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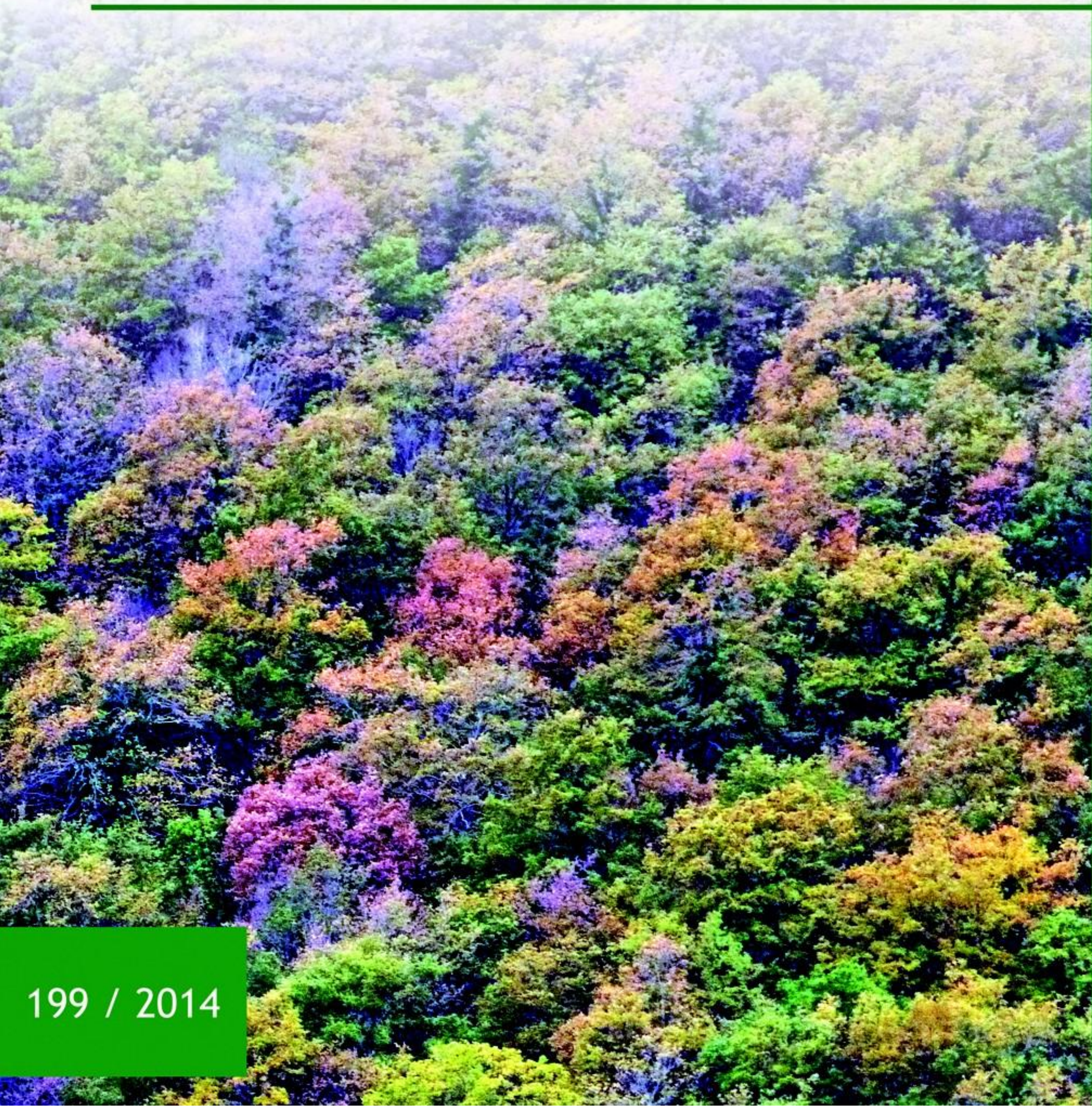
proforbiomed
Promotion of residual forestry biomass in the Mediterranean basin

With the patronage of
REGIONE LAZIO

RAPPORTI

Assessing the bioenergy potential of forest and out of forest in Latium



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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 environmental terms). It implies the involvement of all stakeholders of rural areas, the development 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 Cooperation objective” of the EU Cohesion Policy.

PROFORBIOMED involves 18 partners, including 4 national bodies, 5 regional bodies and 3 local authorities (and other 6 different structures) from 5 different countries: Greece, Italy, Portugal, Slovenia and Spain.

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SUMMARY FOR POLICYMAKERS

Increasing the use of wood for energy may offer significant prospects for EU Mediterranean countries, including the reduction of greenhouse gas emissions and provision of 'territorial' energy. On the other hand, the substantial rise in the use of biomass from forestry might put additional pressure on forests which should be rightly safeguarded for ensuring the provision of services such as nature conservation, soil protection, water supply or recreation.

To meet both the increasing needs of the wood-processing industry as well as the needs of the bioenergy sector and policy targets for bioenergy consumption more woody biomass needs to be mobilized on a sustainable basis in Italy and in EU countries. Data about potential wood supply and its availability is however scarce or imprecise. Transparent and comprehensive information is necessary as a basis for decision-making.

The objective of the report is to list the elements of wood supply in Lazio and develop a methodology—to be easily used for other regional context in Italy as well as in other regions of the Mediterranean—for wood resource assessment. In addition, estimates and quantitative analysis on potential additional wood supply, without increasing the pressures on and harming the environment, are made, based on best available data. Finally, policy measures to achieve an actual increase in wood supply are discussed.

The study concludes that significant amounts of biomass can technically be available to support renewable energy targets, even if strict environmental constraints are applied. The environmentally-compatible primary biomass potential amounts to 0.67 dry matter (d.m.) million tons (Mt) of wood. Large part of this amount would derive from the utilisation of coppices (0.47 d.m. t), a significant contribution from forest tree hedgerows (0.06 d.m. Mt) and from short rotation plantations (0,11 d.m. Mt). This bioenergy potential represents around 219,000 tons oil equivalent (Toe), 2.4% of the primary energy requirements of Lazio region, and 2.3% of the current primary energy consumption (9,801 kToe).

ABBREVIATIONS AND ACRONYMS

a.s.l.	Above Sea Level
Cd	Cadmium
CRA-PLF	Research Unit for Intensive Wood Production of Council for Agricultural Research
AAC	Annual Allowable Cut
ABD	Above-ground Biomass Density
ACA	Annual Cutting Area
BEF	Biomass Expansion Factor
C	Carbon
CAI	Current Annual Increment (m^3/ha/year)
CAP	Common agricultural policy
CE	Commissione Europea
CFS	Corpo Forestale dello Stato, Italian Forest Service
CLC	Corine Land Cover
CORINE	Coordination de l’Information sur l’Environnement
D	Wood density
DM	Dry matter
ECE	Economic Commission for Europe
EEA	European Environment Agency
EFISCEN	European Forest Information Scenario
EU	European Union
EUROSTAT	Statistical Office of the European Communities
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment
FSC	Forest Stewardship Council
GHG (s)	Greenhouse gas
GIS	Geographic information system

GPS	Global positioning system
GJ	GigaJoules
GS	Growing stock
HNV	High nature value farming
INFC	Inventario Nazionale delle Foreste e del Carbonio (National Inventory of Forests and Carbon)
ISPRA	Istituto Superiore per la Protezione e la Ricerca Ambientale
ISTAT	Istituto Nazionale di Statistica (Italy's Statistics Office)
LHV	Lower heating value (also net calorific value)
LIDAR	Light Detection and Ranging
MAI	Mean Annual Increment (m^3/ha/year)
MCPFE	Ministerial Conference on the Protection of Forests in Europe
MS	Member States of the European Union
MSW	Municipal Solid Waste
MSW	Municipal Solid Waste
MTBE	Methyl Tertiary Butyl Ether
MtOE	Million tons of oil equivalent
n.a.	not available
NAI	Net Annual Increment
NBP	Net Biome Production
NCV	Net calorific value (also lower heating value)
NEE	Net Ecosystem Exchange
NEP	Net Ecosystem Production
NGO	Non government organisation
NPP	Net Primary Production
NWFP (s)	Non-wood Forest Product (s)
OWL	Other Wooded Land
PAES	Action Plan for Sustainable Energy
PHL	Potential Harvesting Level

RED	EU Renewable Energy Directive
R/S	Root-to-shoot ratio
R&D	Research and Development
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SCI (s)	Site of Community Importance (s)
SFM	Sustainable Forest Management
SOM	Soil organic matter
SPA (s)	Special Protection Area (s)
SRF	Short rotation forestry
SRP (s)	Short Rotation Plantation (s)
UAA	Utilised Agricultural Area
UN	United Nations
UWET	Unified Wood Energy Terminology, Definitions and Conversion Factors
WEIS	Wood Energy Information System

UNITS OF MEASURE AND CONVERSION FACTORS

Cubic metre	m^3
Calorie	cal
Cubic meter	m^3
Dry matter	d.m.
Exajoule (1,018 joule)	EJ
Gigagram (1,000 tons)	Gg
GigaWatt per hour	GWh
Hectare	ha
Joule	J
MegaJoules	MJ
Megatonne (106 tons)	Mt
Megawatt	MW
Meter (s)	m
Million (s)	M
Million TOE	Mtoe
Petajoules	PJ

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). In 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.
ALLOWABLE CUT	A dearly expressed specification of the average quantity of wood, usually in an approved management plan, that may be harvested from a forest management unit, annually or periodically over a five- or ten-year period.
ANNUAL ALLOWABLE CUT (AAC)	The Allowable Cut expressed on an annual basis.
ANNUAL CUTTING AREA (ACA)	The area of productive forest which may be cut in one year. The ACA is synonymous with Felling Area, Cutting Area and Annual Coupe.
ANNUAL FELLINGS	The average annual standing volume of all trees that are felled during a given period. It includes the volume of trees or parts of trees that are not removed from the forest. It also includes silvicultural and pre-commercial thinning. These fellings are further divided into removals and logging residues.
ANNUAL YIELD AND PERIODIC YIELD	The volume or number of stems that can be removed in a specific area in one year, or during a specified period, respectively. Average annual volume over the given reference period of gross increment minus natural mortality (or losses), of all trees to a specified minimum diameter (0 cm according to the FAO) at breast height.
BELOWGROUND BIOMASS	All living biomass of live roots. Fine roots of less than 2 mm diameter are normally excluded (as they often cannot be distinguished empirically from soil organic matter or litter).
BIOENERGY	Renewable energy produced from material derived from biological sources.
BIOFUEL	Transport fuel derived from biological sources — these include wood, wood waste, agricultural crops, straw, manure, sugarcane, organic waste and by-products from food and feed production. They are often divided into first generation biofuels (based on current technology) and second generation biofuels (based on more advanced biomass conversion technologies that are mostly still under development).

BIOMASS	Any form of biological material. When used in reference to renewable energy, biomass is any biological (plant or animal) derived from forestry and agriculture output and by-products, as well as sewages, sludge, manure, industrial by-products and the organic fraction of municipal solid waste, that can be converted to electricity or fuel. Woody biomass refers to biomass material specifically from trees and shrubs, both aboveground and belowground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc. 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 RATES	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 (BEF)	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 twigs and foliage 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. Cannot exceed 100%. (also called crown closure). Same as crown cover.
CARBON DEBT	The GHG emission peak that can arise from the combustion of biomass when the replacement of the biomass through plant growth (which captures carbon) takes a long time. This is not relevant for plant material with a short life cycle but can reach 100 years and more if mature trees are harvested for energy production. During the period when the plant material re-grows there will be a carbon debt arising from the original combustion of biomass.
CARBON DIOXIDE 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 radioactive forcing of one kilogramme greenhouse gas emitted to the atmosphere to that from one kilogramme CO_2 over a period of time (usually 100 years).
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.

CARBON STOCK — The overall quantity of carbon accumulated in a ecosystem pool. These pools include carbon in living biomass (above and below ground), dead organic matter (e.g. deadwood and litter) and soil organic carbon.

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 hornbean (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, et cetera, but not structural timber.

COPPICE WITH STANDARDS — A traditional system of woodland management whereby timber trees are grown above a coppiced woodland. It is used in particular as a method of exploiting oak woods, in which all the trees except a rather open network of tall, well-formed oaks - the standards at about fifty per hectare - are felled, leaving plenty of space for hazels and other under-wood to grow and be coppiced at intervals of ten to fifteen years.

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.

CURRENT ANNUAL INCREMENT — It corresponds to the increase in volume of stand (measured as $m^3\ ha^{-1}\ yr^{-1}$) at a particular age and is determined by annual measurements of standing volume. For example, CAI at age 2 ($m^3\ ha^{-1}\ yr^{-1}$) = (Volume at age 3) - (Volume at age 2). In dense plantations, the CAI will increase rapidly up in the early years, until competition for light, moisture or nutrients causes CAI to reach its peak. The decline in CAI can be more rapid than the early rise. In a mature native forest, the CAI is often close to zero, meaning there is no change in the total wood volume on the site from year to year. For some trees to grow others must die. When the CAI drops to the point that it is the lower than the MAI, then MAI will also fall because the increase in the next year will be less than the average. MAI is a much used (and often abused) forestry measurement for tree growth, but whenever a MAI or CAI figure is quoted, the age of the forest must also be known. This is because MAI changes with time. So for example, a plantation that has grown at 20 m^3 ha^{-1} yr^{-1} over 10 years might have 200 m^3 ha^{-1}, but if grown for another 10 years it will not necessarily achieve 400 m^3 ha^{-1}.

CUTTING	Includes all activities undertaken to fell and prepare trees for extraction, including felling a standing tree, measurement to determine best log lengths, limb removal and cross-cutting to form logs.
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. Deadwood is often present within the crown or on the stems of trees. It may be an indication of ill health, however, it may also indicate natural growth processes. If a target is present beneath the tree, deadwood may fall and cause injury or damage and should be removed, otherwise deadwood can remain intact for conservation purposes (insects, fungi, birds etc.).
DRY MATTER (d.m.)	Dry matter 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.
ECOSYSTEM RESILIENCE	It describes two aspects of ecosystem stability: 'engineering resilience' and 'ecological resilience'. Engineering resilience describes the time it takes for an ecosystem to recover to a quasi-equilibrium state following a disturbance. Ecological resilience denotes the capacity of ecosystems to absorb disturbance without collapsing into a qualitatively different state that is controlled by a different set of ecological processes.
ENERGY CROPS	Plants grown with the explicit purpose of producing biofuel or other forms of bioenergy. These can be traditional agricultural crops or special crops that are cultivated for energy production only.
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	There is no single definition globally, and countries have tended to define their forests according to legal, administrative or cultural requirements; land use; canopy cover; or biomass According to the Italy's National Inventory of Forests and Carbon (INFC), forest is a land spanning more than 0.5 ha with trees higher than 5 m 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 a 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 regenerate 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	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.
FORMATIVE PRUNING	The trimming of a tree to remove weaknesses and irregularities which may lead to problems. The formative pruning operation is aimed at reducing the potential for future weaknesses or problems within the tree's crown.
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.

GROSS INCREMENT	The average annual volume of increment (an increase of growing stock) that over the reference period of all trees is measured by a minimum diameter breast height (d.b.h.) of 0 cm. It includes the increment of trees that have been felled or have died during the reference period. This increment is usually measured every 5 or 10 (although rarely) years and this annual increment becomes the average for that reference period.
GROWING STOCK	According to the current international definition, growing stock refers to: "The living tree component of the standing volume. Volume is intended over bark of all living trees more than X cm in diameter at breast height (d.b.h.), or above buttress if higher. It includes the stem from ground level or stump height up to a top diameter of Y cm, and may also include branches to a minimum diameter of W cm. Countries must indicate the three thresholds (X, Y, W cm) and the parts of the tree that are not included in the volume (FAO 1998; UNECE, 2000; Tomppo et al., 2010). By convention, the volume of dead trees is not included. Growing stock volume is the main measure used in reporting of estimates of growing stock. Ideally growing stock estimates are based directly on national inventory assessments taken for an appropriate base year. Growing stock volume is usually the measure from which estimates of increment are derived. Growing stock forecasts, in conjunction with removals and increment forecasts are a strategic measure of the sustainability of intended forest management. Forecasts of growing stock volume are needed as a component in the calculation of standing biomass and carbon.
ILUC	Stands for indirect land use change. The term describes the displacement of (agricultural) land use to third countries that results when (agricultural) production capacity in one country is eliminated due to the diversion of original output to other uses (such as diverting wheat or oilseed rape area from food to energy production).
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.
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.
LOGGING RESIDUES	They are represented by that part of felled stem wood, which remain in the forest. Together fellings and natural losses constitute the drain, meaning all wood material that has died from natural causes (natural loss) or has been taken by people from the growing stock.
MEAN ANNUAL INCREMENT (MAI)	The average volume production per year for a forest of known age. It corresponds to the increase in volume of stand (measured as m^3 ha^{-1} yr^{-1}) at a particular age and is determined by dividing the volume of the stand (m^3 ha^{-1}) over the age of the stand (yrs).
NATURAL LOSSES	Constitute all wood material that has died from natural causes.
NET ANNUAL INCREMENT	The average annual volume over the given reference period of gross increment minus natural mortality (or losses), of all trees to a specified minimum diameter (0 cm according to the FAO) at breast height.
NREAP	National renewable energy action plans. Article 4 of EU Directive 2009/28/EC on Renewable Energy required EU Member States to submit national renewable energy action plans by 30 June 2010. These plans provide detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption.
OTHER WOODED LAND	According to the Italy's National Forest Inventory, other Wooded Land is a land not defined as forest, spanning more than 0.5 ha; with trees higher than 5 meters and a canopy cover of 5-10 %, or trees able to reach these thresholds; or with a combined cover of shrubs, bushes and trees above 10 percent. Sub-categories of OWL are low woods, sparse woods, bushes, shrubs, and inaccessible forest areas.
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 CO2 so that the initial burst of GHG emissions that resulted from the combustion of the biomass is fully absorbed again in plant biomass. 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.
PERENNIAL CROP	Agricultural crops that have a multi-annual growth cycle, i.e. do not need to be planted every year. Their lifetime can be a few years (e.g. some energy grasses)

to several hundred years (e.g. olive trees). Perennial cropping generally reduces topsoil losses due to erosion, increases biological carbon sequestration within the soil and reduces waterway pollution from leaching of nutrients.

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.

REMOTE SENSING — Practice of acquiring and using data from satellites and aerial photography to infer or measure land cover/use. May be used in combination with ground surveys to check the accuracy of interpretation.

REMOTELY SENSED DATA — Data generally acquired by means of scanners or cameras onboard of aircraft or satellites.

REMOVALS — Removals are a subset of fellings that are transported out of the forest (the commercial part destined for processing).

RESIDUES — The by-products from the harvesting of agricultural crops (annual and perennial) and from forest operations (e.g. thinning of stands or felling trees). These are normally left in the field or forest but can be employed as biomass for energy generation.

RESOURCE EFFICIENCY — This term stands for an approach that focuses on increasing the efficiency of using natural resources and while decreasing associated environmental impacts. The approach covers production processes over their entire life cycle and has been adopted as a key policy goal in the EU 'Roadmap to a Resource Efficient Europe'.

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 monocyclic silvicultural system.

SETTLEMENT — This category includes all developed land, including transportation infrastructure and human settlements of

	any size, unless they are already included under other categories. This should be consistent with the selection of national definitions.
SHORT ROTATION COPPICE (SRC)	It stands for short rotation coppice which is plants grown under a coppicing regime. It means that plants are harvested every few years rather than when they are fully grown. High yield varieties of poplar and willow, for example, are grown as an energy crop under a coppicing regime with a short‑term (5–8 year) cycle.
SHORT ROTATION FORESTRY (SRF)	Practice of cultivating fast-growing trees that reach their economically optimum size between few years, from 1 to 8 years, employing intensive cultural techniques such as fertilization, irrigation and weed control, and utilizing genetically superior planting material, relying on coppice regeneration. In literature many definitions have been used to identify.
SINK	Any process, activity or mechanism which 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 organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series. 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	The standing volume of trees refers to the volume of standing trees, living or dead, above-stump measured overbark to top (0 cm). Standing volume includes all trees with diameter over 0 cm diameter breast height (d.b.h. -- typically at 130 cm above stump). It includes: tops of stems, large branches, dead trees lying on the ground which can still be used for fibre or fuel; it excludes: small branches, twigs and foliage. (UNECE, 2000).
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.
THINNING	Pre-commercial cultural practice aimed at lowering stand densities and improving growing conditions for the remaining trees. Dense forest tree populations are thinned so trees do not compete for limited resources such as nutrients, sun and moisture. Stands are typically thinned between the ages of three and twelve years of age. Excess trees are removed mechanically or manually, depending on the site conditions.

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.

INTRODUCTION

Currently bioenergy contributes some 55 Esajoule (EJ) or 14% of global energy supply. This makes up bioenergy the largest renewable energy source and the world's fourth energy source (following oil, coal, and natural gas). The production of modern bioenergy for heat, electricity and transport is growing rapidly worldwide. This is because bioenergy is considered —among many other sources such as wind, solar, hydraulic, geo-thermal— a renewable form of energy and, if produced sustainably, avoid greenhouse gas (GHG) emissions compared to the use of fossil fuels, such as coal, crude oil or natural gas.

In addition bioenergy is an energy source that is available locally and in inland and remote areas, as such providing a host of other environmental and development benefits, such as mobilization of investment and generation of jobs, the diversification and stabilization of rural economies, the opportunities for alternative use of land currently allocated to the surplus agricultural for specialized production of woody biomass and respond to realise the transformation of the energy system to more decentralized forms of renewable energy supply.

Heating accounts for the vast majority of biomass use (46 EJ), including heat produced from modern biomass and the traditional, inefficient use of animal dung, fuel-wood, charcoal, and crop residues for domestic cooking and heating of dwellings and water in developing countries. Biomass of around 4.5 EJ of primary energy is consumed for electricity generation, and a similar amount for bio-fuels.

Traditional biomass heating contributes an estimated 6–7% of total global primary energy demand in 2012. In the EU-27, the role of wood in total primary energy supply increased slightly from 4.3% to 5.4% while the share of wood energy among renewable energy sources increased from 46.1% to 48.7%, making wood biomass the most important source of renewable energy.

For the next future, the objectives for development of bioenergy as a means to improve energy security and reduce GHG emissions in the EU are high. The Renewable Energy Directive (RED) adopted in 2009 sets binding targets for renewable energy: 20% share of renewable energy in the EU overall energy consumption by 2020 (see http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=Oj:L:2009:140:0016:0062:en:PDF).

Most EU member states assign a crucial role to bioenergy in their specific national renewable energy plans (NREAPs) for meeting the EU Renewable Energy Directive (RED), which mandates levels of renewable energy use and also includes a sustainability scheme for liquid biofuels. For Italy this target amounts to 17% of the gross final consumption. Bioenergy is a focal point in this effort, as it is expected to be the main contributor to the 2020 renewable energy target, with an anticipated contribution of more than half of it. In order to comply to this objective, in 2009 the Italian Ministry of Economic Development has given off the National Action Plan for renewable energies. One of the plan's main objectives is to reach, by the end of 2015, an economic potential of 4 million tons (Mt) of dry matter (d.m.) per year (yr^{-1}); and, by the end of 2020, of 10 Mt d.m. yr^{-1}.

Furthermore, the plan calls for the identification of priorities of end-use of biomass other than energy and, particularly, for integrating criteria assessing the sustainable use of biomass when making plans for agro-energy chains, including the forest-timber-energy one. Interestingly, alongside the objectives related to the mandatory national overall targets and measures for the use of energy from renewable sources, local authorities can take on a voluntary basis for concrete commitments to reduce emissions of greenhouse gases, adhering to the so-called Patto dei Sindaci (or Covenant of Mayors). The initiative commits the signatory municipalities to prepare an Action Plan for Sustainable Energy (PAES) with the goal of reducing, by 2020, GHG emissions by 20% through policies and measures aimed at increasing inter alia, the use of local renewable energy sources, including forest biomass (see http:// www.pattodeisindaci.eu).

Yet while these targets offer potentially significant environmental benefits, it is clear that the extent of those benefits will vary hugely depending on how bioenergy is developed (EEA, 2013). In particular, a substantial rise in the removal of biomass from forestry might put additional pressure on forests, which should be rightly safeguarded for ensuring the biodiversity conservation and the provision of ecosystem services, such as soil protection, water supply, carbon sequestration, or recreation.

To ensure that potential benefits from dendro-energy development materialize and potential risks are minimized, government authorities and decision-makers at national, regional and local levels need to make choices, both in bioenergy strategy development and decisions on promotion and licensing of investment options.

Such choices may be complex and a range of analyses should be undertaken as part of the policy and strategy formulation process. Assessing options and potentials, including the analysis of what is a sustainable dendro-energy potential by considering several factors that are relative to specific geographical locations, is acknowledged as one of the main broad steps as in the national and regional policy and strategy formulation process.

Starting from results of the survey titled “Structural diversity of forests in Lazio” (Bianco and Ciccarese, 2013) we try here to assess how much forest woody biomass could ‘technically’ and ‘economically’ be available for energy production without increasing the pressures on and harming the regional ‘forest’ and ‘outside forest’ resources. It should be stressed that throughout this report “potential wood supply” should be understood as “sustainable potential wood supply” or the level of supply which can be maintained for the foreseeable future without compromising the ability of the system to supply goods (including wood itself) and services.

In the last part the study discusses policy measures to achieve an actual increase in wood supply and pointing out the challenges between theoretical, bio-technical potential in wood supply, and a socio-economic potential supply.

Regional and national official and experts are encouraged to review this report, the methodology used and to correct the figures and data, in order to get a better understanding on wood energy potential in Lazio, therefore in other regions of Italy.

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1. FOREST RESOURCES: EXTENSION AND MAIN SPECIES

Figure 1 provides a depiction of forest extent and forest types in Lazio. It is based on habitat maps (scale 1:50,000), produced by ISPRA (Casella et al., 2008). They discriminate all the wooded areas bigger than 1 hectare and differentiate the major forest types.

The broadleaved deciduous forests dominate (466,387 ha, or 85.5% of total woodland surface), but Mediterranean forests have a significant incidence too (50,115 ha, 9.2% of total woodland surface), even although the major agricultural and urban pressures, from coastal to montane belt, on all their potential areal. Coniferous forests (7,010 ha, 1.3% of total woodland surface) are very limited and refer principally to *Pinus nigra* plantations on the Apennine and Antiapennine, and *Pinus pinea* and *Pinus halepensis* plantations on coastal and sub-coastal belt. In presence of low anthropogenic pressure coniferous forests have turned out to be mixed woods after ingression of nemoral species. At present the ecological value of these mixed woods can be very high and some of them are located within protected areas.

Lazio's forests, according the syntaxonomical classification system, can be grouped within the following main types (Figure 1):

1. Mediterranean evergreen forest (*Quercetea ilicis*)
2. Thermophilous decidous oak woods and other mixed forests (Quercetalia pubescentis-petreae)
3. Montane beech woods and other mesic forests (Fagetalia sylvaticae)
4. Hygrophilous woods (Alnetalia glutinosae, Salicetalia purpureae, Populetalia albae)

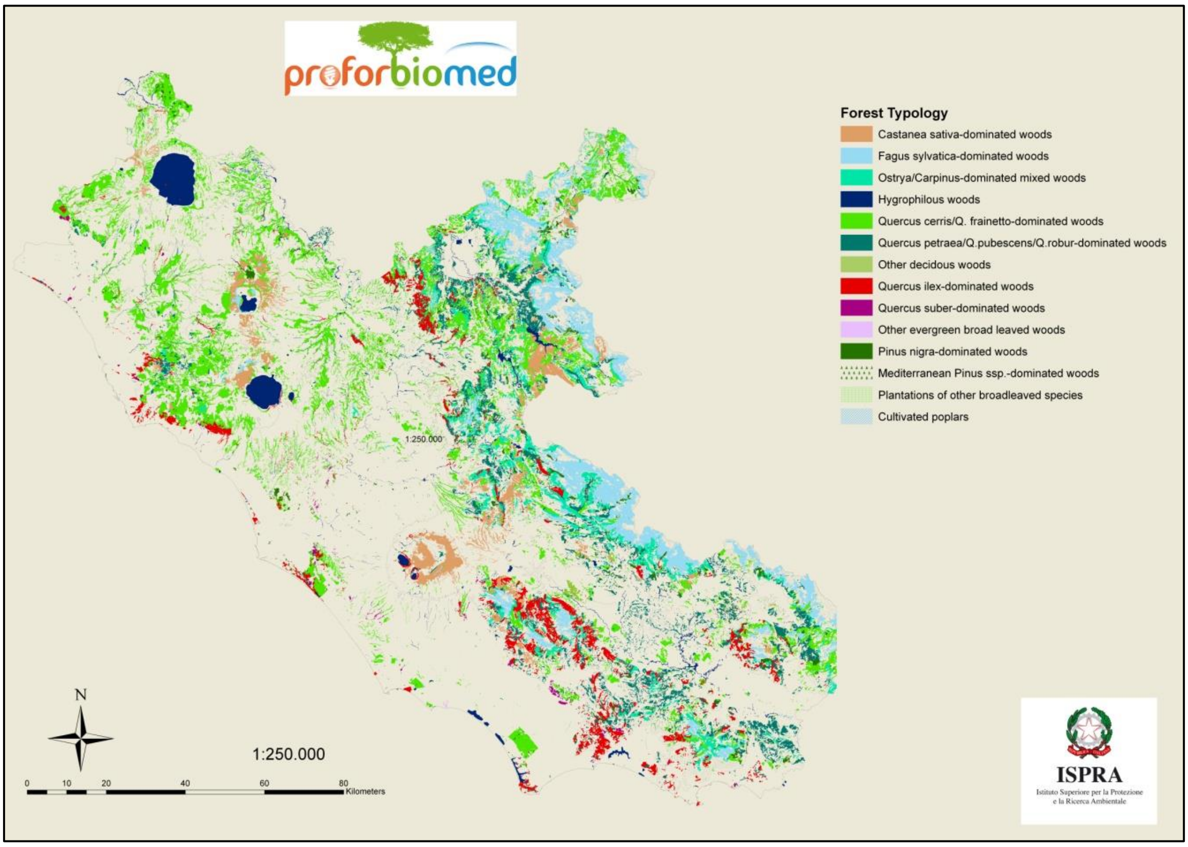

Figure 1 - *Forest cover and forest types in Lazio*

The main source of information on the forest cover structure and distribution available in Italy is represented by the Italian Inventory of Forest and Carbon (INFC, 2008). According to it, total forestland in Lazio is 605,859 ha, about 35.2% of the region's total land area (1,720,768 ha). About 89.8% (543,884 ha) is classified as 'wooded land' and 10.2% (61,974 ha) of the forestland is classified as 'other wooded land' (OWL) (Table 1). According to the Forest Map produced by Lazio Region, the forest area amounts to 619,574 ha, or 36 percent of the entire regional land.

Table 1- *Forest land in Lazio by different forest types*

Forest type		*Area, ha*	*% to the forest type*	*% to the total*
1. Wooded land	Coppice (without standards)	46,425	13.6	7.7
	Coppice with standards	262,176	77.0	43.3
	Simple coppice	32,056	9.4	5.3
	Total coppice	340,657	100.0	56.2
	In-transition high forests	12,527	12.9	2.1
	Even-aged high forests	31,687	32.6	5.2
	Uneven-aged high forests	41,333	42.5	6.8
	Irregular high forests	11,791	12.1	1.9
	Total high forest	97,338	100.0	16.1
	Special forest (*Castanea sativa, Juglans regia, Quercus suber)*	4,053	100.0	0.7
	Undefined	28,003	100.0	4.6
	Areas not classified for a forest type category	73,834	13.6	12.2
	Total wooded land	543,885	100.0	89.8
2. Other wooded land, OWL	Areas not classified for a forest type category	61,974	100.0	10.2
	Total	61,974	100.0	10.2
Total (1+2)		605,859	100.0	100.0

Source: INFC 2008

The INFC data report the extent of 'tall forests' (boschi alti, according to the classification adopted), planted forests and forest areas temporarily unstocked, under the same 'forest' macro-category.

Quercus cerris, *Q. frainetto* and forests are the most prevailing forest type (122,900 ha, 23.0% of total tall forests), followed by Ostrya spp. and Carpinus spp. forests (96,167 ha), Quercus petraea, Q. robur and Q. pubescens forests (79,816 ha) and Fagus sylvatica forests (71,710 ha). Castanea sativa forests (35,003 ha) are still significant in terms of extent, as well as Quercus ilex forests

(47,899 ha) and Quercus suber forests (2,211 ha). ‘Tall forests’ include the remaining area of ‘forest’ macro-category not falling in the previous groups.

According to the INFC classification, planted forests are distinguished from high forests (*fustaie*) due to artificial origin, the presence of a specific planting layout, and the running of typically agronomic practices (INFC, 2008). Planted forests cover about 1,705 ha (about 0.3% of total forests). Most planted forests are ‘other broadleaved planted forests’ (1,336 ha), while Populus spp. planted forests cover 369 ha. Forests areas temporarily unstocked take in those forest areas temporarily without tree cover—due to natural or anthropogenic causes—for which forest restoration is foreseen in a relatively short period of time and cover 7,282 ha, 1.3% of total forests.

Since the latest decades the region’s forestland is gradually expanding. This trend is not only due to new forest planting activities, but also to an increasing and continuous natural re-colonisation of abandoned farmland and pastures. The difficulty in monitoring this phenomenon may explain the apparent contrast between the official ISTAT (National Institute of Statistics) data sources and other sources, in particular the INFC and the most recent survey CORINE land cover.

2. STANDING VOLUME, GROWING STOCK AND GROWTH

For estimating and forecasting the bioenergy potential of a forest it is central to assessing how much standing volume there is in the forest, how quickly the forest is growing (and gaining standing volume) and when and how much of this growth in standing volume will be harvested. This is achieved firstly by estimating three key elements of the forest as it stands: the area of woodland, the type of woodland and its rate of growth. The annual gain in standing volume is known as the increment (see glossary in this report). Growing stock volume is the main measure used in reporting of estimates of growing stock. Ideally growing stock estimates are based directly on national inventory assessments taken for an appropriate base year. Growing stock volume is usually the measure from which estimates of increment are derived.

Growing stock forecasts, in conjunction with removals and increment forecasts are a strategic measure of the sustainability of intended forest management. Forecasts of growing stock volume are needed as a component in the calculation of standing biomass and carbon.

Gross increment is the average annual volume of increment (an increase of growing stock) that over the reference period of all trees is measured by a minimum diameter breast height (d.b.h.) above 0 cm. It includes the increment of trees that have been felled or have died during the reference period. This increment is usually measured every 5 or 15 years and this annual increment becomes the average for that reference period.

Net annual increment is the average annual volume over the given reference period of gross increment but less than that of natural losses of all trees to a minimum diameter of 0 cm (d.b.h) (UNECE, 2000). In order to monitor the annual production and sustainability in forestry, one also has to be aware of three other terms related to fellings and other losses in forests. Annual fellings refer to the average annual standing volume of all trees that are felled during a given period. It includes the volume of trees or parts of trees that are not removed from the forest. It also includes silvicultural and pre-commercial thinning. These fellings are further divided into removals and logging residues. Removals represent those parts of fellings that are transported out of the forest. Logging residues are represented by that part of felled stem wood, which remain in the forest. Together fellings and natural losses constitute the drain, meaning all wood material that has died from natural causes (natural loss) or has been taken by people from the growing stock.

The data source for standing volume and increment is the National Inventory for Forests and Carbon (INFC, 2008). According to it, the national standing volume of high forests is about 405 millions of m^3 (about 211 m^3 ha^{-1}), with a total annual increment of 15,127,900 m^3 (on average, 7.9 m^3 ha^{-1} yr^{-1}). Considering only the trees with d.b.h. >17.5 cm the total growing stock lowers down to 341 millions of m^3 and the current annual increment is 5.1 m^3 ha^{-1} yr^{-1}. Among spontaneous species, Norway spruce and European beech have the greatest net annual increment (NAI): 9.4 m^3 ha^{-1} yr^{-1} and 8.5 m^3 ha^{-1} yr^{-1} respectively.

In the last decades, the annual yield in high forests rarely exceeds 50% of the annual growth and harvesting, on average, is 35% of the current increment. On the whole, this has led to a general increase of the growing stocks in forests.

Standing volume and current increment of forests in Lazio are reported respectively in table 2 and 3, distributed by main species and management types. In Lazio wooded areas produces a current increment of 1,548,090 m^3 per year (average net increment of 2.9 m^3 ha^{-1} yr^{-1}). About 70.8% of the current increment is produced by coppices, about 23.8% by high-forests (Figure 2).

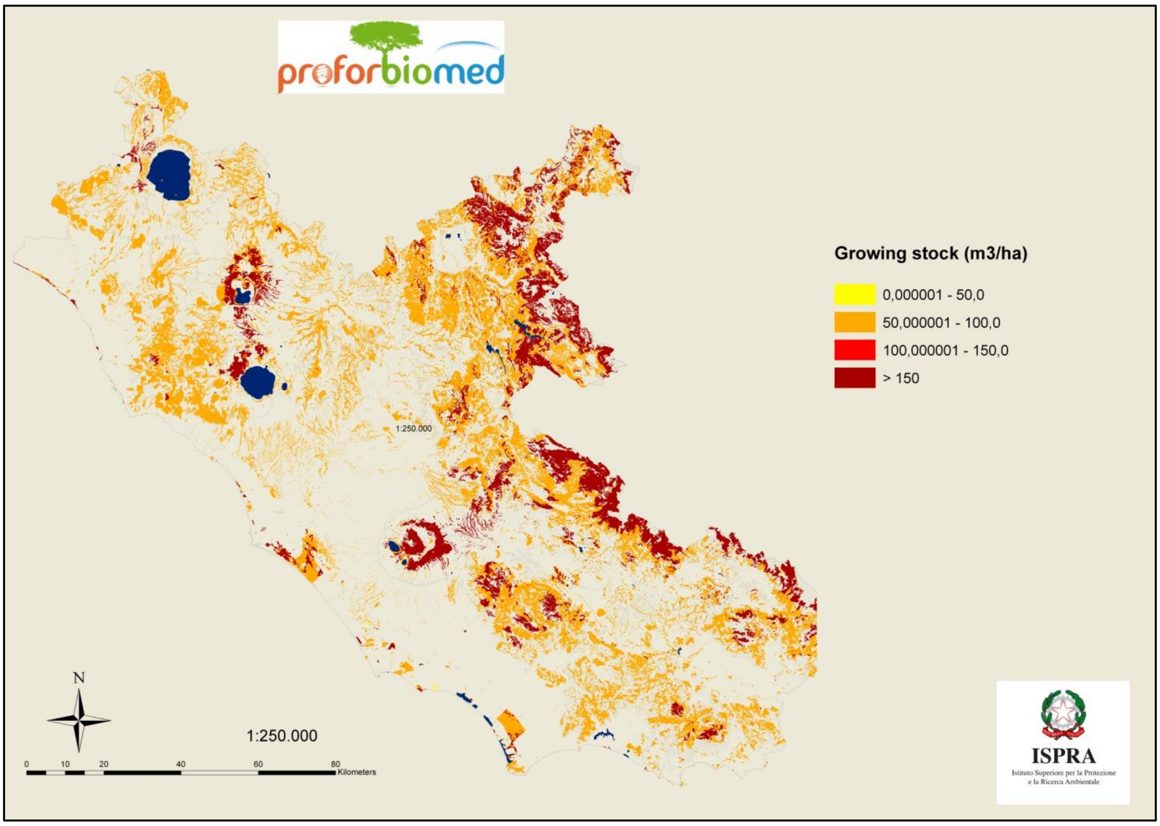

Figure 2 - *Map of standing volume (m^3 ha^{-1}) of forests in Lazio*

Table 2 - *Forests in Lazio: total and unit area standing volume by management type and species*

	Coppice		High Forest		Special cultural type		Undefined cultural type		Unclassified cultural type		Total	
	Total standing volume(m^3)	Standing volume per hectare (m^3 ha^{-1})	Total standing volume (m^3)	Standing volume per hectare (m^3 ha^{-1})	Total standing volume (m^3)	Standing volume per hectare (m^3 ha^{-1})	Total standing volume (m^3)	Standing volume per hectare (m^3 ha^{-1})	Total standing volume (m^3)	Standing volume per hectare (m^3 ha^{-1})	Total standing volume (m^3)	Standing volume per hectare (m^3 ha^{-1})
Picea abies forests	0	0	40,863	110.0	0	0	0	0	0	0	40,863	110.0
Pine forest (*P. nigra. P. laricio. P. loricatus*) forests	0	0	1,550,386	200.4	0	0	0	0	0	0	1,550,386	200.4
Mediterranean pine forests	0	0	1,282,012	194.0	0	0	0	0	0	0	1,282,012	194.0
Other coniferous forests, pure or mixed	0	0	516,942	350.8	0	0	0	0	0	0	516,942	350.8
Fagus sylvatica forests	6,366,964	192.0	11,368,810	352.1	0	0	0	0	0	0	17,735,774	247.3
Quercus petraea. Q. pubescens and *Q. robur* forests	2,836,674	55.1	1,031,035	82.3	0	0	417,806	75.6	0	0	4,285,515	53.7
Quercus cerris and *Q. frainetto* forests	8,099,652	88.7	4,173,330	219.4	0	0	0	0	0	0	12,272,983	99.9
Castanea sativa forests	4,747,142	174.1	565,930	384.0	406,049	110.2	0	0	0	0	5,719,120	163.4
Ostya and *Carpinus* forests	6,026,550	75	223,645	67.4	0	0	37,293	33.7	0	0	6,287,488	65.4
Hygrophilous forests	286,602	194.5	417,193	125.8	0	0	186,612	126.6	0	0	890,407	96.7
Other deciduous broadleaved forests	1,560,165	83.0	569,146	90.9	0	0	898,873	56.7	0	0	3,028,184	60.9
Quercus ilex forest	3,220,154	91.0	0	0	0	0	0	0	0	0	3,220,154	91.0
Quercus suber forests	197,478	109.3	19,509	27.0	336.274	93.1	0	0	0	0	553,261	90.1
Evergreen broadleaved forests	19,262	17.4	0	0	0	0	87,253	78.9	0	0	106,515	41.3
Total tall forests	*33,180,999*	*97.4*	*21,990,980*	*225.9*	*449,785*	*111*	*1,627,837*	*58.1*	*0*	*0*	*57,249,600*	*107*
Poplar plantations	0	0	0	0	0	0	0	0	107,123	290.7	107,123	290.7
Other broadleaved planted forests	0	0	0	0	0	0	0	0	73,360	54.9	73,360	54.9
Coniferous planted forests	0	0	0	0	0	0	0	0	0	0	0	0
Total Planted forests	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*180,483*	*105.9*	*180,483*	*105.9*
Forest areas temporarily unstocked	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*80,552*	*11.1*	*80,552*	*11.1*
Total forests	**33,180,999**	**97.4**	**21,990,980**	**225.9**	**449,785**	**111**	**1,627,837**	**58.1**	**261,036**	**3.5**	**57,510,635**	**105.7**

Source: INFC 2008

Table 3 - *Forests in Lazio: current increment by management type and species*

Forest category	Coppice		High Forest		Special cultural type	Undefined cultural type			Unclassified cultural type		Total	
	Total Current Annual Increment (m^3)	Current Annual Increment per hectare (m^3 ha^{-1})	Total Current Annual Increment (m^3)	Current Annual Increment per hectare (m^3 ha^{-1})	Total Current Annual Increment (m^3)	Current Annual Increment per hectare (m^3 ha^{-1})	Total Current Annual Increment (m^3)	Current Annual Increment per hectare (m^3 ha^{-1})	Total Current Annual Increment (m^3)	Current Annual Increment per hectare (m^3 ha^{-1})	Total Current Annual Increment (m^3)	Current Annual Increment per hectare (m^3 ha^{-1})
Picea abies forests	0	0	7,437	20.2	0	0	0	0	0	0	7,437	20.2
Pine forest (*P. nigra. P. laricio. P. loricatus*) forests	0	0	46,693	6.0	0	0	0	0	0	0	46,693	6.0
Mediterranean pine forests	0	0	24,576	3.7	0	0	0	0	0	0	24,576	3.7
Other coniferous forests, pure or mixed	0	0	12,213	8.3	0	0	0	0	0	0	12,213	8.3
Fagus sylvatica forests	113.897	3,4	133,972	4.1	0	0	0	0	0	0	247,869	3.5
Quercus petraea. Q. pubescens and Q. robur forests	79.218	1,5	24,190	1.9	0	0	12,511	2.3	0	0	115,919	1.5
Quercus cerris and Q. frainetto forests	286.246	3,1	87,985	4.6	0	0	0	0	0	0	374,231	3.1
Castanea sativa forests	220.566	8,1	1,825	1.2	6,821	1.9	0	0	0	0	229,212	6.6
Ostya spp. And *Carpinus* spp. forests	202	2,5	4,430	1.3	0	0	1,974	1.8	0	0	208,404	2.2
Hygrophilous forests	11.947	8,1	10,240	3.1	0	0	7,912	5.4	0	0	30,099	3.3
Other deciduous broadleaved forests	90.8	4,8	12,688	2.0	0	0	30,302	1.9	0	0	133,790	2.7
Quercus ilex forest	89.733	2,5	0	0	0	0	0	0	0	0	89,733	1.9
Quercus suber forests	498	1,4	2,963	2	1138	3.1	0	0	0	0	4,599	4.4
Evergreen broadleaved forests	1116	1,0	0	0	0	0	1,784	1.6	0	0	2,900	1.1
Total tall forests	*1.096.021*	*3,2*	*369,212*	*3.8*	*7,959*	*2.0*	*54,483*	*1.9*	*0*	*0*	*1,527,675*	*2.9*
Populus spp. plantations	0	0	0	0	0	0	0	0	9,448	25.6	9,448	25.6
Other broadleaved planted forests	0	0	0	0	0	0	0	0	8,009	6	8,009	6
Coniferous planted forests	0	0	0	0	0	0	0	0	0	0	0	0
Total Planted forests	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*17,457*	*10.3*	*17,457*	*10.3*
Forest areas temporarily un-stocked	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*2,958*	*0.4*	*2,958*	*0.4*
Total forests	**1,096,021**	**3.2**	**369,212**	**3.8**	**7,959**	**2.0**	**54,483**	**1.9**	**37,872**		**1,548,090**	**2.9**

Source: INFC 2008

3. PROTECTED AREAS

In Lazio there are 3 national parks, 10 regional parks, 182 Sites of Community Importance (SCI) and 39 Special Protection Areas (SPA). In total the region's protected area is about 424,000 ha; woodlands in protected area represent 50.8% of protected areas (about 215,478) and 39.6% of total woodland (Figure 3).

Within the Sites of Community Importance (SCI) and Special Protection Areas (SPA) were identified 14 forest habitat types according tipology proposed by EU Manual (ARP, 2008). They are much diversified in relation to litological, climatic, edaphic and phytogeographic diversity, but the predominant structure is coppicing, in particular at low altitude, where high forest stands are extremely rare.

Conventional silviculture operations in protected areas of Lazio have not always given the due priorities to the objectives of conservation and natural improvement of the forest resources. Approaches to silvicultural management vary quite significantly depending on many factors. In some cases most of the forests are left to free dynamics and succession stages or at least treated by natural criteria in cutting, thus obtaining significant improvements in population structure and biodiversity; in other cases, no particular conservation measures have been adopted, and thus currently there is no substantial differentiation in terms of utilisation between forests inside and forest outside protected areas. Of particular importance is the possibility of and need to create Zones in the Parks (whole reserves) to maintain some significant sections of forests, excluding any anthropogenic intervention, in order to allow conservation of all extent forest associations and thus their species richness and genetic variation.

In Natura 2000 sites forest operations are subjected to Environmental Incidence Assessment, according to DPR 357/1997. Forest harvesting has to defer to the regional purpose to obtain adequate conservation. Lazio Region promotes long-term sustainable use of forest resource and the restoration of environment in order to protect biodiversity of natural habitats (Gaglioppa and Zani, 2011). At the same time it promotes sustainable agrosilvocultural activities to help local economy in marginal lands and rural areas with the development of local cooperative related to forest products. The revision of Natura 2000 and of DGR about forest planning, currently in progress, is aware of these problems and of the protected surfaces.

Some forest types, such as Quercus suber and Fagus sylvatica dominated forests, are predominantly situated within protected areas. Given their ecological importance, such forests should be excluded from forest wood removals, thus not to be considered when assessing the potential for bio-energy. Quercus ilex-dominated forest and Quercus cerris and Q. frainetto forests are referred to Natura 2000 habitats, according to Italian Interpretation Handbookl of 92/43/CEE Directive habitats (Biondi and Blasi, 2009; Biondi et al., 2012) and they only have to go through low-impact operations or disturbances (Table 4).

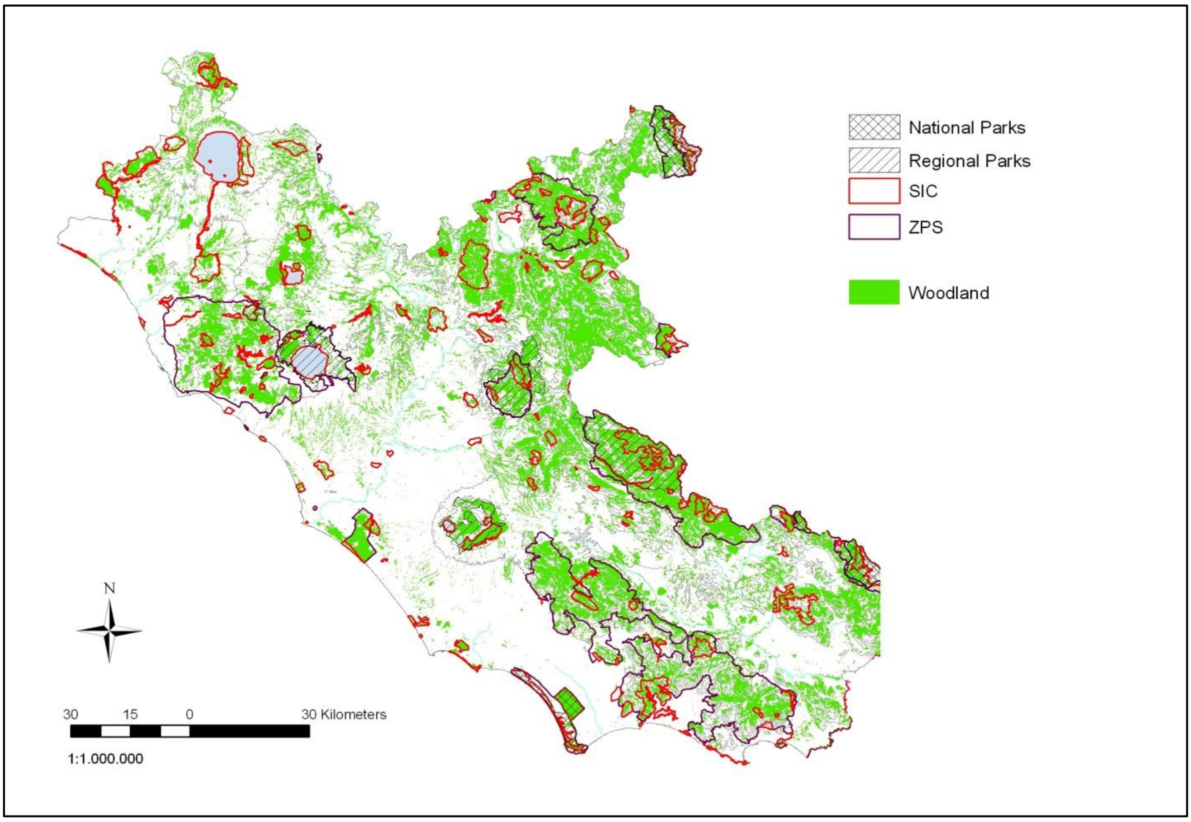

Figure 3 - *Protected areas and forests in Lazio*

Table 4 - *Forests within protected areas by forest types in Lazio*		
Forest type	*Hectares*	*% of forest type*
Quercus suber-dominated forests	1,717.2	0.8
Fagus sylvatica-dominated forests	54,190.8	25.1
Pinus nigra-dominated forests	5,018.8	2.3
Quercus ilex-dominated forests	27,945.4	13.0
Quercus cerris/Quercus frainetto-dominated forests	57,412.1	26.6
Castanea sativa-dominated forests	13,944.6	6.5
Ostrya/*Carpinus*-dominated mixed forests	28,897.4	13.4
Quercus pubescens. *Q. robur*. *Q. petraea*-dominated forests	22,554.0	10.5
Mediterranean pine forests	1,991.6	0.9
Plantations of other broadleaved species	213.6	0.1
Hygrophilous forests	1,431.8	0.7
Other evergreen broadleaved forests	51.4	0.1
Populus sp. Planted forests	2.1	0.1
Other deciduous broadleaved forests	107.5	0.1
Total forests	*215,478.3*	*100.0*

4. ELEMENTS OF FOREST WOOD SUPPLY FOR ENERGY

Forest wood for energy include the following sources:

1. natural/semi-natural forests that produce biomass growth which is not required for industrial round wood;
2. natural/semi-natural out-of-forest that produce biomass growth which is not required for industrial round wood;
3. forest sector by-products primary residues, resulting from thinning and logging (e.g. tree tops, limbs, slash and small round wood);
4. forest sector by-products secondary residues, such as sawdust and bark from wood processing;
5. dead wood from natural and human-induced disturbances, such as fires, insect outbreaks, pathogens and pollution;
6. had-hoc forest tree plantation to meet projected demand for timber/traditional biomass.

5. CURRENT WOOD REMOVALS IN LAZIO

Figures of Italy's forest wood removals (or production) cover removals of fuel-wood including wood for charcoal and round-wood (trunk and branch wood) only, of both coniferous and broadleaved forests, as a result of logging. Data on removals of brash (branch wood and leaf material) and stumps (above-ground base part of trees) are not provided.

The latest figures on forest wood removals were released in 2014 and refer to 2012 (Figure 4). In Lazio, the annual forest wood removals reached 706 thousand cubic meters (m^3) in 2010, about 6.5% of total wood removed from Italy's forests. In 2001 the total wood removals reached an all-decade high at 829 thousand cubic meters. It declined notably in 2007 and 2008, but increased soon again and has remained at an average of approximately 721 thousand cubic meters during the past decade. The 88% (or 619,525 m^3) of total wood removals is represented by wood for fuel; about 98% (or 607,424 m^3) of wood for fuel is removed from broadleaved forests, namely coppices.

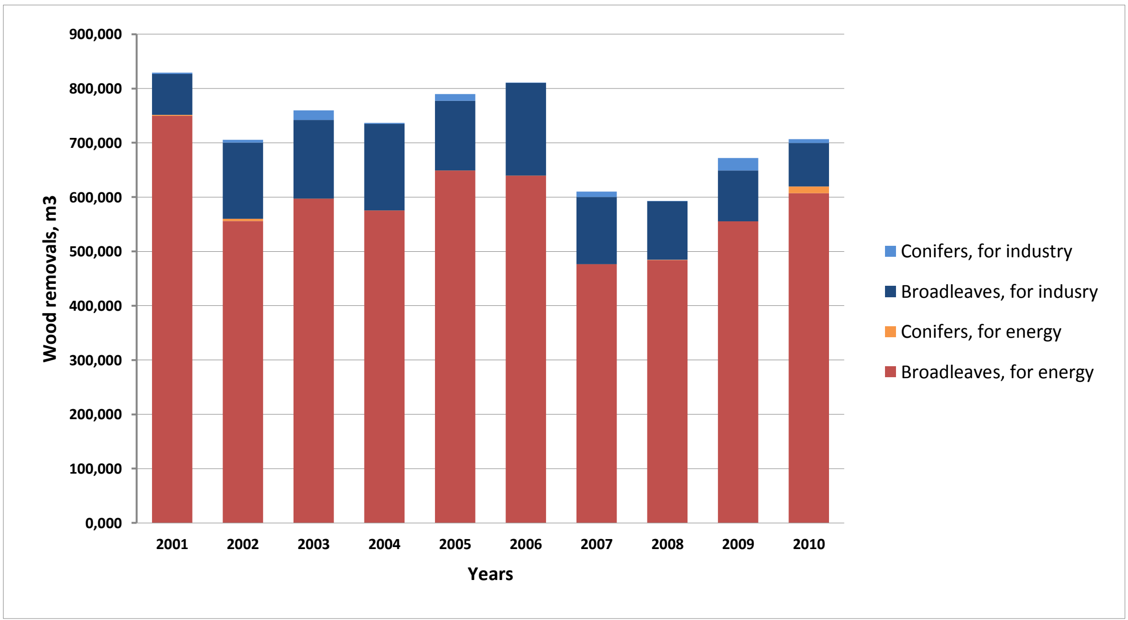

Figure 4 - *Evolution of wood removals from forests in Lazio, thousand m^3 (ISTAT)*

6. METHODS USED FOR ASSESSING WOOD SUPPLY FOR ENERGY

In assessing the wood supply potential for the region, we assume that forest wood for energy includes the following sources:

- natural/semi-natural forests that produce biomass growth which is not required for industrial round wood;
- natural/semi-natural out-of-forest that produce biomass growth which is not required for industrial round wood;
- forest sector by-products primary residues, resulting from thinning and logging (e.g. tree tops, limbs, slash and small round wood);
- forest sector by-products secondary residues, such as sawdust and bark from wood processing.
- dead wood from natural and human-induced disturbances, such as fires, insect outbreaks, pathogens and pollution
- *ad-hoc* forest tree plantation to meet projected demand for timber/traditional biomass.

These main sources of biomass for energy can be grouped into two categories: forest sources and out-of-forest sources.

Within the particular Italian forest and silvicultural conditions, in the first category we consider: woody biomass from coppices, logging residues from high forest stands, primary residues from cultural practices (thinning, pruning, etc.), woody biomass from other wooded lands. In the second category we consider: woody biomass from woodlots, woody biomass from line forest or trees outside the forest, biomass from short rotation forestry crops.

In the following paragraphs, for each category of source of wood for fuel listed above the current wood removal is presented, then the bio-technical potential and the socio-economic potential of wood supply are assessed.

The scheme used for the estimation of forest and outside forest woody biomass potential develops according to the following steps:

- identification of forest and outside forest resource base in the region;
- estimation of the standing volume and rate of growth for different forest types present;
- detection and exclusion of all forest and outside forest areas which may present some restrictions for forestry activities, namely accessibility and nature conservation constraint;
- estimation of the economic potential of wood energy.

As such, the estimate is based on a number of silvicultural and environmental criteria for bioenergy production, which are then used as assumptions for modelling this potential.

7. CONCEPT OF SUSTAINABILITY

As stated before here the overall EU objectives for development of bioenergy as a means to improve energy security and reduce GHG emissions in the EU are high. The environmental impacts and the ultimate sustainability (social, economic, and environmental) of biomass production for energy purposes, especially regarding the conversion to bio-fuels and bio-based products, have been raised significant concerns. These concerns are common worldwide, but it is in Europe that they are particularly marked, mostly because the current ambitious EU goals to displace large portions of fossil fuels with bio-fuels in a relatively short time[1].

The contribution of EU forest resources to the total energy demand is already significant: forest biomass is currently the most important source of renewable energy and now accounts for around half of the EU's total renewable energy consumption. Countries that have considerable forest resources and a mature forest industry (e.g., Sweden and Finland) can obtain substantial amounts of biomass feedstock from their forest resources. In most European countries, however, forest biomass flows are relatively small compared to the biomass supply needed for reaching RED and longer-term targets. It is obvious that a substantial rise in the wood removal from forestry might put additional pressure on forests, in the Mediterranean region, which should be rightly safeguarded for ensuring the biodiversity conservation and the provision of related ecosystem services.

For ensuring that potential benefits from forest energy development materialize and potential risks threats are minimized, government authorities and decision-makers at national, regional and local levels need to make choices, both in bioenergy strategy development and decisions on promotion and approval of forestry investment options.

In this respect it must be underlined that the concept of sustainability in forestry has changed over time and over regions. Early concepts of sustainability in forestry focused purely on economic sustainability: ensuring that the wood supply would be sustainable. In the 1980s and 1990s the three dimensions of sustainability (ecologic, social and economic) became widely accepted. This implies that not more wood than what re-grows in a given area and time should be harvested and that forest management should respect environmental and social standards and preserve all ecosystem services provided by forests. This basic axiom captures its basic indicator in the net annual increment (NAI), defined as the 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[2].

Based on this, it follows that—in Italy as well as in most EU countries—there is abundant room to increase the removal of biomass for energy from regional forest resources. In fact, forestry in Latium removes timber at a rate slower than the increment in standing volume, about 46.1% of the estimated annual increment as estimated by INFC (1,548,090 m^3).

Potential additional removals take in woody biomass that could enter the market when forest resources, at present under-utilised, would appropriately be exploited, evidently in a logic of sustainable management of resources. This is the case of a large proportion of wood for fuel that could be removed from the recovery to management of abandoned coppiced forests, from silvicultural treatments of planted forests, from the valorisation for energy purposes of wood residues of fellings in high forests. The conditions for which these resources could actually become accessible are very different, and are not tied exclusively to the market of biomass for energy use, but also to choices of environmental and forest policies.

1 The Renewable Energy Directive (RED) adopted in 2009 sets binding targets for renewable energy: 20% share of renewable energy in the EU overall energy consumption by 2020.

On the other hand it must be underlined that current low level of fellings, in Lazio as well in the rest of Italy, has advantages for biodiversity conservation, as forests are growing older, thus restoring under-represented late succession stages. Bigger, older trees host a number of species confined to late forest successions and produce deadwood (standing and downed deadwood, resulting from mortality, and stem residues from felling activities) of specific qualities for a number of deadwood-dependent species and organisms, which constitute an important part of biodiversity in European forests.

Intensified biomass removal could lead to a significant reduction of deadwood which is a key indicator for assessing policy and management impacts on forest biodiversity and related services. In fact forest policies aim to increase the amount of deadwood in forest lands and the Ministerial Conference on the Protection of Forests in Europe and, consequently, many EU environment agencies have identified deadwood as an indicator of forest biodiversity.

However, this methodology should only be seen as a rough approach to estimate the potential wood supply, and to start a discussion on levels of sustainable wood supply in the different countries.

To start with, logging technologies and practices should take into account measures to reduce the damage to forest soils. Negative effects of use of heavy machines can include soil compaction and higher levels of erosion. When harvesting wood for biomass a much larger proportion of the biomass is removed (in comparison with conventional harvesting methods). This inevitably means increased intervention and transportation on the logging sites. Good practice would require the tree roots to be left in the ground and a proportion of branches to be used as 'mats' on forwarder routes to protect the soil. This would place a limit on the maximum rates for extraction of biomass.

For instance, intensified biomass removal could lead to a significant reduction of deadwood (standing and downed deadwood, resulting from mortality, and stem residues from felling activities) and, in turn, this could negatively affect deadwood-dependent species, which constitute an important component of biodiversity in forests. Forest residues and deadwood, have a number of important environmental functions. These include: provision of a source of nutrients; regulation of water flows; prevention of soil erosion; habitats foundation

It is important that any enhanced use of either forest residues or complementary fellings for bioenergy does not increase the existing environmental pressures from forest resource utilisation.

It must also be stated that enhanced use of either forest residues or complementary fellings for bioenergy can also bring positive benefits. These benefits include reduced fire risk and lower nutrient leakage on eutrophicated sites.

Residue extraction also affects the composition of flora and fauna through habitat homogenisation and more intense soil disturbance. However, there are also some planted forests that are not thinned due to a lack of market demand and low prices. In such cases thinning for biomass utilisation provides an opportunity to open very dense forest plantations, and thereby improve the habitat value of these forests for many species.

A certain amount of deadwood per ha is increasingly recognised as an important factor in the protection of biodiversity in forests. Of particular importance is deadwood of a large diameter. Although the removal of fine and small woody debris also has an effect on biodiversity, there are many more species that depend on large dead trees. Currently, the amount of deadwood is low in many European countries, especially in Mediterranean ones. Thus, when extracting forest residues or complementary fellings, it is thus important to leave behind a proportion of residues, deadwood and old trees in order to reduce or not to increase the pressure on biodiversity.

Regarding site fertility, it must be noted that biomass removal from forests always results in the export of nutrients. The various parts of a tree contain different levels of nutrients. The lowest nutrient concentration is generally in the wood and the highest contents are in the foliage. The nutritional impact of biomass extraction from forests is therefore strongly influenced by the rate of extraction and the degree to which foliage and small branches are left on site. The natural replacement of nutrients from weathering and atmospheric deposition varies between soil types and region. Mineral nutrients are naturally achieved through weathering and the availability is part of the site productivity. It is usually assumed that there are no problems associated with site productivity when removing woody biomass from forests managed with sustainable harvest levels.

Even on more fertile soil types it is important to retain foliage on the site. Therefore, it is beneficial to exclude small branches and foliage from the biomass removals. In the case of coniferous species this can be realised by extracting dry residues, which allows needles to drop before chipping. In the case of broadleaved species harvesting should take place in the winter months.

Secondly, logging residues and deadwood have a role to play in regulating the water flows through the forest ecosystem and to act as filters to improve water quality. They do this by capturing and storing significant amounts of water and reducing water run-off on slopes. Harvesting for biomass may significantly reduce the potential to regulate water flows. Forests in water protection areas are usually managed at low intensity. This means that large-scale removal of trees have to be avoided in order to prevent an increase in risk of surface run-off after heavy rainfall and release of nutrients into the groundwater. Nutrient export associated with intensive biomass utilisation could also intensify the acidification of water bodies.

7.1 Environmental considerations

In order to avoid increased environmental pressure from bioenergy production from forestry a number of criteria may be applied. Some of these criteria are as follows.

1. no intensification of use should occur in forest areas protected either by national legislation or within the European Community Natura 2000 network. As legal constraints imposed by protection regime vary from a total ban on management to no limitations for sustainable management, in the latter case it can be assumed that only low-impact management is allowed, at least in SCI sites.
2. foliage and roots are always left on site. Forest residues supply the ecosystem with nutrients, reduce the risk of soil erosion, regulate the water flows through the forest ecosystem and improve water quality. This occurs through the capture and storage of significant amounts of water, and reduced water run-off on slopes. A central assumption was that foliage was left on site as it contains the highest nutrition concentration. They account for approximately 20% of all the aboveground residues biomass. Furthermore, roots were assumed to be always left on site in order to prevent soil erosion and disturbance of the soil.
3. the extraction rate for residues from stem and branches is limited according to the suitability of the site. As residues provide nutrients, their extraction should be adapted to the soil fertility of the site. Proxies for soil fertility are different soil types and base saturation. The latter measures the degree of acidity of the soil — a low base saturation corresponds to acidic soils and low nutrient availability. To some extent, ash recycling may increase the suitability for residues extraction on nutrient poor soils.

For complementary fellings, where dedicated harvesting for bioenergy was considered, additional criteria comprise:

- a reduction of the area available for wood supply in each administrative ambit by a certain rate (bare minimum 5%), in order to allow for an increase in protected areas.
- a set-aside of 5% of wood volume as individual and small groups of retention trees after harvesting in order to increase the amount of large diameter trees and deadwood.

- site-specific residue extraction rate: The extraction of residues was adapted to the 'environmental suitability' of the site with regard to the functions of residues in the forest ecosystem.
- on sites with a higher risk of soil erosion — as measured by a combination of soil steepness and elevation — a reduced residue extraction rate is appropriate to protect erosion.

8. DIFFERENT LEVELS OF POTENTIALS

When discussing potential wood supply, it is essential to define the meaning of the word "potential". In this study we distinguish the bio-technical potential and socio-economic potential of wood supply.

The bio-technical potential describes how much wood could be physically removed from the forest and out-of-forest resources on a sustainable level, in addition to the current harvest, based on the biological increment which grows in the forest, and subtracting harvest losses.

On the one hand, this number is influenced by site conditions (soil and climate), by forest management and by the presence of forestry infrastructures . On the other hand it is influenced by efficiencies in harvesting operations. Different measurement systems and inaccuracies (intentional and unintentional) have to take into account when assessing these figures, since measurements for forest inventory and for wood removal statistics often differ. However, these sources might be underestimated due to particularly weak or non-existing statistics related to woody biomass outside the forest, utilization of branches for firewood, post-consumer recovered wood.

For residues and post-consumer recovered wood, the technical potential is the maximum assuming a maximum recovery rate.

The additional socio-economic potential express how much wood could be cut and brought to use or market, in addition to what is already used and marketed. This figure is mainly driven by behaviour and motivation of forest owners, with two important factors being wood prices and costs for harvesting.

Of course the difference between bio-technical and socio-economic potential also applies to post-consumer recovered wood and industry co-products.

Box 1- Methods for assessing bio-energy potential

Geospatial Technologies

These include remote sensing (RS), geographic information systems (GIS), and global positioning systems (GPS). Remotely sensed images, such as aerial and satellite imagery provide an efficient and reliable way to monitor biomass resources over time. Remote sensing images have relatively fine spatial and temporal resolutions, similar to the data obtained by field surveys. These products range in spatial resolution from as coarse as every degree of latitude and longitude to as fine as every few meters, and can be at repeatable time scales.

RS is the only technique available to monitor biomass resources at local, regional and global scales. This technique is used to estimate growing stock of biomass and forecast its productivity. RS provides a cost-efficient way to collect the required information at areas that are remote and poorly accessible. Remote sensing images are also the only practical approach to analyze land use and land cover change at economy-wide, regional, and global scales. Their patterns can be studied by comparing images acquired at different times.

Data derived from remote sensing imagery, such as land use/cover, elevation, and surface temperature, is further used in geographic information systems (GIS). GIS is a computer-based information system used to create, manipulate, analyze, and visualize geographically referenced information. It is a powerful tool for assessing biomass potential: It integrates many different types of data and provides a means of examining their spatial relationships.

GIS is particularly useful in estimating technical biomass resource potential by integrating various datasets such as crop/forest production statistics, land use, terrain, transportation infrastructure, and protected areas. It also can identify areas where the agro-climatic conditions are suitable for growing a particular crop or assess biomass resources available within a certain radius from a processing facility.

Field surveys

Field surveys are used to collect data as part of site-specific evaluation. Usually, a field plot (the size can vary on the different approaches) is selected as representative of the vegetation type in a study area, and parameters such as tree stem diameter, tree height, or crown dimensions for forest resources and density, height, health status, and phenological development are easily measured. The results are further extrapolated over a larger area and used to develop equations that predict biomass availability. This sampling technique provides the most accurate estimate of biomass resources at a given location; however, it is not practical for broad scale inventory. It is a time-consuming, labor-intensive, and therefore costly procedure, even with today’s satellite communication technology. Data collected by the GPS operations can be automatically recorded with a GIS program to further analyze the data or validate model-derived estimates. Currently, field surveys in biomass resource assessments are used when other methods prove insufficient or when capabilities to use other methods don’t exist.

Another way of collecting field data is sending questionnaires to farmers and cooperatives and asking them to report information such as planted acres, harvested yield, harvesting methods, and water management (irrigation or no irrigation). But this method of collecting field data relies on voluntary participation, creating a potential for informational gaps. Information can also be collected by face-to-face and telephone interviews, which are only applicable to local surveys; otherwise, it could be a time-consuming process. The “paper” survey method is often used for collecting crops-related information while the sampling technique described above is usually applied in forest resource estimates.

Modelling

Models are simplified frameworks designed to illustrate a system or process often using mathematical techniques to facilitate calculations or predictions. The complexity of a model and the modelling procedure depend on the needs of the assessment and availability of data and information. Models can be as simple as extrapolating measured data using statistical methods, or as complex as balancing numerous processes (organized in separate modules) to derive resource characteristics.

Both, static (analytical) and dynamic (simulation) models are used in biomass resource assessments. Static models describe a system mathematically, in terms of equations, and can be built in a spreadsheet. An example is estimating the amount and cost of crop residues (olive or vineyard pruning residues, for example) by specifying values (usually averages) for several variables such as crop production, residue generation, labour cost, and prices (chemical, fertilizer, fuel, and planting).

Simulation models describe a system dynamically over time and are built using specific software. While static models ignore time-based variances and the synergy of the components of the system, dynamic models explore “what-if” scenarios and the sensitivity of a system to variations in its different components as time progresses. For example, simulation techniques can be used in a crop-simulation model to examine the effects of climate, soil, and management practices on crop production. Another example is the use in biomass resource elasticity studies to examine the effect of land use change, market price, and policy measures on feedstock supply. When combined with optimization algorithms, simulations can indicate what policy choices or other decisions may lead to particular desired outcomes.

A more advanced, and perhaps the most comprehensive, type of modelling is the integration of simulation techniques with GIS to capture temporal and spatial perspectives of a system together. For example, incorporating soil type, climate, land use and—very important for the scope of this survey— road network information with advanced transportation and economic models, it is possible to predict both where dedicated energy crops could be grown and their marginal cost. Depending on the purpose of the model and input data resolution, the GIS system allows visualization of the outcome at different geographic levels – regional, sub-regional, economy-wide, state, provincial, municipal, or site specific.

In the past, using the modelling method for biomass resource assessments has been criticized for relying on highly simplified assumptions. Today however, simulation models allow examining the theoretical consequences of more complex assumptions. Increased computational power and speed of today's computers has vaulted dynamic modelling ahead of static modelling as the method of choice, and made it possible to improve intuition about the feedback and interaction among regions, sectors, and other components of the biomass “landscape”. Moreover, data are becoming organized into common databases at finer levels of granularity and sharing data has never been easier. Micro-data can now support micro-simulations. It is possible to compute large-scale micro-simulation models that would not have been possible just a few of years ago.

9. FOREST

There is no single definition globally, and countries have tended to define their forests according to legal, administrative or cultural requirements, land use, canopy cover, or biomass (Neef et al. 2006).

The majority of definitions are based on a single variable – canopy cover – exceeding a given minimum threshold. Canopy cover in this context is defined as 'the percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage of plants' (IPCC, 2003). Within the UNFCCC context, this canopy cover approach was loosely adopted, but countries were also allowed to choose a forest definition based on threshold values for two additional variables.

Furthermore, the choice of definition greatly affects the land available for afforestation and reforestation activities (Zomer et al., 2008), whether trees outside of forests are to be accounted for, the baseline deforestation rate and the speed at which forests will regenerate on abandoned lands.

Area and tree height thresholds also have considerable impact. Low minimum forest area permits patches around farms and settlements, often serving as woodlots, to be included. High forest area thresholds encourage contiguous areas of forest, which deliver co-benefits such as biodiversity. Low tree height thresholds permit short, woody, forest vegetation to be included (which often grow on poor soils or at altitude) in addition to commercial woody species.

According to the FAO (2012), forest is a land spanning more than 0.5 hectare 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 is determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5m in situ. Areas under reforestation that have not yet reached but are expected to reach a canopy cover of 10% and a tree height of 5m are included, as are temporarily unstocked areas, resulting from human intervention or natural causes, which are expected to regenerate. Forest also includes windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and width of more than 20m, Includes plantations primarily used for forestry or protection purposes, such as cork oak stands. Viceversa, the term forest excludes tree stands in agricultural production systems, and trees in urban parks and gardens.

According to the Italy's National Inventory of Forests and Carbon (INFC), forest is a land spanning more than 0.5 ha 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 forest stands, where forest formations with a continuous vegetation cover exceeds 10 percent. Young forest stands—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 lands. 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, together with fruit chestnut stands, and cork oak stands are included.

10. FOREST AVAILABLE FOR WOOD REMOVALS

Forest primarily intended for wood removal is a forest not subject to significant limitations of forestry activities because of physical causes (inaccessible areas) or rules or constraints (e.g. integral nature reserve). The FAO considers as unavailable to wood removal those forests where the constraints and restrictions arising from legislation or special scientific, cultural or spiritual, as well as the forests where the productivity or the value of the timber is too low to make it convenient for harvesting timber. Are deemed to be available, therefore, also stands no longer used for a long time for abandonment of management, as wood extraction still has a certain cost-effectiveness, as well as those treated with very long rotation cycle.

According to this requisite, in Lazio the rate of forest area *not available* for wood removals includes:

- protected areas[3] for which it is not possible any form of fellings including priority conservation habitats areas—Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) as established according to the requirements of the Birds and Habitats Directives[4];
- areas classified 'wooded land' or 'other wooded land' temporarily unstocked[5];
- forest areas not 'accessible according to the figures provided by INFC (2008);
- forest areas with landslide risk or characterised by high slope (Table 5);

Most of Lazio's territory has been anthropised since ancient time and has a very developed roads system. Overlapping the local road map over the forest areas it results that only a small rate of the regional forests is lacking of a good transport system.

It comprises Castelporziano estate, National Park of Circeo, Appennines range, Tolfa hills and some areas of Lepini-Aurunci-Ausoni range. Some wooded lands (principally Fagus and Ostrya dominated forest) are on high slope and without road of access. These woods have a high conservation value and are important from hydro-geological point of view so they can't to be used for biomass removal. In Lazio, according to the figures presented by the INFC, 89.0% of the total 'wooded land' category (484,307 ha) is available for wood removals; 9.2% (or 50,136 ha) is not available for wood removals; 1.7% (or 9,441 ha) is not classified as available for wood removals (Table 6). Within the category 'other wooded land', only 39.2% (or 24,293 ha) is available for wood removals[6]; 38.9% (or 24,103 ha) is not available; 21.9% (or 13,579 ha) is not classified as available for wood removals.

The new forest plantings for timber production are all available for wood removals; among the category 'other wooded lands' only shrub is less frequently available for wood removal (57.4%).

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3 Some of the woodlands in Lazio are part of a system of protected areas (named Roma Natura, http://romanatura.roma.it) within the municipality of Rome's land.

4 The first group comprehends woods referred to 9210 "Apennine beech forests with Taxus and Ilex", 2270 "Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*", 91EO "Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)" and 9180 "Tilio-Acerion forests of slopes, screes and ravines according to Italian Interpretation Manual of 92/43/EEC Directive Habitats (Biondi and Blasi, 2009). Prioritary forest habitat according to directive 92/43/EEC. The second group includes integral reserves as Castelporziano Estate, National Park of Circeo, Manziana forest and Roma Natura systems (urban forest of cities of Rome).

5 A criterion used to determine if a forest is available for wood removal has been developed by Ciancio (1981; 2002; 2009), who introduced the so so-called «minimal standing volume», defined as the minimum level under which it is not possible to remove wood without compromising the biological equilibrium. This criterion fits the acknowledged requisite to act whenever according to the precautionary principle (Ciancio and Nocentini, 1999) and corresponds to the concept of safe minimum standard (Toman, 1992; Callicott, 1997).

6 When we exclude the category 'bushes', which is 100% not available for wood removals, the percentage of accessible surface area for other categories of around 80% (73.3% for low-forest, 45.0% for sparse forest e 48,5% for shrub). The category of wooded land 'not classified' or 'not accessible' is 100% unavailable for wood removals.

Table 5 - *Forest typology and class of slope in Lazio*

Forest types, percentage	***Category of slope***				
	0-5°	5-10°	10-20°	20-30°	> 30°
Populus spp. plantations	95.52	4.48	-	-	-
Fagus sylvatica-dominated woods	2.82	9.37	31.67	39.91	16.22
Hygrophilous woods	49.38	32.81	15.20	2.46	0.15
Mediterranean *Pinus*-dominated woods	7.80	20.08	39.33	31.37	1.43
Ostrya- and/or *Carpinus*-dominated woods	3.30	10.38	30.55	40.88	14.89
Other deciduous woods	30.34	46.08	19.03	4.16	0.39
Other evergreen broadleaved woods	61.21	38.79			
Plantations of other broadleaved species	6.65	47.83	31.79	13.68	0.05
Quercus cerris and/or *Q. frainetto*-dominated woods	13.05	39.61	36.16	9.16	2.03
Quercus ilex-dominated woods	3.53	11.71	34.84	36.14	13.78
Quercus petraea/*Q. pubescens*/*Q. robur*-dominated woods	8.04	23.20	41.01	22.97	4.79
Quercus suber-dominated woods	13.19	34.04	35.85	15.04	1.88

Table 6 - *Forest land base in Lazio: availability to wood removals by category of forest*

Category of forest		*hectares*	*Percentage*
Wooded land	Area available for wood removals	484,307	89,0
	Area not available for wood removals	50,136	9,2
	Area not classified as available for wood removals	9,441	1,7
	Total	*543,884*	*100,0*
Other wooded land	Area available for wood removals	24,293	39,2
	Area not available for wood removals	24,103	38,9
	Area not classified as available for wood removals	13,579	21,9
	Total	*61,975*	*100,0*
Total		*605,859*	*100,0*

11.WOODY BIOMASS FROM FOREST

11.1 Coppices

Coppicing represents a traditional method of woodland management and wood production in Italy, 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 spp.) ash (Fraxinus spp.) or European hop hornbeam (Ostrya carpinifolia), are cut, leaving a massive stool from which up to 10 trunks arise; or small, in which case trees, usually hazel (Corylus avellana) or willow (Salix spp.), 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. Initial growth of a coppice shoot is very vigorous; oak may reach 1 m and ash, beech and sweet chestnut as much as 2 m in the first year. Mean annual increments over a coppice rotation, in terms of dry wood per ha per year to 5 cm diameter, are typically 2 tons per oak, lime and shorn alder and sweet chestnut. Poplar and willow may produce as much as 6 tons per ha per year (t ha^{-1} y^{-1}). In Italian forestry coppicing is widespread due to socio-economic (property in mountain areas) and site characteristics (high slope, poor soil quality, etc.). Umbria, Emilia Romagna, Toscana and Lazio are the regions in which coppice is the most represented method of woodland management (about 75%), while high forest, tied to public properties, is concentrated in the northeast of the country Coppices in Lazio extend over 387,082 ha, about 52.2% of total forests and 62.6% of total wooded lands. Of these coppices, 46,425 ha are classified as coppices without standards (or 12,0% of total coppices), 262,176 ha as coppice with standards (or 67.7% of total coppices) and 32,056 ha as compound coppice (or 8.3% of total coppices).

11.1.1 *Current use*

Currently about 607,424 m^3 of wood are removed from Lazio's coppices, equivalent to 364, 454 oven dry tons of wood. The current use is derived from the ISTAT and other independent studies, which are reporting the fellings (over bark) in 2010. Since all figures in this study are calculated in round wood equivalent under bark, 12% of the felling are considered to be bark, and 10% are deducted for losses during harvesting.

11.1.2 *Additional bio-technical potential*

The annual increment from coppices equals 1,096,021 m^3, a value that is three times higher than the current use. Overall in Lazio the net annual increment of forest area available for wood supply is 767,457 million cbm (over bark). The annual fellings (over bark) are 460,792 million cbm. In order to determine the sustainable bio-technical potential of stem wood removal, bark and harvest losses have to be subtracted from the difference of increment and felling.

(NAI – F) * (1 – BF) * (1 – HL) = additional biotechnical potential (stem wood)

(1,096,021 – 607,424) * (1–0.12) * (1 – 0.10) m^3 = 386,969 m^3

where

NAI: net annual increment

F: Fellings

BF: Bark factor (0.12) HL: Harvest losses (0.10)

Unrecorded removals (not reported to statistics, which does not imply that these are illegal cutting) are not captured in this figure (since this number is inherently unknown).

11.1.3 *Socio-economic potential for additional wood supply*

There are a number of factors influencing the potential wood supply, and the actual supply. These factors are foremost the motivation and attitude of forest owners on forest management, economic factors (wood prices, costs for wood harvesting, etc), and nature conservation. In this study, we assumed that 35% of the additional bio-technical potential could be mobilized with appropriate measures. It means the socio-economic potential of the regional coppices forests may be as big as 742,863 m^3 (135,439 + 607,424).

11.2 Logging residues

Residues from logging operations that are normally left in high forests after stem removal—such as stem tops and stumps, branches, foliage, and roots—represent a significant amount of biomass that can be used for energy purposes. Recently, in several countries, there has been a trend towards collecting forest biomass residues after harvest operations for bioenergy making.

Assessing the bioenergy potential of logging residues is not an easy task, as it cuts across several factors, including tree species, site characteristics, age-class. According to ISTAT, in 2010, about 80,096 m^3 of wood for industry were removed from the Lazio region’s forest. Applying the methodology utilised by Ciccarese et al. (2003)—which assumes that the amount of logging residues left in high forests represents a rate ranging from 15% to 35% of the wood removed after fellings operations, depending on the factors mentioned above in this paragraph—current wood-based bioenergy potential ranges from 12,014 m^3 to 28,034 m^3 (average 20,024 m^3), or about 12,014 t of wood.

A further contribution of logging residues is conceivable only assuming an increase of removals of wood for industry from high forests. In this regard it is important to underline that not all high forests in Lazio are available for wood removals. According to the latest national forest inventory, about 89,9% is available for wood removals (Table 6). In this respect we decided to exclude those stands that—because of their structure and type of management—should be not considered ‘productive', such as forests with high-nature value (integral nature reserves), coppices in the stage of conversion to high forest, or forests managed for purposes other than wood production (soil protection forests, recreational forests, etc.). The percentage of high forests available for wood removals in Lazio is derived from the INFC (Table 9), then assuming that the situation has not changed over time.

All high forests (97,338 ha) are consistently subjected to forestry operations and that all increment (369,212 m^3) to the wood standing volume is extracted, logging residues would ranges from 55,382 m^3 to 129,224 m^3 (average 92,303 m^3), or about 55,382 t.

The problem is more complex in the case of high forests is that in our country the stands classified as such only rarely have a structure and a composition refers to one of the structural models classic, contemporary or felled (INFC, 2008). In most cases, especially in environments Apennine, it stands with the composition and structure of complex, not easily classifiable into one of these two categories. Often we are in the presence of unmanaged stands for a period of time longer or shorter - for example high forests resulting from afforestation where over time the reduction in coverage has favoured the phenomena of spontaneous introduction of sawmills (Nocentini et al., 2011) or coppice under high forest (Corona et al., 2002).

The extraction of logging residues can remove a significant amount of organic matter and nutrients, such as nitrogen (Samuelsson, 2002). At regional level, nutrient export with forest residues can thus have a positive effect in certain ecosystems on forest land with a high nitrogen load. Removal of logging residues may increases the direct exposure of the soil to rainwater, sun or wind, and thereby reduce the risk of erosion.

11.2.1 *Current harvest*

Total above-ground biomass was analysed. The results showed that the above-ground biomass varied depending on site quality and silvicultural treatment. Residual biomass constituted between 13 and 25% of the above-ground biomass. Waste logs and branches of greater than 80 mm (3.15 inches) made up 35% of the residue biomass. However, less than 40% of the research sites had sufficient residue biomass to be considered for harvesting with a separate dedicated system, with the result that integrated systems that simultaneously harvest the conventional product and the residues are preferred.

11.2.2 *Bio-technical and socio-economic potentials*

The bio-technical potential of biofuel arising from logging residues has been estimated in 46,236 m^3. However, considering various obstacles and limitations, including the high costs of harvest and transport under the current market conditions, the socio-economic potential is ranges from 36,988 to 55,483 m^3 (average 46,236 m^3).

11.3 Cultural practices

Cultural practices include those operations, like pruning and thinning, which are carried out before the end of the rotation cycle of a forest stand and in the even-aged high forests and in correspondence of cultural practices in uneven-aged high forests. In essence, cultural practices are not put into practice as wood products available from these operations hardly have a market, while costs for felling and removal are considerable.

Assessing the mass of wood that can be taken from cultural practices is not an easy task, as:

- the operations are determined on a case by case basis, and depends on the characteristics of the forests, the soil fertility and sets you want to achieve;
- the simplification of the official statistics related to the different forest types does not allow to obtain some critical information, such as the management system (even-aged or uneven-aged forest), the objectives, the treatment;
- the bibliographical references (auxometric tables, management plans, etc.) usually refer to optimal conditions, in which the treatments are performed with evenness, and in specific cases, it is preferred to provide a rough indication of what it could be extractable by the size of the mass cultivation, without details of the production of single-cut forests.

Extrapolation of the data from auxometric tables derived from National Forest Inventory of the main species shows that obtainable biomass from cultural practices could be estimated in between 2,044 to 3,749 m^3 (average 2,897 m^3).

11.4 Other wooded lands

In addition to the 543,885 ha of wooded land, there are 61,974 ha of forestland that Italy's Forest Service classifies as "other wooded land." This "other" forestland has low productivity due to site conditions or a variety of factors that adversely affect tree growth.
Current harvests from other wooded lands (OWL) are not reported to statistics.

The bio-technical potential may be calculated based on the net annual increment (average: 2,90 m^3 ha^{-1}) per ha and multiplied by the area of OWL reported by official figures, the total increment is 179,725 m^3. Since the reference in this study is calculated below bark, 12% of were deducted for bark (or country values), as well as 10% for harvest losses. The bio-technical potential may be estimated in about 140,185 m^3. Assuming that 78% of the additional available bio-technical potential could be mobilized, the bioenergy socio-economic potential of OWL in Lazio may be estimated in between 72,510 m^3 and 207,861 m^3 (average 140,185 m^3).

12. WOODY BIOMASS FROM OUTSIDE FOREST

Trees outside forest include forest trees that are present on lands which do not fit in the definition of forest since they do not reach the minimum parameters to be a forest (less than 20 m in width and 0.5 ha in area). Outside forest includes scattered trees in permanent meadows and pastures; or group of trees or trees in lines along roads, railways, rivers, streams and canals. As suggested by Corona et al. (2009), the standards for identifying the trees outside forests are the followings:

- small woodlot: group of trees with and area between 500 e 5,000 m^2 and width less of 20 m;
- line forest trees of at least three plants having a width between 3 and 20 m and a length of at least 20 m (INFC, 2008);
- scattered trees: all forest trees not included in small woodlot and line forest (hedgerows and forest tree windbreaks).

Trees outside forest are a constitutive element of traditional Italian agricultural landscape. The intensification of agriculture and mechanization of farming operations have led up to strong contraction of these formations, especially in lowland areas. In recent years, thanks to an active policy of some regional and local governments and the use of EU funds, several linear plantations or small woodlots have been restored or established. This is also the case of Lazio, where the Regional Government has launched a measure to support restoration or establishment of woodlots and linear forests (http://www.agricoltura.regione.lazio.it/binary/prtl_psr/tbl_bnd_bandi/Allegato_alla_DGR_n.369_del_2_settembre_2011_Bando_Misura_216_pdf).

Outside forest is an important source of wood for fuel (not necessarily stem wood, but woody biomass from shrubs and trees), mostly used as a supply of firewood for domestic use.

Many studies carried out in the last years show much higher estimates of both fellings and increment of woody biomass outside the forest.

Despite having a great interest, not only for the provision of wood and other goods, but also for the diverse ecological services delivered, data and quantitative information on extension of outside forest are scarce and fragmentary. Data and information about extent of small woodlots and windbreaks are sourced by ISTAT while the other silvicultural metrics (namely net annual increment and fellings) are sourced by the INFC. The reference for the extent of both small woodlots and windbreaks is relatively aged, as such not really consistent, but still is the only data available, acceptable enough for giving an indication of the order of magnitude.

12.1 Windbreaks and forest tree lines

The biomass available in the category "outside the forest" is mainly composed of windbreaks and forest tree lines that are characterized by trees or shrubs that do not constitute a predominantly linear forest.

Data referring to the extent of trees outside forest are reported by ISTAT. This should give a broad indication about orders of magnitude. However, substantial volumes might be missing, since data regarding hedgerows and roadside greening for example are not available.

12.1.1 *Current harvest*

According to the 2010 agricultural general census (ISTAT) in Lazio the number of farms characterized by the presence of windbreaks and forest tree lines is 16,592, about 7 % of the entire national territory. According to less recent estimate (ISTAT, 1997 Section VI, environment and territory of the survey on the structure and production of agricultural holdings), the total size of windbreaks and forest tree lines for the Lazio region was estimated up to 5,773 Km. No official data are available for wood harvesting and removal from the category.

12.1.2 *Bio-technical potential*

The bio-technical potential is calculated based on the net annual increment which was reported to INFC, and multiplied with the figures of area of OWL. Since the reference in this study is calculated below bark, 12% were deducted for bark (or country values), as well as 10% for harvest losses. The total size of the whole windbreaks and Forest Tree Lines for the Lazio region was estimated up to 5,773 Km. Assuming that the average density of a hedge is around 1 stump every 2-3 meters and that the average production of 100 linear meters of hedge can vary from 5 to 8 tons of fresh matter per year (Serafin, 1997), for the Lazio region the estimated production is about 288,650 m^3.

12.1.3 *Socio-economic potential*

The average biotechnical production of windbreaks and forest tree lines as estimated here is about 288,650 m^3, or 173,190 odt assuming a basic wood density of 0.6 t/m^3. Assuming that part of the production available for these formations is used to support agricultural activities (poles) and only 60% is used for energy, and considering the obstacles and limitations (accessibility, protection, economy and market, technical, policy) the socio-economic potential is about 81,053 m^3, or 48,632 odt (Table 7).

12.2 Small woodlots

Trees outside forest include forest small woodlot, group of trees with a unit surface area less than 5,000 m^2. The extent of this kind of forest types in Lazio amounts to about 852 ha.

12.2.1 *Current harvest*

No data are available

12.2.2 *Bio-technical potential*

The bio-technical potential estimated is based on the net annual increment which was reported to the INFC, and multiplied with the figures of area of OWL reported above here. Assuming a productivity of about 3.2 m^3 ha^{-1}, the bio-technical potential may be estimated in about 2,726 m^3 (Table 7).

12.2.3 *Socio-economic potential*

Assuming that only 60% of these formations is used in agriculture for energy, the biomass potentially available is approximately 982 t. Considering the obstacles and limitations (accessibility, protection, economy and market, technical, policy) the disposable production is 609 tons and the potential is 0.001 Mt (Table 7). The total biomass potentially available from outside forest is about 81,818 odt.

Table 7 - *Woody biomass from outside forest*

Outside forest	Extension	Productivity per unit (m^3)	Biological Potential (m^3)	Productivity (odt)	Escluding poles	Socio-economic Potential	Productivity (odt)
Hedgerows (km)	5773	50,0	288650	173190	103914	81052,92	48631,752
Woodlots and scattered trees (ha)	852	3,2	2726	1636	982	766	459
Total	-	-	**291376**	**174826**	**104896**	**81818**	**49091**

12.3 Short-rotation forestry plantations

A significant contribution to the availability of wood for energy in Lazio, as well as in other regions of Italy, could derive from Short Rotation Forestry, or SRF, the practice of cultivating fast-growing forest tree species 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, relying on coppice regeneration.

In literature many definitions have been used to identify SRF: short-rotation woody crops, short-rotation intensive culture, short rotation forestry, intensive culture of forest crops, intensive plantation culture, biomass and/or bioenergy plantation culture.

In Italy, the expression used for SRF is "*Selvicoltura a Breve Rotazione*" or "*Cedui a Turno Breve*" (Mughini et al., 2007). The concept has evolved over the years. Now it can be meant as a forest plantation at a tree density between 1,100 and 16,000 plants/ha and coppiced from 1 to 5 years, with a length inversely proportional to the planting density. The duration of the planting is provided up to a maximum of 15-20 years. The biomass produced by a 1- or 2-year rotation may be used only to produce energy, because of the high content of bark, including that of 2- or 3- year of industry panels. With the biomass produced in 5 years the options for the farmers are greater: the portion of the stem up to 10 cm in diameter at the upper part may be allocated to the paper mills and the remaining part for producing boards or for energy, depending on the respective market prices (Frison, 1974; Frison, 1975; Frison, 1980; Paiero and De Battisti, 1984; Facciotto and Mughini, 2003).

In the period 2009-2010 about 7,000 ha of SRF plantations have been established in Italy, mainly due to EU funding. Large part of the SRF acreage is located in the northern Italy and especially in the Po Valley and Friuli's lowlands. A few hundred hectares are reported to be located in Southern Italy (Boccasile, 2007; Salvati et al, 2007; Verani and Sperandio, 2008).

However the launch of a large-scale plantations program is problematic, as quoted by Pellegrino et al. (2014).

This section of the report concerns the evaluation of wood biomass from SRF produced annually in Lazio that can be used for the production of sustainable energy.

The estimate was achieved through an empirical model, using available data and information obtained from the literature.

The estimate of the productivity of woody biomass required the comprehension of three elements described below:

- the extension of the area, actual and potential, that can be used for SRF plantations;
- the average wood density of the species used
- the net annual increment (NAI) of wood for energy production. In this study, is considered a value of 21 m^3 corresponding to the weighted average- NAI of the four taxa (Ailanthus altissima, Eucalyptus spp., Populus spp, Robinia pseudoacacia) identified for SRF in Lazio Region (Table 8).

The extension of areas for SRF was estimated by geoprocessing analysis (Geographical Information System - GIS) using the data of Corine – Biotope (ISPRA, 2009).

For the aims of this analysis, the Community importance habitat, the protected areas and the Natura 2000 Network sites were excluded. Table 9 shows the selected habitats.

Table 8 - *Characteristics of selected species for the cultivation of SRF*

CHARACTERISTICS		*Ailanthus altissima*	*Eucalyptus*	*Populus*	*Robinia pseudoacacia*
Climate	Pedoclimatic belt	humid mediterranean, humid submediterranean, montane	humid mediterranean, humid submediterranean	humid mediterranean, humid submediterranean	humid mediterranean, humid submediterranean
	Precipitation (mm)	14/4010	300/400*	700	>800
	Temperature (°C)	13.8-25.5	12-18 resistant up to -6 °	8.5-17 do not tolerate dry season of more than 1-2 months****	10-17
Soil	Depth (cm)	72	20-50	50	30
	PH	4.9-7.5	4.5-8**	5.5-7.5	≈6
	Composition	clay, sandy, silty, mixed soil and in low fertility soils	various, including peaty or clay soil with the presence of chloride***	ex-sandy and clay soil with calcium concentration of 6% max	various, excluding land extremely dry, sandy or asphyxiated
Productivity	Net annual Increment - NAI (t/year)	15	15	22	18

* for the E. *globulus subsp. bicostata* the average annual precipitation must be at least 700mm

** *the Eucalyptus camaldulensis* prefers a pH that varies between 4.5 and 8 while the *Eucalyptus globulus* a pH between 5 and 7.5 http://ecocrop.fao.org/ecocrop/srv/en/dataSheet?id=14054)

*** the E. *globulus subsp. bicostata* prefers sandy soils and ex-sub-acidic or neutral pH

**** the P. *canadensis* e il P. *alba* tolerate temperatures up to -20 ° C, while P. nigra and P. tolerate respectively up to -28 to -30 °C

Table 9 - *Selected habitats for localization of SRF*

CORINE Biotopes Code	EUNIS Code	Habitat	Description	Altitudinal belt
34.81	E1.61	Mediterranean subnitrophilous grass communities	Subanthropic graminoid formations that cover vast expanses of post-cultural or extensive pasture lands	Coastal, lowland, hilly
38.1	E2.1	Permanent mesotrophic pastures and aftermath-grazed meadows	Regularly grazed mesotrophic pastures of Europe, fertilised and on well-drained soils and post-coltural mesotrophic grasslands	Hilly, montane
82.1	I1.1	Intensive unmixed crops	Cereal and other crops grown on large, unbroken surfaces in open field landscapes	lowland, hilly
82.3	I1.3	Arable land with unmixed crops grown by low-intensity agricultural methods	Traditionally and extensively cultivated crops, in particular, of cereals, harbouring a rich and threatened flora of field weeds	Lowland, hilly, montane

Generally, it is specified that, the estimate of the productivity of the wood is conditioned by the site conditions (soil and climate) and by the forest management and by the harvesting operations.

12.3.1 *Current harvest*

According to the literature (Bianco and Ciccarese, 2013), the current used surface for SRF is about 80 hectares (0,01% the cropping area in Lazio). Assuming that, the NAI - weighted average of 21 $m^3\ ha^{-1}\ yr^{-1}$ and the wood density of 0.4 t m^{-3} the production is about 1,680 m^3 and 672 t (Table 12).

12.3.2 *Bio-technical potential*

The sustainable bio-technical potential of wood removal, was estimated as the product of the NAI and cropping area (EEA, 2013). The cropping area is the total potentially soils that could be used for energy purposes (Table 9) in Lazio: uncultivated and agricultural habitats and disused habitats affected by past agricultural practices and characterized by a very high human pressure according to the "Carta della Natura" (ISPRA, 2009).

Assuming that the potentially surface for energy purposes in Lazio is about 637,904 ha and considering the value of NAI and basic wood density, the total productivity of wood is 13,395,984 m^3 and 5,358,394 odt (Table 10).

12.3.3 *Socio-economic potential*

The socio-economic potential, the most objective and realistic, was quantified considering the production of wood that may be generated from the concretely usable areas for the plantations of SRF. To estimate this potential was quantified the areas corresponding to habitat 38.1 and the "buffer zones7" located in the all habitats mentioned in Table 9.

These areas of about 10,131 ha (1.58% of the cropping area in Lazio) would be suitable for a supply basin of wood for the production of energy generating so productivity of a local biomass equal to 212,756 m^3 and to 85,102 t (Table 10).

Table 10 – *Productivity of SRF in Lazio: current, bio-technical, socio-economic potential*

Potential	**Surface (ha)**	**NAI (m^3 ha^{-1} yr^{-1})**	**Productivity (m^3)**	**Productivity (t)**
Current	80	21	1,680	672
Bio-technical	637,904	21	13,395,984	5,358,394
Socio-economic	10,131	21	212,756	85,102

[7] According to the provisions of DM n.27417 of 22 December 2011 the buffer zones are the areas of width 5 meters that line the waterways.

13. MAIN RESULTS AND RECOMMANDATIONS

Main results of the study aimed at quantifying the biotechnical and socio-economic potential of Latium's forest and out of forest resources are shown in table 11. We estimated the potential of sustainably supplying about 1,075,053 m^3 of wood, equivalent to 573,690 odt of wood.

This amount equals 203,911 tons of oil equivalent (toe), which is about 2 percent of the region's final energy consumption. The estimate includes: the residues generated by logging residues from high forest stands; fuel-wood removals from coppiced forests; wood generated by cultural practices such as thinning and pruning in forest plantations; woody biomass from outside the forest (other wooded land and trees outside the forest); short-rotation plantations. About 60 percent of this potential is currently being utilised and there are significant efforts under way to use these resources much more efficiently.

Current circumstance represents a major momentum for the forestry sector to find new roles and to contribute to the security of energy supply and to the mitigation of climate change by replacing fossil fuels and by sequestering carbon in forests and in forest products, as well as to produce local energy and to stimulate economic growth.

The utilization of a significant amount of these biomass resources would also require a concerted research and development effort to develop technologies to overcome a host of technical, market, and cost barriers. Demonstration projects and incentives (e.g., tax credits, price supports, and subsidies) would be required. Additional analyses would be required to discern the potential impact that a more extensive wood removal and production of woodfuel from SEF stands could have on traditional markets for forest products and on environment and landscape.

The main factors driving the increase in Latium's dendro-energy potential are productivity increases and the additional area available for dedicated short rotation forest plantations. However, unless the correct incentives and safeguards are put in place to mobilise the potential in an environmentally-friendly way, even a significantly lower exploitation of the biomass resource than projected could lead to increased environmental pressures, especially if sites are severely disturbed. The impact of erosion and consequent movement of sediments into surface waters is a particular concern. (However, studies suggest that there is often a much higher flow of sediments into surface waters as a consequence of wildfires than as a consequence of fuel treatment thinning operations.)

More cost-effective fuel-wood treatment operations and recovery of logging and other removal residue will require the development of more efficient and specialized equipment that can accommodate small-diameter trees. The availability of more efficient equipment will make the recovery of biomass for bioenergy and bio-based products much more cost-effective.

To ensure that dendro-energy production develops in an environmentally-compatible way and to further explore co-benefits with nature conservation, environmental guidelines need to become an integral part of planning processes at the regional level. This is particularly true in the case of programming SRF plantation establishment. The national Biomass Action Plans (as proposed in the recent EU Biomass Action Plan) could be a first step in this direction. Furthermore, wider involvement of stakeholders (policy-makers, local governments, businesses, researchers, NGOs and consumers) in participation processes is essential.

Strategies for the development of woody biomass-based energy should recognize the place of all actors, including in particular the existing forest-based and related industries, and the role that forestry and the forest-based and related industries can play in fulfilling these strategies. Regional development plans and programmes should be used in particular to facilitate small and medium enterprises (SMEs), including forestry contractors. Empower forest owners to form "clusters" and improve wood supply capacities, by co-operation and servicing professional units (consortia).

Governments, academic institutions and professional bodies should address education, training and awareness-raising of forest owners, forest work force, small and medium enterprises in forest operations and energy consumers, with regard to expertise and entrepreneurship. Governments, the research community and industry should stimulate knowledge development, identification and transfer, as well as innovation. The following points should be considered when developing wood energy policy at the national level:

- policy processes should address bioenergy as a cross-sectoral issue and integrate energy into forest, agriculture and other land-use policies.
- policy processes should involve adequate consultation and analysis of environmental, economic and social impacts in the context of specific regional, national and local conditions.
- information flow to forest owners, tenure holders, the general public and consumers should be improved to support informed decisions about management of forest resources.
- policy processes should consider rural employment, environment protection, land-use management, the forest products sector and other relevant areas to tap possible synergies and avoid negative impacts.
- policy should provide broad support for facilitating bioenergy development including education and training, research and development and through transport and infrastructure measures, and not only incentives to producers, distributors and consumers.
- policy processes should strive to create an appropriate balance between agriculture and forestry, as well as between imported and domestic biomass sources. Contingencies should also be taken to avoid competition with food production.
- The impacts of bioenergy policy on other economic sectors should be considered to avoid creating market distortions.

Governments should verify that strategies and legislation outside the forestry sector do not have a negative effect on wood mobilization for bioenergy.

Policies should be monitored regularly and systematically to avoid negative impacts on the environment and rural communities.

Transfer of energy- and resource-efficient technologies for wood-based bioenergy will be of considerable importance in achieving the bioenergy development.

Table 11 - *Summary table of Lazio forests' energy potential by different sources*

		Current use			Bio-technical potential			Socio-economic potential		
		wood			wood			wood		
		m^3	odt	toe	m^3	odt	toe	m^3	odt	toe
A	**Woody biomass from forest**	617,436	370,462	119,103	1,043,525	625,825	228,245	886,857	471,410	171,028
1	Wood for fuel from coppices	607,424	364,454	117,172	994,393	596,636	191,818	742,863	445,718	143,298
2	Logging residues from HF	10,012	6,007	1,931	46,236	27,741	8,919	41,612	24,967	8,027
3	Cultural practices on planted forests	0	0	0	2,897	1,448	466	1,448	725	233
4	Other wooded land	0	0	0	140,185	84,111	27,042	100,933	60,560	19,470
B	**Woody biomass from outside forest**	1,680	0	270	504,132	281,204	90,407	188,196	102,280	32,883
5	Woodlots and scattered trees	0	0	0	2,726	1,636	526	766	459	148
6	Hedgerows	0	0	0	288,650	173,190	55,681	81,053	48,632	15,635
7	Short-rotation plantations	1,680	840	270	212,756	106,378	34,200	106,378	53,189	17,100
Total		**619,116**	**370,462**	**119,373**	**1,547,657**	**907,029**	**318,652**	**1,075,053**	**573,690**	**203,911**

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