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Biodiversity assessment in forests - from genetic diversity to landscape diversity

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Assessing biodiversity in forests requires a reliable and sustainable monitoring concept, which must include all levels of diversity, the genetic, the species and the landscape level. Diversity studies should not be reduced to quantitative analysis, but qualitative interpretations are an important part for the understanding of the results. Also, the linkage of terrestrial data and remote sensing data as well as the implementation of abiotic and biotic data collected on existing monitoring systems are useful sources to analyse cause-effect relationships and interactions between the different aspects of diversity.

Keywords: Biodiversity, Monitoring, Remote sensing, Habitat modelling, Beech provenances

Introduction

Biodiversity has gained global attention particularly since the UNCED conference in Rio de Janeiro in 1992 and the adoption of the Convention on Biological Diversity. Even after a long time of discussion and numerous studies on biodiversity, there is still a need to differentiate the term biodiversity depending on the objectives of the respecting assessment (*e.g.*, Larsson 2001, Van der Maarel 1997). One possibility is to order biodiversity by the level of organization of the assessed entity (*e.g.*, Harper & Hawksworth 1994, Beierkuhnlein 2003). From the viewpoint of monitoring systems three different levels can be defined: genetic, species, and landscape diversity (Whittaker 1972). All levels are interacting with the environment, thus indirect (*e.g.*, climatic change, deposition) or direct human influences (deforestation, fragmentation, etc.) affect all these levels. For the assessment of biodiversity it is necessary to focus on all levels and if possible to integrate between different spatial scales. At the Institute for World Forestry of the Johann Heinrich von Thunen-Institute (vTI - http://www.worldforestry.de/) different approaches are used to evaluate biodiversity from the genetic to the landscape level.

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Genetic diversity

For Central Europe, climate scenarios also indicate a decrease of mean precipitation, an increase of mean temperature during the vegetation period and an increased frequency as well as severity of drought events (IPCC 2007). Already in recent years, drought periods affected the ecosystems in Western Europe. In 2003, spring and summer were characterized by extremely low precipitation accompanied by high temperature.

It is postulated that a higher genetic diversity in tree populations increases their adaptability to environmental changes (Wehenkel et al. 2006). Due to their natural dominance in temperate European Forests, six different provenances of *Fagus sylvatica L.* were studied as an example for a better understanding of the responses of tree species to environmental changes.

Preliminary results show that mean leaf conductance (LC), mean transpiration and mean electron transport rates (ETR) of the six provenances differ strongly, and mean LC and mean ETR of the respective provenance are closely correlated. The provenances differ in the mean yearly basal area increment rates, in the growth reaction to the dry summer 2003 as well as in the following development of the tree ring increment. Furthermore a strong correlation between the basal area increments in 2005 and the mean ETR and LC of the provenances in 2006 were found. Thus, extreme dry periods can result in decreasing biomass increment in following years. Hence, an increasing frequency of drought events may contribute to a destabilization of beech forests build up by less resilient populations (Kriebitzsch et al. 2008).

Based on the outcome of the field trial, it is recommended to integrate genetic monitoring into the exiting forest monitoring systems and to investigate the level of genetic variation (*e.g.*, percentage of polymorphic loci, effective number of alleles, and number of potential parents) at the established plots. In addition genetic information should be linked to responses of forest ecosystems to ecological and environmental factors.

Species diversity

In the context of intensive and large scale forest monitoring the survey of structural parameters or selected indicator species groups like plant species or epiphytic lichens can provide information on the status or the development of biodiversity at different levels: on site level (alpha-diversity) and on landscape level (gamma diversity - Whittaker 1965, Whittaker 1972). Harmonized and standardized sampling methods are of fundamental importance for a reliable assessment and evaluation (Köhl & Päivinen 1996).

Aspects of species diversity (ground vegetation) are assessed in the Pan-European Level II monitoring system in some cases already since the end of the 1980s (http://www.icp-forests.org). In 2004, cofinanced by the European Commission (Forest Focus Regulation), the Forest Biodiversity Test Phase Assessments (ForestBIOTA) project (http://www.forestbiota.org/) was launched. Apart from structural diversity indicators like deadwood or stand structure, epiphytic lichens and ground vegetation were assessed on 97 intensive monitoring plots located in 12 European countries (Granke 2006). The main objective was the development and testing of a harmonized methodology of selected key factors of biodiversity in forests.

On the systematic transnational Level I grid of 16 x 16 km the Forest Focus EU demonstration project BioSoil has assessed the richness of vascular plant species on approximately 4000 plots. Also in some national forest inventories, ground vegetation information on species level is available in addition to tree species data.

The above mentioned species based datasets including the abundance of each species permit the calculation of specific diversity indices like Shannon-Wiener-Index (Shannon & Weaver 1949), Evenness or Simpson-Index (Simpson 1949, Pielou 1966, McGarigal & Marks 1994, O'Neil et al. 1988, Walz 1999). Correlative studies using key factors from forest biodiversity and site or external factors like pollution offer valuable clues to the effects of single factors (*e.g.*, Thimonier et al. 1992, Seidling et al. 2008).

Landscape diversity

Species based surveys from representative large-scale inventories also provide information on landscape diversity by aggregating data for, *e.g.*, geo-botanical or administrative regions (Jennings 2000). Using for example geo-statistical methods, maps could be produced showing landscape pattern for species richness and derived diversity indices. For instance hot spots of vascular plant diversity in forests could be identified with this method (Guisan & Zimmermann 2000).

The linkage of remote sensing data and terrestrial data using, *e.g.*, the kNN method (*k*-Nearest Neighbours - Kilkki & Päivinen 1987, Tomppo 1991, Stümer 2004) or regression analysis is another tool for landscape analysis, which provides objective data for landscape planning and for political decision support. This method could be used to calculate a large number of landscape indices like Shannon-Wiener-Index or specific fragmentation indices (Köhl & Oehmichen 2006). Landscape indices quantify, *e.g.*, biodiversity in more or less useful ways (Köhl & Zingg 1996).

However, the prediction of effects of political decisions on landscapes and e.g. habitat suitability is limited especially in the case of those species that use specific habitats in landscapes with diverging structures. With the kNN method for instance, *in situ* data can be combined with ancillary data such as remote sensing imagery to realise an objective, but species specific landscape analysis in terms of a habitat suitability modelling (Kenter 2007). The spatial information as a pre result of the kNN combination can be recalculated to specific attribute maps. The different attribute information can be combined and weighted to a habitat suitability index. An open habitat model can be applicable for various key species on different scales. Simulation and modelling of habitats can offer politically relevant information by forecasting the implications of potential land use activities on spatial and temporal scales. Different model approaches (binary, fuzzy logic and home range), considering climate change or land use changes, provide an estimation of the temporal development of a landscape as a potential habitat (Kenter 2007).

Quantitative information about changes of land cover and land use, based on remote sensing data, enable on landscape level the identification of the main pressures on biodiversity in the past. In the international cooperation project BIOPRESS long-term land use changes were analysed on several 30 x 30 km windows and 2 x 15 km transects in Europe by interpretation of historical aerial photos using standardized land use classes. Increased annual change rates were observed in the period from 1990-2000 as compared to 1950-1990. Changing patterns are different for bio-geographic regions and individual countries. The comparison of results derived from detailed aerial photographs and CORINE 1990 demonstrated, that based on the aerial photos the number of detected changes can be doubled. An overlay with Natura 2000 sites showed less changes within protected sites compared to the surrounding. With BIOPRESS the capability of remote sensing for landscape dynamics assessments could be demonstrated and a need for frequent and more detailed landscape assessments as indicator for changes in biodiversity was substantiated (Köhler et al. 2006).

The monitoring of forest biodiversity in the sense of conservation and sustainable management needs tools which allow evaluating the assessed parameters with reference to naturalness. Such tools can be applied e.g. by using a common and accepted regionalised list of plants growing exclusively or mainly in forests. Such a list of forest vascular plant species was developed for Germany by Schmidt et al. (2003). The further development of those evaluation tools on European level will be an important task in future.

Conclusions

Considering global changes and their impacts on ecosystems, monitoring of biodiversity needs a reliable and sustainable monitoring concept, which should include all levels of diversity, the genetic, the species and the landscape level. Diversity studies should not be reduced to quantitative analysis; qualitative interpretations are an important part for the understanding of the results. Applicable and accepted reference systems (*e.g.*, potential natural vegetation - Tüxen 1956, Kowarik 1987, Bohn et al. 2003 -, forest types - EEA 2006) and evaluation tools (classification of species groups - *e.g.*, Ellenberg et al. 1992, Grime 1979, Schmidt et al. 2003 - or forest status indicator - Petriccione et al. 2007) are useful to implement also naturalness concepts.

Despite numerous studies on biodiversity aspects, there is still a high need for future research. The linkage of terrestrial data and remote sensing data as well the implementation of abiotic and biotic data collected on existing monitoring systems are useful sources to analyse cause-effect relationships and interactions between the different aspects of diversity.

References

Beierkuhnlein C (2003). Der Begriff Biodiversität. Nova Acta Leopoldina NF87 328: 51-71.

Bohn U, Gollub G, Hettwer C, Neuhäuslová Z, Schlüter H, Weber H (2003). Map of the natural vegetation of Europe. Federal Agency for Nature Conservation, Bonn, Germany.

EEA (2006). European forest types - Categories and types for sustainable forest management reporting and policy. EEA Technical report No 9/2006. European Enviroment Agency, Copenhagen, Denmark. [online] URL:http://reports.-eea.europa.eu/technical_report_2006_9/en

Ellenberg H, Weber, HE, Dà¼ll, R, Wirth V, Werner W, Paulissen D (1992). Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica 18: 6-199.

Granke O (2006). Assessment of Ground Vegetation. ForestBIOTA work report. [online] URL:http://www.forestbiota.org/

Grime JP (1979). Plant strategies and vegetation processes. Wiley, London, UK, pp. 222.

Guisan A, Zimmermann NE (2000). Predictive habitat distribution models in ecology. Ecological Modelling 135: 147-186. - doi: 10.1016/S0304-3800(00)00354-9

Harper JL, Hawksworth DL (1994). Biodiversity: measurement and estimation. Philosophical transactions of the Royal Society of London Series B Biological sciences 345: 5-12. - doi: 10.1098/rstb.1994.0081

IPCC (2007). Climate change 2007: the physical science basis. Summary for policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. WMO, Geneva, Switzerland, pp. 21.

Jennings MD (2000). GAB analysis: concepts, methods, and recent results. Landscape Ecology 15: 5-20. - doi: 10.1023/A:1008184408300

Kenter B (2007). Applying objective data for a multi temporal analysis of habitat suitability indices to monitor biodiversity: a case study for the example key species Red kite (*Milvus milvus*) and Black stork (*Ciconia nigra*). Dissertation Universität Hamburg, Hamburg, Germany, pp. 221. [online] URL:http://www.sub.uni-hamburg.de/opus/volltexte/2008/3518/

Kilkki P, Päivinen R (1987). Reference sample plots to combine field measurements and satellite data in forest inventories. Research Notes 19, Department of Forest Mensuration and Management, University of Helsinki, pp. 209-215.

Kowarik I (1987). Kritische Anmerkungen zum theoretischen Konzept der potentiellen natürlichen Vegetation mit Anregungen zu einer zeitgemäßen Modifikation. Tüxenia 7: 53-67.

Kriebitzsch WU, Beck W, Schmitt U, Veste M

(2008). Bedeutung trockener Sommer für Wachstumsfaktoren von verschiedenen Herkünften der Rotbuche (*Fagus sylvatica* L.). AFZ - Der Wald 62: 246-248.

Köhl M, Oehmichen K (2006). Weiterentwicklung von Indikatoren zur Erfassung der Fragmentierung von Wäldern unter Berücksichtigung der Datenverfügbarkeit. Arbeitsbericht des Instituts für Weltforstwirtschaft der Bundesforschungsanstalt für Forst- und Holzwirtschaft und dem Zentrum für Holzwitschaft Universität Hamburg, 2006/2, pp. 43.

Köhl M, Päivinen R (1996). Definition of a system of nomenclature for mapping European forests and for compiling a pan European forest information system. FIRS Final Report.

Köhl M, Zingg A (1996). Eignung von Diversitätsindizes bei Langzeituntersuchungn zur Biodiversität in Waldbeständen. Allgemeine Forst- und Jagdzeitung 167 (4): 76-85.

Köhler R, Olschofsky K, Gerard F (2006). Land cover changes in Europe from the 1950's to 2000. Institute for Wordforestry, University of Hamburg, Hamburg, Germany, pp. 364.

Larsson TB (2001). Biodiversity evaluation tools for european forests. Ecological Bulletins 50, pp. 237.

McGarigal K, Marks B (1994). FRACSTATS. Spatial pattern analysis program for quantifying landscape structure - version 2.0. Corvallis, pp. 67.

O'Neil RV, Krummel JR, Gardner RH, Sugihar G, Jachson B, Deangelis DL, Milne BT, Turner MG, Zygmunt B, Christensen SW, Dale VH, Graham RL (1988). Indices of landscape patterns. Landscape Ecology 5: 153-162. - doi: 10.1007/BF00162741

Petriccione B, Cindolo C, Cocciufa C, Ferlazzo S, Parisi G (2007). Development and harmonization of a Forest Status Indicator (FSI). European Enviroment Agency and Italian Forest Service, CONECOFOR Board. [online] URL:http://biodiversity-chm.eea.europa.eu/information/indicator/F1090245995/fol365614/F1115187844/fol836804/fol042007

Pielou EC (1966). The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131-144. - doi: 10.1016/0022-5193(66)90013-0

Schmidt M, Ewald J, Fischer A, von Oheimb G, Kriebitzsch, WU, Schmidt W, Ellenberg H (2003). Liste der in Deutschland typischen Waldgefäßpflanzen. Mitteilungen der Bundesforschungsanstalt für Forst- und Holzwirtschaft 212, pp. 66.

Seidling W, Fischer R, Granke O (2008). Relationships between forest floor vegetation on ICP Forests monitoring plots in Europe and basic variables in soil and nitrogen deposition. International Journal of Environmental Studies 65 (3): 309-320. - doi: 10.1080/00207230701862538

Shannon C, Weaver W (1949). The mathematical theory of communication. University of Illinois Press, Urbana 1949.

Simpson EH (1949). Measurement of diversity. Nature 163: 688. - doi: 10.1038/163688a0

Stümer W (2004). Kombination von terrestrischen Aufnahmen und Fernerkundungsdaten mit Hilfe der kNN-Methode zur Klassifizierung und Kartierung von Wäldern. Dissertation. Technische Universität Dresden. Lehrstuhl für Forstliche Biometrie und Informatik.

Thimonier A, Dupouey JL, Timbal J (1992). Floristic changes in the herb-layer of a deciduous forest in the Lorraine Plain under the influence of atmospheric deposition. Forest Ecology and Management 55: 149-167. - doi: 10.1016/0378-1127(92)90098-T

Tomppo E (1991). Satellite image-based national forest inventory of Finland. International Archives of Photogrammetry and Remote Sensing 28 (7-1): 419-424.

Tüxen R (1956). Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung. Angewandte Pflanzensoziologie 13: 64-98.

Van der Maarel E (1997). Biodiversity: from Babel to biosphere management. Special features in biosystematics and biodiversity 2, Uppsala, Sweden, pp. 59.

Walz U (1999). Charakterisierung der Landschaftsstruktur mit Methoden der Satelliten-Fernerkundung und der Geoinformatik (Dissertation). TU Dresden, pp. 190.

Wehenkel C, Bergmann F, Gregorius H-R (2006). Is there a trade-off between species diversity and genetic diversity in forest tree communities? Plant Ecology 185: 151-161. - doi: 10.1007/s11258-005-9091-2

Whittaker RH (1965). Dominance and diversity in land plant communities. Science 147: 250-260. - doi: 10.1126/science.147.3655.250

Whittaker RH (1972). Evolution and measurement of species diversity. Taxon 21: 213-251. - doi: 10.2307/1218190