

# Estimation of costs for maintaining landscape elements by the example of Southwest Germany

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# **Estimation of costs for maintaining landscape elements by the example of Southwest Germany**

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## **Abstract**

In comparison to large-scale natural landscapes separated from extensively used agricultural production landscapes in North America or Australia, German and Central Europe landscapes are all characterised by predominantly agricultural landscapes with few “rests of nature”. Due to the high population density, different types of land users demand different functions of the landscape. In addition to food production, there is a high demand for protection of cultural heritage by caring for e.g. hedgerows in the landscape. The aim of this study was to estimate the costs arising from the maintenance of landscape elements in landscapes situated on land with different site conditions. As an example, the distribution of hedgerows on sites of varying agricultural quality were considered. The calculations were undertaken on the entire area of Baden-Wuerttemberg in Southwest Germany, comprising various administrative districts. The association between ecological and economic information was analysed statistically and with the help of GIS. The results indicate that the costs for landscape element protection differ within the state of Baden-Wuerttemberg and that there is a lot of economic pressure against hedgerow biotopes existing in certain districts. Measures for protection such as agri-environmental programmes should consider the different landscape-dependent costs.

**Keywords:** landscape elements, economic model, geographic information system, plot size

## **1. Introduction**

The ecological values of landscape elements such as hedgerows, copses and edges are well known (Baudry et al., 2000). Certain hedgerows offer specific habitats for fauna and flora in agricultural landscapes, habitat networks are built by several hedgerows and edges situated close to each other. They came into being by the action of land users for preventing wind erosion or by spontaneous vegetation succession over several decades. On the other hand, these elements are cost intensive for farmers (Heissenhuber, 1999). There are three main points to mention. The area that cannot be used for production purposes, the costs caused by maintenance and caring for the hedgerows and the higher costs due to

inhibited agricultural practice. There are higher labour and machine costs arising from a restricted use of technical progress on these parts of the landscapes with high numbers of hedgerows.

Landscapes in Central Europe show a high variance in site conditions and therefore, in suitability for agricultural purposes but also in distribution of landscape elements.

The correlation between the agricultural site quality and the distribution of hedgerows was already studied in the example of Baden-Wuerttemberg (Kantelhardt et al, 2003). In the case of a strong spatial correlation between a high amount of hedgerows and low site quality, the management of hedgerow maintenance could be determined by this relationship. But this correlation was only found on the level of single regions. The new approach is, therefore, aiming for the region by region calculation of costs arising for farmers farming in landscapes with hedgerows.

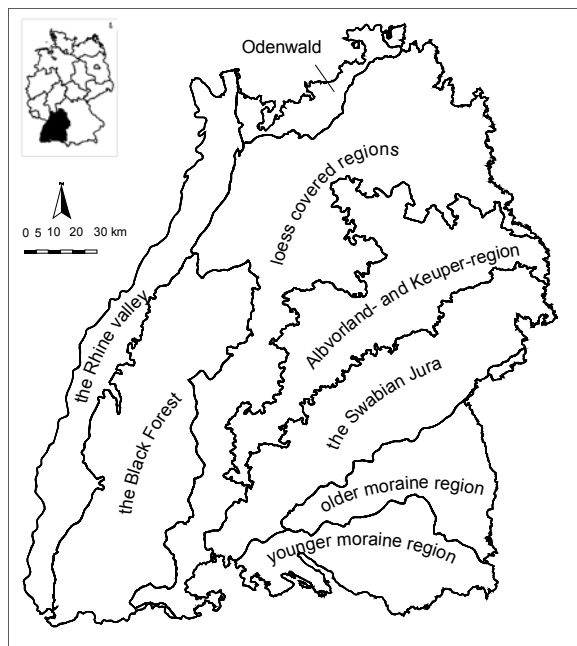
## **2. Materials and Methods**

In this section the study region, the data base and the method for calculating the costs for preserving hedgerows will be described.

### **2.1. The study region in Southwest Germany**

In Central Europe there is a high interest in protection of cultural heritage landscapes. They are products of the land use history of the last centuries. These landscapes are characterised by farming plots of different sizes and non-used areas in between. These non-used areas often have a function as habitats for several wildlife species. Not only in France (*bocage*) but also in Germany, some areas are well known for their networks of hedgerows. This type of landscape still exists especially in the southwestern part of Germany. The study region Baden-Wuerttemberg is one of the German federal states situated in the Southwest of Germany. It is approximately 35,000 km<sup>2</sup> in size and is subdivided into 1,111 communities and 44 administrative districts. Regarding agriculture, Baden-Wuerttemberg shows a wide variance in site and production conditions.

The parts better suited for agricultural purposes are currently dominated by intensively used arable plots (e.g., Rhine valley, Kraichgau). The less-favourable natural units, situated predominantly in mountainous areas (e.g. the Black Forest, the Swabian Jura), are used as grassland interspersed with arable land. Certain parts such as parts of the Swabian Jura are dominated by a high density of hedgerows.



*Fig. 1: Study region Baden-Wuerttemberg in South West Germany*

## **2.2. Data base**

Two types of data bases and methods are used.

1. The information about the landscapes consists of the distribution of plot sizes and the amount of hedgerow area. Both data bases are derived from an aerial photo (orthophoto) classification (Fichtner et al., 1994). For this analysis the entire area of Baden-Wuerttemberg was subdivided into a grid of about 1 km<sup>2</sup> size and, for each grid, the average plot width (< 50, 50 – 100, 100 – 200 and > 200 m) and the percentage of linear hedgerows (< 1, 1-2.5, 2.5-5 and > 5%) was estimated (result see Fig. 2). In a second step, the plot width was transformed to plot sizes, whereby the corresponding plot size classes were assumed to be 0.5 ha, 1.5 ha, 3.5 ha and 10 ha.

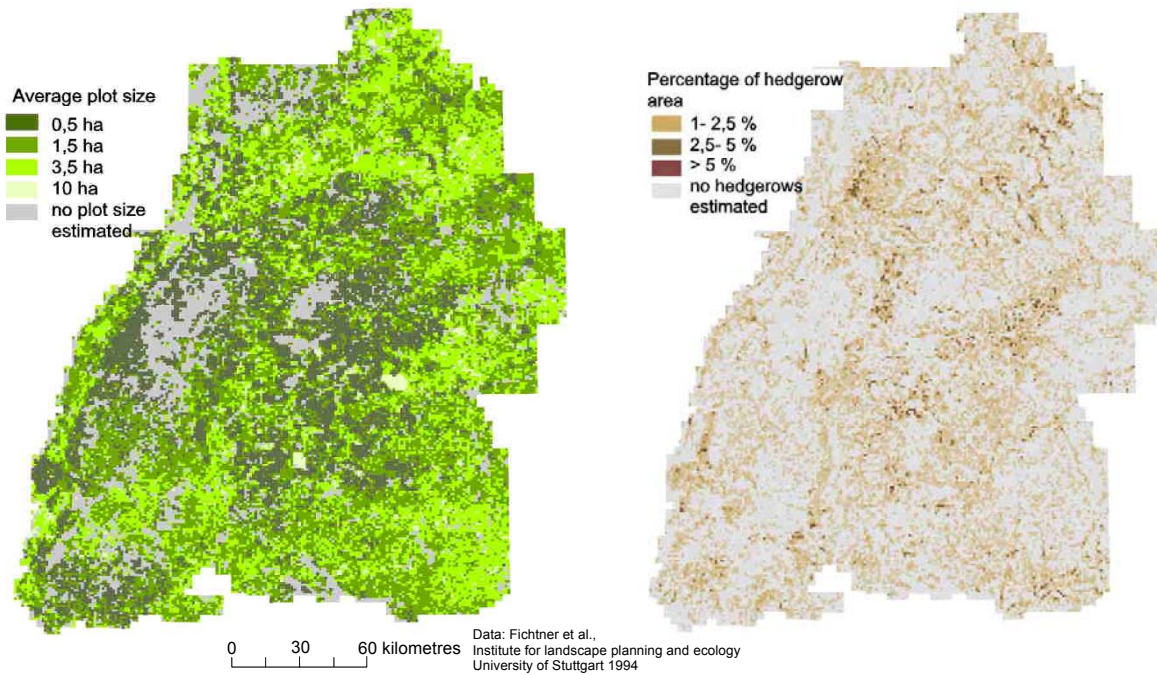


Fig. 2: Distribution of different plot sizes and hedgerows in Baden-Wuerttemberg

2. The yield data and the data on crop rotation were gathered from statistical data (Stat. Bundesamt, several years). The yield data are the long-term averages of the main crops, regionalised for the different regions of Baden-Wuerttemberg. The extent of the different crops in the rotation is based on statistical data with a resolution of district level. (see Tab. 1)

Tab. 1: Data base (yield, crop rotation, etc.)

<u>DATA</u>	<u>SOURCE</u>	<u>LEVEL</u>
⇒ Yield	Official statistics	District
⇒ Crop rotation		
⇒ Plot size	Orthophoto	Square kilometre
⇒ Hedgerow area		

The indicators actually used in the study were derived by overlaying the different digital maps and by determining a common spatial resolution. Since the administrative district was the lowest common data resolution, all other databases having different resolutions such as square kilometre (average plot size and hedgerow areas) were adapted to that resolution.

### 2.3. Calculation of plot-specific costs

In order to calculate the costs caused by hedgerows it is necessary to know the number of plots with hedgerows and the costs per single plot. First, the calculation of the plot specific costs will be demonstrated. The data base consists of the following:

(1) the area covered by hedgerows, (2) the size of plots, (3) the different yield levels and the extent of the different crops in the rotation (percentage of crops) (see Fig. 3).

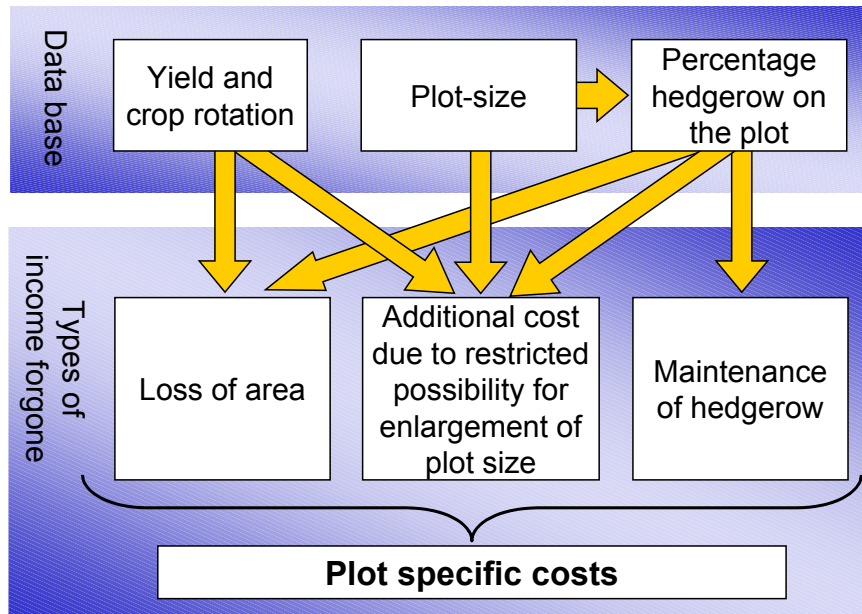


Fig. 3: Model for the calculation of plot-specific costs

There are three main factors influencing the costs caused by hedgerows adjacent to agricultural land:

(1) The area for hedgerows compete with the agricultural use of the soil resource. The resulting costs of this loss of area depends on the amount of area covered by hedgerows and the gross margin that the farmer could receive for this area. The amount of the gross margin depends on the yield and the crop rotation.

(2) In landscapes with many hedgerows there is only a low possibility to realise land consolidation or other measures to improve farming conditions. This results in higher labour costs and higher variable machine costs. The labour requirement and the variable machine costs for production of the most important crops are calculated with the help of AVORWin Version 1.0 (a programme for the calculation of land cultivation costs on farm level; KTBL, 1999). The calculation considers the four assumed plot size classes 0.5 ha, 1.5 ha, 3.5 ha and 10 ha (see chapter 2.2). Furthermore there was assumed a mean level of farm mechanisation for all of Baden-Wuerttemberg.

Labour requirements and variable machine costs depend on the type of crop cultivated and the plot size. Crops were summarised in groups of „grandes cultures“ (winter wheat, winter barley, winter rye, summer barley, oat and winter rape), root crops (potatoes, sugar beet), forage crops (forage maize, grass-clover mixture), fallow land and grassland. Fig. 4 shows that the costs for cultivation are extremely high for small plots. This applies to cost- and work-intensive root crops as well as for the less-intensive cereal production.

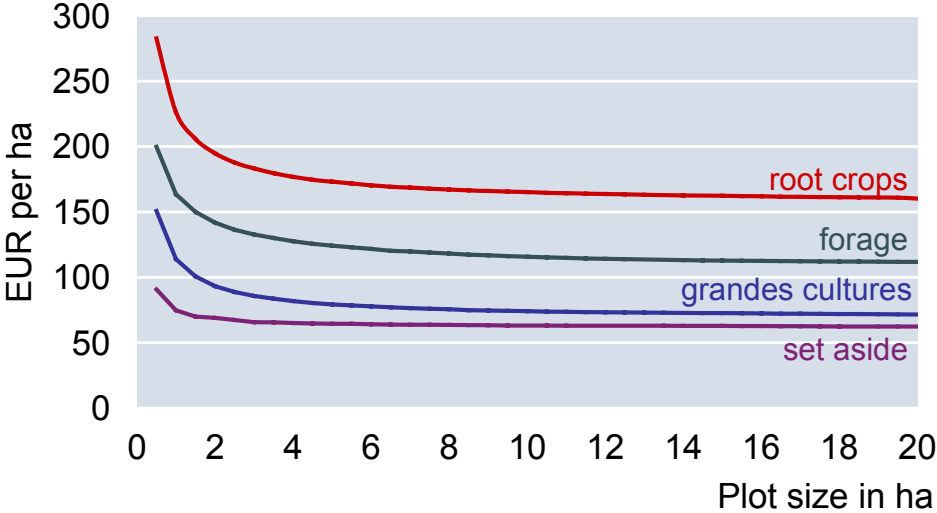


Fig. 4: Plot size and machine costs for different types of crops

For calculation of additional costs due to the restricted opportunity to enlarge the plot size caused by the hedges there is a need for a reference value. In Figure 4 it is shown that starting with a plot size of 10 hectares there is no longer a scale effect. This is assuming the average type of machine equipment. Consequently, the average machine costs are constant. The current size of the plots is, therefore, compared to a reference plot of the size of 20 ha, because there are no longer changes in costs due to the scale effect.

(3) The maintenance of hedgerows requires additional labour. The cost of maintenance of the hedgerow is dependant on the size of area covered by hedgerows. Assuming that all plots are rectangle and one hedgerow of three metres width is bordering one side, the percentage of area covered by hedgerows can be calculated as follows: In the case of a 0.5 ha plot, 6.0 % of the area would be covered by hedgerows, in the case of a 20 ha plot this would amount 0.9 % (see Fig. 5)

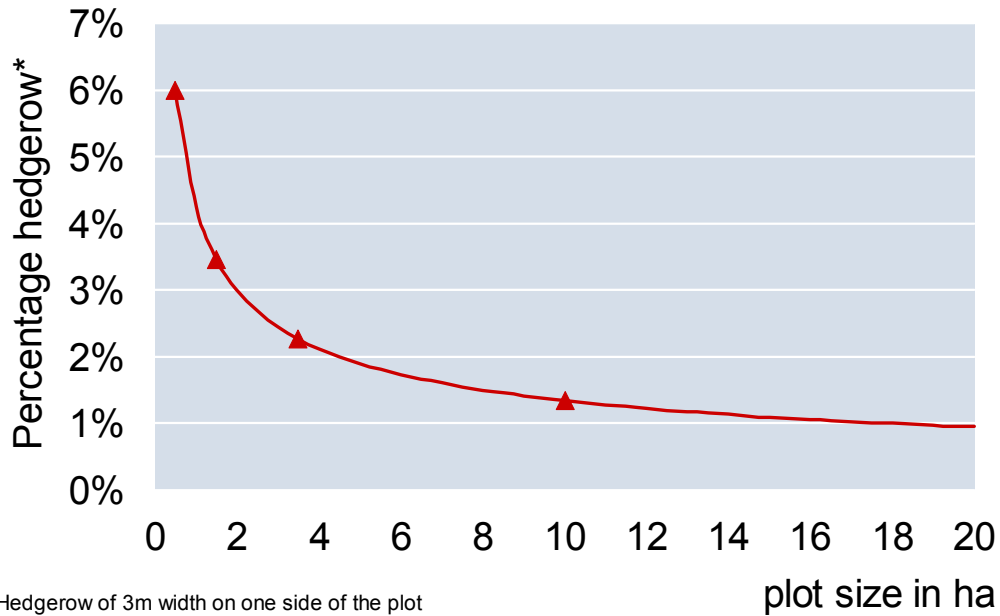


Fig. 5: Plot size and corresponding size of hedgerow area

All these costs together (loss of area, additional costs due to restricted possibility for enlargement of plot size, maintenance of hedgerows) result in the amount of money which is needed to preserve a certain kind of hedgerows or to maintain a well structured landscape.

#### 2.4. Calculation of district-specific costs

In the previous section, the calculation were for plot specific costs, in this section the district specific costs will be calculated. In order to calculate the district-specific costs it is necessary to determine the amount of plots with adjacent hedgerows. A data base for this step with orthophotos (aerial photo classification) from Baden-Wuerttemberg was used. The orthophotos were subdivided into a square-kilometre grid. For each grid the percentage of linear hedgerows and the predominant plot size was estimated (see Fig. 6 and chapter 2.2).



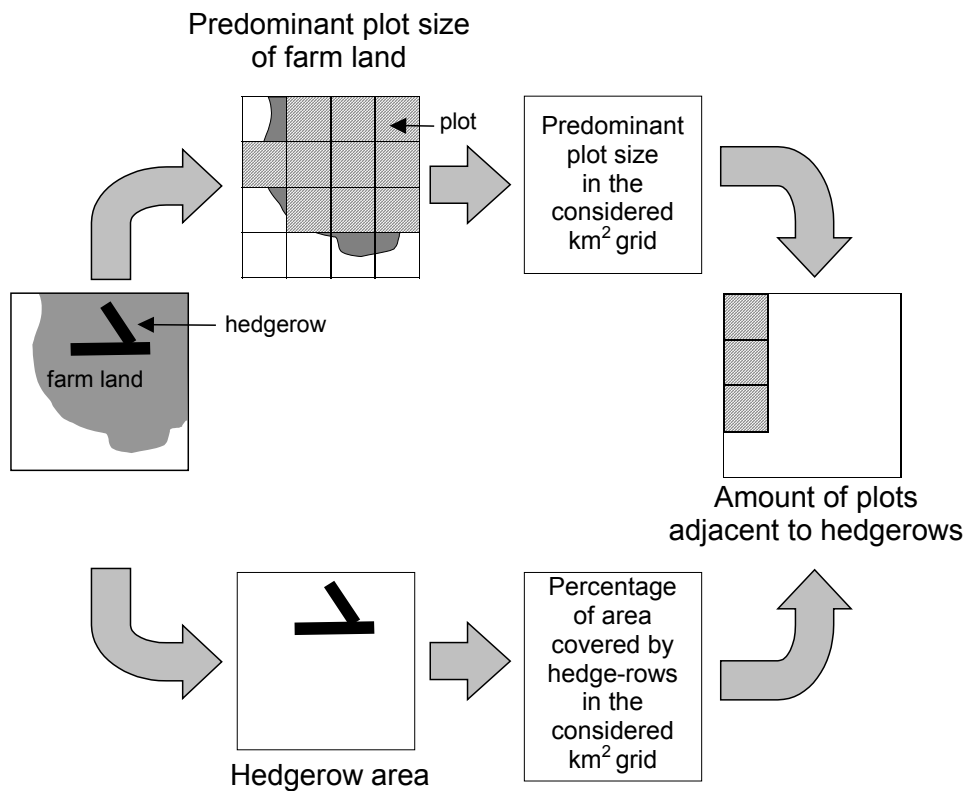


Fig. 6: Estimating predominant plot size, hedgerow area and plot adjacent to hedgerows on square kilometre grid

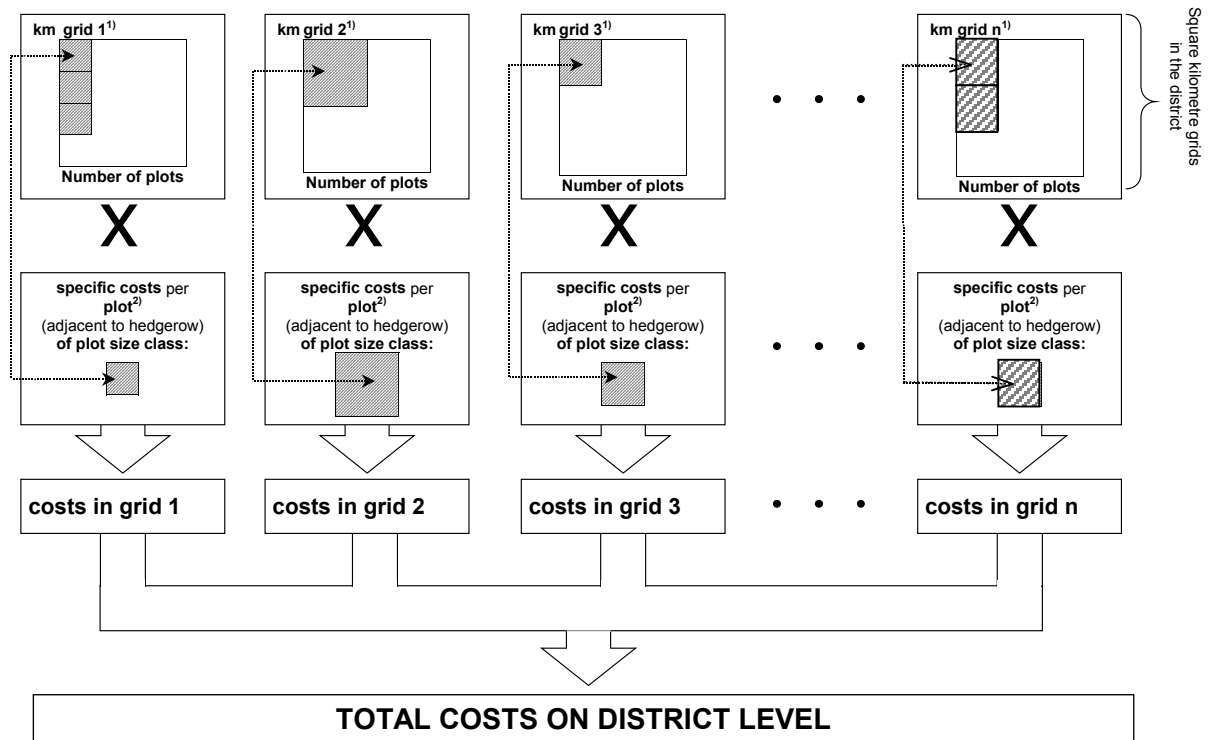
In accordance with the assumption that hedgerows border plots only on one side and have a width of three metres, the amount of plots with adjacent hedgerows can be calculated for each square kilometre. For calculation of the amount of plots adjacent to hedgerows the area of hedgerows in each grid has to be divided by the calculated plot-size specific hedgerow area (compare Fig. 5):

$$\text{Amount of plots adjacent to hedgerows} = \frac{\text{Area of hedgerow in each grid}}{\text{Plot specific hedgerow area}}$$

For example: Calculation of amount of plots in a grid with predominant plot size of 0.5 ha and 1% hedgerow area.

$$33 \text{ plots adjacent to hedgerows in the grid} = \frac{10,000 \text{ m}^2 \text{ of hedgerow in the grid}}{300 \text{ m}^2 \text{ (for a plot size of 0.5 ha)}}$$

The final step of the calculation is to multiply the amount of plots adjacent to hedgerows in a certain square kilometre by the plot-specific costs. The resulting costs can be summed up on a district level or the state level comprising all of Baden-Wuerttemberg (see Fig. 7)



1) See Fig. 6

2) See Fig. 3


 Plot adjacent to hedgerow

Fig. 7: Calculation of costs for maintenance of hedgerows on the district-level

### 3. Results

This study resulted in a model for calculation of the costs arising from cultivation of single plots adjacent to hedgerows. It becomes clear that these costs are increasing with rising intensity of land use and decreasing plot size. Some examples are given in Figure 8. Hedgerows adjacent to small plots in high yield areas and cultivated with root crops cause costs up to 220 EUR/ha. Important to note is that in such regions hedgerows are especially important for soil protection purposes (preventing soil erosion). On the other hand, hedgerows adjacent to grassland in well-structured areas entail low costs.

Figure 8 shows that the cost differences between the different types of plots result mainly from the plot-size related costs (labour and machine costs) and the costs due to maintenance of hedgerows. The costs arising from the loss of area (loss of income) are comparatively low in all cases (see Fig. 8).

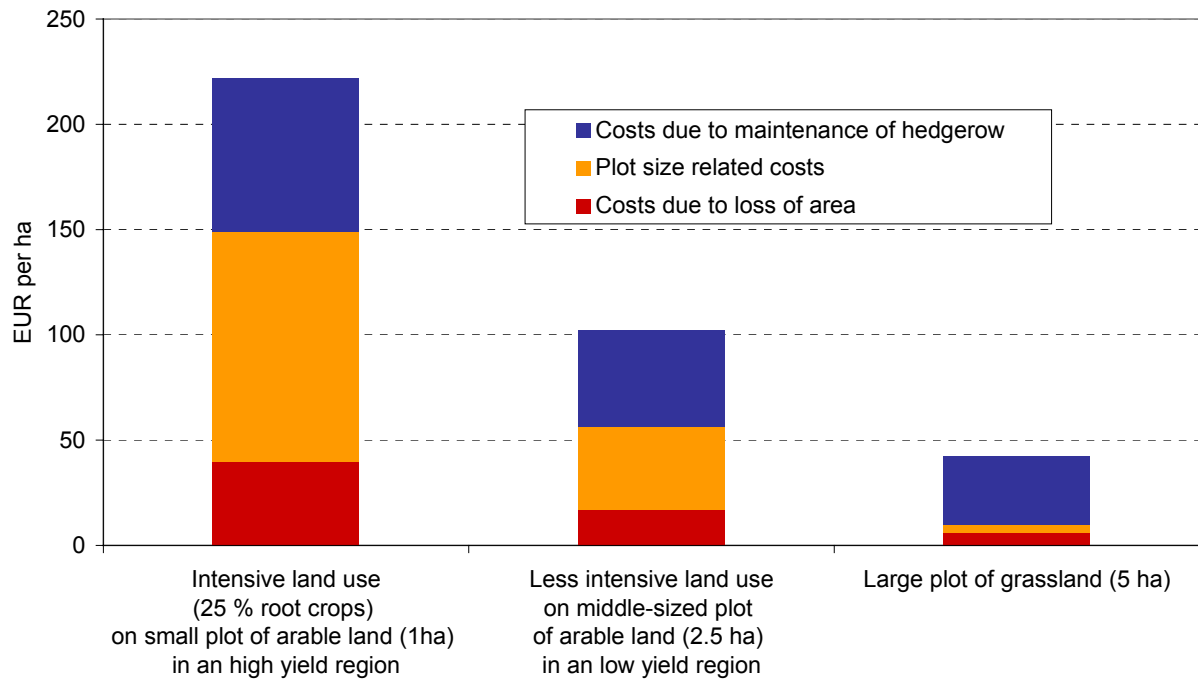


Fig. 8: Examples for plot-size specific costs

Figure 9 shows the spatial distribution of the costs arising from the existence of hedgerows on agricultural land. The left part of the Figure shows the consequences for farmers. It depicts the costs that arise for farmers with plots bordered by hedgerows. These costs can also be interpreted as economic pressure against hedgerows. High costs for farmers can be found in central Baden-Wuerttemberg. This area can be characterised by its small-scaled plot structure. The lowest costs arise for those farmers who are situated in grassland areas.

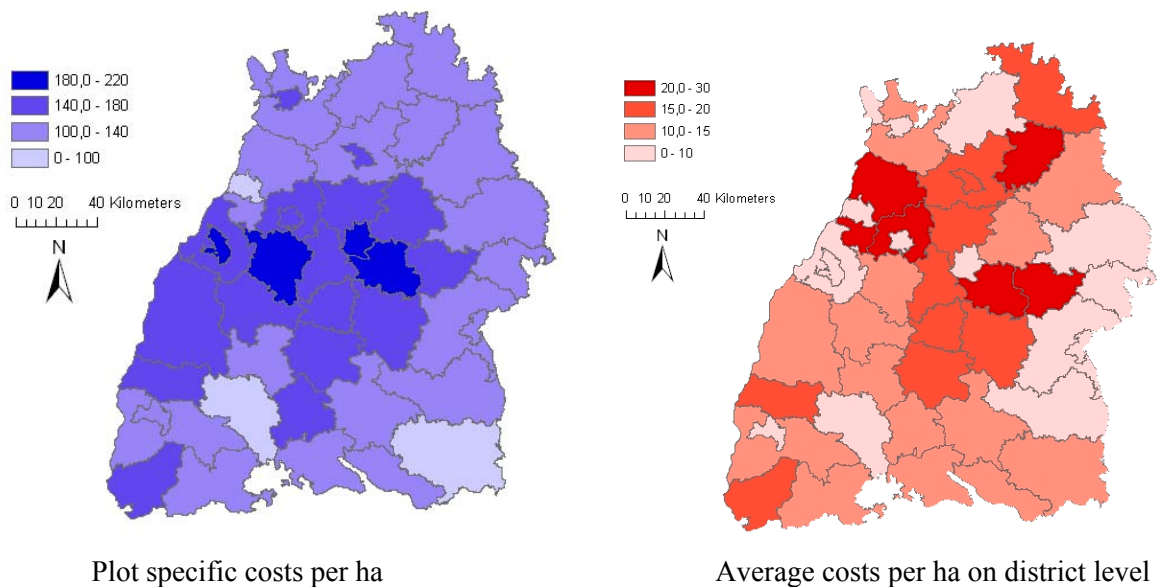


Fig. 9: Spatial distribution of costs caused by hedgerows

The right part of the Figure 9 concentrates on the administrative district. It shows how much a district has to pay per hectare, if all costs caused by hedgerows would be compensated. High costs are found in areas with high site quality (north-eastern part) as well as in marginal areas (central part). The lowest costs can be observed in the eastern part of Baden-Wuerttemberg.

In order to explain the results in greater detail, selected single districts were focused upon (Tab. 3); For example, in the district of Esslingen the high percentage of small plots dominate all other factors. Consequently, the costs caused by hedgerows are the highest in the whole state of Baden-Wuerttemberg. Even in the district of Heilbronn where the productivity is higher than in Esslingen, the costs related to hedgerows are lower. This is the consequence of the more favourable plot structure.

*Table 3: Economic indicators for selected districts*

	<b>Esslingen</b>	<b>Heilbronn</b>	<b>Ravensburg</b>	<b>Rastatt</b>	<b>Hohenlohe</b>
<b>Plot specific costs (EUR/ha)</b>	205	126	76	165	115
<b>Average costs (EUR/ha)</b>	23	15	10	10	17
Costs due to					
maintenance of hedgerows (%)	37	40	57	40	44
loss of area (%)	10	18	13	11	15
plot-size related (%)	53	42	29	49	41
<b>Productivity (gross margin in EUR/ha)</b>	473	753	403	478	586
<b>Hedgerows (% of district area)</b>	0,49	0,36	0,35	0,23	0,52
<b>Small plots (0.5 ha) (% of UAA)</b>	61	17	1	53	9

Due to the low productivity and the fact that there are only a few small plots in the grassland-dominated district of Ravensburg, the costs of maintaining hedgerows are low. In the district of Rastatt plot-specific costs are high, while average costs per ha are low. This is the consequence of the small percentage of hedgerows in this district. In the district of Hohenlohe the situation is quite the contrary.

#### **4. Discussion and Conclusion**

Landscape elements, such as hedgerows must be seen in the context of the agricultural land use. In this article we have shown that there are several interrelations between land use and hedgerows. In order to maintain hedgerows we conclude that it is necessary to compensate the disadvantages for farmers arising from the type of cultivated crops and the plot-size. We demonstrated regionally differentiating costs of maintaining hedgerows using the example of Baden-Wuerttemberg.

The most important economic disadvantage results from restricted possibilities for farmers to enlarge the plot-size. Due to this fact, the implementation of new technologies, e. g. winning management, is prohibited. On the other hand, the question remains whether it is justified to charge the hedgerow for

all plot-size related costs. There are other factors, which also prohibit the enlargement of plot-sizes (compare Kantelhardt et al., 2003). This is, for example, the case in districts of gavelkind tenure.

In the future it is expected that with technical progress the question of plot sizes will gain importance. Figure 10 shows that the disadvantage of the cultivation of a small plot (0.5 ha) compared to a large plot (20 ha) has obviously increased during the last twenty-five years. This applies in particular to the variable machine costs. For root crops the potential of reduction of costs increased between 1975 and 2003 from 100 to 400 EUR/ha. Since hedgerows are often accompanied by a small-structured landscape, in the future it is expected that the agricultural land use is in danger of being abandoned.

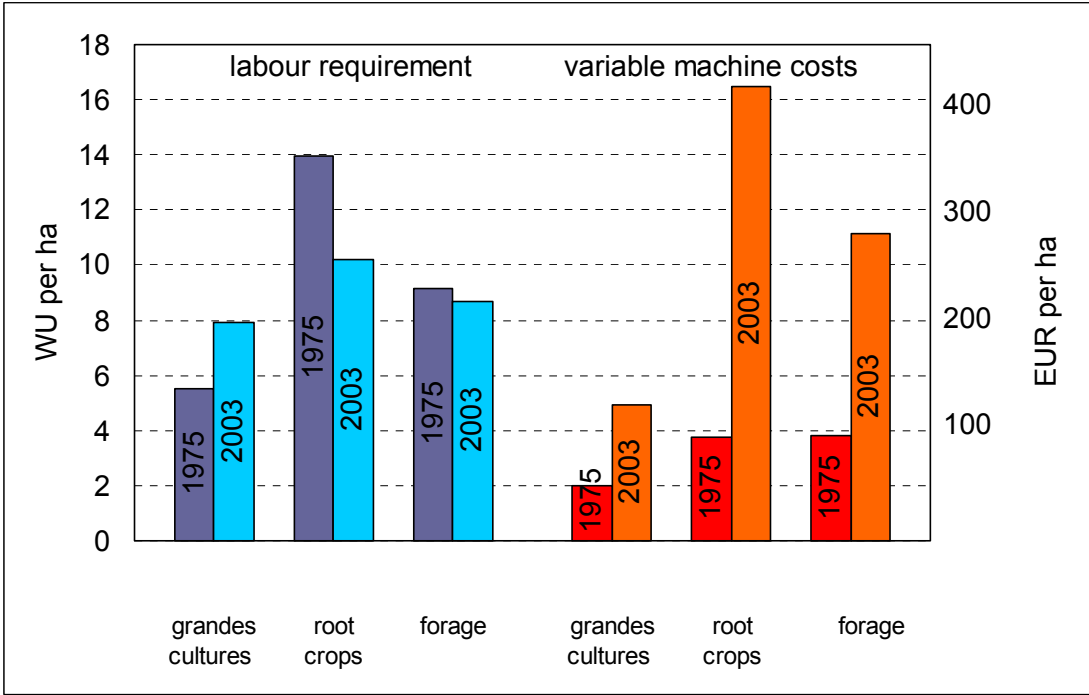


Fig. 10: Disadvantage of the cultivation of a small plot (0.5 ha) compared to large plot (20 ha) in 1975 and 2003 (WU: working unit)

Consequently, in order to maintain the landscape shaped by hedgerows it is necessary to develop an agri-environmental programme. Such a programme should, of course, consider regional aspects in order to avoid windfall effects. The presented method shows such a way to regionalise agri-environmental programmes.

From a methodological point of view, it is necessary to say that it was extremely work intensive to create this data base. Therefore, we encourage further studies to make improvements to the data base. Modern techniques like remote sensing could help here. Furthermore, the applied method should be enhanced by considering positive effects of hedgerows. Conceivable positive functions of hedgerows are soil protection and providing a habitat for beneficial insects.

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