iForest Biogeosciences and Forestry

Commentaries & Perspectives
doi: 10.3832/ifor3943-015
vol. 15, pp. 229-233

Forest plantations with public subsidies: to harvest or not to harvest, this is the question

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In the last three decades the European Union has supported the afforestation of lands previously devoted to agriculture through targeted subsidies, thus enhancing the provision of many ecosystem services (ESs). However, most of these plantations are close or even above the minimum permanence period and will be likely eradicated by landowners to restore the previous land use (*i.e.*, croplands). In this scenario, the investments for carbon (C) sequestration will be nullified and the supply of many other ESs, which have developed along with plants growth, will be drastically reduced. In this commentary, using as reference a case study in the Friuli Venezia Giulia Autonomous Region (NE Italy), we quantify the value of wood production and C sequestration ESs of tree plantations, simulating a present and a future scenario. Our simulations show that by extending the permanence of these stands for 20 more years, a 34% increase of biomass annual Net Present Value will be expected on average, according to its final use. Regarding C sequestration, a total C stock of 167 tC ha^{-1} can be estimated in 40 years, corresponding to a cumulative Net Present Value of more than 11 million euro. Thus, if C sequestration is considered, the overall annual Net Present Value shows a 35% increase on average, when compared to a reconversion to corn. These data suggest the need for a new national and European strategy, which not only considers well-planned new afforestation campaigns, but also aims at maintaining at least part of the afforested lands, thus maximizing ESs and supporting high quality wood production. At the end of the rotation period, new cycles can be promoted on the same surfaces through natural gamic or agamic regeneration. An additional important aspect to consider is also related to the active management of these stands, thus to improve their growth (quantity and quality), *in situ* C storage as well as storage in final products.

Keywords: EU-afforestation Policy, Carbon Sequestration, Italy, Reg. 2080/92, Wood Quality

Recent studies have quantified the reforestation and afforestation potential at both global and national scale, revealing a potential important contribution to ecosystem services' (ESs) provision, first of all climate regulation through carbon (C) sequestration (Calfapietra et al. 2017, Bastin et al. 2019). Recently, urban trees and greenery have retrieved huge interest as a source of many benefits for people health, safety and wellness (Pataki et al. 2021, Wong et al. 2021). However, also tree plantations in peri-urban and rural areas provide several important ESs such as: wood production, climate regulation, habitat provision and recreation (Yamaura et al. 2021). For this reason, in the last thirty years, the European Union has supported the conversion of croplands to forest plantations through many regulations, namely Reg. 797/1985, Reg. 2328 /1991, Reg. 2080/1992, Reg. 1257/1999, Reg. 1698/2005 and Reg. 1305/2013. At the beginning, the introduction of these regulations was mainly aimed at reducing agricultural areas and European food production surplus, thus to maintain stable crop commodity prices (Weber 2000). Since 2000, the economic support to farmers for afforestation has been also pushed by environmental purposes. Several new initiatives have been launched in the last few years to support widespread tree planting in either urban or rural areas. At European level, under the European Green Deal, the EU Biodiversity Strategy for 2030 commits to planting at least 3 billion trees in forests, agroforestry, agricultural and urban areas by 2030. In Italy, the Recovery and Resilience Facility program foresees to plant at least 6.6 million trees around the largest cities to reduce the effects of atmospheric pollution and climate change, while the foundation "Alberitalia" is committed to plant 60 million trees in urban and peri-urban areas, one tree for each Italian citizen. However, little attention has been paid on the fate of the already established forest stands. In

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Received: Aug 03, 2021 - Accepted: Apr 30, 2022

Citation: Olmo V, Sigura M, Alberti G (2022). Forest plantations with public subsidies: to harvest or not to harvest, this is the question. iForest 15: 229-233. - doi: 10.3832/ifor3943-015 [online 2022-07-12]

Communicated by: Giorgio Vacchiano

Tab. 1 - Mean and total costs per hectare for afforestation of agricultural lands aid scheme in Friuli Venezia Giulia (NE Italy) according to Reg. 2080/92, Reg. 1257/1999, Reg. 1698/2005 and Reg. 1305/2013.

Aid scheme	Unit value	Total value
Afforestation cost	4,000 euro ha^{-1}	4,000 euro ha^{-1}
Maintenance costs for the 1st, 2nd, 3rd year	500 euro ha^{-1} year^{-1}	1,500 euro ha^{-1}
Maintenance costs for the 4th-5th year	250 euro ha^{-1} year^{-1}	500 euro ha^{-1}
Premium for income losses	400 euro ha^{-1} year^{-1}	8,000 euro ha^{-1}
Total costs per hectare	-	14,000 euro ha^{-1}
Afforested surface (ha)	-	2,547
Total costs	-	35,403,300 euro

fact, most of the realized plantations are approaching or are above the minimum permanence period (15-20 years) established by the European financing body, allowing the owners to remove them and re-establish the original land use. Thus, despite the interest regarding the possibility to increase the tree capital at national and international level, a deep discussion among policymakers, scientific community and local stakeholders is needed to prevent the loss of important ESs provided by existing tree plantations which would not be offset in the short/medium term by new afforestation practices.

The present commentary aims to enlighten this issue by quantifying the value of wood production and C sequestration ESs of tree plantations realized following the financing schemes cited above in Friuli Venezia Giulia (Northeastern Italy), as a case study representative of a common situation in other Italian and European regions. From 1994 to 2020, following the Reg. 2080/92 and three rural development programs (PSR 2000-2006, 2007-2013, 2014-2020), 2,547 ha have been planted in Friuli Venezia Giulia, corresponding to around 3.5 million trees (Alberti et al. 2014), for an estimated total public investment of more than 35 million euro (Meuro – Tab. 1). Two types of plantations have been subsidized: mixed stands planted for environmental purposes (94% of the total area) and stands for high quality wood production (6% – Alberti et al. 2014). In this perspective, we focus our attention only on mixed stands and we consider two alternative scenarios: harvest 20 years after planting (*i.e.*, at the end of the compulsory rotation period) or prolonging their permanence to 40 years. According to the yield curves developed by Tomat et al. (2005) and Alberti et al. (2006), the total aboveground biomass is expected to be 74 t ha^{-1} and 80 t ha^{-1} at 20 and 40 years, respectively. Alberti et al. (2014) has reported that 24% of this biomass on average is represented by trees of potential high wood quality as not showing any relevant defects such as burls, twisted fibres, tree knots, etc. and potentially able to reach the required size for timber production. A preliminary quality assessment on the oldest plantations in Friuli Venezia Giulia has reported overall good wood technological properties for these trees (Domini et al. 2018).

Starting from these data, we simulated two different scenarios according to the final possible use of the harvested material (fuelwood, wood chips, sliced and rotary cut veneer for furniture) and to the stand permanence (20 years after planting: t_{20}; 40 years after planting: t_{40} – see Appendix 1 in Supplementary material for detailed equations and data sources). As most of the plantations have not undergone any thinning so far (Alberti et al. 2014), biomass at the end of the rotation period was estimated excluding any silvicultural interventions and according to the yield curves cited above. We assumed stumpage prices of 9 (Billi 2019), 20 (Billi 2019) and 55 euro t^{-1} (Camera di Commercio di Cuneo 2018) for wood chips, fuelwood, sliced and rotary cut veneer for furniture, respectively. For all calculations and actualizations, we adopted a discount rate of 1.51%, corresponding to the average interest rate of twenty-year Italian bonds (BTP Rendimenti netti 2021). In order to compare possible owner alternatives, we suppose that at t_{20} the land is converted back to corn with an annual income, EU subsidies included, of 124 euro ha^{-1} year^{-1} (ISMEA 2020). As far as C sequestration is concerned, we quantified the total C stock in the different C pools (above and below-ground tree biomass and soil up to 60 cm depth) using available data for the plantations in the region (Del Galdo et al. 2003, Alberti et al. 2006, Palandrani & Alberti 2019). Litter and deadwood C pools were not considered due to their small contribution to the overall C stock because of the relatively young age of the stands. Thus, we estimated a mean total C stock in mixed plantations of 150 tC ha^{-1} and 167 tC ha^{-1} at t_{20} and t_{40}, respectively (Fig. 1a). Taking into account the initial soil C stock (t_0), this translates into a total mean net annual uptake during the first 20 years of 3.2 tC ha^{-1} year^{-1} and 0.8 tC ha^{-1} year^{-1} in the next twenty years (Fig. 1b). In contrast, C uptake in land remaining cropland under ordinary management conditions can be approximated to zero as the annual C inputs equate the outputs (Alberti et al. 2010).

The annual Net Present Value (NPV) of a plantation (wood) with a minimum permanence of 20 years (t_{20}) using the harvested biomass for energy as wood chips (Fig. 2a) or as fuelwood (Fig. 2b) is estimated to be 39 or 86 euro ha^{-1} year^{-1}, respectively. Considering the annual value of corn (124 euro ha^{-1} year^{-1}), the annual Net Present Value over the next twenty years is 163 and 210 euro ha^{-1} year^{-1}, respectively, mainly because of EU subsidies to support agricultural production. On the contrary, the annual Net Present Value at t_{40}, assuming that 24% of the future total biomass will be employed for the production of sliced and rotary cut veneer for furniture and assuming no subsidies for agriculture, is 69 and 98 euro ha^{-1} year^{-1}. However, such values increase up to 236 and 265 euro ha^{-1} year^{-1} if payments for the stored C (167 euro ha^{-1}

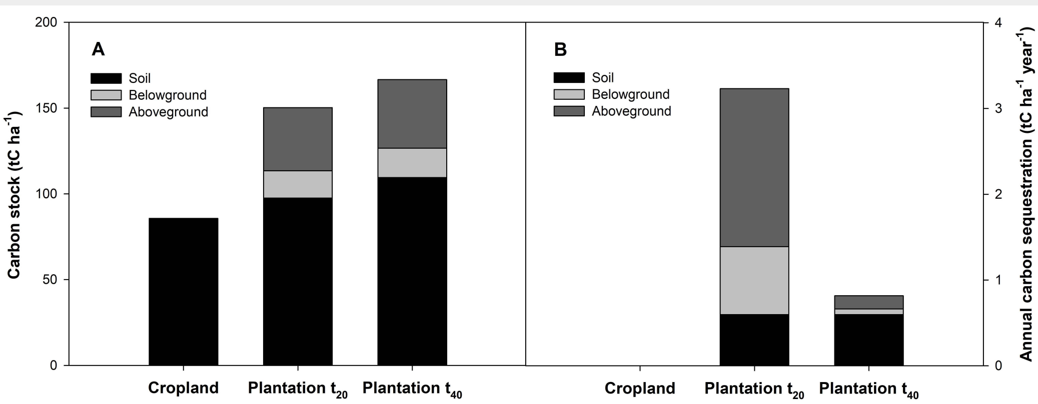

Fig. 1 - Carbon stock (A) and mean annual carbon sequestration (B) in aboveground biomass, belowground biomass and soil (0-60 cm) for cropland (corn) and mixed plantation land use types after 20 and 40 years. Carbon stock in belowground biomass derives from aboveground biomass using a conversion factor of 0.43 (Penman et al. 2003).

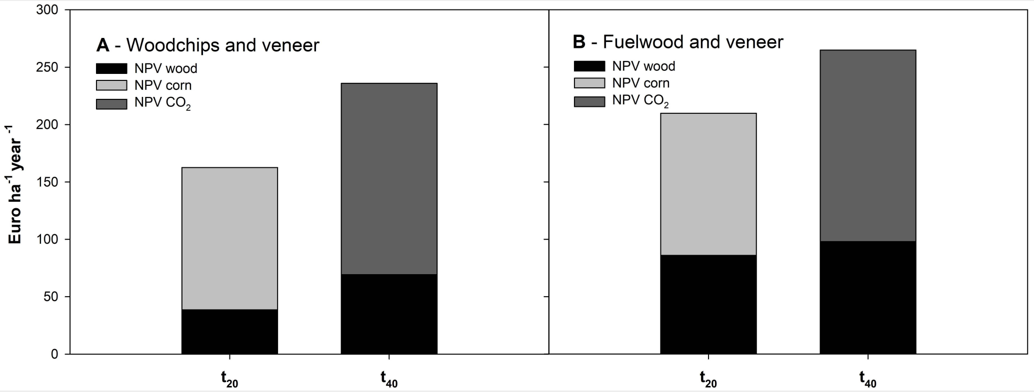

Fig. 2 - Estimated annual Net Present Values (NPV) of Friuli Venezia Giulia mixed plantations after 20 (t_{20}) and 40 (t_{40}) years plantations. t_{20}: Trees removal after 20 years and production of wood chips (A) or fuelwood (B); t_{40}: Trees removal after 40 years and production of sliced and rotary cut veneer for furniture (24% of total biomass) and 76% of wood chips (A) or fuelwood (B). Scenario t_{20} assumes a NPV of the wood of 39 and 86 euro ha^{-1} year^{-1} for wood chips and fuelwood, respectively and 124 euro ha^{-1} year^{-1} as NPV of corn. Scenario t_{40} assumes a NPV of the wood of 69 and 98 euro ha^{-1} year^{-1} for wood chips and fuelwood, respectively and 167 euro ha^{-1} year^{-1} as NPV of CO_2. Stumpage fuelwood price: 20 euro t^{-1} (Billi 2019); stumpage wood chips price: 9 euro t^{-1} (Billi 2019); stumpage sliced and rotary cut veneer price: 55 euro t^{-1} (Camera di Commercio di Cuneo 2018); CO_2 price for t_{40} calculated as the average between 2021 (SENDECO2 2021) and 2030 (Bloomberg 2021) CO_2 price, corresponding to 65 euro tCO_2eq^{-1}.

year^{-1}) are included using an estimated t_{40} CO_2 price of 65 euro tCO_2eq^{-1}, calculated as the average between the current price (SENDECO2 2021) and the projected one to 2030 (Bloomberg 2021). Thus, considering both wood production and CO_2 sequestration, a 45% and 26% increase in annual NVP for wood chips and fuelwood, respectively, will be expected at t_{40} with respect to t_{20}. Such a positive effect could be even larger if plantations would be properly thinned, a practice that stimulates tree growth and C sequestration, improves wood quality and has been demonstrated to be economically affordable for these plantations, when proper mechanization and logistic are adopted (Spinelli et al. 2014). Even if a 10% prudential reduction due to possible disturbances and C losses during the rotation period was considered, the NVP increase at t_{40} would be still positive (31% and 14% for wood chips and fuelwood, respectively).

In order to reveal the total value of C sequestration ES in FVG plantations, CO_2 sequestration Net Present Value was estimated for the 20 and 40-years rotation periods (Tab. 2 – see Appendix 1 in Supplementary material for detailed equations and data sources). Fig. 3 provides the CO_2 accumulation curve in aboveground biomass and its current increment for a period of 40 years, according to Alberti et al. 2006 biomass yield function. In the first 20 years, assuming an average CO_2 price of 15 euro tCO_2 eq^{-1} (SENDECO2 2021), the total C benefit corresponds to a NPV of 4,181 euro ha^{-1}, while, in the next 20 years, assuming an average CO_2 price of 65 euro tCO_2 eq^{-1} (SENDECO2 2021), the total C benefit corresponds to a NPV of 4,475 euro ha^{-1}. Thus, the cumulative NPV of C sequestration of the entire regional area planted with mixed stands (2,547 ha) is around 10.6 MEuro for the first 20-years rotation and 11.4 MEuro for the next 20 years (Tab. 2). C sequestration potential and, consequently, his NPV would be drastically increased if new afforestation is realized alongside the oldest one and a proper management is adopted in the latter, also in view of the expected future rise in CO_2 price (SENDECO2 2021).

Tab. 2 - Mean annual carbon and CO_2 sequestration per hectare after 20 (t_{20}) and 40 years (t_{40}) since planting and associated economic value of the ecosystem service estimated by final accumulation of limited deferred annuities. The CO_2 price for t_{20} is calculated as the average between 2008 and 2021 CO_2 price (SENDECO2 2021), corresponding to 15 euro tCO_2eq^{-1}, while the estimated future CO_2 price for t_{40} is calculated as the average between 2021 (SENDECO2 2021) and 2030 (Bloomberg 2021) CO_2 price, corresponding to 65 euro tCO_2 eq^{-1}. A discount rate of 1.51%, corresponding to the average interest rate of twenty-year Italian bonds, is adopted (BTP Rendimenti netti 2021).

Parameters	0-20 years	20-40 years
tC ha^{-1} year^{-1}	3.23	0.82
tCO_2 ha^{-1} year^{-1}	11.85	2.99
euro tCO_2^{-1}	15	65
CO_2 Net Present Value (euro ha^{-1})	4,181	4,475
Hectares	2,547	2,547
CO_2 Net Present Value (euro)	10,649,637	11,396,914

All these data support the idea that plantations in the plain, if properly managed throughout the rotation period, might represent an important economic source for the landowners, also considering that most of them have been realized on marginal land. Furthermore, the reported data underline the potential of these stands to contribute to the climate change mitigation effort, as also recently underlined by Magnani & Raddi (2021). However, a careful planning of new plantations in space

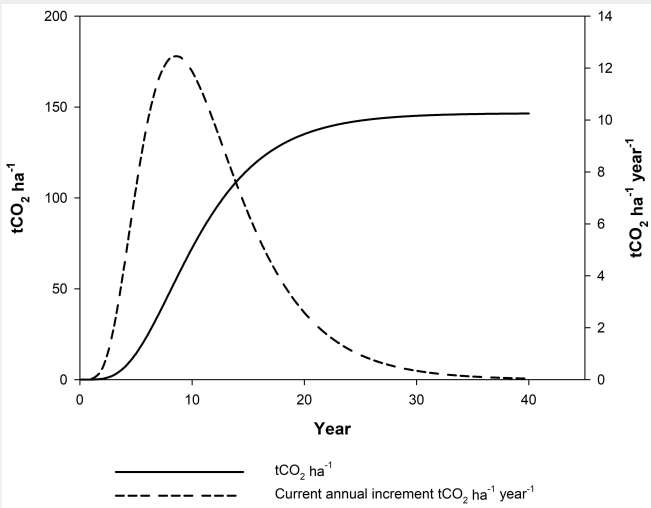

Fig. 3 - CO_2 accumulation curve in the aboveground biomass according to the age of the plantation and current annual increment. The curve is derived from biomass yield function = 80 [1 - exp(-0.21 year)]$^{5.4}$ from Alberti et al. (2006).

and time is needed in order to not vanish all the benefits already gained with existing stands. In fact, our simulations suggest that maintaining at least a quote of afforested land in the next programming period for the rural development policy will be essential to not waste all the C gained in the last 20 years, which could not be immediately restored in new plantations as, while C storage is a slow process ("slow-in"), the C release after re-conversion to the original land use is a fast process ("fast-out"). We expect that all the C gained in tree biomass (above and below) and in the soil in the last 20 years will be re-emitted into the atmosphere in 1.5-2.0 years if plantations would be re-converted in agricultural areas (Murty et al. 2002). Furthermore, by prolonging the permanence of forest plantations for 20 more years and assuming the use of 24% of harvested material for furniture production, a portion of the C removed from forests through harvest will be stored in the so-called harvested wood products (HWP), often for many decades (Stockmann et al. 2012). This form of C stock is particularly significant since, as underlined in the New EU Forest Strategy for 2030, can extend the C removal period from the atmosphere. Thus, targeted afforestation campaigns might gradually compensate over time for CO_2 emissions caused by the partial re-conversion of the oldest stands back to cropland. This combined strategy (maintenance of part of existing stand and new afforestation programs) will also enhance the ecological connectivity and will support biodiversity conservation, which are fundamental for overall ESs provision in the often poorly connected and ecologically monotonous cultivated landscape. However, prolonging the permanence period over 20-30 years might require changes in the actual regional legislations, which consider plantations older than 30 years as woodlands, with the consequent possible legislative constrains (*i.e.*, the impossibility for the owner to re-convert the plantation to cropland without specific authorization).

In conclusion, we encourage a mechanism of subsidies in the next application of EU's Common Agricultural Policy (*i.e.*, rural development plan) to support owners who will maintain their plantation while adopting proper management (*i.e.*, pruning, thinning, etc.) to improve either the overall tree quality and to increase the C sequestration. An alternative to maximize the success of afforestation programs could combine compensation with marked-based tools. In the national context, many voluntary markets and funding for ESs strategies, with particular reference to forest projects of emission compensation, have been launched in the last decade (CREA 2021). More recently, the European Commission's Carbon Farming initiative should activate an institutional system of payment for C sequestration in farm- and forestland before the end of 2022, thus becoming a leverage to promote further afforestation of agricultural land. In this context, subsidies will compensate for the existing supports to agriculture and together with marked-based tools will act as a form of quasi-payment for the ES of climate regulation. Both will simultaneously favour the permanence of the already stocked C and its further sequestration through both old and new plantations growth. Furthermore, the expected future rise of C sequestration value, driven by higher projected CO_2 price, further endorse this strategy (Bloomberg 2021). Asking for proper plantation maintenance goes in the direction of additionality to a "business as usual" scenario as well as will favour an improvement of the stems' quality with a consequent increase in the overall stand value. Moreover, an active management of these plantations will support further *in situ* C sequestration as well as in final wood products at the end of the rotation period. New cycle could be started after the final harvest using natural (gamic or agamic) regeneration, thus further enhancing the C uptake and maintaining all the other ESs in the long term. As a final consideration, it should be mentioned that although afforestations have been supported at national and European level as important measures to deliver multiple ESs, their success depends ultimately on farmer- or owner-level decisions. Some negative aspects, such as management costs and administrative burdens, may be associated to these measures. Therefore, considering stakeholders' perceptions on afforestation projects is essential to design effective policy measures and tools (García De Jalón et al. 2018).

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Supplementary Material

Appendix 1 - Detailed description of equations and data sources used to estimate the value of C sequestration and wood production ecosystem services under the two scenarios presented.

Link: Olmo_3943@suppl001.pdf