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Promotion of residual forestry biomass in the Mediterranean basin

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Istituto Superiore per la Protezione e la Ricerca Ambientale

Impacts of short rotation forestry plantations on environment and landscape in Mediterranean basin

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The project is linked to the promotion of the use of renewable energies by the development of an integrated strategy for the use of the forest biomass as a renewable energy source that demonstrates, apply and transfer sustainable management systems adapted to the different MED forest conditions.

The strategy relies on the valorisation of the forests and their consideration as potential source of incomes in rural areas that need proper management and maintenance (in envi-ronmental terms). It implies the involvement of all stakeholders of rural areas, the devel-opment of clusters and networks and the strengthening of the cooperation between public and private actors, developing political and social commitments and joint initiatives.MED Programme is a EU transnational cooperation programme among the “Territorial Coopera-tion objective” of the EU Cohesion Policy.

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ABBREVIATIONS AND ACRONYMS

a.s.l.	Above Sea Level
Cd	Cadmium
CRA-PLF	Research Unit for Intensive Wood Production of Council for Agricultural Research
CNR	National Research Council
D	Wood density
d.m.	Dry Matter
DOM	Dead Organic Matter
DWLSOC	Dead Wood, Litter and Soil Organic Carbon—the three carbon pools of non-living biomass in an ecosystem
EC	European Commission
EEA	European Environment Agency
EEC	European Economic Community
EU RED	Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC
FAO	Food and Agriculture Organization of the United Nations
GHG (s)	Greenhouse gas (es)
GS	Growing Stock
IEA	International Energy Agency
iLUC	Indirect Land Use Change
INFC	National Inventory of Forests and Carbon (*Inventario Nazionale delle Foreste e del Carbonio*)
IPCC	Intergovernmental Panel on Climate Change
ISPRA	Istituto Superiore per la Protezione e la Ricerca Ambientale
ISPM	International Standard for Phytosanitary Measures

MCPFE	Ministerial Conference on the Protection of Forests in Europe
N	Nitrogen
NAI	Net Annual Increment
P	Phosphorus
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SRC (s)	Short Rotation Coppices
SRF	Short Rotation Forestry
SRP (s)	Short Rotation Plantation (s)
toe	Tonnes of Oil Equivalent
UNFCCC	United Nations Framework Convention on Climate Change

UNITS OF MEASURE AND CONVERSION FACTORS

Cubic metre	m^3
Hectare	ha
Megatonne (10^6 tonnes)	Mt
Metre (s)	m
Million (s)	M
Tonne (s)	t
Year	yr
1 Gg biomass (oven-dry)	18.6 TJ
1 m^3 wood (oven-dry)	8.714 GJ
1 toe	41.87 GJ

GLOSSARY

BELOWGROUND BIOMASS	All living biomass of live roots. Fine roots of less than 2 mm diameter are normally excluded (as they often cannot be empirically distinguished from soil organic matter or litter). As a matter of fact, belowground biomass should include not only plant roots but also soil biota, like fungi and microbes, invertebrates of the soil food web and some vertebrates adapted to soil environment.
BIODIVERSITY	The variety of life on Earth, including diversity at the genetic level, among species and among ecosystems and habitats. It includes diversity in abundance, distribution, functionality and behaviour. Biodiversity also encompasses human cultural diversity, which can both be affected by the same drivers as biodiversity, and itself has impacts on the diversity of genes, other species and ecosystems.
BIOFUEL	Fuel produced from dry organic matter or combustible oils from plants, such as alcohol from fermented sugar or maize, and oils derived from oil palm, rapeseed or soybeans.
BIOMASS	Organic material both aboveground and belowground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc. Biomass includes the pool definition for above - and below - ground biomass. When used in reference to renewable energy, biomass is any biological (plant or animal) matter that can be converted to electricity or fuel. Woody biomass refers to biomass material specifically from trees and shrubs. It is most often transformed to usable energy by direct combustion, either alone or co-fired with coal; however, efforts are underway to develop methods to cost effectively convert woody material to liquid fuels.
BIOMASS ACCUMULATION RATE	Net build up of biomass, i.e., all increments minus all losses. When carbon accumulation rate is used, only one further conversion step is applied: i.e., the use of 50% carbon content in dry matter (IPCC default value).
BIOMASS EXPANSION FACTOR	A multiplication factor that expands growing stock, or commercial round-wood harvest volume, or growing stock volume increment data, to account for non-merchantable biomass components such as branches, foliage, and non-commercial trees.
CANOPY	The topmost layer of foliage and branches in a woodland, tree or group of trees.

CANOPY COVER	The percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants. Same as crown cover.
CARBON DEBT	The excess of GHG emissions from the burning of a source of bioenergy over that from the reference energy source, usually fossil fuel (net emissions over fossil). There is a time delay before the emissions from exploiting bioenergy systems will have reached a breakeven point relative to the fossil fuel systems. We recognise that this definition simplifies the GHG debt incurred by the burning of bioenergy (eg by neglecting the effect of black carbon and aerosol particles). An alternative definition of 'carbon debt' refers to all the CO_2 released from the combustion of biomass (absolute emissions). However, this definition is less frequently adopted and it is therefore not used in this report.
CARBON LEAKAGE	The term refers to emissions from biomass produced within one geopolitical/national unit which have been displaced beyond the boundaries of this area (geographical understanding). In another sense, the term refers to a concealed breach of the boundaries of the accounting framework, as in the case of indirect land use change (climate policy understanding). Another example of the latter aspect is 'leakage' defined in the principles of the Clean Development Mechanism as the prohibited displacement of emissions beyond the project boundaries. A 'project' in this policy context is not a geographic realisation of a mitigation activity but an accounting framework for such an activity. Both aspects of the term are of relevance in understanding the effects of bioenergy use.
CARBON SINK	Any process, activity or mechanism which removes a greenhouse gas (or an aerosol) from the atmosphere (UNFCCC, 1992). The sink function of a forest can best be described in terms of change in the growing forest carbon stock. This occurs for example when a forest is growing (quite naturally or in response to arrangement) and reverses in the case of dieback, decay and fire. The sink function of a newly created woodland is typically high because the stock is in a steep growth curve and the rate of carbon absorption from the atmosphere through photosynthesis is high, whilst the sink function of a mature forest is approaching zero. The accumulation of carbon by terrestrial biomass is reversible since greenhouse gas emissions can be returned to the atmosphere through natural disturbances or premature harvest. Carbon sinks are sometimes mistakenly equated with carbon stocks under the assumption that eg mature forest holds more carbon from the atmosphere than a newly created woodland. Such misapplication of the term can significantly distort life cycle assessments of the impacts of biomass use.

CARBON STOCK	Pools of carbon, i.e. the overall carbon content accumulated in ecosystems. These pools include carbon in living biomass (above and below ground), dead organic matter (e.g. deadwood and litter) and soil organic carbon (UNFCCC, 1992). Carbon is accumulated by a forest only up to a point when a steady state is reached so the carbon stock of a given forest stand is finite.
CARBON STOCK CHANGE	The carbon stock in a pool can change due to the difference between additions of carbon and losses of carbon. When the losses are larger than the additions, the carbon stock becomes smaller and thus the pool acts as a source to the atmosphere; when the losses are smaller than the additions, the pools acts as a sink to the atmosphere.
CO_2 EQUIVALENT	A measure used to compare different greenhouse gases based on their global warming potentials (GWPs). The GWPs are calculated as the ratio of the radiative forcing of one kilogramme greenhouse gas emitted to the atmosphere to that from one kilogramme CO_2 (carbon dioxide) over a period of time (usually 100 years).
COPPICE	A growth of small trees that are repeatedly cut down at short intervals; the new shoots are produced by the old stumps. Coppicing represents a traditional method of woodland management and wood production, in which shoots are allowed to grow up from the base of a felled tree. Trees are felled in a rotation. Rotation lengths of coppices depend on the desired size and quality of poles and are typically 10-30 years depending on species and site. A coppice may be large, in which case trees, usually oak (*Quercus*), ash (*Fraxinus*) or *Ostrya*, are cut, leaving a massive stool from which up to 10 trunks arise; or small, in which case trees, usually hazel (*Corylus*) or willow (*Salix*), are cut to leave small, underground stools producing many short stems. The system provides a continuous supply of timber for fuel, fencing, etc., but not structural timber.
CROPLAND	Category of land-use that includes arable and tillage land, and agro-forestry systems where vegetation falls below the threshold used for the forest land category, consistent with the selection of national definitions.
DEAD WOOD	Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country.
DRY MATTER	Dry matter (d.m.) refers to biomass that has been dried to an oven-dry state, often at 70 °C. Dry matter includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil.

FELLING CYCLE	The planned period, in years, within which all parts of a forest zoned for wood production and being managed under a selection silvicultural system should be selectively cut for logs. The term is synonymous with Cutting Cycle.
FOLIAGE	The live leaves or needles of the tree; the plant part primarily responsible for photosynthesis.
FOREST	According to the Italy's National Inventory of Forests and Carbon (INFC), forest is a land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use. Forest may consist either of closed forest stands where trees of various storeys and undergrowth cover a high proportion of the ground; or of open where forest formations with continuous vegetation cover in which tree crown cover exceeds 10 percent. Forest can be open forest or closed forest. Young forest stand, even if derived from planting, or areas that are temporarily unstocked due forest management practice or natural disturbances, and which are expected to be regenerated within a short period of time, are considered forest. Forest also includes forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, cleared tracts, firebreaks and other small open areas within the forest; forest in national parks, nature reserves and other protected areas such as those of special environmental, scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5 ha and a width of more than 20 m. Plantations and cork oak stands are included.
FOREST INVENTORY	System for measuring the extent, quantity and condition of a forest, usually by sampling.
FOREST MANAGEMENT	A system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.
FOREST RESIDUES	Residues resulting from tree harvesting (thinning or regeneration felling), e.g. those parts of the tree that are not removed in the roundwood extraction (stem top and stump, branches, foliage and roots). In this study the assessment of biomass potentials from forest residues is limited to stem tops and branches.
GHG EMISSION INTENSITY	The GHG emissions emitted as a result of combustion per unit of energy use at a point in time. This concept is frequently referred to as the GHG emission intensity of energy use as a form of shorthand. It is important to note, however, that the greenhouse gas emissions associated with

land use activities for the production of bioenergy feedstocks include not only carbon dioxide (CO_2) but also other gases such as reactive compounds of nitrogen, methane, aerosol particles, e.g. black carbon, etc.[1] Its value will depend on many bio-physical, environmental, climatic and agronomic or silvicultural factors affecting the nature of carbon stocks in the particular forest or agricultural ecosystem at a particular place and point in time when the biomass in question is harvested. We recognise that this term is not based on a scientific definition underpinned by an IPCC global assessment, but we use it in this report because it is commonly utilised in the life cycle assessments developed in the energy sector, typically at national level.

GHG EMISSIONS BALANCE	The overall atmospheric balance of life cycle greenhouse gases over a stated period of time for a given level of energy use. It is determined by the balance between emissions (from human activities and natural systems) and removals of gases from the atmosphere (by conversion to a different chemical compound) (IPCC, 2007). The long term EU targets are expressed as a reduction of the overall GHG emission balance by 80 to 95 per cent by 2050 in comparison with 1990.
GLOBAL WARMING IMPACT	The net global warming impact over a stated period of time for a given level of energy use.
GRASSLAND	Category of land-use which includes rangelands and pasture land that is not considered as cropland. It also includes systems with vegetation that fall below the threshold used in the forest land category and is not expected to exceed, without human intervention, the thresholds used in the forest land category. This category also includes all grassland from wild lands to recreational areas as well as agricultural and silvo-pastural systems, subdivided into managed and unmanaged, consistent with national definitions.
GROWING STOCK	The living tree component of the standing volume (measured in m^3 overbark).
LAND COVER	The type of vegetation covering the earth's surface.
LAND USE	The type of activity being carried out on a unit of land.
LANDSCAPE	For the purpose of this study, two different meanings are used for the concept of landscape. From a ecology perspective, a landscape is a heterogeneous land area composed of a cluster of interacting ecosystems that is

[1] Aerosols may have either a cooling effect on the climate by reflecting incoming solar radiation or a warming effect, by directly absorbing heat radiation and indirectly by changing surface albedo (e.g, black carbon soot from biomass combustion) (IPCC, 2007; IPCC, 2011).

repeated in similar form throughout. Most generally, a landscape is an area that is spatially heterogeneous in at least one factor of interest. The causes and consequences of spatial heterogeneity and how they vary with scale and has influenced management of both natural and human-dominated landscapes.
From the European Landscape Convention the landscape is an area as perceived by people, whose character is the result of the action and interaction of natural and/or human factors. This concept refers to the features displayed by a particular territory as a results of the interactions that take place between the various components (cultural, ecological, environmental and socio-economic) and in which it is perceived by citizens. It highlights the importance of developing landscape policies dedicated to the protection, management and creation of landscapes, and establishing procedures for the general public and other stakeholders to participate in policy creation and implementation.

LITTER

Includes all non-living biomass with a diameter less than a minimum diameter chosen by the country (for example 10 cm), lying dead, in various states of decomposition above the mineral or organic soil. This includes litter, fumic, and humic layers. Live fine roots (of less than the suggested diameter limit for belowground biomass) are included in litter where they cannot be distinguished from it empirically.

NET ANNUAL INCREMENT

Average annual volume over the given reference period of gross increment minus natural mortality, of all trees to a specified minimum diameter at breast height.

OTHER WOODED LAND

Land with either: (i) a tree-crown cover (or equivalent stocking level) of 5–10 % of trees which can reach a height of 5 m at maturity; or (ii) a crown cover (or equivalent stocking level) of more than 10% of trees which can reach a height of 5 m at maturity (e.g. dwarf or stunted trees) and shrub or bush cover.

PASTURE

Grassland managed for grazing.

PAYBACK TIME

The time it takes to ‘pay off’ the carbon debt, i.e. the time it takes for biomass to grow and absorb CO_2 so that the excess emissions that resulted from the combustion of the biomass over the comparable use of fossil fuel are sequestered. Achieving this balance may take decades or even centuries in the case of forest biomass and greenhouse gases will therefore reside in the atmosphere for a long time.

POOL/CARBON POOL

A reservoir. A system which has the capacity to accumulate or release Carbon. Examples of carbon pools are forest biomass, wood products, soils and the atmosphere. The units are mass.

PRIMARY ENERGY CONSUMPTION	Indicates how much energy is directly available for use in the country (such as electricity imported or produced by hydroelectric power plants), or indirectly available after having been converted into products to be sent to the end market (such as crude oil, which goes to refineries to be transformed into petrol or diesel oil) or having been transformed into electricity (for example, fossil fuels utilised by thermoelectric power plants to produce electricity).
PRUNING	The cutting off or removal of dead or living parts or branches of a plant to improve shape or growth.
RELATIVE GHG SAVINGS	The reduction of emissions relative to the fossil fuel alternative for a specific biomass use. As an indicator, it does not distinguish between different bioenergy pathways and biomass uses.
REMOVALS	Removals are a subset of fellings (the commercial part destined for processing).
ROTATION	The planned number of years between the establishment of a crop (by planting or regeneration) and final felling. The term is applied where forest is managed under a monocylic silvicultural system.
SHORT ROTATION FORESTRY	It is a forestry practice with the primary aim of dendromass production, particularly for energy purposes, with the basic principle of growing fast-growing, deciduous tree species on forest or agricultural land at a denser spacing and higher levels of maintenance (e.g. weed control, irrigation) compared to traditional forestry. The biomass is harvested when the trees have reached a size that is easily handled and economically sound, typically between 2 and 25 years of growth. It is a system for optimum utilization of natural resources using biological, physical, theoretical and practical knowledge in an ecologically acceptable manner. The size at harvest depends on plant material, growth conditions, culture technology and desired end-product and is frequently between 10 and 20 cm diameter at breast height. SRF may be regarded as forestry or agricultural practice depending on whether a plantation is grown on forest or agricultural land. However, a sharp distinction between forestry and SRF is often impossible.
SHORT ROTATION COPPICE	Short Rotation Coppice (SRC) is an intensive practice of growing multi-stemmed woody material over short rotations, usually of less than five years, depending on plant material, growth conditions and management practices. Harvesting takes place using a process whereby the stump is left and new shoots can emerge from the rootstocks or stools. Species used in SRC, such as eucalypt (*Eucalyptus* spp.), black locust (*Robinia pseudoacacia* L.), willow (*Salix* spp.) and poplar (*Populus* spp.), are fast-growing tree species that

are able to be coppiced successfully, relatively high rates of growth and being productive on short rotations, high density wood, suitable chemical characteristics, low moisture content; easily harvested, using conventional machinery; capable of being harvested all year round. Planting, maintenance and harvesting is predominantly done by established agricultural practices allowing farmers to use methods and machines already known from annual cropping. According to this definition, SRC falls within SRF and it simply represents a specialized form of SRF more specifically oriented to meet energy requirements. The abovementioned definitions will help the reader understand the following chapters to a greater degree.

SHORT ROTATION FORESTRY (SRF)

Practice of cultivating fast-growing trees that reach their economically optimum size between few years, from 1 to 15 years, employing intensive cultural techniques such as fertilization, irrigation and weed control, and utilizing genetically superior planting material. Each plant produces a single stem that is harvested at around 15 cm diameter. The crops tend to be grown on lower-grade agricultural land, previously forested land or reclaimed land and so do not directly compete with food crops for the most productive agricultural land.

SINK

Any process, activity or mechanism that removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere. Notation in the final stages of reporting is the negative (-) sign.

SOIL ORGANIC MATTER

Includes living and dead organic matter carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series. Living soil organic matter refers to soil biota as a whole: bacteria, algae, fungi, soil fauna and plant roots. Soil fauna is typically divided in microfauna (nematodes, protozoa, tardigrads and rotifers), mesofauna (soil micro-arthropods, i.e. mites, springtails, pseudoscorpions, protura, diplura, insect larvae and so on, and enchytraeids), macrofauna (ants, termites, beetles, diplopods and chilopods, isopods, earthworms), and megafauna (soil vertebrates). Live fine roots (of less than the suggested diameter limit for below- ground biomass) are included with soil organic matter where they cannot be distinguished from it empirically.

STANDING VOLUME

Volume of standing trees, living or dead, above stump measured over bark to a predefined top diameter. Includes all trees with diameter above a given diameter at breast height (d.b.h). The minimum d.b.h and the top diameter vary by country and are usually country defined.

SUSTAINABLE YIELD	The equilibrium level of production from the growth rate of trees comprising a forest, annually or periodically, in perpetuity. It means the continuous production with the aim of achieving an approximate balance between net growth of a forest and harvest.
UNDERSTORY	It refers to plant life growing beneath the forest canopy without penetrating it to any extent. Plants in the understory include an assortment of seedlings and saplings of canopy trees together with specialist understory shrubs and herbs.
WETLANDS	Category of land use which includes land covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the forest land, cropland, grassland or settlements categories. This category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.
WOOD DENSITY	Ratio between oven dry mass and fresh stem-wood volume without bark. It allows the calculation of woody biomass in dry matter mass.
YIELD DETERMINATION	The calculation, by volume or by area (or a combination of both), of the amount of forest produce that may be harvested annually, or periodically, from a specific area of forest over a stated period, in accordance with the objects of management.
YIELD PLANNING	The allocation over time of land units within a productive forest for harvesting in a manner calculated to yield sustainable amounts of logs and other products, while ensuring the maintenance and regeneration of the forest's productive capacity which may be required to support that production.

SUMMARY FOR POLICYMAKERS

The establishment and management of short rotation forestry (SRF) and short rotation coppice (SRC) plantations pose a number of potential threats and benefits to the environment *lato sensu* and landscape. This report provides some insights, mainly based from findings taken from literature, on the effects on water, biodiversity, historical heritage, landscape.

Potential threats to water quality mainly arise from soil preparations and harvesting operations. Both stages can be controlled by good practice. The overall quality impact of SRF and SRC is expected—mainly thanks to legislative constraints—to be largely beneficial compared to the alternative land uses currently practised in areas generally considered appropriate for conversion to SRF and SRC. In particular, SRF and SRC are expected to significantly improve water quality compared to arable cropping or other forms of land-use, and while conversion of only limited areas of more intensively farmed land may be appropriate, there are believed to be major opportunities for targeted planting of SRF and SRC to mitigate potential pollutant sources and interrupt delivery pathways to watercourses. Thus thoughtful establishment of SRF and SRC could help to deal with the major diffuse nutrient and sediment pollution pressures associated with agriculture and urban activities.

The principal water concern relates to the potential high water use of SRF crops, which could have a major impact on local water resources. Much will depend on location and scale of planting, with inevitable trade-offs between improved biomass yield, carbon sequestration, and water quality on one hand and reductions in the volume of water reaching rivers and groundwater on the other. Specific opportunities exist for utilising the high water use of particular SRF crops for environmental gain, such as for wastewater treatment and flood risk management.

Regarding the likely impacts of SRF and SRC on soil quality (including attributes like organic matter, nutrient content, compaction, erosion, and soil biodiversity), it must be stated that land available for SRF in the Northern Mediterranean countries comes mainly from former agriculture. It is normally rich in base cations, nitrogen and phosphorus. Growing SRF and SRC crops for biomass may potentially lead to significant soil nutrient reduction and acidification over time. However, these effects may be species specific, as under *Salix* and *Populus* base cations have been seen substantially reduced, whilst under other species like *Robinia* soils have become less acidic. Litterfall quality and quantity, in addition to original soil *status*, play an important role in altering soil organic matter content and carbon sequestration under SRF and SRC.

Soil C sequestration rate is likely to increase along a gradient from broadleaves to spruce conifers. Conversion of agricultural land to SRF has potentially beneficial effects on soil carbon dynamics, with reported gains in soil carbon of up to 20%. Soil carbon sequestration by SRF and SRC is highest on arable soils, as commonly they possess very low soil carbon content in the Mediterranean region. Leaf litter inputs and tree rooting will enrich the low soil carbon levels, improving soil quality and biodiversity. The impact of SRF on the higher carbon stocks of grassland soils is less certain, although any reductions are likely to be outweighed by the carbon gain in woody biomass.

Management of SRF and SRC plays a significant role in the impacts on soil sustainability. Although the need for N fertilisation under SRF and SRC is much reduced compared to arable crops, there is the possibility of leaching from excessive applications to young tree stands.

SRF aids long term soil stability, and physical soil erosion should be much reduced compared to annual cultivation, with improved infiltration from greater litter and deeper rooting depth. However, during site preparation and harvesting there may be compaction of soils through frequent machinery movements.

The effects of climate change on soil quality under SRF and SRC plantations are rather uncertain. There may have to be very different regional responses to projected changes, from East to West Mediterranean countries and depending on the latitude and altitude. In general, SRF and SRC are expected to have reduced productivity under increased temperature and moisture stresses, resulting in lower carbon sequestration in the soil.

Regarding biodiversity, experience of SRF in the Mediterranean countries is restricted to few and normally small-scale plantings and there are no systematic assessments of their actual impact on biodiversity. Potential impacts are therefore estimated on the basis of available literature. Here, through an understanding of the early successional nature of the structure and composition of SRF stands, an evaluation of species' capability to utilise these habitats has been made. The findings suggest these stands will have a positive biodiversity impact on woodland generalist species when planted on previously agricultural land. Also depending on placement, SRF stands can reduce woodland fragmentation. These benefits can be enhanced if complemented with good management and design practices that promote biodiversity.

Novel silvicultural techniques and tree species are being proposed for short-rotation biomass forests in the Mediterranean basin's countries. We review evidence to ascertain the risks of damage by mammals if these crops become more widely established in the region. There are a number of aspects of the proposed silviculture which gives cause for concern.

Planting containerised stock, especially in cleared sites, will make the young trees particularly vulnerable to damage by mammals. Furthermore, the short rotation and low-value product may make the use of tree protection un-economic. Crops grown on rotations longer than 10 years will become increasing vulnerable to damage by squirrels. Plantations established close to existing woodland are likely to suffer more damage from deer and squirrels than sites well away from woodland cover. In contrast, rodents, such as rabbits and voles, are more likely to be a problem in former agricultural sites.

Amongst the tree species proposed, hybrid aspen is likely to be the most vulnerable to deer and sycamore to squirrels. The Eucalyptus species are the least likely to suffer damage. Given the novelties of both species and silviculture, it is recommended that trials comparing growth and performance between protected and unprotected plots of each species in several sites where the target mammalian pest species are present should be established as a priority. Once crops are established, regular monitoring of damage is recommended, to provide warning and evidence of any change in the levels of damage that may warrant additional management action.

INTRODUCTION

Short Rotation Forestry (SRF) and Short Rotation Coppice (SRC) systems can play a role as feedstock for bioenergy supply contributing to EU energy and climate policy targets. However, substantial expansion of SRF and SRC stands would have impacts on soil and water resources, biological diversity and subsequent ecological services.

The scope of this report is to review the potential impacts of bioenergy forest tree plantations on different features of the environment, including soil and water quality, cultural heritage and landscape, and biodiversity. In this respect, we distinguish two types of energy forest tree plantations: Short Rotation Forestry (SRF) and Short Rotation Coppice (SRC) plantations, respectively defined as follows.

SRF is the practice of cultivating fast-growing tree species that reach their economically optimum size (from 10 to 40 cm diameter at breast height (Hardcastle, 2006) between 2 and 25 years, depending on the desired end-product, and employing intensive cultural techniques such as fertilization, irrigation and weed control, and utilizing genetically superior planting material. The crops tend to be grown on lower-grade agricultural land, previously forested land or reclaimed land and so do not directly compete with food crops for the most productive agricultural land.

SRC is the practice of growing multi-stemmed woody material over short rotations, usually of less than five years. Harvests take place on a two to five year cycle. The established root system and the nutrients stored in the roots and stumps guarantee vigorous re-growth for the shoots. A plantation can be harvested for up to thirty years before the site needs to be restored and the stand replanted. Species used in SRC, such as willow (*Salix* spp.) and poplar (*Populus* spp.), despite having relatively high rates of growth (from 8 to 18 tons of dry woodchip per hectare per year) and being productive on short rotations, do not meet the following six other criteria for an ideal fuel wood as suggested by Ramsay (2004): produce high density wood; have suitable chemical characteristics; exhibit low moisture content; be easily harvested; be harvested using conventional machinery; be capable of being harvested all year round. SRC of species like willow and poplar produces small diameter material with a high moisture content, low wood density and high bark content, which can produce corrosive substances when burned. SRC plantation is harvested using converted agricultural machinery and this limits harvesting to periods when the soil is relatively dry.

In this respect we consider SRC a variety of SRF, which is a broader term describing forest systems for biomass production (for energy purposes among others). Therefore, SRC falls within SRF and represents a more specialised and intense practice of SRF dedicated mainly for energy purposes. In this report, we explicitly describe the effects of SRC on the environment, referring in a few parts also to effects of single stem trees used in SRF.

Currently, about 14,000 ha of willow SRC plantations have been established in Sweden, mostly on productive agricultural land. The extend of SRC stands is much more modest in the other EU countries: about 6,000 ha in Italy, mostly poplar; about 3,000 ha in Poland, mostly willow; about 3,000 ha in the UK, mostly willow; about 1,500 ha in Germany, mostly poplar (Dimitriou et al., 2011).

A further increase of SRC plantations is expected in the future: many country of Europe have planned a big increase of area extent for SRC. In Sweden the Swedish Board of Agriculture predicts a short-term increase of SRC to 30,000 ha (Jordbruksverket, 2006); the UK Biomass Strategy predicts that perennial energy crops will occupy some 350,000 ha by 2020 (DEFRA, 2007), and in Germany, SRC cultivation area may also increase markedly during coming years due to a changing subsidy policy and the identification of high cultivation potentials for certain areas (e.g., 200,000 ha for the federal state of Brandenburg; Murach et al., 2008).

In Italy the contribution of agro-energy to national energy demand is still modest; nevertheless, even if slowly, its relevance has increased in recent years.

Over the last 20 years in Italy, supported by favourable public grant programs, SRC has grown to comprise about 6,500 ha, mainly in the Po Valley area. Leaders in the Lombardy and Veneto Regions have been the first to give subsidies for SRC, and the planting areas in these regions now account for almost all the Italian land area dedicated to this energy crop, 4,000 and 1,300 ha, respectively (Bacenetti and Fiala, 2011).

SUMMARY

PART A - IMPACT ON MEDITERRANEAN ECOSYSTEMS

1. POTENTIAL IMPACTS ON BIODIVERSITY

The level of impact of a SRF plantation on biodiversity largely depends on the environmental quality, and particularly on the quality and type of land use being replaced. If degraded or crop lands are replaced by SRF, in most cases there will be a positive effect on biodiversity. This positive effect, in the case of cropland replaced by SRF, is mainly due to a reduced application of herbicides and pesticides, which enhances the habitat quality for the biota.

Principally in highly fragmented areas and in low production agricultural areas, the plantation of SRF stands can protect the environment from contamination and increase economical income to farmers. SRF plantations can be used to create unsprayed strips according to EU Directive 128/2009, limiting the impact of pesticide used in agriculture on natural and seminatural areas.

Literature suggests that the establishment of SRF stands can have a positive biodiversity impact on woodland generalist species, when planted on cropland or degraded land. SRF stands can reduce woodland fragmentation and decrease the environmental pressure by agriculture (Hardcastle et al., 2006; McKay, 2011).

The potential increase in biodiversity will be strongly affected by the pattern and scale of the new plantation, in particular the relative edge length and the linking up of set aside areas, hedges and existing trees in contiguity (Hardcastle et al., 2006). SRF established on intensively farmed agricultural land have shown to cause a positive effect on biodiversity at local scale. The same crops planted on pastures, shrublands or wetlands might, on the other hand, have negative effects on local biodiversity. At the site scale SRF systems can introduce additional habitat and niches into the environment (Tubby, 2007).

Although usually there is an increase in biodiversity compared with cropland, climax taxa requiring mature trees and/or dead wood will not benefit from SRF establishment.

The impact of SRF plantations can be positively enhanced by having mixed species/clones and diverse planting arrangements and the following points should be considered (Schulz et al., 2010):

- plantation diversity: different rotation periods; different tree species; different ages;
- diversity of structures between stands: balk structures; inner borders; conservation of glades or derelict land areas; special structures, e.g. stone or deadwood piles;
- diversity of structures along the plantation borders and other areas: hedges, balk structures, solitary trees, special structures.

Regarding levels of biodiversity, there is a gradient of useful species which should be used in SRF, with willow at the top, followed by poplar, black locust and ailanthus (Schulz et al., 2010).

The biodiversity in SRC is enhanced most significantly by the structural richness within the poplar or willow blocks and in the peripheral areas. As a result, several animal species of conservational value can find a suitable habitat in SRCs. The increasing cultivation of Short rotation coppice (SRC) can lead to a slight improvement in biodiversity particularly in cleared agricultural landscapes, but also to significant adverse effects in landscapes with high conservational value. Therefore, further research is required, especially regarding species-rich invertebrate groups (Schulz et al., 2009).

Short rotation coppice as a source of renewable energy production is a new kind of crop management in European Countries; different subsidies for growing SRC have been introduced in several European Countries. The main end-use of the material produced by SRCs is woodchips to be used in combustion plants to generate heat and/or electricity.

The management practices for SRC (soil preparation, weed control, planting, fertilisation, harvest, etc.) are more similar to those of agricultural annual crops than to forestry practices (see Introduction).

From a nature conservation point of view, arable land is suitable for establishing a SRC plantation, once established that plantation sites do not negatively affect adjacent or nearby protected areas, and if the establishment does not have negative influence on endangered species or creates excessive disturb on wildlife corridors (Baum et al., 2009a; Schmidt and Glaser, 2009).

Once established, SRC requires no annual soil cultivation and considerably less agrochemical input. The lower intensity of SRC cultivation, particularly the lower nitrogen fertiliser application, results in a much lower carbon footprint compared with food or biofuel production based on annual agriculture food crops (Heller et al., 2004).

SRC might require to be cultivated on a substantial fraction of all available agricultural land to economically and energy-efficiently meet the biomass needs for fuel. This, coupled with the peculiar features of SRC, will surely alter the appearance of the landscape and have potential implications for the local water and soil quality, hydrology, carbon storage in soil, and biodiversity. Possibly, habitats of threatened species, as well as areas adjacent to wetlands should be avoided, whereas former arable lands and grassland fallows are generally well suited (Baum et al., 2009a).

When comparing SRC plantations with other land uses, biological diversity is often higher than in arable fields, but lower than in old growth mixed deciduous forests. So, actually, only if established in areas dominated by agriculture, these plantations may increase regional diversity.

The animal diversity in SRC stand has not yet been adequately investigated. Most recent research did focus merely on birds and ground insects.

Their biodiversity, equated with species richness, differs considerably. Diversity of breeding birds is higher in SRC than in agricultural cropland, but generally lower than in forest ecosystems. Diversity of ground beetles has been recorded being higher in arable fields than in SRC. In general, the portion of forest species is lower in SRC than in typical forest habitats but rises with increasing age of stands.

The animal diversity depends on various environmental factors. These include the surrounding landscape, the shape and size of the plantation. For example, small and oblong SRC are more favourable due to the edge effect, for example. Besides these landscape ecological parameters, there are other important factors. Willows contain both a greater diversity and higher abundance in most animal groups than poplars. Some birds even prefer certain clones when selecting a nesting site. Moreover, the habitat quality, the soil type and the relationship with the surrounding environments are also important factors.

The habitat structures of a short rotation coppice change as its age increases and the composition of the biocoenoses also changes as a result.

1.1 STAND STRUCTURE

Compared to natural woodlands, and even to mature plantations, SRF stands are obviously more homogeneous in terms of species and age class. The short rotation length is a typical significant factor limiting the structural diversity of the habitat. The high stock densities expected in SRF will result in low daylight levels reaching the ground, with subsequent impacts on the ground flora (Hardcastle et al., 2006).

The canopy of early stages of the cycle can support a wide variety of herbivorous and phytophagous invertebrates (Oxbrough, 2010), which in turn support predatory ground invertebrates. Older stands can provide habitat for indigenous shade-tolerant species that are typical of natural forest understory (Allen et al., 1995; Brockerhoff et al., 2001).

The biodiversity of SRF plantations of different species appears to be strongly correlated with the density of the canopy, which influences the light level reaching the ground and hence the abundance of the herbaceous layer, as well as the pace of litter breakdown.

In general, the litter of exotic species breaks down more slowly than similar material from native species. It also carries lower numbers of phytophages (McKay, 2011). Coniferous or sclerophyllous species usually determine more acid litter, bringing to slower decomposition rates and changes in the composition of soil biota, compared to broadleaved species (Lal, 2006).

Regarding the SRC the heterogeneity and spatial structures play a critical habitat role. Many intensively managed plantations have little ground vegetation, as a result of chemical or mechanical weed control early in the rotation cycle and of canopy shading later in the rotation (Christian et al., 1998). Others have gaps in the canopy that allow other plant species to grow, differences in canopy height or woody debris (Christian et al., 1998). This has strong influences on animal diversity (Shulz et al., 2009).

The ground vegetation cover was negatively correlated with the plantation age component and positively with the nutrient component. With an increase in the plantation age component, a shift in species composition was proven towards more forest habitat species, more nutrient-demanding species, and increasing occurrence of indicator species for basic soils corresponded in occurrence to increasing nutrient availability (Baum et al., 2012).

Species composition in SRC plantations was influenced by plantation age/irradiance, and nutrient availability; soil acidity and shoot age had no significant influence. Findings suggest that phytodiversity in SRC plantations depends mainly on plantation age and thus shifts over time (Baum et al., 2012).

Where SRC is grown to supply small local heat and/or power stations, plantations will be much smaller in scale, although they may still be concentrated (Dimitriou et al., 2011).

In mini-rotation, which is the main cultivation method for willow, the trees are harvested after two or three years. The tree density is 16,000 to 20,000 per hectare. Midi-rotation takes four to six, at most ten years with a tree density of 6,000 to 9,000 per hectare and is often used for poplar.

The third rotation type can be a maxi-rotation, suitable for trees like *Populus*, *Alder*, *Acer*, *Tilia*, *Sorbus* and takes 10 to 20 years with densities between 1,500 and 3,000 trees per hectare (NABU, 2008).

The establishment of small-structured plantations with different species and different rotation times is advisable to enhance structural, and therefore biological, diversity (Dimitriou et al., 2011).

Variable SRC structures (shoot age, species/clones, area shape) and habitat diversity (intensive land use mixtures) are recommended for sustainably SRC practice and to increase ecotone area and thus phyto- and zoo-diversity (Dimitriou and Bolte, 2012).

Plantation size and shape also seem to be important for biodiversity, with higher species numbers recorded at the edge of a plantation than within it (Augustson et al., 2006; DTI, 2004; DTI, 2006; Gustafsson, 1987; Weih et al., 2003).

Table 1. Characteristics of the species used for SRC

	***Salix* spp.**	***Populus* spp.**	***Robinia pseudoacacia L.***
Crop density stools*ha^{-1}	12,500-15,000	8-12,000	8-12,000
Harvesting cycle (years)	1-4	1-6	2-4
Average butt diameter at harvest (mm)	15-40	20-80	20-40
Average height at harvest (m)	3.5-5.0	2,5-7,5	2.0-5.0
Growing stock at harvest (fresh t*ha^{-1})	30-60	20-45	15-40
Moisture content (% weight)	45-62	50-55	40-45

Source: Source: EUBIA, 2007; EEA/JRC/Rothamsted Institute expert consultation workshop, 2007 (http://www.eubia.org/index.php/about-biomass/biomass-procurement/short-rotation-forestry)

1.2 SPECIES TO BE USED FOR SRF AND SRC PLANTING

Ecosystems characterised by low-intensity management, such as wetlands, shrubs, or abandoned farmlands, often provide ideal habitat for a large number of plant and animal species, and establishing an SRF on such a site would invariably lead to a decrease in conservation value (McKay, 2011).

SRF can have a beneficial impact compared to arable land and grassland on a number of species from a range of taxon of *Diptera*, *Arachnids*, *Birds* and *Fungi* (Sage et al., 2006). In particular, soil mycorrhizas can enhance the total soil biodiversity of the areas involved, increasing both soil resilience and quality of crop yields.

A survey for rare or threatened species should be undertaken before SRF is established, especially where the biodiversity is not well studied.

Although there is evidence that SRF benefits several groups, others such as bryophytes, lichens and soil fauna have limited dispersal distances and are likely to take time to colonise sites and subsequent recolonisation after each rotation.

In commercially managed SRC plots a greater diversity of wildlife and higher densities of birds were recorded compared to proximal arable plots. The number of species usually increases in the first two years after establishment, and it decreases thereafter with increasing age of the plantation (Burger et al., 2005; Delarze and Ciardo, 2002; DTI, 2004; Gustafsson, 1987, Wolf and Böhnisch, 2004).

Different tree species and clones are planted for energy crops, however little is known about how the different crops influence phytodiversity and about the variations concerning species composition and vegetation development on the ground over time (Baum et al., 2009a). Such information is to be acquired for Mediterranean Countries.

1.3 INVERTEBRATES

Several surveys state that SRF has positive effects on populations of honey bees and wild bees (Lewis et al., 2010), as well as small mammals, evidenced by raptorial birds being able to catch more mice (Best Practices 2011).

Eucalyptus spp. are likely to support less diverse arthropod assemblages than the other trees recommended for SRF (McKay, 2011).

Molluscs (mainly snails) are not well suited to withstanding the disturbances caused by the soil cultivation of cropland, and are poorly adapted to quickly recolonise fields once annual crops have become established. The relative stability of the SRF system, combined with the higher humidity of the understory environment, will provide habitat better suited to molluscs (Tousignant et al., 1988).

Worms also benefit from the reduced exposure to disturbances and are well adapted to the cool and moist understory environment and benefit from the provision of large quantities of organic material in the form of leaf litter (Hubbard et al., 1999; Whalen, 2004).

Many insect groups benefit from the decreased use of pesticides in SRCs, and soil fauna as a whole has showed high values of diversity, both in richness and abundance, where cultivation areas were transformed in forestry plantations, such as SRF. Moreover, earthworms are favoured by the longer soil rest period (Makeschin, 1989; Makeschin, 1994).

The relatively wider, more sheltered and less intensively managed headlands of SRC plots provides a potentially good habitat for butterflies. Butterflies were restricted to the headlands of both the SRC and arable control plots. However, the SRC headlands contained higher numbers of butterflies than the arable headlands (Cunningham et al., 2004). In more established willow coppice, both the number of individual butterflies and the number of butterfly species recorded within the SRC increased over four year (Cunningham et al., 2004).

Coleoptera are generally species-poorer in some SRCs than on agricultural crop land. For example, on English sites significantly more ground beetle species were found in arable fields than in poplars SRC (Britt et al., 2007; Liesebach and Mecke, 2003; Lamersdorf et al., 2008; Brauner and Schulz, 2009). It is hard to demonstrate that this might happen even in Countries like Italy, where the beetle biodiversity is much higher and their coenoses show higher values both in richness and abundance than in the UK (Vigna Taglianti, pers. comm.)

About arachnids, more individuals and species are generally found in SRCs than on nearby agricultural crop land (Blick and Burger, 2002; Blick et al., 2003).

The total number of invertebrates was highly variable between sites although there was a tendency for the edge of the plots to have higher numbers of invertebrates than the interior. The mean number of invertebrate orders increased with subsequent growth of the coppice. The majority of invertebrates recorded from the SRC belong to the Coleoptera and Hemiptera orders, with other orders present in low numbers (Cunningham et al., 2004).

In general, a higher zoodiversity for native autochthonous tree and plant species was demonstrated, (Thüring, 2007; Schulz et al., 2008b). Large numbers of invertebrates are known to be associated with *Salix* spp. (Kennedy and Southwood, 1984).

Italian soil biota shows values higher than other European or Mediterranean Countries, therefore a detailed programme of soil biota monitoring has been proposed to assess the role the value and quality of such assemblages (ISPRA, 2012).

1.4 BIRDS

An increase of invertebrate densities in SRF compared to arable land and grasslands has been shown to lead to an increase in the diversity of birds. These trials in both *Salix* spp. and *Populus* spp. SRF contained higher densities of resident birds, while willow also contained higher numbers of migrant bird species compared to surrounding open habitat (Sage et al., 2006). In particular, canopy of *Alnus* may support high aphid biomass, providing food for insectivorous birds (Hardcastle et al., 2006). Some rare bird species adapted to open habitats would be threatened by the addition of SRF to a landscape, and could become locally extinct if significant areas of SRF were planted (McKay 2011).

Animals that depend heavily on the vertical structure, such as many breeding birds, can benefit from the growth characteristics of SRC. This is particularly the case when SRCs are planted in an agricultural landscape with little structural diversity (Schulz et al., 2009).

Results obtained in the USA, the UK, and Sweden show that bird abundance and diversity is generally high in short rotation coppices (Anderson et al., 2004; Berg, 2002; Christian et al., 1997; Dhondt and Sydenstricker, 2000; Dhondt et al., 2007; Sage and Robertson, 1996). Some species, as snipe, woodcock, finches, thrushes, tits and warblers prefer short rotation coppice crops to arable and grass fields nearby. Different bird species are associated with different age classes of SRCs (Sage et al., 2006; Jedicke, 1995; Gruß and Schulz, 2008).

Densities of migrant bird species were as high in the edge of established SRC as they were in the surrounding hedgerows and adjacent boundaries. Resident bird species tended to prefer the hedgerows to the SRC. Bird species associated with open habitats were largely absent from established SRC (Cunningham et al., 2004). Some birds even prefer certain clones when selecting a nesting site (Schulz et al., 2009).

Thus, SRC crops can surely help bird biodiversity in antropized areas in Mediterranean countries.

1.5 MAMMALS

The establishment of SRF in an agricultural landscape can potentially benefit most species of mammal due to the provision of additional cover by the tree crop and by the herbaceous vegetation associated with unplanted zones. Much like set-aside, these zones will also provide forage for both large and small mammals, and cover for smaller species (McKay, 2011). SRF plantations can widely be exploited by small mammals, especially in autumn and that capture rate is highest in “double-row” stands. The distance from woods or other arboriculture stands was negatively correlated to small mammal’s abundance. SRF plantations can be considered a suitable habitat for small mammals and may work as a “corridor habitat” between fragmented patches of suitable habitats (Giordano and Meriggi, 2009).

The suitability of the understory habitat for small mammals depends mainly on the abundance of understory vegetation (Christian et al., 1998). Stands with sparse understory vegetation will provide neither cover nor forage for small mammals, but if a degree of understory cover is achieved, species such as field vole, bank vole, common shrew, and wood mouse will find cover and forage. These mammals will benefit from the cover and relative lack of disturbance compared with agricultural land of the unplanted zones associated with the stand. This general increase in mammal biodiversity will need to be balanced against the possible increase of rabbits and deer, both potential pest species for trees and other crops. Mammalian predators such as foxes, badgers, polecats, stoats, and weasels will be attracted by the presence of prey species, by the relative habitat stability, and by the provision of cover, whence they can also make foraging trips into the surrounding landscape (McKay, 2011).

1.6 SOIL FAUNA AND MICRO-ORGANISMS

Natural ecosystems and low-intensity farming systems show a more diverse, fungal-dominated soil food-web with larger organisms, compared to intensive agricultural systems (Bardgett, 2005).

Generally foresters are least disturbers of soil biota, nevertheless logging equipments tear up the vegetative cover and compact the soil. Increased erosion might result, and the new seedlings hardly find a favourable medium for their growth. Each soil type has a range of best tree species that grow on it, and careful attention has to be placed on this issue (Plaster, 2003).

Changes in plant species composition and the dominance of fast growing species that produce litters and rhizodeposits, reductions in the complexity and heterogeneity of organic matter inputs, reductions in the habitat complexity of the soil environment and increases in physical disturbance of soil from vehicle traffic, grazing and tillage, are all factors that encourage bacterial growth (Bardgett, 2005). Fertilizers have been shown produce a direct inhibitory effect on the growth of both decomposer fungi (Donnison et al., 2000) and arbuscular mycorrhizal (AM) fungi (Johnson et al., 2003a, b).

Although intensification of agricultural management can rapidly replace fungal-dominated soil food-webs by bacterial-dominated ones, the reversal of this shift in community composition is a long-term process (Bardgett, 2005). Therefore, short-term forestry does not seem to increase soil biodiversity if not on the long run, provided that soil biota quality and diversity are preserved.

The diversity of soil fauna is generally increased in SRF, compared to arable land (Makeschin, 1994). Soil biota can benefit from SRF, in terms of both soil fauna and microorganisms. SRF differentiates homogeneous upper soil horizons into several distinct horizons thereby increasing soil biomass and biodiversity (Baum et al., 2009).

Fundamental components of microbial biomass, which might be affected by SRF, is represented by AM fungi (Rooney et al., 2009), mutualistic associations between the roots of the majority of plant species and soil borne fungi belonging to Glomeromycota (Schüβler et al., 2001; Smith and Read, 2008).

Despite the relevant changes in plant communities and the rapid recolonization of uncultivated soils by mobile macrofauna, following cessation of cultivation activities Scheu and Schultz (1996) found a very slow change in the oribatid mite community, one of the most abundant soil conenoses in a vast majority of soil types and climates. In this case, plantation of SRF can increase the diversity of soil mesofauna and accelerate the resilience of the pristine soil community as a whole.

1.7 FLORA AND VEGETATION

Many factors influence the vegetation in a SRC plantation: light climate and the tree age play a key role for species composition, species number and vegetation cover. Furthermore, the land use history and the vegetation in the surrounding landscape have considerable influence on species composition in SRC plantations. The more diverse the surrounding landscape, the more species are able to establish in the plantation (Baum et al., 2009a).

Generally, SRC stands in homogenous arable landscapes have highest positive effects on phytodiversity and established SRC stands contain more species of plants and greater levels of vegetation cover than traditional arable crops (Dimitriou and Bolte, 2012). This reflects the fact that the headlands of the SRC plots tended to be wider and subjected to lower levels of chemical drift from herbicides and fertilisers than the headlands of the arable plots.

Vegetation cover (DTI, 2004) and floristic heterogeneity (Weih et al., 2003) have been reported to be higher in SRC fields than in arable land. In comparison to arable fields and grassland fallow, willow and poplar plantations have been shown to contain more species than arable land and higher or similar species richness to grasslands (DTI, 2004; Fry and Slater, 2009; Heilmann et al., 1995).

Species composition in SRC stands depends very much on light intensity which is highest in young plantations due to the lack of canopy closure. Light intensity is also dependent on the planted tree species and greatly influences the development and composition of the ground vegetation.

The first species able to establish in SRC are naturally pioneer ones. Species that demand large amounts of light and nutrients, along with mild temperatures, typically colonize the plantations in the early stage (Delarze and Ciardo, 2002), in which the ground vegetation is dominated by annuals (Delarze and Ciardo, 2002; DTI, 2004; DTI, 2006; Baum et al., 2009a).

As a consequence of increasing canopy closure, radiation and temperature decrease, ground vegetation shifts from the initially ruderal and pioneer species towards woodland species (Britt et al., 2007; Delarze and Ciardo, 2002; Kroiher et al., 2008), and from annuals and biennials towards perennials (DTI, 2004; DTI, 2006; Baum et al., 2009a).

Ground vegetation cover is also dependent on the planted crop. Different species and genotypes have different growth habits and are differently affected by habitat conditions. There is an increasing gradient in ground vegetation cover from poplar to hybrid aspen and willow due to differences in radiation climate resulting from different leaf phenology, growth habit and biomass of the trees (Heilmann et al., 1995).

Many plants currently found in SRC may compete with the crop for moisture. Slow growing perennial species associated with more stable woodland habitats have low water and nutrient requirements and are to be encouraged as they reduce the amount of competition within the willow crop for water. The presence of these species within headlands and rides could provide nectar sources for beneficial insects such as parasitic wasps, with the ability to control pest outbreaks (Cunningham et al., 2004).

1.8 FUNGI

Over 80% of plant families are mycorrhizal, and this mutualistic association between plant roots and fungi are the norm in Nature, not the exception (Malloch et al., 1980). Most terrestrial ecosystems depend on mycorrhizae, which promote the establishment, growth, and health of plants. Mycorrhizal fungi are particularly crucial in forest systems where they benefit trees by augmenting inorganic nutrient uptake and providing protection from heavy metals, drought, pathogens, grazers, and other organisms (Fogel, 1980).

In response to such symbiosis, bioenergy crops could in turn benefit by an increased biomass yield and a greater cropping resistance (Rooney et al., 2009), since AMF are largely known to have a fundamental role in plant nutrition and protection against root and shoot pathogens (Smith and Read, 2008).

Some tree species used in SRF, i.e. *Salix, Alnus, Eucalyptus* and *Populus*, are capable of hosting two types of mycorrhizal associations simultaneously (ectomycorrhizas and endomycorrhizas), which has been shown to increase the fungal diversity of an area (Puttsepp, 2005).

Salix and *Populus* SRF and SRC stands in Mediterranean environment can host species of natural riparian forest as *Lactarius* controversus, *Leccinum aurantiacum*, *Xerocomus ripariellus*, *Tricholoma populinum* together with more generalist or forest ubiquist species (Table 2).

Table 2 Ectomycorrhizal fungi in SRC and SRF compared with natural Mediterranean riparian woods

Host species		***Populus alba***	***Populus nigra***	***Populus tremula***	***P. × canescens, P. deltoides × nigra***	***Populus tremula × Populus alba* (#)**	***Salix caprea***	***Salix viminalis***	***Populus x euramericana* ****	**Habitat Natura 2000 92A0**
Authors		(1) = Jakucs and Agerer, 1999a, 1999b, 2001; Jakucs, 2002	(2) = Beeneken et al., 1996; Data from: ISPRA "Progetto Speciale Funghi" Database	(3) = Godbout and Fortin, 1985; Data from: ISPRA "Progetto Speciale Funghi" Database	(4) = Danielsen L. et al., 2013a	(5) = Danielsen L. et al., 2012	(6) = Hrynkiewicz and Baum, 2003	(7) = Baum et al., 2002	(8) = Data from: ISPRA "Progetto Speciale Funghi" Database (releves by C. Lavorato e M. Rotella)	(9) = Data from: ISPRA "Progetto Speciale Funghi" Database
Location		Hungary	Germany; Italy (Emilia Romagna, Veneto)	Canada, Italy (Emilia Romagna);	France (Orléans, Sologne),	France (Orléans, Sologne),	Germany (Freiburg)	Germany (Abbachhof, Wildeshausen)	Calabria (Italy)	Italy
Species	**Natural forest in Mediterranean climate** (ISPRA "Progetto Speciale Funghi" Database)									
Agaricus praeclaresquamosus	Broadleaved woods, mixed broadleaved and coniferous woods, *Acacia cyanophylla* stands								+	
Agrocybe aegerita	Ubiquist		+						+	+
Cenococcum geophilum	Roots				+	+	+			
Coprinus micaceus	Temperate Forest ubiquist								+	+
Cortinarius atrocoeruleus	Temperate Forest ubiquist, shrublands						+			
Cortinarius decipiens	Temperate Forest ubiquist			+						
Cortinarius trivialis	Forest ubiquist								+	
Entoloma sinuatum	Broadleaved forests				+					
Hebeloma helodes	Bog woodlands						+			
Hebeloma sacchariolens	Broadleaved forests				+	+				
Inocybe curvipes	Mixed Coniferous and broadleaved forest, *Picea* and *Cedrus* pkantations				+					
Inocybe fuscomarginata	Riparian woods, Mediterranean maquis		+							
Inocybe glabripes	Temperate woods							+		
Laccaria laccata	Ubiquist				+					
Lactarius pubescens	*Betula* and *Betula-Picea* woods						+			+
Laccaria tortilis	Forest ubiquist				+	+			+	
Lactarius controversus	Riparian woods	+							+	+
Leccinum aurantiacum	Riparian and Temperate forests			+					+	
Lyophyllum decastes	Ubiquist								+	
Paxillus involutus	Forest ubiquist				+	+	+			+
Peziza ostracoderma	Greenhouse soil				+	+				
Phialophora finlandia	Boreal forest						+			
Russula amoenolens	Temperate and Mediterranean forests	+								
Scleroderma citrinum	Ubiquist			+						
Scleroderma areolatum	Forest ubiquist			+						

Host species		***Populus alba***	***Populus nigra***	***Populus tremula***	***P. × canescens, P. deltoides × nigra***	***Populus tremula × Populus alba* (#)**	***Salix caprea***	***Salix viminalis***	***Populus x euramericana* ****	**Habitat Natura 2000 92A0**
Authors		(1) = Jakucs and Agerer, 1999a, 1999b, 2001; Jakucs, 2002	(2) = Beeneken et al., 1996; Data from: ISPRA "Progetto Speciale Funghi" Database	(3) = Godbout and Fortin, 1985; Data from: ISPRA "Progetto Speciale Funghi" Database	(4) = Danielsen L. et al., 2013a	(5) = Danielsen L. et al., 2012	(6) = Hrynkiewicz and Baum, 2003	(7) = Baum et al., 2002	(8) = Data from: ISPRA "Progetto Speciale Funghi" Database (releves by C. Lavorato e M. Rotella)	(9) = Data from: ISPRA "Progetto Speciale Funghi" Database
Location		Hungary	Germany; Italy (Emilia Romagna, Veneto)	Canada, Italy (Emilia Romagna);	France (Orléans, Sologne),	France (Orléans, Sologne),	Germany (Freiburg)	Germany (Abbachhof, Wildeshausen)	Calabria (Italy)	Italy
Scleroderma bovista	Temperate forests, *Juniperus* coastal dunes, Mixed woods	+			+					
Scleroderma verrucosum	Forest ubiquist								+	
Tomentella ellisii	Riparian woods; *E. angustifolia* and hymenial surface of old *Phellinus punctatus*				+	+				
Tomentella pilosa	Roots of *Fagus sylvatica*, *Carpinus*, *Populus*; lower surfaces of pumice boulders lying upon the ground.	+								
Tomentella subtestacea	Decayed wood of broadleaved trees; roots of *Populus* sp.	+								
Tricholoma cingulatum	Riparian woods						+			
Tricholoma populinum	Riparian woods		+	+					+	+
Tricholoma ustaloides	Temperate and Mediterranean forests, mixed woods								+	
Tuber albidum	Forest ubiquist									
Tuber magnatum	Broadleaved forests									+
Volvariella bombycina	Riparian woods		+						+	+
Xerocomus bubalinus	*Betula* and *Populus* woods on sandy soils								+	
Xerocomus ripariellus	Riparian forest, Reforestation stands with *Pinus* spp. or *Eucalyptus*, on coastal sand dunes too				+	+				

1.9 LICHENS

Lichens may be associated with poplar plantation. In a study conducted in poplar stands of different age, in Veneto (Northern Italy), 17 species of lichens were found. Most of them are eliophilous and tolerant of high level of nutrients. The number of species grows with the age of stand (Guido, 2010).

Table 3 Lichens in poplar stands, at different age

Species	**Age of stand**		
	4-5 years	5-8 years	>8 years
Arthrosporum populorum A. Massal.	+	+	+
Caloplaca cerinella (Nyl.) Flagey.	+	+	+
Candelaria concolor (Dicks.) Stein	+	+	+
Candelariella efflorescens auct. eur.			+
Candelariella reflexa (Nyl.) Lettau.			
Catillaria nigroclavata (Nyl.) Schuler		+	+
Hyperphyscia adglutinata (Flörke) H. Mayrhofer and Poelt.	+	+	+
Lecania cyrtella (Ach.) Th. Fr.	+	+	+
Lecania koerberiana J. Lahm.			+
Lecidella elaeochroma (Ach.) M. Choisy			+
Lecanora sambuci (Pers.) Nyl.	+		
Lecidella elaeochroma (Ach.) M. Choisy.			+
Phaeophyscia chloantha (Ach.) Moberg.	+	+	+
Phaeophyscia hirsuta (Meresck.) Essl.			+
Phaeophyscia orbicularis (Neck.) Moberg.		+	+
Physcia adscendens (Fr.) H. Olivier	+	+	+
Xanthoria parietina (L.) Th. Fr.	+	+	+

In general, poplar SRF are a lichen-poor environment s compared to natural forests, and most lichen species are to be found on trees of surrounding agro-ecosystem.

1.10 DIVERSITY IN DEAD WOOD

In the past, deadwood was perceived as a negative element of forest management, normally associated to mismanagement, negligence, and wastefulness of the applied forest management (Stachura et al., 2007). It was regarded as a potential source of biotic pests, mainly insects (Bütler, 2003; Marage and Lemperiere, 2005). The presence of deadwood was also seen as a threat of the spread of abiotic disturbances, e.g fire (Thomas, 2002; Travaglini et al., 2007). In managed stands, deadwood represented an obstacle to silvicultural activities (Travaglini and Chirici, 2006; Travaglini et al., 2007) and regeneration (Thomas, 2002).

However, from the ecological point of view, dead wood is vitally important for habitat provision for a number of species. As a matter of fact, dead wood has been selected as one of the Pan-European indicators of sustainable forest management (MCPFE, 2002). Deadwood is also one of 15 main indicators of biodiversity proposed by European Environmental Agency (Humphrey et al., 2004).

In natural forests, deadwood originates from tree mortality, which either is the result of inter-tree competition or senescence processes, or it is caused by natural disturbances, which can differ in terms of quality and quantity (Rahman et al., 2008).

The biological importance of deadwood depends on several factors, in particular on tree species, dimension, vertical and horizontal position, decay stage, and micro-environmental conditions (Radu, 2007).

The rate of deadwood decay depends on the chemical composition of wood, which is specific for each tree species. Some tree species are decay resistant, for example oak or pine. Softwood species such as willow, birch, and poplar, have a much shorter period of decomposition (Radu, 2007).

From all deadwood characteristics, the amount of deadwood is usually taken as an indicator of biodiversity (Stokland et al., 2004; Vandekerkhove et al., 2009).

Short rotation management produces little quantity of dead wood that are beneficial to saproxylic insect species (Jukes et al., 2002), several of which have a high conservational value (Campanaro et al., 2011). In SRF rotations there will not be enough time for dead wood resources to develop and therefore the ability of this habitat to support saproxylic species will be low. Within plantation forests the proportion of dead wood capable of supporting dead wood species does not accumulate until 80 years after planting (Brin et al., 2008). Short rotation management produces little quantity of dead wood that are beneficial to saproxylic insect species (Jukes et al., 2002). In SRF rotations there will not be enough time for dead wood resources to develop and therefore the ability of this habitat to support Saproxylic species will be low.

Native species will generally have a higher arthropod loading than exotics and their litter is usually broken down more rapidly by micro-organisms which have adapted to it (Hardcastle et al., 2006).

If SRF plantations are located in close proximity to old growth native woods or mature plantations then SRF may have a use as foraging ground (Afas et al., 2008) which could benefit species from several taxonomic groups, as Syrphidae. The majority of Syrphidae larvae require dead wood to complete their early development stage, but adults feed off flowers within more open habitat so SRF planted within their range may be beneficial (Gittings et al., 2006; ISPRA, in press).

Future research should focus on belowground characteristic and on the components of different type of deadwood in SRF, which is currently not sufficient for inventories. For forest management, more specific guidelines with regard to forest type and/or region would be helpful to favourish sufficient amount of deadwood for biodiversity (Merganičová et al., 2012).

The potential biodiversity of arthopods that directly populate the individual trees and plants – particularly phytophagous beetles and butterflies – can vary significantly between tree and plant genera. Kennedy and Southwood (1984) only found two species of insects on the *Robinia genus*, which is a neophyte in Europe, but 450 on *Salix*. *Salix* genus is known to provide a habitat for more arthropod species than most other trees and, in general, displays the greatest potential of animal diversity (Brändle and Brandl, 2001).

1.11 INVASIVENESS

Many tree forest species proposed for bioenergy production are selected for precisely the same traits which make invasive species successful. Several species are, in fact, already considered invasive elsewhere. Species/genotypes used for SRF have to be subject to pre-entry weed risk assessments before cultivation and to a post-entry monitoring programme for those species that passed the initial risk assessment (Crosti, 2010a).

The potential adverse impacts of new biofuel crops or biofuel cropping systems should be balanced with the short-term commercial benefits. Introductions that cause accidental damage to habitats and ecosystems could be significantly cut by minimizing invasive traits during horticultural breeding programs and by adopting cultivation criteria to mitigate the invasiveness of biofuel crops (Crosti, 2010b).

Many invasive plant risk systems have been developed for Central Europe (Weber and Gut 2004), North America (Reichard and Hamilton, 1997), and by FAO (2005) for developing countries (Crosti, 2010b).

Several countries have adopted formal risk assessments to identify high-risk species, facilitate decision-making on prevention and eradication and to avoid ecological and economic harm. IPPC, EPPO, and ISPM were involved in Pest risk analyses (Crosti, 2010).

Between species used in SRF *Ailanthus altissima* e *Robinia pseudoacacia* are particularly invasive but don't show to penetrate in Mediterranean context, for example in natural woods of oaks if they are correctly managed.

However *Robinia* and *Ailanthus* have to be used with caution. They can become a dangerous weed in places where their presence is not desired, since they are difficult to eradicate and cutting stimulates the emission of new suckers.

In case of *Ailanthus altissima plantation*, a large buffer zone of 100 metres should be ploughed at least once every three years to reduce the likelihood of establishment of species (Crosti, 2010b).

The clones of *Populus* x *euramericana* can hibrydize with *Populus nigra* and to influence the genetic quality of natural *Populus* spp. In the important communitary habitat (according directive 92/43/ECC) 92A0 "*Salix alba* and *Populus alba galleries*". So they have not to be planted near areas where this habitat is established.

Eucalyptus spp. show no invasive capacity and its capacity of reproduction in Mediterranean climate is very low and rarely it penetrate natural environments.

Therefore potentially invasive SRF species should not be planted close to sites that can act as source systems, stepping stones, or ecological corridors (Crosti, 2010a).

Robinia and *Ailanthus* have to be used with caution. They can become a dangerous weed in places where their presence is not desired, since they are difficult to eradicate and cutting stimulates the emission of new suckers.

However, *Ailanthus altissima* and *Robinia pseudoacacia* are particularly invasive in Mediterranean climate anthropic context (urban sites, railway and highway embankment, degraded or artificial river shore). However, these species do not penetrate in natural woods when they are correctly managed.

The clones of *Populus x euramericana* can hibrydize with *Populus nigra* and to influence the genetic quality of natural *Populus* spp. Where the 92A0 "*Salix alba* and *Populus alba galleries*" important habitat (according to Directive 92/43/EEC) is established, these cultivars should not be planted to prevent genetic pollution of natural stocks.

1.12 IMPACTS ON LANDSCAPE-LEVEL BIODIVERSITY

The reduction of habitat quality and the increase in homogeneity of agricultural landscapes are major causes of biodiversity loss (Benton et al., 2003; Donald et al., 2006). These changes have reduced the availability of resources such as food, shelter and breeding sites for birds and mammals both in arable and pastoral lands (Vickery et al., 2001; Firbank, 2005).

The size and distance between suitable habitat patches play an important role in the survival of animal populations; the connectivity between these patches within the landscape matrix has therefore become a key issue in the conservation of biodiversity (Hanski, 1999).

For some animals good management of SRF in high intensity cultivated lands can help the establishment of "stepping stones areas" and the establishment or maintenance of green corridors. However, a rapid large-scale shift from "conventional" agricultural crops to SRC may create negative implications on a range of environmental issues.

In areas neighbouring power stations using biomass as a fuel (with approximate radius from power stations of up to 100 km) SRF and SRC should be cultivated on a substantial fraction of all available agricultural land to fulfill biomass needs for fuel in power stations, simultaneously being economically and energy efficient (Dimitriou et al., 2009b).

Impact assessments and ecological evaluations of landscape functions need to carefully consider site-specific conditions (soil type, climatic parameters, etc.) as well as existing environmental goals. Furthermore, the land use history and the vegetation in the surrounding landscape have considerable influence on species composition in SRC plantations.

Maintaining SRF stands of different ages provides alternative habitat for animals displaced by the clear-cut felling of a stand (Sage, 1995). Also, given a heterogeneous landscape with differing aspect, exposure, soils and soil moisture, greater conservation value would be achieved by siting new plantations so as to cover a range of these differing abiotic conditions. Although a buffer zone should be left between SRF and existing woodlands or hedges (Maudsley, 2000).

Planning will also need to take account significant 'views', wider setting of heritage sites and the identification of most sensitive landscapes that have to be excluded by SRF establishment (McKay, 2012).

The contribution of SRC species composition to gamma diversity at the landscape scale depends strongly on landscape structuring, land-use variability and habitat diversity (NABU, 2008). Positive effects of SRC plantations were found in agrarian regions with uniform landscape structures where SRC sites are reputed to be a source for plant species richness (Gustafsson, 1987; Weih et al., 2003, Kroiher et al., 2008). The temporal variation of SRC structure is an important reason for the positive phytodiversity effects on them (Bolte, 2012).

To have positive effects on landscape, it is necessary to locate, design and manage the plantations in such a way that they maximize variation in habitat type and landscape. A good biodiversity management would be to plant several varieties (preferably of different gender) within the same plantation in sections or parallel stripes in order to facilitate harvest actions.

Following correct, ecology-wise strategic decisions, the biodiversity increase effects of SRC show their best performance in homogenous, species-poor, anthropized and degradated landscapes.

2. IMPACTS ON SOIL SUSTAINABILITY

It is important to evaluate impacts of SRF on soil quality, including organic matter, nutrient capital, compaction, erosion, and soil biodiversity. SRF could affect soil quality by causing changes in organic matter, soil acidity, flux of nutrients and nutrient capacity, soil biodiversity, erosion (Doran et al., 1994; Paul et al., 1997; Reeves, 1997; Lal et al., 1998).

The absolute impacts of SRF can be summarised into two sections:

- direct soil effects of the crop on Organic matter, Acidity Nutrient dynamics and Biodiversity;
- effects of silvicultural and management operations, including the impacts on soil erosion and compaction.

The SRF management is associated with minimal mechanical disturbance of the soil and less agrochemical inputs in comparison with conventional cropping systems (Lemus and Lal, 2005; Dickmann, 2006). This, together with the leaf litterfall of deciduous trees, is likely to promote the increase of soil organic carbon (SOC), nitrogen (N) and phosphorus (P) content, as well as of soil microbial biomass (Lal, 2003; Liebig et al., 2005; Ritter, 2007; Iovieno et al., 2010).

The reduced cultivation of soil associated with a change of land management from annual crops to SRC or SRF could reduce erosion and increase the organic matter content of soil (Tubby, 2007).

Short-term studies have demonstrated increases in surface soil organic-matter content, reduction in erosion and nutrient losses in surface runoff (Mann and Tolbert, 2000). Increasing soil organic carbon, structure, water-holding capacity and storage and availability of nutrients SRF systems can facilitate abundance and diversity of soil biota and increased resistance to compaction (Mann and Tolbert, 2000).

Growing SRF crops for biomass may potentially lead to significant soil nutrient depletion and acidification over time. These effects are species-specific: for example under *Salix* and *Populus* base cations were substantially reduced, whilst under *Fraxinus*, *Tilia* and *Alnus* an increase was registered. Removal of essential major and micro nutrients (e.g. nitrogen, phosphorus, potassium and boron), eventually leading in subsequent rotations to lower soil fertility and potential loss of tree growth (Nisbet, 2012).

Land available for SRF in the region comes mainly from former agriculture, where soil is generally enriched by nitrogen and phosphorus fertilizers. Most agricultural areas that can be used for SRF in Mediterranean and sub-Mediterranean climate are on acidic to subacidic vulcanic soils, or on near-to-neutral alluvial soils. These soils are fertile in particular where they had a long history of agricultural activities. In these areas, the best species for SRF were recognized as *Ailanthus altissima*, *Eucaliptus* spp., *Populus* spp., *Robinia pseudoacacia*, *Salix* spp..

Secondary surfaces, like small agricultural and ex-agricultural places on mountain range, are often on steep slopes and in absence of management they became easily erodible. In these areas, SRC with *Populus tremula*, *Salix* spp., *Acer* spp., *Castanea sativa* can be used in to fight soil erosion and to give economic revenue to the remnant farmers. Where the soil is wet for all the year, or frequently waterlogged, the establishment of multiple willow rotations in SRC has been found to contribute to the long-term enrichment of soil organic carbon (Lockwell et al., 2012).

2.1 CHANGES IN ORGANIC MATTER AND SOIL CARBON SEQUESTRATION POTENTIAL

SRF may play an increasing role as a source of renewable energy and could be very important for yield estimates on the one hand and for C sequestration on the other hand.

Using short rotation forests might reduce C emissions with direct carbon sequestration by reforestation and afforestation that yields a stock of carbon in standing trees. Furthermore the forest products can substitute fossil fuels or fossil fuel intensive goods such as steel and concrete. In both instances, carbon offset occurs by preventing the emissions from fossil fuels, which would otherwise have been used (Baral, 2004).

The decomposition of leaf litter is largely influenced by the concentrations and ratios of nutrients (Berg and McClaugherty, 2008). In general, decomposition rates increase with a decrease in the ratio of carbon to N (C/N ratio), which is an important indicator of litter quality (Heal et al., 1997). In general, the litter of exotic species breaks down more slowly than similar material from native species. It also carries lower numbers of phytophages (McKay, 2011).

A constituent limiting the rate of litter degradation is lignin (e.g., Melillo et al., 1982; Osono and Takeda, 2005), a complex aromatic heteropolymer in cell walls, which is one of the litter components that are most recalcitrant to decomposition (Osono, 2007; Berg and McClaugherty, 2008). Therefore, not only the species mixture of the litter but also the presence or absence of individual litter species can influence the decomposition rate.

Conversion of agricultural land to SRF has potentially beneficial effects on soil carbon dynamics, with reported gains in soil C of up to 20%. Crop residues and their decomposition are the main factors determining the organic matter content of soils (Paul et al., 1997). Minimum tillage can increase the organic carbon content in soils of crop systems, especially in surface soil layers (Johnson et al., 1995; Paul et al., 1997; Baum et al., 2009).

Under plantations, the high deposition of organic matter in the form of leaves and woody debris provides soil organisms with a more varied and abundant resource than is provided by agricultural crops, and this leads to a more species-rich and abundant assemblage of litter and soil-living organisms (Makeschin, 1994; Bardgett, 2002).

Inputs of crop residues and their decomposition are the main factors determining the organic matter content of soils (Paul et al., 1997). Minimum tillage, in particular, can increase the organic carbon content in soils of SRF crop systems, especially in surface soil layers (Johnson et al., 1995; Paul et al., 1997; Baum et al., 2009).

Litterfall quality and quantity, in addition to original soil status, play an important role in altering soil organic matter content and C sequestration under SRF. Soil C sequestration rate is likely to increase along a gradient from broadleaves to conifers.

Leaf litter from broadleaved trees provides organic material is generally decomposed and incorporated into the upper soil horizon (Drift, 1961). Litter decomposition strongly relate to N and lignin content, C/N ratio, leaf area and Ca content (Cornelissen, 1996; Wedderburn and Carter, 1999; Peterken, 2001; Reich et al., 2005; Hobbie et al., 2006; Vesterdal et al., 2008).

Additional important factors affecting the rate of leaf decomposition are soil pH and soil moisture, with moist, base-rich soils providing conditions for the quickest rate of decomposition (Witkamp and Drift, 1961; Pereira et al., 1998; Hunter et al., 2003; Reich et al., 2005).

Broadleaved and deciduous exotics have a similar effect on soils to native broadleaves (Peterken, 2001). In general, the litter of deciduous broadleaved trees has a beneficial effect on soil chemistry and structure.

Eucalyptus species takes longer to decompose (Cornelissen, 1996), but will decompose more quickly than that of native conifers (Wedderburn and Carter, 1999). The soil of *Eucaliptus* stands can be relatively dry dued to high capacity of *Eucalyptus* species for water uptake and interception. This may slow the decomposition rate.

A pronounced increase of soil organic matter content was evident due to the presence of poplar plantations on arable soil (Moscatelli, 2008).

Litter of *Robinia* stands, as species occurring early in natural succession, have both high lignin and high N contents. The shorter term effects of its presence appear to be increased N availability (Montagnini et al., 1986).

Table 4 Rate of decomposition of some tree species used in Short Rotation Forestry

Species	Litter Breakdown Rate
Acer spp. [1]	Fast
Alnus glutinosa[1]	
Corylus avellana[1]	
Robinia pseudoacacia[2]	
Castanea sativa[1]	Intermediate
Salix alba [1]	
Populus spp[1].	
Eucalyptus spp. [1]	Slow

[1] Hardcastle et al, 2006;[2] Lee 2011

Table 5 Nutrients in the litter of some species

Species	Litter N %	Litter BC content	Litter C %	pH	C/N
Acer pseudoplatanus	0.94[1]	3.03[1]	46.2[1]	6,4[5]	30.1-49[1, 9]
Castanea sativa	0.48-1.31[1, 5]	1.19-1.28[1]	49.7-50[1]	4.46 [6]	38,2--103 [5, 6]
Alnus *Glutinosa*	2.14- 2.664	4.82-5.63[4]	4.09-32.48 [2,3,4]	7.92-7.96[2]	10.06-13.74[2,4]
Corylus avellana	1.34[1]	2.6[1]	4-20[10]	4.3-5[8]	39,4[9]
Populus x euramericana	1.93,[7]	4,8,[7]	2,44-2,72[2]	7.9-8[2]	8.12-9,08[2]

BC = base cation Ca+K+Mg% as defined by Cornelissen and Thompson, 1997
1 Mc Kay, 2012; 2 Perez-Corona et al., 2006; 3 McTiernan et al., 1997; 4 Miletić Z. et al., 2012; 5 Scheid et al., 2009; 6 Marschnera and Noble, 2000;,7 Kaushal and Verma, 2003; 8 Remacle, J., 1970; 9 Hladyz et al., 2009, 10 Smith, 2004

The quantity of litter influences soil organic matter and it can vary over time and with species, age and planting density.

The amount of litterfall can be influenced by difference in climate and deposition. For example, total annual litterfall of pine is 3.8 t/ha for year and of beech is 2.9 t/ha for year in low N deposition areas compared to 8 t ha-1 y-1 and 3.9 t ha-1 y-1, in a high N deposition area (Vanguelova and Pitman, 2009).

The following 'bad practise' can reduce the potential for biomass systems to reduce carbon emissions from a 'whole life cycle' perspective:

- Cultivating soils with a high carbon content for the production of energy crops.
- Using intensive crop management regimes including inorganic fertilisers, irrigation and pesticides.
- Inefficient fuel processing and fuel transport logistics.
- Sub optimum conversion technologies (Tubby, 2007).

There is a significant increase in the horizon surface due to nitrification of organic matter if the killed strains are grinded the residual organic of works remains in site.

The impact of SRC on soil affects C sequestration, nutrient cycling from litter and soil microorganisms. The C turnover under SRC grown on agricultural soils previously cultivated with conventional crops is more similar to that in forests than in arable soils (Svensson et al., 1994).

The C accumulation after conversion of fields with conventional arable crops to SRC is reported to be concentrated in the topsoil (Makeschin, 1994; Stetter and Makeschin, 1997; Neergaard et al., 2002; Dowell et al., 2009). Estimated rates of C accumulation in topsoil, e.g. 0-40 cm, of arable sites were 40-170 g C/m2/yr during the first decade following SRC establishment (Garten, 2002).

The increased C concentrations in SRC soils can be explained by the lack of tillage in SRC (Dimitriou et al., 2011) and the high annual amounts of leaf litter deposited on the soil surface (average 1 to 5 t/ha) (Verwijst and Makeschin, 1996; Bowman and Turnbull, 1997) and by the increased transfer of assimilates into external mycelium of mycorrhizal fungi (Ek, 1997).

2.2 CHANGES IN SOIL ACIDITY AND BASE CATION CONTENT

It was reported for former agricultural sites a slight increase of soil pH after tree establishment of Salix but a drastic decrease under *Alnus* plantations. *Alnus*, *Prunus*, *Fraxinus* and *Tilia* have been shown to raise the soil pH. *Tilia cordata*, *Betula pendula*, *Acer pseudoplatanus* and *Fagus sylvatica* litter increased soil pH and base saturation the most in the organic and top mineral soils compared with coniferous species (Reich et al., 2005).

Most planting and potential planting places of SRF in Latium are ex-agricultural land which is rich in base cations, nitrogen and phosphorus. Removal of base cations can reduce soil buffering capacity and leading to increased soil and stream water acidification. Over time, growing SRF may lead to significant soil nutrient depletion and soil acidification. During the growth of SRF, pH is likely to be reduced, particularly if the land use change is from arable to woodland. However, this effect may be species specific.

Ad example short rotation afforestation with *Populus* spp. and *Salix* spp. on former arable soils in Germany decreased soil pH in topsoil and Cation Exchange Capacity (CEC) after 10 years. Soil Ca saturation decreased but Mg increased over seven years of planting combined with fertilisation treatments (Jug et al., 1999).

About *Robinia pseudoacacia*, fast decomposition of flower and leaf litter significantly increased membrane phosphate in the soil.

2.3 CHANGES IN SOIL NUTRIENT DYNAMICS AND NUTRIENT CAPACITY

The long-term sustainability of soils in short-rotation biomass production depends by the balance between removal of nutrients by harvesting and nutrients added by natural or induced fertilisation.

Nutrients can leach from the soil or move with eroded soil particles so it's important to choose flat or low degree areas.

Harvesting can remove large amounts of total nutrients (Mann et al., 1988; Ranney and Mann, 1994; Heilman and Norby, 1998). Research in short-rotation systems of aspen, hybrid poplar, sycamore, willow, and alder have demonstrated that the amount of nutrients removed in harvested wood is approximately proportional to the accumulation of biomass without leaves over the time of each rotation (Mann and Tolbert, 2000, Perala, 1979; Korsmo, 1982; Börjesson, 1999).

Poplar cultivated as SRF stand removes nitrogen at the much higher quantity than the traditional poplar stands, as rotation cycle of the latter is about 10 year, with a planting density of approximately 300 stems for hectare. The removal of N at harvesting in a SRC plantation equal the amount of N removal in a conventional agriculuture crop, like wheat or corn.

Table 7 Comparison of removal of nitrogen (N) in poplar SRF with long term plot and some of the most common herbaceous crops (from: Massacci *et al*., 2012)

Farming	Product	Yield (t ha^{-1})	Dry matter (%)	N In Dry matter (%)	N removal (kg ha^{-1} $year^{-1}$)
Mais	Grain	9	84,5	1,7	182
	Stalks and leaves	15	50	0,7	
Wheat	Grain	4	86	2,3	117
	straw	5	86	0,5	
Poplar srf (10-15 years)	Industrial wood	200	50	0,4	31-40
Poplar SRC (First harvest of 2-year rotation cycle)	Biomass fuel	42	45	0,7	70
SRF Poplar (Second harvest of 2-year rotation cycle)	Biomas fuel	66	45	1,01	151

Eucalyptus (*E. globulus*) leaves caused strong soil inorganic N immobilisation (-7 mg N g-1 residue – C) compared to legume species as *black locust* leaves immobilised nitrogen first and then remineralised the N later (Adams and Attiwill, 1990; Corbeels et al., 2003).

The rapid nutrient-cycling of *Robinia pseudoacacia* through flower litterfall and rapid decomposition benefit the plant itself in the growing season, when nutrients demand is increasing. Rapid nutrient-cycling is a strategy that helps *R. pseudoacacia* to persist in poor soil environments (Lee et al., 2011).

Robinia causes an increase of nitrogen in soil through its symbiosis with nitrogen-fixing bacteria belonging to the Rhizobia family and other mycorrhizal fungi. The amount of nitrogen made available from *Robinia* is considerable: in a population of 4 years has been estimated that fixing nitrogen for the benefit of the species itself amounts to 30 kg / ha (IPLA, 2000).

Deposition of nitrogen compounds from the atmosphere can increase biomass productivity, especially near urban areas, and this has reduced the need for nitrogen fertiliser. The availability of nitrogen-rich waste (e.g. sewage sludge) provides opportunities for the recycling of nitrogen in the urban-rural environment. In some areas, the abundance of nutrient-rich sludge and waste-water can trigger the establishment of short-rotation crops for bioenergy purposes (Verwijst, 2008).

It is therefore appropriate to explore new systems of plantation management in which N may be added via fixation (Khanna, 1997). Mixed plantation systems seem to be the most appropriate for providing a broader range of options, such as production, protection, biodiversity conservation, and restoration (Montagnini et al., 1995; Keenan et al., 1995; Guariguata et al., 1995; Parrotta and Knowles, 1999).

In intensive SRF crops large losses of K occurred and overall decline in soil Mg and Ca was evident (Ranger and Belgrand, 1996). The recommendations were to leave behind finer parts of trunks at harvesting to maintain fertility of the soil for regrowth, and create as little soil disturbance as possible (should replanting be necessary) to minimise nitrification losses in the soil beneath (McKay, 2011).

In Northern Europe some studies show the capability of SRC to absorbe nitrogen. Drainage water and groundwater under the plantation shows low values of N despiting the use of fertilizer during the time of observations (Aronsson et al., 2000, Bergström and Johansson, 1992, Goodlass et al., 2007, Mortensen et al., 1998).

It’s recommended for sustainably SRC practice cultivate them in fields located close to N sources (animal farms, wastewater treatment plants etc) to decrease N outflow to adjacent water bodies (Dmitriou and Bolte, 2012).

Deposition of nitrogen compounds from the atmosphere has increased biomass productivity, especially near urban areas, and this has reduced the need for nitrogen fertiliser. The availability of nitrogen-rich waste (e.g. sewage sludge) provides opportunities for the recycling of nitrogen in the urban-rural environment. In some areas, the abundance of nutrient-rich sludge and waste-water can trigger the establishment of short-rotation crops for bioenergy purposes (Verwijst, 2008).

In Sweden after testing different irrigation regimes with wastewater under different soil conditions, wastewater application at least 150 kg N/ha yr should not pose any threat to extensive NO3-N leaching (Aronsson, 2000).

About *Robinia* feature of its root system is the presence of symbiosis with nitrogen-fixing bacteria belonging to the Rhizobia family and fungi (mycorrhiza). The amount of nitrogen made available from locust is considerable: in a population of 4 years has been estimated that fixing nitrogen amounts to 30 kg/ha (IPLA, 2000).

In forests of poor environments proximal formations of *Robinia* are able to modify the nitrogen cycle giving rise to an increase of the quantity to the ground, to a contribution increased through precipitation and to an increase of mineralization rate of this element (Rice et al., 2004).

2.4 IMPACTS ON SOIL BIODIVERSITY

As there is no need for annual cultivation in SRC and SRF systems the biodiversity value of soils under these crops may be higher than for soils under conventional agricultural crops. Fungicide, herbicide and insecticide applications are likely to be absent or less frequent in SRF systems compared with conventional agricultural crops (Tubby, 2007).

Soil biodiversity is directly linked with the soil quality including soil texture, nutrient regime, organic matter, moisture, acidity and Green House Gases (GHG). In addition, as tree species differ in the amount and quality of litter produced, these differences may directly or indirectly affect the associated soil invertebrates.

Whereas earthworm populations are likely to increase with increasing litter, numbers of Carabid beetles are likely to decrease. However, balancing positive impacts due to the non-tillage management might increase both abundance of earthworms and an increased diversity of Carabids (Baum et al., 2009).

The effects of SRF on earthworm populations appears most closely related to soil C/N ratio, the phenol content of the litterfall and the soil status in terms of mull or modern humus type development. Earthworms role in organic mixing is vital, but where worms might increase under heavier litterfall, Carabid beetle populations might well fall.

The beneficial presence of ectomicorryhizal fungi has been demonstrated under *Populus, Salix, Betula* and *Eucalyptus* species, present in much higher numbers than in similar arable soils.

Soil biodiversity is directly linked with the soil quality including soil texture, nutrient regime, organic matter, moisture, acidity and green-house gases (GHGs). In addition, as tree species differ in the amount and quality of litter produced (Table 6), these differences may directly or indirectly affect the associated soil invertebrates. Generally higher diversity of epigeal invertebrates is present in SRC respect intensively cultivated soils (Liesebach et al., 2000).

Under plantations, the high deposition of organic matter in the form of leaves and woody debris provides soil organisms with a more varied and abundant resource than is provided by agricultural crops, and this leads to a more species-rich and abundant assemblage of litter and soil-living organisms (Makeschin, 1994; Bardgett, 2002).

Soil microbial communities are important regulators of processes such as nutrient cycling and decomposition, and can offer protection against pests and diseases. These microorganisms rely predominantly on organic matter provided by root exudates, secretions and other rhizodeposits, including root turnover.

Microorganism communities in SRC are greatly influenced by plant species and genotype. For example, the diversity of saprotrophic microfungi in the rhizosphere depended on the willow variety grown in SRC plantations (Šlapokas and Granhall, 1991; Baum and Hrynkiewicz, 2006).

The change in vertical distribution of soil microorganisms under SRC on former arable sites was caused by lack of tillage in SRC. The microbial biomass in the soil increased in the upper 5 cm of soil but decreased in subsoils compared to the agricultural soil under SRC (Makeschin, 1994).

Investigations have revealed that above-ground vegetation can have a great influence on the below-ground earthworm population and diversity (Muyset al., 1992; Zou, 1993; Sarlo, 2006).

Earthworms are favoured by the longer soil rest period the decreased use of pesticides (Makeschin, 1989; Makeschin, 1994). Earthworm communities varied considerably between grassland sites that were afforested with different tree species depending on the quality and quantity of the litter produced (Muys et al., 1992).

2.5 DECONTAMINATION OF SOIL BY SRF AND SRC CROPS

Important environmental functions in some polluted areas can be grouped under the phytoremediation, ie the use of plants for environmental clean up, by absorption or degradation or stabilization of various forms of compounds dangerous in the soil, water and air (Lichta and Isebrands, 2005). The hazardous compounds that can be deactivated through phytoremediation are several: nutrient elements to plant or phyto-nutrients (primarily nitrogen-N, and phosphorus-P), many heavy metals (Cu, Cd, Zn, Pb), many organic pollutants, petroleum hydrocarbons (Lichta and Isebrands, 2005; Rockwood et al., 2004).

In Mediterranean coastal land are very anthropized and polluted, there are big industrial areas, intensive agriculture, traffic and cities. So in these areas SRF can help to decrease air pollution (McKay, 2011).

The species of genera *Populus* spp. and *Salix* spp have been proposed in recent years for the ability to accumulate heavy metals (Robinson et al., 2000) and many toxic organic compounds (Lunackova et al., 2004; Hinchman et al., 1996), including atrazine (Burken & Schnoor, 1997), hydrocarbons (Jordahl et al., 1997), herbicides (Gullner et al., 2001) and trichlorethylene (Newman et al., 1997) belong to this family.

The poplars are generally able to accumulate Zn and Cd in Poplar in turn cut short for bio-energy and phytoremediation leaf tissues (Gallagher et al., 2008; Chang, et al., 2008), and are also been used as bio-indicators for pollution of As in soil, some clones of willow showed good ability to relocation of Zn and Cd in the leaves and branches (Rosselli et al., 2003).

Some poplars also seem to tolerate well the presence of some heavy metals in soil managing to maintain a good rate growth in soils strongly degraded by the presence of these pollutants (Massacci et al., 2012).

The tolerance of *P. x canadensis* towards high Cu concentrations (TI25 = 93.0 and TI75 = 77.2) was remarkable, as well as its ability to accumulate the metal in the root system without suffering from toxicity. The wide and well-expanded root apparatus of this clone could be advantageously exploited in phytostabilization programs to avoid the spreading of pollutants through the environment (Borghi et al., 2008).

In the Valley of River Sacco were identified many agricultural areas off-limits to human activity for industrial pollution, as a measure of safety measures for the elimination of the risk of contamination in the food chain and for protection of public health and the environment. In these areas has been activated cultivation of biomass for processing agroenergetic (poplar Short Rotation Forestry) in substitution of intensive crops (Massacci et al., 2012).

The characterization of *Salicaceae*, driven by small genome, easiness of agamic propagation, genetic susceptibility to transformation and the availability of genetic maps and genomic resources appear promising for selecting candidates for phytoremediation (Tognetti et al., 2013).

In roots of *Salix* spp., the capacity to bind heavy metals, such as Cu and Zn, in the cell wall has a protective action against the deleterious effect of metals by reducing the amounts of cytosolic metal, and representing plant suitability for phytostabilisation (Brunner et al., 2008).

The establishment of willow for urban green structures able to be used as SRF, such as sound barriers, snow fences and wind breaks, along highways and streets could replace exotic trees, promotes air quality and remedy to water and soil multi-metal pollution.

Research to examine the ability of *Paulownia* to take up nitrates, heavy metals and land contaminants has been conducted over the past two decades (www.worldpaulownia.com/html/remediation.html).

Paulownia is an ideal crop for use in areas where large amounts of manures have to be spread. Pig and poultry farmers in the USA are using the trees to spread manure on as they can utilise a huge amount of nutrients (Woods, 2008) It has a very high uptake of nitrates, heavy metals, contaminants and other elements from shallow and deep sub soil (World Paulownia Institute).

SRC plantations can be used as vegetation filters for treatment. It is possible to locate plantations as buffer strips for capturing the nutrients in passing run-off water (Berndes et al., 2008). When planted and managed as part of a controlled programme, trees and woodland can play an important role in the rehabilitation of derelict land, including landfill sites (Jones Jr. et al., 2001; Pulford and Watson, 2003; French et al., 2006; Strycharz and Newman, 2009). A key benefit for water quality is reducing the mobilisation and leakage of contaminants that have the potential to pollute both surface and groundwaters.

Trees can assist remediation in a number of ways: by helping to enrich the soil with organic matter, which is important for immobilising many contaminants (Hutchings, 2002); by providing a semi-permanent landcover, reducing the risk of soil disturbance and erosion y reducing surface runoff/groundwater recharge and thus the potential for leaching of contaminants to water; and by the active uptake of contaminants and fixation in woody biomass (Dickinson et al., 2009). There is also a role for planting woodland adjacent to contaminated land, which can help to reduce the offsite migration of contaminants by intercepting polluted runoff and by reducing wind erosion and trapping airborne contaminated soil.

The shallow rooting behaviour of willow, combined with a high planting density, makes SRC of this species particularly suitable for use as a vegetation filter. Around 80% of the root hairs of willow are found at depths of less than 40cm (Rytter and Hansson, 1996; Crow and Houston, 2004). The high planting density (> 15,000 stools/ha) allows the development of a dense root hair system over the entire area occupied by the crop. Many scientists have applied the concept of a vegetation filter to SRC, in particular for the treatment of organic compounds and the absorption of directly assimilable nutrients and some heavy metals (Perttu and Kowalik, 1997; Aronsson, 2001).

Furthermore willows have been reported from early stages of their commercial bioenergy use to take-up large amounts of Cd (Perttu, 1992; Riddell-Black, 1994).

Willow SRC is of particular interest for collective tertiary treatment of effluents from small settlements (domestic effluents for less than 500 inhabitant equivalents) or industries.

Large difference may occur in environmental performance between different species of SRC. The species of genera *Populus* spp. and *Salix* spp have been proposed in recent years for the ability to accumulate heavy metals (Robinson et al., 2000) and many toxic organic compounds (Lunackova et al., 2004; Hinchman et al., 1996), including atrazine (Burken & Schnoor, 1997), hydrocarbons (Jordahl et al., 1997), herbicides (Gullner et al., 2001) and trichlorethylene (Newman et al., 1997) belong to this family.

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Besides the positive effects of SRC to reduce heavy metal concentrations in soil, willow and poplar SRC have been reported to remediate soils from various organic compounds such as chlorinated solvents, explosives, petroleum hydrocarbons, cyanides, pesticides, and others (Schnoor et al., 1997; Aitchison et al., 2000; McMillan and Schnoor, 2000; Corseuil and Moreno, 2001; Predieri et al., 2001; Kelley et al., 2001; Ciucani et al., 2004; Ma et al., 2004; Ucisik et al., 2007).

Mediterranean Europe coastal lands are very anthropized and polluted, there are big industrial areas, intensive agriculture, traffic and cities. In these areas SRC can help to decrease air pollution (McKay, 2011). For example in hardly polluted area of Sacco Valley in Lazio, CNR have begun experimental plots against β-hexachlorocyclohexane pollution using Poplar (Massacci et al., 2012). In these areas has been activated cultivation of biomass for processing agroenergetic (poplar Short Rotation Forestry and Short Rotation Coppice) in substitution of intensive crops (Massacci et al., 2012).

3. IMPACTS ON HYDROLOGY

The principal water concern relates to the typically high water use of SRF crops, which could have an adverse impact on local water resources. Potential threats to water quality is likely to be the delivery of sediment to watercourses as a result of ground damage caused by harvesting operations, which can be controlled by good practice (Armstrong, 1999).

The overall quality impact of SRF is expected to be largely beneficial compared to the alternative land uses currently practised in areas generally considered appropriate for conversion to SRF (McKay, 2011).

The generally reduced fertilizer and pesticide applications in SRF compared with agricultural lands will benefit runoff and recharge water quality.

There are serious potential impacts from SRF on hydrology in some parts of Mediterranean Europe, especially when climate change predictions are included. The provision of advice to potential planters on where SRF could affect critical water supplies, and may need to be controlled, seems to be a high priority (Hardcastle, 2006).

The principal hydrological concerns associated with changes in land use are:

- annual or long term flow out of a catchment as a result of differences in evaporation;
- dry season flows;
- flood flows;
- water quality;
- changes to the above under a future climate change scenario.

About the impacts of SRF on dry season it would be expected: increase in interception and transpiration that can cause soil moisture deficits and reduce flows and an Increase of soil infiltration rates will lead to higher soil water recharge and increased dry-season flows (Harcdastle et al, 2006).

In general run-off quality should be superior to that from agricultural land, but quantity likely to be reduced (Hardcastle et al., 2006).

The greatest threat is presented by conifer and some broadleaved SRF crops such as Eucalyptus, while the use of other broadleaved species could possibly benefit water resources (McKay, 2011). In particular E globulus, the species widely planted in Spain and Portugal, is controversial because of its negative hydrological impact is not hardy in UK (Evans, 1986).

The production of food crops reliant on unsustainable irrigation in southern Europe could be replaced by growing less demanding SRC or SRF species. Large areas of land equipped with irrigation infrastructure have been abandoned in Southern Europe. SRC or SRF could be grown on this land using modest amounts of irrigation compared to fruit and vegetable crops (Hardcastle et al., 2006).

However it’s important to note that most of used plants are deeper-rooted and generally have high water consumption compared with conventional crops (Dimitriou et al., 2011).

To reduce the ecological and economic risk of SRC, the knowledge of same parameters as clone/species-specific water demand for a different rotation management, annual precipitation, precipitation during the vegetation period are essential. However SRC and SRF with high consumption of water could be used to manage flood risk in alluvial plains (Hardcastle et al., 2006).

The levels of water consumption of SRC in relation to other crops grown in the same area seem to depend on site-specific factors such as soil type, precipitation and others, and may vary from case to case.

Although results obtained in Germany suggested that infiltration from poplar SRC fields was almost 3 times less than neighbouring agricultural fields (Knur et al., 2007), others suggest that such differences are significantly lower (Dimitriou et al., 2009; RELU, 2009) and that the water use by SRC in comparison to other crops largely depend on site-specific factors.

SRC is generally considered to improve the water quality relative to conventional agricultural crops in a given area (Hardcastle et al., 2006) due to the management practices of SRC (weed control only during the establishment phase, tillage only before the establishment phase, and lower inorganic fertilization than other crops).

All the above about water quality and SRC indicate that when SRC replaces conventional agriculture crops, groundwater quality improvement is anticipated. In fact, several authors suggest the use of SRC in intensively managed agricultural areas to improve the current water quality and meet EU obligations in terms of water quality expressed in the Water Framework Directive (Jørgensen and Mortensen, 2000; Eppler et al., 2007; EEA, 2008).

Fast canopy development and high leaf area index during the growing season are the special features significantly affecting transpiration rates from leaves and interception evaporation from the canopy. Potential deeper rooting of SRC species compared to annual crops may also favour higher rates of water consumption.

A potential impact of SRC on the water use and balance in a certain area should be judged in comparison with the crops that will be replaced in a potential shift to SRC. Several authors report that evapotranspiration from SRC fields with willow and poplar is in most cases significantly higher than arable crops but lower than conventional forest (Persson, 1995; Stephens et al., 2001; Hall, 2003; Knur et al., 2007). Interception and transpiration of a regrowing willow stand are comparatively small until canopy closure is achieved (Dmitriou and Bolte, 2012).

As a consequence of the higher evapotranspiration rates reported, assumptions concerning the effect of willow and poplar SRC were reported (Hall, 1998; Allen et al., 1999; Perry et al., 2001) suggesting potential negative effects to water body enrichment from reduced percolation to groundwater due to willow and poplar SRC.

Modelling exercises (Stephens et al., 2001) indicated 10-15 % reductions of the hydrologically effective rainfall in SRC fields compared to arable crops in the UK.

Relatively high-yielding SRC plantations (above 12 t DM/ha/yr) should be avoided – as a precaution – in areas where precipitation is below 550 mm, since the consequences of reduced hydrologically effective rainfall can be much more serious in such areas (Hall, 2003).

4. IMPACTS ON LANDSCAPE AND CULTURAL HERITAGE

The European Landscape Convention[2], article 1, defines the landscape as "*an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors*" and in article 2 specifies that "*this Convention applies to the entire territory of the Parties and covers natural, rural, urban and peri-urban areas. It includes land, inland water and marine areas. It concerns landscapes that might be considered outstanding as well as everyday or degraded landscapes*".

The landscape, thus conceived, has a broad meaning that encloses the sites (with value or not), and a complex system of relationships between population and territory.

In spite of the somewhat subjective nature of landscape appreciation, there is general consensus as to what constitutes good design in the creation of new planting in the landscape.

The landscape analysis to that extent assess the visual character of the plantations as a landscape element in interaction with their surroundings. The assessment finds its theoretical references in the perceptive studies developed by K. Lynch (Lynch, 1964) declined at the territorial scale. The appearance of the energy forests and their impact on the landscape were analyzed and described on the basis of the aesthetic and of the visual and perceptive character of the forests as an element of the landscape in interplay with their surroundings.

To achieve this, in the first place it is necessary to consider the physical and aesthetic character of the plantation in reference to the surrounding landscape. These are:

- **Form** of new planting, whether 'geometrical' or 'natural'. The results of a Swedish study defined that the form is understood to be its linear perspective and its sculptural expression. The linear perspective can be described in terms of even or uneven. The structure is conditioned by the time of growth of the plants: when newly planted, a field may appear irregular since different plants receive a different start. However, after a few years the cultivation appears more compact. The sculptural impression of the form of SRF depends partly on the *structure,* i.e. the skeleton of the forest and the plants that characterize the type of growth and the sculptural structure, and partly on the *texture*, i.e. the external impression, the pattern, that is created by the foliage, the density of the plants, etc (Skärbäck, 2008).

- **Extension** of new planting within an established landscape framework.

- **Diversity of species/colour/texture**, reflecting the inherent diversity of the landscape. According to the study the colour can be characterized on three parameters:

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[2] The European Landscape Convention puts the landscape in the center of the European policy and introduces important innovations. It identifies the landscape both as representative of the identity of the people, and as an economic, ecological and cultural resource. A resource that needs protection, management and planning. It defined a policy for the landscape that provides "strategies and guidelines that permit the taking of specific measures aimed at the protection, management and planning of landscapes".
The term "landscape protection" defines the actions aimed at safeguarding the part of the territory which is characterized by an identity value derived from its natural configuration and/or from human activity.
The policy of "landscape management" aims at ensuring sustainable development and to harmonize the changes brought about by socio-economic and environmental processes.
The Convention provides the "active planning" understood as both the enhancement and renovation of part of the territory and as the creation of new landscapes to fulfill the needs of the population.
The main innovation of the Convention consist in being able "to recognise landscapes in law as an essential component of people's surroundings, an expression of the diversity of their shared cultural and natural heritage, and a foundation of their identity" (art. 5.a).

- lustre, ranges from matt to shiny. Newly planted fields are shiny but change after one or two year to matt;

- grey scale, from dark to light- grey;

- colour scale, defined on the basis of the composition of the colour (green, yellow, red, etc.).

The Swedish study defines the texture as compact or dense or alternatively elegant o pervious. The feeling of compactness has very much to do with direction of the sun light and with growth of the plants (Skärbäck, 2008). These characteristics are strongly linked to the choice of species. The choice do not always coincide with the traditional tree species present on the site, particularly if we consider the growth factor and resistance.

- **Unity of the new planting**, meaning its coherence and degree of harmonization with the existing/surrounding landscape (LTS, 2006).

- **Speed of change** of planting, a characteristic of SRF which makes the site of the plantation variable over time. It is important to consider this factor during the design stage because it causes a visual impact on the landscape. However, the fact that the SRF cultivation is a relatively dynamic form of cultivation that varies over the course of time, and which is a subject of relatively intense upkeep, means that the land does not appear to be abandoned, like waste ground, and is therefore regarded in a relatively positive light (Skärbäck, 2008).

These physical characteristics are related to the main factors for the localization and introduction of SRF in a specific area have to coincide with those used in good landscape design (Table 8).

Assuming that SRF is carried out within this design principles, the forecast of the new planting within the landscape is likely to be related to another number of factors, amongst which are:

- **Functional Location**, the new plantations are likely to meet less resistance in less densely populated landscapes where the primary land use and employment is to be found in intensive arable cultivation. The SRF, when newly planted, are most similar to fields growing agricultural crops. Then, as the fields gradually develop they begin to take on the appearance of overgrown land, or in other words waste land. When fully grown the SRF is reminiscent of a forestry (Skärbäck, 2008). The localization in the agricultural, industrial, polluted and degraded context can foster public acceptance. The latter is greater if the activity of SRF is related to the local needs (LTS, 2006). Resistance is likely to be greater where there are long-established and settled communities characterized by a greater range of employment opportunities (LTS, 2006). The new planting is likely to be regarded favorably by the public if it's related to energy generation projects and if the benefits directly involve the community.

- **Accessibility**, the new planting needs the infrastructures for the implementation of the production process. The visual impact of related features such as access roads and buildings involved in the transport, storage and processing of SRF products needs to be considered.

- **Landform,** it is a fundamental characteristic to consider in the decisive phase of landscape design. Careful thought will need to be given to the design of SRF plantations in areas of higher relief, where they may be visible from a distance.

Table 8 Key principles for the landscape insertion of a new planting of SRF

VISUAL IMPACT	The relationship of the planting with the natural landform and surrounding landscape. The visual impact of the planting of SRF strongly depends on its location. A new planting situated on a ridge area has a greater visual impact than a planting located in a downstream zone. Planning also need to take into account significant 'vistas' and the wider setting of heritage sites.
PERCEPTION OF THE PLACE	The landscape effect of SRF plantations is likely to be very strong due to the dense structures they are going to create. As with biodiversity the establishment of permanent energy crop plantations at a small-scale in intensively used and open agricultural landscapes will contribute to landscape diversity. Where they become dominant, however, or destroy the characteristics of traditional open landscapes they bring about a very strong change of landscape characteristics. It is likely that this will be perceived as a negative impact by most observers and users of the landscapes. Especially for landscapes that have a strong identity value which gives a particular landscape its unique character or significance. One should use caution with extensive SRF planting in the most sensitive landscapes if there is a lack of a high level of design input.
OBSERVANCE OF SYSTEM OF PROTECTION	The analysis of the system of protection in the area of intervention is detectable by tools of the landscape, territorial and urban planning and from any source of law.
PRESENCE OF HISTORICAL-ARCHITECTURAL AND ARCHAEOLOGICAL ELEMENTS	By comparing historical and current cartographies it is possible to identify the historical permanence of the territory. The historical knowledge enables us to understand the characteristics of each landscape to address the design choices. The main categories of historical elements can be: punctual, linear and areal.

4.1 KNOWLEDGE OF THE TERRITORY AND LANDSCAPING

Understanding the landscape of the sites likely to be used for SRF planting is considered a fundamental phase for the selection of areas for the location of cultures of SRF. It is realized through the analysis that highlights the natural and human elements that determine the characteristics of the site: hydrography, landform, vegetation, land use, urbanization, presence of protected areas, presence of protected natural sites, presence of historic and landscape areas of international interest, national and local points and scenic routes, areas characterized by a high value of perceptual and identity.

In general, the knowledge and evaluation of the features of the landscape are moments preparatory for the landscape design and then for the location and the inclusion of areas for the SRF.

Following the basic types of landscape analysis are described:

Table 9 Types of Landscape Analysis

Types of Landscape Analysis	Sources
Analysis of the levels of landscape and environmental protection	• Tools of the landscape, territorial and urban planning, in particular the landscape territorial plan • Sectoral plans • National, regional and local regulations
Analysis of the natural, ecological and human components of the landscape	• Cartographies and territorial and urban plan • Direct Survey
Analysis of the historical evolution of the territory It considers the transformation of the places during the years (study for significant phases)	• Historical cartographies • Historical Aerial Photography
Visual quality analysis of the landscape	• Cartographies • Aerial Photography • Direct Survey

The knowledge and evaluation involve different varies spatial scales according to the general and specific geographical features of the places. There are at least two levels: the local and territorial scale.

The basic knowledge are sometimes largely already available, sometimes they are to be built. they are a precise reference for the interdisciplinary study of the landscape the documents (technical and non) developed in the sector of planning, but also of the protection of historical and artistic heritage and landscape, as well as those explicitly dedicated to renewable energies. The Italian articulated reality requires verification of regulations and guidance documents prepared by the authorities and prescriptive (Regions, Provinces, Municipalities, etc.).

5. EFFECTS ON SILVICULTURAL AND MANAGEMENT OPERATIONS

Arguably the most important factor affecting soil loss and quality of run-off during site preparation is the quality of the planning and execution of operations (Kort et al., 1998).

Silvicultural and management operations on soils can cause erosion and compaction. Existing publications provide a protocol for sensitive management in this regard (e.g. DEFRA 2002; Hall, 2003). Protocols for sensitive management in this regard include use of low-pressure tyres, driving on lop and top to reduce soil compaction. Minimisation of soil compaction during harvesting should be assured through judicial timing and the exercise of care during operations. Soil compaction and the potential for gully erosion are reduced if there are not mechanised applications of agrochemicals and fertiliser (LTS International, 2006).

The periodic removal of the canopy may subject the unprotected ground to increased risk of erosion. This can be reduced using for SRF areas with low steepness according to characteristic of soil and climate. Compared with arable land use, good management of SRF crops has a stabilising effect on the soil, due to the relative infrequency of soil cultivation (Makeschin, 1994).

The high water use of SRC may be used to advantage to reduce peak flows and delay the onset of local flooding: using them to dry the soil profile on deep soils with large potential water storage would result in the soil accepting more winter rainfall before reaching saturation (Tubby, 2007).

During the planting and establishment of SRC on former arable soil initial high nutrient losses are possible because tillage promotes the mineralization and weed control reduces the organic matter input (Granhall and Šlapokas, 1984; Makeschin, 1994; Jug et al., 1999b; Baum et al., 2009b).

5.1 FERTILISATION

The high productivity of the crop and the periodic removal of the above-ground biomass making SRF systems particularly demanding in terms of soil nutrients (Perttu and Kowalik, 1997; Borin, 2003; Uri et al., 2007).

The intake of nutrients by spreading manure could be a valuable option (Osservatorio agroambientale, 1997; Heinsoo, 2002; Regione Lombardia, 2004; Rockwood et al., 2004; Mirck et al., 2005; Bisoffi et al., 2009), allowing the disposal of waste in an effective way from the environmental point of view (Laureysens et al., 2005c; Borjesson et al., 2006; Scarascia Mugnozza and Paris, 2007), thanks to the strong ability of phytoremediation of SRF (Rosenqvist et al., 1997; Vandenhove et al., 2001; Mertens et al., 2004; French et al., 2006; AA.VV., 2008; Rossignolo, 2008). A correct spreading of manure can help to hinder the pressing needs of the livestock system, characterized by strong excess waste and serious problems for their disposal due to the lack of available agricultural land (Bassanino et al., 2006) and severe limitations of regulatory systems (Sangiorgi, 2003; Ecosse et al., 2007).

A correct use of agronomic manure must take into account a variety of factors, including the content of nutrients in the wastewater, the homogeneity of distribution, the mode and timing of spreading in relation to the need of the crop (Grignani et al., 1999) and the ability to remove nutrients from the soil by plants, but which vary in relation to their availability in the ground, at the growth stage of the plant, the availability of water, temperature, and other factors (Tano and Livini, 1986). For a proper management of the sewage is necessary to set up a correct calculation of the N balance that determines the dose of N to be made (Nnex) in relation to excision of culture (Na), and the availability both from residual and natural flows. The formula most frequently used is the following: Nnex = Na **-** (Np + Nm + Nr + No).

5.2 PREPARATION OF SITE FOR PLANTING AND HARVESTING

Only the rows where planting stock is to be planted require soil cultivation. The initial site preparation associated with SRF establishment is likely to raise fewer environmental concerns as loss in soil C than soil cultivation associated with the establishment of annual crops (McKay, 2011). Compared with arable land use, SRF is likely to have a stabilising effect on the soil, due to the relative infrequency of soil cultivation (Makeschin, 1994). The frequency of site preparation necessary for SRF, i.e. once every 8 - 20 years (LTS International, 2006).

Northern European countries have put into practice a model of cultivation based onextremely high density (15,000-20,000 plants/acre) and the use of clones of willow particularly resistant to cold. Harvest can be annual, biennial or, where the growth slowed by climatic conditions, also for three years and four (Scandinavia). This model in Mediterranean zone was adjusted by increasing the density from 6,000 to 14,000 plants/ha, using species such as poplar, black locust and eucalyptus (Veneto Agricoltura, 2013).

Table 10 Cultivation models for SRC in Europe and USA

Cropping pattern	Shift coppicing	Species or clones used	Planting density (plants ha^{-1})	Productivity (t ha^{-1} yr^{-1})
European model	Annual coppicing	*Populus, clone "Pegaso"*	12,689	16.2
	Coppicing biennial with single row	*Robinia pseudoacacia*[1]	8,000-12,000	11.1-12.5
		Robinia pseudoacacia[2]	3,333	4.9
	Coppicing biennial with twin row	*Populus*[1]	10,000	11.5
		Populus clone "Monviso"[1]	9,009	9.0
		Salix[1]	10,000	12.2-20
USA Model	Round five years, first round	*Populus alba*	1,667	7.9
		Populus, clone "Monviso"[1]	1,667	11.1
	Round five years, second round	*Populus*[1]	1,333	14.7
	Round five years, , first round	*Salix*[1]	1,333	16.2
	Round five years, second round	*Salix*[1]	1,333	20.3
	Round five years, first round	*Robinia pseudoacacia*[1]	1,500	6.6

[1]Veneto Agricoltura, 2013, [2]Baldini et al., 2008

About the hedge effect, important in biodiversity terms, smaller blocks have a higher proportion of hedge than large blocks, thus favouring richness in species (Hardcastle, 2006).

5.3 CONTROL OF COMPETING VEGETATION

Especially in the first stages of development, if not properly contained, herbaceous weeds may limit the rooting of cuttings choking sprouts issued, determining limitations up to 50% of the seedlings accretion after the onset of phenomena of competition for space and nutrients (Covarelli et al., 2009). Such interventions turn out to be an expensive operation for the farmer (Bergante et al., 2006).

Compared to conventional agricultural crops, the application of weed-control chemicals during the entire plant rotation cycle is limited, since after canopy closure there is no further requirement for weed control until the start of the next rotation cycle.

Active ingredients of the most common herbicides used in farming are regarded as quickly biodegradable into environmentally friendly or benign compounds, thus not causing negative effects on water or soils. However it’s best to minimise application of herbicides ensuring rapid canopy closure through vigorous tree growth after a good choice of place and species (LTS International, 2006). Herbicide or insecticide application can result in decrease in plant, fungi and insect biodiversity (Dreyfus, 1984).

5.4 CHOICE OF SPECIES AND PROVENANCE

About SRF in general, exotic species have less biodiversity potential than native species, as animals, especially arthropods (an important basis of the food chain), are not adapted to them. The understory vegetation is also very important and is largely dependent on the canopy density. Species such as ash and birch have a much lighter canopy than Sycamore or Eucalyptus (McKay, 2011).

About species likely to be used in Mediterranean climates it is important to identify ecological necessity of species in relation to typical summer dryness.

For example *Eucalypts* are particularly sensitive to low winter temperatures and can be planted in coastal areas with good water supply; Poplar and Willows are sensitive to water limitations and can be used only in reclamation areas and in flood valley.

The species typically used for SRC for production of biomass for energy mainly are fast-growing and produce more biomass, compared to other tree species. For Europe adapted to this activity are the autocnous *Betula pendula*, *Betula pubescens*, *Corylus avellana*, *Populus* ssp., *Salix* ssp, *Rhamnus frangula*, *Juglans regia*, the exotic *Acer negundo*, *Ailanthus altissima*, *Juglans nigra*, *Eucalyptus camaldulensis*, *Pawlonia tomentosa*, *Robinia pseudoacacia* and various clones of *Populus* x *euramericana*. However, most plantations consist of specific poplar clones.

The use of native trees in SRC, can provide a natural habitat for many species of wildlife including some that are suffering because of intensification of land use over the last 50 years.

Table 11 Ability of vegetative reproduction and yield of wood of deciduous trees

Species	Coppice shoots (length of annual shoot [cm])[1]	Yield of wood (annual volume increment: $m^3 * ha^{-1} * year^{-1}$)	Calorific value ($GJ * m^{-3}$)	Biomass production ODT (Oven dry tons) * $ha^{-1} * year^{-1}$
Acer pseudoplatanus	150[1]	15 -19,5[5]	10,1	3-7[9]
Ailanthus altissima	80-180[7]	20	4,9[6]	
Alnus glutinosa	120[1]	> 10[2]	9,2	3-5[9]
Castanea sativa	100[1]	10,43 (3 ys)[8]	16	3-6
Corylus avellana		> 6[2]	10,79[13]	1-2
Populus x euramericana		> 10[2]	9,8-9,9[18]	5–24
Populus nigra	150[1]	> 10[2]	7,4[17]	7,5[14]
Populus alba	100[1]	> 10[2]	7,4[17]	9[15]
Populus tremula		> 10[2]	8.6 [16]	10[19]
Robinia pseudoacacia	150[1]	23 (ten ys)[3]	17.83- 18.62[10]	10-15[10]
Salix sp.	150[1]	> 10[2]	7.7	2,95-36,61[4,10,11]

1Stähr., 2006; 3National Research Council (U.S.). Advisory Committee on Technology Innovation, 1983; 4Tubby and Armstrong, 2002;5Hein, 2008; 6Sheikh, 1993; 7Illick and Brouse, 1926; 8Marziliano et al., 2013; 9Hardcastle, 2006; 10https://www.ecn.nl/; 11Bergante and Faccioto, 2011; 12http://www.tsec-biosys.ac.uk/; 13Murgante et al., 2013; 14Benetka, 2007; 15Confalonieri et al., 2000; 16Jardine, 2009; 17Francescato et al., 2008; 18Kačík et al., 2012; 19van Oosten

5.4.1 *Acer pseudoplatanus* L.

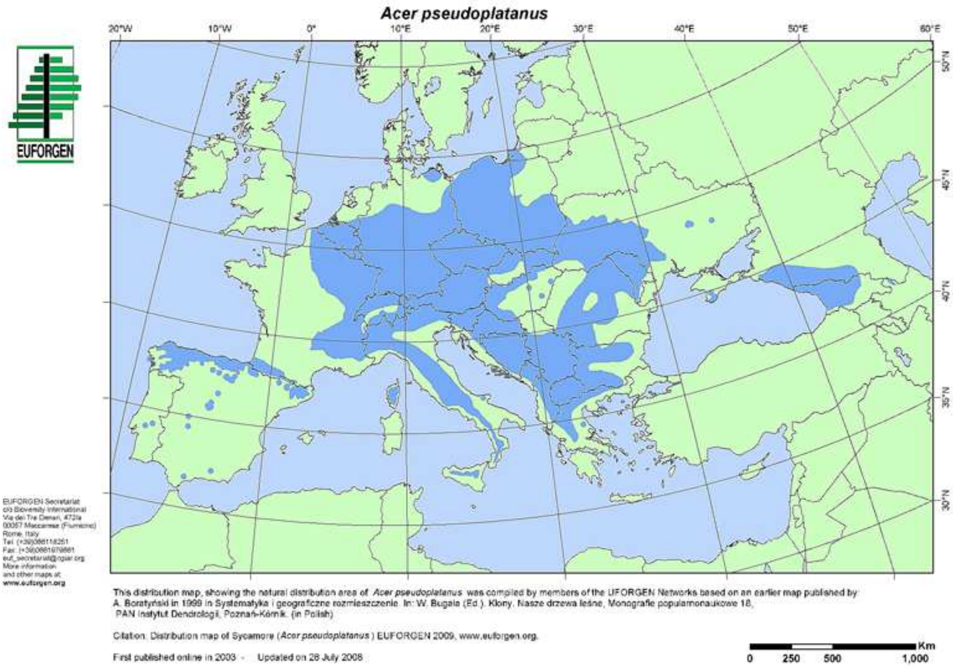
There is a growing interest in using *A. pseudoplatanus* in SRC more widely because of its potentially high economic and ecological values. This tree regenerates easily, although competing ground vegetation, damage by browsers and bark stripping by grey squirrels may endanger (Hein, 2008). It can reach over 35 m on suitable sites. Coppices well but stools are often quite short lived. This species is suited to a wide range of fertile and deep soils, but growth is poorer on acid or poorly drained soils.

Its current distribution extends from Turkey and Spain to Ireland and Sweden (Fremstad and Elven, 1996; Rusanen and Myking, 2003) and even to North America, South America, New Zealand, and India (Binggeli, 1992). Beech is the species most commonly found in European forests in association with sycamore (Jones, 1945; Bartelink and Olsthoorn, 1999; Piovesan et al., 2005). In Europe this species is frequent in beech dominated woods and mesophile oaks woods, from hilly to montane belt. At the regeneration stages the two species are often seen in intimate mixture.

The rapid coppice regrowth on clearfelled sites has often been exploited to restock stands and archive good quality sprouts (Bryndum and Henriksen, 1988; Henriksen and Bryndum, 1989; Tillisch, 2001).

From the ecological point of view *A. pseudoplatanus* supports a wide range of epiphytes, herbivores and ground flora (Bingelli, 1993). Its litter improves humus formation and nutrient cycling (Wittich, 1961; Weber et al., 1993; Heitz and Rehfuess, 1999). Maintaining or promoting sycamore may therefore enhance the ecological values of a stand and contribute to habitat and landscape diversity (Stern, 1989; Pommerening, 1997; Bell, 2008). It can be used in abandoned lands on supra – and oro-mediterranean climate in areas relatively wet with alkaline or sub-alkaline soils. In this climatic context is more frequent in Italy and Balkans, only sporadic in Iberian Peninsula Mediterranean zone, more frequent on Atlantic coast of Spain.

Figure 1 Distribution of *Acer pseudoplatanus* (EUFORGEN)



5.4.2 *Ailanthus altissima* L.

This fast growing tree in optimal conditions can grow to an height of 3 to 4 m in a period of 5 months. It was introduced into Europe from China in 1760 and has established in temperate climates throughout the world. The tree extends from subtropical dry to wet through cool temperate dry to wet forest zones. It tolerates frost and chilling winters and grows well with an annual precipitation of 300-2500 mm tolerating a dry season of up to 8 months, optimal annual temperature of 10-20 °C, and pH of 5.5-8.

It’s naturalized throughout the region and used for coating slopes, given which spreads rapidly on marginal or abandoned lands. This is due to its abundant production of root suckers, some of which emerge at distances notable from the tree of origin to distances of the order of one hundred feet, and damage rise to plants "daughters." It is a species very hardy and resistant to drought.

Ailanthus grows in all types of land (even in the cracks of the old walls) and has no special requirements for the water supply because the water stored in the roots allows the tree to tolerate dry, rocky soils and extended drought. Even the seedlings show a good tolerance to drought.

It can grow in arid soils in warm lowland stations and the horizon hilly in marginal lands, wetlands, places built, industrial areas, docks and railway embankments, walls, flower beds, gardens, grounds and it can colonize grasslands. It tolerates the presence of salt, drought and air pollution. However the best development of *Ailanthus* occurs on nutrient-rich soils and clayey soils.

If the initial regeneration is accomplished from seed or from cuttings, once it is stabilized, *Ailanthus* grows extremely fast and reach great heights quickly. The seedlings reach 1-2 m during their first year of life.

Through its allelopathic properties, high capacity for vegetative and generative reproduction, rapid growth, pioneer character, superior competitive ability against other alien or native plants, Ailanthus altissima is able to form dense populations wich dominates the invaded plant communities and inhibits growth of other plant species, often displacing native vegetation (Sîrbu and Oprea, 2010).

The ecological consequences of *A. altissima* invasion have long been recognized especially in the Mediterranean basin, where it has been recently included in the EPIDEMIE project ("Exotic Plant Invasions: Deleterious Effects on Mediterranean Island Ecosystems"), supported by the European Commission (Traveset et al., 2008; Vilà et al., 2008; Affre, 2012). So it's best to manage existing plots than plants news and however to be carefully respect at the possibility of invasion of natural plots.

If the initial regeneration is accomplished from seed or from cuttings, once it is stabilized, *Ailanthus* grows extremely fast and reach great heights quickly. The seedlings reach 1-2 m. during their first year of life.

The Ailanthus stands in National Forest Inventory (INFC, 2007a, 2007b) are associated together with *Robinia* in a category that covers 4053 hectares, 1,74% of regional forest surfaces.

In Mediterranean Countries, the *Ailanthus* its use is good in Short Rotation Forestry, while SRC is recommended only in contaminated and degradated lands, to counteract erosion and in abandoned industrial sites and, naturally, in existing stands.

5.4.3 *Alnus cordata* L.

In its native range Italian alder has a very limited distribution, and it is present only in Southern Italy and Corsica. This species was introduced to Britain in 1820 and has since been planted widely in shelter-belts and woodland grant schemes. It thrives best on sites with high rainfall and relatively mild winters (Claessens, 2003; McKay, 2012).

The use of *Alnus cordata* in Europe, although also species indigenous only in Italy, starts to become more popular because alder is preferred to black locust for the lightness of the wood, for the ability to retain the leaves for a longer period vegetation and because more controllable in terms of intrusiveness (Regione Toscana, 2012).

In the natural distribution area the average temperature in the coldest month, do not fall under -1/-2 °C. Mean annual rainfall: 700 - 2000 mm; Mean annual temperature: 10 – 17 °C; Mean maximum temperature of hottest month: 23 – 30 °C; Mean minimum temperature of coldest month: 0 – 4 °C.

Occurs naturally on damp, moist or wet soil. It's suitable for loamy and clay soils and can grow in heavy clay and nutritionally poor soils. pH can variate from acid to basic. It can grow in semi-shade (light woodland) or no shade and can tolerate maritime exposure.

5.4.4 *Alnus glutinosa* L.

In addition to natural seed stands, black alder very often forms coppice. This is due to the strong ability of the species to sprout from stumps, especially while relatively young. Black alder trees grow intensively in height between years five and ten, and in diameter between the fifteenth and twentieth year of age.

European alder has a broad natural range that includes most of Europe and extends into North Africa, Asia Minor, and western Siberia (Robinson et al., 1979). It is naturally widespread from mid-Scandinavia to the Mediterranean countries, including northern Morocco and Algeria (Meusel et al., 1965; Jalas and Suominen, 1976; Kajba and Gracan, 2003). Densest distribution is in the lowlands of northern Germany, northern Poland, White Russia, and the northwestern Ukraine (Glavac, 1972). At the drier limits of its range, it finds refuge in the humid microclimates of valleys and along rivers (Claessens et al., 2010). This species in Mediterranean climate can be found on stream sides and on poorly drained areas. It can grow up to 30 m tall but coppices well and grows rapidly when it is young.

The duration of low winter temperature limits the range of European alder and the species does not extend into regions where the mean daily temperature is above freezing for less than 6 months of the year. Black alder is relatively tolerant to late autumnal and early spring frosts (Claessens et al., 2010).

Tolerant of wide range of soils, preferably moist ones with a pH of more than 6. It should not be used on acid peats or badly aerated soils.

Alnus glutinosa is a species capable of symbiotic nitrogen fixation (Akkermans and Van Dijk., 1976; Blom et al., 1981). It can fix nitrogen through association with the micro-organism Frankia which forms nodules on the root systems. So this species is often used on degraded or impoverished soils to improve fertility.

Optimum soil pH for nodulation appears to be between 5.5 and 7.0 (Griffiths and McCormick, 1984), Seedlings already nodulated grow satisfactorily when outplanted on sites with pH as low as 3.3 (Ferguson and Bond, 1953; Quispel, 1958). This tree add significant amounts of nitrogen to soil. Canopy of *Alnus* may support high aphid biomass, providing food for insectivorous birds. (Hardcastle et al., 2006). Flowers provide an early source of food. Seeds remain on tree during winter, and are fed on by many birds, in particular redpoll, siskin, and tits (Eppler and Petersen, 2007).

The presence of small mammals such as the woodmouse (*Apodemus sylvaticus*), the common shrew (*Sorex araneus*) and the field vole (*Microtus agrestis*) will depend mainly on the presence of understory vegetation. Deer will be attracted by the cover provided by the tree crop. Predators such as badger, fox, stoat and weasel will be attracted by the presence of prey species and the relative stability of the SRF habitat (Eppler & Petersen, 2007). It can support rich lichen flora (Eppler and Petersen, 2007).

Alders have been recommended for afforestation of disturbed areas throughout much of the temperate world (Knabe, 1965; Limstrom, 1960). Their tolerance of low pH and their rapid growth, abundant leaf litter production, and ability to fix atmospheric nitrogen combine to make European alder especially desirable for planting on spoil banks, which typically contain little organic matter and available nitrogen. In Mediterranean countries *Alnus* SRC needs adequate experimentation in its natural areal.

5.4.5 *Castanea sativa* L.

Chestnut is a species typical of the area of the Mediterranean and Eastern Europe, but it was exported from long time outside its native distribution. Now, it is so extensive that it is difficult to understand what is its true distribution area of origin.

The phytoclimatic range of the chestnut goes from the upper limits of the olive (termomediterranean), until the whole strip of grapevine (meso – and supramediterranean), with the transgressions in the upper regions (subcontinental).

In Italy it is widespread both on the mainland and on the islands of Italy and, according the National Inventory of Forests and Tanks Forestry Carbon (INFC, 2005), covers an area of about 790,000 hectares. In the Alps and the Alpine foothills it does not exceed 900-1000 meters a.s.l., while in the Apennines goes up to 1200 m. and up to 1500 m. in Sicily. Up to half of last century it has played a major role in the economy of rural areas for the wide variety of products that could be obtained from it (Manetti et al., 2006).

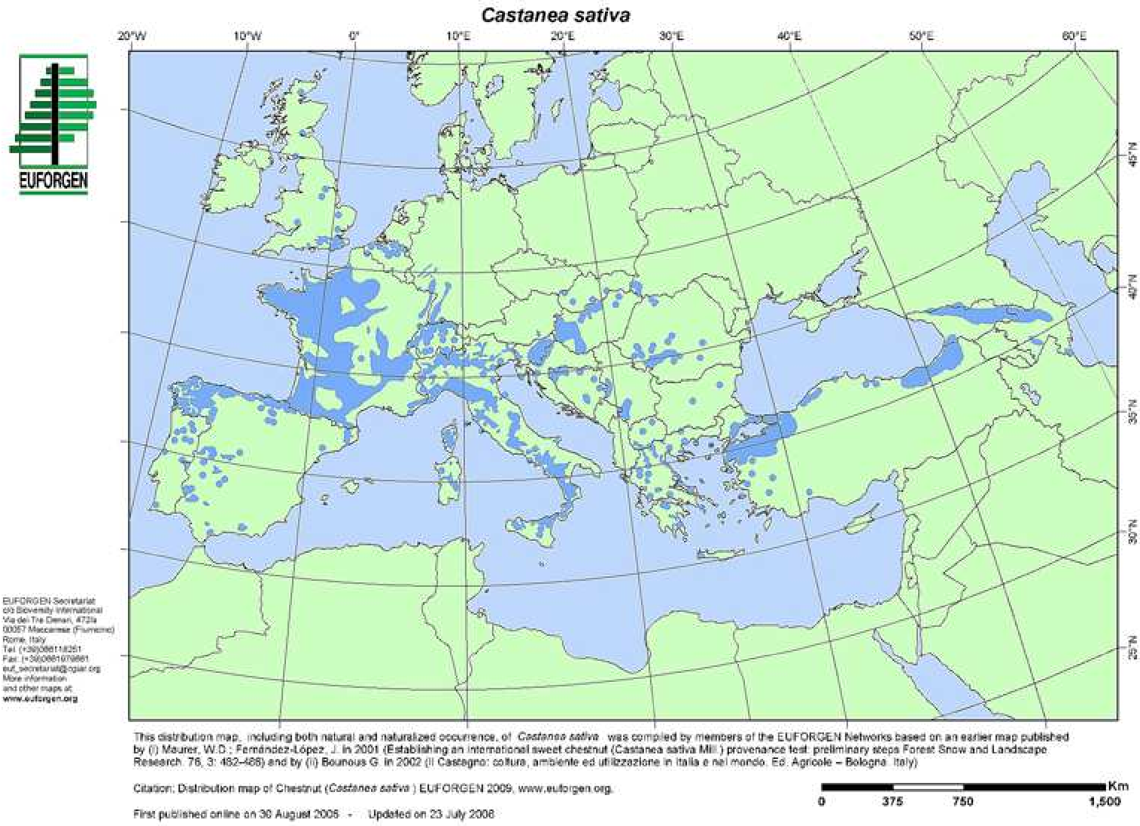
The distribution of chestnut in Spanish territory is disjoint, monospecific stands occupy 137,657 ha. The biggest range is in the north, between Galicia and Navarra, with 70% of the total (Melicharová and. Vizoso-Arribe, 2012).

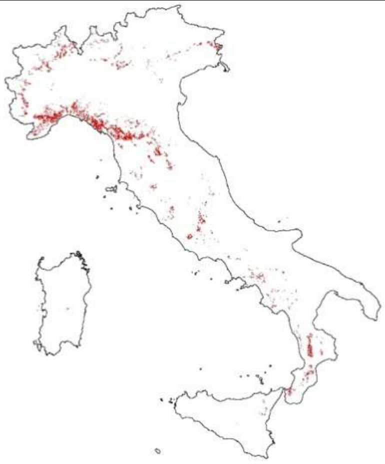
Castanea sativa Mill. forests in Greece occupy 33.000 ha of mostly mountainous land, extending from 400 to 1000 m in altitude and are considered to be wild, native ecosystems (National Forest Survey, 1992).

This tree, that grows to 30 or more metres tall, is considered an excellent coppicing species. Smaller sizes of timber can also be used to make cleft chestnut paling. It’s a calcifuge species and prefers deep acid sandy, loamy and clay with good drainage. It is not suited to poorly drained or calcareous soils. The optimum pH value for the species is around 5.5 (Bourgeois et al., 2004). It prefers sandy, loamy and clay well-drained, dry or moist acid to neutral soils. It can grow in very acid and poor soil and can tolerate drought.

For example in Lazio (Italy) grew good from the hilly belt to montane one on volcanic and arenaceous substrata where it’s largely managed from many centuries.

Figure 2 Distribution of *Acer pseudoplatanus* (EUFORGEN)





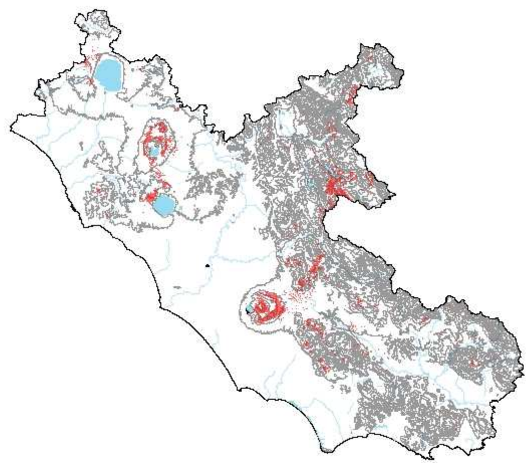


Figure 3 *Castanea sativa* dominated woods in Italy (ISPRA: Landcover Project, 2006)	**Figure 4** *Castanea sativa* dominated woods in Latium (Carta della Natura Project, 2008)

Both coppice and fruit cultivation of *Castanea sativa* are good for biodiversity. For example in *Castanea sativa* populations in northwestern Spain were reported 156 species of plants, 39 of Birds, 10 of ants, 78 of beetles (Guitián et al., 2012).

Chestnut forest, cultivation and coppice systems are particularly rich in Basidiomycotina and Ascomycotina. In Greece are reported 168 species, with 56 mycorrhizal fungi and 57 saprotrophic and soil fungi (Diamandis & Perlerou, 2001), in Italy 338 species (Database ISPRA). The mycorrhizal group includes some highly valued edible species as *Amanita caesaria*, *A. rubescens*, *Boletus edulis*, *B. aereus*, *Cantharellus cibarius*, *Craterellus cornucopioides*, *Hydnum repandum*, *H.rufescens*.

5.4.6 *Corylus avellana* L.

Native across a wide area of Europe, parts of north Africa and western Asia normally it lives as a shrub species in the understory of native broadleaved woodland. In Europe it is commonly found as an understory species in lowland oak, ash or birch woodland as well as in scrub and hedgerows. It is an important component of the hedgerows that were the traditional field boundaries in lowland England.

European natural population are spread in oceanic to subcontinental temperate meso- to lower orotemperate humid to hyperhumid climate with enclaves in supramediterranean belt.

In Mediterranean area it finds a favourable habitat in coastal parts of Black Sea of Turkey, Adriatic coasts, Apennines and Vulcanic hills of Italy, Catalonia region of Spain where it can form distinct natural forest association refered to Corylo-Populion tremulae (Br.-Bl. ex O. Bolòs 1973; Rivas-Martínez and Costa, 1998).

It grows better in areas where the annual average temperature is 13-14 ºC, the average temperature in the coldest month is not more than 3.5-5.5 ºC, the average temperature in the warmest month reaches 22-23 ºC, and annual rainfall is 1500-2000 mm (900-1200 mm during the growth period) (Mirotadze et al., 2009).

It can be cultivated under humid temperate climatic conditions (Mehlenbacher 1991). Regions with annual mean temperature of 13-16 °C have the most favourable conditions for cultivation. Such regions must not have a minimum temperature in winter months below -8,-10 °C and the highest temperature in summer months above 36-37 °C. Yet, in order to ensure pollination, such regions should have maximum temperatures exceeding 21 °C for at least three days and, on average, two weeks at the beginning of June (Beyhan and Odabaş 1996; *Tous* 2001). Also, total annual precipitation should be over 750 mm. And it should have a regular distribution over months.

Relative humidity should not go down below 60% during the months June and July (Köksal, 2002). Although it is possible to cultivate it in regions with half-humid climate, it needs irrigation due to lack of precipitation.

Corylus is one of the excellent shrub species that can improve the soil fertility by promoting the formation of soil water stable aggregate. The corylus litter contains rich mineral elements and its mineralization speed is faster. In consequence, the soil base amounts under the *corylus* clusters increase and the soil acidity is neutralized. *Corylus* promotes the activities of bacteria and other of microorganisms, which accelerate the humus-forming process (Chen et al., 2000).

In Mediterranean region it's intensively cultivated for hazelnut production in commercial orchards in Europe, Turkey, Iran and Caucasus. The three greatest producers of hazelnuts are (percentage of the world production), Turkey (70%), Italy (12%), United States (6%) and Spain.

Hazel is particularly suited to coppice management, producing large numbers of shoots or rods from the cut stools, which can be harvested on a 6 to 10 year rotation (Durham, 1956). Stools can survive for several centuries and tends to produce a number of small diameter stems. It can grow on a wide range of fertile soils, but best where there is some moisture as clay-loams.

In Mediterranean European countries it’s possible to introduce in the bioenergy systems the harvesting of this species made in agricultural contexts.

5.4.7 *Eucalyptus* spp.

This genus of evergreen tree is indigenous in Oceania (especially Tasmania, Australia and New Guinea) and belonging, with about 600 species, to the family Mirtacee.

Two species, *Eucalyptus globulus* and *Eucalyptus grandis* form very extensive industrial plantations in the tropical and sub-tropical regions of the globe. *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* are widely used in semi-arid zones. *E camaldulensis* and *E. globulus* are most used in forestry in mediterranean context.

Among the species identified for the implementation of interventions and the SRF in thermomediterranean areas *E. camaldulensis* is that with increased plasticity with wide tolerance for temperature and precipitation (Ciancio et al., 1981) and 'able to withstand long periods of drought, It lives in environments with average rainfall of 300-400 mm per year and average annual temperatures between 12 and 18 °C and can withstand temperatures only up to - 6 °C. It is very rustic and adapts to a wide range of soils, from clay to peaty.

It has good capacity of resprouting and it has a large adaptation to difficult terrain, dry, clay or even periodically submerged (Ciancio et al., 1981).

There is also widespread use of hybrid and clonal material. For example in the 90's with a genetic improvement program fifteen new clones were selected by CRA-PLF of Rome within crosses between *E. camaldulensis* with *E. globulus subsp. globulus*, *E. globulus subsp. bicostata*, *E. viminalis* and *E. geandis*.

Eucalyptus species have characteristically high nutrient uptake and water use. So they usually are planted on alluvial plains to keep them dry. As *Populus* spp. *Eucalyptus* are efficient in removing nitrate, phosphorus and potassium, providing scope for forming an effective wastewater polishing system (Sugiura et al., 2008).

Eucalyptus has been used from the beginning of 20th century to “drain” marshland and to deliberately lower the water table where saline water has risen to the surface (Calder, 1992). In reference to actual distribution and very high water table best areas for *Eucalyptus* plantation are coastal flat and remediation lands.

5.4.8 *Fraxinus excelsior* L.

Fraxinus excelsior (European ash) is the fast growing species most widely distributed ash species in Europe. It is a valuable broadleaved tree for SRC due to its ecological characteristics, outstanding wood properties and high economic value *Fraxinus excelsior* coppices well, and natural regeneration is often so prolific that the species can become invasive. Regeneration is particularly good in woodlands where canopies are dense. The species is strongly shade-tolerant for its first seven years or so (up to about 4 m tall), but becomes very light-demanding thereafter.

In particular in central Europe silvicultural methods have promoted common ash in the last 30-40 years due to the high economic value, supporting natural regeneration, planting and thinning (Pliûra and Heuertz, 2003).

Its distribution extends across Europe from the Atlantic coast in the west into continental Russia, almost to the River Volga, in the east. Its northern limit (in Norway) is at 64 °N, and it extends south to the Mediterranean, through the northern parts of Spain, Italy, and Greece, and as far south as 37 °N in Iran.

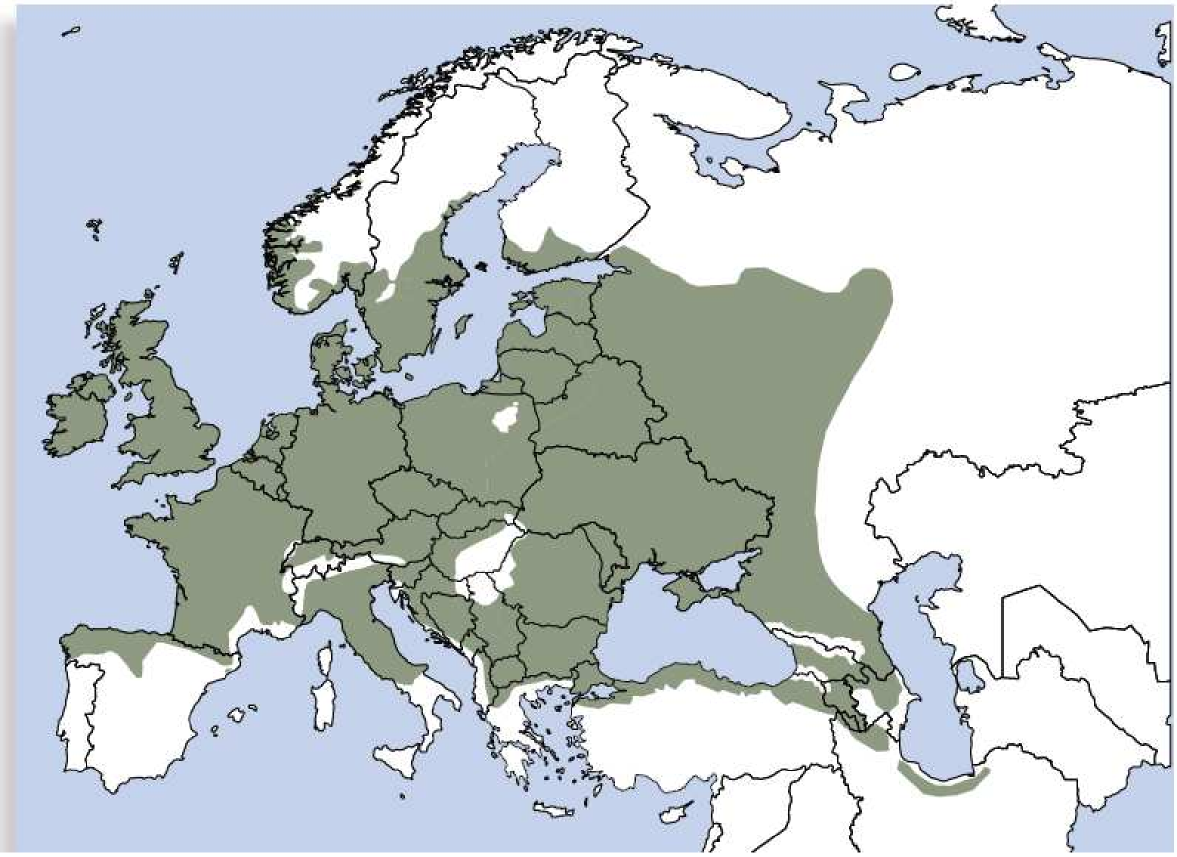


Figure 5 Distribution of *Fraxinus excelsior* in Europe (Fraxigen, 2005)

It requests fertile, rich in humus, moist and deep soils and usually occurs in woodlands formed on lime-rich soil, doing best where the pH is greater than 5.5 (Pliûra and Heuertz, 2003; Nelson and Walsh, 1993; Silva-Pando and Rigueiro, 1992).

Ash have a high demand for nitrogen, calcium, magnesium and phosphorous. The nutrient supply depends on the nutrient content of the soil with respect to exchangeable cations and citric-acid-soluble phosphorous (Dobrowolska et al., 2011).

To grow well *F. excelsior* requires base-rich, y sandy, calcareous loams, with pH 7–8, especially in the lower parts of the soil profile (Silva-Pando & Rigueiro, 1992). The ideal site is a well-drained alkaline soil, that be a rich deep marl, or a shallow soil over limestone (FRAXIGEN, 2005).

Hilly and mountain mixed mesophilous woods dominated by *Acer* spp. and *Fraxinus excelsior* are considered of great scientific and conservation interest in Europe and are considered a priority habitat by the European Union (cod. Natura 2000: 9180, Annex I of Directive 92/ 43).

5.4.9 *Paulownia tomentosa* (Thunb.) Sieb. & Zucc. ex Steud.

Paulownia trees originate from China and are also grown throughout Asia, USA, Australia and Europe. Although a number of *Paulownia* species exist, only the ornamental species *Paulownia tomentosa* is currently grown in SRF.

Paulownia trees can tolerate a range of temperatures and have been reported to grow at altitudes up to 2000 m and latitudes 40° N and 40° S, but can be damaged by frost and require a sheltered place for growth (Woods, 2008). Optimal temperatures for growth are reported to range from 24-29 °C and have been reported to withstand temperatures ranging from -10 °C to +40° C. *Paulownia tomentosa* grows best in temperatures ranging from 24-30° C but that mature individuals can endure temperatures as low as -20* C.

Paulownia tomentosa requires minimal management and little investment (El-Showk and El-Showk, 2003) and has been receiving greater attention as a short-rotation woody crop in recent years (Bergmann et al., 1997) because with optimal conditions in terms of light and moisture, *Paulownia* is one of the fastest growing trees in the world: it can grows 5-6 m tall during the first growing season and adds 3 to 4 cm in diameter annually if optimal growing conditions are present (El-Showk and El-Showk, 2003; Woods, 2008), with yields of more than 80 t/ha x year (Woods, 2008).

The site requirements for successful growth of *Paulownia* were:

- sloping and effectively drained site;
- site with no frost hollows and with sufficient air drainage as heavy frosts in spring can damage the stems of young trees and kill new growth;
- sheltered site, which is especially important when the trees are young ((Lyons, 1993; Woods, 2008);

For the efficient production of biomass, *Paulownia* trees are planted at a higher density than that required for timber production (1960 and 750/ha respectively). The recommended density for biomass purposes is 1680 trees/ha (Woods, 2008).

Paulownia wood is used in house construction, for paper pulp, furniture making, farm implements and musical instruments (Ayan et al., 2003). *Paulownia* timber air dries readily and has excellent thermal and electrical insulation characteristics (Lyons, 1993).

The branches of the tree can be used for household energy and a 10 year old trees can produce 350-400 kg branches for fuel (Zhaohua, 1987).

Paulownia also has a range of medicinal properties (Ayan et al., 2003), and the leaves can be used for animal fodder. In China, after one year's growth when *Paulownia* was cut down, the leaves were offered to pigs and sheep (Zhaohua, 1987). *Paulownia* leaves are suitable for combining with wheat straw or hay for feeding to cattle, sheep or goat (Woods, 2008). Naturally for its palatability *Paulownia* should be protected from grazing animals which would damage the bark whilst feeding.

At difference of other species the application of animal waste or different N application rates as an inorganic fertiliser did not have a pronounced effect on tree survival and growth (Woods, 2008).

5.4.10 *Platanus* spp.

Eastern plane (*Platanus orientalis* L.) occurs in Europe only in the eastern part of Mediterranean region, including some remnants in Calabria and Sicily. Its natural range spreads eastward through Caucasus and Asia Minor to Iran (Mossadegh, 1979; Panetsos, 1984). The natural forest of *Platanus orientalis* are of European interest according to Habitat Directive 92/43/CE, as of Code n. 92C0 *Platanus orientalis* and *Liquidambar orientalis* woods (Plantanion orientalis).

P. orientalis is a fast growing species having both economical and ornamental importance. It hybridizes with american *Platanus occidentalis* and selection could produce high yielding varieties capable to establish short-rotation plantation for fibers or energy.

A limitation for a wider cultivation of the species in Europe is its frost sensitivity and therefore in the other parts of central and western Europe hybrid plane (London plane, Platanus × acerifolia Willd.) is preferred (Santamour, 1970; Panetsos et al., 1994).

Platanus orientalis is cultivated with success in Greece, where it shows considerable plasticity, growing on a variety of soils and climate all over the country (Panetsos, 1984). It can be propagated vegetatively and planted without difficulty.

Other advantages include a moderate shade that is sufficient to allow grass or other plants to grow below it, tolerance of city conditions, tolerance of difficult soil conditions, drought and tolerance to pruning.

5.4.11 *Populus* spp.

The genus *Populus* is particularly adapted to SRC for various reasons:

- rapid growth in the juvenile stage (Dickmann, 2006);
- easy asexual propagation through cuttings (Sekawin and Prevosto, 1980; Afas Al et al., 2008);
- easy genetic selection and hybridization with the creation of numerous intersections or hybrids;
- very high production of biomass (Frison, 1974, Laureysens et al., 2005 a, b);
- emission capacity of numerous suckers after coppicing (Jordan, 1974);
- good resistance to parassites and pathogen;
- high survival rate of stumps to coppicing repeated frequently over time (Herve and Ceulemans, 1996);
- good capacity adaptive to different site conditions (Mitchell et al., 1999; Ceulemans and Deraedt, 1999; Salvati et al., 2007).

Artificial poplar stands with no use of pesticide can accommodate bird communities in a very similar way to the one of natural riparian forests (Archaux and Martin, 2009) and are home to more species than cropland or conifer plantations (Baum, 2009). They contribute to increase the biodiversity of vascular plants in the agricultural landscape hosting community different from the surrounding fields and meadows (Weih et al., 2003).

However species richness of young poplar plantations was similar or slightly lower in comparison to old-growth mixed deciduous forests (Weih et al., 2003).

The increase in biodiversity would be significant if the plantation is placed in areas devoted to agriculture. SRC of *Populus* can be an important habitat for beetles, as are found in these plantations more species than in cultivated fields (Berthelot et al., 2005).

The genus *Populus* due to its characteristics of rapid growth in the juvenile stage (Dickmann, 2006), ease of asexual propagation through cuttings (Sekawin and Prevosto, 1980; Afas Al et al., 2008), ease of genetic selection and hybridization with the creation of numerous intersections or hybrids, high production of woody biomass (Frison, 1974), emission capacity of numerous suckers after coppicing (Jordan, 1974) involving increased production of biomass (Laureysens et al., 2005 a, b), good resistance to attacks parasites pathogens, high survival rate of stumps to coppicing repeated frequently over time (Herve and Ceulemans 1996), good capacity adaptive to different site conditions (Mitchell et al., 1999; Ceulemans and Deraedt, 1999; Salvati et al., 2007).

The Short Rotation Forestry (SRF) of poplar is a crop of potential interest for our territories as it presents productions high quantity and quality. Poplars (*Populus* spp.), especially modern hybrids, are well adapted to site conditions in Italy, and are the most common tree species used in SRF plantations (Paris et al., 2011). Some hybrids growing vigorously especially in the juvenile stage, and they are particularly suitable for realize high-density plantations of trees per hectare (5 -10,000). The calorific values for the components of the poplar biomass are between 4.3 and 4.8 kcal/g (Kellezi, 2006).

Best areas for this kind of plantation are represented by big fluvial valley. These areas are flat, with high water table and alluvial soils and good fertility. In SRF crops in Po Valley (Lombardy) poplar clones in turn have given annual production of 30-40 t/hectare/year of fresh matter (Spinelli et al., 2006).

The river plain and reclaimed area in mediterranean climate offers favourable conditions for biomass production of selected hybrid poplar clones, highlighting very high productive potential. The poplar clones AF2, tested in Tiber plains near Monterotondo, at about twenty kilometers from Rome. It had the best performances in terms of growth and yield in submediterranean climate on alluvial soils (Di Matteo et al., 2012).

Poplar trees prefer soils rich in organic matter; they do not tolerate drought of long duration and they have difficult to grow on inconsistent and sterile well-drained soils and in nature they prefer the wetlands near rivers and streams.

To avoid diminution of nutrient in the soil it is should therefore periodically bury good organic fertilizer at the foot of plant, at least twice a year. It’s also recommend watering the poplars during prolonged periods of drought. In the selection of land to be dedicated to poplar, the early risk factors are the availability of fine soil, or the presence of a lot of clay. The second factor can create hydromorphic horizons that are already risky when you are 1.5 m deep (Kellezi, 2006).

In Europe poplar plantations cover a total area of 940.200 hectares and the major countries for poplar plantations are France (236,000 ha), Italy (118.500 ha), Hungary (109.300 ha), Spain (98.500 ha) and Romania (55.300 ha). In Croatia they cover 13.056 hectares (Croatian Poplar Commission).

5.4.12 *Populus* clones

The clones of poplar are considered most important tree species for SRC in Italy. They required good water supply but no waterlogged conditions, average annual temperature above 7,6 °C, yield depends on soil fertility and water availability, neutral to mildly alkaline pH.

Populus clones has proven the most adaptable for biofuel production. Over the years, the development of new specific clones for biomass production (at the moment, the most important are AF2, Monviso, and Pegaso) and improvement in cultivation techniques have made it possible to obtain remarkable yield increases.

Poplar clones are highly suitable for phytoremediation of contaminated soils (e.g. extraction of Cd, Zn and degradation of organic pollution) caused by their high biomass production in combination with high fine root density.

The Italian poplar can currently count on about forty clones enrolled in the National Register of Clones Forestry (which will be merged into the registry of the basic materials, "tested" category by virtue of Decree Law 386/03 of transposition of Directive 1999/105/EC), of which almost enrolled half over the past decade, thanks introduction into the national legislation of the institute of provisional registration, implemented at the level Committee (Facciotto, 2008). Most of clones are being evaluated officially by the National Commission for the poplar.

Gene introgression from cultivated poplars is a potential threat for *P. nigra*. Very few clones are extensively cultivated and contribute to a large extent in the pollen and seed pools. Also pure *P. nigra* varieties are concerned like the male tree 'italica' distributed all over the continent (Cagelli and Lefévre, 1995). In addition, the cultivated poplars seem to alter the preexisting pathogen populations (Pinon and Frey, 1997). In particular the widespread cultivation of the euramerican hybrids (*P.* x *euramericana* (Dode) Guinier), represents a risk of genetic pollution; introgression by P. deltoides, the female parent of the euramerican hybrid is very often observed in areas of spontaneous regeneration (Cagelli and Lefévre, 1995).

5.4.13 *Populus alba* L.

Populus alba (White poplars) is a tree species, closely related to American aspen (*Populus deltoides*), distributed naturally on the bank of rivers in arid and semi-arid regions, it covers a natural range which includes Central and southern Europe, North Africa, western Asia and Central Asia (FAO, 1980).

Actually its habitat is highly fragmented and its distribution range has been subject to long-term human interference, resulting in debate surrounding whether certain populations are native or exotic in origin.

In Mediterranean basin White poplar represents an important native species of the riparian plant communities and partecipates to comunitary interest habitat cited in directive 92/43/EEC "3280 Constantly flowing Mediterranean rivers with Paspalo-Agrostidion species and hanging curtains of *Salix* and *Populus alba*" and "92A0 *Salix alba* and *Populus alba* galleries".

It has low demands about soil and water respect to other *Populus* species. Although growth may be best in moist but not saturated soils, white poplar and its hybrids grow in a variety of soil types and textures. It can grow on sandy loam and clay loam soils and tolerates high PH of soils (8-9.9) as well as high density of soluble salts up to 4.53 (Chitsazi, 2012). Growth is much less on wet soils, on poor acid soils and on thin dry soils, for natural mediterranean riparian environments are observed Typic Xerofluvent soils with little evolution.

Several cultivars are traditionally cultivated in the Near and Middle East (‘Roumi’; ‘Ankara AT’; ‘Kabudeh Schirazih’; ‘Kabudeh Bumi’) and many more were selected and introduced to commercial culture in the second half of the twentieth century.

The clone named ‘Villafranca’ was obtained at the Poplar Research Institute, Casale Monferrato (Italy) in 1954 by crossing a female *P. alba* from Villafranca Piemonte (Piedmont, Italy) and a male specimen of the same species from Lucca (Tuscany, Italy). This clone was registered for commercial use in Italy (1989) and Hungary (1987). ‘Villafranca’ is used for reforestation in the plains along rivers and in specialized stands for the production of sawlogs (Confalonieri et al., 2000).

More recently, ‘Villafranca’ was tested in a research and demonstration program undertaken by ENEL (Italian Electric Company) with the aim of setting up suitable culture models for large-scale production of wood for energy by means of short rotation forestry systems (Schenone et al., 1997). ‘Villafranca’ showed good production of biomass (about 9 oven dry t ha^{-1} $year^{-1}$).

Populus alba forms hybrids with *Populus tremula*. In its native habitats, *P. alba* × *P. tremula* backcrossed with white poplar more often than with European aspen. Along the Ticino River in northern Italy, *P. alba* × *P. tremula* backcrossed with white poplar but not with *P. Tremula* (Fossati et al., 2004). In Italy were obtained the clones[3] Marte and Saturno with high productivity and suitable for bioenergy purpose.

5.4.14 *Populus nigra* L.

Populus nigra L. (European black poplar) is a pioneer tree species of the riparian ecosystem, strictly heliophilous, which forms metapopulations by colonising open areas through seeds and propagules (cuttings, root suckers) (Herpka, 1986). *Populus nigra* L., has a wide distribution area ranging from the Mediterranean border in the south to 64° latitude in the north, and from the British Isles to western Asia mostly along rivers and streams. Due to its plasticity, *P. nigra* is of economic interest and is used for wood production, soil protection, and afforestation in polluted industrial zones (Popivshchy et al., 1997). It has a very high demand on temperature and soil and it can be grown in warmer climates than willow, as in Italy and Spain (Dallemand et al., 2008). It widespreads from temperate to mesomediterranean belts. In presence of high water table it can be cultivated in thermomediterranean belt too.

Poplar prefers soils rich in organic matter and has difficult to grow on inconsistent and sterile well-drained soils. Natural populations usually grew on Typic Xerofluvents, with profile AC or AA/C, always very rich in skeleton, especially in the sub-surface horizons or deep gravel processed and average size highly variable (Bacchetta et al., 2005). This species is sensitive to water limitations and do not tolerate drought of long duration, so It can be used only in reclamation areas and in flood valley. Although hygrophilous itself, it does not tolerate prolonged flooding (Cagelli & Lefévre, 1995).

Populus nigra is widely planted in Turkey for domestic use: 60 000 ha of row plantations, compared to 70.000 ha of hybrid plantations for industry (Tunçtaner, 1995).

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[3] Selectors: Franco Alasia, Cavallermaggiore (CR), Sabatti e Scarascia Mugnozza, Università della Tuscia (VT)

The species is used as a parent pool for poplar breeding programmes. *P. nigra* is hybridised with *P. deltoides* and other exotic *Populus* species, providing adaptability to various soil and climate conditions, in relation to rooting and transpiration ability (Lefèvre et al., 1998).

The European black poplar was recognised as a priority species for international collaborative activities on forest genetic resources in Europe. A political framework for strengthening gene conservation activities was created by adopting Resolution 2 at the Strasbourg Ministerial Conference on the Protection of Forests in Europe in 1990.

The follow-up committee then organised an international survey on the status and perspectives of forest genetic resources in European countries and suggested collaboration in networks of the EUFORGEN.

5.4.15 *Populus tremula* L.

European aspen is one of the most widely distributed trees in the world, with a natural range that stretches from the Arctic Circle in Scandinavia to North Africa, and from Britain across most of Europe and north Asia to China and Japan. It also occurs at one site in northwest Africa in Algeria. In the south of its range, it occurs at high altitudes in mountains.

Eurasian aspen occurs where annual precipitation exceeds evapotranspiration, in oceanic to subcontinental temperate meso- to lower orotemperate humid to hyperhumid climate and also in the humid or hyperhumid supra and orotemperate thermoclimatic belts of submediterranean mountains of Western Mediterranean Subregion.

All around Mediterranean, in particular in oro-mediterranean context, natural forest of *Populus tremula* are locally frequent. It can be used as SRC and SRF species in montane and submontane context on poor soils for its low demands but it have a low growth and difficult clone production. However in Mediterranean climate, in particular in place with more than 600 mm of rainfall on soils from sandy clay to clay sandy reported growth of *Populus tremula* was higher than in northern countries were it's normally used in SRC and SRF. So this native species have to be investigated to be used in SRC and SRF in Mediterranean contest in particular in supramediterranean context with relatively high rainfall.

It is able to grow in a wide variety of soils (mainly Alfisols, Spodosols, and Inceptisols) ranging from shallow and rocky to deep loamy sands and heavy clays (von Wühlisch, 2009). Easy to grow in moist, humus-rich, fertile soils rich of sandy or Clay and with pH: between 4.5 to 8. It favours moist soils so long as they are well aerated and not stagnant (von Wühlisch, 2009).

Aspen's main method of reproduction is vegetative, with new suckers, or ramets, growing off the roots of mature trees. The numbers of new shoots produced in this way can be very prolific, especially after a major disturbance such as fire, with the density of ramets reaching 70,000 per hectare.

Eurasian aspen hybridises naturally with *Populus alba* forming *P.* x *canescens*. Artificial hybrids have been produced with a number of other poplar species (e.g. *P. tremuloides*, *P. grandidentata*, *P. davidiana*). Some hybrid progenies, as those of *P. tremula* by *P. tremuloides* and *P. davidiana* and vice versa are significantly faster growing and less susceptible to diseases than the parental species.

Like other poplar species, aspen has been subject of a variety of research, especially in tree improvement including genetic modification since 1990 (von Wühlisch, 2009).

Many insect species benefit from aspen and it provides habitat for a wide variety of mammals and birds requiring young forests. Numerous leaf, bark and wood inhabiting insects and fungi exist on aspen (von Wühlisch, 2009). Aspen is resistant to browsing pressure by deer and rabbits due to its unpleasant taste.

5.4.16 *Robinia pseudoacacia* L.

The *Robinia pseudoacacia* is a species of North American origin, although surveys fossil seems to be present in Europe, from southern France to the valleys of the Rhine, in the tertiary (Schimper and Scenk, 1890). To date *Robinia* occupies the third place after poplars and eucalyptus, to spread productive plantations in the world (Demenè and Merzeau, 2007). It was estimate the second species among the most abundant broadleaf deciduous trees in the world (Boring and Swank, 1984).

The wood of *Robinia*, due to its high calorific value, is considered a good source of energy. Several tests have shown values equal to 18.2 to 19.8 KJ/Kg. For his qualities as a consolidator of the soil has been spread especially along the railway embankments and roads, from sea level up to 1000 meters altitude in all the region.

In the natural zone of distribution the average temperature of the warmest month ranges of between 21 and 26 °C (with peaks up to 37° C) and that of the coldest month between 1 and 7 °C. *Robinia* also tolerates temperatures up to -23 °C. and prolonged frost in late winter due to the location protected gem and for the late entry in vegetation (Bernetti, 1995; Converse, 1984). The seedlings are instead much more sensitive especially if late frosts (Allegri, 1935). During the growing season is very demanding in the summer heat: it has a short period of vegetation, given the late foliation, and with longitudinal development concentrated in the months long day (Bernetti, 1995). In natural distribution areas the average number of days without frost in a year varies between 140 and 220 (Converse, 1984).

This species is good in warm and wet sites but it rejects waterlogged soils and is frost sensitive. It is resistant to pest and contaminant and tolerant to air pollutants so it can be used on polluted soils and contaminate areas. It grows at pH 4,6 - 8,2 and it has an high resprouting capacity. The soils more favourable to the productivity of *Robinia* are those loose and fresh (Bernetti, 1995; Maltoni et al., 2012).

It has a remarkable ability to adapt to all soils except those excessively dry or excessively drained compact or not. It is well on calcareous soils so as in those not particularly advanced, is also able to survive and grow on deposits of debris with an acid reaction, resulting from mining activity, better than any other species except perhaps Neapolitan alder (Converse, 1984). It is indifferent to the reaction of soil: pH values between 4.6 and 8.2 do not seem to have particular influences on growth (Converse, 1984). *Robinia* also has a good tolerance to salinity (Watson Gilman, 1994). The adaptability to difficult situations and poor soils has favoured the use in urban and degradated environments.

The high calorific value and low water content in the fresh state are of a locust species suitable to be exploited for firewood and biomass for energy use (IPLA, 2000). *Robinia pseudoacacia*, have a significantly lower yield production compared to *Populus* and *Eucaliptus* in terms of biomass, but exhibits characteristics of extreme interest for SRF system (Maltoni et al., 2012):

- high resistance to parasites that allows to avoid the pesticide treatments;
- ability of the plant to fix atmospheric nitrogen through symbiosis with bacteria of the genus Rhizobium, thus not having to resort to the contribution of fertilizer organic or chemical; strong ability pollonifera;
- Resistance of the stumps to rot that allows you to preserve the wine's ability pollonifera over time, even after the inevitable damage sustained during the uses;

- strong competitiveness of this species in relation to herbaceous weeds that allows you to not having to carry out weeding;
- resistant to periods of drought;
- low tendency to invade good managed natural woods.

The largest area of black locust SRC is found in Hungary, but Italy (Spinelli, 2007) and Poland (Dallemand et al., 2008) also have significant plantations. Black locust grows fast in youth, sprouts well both from root and trunk, has got large volume density and low moisture content, but burns well even when it is wet. A ten year old black locust plantation contains as much dry matter rate as a twenty year old traditional forest (Dallemand et al., 2008).

It was shown in studies conducted in Montalto di Castro (province of Rome) and referred to the first two-year cycle that in a context of low-intensive farming modules, without contributions of fertilization and irrigation, the locust is able to provide productions quantitatively very close to those obtained with poplar plant chosen for SRF: respectively 2.9 t/ha/year of dry matter for *Robinia*, 3.75 t/ha/year poplar planted in single row, 4.14 t/ha/year for the poplar planted on double rows (Regione Toscana, 2012).

Shifts of utilization are reduced to two or three years. They involve the removal of young plants with a high ratio in terms of mass of branches and bark with respect to the mass of lignified, with consequent impoverishment of the soil with regard to the mineral substances available. However, nitrogen fixation atmospheric typical of this species prevents impoverishment of the soil regarding this nutrient.

The black locust produces an excellent wood for building, considered competitive with that of some exotic hardwood and more regular and quality equivalent to teak (Debenne, 2007). In addition, this species is long used for parquet, kitchen furniture, handles for tools and solid wood panels (Regione Toscana, 2012).

The bark of *Robinia* is very resistant to fire (IPLA, 2000), so as to facilitate their use in the constitution fire fender of green type (Leone and Signorile, 1997).

SRC stands can be associated with bee-keeping. In fact *Robinia* is one of the main species of bees in the United States, Asia and Europe and is included in the class of species to increased production of nectar (> 500 kg * ha^{-1}). It produces a honey monofloro along to crystallize (thanks to the high content fructose), very light, smooth, fragrant and flavour delicate and vanilla. In Italy, the acacia honey is produced primarily in the foothills of the Alps, Tuscany and, to a lesser extent, in Emilia Romagna, Abruzzo and Campania. But large quantities are importing from Eastern European countries and China, because domestic production is not able to satisfy the request internal (Regione Toscana, 2012).

In Mediterranean countries its use is good in Short Rotation Forestry, while SRC is recommended only in contaminated and degradated lands, to counteract erosion and in abandoned industrial sites and, naturally, in existing stands.

5.4.17 *Salix* spp.

Willow (*Salix* spp.), a genus of more than 300 species and numerous hybrids (Meikle, 1984), are mostly pioneer species (FAO, 1979; Verwijst, 2001) adapted to occupy disturbed habitats and many of them are characterised by a fast juvenile growth. Like several other broadleaved tree species (*Populus* sp., *Alnus* sp., *Eucalyptus* sp.), willows have an ability to tolerate repeated disturbances.

The intensive planting of willow stakes is a recognised bioengineering solution for speeding up the protection of actively eroding river banks, but SRF cultivation and harvesting operations would have to be carefully managed to ensure that they did not cause significant damage to riparian soils, which are particularly vulnerable to disturbance and erosion (McKay, 2012).

The species is characterized by considerably high water demand. It asks an average annual temperature more than 7.5°C, during the growing season more than 13.5°C and a pH above 5.0. Best sites are sunny with good ground and water supply.

Like several other broadleaved tree species (*Populus* sp., *Alnus* sp., *Eucalyptus* sp.), willows have an ability to tolerate repeated disturbances and after being coppiced, new shoots sprout from the stump, forming a stool (Sennerby-Forsse et al., 1992).

Many willows can also be vegetatively propagated and planted as clones by stem cuttings. These characteristics are of main interest when cultivating SRWC. By applying short harvest intervals, referred to as cutting cycles of 3-5 years, shoots are kept in a juvenile stage with high growth rate and hence, biomass yield is optimised (Nordh, 2005).

Willow is grown in SRC mainly in the northern parts of the European Union. Sweden, UK, Finland, Denmark, Ireland and the Netherlands produce willow for energy purposes. Romania also holds substantial willow plantations, planted for wood production and environmental purposes (Dallemand et al., 2008).

In driest places the species of this genus have no interest for Short Rotation Forestry. In Mediterranean areas they can be planted only in alluvial plain or in remediate lands where the availability of water is good in driest period too.

Measures of abundance, species diversity and community structure of two groups of mites. Under willow (Salix sp.) on ex-agricultural land suggested that soil cultivation had negative effects on their abundance and diversity during the first year of establishment (Minor et al., 2004). However, following the initial disturbances, the abundance and diversity of soil mites increased significantly over time.

The diversity of saprotrophic microfungi in the rhizosphere depended on the willow variety grown in SRC plantations (Šlapokas and Granhall, 1991; Baum and Hrynkiewicz, 2006).

The abundance of earthworms (Lumbricidae) (Makeschin, 1994), harvestmen (Opilionida) and woodlice (Isopoda) increased on experimental sites with willows on former arable soils after the conversion to SRC (Makeschin, 1991).

The abundance of carabids (Carabidae) and spiders (Araneida) decreased after this conversion. However, under fast growing trees a greater diversity of carabids (Carabidae) was detected. Centipedes (Chilopoda) and millipedes (Diplopoda) did not change after conversion from arable to forest land use.

Number of individual butterflies and number of butterfly species recorded within Salix SRC increased as the willow coppice became more established The Mean number of invertebrate orders increased with subsequent growth of the willow coppice (Cunningham et al., 2004).

The bird community changed in response to increased willow growth. For example in some plot studies the densities of Tits, Finches and Warblers increased over the time. Thrushes reached a maximum density in 2 year-old SRC, Game birds in 1-year old SRC and those species identified as preferring open habitat such as Skylarks and Wagtails declined as the willow became established (Cunningham et al., 2004).

5.5 FERTILISATION

Depending on management regimes, SRC and SRF have the potential to reduce fertiliser input on agricultural land compared to conventional crops (Hardcastle et al., 2006). Typically, much less nitrogen fertiliser is applied to SRC compared with agricultural crops (Gustafsson et al., 2007). The vast majority of SRC standsin Europe are not supplied with inorganic fertilizer at all. Normally minimal or no fungicide and insecticide are applied, although sometimes herbicides are used during the establishment phase (Dimitriou et al., 2011).

If there is good nutrient supply from former land use, nutrient fertilization is not needed in the establishment year (Boelcke, 2006; DEFRA, 2004; Fry and Slater, 2009; Larsson et al., 2007).

For some species or clones the high productivity making SRC systems particularly demanding in terms of soil nutrients respect to fertility of soils (Perttu and Kowalik 1997; Borin 2003; Uri et al., 2007). So in some European country it is common to use sewage sludge as fertilizer in SRC plantations. The practice may solve a waste problem, but is debated, because of environmental concerns (Dimitriou et al., 2006; Hasselgren, 1999).

A correct spreading manure can help to obviate the pressing needs of the Italian livestock system, characterized by strong excess waste and serious problems for their disposal due to the lack of available agricultural land (Bassanino et al., 2006) and severe limitations of regulatory (Sangiorgi, 2003; Ecosse et al., 2007).

The intake of nutrients by spreading manure could be a solution to this problem and to low fertility of many soils damaged by secular of bad management (Osservatorio agroambientale, 1997; Heinsoo, 2002; Regione Lombardia, 2004; Rockwood et al., 2004; Mirck et al., 2005; Bisoffi et al., 2009), allowing to dispose of the waste in an effective way from the environmental point of view (Laureysens et al., 2005c; Borjesson et al., 2006; Scarascia Mugnozza and Paris, 2007), thanks to the strong ability of phytoremediation of SRF (Rosenqvist et al., 1997; Vandenhove et al., 2001; Mertens et al., 2004; French et al., 2006; AA.VV., 2008; Rossignolo, 2008).

The sludge is normally dewatered and applied in spring after winter harvest every 3 to 5 years. Nutrient losses and leakage to the groundwater zone are reduced by applying sludge to an actively growing crop instead of bare soil (Hasselgren, 1998; Hasselgren, 1999).

Sludge application as a fertilizer may influence the ground vegetation and has been reported to affect ground vegetation cover (Hasselgren, 1999), but very little knowledge of sludge application on phytodiversity in Italy is currently available.

5.6 PREPARATION OF SITE FOR PLANTING AND HARVESTING

For economic reasons chemical treatment are used in most cases before establishing a SRC plantation (Boelcke, 2006; Stjernquist, 1994), but it’s possible to use only mechanical methods (Sage, 1998), However, the options of mechanical treatments have not yet been fully explored (NABU, 2008, Baum et al., 2009a). For creating optimal conditions it is common practice to plough or grub up to 30 cm depth and harrow afterwards like in conventional agriculture (Baum et al., 2009a).

In spring, before planting, the field is grubbed (Schildbach et al., 2009), ploughed (Burger et al., 2005) or harrowed (Boelcke, 2006; Burger et al., 2005).

Treatment is recommended in autumn for cohesive soils whereas spring is the best time for more loose soil, so that already germinating seeds can be ploughed in (Larsson et al., 2007; Röhle et al., 2008).

5.7 CONTROL OF COMPETING VEGETATION

In the first stage of stand establishment willows and poplars are intolerant of weed competition, and even low levels of weed cover will cause uneven growth and greatly reduced yields. A completely weed-free site is required at planting and must be maintained until the crop foliage shades out the weeds (Tubby and Armstrong, 2002).

The dense canopy of a vigorous SRC crop should shade out most weeds once the crop has become established. Subsequent weeding should only be required after harvesting.

PART C - POTENTIAL IMPACTS OF PESTS AND PATHOGENS ON SRC AND SRF

1. INTRODUCTION

The species suitable for short rotation forestry should have to show resistance to pests, parasites, pathogens, etc. There are potential threats to SRF plantations from the pests and pathogens already present in Mediterranean European countries.

A relatively high level of leaf damage can be tolerated by SRC with little adverse effect but severe or repeated attacks will reduce yield. For example, removal of 30% of leaves had little effect on yield whereas removal of 90% of leaves in June and August reduced yield by 40% (Kendall et al., 1996).

1.1 *Acer Pseudoplatanus* L.

The most common diseases of this species are sycamore anthracnose, powdery mildew, cankers, root rot, and wood roots. Anthracnose is one of the most severe diseases that this kind of tree can get. This disease causes defoliation. Death of the leaves and new growth can eventually cause the death of the tree due to it not receiving nutrients from the sun and the inability to complete photosynthesis.

Rhytisma acerinum, *Verticillium dahliae*, *Nectria cinnabarina* can cause significant local mortality. Cryptostroma species cause sooty bark disease and can kill trees which are under stress due to drought. Death of maples can rarely be caused by Phytophthora root rot and Ganoderma root decay.

Cryptostroma species cause sooty bark disease and can kill trees which are under stress due to drought. Death of maples can rarely be caused by *Phytophthora* root rot and *Ganoderma* root decay.

About insects leaf-mining Lepidopter *Phylonorycter geniculella* and various species of aphids, can cause damage and loss of production (Phillips and Burdekin, 1992).

The reports of damaging biotic agents included more than 30 genera, but certain root rot and decay fungi were consistently associated with sycamore, particularly *Armillaria* and *Krezschmaria*. A number of foliar pathogens also frequently infected sycamore. These included: *Cristularia depraedans*, which causes striking white spots on leaves and leads to early leaf fall; *Rhytisma acerinum*, cause large, black leaf spots; and *Ophiognomonia pseudoplatanus* (giant leaf blotch of sycamore), that spreads rapidly to form a large, necrotic lesion, which can occupy 20-70% of the lamina and premature leaves fall (Barrett and Pearce, 1981).

However, all pathogens are considered to be conspicuous but unimportant, as they normally cause little if any lasting damage to affected trees (Strouts and Winter, 2000). The species is often damaged by grey squirrels.

1.2 *Ailanthus altissima* Mill.

Ailanthus has the reputation of being disease and insect free. In reality at least six species of fungi attack foliage, stem and vascular system; five species of decay fungi have been isolated from the roots and rotting trunks.

Wilt diseases, caused by *Verticillium* spp., remain the most potentially important fungus disease of this species (Hepting, 1971).

Damage to *Ailanthus* from insects is rare and largely undocumented. Webworms on the leaves were recorded in North America (Feret, 1985).

1.3 *Alnus cordata* (Loisel.) Desf.

The most common pests of Neapolitan alder is the beetle crisomelide *Agelastica alni*, which feeds on the leaf parenchyma, leaving intact only the ribs. The blight, results in the woody tissue necrosis, infection at the beginning of lenticels, with the emission of a reaction liquid and viscous brownish. *A. cordata* is susceptible to chlorosis in very alkaline soil.

1.4 *Alnus glutinosa* (l..) Gaertn.

A number of weak pathogens were implicated in the dieback of branches and stems, but they were unlikely to be very damaging unless alders are weakened by other factors such as fluctuating water tables or climatic factors (McKay, 2012).

Between acari the *Eriophyes laevis* (Eriophyoidea) can cause galls on the leaves. Other pests included *Chionaspis salicis* (Rhynchota, Diaspididae), *Croesus sempentrionalis* (Hymenoptera, Tenthredinidae) and *Phalera bucephala* (Lepidoptera, Notodontidae) (McKay, 2012).

Among pests recognized as potentially troublesome is the striped alder sawfly, *Hernichroa crocea*, a Hymenoptera Tentredinae native of Europe that is now found across northern United States and Canada (U.S. Department of Agriculture, Forest Service, 1985). It produces two generations per year. From July through September larvae occasionally eat all of the alder leaves except the midrib and larger veins

The most serious pathogen is the alder oomycetes *Phytophthora* (Gibbs et al., 1999) and by ascomycetes *Taphrina tosquinetii*, provocating heavy foliar damage, and *Nectria galligena* that can cause cancer of the trunks and leads to the breaking off of bark. *Armillaria* root rot was considered to occur quite commonly on alder.

European alder suffered less damage by deer browsing and rubbing than birch, willow, or other hardwood species.

1.5 *Castanea sativa* Mill.

As *Alnus* and *Acer* this species can be damaged by oomycetes *Phytophthora* and by ascomycota *Cryphonectria parasitica*, agent of the chestnut cancer. Native to Asia, chestnut blight, *Cryphonectria parasitica*, was first discovered in 1938 in Europe in northern Italy. Since then the fungus has spread rapidly throughout southern and Central Europe where chestnuts are cultivated and has been recorded in Austria, Belgium, Bosnia and Herzegovina, Croatia, France, Germany, Greece, Hungary, Montenegro, Poland, Portugal, Serbia, Slovakia, Slovenia, Spain, Switzerland, the former Yugoslav Republic of Macedonia, Turkey and Ukraine (Smith et al., 1997).

Armillaria mellea, *Armillaria gallica*,, *Melanconis modonia*, *Microsphaera castanae*, *Mycosphaerella castanicola* and *Mycosphaerella maculiformis* also cause damage to chestnut, while *Cryphonectria radicalis* has attracted a lot of attention due to its weak pathogenicity (Diamandis & Perlerou, 2001).

Dryocosmus kuriphilus (Oriental chestnut gall wasp; Hymenoptera: Cynipidae), is a serious pest of chestnut worldwide with a high potential for spread throughout the region through female flight and movement of infested chestnut plants and plant materials. It has been discovered in the southern part of the Piemonte region of Italy, where management attempts include classical biological control (FAO, 2009).

In particular ancient no longer cultivated chestnut orchards were hardly damaged by these disease. In the fight against these two pathogens, the conversion to coppice of old abandoned chestnut orchards allowed to retain this species in almost all areas where it was present (Marziliano et al., 2013).

1.6 *Corylus avellana* L.

In central Italy (Viterbo province) and northern Greece, *Pseudomonas avellanae*, the agent of bacterial canker, provokes serious economic losses (Scortichini, 2002a).

It can be attacks by various Coleoptera (*Lepersinus fraxini*, *Lytta vesicatoria*, *Stereonychus fraxini, Xyleborus dispar Obera linearis, Melolontha melolontha* Polyphylla fullo) and Hymenoptera (*Tomostethus melanopygus*) whom larvae or adult destroy wood with their galleries. *Curculio nucum* (Coleoptera, Curculionidae), can cause major damage if left untreated. *Palomena* prasina (Rhynchota, Pentatomidae) causes the death of the flower buds and the deterioration of the plant.

Between Lepidoptera *Gypsonoma dealbana*, *Archips rosanus*, *Choristaneura rosaceana* (Tortricidae) and *Hyphantria cunea* (Erebidae) can cause damage with feeding of larvae on the leaves in autumn and eating buds, catkins, young shoots and then spun leaves in the spring.Other important pest in Europe are *Phytoptus avellanae* (*Arachnida, Eriophyidae).*

1.7 *Eucalyptus* spp.

The most common disorders of *Eucalypts* seen in Mediterranean stands tend to be common decay fungi as *Armillaria* spp., *Chondrostereum purpureum*, *Hypholoma fasciculare*.

Table 12 Most common disorders of Eucalypts in Italy

Disorder/Pathogen	Type of damage/symptoms
Armillaria spp.	Root rot/decay
Chondrostereum purpureum	Decay
Hypholoma fasiculare	Decay
Weather related	Winter cold damage
Water excess oedema	Over-watering damage
Cultural/miscellaneous	Multiple symptoms

The numerous pathogens of eucalypts elsewhere in the world highlights the impact on SRF plantations and they should ever arrive in Italy. It underlines the need for effective plant health measures if seeds or cuttings are imported from major Eucalyptus growing regions around the world such as Australia and South America.

In the first decades of XXI century knot insects *Ophelimus maskelli* and *Leptocybe invalsa* (Hymenoptera Eulophidae), parasites of most species of *Eucalyptus*, have spread along Mediterranean basin. But they were controlled with biological fight using parasitoids. In the 2010 a new parasite, *Glycaspis brimblecombei* (Hemiptera, Psyllidae) was identified.

Adults and nymphs of this specie, native of Australia, feed on sap and produce large amounts of honeydew on which sooty mould develops. Damage caused includes leaf discoloration and, in heavy infestations, severe leaf drop and twig dieback. Infested trees are susceptible to attacks by secondary pests such as cerambycid beetles. Severe and multiple defoliations can result in tree death.

Three other exotic psyllid are reported in mediterranean countries: *Ctenarytaina eucalypti*, *Ctenarytaina spatulata* and *Blastopsylla occidentalis* all natives of Australia (Garonna et al., 2011).

Ctenarytaina eucalypti (blue gum psyllid) prefers immature foliage for oviposition and development of the nymphs. It is primarily a pest in *Eucalypt* plantations outside Australia, where it has been introduced in the absence of natural controls. In southern France and northern Italy, *Ctenarytaina eucalypti* is usually well controlled by an introduced hymenopteran parasitoid *Psyllaephagus pilosus*.

In Europe *Ctenarytaina spatulata* was first found in Portugal and later in France (in 2003), Italy (Liguria in 2003), Portugal (central part in 2002, widespread in 2003), Spain (Galicia in 2003, Extremadura and Andalucía in 2004). C. spatulata has been observed on *Eucalyptus camaldulensis*, *E. globulus*, *E. grandis*, *E. parvifolia*, *E. viminalis*). In France and Italy, it was only seen on *E. parvifolia*, cultivated for cut foliage. In Spain it was found on *E. globulus*.

Blastopsylla occidentalis was recently reported for *E. camauldulensis* in a park of Napoli.

Leptocybe invasa (Hymenoptera, Eulophidae, blue gum chalcid), native to Australia, is a serious pest of young eucalypt trees and seedlings currently. It's spreading through Africa, Europe and the Near East and attacks many Eucalyptus species (*E. botryoides*, *E. bridgesiana*, *E. camaldulensis*, *E. deanei*, *E. globulus*, *E. gunii*, *E. grandis*, *E. maidenii*, *E. nitens*, *E. robusta*, *E. saligna*, *E. tereticornis*, *E. viminalis*) (Mendel et al., 2004; EPPO, 2008).

Leptocybe invasa causes galls on the mid-ribs, petioles and stems of new shoots of eucalyptus trees. Heavy infestations can lead to deformed leaves and shoots, and a growth reduction of the tree. Serious damage to young plantations and nursery seedlings has been reported reported in Mediterranean countries, including France, Italy, Portugal and Spain, where eucalypts are widely grown for forestry (EPPO, 2008).

Gonipterus scutellatus is a indigenous to Australia leaf-feeding beetle that is a major defoliator of eucalypts. Now it occurs in many countries throughout the world where eucalypts are grown. Infestations of this beetle are known to cause serious damage. This pest is a major threat worldwide as it continues to spread, both within continents where it currently occurs and to previously uninfested continents. In Europe is reported for France, Italy, Portugal, Spain (FAO, 2009). In Spain and Italy, *Gonipterus scutellatus* showed a clear preference for the leaves of *E. globulus*, *E. obliqua*, *E. longifolia*, *E. grandis* and *E. propinqua* and did not attack *E. cinerea*, *E. gunnii*, *E. polyanthemos*, *E. stuartiana* and *E. Rostrata* (Rivera and Carbone, 2000; FAO, 2009).

Biological control of this species by means of the importation of *Anaphes nitens* (Hymenoptera: Mymaridae), an egg parasitoid, has been highly successful in many areas. Where the biological control of *G. scutellatus* is unsuccessful, the alternative is to use tolerant host plant species (Rivera and Carbone, 2000).

Phoracantha recurva and *Phoracantha semipunctata* (Coleoptera: Cerambycidae) are both serious borer pests of eucalypts, particularly those planted outside their natural range. In their native Australia they are considered minor pests (FAO, 2009). The larvae dig tunnel under the bark and into the cambium layer and ring bark the host trees. The larval feeding can rapidly kill the trees or cause significant damage to the timber of affected trees. About Mediterranean countries they are reported in France, Italy, Portugal, Spain, Turkey (FAO, 2009).

Biological control with natural enemies is possibly the best solution to controlling long horned borer populations. Some examples of biological control agents for *Phoracantha* species include the Australian parasitic wasps *Avetianella longoi*, *Callibracon limbatus*, *Jarra maculipennis*, J. *phoracantha* and *Syngaster lepidus*, and *Helcostizus rufiscutum* from California (Paine et al., 2000).

1.8 *Fraxinus excelsior* L.

Common stem defects in F. excelsior are canker and forking. Bacterial cankers can be caused by the bacterium *Pseudomonas savastanoi* or the fungus *Nectria galligena* and these may damage trees badly if they are grown on unsuitable sites.

Between fungus *Fomes ignarius* and *F. fomentarius* attack the wood deeply with loss of consistency and giving it a spongy appearance whitish for the destruction of lignin, the fruiting bodies of the parasites are visible on the outside of the logs are attached and shaped bracket or socket; same type of damage due to the *Schizophthora omnivora* with fruiting bodies shaped orecchiette grayish.

Phytophthora omnivora affects young seedlings in seedbeds with necrotic lesions of the neck. *Microsphaera alni* and *Phyllactinia sufflata* attack the leaves and young green twigs, causing whitish patches powdery consistency.

1.9 *Paulownia tomentosa* (Thunb.) Sieb. & Zucc. ex Steud.

Little is known regarding potential disease issues for *Paulownia* in mediterranean climate. *Paulownia* grown in China may be attacked by many diseases and insects, the most serious being witches broom.

Witches broom symptoms are characterised by a clustering of branches and it impairs tree growth and vigour and can lead to premature death. The disease affects the branches of the tree, trunk, flowers and roots. The wood of an infected tree is of poor quality as growth rates are reduced substantially and is then often unfit for commercial use (Lyons, 1993).

Other diseases reported to have occurred in China are: Anthracnose, a fungal disease also known as leaf blight; and *Sphaceloma paulowniae* and mistletoe (*Loranthus* sp.) can also cause some considerable damage (Lyons, 1993).

1.10 *Platanus* spp.

Platanus belong to woody plants seriously attacked by microscopic parasitic fungus *Apiognomonia veneta* that cause the disease known as anthracnose. This disease was first recorded on Platanus occidentalis in Britain in 1815 (Neely, 1976). Leaves are disfigured and shoots and twigs sometimes go away.

The asexual stage of *Apiognomonia veneta* is *Gloeosporium platani* (Mont.) Oud., occurring only on leaves of *Platanus* spp. (Ivanova et al., 2007). This disease is a regular problem but it rarely causes minor damage to most trees. When this necrosis affects the petiole, it provokes premature desiccation and leaf-fall. This type of attack is not normally very important, although it produces a defoliation that in exceptionally favorable years can reach a greater importance and cause premature leafdrop.

The fungus can enter the buds and overwinter there, producing bud death and preventing shooting. This can lead to the formation of adventitious buds around the dead bud and the sprouting of leaves from these adventitious buds. More commonly, as a reaction to the fungal attack, the shoots from these adventitious buds grow in whorls (when there is a proliferation of too many buds at the base of the shoot). They are shorter than normal, with shorter internodes.

An other frequent disease is powdery mildew (*Microsphaera alni* (DC.) Wint.). It can cause severe early defoliation occurred during July and August (Tello et al., 2000).

More harmful fungus, in particular for old exemplars, is the Canker stain *(Ceratocystis fimbriata).* It causes reddish brown lesions on old branches and the trunk, in a vertical strip and lightly depressed. The disease is transmitted by natural grafting between roots of nearby trees or by water runoff. Pruning utensils also can carry the inoculum.

1.11 *Populus* spp.

The high incidence of damage caused by pests is linked to the characteristics of extreme specialization of poplar plantations, that are more similar to an ecosystem type of agrarian than to a forest environment. Planted forms of *Populus* include numerous cultivated hybrids, varieties and clones of poplar, many of which have been produced from plant breeding programmes to offer rapid growth as well resistance to various diseases: particularly rust fungi of the genus *Melampsora* and bacterial canker *Xanthamonas populi*.

Other species or clones of poplar have a considerable sensitivity to insect and fungi, with a major impact on biomass production (Gielen and Ceulemans, 2001). The different clones and species can vary greatly in their susceptibility to the many diseases that affect poplar. In addition, the high density plants in SRF poplar create a microclimate characterized by a high humidity, condition optimal for the development of parasites.

Several insects can be harmful to the poplar, insects defoliators (*Chrysomela populi*, *Phyllodecta vitellinae*, *Leucoma salicis*, etc.), aphids (*Phloeomyzus passerinii*), cochineal (*Diaspis pentagona*, *Chionaspis salicis*, *Quadraspidiotus* spp.), insects and corticicoli silofagi (*Cossus cossus*, *Paranthrene tabaniformis*, *Saperda carchariase*, *Cryptorhynchus lapathi*), over which to different crittogame as rusts (*Melampsora* spp.), the bronzing (*Marssonina brunnea*), or forms of cancer (*Septoria mosaic*) (FAO, 1979; Steenackers et al., 1996; Gruppe et al., 1999; Samson et al., 1999).

Agrilus suvorovi populneus (Coleoptera, Buprestidae) is an insect particularly linked to *Populus nigra* and cultivated hybrids. The larvae, that feed for a certain period in the subcortical area, cause cracking and necrosis of the cortex. It is important, when there are water shortages, intervene promptly with emergency irrigation, which are in many case sufficient to stop infestation, for example of *Agrilus suvorovi populneus*, causing the immediate reaction of the plant.

At CRA-PLF in Monferrato (Piedmont) are in course of process genetic improvements through selection of parent species *Populous deltoides* and *Populus nigra* used in the creation of hybrids of *P. canadensis* resistant to attack by *Marssonina brunnea* and *Mekampsora* spp.

In experiments conducted by near Rome on three different SRF implants of clones of Poplar (*Populus* x *canadensis* AF2, *Populus* x *generosa* x *Populus nigra* AF6 e "Monviso") were identified various potential pathogens and parassite (Giorcelli et al., 2008). It was observed the first year the presence of *Gypsonoma aceriana* (Lepidoptera, Torticidae) whose larvae develop in the leaves first and then in the shoots blocking their growth. However, the development of supernumerary buds can compensate the loss due to the deformation and It not necessary to use specific methods of struggle.

Then it was observed the presence of *Monosteira unicostata* (Heteroptera, Tingidae) on the low leaves. The insect causes with his repeated bites leaf discoloration. Again, with low frequence, sporadic attacks of *Chrysomela populi* (Coleoptera, Chrisomelidae). During second year, despite a specific pesticide treatment, *Chrysomela populi* infected again the plantation. The diffusion of pests was helped by presence of savage plants of *Populus* near SRF stands.

The different clones and species can vary greatly in their susceptibility to the many diseases that affect poplars. Between identified species that could attack poplars, *Anoplophora glabripennis* is particularly dangerous because the only control strategy is based on destruction of affected plant by shredding and burning of debris. Some countries are experimenting chemical and biological means of control.

A wood destroying basidiomycete, *Phellinus pilatti*, caused serious symptoms to *Populus alba* trees in low Po Valley in Italy, with decay extends from the stem base to the branches (Bernicchia et al., 1995).

About mammals browsing, bark stripping, and fraying damage by deer can damage *Populus* plantations.

1.12 *Robinia pseudoacacia* L.

The only insect able to compromise, in general only partially, the photosynthetic capacity of *Robinia pseudoacacia*, causing damage to its leaves, is *Parectopa robiniella*. It is a species belonging to the order of *Lepidoptera* and the family *Gracillaridae* and native of natural areas of locust and its presence in Italy has been recorded since 1970 in Lumbardy. The female lays her eggs on the underside of the leaf and the caterpillar digs tunnels inside the leaf (Regione Toscana, 2012).

The bug potentially more dangerous for black locust tree is *Megacyllene robinia*. It is a beetle that belongs to Cerambycida, which compromises, digging tunnels in the wood, the possibility to obtain the production of poles or of sets of good quality from entire plantations of this species in America (IPLA, 2000).

Among the fungi, harmful pathogens are not reported, only borne pathogens of weakness especially of the root mainly including species of the genus Armillaria (A. mellea and A. gallica). Of senescent individuals manifest often root rot and it is common to tip of stumps that show obvious signs of deterioration of the roots main. In Piedmont hymenomicete Ungulinea fraxinea is present mainly in populations of locust aged or fresh stations (IPLA, 2000).

PART D - RELATIVE IMPACTS OF LAND-USE CHANGE

Land use change can be positive or negative for the environment, depending on the type of original land use and the land use to be established.

The SRF, owing to the high density and competition, grows with water and light limitations, associated with susceptibility to pest attacks (Giorcelli et al., 2010). Hence, SRF plantations should be planted on “optimal sites”, with the support of “optimal cultural practices.

We take only in consideration the change of destination from arable and ex-agricultural land to SRF because all native forests in Latium are protected by national and regional laws. About the pasture land most of them are protected by directive 92/43/EEC “Habitat” belonging to 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (prioritary if “important orchid sites”) and prioritary Habitat 6220 “Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea” according to Natura 2000 classification.

On productive cropland the establishment of SRC will in most instances lead to a positive environmental balance, but there can also be no-go areas for energy crop plantations, e.g. semi-natural grasslands or wetlands. SRC plantations may also be established to treat wastewater, create flood retention areas and riparian buffer zones, or for phyto-remediation purposes (Dallemand et al., 2008).

1. ARABLE TO SRF AND SRC

The production of food crops dependent on unsustainable irrigation or on poor soils could be replaced by growing less demanding SRF species. Land mainly available for SRF is former agricultural land, which is rich in base cations, nitrogen and phosphorus. Growing SRF crops for biomass over time, potentially can lead to significant soil nutrient depletion and soil acidification.

After afforestation an enhanced mobilization of easily decomposable above ground and root litter residues takes place. Subsequently the carbon and nitrogen contents of afforrested soils increase in the long term mainly due to the litter input and the lack of frequent soil cultivation (Makeschin, 1994).

Studies of invasion of old field by forest, and limited information from short rotation plantations, lead to suppose that SRF increases soil C (McKay, 2011). Soil C under arable land use has usually been reduced from native, undisturbed levels (Grigal and Berguson, 1998), by as much as 30% or more of their organic carbon content (Paul et al., 1997).

Within 2-3 years after plantation establishment, mulching by leaf litter, the lack of cultivation and increased rhizodeposits (Baum et al., 2009) slow decomposition and help retain C. This effect is specie-specific; for example, some experimental results with five hybrid poplar plantations, from 6 to 15 years old, found no differences in soil C compared to adjacent row crops or hayland (Grigal and Berguson, 1998). By contrast, other studies have shown increases in stored C under conifers (Vesterdal et al., 2008).

Studies carried out in the experimental area POPFACE (Tuscania, Viterbo), shows that a poplar short rotation forest (SRF) in comparison with the previous culture crop, increased the organic C storage in soil by about 23% in the second rotation cycle. Under elevated CO_2, the increase of above- and belowground productivity supported a greater accumulation of labile C in soil, favouring a microbial C immobilization process. Fertilization treatment induced short-term changes in the soil C content, without overall modifications in the second rotation cycle (Lagomarsino, 2009).

SRF may affect soil moisture (McKay, 2011). After the initial year of establishment, as trees become taller and structurally more complex than agricultural crops, they intercept and subsequently evaporate a greater proportion of incipient rainfall, and thus reduce the net amount of water reaching the soil. In addition, their greater leaf area index (LAI) enables higher potential water uptake from the site.

Net effects on hydrology of conversion from agricultural use to SRF production of biomass are reduction in percolation to aquifers, plant-available soil water, surface run-off from site. It is possible that the reduced percolation under SRF as compared with agricultural lands will result in less leaching of soil nutrients, which may represent a water quality benefit in nitrate vulnerable zones, but these benefits might not always be realisable (Hardcastle, 2006). If trees have no access to the water table and they are therefore dependent on soil water recharge via local precipitation, their water consumption is likely to be similar to that of agricultural crops in drier areas, but may exceed that of agricultural crops in areas of higher rainfall (Cannell, 1999). There may be increased water uptake from evergreen species such as Eucalyptus.

Converting arable land to short-rotation forestry can result in reduced amounts of nitrate, phosphorus, pesticides, and herbicides in runoff and groundwater (Hohenstein and Wright, 1994; Ranney and Mann, 1994; Lal et al., 1998; McLaughlin and Walsh, 1998; Börjesson, 1999). So changing land use to SRF may improve water quality by reducing soil erosion as well as level of nitrate, phosphorus and other chemicals and surface runoff and ground water. This land conversion may improve soil biodiversity and quality habitat.

During the life-span of the SRF plantation physical soil erosion should be much reduced compared to annual cultivation, and infiltration should be improved with greater rooting depth. During site preparation and harvesting there may be increased compaction of soils through frequent traffic movements (McKay, 2011).

Among soil organisms, microbial biomass and most faunal groups, especially decomposers, are advanced under tree plantations. The diversity of soil fauna is generally increased compared to arable land (Makeschin, 1994).

The conversion of current arable land to SRC plantations should in most instances bring positive benefits for soil resources and water quality. Due to the high water requirements of many perennial energy crops there could be, however, negative consequences for groundwater re-charge or water cycles (Dworak et al., 2007).

The reduced cultivation of soil associated with a change of land management from annual crops to SRC or SRF could reduce erosion and increase the organic matter content of soil (Hardcastle et al., 2006).

2. GRASSLAND TO SRF AND SRC

The conversion of grassland to SRF or SRC may be taken into consideration only for grassland deriving by abandonment of marginal agriculture in irrigated land, referred by phytosociology to the order of *Agropyretalia* (on clay soils) and *Potentillo-Polygonetalia* (temperate and mesophilous climates, in Mediterranean area principally on alluvial soils). The grasslands on limestone in Mediterranean belt ought to be excluded because they are referred to *prioritary habitat* according to Directive 92/43/CE “6220 Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea”. For the same reason, we don’t take into account in our analyses the Apennine pasture referred to habitat “6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites) of supramediterranean and oromediterranean belts.”

About impacts on biodiversity we have to underline that *Brometalia rubenti-tectorum* are very rich in species. The land-use dchange for example, to poplar cultivation led to a significative reduction of plant species richness.

Table 13 Comparison of the effects on hydrology of agriculture, SRC and SRF

Aspect	Pasture	Agriculture	SRF
Rainfall interception	medium	low	high
Evapotranspiration	low	medium	medium-high
Groundwater use	low	medium	medium-high
Percolation to aquifer	low	medium	high
Soil moisture	low	medium	high
Quantity of runoff	medium	high	low-medium
Quality of runoff	high	low	high

PART E - DAMAGE BY MAMMALS

Foresters and conservationists are increasingly aware of the negative effects of heavy deer browsing in wooded habitats: these include prevention of natural tree regeneration, browsing of planted trees, damage to the stems of young trees, and reduction of the structural complexity of the understory (Baines et al., 1994; Rambo and Faeth, 1999; Fuller and Gill, 2001; Stewart, 2001).

However, exclusion of deer from stands of SRF is likely to further reduce the rate at which shade tolerant plants are able to colonise the area, as in some cases deer act as seed vectors for such species (Vellend et al., 2003; Mouissie et al., 2005).

Wild boar is an other animals that can impact negatively with stand of SRF and young SRC plantation seldom damage trees and their grubbing activity favours the establishment and spread of understory plants.

Acer pseudoplatanus seedlings are highly palatable to *Capreolus capreolus*, *Cervus elaphus* and *Dama dama L.* which feed on the leaves, buds, and young shoots (Gill, 1992).

Young seedlings (less than 3years) can be severely browsed and show low survival rates after damage (Eiberle and Nigg, 1987) or reduced growth in subsequent years (Kupferschmid and Bugmann, 2008). Older seedlings are more resilient to repeated browsing (Heim et al., 2008).

The sensitivity of sycamore to browsing is comparable to that of ash (Kupferschmid and Bugmann, 2008) and higher than beech (Modrý et al, 2004); where the species grow in mixture, a high browsing pressure leads to the dominance of beech in regeneration.

Sycamore is very susceptible to bark damage by squirrels. Often suffers from tar spot in autumn (Hardcastle, 2006). Bark stripping of sycamore by the American grey squirrel (*Sciurus carolinensis* Gmelin) has repeatedly been reported recently from Northern Italy (Bertolino and Genovesi, 2002; Signorile and Evans, 2007). Stems below 30 cm DBH are the most vulnerable to debarking by the grey squirrel, and the fastest growing individuals seem to be the most affected (Harris, 2005).

CONCLUSIONS

As discussed in previous chapters of this report, the establishment of SRC and SRF plantations in Mediterranean arable cropping and other land-use systems may have both positive and negative effects on environment features and landscape.

In order to achieve maximum positive effects and minimize potential negative effects from SRC cultivation, proper site selection and management adjustments are key factors. These factors should be implemented taking into account the research results related to each of the aspects affected by forest bioenergy cultivation.

Unfortunately, as SRF and—particularly—SRC cultivation is quite a new approach, research results on the effects on environment features, cultutal hetitage and landscape are limited and do not cover cover spatial diversity and dynamic processes. In addition, they derive from specific field observations carried out in few plots, mainly relatively small.

The assessment of environmental positive and negative effects is a big challenge that all stakeholders involved in SRF and SRC cultivations must consider. Of course farmers need to be convinced to grow forest energy crop because it provides an economic profit equal to or higher than that of alternative farming crops. As demonstrated by the economic analysis carried out within the Proforbiomed project the profit of such investments is not certain. Thus, decision-makers may consider various direct or indirect incentives for farmers, to encourage shifts in land use from conventional farming to forest energy crop if this would result in environmental benefits. For instance, a potential economic compensation could be a form of “reward” to farmers helping to fulfill set environmental goals (including carbon sequestration), while keeping agricultural land in production.

A prerequisite for such incentives is, however, science based methods for quantification of the environmental benefits of shifting to SRC cultivation and evaluation of the value of these benefits for society. In this regard, the results of ongoing and new research programs will assist in underpinning the understanding of the interactions between SRF and SRC crops, environment, landscape and cultural heritage and promoting SRF and SRC as valuable component in future sustainable land use and energy systems.

REFERENCES

Aitchison E.W., Kelley S.L., Schnoor J.L., 2000: Phytoremediation of 1,4-dioxane by hybrid poplar trees. Water Environ. Res, 72: 313–321.

Akkermans A.D.L., van Dijk C., 1976: The formation and nitrogen-fixing activity of the root nodules of Alnus glutinosa under field conditions. In: Nutman P.S., (ed.) Symbiotic nitrogen fixation in plants, Cambridge University Press, Cambridge, England: 511-520.

Al Afas N., Marron N., Van Dongen S., Laureysens I., Ceulemans R., 2008: Dynamics of biomass production in a poplar coppice culture over three rotations (11 years). Forest Ecology and Management, 225: 1883-1891.

Allen S.J., Hall R.L., Rosier P.T., 1999: Transpiration by two poplar varieties grown as coppice for biomass production. Tree Physiol, 19: 493-501.

Anderson G.Q.A., Haskins L.R., Nelson S.H., 2004: The effects of bioenergy crops on farmland birds in the United Kingdom: a review of current knowledge and future predictions. In: Biomass and agriculture: sustainability, markets and policies; OECD workshop, Vienna, 10-13 June 2003. Paris: 199-218.

Andrén O., Lagerlof J., 1983: Soil fauna (Microarthropods, Enchytraeids, Nematodes) in Swedish agricultural cropping systems. Acta Agriculturae Scandinavica 33: 33-52.

Archaux F., Martin H., 2009: Hybrid poplar plantations in a floodplain have balanced impacts on farmland and woodland birds - Forest Ecology and Management, 257: 1474–1479.

Armstrong, A., 1999: Establishment of Short Rotation Coppice. Forestry Commission Practice Note No. 7. Forestry Commission, Edinburgh.

Aronsson P.G., 2001: Dynamics of nitrate leaching and 15N turnover in intensively fertilized and irrigated basket willow grown in lysimeters. Biomass and Bioenergy, 21: 143-154.

Aronsson P.G., Bergstrom L.F., Elowson S.N.E., 2000: Long-term influence of intensively cultured short-rotation Willow Coppice on nitrogen concentrations in groundwater. J. Environ. Manage. 58(2): 135-145.

Augustson A., Lind A., Weih M., 2006: Floristik mångfald i Salix-odlingar. Sven Bot Tidskr 100: 52-58.

Ayan S., Sadlam I., Sivaciodlu A., 2003: Paulownia Sieb. & Zucc: a new exotic genus for multi-purpos e uses in Kastamonu-Turkey. Decision support for multiple purpose forestry. April 23-25, Vienna, Austria.

Bacchetta G., Orrù M., Serra G., Vacca A., 2005: Studio pedologico-forestale dei boschi e delle boscaglie ripariali del Sulcis (Sardegna sud-occidentale). Bollettino della Società Italiana della Scienza del Suolo 54(1-2): 16-24.

Bacenetti J., Fiala M., 2011: Short Rotation Coppice in Italy: a model to asses economic, energetic and environmental performances of different crop systems. Act of “World Renewable Energy Congress, 8-13 may 2011, Linköping, Sweden.

Baines D., Sage R.B., Baines M.M., 1994: The Implications of Red Deer Grazing to Ground Vegetation and Invertebrate Communities of Scottish Native Pinewoods. Journal of Applied Ecology, 31: 776-783.

Baral A., Guha G.S., 2004: Trees for carbon sequestration or fossil fuel substitution: the issue of cost vs. Carbon bnefit. Biomass and Bioenergy, 27: 41-55.

Bardgett R.D., 2002: Causes and consequences of biological diversity in soil. Zoology, 105: 367-374.

Bardgett R.D., 2005: The Biology of Soil. A community and ecosystem approach. Oxford University Press.

Barrett D. K.; Pearce R. B., 1981: Giant leaf blotch disease of sycamore (Acer pseudoplatanus) in Britain. Journal Transactions of the British Mycological Society Vol. 76 No. 2 pp. 317-320.

Bartelink H.H., Olsthoorn, A.F.M., 1999: Introduction: mixed forests in Western Europe. In: Olsthoorn A.F.M., Bartelink H.H., Gardiner J.J., Pretzsch H., Hekhuis H.J., Franc A. (Eds.): Management of mixed-species forest: silviculture and economics. IBN Scientific Contributions: 9-16.

Baum C., Hrynkiewicz K., 2006: Clonal and seasonal shifts in communities of saprotrophic microfungi and soil enzyme activities in the mycorrhizosphere of Salix spp. Journal of Plant Nutrition and Soil Science, 169: 481-487.

Baum C., Leinweber P., Weih M., Lamersdorf N., Dimitriou I., 2009b: Effects of short rotation coppice with willows and poplar on soil ecology./Landbauforschung–vTI Agriculture and Forestry Research, 3(59): 183-196.

Baum C., Makeschin F., 2000: Effects of nitrogen and phosphorus fertilization on mycorrhizal formation of two poplar clones (*Populus trichocarpa* and *P. tremula* x *tremuloides*). Journal of Plant Nutrition and Soil Science 163: 491-497.

Baum C., Weih M., Verwijst T., Makeschin F., 2002: The effects of nitrogen fertilization and soil properties on mycorrhizal formation of *Salix viminalis*. Forest Ecology and Management, 160: 35-43.

Baum S., Weih M., Bolte A., 2012: Stand age characteristics and soil properties affect species composition of vascular plants in short rotation coppice plantations. BioRisk ,7: 51-71.

Baum S., Weih M., Busch G., Kroiher F., Bolte A., 2009a: The impact of Short Rotation Coppice plantations on phytodiversity. Landbauforschung - vTI Agriculture and Forestry Research 3(59): 163-170.

Baum S., Weih M., Busch G., Kroiher F., Bolte A., Boelcke B., 2006: Schnellwachsende Baumarten auf landwirtschaftlichen Flächen: Leitfaden zur Erzeugung von Energieholz: http://www.dendrom.de/daten/downloads/boelcke_leitfaden%20energie-holz.pdf>

Beeneken L., Agerer R., Bahnweg G., 1996: Inocybe fuscomarginata Kühn. + *Salix* spec. / *Populus nigra*. In: Agerer R. (ed.): Descriptions of ectomycorrhizae. Schwäbisch Gmünd: Einhorn-Verl, 1: 41-46.

Bell S., 2008: Valuable broadleaved trees in the landscape. In: Spiecker H., Hein S., Makkonen-Spiecker K., Thies M. (Eds.): Valuable broadleaved forests in Europe, EFI Research-Report, European Forest Institute.

Benetka V., Vrátný F., Šálková I., 2007: Comparison of the productivity of Populus nigra L. with an interspecific hybrid in a short rotation coppice in marginal areas. Biomass and Bioenergy, 31(6):367-374.Benton T.G., Vickery J.A., Wilson J.D., 2003: Farmland biodiversity: is habitat heterogeneity the key? Trends in Ecology and Evolution., 18 (4): 182-188.

Berg A., 2002: Breeding birds in short-rotation coppices on farmland in central Sweden: the importance of Salix height and adjacent habitats. Agric Ecosyst Environ, 90(3): 265–276.

Berg N.W., Pawluk S., 1984: Soil mesofauna studies under different vegetative regimes in north central Alberta. Canadian Journal of Soil Science, 64: 209-223.

Bergante S., Facciotto G., 2011: Biomass productions with new poplar and willow clones in SRC plantation in Northern Italy. In: Proceedings 'STREPOW' International Workshop, 23-24 February, 2011, Andrevlje-Novi Sad, Serbia: 183-192.

Bergmann B.A., Rubin A.R., and Campbell C.R., 1997: Potential of *Paulownia elongata* tress for swine waste utilization. American Society of Agricultural Engineers, 40(6): 1733-1738.

Bernetti G, 1985: Selvicoltura speciale. Ed. UTET, Torino: 415.

Bernicchia A., Padovan F., Nipoti P., 1995: An insidious pathogen of white poplar. Monti e Boschi, 46(3): 23-31.

Bertolino S., Genovesi P., 2002: Spread and attempted eradication of the grey squirrel (*Sciurus carolinensis*) in Italy, and consequences for the red squirrel (*Sciurus vulgaris*) in Eurasia. Biological Conservation, 109: 351-358.

Beyhan N., Odabaş F., 1996: The climate factor's effects on the yield in hazelnut and importance for growing (in Turkish: İklimsel faktörlerin fındıkta verimlilik üzerine etkileri ve yetiştiricilik açısından önemi)". Ondokuz Mayıs University, Journal of Agricultural Faculty, Samsun, 11: 177-188.

Binggeli P., 1992: Patterns of invasion of sycamore (*Acer pseudoplatanus* L.) in relation to 819 species and ecosystem attributes. D.Phil. Thesis, The University of Ulster.

Binggeli P., 1993: The conservation value of sycamore. Quarterly Journal of Forestry 87: 143–146.

Bisoffi S., Minotta G., Paris P., 2009: Indirizzi colturali e valorizzazione delle produzioni legnose fuori foresta. Atti del Terzo Congresso Nazionale di Selvicoltura. Taormina (ME), 16-19 ottobre 2008. Accademia Italiana di Scienze Forestali, Firenze: 729-736.

Blick T., Burger F., 2002: Wirbellose in Energiewäldern: am Beispiel der Spinnentiere der Kurzumtriebsfläche Wöllershof (Oberpfalz, Bayern). Naturschutz Landschaftsplanung, 34(9): 276–284.

Blick T., Weiss I., Burger F., 2003: Spinnentiere einer neu angelegten Pappel-Kurzumtriebsfläche (Energiewald) und eines Ackers bei Schwarzenau (Lkr. Kitzingen, Unterfranken, Bayern). Arachnol Mitt, 25: 1–16.

Blom J., Roelofsen W., Akkermans A.D.L., 1981: Assimilation of Nitrogen in Root Nodules of Alder, *Alnus glutinosa*. New Phytologist, 89(2): 321-326.

Borin E., 2003: Fitodepurazione. Soluzioni per il trattamento dei reflui con le piante. Edagricole. Bologna.

Borjesson P., Berndes G., 2006: The prospects for willow plantations for wastewater treatment in Sweden. Biomass and Bioenergy, 30: 428-438.

Bourgeois C., Sevrin E., Lemaire J., 2004: The Chestnut Tree and Wood. 2nd revised Edn., Institut pour le Developpement Forestier, Paris.

Bowman U., Turnbull J., 1997: Integrated biomass energy systems and emission of carbon dioxide. Biomass Bioenergy, 13: 333-343.

Brändle M., Brandl R., 2001: Species richness of insects an mites on trees expanding Southwood. Journal of Animal Ecology, 70: 491–504.

Brauner O., Schulz U., 2009: Heuschrecken (Saltatoria) und Tagfalter (Lepidoptera: Rhopalocera & Hesperiidae) auf Energieholzplantagen und angrenzenden Vornutzungsflächen in Brandenburg, Hessen, Niedersachsen und Sachsen.

Britt C.P., Fowbert J., McMillan S.D., 2007: The ground flora and invertebrate fauna of hybrid poplar plantations: results of ecological monitoring in the PAMUCEAF project. Aspects of Applied Biology, 82: 83-90.

Brunner I., Luster J., Günthardt-Goerg M.S., Frey B., 2008: Heavy metal accumulation and phytostabilisation potential of tree fine roots in a contaminated soil. Environmental Pollution, 152: 559-568.

Bryndum H., Henriksen H.A., 1988: Hugst i ær. Skoven, 20: 89-91.

Burger F., Sommer W., Ohrner G., 2005: Anbau von Energiewäldern. Landesanstalt für Wald und Forstwirtschaft 19 LWF Merkblatt der Bayerischen: http://www.lwf.bayern.de/publikationen/daten/merkblatt/p_33128.pdf

Burken J.G., Schnoor J.L., 1997: Uptake and Metabolism of Atrazine by Poplar Trees. Environ. Sci. Technol., 31: 1399-1406.

Bütler S.R., 2003: Dead wood in managed forests: how much and how much is enough? Development of a Snag Quantification Method by Remote Sensing & GIS and Snag Targets Based on Three-toed Woodpeckers Habitat Requirements. PhD. Thesis, Lausanne EPFL 184: http://biblion.epfl.ch/EPFL/theses/2003/2761/EPFL_TH2761.pdf

Cagelli L., Lefévre F., 1995: The conservation of *Populus nigra* and gene flow with cultivated poplars in Europe. For. Genet. 2: 135-144.

Campanaro A., Bardiani M., Spada L., Carnevali L., Montalto F., Antonini G., Mason F., and Audisio P. (Eds.), 2011: Linee Guida per il monitoraggio e la conservazione dell’entomofauna saproxilica. Quaderni Conservazione Habitat, 6. Cierre Grafica, Verona, 8 pp. + CD-ROM.

Carbonara L., 2004: Progettando il paesaggio, Aracne, Roma.

Cernova N.M., 1970: The main features of the distribution of microarthropods in compost heaps. Pedobiologia, 10: 365-372.

Ceulemans R., Deraedt W., 1999: Production physiology and growth potential of poplar under short rotation forestry culture.Forest Ecology and Management, 121: 9-23.

Chen Y.-l. , Cheng G.-l., Han S., 2000: Effect of Corylus clusters on the physicochemical properties of soil. Journal of Forestry Research, 11(3): 173-176.

Chitsazi H., 2012: Ecological and Physiological Study of White Poplar (Populus alba) on the Bank of Zayandeh Rood River. J. Appl. Environ. Biol. Sci., 2(4): 140-153.

Christian D.P., Hoffmann W., Hanowski J.M., Niemi G.J., Beyea J., 1998: Bird and mammal diversity on woody biomass plantations in North America. Biomass Bioenergy, 14(4): 395–402.

Ciancio O., Iovino F., Maetzke F., Menguzzatto G., 1981: Gli eucalitti in Sicilia: problemi tecnici ed economici. Quaderni forestali, 3. INSUD Nuove iniziative per il sud s.p.a.: 157.

Ciucani G., Mosbaek H., Trapp S., 2004: Uptake of tributyltin into willow trees. Environmental Science and Pollution Research, 11(4): 267-272.

Claessens H., 2003: The alder populations of Europe. In: Gibbs J., van Dijk C., Webber J., (eds.): Phytophthora Diseases of Alder in Europe. Forestry Commission Bulletin 126. Forestry Commission, Edinburgh, UK.

Claessens H., Oosterbaan A., Savill P., Rondeux J., 2010: A review of the characteristics of black alder (Alnus glutinosa (L.) Gaertn.) and their implications for silvicultural practices. Forestry, 83 (2):163-175. http://forestry.oxfordjournals.org/content/83/2/163.full

Clark J., Darlington J., Fairclough G., 2004: Using Historic Landscape Characterisation. English Heritage & Lancashire County Council.

Clementi A., 2002: Interpretazioni di paesaggio. Meltemi, Roma.

Confalonieri M., Belenghi B., Balestrazzi A., Negri S., Facciotto G., Schenone G., Delledonne M., 2000: Transformation of elite white poplar (Populus alba L.) cv. ‘Villafranca’ and evaluation of herbicide resistance. Plant Cell Reports (2000) 19: 978–982.

Converse C.K., 1984: Element stewardship abstract for *Robinia pseudoacacia* Black Locust: http://www.imapinvasives.org/GIST/ESA/esapages/robipseu.html

Corseuil H.X., Moreno F.N., 2001: Phytoremediation potential of willow trees for aquifers contaminated with ethanol-blended gasoline. Water Research , 35(12): 3013-3017.

Croatian Poplar Commission: Period: from 2008 to 2011. Republic of Croatia, Ministry Of Agriculture.

Crosti R., (a cura di), 2010b: Invasiveness of biofuel crops and potential harm to natural habitats and native species. Convention on the Conservation of European Wildlife and Natural Habitats, Standing Committee, 30th meeting Strasbourg, 6 – 9 December 2010, T-PVS/Inf: 6.

Crosti R., 2010a: Short Rotation Forestry for bio-energy: potential threat to Mediterranean forest ecosystem services by invasive species. Latest on Mediterranean Forest: 3-4.

Crow P., Houston T.J., 2004: The influence of soil and coppice cycle on rooting habit of short rotation poplar and willow coppice. Biomass and Bioenergy, 26: 497-505.

Cunningham M.D., Bishop J.D., McKay H.V., Sage R.B., 2004: Arbre Monitoring Ecology of Short Rotation Coppice. URN 04/961, Game Conservancy Trust (GCT), Central Science Laboratory (CSL), Contract number B/U1/00627/00/00.

Dallemand J.F., Petersen J.E., Karp A., 2008: Short Rotation Forestry, Short Rotation Coppice and perennial grasses in the European Union: Agro-environmental aspects, present use and perspectives. 17 and 18 October 2007, Harpenden, United Kingdom.

Danielsen L., Lohaus G., Sirrenberg A., Karlovsky P., Bastien C., et al., 2013: Ectomycorrhizal Colonization and Diversity in Relation to Tree Biomass and Nutrition in a Plantation of Transgenic Poplars with Modified Lignin Biosynthesis. PLoS ONE 8(3): e59207. doi:10.1371/journal.pone.0059207.

Danielsen L., Thürmer A., Meinicke P., Buée M., Morin E., Martin F., Pilate G., Daniel R., Polle A., Reich M., 2012: Fungal soil communities in a young transgenic poplar plantation form a rich reservoir for fungal root communities. Ecology and Evolution, 2(8): 1935–1948.

DEFRA, 2007: UK Biomass Strategy, Joint Research Centre 47547: http://www.defra.gov.uk/Environment/climatechange/uk/energy/renewablefuel/pdf/ukbiomassstrategy-0507.pdf

Delarze R., Ciardo F., 2002: Rote Liste-Arten in Pappelplantagen. Informationsbl Forschungsber Wald Birmensdorf, 9: 3-4.

Dhondt A.A., Sydenstricker K.V., 2000: Birds breeding in short-rotation woody crops in upstate New York : 1998 – 2000. In: Volk T.A., Abrahamson L.P., Ballard J.L. (eds): Proceedings of the Short-Rotation Woody Crops Operations Working Group: 3rd Conference; October 10-13, 2000, Syracuse, NY. Syracuse NY: Faculty of Forestry: 137–141.

Diamandis S., Perlerou C., 2001: The mycoflora of the chestnut ecosystems in Greece. Forest Snow and Landscape Research, 76(3): 499–504.

Dickinson N., Baker A., Doronila A., Laidlaw S., Reeves R., 2009: Phytoremediation of inorganics: realism and synergies. International Journal of Phytoremediation, 11: 97–114.

Dickmann D.I., 2006: Silviculture and biology of short – rotation woody crops in temperate regions: Then and now. Biomass and Bioenergy, 30: 696–705.

Dimitriou I., Baum C., Baum S., Busch G., Schulz U., Bergström L., Johansson R., 1992: Influence of fertilized short-rotation forest plantations on nitrogen concentrations in groundwater. Soil Use Manage, 8: 36-40.

Dimitriou I., Baum C., Baum S., Busch G., Schulz U., Köhn J. Lamersdorf N., Leinweber P., Aronsson P., Weih M., Berndes G., Bolte A., 2009b: The impact of Short Rotation Coppice (SRC) cultivation on the environment. In: Dimitriou I., Baum C., Baum S., Busch G., Schulz U., Köhn J., Lamersdorf N., Leinweber P., Aronsson P., Weih M., Berndes G., A. Bolte / Landbauforschung - vTI Agriculture and Forestry Research, 3(59): 159-162.

Dimitriou I., Baum C., Baum S., Busch G., Schulz U., Köhn J., Lamersdorf N., Leinweber P., Aronsson P., Weih M., Berndes G., Bolte A., 2011: Quantifying environmental effects of Short Rotation Coppice (SRC) on biodiversity, soil and water. IEA BIOENERGY: Task 43.

Dimitriou I., Bolte A., 2012: RATING-SRC Reducing environmental impacts of SRC through evidence-based integrated decision support tools. ERA-NET Bioenergy, 4th WoodWisdom-Net Research Programme Seminar in collaboration with ERA-NET Bioenergy, Helsinki, 7/2/2012.

Dimitriou I., Busch G., Jacobs S., Schmidt-Walter P., Lamersdorf N., 2009: A review of the impacts of Short Rotation Coppice cultivation on water issues. Landbauforschung, 3(59): 197-206.

Dimitriou I., Eriksson J., Adler A., Aronsson P., Verwijst I., 2006: Fate of heavy metals after application of sewage sludge and wood-ash mixtures to short rotation willow coppice. Environ. Pollut., 142: 160-169.

Dobrowolska D., Hein S., Oosterbaan A., Wagner S., Clark J., Skovsgaard J. P., 2011: A review of European ash (*Fraxinus excelsior* L.): implications for silviculture. Forestry (2011) doi: 10.1093/forestry/cpr001 . First published online: March 2, 2011.

Donald P.F., Sanderson F.J., Burfield I.J., van Bommel F.P.J., 2006: Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990–2000. Agr. Ecosyst. Environ., 116: 189–196.

Donnison L.M., Griffith G.S., and Bardgett R.D., 2000: Determination of fungal growth and activity in botanically diverse haymeadows: effects of litter type and fertilizer additions. Soil Biology and Biochemistry 32: 289-294.

Dowell R.C., Gibbins D., Rhoads J.L., Pallardy G., 2009: Biomass production physiology and soil carbon dynamics in short-rotation-grown Populus deltoides and P. deltoides x P. nigra hybrids. Forest Ecol Manage, 257: 134-142.

DTI, 2004: Arbre monitoring: ecology of short rotation coppice; four year study involving wildlife monitoring of commercial SRC plantations planted on arable land and arable control plots: http://www.berr.gov.uk/files/file14870.pdf

DTI, 2006: The effects on flora and fauna of converting grassland to Short Rotation Coppice (SRC): http://www.berr.gov.uk/files/file29233.pdf>[zitiertam22.07.2009

Durham C.B., 1956: 'Management and Utilisation of Hazel Coppice' in Utilisation of Hazel Coppice Forestry Commission Bulletin, 27 HMSO, London.

Ecosse A., Paris P., Mareschi L., Olimpieri G, Scarascia Mugnozza G., 2007: Smaltimento di reflui zootecnici in piantagioni da biomassa (srf): prime esperienze in un sito sperimentale di pioppo nel centro - Italia. 6° Congresso Nazionale SISEF - Arezzo, 25-27 Sep 2007, Contributo no. 6.3.2: http://www.sisef.it/

EEA (European Environmental Agency), 2008: A review of the possible impact of biomass production from agriculture on water. Background paper for the conference "WFD meets CAP – Looking for a consistent approach". Copenhagen, Denmark: http://ecologic-events.eu/capwfd/conference2/en/documents/Biomass_WFD_report_V7_final260108-2.pdf

EEA, 2006: How much bioenergy can Europe produce without harming the environment. EEA Report, 7/2006, ISSN 1725-9177, Copenhagen, Denmark.

Eiberle K., Nigg H., 1987: Grundlagen zur Beurteilung des Wildverbisses im 888 Gebirgswald. Schweizer Zeitschrift für Forstwesen 138: 747-785.

Ek H., 1997: The influence of nitrogen fertilization on the carbon economy of Paxillus involutus in ectomycorrhizal associations with Betula pendula. New Phytol 135: 133-142.

El-Showk S., El-Showk N., 2003: The *Paulownia* tree – An alternative for sustainable forestry. The Farm: http://www.cropdevelopment.org/paulownia/Brochure.pdf

ELU, 2009: Assessing the social, environmental and economic impacts of increasing rural land use under energy crops. Policy and Practice Note, 9 "Assessing the social, environmental and economic impacts of increasing rural land use under energy crops", RELU, Newcastle Upon Tyne.

Eppler U., Petersen J. Couturier C., 2008: Short Rotation Coppice and Perennial Energy Grasses in the European Union: Agro-environmental aspects, present use and perspectives. JRC Scientific and Technical Report EUR 23569 EN-2008: 95-133.

Eppler U., Petersen J.-E., 2007: Short Rotation Forestry, Short Rotation Coppice and energy grasses in the European Union: Agro-environmental aspects, present use and perspectives (Final draft document for comments), October 2007. EEA Specific Contract No 2 3604/B2006/EEA.52793 - Deliverable Task 2b: Background report on current SRF/SRC cropping patterns in Europe.

EPPO, 2008: EPPO alert list. Available at: www.eppo.org/QUARANTINE/Alert_List/alert_list.htmFAO, 1979: Poplars and willows in wood production and land use. FAO Forestry Series, 10, Rome, Italy: 511.

European Council (2009) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

FAO, 1980: Poplars and willows in wood production and land use. FAO Forestry Series no. 10. FAO, Rome.

FAO, 2009: Global review of forest pests and disease. FAO Forestry paper 156. ftp://ftp.fao.org/docrep/fao/011/i0640e/i0640e.pdf

Feret P.P.,1985: Ailanthus: Variation, cultivation, and frustration. Journal of Arboriculture, 11 (12): 361-368.

Ferguson T.P., Bond, G., 1953: Observations on the formation and function of the root nodules of *Atnus glutinosa* (L.) Gaertn. Ann. Bot., Lond., N.S., 17: 175.

Firbank L.G., 2005: Striking a new balance between agricultural production and biodiversity. Ann. Appl. Biol., 146: 163–175.

Fogel R., 1980: Mycorrhizae and nutrient cycling in natural forest ecosystems. New Phytologist, 86: 199–212.

Fontana A., Palenzona M., 1969: Sintesi micorrizica di Tuber albidum in coltura pura con Pinus strobus e pioppo americano. Allionia, 15: 99-104.

Fossati T., Patrignani G., Zapelli I., Sabatti M., Sala F., Castiglione S., 2004: Development of molecular markers to assess the level of introgression of *Populus tremula* into *P. alba* natural populations. Plant Breeding. 123(4): 382-385.

Francescato V., Antonini E., Zuccoli Bergomi L., Metschina C., Schnedl C., Krajnc N., Koscik K., Nocentini G., Stranieri S., 2009: Wood fuels handbook. AIEL (Italian Agroforestry Energy Association, Legnano (PD).

Fremstad E., Elven R., 1996: Fremmede planter i Norge – Platanlønn. Blyttia, 2/96.

Fremstad E., Elven R., 1996: Fremmede planter i Norge – Platanlønn. Blyttia, 2/96.

French C.J., Dickinson N.M., Putwain P.D., 2006: Woody biomass phytoremediation of contaminated brownfield land. Environmental Pollution, 141: 387-395.

Frison G., 1974: Piantagioni di pioppo con turno biennale. In: “Distanziamenti, turni e produttività dei pioppeti. Il contributo degli Istituti di ricerca dell’ENCC”. excerpt from: Cellulosa e carta, 9, Roma.

Fuller R.J. and Gill R.M.A, 2001. Ecological impacts of deer in woodland. Forestry, 74: 193-199.

Gallagher F.J., Pechmann I., Bogden J.D., Grabosky J., Wies P., 2008: Soil metal concentrations and vegetative assemblage structure in an urban brownfield. Environmental Pollution, 153: 351-361.

Garten Jr. C.T., 2002: Soil carbon storage beneath recently established tree plantations in Tennissee and South Carolina, USA. Biomass Bioenergy, 23: 93-102.

Gibbs J.N., Lipscombe M.A., Peace A. J., 1999: The impact of Phytophthora disease on riparian populations of common alder (Alnus glutinosa) in southern Britain. European Journal of Forest Pathology, 29(1): 39–50.

Gielen B., Ceulemans R., 2001: The likely impact of rising atmospheric CO_2 on natural and managed Populus: a literature review. Environmental Pollution, 115: 335-358.

Gill R.M.A., 1992: A review of damage by mammals in north temperate forests: 3. Impacts on 901 trees and forests. Forestry, 65: 363-388.

Gill R.W., 1969: Soil microarthropod abundance following old-field litter manipulation, Ecology, 50: 805-816.

Giorcelli A., Allegro G., Verani S., 2010: Phytosanitary concerns in the biomass poplar plantation of the COFEA Project (Monterotondo - Rome). In: IPC WP6 Working party, Workshop meeting “Environmental applications of poplar and willow”. Montelibretti (RM - Italy),17-18 September 2010.

Godbout G., Fortin J.A., 1985: Synthesised mycorrhizae of aspen: fungal genus level of structural characterization. Can J Bot, 63: 252-262.

Goodlass G., Green M., Hilton B., McDonough S., 2007: Nitrate leaching from short-rotation coppice. Soil Use Manage 23(2): 178-184.

Granhall U., Šlapokas T., 1984: Leaf litter decomposition in energy forestry : first year nutrient release and weight loss in relation to the chemical composition of different leaf litter types. Rapport / Institutionen för ekologi och miljöv°ard. Sveriges lantbruksuniversitet, 15: 131-153.

Griffiths A.P., McCormick L.H., 1984: Effects of soil acidity on nodulation of *Alnus glutinosa* and viability of Frankia. Plant and Soil, 79: 429-434.

Gruppe A., Fubeder M., Schopf R., 1999: Short rotation plantations of aspen and balsam poplar on former arable land in Germany: defoliation insects and leaf constituents. Forest ecology and management, 121: 113-122.

Gruß H., Schulz U., 2009: Brutvogelfauna auf Kurzumtriebsplantagen in Brandenburg, Hessen und Sachsen Lebensraumpotential verschiedener Strukturtypen. Naturschutz Landschaftsplanung.

Guitián J., Guitián P., Munilla I., Guitián J., Garrido J., Penín L., Domínguez P., Guitián L., 2012: Biodiversity in Chestnut Woodlots: Management Regimen vs Woodlot Size Open Journal of Forestry, 2(4): 200-206.

Gullner G., Komives T., Rennenberg H., 2001: Enhanced tolerance of transgenic poplar plants overexpressing g-glutamylcysteine synthetase towards chloroacetanilide herbicides. Journal of Experimental Botany, 52: 971-979.

Gustafsson J., Larsson S, Nordh N-E., 2007: Manual for Salix growers (In Swedish), Lantmännen Agroenergi AB/Salix, Örebro, Sweden.

Gustafsson L., 1987: Plant conservation aspects of energy forestry: a new type of land-use in Sweden. For Ecol Manage 21: 141-161.

Hall R.L., 2003: Short rotation coppice for energy production hydrological guidelines. URN 03/883, DTI.

Hall R.L., Allen S.J., Rosier P.T.W., Hopkins R., 1998: Transpiration from coppiced poplar and willow measured using sap-flow methods. Agric Forest Meteorol, 90: 275.

Hamm, J., 1896: Der Ausschlagwald. Verlag Paul Parey, Berlin.

Hansky I., 1999: Habitat connectivity, habitat continuity, and metapopulations in dynamic landscapes. Oikos, 87: 209-219.

Hansky I., 1999: Habitat connectivity, habitat continuity, and metapopulations in dynamic landscapes. Oikos, 87: 209-219.

Hardcastle P.D., Calder I., Dingwall l., Garrett W., McChesney I., Mathews J., Savill P., 2006: A review of the impacts of short rotation forestry. Final Report on SRF by LTS International.

Harris E., 2005: Grey squirrel attacks. Quarterly Journal of Forestry, 99: 258-259.

Hasselgren K., 1998: Use of municipal waste products in energy forestry: highlights from 15 years of experience. Biomass Bioenergy, 15: 71-74.

Hasselgren K., 1999: Utilization of sewage sludge in short-rotation energy forestry: a pilot study. Waste Mgmt. Res.,17: 251-262.

Heilmann B., Makeschin F., Rehfuess K.E., 1995: Vegetationskundliche Untersuchungen auf einer Schnellwuchsplantage mit Pappeln und Weiden nach Ackernutzung. Forstwissenschaftliches Centralblatt, 114: 16-29.

Hein S., Collet C., Ammer C., Le Goff N., Skovsgaard J.P., Savill P., 2008: A review of growth and stand dynamics of Acer pseudoplatanus L. in Europe: implications for silviculture: 52. http://www.valbro.uni-freiburg.de

Heinsoo K., Sild E., Koppel A., 2002: Estimation of shoot biomass productivity in Estonian Salix plantations. Forest Ecology and Management, 170: 67-74.

Heisler C., 1995: Collembola and Gamasina: bioindicators for soil compaction. Acta Zool. Fennica, 196: 229-231.

Heitz, R., Rehfuess, K.E., 1999: Reconversion of Norway spruce (Picea abies (L.) Karst.) stands into mixed forests: effects on soil properties and nutrient fluxes. In: Olsthoorn A.F.M, Bartelink H.H., Gardiner J.J., Pretzsch H., Hekhuis H.J., Franc A. (Eds.): Management of 949 mixed-species forest: silviculture and economics. IBN Scientific Contributions: 46-57.

Heller M.C., Keoleian G.A., Mann M.K., Volk T.A., 2004: Life cycle energy and environmental benefits of generating electricity from willow biomass. Renewable Energy, 29(7): 1023-1042.

Henriksen H.A., Bryndum H., 1989: Zur Durchforstung von Bergahorn und Buche in Dänemark. Allgemeine Forst- und Jagdzeitschrift 38-39/1989: 1043-1045.

Hepting G. H., 1971: Diseases of Forest and Shade Trees of the United States. U.S. Dept. of Agric. U.S. Forest Service. Agric. Handb.: 386.

Herpka I., 1986: A survey of development and possibilities of growing: natural forests of poplars and willows, in: Poplars and Willows in Yugoslavia, Poplar Research Institute, Novi Sad: 21-36.

Herve C., Ceulemans R., 1996: Short rotation coppiced vs. non-coppiced poplar: a comparative study at two different sites.Biomass and Bioenergy, 2-3: 139-150.

Hinchman R.R., Negri M.C., Gatliff E.G., 1996: Phytoremediation using green plants to clean up contaminated soil, groundwater and wastewater. In “Phytoremediation” Argonne National Laboratory Applied Natural Sciences, Inc: 1-10.

Hrynkiewicz K., Haug I., Baum C., 2008: Ectomycorrhizal community structure under willows at former ore mining sites. Europ J Soil Biol, 44: 37-44.

Hubbard V.C., Jordan D., Stecker J.A., 1999: Earthworm response to rotation and tillage in a Missouri claypan soil. Biol. Fertil. Soils, 29: 343-347.

Hutchings T., 2002: The opportunities for woodland on contaminated land. Forestry Commission Information Note. Forestry Commission.

Illick J.S., Brouse E.F., 1926: The ailanthus tree in Pennsylvania. Bulletin 38. Harrisburg, PA. Pennsylvania Department of Forests and Waters, 29.

INFC, 2007a: Le stime di superficie 2005. Prima parte. Autori G. Tabacchi, F. De Natale, L. Di Cosmo, A. Floris, C. Gagliano, P. Gasparini, L. Genchi, G. Scrinzi, V. Tosi. Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. MiPAF – Corpo Forestale dello Stato - Ispettorato Generale, CRA - ISAFA, Trento: http://www.infc.it

INFC, 2007b: Le stime di superficie 2005. Seconda parte. Autori G. Tabacchi, F. De Natale, L. Di Cosmo, A. Floris, C. Gagliano, P. Gasparini, I. Salvadori, G. Scrinzi, V. Tosi. Inventario Nazionale delle Foreste e dei Serbatoi Forestali di Carbonio. MiPAF – Corpo Forestale dello Stato - Ispettorato Generale, CRA - ISAFA, Trento: http://www.infc.it.

IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 996 p. ISBN 978-0-521-88009-1 hardback - ISBN 978-0-521-70596-7 paperback.

ISPRA, 2012. Program ReMo. National Monitoring Network on Soil Biodiversity and land Degradation. Quaderni Natura e Biodiversità 4/2012, ISBN: 978-88-448-0570-8. Available [in Italian], as of Jan. 28, 2014 at www.isprambiente.gov.it/en/publications/booklets/nature-and-biodiversity/program-re-mo.-national-network-on-soil-biodiversity-and-land-degradation?set_language=en

ISPRA, in press. I Sirfidi (Ditteri): biodiversità e conservazione. Manuale operativo. Manuali e Linee Guida 2014.

Jakucs E., 2002: Ectomycorrhizae of *Populus alba* L. In South Hungary. Phyton Vol. 42: 199-210.

Jakucs E., Agerer R., 1999a: Scleroderma bovista Fr. + *Populus alba L.* In: Agerer R., (ed): Descriptions of ectomycorrhizae. Schwäbisch Gmünd : Einhorn-Verl, 4: 121-126.

Jakucs E., Agerer R., 1999b: Tomentella pilosa (Burt) Bourdot & Galzin + *Populus alba* L. In: Agerer R., (ed): Descriptions of ectomycorrhizae. Schwäbisch Gmünd: Einhorn-Verl, 4: 135-140.

Jakucs E., Agerer R., 2001: Tomentella subtestacea Bourdot & Galzin + *Populus alba* L. In: Agerer R., (ed): Descriptions of ectomycorrhizae. Schwäbisch Gmünd : Einhorn-Verl, 5: 213-219.

Jalas J., Suominen J., 1976: Atlas Florae Europaeae; 3: Salicaceae to Balanosphoraceae. Helsinki, Finland: 59.

Jardine D.C., 2009: Not merely a habitat: utilisation of Aspen. In Parrott J., MacKenzie N. (eds.) "Aspen in Scotland: biodiversity and management. Proceedings of a Conference held in Boat of Garten, October 2008: 43-47.

Jedicke E., 1995: Naturschutzfachliche Bewertung von Holzfeldern: schnellwachsende Weichhölzer im Kurzumtrieb, untersucht am Beispiel der Avifauna. Mitt NNA: 109-119.

Johnson D.W., Cheng W., and Ball J.T., 2000a: Effects of [CO_2] and nitrogen fertilization on soils planted with ponderosa pine. Plant and Soil 224: 99-113.

Johnson D.W., Rowland D.L., Corkidi L., Egerton-Warburton L.M., and Allen E.B., 2000b: Nitrogen enrichment alters mycorrhizal allocation at five mesic to semi-natural grasslands. Applied Soil Ecology 11: 135-146.

Jones E.W. 1945: Biological flora of the British Isles, Acer L. Journal of Ecology, 32: 215-252.

Jones P.B. Jr., Kommalapati R.R., Constant W.D. 2001: Phytobuffering of Lower Chlorinated Benzene Contamination via Willows at the PPI Superfund Site. Journal of Hazardous Substance Research, 3: 5-17.

Jordahl J.L., Foster L., Schnoor J.L., Alvarez P.J.J., 1997: Effect of Hybrid Poplar Trees on Microbial Populations Important to Hazardous Waste Bioremediation. Environmental Toxicology and Chemistry, 16: 1318-1321.

Jordan A. M., 1974: Recent development in the ecology and methods of control of tsetse flies (*Glossina* spp.), a review. Bull. Ent. Res., 63: 361–99.

Jordbruksverket, 2006: Bioenergi – ny energi för jordbruket (in Swedish). Rapport 2006: 1.

Jørgensen U., Mortensen J., 2000: Combined energy crop production and groundwater protection. In: Jørgensen U. (ed.): Do energy crops have a future in Denmark?. DJF rapport Markbrug, 29: 97-104.

Jug A., Hofmann-Schielle C, Makeschin F., Rehfuess K.E., 1999b: Short-rotation plantations of balsam poplars, aspen and willows on former arable land in the Federal Republic of Germany: III. Soil ecological effects. Forest Ecology and Management, 121: 85-99.

Jug A., Hofmann-Schielle C., Makeschin F., Rehfuess K.E., 1999a: Short-rotation plantations of balsam poplars, aspen and willows on former arable land in the Federal Republic of Germany: II. Nutritional status and bioelement export by harvested shoot axes. Forest Ecology and Management, 121: 67-83.

Kačík F., Ďurkovič J., Kačíková D., 2012: Chemical Profiles of Wood Components of Poplar Clones for Their Energy Utilization. Energies 2012, 5: 5243-5256.

Kajba D., Gracan J., 2003: EUFORGEN Technical Guidelines for genetic conservation and use for Black Alder (Alnus glutinosa). Rome, Italy: International Plant Genetic Resources Institute: 6.

Karg W., Freier B., 1995: Parasitiforme Raubmilben als Indikatoren fur den okologischen Zustand von Okosystemen. Mittlg. BBA f. Land- und Forstwirtschaft Berlin-Dahlem, Heft ,308: 96.

Kendall D.A., Wiltshire C.W. Butcher M., 1996: Phenology and population dynamics of willow beetles (Coleoptera:Chrysomelidae) in short rotation coppiced willows at Long Ashton. Final report to ETSU for DTI on contract B/M4/00487/14/00/00.

Kennedy C.E.J., Southwood T.R.E., 1984: The number of species of insects associated with British trees : a reanalysis. J Anim Ecol (53): 455–478.

Khasa P.D., Chakravarty P., Robertson A., Thomas B.R., Dancik B.P., 2002: The mycorrhizal status of selected poplar clones introduced in Alberta. Biomass Bioenergy, 22: 99–104.

Knabe W., 1965: Observations on world-wide efforts to reclaim industrial waste land. In: G. T. Goodman, Edwards R. W., and Lambert J.M. (eds.): Ecology and the industrial society, p. 263-296. Blackwell Scientific, Oxford, England.

Knur L., Murach D., Murn Y., Bilke G., Muchin A., Grundmann P., Eberts J., Schneider U., Grünewald H., Schultze B., Quinkenstein A., Jochheim H., 2007: Potentials, economy and ecology of a sustainable supply with wooden biomass. In: 15th Europ. Biomass Conf. Proceedings, Berlin, May 2007.

Koehler H.H., 1997: Gamasina (Gamasina, Uropodina), efficient predators in agroecosystems. Agriculture, Ecosystems, and Environment, 62: 105-117.

Koehler H.H., Born H., 1989: The influence of vegetation structure on the development of soil mesofauna. Agriculture, Ecosystems and Environment, 27: 253-269.

Köksal A.İ., 2002: Turkish hazelnut cultivars. Hazelnut Promotion Group, Ankara, p. 136.

Kroiher F., Bielefeld J., Bolte A., Schulter M., 2008: Die Phytodiversität in Energieholzbeständen: erste Ergebnisse im Rahmen des Projektes NOVALIS. Archiv für Forstwesen und Landschaftsökologie, 42: 158-165.

Kupferschmid A.D., Bugmann H., 2008: Ungulate browsing in winter reduces the growth of Fraxinus and Acer saplings in subsequent unbrowsed years. Plant Ecology, 198(1): 121-134.

Lal R., 2006: Encyclopedia of Soil Science, Second Edition. CRC Press, ISBN 0-8493.3830-1.

Lamersdorf N., Bielefeldt J., Bolte A., Busch G., Dohrenbusch A., Knust C., Kroiher F., Schulz U., Stoll B., 2008: Naturverträglichkeit von Agrarholzanpflanzungen – erste Ergebnisse aus dem Projekt NOVALIS. Cottbuser Schr Ökosystemgenese und Landschaftsentwickl, 6: 19–32.

Larsson S., Nordh N-E., Farrell J., Tweddle P., 2007: Manual for SRC willow growers: http://www.agroenergi.se/

Laureysens I., De Temmerman L., Hastir T., Van Gysel M., Ceulemans R., 2005c: Clonal variation in heavy metal and biomass production in a poplar coppice culture. II. Vertical distribution and phytoextraction potential. Environmental Pollution, 133: 541-551.

Laureysens I., Deraedt W., Ceulemans R., 2005a: Population dynamics in a 6-yearold coppice culture of poplar. II. Size variabilityand one-sided competition of shoots and stools. Forest Ecology and Management, 218: 115-128.

Laureysens I., Pellis A., Willems J., Ceulemans R., 2005b: Growth and production of a short rotation coppice culture of poplar. III. Second rotation results. Biomass and Bioenergy, 29: 10-21.

Ledin S., 1998: Environmental consequences when growing short rotation forests in Sweden. Biomass and Bioenergy, 15 (1): 49-55.

Lefèvre F. , Légionnet A., de Vries S., Turok J., 1998: Strategies for the conservation of a pioneer tree species, *Populus nigra* L., in Europe. Genet. Sel. Evol. 30 (suppl.1):181-196

Lefèvre F. , Légionnet A., Valadon A., Villar M., 1996: Programme national de conservation de Populus nigra. Document de la Commission technique nationale de conservation des ressources génétiques forestières, Inra, Avignon, 1996.

Leone V., Signorile A., 1997: Viali parafuoco: tipologia ed efficacia. L'Italia Forestale e Montana, 52 (5): 307-328.

Licht L.A., Isebrands J.G., 2005: Linking phytoremediated pollutant removal to biomass economic opportunities. Biomass and Bioenergy, 28: 203-218.

Liebhard P., 2010: Short Rotation Coppice – Interaction with Ecosystems, University of Natural Resources and Applied Life Sciences, Vienna.

Liesebach M., Mecke R., 2003: Die Laufkäfer einer Kurzumtriebsplantage, eines Gerstenackers und eines Fichtenwaldes im Vergleich. Holzzucht, 54: 11–15.

Liesebach M., Mecke R., Rose A., 2000: Epigäische Wirbellosenfauna einer Kurzumtriebsplantage im Vergleich zu der eines angrenzenden Gerstenackers und der eines Fichtenwaldes. Holzzucht, 53: 21–25.

Limstrom G. A. 1960. Forestation of strip-mined land in the Central States. U.S. Department of Agriculture, Agriculture Handbook 166. Washington, DC.: 74.

Lockwell J., Guidi W., Labrecque M., 2012: Soil carbon sequestration potential of willows in short-rotation coppice established on abandoned farm lands. Plant and Soil, 360: 299-318.

Lodge D.J., 1989: The influence of soil moisture and flooding on formation of VA-endo and ectomycorrhizae in Populus and Salix. Plant Soil, 117: 255-262.

Lunackova L., Sottnikova A., Masarovicova E., Lux A., Stresso V., 2004: Comparison of cadmium effect on willow and poplar in response to different cultivation conditions. Biologia Plantarum, 47 (3): 403-411.

Lynch K., 1964: L’immagine della città, Ed. Marsilio, Venezia.

Lynch K., 1990: Progettare la città. La qualità della forma urbana Ed. Etas Libri, Milano.

Lyons A., 1993: Paulownia. In: Race D., (Ed.): Agroforestry - Trees for Productive Farming. Agmedia East Melbourne.

Ma X.M., Richter A.R., Albers S., Burken J.G., 2004: Phytoremediation of MTBE with hybrid poplar trees. International Journal of Phytoremediation, 6(2): 157-167.

Makeschin F., 1994: Effects of energy forestry on soils. Biomass Bioenergy, 6: 63-79.

Makeschin F., 1994: Effects of energy forestry on soils. Biomass Bioenergy, 6: 63-79.

Makeschin F., Rehfuess K.E., Rüsch I., Schörry R., 1989: Anbau von Pappeln und Weiden im Kurzumtrieb auf ehemaligem Acker: standörtliche Voraussetzungen, Nährstoffversorgung, Wuchsleistungen und bodenökologische Auswirkungen. Forstwiss Centralbl, 108(3): 125-143.

Malloch D., Pirozynski K., Raven P., 1980: Ecological and evolutionary significance of mycorrhizal symbiosis in vascular plants (a review). Proc. Natl. Acad. Sci. 77: 2113–211.

Maltoni A, Mariotti B, and Tani A., 2012: La gestione della Robinia in Toscana. La gestione dei popolamenti, l’impiego in impianti specializzati, il controllo della diffusion. DEISTAF – Dipartimento di Economia, Ingegneria, Scienze e Tecnologie Agrarie e Forestali, Università di Firenze, 167p.

Manetti M.C., Amorini E., Becagli C., 2006: New silvicultural models to improve functionality of chestnut stands. Advances in Horticultural Science, 20 (1): 65-69.

Marage D., Lemperiere G., 2005: The management of snags: A comparison in managed and unmanaged ancient forests of the Southern French Alps. Annals of Forest Science, 62 (2): 135-142.

Marziliano P. A., Iovino F., Menguzzato G., Scalise C., Nicolaci A., 2013: Aspetti dendroauxometrici, assortimentali e caratteristiche della necromassa in cedui di castagno. Forest@, 10: 14-25.

Massa N., Andreucci F., Poli M., Aceto M., Barbato R., Berta G., 2010: Screening for heavy metal accumulators amongst autochtonous plants in a polluted site in Italy. Ecotoxicology and Environmental Safety, 73: 1988-1997.

Massacci A., Bianconi D., Paris P., 2012: Pioppicoltura a turno di taglio breve per bioenergia e fitorimedio. SILVÆ, Anno VII, 15/18: 125-144.

McKay H. (ed.), 2011: Short Rotation Forestry: review of growth and environmental impacts. Forest Research Monograph, 2, Forest Research, Surrey: 212.

MCPFE, 2002: Improved Pan-European indicators for sustainable forest management as adopted by the MCPFE Expert Level Meeting 2002. 27.04.2011: http://www.mcpfe.org/system/files/u1/Vienna_Improved_Indicators.pdf

McTiernan K.B., Ineson P., Coward P.A., 1997: Respiration and Nutrient Release from Tree Leaf Litter Mixtures. Oikos, 78(3): 527-53.

Melicharová L., Vizoso-Arribe O., 2012: Situation of sweet chestnut (Castanea sativa Mill.) in Spain, Galicia: a review. Scientia agriculturae bohemica, 43(2): 78–84.

Mendel Z., Protasov A., Fisher N., La Salle J., 2004: Taxonomy and biology of Leptocybe invasa gen. & sp.n. (Hymenoptera: Eulophidae), an invasive gall inducer on Eucalyptus. Australian Journal of Entomology, 43(2): 51–63.

Merganičová K., Merganič J., Svoboda M., Bače R., Šebeň V., 2012: Deadwood in Forest Ecosystems, In: Blanco J.A.: Forest Ecosystems - More than Just Trees, ISBN: 978-953-51-0202-1, InTech, DOI: 10.5772/31003: http://www.intechopen.com/books/forest-ecosystems-more-than-just-trees/deadwood

Meusel H., Jager E., Weinert E., 1965: Vergleichende Chorologie der Zentraleuropaïschen Flora.. Jean, Gustav Fisher Verlag, 120 pp.

Miletić Z., Knežević M., Stajić S., Košanin O., Đorđević I., 2012: Effect of European Black Alder Monocultures on The Characteristics of Reclaimed Mine Soil. Int. J. Environ. Res., 6(3): 703-710.

Mirck J., Isebrands J.G., Verwijst T., Ledin S., 2005: Development of short-rotation willow coppice systems for environmental purposes in Sweden. Biomass Bioenergy, 28: 219-228.

Mirotadze N., Gogitidze V., Mikadze N., Goginava L., Mirotadze M., 2009: Agro-ecological zones of hazelnut in Georgia. Acta Hort. 845: 291-294.

Mitchell C.P., Stevens E.A., Watters M.P., 1999: Short-rotation forestry and operations, productivity and costs based on experience gained in the UK. Forest Ecology and Management,121: 123-136.

Modrý M., Hubený D.m Rejšek K., 2004: Differential response of naturally regenerated European shade tolerant tree species to soil type and light availability. Forest Ecology and Management, 188: 185-195.

Mortensen J., Nielsen K.H., Jørgensen U., 1998: Nitrate leaching during establishment of willow (Salix viminalis) on two soil types and at two fertilization levels. Biomass Bioenerg, 15(6): 457-466.

Mouissie A.M., Van der Veen C.E.J., Veen G.F., Van Diggelen R., 2005: Ecological correlates of seed survival after ingestion by Fallow Deer. Functional Ecology, 19: 284-290.

Murach D., Murn Y., Hartmann H., 2008: Ertragsermittlung und Potenziale von Agrarholz. Forst und Holz 6: 18-23.

Muys B., Lust N., Granval P.H. 1992: Effects of grassland and afforestation with different tree species on earthworm communi ties, litter decomposition and nutrient status. Soil Biology and Biochemistry, 24(12): 1459-1466.

NABU (Naturschutzbund Deutschland), 2008: Energieholzproduktion in der Landwirtschaft: Chancen und Risiken aus Sicht des Natur- und Umweltschutzes. Zu finden: http://wwwuser.gwdg.de/~hschult1/gbi/nabu-studie_energieholz.pdf

National Research Council (U.S.). Advisory Committee on Technology Innovation, 1983: Firewood crops: shrub and tree species for energy production, Vol. 2, National Academy Press.

Neal C., 2002: Interception and attenuation of atmospheric pollution in a lowland ash forested site, Old Pond Close, Northamptonshire, UK. The Science of the Total. Environment, 282-283: 99-119.

Neergaard A., Porter J.R., Gorissen A., 2002: Distribution of assimilated carbon in plants and rhizosphere soil of basket willow (Salix viminalis L.). Plant Soil, 245: 307–314.

Nelson E.C., Walsh W.F., 1993: Trees of Ireland: native and naturalized. The Lilliput Press, Dublin. 160 pp.

Newman L.A., Strand S.E., Choe N., Duffy J., Ekuan G., Ruszaj M., Shurtleff B.B., Wilmoth J., Heilman P., Gordon M.P., 1997: Uptake and Biotransformation of Trichloroethylene by Hybrid Poplars. Environ. Sci. Technol., 31: 1062-1067.

Nordh N.E., 2005: Long Term Changes in Stand Structure and Biomass Production in Short Rotation Willow Coppice. Doctoral tesi Swedish University of Agricultural Sciences Uppsala.

Osservatorio Agroambientale (a cura di), 1997: Guida tecnica e normativa per l’utilizzazione agronomica delle deiezioni zootecniche.Provincia di Vicenza.

Paine T.D., Millar J.G., Dreistadt S.H., 2000. Pest notes: Eucalyptus longhorned borers by UC ANR Publication 7425. University of California, Division of Agriculture and Natural Resources. www.ipm.ucdavis.edu/PDF/PESTNOTES/pneucalyptuslonghornedborer.pdf

Paustian K., Andrén O., Janzen H.H., Lal R., Smith P., Tian G., Tiessen H., Van Noordwijk M., Woomer P.L., 1997: Agricultural soils as a sink to mitigate CO_2 emissions. Soil Use and Management ,13: 230-244.

Perez-Corona M. E., Perez Hernandez M. C., Bermudez de Castro F., 2006: Decomposition of Alder, Ash, and Poplar Litter in a Mediterranean Riverine Area. Communications in Soil Science and Plant Analysis, 37: 1111–1125.

Perry C.H., Miller R.C., Brooks K.N., 2001: Impacts of short-rotation hybrid poplar plantations on regional water yield. Forest Ecology and Management, 143: 143-151.

Persson T., Svensson R., Ingelog T., 1989: Floristic changes on farm land following afforestation. Svensk Botanisk Tidskrift, 83: 325-344.

Perttu K.L., 1992: Sludge, wastewater, leakage water, ash: a resource for energy forestry (in Swedish). Rapport / Avdelningen för Skoglig Intensivodling, Institutionen för Ekologi och Miljövard, Sveriges Lantbruksuniversitet, 47: 7-19.

Perttu K.L., Kowalik P.J., 1997: Salix vegetation filters for purification of waters and soils. Biomass and Bioenergy, 12: 9-19.

Phillips D.H., Burdekin D.A., 1992: Diseases of Forest and Ornamental Trees. Macmillan.

Pinon J., Frey P., 1997: Structure of *Melarrtpsora larici-populiua* populations on wild and cultivated poplar, Eur. J. Plant Pathol. 103:159-173.

Piovesan G., Di Filippo A., Alessandrini A., Biondi F., Schirone B., 2005: Structure, dynamics and dendroecology of an old-growth Fagus forest in the Apennines. Journal of Vegetation Science 16: 13-28.

Plaster E.J., 2003: Soil Science & Management, 4th Edition. Delmar Learning, Thomson Learning Inc.

Pliûra A., Heuertz M., 2003: EUFORGEN Technical Guidelines for genetic conservation and use for common ash (*Fraxinus excelsior*). International Plant Genetic Resources Institute, Rome, Italy. 6 pp.

Pommerening A., 1997: Erwartete und beobachtete Artendurchmischung am Beispiel von Buchen-Edellaubholzbeständen. Sektion Ertragskunde im Deutschen Verband Forstlicher Forschungsanstalten, Jahrestagung 1997, Grünberg, 12.-14. Mai 1997: 45-59.

Popivshchy I.I., Prokazin A.E., Routkovsky LV., 1997: Black poplar in the Russian Federation, in: Turok J., Lefevre F., de Vries S., Toth B. (Eds.), *Populus nigra* Network. Report of the third meeting, Sarvar, Hungary, 5-7 October 1996, IPGRI (International Plant Genetic Resources Institute) Rome: 46-52.

Predieri S., Figaj J., Rachwal L., Gatti E., Rapparini F., 2001: Selection of woody species with enhanced uptake capacity: the case-study of Niedzwiady resort pollution by pesticides stored in bunkers. Minerva Biotecnologica, 13: 111-116.

Pulford I.D., Watson C., 2003: Phytoremediation of heavy metal-contamined land by trees – a review. Environment International, 29: 529-540.

Püttsepp Ü., Rosling A., Taylor A.S.F., 2004: Ectomycorrhizal fungal communities associated with *Salix viminalis* L. and *S. dasyclados* Wimm. clones in a short rotation forestry plantation. Forest Ecology and Management, 196: 413-424.

Quispel A., 1958: Symbiotic nitrogen fixation in non-leguminous plants iv. the influence of some environmental conditions on different phases of the nodulation process in Alnus glutinosa. Acta Botanica Neerlandica, May, 7(2): 191–204.

Radu S., 2007: The ecological role of deadwood in natural forests, In: D. Gafta, and J. Akeroyd, (Eds.): Nature Conservation: Concept and Practice, Springer, Berlin: 137–141.

Rahman M.M., Frank G., Ruprecht H., Vacik H., 2008: Structure of coarse woody debris in Lange-Leitn Natural Forest Reserve, Austria. Journal of Forest Science, 54 (4): 161-169.

Rambo J.L., Faeth S.H., 1999: Effect of vertebrate grazing on plant and insect community structure. Conservation Biology, 13: 1047-1054.

Regione Lombardia, 2004: Forestazione a rotazione breve e recupero residui quali alternative per la fitodepurazione dei reflui civili e agricoli per la produzione di energia. Allegato1. fitodepurazione – Aspetti generali e impiego energetico della biomassa prodotta. Attività PROBIO 1999 (1° anno), Regione Lombardia.

Regione Toscana, 2012: La robinia in Toscana. Supporti tecnici alla Legge Regionale Forestale della Toscana, 7.

Rice S.K, Westerman B., Federici R., 2004: Impacts of the exotic, nitrogen-fixing black locust (Robinia pseudoacacia) on nitrogen-cycling in a pine–oak ecosystem. Plant Ecology, 174: 97–107.

Riddell-Black D.M., 1994: Heavy metal uptake by fast growing willow species. Rapport / Avdelningen för Skoglig Intensivodling, Institutionen för Ekologi och Miljövard, Sveriges Lantbruksuniversitet, 50: 133-144.

Rivera A.C., Carbone S.S. 2000: The effect of three species of *Eucalyptus* on growth and fecundity of the *Eucalyptus* snout beetle (*Gonipterus scutellatus*). Forestry, 73(1): 21–29.

Robinson B.H., Mills T.M., Petit D., Fung L.E., Green S.R., Clothier B.E., 2000: Natural and induced cadmium-accumulation in poplar and willow: Implications for hytoremediation. Plant and Soil, 227: 301-306.

Rockwood D. L., Naidu C. V., Carter D. R., Rahmani M., Spriggs T. A., Lin C., Alker G. R., Isebrands J. G., Segrest S. A., 2004: Short - rotation woody crops and phytoremediation: opportunities for agroforestry? Agroforestry Systems, 61: 51-63.

Röhle H., Böcker L., Feger K-H., Petzold R., Wolf H., Ali W., 2008: Anlage und Ertragsaussichten von Kurzumtriebsplantagen in Ostdeutschland. Schweiz Z Forstwes, 159: 133-139.

Rusanen M., Myking, T., 2003: EUFORGEN technical guidelines for genetic conservation and use for Sycamore (*Acer pseudoplatanus*). International Plant Genetic Resources Institute, Rome.

Rytter R.M., Hansson A.C., 1996: Seasonal amount,growth and depth distribution of fine roots in an irrigated and fetilized Salix viminalis L. plantation. Biomass and Bioenergy, 11: 129-137.

Sage R., Cunningham M., Boatman N., 2006: Birds in willow short-rotation coppice compared to other arable crops in central England and a review of bird census data from energy crops in the UK. Ibis, 148(1): 184–197.

Sage R.B., 1998: Short rotation coppice for energy: towards ecological guidelines. Biomass Bioenergy, 15: 39-47.

Salvati R., Chirici G., Corona P., 2007: Modello di valutazione dell'attitudine fisica del territorio per la realizzazione di impianti cedui da biomassa in Italia. L'Italia forestale e montana, 5/6: 399-410.

Samson R., Girourard P., Zan C., Mehdi B., Martin R., Henning J., 1999: The implications of growing short-rotation tree species for carbon sequestration in Canada. Final Report. R.E.A.P. Canada.

Sangiorgi F., 2003: Il progetto "reflui" del CNR per la gestione dei reflui zootecnici. L'Informatore Agrario, 45: 69-70.

Sarlo, M., 2006: Individual tree species effects on earthworm Biomass in a tropical plantation in Panama. Caribbean Journal of Science, 42: 419-127.

Scarascia Mugnozza G., Paris P., 2007: Nuovi impieghi ambientali per il pioppo. In: "Il libro bianco della pioppicoltura". Agrisole (suppl.): 44-46.

Scazzosi L., 2003: Leggere il paesaggio. Confronti internazionali. Gangemi, Roma.

Scheu S., and Schultz E., 1996. Secondary succession, soil formation and development of a diverse community of oribatids and saprophagous soil macro-invertebrates. Biological Conservation 5: 235-250.

Schildbach, Grünewald H., Wolf H., Schneider B.U., 2009: Begründung von Kurzumtriebsplantagen : Baumartenwahl und Anlageverfahren. In: Reeg T., Bemmann A., Konold W., Murach D., Spiecker H., (eds): Anbau und Nutzung von Bäumen auf landwirtschaftlichen Flächen. Weinheim: WILEY-VCH: 57-71.

Schnoor J.L., Aitchison E.W., Kelley S.L., Alvarez P.J.J., Wakefield S., Burken J.G., Just C.L., 1997: Phytoremediation of 1,4-dioxane by hybrid poplars. Abstract Of Papers American Chemical Society, 213: 195

Schulz U., Brauner O., Gruß H., 2009: Animal diversity on short-rotation coppices – a review. Landbauforschung - vTI Agriculture and Forestry Research 3 (59): 171-182.

Schulz U., Brauner O., Sachs D., Thüring M., 2008: Insekten an Pappeln und Weiden : erste Ergebnisse aus dem Projekt NOVALIS und Auswertung von Wirtspflanzenangaben. Cottbuser Schr Ökosystemgenese Landschaftsentwickl, 6: 171–173.

Sekawin M., Prevosto E., 1980: Pioppicoltura. La scelta del clone. L'Italia Montana, Anno 117, 1: 174-177.

Sennerby-Forsse L., Ferm A., Kauppi A., 1992: Coppicing ability and sustainability. In: Mitchell C.P., Ford-Robertson J.B., Hinckley T., Sennerby-Forsse L., (Eds): Ecophysiology of short rotation crops. London and New York, Elsevier: 146-184.

Sheikh M.I., 1993: Trees of Pakistan: http://pdf.usaid.gov/pdf_docs/PNABW250.pdf

Signorile A.L., Evans J., 2007: Damage caused by the American grey squirrels (Sciurus 1130 carolensis) to agricultural crops, poplar plantations and semi-natural woodland in Piedmont, Italy. Forestry, 80: 89-98.

Silva-Pando F.J., Rigueiro A., 1992: Guía das árbores e bosques de Galicia. Galaxia, Vigo, Spain. 294 pp.

Sîrbu C., Oprea Ad., 2011: Contribution to the study of plant communities dominated by Ailanthus altissima (Mill.) Swingle, in the eastern Romania (Moldavia). Cercetări Agronomice în Moldova, 44(3): 51-74: http://www.soilhealth.com/soils-are-alive/

Skärbäck E, 2007: A creative designer's view: landscape perspective on SRF. NJF Report vol. 3, 3.

Skärbäck E, 2008: Landscape Perspective on Energy Forests. In Weih M. (ed.) "Short Rotation Forestry (Srf) on Agricultural Land and Its Possibilities for Sustainable Energy Supply" Temanord, Copenhagen.

Skärbäck E, Becht P., 2005. Landscape Perspective on Energy Forests. Biomass and Bioenergy, 28.2: 151-159.

Šlapokas T., Granhall U., 1991: Decomposition of litter in fertilized short-rotation forests on a low-humified peat bog. For Ecol Manage, 41:143-165.

Smith I.M., McNamara D.G., Scott P.R., Holderness M., (eds). 1997: Quarantine pests for Europe, EPPO (European and Mediterranean Plant Protection Organization), CABI (CAB International), Wallingford, UK, CABI International. (2nd ed.).

Smith S., 2004: Habitat Changes in Coppiced Hazel *Corylus avellana*(L.) Woodland with Time. Professional training report presented in part fulfilment of BSc. (Hons) Ecology and Environmental Management. Paignton Zoo Environmental Park, Cardiff University.

Smith S.E., Read D.J., 2008: Mycorrhizal symbiosis, New York : Academic Press: 787.

Spinelli R., 2007: Short rotation coppice production in Italy. Bornimer Agrartechnische Berichte, Heft 61, Potsdam-Bornim, Germany.

Stachura K., Bobiec A., Obidziñsk A., Oklejewicz K., Wolkowycki D., 2007: Old trees and decaying wood. In forest ecosystems of Poland “Old Wood". A toolkit for participants, Version 07, 05.08.2011: http://oldwood.dle.interia.pl/OW_07.pdf

Stähr F., 2006: Renaissance and global utilisation of the coppice system - Is the historical silvicultural system „coppice forest“ topical again? Future-oriented Concepts, Tools and Methods for Forest Management and Forest Research Crossing European Borders, Contributions to Forest Sciences, Ulmer: 131-142.

Steenackers J., Steenackers M., Steenackers V., Stevens M., 1996: Poplar disease, consequences on growth and wood quality. Biomass and bioenergy. 10, (5/6): 267-274.

Stephens W., Hess T., Knox J., 2001: Review ofthe effects of energy crops on hydrology. Institute of Water and Environment, Cranfield University, Silsoe, Bedford MK45 4DT, UK.

Stern R.C., 1989: Sycamore in Wessex. Forestry, 62: 365 - 382.

Stetter U., Makeschin F., 1997: Kohlenstoff- und Stickstoffdynamik vormals landwirtschaftlich genutzter Böden nach Erstaufforstung mit schnellwachsenden Baumarten. Mitt Dt Bodenkundl Ges, 85: 1047-1050.

Stewart A.J.A., 2001: The impact of deer on lowland woodland invertebrates: a review of the evidence and priorities for future research. Forestry, 74: 259-270.

Stjernquist I., 1994: An integrated environmental-analysis of short-rotation forests as a biomass resource. Biomass Bioenergy, 6: 3-10.

Stokland J.N., Tomter S.M., Söderberg U., 2004: Development of Dead Wood Indicators for Biodiversity Monitoring: Experiences from Scandinavia. EFI Proceedings: 207-228.

Strycharz S., Newman L., 2009: Use of native plants for remediation of trichloroethylene: I. Deciduous trees. International Journal of Phytoremediation, 11: 150-170.

Styles D., Jones M., 2007: Energy crops in Ireland: Quantifying the potential life-cycle greenhouse gas reductions of energy-crop electricity, Biomass and Bioenergy, 31(11-12): 759-772.

Sugiura A., Tyrre, S.F., Seymour I., Burgess P.J., 2008: Water Renew systems: wastewater polishing using renewable energy crops. Water Science and Technology, 57(9): 1421-1428.

Teodorescu T.I., Guidi W., Labrecque M., 2011: The use of non-dormant rods as planting material: a new approach to establishing willow for environmental applications. Ecological Engineering, 37: 1430-1433.

Thomas J.W., 2002: Dead Wood: From Forester's Bane to Environmental Boom. USDA Forest Service Gen. Tech. Rep. PSW-GTR-181.

Thüring M., 2007: Zoodiversität auf Weiden (Salix spp.) und Pappeln (Populus spp.). Eberswalde: Fachhochschule: 52.

Tillisch E., 2001: Æren trænger sig frem. Dansk Skovbru Tidsskrift, 86: 1-96.

Tillisch, E. 2001: Æren trænger sig frem. Dansk Skovbrugs Tidsskrift, 86: 1-96.

Tognetti R., Cocozza C., Marchetti M., 2013: Shaping the multifunctional tree: the use of Salicaceae in environmental restoration. iForest, vol. 6: 37-47.

Tous M.J., 2001: Hazelnut technology for warm climates. Proceedings ninth Australasian Conference on trees and nut crops, Perth, Western Australia.Tousignant S., Coderrde D., Popovich S., 1988. Influence of tillage and harrowing on soil mesofauna of hardwood plantations, 31(3-4): 283-291.

Travaglini D., Barbati A., Chirici G., Lombardi F., Marchetti M., Corona P., 2007: ForestBIOTA data on deadwood monitoring in Europe. Plant Biosystems, 141(2): 222-230.

Travaglini D., Chirici G., 2006: ForestBIOTA project. Forest Biodiversity Test-phase Assessments: Deadwood assessment. Work report. Accademia Italiana di Scienze Forestal: 19: http://www.forestbiota.org/docs/report_DEADWOOD.pdf

Traveset A., Brundu G., Carta M., Mprezetou I., Lambdon P., Manca M., Médail F., Moragues E., Rodriguez-Perez J., Siamantziouras S., Suehs C.M., Troumbis A., Vilà M., Hulme P.E., 2008: Consistent performance of invasive plant species within and among islands of the Mediterranean basin. Biological Invasions, 10: 847-858.

Trowbridge J., Jumpponen A., 2004: Fungal colonisation of shrub willow roots at the forefront of a receding glacier. Mycorrhiza, 14: 283-293.

Trusiani E., 2008: Orientarsi nell'urbanistica, Carocci, Roma. 164 p.

Trusiani E., 2009: Struttura paesaggistica e valori percettivi. In Nuti G.C.; Trusiani E., D'Astoli S. B. (a cura di) "Montalto Uffugo e il suo territorio. Metodo e studi per il Piano Strutturale Comunale", Officina edizioni, Roma.

Trusiani E., 2010: Il progetto paesaggistico territoriale. In: Rossi F. (a cura di) "Letture di paesaggio". Aracne, Roma: 91-99.

Trusiani E., 2010: La scala territoriale del paesaggio. In: Rossi F. (a cura di) "Letture di paesaggio". Aracne, Roma: 15-18.

Tubby I., Armstrong A., 2002: Establishment and Management of Short Rotation Coppice: practice note. Forestry Commission, Edimburg: http://www.forestry.gov.uk/PDF/fcpn7.pdf/$FILE/fcpn7.pdf

Tunçtaner K., 1995: Conservation of genetic resources of *Populus nigra* in Turkey, in: Frison E., Lefevre F., de Vries S., Turok J. (Eds.): *Populus nigra* Network. Report of the first meeting, Izmit, Turkey, 3-5 October 1994, IPGRI (International Plant Genetic Resources Institute), Rome: 41-44.

Tunçtaner K., 1995: Conservation of genetic resources of Populus nigra in Turkey, in: Frison E., Lefevre F., de Vries S., Turok J. (Eds.): Populus nigra Network. Report of the first meeting, Izmit, Turkey, 3-5 October 1994, IPGRI (International Plant Genetic Resources Institute), Rome: 41-44.

U.S. Department of Agriculture, Forest Service, 1985: Insects of eastern forests. Miscellaneous Publication 1426. USDA Forest Service, Washington, DC: 608.

Ucisik A.S., Trapp S., 2008: Uptake, accumulation, phytotoxicity and removal of 4-chlorophenol in willow trees. Archives of Environmental Contamination and Toxicology, submitted, 54 (4): 619-627.

Uri V., Vares A., Tullus H., Kanal A., 2007: Above-ground biomass production and nutrient accumulation in young stands of silver birch on abandoned agricultural land. Biomass and Bioenergy, 31: 195-204.

van Oosten C., 2008: Purpose-grown woody biomass crops: State of knowledge (FDF # 200723) SilviConsult Woody Crops Technology Inc.

Vandekerkhove K., Keersmaeker De L., Menke N., Meyer P., Verschelde P., 2009: When nature takes over from man: Dead wood accumulation in previously managed oak and beech woodlands in North-western and Central Europe. Forest Ecology and Management, Vol. 258: 425-435.

Vellend, M., Myers, J.A., Gardescu, S. and Marks, P.L. 2003: Dispersal of Trillium seeds by deer: Implications for long-distance migration of forest herbs. Ecology, 84: 1067-1072.

Verwijst T., 2008: Improving the efficiency of production systems for short-rotation bioenergy crops. IEA Bioenergi, Task 30, Technical Review, 1: http://www.shortrotationcrops.org/PDFs/TechnicalReviewFinal.pdf

Verwijst T., Makeschin F., 1996: Environmental aspects of biomass production and routes for European energy supply. Concertes action AIR 3-94-2466. Report from the working group.

Vickery J.A., Tallowin J.R., Feber R.E., Asteraki E.J., Atkinson P.W., Fuller R.J., Brown V.K., 2001: The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. Journal of Applied Ecology, 38: 647-664.

Vilà M., Siamantziouras A.S.D., Brundu G., Camarda I., Lambdon P., Médail F., Moragues E., Suehs C.M., Traveset A., Troumbis A.Y., Hulme P.E., 2008: Widespread resistance of Mediterranean island ecosystems to the establishment of three alien species. Diversity and Distributions, 14: 839-851.

von Wühlisch G., 2009: EUFORGEN Technical Guidelines for genetic conservation and use of Eurasian aspen (*Populus tremula*) Bioversity International, Rome, Italy. 6 pages.

Vreeken-Buijs M.J., Hasslink J., Brussaard L., 1998: Relationships of soil microarthropod biomass with organic matter and pore size distribution in soils under different land use. Soil Biology and Biogeochemistry, 30: 97-106.

Weber G., Rehfuess K.E., Kruetzer K., 1993: Über den Einfluß naturnaher Waldwirtschaft auf den chemischen Bodenzustand. Allgemeine Forst Zeitschrift, 48: 68-71.

Weih M., Karacic A., Munkert H., Verwijst T., Diekmann M., 2003: Influence of young poplar stands on floristic diversity in agricultural landscapes (Sweden). Basic Appl Ecol, 4:149-156.

Whalen J.K., Sampedro L., Wakeed T., 2004: Quantifying surface and subsurface cast production by earthworms under controlled laboratory conditions. Biology and Fertility of Soils, 39(4): 287-291.

Wittich W., 1961: Der Einfluß der Baumart auf den Bodenzustand. Allgemeine Forstzeitschrift, 16: 41-45.

Wolf H., Böhnisch B., 2004: Modellvorhaben StoraEnso/Verbundvorhaben - Pappelanbaufür die Papierherstellung. Pirna-Graupa : Landesforstpräsidium: 73.

Woods V.B., 2008: Paulownia as a novel biomass crop for Northern Ireland? Occasional publication, 7 Global Research Unit AFBI Hillsborough.

Zhaohua Z., 1987: A new farming system Crop/Paulownia intercropping. Multipurpose tree species from small-farm use. Proceedings of an international workshop held in November 2-5, 1987, Pattaya, Thailand: 65-69.

Zimmer D., Baum C., Leinweber P., Hrynkiewicz K., Meissner R., 2009: Associated bacteria increase the phytoextraction of cadmium and zink from a metal contaminated soil by mycorrhizal willows. Int J Phytorem, 11:200-213.

Zorzi R., 1999: Il paesaggio. Dalla percezione alla descrizione. Marsilio, Venezia.

Zou X., 1993: Species effects on earthworm density in tropical tree plantation in Hawaii. Biology and Fertility of Soils, 15: 35-38.

Zsuffa L., Giordano E., Pryor L.D., Stettler R.F., 1996: Trends in poplar culture: some global and regional perspectives. In: Stettler R.F., Bradshaw Jr H.D., Heilman P.E., Hinckley T.M. (Eds.): Biology of Populus and its implications for Management and Conservation Part II, Chapter 19: 515-539.