MODELLING OF NATURA 2000 HABITAT TYPES IN DIFFERENT BIOGEOGRAPHIC REGIONS – EXPERIENCES FROM SPAIN AND GERMANY

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ABSTRACT

To implement a functional monitoring system, a way to support the terrestrial mapping and monitoring of extend and quality of different habitat types of NATURA 2000 areas has to be established. This can be achieved by combining GIS-based models of the Potential Natural Vegetation (PNV) with remote sensing classification or interpretation results. The presented study focuses on the transferability of rules for the PNV. Therefore, forested test areas in two different biogeographic regions are selected. Within these NATURA 2000 areas, geo-factors of potential forest types, such as altitude, aspect, soil-wetness or soil acidity, were taken into account. From a defined rule-set, the habitat types with the highest possibility of occurrence could be ranked accordingly. In order to derive the actual forest habitats, the PNV was verified using available satellite data (LANDSAT TM and ASTER). This task was carried out in an object-based approach using the software eCognition. The results of the classification and the GIS analysis are combined to obtain preliminary habitat types. These types were verified with existing Forest Management Plans or local terrestrial mapping. First results of the habitat derivation show that a modelling of the PNV is applicable for large areas of the biogeographical level with medium and high resolution satellite data. However, different ecosystems or biogeographic regions require adapted approaches. While the rule-base for mid-European forest conditions depend gradually more on an additive approach of environmental geo-factors for preferred ecological niches for habitat types, the rule-base for Mediterranean habitats relates stronger to limiting factors for certain habitats.

Keywords: Potential Natural Vegetation, geo-factor, object-based classification

1 INTRODUCTION

The monitoring of NATURA 2000 areas within the EU is still a challenging task. Recently, there are more precisely defined monitoring guidelines available on European level (European Commission, 2006). Therefore, it is not sufficient to assess and evaluate the conservation status of habitats and species only within the Special Areas of Conservation (SAC) of the NATURA 2000 network, but additionally on the biogeographical level. The EU defines biogeographic regions as a geographical framework for the establishment of a draft list of sites of Community importance from the membership states. This area-wide assessment is necessary because of possible small scale changes of the biodiversity network.

To assess changes of range and covered area of habitats on biogeographic level it is more appropriate to use satellite data, which cover large areas multitemporally while accepting a slight decrease in spatial resolution. This satellite data can be combined with an a priori information of the possibility of an area to be assigned to a NATURA 2000 habitat type.

Therefore, the objective of this study is to utilize the derived information of the PNV together with spatial high resolution satellite systems, such as Landsat TM (30 m) and ASTER (15 m) for a screening of potential areas of actual habitat types within two biogeographic regions. Moreover, it has to be evaluated whether different strategies of deriving habitat types have to be developed for different biogeographic regions.

2 STUDY AREA

Forested areas in the Mediterranean and in the Continental biogeographical region were selected within this study. The test site „Taubenberg“ is located in the federal State Bavaria, Germany and belongs to the Continental region. This biogeographic region covers over a quarter of the European Union and extends in a broad band from west to east, covering eleven EU countries, with a 25 % of the EU territory. The climate of the Continental region is generally characterized by strong contrasts between cold winters and hot summers. Due to this factor, the continental nature is dependent and well adapted to the natural conditions (European Commission, 2005).

The second test area (Ávila, Spain) is located in the Mediterranean region. The Mediterranean region covers 22.5 % of the EU territory and can be observed in the countries of the Mediterranean Basin plus Portugal (European Commission, 2005). The climate of this region is characterized by mild and wet winters and dry and hot summers. The principal characteristic of this region are 2-3 months of dryness (Muñoz Jiménez, 1999).

2.1 REGION AVILA (SPAIN)

The forest test area "Ávila" (Castilla y León Region) is located in, Central Spain. The medium height of this area is 1308 m and the slopes are between 5 and 12 %. This region is characterized by a fresh mild Mediterranean weather, with hydric stress during the summer and pluviometric maximum in autumn and winter (MAPA, 1984).

The 815 hectares of the forest area are included in the Site of Community Interest (SCI) and SAC "Pinares del Bajo Alberche". The area is dominated by a natural Oak Forest stand of Luzulo foresteri-Quercetum pyrenaicae (habitat type 9230) and patches of Junipero oxycedri-Quercetum rotundifoliae (9340). The pastures areas are dominated by the habitats 3170* and 6220*. The types of shrubs detected in this area are steppe plant associations of the habitat 5120. The areas without vegetation, bare soil or rocks are dominated by the habitats 8130 (Tejera Gimeno et al., 2007).

2.2 REGION TAUBENBERG (GERMANY)

The region "Taubenberg" is situated in the southern pre-alpine area of Bavaria. The altitude ranges from 620 to 896 m. Almost the whole area is built from tertiary material named "Obere Süßwassermolasse". However, the surroundings are covered by old glacial moraines and river terraces. Mean annual rainfall is approximately 1.500 mm, mean annual temperature is from 6 to 7°C (Walentowski, 2005).

The "Taubenberg" covers an area of ca. 1.600 ha. It is dominated by Beech, mainly Asperulo-Fagetum (habitat type: 9130; coverage: 28.9 %) and small amounts of Luzulo-Fagetum (9110; 1.9 %) with mixtures of Fir. Smaller areas are covered with Tilio-Acerion (9180; 0.27 %), Bog woodland (91D0; 0.16 %), Alluvial forests (91E0; 7.9 %), and Acidophilous Picea forest (9410; 0.9 %). However, large parts of the area are covered by Norwegian Spruce, which is due to silvicultural practices.

3 DATA AND METHOD

The occurrence of specific forest types depends on natural conditions. These conditions are basically predefined by soil, relief, climatic conditions and associated factors, such as soil type, height and steepness of an area, or availability of water. Consequently, spatial modelling of the PNV from natural location-factors and knowledge about the growing conditions of different tree types can help to determine Potential Natural Forest (Jansen et al., 2002).

3.1 AVAILABLE DATA

For the modelling of the Potential Natural Forest Associations Digital Terrain Models (DTM), Soil Maps as well as Forest Site Maps and derived geo-factors were used (see Table 1). To exclude regional knowledge and receive results transferable to other NATURA 2000 sites, the data was processed without a field survey.

Table 1. List of existing spatial data

Data Type	Avila	Taubenberg
Map of habitat types	available (1 : 50,000)	available (1 : 5,000)
DTM	available (DTM 25)	available (DTM 5)
Soil Map	available (1 : 50,000)	available (1 : 25,000)
Forest Site Map	available	partly available
Manage-ment Plan	available (May, 2007)	not available
Remote Sensing Data	Landsat (30m) orthophoto image (0.5 m)	ASTER (15m) orthophoto image (0.2 m)

For the classification of the actual vegetation LANDSAT TM and ASTER satellite data as well as true colour orthophotos were available.

3.2 METHOD

3.2.1 Rule-base for deriving of PNV

For habitat types, which could exist in this natural woodland composition, a register of location-factors was developed, including soil type, relief type, water balance, and site- related additional attributes, such as the location of very dry areas. Sites with a high (H) suitability for specific habitat types and sites where the existence of the habitat type is generally possible (P) or excludable (E) were distinguished (Förster et al., 2005). Based on the existing suitability the geo-data are combined to a rule-set adapted to conditions of the biogeographic region (see 3.2.2 and 3.2.3). The rules are developed together with local experts and literature sources from the region (Walentowski, 2005; Tejera Gimeno et al., 2007; San Miguel et al., 2004)

3.2.2 Adaptation to Mediterranean Habitats

The modification of the rule set to the Mediterranean Habitats has been driven by the limiting factors of the Mediterranean characteristics. Mediterranean Habitats are very much adapted to extreme or limiting conditions, such as hydric stress or illumination. This is why the rules to define the Potential Natural Vegetation of these habitats had to be modified to the conditions occurring in the territory (Chefaoui et al., 2005).

Aspects of the evaluation depending on the position (Digital Terrain Model analysis) have been valued as excludable, because of their inadequate positions for the presence of the habitats. Moreover, extreme slopes, curvature, aspect, and height have been evaluated as excludable for the given habitats (see Figure 1). Analysis of growth condition factors, type of relief and soil with a high suitability for the given habitats have been combined with DTM analysis to produce the PNV.

Forest type		Soil map	Reflief-type						DTM			
Habitat Type (Code)		Assignment of soil type	Valley depression	Small depression	Shadowing aspect	Very steep slope	Sunny Aspect	Hilltop	Type of curvature (cc =concave; cx = convex)	Aspect	Slope (st = steep)	Altitude
3170*	Pulicario uliginosae-Agrostietum salmanticae	3 types							cc		<10	
5120	Cytiso scoparii-Retametum sphaerocarpae	2 types							cx	S,E,W	<30	>1400
5120	Genisto floridae-Cytisetum scoparii	2 types							cx		>10	>1200
6220*	Festuco amplae-Poetum bulbosae	2 types							cc		<20	<1400
8130	Digitali thapsi-Dianthetum lusitani	3 types							cc,cx		st	
8220	Asplenio billotii-Cheilanthetum duriensis	3 types							cc,cx			
9230	Luzulo forsteri-Quercetum pyrenaicae	2 types										100-1400
9340	Junipero oxycedri-Quercetum rotundifoliae	2 types								S,E,W		<1100

existence is possible
existence excludable out of the ranges

Figure 1. Analysis of growth condition factors for Mediterranean Habitats in Ávila, Spain.

3.2.3 Adaptation to Mid-European Habitats

The adaptation of the rules shows that the rule-base for the Continental Biogeographic Region is less driven by limiting factors, but by the summation of the possible factor or the highly suitable factors. The vegetation in this region is more affected by competitive than by limiting factors. As an example, Beech forest covers large parts of the area as PNV, because of the wide ecological niche of this tree type.

Forest Type		Soil Map	Forest Map		Reflief-type						DTM		
Habitat Type (Code)		Assignment of soil type	Assignment of characteristics (rh = rich in humus; b = boggy soil	Assignment of water balance (from 0 = dry to 9 = very moist	valley depression	small depression	shadowing aspect	very steep slope	sunny Aspect	hilltop	Type of curvature (cc = concave; cx = convex)	Aspect	Slope (st = steep)
9110	Luzulo-Fagetum, kollin-submontane Type	3 types									cc, cx	N,S	st
9130	Galio odorati-Fagetum, kollin-submontane Type	3 types									cc	N,S	st
9160	Stellario holosteae-Carpinetum	4 types		8, 9							cc		
9180	Aceri-Tilietum	1 type		0, 1								S	st
9180	Fraxino-Aceretum	4 types										N	st
9410	Vaccinio vitis-idaeae-Abietetum	1 type	rh, b	8, 9							cc	N,S	
91D0	Vaccinio uliginosi-Pinetum sylvestris		b	8, 9							cc		
91E0	Salicion albae / Carici remotae-Fraxinetum / Pruno padis-Fraxinetum / Circaeo alpinae-Alnetum glutinosae / Stellario-Alnetum	all types	b	5, 8, 9							cc		

existence is possible
existence is excludable
existence is highly likely

Figure 2. Selected parameters for the analysis of growth condition factors for Continental Habitats in Taubenberg, Germany.

However, some habitats are adapted to limiting factors as well. Especially the Aceri-Tilietum forest and bog woodland are restrained to a small ecological niche. Mainly relief-type depending parameters (e.g. slope) are more often excludable or highly likely than factors derived from the Soil Map or the Forest Site Map (see Figure 2).

3.2.4 Classification of the real vegetation

The implementation of remote sensing in detection and monitoring of NATURA 2000 habitats and site quality key parameters is stated by various authors (Lang and Langanke, 2005). In order to identify real forest habitat types, the modelled Potential Natural Forest associations had to be combined with a classification of the in situ vegetation because all European forests are influenced by anthropogenic practices. The satellites LANDSAT TM and ASTER were considered suitable for the differentiation of coniferous, deciduous, and mixed forest as they offer a spatial resolution of 15 m to 30 m and spectral bands in the infrared and near infrared region.

For the Taubenberg region, true colour air photographs and silvicultural maps are used to select training areas for all existing principal tree species and types of mixture. With these samples a pixel-based maximum likelihood classification of the ASTER scene was carried out. Simultaneously, the image was delineated by the software eCognition. The segmentation was based on spectral attributes. Because of the limited spatial resolution, the pixel-based result was summarized within the defined objects to higher-ranking classes (e.g. more than 90 % of Beech, Alder, and Oak to Deciduous forest). After merging, the classes deciduous, coniferous – non fir, coniferous – fir and mixed forest were recognized, which corresponds with the results of Blaschke (2003). The result was validated by the use of Forest Management Maps and local knowledge of forest officials.

Classification of actual vegetation for Avila region, as in Taubenberg region, has been implemented by pixel-based maximum likelihood classification (software PCI Geomatica) using LANDSAT TM and high resolution orthophotos. The territory has been classified in three different classes: forested areas (habitats 9230 and 9340), pasture and shrub lands (habitats 3170, 5120 and 6220*) and bare soil areas (habitats 8130 and 8220).

The results of the satellite classification were combined with the modelled PNV (see 3.2.2 and 3.2.3). The potential forest habitat type is only selected if the classified real vegetation corresponds to the forest habitat. Consequently, if a potential forest habitat is modelled in an area classified as pasture land it is not considered as a potential habitat type.

4 RESULTS

4.1 AVILA REGION

Results show that modelling of PNV is possible for Mediterranean Habitats. 26.6 % of the rules defined for PNV mapping were based on excluding factors of the territory for suitability of habitats in Mediterranean conditions (altitude, slope, type of slope and aspect). 73.4 % of the rules have been based on additional factors (type of relief and soil types).

PNV mapping for the study area has improved the accuracy of information for potential vegetation (scale 1 : 400.000) available for the territory (Rivas Martínez, 1987). The comparison with the information available has shown differences. While Rivas Martínez characterized the whole territory as potential area of Luzulo forsteri-Quercetum pyrenaicae (habitat 9230), PNV mapping was able to differentiate four habitats with potential distribution in the territory: habitat 9230 with 85 % of the territory, 10 % for habitat 9340 and 5 % for habitats 5120 and 3170. In addition, implementation of a PNV mapping at project scale has lead to a better understanding of the natural dispersion of the habitats and natural succession after impacts.

Delimitation with remote sense techniques of forest structure, pasture lands and bare soil areas has been a suitable tool for the definition of main groups of actual vegetation. Classification of actual vegetation with LANDSAT TM and high resolution orthophoto image, combined with PNV mapping has resulted a good tool for the actual location of habitats.

Validation of the results has been carried out with Management Plan Maps and terrestrial mapping of actual vegetation available for the test area (see Figure 3). The model could detect 70 % of the habitats referenced for the study area. Final result shows a good representation of the reality for main habitats; accuracy for forested areas (habitats 9320 and 9340) is 60 % and 80 % accuracy for pasture lands (habitats 6220 and 3170). The accuracy for bare soil areas is lower than 50 % because this class is difficult to detect via remote sensing and on-site inventory.

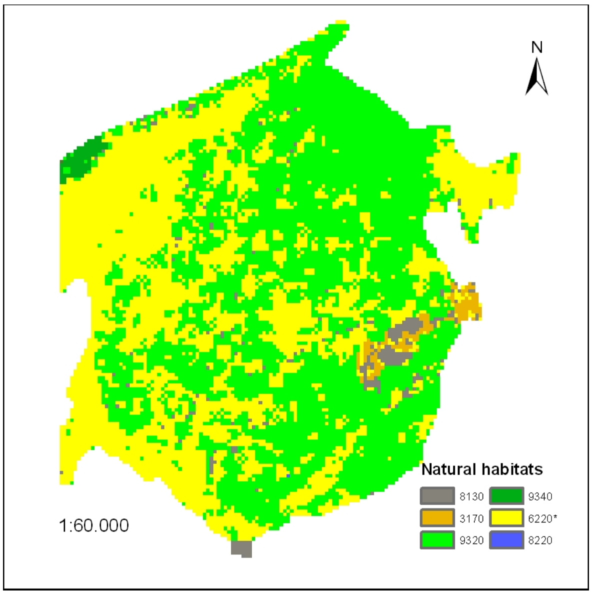

Figure 3. Classification of Natural Mediterranean Habitats for forest test area in Ávila, Spain.

4.2 TAUBENBERG REGION

The results were compared to the terrestrial mapped habitat types from the Forest Management Plans of the test sites (see Figure 4). Between 40 % and 80 % of the considered habitat types are detected by the use of the combined modelling and classification approach. The area considered to be a potential habitat is 19.8 %.

Because of missing data for the Taubenberg region, the rules of the Forest Site Map (FSM) could not be applied. The results indicate that without the information of this map, the classification accuracy is higher when applying summed “possible” rules instead of “highly likely” or “excludable” rules (see Figure 4). So is the Alluvial forest with a classify-cation accuracy of 37.5 % very difficult to differentiate without the FSM, although 50 % of the rules are limiting (H or E see 3.2.1). Contrary, areas of Beech Forest are classified better (> 60 %) while utilizing more “possible” rules. This might indicate a trend of preferring additional factors to exclusive factors in this region. However, the correlation could be connected to the amount of rules. Moreover, including the FSM could improve the accuracy of the habitat types and show different results for rule-accuracy relation.

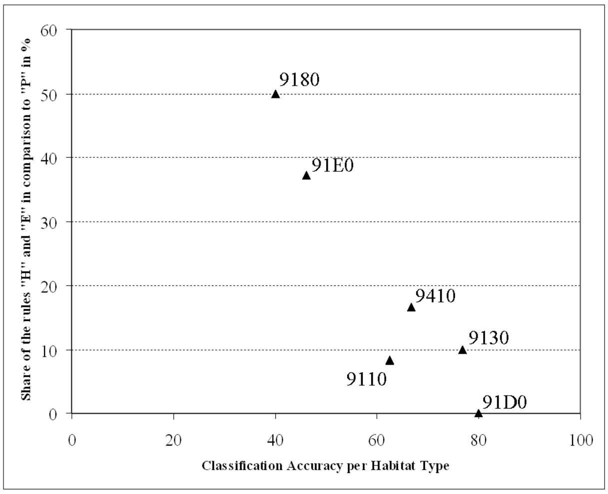

Figure 4. Correlation of Classification Accuracy and different rule-types for the Taubenberg Region.

5 DISCUSSION AND OUTLOOK

The results of this study have shown great potentials of the modelling of forest vegetation. They are especially valuable when combined with remote sensing data. These results can support mapping as well as monitoring of biodiversity within and outside of the declared boundaries of NATURA 2000 areas and narrow the area of terrestrial mapping. Additionally, a trend of different strategies of building rule-sets could be detected. While for the Avila region more limiting rules were used due to the local conditions, in the Taubenberg region more additive rules are applied with more accuracy.

However, there are large differences within the biogeographic regions. The continental region includes such different habitats as the pre alpine zones, the Baltic Sea coastal area, and the Po Plain. To be able to transfer the presented approach, sub-regions have to be defined. Moreover, the transitions in between habitat types or between a habitat type and other forest are not clearly to detect, even when the area is terrestrially mapped.

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