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FOREST BIOMASS FOR BIOENERGY: OPPORTUNITIES AND CONSTRAINTS FOR GOOD GOVERNANCE. A CASE STUDY FROM ITALY

Interest in the use of biomass for energy has increased significantly in the last few years. The latest report by the Intergovernmental Panel on Climate Change highlights the influence mankind has had on the climate: an unprecedented increase in GHG levels in the last 800,000 years and a rise of 40% in CO_2 concentrations since pre-industrial times. The challenge now is to find energy alternatives, and in this context, one important option is bioenergy, one of the most important energy sources of the future. In light of this, the goal of this paper was to assess the sustainable potential of woodfuel resources in Italy using WISDOM methodology. WISDOM, developed by the FAO, has been applied in many countries around the world. From this study, at national level, household consumption was at 19.3 Mt in 2003 (average value), while the potential supply of woody biomass (productivity) was 24.9 Mt (average value), with a surplus of almost 6 million tons between household consumption and productivity. This study represents an advance in knowledge of the biomass potential for energy use in Italy, and, as such, is subject to possible future improvement. Forest bioenergy development creates good opportunities to mobilize the production potential of European forests, and to contribute to a more climate-friendly, bio-based economy.

Keywords: Biomass estimation, WISDOM, SFM, climate change, GHG

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Introduction

Over the last few years, the interest in climate-policy-related questions and the use of biomass for energy has increased greatly, due to its potential for fossil fuel replacement and for forest product diversification [Lamers et al. 2013]. The forest biomass also has a very important role within the global carbon balance, and its utilization is influential in the mitigation of climate change [Fiorese, Guariso 2013].

The latest report by the Intergovernmental Panel on Climate Change [IPCC 2013] gives prominence to human influence on the climate system and highlights how the atmospheric concentration of carbon dioxide, methane, and nitrous oxide has increased to unprecedented levels in the last 800,000 years. In this report, four scenarios for future emissions and projections of climate change have been generated, namely RCP8.5, RCP6, RCP4.5 and RCP2.6. The RCP8.5 scenario corresponds to the baseline where no direct action for the mitigation of climate change has been set, while the other scenarios have targets for mitigation that should be reached by the end of the century, with forcing levels of 6, 4.5 and 2.6 W/m^2 [Masui et al. 2011; Thomson et al. 2011; van Vuuren et al. 2011]. The baseline scenario is of a continuously increasing global population to the tune of approx. 12 billion by 2100, with slow economic development and little progress in terms of efficiency. This context would lead to high-energy demands. The RCP 8.5 represents the highest RCP scenario in terms of Greenhouse Gas (GHG) emissions [Riahi et al. 2011] and would lead to a temperature increase from 4 to 6.1 degrees with respect to the pre-industrial era.

Mitigation scenario RCP2.6 would need to decrease substantially in order to demonstrate a considerable improvement in energy efficiency, fossil fuel replacement and an increase in renewable energy and nuclear power [van Vuuren et al. 2011]. RCP2.6 is the scenario virtuous of "green" conversion where the temperature should increase within a range of 1.3–1.9 degrees from the pre-industrial era. Between these, there are two other scenarios (RCP4.5 and RCP 6.0) with an intermediate hypothesis. According to the above-mentioned scenarios, the goal is to remain below 420 ppt of CO_2 by the end of the century, although the Global Monitoring Division of NOAA/Earth System Research Laboratory describes the target as ambitious.

Presently, the mean carbon dioxide concentration is more than 390 ppt with respect to 280 ppt in the pre-industrial era [NOAA]. The source of anthropogenic emissions has increased by 40% from 1920 until the present day, both for fossil fuel emissions and for net land use change emissions [Quéré et al. 2012].

Land Cover and Land Use Changes (LCLUC) are an important factor in environmental alterations [García-Ruiz et al. 2011], they are significant both within the global carbon budget [Houghton et al. 2012] and in the supply of/demand for biomass for bioenergy. From 2000 to 2009, anthropogenic carbon emissions due to LULCC were 12.5% of the total [Friedlingstein et al. 2010], taking into account the switch from fossil fuels to renewable energy such as wind, hydropower, biomass and solar power.

This high percentage challenges humankind to enhance the use of renewable energy, especially bioenergy from forests [Schulze et al. 2012].

Globally, forests represent a significant carbon stock and their management influences the carbon cycle, although according to Nabuurs et al. [2013] the first signs are visible of carbon sink saturation in European forests.

However, managed forests can provide valuable feedstock for energy production, though harvesting operations produce a variety of changes to the forest structure and ultimately to biodiversity [Fiorese, Guariso 2013].

The forest biomass is considered a renewable energy source, which is almost carbon-neutral, as the carbon balance is approx. zero between the atmospheric carbon sequestered during growth and its release to produce energy while burning [Lattimore et al. 2009]. Within the carbon balance, it is essential to consider the whole Life Cycle Assessment (LCA) of biomass, as fossil fuels are needed for harvesting operations and a decrease in the standing volume of the forest should be taken into account [Schulze et al. 2012]. The substitution of fossil fuels for biomass avoids GHG emissions to the atmosphere, in addition to the creation of carbon stock in wood products [Fiorese, Guariso 2013].

In Europe, the Renewable Energy Directive (RED) established a target of 20% renewable energy to be reached by 2020 through the adoption of national action plans for renewable energy, which are compulsory for Member States [EU]. Bioenergy represents a great opportunity to mitigate GHG emissions in the short and medium term. Beringer et al. [2011] estimate that 15–25% of global primary energy could come from bioenergy in the year 2050.

Furthermore, the RED directives define sustainability criteria for liquid bio-fuels, which in turn could be linked to criteria for solid bio-fuels.

Considering the biomass potential available, biomass from forests will be among the most important energy sources of the future [Ciccarese, Oriani 2013] and it will be the largest fuel used in Europe in its various forms with various advantages, one being that it is continuous energy and always available [Economist, 6th April 2013].

The question and the challenge nowadays is to understand if biomass is carbon neutral, what its impact on climate change and the environment is, and, above all, how to mobilize the biomass from our forests [Muys et al. 2013].

Forest bioenergy development creates a good opportunity to mobilize the production potential of European forests, and to contribute to a more climate-friendly, bio-based economy. However, this development also holds risks, such as the possible competition for feedstock with the traditional forest industry [Muys 2013].

In light of this, the aim of this paper was to assess the sustainable potential of woodfuel resources in Italy, to improve the understanding of the role currently played by Italian forests and other woody biomass sources, and of their potential as a renewable energy source and in GHG emission reduction. The study was based on the information available throughout the country, using WISDOM methodology.

Materials and methods

In this study, WISDOM (Woodfuels Integrated Supply/ Demand Overview Mapping) methodology was applied. The WISDOM approach has already been applied in Slovenia [Drigo 2004a], Senegal [Drigo 2004b], East Africa [Drigo 2006], Southeast Asia [Drigo 2007], and Mexico [Ghilardi et al. 2007] and was developed by the FAO, in cooperation with the Center for Ecosystem Research at the National Autonomous University of Mexico (UNAM). This methodology combines a geo-database with statistical data on woodfuel production and consumption, integrating forestry, energy and socio-economic data and information.

The study area was analyzed using a Geographic Information System (GIS), producing an estimate of net balance between supply and geographically-localized demand.

The method to estimate the potential of woodfuel resources in Italy comprised the following five steps:

1. Definition of the cartographic base for analysis and data collection of the necessary layers.
2. Development of the demand module.
3. Development of the supply module (potential and current).
4. Development of the integration module between supply and demand for production of the geo-referenced net balance.
5. Identification of priority woodfuel hotspots.

The analyses were carried out at the lowest administrative level for which demographic, social and economic parameters were available, namely the municipality.

The data sources used for this constituted a layer of 8,095 municipalities, 103 provinces, 20 regions and, for some variables, it was necessary to use a raster approach on a 300 × 300 meter grid (pixels). The national territory was covered by 3,356,451 pixels in this resolution.

Demand module

In this study, the demand for woodfuel was related to household use only. The two sources of information taken into account in the demand estimation were from ISTAT (the Italian National Institute of Statistics) and ENEA (the Italian National

Agency for New Technologies, Energy and Sustainable Economic Development). ISTAT publishes statistical data on forestry related to wood harvested for energy purposes, while in 1997 and 1999 ENEA published data on biomass consumption for energy use, based on sample surveys by telephone interviews (6,000 interviews per year) [as cited in Gerardi et al. 1998; Gerardi, Perella 2001].

The consumption of household wood fuel estimated by the two information sources is very different: ISTAT's data reported approx. 4.4 million m^3 (equal to 3.26 Mt considering an average humidity of 20% and an average wood basal density of 600 kg m^{-3}), while ENEA's data reported 21.6 Mt in 1997 and 14.7 Mt in 1999. Hellrigl [2002] reported that the real value of consumption between 1997 and 1999 was between 16 and 20 Mt per year.

Consumption in the residential and industrial sectors was estimated according to three different scenarios: 1) an estimate of the maximum values extracted by ENEA data [1997]; 2) an estimate of the minimum values extracted by ENEA data [as cited in Gerardi, Perella 2001]; 3) an estimate of the intermediate values extracted from the average of the previous values.

For each municipality the degree of urbanization, the altitude zone according to the Statistical Atlas of Municipalities [ISTAT 2006] and the number of households were determined. Based on these data, the annual average consumption per household was identified for the three scenarios (fig. 1).

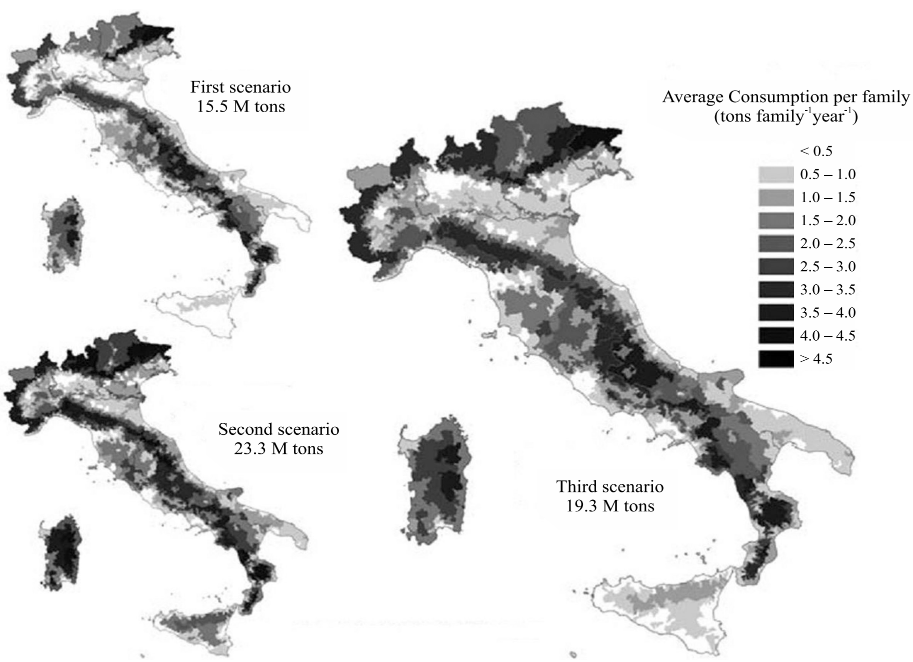

Fig. 1. Average annual household consumption of woody biomass for energy use per family in Italian municipalities within the three scenarios defined

Supply module

The estimated supply of woodfuel for each of the 8,095 municipalities considered was calculated from the potential total productivity of woodfuel for categories of land cover weighted attentively considered the accessibility level of the area under analysis. This land cover dataset was derived from the Corine Land Cover level-IV Map (CLC2000). For each forest polygon in CLC2000, woody biomass productivity for energy use was estimated. The 1985 National Forest Inventory data were used to estimate the stock and productivity (min, med and max), as well as a literature review on biomass productivity [APAT 2003], and a yield table for coppice by Ciancio and Nocentini [2004].

The branch and crown volumes were taken into consideration for high forests and standard trees found in coppice stands, and they were estimated as a fraction of total dendrometric volume, equal to a range of values between 15 and 35% of the total [APAT 2003].

In the coppice forests, productivity was estimated on the basis of the coppice shoots present, while the biomass for energy use in chestnut coppices was estimated as a value equal to 50% of the total volume (for the production of poles). The coppice shoot productivity was estimated according to the national average volumes by species and forest inventory types [IFNI 1985]. The coppice rotation cycle was considered between 20 and 25 years.

In the productivity assessment, for biomass outside forests, reference values associated to the CLC2000 classes for crops and for poplars [APAT 2003] were used.

The productivity values for land use and land cover classes (CLC2000) used for the analysis, according to the MAF-ISAFA [1988], are shown in fig.1.

Fig.1 only shows the main forest classes (CLC codes) that as a whole, they cover globally more than 80% of the national forest area. The CLC forestry classes not shown within the graph have an average potential productivity between 1.7 and 4 tons per hectare per year. Non-forest classes, such as urban forestry and urban greening, heterogeneous agricultural areas and shrub vegetation areas, have an average potential productivity between 0.5 and 1.6 tons per hectare per year.

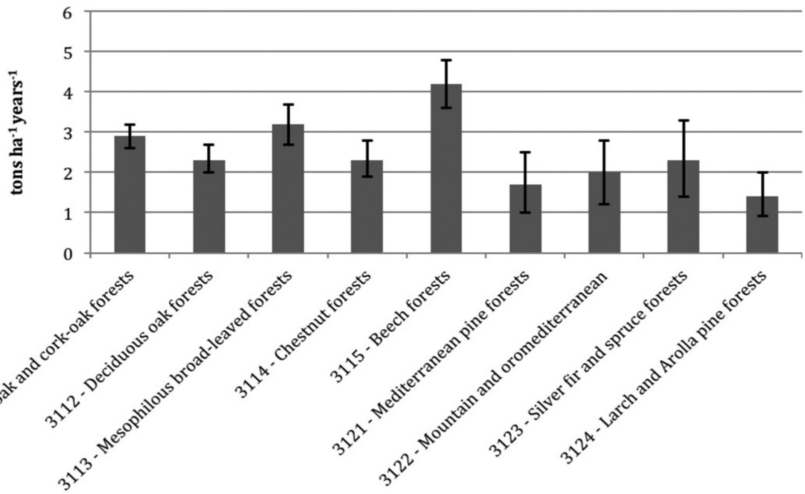

Fig. 1. Estimation of potential productivity at national level (minimum, average and maximum) of woody biomass for energy purposes according to the main forest CLC classes (tons ha^{-1} years^{-1})

Estimate of the limitations

The woodfuel supply capacity is dependent on physical factors limiting accessibility. The main aim of accessibility analyses is to relate woody biomass supply to population distribution [Millington et al. 1994; Top et al. 2006]. An estimate of accessibility was reached through an algorithm of cost distance [Eastman 1989] based on the distance from roads, distance from main residential areas and the slope of the land [Chirici et al. 2003].

The roads were derived from a vectorial geographical database containing a total of 168,499 km of different types of roads. In the model, road network was only related to asphalt roads and was therefore only a part of the road network [Hippoliti, Piegai 2000] useful for forestry purposes. Urban centers were derived from a vectorial database containing 59,700 units. The slopes map was derived from a Digital Terrain Model (DTM) with a 75 m grid.

Estimate of potential supply considering limitations

A supply and demand balance was estimated at municipality level through a raster data analysis. The vectorial data layer, with the values of potential productivity gross, was rasterized based on the raster grid reference with a 300 m resolution. At raster layer, the limitations map multiplied potential gross productivity. The result of this process was a raster map containing an estimate of the net potential productivity (fig. 3). This map was associated with the vectorial boundaries layer of the municipalities.

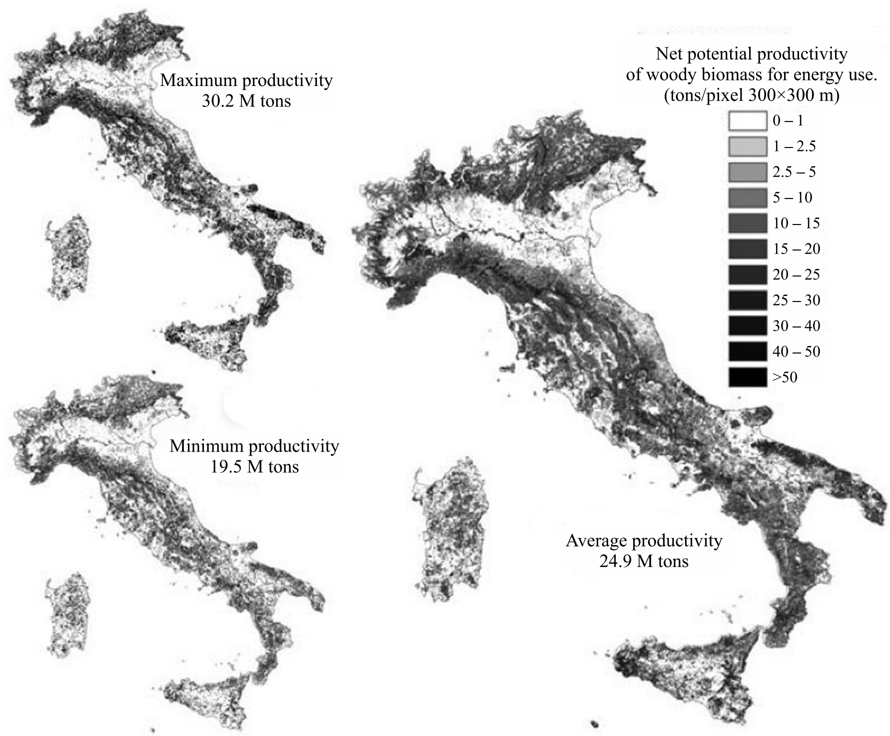

Fig. 3. Annual productivity potential of woody biomass for energy use. Minimum, maximum and average values for 300 × 300 m pixels

Results and discussion

At national level, the estimated demand for woodfuel for household consumption was between a minimum of 15 Mt and a maximum of 23.3 Mt, with an average value of 19.3 Mt in 2003. At regional level, the aggregate data showed a great variability of consumption with values from a minimum of 0.06 Mt to 3.25 Mt maximum. These variations can be ascribed to several factors, such as regional extension, the availability of other energy sources (i.e. methane), the population density and the local customs and traditions.

The data analysis highlighted the largest consumption in the Alpine and Alpine foothill areas, along the Apennine ridge up to the Calabria mountains, and in the mountainous areas of Sardinia, with values generally higher than 3.5 tons per family^{-1} per year^{-1} (fig. 1).

At national level, the potential supply of physically accessible woody biomass (productivity) for energy use ranged from a minimum of 19.5 Mt and a maximum of 30.2 Mt, with an average value of 24.9 Mt. Approx. 82% of woodfuel supply was provided by forestry production. At regional level, the aggregate data varied from a minimum of 0.11 Mt and a maximum of 2.9 Mt. In this case, the variability of the potential productivity was mainly due to regional extension, the forest coverage in the region and the biomass availability, bearing in mind limiting factors (i.e. accessibility). Fig. 3 shows the spatial distribution of potential productivity across the country. The figure identifies a large area called the Po Valley characterized by low productivity values due to the presence of arable land, currently unsuitable for biomass production for energy purposes.

At municipality level, by combining the values of the potential productivity and household consumption, the first maps on supply and demand balance were produced. Three different scenarios were produced, with the aim of highlighting the uncertainty level in the available data: 1) a minimum balance, given by the minimum productivity and maximum consumption; 2) a maximum balance, given by the maximum productivity and minimum consumption; 3) an average balance, given by the average productivity and consumption (fig. 4).

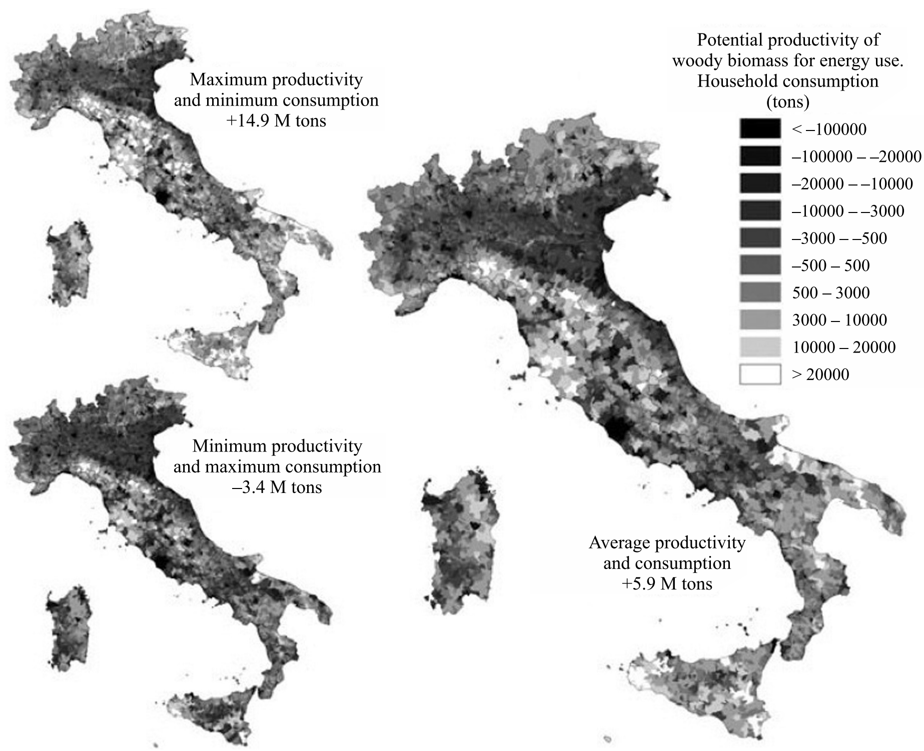

Fig. 4. Net balance between the potential productivity and household consumption of woody biomass for energy purposes

The balance at municipality level was divided based on elevation and urbanization zones allowing characterization of the supply and demand balance in Italy. Fig. 5 shows the regional values for the average scenario balance while Table 1 shows the balance between the average productivity potential and average household consumption at national level, according to elevation and urbanization zones.

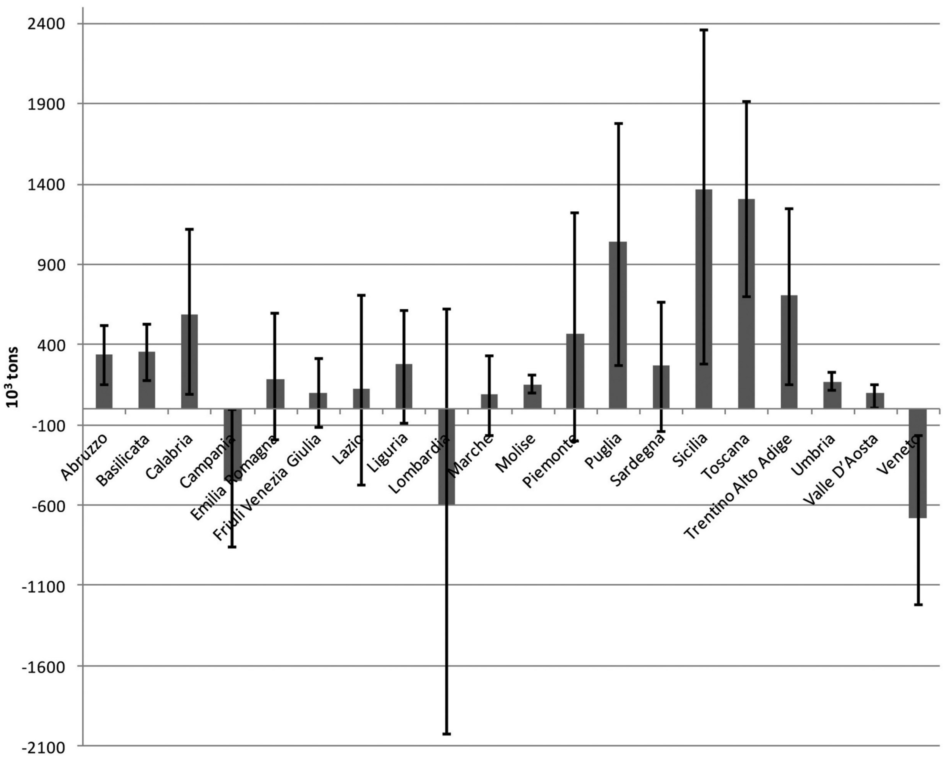

Fig. 5. Minimum, maximum and average values per district of annual balance between average potential productivity and average household consumption

In Italy, in average conditions of consumption and productivity, there was a surplus of almost 6 million tons localized predominantly in the inland mountainous and hilly areas with low urbanization (table 1), while in the minimum scenario there was a deficit of 3.4 Mt and in the maximum, a surplus of almost 15 Mt (Fig. 3).

Table 1. Balance between the average productivity potential of sustainable biomass for energy and average household consumption per degree of urbanization and elevation (10^3 tons)

Urbanization	Inland mountain	Coast mountain	Inland hill	Coast hill	Flatland	Total
Low	5740	122	2000	741	-39	8565
Average	-169	-3		210	-318	-280
High	-89	-201	-506	-593	-980	-2368
Italy	5483	-81	1493	358	-1337	5916

The analysis of the regional totals in the average scenario showed that all the regions were potentially self-sufficient with the exception of Veneto, Lombardy and Campania, which had a negative balance, equaling 0.7, 0.6 and 0.45 Mt, respectively.

Conclusions

The Methodology applied on a national scale should not replace studies and investigations on woodfuel demand and supply on a local scale but should support a higher level of planning by directing policy in the bioenergy sector. Combined with other energy planning tools, the WISDOM approach could help in the design of robust policies and actions that are more effective.

The main goal of the WISDOM approach is to evaluate the use of woody fuel for energy production in a sustainable manner, and to be a point of departure for strategic planning and policy [Masera et al. 2006].

This study represents an advance in knowledge of the biomass potential for energy use in Italy, and, as such, is subject to possible future improvements. The woody biomass chain can contribute to local development in terms of environmental benefits, in employment opportunities [Lasserre et al. 2011] and in the creation of products for local trade. Wood harvesting for energy purposes can be integrated into forest management activities (residues from others activities in forests e.g. thinning, logging) or can be the main objective of management activities (Short Rotation Coppice), although this could have some impact on the local ecosystem according to the scale, intensity and type of management system used [Lattimore et al. 2009]. The adoption of site-specific best management practices (or counter measures) can help reduce risks connected to soil productivity and biodiversity [Lamers et al. 2013].

Even the new 2013 EU forest strategy defines the importance of the products from forests, encouraging a cascading use of wood, LULUCF carbon accounting, the promotion of energy efficiency measures and biodiversity safeguards [Muys et al. 2013]. These are challenges for the whole forestry sector.

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