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Landscape Monitoring in Berchtesgaden National Park – Comparative spatio-temporal Analysis of Land Cover Inventories

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Abstract

Berchtesgaden National Park uses aerial image interpretation to produce complete inventories of its land cover. The approach basically ensures data comparability between time slices and allows for change detection on different temporal and spatial scales. Experiences of HABITALP and cc HABITALP projects show increasing expectations of monitoring benefits in protected areas. For the first time since 1980 we analyze comparatively time slices of interpretation layers for the entire area. This leads to extended knowledge about landscape evolution and meets essential requirements of adaptive management.

Keywords

landscape, monitoring, change detection, time slices, aerial image interpretation, Berchtesgaden, National Park, HABITALP, cc HABITALP, ALPARC

Background and objectives

Founded in 1978 Berchtesgaden National Park (BNP) looks back on almost 40 years of protected area management. In contrast to the founding days current environmental data has to meet not only demands of topicality but also growing demands of comparability to the past decades.
Beside the concern for specific species, communities and habitats protected areas are responsible for mapping and monitoring their total landscape. Monitoring obligations require spatially explicit and fully covering information on the proportions and mosaicking of all land cover types. Suitable classifications and repeated inventories are needed to detect and monitor land cover changes on the desired spatial and temporal resolution. The analysis of these changes is essential to assess impacts of natural dynamics and management measures.
Collection intervals and availability of remote sensing data are accelerating. Image data allows for comprehensive and repeated assignment of visible landscape units including difficultly accessible areas. Manual and automatic delimitation methods equally require suitable means of standardization if applied in time series analysis.
In BNP the decision for comprehensive landscape monitoring by the manual interpretation of color infrared aerial images dates back to the 1980ies. The objective has always been to create a versatile layer of spatial information that is able to serve manifold aspects of research and management on different scales and that is at the same time suitable for reproducible inventories. Based on aerial image interpretation quite a number of mono-temporal applications have been developed in BNP (mainly ecological modelling and integration of terrestrial surveys) but the question of time series analysis has not yet been tackled systematically.

Methods

Starting with a first self-made interpretation key (list of land cover types that are detectable on aerial images) and its application to the 1980 flight campaign (MaB 1991) the method has continually evolved in BNP. It soon became obvious that the initial classification of land cover types was not differentiated enough and needed specific adaptations for the mosaic structure of natural habitats and alpine environmental dynamics.
Major steps of development were the introduction of the German national land cover classification and its revised issue (Bundesamt für Naturschutz 2002), the first common enhancement for alpine protected areas (1999-2001) by the Berchtesgaden, Hohe Tauern and Swiss National Parks (Kias et al. 2001) and the enlarging to an alpine scale (2002-2006) by 11 members of the Alpine Network of Protected Areas in the HABITALP project (Lotz 2006). As questions of change detection could not yet be answered satisfyingly the cc HABITALP project community (Swiss, Hohe Tauern, Gesäuse and Berchtesgaden National Parks) advanced the method from the mere status inventory to the cartography of changes by the comparison of two image generations (Haller et al. 2013, Hauenstein & Haller 2013).
Up to now four time slices of landscape inventories have been created in BNP for the years 1980, 1990, 1997 and 2003. The fifth time slice is presently under construction for 2015 including change cartography to 2003. Simultaneously BNP engages into the processing of datasets created in the past in order to exploit the potential of change analysis on a spatially comprising level.

Preliminary results

Even though comparability has always been of high concern in BNP, the topic has not yet received enough attention. First experiences show that quality-proven land cover inventories for each time slice as well as consistency-checked series of time slices are both indispensable pre-conditions for reliable long-term comparative analysis. The evolving interpretation method as well as the technical progress in image quality and spatial accuracy have a great impact on BNP data series and limit the possibilities of consistent spatio-temporal analysis.

Up to now data comparisons reveal the following natural processes as most relevant for BNP: forest successions, bark beetle infestations in various combinations with windthrows, avalanches (see example in Fig. 1 and Fig. 2) and mass movements (e.g. rock falls, landslides, fluvial activities). Concerning human influence certain management measures and infrastructural changes are of landscape relevance.

Figure 1: Aspect of avalanche zone (October 2015, downhill line of sight) shown in time series of Fig. 3 (Photo credit: Linda Camathias)

Figure 2: Aspect of avalanche zone (August 2016, uphill line of sight) shown in time series of Fig. 3 (Photo credit: Andrej Oravec)

For a selected area Fig. 3 shows land cover changes observed since 1980. Apparently no changes occurred from 1980 to 1990 as the same coding is applied (see code table in Fig. 3). In the period from 1990 to 1997 the hatched polygon in the center developed from a two-storeyed forest with rejuvenation (7021) into a coniferous mixed forest (7600). A smaller hatched area on the right margin developed from a windthrow (7700) into a forest with young tree growth (7011). Delimitations of all polygons remain unchanged although vegetation changes are clearly visible in the underlying CIR images. These changes are documented in the secondary levels of the hierarchical habitat code which are not displayed in the figure for practical reasons.
In 2003 the effects of an avalanche incident become visible. The hatched area described first was cut by the avalanche which resulted in the two areas coded as temporarily non-stocked (7710). The type of process observed as well as the degree of vegetation cover are both defined in the secondary coding levels. Differences in subordinate categories lead to adjacent polygons with identical main code.
The 2003 inventory not only shows natural changes but also the effects of the progressing interpretation method. The evolution of the habitat code from the coding of a mono-temporal status into a coding of changes between two inventories requires a more detailed differentiation of polygons (e.g. with regard to the degree of vegetation cover). Consequently the current image interpretation process applies coding of changes to 2015 and 2003 image generations. The outlines of the new polygons in 2003 loose comparability to the previous polygons in 1997 which were coded – due to the technical possibilities at that time – in much coarser spatial and attributional units. The polygons hatched in 2003 (in spite of being 'textually back-coded' to the 1997 syntax) thus also represent differentiations that are not due to real changes.
Looking at the hatched polygons 2015 we can see the changes observed in comparison to 2003. Within 12 years the avalanche areas (7710 in 2003) developed into forest types of different species composition (7311 and 7411 in 2015). Other 2015 polygons show progressing forest succession (7310 to 7311, 7311 to 7312, 7612 to 7613) or stages of natural disturbance and forest regeneration (7615 to 7710, 7614 to 7422).
Although covering only 0,09 km² out of a total of 210 km² this example gives an impressive insight into the history of changes occurring between habitat inventories on a time scale of several decades.

The challenge of time series analysis is now to gain optimal comparability and to benefit as far as possible from the information content of each land cover inventory. Therefore we presently focus on the standardization between time slices.
Due to the fact that the question comparability of has always been in mind since 1980 it is possible to compare pairs of interpretation layers (1980-1990, 1990-1997, 1997-2003, 2003-2015) without methodological restraints. However a consistent analysis thread covering the entire time series appears to be reasonable only for aggregated habitat groups or generalized layers of derived habitat information. Data processing is ongoing and further analysis is still to come until mid-2019.

Discussion and current conclusions

The present study is the first attempt of genuine multi-temporal analysis of BNP datasets with high spatial and attributional complexity. Unexpected efforts have to be invested into the upgrading of existing datasets and the consistency between time slices. However we consider these investments as crucial to achieve a genuine added value through comparative analysis.
Continued studies will aim at the development of adapted analysis methods to profit maximally of the existing information content in spite of the necessary aggregations and generalizations. Results should give hints to which degree the landscape inventories created in the past and at present are suitable for long-term comparative studies. Aspects of spatial scale and temporal interval have to be re-discussed in the light of time series analysis.

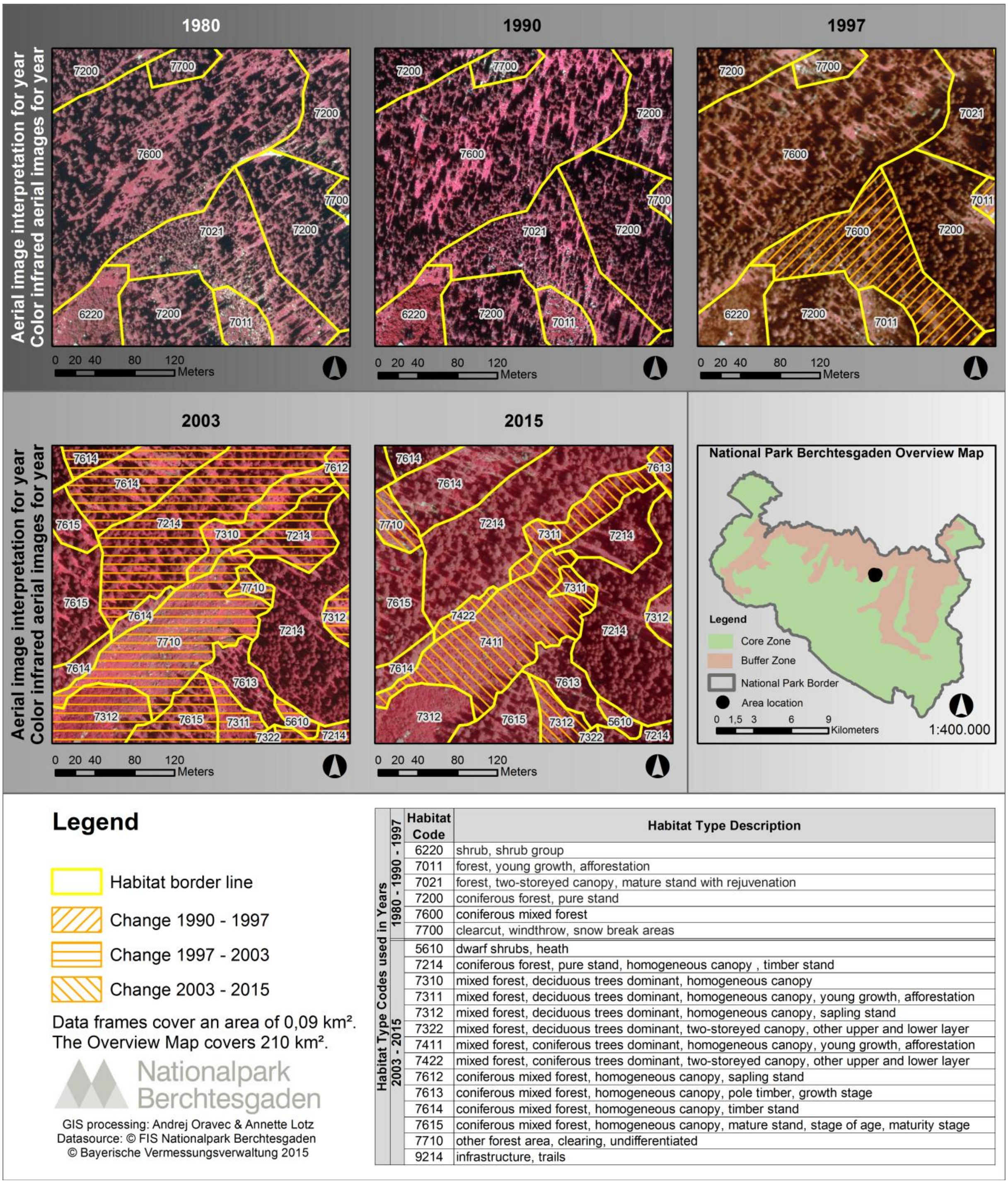

Figure 3: Exemplary time series of land cover changes in the period 1980-2015 in the Watzmann area (Berchtesgaden National Park). Partly simultaneous processes visible in the data frames are progressing forest succession, an avalanche incident, effects of other natural disturbances and forest regeneration stages.

Outlook and perspectives

In BNP the current method of aerial image interpretation is adapted to the documentation of thematic and geometric changes. Former landscape inventories require processing to achieve maximum comparability. Still prevailing consistency limitations suggest the potential alternative to apply the current method backwards to previous image generations. Future inventories are specifically designed for time series analysis. Nonetheless they should undergo plausibility checks for each time slice and repeated backward consistency-checks for the growing time series.

Experiences in Gesäuse National Park (Austria) show that the simultaneous consideration of three image generations helps to improve cartography of changes (oral communication Kreiner 2017). However the question of how to handle consistently more than three interpretations still has to be discussed. Furthermore future analysis workflows will have to foresee the updating of past landscape inventories.

With increasing time series the issue of adapted visualization becomes more urgent. This will be considered in the current project as time series visualization of progressing habitat mosaics can give insights into natural dynamics that might not have been obvious before.

Land cover inventories that can meet multi-temporal requirements need a time consuming process of creation if the current manual method is applied. The degree of differentiation results from a preceding inquiry of users (HALLER et al. 2013). On the other hand the facilitated availability of remote sensing data (e.g. two years repetition rate for federal Bavarian image flights) implies an enormous potential for complementary methods of automated evaluation. Nowadays image data is not the problem but affordable and standardized processes of evaluation that meet the actual demands of protected area management.
At the same time the expected benefit of monitoring in protected areas is a subject of rising importance. With the increasing protection duration demands of both topicality and comparability become more evident. In addition, natural dynamics create a complex mosaicking of habitats. This leads to the loss of former management dominated habitat boundaries (especially in forested areas) and increases the need for a spatial reference system that supports monitoring of land cover units all over the protected area and all over time.
Taking into account these conditions expectations of what land cover inventories and derivable spatio-temporal analysis actually should deliver have to be revised and defined into adapted demands of spatial and temporal scale as well as attributional content. In the frame of the present study BNP takes the chance to valorize previous efforts in the field of landscape monitoring dating back to 1980. The evidence that time series analysis can contribute to assess landscape evolution will influence future landscape monitoring in BNP.

As shown by the example of landscape monitoring BNP assumes its responsibility as long-term organization for archiving environmental data and for keeping it available for monitoring studies. These aspects have often been underestimated in previous database management. With respect to improving the data fundament for adaptive management decisions these aspects should be considered in administrative planning processes.

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