

Mapping uncertainty in perceptions of landscape ‘wildness’

Alexis (Lex) Comber¹, Steve Carver², Steffen Fritz³, Robert McMorran⁴,
Justin Washtell²

¹Department of Geography, University of Leicester, Leicester, LE1 7RH, UK,
Tel +44 (0)116 252 3812, Fax +44 (0)116 252 3854
ajc36@le.ac.uk;

²School of Geography, University of Leeds, Leeds, LS2 9JT

³International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361, Laxenburg,
Austria

Tel +43 (0)2236 807 0, Fax: +43 (0)2236 71 313

⁴Centre for Mountain Studies, Perth College-UHI, Perth, PH1 2NX, UK
Tel +44 (0)1738 877761, Fax +44 (0)1738 877018

KEYWORDS: Uncertainty, wildness, Fuzzy, Dempster-Shafer, Bayes

Introduction

There is much interest in identifying the landscape features that contribute perceptions of ‘wild’ areas, such as are found in the Cairngorms National Park (CNP) area. Understanding public perceptions of the features that contribute to ‘wild-ness’ allows decisions about the future management of such areas to be responsive to that opinion and safeguards against inappropriate development or changes in land-use. A recent survey on behalf of Scottish Natural Heritage (SNH) and CNP evaluated public perceptions of wild places held by a cross-section of Scottish residents including a subset of living within CNP boundaries (SNH, forthcoming)

This work is part of ‘perception mappings’ study which has sought to use the data collected from a recently commissioned survey of public perceptions of wild places in Scotland (SNH, forthcoming).

SNH and CNPA commissioned a market research study to evaluate public perceptions of wild places amongst a representative cross-section of Scottish residents and a subset amongst those living within the boundaries of the Cairngorms National Park (CNP). The study identifies the level of support for wild places and whether the views of those who live within CNP match the population of Scotland as a whole. A total of 1,304 face to face interviews were conducted (1,004 across Scotland and 300 with residents of the CNP).

The project, of which the work reported here is a part, has developed a GIS-based methodology, which incorporates the results of the perception study and maps the attributes contributing to perceptions of wildness. The mappings were developed using GIS-based multi-criteria evaluation (MCE) and fuzzy mapping methods, using fuzzy membership functions derived from the results of the perception survey to parameterise existing digital datasets. The mapped data describe the four principal attributes that contribute to wildness in the CNP as defined by SNH, namely

- perceived naturalness of land cover;
- absence of modern artefacts;
- rugged/physically challenging terrain;
- remoteness.

The attribute maps were combined into a single wildness map for the CNP using MCE/fuzzy methods as in Figure 1. This allowed the relative priorities derived from the perception study to be reflected in the wildness map without the need for deterministic criteria or sharp boundaries for defining what is considered wild and that which is not.

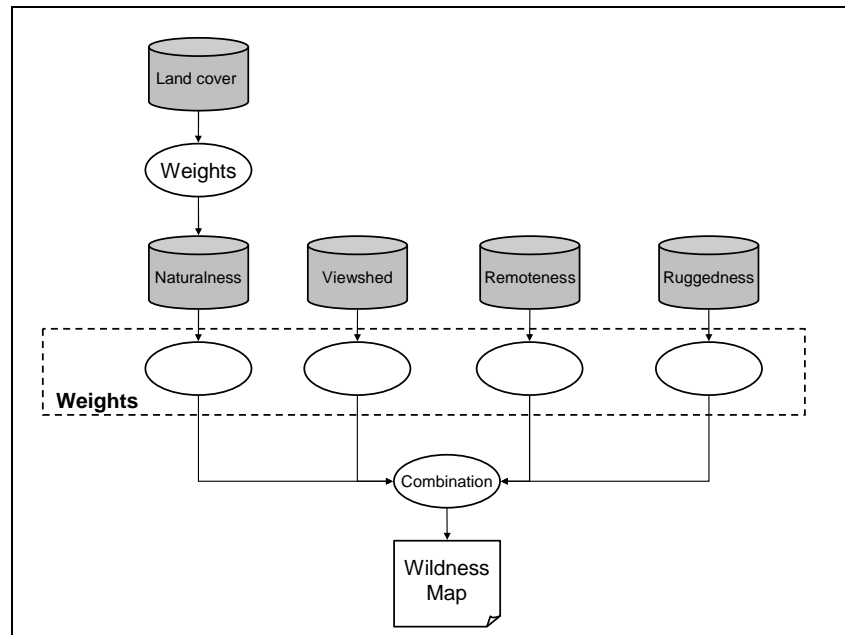


Figure 1. The overall schema showing how the data are parameterised by weights and combined to generate wildness mappings

In many cases, a range of values were identified in the perception survey for specific landscape features. As an example, one of the locations that the public associated with wild areas in Scotland was ‘Woodland/forest’, identified by 86% of the CNP residents and 83% of the respondents across Scotland. Whilst, 19% of CNP residents and 28% of respondents across Scotland identified ‘Forest / woods / trees’ as features that make an area wild. In order to generate the maps of wildness a single set of weightings were derived from the various survey data and applied to the features identified as contributing to wildness. This required decisions to be made about the final weights or membership functions that were used to relate each data feature (e.g. woodlands in land cover data) in order to generate the final fuzzy perception mappings.

The objective of this work was to explore i) the influence of different weightings derived from the perception survey on the mapped outcomes, and ii) the effect of using different formalisms for combining the weightings. Different formalisms for combining belief (or *evidence* or *weights* or *membership functions*) have different conceptual approaches that underpin them. Fuzzy Set Theory uses a *MIN* operator. Bayesian Probability assumes the weights or Beliefs to be a series of independent outcomes (which they may not be). Any evidence that does not support the hypothesis is allocated \neg Belief (that is there no ‘don’t know’ option). Dempster-Shafer operates under the assumption of conjunctive evidence and provides clear indications of the combined belief *plus* the associated uncertainty. In this work we applied Dempster-Shafer to combine the weights

2. Background

The alternative to a Boolean map is a one where the assumption is that any location can always belong to a finite number of classes up to the number of classes being mapped over an area. Fisher (1997) identified 4 possible reasons that would justify the conceptualisation of land cover as suitable for classification by fuzzy sets, which included situations where classified areas are *Intergrades*, *merging* into each other over space or where the boundaries between different areas are not crisp. In this work the classes are the four attributes of

wildness defined above and any location is represented by a matrix of values recording the degree to which that location belongs to each class. The overall fuzzy membership to each class is defined by applying the minimum operator in fuzzy logic to the parameterised data representing the wildness features

Bayes' theorem computes the probability of an hypothesis or event, h given the evidence, e in support of that event, $P(h|e)$:

$$P(h|e) = \frac{P(h) \times P(e|h)}{P(e)} \quad (1)$$

where:

$P(h|e_i \& \dots \& e_m)$ is the posterior probability of hypothesis h given evidence e_i to e_m ;
 $P(h_i)$ is the prior probability;
 $P(e_i|h_i)$ is the likelihood

Dempster-Shafer can be considered as an extension to Bayesian statistics which contains an explicit description of uncertainty, plausibility. It assigns a numerical measure of the weight of evidence (mass assignment, m) to *sets of hypotheses* as well as individual hypotheses. It does not consider the evidence hypothesis by hypothesis as Bayes' theorem does, rather the evidence is considered in light of the hypotheses. A second piece of evidence is introduced by combining the mass assignments (m and m') using Dempster's rule of combination, to create a new mass assignment m'' . Dempster's rule of combination is defined by:

$$m''(C) = \sum_{\substack{i,j \\ A_i \cap B_j = C}} m(A_i) \times m'(B_j) \quad (2)$$

Dempster-Shafer accommodates explicit representations of uncertainty, plausibility, which equates to belief plus uncertainty. Therefore a weak belief in a hypothesis does not imply a strong belief in its negation. One of the weaknesses of Dempster's rule is that it can favour a class which has low mass in two data sets over any class that has a high mass in only one data set. The classic example is that of the two doctors, one of which is 90% certain the patient has disease A and 10% disease B; the other 90% convinced over disease C and 10% disease B. DS will give 100% support for disease B, even though neither doctor thought it likely (although this can be overcome by the use of alternative fusion rules).

3. Results

The data for each layer (remoteness, visibility, ruggedness, naturalness) were using a cumulative distribution function:

$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(x-\mu)^2/2\sigma^2} \quad (3)$$

where x is the original score, μ the group mean and σ the group standard deviation.

The results, to be presented at the conference, are a series of mapped outcomes, describing the different attributes contributing to wildness in the CNP area (perceived naturalness of land cover, absence of modern artefacts, rugged / physically challenging terrain and remoteness). The results of combining this information use Dempster-Shafer are compared with Bayesian and Fuzzy approaches. The results provide CNP management with an alternative mapping of perception and with uncertainties in the weightings to augment the final deliverables of the perception mapping project. These include alternative mappings of the importance of wild

places in Scotland, perceptions of wild places and the location of wild places in the Cairngorms National Park.

References

SNH, (forthcoming). Public Perceptions of Wild Places and Landscapes in Scotland, Report No. XXX (ROAME No. F06NC03), SNH, Edinburgh.

Biographies

Steve Carver is a Senior Lecturer at the University of Leeds with over 20 years experience in the field of GIS and multi-criteria evaluation and interests in wild land, landscape evaluation and public participation. Steve has worked extensively on the development of wild land mapping and evaluation methodologies.

Steffen Fritz works on the Forestry Program at the International Institute for Applied Systems Analysis in Laxenburg, Austria and is involved in an EU-funded project Geo-bene assessing the socioeconomic benefits of earth observation. He has worked and published extensively on wild land mapping. From 2001 – 2006 he was at the JRC working on the Global Land Cover 2000 database and the GEOLAND project.

Lex Comber is a lecturer in GIS at the University of Leicester with research interests in land cover analysis, managing ontological uncertainty in geographical information, the application of different uncertainty reasoning formalisms for combining weighted evidence from spatial data.

Robert McMorran is completing his PhD research at the Centre for Mountain Studies, Perth College-UHI. His research is based on the opportunities and challenges of multi-functional forest management in the Cairngorms region. The PhD incorporated in-depth interviews with forest managers, a postal questionnaire survey of the regions landowners and GIS analysis of forest cover and ownership.

Justin Washtell is a PhD student in the School of Computing's Natural Language Processing Group at the University of Leeds with research interest in the modelling of natural systems. Recently he has been working with Dr Carver on developing voxel-based viewshed transforms for rapid landscape assessment and real-time viewshed calculations.