Methodologies to improve Landsat TM forest classifications of alpine regions through the removal of some radiometric and geometric distortions are tested. Besides correcting for sensor and system induced errors, geometric corrections are performed using a digital elevation model. Then scene related effects such as differences in illumination as well as the height dependent atmospheric influence and adjacency effects are corrected. The obtained improvement of the forest classification accuracy can be demonstrated against excellent ground truth.

Keywords: Topography, geometry, radiometry, atmosphere, adjacency, forest, classification

1. BASE OF THE STUDY

In remote sensing applications precise geometric and radiometric corrections are getting more and more important. They result not only in improvements in classification accuracy but are a prerequisite in any multitemporal approach.

In this study the impact of topography on the geometry and radiometry on a Landsat TM scene of Central Switzerland is investigated and corrected in order to improve a forest versus non forest as well as a stand / forest type classification.

The base dataset consists of a 7-band TM scene (194-27) of 3 July 1985. Fall, winter or spring imagery is not suited for forest classifications due to the lower sunangles which cast shadows, and due to the fact that the foliage of the various forest types is not fully developed. Within the selected cloudfree scene a testsite "Beckenried" (12 km x 17.5 km) was selected, which is situated in the mountainous pre-alps of the Canton of Nidwalden in Central Switzerland.

For this testsite the green plate 1, containing the class forest, of the 1:50'000 topographic maps was scanned. Additionally maps of about 900 hectares on forest stands were digitized. These maps had been generated by the Swiss Forest Damage Assessment Project using color-infrared airphotos in scales 1:10'000 which had been flown on 25 July 1985. Thus excellent timely ground truth was available, which in part contained also information on forest type, degree of mixing, crown closure, growth status and vitality.

A digital elevation model (DEM) was available from the Swiss Federal Office of Topography with 25 m resolution in x and y and 10 cm for elevation. From this elevation model the following datasets were generated: slope, aspect, illumination and masks for cast shadow and eigenshadow. The illumination is defined as the cosine of the incident solar angle, thus representing the proportion of the direct solar radiation hitting a pixel.

All datasets were geocoded on the topographic maps of the Swiss Federal Office of Topography.

2. IMPACT OF TOPOGRAPHY ON THE GEOMETRY OF A TM SCENE

Geometric distortions are not only related to the sensor and imaging geometry but also to the topography. Especially in mountainous regions image points are shifted due to scan line perspective displacement.

Although this relief effect is not eliminated neither during system correction nor during the normal geocoding with "normal" polynomial transformations, it is of great significance in mountainous regions.

In our testsite Beckenried with an average scan angle of 4.5°, an elevation difference of 300 m shows already a linear shift of one 25 m pixel. In the testsite Beckenried the elevation differences amount to 1970 m. Thus the topography especially in hilly or mountainous terrain has a major distorting impact and consequently had to be corrected by a shift-correction algorithm [1].

3. IMPACT OF TOPOGRAPHY ON THE RADIOMETRY OF A TM SCENE

For the rather small testsite Beckenried a correction of the viewing angle effect, a so called path length correction, was not neces-
3.1. Impact of the illumination

The same object displays totally different intensity values under varying sun position and topography. With a synthetic example we can demonstrate this effect.

In Fig. 1 the illumination of the testsite Beckenried is shown. In the upper image the illumination is modelled for the date and time of the actual satellite overpass (3 July, 09:40 GMT) whereas in the lower image the same view is produced for two months later at the same time.

An object lying in shadow receives and reflects less radiation than the same object on the sunny side. These same objects therefore despite their equal reflectance display varying intensity values according to their position to the sun.

This fact is a major problem for the classification of satellite imagery. For a precise and efficient detection of objects, the topographic influence on the illumination has to be eliminated.

Another approach corrects the illumination variation as a preprocessing step. This second method was used in our study.

Four models for the correction of the slope-aspect effect were tested and discussed in view of their effectiveness to improve forest classifications in alpine terrain [2].

The common cosine correction method is not being recommended for forest and forest-stand / forest-type classification improvements. The statistic-empirical, the semi-empirical and the Minnaert correction however led to substantial improvements.

Control classifications in a midland testsite revealed that the empirical constants are topography dependent and should be recalibrated in each topographic region. Another important result relates to the quality and resolution of the DEM. Ideally the DEM should have a better resolution than the satellite scene, but at least the same!

3.2. Impact of the atmosphere

Atmospheric scattering and absorption influence the incoming (τ_D) and reflected (τ_Up) radiation in the following ways (see Fig. 2):

- the atmosphere contributes its own part in reflected radiation (path radiance, ρ_a)
- it absorbs parts of the incident as well as the reflected radiation
- it scatters reflected radiation in the vicinity around objects (s, τ_up'). This so-called adjacency effect reduces the contrast and may smear the boundaries of objects. This effect is to be expected especially with high resolution satellite sensors [3].

Since these effects are mainly tropospheric and depending on the path length, low lying objects (e.g. in valleys) are more affected than mountain tops. The scattered component is added to the normal reflection, dark objects become brighter. This scattering also reduces the spatial resolution of the sensor system because the contrasts are fainter.

Fig. 1: Illumination calculated for date of overflight on 3 July, 09:40 GMT (top), and illumination calculated for 3 September 09:40 GMT (bottom)

Fig. 2: Atmospheric factors influencing the radiance reaching the sensor
In our study we tried to correct this elevation dependent factor as well as to bring back the original contrast in the lower zones.

The basis for these tests was the atmospheric model developed by TANRé et al. at the "Laboratoire d'Optique Atmosphérique" of the "Université des Sciences et Techniques de Lille", France, called "5S", which stands for "Simulation of the Satellite Signal in the Solar Spectrum" [4].

The 5S code takes into account Rayleigh and aerosol scattering, as well as gas absorption due to water, carbon dioxide, ozone and oxygen. Input parameters can be chosen from preprogrammed standard conditions and models, or specified by the user. The main output of the program are the various components of the apparent reflectance (and radiance) at satellite altitude, the different components of the irradiance at the surface and the scattering and gaseous transmittances.

4. RESULTS

4.1. Visual evaluation

Due to the contrast enhancement single objects can better be distinguished in the slope-aspect and atmospherically corrected image compared to the just slope-aspect corrected one. Fine structures or linear elements however are not enhanced. Unfortunately slight banding and bright target effects are getting visible in the lake because of the increase in contrast.

If the adjacency effect is also taken into account and corrected, fine details and linear elements, such as some textural features or the streets in cities are enhanced without causing new unwanted side effects.

4.2. Classification results

Through the atmospheric and especially the slope-aspect corrections a classification accuracy of forest vs. non forest of almost 90 % could be achieved in our Beckenried test area.

The slope-aspect correction alone improved the classification accuracy of faintly illuminated areas by about 5 %, and the subsequent atmospheric correction yielded in the same problem areas another 2 % increase (see Fig. 3)

In the forest stand / type classification the accuracy improvement with the slope-aspect correction was between impressive 10 % and 30 % for brightly illuminated areas, whereas the correction of the atmospheric effects had a slight worsening effect on the result (see Fig. 4).

Overall forest stand / type classification accuracies for the Beckenried testsite were in the region of 62 %. This accuracy is surely not high. We have to remember however, that the alpine forest ecosystem encountered in the Beckenried area is composed of a large variety of deciduous trees and also heavily mixed with conifers. Therefore we have to contend ourselves with this result under the specific conditions. While interpreting the percentages it has to be kept in mind, that a specific rigorous pixel per pixel accuracy measure was applied.

For the classification of forest vs. nonforest a parallel-epiped method using the original TM bands 2 and 5 is proposed. For the forest stand classification best results were obtained in a binary hierarchical procedure. Starting from the classified forest using TM 2 and TM 5, with TM 4 the coniferous forest is separated in a first step. The subsequent subdivision into the classes mixed forest and deciduous forest is performed using a synthetic band TM 4 minus TM 2 [1].

As overall result it can be stated that a methodology of improving forest classifications in alpine terrain can be proposed. Geometric and radiometric correction methods, among the latter especially the correction of illumination differences improved the classification accuracies considerably. This is also true for the forest stand classifications were one has to remain modest in the overall expectations due to the spatial mixing of the tree types.

5. REFERENCES


