Object Oriented Land Cover Mapping of the Kanchenjunga Conservation Area (KCA) in Nepal, for Sustainable Development and Use of Natural Resources

Tobias W. Kellenberger, Walter A. Schubiger, Klaus I. Itten
Remote Sensing Laboratories (RSL), Department of Geography
University of Zürich, Switzerland
knelle@geo.unizh.ch, walibi@bluewin.ch

Abstract - **As a part of the collaboration with the WWF Nepal Program in strengthening the sustainability of natural resource use, the authors aimed at detecting the changes in forest and land cover in the Kanchenjunga Conservation Area (KCA) in eastern Nepal during the last 30 years. This goal was achieved through multitemporal land cover classification of Landsat TM and ETM+ data, based on an object oriented image analysis approach by eCognition software. The resulting land cover maps showed an overall accuracy of nearly 0.90 and a Kappa coefficient of 0.87 for the classification of the 2000 scene, and a value of 0.94 for both these accuracy measures for the 1989 classification. Forest cover in the KCA increased about 1% between the years 1989 and 2000. The study provides for the first time a reliable database including comparable maps on land cover and forest area in the study area. The availability of such data so far has been highly limited for the KCA. Consequently, the results provide a clear gain of information for decision makers as they can now be used for different ecological or political purposes by WWF Nepal as well as in University research groups or by local institutions in the KCA.**

Landsat, eCognition, object oriented classification, forest change, sustainable development, Kanchenjunga Conservation Area, Nepal

I. INTRODUCTION

Forested areas in the mountainous region of eastern Nepal have undergone continuous changes through the growing impact of human activities since the 1950s. Until today, the kind and severeness of the land degradation in wide areas of the Himalaya Mountains have been subject to disputes carried out by different organisations, scientists and policymakers with often opposing attitudes. This debate and its influence on nature conservation in this region is also known as 'The Himalayan Dilemma' [1].

Within this context, this study aims to provide for the first time a reliable database of land cover changes in the region of the todays 'Kanchenjunga Conservation Area' (KCA) before and after its establishment in 1998. Actual land cover developments - especially those of forested area – are quantified. The results help to evaluate the influence of the so called Kanchenjunga Conservation Area Project (KCAP) on land cover development in the study area [2].

Multitemporal land cover classifications based on Landsat TM and ETM+ data sets from 1989 and 2000 have been performed, following an object oriented classification approach using 'eCognition' software. Vegetational and water indices as well as a Digital Elevation Model were integrated into the land cover mapping scheme. Out of the classification results comparable land cover maps were created to visualize the land cover at different time steps. Changes which have taken place during the eleven years period were visualized.

The study is part of a cooperation between the WWF Nepal Program, which has been playing a leading role in the development and implementation of the KCAP, and the Department of Geography, University of Zurich.

II. DATA COLLECTION AND PREPROCESSING

The availability and lower price in relation to comparable data sets like SPOT HRV/PAN was a crucial argument for choosing Landsat images for the land cover classifications. Landsat data were additionally highly adequate due to better spectral resolution. Their six (TM) or seven (ETM+) reflective bands were needed to separate the specific land cover classes in the classification process. Taking into account the vegetation status and the precipitation regime in the study area only data taken during the early stage of the dry period could be used. The sky is usually less covered with disturbing clouds than during the monsoon season. At this season time the vegetation is still in good condition and thus better distinguishable in multispectral satellite images, especially in the near infrared part of the electromagnetic spectrum. Two suitable scenes from WRS 2 path/row: 139/041 were chosen:

- A geometrically uncorrected Landsat TM data set from 11-10-1989 which showed a cloud coverage of less than 10% in the KCA study area.
- A geocoded Landsat ETM+ data set from 12-26-2000 which was completely cloudless.

The image preprocessing was performed using the software PCI Geomatica 9.1. First, the uncorrected 1989 raw image was georeferenced with respect to the geocoded image from 2000. Subsets containing the KCA region, ranging from 27°20′ to 27°55′N and from 87°35′ to 88°15′E, were cutted out of the two scenes and reprojected to a UTM projection (Zone 45, Northern Hemisphere). The subsets of the study area coincide geometrically with a maximum local displacement of two pixels in some of the strong reliefed parts.

Several vegetation indices were calculated and evaluated. The Normalized Difference Vegetation Index (NDVI) [8] and the Optimized Soil-Adjusted Vegetation Index (OSAVI) [7] turned out to be of highest quality and most useful to separate different vegetation types and other land cover in general. Thus these two indizes as well as a water index were used as additional data layers in the classification process.

A Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) was included. This DEM with a spatial resolution of about 85m had first to be preprocessed as it showed several unnatural peaks and sinks which could not be retraced in the real topography of the KCA. For the correction an existing algorithm, developped at the RSL was applied, though in a modified form that matched the circumstances and data of this current study. This algorithm looks for unnatural relief forms in the data and interpolates them considering their surroundings, resulting in a more accurate DEM [3].

III. OBJECT ORIENTED LAND COVER MAPPING

A. Multitemporal Land Cover Classifications with eCognition

For the mapping of KCA's land cover an object oriented approach was chosen considering its expected advantages over a 'classical' pixel based approach for the projects purposes in this strong reliefed and relatively homogenous covered area. The fundamental difference between the object oriented classification approach by eCognition and pixel based ones is that with this software instead of single pixels larger image objects with a higher semantic meaning were classified. In a first step the two images were segmented into image objects each containing a number of pixels with similar spectral attributes. These segments built the very basic unit for the classification process and enabled many additional features besides spectral characteristics. Different topological relationships between image objects, their form parameters as well as their texture and further properties were taken into account.

After the segmentation process was completed ground truth was taken both as testsites for the classification process as well as for the later verification of the results. As it was not possible to visit the study area due to the current political instability inside Nepal, the training samples had to be directly assessed on the satellite images. This step was conducted together with local experts from WWF Nepal sharing both their local expert knowledge and an already assessed in situ ground truth from earlier research in the KCA. The following classes were identified:

- Dense Forest
- Open Forest & Shrubland
- Cultivated Land
- Grass- & Meadow Land
- Alpine Grasses
- Rocks / Bareland
- Ice / Glaciers
- Snow Covered Land
- Waterbodies (Lakes & Rivers)
- Clouds
- Shadows

For the separation of these classes all data layers were compared and class descriptions were built based on the spectral as well as on topological and textural features, often in combination with an automatic Nearest Neighbor classifier. The DEM was of high importance mainly to distinguish different vegetation types. It was additionally used to limit the upper forest boundary. After the class descriptions and organizing them in a hierarchical order the classification was performed and successively enhanced by adjusting and complementing the used features. During this process mainly topological functions were added to the class descriptions.

B. *Strengths and Limitations of the approach*

The applied object oriented approach with its many possibilities in creating different land cover separating rules resulted quickly in classifications of high quality. Of more importance than the quickness were the advantages for the land cover classification of this steep study area that arose from this much wider range of applicable class descriptions compared to pixel based approaches. The most important of these advantages was that the ability of using various topological, textural, form and other features in addition to spectral information enabled the minimization of shadows to a significant extent. Considering the steepness of the KCA region with ten peaks reaching higher than 7000 meters above sea level and the forelands at 1000 meters above sea level, all within a horizontal distance of less than 80 km, shadows were highly abundant in both satellite images covering up to 15% of the area [2]. Applying mainly topological functions it was possible to eliminate many shadowed areas where the real 'underlying' land cover was obvious. For example this was the case wherever shadowed areas of a limited size were fully surrounded by one and the same land cover class in temporary classification results. Areas classified as shadows could be reduced about 25% in the classification of 2000 and even about 33% in the classification of 1989. The proportion of shadows of all land cover could be reduced to less than 10% coverage. The same techniques were applied for the elimination of several clouded areas on the 1989 satellite image. The significant minimizing of shadows and clouds was especially important for the later mapping of land cover changes during the eleven years period. All shadows, clouds and even seasonal snow covering had to be excluded and set to 'nodata'. These procedures were highly valuable for getting results of a higher quality and would not have been possible using a classical pixel based approach.

C. *Mapping of Land Cover and its Changes*

The final classification results served as the base for comparable land use maps for 1989 and 2000 on different generalization levels. Besides mapping all classes separately also more generalized forest cover maps were produced combining various vegetation types to common land cover classes. At the same time the classification results were used to visualize the changes that had taken place in land cover between 1989 and 2000. The classification results of both years were overlayed and set against each other. Again, the observable land cover changes were visualized on different generalization levels. A special focus was laid on the analysis and visualization of forest cover changes in the KCA. Hereby, all remaining areas that had been classified as clouds or shadows in both scenes were set to 'nodata' and excluded from the mapping in order to get a common denominator where both final classifications showed only proofed land cover. Even the seasonal fluctuations in snow cover were excluded from mapping to ensure that only meaningful land cover changes were evaluated and finally mapped. A map showing the changes in all vegetational land cover classes as well as land cover maps of each 1989 and 2000 built the study's basic cartographic outputs, and additionally a few cartographic products concerning different abstraction levels were created.

IV. VALIDATION

To assess the quality of the final land cover classifications they were subject to a verification process. First an accuracy assessment was conducted on the final classifications in eCognition. This verification bases on check samples that had been taken together with two local experts working in WWF Nepal. As these samples had been taken before the classification process was started they were independent from the land cover classifications, which was an important requirement for the validation. The accuracy assessment showed an overall accuracy of nearly 0.90 and a Kappa coefficient of 0.87 for the classification of the 2000 scene, and a value of 0.94 for both these accuracy measures for the 1989 classification. To assess the classifications accuracy fully independently of the WWF Nepal experts and to verify the high received values, another accuracy assessment was conducted on the 2000 final classification. This verification is based on 45 random sample points distributed over the whole satellite image and was performed in PCI Geomatica. All sample points were assigned to a land cover class through interpretation by the authors with their gained knowledge during the classification process and with additional help of a few existing maps of the KCA area also including land cover [4]. The accuracy measures reached very similar values as the ones obtained in eCognition. Considering the highly corresponding results of both accuracy assessments and taking into account the statements and tips of a GIS specialist from

WWF Nepal during the classification process it could be ensured that the classification results reflected the reality with approximately 80% to 90% accuracy. Consequently they were of an adequate quality for making further reaching assessments about the developments of land cover during the research period.

V. RESULTS AND CONCLUSIONS

According to the produced map showing land cover changes the proportion of forest cover in the KCA increased about 1% between the years 1989 and 2000. Looking at forest covered areas only the gain reaches nearly 4%. At the same time a slight thinning in forested area was observed looking at the positive development of open forests & shrubs at the cost of densely forested areas *(Tab. 1)*. These changes were observed mostly at transition zones between cultivated land and forested area and in relatively close distance to the main rivers. This made the outcomes concerning forested area well comprehensible and brought them into connection with human use. The increase in forest cover in general could partly be explained by changing habits of local people, for example through the planting of trees on private land which was observed to be practiced in Nepal's mountainous regions since the mid 1980s [5]. Besides this moderate gain in forest cover the maps also showed an increase in Alpine Grasses at the cost of frozen underground and barren land, concentrated around the upper vegetation boundary *(Tab. 1)*. This may be explained by effects of global warming, annual fluctuations in temperature and rainfall rather than by human impacts. The results of the study were traceable to a high degree and with the validation proving the quality of the land cover maps clear assessments on land and forest cover changes could be made. The selected object oriented approach by eCognition turned out as a highly promising method to achieve reliable land cover classifications with the given data through its many new possibilities preferable to the classical pixel based approaches. The fact that forest cover increased about one percent during the eleven years study period drew a good picture of the KCAP efforts to protect the natural environment through encouraging a more sustainable resource use by the inhabitants of the KCA who nearly all count on farming for their surviving [2]. This was strengthened by the results of earlier investigations showing a decrease in forest cover inside the KCA during the 1970s and 1980s [6]. Additional studies should be applied to investigate the future influence of KCAP on the use of natural resources and the development of forest cover in the KCA. It would also be favourable to include field research in further investigations. This would enable stronger quantitative assessments on local detected land cover changes than the methods used in this study.

TABLE I. LAND COVER AND ITS CHANGES (1989-2000)

Land Cover Class	1989		2000		Changes	
	Area in km^2	*% of Land Cover*	*Area in km^2*	*% of Land Cover*	*Area in km^2*	*% of Land Cover*
Dense Forest	286.95	14.1	270.18	13.28	-16.77	-0.82
Open Forest	183.65	9.03	217.71	10.7	34.06	1.67
All Forested Area	470.6	23.13	487.9	23.98	17.29	0.85
Alpine Grassland	313.52	15.41	390.59	19.2	77.07	3.79
Grassland/ Meadows	24.92	1.22	20.92	1.03	-4.0	-0.2
Cultivated Land	33.73	1.66	36.64	1.8	2.91	0.14
Rocks/ Bareland	214.69	10.55	183.91	9.04	-30.78	-1.51
Ice/Glaciers & Snow	690.12	33.92	629.13	30.92	-60.98	-3.0
Waterbodies	4.89	0.24	3.37	0.17	-1.52	-0.07
No data	282.27	13.87	282.27	13.87	0.0	0.0

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