HIGH RESOLUTION DIGITAL SURFACE MODELS FOR ENVIRONMENTAL MONITORING

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Working Group VII/2, TC VII/1

KEY WORDS: DSM, Forestry, Monitoring, Natural Disaster, High-resolution data

ABSTRACT

Remote sensing has long been used as a tool for environmental monitoring. Developments in digital photogrammetry now open new possibilities. Automatic procedures have become more reliable by using different data sources, rather than only radiometric information. In the research outlined here color infrared images with a scale of 1:5000 were scanned with a resolution of 28 µm and digital surface models with grid sizes of 0.5 and 1m were calculated. Using slope-data, the probability of tree and forest occurrence in given polygons was computed. This method allows the monitoring of environmental features over several years. In Switzerland aerial images are available for almost a 60 years period. The advantage of using DSMs derived of digital images in comparison to modern and perhaps more accurate methods (laser scanning, radar) is that it provides the user with the possibility to do retrospective analysis.

KURZFASSUNG

Fernerkundungsmethoden werden seit langer Zeit für Umweltbeobachtung eingesetzt. Durch den vermehrten Einsatz der digitalen Photogrammetrie eröffnen sich neue Möglichkeiten. So können mit feinmaschigen Oberflächenmodellen aus verschiedenen Zeitschnitten Veränderungen bei Einzelbäumen, Baumgruppen und Waldrändern fast automatisch beobachtet werden. Aus IR-Luftbilder im Massstab 1:5‘000 wurden digitale Oberflächenmodelle mit einer Maschenweite von 0.5 x 0.5 und 1 x 1 Meter berechnet. Anhand von abgeleiteten Neigungsdaten wurden Baumwahrscheinlichkeiten und Waldwahrscheinlichkeiten für vorgegebene Flächen berechnet.

1 INTRODUCTION

Remote sensing has been used in environmental monitoring for a long time. The developments in digital photogrammetry, have now opened new possibilities. Larger scales are now handled within a reasonable timescale, time consuming procedures such as the measurement of digital terrain models are now automated and different types of data can now be combined. This is performed by Eckstein et all (1996) and Mayr et all (1999) to extract trees automatically. Digital photogrammetry is particulary apt for the monitoring of large-scale applications such as that of bogs (Ginzler et all 1999). To date few investigations have been performed in environmental monitoring using digital photogrammetry. By using high-resolution digital data it is possible to monitor in detail slow environmental changes (e.g. afforestation) as well as changes due to natural disaster (e.g. mountain slides or storms). In contrast satellite images due to restrictions in their resolution do not allow such a detailed study for these changes.

This article describes the monitoring of a region where a bogburst occurred. The first part of the paper describes a specially developed strategy for the calculation of a Digital Surface Model (DSM). Subsequently different GIS analyses are performed with the DSMs. The environmental changes observed are described and discussed.

2 METHODS AND MATERIAL

2.1 Location of the investigation site

The mire of Vraconnaz is located in the Jura Mountains (canton Vaud; Fig. 1). In September 1987 a bog slide occurred here due to exceptional climatic conditions. Three weeks of drought were followed by heavy rainfall on 25 and 26 September. The rainfall was so extraordinary that even the well-developed natural drainage system in the surroundings of the bog were probably full to overflowing. Under such conditions the large amount of water could not be soaked up by the peat and a spring in the upper edge of the bog swelled to such an extent that the peat body was torn away from the mineral sub-soil resulting in a downward slide (Grünig 1994).

Figure 1: Mire of Vraconnaz, Canton Vaud.

2.2 Images

Color infrared images from three time periods were used (Figure 2):

Date	Scale	Scan resolution	Focal length
July 1984	1:10000	28 µm	213.77 mm
October 1987	1:5000	28 µm	214.74 mm
August 1998	1:5000	28 µm	214.744 mm

Table 1: Image specifications

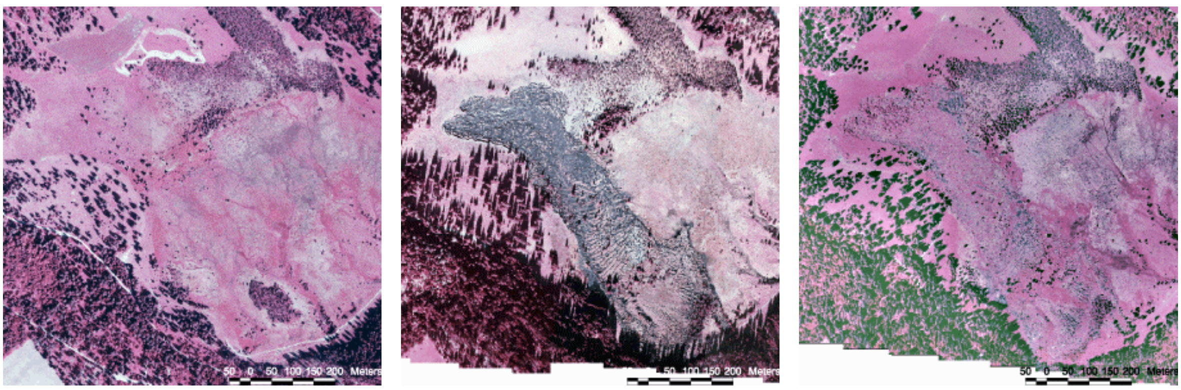

Figure 2: Orthophoto 1984 Orthophoto 1987 Orthophoto 1998

The images were oriented using standard procedures. Natural points were used as control points and were measured by tachymeter and GPS. A problem which occurred using this kind of points was that not all control points were visible and therefore measurable for all time periods. As a result the models are slightly tilted against each other.

2.3 Digital Surface Model

Automatic Terrain Extraction (ATE) with image correlation is widely used and is proven to provide both, a reliable and accurate algorithm. A successful image correlation largely depends on having a set of correct parameters which control the algorithm (Zhang et al. 1997). Mostly the standard parameters of the ATE algorithms are optimized to obtain ground height. The algorithms try to filter all obstacles such as houses, bushes and single trees or at least to smooth out the surface of the DTM thus they get smaller. The ATE of SocetSet® from LHSystems allows the individual setting of many parameters to adapt them to the needs of the user. For the purpose of the research the DTM has to be a Digital Surface Model (DSM) adapted as good as possible to all "obstacles" such as bushes and trees. Therefore DSMs with grid spacings of 1m and 0.5m were calculated and the parameters of the slope and spike limit and the size of the correlation window were changed. The maximal allowed slope was set to 85 degrees and the threshold to decide if a point is a spike or not was set to 30 degrees. The size of the correlation window was reduced in the last correlation passes. DSMs were calculated of all three time periods.

2.4 GIS - Analysis

2.4.1 Change Detection

The DSMs were imported into Arc/INFO. To detect changes over a period of time the DSMs of 1984 and 1998 were compared. To quantify the amount of peat which slid the DSM of 1987 was subtracted from the DSM of 1984.

2.4.2 Tree-probability

To detect trees in every type of terrain the homogeneous slope areas has to be calculated first. Deviating slopes will be interpreted as non-terrain elevations and a slope-grid was derived from the DSM. The range from 0 to 90 degrees was reclassified in 10 slope-classes. To calculate the general slope of the terrain areas (cohered pixel) with the same slope-class are grouped in zones. Zones with areas smaller than 200 m^2 were masked. For the unmasked area the mean and standard deviation of the original slope values were calculated. Pixel with a slope-value higher than *mean + 3*s were labeled as potential tree-pixel.

2.4.3 Decision support for forest probability

A classic interpretation of the aerial photographs of 1998 was performed. Areas of homogenous color, structure and texture were delineated. They have a size between 25 and about 2000 m^2. The reclassified slope-grid was overlaid by these polygons of interpretation. For each area the relative amount of potential tree-pixel was calculated. This was undertaken for the DSM of 1987 and the DSM of 1998 to demonstrate the reforestation.

3 RESULTS

3.1 High resolution DSM

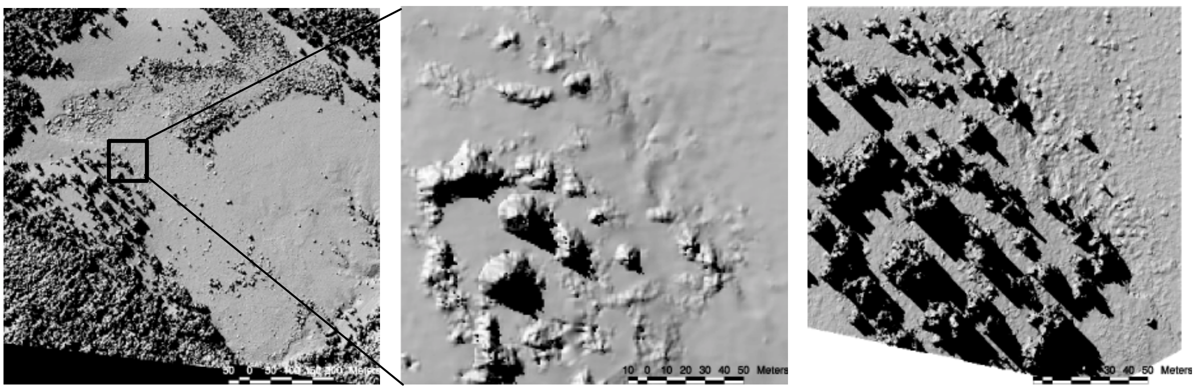

Figure 3: Hillshaded DSM 1998   Detail with standard parameters   Detail with user adapted parameters

The differences between the DSMs with a grid spacing of 0.5m and 1m were not so important than the differences in the DSM due to the parameters. Figure 3 shows that the DSM calculated with standard parameters smoothes the trees slightly and that some of the bushes even disappear. The DSM with the user adapted parameters reveals more details, the tree height is more realistic and the smaller bushes are visible.

3.2 Change Detection

During the night of the bog burst about 240'000 m^3 slid along the gentle slope for a distance of at least 300 m. Most of the peat was dislocated from the top of the slope to the very bottom. During the process a small pine forest was almost completely crushed (see arrow in Figure 4). Only view trees remained standing and were carried with the peat-rafts.

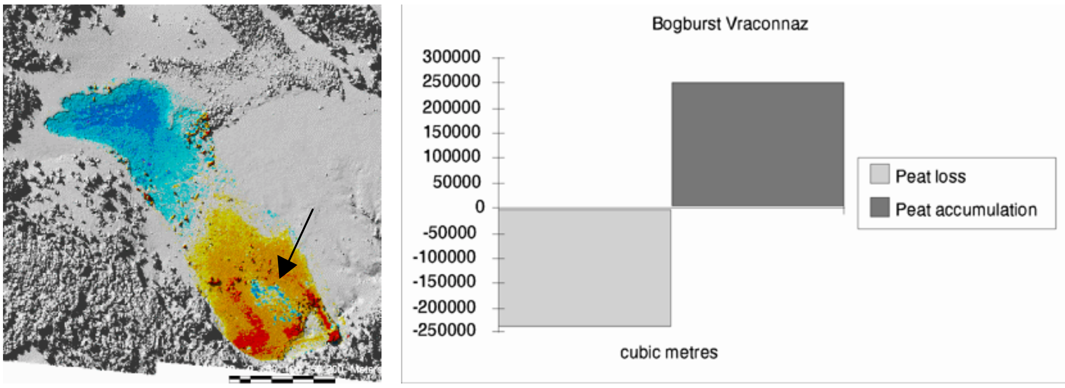

Figure 4: Change detection 1984 - 1987 (DSM 1987)

3.3 Decision support for forest probability

The result of the decision support for forested areas is shown in Figure 5. Most of the areas were correctly detected as forest areas. For the areas in the middle of the scene the density of the trees is too low to be classified as forest by the algorithm.

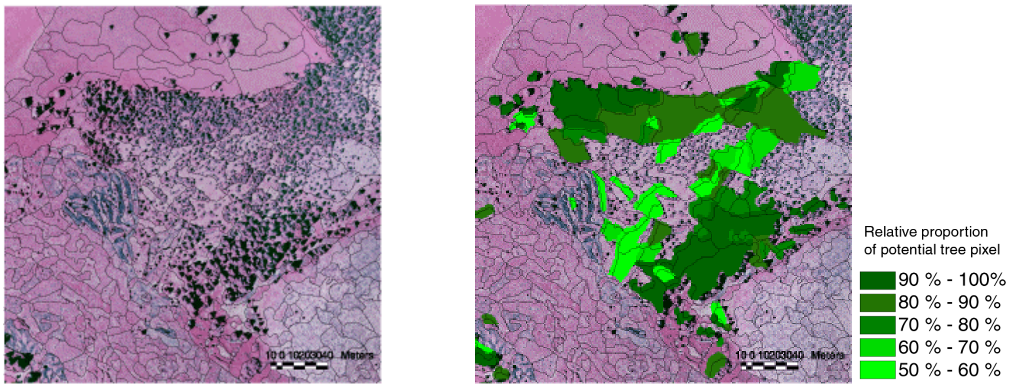

Figure 5: Orthophoto with interpretation   Forest probability 1998

4 CONCLUSIONS

This method of the GIS-analyses of high-precision Digital Surface Models allows the monitoring of environmental features over several years as of the qualitative and quantitative changes in tree and shrub structure. The advantage of this being that forest borders, tree groups and single trees in many different types of terrain can relatively easily be automatically recognized. In Switzerland aerial images are available for almost a 60 years period, so retrospective analysis can be undertaken in using DSMs derived from digital images. This is a great advantage in comparison to modern and perhaps more accurate methods (laser scanning, radar). For future analysis, also high precision digital surface models generated by laserscanning could be applied as well as other data sources.

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