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Taking the pulse of forest plantations success in peri-urban environments through continuous inventory

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Abstract Urban expansion increases the need for, and pressure on, green areas. Reforestation projects in the rural–urban fringe represent an opportunity for enhancing the environmental quality of peri-urban spaces and a means to contribute to cities carbon neutrality policies. Yet, relatively little information exists regarding the long term (10–25 years) survival and growth rate in urban and peri-urban plantations. This paper reports and discusses the results achieved by a reforestation in the peri-urban space of Rome (Italy), 25 years after its establishment. The plantation has been periodically surveyed between 6 and 24 years of age by means of continuous inventories, with the aim of monitoring growth dynamics. Permanent sample plots have been investigated and stratified by tree species composition (broadleaves vs. conifers, single vs. multispecies) for data analysis. On the whole, plantations show suitable results in terms of rate of growth, carbon storage and uptake, especially in coniferous and mixed stands. The average stand volume of the forest plantation, currently ranges from one-and-a third to one-and-a-half times the average values estimated for natural high forest stands of the same age and species groups at country level. The species groups exhibit differential growth patterns over the observed period, that are mainly due to differences in the ecological traits of the planted trees. Ten years after the establishment, the average annual value of carbon uptake in conifer and mixed species group exceeds 10 Mg CO_2 equivalent ha^{-1} $year^{-1}$, a figure corresponding to 4 times the value of deciduous broadleaves (oaks and other species) and 1.5 times the value of evergreen oaks. Twenty years after the establishment, the average annual carbon uptake peaks to 25 Mg CO_2 equivalent ha^{-1} $year^{-1}$ in the mixed species group, exceeds 15 Mg CO_2 equivalent ha^{-1} $year^{-1}$ in the conifers, and ranks between 6 and 12.5 Mg CO_2 equivalent ha^{-1} $year^{-1}$ in the groups dominated by broadleaved species. Overall with a

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surface area just under 300 ha, the carbon uptake level of the Castel di Guido reforestation allows to offset the 0.04% of CO_2 emissions of the city of Rome. Although the spatial coexistence of even-aged plantation blocks characterized by a range of ecological traits, is expected to ensure a more continuous carbon sequestration, being less susceptible to damage of any kind, the current lack of silvicultural management may also lead to degradation processes, by triggering e.g. fuel accumulation and, by consequence, forest fires. In this line, recommendations are provided in order to improve the ecological and functional efficiency of the investigated reforestation. The field experiment demonstrates, ultimately, the capability of the continuous forest inventory to take the pulse over several decades of tree species performance and carbon uptake levels in urban and peri-urban reforestations.

Keywords Peri-urban reforestation · Continuos forest inventory · Growth dynamics · Tree species performance · Carbon sequestration · Carbon uptake

Introduction

As urban populations continue to increase, investing in green spaces has become a key issue for promoting the sustainable growth of rapidly expanding cities (Angel et al. 2011; Oldfield et al. 2013; Ostoic and van den Bosch 2015). These spaces are expected to serve as multifunctional landscapes that capture carbon, mitigate urban heat island, enhance native biodiversity and promote recreation (Nowak 2006; Pataki et al. 2011; Gaffin et al. 2012). Planting trees is one of the primary means to achieve these services, and the benefits of the urban tree canopy are increasingly recognized (Long and Nair 1999; Nowak et al. 2001; McPherson et al. 2005). Several urban reforestation initiatives (sensu FAO 2004) have been undertaken e.g. in the US, Europe, New Zealand (Oldfield et al. 2013) and Japan (Nakamura et al. 2005; Hotta et al. 2015) at city and municipal levels (UN-HABITAT 2015).

At present, despite the huge amount of investments in urban and periurban reforestation, little attention has been paid to monitoring activities aimed to verify the rate of survival and growth of planted trees. Oldfield et al. (2013) show that current experimental research on urban forest plantations covers only short time frames (<5 years after the initial year). Only a few studies provide for monitoring reforestations over decades (e.g. Hotta et al. 2015; Nakamura et al. 2005). Long-term (10–25 years) studies are particularly necessary, in order to understand the performance of the species and to assess the outcome of planting efforts in urban and peri-urban environments. Understanding how species will interact with each other and with their environment is essential to achieve success in reforestation programs (Oldfield et al. 2015), especially under the uncertainties of the effects of global change on forest ecosystems (Jacobs et al. 2015).

At the same time, due to logistic and budgetary constraints, reforested sites often remain unmanaged. The lack of maintenance, combined with high levels of continued disturbances, like wildfires, might negatively affect reforestation success (MacKay et al. 2011). Therefore, it would be crucial to implement permanent monitoring activities in reforestation projects at city and municipal levels, in order to assess the forest plantation success, like any other restoration project (Ruiz-Jaén and Aide 2006). In broad terms, forest monitoring represents an essential prerequisite to support decision-making to