Estimation of Costs for Maintaining Landscape Elements by the Example of Baden-Wuerttemberg

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Abstract
The aim of this study was to estimate the costs arising from the maintenance of landscape elements in landscapes with different site conditions. For example, the distribution of hedgerows on sites of varying agricultural quality were considered. The calculations were undertaken on the entire area of Baden-Wuerttemberg, 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 high pressure on hedgerow biotopes existing in certain districts. Measures for protection such as agri-environmental programmes should consider the different landscape-dependent costs.

1. Introduction
The ecological values of landscape elements such as hedgerows, copses and edges are well known (Baudry et al., 2000). On the other hand these elements are cost intensive for farmers (Heissenhuber, 1999). Landscapes 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 studied in the example of Baden-Wuerttemberg (Kantelhardt et al, 2002). In the case of a strong correlation the payments for hedgerow maintenance could have been oriented at a low site quality. This correlation was found on the level of single natural units. The new approach is therefore aiming at the calculation of costs arising for farmers by farming in landscapes with hedgerows.

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2. Materials and Methods

The study region, the database and the method for calculating the costs for preserving hedgerows are described.

2.1. The study region Baden-Wuerttemberg

The study region Baden-Wuerttemberg is one of the German federal states situated in the Southwest of Germany. It is approximately 35,000 km² in size and is subdivided into 1,111 communities and 44 administrative districts. Regarded from an agricultural viewpoint, Baden-Wuerttemberg shows a wide variance in site and production conditions.

Parts better suited for agricultural purposes are currently dominated by intensively used arable fields (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. Single parts such as parts of the Swabian Jura are dominated by a high density of hedgerows.

2.2. Data base

Two types of data bases and methods are used.

1. The information about the landscapes consists of the distribution of field sizes and the amount of hedgerow area. Both data bases are derived from an aerial photo classification (Fichtner et al., 1994). For this analysis the entire area of Baden-Wuerttemberg was subdivided in raster of about 1 km² size and, for each raster, the average field 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. In a second step the field width was transformed to field sizes, whereby the corresponding field size classes were assumed to be 0.5 ha, 1.5 ha, 3.5 ha and 10 ha.

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 parts of Baden-Wuerttemberg. The extent of the different crops in the rotation is based on statistical data with a resolution of district level.

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 resolution such as square kilometre (average field size and hedgerow areas) were adapted to that resolution.
2.3. Calculation of plot-specific costs

There are three main factors influencing the costs caused by landscape elements adjacent to agricultural fields:

1. The area for landscape elements compete with agricultural use of the resource soil.

2. In element-rich landscapes there is only a low possibility to realise land consolidation or other measures improving farming conditions. This is resulting in higher working costs and higher variable machine costs.

3. The maintenance of hedgerows requires additional labour.

The calculation procedure considers the area covered by landscape elements (hedgerows), the size of field-plots, the different yield levels and the extent of the different crops in the rotation (percentage of crops) (see Fig. 1).

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 (KTBL, 1999) considering the four plot sizes of 0.5 ha, 1.5 ha, 3.5 ha and 10 ha. As a prerequisite a mean level of farm mechanisation is considered for typical Baden-Wuerttemberg farms. The results of the single crops are summarised by groups of „grandes cultures“ (winter wheat, winter barley, winter rye, summer barley, oat and winter rape), row crops (potatoes, sugar beet), forage cropping (forage maize, grass-clover mixture), fallow land and grassland. The plot specific labour requirement and
the plot specific variable machine costs are calculated considering the average percentage of the main crops per district and the plot size.

For calculation of extra expenses caused by the hedges there is a need for a reference value. Supposing the mean machine equipment, by a plot size of 15 to 20 ha there are no more scale effects of labour of machine costs. The current size of the plots is therefore compared to a plot of 20 ha. The additional labour requirement and the additional machine costs are calculated due to the different plot sizes.

The costs of maintenance of the hedgerow is varying depending on the size of area covered by the landscape element.

All these costs together represent the amount of money which is needed to preserve a certain kind of landscape element or to maintain a well structured landscape (Fig. 1).

Generally, a high density of hedgerows requires a landscape pre-dominated by small plots. Assuming that the hedgerow of 3m width is bordering one side of a plot the percentage of area covered by hedgerows can be calculated as follows. In the case of a 0.5 ha field, 18% of the area would be covered by landscape elements, in case of a 20 ha field this would amount 2.8 %. Consequently for estimation of costs for maintenance of landscape elements the whole unit of field and hedgerow has to be considered.

Based on empirical data the statistical association between landscape elements and site condition was calculated (Kantelhardt et al., 2002). This resulted in a verified correlation only on the basis of regions. In the new approach it is thus tested to calculate the costs for the maintenance of hedgerows and edges in different regions.

2.4. Calculation of district-specific costs

Firstly, the percentage of field-plots with adjacent hedgerows has to be calculated: This is done on the basis of the aerial percentage of linear landscape elements per km² and the mean size of field-plots per km² (see Fichtner et al., 1994). Furthermore, it was assumed that the whole landscape is consisting of rectangle plots. Hedgerows are bordering plots only on one side and have a width of 3 m.

By using GIS technology the km²-coverage is combined with the coverage of administrative districts (Fig. 2). For each district the percentage of the four plot size classes (see 2.2) with and without adjacent hedgerows is provided. The distribution of plot-size classes per district is combined with the costs per single plot (see 2.3).

The following indicators are determined:
1. Costs of hedgerows per ha on single plot with hedgerows
2. Costs of hedgerows per ha in each district
3. Results

Fig. 3 shows the spatial distribution of the costs arising from the existence of hedgerows adjacent to agricultural used land. The figure distinguishes two aspects of scale.

The upper part of the figure concentrates on the administrative district. It shows how much a district has to pay per hectare, if all costs caused by hedgerows are compensated.

The lower part shows the consequences for farmers. It describes the costs which arise farmers on plots bordered by hedgerows. These costs can also be interpreted as the economic pressure on hedgerows.

Obviously the amount of costs is not related to the site quality. Therefore high costs are found in areas with high site quality (northeastern part) as well as in mar-
ginal areas (central part). The lowest costs can be observed in the eastern part of Baden-Wuerttemberg.

Fig. 3: Spatial distribution of costs caused by hedgerows
In contrast to these results there seems to be a correlation between the costs for farmers and the site quality: high costs can be found in central Baden-Wuerttemberg. This area can be characterised by its low quality of arable land. The lowest costs arise for those farmers who are situated in grassland areas.

For explaining the results in detail, a focus is put on selected single districts (Tab. 1): In the district of Esslingen the high percentage of small plots predominate all other factors. Consequentially the costs caused by hedgerows are the highest in the whole state of Baden-Wuerttemberg. Even if in the district of Heilbronn 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>
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<tr>
<th>Table 1: Economic indicators for selected districts</th>
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<td><strong>Plot specific costs (EUR/ha)</strong></td>
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| **Average costs (EUR/ha)**                        | 23        | 15        | 10         | 10      | 17         |

| **Costs due to maintenance of hedgerows (%)**     | 37        | 40        | 57         | 40      | 44         |
| **Costs due to loss of area (%)**                 | 10        | 18        | 13         | 11      | 15         |
| **Costs due to plot-size related (%)**            | 53        | 42        | 29         | 49      | 41         |

| **Productivity (gross margin in EUR/ha)**         | 473       | 753       | 403        | 478     | 586        |

| **Hedgerows (% of district area)**                | 0.49      | 0.36      | 0.35       | 0.23    | 0.52       |

| **Small plots (0.5 ha) (% of UAA)**               | 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

Landscape elements, such as hedgerows must be seen in the context of the landscape, especially in context to the agricultural used area adjacent to the hedgerow. In this article we have shown that there are several interrelations between land use and
landscape elements. In order to maintain hedgerows it seems to be necessary to compensate the disadvantages for farmers arising from the type of cultivated crops and the plot-size.

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 it is to question if 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., 2002). This is, for example, the case in districts of gavelkind tenure.

We demonstrated regionally differentiating costs of maintaining hedgerows by the example of Baden-Wuerttemberg. In order to develop an agri-environmental programme for protecting landscape elements as part of the cultural heritage it is therefore absolutely necessary to consider various regional aspects.

Bibliography


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