Remote Sensing of Environment 117 (2012) 381–393

Contents lists available at SciVerse ScienceDirect

Remote Sensing of Environment

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

Evaluation of Landsat and MODIS data fusion products for analysis of dryland forest phenology

J.J. Walker [a], K.M. de Beurs [b,*], R.H. Wynne [a], F. Gao [c]

[a] Virginia Polytechnic Institute and State University, Blacksburg, VA, USA
[b] The University of Oklahoma, Norman, OK, USA
[c] Hydrology and Remote Sensing Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, MD, USA

ARTICLE INFO

Article history:
Received 9 April 2011
Received in revised form 4 October 2011
Accepted 4 October 2011
Available online 10 November 2011

Keywords:
Land surface phenology
Drylands
Data fusion
Landsat
MODIS
STARFM

ABSTRACT

Current satellite sensors provide data of insufficient spatial and temporal resolutions to fully characterize the patchy phenology patterns of dryland forests. The spatial and temporal adaptive reflectance fusion model (STARFM) is an algorithm that fuses Landsat 30 m data with MODIS 500 m data to produce synthetic imagery at Landsat spatial resolution and MODIS time steps. In this study, we evaluated the feasibility of using STARFM to produce synthetic imagery over a dryland vegetation study site for the purpose of tracking phenological changes. We assembled subsets of six Landsat-5 TM scenes and temporally-coincident MODIS datasets spanning the 2006 April–October growing season in central-northern Arizona, which is characterized by large tracts of dryland forest. To investigate the effects of temporal compositing, BRDF-adjustment, and base pair timing on the accuracy of the resulting synthetic imagery, we employed a range of MODIS 500 m surface reflectance datasets (daily, 8-day composite, and 16-day Nadir BRDF-Adjusted Reflectance (NBAR)) as well as initial Landsat/MODIS imagery pairs from opposite ends of the growing season. The STARFM algorithm was applied to each MODIS data series to produce up to twelve synthetic images corresponding to each Landsat image. We evaluated the accuracy of the synthetic images by comparing the reflectance values of a random sample of the vegetation pixels with the corresponding pixel values of the reference Landsat image on a band-by-band basis. Our results indicate that the NBAR imagery is the optimal dataset for use with Landsat-5 TM data in this area. The NBAR dataset consistently returned the lowest absolute difference values and the highest correlations. A comparison of landscape-scale maps of the timing and value of the peak NDVI derived from STARFM, Landsat, and MODIS (NBAR) time series across the full 2006 growing season shows the effect of the heightened spatial and temporal resolution offered by a STARFM-based dataset. This work demonstrates the feasibility of using the STARFM algorithm to assemble an imagery time series at Landsat spatial resolution and MODIS temporal resolution in vegetated dryland ecosystems.

1. Introduction

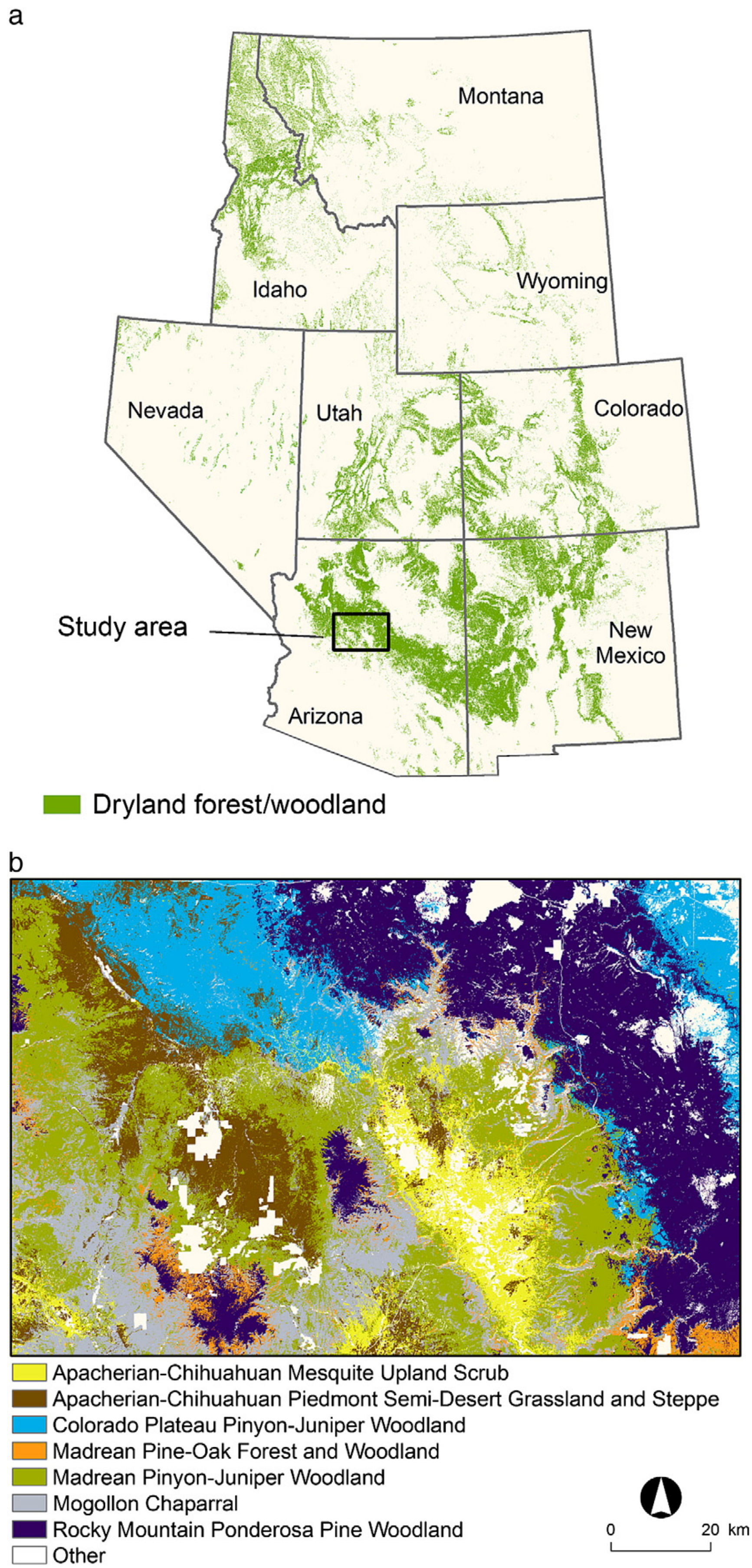
1.1. Dryland forests

Arid and semi-arid ecosystems (i.e., "drylands") are characterized by their scarcity of water; they are typically defined as areas in which annual water loss through evapotranspiration exceeds annual moisture inputs from precipitation (Bailey, 1998; Neary et al., 2002; Safriel et al., 2005). These ecosystems are not exclusively composed of isolated and barren desert landscapes. Of the 41% of the Earth's terrestrial surface that comprises drylands, 18% is covered by forest and woodland systems (Safriel et al., 2005). Dryland forests occupy large swaths of the western conterminous United States; more than 24 million hectares of dryland forest are found in the interior western states (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) (Smith et al., 2009). Extensive tracts of dryland forest are also found in western Texas (Coulston et al., 2010), the southern Black Hills of South Dakota (Shepperd and Battaglia, 2002) and along the central and eastern portions of California, Oregon, and Washington (Bolsinger and van Hees, 1989).

The behavior of dryland forests under altered climatic conditions is a matter of environmental and societal importance given the critical ecosystem services these forests supply to human populations (Safriel et al., 2005). Diverse forest ecosystems may have already begun to respond to the elevated temperatures and/or water stress associated with climate change through an increase in mortality events across the globe (Allen et al., 2010). The sensitivity of drylands to climate variability (Hufkens et al., 2008) may exacerbate the reactions of dryland forests to future climate alterations. Dryland vegetation is acutely vulnerable to changes in rainfall timing or amount (Brown et al., 1997), while drought-induced mortality in dryland tree species has been observed to increase in the presence of higher temperatures (Adams et al., 2009; Breshears et al., 2005). Given

* Corresponding author at: Department of Geography and Environmental Sustainability, The University of Oklahoma, 100 East Boyd Street, Norman, OK 73019, USA. Tel.: +1 405 325 9129; fax: +1 405 325 6090.
E-mail address: kdebeurs@ou.edu (K.M. de Beurs).

0034-4257/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.rse.2011.10.014


a
Montana
Idaho
Wyoming
Nevada
Utah
Colorado
Study area
New Mexico
Arizona
Dryland forest/woodland
b
Apacherian-Chihuahuan Mesquite Upland Scrub
Apacherian-Chihuahuan Piedmont Semi-Desert Grassland and Steppe
Colorado Plateau Pinyon-Juniper Woodland
Madrean Pine-Oak Forest and Woodland
Madrean Pinyon-Juniper Woodland
Mogollon Chaparral
Rocky Mountain Ponderosa Pine Woodland
Other
0
20 km