Summary

Mediterranean land cover change:
modelling and monitoring natural vegetation using GIS and remote sensing

Mediterranean areas in Europe are subject to human induced changes. In Mediterranean France, land abandonment is the most widespread change, caused by a variety of reasons among which technological developments and social and economic changes. The land abandonment process had several unfavourable consequences for biodiversity, soil erosion and fire risks.

To formalize our knowledge of the land abandonment process and to analyze, understand and predict the land abandonment process and its consequences, land cover change models are valuable tools. Such models account for the most important driving forces behind land abandonment and aim at predicting the spatial and temporal patterns of land abandonment. Furthermore, the models are useful to test hypotheses about future development of the land. Validation of such models is essential. In many semi-natural areas the only source of continuous spatial and temporal validation data are various types of remote sensing data. Therefore, this research aims at developing a land cover change model of semi-natural Mediterranean vegetation communities that integrates with remote sensing observations for validation purposes and for data input collection. To achieve this integration I first focus on the optimization of the detection of Mediterranean vegetation communities by remote sensing in time and in space using more traditional image analysis methods and using newly developed innovative information extraction approaches. Second, I constrain the land cover change model to the level of detail that can be obtained from the remote sensing data.

A Mediterranean ecosystem in the Peyne area, approximately 60 km west of Montpellier in France, is selected as study site. In this area Mediterranean oak forest, natural shrub lands and agricultural areas are found. Human and natural disturbances of these ecosystems occur scattered over the area. The area has known a rural depopulation over the last century. For the study site an extensive dataset including hyper-spectral airborne remote sensing data is available.

To determine and describe changes in vegetation communities in time I carried out a GIS based change detection study using a time series of 8 aerial photograph mosaics from 1946 to 2001. With this part of my study I determined the location of land cover change, the type of change, time of occurrence of the change, the most important driving forces of land cover change and the transition paths and transition rates of the vegetation communities in this ecosystem. Several environmental and non-environmental factors like distance to roads and urban areas, wetness index, potential radiation, elevation, slope and lithology were found to be important variables for the land abandonment process. Within lithology classes, different transition paths and transition rates of the vegetation were recognised but precise rates of vegetation conversion were difficult to derive from the data because the availability of aerial photographs is limited and does not provide a continuous time series. In recently abandoned fields expected transitions from pioneer vegetation to vegetation higher in the succession were only found for some vegetation/

soil combinations and I found that not all low shrublands evolve to the expected climax vegetation of oak forest. Although the identified transition paths of land cover change are not all unambiguous, the collected knowledge about driving forces and transition paths and rates form an appropriate theoretical basis for the land cover change model.

I followed three different approaches to optimise the detection of Mediterranean vegetation communities by remote sensing. In the first approach I have set up an experiment to evaluate the predictive power of 7 statistical techniques including innovative techniques like classification trees, random forests and support vector machines, to find the most important predictive factors and to define the extra value Hyper-spectral HyMap data over multi-spectral ASTER and Landsat 7 ETM+ data. With increasing number of classes the innovative methods random forests and support vector machines outperformed the conventional classification techniques. Moreover the innovative techniques proved to be very suitable for the incorporation of continuous and categorical ancillary data, as overall accuracies and accuracies for individual classes improved considerably when many classes were taken into account that are difficult to separate. The Landsat 7 ETM+ classification yielded less good results than either the ASTER and HyMap classification results. However, I concluded that the extra value of Hyper-spectral HyMap data over multi-spectral ASTER data is only limited for 'common thematic vegetation classification purposes'.

In the second approach I included the spatial domain to analyze and classify remote sensing imagery. This approach not only uses the per-pixel spectral information but also the spectral information of neighbouring pixels. I used a contextual technique named SPARK (SPAtial Reclassification Kernel). With SPARK I could successfully detect vegetation classes which could not be distinguished at all by conventional per-pixel based methods. Heterogeneous classes showed a considerable increase of accuracy but less complex heterogeneous vegetation classes showed more improvement than more complex vegetation classes.

The third approach was based on the incorporation of ancillary data or knowledge data into the classification process to enhance spectral and contextual classifications. Ancillary data used in this innovative method comprises information on lithology, soil water availability derived from a wetness index, incoming solar radiance computed from a DEM, land use history and distance factors. I integrated spectral information, ancillary information and contextual information in a spatio-temporal image classification model: the Ancillary Data Classification Model (ADCM). By using these relations the ADCM classification was able to identify heterogeneous vegetation classes much better in the HyMap image, proven by an increase of overall accuracy and by an increase of individual class accuracies: some classes were far better identified by the ADCM than by conventional classifiers.

Finally, I used the classification model as a basis for the land cover change prediction model. I limited the model to classes that I could detect with HyMap imagery. I calculated different scenarios to test the hypotheses formulated in the change detection study in space and time.

The land cover change model proved to be a valuable tool to test hypotheses in space and time: the spatial interpretation of the model results pointed out which factors were important. I concluded that wetness index, solar radiation, lithology, effects of fire, and effects of grazing are key factors that explain land cover change of semi-natural Mediterranean vegetation communities. However, these key factors do not explain the slow replacement of pioneer vegetations by other vegetations which indicates that abandoned fields are degraded with respect to growing conditions.

While running the model, the initial model situation of land cover proved to be very important: the small scale variation found in the remote sensing validation data was not predicted accurately by the model because classified panchromatic aerial photographs that were lacking small scale variation, were used as base map. I concluded that future research should focus on the correct reconstruction of the initial situation from the given remote sensing data and on modelling of spontaneous patterns. Finally, most accuracy assessments of classification results and model accuracy had to be done by using the confusion matrix which is a typical per-pixel approach. The confusion matrix is less suitable for quantifying the accuracy of pattern reproduction of contextual methods. Therefore, overall accuracy results of contextual methods may in fact be much better than the overall accuracies calculated by the confusion matrix, which was confirmed by visual evaluation of the classification and model results.

Keywords:
remote sensing, dynamic modelling, land cover change, mediterranean, HyMap, France, classification, ancillary data