Geofísica Internacional (2014) 53-2: 117-133

Original paper

Morphologic analysis of the temporal change of forest cover

Jorge Lira

Received: November 22, 2012; accepted: July 25, 2013; published on line: April 01, 2014

Resumen

En este trabajo se presenta un análisis morfológico de cobertura forestal en un lapso de doce años. Se emplearon dos imágenes multiespectrales LANDSAT TM-4 de los años 1989 y 2001. Estas imágenes cubren un área forestal donde han ocurrido cambios significativos en tales años. Estas imágenes fueron expandidas en términos de variables canónicas que describen la respuesta espacial-espectral de las masas forestales. Las imágenes fueron modeladas como un campo vectorial de tantas dimensiones como bandas empleadas en el análisis. Se construyó un campo vectorial usando las bandas de variables canónicas.El conjunto de variables canónicas fue usado para cuantificar el cambio vectorial de las masas forestales. Este cambio vectorial cuantifica el grado de alteración de las masas forestales. Se empleó un algoritmo de crecimiento de regiones para segmentar las áreas ocupadas por el bosque. Este algoritmo emplea como entrada las variables canónicas. El resultado de tal segmentación es una imagen binaria llamada el bitmap. A partir de este bitmap, se llevó a cabo un análisis morfológico del área ocupada por el bosque. Se empleó un DEM generado a partir de un par interferométrico del satélite RADARSAT-1 para realizar una referencia cruzada con los bitmaps. Esta referencia cruzada conduce a la determinación de las elevaciones a las cuales ocurren los cambios de las masas forestales.

Palabras clave: cobertura forestal, variables canónicas, morfología, crecimiento de regiones.

Abstract

A morphologic analysis of forest cover in a time span of twelve years is presented in this work. Two multispectral LANDSAT TM-4 images of the years 1989 and 2001 were used. These images cover a forest area where significant changes have occurred in such years. These images were expanded in terms of canonical-expansion variables that describe the spatial-spectral response of the forest masses. The images were modeled as a vector field of as many dimensions as the number of bands employed in the analysis. A vector field was constructed using canonical-variable bands. The set of canonical variables for each year was used to quantify a vector change of the forest masses. This vector change quantifies the degree of alteration of the forest masses. A region-growth algorithm was used to segment the areas occupied by the forest. This algorithm uses as input the canonical variables. The result of such segmentation is a binary image named the bitmap. From this bitmap, a morphologic analysis of the area occupied by the forest was undertaken. A DEM generated from a radar interferometric pair of the RADARSAT 1 satellite, was used to perform a cross-reference with the bitmaps. This cross-reference leads to the derivation of the elevation of occurrence of changes in the forest masses.

Key words: forest cover, canonical variables, morphology, region growing.

J. Lira
Instituto de Geofísica
Universidad Nacional Autónoma de México
Ciudad Universitaria
Delegación Coyoacán, 04510
México D.F., México
Corresponding author: jlira@geofisica.unam.mx

Introduction

The analysis of vector change is used in this work to quantify the change of forest cover in the environs of Mexico City. The vector change is combined with morphologic analysis to derive quantitative evolution of the forest cover. A number of methods of vector change have been published in the literature (Allen and Kupfer, 2000; Fraser *et al*., 2005; Nackaerts *et al*., 2005; Sanchez Flores and Yool, 2007).

A number of change indices have been used to quantify change of temporal phenomena such as deforestation, desertification, urban growth or land cover change (Johnson and Kasischke, 1998; Le Hégarat-Mascle and Seltz, 2004; Cakir *et al*, 2006). A detailed account of change detection methods is given in Coppin *et al*. (2004). Several methods of change detection in remote sensing are given in Canty (2007). Recent advances in tropical forest cover used parametric classification and change vector analysis to detect unchanged and changed areas in the tropical forest of Amazonia (Raši *et al*., 2013).

In the present work, a multispectral image is modeled as a vector field of as many dimensions as bands employed in the analysis (Lira and Rodriguez, 2006; Lira, 2010). In this model, a pixel is defined as a vector of an equal number of elements as the number of bands. Two LANDSAT TM-4 images are used in this model to obtain the change of forest cover in a time span of twelve years. A co-registration of the images was applied in order to implement our method and to evaluate the forest cover change in the time span.

In the present research, the vector change that experiences the vector field associated to the image was considered (Lambin and Strahler, 1994; Warner, 2005; Sanchez and Yool, 2007; Kontoes, 2008). A set of variables were calculated from a canonical-expansion of the image (Lira and Garcia, 2003). This expansion produces three basic canonical variables that characterize the spatial-spectral state of the forest cover. The use of variables to study land cover change, as a basis for change vector analysis, has been proposed (Lambin and Strahler, 1994; Lambin and Ehrlich, 1997). The original Landsat bands define a 6-dimensional vector field. Instead, the canonical variables define a 3-dimensional vector field.

The set of variables were used in a region-growth algorithm to segment the forest cover. This segmentation produced a two-class image named the bitmap. The bitmap depicts the area of the forest cover and the rest of the image. From the bitmaps of the images, morphologic change was evaluated. A digital elevation model (DEM) was constructed using an interferometric pair of the RADARSAT 1 satellite. The DEM was combined with the bitmaps to derive conclusions on morphologic change of forest cover.

In the present work, one vector field was considered: the vector field formed by the canonical variables. Principal component analysis (PCA) was applied to the set of variables of both images. From PCA, changes of the vector field were assessed. The analysis of vector change based on PCA is used there upon and conclusions on the forest cover change were derived. In the ensuing section of methods, details are provided on the vector field analysis.

Materials and methods

Materials

Two multi-spectral LANDSAT TM-4 images are used in this research. From these images, an area was extracted; the resulting sub-images are dubbed 1989 and 2001. Figure 1 depicts a false color composite of the images of 1989 and 2001. Table 1 shows basic technical details of these images. With the exception of band 6, all the bands of the images were used in our research analysis. Band 6 is not included in the analysis due to a different pixel size.

These images cover an area located to the east of Mexico City where a forest mass surrounds two volcanoes. This forest mass is formed by a mixture of coniferous trees, namely pine, oyamel and cedar (Hernandez García and Granados Sánchez, 2006). From March 1989 to January 2001, this forest mass has experienced a change in extension, morphology and heterogeneity (Rzedowski and Rzedowski. 2005; Hernandez García and Granados Sánchez, 2006). This forest masses will be referred in this research as forest cover. In addition to the LANDSAT TM-4 images, an interferometric pair from the RADARSAT 1 satellite was considered (Table 2). From this interferometric pair, a digital elevation model (DEM) was extracted.

The LANDSAT TM-4 images were geometrically corrected and corregistered using the ephemerides of the orbit. On the generation of the DEM from the RADARSAT 1, ground control points were used to corregister