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SHADOWS CORRECTION METHODS FOR LANDSAT SATELLITE IMAGES

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Abstract

This article aims to present the problem about the topographic effects produced by the shadow in the mountain area. The existence of this phenomenon creates confusion between the components of a scene, cause difficulty in establishment with precision the types of land use because the surfaces covered with the same type of vegetation being totally different shown. In this case, even if they represent the same category of use of the land, the pixels found under the shadow have different digital values compared to the sunny ones. Topographic correction, which eliminates the terrain effect caused by the topographic relief, is one of the fundamental steps in data pre-processing. 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. The reflected radiance in topographically complex areas is severely affected by variations in topography; thus, topographic correction is considered a necessary pre-processing step when retrieving biophysical variables from these images. It was assessed the performance of three topographic corrections: Cosine, C-Correction and Minnaert. The performance of topographic corrections on the images was assessed by visual comparison and spectral response analysis. In the majority of cases, C method performed best in terms of eliminating topographic effects comparing with the Cosine and Minnaert methods, which showed the poorest performance.

***Key words**: topographic correction, Landsat satellite images, shadow.*

INTRODUCTION

In the rugged mountainous terrain, topographic effects distort severely the spectrum features of land surface. Slopes facing toward the sun receive more radiation and appear brighter than slopes facing away from the sun. Not only is illumination modified by topography, but the proportion of light reflected toward the satellite also varies with the geometry of sun, target and viewer. There are many of topographic effects that can cause topographic variation in the mountain area, including terrain shadow, slope effect, aspect effect, surrounding-reflected irradiance, and displacement of image points for high resolution image. Therefore, the process of topographic normalization may be critical in areas of rugged terrain, and is a preliminary step for the quantitative evaluation of the multispectral satellite imagery (Zhang et al., 2011). The operational use of remote sensing data is often limited due to sensor variation, atmospheric effects as well as topographically induced illumination effects (Ekstrand, 1996; Twele & Erasmi, 2005). Topographic normalization is therefore, especially in rough terrain, important for improving analysis of remote sensing data (e. g. image classification). Although numerous topographic normalization methods have been proposed in the past, none of them has been found to be universally applicable and therefore topographic normalization is still a pre-processing issue rarely used (Füreder, 2010). The intensity of illumination on the surface depends on the orientation of the surface in respect to the sun. Different slope and aspect angles are inducing variable illumination angles and thus diverse reflection values. Areas of high relief therefore show high radiometric variation. Depending on topography reflection values within one land cover type can vary a lot. The illumination variations result in lower reflection values in the shadow and higher values in the sun for the same land cover class. Hence, reflection values of different land cover types in equal conditions of illumination can be more similar than within one land cover type in shadow and sun, leading to problems in image segmentation and possible misclassifications (Twele & Erasmi 2005; Civco, 1989). Topographic normalization methods try to compensate for the topographically induced illumination variations in advance (Füreder, 2010). Till now, a variety of topographic correction models have been proposed. Methods for correcting the topographic effect may be grouped into two categories: 1) Empirical correction methods models which mainly correct the solar direct radiance affected by topography, such as solar direct radiance affected by topography, such as ratio model, cosine model, Minnaert model, sun-canopy-sensor (SCS) model, and C model; 2) Radiative transfer models for mountainous area, which employ a radiative transfer code to obtain a deterministic description of the correction of topographic effects. The advantage of the second method is that scene-dependent empirical parameters are avoided. Introducing some terrain factors slope and azimuth, illumination angle, horizon, and view factors for radiation from sky and terrain with the help of the digital elevation model (DEM), investigators have done a lot of work (Yanli Zhang & Xin Li, 2011).

MATERIALS AND METHODS

The selected study area is located in Bucegi Mountains, which are located in central Romania, south of the city Brasov. They are part of the Southern Carpathians group of the Carpathians Mountains. It is characterized as rugged terrain, which has slope ranging from 0 to 254 degrees with an average of 170, the altitude ranging from 1600 m to 2400 m above sea level. The mean annual air temperature is 1.8^{o}C and the mean annual precipitation is about 1200 mm/year.

In preparation of this work they were used Landsat 4-5 TM and Landsat 8 OLI / TIRS satellite images, which were downloaded through theearthexplorer.usgs.gov portal. Choosing the right area is an essential thing, because the image must include the whole area studied, respectively Bucegi Mountains (Figure 1). Since a single image was not sufficient to cover the area, there were downloaded two images, respectively WRS Path 183, WRS Row 28/WRS Path 183, WRS Row 29, taking into account the visibility, cloud coverage and time for optimal comparison. The first step in the pre-processing stage was radiometric calibration, to correct brightness, reflection and image brightness temperature.

Figure 1. Study area

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). These leads, 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 cannot 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).

The simplest method for compensating the topographic induced variable illumination is building of band ratios wherefore no additional data is required. It is based on the assumption that the relative topographic effect is similar in all bands and the quotient of two bands can compensate for this. This method does not account for the diffuse irradiance, which depends on each band, and therefore can only partly compensate the topographic effect, provided that the atmospheric path radiance is eliminated in advance (Ekstrand, 1996). A further disadvantage in terms of multispectral classification is the loss of spectral resolution when using band ratios (Riano et al., 2003). Real topographic correction methods try to model the illumination characteristics of a horizontal surface by means of a DEM. For this purpose, it is required to calculate the local solar incident angle (i), the angle between the current position of the sun (depending on solar zenith angle and solar azimuth) and the local surface (terrain slope and aspect) (Figure 2).

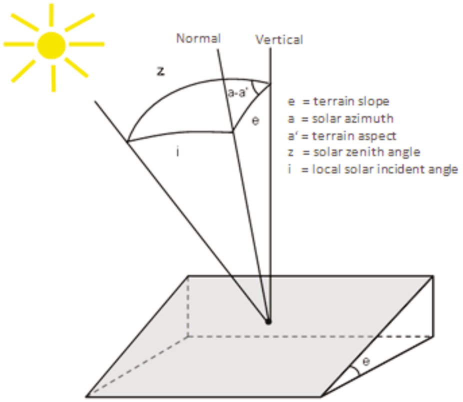

Figure 2. Angles necessary for computing the incident angle (based on Teillet et al., 1982)

The illumination (cos i) can be computed as follows:

$$\cos i = \cos e \cos z + \sin e \sin z \cos (a-a') \quad (1)$$

where:
i - local solar incident angle;
e - slope angle;
z - solar zenith angle;
a - solar azimuth angle;
a' - aspect angle.

The value of cos i varies from -1 to +1, whereas a value < 0 indicates shadowed slopes, which do not receive direct irradiance (Ekstrand, 1996).

The topographic correction methods can be classified in two categories according to their assumption of reflection characteristics of surfaces: Lambertian and non-Lambertian methods. Lambertian methods like the cosine correction are assuming a surface, which reflects the incident radiation in all directions equally, neglecting the atmospherically influences. Non-Lambertian methods are actually not physically based but try to model the diffuse irradiance by means of constants of the bidirectional reflectance distribution function (BRDF), which describes reflection characteristics of surfaces. The amount of the correction depends on the wavelength. So, the assessment of the constants for each band separately is required. The topographic effect is thereby most dominant in the near infrared band (Civco, 1989). As reflection characteristics are related to the land cover, the constants should also be calculated for each land cover individually (Twele & Erasmi, 2005; Teillet et al., 1982; Bishop et al., 2003), resulting in a respectable effort (Füreder, 2010).

Cosine correction

The cosine correction, which neglects the diffuse irradiance, only considers the solar zenith angle and the local solar incident angle for computation of the local illumination (Füreder, 2010). This is an empiric statistic method relying on a significant correlation between a dependent variable and one or more independent variables (Vorovencii, 2005). This method is frequently used because of its implementation in many software programs but it strongly over-estimates the influence of direct irradiance in areas of high incident angles and is therefore problematical for steep and sun-averted slopes, which appear brighter than sunfacing slopes (Civco, 1989; Twele & Erasmi, 2005; Teillet et al., 1982).

$$L_H = L_T \frac{\cos z}{\cos i} \quad (2)$$

where:
L_H - reflectance of a horizontal surface;
L_T - reflectance of an inclined surface;
z - solar zenith angle;
i - local solar incident angle.

Minnaert correction

The most common non-Lambertian topographic correction method is the Minnaert correction, which is based on the ideas of Minnaert (1941), who initially proposed a semi-empirical equation for describing the roughness of the moon's surface. The Minnaert correction extends the cosine correction as follows (Füreder, 2010):

$$L_H = L_T\left(\frac{\cos z}{\cos i}\right)^k \qquad (3)$$

where:
L_H - reflectance of a horizontal surface;
L_T - reflectance of a inclined surface;
z - solar zenith angle;
i - local solar incident angle;
k - Minnaert constant.

The constant k models the extent, to which a surface is Lambertian. It is determined by linear regression between reflection values of the input image (LH) and the angles (i and e). The value of k lies between 0 and 1, whereas 1 characterises a Lambertian surface (Füreder, 2010).

C-correction

This semi-empirical approach, developed by Teillet et al. (1982), is similar to the Minnaert correction. The factor c should model the diffuse irradiance and compensate the over correction effects of the cosine correction (Twele et al., 2006). The factor c can be derived from the quotient of the gradient and intercept from the regression line:

$$L_H = L_T\frac{\cos z + c}{\cos i + c} \qquad (4)$$

where:
L_H - reflectance of a horizontal surface;
L_T - reflectance of an inclined surface;
z - solar zenith angle;
i = local solar incident angle;
c - $\frac{b}{m}$ for L_T= m x cos I +b;
m - gradient of regression line: L_T-cos I;
b - intercept of regression line: L_T-cos i.

RESULTS AND DISCUSSIONS

For reducing the topographic effect, cosine-correction, Minnaert correction and C-correction were tested, in two different software programs - ENVI 5.2 and Rstudio, R version 3.2.0.

The Rstudio program comprises topocorr function, which implements several different methods for topographic correction of remote sensing data. There are currently eight methods available: "cosine", "improvedcosine", "minnaert", "c-correction" (first four from Riano et al., 2003), "minslope" (Minnaert with slope correction, also from Riano et al., 2003), "gamma" (Richter et al., 2009), "SCS" (Gu & Gillespie, 1998; Gao & Zhang, 2009), "illumination" (uncorrected illumination) (R documentation) (Canty, 2014).

topocorr (x, slope, aspect, sunelev, sunazimuth, method = "cosine", na.value = NA, GRASS.aspect = FALSE, IL.epsilon = 0.000001) - this function was used for the available topographic correction methods to compensate for the effects of slope and aspect on reflectance from the land surface (Canty, 2014).

For the topographic normalization, a DEM (Digital Elevation Model) with 30 m spatial resolution has been downloaded, corrected and calibrated (Figure 3). As the quality of the topographic normalization is highly depending on the spatial resolution of the DEM the resolution should be at least as fine as the satellite image (Civco, 1989).

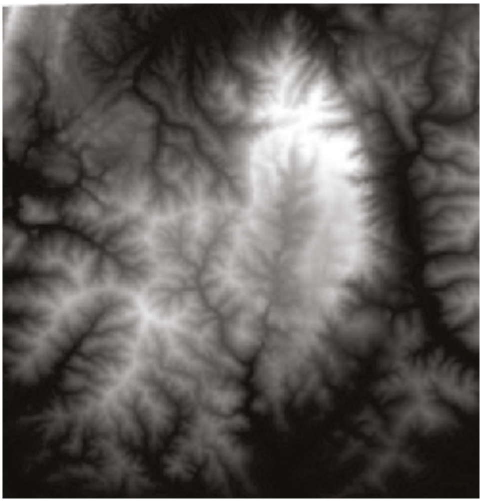

Figure 3. Digital Elevation Model

Also, for the result validation there where needed slope map (Figure 4) and hill shade map (Figure 5), which were extracted from DEM.

Figure 4. Slope map

Figure 5. Hill shade map

As primary results, it was obtained that the topographic variability has been removed and given a more `flat' impression than the non-corrected image (Figures 6, 7, 8 and 9). To evaluate the correction, we randomly compared the spectral response in a point sample from corrected and uncorrected images from shady slope. These results suggest that in the uncorrected image the apparent reflectance of forest on the shady slope is very low.

Figure 6. Original image

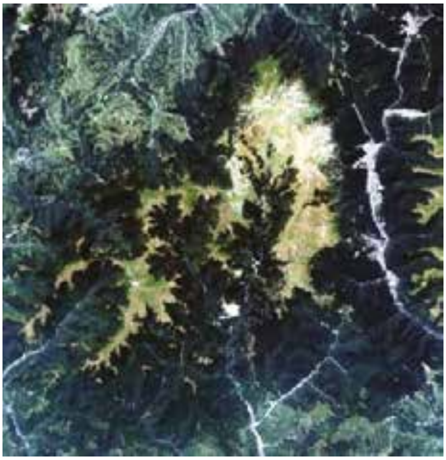

Figure 7. C-correction

Figure 8. Minnaert correction

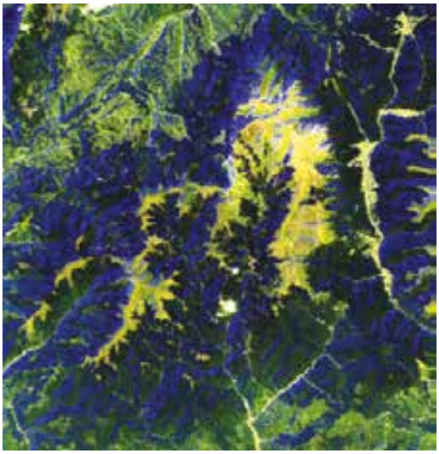

Figure 9. Cosine correction

Spectral differences (Figure 11) between original and topographic normalized image should be low, otherwise it would be a sign of over- or under correction (Figure 10). Slopes facing away from the sun should get higher values, sun-facing slopes respectively lower values. An effective topographic correction should reduce spectral variances and standard deviation and retain the mean (Law & Nichol, 2004).

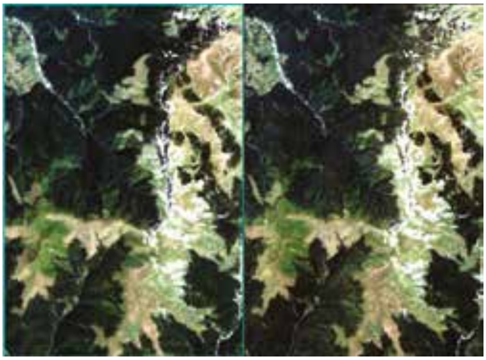

Figure 10. Image before/after correction

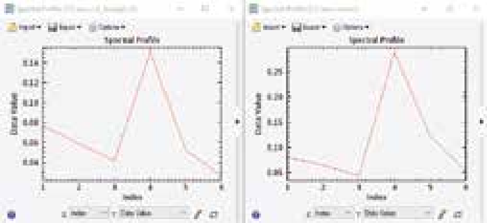

Figure 11. Spectral profile on original/corrected image

CONCLUSIONS

In this study, the results of these three different topographic methods were analysed visually and from the perspective of spectral response. The visual analysis clearly indicates that the C-correction strongly overcorrects weakly illuminated areas like slopes facing away from the sun whereas they appear brighter than sun-facing slopes. Instead of reducing spectral variances, the normalized image appears more distorted (Füreder, 2010). As already observed in other studies (Meyer et al., 1993; Twele et al., 2006) the cosine correction and the Minnaert correction visually do not show major differences and could successfully reduce the topographic effect, which implicates the loss of the three-dimensional impression. Overcorrection of mountain ridges, where illumination is very low, is also showed here.

Topographically normalized satellite images can, in general, obtain better classification results (Meyer et al., 1993; Colby, 1991; Riano et al., 2003; Twele et al., 2006).

The reason for the non-perfect correction lies probably in some reasons. First, the DEM generated from the satellite images may have small errors because of lacking ground control points (Zhang & Li, 2011). A higher resolution of the DEM could compensate the topographic effect better, whereby also smaller illumination variations could be corrected (Füreder, 2010). Second, some of the areas lie in so deep a shadow and thus have very dark pixel values, which lead to no reliable estimations can be obtained (Zhang & Li, 2011).

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