LAND COVER ANALYSIS WITH A COMBINATION OF REMOTE SENSING, LANDSCAPE METRICS AND SOCIAL RESEARCH

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ABSTRACT

This paper presents two separate projects. The first, which expired in 2009, included the land cover classification of the biosphere reserve Schorfheide-Chorin (Germany), and the other project has just been launched, containing a land cover analysis of the biosphere reserve Mittelelbe (Germany) and the national park Bach Ma (Vietnam). Due to this separation, the investigation areas and methods of the current project are described with a closing summary of the findings of the Schorfheide-Chorin project.

The key feature in both projects is the connection of remote sensing and further GIS analysis using landscape metrics with qualitative social research. Caused by isolated projects, unadjusted methods or more than broad results, in fact, often valuable projects are not effective and fail to reach useful aims. The project from 2009 shows, that remote sensing with Landsat images is suitable for monitoring protected areas at a regional level and to depict land cover changes, e.g., measures concerning forest conversion or urban renewal. Hence, the triangulation of methods and data is the most important goal for this monitoring approach.

1. INTRODUCTION

For hundreds of years, human beings change their environment and therefore their basis of life. Recently, more and more humans change the environment considerably faster and with increasing profundity. The results at the global scale of these transformations are deforestation, desertification, degradation of agricultural land or the loss of biodiversity and therewith destruction of our natural resources (Singh 1989; Vitousek *et al.* 1997). Since about 100 years, people try to safeguard their nature with large protected areas, starting with the exclusion of the humans. However, over 100,000 protected areas, covering over 11% of the terrestrial earth's surface with the ongoing environmental damages and climate change, show that this approach is not as efficient as expected (Berghöfer 2008). The UNESCO and its "The Man and the Biosphere" program try to include man and its acts for establishing a sustainable development. This program was launched in 1970. Since that time, the UNESCO formed over 560 model regions in over 100 countries worldwide (UNESCO 2010). Nevertheless, without an effective management there can be no or not enough protection. Hence, for a prospective management, monitoring approaches are indispensable. Most of these monitoring methods are under high-cost pressure, so that expensive and long-term field works cannot be included. A solution can be available by taking the methods of remote sensing into consideration. These techniques can provide a comprehensive monitoring, with comparable data over time and space (Cohen and Goward 2004). The intersection of these data with other additional geodata as well as with monitoring data gives us the opportunity to build a wide-ranging database for an effective management of protected areas and supports regional planning activities (Lu and Weng 2007).

2. INVESTIGATION AREAS

The requirement for the current project was to select investigation areas, which are as dissimilar as possible. Hence, a biosphere reserve in Germany and a national park in Vietnam were chosen. The biosphere reserve Mittelelbe, located in Saxony-Anhalt (Germany), covers about 125,510 ha of an anthropogenic landscape type with a huge dependence of the river Elbe and its short-term alterations, based on his fluvial system. Due to its elongate shape, the biosphere reserve is preferred for remote sensing approaches to save cost intensive field works. Located within a mountainous region, the national park Bach Ma (Vietnam) is covered mostly by tropical forest. With nearly 37,500 ha, the region includes a wide range of vegetation types, varying from the mentioned tropical forest to montane forests. As a consequence of less existing infrastructure and mountainous region, an area-wide monitoring is almost impossible and other indirect approaches should be favored.

3. METHODS

Despite this challenging mission for sustainable development and climate change, all over the world financial resources, especially for ecological projects, are limited. As a result, particular free Landsat TM & ETM^+ images should be used in this project. These images with a spatial resolution of 30 m can be used for regional and national wide approaches and are as a type of standard widespread in remote sensing applications. The extent of the images will be chosen this way, that a wide buffer zone can be established around the protected areas. This allows the comparison between the protected area and its surroundings, and a measure of management effectiveness (Mas 2005). The required preprocessing processes include an atmospheric and radiometric correction as well as a geometric registration. Due to the favored scale independency and comparable results, the subsequent automatic land cover classification should be hierarchical. The incorporation of images with higher resolution is so feasible with a higher level of land cover details and therewith a lower hierarchical level. Especially for the supervised land cover classification, the Spectral Angle Mapping algorithm is favored, caused by the high-quality results in former analysis. For the whole classification process, multiple additional data has to be included. For Ground Truthing in particular biotope and vegetation maps have to be used. For supporting the classification process itself, free SRTM data or other elevation models can be used. Furthermore, for example ATKIS data and climate maps can be integrated as well.

The second step within this project is the further processing of the land cover classifications. These results are often isolated, but include valuable information, not only about the extent of the land cover classes but also about the composition and structure of these classes. The task is to choose the most suitable from the huge amount of different landscape metrics. The origin of such structure metrics lies in the methodological background of Forman & Godron (1986). The three major aspects which can be described with landscape metrics are, in particular, structure, function and change. Decision criterion is the desired scale independency and a possible use as an indicator value for several approaches, for example biodiversity. Some examples are described on the next page in table 1. Possible questions could be: 1) How pervasive is the anthropogenic influence? 2) Where are the most unaffected regions located? 3) How important are different corridors for the habitat protection? Different comparisons between the protected area and its surroundings or core areas with a buffer zone are also planned. The decision whether the analysis will be carried out with the ArcGIS-Extension V-Late or with Fragstats or not, depends on the chosen metrics. After the accomplishment of these two steps it is possible to clarify the major changes within the protected areas over the investigation period. We are able to depict the most fluctuating regions and the most stable regions. The derivation of generally recommended procedures is, therefore, a concluding step.

Table 1. Overview about some favored landscape metrics.

Landscape Metric	Main Aspect	Information about
Mean Patch Size (MPS)	Area	Average size of patches
Core Area Index (CAI)	Core area	The index quantifies the core area of a patch as a percentage of their total area
Mean Patch Edge (MPE)	Borderline	Measures the length of border lines per patch for identifying compact or overlapped shapes
Mean Shape Index (MSI)	Shape	Provides a measure for the shape of patches, compared to a perfect circle
Proximity (PX)	Neighborhood	Includes the size and proximity of all patches in a specific search radius to identify isolated and fragmented habitats
Shannon's Diversity (SHDI)	Diversity	A diversity measure, e.g., for species communities, that take not into account specific species
Patch Richness Density (PRD)	Diversity	Standardized the patch richness per area for comparing different landscapes

The third and final step in this workflow is to adapt and refine the previously developed recommendations. The used method for this concluding approach can be found in the qualitative social research field. This approach is methodologically distal to all remote sensing and GIS approaches. However, it will lead to the desired results in form of problem-oriented semi-standardized questionnaires. The computed results of the analyses are the content of the questionnaires. These interviewees are personified by different stakeholders, from the staff of the protected area management to the point of landowners or mayors. The field survey is, after the creation of the semi-standardized questionnaire, the second part of this methodology. The different stakeholders will be confronted with the results of the remote sensing and GIS analyses, so that a first feedback of the project is given. The questionnaire includes a discussion about the findings as well. Thus, we get a second accuracy assessment for the remote sensing analysis, driven by the knowledge of the local stakeholders. Further content of the field survey is the discussion about previous land cover changes and developments within the protected area and its surroundings. This part should be problem- as well as solution-oriented. Questions would be, where the most valuable and suitable sites for environmental protection can be found or which causes can be identified for the previous developments? Are there any political or financial actions, influencing the current or future development? However, the threats for the prospective policies and procedures must be kept in mind as well. The carried out interviews will be evaluated and analyzed with the software Atlas.ti after returning, which is especially developed for qualitative text analyses. The integration (triangulation) of both research fields: on the one hand, the broad recommended procedures of the remote sensing and GIS part, and the problem-oriented solutions of the social research part on the other hand, gives us a comprehensive background for sustainable policies. The research results should be submitted at the end with a first brief report. Indeed, there is the need for continuative workshops with stakeholders and policy makers to discuss the results in detail and identify further strategies for action.

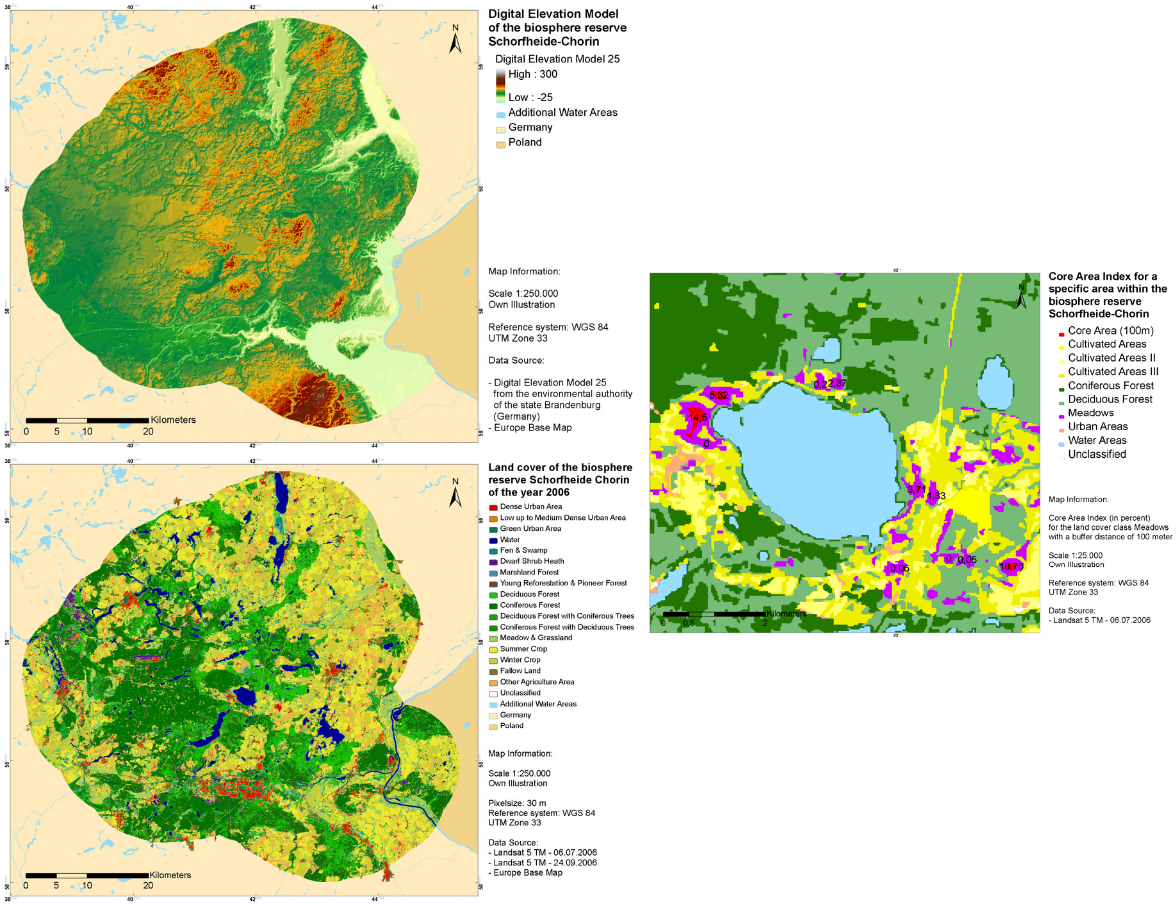

Figure 1. Example of data inputs and possible findings of the analysis workflow.

4. RESULTS

The result of the currently launched project should be an area-wide and comprehensive monitoring approach with the ability to analyze spatial problems on the one hand, and on the other hand, the development of sustainable strategies and the recommendation of further procedures. The former project shows that this combination of remote sensing and a further GIS analysis with qualitative social research has the capability to achieve such valuable aims. Due to the integration of landscape metrics, the analysis of special problems and phenomena in different regions will be possible.

In the following part, selected results of the land cover analysis for the biosphere reserve Schorfheide-Chorin will be presented. Some of the final maps are depicted above. The biosphere reserve is located in the northeast of Germany and covers an area of about 1,291 km². Within this project, the land cover development of the biosphere reserve and a 10 km wide buffer zone was observed with the aid of Landsat and SPOT images between 1986 and 2006. The biosphere reserve was established in 1990 as a part of the environmental framework law. The approach and investigation period makes it possible to compare not only various time stages but also the biosphere reserve with its surroundings. The free Landsat images were classified with the maximum likelihood classification. This supervised classification algorithm is, due to good results, widely used in remote sensing applications. The classification process was supported by additional GIS data, for example ATKIS data from the environmental authority of the state Brandenburg or diverse biotope maps. With a combination of masking techniques and computation of the NDVI, it was possible to depict 17 different land cover classes, in general, with an overall accuracy between 83 % and 89 %.

As usual, water areas or coniferous forest were classified with a high degree of accuracy, whereas marshland forests are connected with a higher degree of uncertainness.

One of the most interesting results can be found within the development of urban areas. Because of the difficult classification of urban structures, these areas were masked with the aid of the ATKIS data and classified via an unsupervised ISODATA classification. Hence, there is no possibility for an increase of urban areas. Just the composition between (i) dense urban areas, (ii) low up to medium dense urban areas, and (iii) green urban areas can change. Due to a rapid decrease of inhabitants and a gradual withdrawal of the military, areas classified as densely urban diminished by nearly 30 %, whereas low up to medium dense urban areas behaved nearly constant over the whole period of 20 years. Surely, these low populated urban areas are also affected by these processes, but suburbanization and designation of industrial estates concealed this development. Beneficiaries are green urban areas with an area enlargement of about 30 %. However, disaggregation of intra-urban areas should be also noted as possible factor for a classified change. These changes are spatially different and very well recognized by local experts, e.g. an expert from an external research institute, who are assisted by their statements at the following example: "Clearly the status of these villages is very diverse. Some villages are threatened with extinction and in other there is a vigorous building activity."

Another important change in the land cover of the biosphere reserve Schorfheide-Chorin is the proportion between coniferous and deciduous forests. Caused by a huge reforestation during the 18th century with coniferous forests, especially pine, the potential natural vegetation is wide-rangingly nonexistent. In combination with variabilities in climate conditions, possibly intensified by climate change, the groundwater sank and led to subsequent problems. By these reasons, the state Brandenburg introduced a huge program of forest conversion, including the prohibition of clear cutting. The dense pine forests were opened and young endemic forest species were planted into these gaps. This process has been undertaken with great effort in the biosphere reserve for 20 years. The first positive results are not only visible in the forests but also in the analyzed Landsat images. Almost 10 %, which means about 40 km² for the biosphere reserve of the coniferous forests, disappeared and probably altered in deciduous forest or forests more influenced by deciduous species. In contrast, about 45 km² of more deciduous forests could be created by these means, which is an increase of approximately 25 % for the biosphere reserve. This has also been perceived by the interviewed experts, in giving answers full of background knowledge with concurrent explanations of various relationships to these developments like the following citation from an external expert: "Now in the last 10 years since so many forest conversion programs exist, I think the Schorfheide has changed pretty much. Also the forest officials are very proud of what could be achieved and it is quite obvious."

Other developments, like the decrease of the marshland forests or the marginal increase of agricultural used land, should be noted, but not be explained in detail. Anyhow, behind all these developments different reasons and explanation were analyzed with the aid of the qualitative social research. These explanations help to develop more sustainable policies for the future and further to find answers for individual problems. Thus, for instance, the intensification of agriculture evoked by the biomass boom. This is connected with an absence of crop rotation, monocultures or the influence of groundwater, for example due to the cultivation of maize. This can be proved as well by the explanation of a staff member from the biosphere reserve management: "They cultivate maize and canola to bring it to the biogas plant. But on fields, that are actually suitable for the cultivating of grain. This is certainly devastating for the characteristic landscape, tourism, soil and the attended biota."

5. CONCLUSION

The results of the land cover analysis for the biosphere reserve Schorfheide-Chorin show the great opportunities, integrated in the concept of remote sensing and GIS analysis in relation with qualitative social research. This approach is capable for monitoring protected areas in various fields. The used Landsat images, which were freely available, provide a database at a regional scale and a long-term data pool for almost every region in the world. Due to the limited lifetime of the satellites, an uncertain future is impended. Hence, scale independent approaches as well as independent metrics are necessary. The integration of hierarchical land cover systems provides one opportunity for scale independency. Another opportunity is the integration of additional geodata, improving the results and increasing the deepness of classification structure. To strengthen the thematic profundity, triangulation of methods and data is required as well. Remote sensing and landscape metrics analysis are able to discover existing spatial problems and can provide general recommendations. However, necessary solution approaches must be developed in collaboration with local stakeholders, experts and residents, because a sustainable development is always a regional development, too.

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