Removal of Topographic Effects from Satellite Images

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Summary: *This article approaches the issues concerning the topographic effects produced by the shadow of mountainsides over the stands in the mountain area. The presence of such phenomenon creates ambiguity among the components of the scene, cause confusion in accurately establishing the categories of land use, surfaces covered with the same type of vegetation being totally different shown. In such situation the pixels found under the shadow have different digital values compared to the sunny ones, even if they represent the same category of use of the land or the same stand. The diminution of the topographic effects can be achieved through various methods which have as result getting clear images by highlighting the information in the shadow.*

1. General issues

The variation of illumination on the satellite images in mountain areas, including Landsat, have as dominant source the shadow due to the mountainside slope. Consequently, there emerge *topographic effects* that create an ambiguity between the scene elements and cause confusion in the accurate establishment of surface categories. Practically, the pixels found in shadow have digital values different from the sunny ones even if represent the same use of the land or the same stand, which leads to the reduction of the accuracy of the classification. In the same sense, season variations, insect attacks, droughts or/and the inclination of land become the main factors which limit the identification of the stands, affected by different illumination conditions in which satellite images were captured, thing noticed, especially, by analysis of series.

The place topography, especially in the case of accidental lands in the mountain area, does not affect geometrical properties of an image but may have, therefore, an impact on illumination and reflectance of the recorded area. Such effect is caused by local variations of angles and illumination due to the rough ground in the mountain area. *Identical surfaces* covered with the same type of vegetation can be represented *entirely different in satellite images* depending on the orientation and position of the Sun on the date the image is captured. Consequently, the image of three-dimensional relief of the scene is lost and the image appears as "*flat*".

The correction of topographic effects is performed through a few methods updated lately using digital models of the land with high resolution and photo metric models. Regardless the model, the principle is the same; *sensor-land-Sun geometry* is changed with the land topography and generates variations in scene illumination.

Besides the empiric methods, such as the relation between bands, that does not take into consideration the physical behavior of the scene elements, recent methods of correction rely on the fact that the recorded surfaces have *lambertinian properties*, i.e. the satellite images are normalized depending on the co-sinus of the effective angle of light (Smith s.o., 1990).

Correction methods of topographic effects of the land are known in the specialty literature and rely on using the slope and orientation got from the land digital pattern processing (DTM) (tab. 1). These lead, eventually, to the *topographic normalization of satellite image.,* being used on extended areas in the forestry fund, and the success is differentiated depending on the aimed objectives because the topographic effects can not be entirely removed. The image, even if it is corrected, can be altered by "*topographic residues*" due to sub-corrections or by „*negative topographies*" because of super-corrections, effects that are allotted to over-*simplification by the photometric model, neglecting the diffuse light and lack of accuracy of the digital pattern* (Vorovencii, 2005).

Corrections of topographic effects

Table 1

Cosine correction	*Minnaert Correction*	*Correction "c"*
$L_H = L_T \dfrac{\cos(z)}{\cos(i)}$ L_H-radiation noticed on the horizontal surface L_T – radiation noticed on the bent land z – zenith angle of the Sun i – incidence angle	$L_H = L_T \dfrac{\cos^k(z)}{\cos^k(i)}$ k –Minnaert constant $k = 1$ for Lambertinian surface (k takes values between 0 and 1)	$L_H = L_T \dfrac{\cos^k(z)+c}{\cos^k(i)+c}$ $c = \dfrac{b}{m}$ - correction parameter b – point of intersection of the regression line m – slope of regression line

The cosine correction is an empiric statistic method relying on a significant correlation between a dependent variable and one or more independent variables (tab. 1). The quality of the correction depends on the degree of clearness of the function of regression. This method is applied seldom, in the case of lands with slow bent, in order to equalize the differences of lightning duet o the position of the Sun and in the analysis of some sets of multi-temporal data. The pattern provides good results on flat ground, in the field, in the situations in which the cosine of the incidence angle is close to one; the more this angle increases and gets to 90^o, the cosine tends to be zero, and the results are weak. This method models only the direct radiation part.

Minnaert correction uses, compared to the above-mentioned formula, a constant with the same name (k) that varies between zero and one and depends on the wave length and surface topography (Minnaert, 1941). Empiric techniques for constant calculation have been described for different surface types (Meyer, 1993; Smith s.o., 1980). The correction application reduces the topographic spectral variation with approximately 69% compared to not-corrected data (Civco, 1989), presents a significant improvement compared to the band reports (Colby, 1991), but there is the difficulty connected to the constant calculation accuracy. Over the degree and precision of its determination, i.e. the quantification degree, the specialty literature is very varied (Schanzer, 1992; Teillet s.o., 1982).

Correction "c" supposes that this term can be mathematically deducted using data collected in situ for different types of surfaces as in the case of Minnaert constant. From mathematical point of view, the effect of the constant c is similar to k since it diminishes the super-correction for less lighted pixels. Certain works show that by applying this correction there appears a slight improvement concerning the removal of topographic effects compared to Minnaert correction (Minnaert, 1941). Both, k and c, seem to be superior to "*cosine function*" from the point of view of quantification and visual aspect (Meyer, 1993; Smith ş.a., 1980).

The bands relation can be used in reducing the same topographic effects having the clear advantage of *simplicity and transparence* (Holben s.o., 1980; Millette, 1995). The obstacle in using this method is the existence of the image errors which, by applying the correction, are multiplied, representing an extremely difficult and undesired problem. The procedure is nevertheless used for correcting the topographic effects in the case of surfaces which do not have a high quality digital pattern of the land. Research have shown that this technique can not highlight the variations of details reflectance with the same spectral response, providing good results in the case of civil engineering (roads and urbane areas) and poorer in case of forests (Millette s.o., 1995).

2. Material used

For the analysis of topographic effect there was used a satellite record *Landsat 5 TM* multi-spectral with spacial resolution of 30 m. The image represents a frame in the scene with 183 orbit 183, row 28 (185x185 km), with centre coordinates of $46^o20'$ latitude and $25^o56'$ longitude. It was captured in 1989 and covers the area between Piatra Craiului mountains and Bucegi mountains, including various categories of land use: forest of resinous, meadows, grass, cultivated and not cultivated agricultural land, inside the built-up area land, s.o.

The image processing was done with the *soft Erdas Imagine v. 8.6*.

3. Satellite images atmospheric correction

The quality of satellite images can be conditioned also by the condition of the atmosphere. The degree of its loading in the moment of capturing may insert in the signal two forms of radiation, the one of *Rayleigh type*, provided by molecular distribution and *aerosols and fog radiation.* For such reasons, it is required that before their processing, there are certain corrections which remove, as far as possible, the perturbation effect of the atmosphere. Its neglecting may prevent and distort the image interpretation.

Practically, depending on the application there can be done an "*absolute atmospheric correction*", when the numerical value of the pixel is converted in reflectance, or "*relative*", when the same numerical value in the corrected image directly represents the reflectance (Chavez andMackinnon, 1994). It is obvious that in most of the cases, the image data calibration in units of radiation is necessary before making the context classification and highlighting the changes by using multi-temporal images.

The dark object subtraction simultaneously removes the forms of radiation above mentioned. Consequently it has become the simplest and the most spread method, based on "*the absolute atmospheric correction*" and used in applications giving as objective the satellite images content classification or highlight of changes. It is recommended in the case of *Landsat TM* images which cover objects with weak contract and are captured in an homogenous atmosphere, case in which the minimum digital values from the histogram of the entire scene are considered to appear because of the effect of the atmosphere and, consequently, can be extracted from all pixels (Chavez, 1989). Algorithms, much more sophisticated, take into account, clear water as object with weak contrast for highlighting optic information of the atmosphere in view of achieving the radiometric normalization. More recently it was underlined the existence of a stable relation between the surface reflecting in average infrared and blue and red band for dense vegetation and dark color.

Relative atmospheric correction has as support the existence of a linear relation in time between the bands of the image established through radiometric measurements over certain *pseudo-invariant features* that represent well identifiable objects and stable from spectral point of view.

The utility of the atmosphere correction, per total, is sometimes contested. Thus, for many applications based on the classification of the image content and highlight of changes, it is considered that its application is unnecessary. A typical example is the classification using the method of *maximum probability* in the case of using a single image. As long as the samples and the image, whose content must be classified, gave the same relative scale, corrected or not corrected, *the atmospheric correction has a minimum effect* on the classification accuracy. For Landsat TM data, the dominant atmospheric effect is the distribution to which it is added on a signal, while the multiplicative effect of the absorption is often neglected because TM bands are selected so that the effects owed to it are avoided.

A large number of studies performed show that the application of the atmospheric correction has a small effect over the classification carried out on an image captured at a single date and in other cases it is not necessary if spectral signatures which characterize the selected classes derive from the image to be classified.

In certain situations, the atmospheric correction must be applied before the classification, of highlighting he changes and use of vegetation index. Thus, the NDVI index, deducted by taking into consideration the effect of the atmosphere is given by the formula:

$$NDVI = \frac{(TM4 - TM3) - (A4 - A3)}{(TM4 + TM3) - (A4 + A3)} \quad (1)$$

where A3 and A4 represent the effect of the atmosphere for bands TM3 and TM4.

The above relation takes into consideration the effects of the atmosphere which influence NDVI signals and the modification is not linear. The research shows that the simple relation IR/R (TM4/TM3 in the case of Landsat data) is affected by atmosphere and the NDVI index calculated above the atmosphere has always a smaller value than the NDVI calculated over the wreath. The effects of the atmosphere over NDVI are significant and can grow to 50% or more in the case of existence of a thin or interrupted vegetal cover.

4. Removal of topographic effects from the studied satellite image

Surfaces considered are found, such as shown, in the mountain area, with rough-ground. Consequently, relying on the above mentions for Landsat images was carried out *the topographic normalization* having as purpose the removal of topographic effects. The main features of the works are:

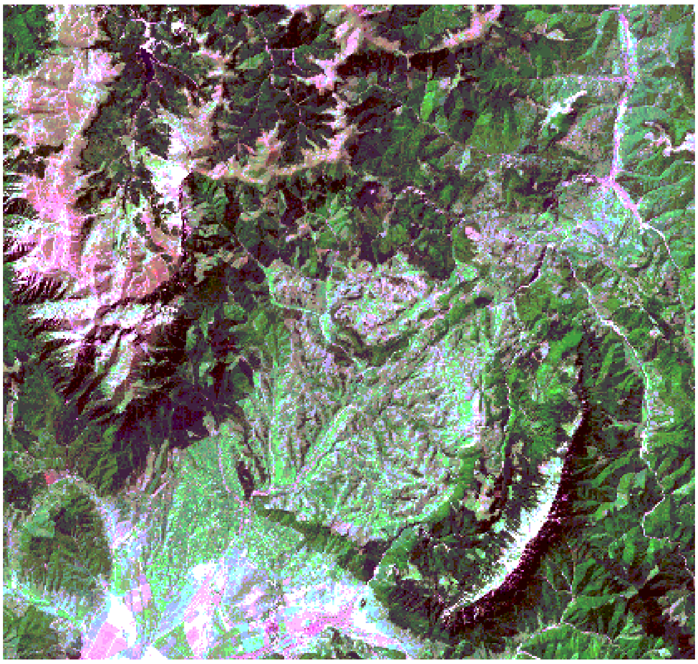
- *materials*, use of *satellite image with atmospheric correction* by the supplier, *digital pattern of the land and the data in the image header* referring to azimuth and the Sun elevation from the moment of their acquire;
- *the digital model of the land* was carried out with the size of the pixel of 5 m;
- *resampling*, in view of reducing the size of DTM pixels from 30 x 30 m to 5 x 5 m, was done in the *Universal Transverse Mercator* sampling system, *WGS 84*, *north, area 35, range 24E – 30E*. The DTM was used in the same sampling system (UTM) in which the satellite image was geo-referenced;
- *method* : "*the closest neighbor*", using a polynomial approximation of the 3rd degree and a tolerance of 0,1 pixels;
- *the topographic normalization* was carried out by applying *lambertinian model* which is incorporated in the program Erdas, using as entry data the image in the combination RGB 432;
- *The final product* in combination RGB 321 rendering natural colors both for images before and after the topographic normalization (drawing 1).

Application of the topographic normalization for removal of topographic effects in the case of satellite images captured in areas with inclined and rough-ground proved to be an operation with significant results (Vorovencii, 2005).

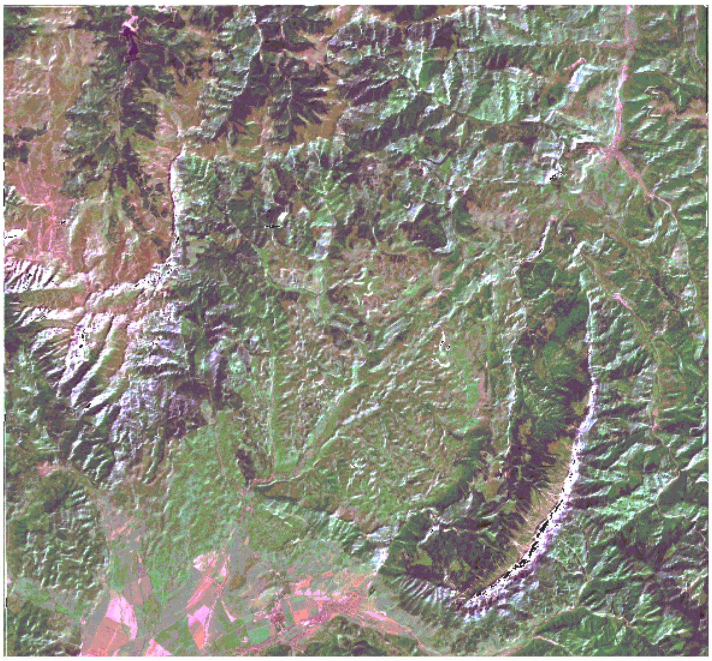
5. Conclusions

Concerning the *influence of the atmosphere* over the content of satellite images was found out :

- *the accuracy of the reflectance* of the surface, taking into account the atmospheric correction, might be assessed through measurements "*in situ*" of the atmosphere properties and of the reflectance itself during the image capture. Unfortunately this ideal means relies on



a.



b.

Drawing 1. Image Landsat 5 TM in natural color, combination RGB 321:
a – before the removal of the topographic effects; b - after the removal of the topographic effects

determinations over the spectral reflectance which is not available but can be replaced, just as well, by relative measurements;

- *concerning the spreading phenomenon*, it was found that the aerosols increase the reflectance of the dark color details and reduces the one of bright details, causing thus losses of information. The atmospheric correction does not allow for their recovery because, basically, it *can not add new information on the original image*; its effects reside in reducing and/or *bringing multi-temporal data to a common radiometric scale*;

- *simple theoretical analysis and empiric results* show that the atmospheric correction must be carried out when making an *extrapolation of some data captured within a certain delay of time and place on other dates from another moment and place*.

The comparative analysis of the two images, before and after *the application of the topographic normalization,* leads to the following conclusions:

- *clear highlight of stands* located on shadowed mountainsides;
- *values of pixels* found on shadowed mountainsides were brought to the level of the pixels found on non-shadowed mountainsides, in the case of the same categories of use and stands. When such a thing was impossible, the pixels values do not differ much one from the other;
- *the topographic normalized images* resemble to the three-dimensional view.

In conclusion, the research revealed that the topographic shadow makes difficult the highlight of the information concerning the texture or the structure of the wreath. The effects are more obvious when the land is more inclined or rough. Moreover, we underline the fact that applying such corrections in surfaces with forest is limited because the wreath does not have properties of bidirectional reflectance, and they vary according to the species, age, consistence and season.

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