

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.

From 1994 to 2020, 2,547 ha have been planted in Friuli Venezia Giulia (FVG – Alberti et al. 2014). Alberti et al. (2014) made a survey of the plantations in FVG established before 2002 (Reg. 2080/92 and PSR 2000-2006), which correspond to 1,996 ha, 78% of the total plantations established until now. According to this study, 52.5% of the plantations in FVG are mixed stands established for environmental purposes and 47.5% are stands for high quality wood production. However, only 13.2% of the latter are pure stands, while the remaining part is comparable to mixed stands in term of composition and stem planting densities. Thus, mixed stands account for the 94% of total area in FVG. On average, 24% of the standing biomass is represented by trees of potential high wood quality (Alberti et al. 2014) and 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.

In order to quantify the value of wood production and carbon sequestration ecosystem services (ESs), 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) of the harvested material and to the stand permanence (20 years after planting: t_{20} ; 40 years after planting: t_{40}). 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).

We assumed the following stumpage prices:

Use	Price (€ t ⁻¹)	Reference	Year	Notes
Wood chips	9	Billi 2019	2018	Average price for Italian mixed deciduous and coniferous forests
Fuelwood	20	Billi 2019	2018	Average price for Italian mixed deciduous forests (<i>Quercus cerris</i> , <i>Fagus sylvatica</i> , <i>Castanea sativa</i> , <i>Quercus spp.</i>)
Sliced and rotary cut veneer	55	Camera di Commercio di Cuneo	2018	Average price for Italian mixed deciduous forests (<i>Prunus avium</i> , <i>Fraxinus spp.</i> , <i>Quercus petraea</i>).

The annual net present value (NPV) of wood used either for wood chips or fuelwood over 20 years at t_{20} was calculated by initial accumulation of limited deferred annuities according to the following equation:

$$a = A_0 \frac{r q^n}{q^n - 1}$$

where a is annual value, A_0 is total value at t_{20} , r is the rate of interest, q^n is the delay factor, with q calculated as $(1+r)$ and n equal to 20 years.

Assuming a reconversion of the plantation to cropland at the end of the 20-years rotation (t_{20}), the annual NPV of corn has been summed to the annual NPV of wood (39 and 86 euro ha⁻¹ year⁻¹ for wood chips and fuelwood, respectively). According to Ismea 2020, the annual income, EU subsidies included, for a farm producing corn representative for the Friuli Venezia Giulia region (mean farm surface below 20 ha) is 124 euro ha⁻¹ year⁻¹ (greening contribution included). Thus, the total NPV for wood chips and fuelwood is 163 and 210 euro ha⁻¹ year⁻¹, respectively.

The annual NPV of wood used either for wood chips or fuelwood, considering a 24% high quality biomass for the production of sliced rotary cut veneer, at t_{40} was calculated by final accumulation of limited deferred annuities according to the following equation:

$$a = A_n \frac{r}{q^n - 1}$$

where a is annual value, A_n is total value at t_{40} , r is the rate of interest, q^n is the delay factor, with q calculated as $(1+r)$ and n equal to 20 years.

Assuming the maintenance of the plantation for 20 more years and a payment for the C sequestration ES, in t_{40} the resulting annual NPV of wood (69 and 98 euro $\text{ha}^{-1} \text{year}^{-1}$ for wood chips and fuelwood, respectively) has been summed to the annual NPV derived from CO_2 sequestration (167 euro $\text{ha}^{-1} \text{year}^{-1}$). The sequestered CO_2 at t_{40} was derived from the total C stock (above and below-ground tree biomass and soil up to 60 cm depth) estimations using existing yield curves (Del Galdo et al. 2003, Alberti et al. 2006, Palandrani & Alberti 2019). 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. This translates into a total mean net annual uptake during the first 20 years of 3.2 $\text{tC ha}^{-1} \text{year}^{-1}$ (11.8 $\text{tCO}_2 \text{ ha}^{-1} \text{year}^{-1}$) and 0.8 $\text{tC ha}^{-1} \text{year}^{-1}$ (3 $\text{tCO}_2 \text{ ha}^{-1} \text{year}^{-1}$) in the next twenty years (Tab. 2). The estimated CO_2 price for CO_2 NPV at t_{40} was calculated as the average between 2021 (SENDECO₂ 2021) and 2030 (Bloomberg 2021) CO_2 price, corresponding to 65 euro $\text{tCO}_2 \text{ eq}^{-1}$. The total NPV for wood chips and fuelwood, taking into account also C sequestration, is then equal to 236 and 265 euro $\text{ha}^{-1} \text{year}^{-1}$, respectively.

The net present value of CO_2 sequestration ES at t_{20} and t_{40} was calculated by final accumulation of limited deferred annuities according to the following equation:

$$A_n = a \frac{q^n - 1}{r}$$

The CO_2 price for t_{20} was calculated as the average between 2008 and 2021 CO_2 price (SENDECO₂ 2021), corresponding to 15 euro $\text{tCO}_2 \text{ eq}^{-1}$, while the estimated future CO_2 price for t_{40} was calculated as the average between 2021 (SENDECO₂ 2021) and 2030 (Bloomberg 2021) CO_2 price, corresponding to 65 euro $\text{tCO}_2 \text{ eq}^{-1}$. The total value for C sequestration service is 4,181 and 4,475 euro ha^{-1} at t_{20} and t_{40} , respectively.