Bayesian Belief Network approach in assessment of agricultural landscapes competitiveness

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Abstract
The study focuses on the relations between landscape structure and composition, functions and benefits, and its contribution to the regional competitiveness. The Bayesian Belief Network method has occurred to be useful for the analysis of the problem, however, the proper determination of the relationship between the variables in the model, requires a large number of observations based on the assessments of experts. It was found that all considered landscape elements (fields, forests, shelterbelts, and water reservoirs) have a positive influence on regional competitiveness and the potential of agricultural land. The strongest, positive impact on the competitiveness of the region have agricultural fields and pastures.

Key words: agricultural landscape, benefits, competitiveness, Bayesian Belief Network,

Introduction

The presented study focuses on a development of knowledge base on the relations between landscape structure and composition, functions and benefits, and the contribution to the regional competitiveness and creation of socio economic effects of typical agricultural landscape in the case study region.

There are many different definitions of the term "competitiveness" or "regional *competitiveness*", as well as different competitiveness indicators used in various studies and papers (e.g. Krugmann, 1994, Porter 1992, EU 1999, Porter and Ketals, 2003). It became clear, that the idea of productivity and employment is a key, common link between all concepts of competitiveness, most of all in connection with the living standard of the regional population (Claim 2012). The European Union's Sixth Periodic Report on the Regions specifies "Regional Competitiveness" as "*the ability of a region to generate, while being exposed to external competition, relatively high income and employment levels*..." (EU 1999, Claim 2012). Therefore in the presented study we understand the regional competitiveness as the ability to generate income, with at the same time, assured employment and wellbeing of the society.

As the case study region we selected "Chlapowski Landscape Park" located in the Central-Western part of Poland. The region is characterized by typical agricultural lowland landscape, rich in small-structured landscape elements like field ponds, water catchments and shelterbelts. Benefits from landscape for the regional competitiveness in the Chlapowski Landscape Park are clearly connected with agriculture supported by shelterbelts and their regulating (protection) function (Johnson, Brandle 2003). This characteristic landscape element allows to increase yields of agricultural production and to produce crops which would not be grown on relatively light soils, if there was no protection against wind erosion (like sugar beets or oil-rape), (Kort, 1988). Therefore increase of the regional competitiveness is mainly attributed to the income from agricultural production and safeguarding employment in rural areas (in agricultural production and to a lesser extent, employment in recreation).

In the presented study we try to answer the question: what might be the potential impact of landscape composition and structure on regional competitiveness?

Method

Assessing influence of landscape on region competitiveness is complicated due to complexity of the issue and dependence of competitiveness also on other factors like: location, human capital and local investments, governance etc., which hide possible relation of landscape elements to regional competitiveness. It is rather a process of many intermediate factors. What is more, there is no exact information about variables dependency, even for those intermediate factors. Usually the only available information are opinions of experts about positive or negative correlation between variables. The lack of experimental data

practically prevents from the use of classical statistical methods. Therefore we decided to use Bayesian Belief Network (BBN) for determining influence of landscape elements on regional competitiveness. The BBN is a directed acyclic graph (DAG) with a set of conditionals probabilities (Korb, Nicholson 2004). There is a number of programs allowing development of BBN. For this analysis we used the Norsys Software Corp. program Netica.

The BBN model was calibrated on the basis of experts judgement. The general model of connections between the tested variables is presented in figure 1. The variables were divided into 4 layers, with elements of each layer affecting directly only elements of the next one. The figure 2 shows the calibrated model in case of 50% chance of all elements being significant part of landscape. In the model we consider four, the most typical landscape elements in the case study area: fields and pastures (*FIELDS*), shelterbelts (*SHELTERBELTS*), forests (*FOREST*), fieldponds and water reservoirs (*WATER*).

The main landscape services in the case study area are food provisioning, protection and regulating (mainly from wind-erosion), aesthetic-cultural and habitat supporting. *Provisioning* is the main output of agriculture - fields and pastures, and depends largely on regulating services provided by shelterbelts. Provision of wood is less important in this region and can be attributed to shelterbelts (4% of area of the park) and forests (11% share). Regarding *regulating services*, shelterbelts have a very important regulation function in this region, protecting the fields against wind and water erosion, and regulating the water and nutrient cycle. Existence of this landscape element allows to increase yields of agricultural production and to produce crops which otherwise could not be grown if there was no protection against wind. Agricultural landscape usually is less attractive to *cultural and recreation* use. However Chlapowski Landscape Park is famous for its specific landscape, shaped by agriculture and characteristic shelterbelts creating green-paths along the roads and fields. The pathways created by windbreaks and local architecture encourage tourists to come for short term visits for biking or walking. Forestry management and wind-breaks maintenance is influencing *habitat and supporting services*. It contributes to the existence of rare species (fauna and flora) living and breeding in the trees, and thus it contributes to rich biodiversity of the region.

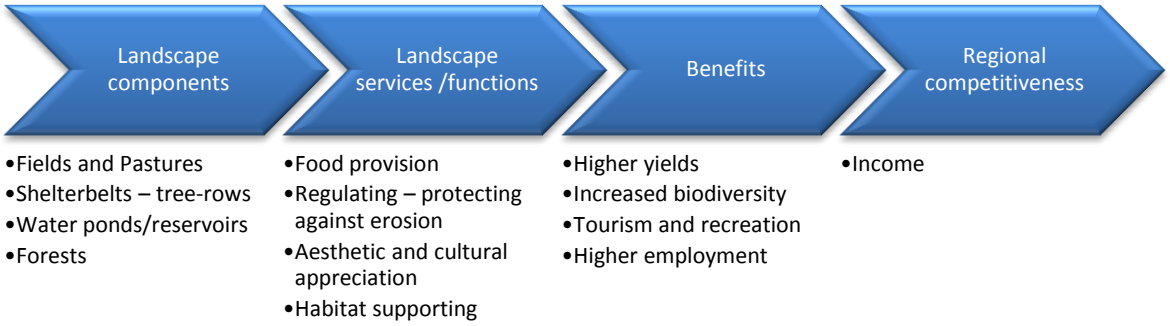

Figure 1. Division of variables into layers.

The following direct and second order (socio-economic) effects/benefits of the use of landscape services were analyzed in the BBN of the case study region: *Increase of productivity* (higher yields and larger variety of crops); *Maintenance and creation employment* (strong agricultural sector provides employment for local inhabitants; inflow of visitors provide possibility of development of the local tourist base); *Tourism and recreation* (specific landscape and cultural heritage attracts tourists); *Increased biodiversity* (diversified landscape trough its habitat supporting function contributes to rich biodiversity).

In general those abovementioned functions and services provided by landscape elements and benefits deriving from its usage, contribute to higher competitiveness of the region, measured by income effects.

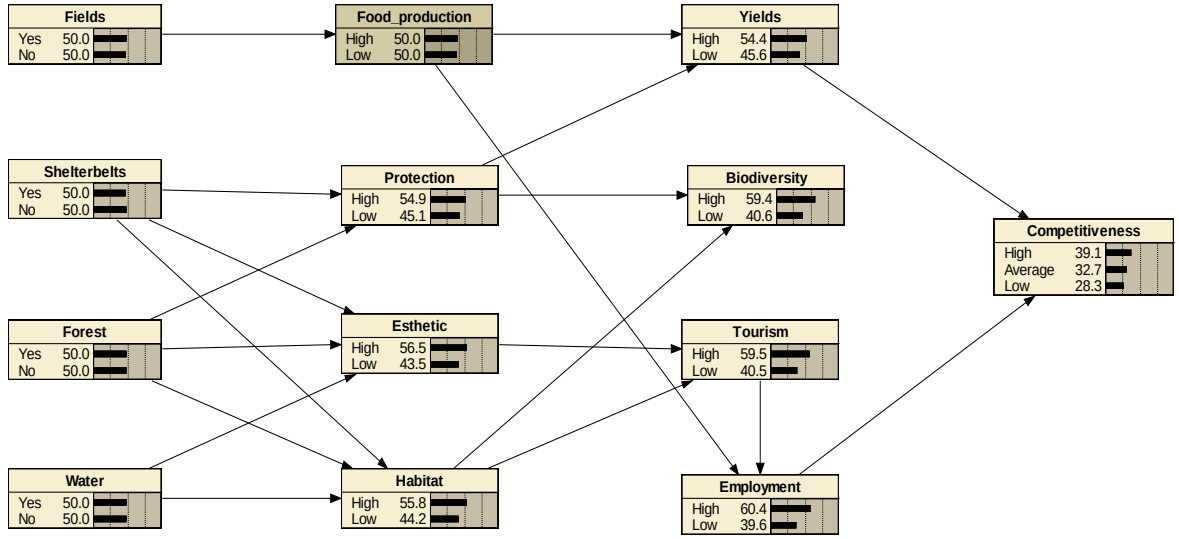

Figure 2. The calibrated BBN belief network for landscape influence on competitiveness.

Results

The changes in probabilities between the model with 0% and 100% of shelterbelts being significant part of landscape were analysed (figure 3 and 4). It was observed that shelterbelts have a strongly positive impact on the realisation of the protection (regulating) function by increasing by 41,6% (percent points) its probability to be at a high level. As it was supposed, these green pathways have a strong positive impact also on the aesthetic appreciation of the landscape, by increasing its valorisation as high as by 26,7%. Existence of windbreaks create as well a good conditions for habitat for species. The probability of realisation of this function rise by almost 30% together with implementing the shelterbelts into the landscape. Realisation of abovementioned services by shelterbelts contributes to generation of certain socio-economic benefits. An increase of the chance for high yields is estimated by the BBN model for 10%, probability of high biodiversity rise by 27,6% and higher tourist movement by 21%. This in turn has an impact on increase of the local employment by 8.9%. In case of regional competitiveness there is 5% increase of a chance of achieving high level of competitiveness and 6% decrease of low level chance due to implementation of the shelterbelts.

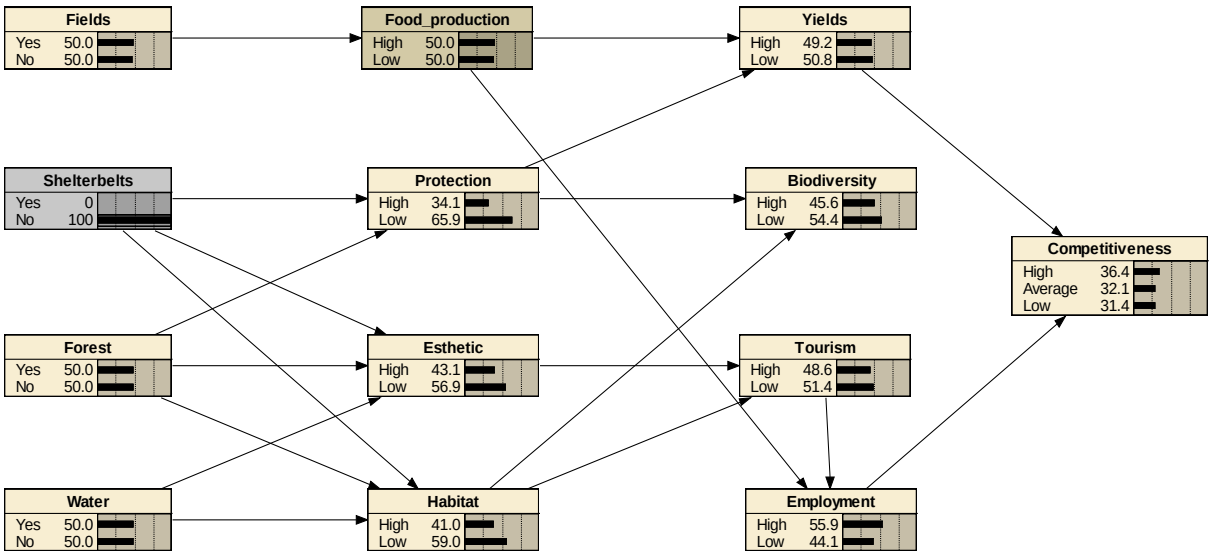

Figure 3. The BBN belief bars in case of 0% chance of shelterbelts being important part of landscape.

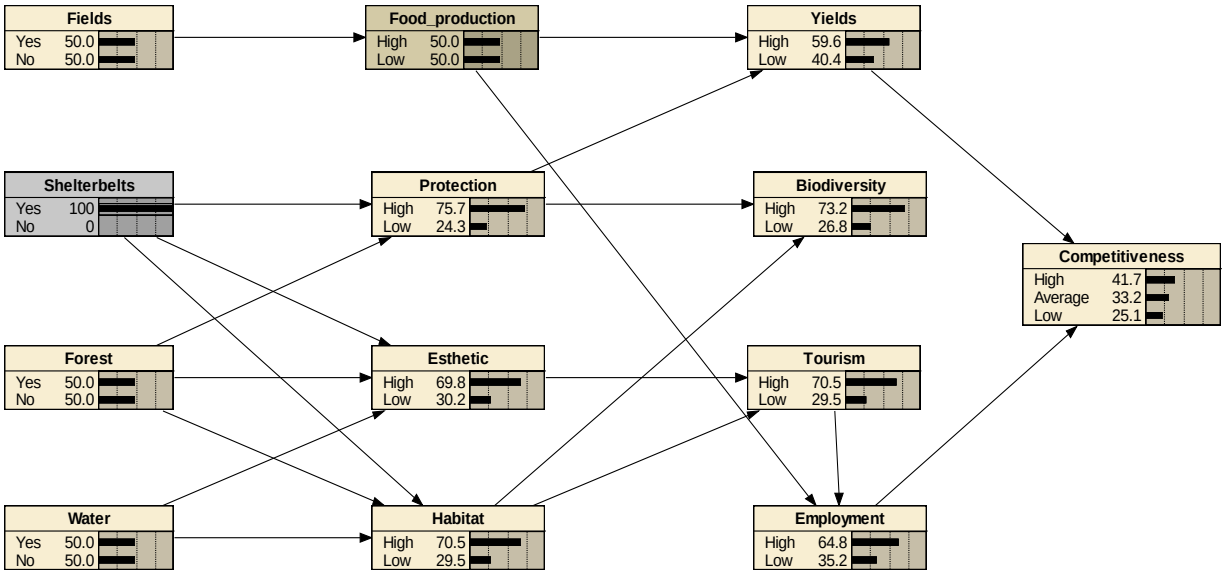

Figure 4. The BBN belief bars in case of 100% chance of shelterbelts being important part of landscape.

Similar calculation was carried out for all landscape elements (table 3). While all considered landscape elements display positive influence on regional competitiveness, the agricultural land shows the strongest impact by increasing chance of high competitiveness by about 20%. Shelterbelts and forest have very similar effects with increase about 5% and water gives almost negligible change of 1.5%.

Table 3. The probabilities for high, medium or low level of regional competiveness for landscape elements.

Landscape element	No			Yes		
	Competitiveness High	Competitiveness Medium	Competitiveness Low	Competitiveness High	Competitiveness Medium	Competitiveness Low
Fields	0.294	0.314	0.392	0.487	0.340	0.173
Shelterbelts	0.364	0.321	0.314	0.417	0.332	0.251
Forest	0.358	0.320	0.322	0.423	0.333	0.243
Water	0.384	0.325	0.291	0.398	0.329	0.274

It was also interesting to observe a reverse causality of the BBN model. On the figure 5 we checked what happens when we assume the high level of competitiveness at 100% probability. We compared the results with figure 2 - the calibrated BBN model. It can be observed that 100% chance of high level competitiveness (increase from 39,1% high to 100%) is assured by an increase of importance of fields and pastures in the landscape from 50 to 62%. The other landscape elements were far less significant. It is also worth mentioning that productivity increase (higher yields) has strongest effect on the competitiveness than the employment (creation of jobs). High competitiveness (100% chance) was obtained through increase of probability of high yields by 28% whereas higher employment by 16,7%.

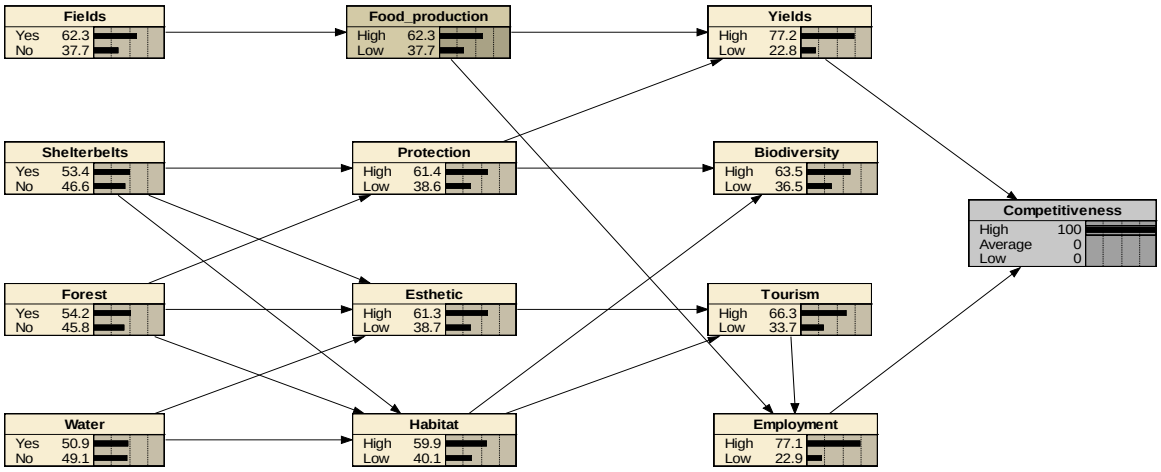

Figure 5. The BBN belief bars in case of 100% chance of high competitiveness.

Conclusions

Assessing influence of the landscape on region competiveness is complicated due to complexity of the problem and relations. The lack of experimental data practically prevents from the use of classical statistical methods. Based on expert judgement, the Bayesian Belief Network (BBN) approach was tested to determine the influence of landscape elements on regional competiveness. The method has occurred to be useful for the analysis of the problem, however, the proper determination of the relationship between the variables in the model, requires a large number of observations based on the assessments of different groups of experts.

Benefits from the landscape for the regional competitiveness in the Chlapowski Landscape Park are clearly connected with agriculture supported by shelterbelts and their regulating (protection) function. However it was found that all considered landscape elements (fields, forests, shelterbelts, and water reservoirs) have a positive influence on regional competitiveness and the potential of agricultural land. The agricultural fields and pastures have the strongest, positive impact on the competitiveness of the region showing the potential to increase the chance of high competitiveness by about 20%. Shelterbelts and forests have very similar effects with an increase about 5%. Shelterbelts, which are a unique and distinctive element of the landscape in the Chlapowski Landscape Park play an essential role in shaping natural conditions for farming in the Park area. It can be stated, that maintaining shelterbelts creates specific landscape features and increases competitiveness of the region, having an impact on productivity and profitability of agricultural sector.

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