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Distance to nature—A new biodiversity relevant environmental indicator set at the landscape level

Johannes Rüdisser[a,b,*], Erich Tasser[c], Ulrike Tappeiner[a,b,c]

[a] *Institute of Ecology, University of Innsbruck, Sternwartestr. 15, 6020 Innsbruck, Austria*
[b] *Research Centre Ecology of the Alpine Region, University of Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria*
[c] *Institute for Alpine Environment, European Academy Bozen/Bolzano, Viale Druso 1, 39100 Bozen/Bolzano, Italy*

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ABSTRACT

The ongoing worldwide biodiversity crisis comes along with a growing demand for feasible environmental indicators to measure, evaluate and communicate anthropogenic influence on biodiversity. Those indicators can be useful tools for national and regional management and support decision making processes. We propose *degree of naturalness* (N_d), *distance to natural habitat* (D_n) and the composite index *distance to nature* (D_2N) as a highly comprehensible environmental indicator set that can be used as surrogate for land use related anthropogenic influence on biodiversity. A high resolution naturalness map for Austria based on the best nationwide available land use data was produced and used to test and demonstrate the applicability of the indicator set. Spatially inclusive and comprehensive indicator maps were calculated for the entire country (83,872 km^2). Exemplary indicator values for all 2359 municipalities and six altitudinal zones were calculated and evaluated. Indicator maps of Austria clearly delimitate regions with elevated anthropogenic pressure on biodiversity due to land use characteristics. A sensitivity analysis conducted to evaluate the effect of land use data with different spatial and thematic resolution on the indicators showed that D_n reacts sensitive to spatially more detailed information about natural and near natural habitats. By contrast N_d and D_2N were robust regarding the spatial and thematic resolution of input data. The proposed indicators do not measure biodiversity or a part of it directly, but the degree of habitat changes caused by anthropogenic land use, therefore they can be used for analysis over wide geographic ranges including different bio-geographic or climatic zones, and different spatial scales.

1. Introduction

With the rising political consensus that socioeconomic development should be based on environmental sustainability, there is a growing need for adequate environmental indicators. Environmental indicators should aid policy- and decision-makers, local administrators, as well as stakeholders in their decision making process to follow sustainable development criteria such as natural resource conservation and long term biodiversity protection (Balmford et al., 2005). In the last years many indicators were developed and adopted by international organisations to measure different aspects of biodiversity and its threats (EEA, 2007a; OECD, 2008; UNCED, 2007). These indicators often are a valuable and comprehensive inventory of the environmental characteristics of the assessed region, but at the same time, they frequently fail to serve as effective decision-management tools due to the large variety of sometimes even contradictory indicators and their missing ability to inform managers, stakeholders, and decision makers about the relative importance of different biodiversity components (Feld et al., 2010). Some authors (e.g. Duelli and Obrist, 2003a; Feld et al., 2010; Tasser et al., 2008) proposed frameworks in the context of sustainable development that incorporate various aspects of biodiversity in a "basket", a set of indicators or indexes adapted to fulfil the specific management or monitoring purpose, which they are needed for.

The goal of the presented study was to develop and test an easy interpretable and highly comprehensible environmental indicator or index that can serve as a tool to support the planning and evaluation of policy measures having impact on biodiversity. The indicator development was integrated in an interdisciplinary project (www.landnutzung.at) focusing on the effects of agricultural policies and was accompanied by stakeholders to assure its applicability.

We use the term "indicator" as defined by Heink and Kowarik (2010) for a component or a measure of environmentally relevant

* Corresponding author at: Institute of Ecology, University of Innsbruck, Sternwartestr. 15, 6020 Innsbruck, Austria. Tel.: +43 0512 507 5921; fax: +43 0512 507 2975.
E-mail addresses: Johannes.Ruedisser@uibk.ac.at (J. Rüdisser), erich.tasser@eurac.edu (E. Tasser), Ulrike.Tappeiner@uibk.ac.at (U. Tappeiner).

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phenomena – used to depict or evaluate environmental conditions or changes – or to set environmental goals. The term "index" is used for "composite indicators" which integrate complex environmental conditions in one parameter and can not be measured directly (Heink and Kowarik, 2010).

To understand and evaluate the influence of land use on biodiversity empiric data about occurrence and abundance of all living species are very important. Therefore various national and international initiatives try to enhance accessibility to species distribution and habitat data by establishing harmonised databases or Clearing House Mechanisms (e.g. GBIF,[1] for Europe: EUNIS,[2] BISE,[3] Nature-SDIplus,[4] etc.).

Nevertheless international or even national fine-scaled distribution data of plants or particularly animals are still rare and data collection, especially if done at regular time intervals, as needed for monitoring purpose, can be very demanding and costly. One attempt to deal with the increasing discrepancy between the demand to measure biodiversity in a comprehensive way and the concrete data availability or the limited financial resources, is to use so called indicator-species or -guilds as surrogates for overall species diversity. Various empirical studies have been done at the landscape level focusing on the relation between individual species, a combination of species or a specific taxonomic group and general species diversity (Maes et al., 2005; Pearman and Weber, 2007). Rodrigues and Brooks (2007) reviewed the power of surrogates comparing 575 tests in 27 studies and found a positive, but relatively weak, surrogacy power. Billeter et al. (2008) concluded in an assessment of biodiversity patterns at a pan-European scale, that it may not be possible to use one species group as an indicator for all others, but that a relative small list of landscape and land use parameter could be used to assess environmental conditions for biodiversity. The indicator set proposed here is a practical attempt to implement this idea – not ignoring that the relation between ecosystem changes caused by anthropogenic land use and biodiversity (including aspects of species richness, evenness, and abundance at different scales as well as for different taxonomic groups) are very complex and often not yet understood. Certainly, different taxonomic groups react specifically to different land use characteristics and grades of intensification. Nevertheless, concerning the result of empiric studies on the relation between land use intensity and plant (e.g. Kleijn et al., 2009; Liira et al., 2008; Niedrist et al., 2009; Tasser et al., 2010), arthropod (e.g. Attwood et al., 2008; Hendrickx et al., 2007), snail (e.g. Horsák et al., 2009) or bird (e.g. Chace and Walsh, 2006; Marzluff, 2001) diversity as well as literature reviews on overall species diversity (Jackson et al., 2007; McKinney, 2008) a trend of decreasing biodiversity along a gradient of increasing anthropogenic disturbance and hence decreasing naturalness can be assumed. This is further supported by theoretical considerations of ecosystem theories (Rosenzweig, 2004; Wright, 1990).

Biodiversity of low to even intensively used landscapes can be enhanced through the proximity to natural habitats. The presence of natural and semi natural habitat patches seem to enhance and sustain regional biodiversity in a number of significant ways. Natural habitats not only serve as habitats for otherwise regionally extinct species (Attwood et al., 2008; Hendrickx et al., 2007; Liira et al., 2008), but are used as temporal retreats or nesting areas for many dispersing species (cf. Devictor and Jiguet, 2007; Duelli and Obrist, 2003b; Jauker et al., 2009) and can be an important source for repeated recolonization of surrounding cultural landscape by animal and plant species (Devictor and Jiguet, 2007; Tscharntke et al., 2005). Furthermore, natural and semi natural habitats can serve as "stepping stones" and habitat corridors between otherwise separated habitats.

Based on the described considerations, experience with existing indicators and focusing on applicability in decision making processes as well as data availability, we propose a simple but smart indicator set. *Degree of naturalness* (N_d), *distance to natural habitat* (D_n) and its combination in the index *distance to nature* (D_2N) aim to measure and describe land use related anthropogenic influence on ecosystems and habitats. The indicator was applied and tested within a case study producing a fine scaled naturalness map for Austria. The naturalness map was produced by combining a manifold set of land use data (for details see Section 2.2.2).

2. Materials and methods

2.1. Description of the indicator set

To guarantee its practical applicability in decision making processes aiding the development of sustainable land use policies, the design of the indicators specifically aims to satisfy the following criteria:

(a) The indicator set should be a surrogate for anthropogenic impact on biodiversity and not a measure for species richness or biodiversity itself, which naturally varies not only with elevation and climatic zones, but is influenced also by various biogeographical characteristics (Rosenzweig, 2004).
(b) The indicator set should serve to evaluate and compare biodiversity relevant land use characteristics at a small-scaled spatial resolution while covering an extensive area.
(c) Indicator estimation should be spatially comprehensive, independent from reporting units and based on already existing data ensuring comparability at different spatial scales (regional to international).
(d) To ensure international comparability, indicator estimation based on land use data with different thematic and spatial resolution should be proportional even though less detailed.
(e) The design should be comprehensible facilitating interpretation and communication of indicator results.

2.1.1. Degree of naturalness

Degree of naturalness (N_d) is status quo-oriented and calculated on the basis of spatial land use and land coverage information. Land use types were classified along a seven staged naturalness scale (Table 1). Expanding the hemeroby concept (Ferrari et al., 2008; Steinhardt et al., 1999), which is mainly used in describing plant species and communities, the character and threshold of the seven staged naturalness scale is determined by the aim to reflect biodiversity relevant anthropogenic interferences on plants, animals and ecosystems as a whole – including aspect of soil biology. The seven qualitative stages are defined by thresholds with proportional stretches within a theoretically continuous interval scale. The seven named naturalness stages can be subdivided using decimals to describe intermediate states depending on available land use and land cover maps as well as thematic focus. Land use information from different sources with varying spatial resolution or only partial spatial coverage due to thematical orientation can be combined to achieve a better spatial and thematical resolution as shown in the case study (see Section 2.2).

Degree of naturalness can be used as a spatially comprehensive map layer for further analysis or it can be summarized and reported

[1] http://www.gbif.org.
[2] http://eunis.eea.europa.eu.
[3] http://biodiversity.europa.eu.
[4] http://www.nature-sdi.eu.