



INFOCARB: A regional scale forest carbon inventory (Provincia Autonoma di Trento, Southern Italian Alps)

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ABSTRACT

The aim of this inventory (acronym: INFOCARB) was to measure the organic carbon stored in the forest ecosystems of the Trento region (Provincia Autonoma di Trento, Northern Italy) in both above- and belowground pools, according to the Kyoto protocol and IPCC requirements. A total of 150 forest sampling points were selected on the entire regional area (6206 km²) with a statistical sampling approach, based on the timber volume as a proxy variable for a stratified sampling. Each sampling point was located with a GPS receiver and a 600 m² circular plot was delimited around each point. Inside the plots, the biomass of trees, shrubs and herbaceous vegetation was measured, while litter was collected in systematically placed subplots. Topsoil (down to 30 cm depth) was sampled with the excavation method on three systematically located pits, to determine the organic carbon content, the bulk density and the volume occupied by stones and roots.

The inventory estimated the regional total carbon content of the forests as 71.9 ± 5.2 Tg C, with an average carbon density of 207.01 ± 14.5 Mg C ha⁻¹. The aboveground biomass and the soil had a similar carbon content, 43.2% and 44.6% of the total ecosystem carbon, respectively, whereas the root systems and the litter accounted for 9.6% and 2.6%, respectively. Due to the high inter-site variability, only weak statistical relationships were found between the soil carbon content and main ecosystem and climatic variables. However, when dividing the plots into different species-dominated forests, the beech sites differed significantly from the conifer sites in the carbon stock and the C/N ratio in the soil organic layers.

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1. Introduction

The quantification of the carbon (C) stored and sequestered by terrestrial ecosystems is today a key issue because it is required by international agreements such as the Kyoto protocol. Besides, a better understanding of the processes regulating the carbon exchange between terrestrial ecosystems and the atmosphere is crucial (Baldocchi et al., 2001) and long term observations are essential to encourage the increase of the organic carbon content in soils and vegetation, as a possible mitigation strategy of climate change (Jones et al., 2005). Yet, very little information is available today in the literature about the different components of the forest aboveground carbon pools (trees, shrubs, herbaceous plants and litter) and even less of the soil and belowground carbon pools.

Soil organic carbon (SOC) is one of the five carbon pools (thus carbon in storage compartments) whose changes have to be

reported under the Kyoto protocol to the United Nations Framework Convention on Climate Change (Jandl and Olsson, 2007). The other four pools are: aboveground biomass, belowground biomass, deadwood and litter. The distribution of carbon in the vegetation and soil is essential to quantify the magnitude of carbon sinks and sources of forest ecosystems (Baritz and Strich, 2000). Moreover, the role of soil organic matter as a carbon and nitrogen reservoir, the sensitivity of soil organic matter to environmental changes and the use of the C/N ratio as an indicator of ecosystem stability require precise estimates of the soil carbon and nitrogen pools at the global scale (Vejre et al., 2003).

The difference in carbon stocks in repeated forest carbon inventories is used to estimate the carbon sink or source strength of an ecosystem (repeated inventory approach; Rodeghiero et al., 2009). Unfortunately, the few existing studies are often based on data collected on plots that were selected to be typical of a location rather than using a statistical sampling method (Brown and Gaston, 1995; Delaney et al., 1998). SOC contents have been measured following a systematical sampling approach only in

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some countries (e.g. United Kingdom, Denmark, the Netherlands and Slovakia), while non-systematically in many others (e.g. in Belgium, France, Hungary and Italy). Moreover data from national field surveys are often not accessible outside the country of origin (Jones et al., 2005). National forest inventories have been designed primarily to measure traditional forest variables as forest area, stem volume of growing stock and net annual stemwood increment, so they often lack information on coarse woody debris, root biomass, soils and litter (Coomes et al., 2002; Lindner et al., 2004). One of the first studies that provided regional estimates on carbon stocks published in a refereed journal was carried out by Coomes et al. (2002), who reported data for forests and shrublands in New Zealand, including coarse woody debris, fine litter and soils. More recently Hudiburg et al. (2009) summarized a comprehensive assessment of the carbon stocks and fluxes in the Western United States (Oregon and Northern California) and also estimated the forest current and potential carbon storage.

It is well known that soils can store as much or even more carbon than vegetation: the stock of soil organic carbon in forests typically accounts for more than 50% of the total ecosystem carbon (Intergovernmental Panel on Climate Change, 2001) and in some cases it exceeds the carbon stored in the aboveground biomass by three times (Eswaran et al., 1993). Batjes (1996) reports that on average 39–70% of the total organic carbon in the upper 100 cm of mineral soil is held in the first 30 cm, and 58–81% in the first 50 cm.

The measurements of SOC are complex, moreover the large variation in soil organic carbon content complicates the estimate of the organic carbon stock in soils (Jones et al., 2005) with sufficient precision (i.e. low estimate errors) and accuracy (i.e. the closeness to the real value to be measured; Zar, 1996). The reliability of the calculation of the soil carbon pool depends on the correct information on organic carbon concentration and bulk density (Arrouays et al., 2001). Batjes (1996) determined a coefficient of variation (CV) in topsoil organic carbon content between 50% and 150% for the same pedological soil group.

The relationships between soil organic carbon (SOC) and site characteristics have been studied at a local and regional scales (Jenny, 1980) with the aim of creating and evaluating process models and of understanding the possible effects of land use and climate change on the soil carbon stores (Turner et al., 1993). For example, Homann et al. (1995) observed through a regression analysis that almost half of the variation of SOC in forest mineral soils in western Oregon (USA) was explained by a combination of site characteristics. In particular the SOC increased with annual temperature, annual precipitation, actual evapotranspiration, clay content and available water-holding capacity, while it decreased with slope (Homann et al., 1995). Other relationships between SOC and soil texture, mean annual temperature, mean annual precipitation and elevation are reported by various authors (Nichols, 1984; McDaniel and Munn, 1985; Sims and Nielsen, 1986; Burke et al., 1989). A higher accumulation of soil organic matter (SOM) is typically observed in north-facing slopes due to micro-climatic conditions that reduce decomposition (Egli et al., 2009).

The objectives of the present work were:

- To quantify the forest carbon stocks at a regional scale, partitioning it into its four main pools, based on a two phases inventory.
- To investigate the drivers of the SOC contents by examining the correlations between the SOC and ecosystem and climatic variables.
- To create a database that will serve as a baseline to verify future changes in the forest soil carbon stocks.

2. Methods

2.1. Study area and aboveground biomass data collection

The forest inventory was conducted in two phases: in the first phase the entire territory of the Trento region (6206 km²) was partitioned into a 1 km × 1 km grids and a point was randomly located inside each grid according to an unaligned systematic sampling strategy (EPA, 2002). Each point was then examined on high resolution aerial digital photographs and classified into four categories: forest, forest land without trees, other wooded lands and non-forest, according to the FAO (FAO/UN-ECE, 1997) and the Italian National Forest Inventory (De Natale and Gasparini, 2003) definitions. A total of 3390 points (54.7% of the total) were found to be forest points and were associated with a timber volume (m³ ha⁻¹), obtained from the local forest inventory plan (SF-SIAT-PAT, 2000). In the second phase a probability proportional to size (PPS) random sampling method (Thompson, 1992) with empirical inclusion probabilities (Fattorini et al., 2006), proportional to the timber volume, was used to select 150 sampling points. Thus, the timber volume was used as a proxy variable for a stratified sampling, which was chosen to reduce the uncertainty of the measurements (Fattorini et al., 2006). Each of these 150 points was located with a GPS receiver and a circular 600 m² plot, centred on the sampling point, was delimited for the biomass measurements (Fig. 1). The actual size of each plot was adjusted depending on the slope angle of the plot and all trees with diameter at breast height (1.30 m; dbh) >2.5 cm were measured with a caliper. Two dbh were measured at right angles and the trees were identified at the species level. In addition the height of at least 25 trees (selected to be representative of the main trees diameter classes of the plot) were measured with a Vertex hypsometer (Haglöf, Sweden). The height of the remaining trees of the plot was estimated from height–diameter exponential functions (Del Favero, 1980) fitted on the collected data. The aboveground biomass of the trees (including stems, branches and leaves) was calculated with biomass equations, using the tree height and dbh diameter as input variables (see Fattorini et al., 2004). Moreover, wood cores

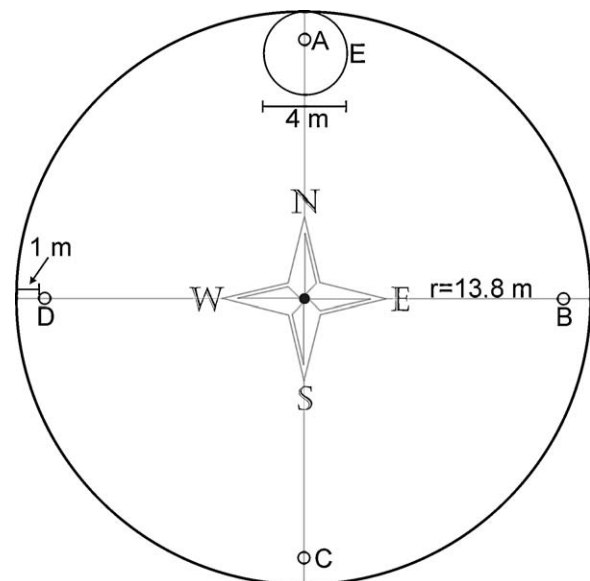


Fig. 1. Plan of the 600 m² sampling plot. Trees with dbh >2.5 cm were sampled on the whole area. Litter and herbaceous vegetation were sampled in the systematically placed subplots, marked with an A, B, C and D. Hemispherical photographs for LAI calculation were taken in the same points other than in the centre of the plot. Shrubs were collected in the point E while soils in B–D.

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