Biomass and Bioenergy 98 (2017) 252–263

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

A method to assess the economic impacts of forest biomass use on ecosystem services in a National Park

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ARTICLE INFO

Article history:
Received 17 December 2015
Received in revised form
27 January 2017
Accepted 30 January 2017

Keywords:
Forest biomass
Decision support system (DSS)
Ecosystem services
Experts
Economic value
Protected area

ABSTRACT

The aim of the paper is to develop a method to assess the effect of forest biomass use for energy on ecosystem services (ES). Such method has been in the GRASS GIS environment, by creating an Decision Support System (DSS) called r.green.biomassfor. The method has been tested in the Triglav National Park in Slovenia. The potential forest biomass was estimated with r.green.biomassfor DSS taking into account the effects of forest biomass harvesting on ES in terms of economic value. The economic value of each ecosystem service to society has been estimated using different economic evaluation methods and were spatially located with a Geographical Information System (GIS) application. Then, a semi-structured questionnaire was administered face-to-face to the experts in order to understand the effects of forest biomass harvesting on the ES at local level. Finally, the results of the questionnaire survey were elaborated to obtain indicators useful to assess the economic gain or loss on the benefits provided by ES based on the results of r.green.biomassfor DSS.

1. Introduction

The use of forest biomass for energy is less polluting than fossil fuels, but this renewable source has several potential effects on the environment [1]. In fact, forest biomass harvesting may have effects on landscape aesthetic [2], biodiversity and habitat quality [3], water quality and soil productivity [4]. The effects are not always negative but they depend on the category of ecosystem services (ES) [5]: removing forest residues improves the aesthetic view and tourist attractiveness [6], reduces the risk of forest fire and prevent from insect damages [7]. Fragile ecosystems with a delicate equilibrium and low resilience - as protected areas in the Alps - are the most endangered when there is a plan to exploit natural resources. Alpine region is characterized by a huge availability of natural resources that can be used for energy purposes [8], so that energy expertise refer to the Alps as the “green battery” of the central Europe. Alpine region provides energy for the needs of its population and for the urban areas, thus causing a considerable impact on the natural resources - with special regard to the protected areas - that may result in an overexploitation. This trend suggests the necessity of effective management strategies, able to consider the effects of forest biomass use for energy in a comprehensive way [9]. Natural resource management should include the value of the ecosystem from different point of view, in order to carry out an effective renewable energy policy. ES have an economic value that includes both use values (direct-use and indirect use values) and non-use values (option and existence values) [10]. As said before, forest ES could benefit or be depleted by the use of biomass energy, so it is important to understand what the economic benefits are or losses occurred. In this sense, effective and sustainable management is not only given by the inclusion of ecological aspects in the decision-making process, but also taking into account the socio-economic aspects. Participative approaches, allowing the inclusion of social aspects in the management activities, are widely accepted to be suitable for forest management [11,12]. In addition, the public participation of the key stakeholders contributes to preserve the environment and the future availability of the natural

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http://dx.doi.org/10.1016/j.biombioe.2017.01.033
0961-9534/

resources [13], for this reason it is important to understand stakeholders' perceptions about ES and the environmental impact of forest activities [14]. The analysis of the public perceptions of using the woody biomass as a renewable energy source is a key issue in order to increase the social acceptance [15] and to reduce the conflicts between users [16].

Starting from these considerations, the aim of the paper is to develop a method to analyze the potential economic effects of forest biomass use for energy on the main ES provided by protected areas. This objective was reached by a procedure based on public perception analysis of the issue, economic assessment of the ES and spatialization of the results. The procedure was implemented in GRASS GIS and now constitutes a downloadable add-on of this software, called "r.impact". The method was applied and tested in the Triglav National Park (Slovenia).

2. Methods

The case study is the Triglav National Park (46°22′00″ N; 13°49′00″ E) in the north-western part of Slovenia along the Italian the Austrian borders. The Triglav National Park covers an area of 838 km^2 (about 3% of the Slovenian surface) and includes 25 settlements with a population of 2444 people (1018 households) for a density of 0.029 inh. ha^{-1}. The climate of the area is continental, with cold winters and warm summers. The average temperature in the warmest month range from 20 °C in the valleys and 5.6 °C in the mountains, and in the coldest month the temperature range between 0.7 °C and −8.8 °C, while the average annual precipitation is about 1500 mm. The landscape of the Triglav National Park is characterized by glacier-shaped valleys, mountain plateaus and steep mountain ridges above the tree line. Forest area covers 62% of the total land area followed by managed grasslands (10%). The main forest types in the Park are: Montane beech forests (27,981 ha), Dwarf pine forests (11,350 ha), Silver fir - beech forests (4925 ha) and Silver fir and Norway spruce forests (4191 ha). In addition, the Triglav National Park is an important touristic destination with more than 580 thousand tourists per year and an average tourists' stay of 2.5 nights [17].

The potential effects of forest biomass harvesting on ES in the Triglav National Park were analyzed using a four-steps approach (Fig. 1): (1) economic evaluation of the ES; (2) estimation of the harvestable forest biomass; (3) estimation of the potential effects of forest biomass harvesting on ES through an experts' survey; (4) analysis of the potential spatial effects of forest biomass harvesting on ES.

2.1. Step 1

In the first step, four ES were identified and analyzed from the economic point of view: wood production (timber for commercial use and fuelwood for domestic use), carbon sequestration, protection against natural hazards and outdoor recreation. The ES values were estimated using different economic evaluation methods, as shown in Table 1. Due to the importance of the spatial component for forest planning [18], the results of the economic valuation of the ES were spatialized through an open-source GIS software.

Several economic evaluation methods were applied taking into account the nature of the ecosystem service and the available data. The wood production and carbon sequestration were evaluated by market prices; the outdoor recreation was evaluated through the Benefit Transfer (BT) method [19], while the replacement cost method was used to evaluate the protection against natural hazards. The economic valuations of all benefits derived from ES have been made in reference to the year 2012.

Table 1
Economic evaluation methods and variables considered in their estimation.

Ecosystem service	Evaluation method
Wood production (timber and fuelwood)	Market Price
Carbon sequestration	Voluntary market price
Natural hazards protection	Replacement cost
Tourism recreation	Benefit Transfer

Subsequently, the results of the economic evaluation were rendered spatially-explicit through a Geographical Information System (GIS) application. We opted for open-source software, in particular we used GRASS GIS for the main analysis, while Quantum-GIS for creating the final layout. A set of thematic layers were chosen and overlaid to analyze the spatial distribution [18]. The maps are presented with a 5-class distribution of the benefits, created by the GIS software following the natural breaks system, in order to facilitate the visualization of the impacts. Only the cultural services are presented in 3 classes of value, because the evaluation highlighted only three different point estimates.

2.1.1. Wood production

Wood production was evaluated through a market price approach considering timber for commercial use and fuelwood for domestic use. Wood production was calculated considering the harvestable quantities by tree species and quality of logs (1st, 2nd and 3rd quality) and applying the local market prices. The main tree species harvested in the Triglav National Park are the following: European beech (*Fagus sylvatica* L.), Silver fir (*Abies alba* Mill.), dwarf mountainpine (*Pinus mugo* Turra). The equation used for the estimation of respectively timber value (V_t) and fuelwood value (V_f) are the following:

$$V_t = \sum_{n}^{i} \sum_{m}^{i} Q_t \cdot p_t$$

where:

V_t = total value of timber (€);
n = number of tree species (European beech, silver fir, etc);
m = qualities of logs;
Q_t = quantity of timber subdivided per species and quality (m^3);
p_t = local price of timber subdivided per species and quality (€ m^{-3}).

$$V_f = \sum_{n}^{i} Q_f \cdot p_f$$

where:

V_f = total value of fuelwood (€);

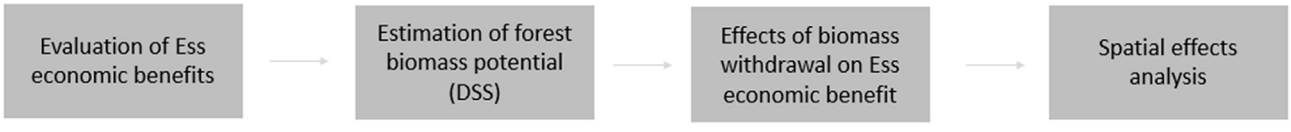

Fig. 1. Four-step approach used to estimate the spatial effects of forest biomass harvesting on ES.