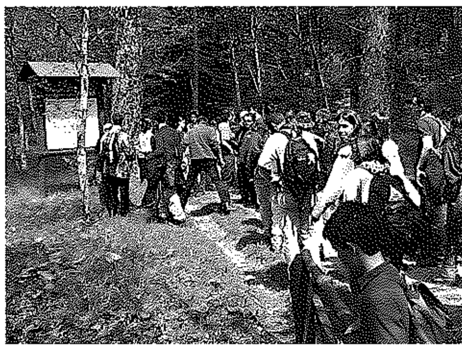
L. Cesaro
P. Gatto
D. Pettenella
(eds.)

The Multifunctional Role of Forests – Policies, Methods and Case Studies



Università degli Studi di Padova

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To the Memory of Maurizio Merlo

'There is a social profitability if forest management is such to produce not only timber but also other social services of unpriced values, such as protection of the environment, watershed regulation, recreation ..... '

Maurizio Merlo wrote this in 1986, as the concluding remarks to a Seminar of the European Association of Agricultural Economists on 'Multipurpose Agriculture and Forestry' held in Motta di Livenza, Italy. A few words reminding us how the concept of multifunctionality was even then animating the meetings of the Society of Forest Economists, of which Maurizio was a distinguished member. After twenty years, we – Maurizio's colleagues and friends who also participated in those discussions – met again in Padova to commemorate his work and retrace our steps and progress along the path of forest multifunctionality.

Maurizio died at the end of August 2003 at the age of fifty-nine, leaving a sudden void in our scientific community. Those who had the pleasure of meeting Maurizio and working with him had always acknowledged his special gifts as a researcher and an academic. He had the intuition of a forerunner, always pioneering innovative research paths; he was endowed with a sensitive grasp of the real world problems and an innate problem-solving capacity; he had valuable communication talent. He deeply and sincerely loved his work and pursued it with constant and tireless day-by-day commitment.

Of all the issues underpinning the discussion on multifunctionality in this book, Maurizio's scientific work was mostly focused on three main questions: the economic evaluation of non-market outputs and services, production relationships and the related optimisation of the multifunctional use of forest resources and, lastly, the design of appropriate policy instruments to pursue multifunctionality.

Today that multifunctionality has become one of the key-concepts in rural development, we take pleasure in dedicating this book to the memory of Maurizio Merlo, in the belief that it contributes to the debate on the role of multifunctional and sustainable forest management to which he devoted such a large part of his research effort.

Ottone Ferro, Francesco Lechi, Vasco Boatto, Edi Defrancesco, Giuseppe Stellin,
Luca Cesaro, Paola Gatto, Davide Pettenella, Giovanna Toffanin

Padova, May 2008

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Executive Summary

This book focuses on forest multifunctionality in its different economic connotations. The fact that multifunctionality is deeply embedded in the nature of forests seems never to have been questioned. However, several definitions of multifunctionality have been proposed over the years from various perspectives: biological, ecological, functional and managerial. Forest economists themselves have been discussing the economic nature of multifunctionality and its consequences on resources allocation for a long time, but they all seem to agree that forest multifunctionality can be meant as the capacity of forests to provide a large array of goods and services – private and public, market and non-market – at the same time.

The idea of multifunctionality, which nowadays might appear to some analysts as fully explored and thoroughly understood, gained new political momentum in 1992, when it was placed by the United Nations Conference on Environment and Development at the core of the definition of the Principles of Sustainable Forest Management: '*...policies, methods, and mechanisms adopted to support and develop the multiple ecological, economic, social and cultural roles of trees, forests and forest lands*'. In 1998, when the European Union adopted its Forest Strategy, the attractiveness to policymakers of multifunctionality as the leading principle for forest management was once again stressed.

More recently, the entry in force of the Kyoto Protocol and the consequent emphasis of the role of forests in the mitigation of climate change, has introduced another good reason for reconsidering the role of multifunctionality in forest management. Trees and woodlands are expected to produce a new kind of public good, and the requirement for a 'human-induced' nature of the provision of C-sink services may trigger new and different compositions of the bundle of private and public goods supplied.

The joint provision of goods and services in the forestry sector is also frequently justified on ethical grounds, recalling the necessity to maintain the capacity to satisfy the needs of future generations. However, as stated by the OECD in 2001 and shown by economics research in this field, multifunctionality in forest production can also represent, from a strictly financial point of view, an option that is cheaper than separate, specialised provision of individual commodities and services. Indeed, a high level of technical interdependence exists among inputs as well as outputs – forest production, biodiversity conservation, protection and provision of rural values in general. This close relationship, together with the existence of economies of scope makes the provision of separate products more difficult to achieve and probably less efficient than the joint production of an equal bundle of goods and services.

Even in the light of these few comments, the subject of forest multifunctionality appears far from obsolete. Conversely, some newly-emerged key issues call for further consideration within a perspective of forest economics and management. The Conference held in Padova at the end of April 2005 and these Proceedings try to provide ground for discussion, voice some of the main concerns, and identify the main research paths.

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A first question is the role of policies: multifunctionality implies problems in forest policy implementation and conflicts between stakeholders. These relate to the joint supply of multiple commodity and non-commodity outputs and the fact that some of the non-commodity outputs are public goods or externalities. In addition, the nature of the jointness among forest outputs is rather complex: relationships of complementarity, indifference or, even more complex to deal with, competition, arise. In order to optimise the multifunctional role of the forest sector, public intervention is needed. As a consequence of the different economic structure of the outputs (private, public, common, club goods), the idea has been proposed that a mix of different instruments should be used. Part 1 of this book contributes to the development of this issue, suggesting that multifunctional management of forests is (or should be) the result of a combined use of regulatory, financial and market instruments. In this context, a governance structure based on a wide participation of stakeholders from institutions and civil society appears to be the most appropriate one for the mitigation of existing conflicts, as underlined by the papers presented in Part 2.

Modern governance systems rely not only on institutions, networks and instruments for policy implementation, but also on the availability of information systems. These can be referred to different spatial scales: a forest region, a single forest enterprise and even a single tree. Multifunctionality can therefore be the result of either a joint provision of several outputs from one individual forest enterprise or of a spatial differentiation at local scale based on a mosaic of specialised forest activities. The topic of 'scale' is transversal to all the contributions in Part 3, casting light on the issue of additionality of forest multiple outputs and stressing once more the importance of the dimension and the level at which managerial decisions are taken.

Poor or asymmetric information also affects the knowledge of values and public perception of public goods and externalities – and sometimes also of market goods. As the papers in Part 4 show, the scenario of forest products and markets is rapidly changing: new products are emerging, often competing with the traditional ones. Globalisation of timber markets and the consequent entrance of new forces and agents are the cause of market tensions and rapid alterations to the price systems, to which some consumers and institutional procurement policies seem to react with an increasing awareness towards social responsibility in the purchase of wood products.

On the other side, the production of non-market goods and services, described in Part 5, still involves some problems in the definition – and acceptance – of appropriate evaluation methods. The characterisation of forest production as a mixed public/private good and the consequent unclear definition of property rights has clear policy and management implications, both in the way distributional and intergenerational questions are considered, and the different actors that are involved in the decisional process at micro and macro level. The papers in Part 5 thoroughly discuss the methodological and operational gaps still existing in the environmental economics approaches, but also show, within these limits, how the environmental and social values produced by multifunctional forest management can often be far more important than the strictly financial revenues of timber production.

Effects of Environmental Benefits from Afforestation on Optimal Harvesting Age in a Mediterranean Marginal Area

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Abstract

This study compares the effect of environmental benefits and subsidies under EU afforestation measures on optimal rotation for new multi-purpose plantation forests in Calabria, a Mediterranean marginal area in the South of Italy. The environmental benefits considered are groundwater recharge, soil erosion reduction and carbon sequestration for three types of marginal land such as arable, pasture and non-cultivated land. Results show, if environmental benefits are considered in the economic valuation of forest plantations the optimal rotation age is increased. Environmental benefits can contribute up to 278 €/ha and year for selected tree species. Furthermore, results show that, in terms of groundwater recharge and soil erosion reduction, afforestation of pasture and non-cultivated land, results in a cost to society that can vary between 35 €/ha and 168 €/ha. Afforestation of arable land provides a benefit that can vary between 61 €/ha and 115 €/ha.

Keywords: afforestation; multi-purpose plantation forest; environmental benefits; Faustmann approach

1. Introduction

An important aspect in the analysis of benefits from plantation forests is the choice of the optimal timber extraction. As pointed out by Hartman (1976) information provided by models, such as the Faustmann model, that consider timber benefits only, may be incorrect as the inclusion of environmental benefits may change the optimal harvesting age. However, as shown by Bowes and Krutilla (1989) the effect on optimal age depends very much on the kind of environmental benefits that are considered. As indicated by Pearce (1991, 1994) afforestation does not always provide net environmental benefits as the overall impact depends on several factors such as the changes in carbon sequestration, soil erosion, and the water balance.

Since 1992 afforestation of land was supported by the European Union (EU) through Regulation EEC 2080/92 with the objective of controlling agricultural production and providing environmental benefits. In 1999 several rural development measures previously applied, including Regulation EEC 2080/92, were unified in a single legislative document. This was the Regulation EC 1257/99, modified in 2003 by Regulation EC 1783/2003. However these last two legislations do not bring in any new elements in the afforestation measures already implemented through Regulation EEC 2080/92.

By using the data related to the afforestation measures implemented in Calabria under EU Regulation EEC 2080/92, Tassone, Wesseler and Nesci (TWN) in a previous work (2004) analyze the impact of carbon sequestration benefits on the optimal harvesting age of plantation forests. TWN show that the inclusion of carbon sequestration benefits lengthens the optimal rotation age whereas the provision of financial incentives to encourage afforestation as set under EU Regulation EEC 2080/92 shortens it; moreover they show that harvesting choices based upon private interests, especially under a subsidy scheme, can lead to a considerable social loss.

In this study we expand the previous research of TWN by including additional environmental effects provided through afforestation such as groundwater recharge and soil erosion reduction. We compare the optimal rotation age with and without environmental benefits. If the rotation ages do not differ, we can conclude that private incentives comply with social incentives. Social incentives are defined as the optimal rotation age of a plantation forest where private plus net environmental benefits are maximized. When the rotation ages differ, private incentives diverge from social ones. In this case, subsidies can be used to provide private incentives for changing the rotation age towards the socially desirable one. Consequently, we add to our analysis the payment of subsidies as set under Regulation EEC 2080/92 and analyze whether they provide incentives for the private forest owner to meet or at least to come closer to the socially desirable rotation age. Moreover, we show the environmental gains and losses for each environmental effect for three types of marginal land afforested.

The paper is divided into 6 sections. A brief description of the study area and background data is provided in Section 2. An evaluation of environmental benefits from afforestation is given in Section 3. Section 4 deals with the monetary quantification of the estimated environmental benefits. Results and conclusions are presented in Sections 5 and Section 6.

2. Evaluation of environmental benefits from afforestation

To assess the environmental benefits promoted through afforestation, it is important to consider that Calabria is a region with a very complex geological structure and an uneven landscape (Regione Calabria 2000). Therefore, we restrict our analysis to a representative area from the region. The selection of this area was not an easy task as some data indispensable for the analysis such as precipitation and evapotranspiration are only available for some areas of the Calabria region. Considering these aspects the Petrace watershed was chosen with an extension of 407 km^2 and an average altitude of 568 m. (Maione et al. 2002) with cambisol as the main soil type present using the FAO-UNESCO (1981) classification.

According to the data provided by the Calabrian Regional Councillorship (2003), 74% of the total land afforested under Regulation EEC 2080/92 was arable land, 24% pasture land and the remaining 2% was non-cultivated land. In our analysis, we differentiate between these three types of land. As farmers can choose between several trees species for afforestation, three representative species were chosen for this study among the three common types of plantation forests (conifer, walnut and cherry, other broadleaf) that are supported in Calabria under Regulation EEC 2080/92. The selected species are silver fir (*Abies alba*) as a representative species for conifers, walnut (*Juglans regia*) to represent walnut and cherry plantations, and beech (*Fagus sylvatica*) to represent other broadleaves. We include walnut and cherry plantations separately as they are distinct by wood quality, growth rate and ground water recharge from other broad leafs planted in the area.

We evaluate the environmental benefits from groundwater recharge and soil erosion reduction when each of the typology of marginal land considered in the analysis is afforested. We refer only to soil erosion due to rainfall events. The estimation of the amount of groundwater recharge is based on the integrated model DSS (Spatial Decision Support system for effects of afforestation on groundwater recharge on a large scale) developed by Kros et al. (subm.) For the evaluation of soil erosion we refer to the Revised Universal Soil Loss Equation whose factors were calibrated for the study area by Aronica et al. (2002).

2.1 Groundwater recharge

The groundwater recharge (GR) in year (t) calculated for each land use, arable land, pasture, non-cultivated land and forest land and expressed in m³/ha/yr is the precipitation reaching the ground, the precipitation excess, PE, minus the runoff and equal to:

$$GR(t) = PE(t)\cdot(1-fr)\cdot\Omega \quad (1)$$

The precipitation excess PE in mm/yr, given for each land use type and at each t, is multiplied by the hydrological runoff fraction for each land use fr and then converted into m³/ha/yr by using the factor Ω with $\Omega = 10$ m²/ha. The amount of precipitation excess is the difference between the precipitation and the sum of the rainfall evaporated and caught by the vegetation calculated as follows:

$$PE(t) = P(t) - rfLAI(t)\cdot[IN(t) + EV(t)] \quad (2)$$

$P(t)$ is the precipitation in mm/yr, $IN(t)$ and $EV(t)$ in mm/yr represent the interception of the canopy and the evapotranspiration for each type of land use, $rfLAI(t)$ is a reduction function for the leaf area index (LAI). The interception of the canopy $IN(t)$ is calculated as a fraction (f) of precipitation:

$$IN(t) = f\cdot P(t) \quad (3)$$

where f is equal to 0.1 for arable land (grain production), 0.05 for pasture and non-cultivated land and 0.2 for forest land (Kros 2002). In the case of forest land the values given to IN and EV refer to a mature forest with a stable canopy. In our analysis we consider the life-span of a forest plantation from planting to harvesting and therefore use the leaf area index, $rfLAI$, to correct for a growing canopy till year 40 where we assume the plantations reaches a stable canopy. The age at stable canopy of the forest is different from the age at maturity of the forest, which is assumed to be 100 yr. The $rfLAI(t)$ is equal to 1 in the case of arable land, pasture and non-cultivated land. The leaf area index increases for new forest plantation over time. In the case of forest land the $rfLAI(t)$ can be expressed as:

$$rfLAI(t) = \frac{1}{1+e^{-K_{gl}\left(age_{vg}+t-\frac{1}{3}T_{N1/2}\right)}}, (4)$$

where K_{gl} in (l/yr) is the logistic average growth rate constant of the tree stem, age_{vg} is the initial age of plantation trees planted and t is the current age of the plantation forest. The last term in the brackets, $\frac{1}{3}T_{N1/2}$, reflects the common assumption (Kros 2002) that the life-time for leaves is three times as low as the natural half life-time at maturity, $T_{N1/2}$, for stems, assuming $T_{N1/2}$ to be 50 yr.

For the value of K_{gl} we use general values for a medium class of soil fertility as provided by De Vries et al. (1990) According to these values, K_{gl} is equal to 0.042 1/yr for beech and 0.090 1/yr for fir. As values for walnut are not reported we use the same as for beech. With regard to the initial age of the forest, after examining several projects presented to the Calabrian Regional Councillorship for the afforestation of marginal land under Regulation EEC 2080/92, we found that bedding plants of about 2 years were planted. Therefore, age_{vg} is set equal to two.

The average precipitation, P in the Petrace watershed is equal to 1238 mm/yr. This value is obtained by calculating the mean of the precipitation data of several weather stations in the watershed namely Cittanova, Gioia Tauro, Molochio, Oppido, Palmi, Rizziconi, Santa Cristina d'Aspromonte, Santa Eufemia, Scilla and Sinopoli as provided by Ciancio (1971).The only data available for the study area on evapotranspiration (EV) are those for grassland by Cantore and Pontecorvo (1988). These data are available for various stations within the Petrace watershed. We have thus used the mean value of the EV for grassland in the study area which is equal to 600 mm/yr. In our analysis grassland is not included among the land uses considered, but we assume that the EV of grassland is equal to the one of pasture and non-cultivated land. EV in the case of arable land and forest within the study area will be estimated as a percentage of the EV for pasture and non-cultivated land. According to Kros (2002) EV in the case of arable land is about 38% of that for pasture and non-cultivated land and about 84% for forest land. Therefore, in the Petrace watershed EV is equal to 220 mm/yr for arable land and 500 mm/yr for plantation forests.

To obtain the value for ground water recharge, GR (Eq. 1), once the PE is calculated, it is necessary to calculate the hydrological runoff fraction, fr, where fr represents that fraction of precipitation excess that does not contribute to groundwater recharge. The runoff fractions vary according to various factors such as the type of land use, the soil characteristics, the intensity of precipitation and the slope (Maione 2002: 286). For the choice of the fractions to be used in this analysis we first searched for studies that have been carried out in Calabria. The few studies available e.g. Avolio et al.1980; Ferrari et al. 2002) refer to specific sites with specific conditions and therefore the runoff values vary considerably. This limits the choice of an average value. We therefore decided to use standard values generally accepted within the literature. According to Costantinidis (1981) and Schwab et al. (1955) considering medium condition of soil and slope (10%) the value of the runoff fraction, fr, is for arable land 0.60, pasture 0.36 and forest land 0.35. As data for non-cultivated land are not available we assume that the runoff fraction for this typology of land equals the one for pasture land. At year zero when trees are planted we assume the runoff fraction in the new plantation forests equals the value of the runoff fraction given for arable land (0.60). From there onwards the runoff fraction linearly decreases to 0.35 at year 40 and is assumed to remain constant thereafter.

As a result, the total groundwater recharge for the different types of land use is about 570 mm/yr for agriculture land and 734 mm/yr for pasture and non-cultivated land. For forest plantations from 40 years of age onwards they are about 679 mm/yr for conifers and about 771 mm/yr for broadleaves (walnut and beech). Generally, during the early growth periods trees use more water than any other vegetation. Hence, water recharge in forests during the early years is less than under arable land. In general, the decrease in water recharge is larger when coniferous species than broadleaves are planted.

2.2 Soil erosion

We follow the study by Aronica et al. (2002) to quantify the soil erosion in the Petrace Watershed and assess annual soil erosion at each station and for each of the four typologies of land. We interpret the mean value for each type of land as the mean annual soil erosion $SE(t)$ in the Petrace watershed. The values are 11.35 tons/ha/yr for arable land, 3.50 tons/ha/yr for pasture and non-cultivated land, and 0.13 tons/ha/yr as an average value for forest land. In our analysis, we consider a plantation forest. Thus we assume that at year zero the value of soil erosion for the plantation forest equals the one for arable land (11.35 tons/ha/yr) and linearly decreases till year 40 when it is equal to the value given for a mature forest and remains constant for the following years.

3. Monetary quantification of environmental benefits

3.1 Methodology

This section presents three possible scenarios to estimate the optimal harvesting age T and the corresponding annuity of plantation forests set up through EU afforestation measures in Calabria. We refer to the afforestation measures implemented under Regulation EEC 2080/92 since the application of other subsequent legislations do not bring any relevant changes. We first calculate the optimal rotation age considering timber benefits only. We then add afforestation subsidies and recalculate the optimal harvesting age. Finally, we add environmental benefits.

We assume that all trees are harvested simultaneously, costs, prices of timber, value of environmental benefits, discount rates and growth function of the trees remain constant over time and there are no scale effects. We consider an infinite rotation model. The reader can refer to the previous work by TWN for a detailed description and explanation of private costs and benefits used in the analysis (wood volume data, prices of timber, costs of afforestation, maintenance costs, opportunity costs of land, represented by farmers' loss of income as a consequence of the afforestation of agricultural land, harvesting costs assuming a clear-cut).

Furthermore, the discount rate r applied in this analysis corresponds to the same one used by TWN and is set equal to 5.2%. All results presented refer to the incremental benefits of one ha of afforested land. We differentiate between private benefits, environmental benefits and social benefits (the sum of private and environmental benefits). All scenarios present the incremental net-benefits from afforestation. The opportunity costs of land are included under the annual costs.

- *Scenario A: Private harvesting age - timber benefits only -*
  Optimal private harvesting age, T^*, and corresponding average annual return (annuity) are calculated considering only the benefits of timber sale (Faustmann approach) as presented in TWN using the following objective function:

$$\max_T \{[B_P(T) - C(T)] \cdot CRF\} \quad (5)$$

where $B_p(T)$ are the private benefits and $C(T)$ the private costs over time period T expressed in present value. The terms are multiplied by the Capital Recovery Factor (*CRF*) to obtain the annuity. The discounted value of private benefits is equal to:

$$B_P(T) = P \cdot v(T) \cdot q^{-T} \quad (6)$$

where the price of timber (P) is multiplied by the volume of wood (v) at T and multiplied by the discount factor q^{-T}.

The present value of the costs is calculated as:

$$C(T) = C_h(T) \cdot q^{-T} + \sum_{0}^{T} C_p(t) \cdot q^{-t} \quad (7)$$

The harvesting costs, (C_h) at T are discounted by q^{-T}. The annual costs (C_p) include afforestation costs, maintenance costs of woodland and the constant opportunity costs of land. They are discounted by q^{-t} and summed up over T years.

- *Scenario B: Private harvesting age - with subsidy -*
  The private benefits include not only timber value but also the subsidies provided under Regulation 2080/92. As set by the Regulation, harvesting is not permitted until 20 years after planting. Considering the constraint T>20 the optimal rotation age and annuity for all plantations are calculated according to

$$\max_T \left\{ \left[B_P(T) - C(T) + S(C,T) \right] \cdot CRF \middle| T > 20 \right\} \quad (8)$$

  $S(C,T)$ presents the total amount of subsidies paid out over 20 years in present value terms. The subsidies under EEC 2080/92 cover the establishment and maintenance costs of the timber plantation during the first ten years. They are reimbursed after farmers' have submitted an application. As the subsidies are not independent from planting trees they do affect the optimal rotation rate. In fact, they reduce the optimal rotation rate as benefits at the early age of the forest do increase.

- *Scenario C: Optimal harvesting age - with environmental benefits -*
  Optimal rotation age T^* is found by adding environmental benefits $B_E(T)$ to Eq. (5). We thus define the objective function as:

$$\max_T \left\{ \left[B_P(T) + B_E(T) - C(T) \right] \cdot CRF \right\} \quad (9)$$

  The present value of environmental benefits is given by:

$$B_E = NPV_{GR}(T) + NPV_{SE}(T) + NPV_{CS}(T) \quad (10)$$

  The terms NPV_{GR}, NPV_{ER}, and NPV_{CS} represent the net-present value (NPV) for groundwater recharge, soil erosion reduction and carbon sequestration over time period T, respectively.

  Subsidies are not included in Scenario C as they are considered to be income transfers. Furthermore, we also calculate the optimal harvest time considering only one environmental benefit at a time.

Finally, all calculations are made for each land use type and each species considered in the analysis. However, where we do not distinct between values for type of land or species we refer to their mean value.

3.2 Benefits and costs of groundwater recharge

The net present value of the groundwater recharge, NPV_{GR}, at harvesting time T, when afforesting land is equal to:

$$NPV_{GR}(T) = P_{GR}\sum_{0}^{T}\left[\Delta GR(t)\cdot q^{-t}\right] \quad (11)$$

where P_{GR} is the price of groundwater, $\Delta GR(t)$ in m³/ha/yr the net yearly increase (or decrease) in groundwater recharge due to afforestation and q^{-t} as defined before. In this paper we value groundwater by the price for water from a well. According to the Land Reclamation Cooperative of Reggio Calabria the average market price of water from a well is equal to 0.06 € per cubic meter of water and equals the social price of water.

3.3 Benefits and costs of soil erosion

The net present value of soil erosion reduction NPV_{SE} at T is equal to:

$$NPV_{SE}(T) = \sum_{0}^{T} B_{SE}(t)\cdot q^{-t} \quad (12)$$

where $B_{SE}(t)$ represents the benefits of soil erosion reduction, for each year t, due to afforestation of marginal land.

To show how we proceeded for the estimation of B_{SE} let us assume for a moment that instead of quantifying soil erosion reduction we want to quantify soil erosion. Soil erosion is recognized as a cost to society, however to measure the costs is a controversial issue (e.g. Van Kooten et al. 1989a; Van Kooten et al. 1989b; Van Vuuren and Fox 1989). For the evaluation of soil erosion we need to consider on-site and off-site effects. There are several on-site and off-site damages due to water such as loss of productivity, loss of soil and plant nutrient, textural change, structural damage, field dissection, and sedimentation (Troeh et al. 1991). The main on-site effect is considered to be the loss of agricultural productivity (Miranowski 1984; Van Kooten 1993; Palmquist and Danielson 1989). However, in our analysis, which focuses on the on-site effect data regarding the loss of crop yield are not available for the study region. As an alternative we choose the replacement-cost approach (RCA) as suggested by Hufschmidt et al. (1983) and applied in a number of studies such as Abeygunawardana and Smarakoon (1994) Kim and Dixon (1986) Vieth et al. (2001), to name only a few. The RCA measures the cost of replacing productive assets, in our case the soil, that have been damaged, in our case by erosion. We consider that the process of soil erosion removes a certain amount of soil containing several components required for plant growth (FAO 1986). Consequently, the costs of soil erosion can be calculated by pricing the loss of nutrients, organic matter and soil volume. The benefit of a change in soil erosion $B_{SE}(t)$ in €/ha/yr can be expressed as:

$$B_{SE}(t) = \Delta SER(t)\left[\sum_{j=1}^{n}\left(N_j p_{n_j}\right) + C_f + C_r\right] \quad (13)$$

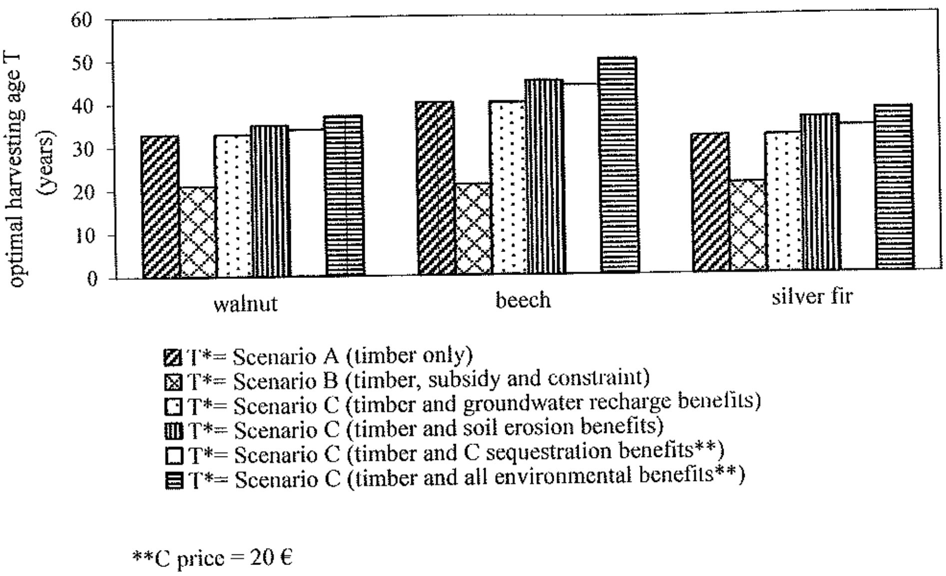

Figure 1. Optimal harvesting age T^* under different scenarios.

where $\Delta SER(t)$ is the change in soil erosion in t/ha/yr multiplied by the value of a ton of soil, the terms in the brackets. The value of a unit of soil is the sum of the soil organic matter and the soil nutrients per unit of soil, multiplied by the market price, $\sum_{j=0}^{n}\left(N_j p_{n_j}\right)$, plus the costs for replacing the soil including freight, C_f, and spreading costs, C_s. N_j for $j = 1, \ldots, n$ is defined as $N_j \equiv n_j \cdot \rho \cdot \phi$ for $j = 1, \ldots, n$ with n_j representing the content of the n^{th} nutrient in mg/liter of soil multiplied by the bulk density factor ρ of ρ=1.5 kg/l and converted into kg/ton by using the factor ϕ= 1000. N_j for $j = 0$ is defined as $N_j \equiv n_0 \Phi$ and provides the contents of organic matter in mg/kg of soil again converted into kg/ton by using factor ϕ. We use for n_j, $j = 1, \ldots n$ and N_0 data published by FAO (Sillanpää 1982). For the content of phosphorus, potassium, magnesium, and calcium we refer to average values given for a Cambisol. These values are equal to 29.5, 179.0, 271.0, 2549.0 mg/litre of soil respectively. The data for nitrogen content in a Cambisol are missing; we use therefore an average value for nitrogen for all soil types in Italy equal to 2674.5 mg/litre of soil. The content of organic matter, n_0, in a Cambisol is equal to $58 \cdot 10^3$ mg/kg of soil. Finally, data regarding average prices of nutrients, organic matter, replacing costs of fertilizer and soil are those used in several projects presented lately at the Calabrian Regional Councillorship of Agriculture (2002). The p_j is equal to 0.15, 0.31, 0.60, 0.30, 0.15 and 0.25 €/kg for phosphorus, potassium, magnesium, calcium, nitrogen and organic matter, respectively. The values for C_f and C_r are equal to 0.05 €/kg and 10 €/ton respectively. Using these data the value of a ton of soil can be calculated. The annual soil erosion reduction, $\Delta SER(t)$, is the difference between the mean annual soil erosion $SE(t)$ from afforested land and from land, differentiated by land use, before afforestation.

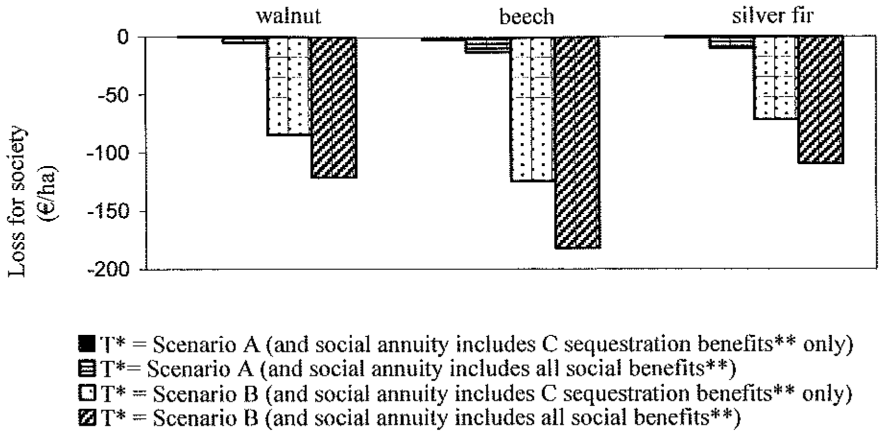

Figure 2. Losses when T^* is set according to Scenario A or B.

4. Results

Figure 1 shows the optimal rotation age under the different scenarios. Under Scenario A the optimal harvesting age T^* is equal to 33, 40 and 32 years for walnut, beech and silver fir, respectively. If the subsidies under Regulation EEC 2080/92 (Scenario B) are added the optimal rotation age is shortened to 21 years for all species. Including environmental benefits (Scenario C) lengthens the rotation age for each species. The optimal rotation age shifts to 37, 50 and 38 years, respectively. The private and the social optimal rotation ages differ and consequently, private incentives do not meet the socially desirable outcome.

The difference between the private and social optimal rotation ages increase under the subsidy scheme as do the social losses as shown Figure 2. Considering carbon sequestration benefits only, the difference between Scenario A and Scenario C is about 0.2 €/ha and year when afforesting with walnut, 1.4 €/ha and year when afforesting with beech and 1 €/ha and year when afforesting with silver fir. If all environmental benefits are considered, the differences increase to about 5 €/ha, 12 €/ha and 10 €/ha and year, respectively. The social losses due to a private optimal rotation rate and the socially desirable one are small. When the rotation age is set according to Scenario B, the social losses increase substantially. When considering only carbon sequestration benefits, the losses are equal to approximately 84 €/ha, 125 €/ha, and 71 €/ha per year in the case of afforestation with walnut, beech and silver fir, respectively. Considering all environmental benefits, the losses increase to 121 €/ha, 182 €/ha and 109 €/ha and year respectively.

Figure 3 shows the social loss or gain on average per year for each of the environmental benefits when afforesting various types of marginal land. No distinction is made between species, thus the annuities considered are the mean values with respect to the three species included in the analysis. The results show when T^* is set according to Scenario A, in terms of groundwater recharge benefits there is a gain of 61 €/ha when afforesting arable land and a

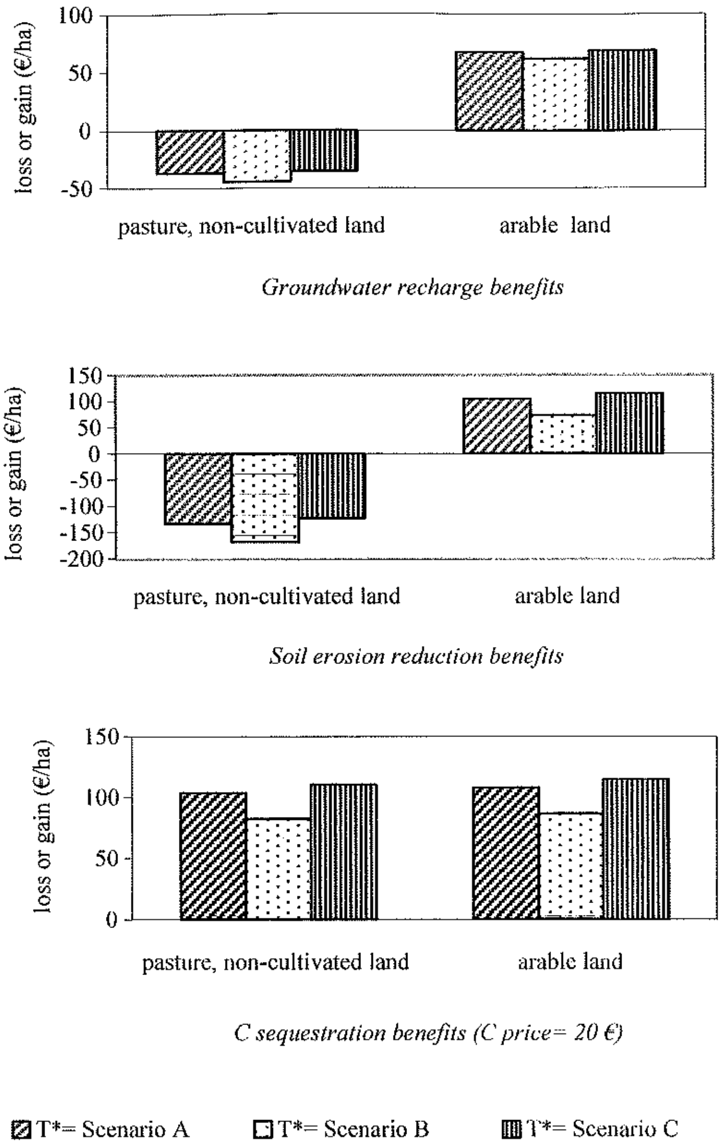

Figure 3. Social losses and gains for different types of land under Scenario A, B, or C.

loss of 44 €/ha in the case of pasture and non-cultivated land. In terms of soil erosion reduction, there is a gain of 73 €/ha in the case of arable land and a loss of 168 €/ha for pasture and non-cultivated land. With regard to carbon sequestration there is a gain equal to 87 €/ha for arable land and 82 €/ha for pasture and non-cultivated land. When the optimal harvesting age is set according to Scenario B, for each type of marginal land afforested losses increase and gains decrease. A lower loss or higher gain is achieved by changing harvesting age *T** according to Scenario C. In fact, for Scenario C, in terms of groundwater recharge the gain increases to 69 €/ha for arable land and the loss is reduced to 35 €/ha for pasture and

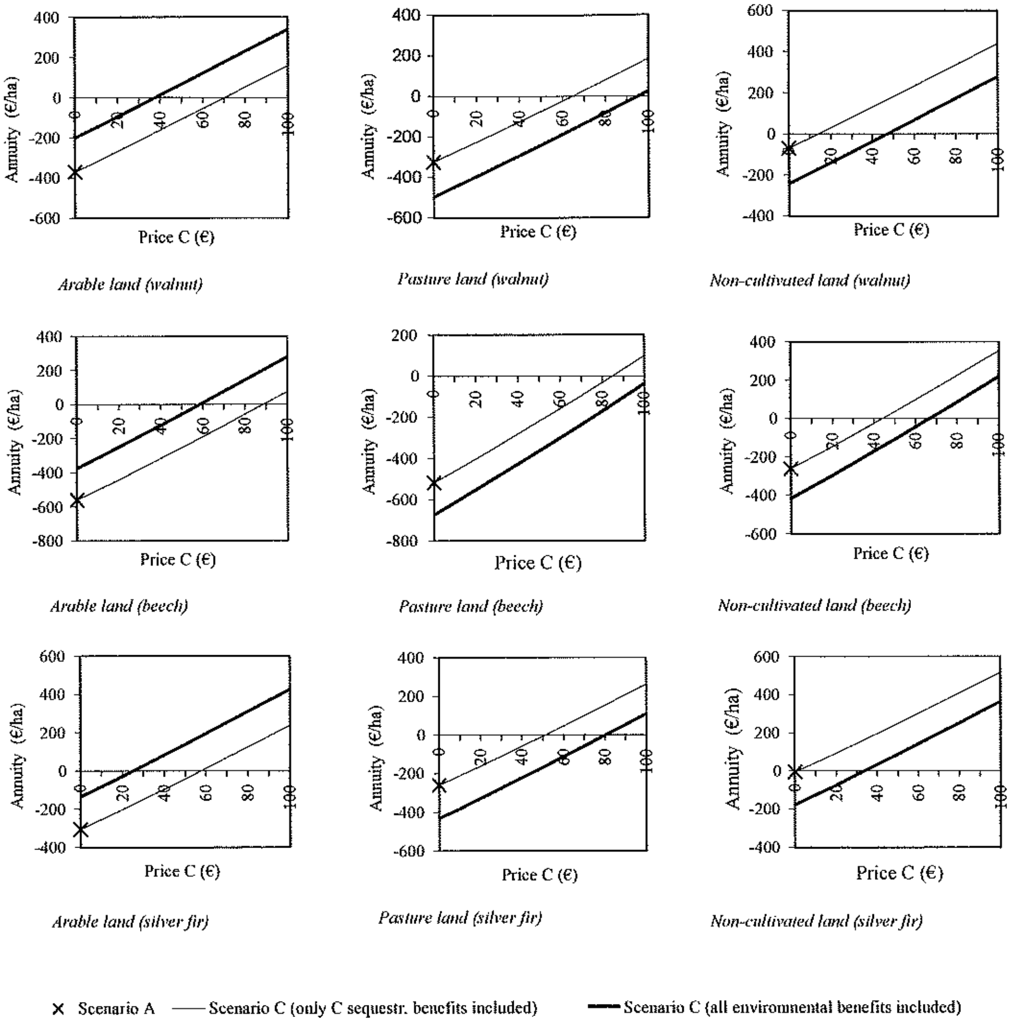

Figure 4. Maximum annuity for each typology of land, species, and carbon prices calculated according to Scenario A and C.

non-cultivated land. In terms of soil erosion reduction, the gain is 114 €/ha in the case of arable land and the loss 123 €/ha for pasture and non-cultivated land. Considering carbon sequestration the gain increases to 115 €/ha for arable land and to 110 €/ha for pasture and non-cultivated land.

Figure 4 presents for each species and type of land use the private maximum annuities under Scenario A, and the social maximum annuities under Scenario C. Scenario C is differentiated between including carbon sequestration benefits only and including all environmental benefits. The annuities are calculated for a range of carbon prices from 0 to 100 €/ton of carbon sequestrated. The private maximum annuity is depicted in each graph of fig. 4 at the left-hand-side where the price carbon is set to zero. As the results indicate, the social benefits do increase with an increase in carbon price (carbon price > 0). This applies for all species and all types of land use. Moreover, when considering carbon sequestration benefits only, higher values of social annuities are given for non-cultivated land followed by pasture and arable land. Results differ when we consider additional environmental effects. For a T^* calculated according to Scenario C including all environmental benefits and for a carbon price of zero, maximum social annuities are lower than the private ones for the case of non cultivated land and pasture and are higher for arable land. In the case of a positive carbon price and considering afforestation of pasture and non cultivated land, the maximum social annuities given for Scenario C, with all social benefits included, are lower than the ones calculated, for the same carbon price, when including carbon sequestration benefits only. The results are reversed for afforestation of arable land. Fig. 4 shows also the minimum price of carbon that provides a positive annuity for each of the land use types and for each species. The × in Fig. 4 indicates the average private benefits from afforestation. They are negative for all types of land use and tree species. This indicates that indeed an afforestation policy is necessary if an increase in forest coverage is wanted. The quantitative results underlying the graphs are available upon request from the authors.

5. Conclusions

This study provides two main results. Firstly, the inclusion of environmental benefits such as groundwater recharge and soil erosion reduction lengthen the optimal rotation age even more than when carbon sequestration benefits only are included. Similar results have been found by Creedy et al. (2001). Harvesting choices made without taking into consideration groundwater recharge and soil erosion reduction benefits lead to a social loss that cannot be ignored. The provision of subsidies to support afforestation sets private incentives that increase the social losses.

Secondly, although afforestation is expected to provide certain benefits for society, findings of this paper indicate that afforestation does not necessarily lead to an improvement of environmental quality and that its social effect depends largely on the type of environmental benefits and land use considered. Our analysis shows that in terms of groundwater recharge and soil erosion reduction, afforestation of pasture and non cultivated land results in economic losses, whereas in terms of carbon sequestration in economic benefits. Nevertheless, afforestation of arable land contributes considerably to an increase of all the three environmental benefits and to an improvement of the state of the environment. However, from the carbon sequestration point of view, afforesting arable land does not provide the highest gain and does not represent the best choice.

As clearly shown, not only private and social interests diverge but also social interests among themselves. Conditional subsidies that consider environmental effects would certainly help to reduce the loss, however, the environmental costs due to a reduction of groundwater recharge and an increase in soil erosion, as a consequence of afforestation of pasture and non cultivated land, would be inevitable. Applying an afforestation policy that has multiple environmental benefits as an objective, as in the case of Regulation 2080/92, can be difficult and often impossible. In the specific case we consider, only if the price for carbon increases above 100€/t does afforestation provide social benefits regardless of the type of land afforested or the type of tree used. If the price for carbon is low, positive social benefits depend on the type of land and type of tree used for afforestation. This requires afforestation policies differentiated by tree species and type of land. A differentiated afforestation policy will not necessarily result in higher economic benefits as the administrative costs of such a policy have to be considered.

It is necessary to point out that the results presented in this paper highlight some environmental effects rather than a detailed quantification of the social consequences of afforestation in the study area. Moreover, in our analysis we do not include the estimation of other important effects of forests such as recreational benefits and amenity values (Pearce 1991, 1994). However, we expect that their inclusion would lengthen the social optimal harvesting age as recreational and amenity values increases with an increase in age of the forest.

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