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Carbon allocation dynamics one decade after afforestation with *Pinus radiata* D. Don and *Betula alba* L. under two stand densities in NW Spain

E. Fernández-Núñez[a,b], A. Rigueiro-Rodríguez[a], M.R. Mosquera-Losada[a,*]

[a] Crop Production Department, Escuela Politécnica Superior, Campus de Lugo, University of Santiago de Compostela, 27002 Lugo, Spain
[b] CIMO, Bragança, Portugal

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ABSTRACT

Silvopastoral systems can contribute to the mitigation of climate change by functioning as sinks for greenhouse gases better than exclusively agricultural systems. Tree species, density, and an adequate management of the pasture carrying capacity contribute to the capacity of carbon sequestration. In this study, the capacities for carbon sequestration in silvopastoral systems that were established with two different forest species (*Pinus radiata* D. Don and *Betula alba* L.) and at two distinct densities (833 and 2500 trees ha^{-1}) were evaluated. Tree, litterfall, pasture and soil carbon storage determinations were carried out to deliver carbon sequestration in the different pools within the first 11 years of a plantation establishment. The results show that the global capacity for carbon sequestration in silvopastoral systems with pine canopy was higher than with birch cover. Independently of the forest species, the capacity for carbon sequestration increased when the systems were established at higher plantation densities. There were found strong differences in the relative proportions of carbon in each component of the system (litterfall, tree, pasture and soil). The soil component was found to be most important in the case of the broadleaf forest established at low density. The establishment of a silvopastoral system enhanced soil carbon storage, since afforestation was carried out, which results in a more enduring storage capacity compared with treeless areas.

1. Introduction

Carbon sequestration by forests is an important environmental issue since the Kyoto Protocol (article 3.3) was adopted in 1997 (http://unfccc.int/resource/docs/convkp/kpeng.pdf). That resolution included the removals by sinks that result directly from human-induced land use changes and forestry activities to meet the Kyoto carbon emissions commitments by the involved countries in the determined periods from 1990 onwards (Mosquera-Losada et al., 2009). These facts make reforestation and afforestation, as well as deforestation, very important for the global carbon balance accounting of different countries. Reforestation of agricultural land will not only contribute to an increase in carbon sequestration on a global scale; it will also increase the supply of lumber, reducing the need for the logging of old-growth forests that, consequently, releases high amounts of stored carbon (Nair et al., 2008).

To verify compliance with the Kyoto Protocol, it is vital to measure the carbon sequestration caused by land use changes from agricultural to forestland, as well as the management of these lands. Reforestation of agricultural land has recently been promoted in Europe and has resulted in the reforestation of more than one million hectares throughout Europe between 1994 and 1999 (EC, 2005), a result of the implementation of Regulation No. 2082/92 (EU, 1992). The establishment of agroforestry in forestlands were promoted through direct payments in the last European Union Rural Development Council Regulation 1698/2005 (EU, 2005), making it necessary to evaluate the gains and losses of carbon caused by changes in tree biomass, pasture production, soil organic matter content and livestock greenhouse carbon (GHC) emissions. This also highlights the importance of evaluating the balance of different alternatives of forest management in different environments, as described by Gordon et al. (2005).

Forest carbon stocks are affected by the previous land use, tree species, tree density and the interaction of all these variables with climate (Reynolds et al., 2007).). In an agroforestry system, edaphic carbon is considered the most important store from a quantitative perspective (Dixon, 1995). The capacity to increase the sequestration of carbon in the soil will largely depend on the tree species used in reforestation and their density. Carbon storage in a silvopastoral system is balanced by the

* Corresponding author. Tel.: +34 982252231; fax: +34 982285926.
E-mail address: mrosa.mosquera.losada@usc.es (M.R. Mosquera-Losada).

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