



**POLISH ACADEMY OF SCIENCES**  
**Systems Research Institute**

**ECO – INFO  
AND SYSTEMS RESEARCH**

**Editors:**

**Jan Studzinski**  
**Olgierd Hryniewicz**





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Polish Academy of Sciences • Systems Research Institute

**Series: SYSTEMS RESEARCH**

**Vol. 52**

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Series Editor:

**Prof. Jakub Gutenbaum**

Warsaw 2006

# **ECO – INFO AND SYSTEMS RESEARCH**

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The purpose of this publication is to present the information technology (IT) tools and techniques that have been developed at the Systems Research Institute of Polish Academy of Sciences in Warsaw (IBS PAN) and at the German Institute for Landscape System Analysis in Müncheberg (ZALF) in the area of applications of informatics in environmental engineering and environment protection. The papers published in this book were presented in the form of extended summaries during a special workshop organized by IBS PAN in Szczecin in September 2006 together with the conference BOS'2006 organized jointly by IBS PAN, University of Szczecin, and the Polish Society of Operational and Systems Research. In the papers the problems of mathematical modeling, approximation and visualization of environmental variables are described. Moreover, some questions concerning the environmental economy are also presented.

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Warsaw 2006

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**ISBN 83-894-7509-X**

**9788389475091**

**ISSN 0208-8029**

CHAPTER 1

# **Specialized Software**





## HABITAT MODELING WITH SAMT-FUZZY - A DECISION SUPPORT SYSTEM IMPLEMENTED IN LANDSCAPE PLANNING

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**Abstract:** *Culturally used landscapes are complex ecosystems. Obviously they change in time and space. But it is not always clear whether natural or anthropogenic alteration - or both - affect the ecosystems and their inhabitants. And not all human interventions are intended or desirable. Therefore, the possible consequences of any projects should be examined carefully. Particularly in or near preserved regions like national parks or special protected areas it is required by law to check all known aspects of possible affections on the ecosystem. The Spatial Analysis and Modeling Tool SAMT ([www.samt-lsa.org](http://www.samt-lsa.org)) is a spatial simulation. SAMT unites features of a grid based geographical information system GIS and modeling methods to evaluate habitat quality and results of spatial changes. As species-habitat relationships are more often qualitative than exactly numeric, implemented fuzzy-techniques allow a suitable management of ecological data and to calculate exact outputs. The precise results are visualized and analysed and can be used as a basis for decisions in planning - in competent authorities, for investors and nature conservation specialists alike. It is essential to support traditional methods with modern solution. Although we do not abandon mapping birds and other fauna or flora rather than we rely on this data basis for modeling species-habitat relationships. One important issue nowadays is the influence of wind turbines on the habitat quality of sensitive bird species. Hence, this paper presents the use of SAMT with a specific ecological issue within legal procedures in landscape planning processes. The implemented fuzzy modeling tool reveals its usability as it integrates ornithological knowledge.*

**Keywords:** Fuzzy-Modeling, Habitat Models, Ornithology, Lesser Spotted Eagle *Aquila pomarina*, Common Crane *Grus grus*, Golden Plover *Apricaria pluvialis*, Ecosystems, Land Use, Geographic Information Systems, Dynamic Simulation System, Environmental Law, Landscape Planning.

## 1. Introduction

Our cooperation started in 1994 in a research project in NorthEast Germany, where scientists and practitioners joined - all involved in land use. The main purpose was a methodological and technological transfer from scientific research to practical use in agriculture and landscape planning (Leberecht, 1994). Among others scientist's mathematicians, engineers and biologists were asked to develop new methods for analysing and forecasting natural and anthropogenic changes in culturally used landscapes (Flade, Plachter, Schmidt et al., 2006; Schultz, Wieland, 1995).

There we made our first steps with a neural-fuzzy approach in an ecological context, combining fuzzy techniques and neural networks. We developed different models on Common Cranes *Grus grus*, Barn Owls *Tyto alba*, Corn Bunting *Emberiza calandra* and Fire-bellied Toad *Bombina bombina* using MatLab and GIS-techniques to calculate scenarios for various land use (Wieland, 1996; Wieland, Wenkel, Voss et al., 1997).

But the results were neither sufficient nor up to standard to be acceptable among zoologists for use in landscape planning. Later we concentrated on one species, the cranes, and their regional breeding and resting habitats. We reviewed the inputs more carefully and advanced in handling the landscape data for our purposes (Schultz, Klenke, Lutze et al., 2002; Wilkening, 2002; 2003).

At that point the newly developed SAMT (Holtmann, Wieland, Schulz, 2004) pushed our issue. It is well usable system not only for independently working biologists. Three main advantages are apparent:

- 1) Constructing and handling fuzzy systems is not only simplified but also directly implemented into the spatial simulation.
- 2) Geographical data are handled and calculated without huge memory cache and commercial software.
- 3) Implemented 3-D-operations analyse and visualize as well relief maps and hights of both biotypes and pillars.

Forthwith we were able to propose our results for considerations in planning processes and to satisfy the requirements of approval procedures. In 2004 we concentrated our cooperation on the effects of wind turbines on birds and constructed hierarchical models summarizing the habitat use of three bird-species. We showed the possible effects of a planned windpark on the habitat quality in the county Uckermark (federal state Brandenburg). For that study (Wilkening, 2005) we chose:

- Common Crane *Grus grus*, a breeding and resting bird in North-East Germany with which we were already experienced and because of its status as a threatened species.
- Lesser Spotted Eagle *Aquila pomarina*, a rare breeding and migratory bird in North-East Germany, a disappearing raptor species and focus of national and international habitat protection projects.
- Golden Plover *Pluvialis apricaria*, a wader with specific habitat requirements during spring and autumn migration in our region.

These species are relevant in environmental risk assessments and ornithological expertises necessary for planning power parks. The results of the SAMT-fuzzy analysis visualize scenarios with and without wind turbines or rather with wind turbines on alternative locations.

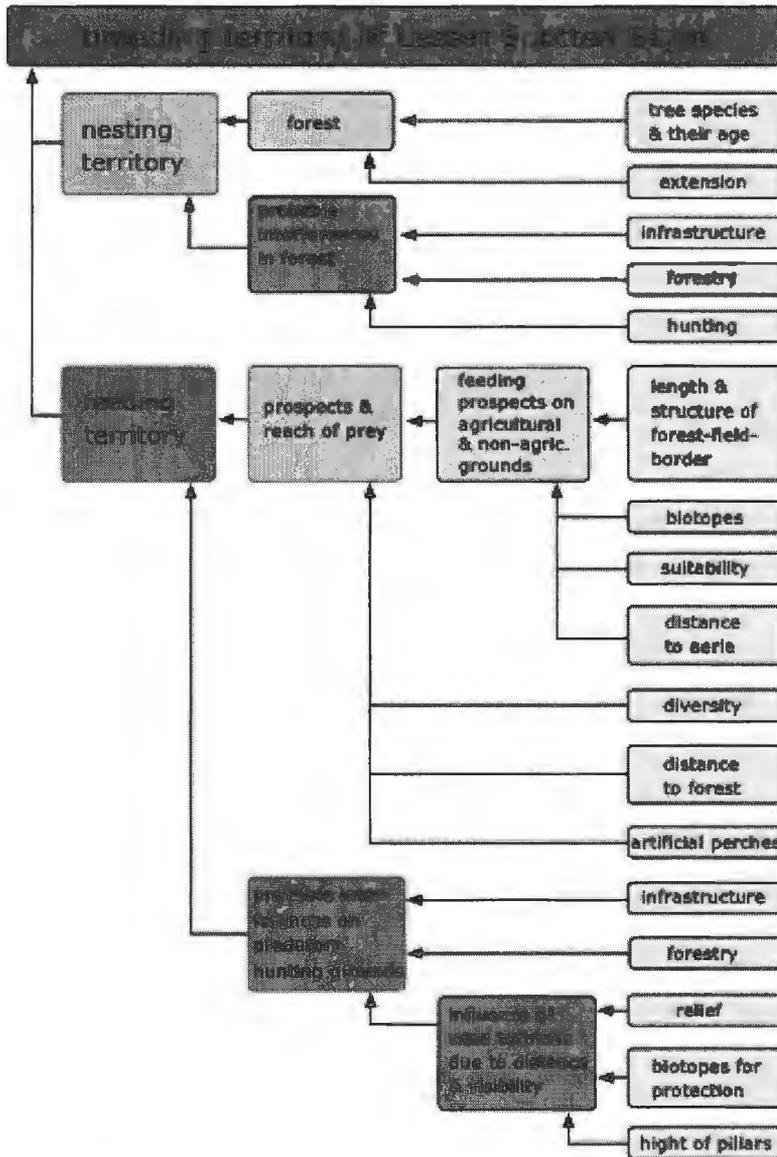
## 2. Methods and Results

Irrespective of species, topic or region, modeling with SAMT-Fuzzy expects a certain way of thinking and computing. To some extent the described steps are worked out simultaneously:

- select relevant inputs on habitat requirements, i.e. in our example to describe the birds' ecology and behaviour in different seasons
- develop a hierarchical habitat model performing the birds' habitat use (Figure 1)
- describe the chosen parameters with vague linguistic terms like <short> or <long>, expressing the birds' necessities for feeding preferences and expressing the birds' sensitivities concerning the observed or presumed distance, unapproachable for this species towards wind turbines and other structures
- articulate rules to combine the inputs (Table 1).

Whereas the first two steps are done more or less without electronic means, the third and fourth steps are computed with SAMT:

- select geographical data for the chosen study area, derived e.g. from biotope and agricultural land use mapping with a GIS-tool
- check how the demanded inputs can be derived from the available landscape data
- supply the fuzzy-models with the acquired data and check the rules with implemented control units.



**Figure 1.** Hierarchical structure of the Lesser Spotted Eagle's habitat requirements. The coloured boxes comprise results calculated with fuzzy-systems. Ecological informations are derived from environmental data (grey boxes).

The procedure to use landscape data of different qualities in mathematic-kybernetic processing is sometimes extensive and complicated. While selecting the data basis a commercial GIS ([www.esri.com/software](http://www.esri.com/software) ...)

is necessary, but once the data are fed into SAMT, we continue without extraordinary hardware or commercial software:

- execute every single fuzzy system; visualize and analyse the results,
- calculate the “top fuzzy” system for achieving the total outcome of all impacts; visualise and analyse its result (Figure 2),
- visualise and analyse scenarios of alternative options in land use or positions of planned objects.

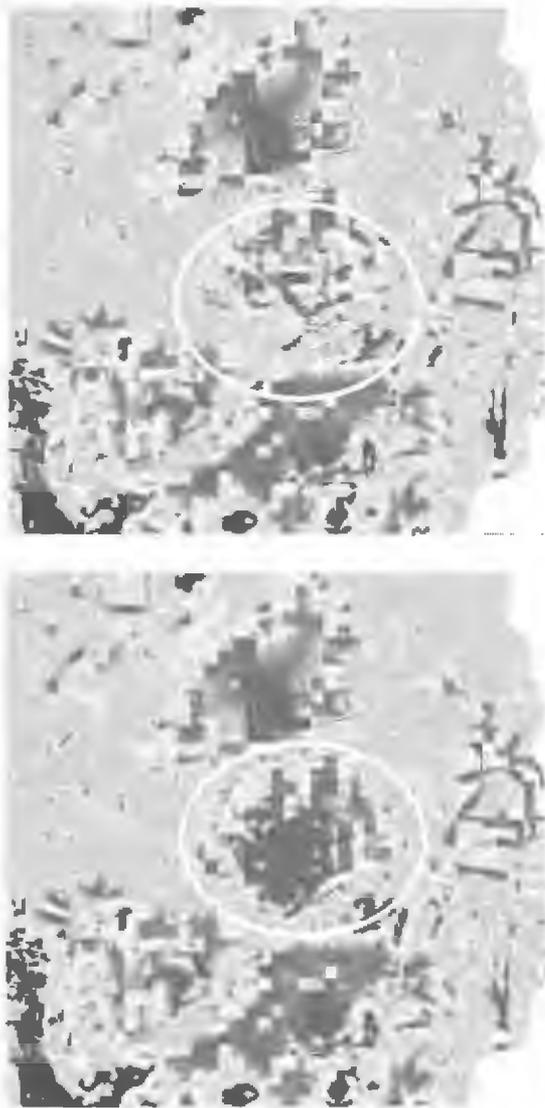
**Table 1.** Rules for fuzzy-system <wt-influence.fis> describing the influence of wind turbines (output) due to their distance (input 1) to each point in the study area and their visibility (input 2) at each point in the study area.

distance to wind turbines 0 250 750 [ m ] 250 750 1000 1500 1000 1500 3000 5000 3000 5000 7500 10000 7500 10000	visibility of wind turbines	influence of wind turbines
	yes - no	0 - 1
very near	no - yes	very intense
near	no	middle
near	yes	intense
middle	no	mild
middle	yes	middle
distant	no	very mild
distant	yes	mild
very distant	no - yes	very mild

**Note:** the parameters, which describe the distance concerning interactions between wind turbines and *Lesser Spotted Eagles* are postulations based on ornithological observations; these are not the rules for the final result on the study area’s habitat quality.

Some mistakes due to failures while creating the model can be revealed with implemented control units. Hence, in every step of this pro-gresse, the results should be analysed carefully to determine mistakes in either data basis or definition of rules and parameters. This includes cooperation with ornithologists and engineers.

Apart from coloured maps, which visualize the result for each point in the study area, elementary statistics implemented in SAMT reveal the variance between scenarios, e.g. the size of areas bothered with disturbances can be measured.



**Figure 2.** SAMT calculated the habitat quality for Lesser Spotted Eagles in a 20 km<sup>2</sup> study area without (top) and with (bottom) a wind farm, visualized in 36 colours from red = poor to green = good habitat quality.

### 3. Conclusions

SAMT-Fuzzy provides landscape planning with well founded results. Due to clear rules and parameters the models can be discussed among all participants. The precise visualization invites to understand and validate the ecological appraisal. The models can be transferred to different areas to predict the consequences of alternatives in land use. The demands of land users and conservationists can be taken into account alike. The development of SAMT for use in ornithology was and is still inspired by the stipulations of ecological requirements, planning reality and environmental law.

### 4. Acknowledgements

In 1994 - 1998 this work was supported by the German Federal Ministry of Education and Research (BMBF Berlin) and the German Foundation for the Environment (DBU). Afterwards scientists of the Institute of Landscape Systems Analysis at the Centre for Agricultural Landscape Research (ZALF Müncheberg, Germany) and an independent biologist (Büro Wilkening, Angermünde, Germany) cooperated informally. In 2004 some further developments were supported by Uckerwerk Energietechnik GmbH (Dauerthal, Germany). The collaboration between the authors continues both freely and regularly. The authors are grateful for their colleagues' encouragement and technical support.

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**ISBN 83-894-7509-X**  
**9788389475091**  
**ISSN 0208-8029**

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