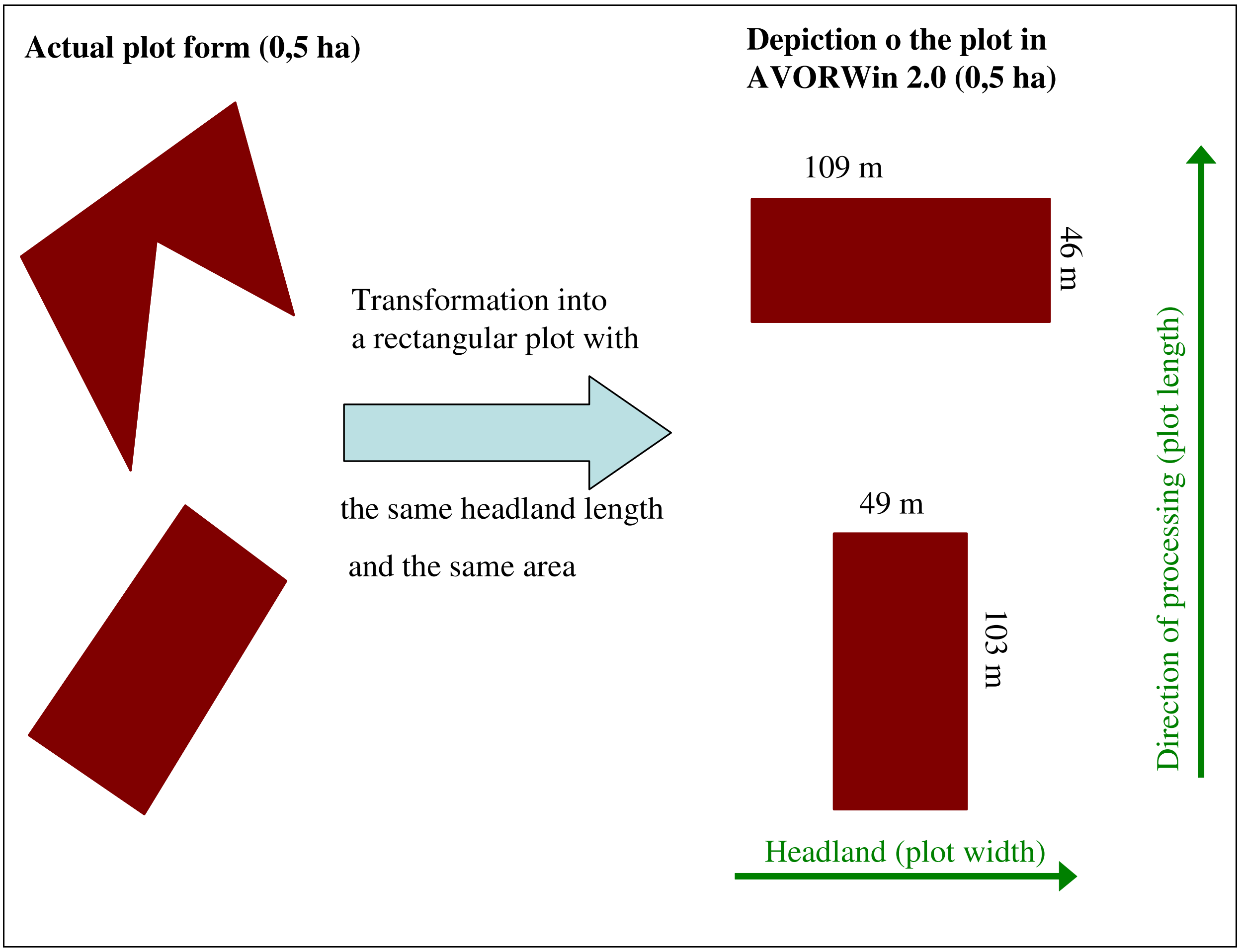
2.2 Modelling the impact of land consolidation on on-plot work

From an economic point of view, an optimal plot is rectangular and has a minimum size of approximately 20 ha. However, plots are often not perfect but small and unfavourably shaped. Such plots require comparatively high labour and machine demand. Land consolidation aims to optimise plot structure and thereby reduces labour demand and machinery costs of on-plot work.

Unfortunately, the applied farm-calculation software AVORWin (KTBL 2002, cf. chapter 2.3) only considers rectangular plot forms. This means that the disadvantages of an imperfect plot form need to be expressed with the help of a rectangular plot. This can be done by varying plot length and width; the broader the plot (this means the greater the plot width or the headland), the higher the number of the necessary turning manoeuvres and, by implication, the required on-plot working time.

The calculation process is demonstrated using the example of two plots with a similar size of 0.5 ha but with different shapes (fig. 3). Plot 1 is unfavourably shaped, plot 2 is rectangular. In order to express the disadvantages of the imperfect form of plot 1 with regard to labour demand and machinery costs, a comparable rectangular plot would have to possess a plot width of 109 m. This is in contrast to the rectangular plot 2 which has the same size, but a plot width of 49 m. Consequently, labour demand is significantly higher for plot 1; for instance, ploughing with a three-share plough and a 74 kilowatt tractor requires 24 % higher labour demand (for a mathematical description of this method cf. KAPFER et al. 2006).

Figure 3: Schematic representation of the derivation of rectangular field piece forms



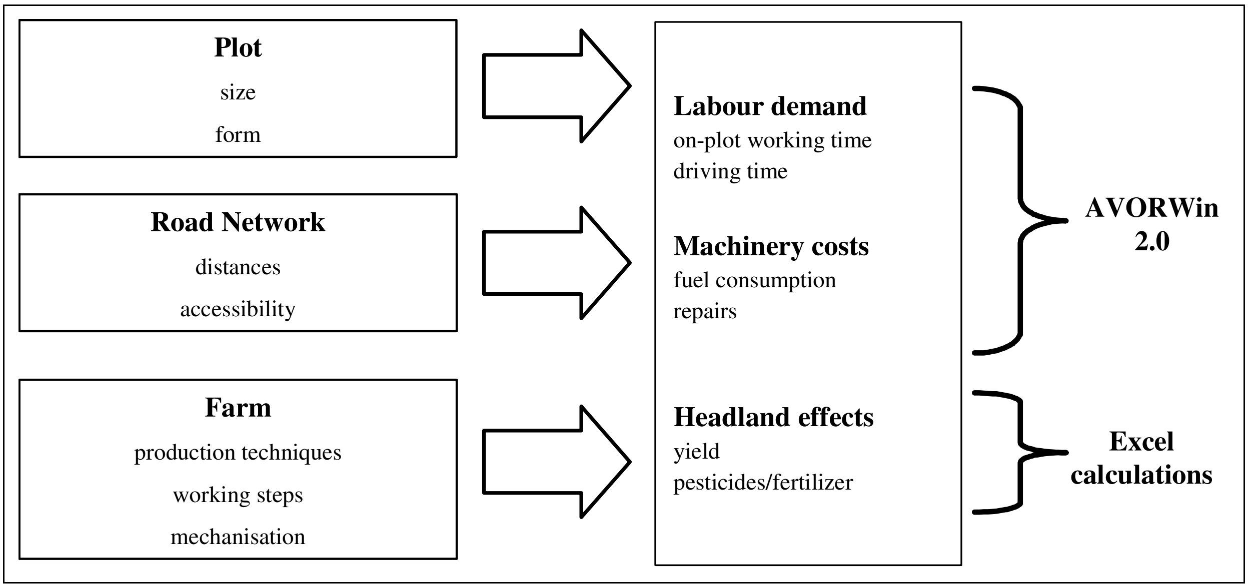
Source: own illustration

2.3 Consideration of farm-specific data and calculation of key figures

As a final step it is necessary to calculate driving times and on-plot work for the specific situation of each individual farm. Therefore farm-specific data, such as mechanisation, crop rotation and intensity of land use is analysed. The database consists of the previously mentioned IACS data and a farm survey covering 80 local farmers working in the project regions. On the basis of this information, nearly 350 production techniques are defined (eg. silage production on a 5-cut grassland with a small tractor, wheat production including straw yield, etc.).

Geographical and farm-specific data is combined in a common database, which makes the calculation of economic key figures possible (see fig. 4). With the help of the software package AVORWin 2.0 (KTBL 2002) labour demand, split up into driving and on-plot working time, and machinery costs, ie. fuel consumption and repairs, are calculated at farm level. In addition, the economic effects of the reduction of headlands are estimated.

Figure 4: Schematic representation of the calculation process



Source: own illustration

In order to determine the economic effects of land consolidation, key figures are calculated for the situation before and after the implementation of the measures outlined previously. Due to the detailed database and calculation process, the economic impact of the considered land-consolidation projects can be shown at crop, farm and project level. In addition, the results can be differentiated with regard to farm size, degree of mechanisation and intensity of land cultivation.

3. Study regions

The conditions for agriculture in Bavaria are very heterogeneous. The *northern parts of Bavaria* are predominantly small-structured and provide unfavourable conditions for agriculture. The structure of agriculture is diverse; the cultivation of low-intensive cereals (rye and barley) and milk production dominate. In addition, part-time farming prevails. In contrast, the *central part of Bavaria* exhibits largely favourable production conditions. Arable land is predominant. Full- time farms cultivating cereals and silage maize are of main importance in this region. The *southern part of Bavaria*, shaped by the proximity to the Alps, is dominated by grassland use and milk production. In addition to these main agricultural areas, a number of *small-scaled loess soil areas* also exist in Bavaria. They show excellent conditions for arable farming. Hence no-stock farms prevail in these areas and sugar beet and wheat dominate the crop rotation.

In order to consider all conditions for agriculture outlined above, four study regions have been selected. In all study regions, land consolidation projects have taken place within the last decade and land-use data is available for the situation pre and post land consolidation. As a result of these projects, field size has increased significantly in all regions (tab. 1):

- The project *Obergessertshausen*, representing the southern part of Bavaria, is located in a grassland area which has a high potential for agricultural yield. As a result of the land consolidation process, the average plot size has grown from 0.4 to 1.6 ha. At the same time the number of plots has decreased from about 750 to only 200.
- The project *Münchsdorf* is a typical example for agriculture in Central Bavaria. The project region shows good conditions for agriculture. It is dominated by arable land used for maize and cereal production. Land consolidation has only slightly improved plot structure and plot accessibility.
- The project *Thann* is situated in Northern Bavaria. This region shows unfavourable productivity. About half of the project region is cultivated as three-cut grassland. Land consolidation has tripled the average plot size to almost 2.1 ha and significantly increased plot accessibility.
- In the project area of *Gaukönigshofen*, a Northern Bavarian loess region, high-yield arable land can mostly be found. Agriculture concentrates on cereal cultivation and sugar beet production. Since labour demand on no-stock farms is small, the region shows a high

percentage of part-time farmers. As a result of land consolidation, the average plot size has risen from 0.9 to 2.8 ha.

Table 1: Key figures in the four project areas after (2004) as well as before and after (1995 and 2004) the land consolidation

	Obergesserts-hausen		***Münchsdorf***		***Thann***		***Gaukönigshofen***	
Grassland in ha	246		60		254		14	
Arable land in ha	86		500		214		718	
Part time farmers in % [1)]	25		30		17		39	
Average farm size in ha [1)]	32		40		45		45	
Year	**1995**	**2004**	**1995**	**2004**	**1995**	**2004**	**1995**	**2003**
Plot accessability in % [2)]	74	100	85	95	73	100	100	100
Average plot size in ha	0.38	1.56	0.67	1.25	0.72	2.08	0.91	2.80
Number of plots	745	200	501	344	575	195	847	204

[1)] *based on farm survey*

[2)] *share of plots with direct access to roads (distance less than 10 m)*

Source: own calculations based on ICAS (1995, 2004) and AGLB-LE (1995, 2004)

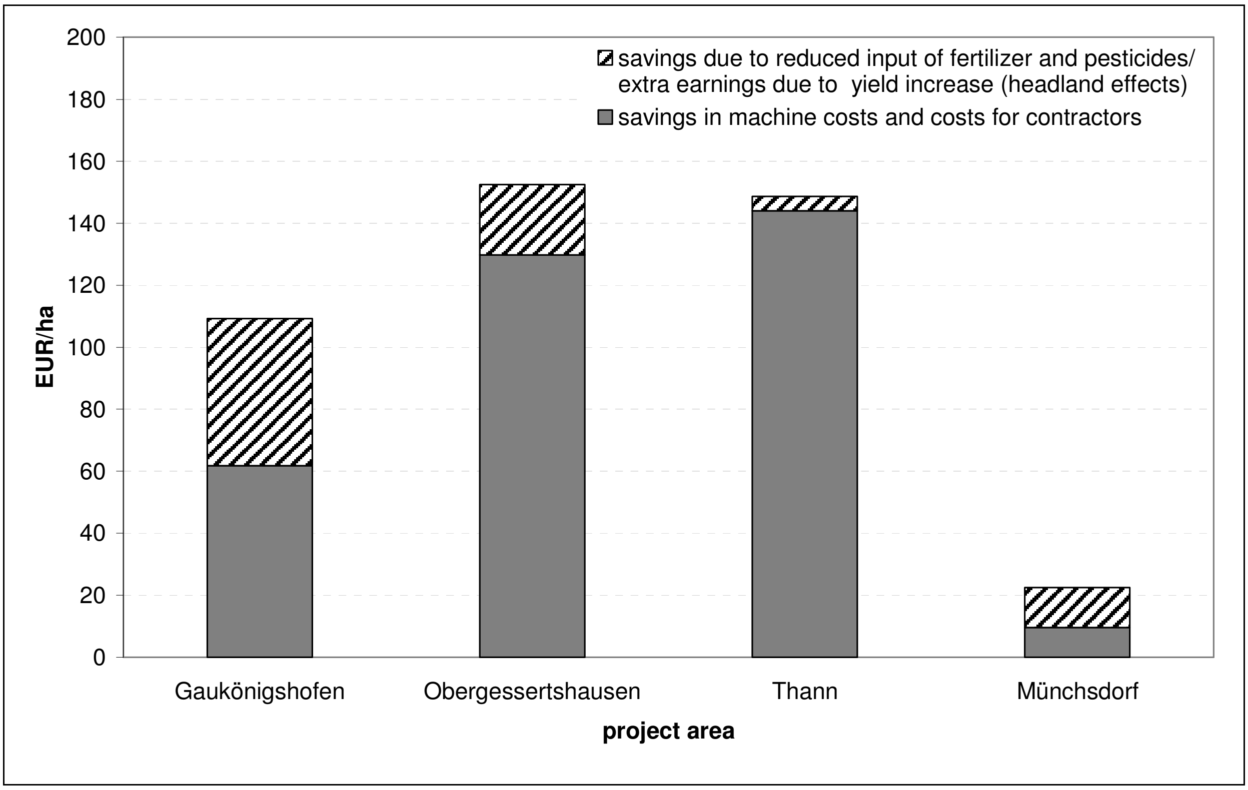
4. Results

The model calculations show that land consolidation has reduced production costs and labour demand required for the production process in all study regions. The actual amount of savings depends on initial plot size and on how much the size of these plots can be increased. In general, it can be said that the smaller the initial plot size and the more this plot size can be increased, the higher the economic savings (cf. also KAPFER et al. 2003).

Furthermore savings clearly depend on the grassland/arable-land share (cf. fig 5): The highest potential for cost and labour savings are found in grassland dominated regions (*Obergesserts-hausen*, *Thann*) where land consolidation has resulted in a saving of up to 20 working hours (WH) per year and 150 EUR per hectare utilised agricultural acreage (UAA). In arable-dominated regions (*Gaukönigshofen*, *Münchsdorf*) there is generally a lower potential for savings. Hence the model calculations show a reduction of labour time ranging only from 1.5-7 WH per year and 20-110 EUR per hectare UAA.

Figure 5 further shows that in grassland-dominated regions, cost savings are almost exclusively based on decreasing variable machinery costs. Economic effects of reduced headlands resulting from a lower input of mineral fertiliser and pesticides are of minor importance. In arable-dominated regions, on the contrary, such headland effects can reach approximately the same extent as savings created by lower variable machinery costs.

Figure 5: Shift in economic success in land use during the land consolidation process

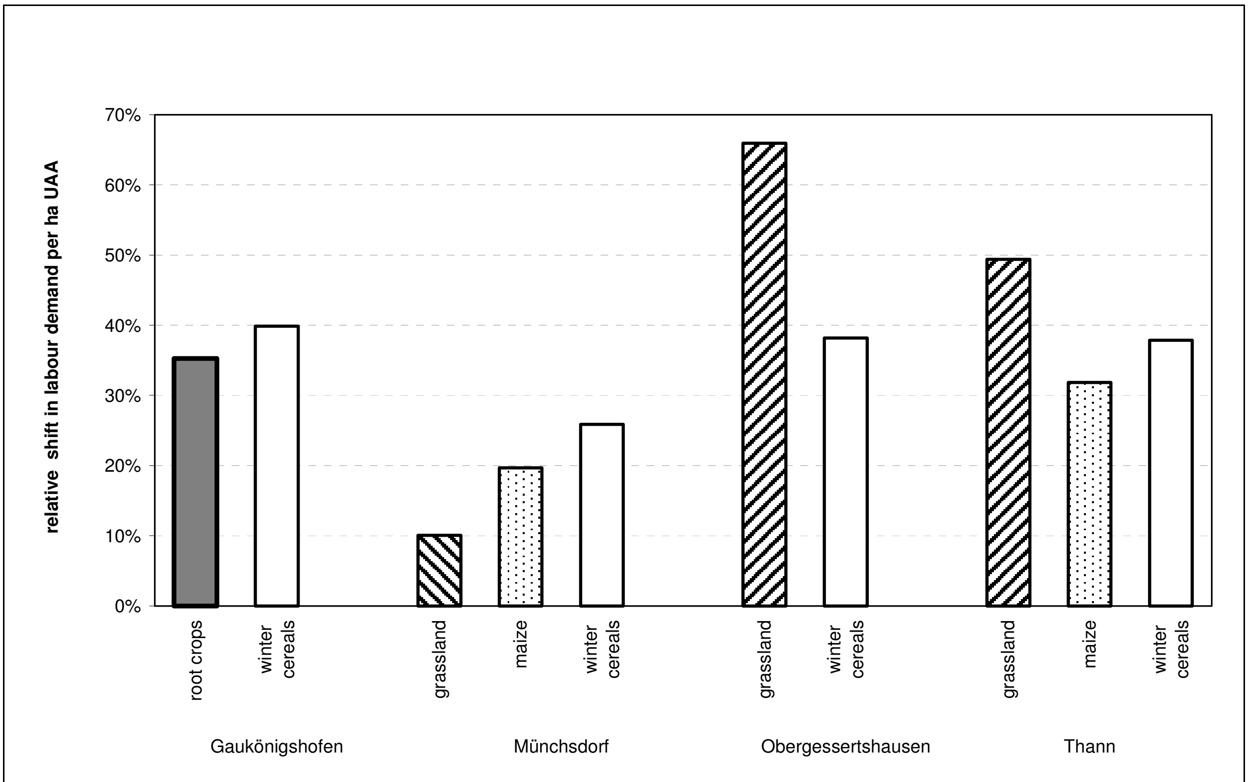


Source: KAPFER et al. (2006, p. 218).

A more in-depth analysis will help to explain these results. Figure 6 demonstrates the relative savings in labour demand differentiated into crop groups and project areas. Clearly the variation of savings is much greater in grassland use than in arable-land use. This greater variation results from the fact that grassland is cultivated in different intensities in the project areas; in *Obergessertshausen* the savings are very high due to the fact that grassland cultivation is extremely work-intensive considering the fact that four to five cuts per year are required. In *Münchsdorf*, on the other hand, only small savings can be achieved because the grassland use in this region is extremely low-intensive, with only few production steps. In addition, the grassland-plot sizes have hardly increased.

In contrast to grassland use, the variation of saving in arable land use is small. One major explanation for this finding is that the cultivation of arable crops such as cereals and sugar beet is highly standardised and does not differ greatly between farms and regions. Arable farming in addition requires comparatively few procedures; hence it does not offer much potential for savings. However, *Münchsdorf* shows a significantly smaller decrease in labour demand than the other project areas; this is due to very small increase in plot sizes.

Figure 6: Relative savings of labour demand in grassland, maize and cereals cultivation due to land consolidation



Source: KAPFER et al. (2006, p. 187)

5. Discussion and conclusions

The method presented in this paper combines a GIS application and an agro-economic data bank application. The resulting economic calculation model allows a detailed analysis of the economic effects of land-consolidation projects. The detailed database and the complex design of the model makes it possible to differentiate the results on various levels such as crop type, farm and project area. Overall the study shows that a detailed analysis based on spatially explicit data and extensive calculations is necessary in order to achieve reliable results. However, the applied approach requires extensive processing of the database. For instance, in order to consider the disadvantages of unfavourable shaped plots it is necessary to express these plots as artificial, rectangular shaped plots. Furthermore, in order to achieve an insight into the farm-specific effects of land consolidation, extensive farm surveys are necessary.

The results obtained show that land consolidation can achieve significant labour and cost savings for agriculture. However, the extent of these savings differs greatly depending on regional conditions. Land consolidation is particularly worthwhile when (1) initial plot structure is extraordinarily unfavourable, (2) initial plot structure is improved significantly and (3) applied agricultural production processes are labour-intensive, as is the case with intensive grassland use. These conclusions are supported by a comparison of the results of the present study with the results of other studies carried out by KEYMER et al. (1989), THOMAS et al. (2003, 2005), KLARE et al. (2005), ENGELHARDT (2004) and Rintelen (2002, 2006; for a detailed description of this comparison cf. KAPFER and KANTELHARDT 2007).

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