Classification of mountain vegetation using plot data from the new National Inventory of the Landscape in Sweden (NILS) and Landsat satellite data

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Abstract – The Swedish Environmental Protection Agency is interested in obtaining current, detailed maps of mountain vegetation in Sweden. A project began in 2003 to map mountain vegetation using Landsat satellite data and field data from a new inventory called NILS (National Inventory of the Landscape in Sweden). NILS is the first country-wide systematic ground inventory to include the mountain area, and it is of interest to use these data for satellite data classification. Three Landsat scenes were topographically corrected and radiometrically corrected (using relative calibration from TERRA MODIS data). This allowed use of field data from all three scenes for classification. Supervised and unsupervised classification were tested and compared. Using NILS field data for accuracy assessment of the unsupervised classification, an overall accuracy for 19 vegetation classes was approximately 74%. The resulting supervised classification was better than expected given the limited amount of NILS field data. Using an increased number of NILS data, supervised classification may be a viable method for future classifications of mountain vegetation.

Keywords: mountain vegetation, field inventory, Landsat

1. INTRODUCTION

For Sweden, there is a need for current and detailed maps of mountain vegetation. This information could be used for applications such as habitat studies, reindeer grazing studies, and the quantification and mapping of the extent of mountain birch forest. Mountain birch forest in Sweden has in the past been officially categorized as "non-productive forest land", however, according to international criteria, it is to be included as forest land, and statistics must reflect the current state of vegetation there. It is an important component in national and international carbon budget reporting. In addition, an EU environmental directive (N2000) to preserve the "Magnificent Mountain Landscape" needs to have detailed and current vegetation information.

By combining remotely sensed data and field inventory, large area maps of vegetation can be made. Previously, SLU has produced nationwide maps of forest land using National Forest Inventory (NFI) data and satellite data. However, the NFI is an inventory of productive forestland only and does not inventory mountain vegetation. With the introduction of a new inventory, NILS (National Inventory of the Landscape in Sweden), which covers all land cover types including the mountains, a valuable source of objectively collected data is now available to be used for satellite image classification over all cover types.

1.1 Objective

The aim of the project described in this paper is to investigate the utility of NILS as reference data in creating a map of mountain vegetation from Landsat ETM satellite images. The project is the first to use NILS data for satellite image classification. Since the number of NILS plots available was limited, unsupervised classification was tried first, and then supervised classification was to be tested as well.

1.2 NILS

NILS is a part of the national environmental monitoring activities of the Swedish Environmental Protection Agency (EPA) and includes all terrestrial environments. NILS is carried out through a nationwide random (systematic) sample of 631 quadrates (Esseen et al., 2003). The "landscape quadrate" is 5x5km and inventoried every 5 years. NILS is based on aerial photo interpretation and field measurements focused on a 1x1 km quadrate in the center of each landscape quadrate. The inventory is based on over 100 variables collected for each sample plot. The photo-interpretation is made from 1:30 000 scale orthophotos and records a smaller number of variables than the field survey.

1.3 The Swedish landscape

The mountain area of Sweden covers 4.4 million ha of the 41.0 million ha land area (Skogsstyrelsen, 2003). Forests cover 22.6 million ha, while wetlands cover 4.6 million ha and agricultural land covers 3.5 million ha (Skogsstyrelsen, 2003).

2. DATA

2.1 Satellite and map data

Three Landsat ETM scenes from July 25, 2000 were obtained through the European-wide Image 2000 dataset, administered by the European Environmental Agency (EEA). The images covered a majority of the Swedish mountain chain (Figure 1). The scenes were relatively cloud-free and geometrically corrected with an overall RMSE of 1 pixel (25m). Bands 2, 3, 4, 5 and 7 were used in the classification.

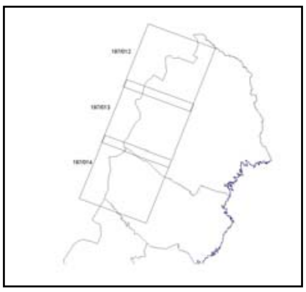

Figure 1. The three Landsat scenes in northern Sweden.

In addition, a reflectance calibrated TERRA MODIS scene was acquired from the same date as the Landsat scenes, for the purpose of reflectance calibrating the Landsat data. The TERRA MODIS scene has a pixel size of 250m, and bands in the red and near-infrared wavelength range. Map data used were a DEM with 50 m resolution, a land-cover map at 1:100,000 scale (the National Mapping Agency's "road map"), and a mountain vegetation map (Liber Kartor, 1981).

2.2 NILS data

In the project area, approximately 200 plots were usable from a total of 18 NILS quadrates available from the 2003 and 2004 field seasons. In addition, five NILS quadrates had been aerial photo interpreted. Figure 2 shows the NILS inventory plots over Sweden.

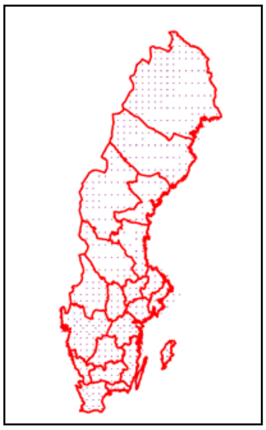

Figure 2. The NILS quadrates for a 5-year cycle.

3. METHODS

In order to map mountain vegetation with satellite data, a large number of field plots with current and detailed information about the vegetation are required. While NILS will inventory 631 tracts over a complete 5-year cycle, the program had begun at the same time as the mountain vegetation mapping project, and field data from only the 2003 season of NILS were available. The project therefore needed to start with an approach requiring a minimum number of plots, such as unsupervised classification. However, it was also of interest to investigate the results of a supervised classification once more NILS plots were acquired.

3.1 Class definitions

Definition of the vegetation classes to be mapped in the project was a first step. The classification system chosen was based upon the vegetation classes found in the existing mountain vegetation maps (Liber kartor, 1981). Those classes were bare rock, grass heath, dry heath, fresh heath, alpine meadow, willow, mountain coniferous forest, mountain birch forest, meadow birch forest, coniferous forest, sparse coniferous forest, birch forest, mixed forest, snowbed vegetation, snow/ice, wetland with forest or grasses, wetland (with surface water) and water.

3.2 Illumination correction

Since topography in the mountains has a strong influence on the reflectance recorded by the satellite, all the images were topographically corrected. Based on earlier results (Zuba, 2002) which showed that the c-correction (Teillet et al, 1982) gave optimal results, each Landsat scene was corrected using this method.

3.3 Unsupervised classification

An unsupervised classification was carried out individually for the three scenes. The classification was done in several steps involving map masks. Using the 1:100 000 scale land-cover map, the satellite image was masked into separate images of "mountain vegetation", "forest", and "other" (water, wetland, agriculture, and urban). The mountain vegetation image was further divided by using an ISODATA clustering to separate it into the classes of "mountain forest" and "heath". The reason for using a classification was that the 1:100 000 map was considered too coarse for a good division of these classes, while the satellite data provide a better separation. Each of these four images was clustered using ISODATA and assigned a class using the mountain vegetation map and the Landsat image as a guide. The four classifications were then put together. Whether a pixel is considered to be wetland, or whether a pixel belongs to the "mountain forest" as opposed to "forest" class was determined by using the 1:100 000 map as a mask. The distinction between "mountain birch" and "birch" is difficult to make even when in the field, and the two are found to be hard to distinguishable spectrally, and thus require a mask to separate the two classes. Using the NILS data, an accuracy assessment was performed on the unsupervised classification.

3.4 Supervised classification

After data from two years of NILS seasons were acquired, a supervised classification could be attempted. In order to use as many NILS plots as possible, the Landsat data were reflectance calibrated using the low-resolution TERRA MODIS data as a spectral bridge. By doing this, a NILS plot from the northernmost scene could be used to classify the same vegetation in the southern scene. The calibration was done bandwise using regression which related the Landsat data's spectral value to the MODIS image. Each Landsat scene was first reflectance calibrated and then topographically corrected and mosaicked into a single file. 200 training sets were used for a total of 17 vegetation classes.

The NILS field data were assigned a vegetation class based on the variables of each plot. Some of the variables used included, for example, the field layers percent coverage of ferns, herbs, and grasses; the shrub layer's percent coverage and species; the tree layer's percent coverage and species; ground moisture and an assigned "nature type". Due to the detailed nature of the NILS field inventory, it was possible to separate the NILS plots into sub-classes and to train based on these sub-classes, for example, dry heath with some large boulders present or dry heath without boulders present. Photo-interpreted tracts were also available, and their value in the supervised classification was considerably high since it was easier to identify homogenous training sets using polygon data as opposed to the singular field plots.

4. RESULTS AND DISCUSSION

4.1 Unsupervised classification

The unsupervised classification was evaluated for accuracy using the NILS field plots. The result shows an overall total accuracy for the 19 classes of 74%. Of the approximately 270 NILS plots, most of the plots belonged to the mountain birch class (67 plots), which had a high accuracy of 80% and 95% producer's and user's accuracy, respectively. However some classes had little or no representation in the NILS field plots, such as willow (4 plots), meadow birch forest (1 plot), and snowbed vegetation (0 plots). These will require more field plots before more can be said about their classification accuracy. Also shown by the accuracy assessment is confusion between dry and fresh heath, which both had a user's accuracy of about 60%, however, if we combine the two classes, a user's accuracy of 88% is met. The confusion between these classes can perhaps be explained by the mosaic-like nature of these two cover types. A summary of the accuracy is given in Table 1.

Class	Users Accuracy	Producers Acc.
Bare Rock	18/18 = 100%	18/21 = 86%
Mtn. Birch	54/57 = 95%	54/67 = 81%
Mtn. Conif	1/1 = 100%	1/3 = 33%
Mtn. Mixed	1/2 = 50%	1/1 = 100%
Mtn meadow birch	1/2 = 50%	1/1 = 100%
Snowbed veg	0/1 = 0%	0/0 = n/a
Alpine meadow	9/9 = 100%	9/13 = 69%
Grass heath	9/11 = 82%	9/12 = 75%
Dry heath	15/25 = 60%	15/27 = 56%
Fresh heath	24/39 = 62%	24/32 = 75%
Willow	1/8 = 13%	1/4 = 25%
Coniferous forest	20/23 = 87%	20/29 = 69%
Sparse conif forest	2/2 = 100%	2/2 = 100%
Birch forest	6/15 = 40%	6/6 = 100%
Mixed forest	12/21 = 57%	12/16 = 75%
Wetland (Forest)	7/12 = 58%	7/16 = 44%
Wetland (Water)	10/14 = 71%	10/11 = 91%
Snow/Ice	8/9 = 89%	8/8 = 100%
Water	5/5 = 100%	5/5 = 100%

Table 1. Accuracy assessment for the unsupervised classification.

4.2 Supervised classification

The result from the supervised classification was not evaluated with NILS plots as all available NILS plots were used for training. However, preliminary results were compared with the unsupervised classification as well as the mountain vegetation map, and were considered to be promising. While the amount of field data currently available is not currently considered a sufficient amount to do a satisfactory supervised classification, in the future, when more NILS field data and especially photo-interpreted tracts are available, supervised classification can be a viable method of classification for the mountain area.

4.3 General discussion

The project has made a first attempt at using the newly started NILS data for satellite image classification with a positive result. NILS collects many variables per plot, and knowledge about the variables and how to interpret them into appropriate cover classes has been necessary. The use of both NILS field plots and photo-interpreted tracts is preferable. In some cases it could be seen from the NILS photo-interpretation polygons and corresponding orthophotos that the satellite imagery had some local geometric displacement of up to three pixels, making use of NILS field plots difficult in these cases.

The result from the unsupervised classification is more spatially detailed than the mountain vegetation map and has the advantage of being current and easily updated. The classification could be used by projects such as the Nature2000 monitoring program, or studying changes in vegetation in the mountain area.

4.4 Future directions

The classification of mountain vegetation from using a combination of Landsat data and NILS data looks promising. There is a great deal of interest in Swedish agencies and the research community in updating the Swedish mountain vegetation maps. While there are currently not a sufficient number of NILS plots to carry out a valid supervised classification, the preliminary result suggests that with more NILS plots, which will be inventoried in the next years, it could be a viable option. It may be possible to create an automated production line using NILS and satellite data to create mountain vegetation maps in the future. In future work, methods should be tried which will improve the accuracy of the classification of dry and fresh heath and willow, which are important vegetation types in the mountains.

5. CONCLUSION

Classification of Swedish mountain vegetation has been carried out using a combination of Landsat ETM data and NILS field data. Currently, after two seasons of the new NILS inventory, a sufficient number of plots were not available to produce a satisfactory supervised classification. However, the initial result was promising, and with more NILS plots, it may be a viable method for automated classification in the future. As an alternative, unsupervised classification was also done, using some NILS plots to identify clusters and other NILS plots for accuracy assessment. The result gave a satisfactory classification of 19 classes with an overall accuracy of 74%. The classification of mountain birch was quite good, with 95% user's accuracy. Classes such as dry heath and fresh heath were confused with each other and the class of willow had a low accuracy, though with so few NILS plots available for that class, further study needs to be taken.

6. ACKNOWLEDGEMENTS

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