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ORIGINAL PAPER

Effects of bioenergy production on environmental sustainability: a preliminary study based on expert opinions in Italy and Turkey

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Abstract In future decades, initiatives on biomass-based energy development in Europe should reduce fossil fuel dependence and help to combat climate change as required by the conference of the parties 21. In this context, forest biomass can play a key role within the bioenergy sector due to its high growth potential. The use of forest biomass for energy has positive and negative effects on other ecosystem services, on stand characteristics, and on forest management practices. The aim of this study is to analyse the effects of forest bioenergy production on six ecosystem services (biodiversity, recreation, landscape aesthetics, carbon sequestration, soil erosion protection, water quality). These effects have been assessed by 80 experts in two countries (Italy and Turkey), considering two different forest management practices (clear-cutting of coppices and woody residue removal after felling in high forests). The results show that coppice clear-cutting has negative effects on almost all ecosystem services according to the experts' opinions. The highest negative effects are on landscape aesthetics and soil protection. The effects of woody residue removal on biodiversity, carbon sequestration, soil erosion protection, and water quality are considered negative by the experts, while the effects on recreation activities and landscape aesthetics are considered positive. The highest negative effects of this forest management scenario are on soil protection and biodiversity. The experts' opinions about the effects of forest management practices on ecosystem services can provide information to understand the environmental sustainability of bioenergy development in future years.

Keywords Forest biomass · Bioenergy · Forest management · Ecosystem services

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Introduction

During the conference of the parties 21 (CoP21) held in Paris in 2015, world leaders defined a global agreement to combat climate change with the aim to achieve neutrality of global greenhouse gas (GHG) emissions in the second half of the twenty-first century and to hold global warming below 2 °C relative to pre-industrial levels (Robbins 2016). In order to contrast the climate change, the European Union (EU) adopted the Climate and Energy Framework (2014) which sets three targets for 2030: at least 40% cuts in GHG emissions from 1990 levels, at least a 27% share for renewable energy, and at least 27% improvement in energy efficiency. To implement these ambitious targets, biomass-based energy (or bioenergy) can play a critical role, considering that in 2014 woody biomass was contributing 44% of overall renewable energy production in the EU member countries (Berndes et al. 2016). The Climate and Energy Framework (2014) is the last step of a political process initiated with the Green Paper (1996) which aimed to increase the proportion of renewable energy sources in the primary energy supply from 6 to 12% in the period 1996–2010 (Ericsson and Nilsson 2006), and continued with the target 20–20–20 of the Renewable Energy Directive 2009/28/EC (Klessmann et al. 2011). EU associate members,—e.g., Turkey—have a similar objective concerning energy policy and renewable energy development. In fact, the aim of Turkey's National Renewable Energy Action Plan (2014), prepared within the scope of Renewable Energy Directive 2009/28/EC, is to implement strategies for the development of renewable energy and reduce GHG emissions in the country (Ministry of Energy and Natural Resources 2014). The Plan also aims to increase the proportion of renewable energy sources in general energy consumption up to 20% by 2020.

Consequently, in the last several years initiatives on biomass-based energy development have grown in many European countries as a response to the increasing cross-cutting issues related to fossil fuel use (Farinelli 2004; Panichelli and Gnansounou 2008). In addition, the use of woody biomass for energy can increase the management of marginal forest areas (Grilli et al. 2015), create new green jobs (Grassi 1999), and reduce carbon dioxide (CO_2) emissions (Berndes and Hansson 2007). With reference to the latter aspect, the scientific community has highlighted the fact that bioenergy systems can have positive, neutral or negative effects on biospheric carbon stocks and consequently on climate change mitigation, depending on the bioenergy system's characteristics and the features of the location where the system is established (i.e., soil and climate factors, land use, vegetation cover). In particular, bioenergy based on tops and branches from silvicultural operations is typically found to contribute positively to short-term climate change mitigation, while the use of small trees and stumps does not contribute to net GHG saving in short- and medium-term periods (Berndes et al. 2016).

From a terminological point of view, bioenergy can be defined as energy derived from the conversion of biomass, where the biomass may be used directly as fuel or processed into liquids and gases (IEA 2016). Bioenergy is produced from organic matter such as crops, plants and waste material and it can be considered one of the key aspects of the EU Strategy for "Innovating for Sustainable Growth: A Bioeconomy for Europe" (EC 2012). Recently in Europe, bioenergy accounted for about 60% of total renewable energy (European Biomass Association 2013) and its importance is likely to grow in response to the EU countries' commitment to have a 27% contribution of renewable energy of the total energy consumption by 2030 (Nikodinoska et al. 2015).

Within the bioenergy sector, biomass from forests plays a key role as evidenced by the EU wood project (2010) that has estimated the EU's biomass supply would increase by 11% from 2010 to 2030 (Mantau et al. 2010). In this estimation, forest biomass is defined as all parts of the tree used for energy purposes such as ends and tops of trunks, cones, branches, twigs, bark, needles/leafs and the stems of small diameter trees. In addition, Beurskens and Hekkenberg (2011) have estimated an increase in the use of renewable biomass equal to 8% of the expected total increase in renewable energy in EU member countries by 2020. With special regards to Turkey, it is estimated that biomass energy production will reach 8205 kilo tons equivalent (ktoe) by modern and classical biomass technology by 2030 (Gokçol et al. 2009). In Turkey, biomass is a sustainable renewable energy source that will be used to meet future national energy demands (Gokçol et al. 2009).

Bioenergy production from forest biomass has positive and negative effects on ecosystem services (ES). However, few studies have investigated the effects (trade-offs and synergies) of forest biomass for energy use on other ES (Jarchow 2012; Meyer et al. 2015; Grilli et al. 2015; Hastik et al. 2015). The concept of ES was first proposed in 1981 (Ehrlich and Ehrlich 1981), and since then its use in the scientific literature has grown rapidly (Mooney and Ehrlich 1997; Vitousek et al. 1997). After two decades, the Millennium Ecosystem Assessment (MEA) (2005) defined ecosystem services as "outputs from ecosystems that benefit directly or indirectly humans and contribute to their well-being". Human well-being depends on ES because most are not replaceable by human-made substitutes, so their preservation and maintenance is a crucial challenge for the future (Briner et al. 2013; Hastik et al. 2015). Forest ES may be divided into four categories following the classification proposed by MEA (2005): provisioning services, regulating services, supporting services and cultural services. Provisioning services are the goods and raw materials that people get from ecosystems such as timber, biomass for energy, non-timber forest products (NWFP), and fresh water. Regulating services are the values people get from the regulation of ecosystem processes (e.g., air quality and climate regulation, erosion control, and water purification). Supporting services are those that are necessary for the production of all other ecosystem services such as primary production, pollination, production of oxygen and soil formation. Cultural services are the non-tangible benefits people get from ecosystems through spiritual enrichment, recreation and aesthetic experiences (Mavsar 2011). Subsequently, the Common International Classification of Ecosystem Services (CICES) has aggregated the regulating services and supporting services into a single category called regulation and maintenance services (Haines-Young and Potschin 2013).

The trade-offs and synergies between bioenergy production and other ES are influenced by forest systems (coppice or high forest) and silvicultural treatments (clearcutting, selective cutting, and thinning). During clearcutting, selective cutting and thinning, logging residues (branches, twigs, tops, small trees, and trees with low stem quality) are produced. Generally, in clearcutting and selective cutting, the primary product is timber, while biomass for energy purposes can be considered a secondary product (Verkerk et al. 2014; Eid et al. 2010). Conversely, during thinning, biomass for energy use is the primary product. Wood materials (primary or secondary products) can be either left in the forest to decompose (deadwood) or be extracted to produce bioenergy (Verkerk et al. 2014). The quantity of woody residues or dead trees removed from the forest is a strategic management decision because this can influence forest productivity and the provision of other ES (Schaich and Plieninger 2013; Pastorella and Paletto 2016). In addition, other forest management options—such as pre-commercial thinning, bioenergy thinning and short rotation forestry (SRF)—play an important role in wood biomass production for energy but with different effects on other ES. Pre-commercial thinning is a useful management option for cutting seedlings wherever narrow spacing and competing tree species limit growth (Lazdiņš and Thor 2009). Bioenergy thinning is similar to commercial thinning but with the purpose of cutting small-dimensional trees not yet economic for commercial thinning for pulp wood (Kellomäki et al. 2013). In pre-commercial thinning, the potential biomass is low, while in bioenergy thinning only small-sized trees are used for energy purposes. Both pre-commercial thinning and bioenergy thinning have minimum effects on other ES. SRF is the production of woody biomass for energy using fast-growing broadleaved species such as poplars, willows, sycamores and eucalyptus (Tognetti et al. 2013). These short-term cultivations have many positive effects on ES by increasing carbon sequestration, structural and biological diversity in open agricultural landscapes (Brockerhoff et al. 2008), but also negative effects by reducing soil fertility and nutrient recycling (McKay 2011).

Starting from these preliminary considerations, the aim of this paper is to analyse the effects of forest biomass production for energy use on six ES (biodiversity, recreation, landscape aesthetic, carbon sequestration, soil erosion protection and water quality) in two different forest management scenarios (clear-cutting of coppices and woody residue removal after felling in high forests). The effects of bioenergy production from forests on ES were assessed by experts in two countries (Italy and Turkey), with a high potential for bioenergy development in future years. The effects of pre-commercial thinning and bioenergy thinning on ES have not been considered in this study because these forest management options are rarely applied in Italy and Turkey for economic reasons.

Materials and methods

Study areas

According to the objectives established by EU Directive 2009/28/EC (target 20–20–20)—adopted in Italy with the D.Lgs no. 28/2011—the Italian National Energy Strategy aims at covering 17% of gross final energy consumption by 2020 with renewable energy. In order to achieve this target, local public administrations in Italy (i.e., Regions and Autonomous Provinces) are obliged to implement the Italian National Energy Strategy through the definition of Regional Energy Plans (REPs).

In 2011, when the D.Lgs n°28/2011 was adopted, the share of renewable energy sources in total energy consumption was 11.2%, while energy from biomass accounted for about 50% of energy consumption from renewables (Nikodinoska et al. 2015). Wood and wood residue based energy amounted for about 25% of the total with about 150 district heating plants located in Italy (European Biomass Association 2013). According to the National Renewable Energy Action Plan (2010), solid biomass should cover 8% of energy needs and 54% of the thermal needs by 2020 (Ministry of Economic Development 2010).

The setup of an optimal forest management regime purely for energy purposes, which includes use of suitable working methodologies and mechanization, could lead to higher wood availability. In this scenario, wood biomass, with special regards to forest biomass, has a high development potential in many Italian regions (Bernetti et al. 2004; Lasserre et al. 2011; Sacchelli et al. 2013). In addition, the potential role of the forest sector in the national bioenergy strategy was recognized by the Framework Programme on Forestry Sector (2008), which included in the key actions aimed to develop an efficient and innovative forestry, "the promotion and optimization of production and sustainable use of forest biomass"—Action 5 (Ministry of Agricultural, Food and Forestry Policies 2008). In particular, three concrete actions are encouraged by the Framework Programme on Forestry Sector: (1) the development of installations for forest enterprises for the production and sale of energy from biomass; (2) support for sustainable forest management (silvicultural treatments); and, (3) incentives for forest planning.

Currently, the forest sector plays a secondary role in national economic growth in Italy because forestry and forest industries contribute only 0.7% of the Gross National Product (GNP) due to the following structural weaknesses of the sector (Marongiu et al. 2012): (1) highly fragmented private ownership; (2) the declining value of the timber market; and, (3) the high costs of harvesting, with the consequent abandonment of active management of mountain forests. In future years, the forest sector could play a more central role in the supply of biomass in accordance with the Italian Bioeconomy Strategy (2016) and the REPs (Renewable Energy Plans).

In Turkey, renewable energy development is one of the national energy priorities because demand is growing rapidly as a result of social and economic development. In addition, energy consumption has been growing much faster than production. This situation makes Turkey an energy importer.

The main indigenous energy resources in Turkey are lignite, hydropower, and biomass (Gokçol et al. 2009). Turkey has potential regarding biomass resources, and the most important one used for energy production is forest residues. These include bark, roots, branches, leaves, and other logging residues (Türkoğlu and Gökoğlu 2017).

Biomass energy includes fuelwood, agricultural residues, animal wastes, charcoal and other fuels derived from biological sources. Biomass is used to meet a variety of energy needs such as heating homes, fueling vehicles, and generating electricity (Kaygusuz and Türker 2002). While the biomass potential of Turkey is approximately 32 Mtoe (million tons equivalent), the amount of recoverable potential is estimated to be approximately 17 Mtoe. Bioenergy production from forest residues is about 7 Mtoe. Furthermore, forest residues have a potential to meet about 2% of Turkey's total energy consumption (BAKA 2012). Wood for energy purposes is available in the form of fuelwood, wood waste, chips and pellets, and willow crops in short rotation forestry (Kaygusuz and Türker 2002).

The general directorate of forestry (GDF) is responsible for the sustainable management of forests. One of the main forestry policies is to meet demands for industrial wood and fuelwood sustainably. At the same time, the GDF aims to increase renewable energy sources using forest residues. The GDF has determined the strategies for meeting the raw material of biomass energy facilities to be established to obtain electricity and heat and continues to work on using energy production of forest residues in accordance with the 2nd decision of the Ministerial Conference on the Protection of Forests in Europe-2007 (GDF 2009). Forest residues are removed in order to reduce the threat of forest fires.

In recent years, forest enterprises use residues such as branches and cones as fuel (Alkan et al. 2014). Some enterprises are heated by wood chips produced from residues. In addition, electrical energy obtained by burning residues is used for the needs of forest villagers. Some enterprises produce wood pellets from residues for meeting the energy needs of the forest industry sector. Nevertheless, there are challenges such as high costs of collection, transportation, and storage of forest residues (GDF 2009).

Identification of experts

The effects of forest bioenergy production on ecosystem services (ES) were assessed by experts in both countries. The experts were identified in three main professional categories: professors and researchers employed in universities and research institutes; officials and managers employed in public administration and private forest enterprises; and consultants (freelance) in the forestry sector. The criteria used to identify and select the experts were: (1) expertise in the bioenergy sector from an economic, political and technical point of view; and, (2) considerable knowledge of forestry and energy issues.

The professors and researchers employed in universities and research institutes were identified on the basis of their publications (e.g., number of peer-reviewed articles, book chapters, and technical reports) on bioenergy or related topics. The publications were identified through a literature review using a set of keywords and synonymous in the main online scientific databases and search engines (e.g., Google Scholar, CAB Abstract, Research Gate, and Elsevier's Scopus). The consultants and the officials/managers in public administration and private forest enterprises were identified on past participation in programs, projects and actions on bioenergy or related topics. As a result, 53 Turkish and 59 Italian experts were identified.

Questionnaire survey

The data were collected through a structured questionnaire (Annex) administered by e-mail to the 112 experts. The reasons for using an e-mail survey are due to the main advantages of this administrative system (Sheehan and Hoy 1999): absence of time constraints, organizational problems and cost; ease and flexibility of responding; higher response rate than postal mail; and, the opportunity to identify and eliminate duplicate responses.

The final version of the questionnaire after the pre-test was formed by eight questions (one open-ended question and seven closed-ended questions), divided into three thematic sections: "personal information"; "clear-cutting of coppices"; and "woody residue removal after felling in high forests".

The four questions (Q1, Q2, Q3 and Q4) of the first thematic section ("personal information") focus on the organization (name) and personal information (profession, field of activity, work experience) of the respondent. In Q1 the respondents report the name of their organization. The professions included in the questionnaire (Q2) are: policy makers in a ministry or local public institution; forest managers and planners in a public administration (e.g., regional forest service) or private enterprise; researchers and academics in a university or research institute; and, freelance consultants in the forestry sector. With regards to the field of activity (Q3), the four activities (forest policy and economics; forest planning and management; ecology and nature conservation; water management) most linked to bioenergy were made in the questionnaire but respondents could indicate other activities. In the last question (Q4) of the first thematic section, respondents indicated the number of years that he/she worked in their field of activity, distinguishing between: < 2 years; 2–5 years; 6–10 years; > 10 years.

The first question (Q5) of the second thematic section ("clear-cutting of coppices") investigates the effects of clear-cutting coppices for bioenergy production on the six ES (first forest management scenario). The ES to be included in the analysis were identified through a brainstorming session during which the researchers involved in the project compiled a list of forest ES. Afterwards, the preliminary list of forest ES was reduced, keeping only the ES closely related to bioenergy production. At the end of this step, six forest ES (one supporting service, three regulating services and two cultural services) were selected and included in the questionnaire (Table 1). The respondents assessed the effects of clear-cutting of coppices on the selected ES using a 5-point Likert scale (from -2 = very negative to $+2$ = very positive). The second question (Q6) of this thematic section investigated in detail the effects of clear-cutting coppice on the different aspects of each ecosystem service.

The respondents assessed the intensity of the effects indicated in the Q5 for each ES aspect using a 3-point Likert scale (1 = high intensity, 2 = moderate intensity, 3 = low intensity).

The last two questions (Q7 and Q8) of the third thematic section ("woody residue removal after felling in high forests"), focused on the positive and negative effects of woody residue removal on the same six ES and the aspects considered in questions Q5 and Q6. For these questions, the respondents assessed the effects using a 5-point Likert scale (from -2 = very negative to $+2$ = very positive) and the intensity of the effects using a 3-point Likert scale (1 = high intensity, 2 = moderate intensity, 3 = low intensity). The removal of 100% of the woody residues (tops and branches) produced by cutting was considered in this management scenario.

Data analysis

For all the questions, descriptive statistics were developed using XLStat 2012: mean, median, minimum, maximum, and standard deviation for the data collected using the Likert scale (Q5, Q6, Q7 and Q8), and percentage of frequency distribution (%) for all other questions (Q1, Q2, Q3 and Q4).

In addition, the data were statistically compared using Mann–Whitney non-parametric tests to highlight the differences between the study areas (Italy and Turkey) and the group of experts (researchers/academics and decision-makers). The non-parametric Mann–Whitney U test compares two population means that come from the same population, and is based on the following assumptions: the sample drawn from the population is random, the samples are mutually independent, and the ordinal measurement scale is assumed.

Results

Characteristics of the experts

This study showed a response of 71.4% corresponding to 80 respondents out of 112. The response in Turkey was 75.5% (40 out of 53) while in Italy it was 67.8% (40 out of 59). Previous studies have shown response rates for e-mail surveys conducted with experts (professors, researchers, other university staff members, managers) were between 19.0 and 58.0% (Schuldt and Totten 1994; Schaefer and Dillman 1998; Weible and Wallace 1998; Balest et al. 2016).

The majority of experts involved are researchers and academics employed in universities and research institutes (68.8%) followed by forest managers and planners employed in public administration or private forest enterprises (16.3%), policy makers (6.3%) and consultants to the forestry sector (3.8%). The remaining 4.8% are experts in environmental and engineering science. The distribution of the sample of experts in the two countries is similar: 72.5% in Italy and 65.0% in Turkey are researchers and academics; 17.5% in Italy and 15.0% in Turkey are forest managers and planners; 5.0% in Italy and 7.5% in Turkey are policy makers; and 2.5% in Italy and 5.0% in Turkey are consultants in the forestry sector.

Considering the fields of activity, the majority of respondents are experts in forest planning and management (30.0%: 37.5% in Italy and 22.5% in Turkey), followed by experts in forest policy and economics (27.5%: 25.0% in Italy and 27.5% in Turkey), and in ecology and nature conservation (22.5%: 17.5% in Italy and 27.5% in Turkey). A minority of respondents in both countries are experts in other fields such as water management, renewable energy development, climate change, soil science, and communication and innovation technologies.

The experts have a high level of expertise (years of work experience): 62.5% have more than 10 years in his/her field (55.0% in Italy and 75.0% in Turkey), 20.0% have 6–10 years of expertise (20.0% in both countries), 13.8% have 2–5 years of expertise (20.0% in Italy and 7.5% in

Table 1 Ecosystem services (ES) investigated with the definition used in the questionnaire

Ecosystem service	Category	Definition
Biodiversity	Supporting services	Biodiversity is the variety and variability of animals, plants and micro-organisms at genetic, species and ecosystem levels; It is necessary to sustain key functions of the ecosystem, its structure and processes. Biodiversity includes diversity within species, between species, and between ecosystems (Millennium Ecosystem Assessment (MEA) 2005). In this study, animals and plants are considered in the context of biodiversity
Carbon sequestration	Regulating services	Carbon sequestration by forests is the amount of carbon immobilized each year in aboveground tree biomass and non-living biomass (Briner et al. 2013)
Soil erosion protection	Regulating services	Soil protection is the protection from erosion and other types of deterioration so as to maintain fertility and productivity. Forest cover plays an important role in soil retention and the prevention of landslides (Notaro and Paletto 2012)
Water quality	Regulating services	Forest cover influences groundwater levels, wells and springs, as well as safeguarding water quality. The presence of forests can substantially reduce the need for treatment of drinking-water and thus radically reduce costs of supplying water (FAO 2008)
Recreation	Cultural services	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area (Millennium Ecosystem Assessment (MEA) 2005). In this study, the recreation activities considered are: hiking, trekking, picking mushrooms, berries, fruits, and picnicking
Landscape aesthetic	Cultural services	Landscape aesthetics are described as a viewing experience of the natural world, landscape as source of inspiration, or cultural values and the sense of place in general associated with recognized environmental features (Grilli et al. 2016)

Turkey). The remaining 3.7% of experts had less than 2 years of expertise. In order to only consider the opinions of the experts with a high degree of experience, the views of experts with less than 2 years expertise have been eliminated during data processing.

Scenario 1: Clear-cutting of coppices

The results show that coppice clear-cutting for bioenergy production (first forest management scenario) negatively effects on almost all ES (Table 2). According to the experts, the highest negative effects of clear-cutting coppice are on landscape aesthetics and soil erosion. The third negative effect is on water quality.

The Turkish experts assigned higher negative effects of coppice clear-cutting for all ES compared to the Italian experts. The non-parametric test of Mann–Whitney shows significant statistical differences between countries for three ES: recreation activities (p value $= 0.008$), soil erosion (p value $= 0.019$), and water quality (p value < 0.0001).

Observing the intensity of the effects of coppice clear-cutting on the different ES (Table 3), the results show that for biodiversity, the highest negative intensity is food resources/winter forage for wildlife, followed by shelter resources. However, according to the expert opinions, the highest negative intensity of forest bioenergy production is on biodiversity between species compared to the biodiversity between habitats.

Considering the effects of clear-cutting of coppice on soil erosion, the experts identified two aspects: risks of floods and risks of landslides. The first is common in the plain areas closest to rivers and streams, while the second risk is more common in the mountainous and hilly areas.

According to the expert opinions, clear-cutting of coppice can influence water quality, with special regards to the use of groundwater for drinking water, and secondarily, for sedimentation in streams, lakes and dams.

In addition, the data distinguished between researchers/academics and decision-makers (forest managers, planners, and policy-makers) in order to highlight any differences of opinion between these two groups (Table 2). The results show that researchers and academics assign a higher negative effect of clear-cutting of coppice on almost all ES than do the decision-makers. In particular, decision-makers consider the effect of coppice clear-cutting on carbon sequestration in a positive way and on biodiversity as neutral. Despite these differences, the non-parametric test of Mann–Whitney shows significant statistical differences between researchers/academics and decision-makers only for soil erosion (p value $= 0.009$). The researchers/academics assign a higher negative effect of coppice clear-cutting on soil erosion than do decision-makers.

With regards to the intensity of the effects (Table 3), decision-makers emphasize more the importance of negative effects of clear-cutting of coppice on two aspects of biodiversity than do researchers/academics: shelter resources for wildlife and habitat fragmentation. Besides,

Table 2 Effects of clear-cutting of coppices on other ES according to experts opinions (5-point Likert scale)

Country/Statistics	Biodiversity	Recreation	Landscape aesthetics	Carbon sequestration	Soil erosion	Water quality
Italy ($n = 38$)						
Mean	− 0.05	− 0.11	− 0.61	− 0.03	− 0.42	− 0.08
Median	0	0	− 1	0	− 1	0
SD	1.01	1.09	0.95	1.05	1.03	0.78
Turkey ($n = 39$)						
Mean	− 0.54	− 0.79	− 1.00	− 0.54	− 0.97	− 0.85
Median	− 1	− 1	− 1	− 1	− 1	− 1
SD	1.14	1.03	1.00	1.31	1.09	1.01
Italian and Turkish researchers/academics ($n = 54$)						
Mean	− 0.33	− 0.43	− 0.83	− 0.39	− 0.85	− 0.54
Median	− 1	− 1	− 1	0	− 1	− 1
SD	1.10	1.19	1.08	1.19	1.02	0.97
Italian and Turkish decision− makers ($n = 18$)						
Mean	0.00	− 0.44	− 0.72	0.06	− 0.11	− 0.06
Median	0	− 1	− 1	0	0	0
SD	1.08	0.92	0.75	1.21	1.08	0.87
Total ($n = 77$)						
Mean	− 0.30	− 0.45	− 0.81	− 0.29	− 0.70	− 0.47
Median	0	− 1	− 1	0	− 1	0
SD	1.10	1.11	0.99	1.21	1.09	0.98

decision-makers emphasize the negative effects of coppice clear-cutting on both aspects of recreation than do researchers/academics: accessibility for picnicking activities and easy movement for hiking and trekking. Conversely, researchers/academics assign a higher negative effect of clear-cutting of coppices on temporarily carbon stocking in deadwood than do decision-makers.

Scenario 2: Wood residue removal after felling in high forests

The results concerning the effects of woody residue removal after felling in high forests (second forest management scenario) show negative effects on biodiversity, carbon sequestration, soil erosion and water quality, and positive effects on recreation activities and landscape aesthetics (Table 4). The experts of both countries have a similar opinion about the effects of the removal of woody residues with small differences in the mean value. In this sense, the non-parametric test of Mann–Whitney shows significant statistical differences between countries only for one ecosystem service: recreation activities (p value = 0.032). The Italian experts assigned a higher positive effect of removal of woody residue than did the Turkish experts. The highest negative effects of this forest management scenario are for two ES: soil erosion and biodiversity.

The results on the intensity (Table 5) show that for biodiversity, the highest intensity is in term of food resources followed by habitat fragmentation. The intensity of the effects on deadwood as shelter resources is considered marginal by the experts.

Considering the effects on soil erosion, the experts identified the same aspects for the clear-cutting of coppices: risk of floods and risk of landslides.

With regards to the effects on water quality, the experts emphasized the high negative intensity in terms of groundwater for quality drinking water, followed by the sedimentation in streams, lakes and dams.

The comparison between the opinions of researchers and decision-makers shows that the two groups have similar ideas of the effects of the removal wood residues on ES. As a matter of fact, the non-parametric test of Mann–Whitney shows no significant statistical differences between researchers/academics and decision-makers.

With regards to the intensity of the effects (Table 5), the differences between the two groups are rather limited and not statistically significant.

Table 3 Intensity (mean, median, min, max and standard deviation) of the effects of coppice clear-cutting on different ES aspects

Ecosystem services		Italy ($n = 38$)	Turkey ($n = 39$)	Researchers/academics ($n = 54$)	Decision-makers ($n = 18$)	Total ($n = 77$)
Biodiversity (negative effect)						
Food resources/winter forage for wildlife	Mean	1.76	1.72	1.70	1.72	1.74
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.75	0.65	0.69	0.67	0.70
Shelter resources for wildlife	Mean	1.84	1.62	1.69	1.94	1.73
	Median	2	1	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.75	0.75	0.72	0.87	0.75
Habitat fragmentation	Mean	1.74	1.59	1.59	1.83	1.66
	Median	2	1	1	2	1
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.76	0.75	0.71	0.86	0.75
Recreation (negative effect)						
Accessibility for picnicking	Mean	1.84	2.03	1.85	2.17	1.94
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.89	0.84	0.88	0.86	0.86
Easy movement for hiking and trekking	Mean	1.97	2.21	2.09	2.11	2.09
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.82	0.77	0.81	0.83	0.80
Landscape aesthetics (negative effect)						
Visual quality of landscape	Mean	1.68	1.64	1.65	1.67	1.66
	Median	2	1	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.74	0.74	0.73	0.77	0.74
Carbon sequestration (negative effect)						
Temporary carbon stocking in deadwood	Mean	2.03	1.64	1.89	1.67	1.83
	Median	2	1	2	1	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.79	0.74	0.77	0.84	0.78
Soil erosion prevention (negative effect)						
Surface runoff	Mean	1.47	1.44	1.39	1.56	1.45
	Median	2	1	1	1	1
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.65	0.68	0.63	0.70	0.66

Table 3 continued

Ecosystem services		Italy ($n = 38$)	Turkey ($n = 39$)	Researchers/academics ($n = 54$)	Decision-makers ($n = 18$)	Total ($n = 77$)
Water infiltration	Mean	1.79	1.64	1.74	1.67	1.71
	Median	2	1	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.62	0.81	0.71	0.77	0.72
Risk of floods	Mean	2.16	1.74	1.91	2.11	1.95
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.86	0.75	0.83	0.83	0.83
Risk of landslides	Mean	2.13	2.05	2.13	2.06	2.09
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.81	0.76	0.75	0.87	0.78
Water quality (negative effect)						
Sedimentation in streams, lakes and dams	Mean	2.03	1.62	1.78	2.00	1.82
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.72	0.67	0.69	0.84	0.72
Use of groundwater for quality drinking water	Mean	2.32	1.87	2.13	2.11	2.09
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.70	0.86	0.80	0.83	0.81

Discussion

The results of this study are comparable with a study that involved 45 experts in four European countries, i.e., Slovenia, Italy, France and Austria (Grilli et al. 2015). The experts indicated a potential negative effect of forest residue removal on habitat quality (− 0.09 in a 5-point Likert scale from − 2 to + 2), and a potential positive effect on carbon sequestration (+ 0.11), soil protection (+ 0.23), landscape aesthetics (+ 0.15), and recreation (+ 0.25). Consequently, for habitat quality/biodiversity, recreation and landscape aesthetic, the expert opinions of the two studies are similar, while for soil erosion protection, the opinions of the experts are different. This difference may be due to the fact that Grilli et al. (2015) investigated Alpine forests while our study focused on the general situation of national forests in Italy and Turkey.

Biodiversity

The experts involved in this study highlighted negative effects of clear-cutting of coppices and very negative effects of woody residue removal. The experts highlighted that the major negative effect in both management scenarios concerns the food resources for wildlife. In addition, the results of this study show that the decision-makers' opinions on the effects of forest management on biodiversity differ from the researchers and academics opinions. The group of decision-makers of forest managers and planners of public administration consider the effect of clear-cutting of coppices as neutral, while researchers and academics point out the negative effects of this management scenario on biodiversity.

In the literature, several studies show that forest biomass extraction for energy use has a negative effect on habitat quality and biodiversity (Harmon et al. 1987; IEA 2002; Nijnik et al. 2014; Grilli et al. 2016). This is owing to the importance of deadwood components (e.g., limbs, twigs,

Table 4 Effects of woody residue removal on other ES according to expert opinions

Country	Biodiversity	Recreation	Landscape aesthetic	Carbon sequestration	Soil erosion	Water quality
Italy ($n = 38$)						
Mean	− 0.92	0.97	0.39	− 0.79	− 0.89	− 0.42
Median	− 1	1	1	− 1	− 1	0
SD	0.85	0.54	0.95	0.93	0.76	0.60
Turkey ($n = 39$)						
Mean	− 0.62	0.46	0.51	− 0.41	− 0.85	− 0.67
Median	− 1	1	1	− 1	− 1	− 1
SD	0.96	1.07	1.10	1.19	1.04	1.03
Italian and Turkish researchers/academics ($n = 54$)						
Mean	− 0.80	0.72	0.43	− 0.69	− 0.89	− 0.57
Median	− 1	1	1	− 1	− 1	− 1
SD	0.94	0.86	1.04	1.08	0.86	0.77
Italian and Turkish decision-makers ($n = 18$)						
Mean	− 0.56	0.78	0.61	− 0.33	− 0.78	− 0.39
Median	− 1	1	1	0	− 1	0
SD	0.92	0.88	0.98	1.08	0.94	0.98
Total ($n = 77$)						
Mean	− 0.77	0.71	0.45	− 0.60	− 0.87	− 0.55
Median	− 1	1	1	− 1	− 1	− 1
SD	0.92	0.89	1.02	1.08	0.91	0.85

fallen logs) to supply food and cover for many wildlife species. Harvesting effects and deadwood removal may produce negative effects on habitat (Grilli et al. 2015) because deadwood is an important factor in the protection of biodiversity in forests. As deadwood has been recognised as an important habitat for many species, it is accepted as a key component of biodiversity (Merganičová et al. 2012). Therefore, during forest management practices, a certain amount of deadwood should be left to protect biodiversity (EEA 2007). The percentage of deadwood should be decided upon case by case in consideration of site and stand characteristics.

Logging residues and deadwood removal changes pest populations and composition and affects their predators. The removal of logging residues affects biodiversity because the deadwood components supply habitat resources for many wildlife species such as saproxylic insects (Schlaghamersky 2003). The saproxylic organisms, either those classified as obligatory or facultative, depend, at some stage of their life cycles, on deadwood of senescent trees or fallen timber. Nijnik et al. (2014) described three types of negative effects related to deadwood removal: (1) residues attract insect species for laying eggs in the wood piles; (2) soil disturbance affects mosses and species reproducing in the vegetation; and, (3) deadwood extraction leads to habitat fragmentation for dependent species. On this last point, several mammal species use hollows, cavities, roots, fallen branches and deadwood for protective cover such as bear, lynx, fox, martens, squirrels, bats and small rodents (Radu 2006). Many Mustelids (weasel family) use the deadwood as shelter: stone marten (*Martes foina* Erxleben), marten (*Martes martes* L.) and wolverine (*Gulo gulo* L.). Tree holes are also used by the common dormouse (*Muscardinus avellanarius* L.) and the fat dormouse (*Myoxus glis* L.) as nesting sites (Paolucci 2003). Bird species hosted by dead trees can be primary excavators of cavities (i.e., woodpeckers) or secondary cavity nesters (Hagan and Grove 1999). The importance of deadwood as an indicator of biodiversity is provided by the diameter of the tree which is closely related, in turn, to the size of the nest holes. Thus, some bird species, such as *Parus palustris* L., *Parus caeruleus* L., *Passer montanus* L., and *Sitta europaea* L. require small cavities with diameters less than 5 cm, whereas other species such as *Strix aluco* L., *Upupa epops* L., *Dryocopus martius* L., *Picoides leucotos* Bechstein and *Picoides major* L. need larger cavities (Longo 2003).

Conversely, some authors have highlighted that one positive effect of forest bioenergy production is the removal of deadwood leads to an increase of saplings of deciduous species (Grilli et al. 2016). Besides, Notaro et al. (2009) emphasized that removing wood residues affects human safety positively, by preventing invasive insects

Table 5 Intensity (mean, median, min, max and standard deviation) of the effects woody residue removal on different ES aspects according to expert opinions

Ecosystem services		Italy ($n = 38$)	Turkey ($n = 39$)	Researchers/academics ($n = 54$)	Decision-makers ($n = 18$)	Total ($n = 77$)
Biodiversity (negative effect)						
Food resources/winter forage for wildlife	Mean	2.18	2.15	2.20	2.17	2.17
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.87	0.78	0.83	0.79	0.82
Shelter resources for wildlife	Mean	1.63	1.62	1.63	1.61	1.62
	Median	2	2	2	1	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.71	0.67	0.65	0.78	0.69
Habitat fragmentation	Mean	2.11	2.08	2.13	2.06	2.09
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.83	0.74	0.75	0.87	0.78
Recreation (positive effect)						
Accessibility for picnicking	Mean	1.66	2.05	1.85	1.83	1.86
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.78	0.86	0.83	0.92	0.84
Easy movement for hiking and trekking	Mean	1.45	2.00	1.76	1.61	1.73
	Median	1	2	2	1	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.69	0.83	0.82	0.85	0.81
Landscape aesthetic (positive effect)						
Visual quality of landscape	Mean	1.97	1.77	1.89	1.89	1.87
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.82	0.84	0.86	0.83	0.83
Carbon sequestration (negative effect)						
Temporarily carbon stocking in deadwood	Mean	1.89	1.79	1.83	1.83	1.84
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.80	0.77	0.82	0.79	0.78
Soil erosion prevention (negative effect)						
Surface runoff	Mean	1.71	1.59	1.72	1.50	1.65
	Median	2	1	2	1	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.65	0.72	0.68	0.71	0.68

Table 5 continued

Ecosystem services		Italy (*n* = 38)	Turkey (*n* = 39)	Researchers/academics (*n* = 54)	Decision-makers (*n* = 18)	Total (*n* = 77)
Water infiltration	Mean	2.08	1.85	2.00	1.89	1.96
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.67	0.72	0.70	0.83	0.73
Risk of floods	Mean	2.26	2.03	2.15	2.39	2.14
	Median	2	2	2	3	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.76	0.84	0.76	0.85	0.81
Risk of landslides	Mean	2.32	2.37	2.36	2.56	2.34
	Median	2	3	2	3	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.68	0.79	0.68	0.70	0.72
Water quality (negative effect)						
Sedimentation in streams, lakes and dams	Mean	2.03	1.92	1.98	2.11	1.97
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.68	0.84	0.74	0.83	0.72
Use of groundwater for quality drinking water	Mean	2.26	2.10	2.26	2.06	2.18
	Median	2	2	2	2	2
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	SD	0.60	0.79	0.68	0.80	0.70

such as the European spruce bark beetle (*Ips typographus* L.).

Recreation

The results show that bioenergy production and recreation is linked to the management practices adopted. The clear-cutting of coppice has a negative effect on recreation, while woody residue removal has a positive effect on tourist attractiveness. The negative effects are highest in relation to hiking and trekking activities compared to the effects on the accessibility for picnicking activities. This negative effect of clear-cutting is linked to the visual quality of the landscape because coppices have a low recreational attractiveness. In particular, the simple coppices managed for bioenergy production are unattractive areas for recreation activities (hiking and trekking), but also for landscape aesthetics. In addition, the positive effects of woody residue removal are highest for accessibility for picnicking. This is due to the fact that the “cleaned forests” are commonly frequented by families.

According to Grilli et al. (2016), the extraction of forest residues has a positive effect on tourists’ perceptions. The reason for this is that the removal of forest residues makes it easier for tourism activities such as hiking, trekking, and picnicking.

Pastorella and Paletto (2016) showed that 40% of tourists in two mountain study areas, one in Northern Italy and one in Bosnia-Herzegovina, preferred intensively managed forests in which deadwood was removed during silvicultural treatments. Tyrväinen et al. (2003) demonstrated that standing dead trees are generally disliked by both tourists in rural areas and visitors in urban forests. Another study carried out in the urban forests of Latvia indicated that people preferred managed forests where dead branches and deadwood were removed and human facilities were implemented (Jankovska et al. 2014).

Edwards et al. (2012) showed that the relationship between deadwood and forest recreational values depends on multiple factors. The experts involved in the survey by Edwards et al. (2012) highlighted that "very low" and "very high" volumes of deadwood are seen negatively in comparison with moderate amounts. The level of respondents' knowledge about biodiversity and the relationship between coarse woody debris and biodiversity are key factors that influence the answers. Finally, Verkerk et al. (2014) highlighted that recreational attractiveness is positively affected when woody residues and stumps are removed from the forest.

Landscape aesthetics

The results of this study show that clear-cutting of coppice has a negative effect from the aesthetic point of view, while the removal of woody residues has a positive effect on landscape aesthetics.

From a theoretical point of view, landscapes can be considered as a dwelling place, which is not something external to human beings and thought, but simultaneously both the object and the subject of dwelling (Ingold 2000). The amenity values are associated with the diversity and fragmentation of the surrounding landscape, considering the mosaics of natural and human-managed elements. With this definition of landscape, it is easy to understand that clear-cutting of coppice can produce negative effects from an aesthetic point of view. Harvesting of sub-standard trees (dead, damaged, small) may cause a positive perception for the visual qualities in the forest landscape. On the other hand, removal of large, old, or dead trees with characteristic shapes may be perceived as negative regarding landscape appreciation (Framstad et al. 2009).

In this ambit, Grilli et al. (2016) have shown that woody residue extraction has also a positive effect on the aesthetic values of the forest. After felling, logging residues are usually perceived as untidy and disturbing to landscape aesthetics. Logging residues and stumps may create an opposite perception to the desired sense of a healthy forest. They make accessibility to the forest difficult. For this reason, removal of these residues has a positive effect on landscape aesthetics (Framstad et al. 2009).

Carbon sequestration

The experts consider that forest bioenergy production has negative effects on carbon sequestration. This is due to the fact that deadwood and woody residues have long times of decomposition, while through the bioenergy cycle, carbon is released in a short time into the atmosphere. Our results show a difference of opinion between decision-makers and researchers/academics. For the first group, clear-cutting of coppices has a positive effect on carbon sequestration, while it has a negative effect for researchers and academics. The opinion of forest managers and planners (decision-makers) of public administrations is the so-called "official opinion", therefore they probably want to emphasize the role of forest biomass as a renewable resource in climate change mitigation.

In the international debate, climate impacts of bioenergy (or "carbon neutrality") is one of the key points because some scientists stress that the use of forest biomass for energy enhances global warming, while others suggest that forest bioenergy can play an important role in climate change mitigation. These differences are due to the objectives of the studies and the methodological approaches adopted (Berndes et al. 2016). In particular, forest bioenergy is an integral part of the forest management and energy-industry system.

Forest bioenergy has the potential to significantly reduce GHG emissions compared with fossil fuel alternatives. By considering the broader impacts of bioenergy production in the forest, particularly carbon pools, policy can lend support to effective use of forest resources for climate change mitigation (McKechnie et al. 2011). Bioenergy from stumps and roots are a part of the solution to reduce emissions. However, using this source for bioenergy would result in a decrease in the carbon stored in dead organic matter. Thus, there is an interesting trade-off between using stumps for bioenergy and adding them to the pool of dead organic matter. As stumps decompose over time, this problem also involves an important temporal dimension (Melin et al. 2010).

Soil erosion

The experts noted the trade-off between bioenergy production and soil erosion in both the scenarios (clear-cutting of coppices and woody residue removal). The Turkish experts recorded the highest negative effects to coppice clear-cutting compared to woody residue removals, while the Italian experts reflected an opposite opinion.

The role of forest protection from soil erosion and other hydrogeological risks is widely documented in the literature (Motta and Haudemand 2000; Dorren et al. 2004). Forests are the most effective cover for preventing mass soil movements. Deep tree roots that penetrate through different soil layers provide some protection against shallow landslips by increasing shear strength. In addition, forests with understory, litter and organically enriched soils are the best watershed land cover for minimizing erosion by water (FAO 2008). With special regards to the deadwood, fallen logs may retard soil and water movement either on slopes or through the ground (Kraigher et al. 2002), while woody residues protect the soil from direct impact by rain. Logging residues have an important role in decreasing the direct exposure of the soil to rainwater, sun and/or wind (EEA 2007). On the other hand, removing logging residues has the effect of increasing soil compaction and erosion in fine-textured and moist soils (Grilli et al. 2015).

Kezik and Acar (2016) also underlined that heavy vehicles used for harvesting compact forest soils which changes in soil structure and moisture regimes. Due to compacted soil, the bulk density increases, infiltration of water decreases, and erosion accelerates.

Water quality

The results of this study show that the relationship between forest energy production and water quality is negative in both the management scenarios.

In the literature, some studies have shown that forested watersheds produce higher-quality water than watersheds under alternative land uses, such as agriculture, industry and settlements which are likely to increase the amounts of pollutants entering headwaters (Stolton and Dudley 2007; FAO 2008). Quality can also be higher because forests help to regulate soil erosion and reduce sediment loads, although the extent and significance of this function will vary. The presence of tree vegetation can substantially reduce the need for treatment of drinking water and thus radically reduce costs of supplying water (FAO 2008).

Extraction of biomass has significant effects on water quality and hydrology since it impacts the soil regulating the water system. Visible trade-offs are generated between energy wood extraction and protection of the water system. Logging residues and deadwood have an important role in regulating water flow by capturing and storing excess water and reducing water run-off on slopes (EEA 2007; Ferranti 2014). Consequently, the removal of logging residues and deadwood has a negative effect on regulating water flow (EEA 2007). Logging operations decrease the hydraulic conductivity and macro porosity and erosion risks increase (Kezik and Acar 2016).

Conclusions

The present study focuses on the assessment of forest bioenergy sustainability based on experts' opinions comparing two different management scenarios. The interactions between ES (ecosystem services) are analysed through the physical approach or the cognitive approach. The first refers to the physical ecosystem service flow, and involves external changes to ecosystems that modify service delivery, while the second refers to the cognitive processes inherent in every individual when perceiving the benefits from a given ecosystem service. Studies concerning the opinions of stakeholders or experts about the benefits of ES fall in the cognitive approach. Such studies are important to integrate social knowledge within scientific knowledge to improve the supply of ES.

From the methodological point of view, the main strength is that the method is very simple and easily replicable in other contexts. The structured questionnaire is a good tool to collect standardized information in a short time which can be easily verified by statistics and compared. Conversely, a crucial point of the survey is the choice of experts to be involved. The selected experts must be representative of different scientific areas. The quality of information may possibly be increased through in-depth interviews with a sub-group of experts. The main scientific contribution of this study was to compare the perception of the effects of forest management practices on ecosystem services between different groups of experts. The knowledge of the representatives of universities and research institutions is the product of studies in specific disciplinary areas, while the knowledge of forest managers and planners is the product of their daily professional experiences. Conversely, the knowledge of policy-makers is a knowledge transmitted by the other two groups of experts. Therefore, a convergence of opinion among these groups denotes a good level of communication between the technical-scientific community and the political community. In contrast, when there is a divergence of opinion, it is necessary to improve the transfer of knowledge between the technical-scientific community and the political community.

In future steps of the study, the questionnaire will be improved and integrated to include other forest management options such as pre-commercial thinning, bioenergy thinning, and short rotation forestry. The survey may be extended to other EU member and associate member countries with a potential for the development of forest biomass for energy use.

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