Vegetation Cover Change Analyses in Norway

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Abstract – Various change analyses based on remote sensing data have been made in different parts of Norway. The objective is to develop robust methods for detecting long term changes in vegetation cover based on monitoring intervals from three to five years. The change monitoring has a long term perspective, and is therefore not tailored to specific satellites or sensors. The changes of interest might be due to changes in agricultural practice, natural hazards, climate change or changes in the hydrological conditions. Preliminary results show the promise of an object based approach. The vegetation change analyses are based on existing land cover mapping which defines the primary segments. The spectral information from remote sensing data is linked to these areas together with relevant supplementary data to identify the most robust measures of change. The main challenges are related to the extreme fragmentation of some landscapes which requires high resolution images, shadow from trees and alignment of the growth season with remote sensing data.

Keywords: change analyses, semi-natural vegetation, biodiversity, satellite data

1. INTRODUCTION

The background for this study is the need for better management of high biodiversity areas in Norway. Changes in the vegetation cover are often an indication of changes in the agricultural practice or other changes in the ecological conditions, which could be critical to certain species.

The reason to consider remote sensing data from satellites in the change detection can be summarized as follows:

- The spatial resolution needed to identify larger changes is on the spatial range 2 – 50 meters.
- Spectral information from the IR band is critical to monitor vegetation cover.
- Good possibilities for cost-effective automatic or semi-automatic processing of images, compared to alternative techniques based on traditional interpretation of aerial photography.
- Vegetation change mapping based on remote sensing data could be used to select representative areas for more detailed sample based investigations.

Some types of changes in vegetation cover can be monitored through existing mapping programs in Norway. In table A the Norwegian Directorate for Nature Management has identified types of changes which are relevant to environmental management and cannot be obtained through existing programs (Table A). The list of relevant types of changes are prioritizes based on relevance to biodiversity. In this study particular focus is on forest growth on previous grassland.

Table A. Types of relevant changes

Type of change	Relevance to biodiversity	Time scale	Spatial scale
Forest growth on previous grassland	High	Continuous change - decades	5-15 meters
Filling of small dams and rivers	High	Change within days - permanent for decades	2-5 meters
Forest clearings	Medium	Change within days - vegetation re-growth	20-50 meters
Changes in forest type	Medium	Continuous change - decades	20-50 meters
Planting of forest on previous non-forested areas	Medium	Continuous change - decades	20-50 meters
Ditches on bogs/ wetland	Low	Change within days	2-5 meters
New cultivated fields	Low	Change within days - permanent change for decades	20-50 meters
Sand- and gravel pits, stone quarry	Low	Continuous change- permanent for decades	20-50 meters

2. TEST AREAS AND DATA

Tests of different methodology have been made in different parts of southern Norway including lowland and mountain areas, inland and coastal areas.

Scenes from Landsat, Spot, Ikonos, Quickbird and IRS have been used. A land cover map provided by the Norwegian Institute for Land Inventory (NIJOS) was available for one of the test areas in lowland south-eastern Norway. A digital elevation model with a spatial resolution of 25 meters together with topographical maps

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on the scale 1:50000 were provided by the Norwegian Mapping Authority.

3. METHODS

This mapping has a long term perspective, and the methodology is not tailored to specific satellites or sensors or a specific classification system. This framework rules out some traditional change analyses methods based on classified images or pixel-to-pixel comparison. Digital change detection methods in ecosystem monitoring have been reviewed by Copping et. al. (2004).

Faced with these challenges it was decided to base the analysis on a segmentation or stratification of the image. This object based approach has been tested, using available digital elevation models and land cover mapping to define an a priori segmentation of the landscape. The spectral information from these predefined areas was parameterized and organized in a geographical information system, focusing on an integrated view on geospatial modeling and monitoring (Ødegård & Solberg, 2002).

The multi-band images were segmented by hyper-clustering in an attempt to reduce some of the noise in the data, and to reduce the total amount of data. Standard ISODATA clustering was used with 250-255 classes. Clouds and their shadows were masked out based on photo interpretation of the classified images. Direct comparisons of hyper-clustered images were attempted following the Pixel Hyperclusters As Segmented Environmental Signals (PHASE) methodology developed through the Landsat Pathfinder program for North American Land Characterization (Myers 1999). This method is based on finding counterpart cluster classes in two or more images. Comparisons of the vector means of the cluster classes are always made within the same image, avoiding the presumption that the same sensor has been used. This method was tested for LANDSAT images, where multi-temporal images were available.

Due to limitations in the availability of multi-temporal high spatial resolution remote sensing scenes, no attempts have been made to directly compare images (spatial resolution better than 10 meters) from different dates. The spectral signal in high resolution data has been analyzed by comparing nearby areas at different stages of change in the same image. This will clearly introduce some limitations in the application of the results.

4. RESULTS AND DISCUSSION

The Norwegian landscape has large height differences even within a scale of 60x60 km (e.g. a SPOT scene), and the northern latitudes have large climate variability causing the growing season to vary considerably from one year to the next. Due to the lag effect of a thick snow cover, the growing season at different altitudes is not necessarily correlated from one season to the next. Problems in the alignment of the growing season in time and at different altitudes will cause the detection of spurious changes in vegetation cover, even when comparing images from the same time but in different years. This is particularly a problem for early summer images.

The comparison of multi-temporal clustered scenes following the PHASE methodology was tested on Landsat images. The method worked well to detect large changes in vegetation cover like recently flooded areas and forest clearings. Spurious change pixels are numerous in scenes with large height differences and in scenes with mixed coastal and inland areas. This is probably related to seasonal variations at different altitudes and areas, which in some cases gives a weak correlation between the spatial patterns in the images. The PHASE method depends on matching cluster classes in two or more images.

An interesting type of change with respect to biodiversity is forest growth on previous grassland (Table A). Preliminary results are available based on exploratory data analyses of the spectral signal from high resolution images, compared with available validation from existing maps, air photographs, orthophotographs and in-situ data collected at selected sites. High spatial resolution images were needed because of the elongated form of the areas of interest, often edge-zones between forests and cultivated fields. One of the test areas is in a mixed lowland landscape with forests, farming land and some urban areas (south-eastern Norway). This is an extremely heterogeneous landscape. The existing land cover map with an inner buffer of 15 meters was overlaid with a Landsat image to investigate the fragmentation. The selected areas of interest were defined as not cultivated, not forest and not urban areas. The inner buffer was used as a rough simulation of positional error in the image. Only 10% of the remaining areas could be identified with one or more Landsat pixels, and only 3% could be identified with two or more Landsat pixels. The rest of the areas of interest contained mixed pixels only. This clearly demonstrates the problem of detection vegetation changes on Landsat images in lowland areas in Norway.

Spectral signatures from high resolution images were investigated using existing land cover mapping and field data as training (less than 10 meters resolution, like resolution merged Spot 5 images to 2.5 meters or 5 meters). The spectral signatures within the areas of interest show considerable overlap with forests and agricultural fields. There is no unique spectral signature that can be used to identify areas subjected to forest growth on previous grassland. This is also the case for most of the other change types (Table A), like filling of dams and rivers. Complicated terrain with small scale relief not accounted for in the available digital elevation models and shadow from trees, will introduce additional noise in the spectral data. Some of the changes (Table A) could probably be identified with supplementary data in combination with careful spectral analyses of multi-temporal images. However, in a multi-sensor approaches there are also problems in detailed comparison the spectral data due to differences in spectral resolution.

The averaging of the spectral signal through hyper-clustering of the images and the use of existing land cover mapping overcomes some of these problems. Changes in the variation of the NDVI in predefined areas were found to be a promising measure of change. Vegetation changes due to changes in management will in some cases be detectable first along the edges of an area. If management of species-rich semi-natural vegetation types ceases they are often invaded by forest from the edges. More weight on the edge areas in the measures of variation of the NDVI seems to give a more sensitive but noisier result. Field data are not sufficient to state if this is a significant improvement.

Shadows from trees must be considered, in particular when investigating the edge area of a field with high resolution data. One way to reduce shadow problems is to mask out the northern part of areas bordering forests.

5. CONCLUSION

There are no unique spectral signatures that can be used to identify the most relevant changes in vegetation cover as defined in table A. Extraction of parameters from predefined areas based on a priori land cover mapping seems to be a promising method to detect change and to identify change type. Measures of variation of the NDVI within an area have shown to be good parameters. More weight to the edge areas compared to the rest of the field might improve the change detection.

Shadows from trees are a very significant problem and should be accounted for. The investigated landscapes in lowland south-eastern Norway is fragmented, especially areas exposed to forest growth on previous grassland. Ecological monitoring of these areas will require images with a spatial resolution better than 10 to 15 meters, like resolution merged Spot 5 images (2.5 meters or 5 meters).

6. REFERENCES

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