International Journal of Applied Earth Observation and Geoinformation 32 (2014) 208–217

Contents lists available at ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

journal homepage: www.elsevier.com/locate/jag

Application and evaluation of topographic correction methods to improve land cover mapping using object-based classification

Eder Paulo Moreira*, Márcio Morisson Valeriano

Instituto Nacional de Pesquisas Espaciais, Coordenadoria de Observação da terra/Divisão de Sensoriamento Remoto (INPE/OBT/DSR), Av. dos Astronautas, 1758, Caixa Postal 515, Jardim da Granja, São José dos Campos, SP 12.227-010, Brazil

ARTICLE INFO

Article history:
Received 2 January 2014
Accepted 9 April 2014
Available online 8 May 2014

Keywords:
Topographic effect
Landsat
SRTM
Classification accuracy
Land cover classification
Radiometric correction

ABSTRACT

This study applies and evaluates topographic correction methods to reduce radiometric variation due to topography characteristics in rugged terrain. The aim of this study was to improve the capability of satellite images to generate more reliable land cover mapping using object-based classification. Several semi-empirical correction methods, which require the estimation of empirically defined parameters, were selected for this study. Usually, these parameters are estimated relying on a previous land cover map. However, in this work the correction methods were applied considering the unavailability of a previous land cover map and the ease for implementation, so the main land cover type was used to estimate correction parameters to be applied to correct all land cover type. Landsat 5 TM image and topographic data derived from SRTM (Shuttle Radar Topography Mission) over an area located in an agricultural region of southeastern Brazil were used. Land cover classification was carried out using an object-based approach, which includes image segmentation and decision tree classification. The evaluation of topographic correction methods was based on: spectral characteristics expressed by standard deviation and mean values of spectral data within land cover classes; relationship between spectral data and solar illumination angle on the slope ($\cos i$); object (segment) mean size; decision tree structure; visual analysis; and classification accuracy. Results show that the standard deviation of spectral data and the correlation between spectral values and $\cos i$ decreased after data correction, but not for all methods for some of the tested TM bands. The methods herein referred as Cosine, S1, Ad2S and SCS methods showed to increase the standard deviation and the correlation compared to the uncorrected data, mainly for bands 1, 2 and 3. Object mean size, in general, decreased after correction, except for C method. The effect on the object size showed to be related to a calculated standard deviation of adjacent pixels values. The decision tree structure given by the number of leaves also decreased after correction. The C, SCS + C and Minnaert methods showed the highest performance, followed by S2 and E-Stat, with a general accuracy increase around 10%. Land cover classification from uncorrected and corrected data differed in a large portion of the total studied area, with values around 29% for all correction methods.

Introduction

The capability of Landsat images to provide information for reliable and detailed land cover/use mapping is restricted by radiometric effects caused by atmosphere and topography. The topographic effect is evident in rugged terrain, and it is caused by the differential spectral radiance due to surface slope angle and aspect variations in combination with solar zenith and azimuth angles (Holben and Justice, 1980). This effect imposes an additional degree of variability on radiometric data within any particular land cover, despite that it does not correspond to true spectral response variations. Consequently, errors may be introduced during image classification, decreasing classification accuracy.

The topographic correction methods can be grouped into three main categories: band ratioing, empirical or semi-empirical and physical based methods (Wen et al., 2009; Zhang and Gao, 2011; Balthazar et al., 2012). Except for the methods based on band ratioing, the correction techniques depend on topographic data, which relatively restricted their application in many regions until the recent availability of digital elevation models (DEM) of broad coverage, like SRTM (Rabus et al., 2003) and GDEM (ASTER GDEM Validation Team, 2009).

Several studies had proposed the evaluation of topographic correction methods, the majority reported improvements after correction (Colby, 1991; Riaño et al., 2003; Cuo et al., 2010;

* Corresponding author. Tel.: +55 12 3208 6437; fax: +55 12 3208 6488.
E-mail addresses: eder@dsr.inpe.br, edericm@hotmail.com (E.P. Moreira), valerian@dsr.inpe.br (M.M. Valeriano).

http://dx.doi.org/10.1016/j.jag.2014.04.006
0303-2434/

Veraverbeke et al., 2010; Hantson and Chuvieco, 2011, for example), but in some cases the correction was not satisfactory (Blesius and Weirich, 2005; Zhang et al., 2011). Noteworthy in many of these studies was the superior performance of semi-empirical corrections, such as, C and the empiric-statistic corrections (Teillet et al., 1982), and Minnaert correction (Smith et al., 1980). In addition, the adapted SCS correction method is appropriated for forest canopies areas (Soenen et al., 2005), while others are more appropriate for non-forest cover types (Gu and Gillespie, 1998).

The approach to apply the correction methods is one of the factors that affect the correction performance, especially the strategy to estimate the empirical parameters for the semi-empirical methods, such as the constant k_λ for Minnaert correction and the parameter c_λ for C correction (Reese and Olsson, 2011). Some authors estimate the correction parameters in a generalized form, i.e., based on a single set of samples comprising different land cover types observed in the area (Teillet et al., 1982; Riaño et al., 2003; Vanonckelen et al., 2013). Others use a land cover map as a guide to stratify the parameter estimation and for the correction of the data (Smith et al., 1980; McDonald et al., 2000; Kobayashi and Sanga-Ngoie, 2009). Some authors state that estimated parameters by land cover classes generate better results and are more suitable than the generalized form (Teillet et al., 1982; Riaño et al., 2003; Kobayashi and Sanga-Ngoie, 2009). Since the parameters are estimated based on functions (e.g., correlation) that include spectral values and solar illumination angle on the slope ($\cos i$), more than a single land cover type is supposed to disturb them due to the specific backscattering behavior of each land cover type (Goel, 1988).

To overcome the need of a previous land cover map in the above mentioned strategy, some authors choose stratifying the data into groups or spectral classes, e.g., by thresholding the NDVI, to estimate distinct correction parameters to apply the correction separately for each land cover type (Bishop and Colby, 2002; Bishop et al., 2003; Hantson and Chuvieco, 2011). In relation to this strategies, we state that the spectral classes defined prior to topographic correction are influenced by topographic effect and can be a source of error for the estimation of the correction parameters and thus for the topographic correction. As an another intermediate approach, which is based on the work of Civco (1989), a single land cover type (called main cover type) is selected to estimate the correction parameters to be applied in the correction of the whole image. This strategy has not yet been tested with different methods, especially in areas with several land cover classes.

The main land cover strategy does not require a land cover map when the parameters are estimated based on samples of the main land cover type collected, e.g., through image interpretation or fieldwork. The main task of this study was to evaluate selected topographic correction methods where there is not a previous land cover map. Considering this strategy, to apply the correction method, it is reasonable to expect that some land cover classes may have a less efficient correction compared to the main land cover, but in many cases the main land cover occupies the larger proportion of the area or is the only mapping objective (Rudorff et al., 2010; Hansen and Loveland, 2012; Vibrans et al., 2013).

Vanonckelen et al. (2013) summarize several studies dealing with the impact of the topographic correction on land cover classification results. It can be observed that most land cover classifications applied in these studies is based on maximum likelihood classification algorithms, as a consequence of the state-of-art of classification methods at the time of those developments. We sought to evaluate the impact of the correction method on object-based classification that employs image segmentation and decision tree classification (Benz et al., 2004; Strobl et al., 2009). This classification method enables the evaluation of topographic correction methods by other strategies, such as, the object (or region) feature and structure of the decision tree.

These constraints led to the objective of this study, which is to apply and evaluate semi-empirical topographic correction methods aiming to improve the capability of satellite images to generate more reliable land cover mapping using object-based classification. The strategy to estimate the topographic correction parameters based on the main cover type is hypothesized to be appropriated to reduce the topographic effect.

Materials and methods

Study area

The study site is an agricultural region of Brazil in the south of Minas Gerais State, with undulating relief type, chosen for its varied conditions of both illumination and land cover types (Fig. 1). It is an area of 11.5 per 11.5 km located in the municipalities of Alfenas and Machado and it is covered predominantly by

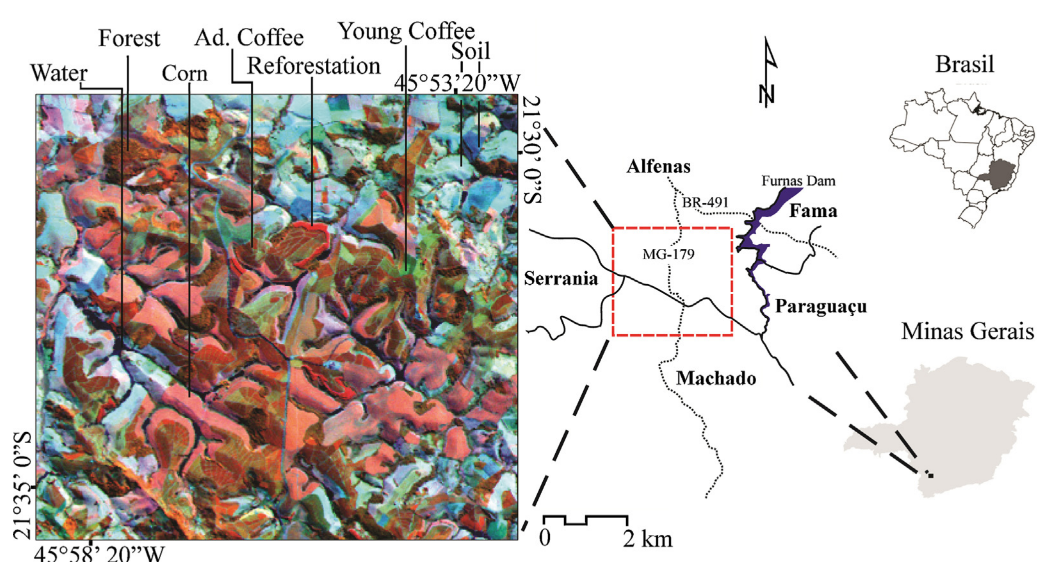

Fig. 1. Location of the test site in south of Minas Gerais State, Brazil. Landsat 5 TM 453 (RGB) composition with the identification of the land cover types.