Remote Sensing of Environment 144 (2014) 152–171

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

Continuous change detection and classification of land cover using all available Landsat data

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ARTICLE INFO

Article history:
Received 25 February 2013
Received in revised form 17 January 2014
Accepted 18 January 2014
Available online 11 February 2014

Keywords:
CCDC
Classification
Change detection
Time series
Land cover
Continuous
Landsat
Random Forest

ABSTRACT

A new algorithm for Continuous Change Detection and Classification (CCDC) of land cover using all available Landsat data is developed. It is capable of detecting many kinds of land cover change continuously as new images are collected and providing land cover maps for any given time. A two-step cloud, cloud shadow, and snow masking algorithm is used for eliminating "noisy" observations. A time series model that has components of seasonality, trend, and break estimates surface reflectance and brightness temperature. The time series model is updated dynamically with newly acquired observations. Due to the differences in spectral response for various kinds of land cover change, the CCDC algorithm uses a threshold derived from all seven Landsat bands. When the difference between observed and predicted images exceeds a threshold three consecutive times, a pixel is identified as land surface change. Land cover classification is done after change detection. Coefficients from the time series models and the Root Mean Square Error (RMSE) from model estimation are used as input to the Random Forest Classifier (RFC). We applied the CCDC algorithm to one Landsat scene in New England (WRS Path 12 and Row 31). All available (a total of 519) Landsat images acquired between 1982 and 2011 were used. A random stratified sample design was used for assessing the change detection accuracy, with 250 pixels selected within areas of persistent land cover and 250 pixels selected within areas of change identified by the CCDC algorithm. The accuracy assessment shows that CCDC results were accurate for detecting land surface change, with producer's accuracy of 98% and user's accuracies of 86% in the spatial domain and temporal accuracy of 80%. Land cover reference data were used as the basis for assessing the accuracy of the land cover classification. The land cover map with 16 categories resulting from the CCDC algorithm had an overall accuracy of 90%.

1. Introduction

Mapping and monitoring land cover have been widely recognized as an important scientific goal (Anderson, 1976; Foody, 2002; Friedl et al., 2002; Hansen, Defries, Townshend, & Sohlberg, 2000; Homer, Huang, Yang, Wylie, & Coan, 2004; Loveland et al., 2000; Wulder et al., 2008). Land cover influences the energy balance, carbon budget, and hydrological cycle as many different physical characteristics change as a function of land cover, such as albedo, emissivity, roughness, photosynthetic capacity, and transpiration. Land cover change can be natural or anthropogenic, but with human activity increasing, the Earth surface has been modified significantly in recent years by various kinds of land cover change. Knowledge of land cover and land cover change is necessary for modeling the climate and biogeochemistry of the Earth system and for many kinds of management purposes. Satellite images have long been used to assess the Earth surface because of repeated synoptic collection of consistent measurements (Lambin & Strahler, 1994).

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http://dx.doi.org/10.1016/j.rse.2014.01.011

1.1. Monitoring land cover change with remote sensing

Images from the Landsat series of satellites are one of the most important sources of data for studying different kinds of land cover change, such as deforestation, agriculture expansion and intensification, urban growth, and wetland loss (Coppin & Bauer, 1996; Galford et al., 2008; Jensen, Rutchey, Koch, & Narumalani, 1995; Seto et al., 2002; Woodcock, Macomber, Pax-Lenney, & Cohen, 2001), due to their long record of continuous measurement, spatial resolution, and near nadir observations (Pflugmacher, Cohen, & Kennedy, 2012; Woodcock & Strahler, 1987; Wulder et al., 2008). One of the drawbacks of Landsat data is the relatively low temporal frequency. For each Landsat sensor, overpasses of the same location occur every 16 days, and data at this temporal frequency are only common within the United States where the sensors are turned on for every overpass. For other parts of the world, the frequency of data collection is generally less, depending on many factors such as cloud cover predictions and availability of international ground stations (Arvidson, Goward, Gasch, & Williams, 2006). Even for images that are collected, clouds reduce the amount of usable data (Zhang, Rossow, Lacis, Oinas, & Mishchenko, 2004). Therefore, most change detection algorithms using Landsat have used two dates of Landsat images (Collins & Woodcock, 1996; Coppin, Jonckheere, Nackaerts, Muys,