Agriculture, Ecosystems and Environment 218 (2016) 58–65

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

New forests and Kyoto Protocol carbon accounting: A case study in central Italy

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ARTICLE INFO

Article history:
Received 16 July 2015
Received in revised form 1 October 2015
Accepted 3 November 2015
Available online xxx

Keywords:
Afforestation
Carbon sequestration
Kyoto Protocol
Airborne laser scanning
CO2Fix

ABSTRACT

Forest expansion into formerly agricultural land plays a relevant role for generating carbon sinks eligible under afforestation activities in the Kyoto Protocol (KP) carbon accounting framework. This paper provides a methodological framework for the multi-temporal assessment of carbon accumulated in these new forest stands, at the reference years of the KP commitment periods: remote sensing analyses, integrating optical imagery and airborne laser scanning data with field survey, are combined with the carbon simulation model CO2FIX to project carbon changes. The approach is applied to a case study in the central Apennines (Italy) to assess the carbon sink associated to these new forests at the years 2008, 2012 and 2020. The approach is based on forest cover change detection and growing stock mapping, while the multi-temporal carbon sink analysis is performed by means of the CO2FIX model. In the considered test area, the results highlight a compound annual rate of forest expansion equal to 0.26% for the period 1990–2012. The overall carbon stored by the new stands is 21.1 Mg ha^{-1} (relative standard error less than 10%) at the year 2012, projected to reach 33.5 Mg ha^{-1} at the year 2020.

1. Introduction

Countries ratifying the United Nations Framework Convention on Climate Change (UNFCCC) Kyoto Protocol (KP) are given the option to meet part of their reduction requirements through the carbon credits generated by afforestation activities after 1990 (Article 3.3). The protocol allows sinks associated with woodland creation in abandoned farmland to be included in the national carbon accounting system to offset emissions, provided that forest expansion can be considered a direct human-induced conversion of land that has not been forested for a period of at least 50 years (UNFCCC, 2001). The possibility to include afforestation as permissible offset activity holds also for the second commitment period of the KP (UNFCCC, 2011).

Italy has expressed a formal position to include the carbon sinks generated by forest expansion as afforestation activities; such a widespread woodland creation phenomenon is regarded human-induced, as it is a natural dynamic that would not otherwise occur without intentional agricultural land abandonment. This phenomenon, widely observed in rural landscapes in Italy (Barbati et al., 2013; Cimini et al., 2013; Corona et al., 2008; Piussi and Pettenella, 2000), is common to many countries of the global north (Beilin et al., 2014). Yet, only few studies have quantitatively analyzed the implications of forest expansion in terms of creation of new carbon sinks (Acosta et al., 2005; Conti and Fagarazzi, 2004; Gils et al., 2008; Mazzoleni et al., 2004).

To bridge this knowledge gap, this paper addresses as a main scientific question the experimentation of a methodological approach, founded on the integration of forest mapping and inventory (Corona, 2010; McRoberts, 2010) with carbon modelling, to assess carbon accumulated in forest stands naturally originated by forest expansion, at the reference years of KP commitment periods (2008, 2012, 2020). Distinctively, simple remote sensing analyses are combined with the carbon simulation model CO2FIX (Masera et al., 2003) to project carbon changes (Fig. 1). The approach allows wall-to-wall mapping of above ground carbon stock, suitable to support decision-making at various administrative levels, from municipality up to subnational scale.

Under such a perspective, the proposed approach has been tested in a case study in central Italy. The experimental framework builds on three steps: (1) forest cover change detection to quantify natural afforestation in the period 1990-2012 by means of optical

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http://dx.doi.org/10.1016/j.agee.2015.11.006
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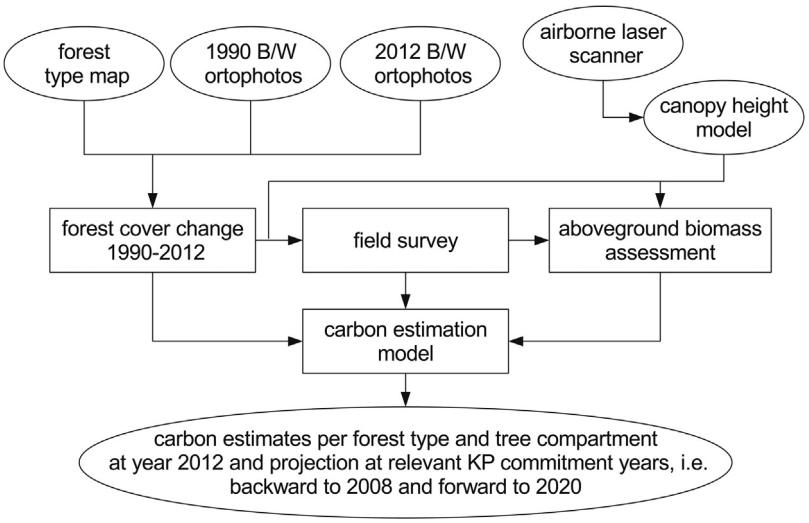

Fig. 1. Methodology approach adopted for the case study.

imagery; (2) above-ground forest carbon stocks estimation in afforested areas at the year 2012, by coupling airborne laser scanning (ALS) data and field survey; (3) estimation of carbon stocks at the years 2008 and 2020 by means of the CO2FIX model. This paper describes and discusses the methodology applied and the results. Highlights on management issues that may become relevant for the second commitment period of the KP are also outlined.

2. Materials and methods

2.1. Study area and available data

The study area is located in the mountain ranges of Gran Sasso e Monti della Laga National Park and covers 26 km^2 (Fig. 2).

Available remotely sensed imagery for the study area was two sets of orthocorrected airborne photos dated 1990 (spring) and 2012 (summer); the 1990 images are black and white one meter/pixel resolution orthophotos, while the 2012 images are half meter/pixel resolution in true-color. A digital terrain model (DTM) and an upper canopy height model (CHM) with pixel size of 1 m^2 were developed from an ALS discrete-return dataset (average data density = 1.5 points m^{-2}; laser wavelength = 1064 nm; light beam width = 1 cm; vertical accuracy = 15 cm) acquired in the spring of 2012.

As further ancillary data, the forest types map of the Gran Sasso e Monti della Laga National Park, dated 2012, was also available; this map adopts the forest definition of the Food and Agriculture Organization of the United Nations (FAO, 2004), with minimum mapping unit of 0.5 ha (nominal scale 1:10,000).

2.2. Forest cover change detection and field survey

Forest cover change in the period 1990–2012 was quantified by the intersection of 1990 and 2012 land cover maps, digitized by on-screen interpretation of the orthophotos. Land cover was mapped into four broad classes: grazing land, forest land, shrub land, other land. The forest class was delineated with a minimum mapping unit of 0.5 ha. The new forest stands at the year 2012 included patches with forest tree vegetation already existing at the year 1990 but whose size was smaller than 0.5 ha at that time.

The National Park forest type (sensu Barbati et al., 2007) map (Fig. 3,Table 1) was applied to stratify the new forest stands, established after year 1990 in the study area, into four physiognomic types: mixed broadleaf forest stands, Turkey oak (*Quercus cerris* L.) stands, European beech (*Fagus sylvatica* L.)

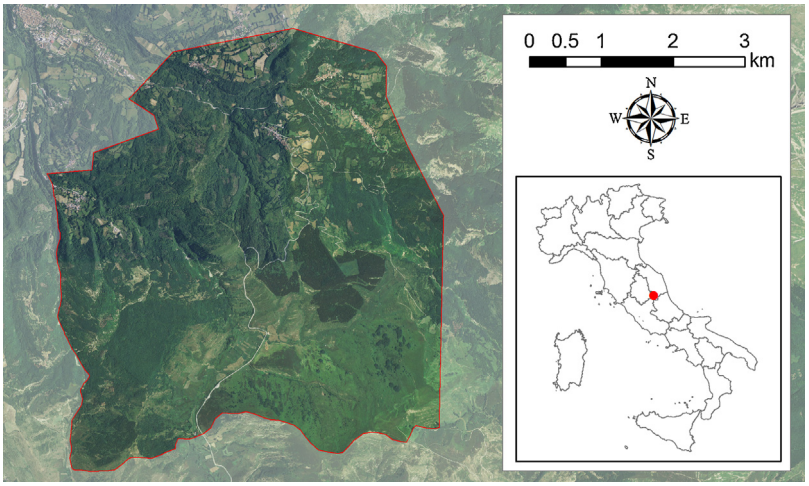

Fig. 2. Study area (upper left: long. 13.286, lat. 42.629; lower right: long. 13.379, lat. 42.570; altitude 734–2458 m a.s.l.).