# On Estimating Ecotone Occurrence from Land Cover Data Using Type 2 Fuzzy Sets

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## 1. Introduction

The term ecotone was first used in 1905 by F. E. Clements (1905) to describe visually different area between two ecological systems . Lately there has been a lot of attention to model and describe those transitional zones between ecological classes (Kilianová et al., 2009, Arnot and Fisher, 2007, Hufkens, 2008). Most of this research aims either to identify the best border between ecological systems or to identify ecotones as fuzzy objects mainly on data from remote sensing or some other very specific type of data (Fisher, 2006, Hufkens, 2008).

The aim is to identify areas where ecotones are most likely present using land cover and/or land use data, because those type of data are very common and can be easily obtained almost for any area of interest.

Theidea of estimating ecotone occurrence from such data is based on several assumptions including facts that specific landscape indexes correlates with ecotone occurrence and that geometric characteristics of adjacent ecological areas can affect quality of the ecotone between those classes. However a great amount of uncertainty is present in this knowledge because so far no study proved exact link between those factors and ecotone presence. For those purposes fuzzy type 2 sets were used to incorporate the correct amount of uncertainty in the output.

## 2. Theory and Model

According to Holland et al. (1991) ecotones are defined as “zones of transition between adjacent ecological systems, having a set of characteristics uniquely defined by space and time scales and by the strength of interactions between adjacent ecological systems“. Such definition is applicable to ecological systems in any scale and the output ecotones thus may vary in their size from few centimeters to several kilometers (Holland et al.,

1991, Kiliánová et al., 2009). Another definition describes ecotone as area with high rate of change when compare to surrounding areas (Kiliánová et al., 2009). Same sources also claim that ecotone might contain more species and provide very specific conditions that couldn't be found in any of neighbouring area.Ecotones based on its characteristics can be linked with many ecological factors such as barrier, corridor or edge effect which makes the important part of landscape matrix. Because of the given characteristics is identification and monitoring of those spatial structures crucial to understanding biodiversity (Holland et al., 1991)

Several approaches on mapping ecotones exist. It is possible to represent them as crisp areas or as lines that have no area (Arnot and Fisher, 2007), but none of those is precise enough because the first treats ecotone as homogenous area which according to its definition isn't correct and the second omits the fact that ecotone may occupy quite significant area and thus representing it as line is too much generalization. The most correct representation of ecotone based of several sources (Arnot and Fisher, 2007, Kiliánová et al., 2009) that follows its definition is such where ecological systems are represented as spatial fuzzy sets and ecotone is an area that has specific degree of membership to more than one fuzzy set (Fig. 1). Different variations of this approach are presented in several sources(Arnot and Fisher, 2007, Hufkens, 2008). Given those reasons the fuzzy representation of ecotone seems the best for modeling both spatial extent as well as quality.

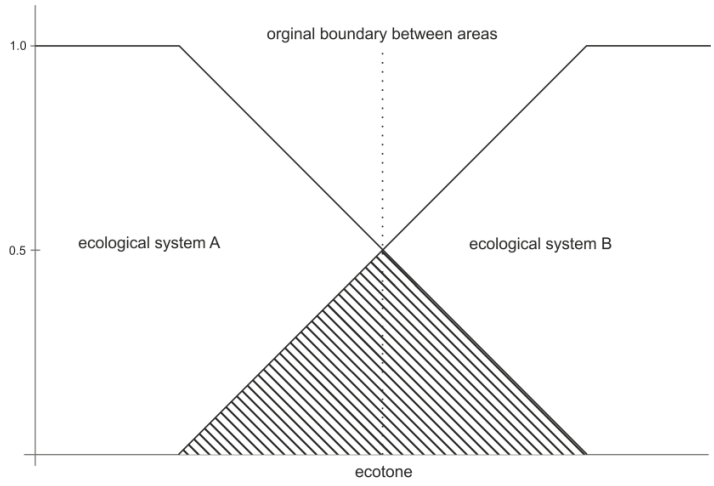


Figure 1. Representation of ecotone as intersection of two fuzzy sets

The main step in estimating the occurrence of ecotone with use of fuzzy sets is to fuzzify the input land cover data. As suggested above the landscape indexes, geometric properties and indexes of area and the relation between neighboring areas affect spatial extent and quality of ecotone. Fig. 1 shows how result of such fuzzifying may look like. Areas with membership value 1 are so called core areas of the ecological unit. Original boundary shows where originally was the border when area was classified into crisp sets of land cover categories. Wide of support of fuzzy set is defined by function that derivate its result from values of several landscape indexes, geometric properties of area and relation to neighbor. In practical example the wide of support of fuzzy set for forest with very complex shape in highly heterogeneous landscape that neighbors meadow will be

much higher than for field with almost geometric shape in homogeneous landscape that neighbors road. This is based on premises that ecotones tend to be of higher quality and have bigger spatial extent in more heterogeneous landscape, on border of areas that have more complex shapes and between ecologically more stable and quality areas. All of mentioned parameters have impact on creating each area's fuzzy sets that determines areas zone of influence. Result ecotone is then created as intersection of two or more fuzzy sets. The quality of ecotone is determined based on ecotone's geometric properties and spatial statistics of overlapping fuzzy sets. The area occupied by the ecotone and the grade of union of membership values are the factors that are used in this part of model. This assessment of quality helps in estimating the uncertainty with witch was the given ecotone's spatial extent calculated. Low quality ecotones tend to be of lower spatial extent, resulting in extreme cases to state called ecoline, almost crisp border between two ecological systems.

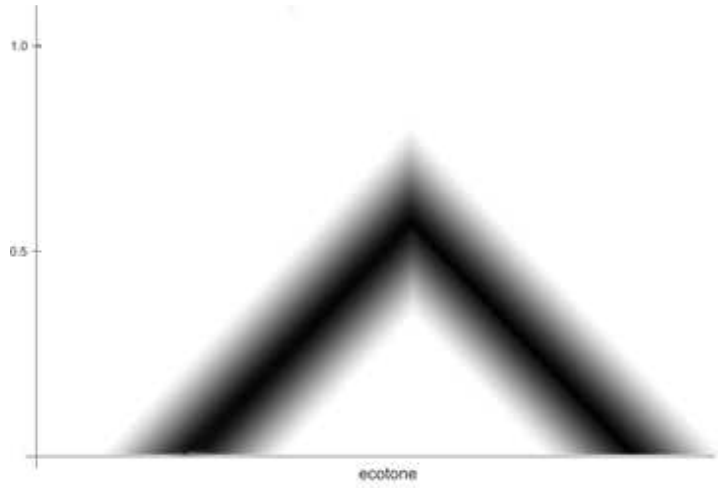


Figure 2. Representation of spatial extent of ecotone as type 2 fuzzy set

Quality of ecotone is in the model perceived as type 2 fuzzy set that modifies membership value into interval of values (fig. 2). The extent of this type 2 fuzzy set indicates how precise the estimation of spatial extent of ecotone is. This brings to the model fact, that for ecotones with low quality it could be much more complicated to estimate its occurrence and such ecotones are also much vaguer than the ones with higher quality.

Proposed model estimates occurrence of ecotones from common land cover and/or land use datasets and is suitable for modeling of ecotones in big scales. In the case study the aim was to catch even small ecotones that occur between roads and meadows as well as rivers and forests.

## 3. Case study

Area of interest is protected landscape area Litovelské Pomoraví located at north part of central Moravia between cities Mohelnice and Olomouc (fig. 3) with city Litovel being located almost exactly in the middle of protected area. The main reasons for protection are natural meanders of river Morava and floodplain forests that surround the river. The area is characterized by having many small ecological systems resulting in quite

oftentransitions between those various ecological units.Such locality provides optimal space for testing proposed model because it provides great diversity in land cover/land use types.

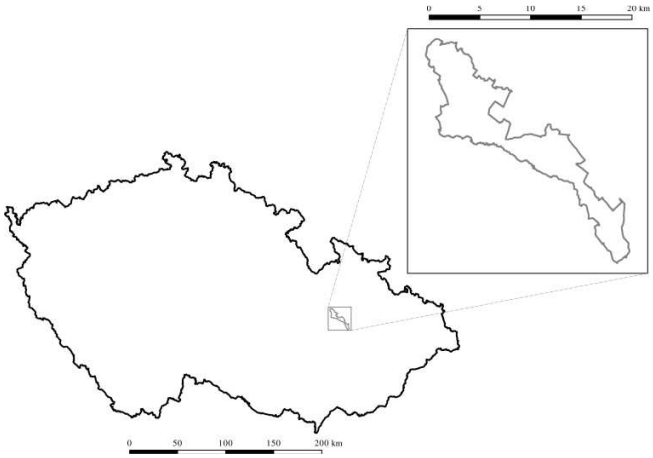


Figure 3. Localization of protected landscape area Litovelské pomoraví

## 6. Acknowledgements

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