The mind in the model: capturing expert knowledge with the help of fuzzy logic

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Abstract
Fuzzy logic offers a way of capturing qualitative knowledge in models. We tested its application in modelling for long term river management planning. We used fuzzy logic to model landscape impacts of different river measures. Preliminary results show that the method allows for modelling expert knowledge concerning landscape effects. The resulting model is rapid and transparent. However, the elicitation of the -often ambiguous- expert knowledge remains one of the major concerns.

Introduction
River management involves a lot of qualitative knowledge. Dealing with qualitative knowledge has the disadvantages that 1) the qualitative information is not always reproducible and that 2) a high dependency on the experts remains existent throughout the planning process. Previous work (De Kok et al., 2000) suggests using fuzzy logic as a tool for capturing expert knowledge, in this way improving model performance. The expert knowledge we used is extracted from the Integrale Verkenning Maas -1 (IVM-1) project and then implemented in a model based on fuzzy set theory. In this way we attempt to make the expert knowledge explicit and to extend modelling into the qualitative domain.
IVM-1 is an integrated explorative study of measures proposed for improvement of flood safety along the Meuse in the Netherlands. One of the effects assessed in the IVM-1 study is the effect on space and landscape (Ministerie van Verkeer en Waterstaat, 2002). The background report on space and landscape, containing the outcomes of expert studies, forms the basis for our fuzzy logic model.

Method
We will implement the expert knowledge from the IVM-1 project in a fuzzy logic model to assess the effect on landscape quality of ten different measure types on eight river stretches in the Dutch Meuse. According to the IVM-1 background study 'Space and landscape effects' the eventual effect of a measure on landscape quality is determined by a combination of landscape and measure characteristics. With a selection of these characteristics we obtained the conceptual model shown in Fig. 1. Both landscape and measure characteristics are represented as fuzzy inputs. The next step was to implement the variables as fuzzy membership functions (MFs) into the Matlab Fuzzy Toolbox®. The membership functions are overlapping classes to which the qualitative parameters are mapped. Nguyen (2005) has shown that the outcomes of the fuzzy model have a low sensitivity to the shape MFs, so we opted for the relatively simple triangular MFs, implemented in a Mamdani inference system.

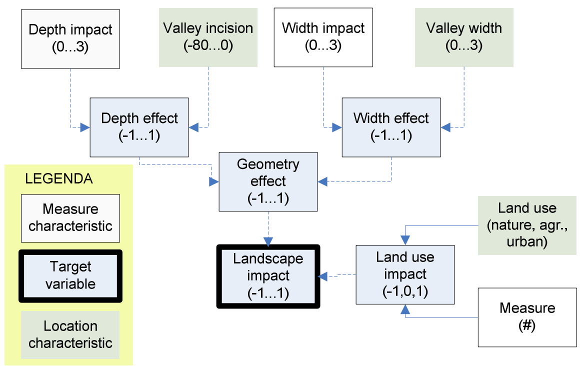

Figure 1. Conceptual model; fuzzy relations are dashed.

Results
In the IVM-1 background report measures, or some of their characteristics, are linked to the landscape. Features like incision, valley width, and land use return for every river stretch as determinative elements for landscape quality. In combination with the measure characteristics (width, depth and impact on land use) that affect these, they form the inputs for the model. The land use and land use impact could not be modelled fuzzy because the variables cannot be scaled on a continuous range. In Fig. 1 the fuzzy model relations are indicated by dashed lines. Running this model gives a non-fuzzy score on landscape quality between -1 and 1 for every measure type on every river stretch. To render justice to the

Table 1. Scores on landscape quality of fuzzy model and IVM-1. Names of river stretches are in Dutch from upstream (Bovenmaas) to downstream (Getijdenmaas).

	RIVER STRETCH							
■ = enforcing measure (IVM-1) ■ = neutral measure (IVM-1) ■ = deteriorating measure (IVM-1) +,0,- = score in fuzzy model	Bovenmaas	Grensmaas	Plassenmaas	Peelhorstmaas	Z. Venloslenk	N. Venloslenk	Benedenmaas	Getijdenmaas
MEASURE TYPE								
Retention	-	0	+	0	0	+	0	0
Lowering river bed	0	0	+	0	0	+	+	+
Widening river bed	0	+	+	0	0	+	+	+
Remove obstacles	-	+	-	+	-	+	-	+
Lowering floodplain	-	-	+	+	-	0	+	+
Lowering bank	+	+	+	+	+	-	+	+
Widening bank / floodplain	-	+	+	+	-	+	-	+
Relocate dyke	0	+	+	+	-	+	+	+
Green river	0	+	+	+	0	+	+	0
Quay relocation	+	0	+	+	+	+	-	+
Flood channels	-	+	+	+	-	+	-	+

uncertainties involved (Janssen et al., 2006) and to make a comparison with the original IVM-1 scores possible, we categorized the crisp values into three categories: negative landscape effect (-), neutral (0) or positive effect (+). The result is shown in Table 1. The shades represent the IMV-1 scores. Since not all measures were scored for every stretch most of the cells remain blank.

Conclusions

The results resemble the IVM-1 results fairly well; the score was identical in 46% of the cases, 1 class different in 43% of the cases and 2 classes different in 11% of the cases. Differences may be caused because a) not all relevant characteristics of both measures and location (stretch) are taken into account and b) due to the classification of the original (more significant) defuzzified outcomes.
However, the speed of calculation and the relative transparency of the method which helps making the landscape quality discussion more concrete, make further research promising. One of the most important steps in future research will be to optimize the expert knowledge elicitation.

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References

Janssen, J. A. E. B., J.L. de Kok, A. Y. Hoekstra, R. M. J. Schielen (2006) Incorporating qualitative indicators to support river managers; application of fuzzy sets, In: Voinov, A., Jakeman, A., Rizzoli, A. (eds). Proceedings of the iEMSs Third Biennial Meeting: Summit on Environmental Modelling and Software. Burlington, USA, July 9-13, 2006.

Kok, J. L. de, M. Titus, H. G. Wind (2000) Application of fuzzy sets and cognitive maps to incorporate social science scenarios in integrated assessment models: A case study of urbanization in Ujang Pandang, Indonesia. Integrated assessment 1: 177-188.

Ministerie van Verkeer en Waterstaat (2002) Sectorale verkenning ruimte en landschap. Integrale Verkenning Maas, Rapport IVM-R&L-01, Rijkswaterstaat, 56 pp.

Nguyen, T. G. (2005) A methodology for validation of integrated systems models with an application to coastal-zone management in Southwest Sulawesi, PhD thesis, University of Twente, Enschede, The Netherlands.