Remote Sensing of Environment 113 (2009) 657–667

Contents lists available at ScienceDirect

Remote Sensing of Environment

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

Combining remote sensing and ancillary data to monitor the gross productivity of water-limited forest ecosystems

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ARTICLE INFO

Article history:
Received 11 July 2008
Received in revised form 21 November 2008
Accepted 22 November 2008

Keywords:
NDVI
fAPAR
C-Fix
Forest
GPP

ABSTRACT

This paper describes the development and testing of a procedure which combines remotely sensed and ancillary data to monitor forest productivity in Italy. The procedure is based on a straightforward parametric model (C-Fix) that uses the relationship between the fraction of photosynthetically active radiation absorbed by plant canopies (fAPAR) and relevant gross primary productivity (GPP). Estimates of forest fAPAR are derived from Spot-VGT NDVI images and are combined with spatially consistent data layers obtained by the elaboration of ground meteorological measurements. The original version of C-Fix is first applied to estimate monthly GPP of Italian forests during eight years (1999–2006). Next, a modification of the model is proposed in order to simulate the short-term effect of summer water stress more efficiently. The accuracy of the original and modified C-Fix versions is evaluated by comparison with GPP data taken at eight Italian eddy covariance flux tower sites. The experimental results confirm the capacity of C-Fix to monitor national forest GPP patterns and indicate the utility of considering the short-term effect of water stress during Mediterranean dry months.

1. Introduction

Assessing large scale patterns of forest productivity is important for both scientific and practical purposes. Such an assessment is necessary to study the global carbon cycle and can produce useful information for planning and managing forest resources (Corona & Marchetti, 2007; Waring & Running, 2007). Unfortunately, regional-scale applications of field-based measurement techniques are economically expensive and time-consuming, due to the high spatial and temporal variability of the factors which affect forest production (climate, meteorology, topography, soil fertility, management practices, etc.). Thus, a procedure mostly independent of field measurements and driven by remote sensing data would be of extreme utility to routinely yield spatially extended estimates of forest productivity (Running et al., 1999). Trials in this direction have been made in Europe and North America using diverse types of ground and remote sensing data (Papale & Valentini, 2003; Beer et al., 2007; Jung et al., 2008; Running et al., 2004; Veroustraete et al., 2002, 2004; Yang et al., 2007). These studies have generally given promising results but have also indicated the need for improving and standardizing the existing methodologies which work on regional to national scales.

In response to this need research efforts have been recently conducted by our research group on the Italian national territory (Maselli et al., 2006; Chirici et al., 2007). The basic consideration underlying these efforts is that the estimation of forest productivity over large areas is improvable by suitably integrating multi-source remotely sensed and ancillary data. The research therefore aimed at developing a methodology of relatively simple implementation capable of utilizing widely available earth observation and ancillary data. This methodology is based on a straightforward model of forest productivity (C-Fix) which uses the relationship between the fraction of photosynthetically active radiation absorbed by plant canopies (fAPAR) and the productivity of those canopies. The strategy is similar to that originally proposed by Veroustraete et al. (1994), and produced estimates of both forest Gross Primary Productivity (GPP) and Net Primary Productivity (NPP) (Chirici et al., 2007; Maselli et al., 2006). Those experiments, however, did not address the issue of estimating multi-year variations in production patterns, which is relevant especially to evaluate the effects of ongoing changes of climate and land use.

The present investigation is directed to fill this gap by looking through the potential of a similar methodology to analyze multi-year GPP variations of Italian forest ecosystems. Distinctively, C-Fix is applied to a multi-year data set (1999–2006) in order to yield monthly forest GPP estimates on a national scale. A modification of the model is also presented to improve the simulation of forest response to

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doi:10.1016/j.rse.2008.11.008