

Variações da reflectância e dos índices de vegetação em função dos parâmetros da modelagem topográfica no Parque Estadual do Turvo, Rio Grande do Sul, Brasil

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William Gaida*
Fábio Marcelo Breunig*
Lênio Soares Galvão**
Thiago Sousa Teles**
Rafael Balbinot*

Resumo: Técnicas de sensoriamento remoto têm sido amplamente utilizadas em estudos florestais, por permitirem avaliar e monitorar importantes áreas florestais, como as do Parque Estadual do Turvo (PET). O PET é o maior remanescente de floresta subtropical decídua do sul do Brasil. Contudo, fatores externos como efeitos topográficos podem influenciar a resposta espectral dos alvos nos produtos de satélites. Este estudo teve como objetivo avaliar a magnitude das variações na reflectância de superfície e nos índices de vegetação em função das características topográficas locais. A metodologia desenvolvida incluiu a aquisição de dados do sensor RapidEye e o modelo digital de elevação ASTER GDEM 2. O efeito da variação da geometria de iluminação foi avaliado a partir de duas cenas RapidEye: junho e outubro de 2012. Dados de orientação de vertentes, altimetria e relevo sombreado foram gerados a partir do ASTER GDEM 2,

permitindo avaliar o efeito topográfico sobre a reflectância e os índices de vegetação *Normalized Difference Vegetation Index* (NDVI) e *Enhanced Vegetation Index* (EVI). Os resultados mostraram que as variáveis topográficas afetam a reflectância de todas as bandas RapidEye e os índices de vegetação, especialmente o EVI. Os efeitos topográficos foram mais pronunciados em junho (maior ângulo zenital solar - AZS) do que em outubro (menor AZS). O NDVI foi menos afetado pelas variações sazonais das condições de iluminação e da fenologia do que o EVI. Quanto a orientação, os maiores valores de reflectância e índices de vegetação foram encontrados na orientação norte e os menores na orientação sul.

Palavras-chave: Sensoriamento remoto, estudos florestais, geometria de aquisição de dados, relevo.

* Universidade Federal de Santa Maria (UFSM), Departamento de Engenharia Florestal, Linha Sete de Setembro s/n, sala 59, bloco de apoio 4, CESNORS/UFSM, 98400-000, Frederico Westphalen, RS, Brasil. Tel.: 55 37448964 ext. 8783. E-mail: ufsm.william@gmail.com; breunig@ufsm.br; rafaelbalbinot@gmail.com

** Instituto Nacional de Pesquisas Espaciais (INPE), Divisão de Sensoriamento Remoto, Caixa Postal 515, Av. dos Astronautas, 1758, Bairro Jardim da Granja, 12245-970, São José dos Campos, SP, Brasil. Tel.: 55 12 3208-6443. E-mail: lenio@dsr.inpe.br; tsteles@dsr.inpe.br

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Variations of reflectance values and vegetation indices as a function of topographic modeling parameters in the Parque Estadual do Turvo, Rio Grande do Sul, Brazil

Abstract. Remote sensing techniques have been widely used in forestry studies as they allow evaluation and monitoring of large forested areas. The Parque Estadual do Turvo (PET) (17 491 ha) is the largest remaining tract of well-preserved subtropical deciduous forest in Southern Brazil, it constitutes the northern-most portion of the Misiones forest of Argentina (10 000 km²). The area is of great environmental importance and is suitable for conducting remote sensing studies using high or even coarse-to-moderate spatial resolution data and related vegetation indices. Both, reflectance values and vegetation indices are affected by external factors that modify the spectral response of surface elements. Among the factors that can induce errors in image interpretation are topographic effects that add spectral variability to satellite products. In addition, previous studies in subtropical forests have shown that the geometry of data acquisition also affects significantly the estimates of vegetation parameters derived from images acquired at off-nadir viewing or by sensors with large field-of-view (FOV).

This study aimed to evaluate the magnitude of variations in bidirectional reflectance values and in vegetation indices derived from those, as a function of local topography, using high spatial resolution data acquired by the RapidEye satellite constellation.

The method included the use of a digital elevation model (DEM) from the Advanced Space-borne Thermal Emission and Reflection Radiometer – Global Digital Elevation Map version 2 (ASTER GDEM v2) and two RapidEye scenes. From the DEM, topographical parameters including slope aspect (eight classes), elevation (nine classes with 120-m spacing interval) and shaded relief (shaded, intermediate and sunlit surfaces) were derived. These data provide information on areas with or without direct exposure to solar radiation, depending on topographic features. RapidEye data were acquired on June 28, 2012 and October 17, 2012, corresponding to dates when the forest shows low or high leaf area index (LAI), respectively. Both scenes were acquired with a view angle close to nadir. Solar elevation angles for the June and October images were 37.93° and 71.25°, respectively. The RapidEye data were corrected for atmospheric effects using the Fast Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH[®]). The next step was to perform topographic modeling in order to extract slope, aspect and elevation data. From the topographic variables and the RapidEye metadata, shaded relief was calculated for both scenes. After segmenting the scenes based on the topographic variables, we evaluated the spectral reflectance and vegetation indices, as measured by RapidEye, as a

function of topographic parameters. For this purpose, we randomly sampled 1000 pixels from each topographic class. The Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) were calculated from the RapidEye data. The samples were averaged and analyzed using graphics and descriptive statistics. Select transects were analyzed in more detail to evaluate the effects of local topographic parameters on the remote sensing products. In addition, we conducted forest surveys in 14 plots (20 x 50 m) to produce a floristic-structural characterization of the deciduous forest.

The field inventories identified a total of 74 plant species (in 31 families) distributed in three strata and showed the presence of discontinuities within the forest. The results showed that, in addition to seasonal phenological variations, local illumination conditions caused by the relief in the PET contributed to explain the forest spectral response. The topographic variable that most importantly affected the PET spectral response, as measured by RapidEye, was slope aspect. Despite being affected by varying illumination conditions in the two dates, the reflectance and vegetation indices of the June image were most impacted by the shaded relief caused by the low solar elevation and large amount of shadows in the scene. The illumination effects were compounded by the seasonal leaf shedding in the deciduous forests, especially in the upper canopy layer. The winter time (June) scene showed more shaded relief and lower LAI values. In the October scene the shade fraction was substantially reduced and leaf shedding reduced the forest canopy anisotropy. A per band analysis showed that the red and near infrared bands were the ones with the highest dependence on aspect and shaded relief. Increases in elevation caused a positive change in near infrared reflectance and a lower reflectance in the visible bands. The NDVI showed lower dependence on topographical conditions than the EVI. The EVI showed higher sensitivity to illumination conditions, shade and seasonal LAI variations.

We concluded that the analysis of remote sensing data (reflectance values or vegetation indices such as NDVI and EVI) should take into account local topographic effects. In general, the spectral anisotropy in the June scene was higher than in the October scene due the combined effect of deciduousness (leaf shedding), the lower solar elevation and larger amount of shadows.

Keywords: Remote sensing, forestry studies, data acquisition geometry, relief.

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