Ecosystem Services 18 (2016) 1–19

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Sustainable energy potential from biomass through ecosystem services trade-off analysis: The case of the Province of Rovigo (Northern Italy)

Elena Gissi [a,*], Mattias Gaglio [a,b], Matelda Reho [a]

[a] Department of Design and Planning in Complex Environment, University Iuav of Venice, S. Croce 1957, 30135 Venice, Italy
[b] Department of Life Sciences and Biotechnology, Section of Evolutionary Biology, University of Ferrara, Via Borsari 46, 44121 Ferrara, Italy

ARTICLE INFO

Article history:
Received 19 May 2015
Received in revised form
15 January 2016
Accepted 19 January 2016

Keywords:
Bioenergy
Aesthetic values
Carbon storage
Food provisioning
Habitat services
Trade-offs

ABSTRACT

Bioenergy production is an important Ecosystem Service (ES) provided by natural and semi-natural ecosystems, which can concur to reach EU targets of 20% of total energy production from renewable sources. Environmental concerns with respect to bioenergy are multiple. Certification Schemes, aimed at reducing the negative effects of biomass energy supply chains, are not effective in controlling possible cumulative effects at regional level caused by both macro and micro feedstock producers and users. Sustainable feedstock production is often underestimated in energy planning and in the issuing of plant permits. This study applies an ES-based approach in order to quantify and map bioenergy sustainable potential in the Province of Rovigo (Region of Veneto, Italy), an intensively farmed agro-environment, and translate bioenergy environmental impacts in terms of ES trade-offs. The results show that the share of bioenergy potential from trade-offs with other ESs is limited. The magnitude and variability of ESs trade-offs are analyzed and discussed, resulting in a spatial distribution which is place-based and context dependent. Management solutions should be considered in order to mitigate trade-offs with other ESs, increasing ecological and social acceptability.

1. Introduction

Ecosystem Services (ESs) has taken on a significant role in international debate as an effective tool to structure decision-making processes. Trade-offs occur among land-dependent services (González-Esquivel et al., 2015, Yang et al., 2015) and their complex interactions (Rodríguez et al., 2006, Bennett et al., 2009) make their management a challenge in landscape planning (Burkhard et al., 2012, Cavender-Bares et al., 2015). Trade-offs occur when the supply of one or more services results in one or more disservices (Bennett et al., 2009, Raudsepp-Hearne et al., 2010), which are somehow connected by common drivers or biological inter-dependences (Bennett et al. 2009).

Human impact and management strongly affect ecosystems, including their processes and functions. Among these, ESs provided by agro-ecosystems are often underestimated and not fully considered (Porter et al., 2009, Power, 2010). Agro-ecosystems provide several ecosystem services to human wellbeing, mostly based on their surplus production (Tilman et al., 2002). According to the cascade model proposed by Haines-Young and Potschin (2010), an ecological function provides a service when it meets a human demand. Changing of human needs results in modifications in human demands, and therefore in new perceptions of services supplied by ecosystems (Castro et al., 2013).

In order to mitigate climate change and to increase energy security, demand for renewable energy has been increasing in recent years and the trend is expected to continue (McBride et al., 2011). In line with the general strategy of "Europe 2020", as part of the priorities of the medium-term economic vision concerning sustainable growth, the European Commission, with the Renewable Energy Directive 2009/28/EC (EU RED) on the promotion of the use of energy from renewable sources, establishes that 20% of total EU energy production should come from renewable sources. National targets outlined in EU RED must be achieved by sustainable production. Among other sources, the EU Commission acknowledges concerns about the sustainability of biomass production, in terms of protecting the biodiversity of ecosystems and carbon stocks (Scarlat and Dallemand, 2011). Environmental concerns with respect to bioenergy are related to soil quality, water quality and quantity, greenhouse gases, biodiversity, air quality, and productivity (GBEP Task Force, 2011, McBride et al., 2011).

Sustainability requirements for the use of biomass sources for bioenergy present several unresolved issues concerning the certification of sustainable production. To assess the sustainability of feedstock for biomass and bioenergy, Certification Schemes (CS) are considered both at National and International level.

* Corresponding author.
E-mail address: egissi@iuav.it (E. Gissi).

http://dx.doi.org/10.1016/j.ecoser.2016.01.004

According to the revisions of CS performed by Scarlat and Dallemand (2011) and Meyer and Priess (2014), CS identify sustainability requirements for biomass production at a company level, considering single farms/fields. Only the Dutch certification scheme of the Netherlands Technical Agreement NTA 8080:2009 (2009) envisages a system of monitoring at macro-scale (Scarlat and Dallemand, 2011). However, the exclusion of small-scale producers and users below 1 MW capacity from the application of sustainability criteria (Directive 2009/28/EC, 2009) makes it impossible to monitor and evaluate possible cumulative effects at regional level indirectly caused by the combined actions of macro and micro feedstock producers and users (McBride et al., 2011).

In addition, Life Cycle Assessments are not able to assess the "highly site-specific and locally/regionally occurring environmental impacts of feedstock production in the first step of most of the bioenergy supply chains" (Meyer and Priess, 2014: 152), as the application of environmental indicators of bioenergy needs to adapt to site-specific and place-based conditions (McBride et al., 2011). The accumulation of environmental impacts beyond the level of farm/field, but on local and regional scales (i.e. on multiple scales) and the related cumulative effects on different ecosystem services is not considered.

Formally, CS do consider sustainable cropping through the so-called "cross-compliance" with agricultural regulations established by Common Agricultural Policy schemes concerning sustainable management practices in agriculture (McBride et al., 2011). However, in practice, the certification process only results in the verification of compliance with pre-established regulations, instead of in an on-site environmental assessment (Scarlat and Dallemand, 2011, Meyer and Priess, 2014).

Indirect Land Use Change (ILUC), defined as the process of displacement of agricultural production to non-cropland, such as grasslands and forests (EC, 2012), is accounted for in terms of the increase of greenhouse gas emissions resulting from the conversion of grasslands and forests for biofuels, but impacts on structures and process and on other ecosystems services are not considered. This results in several uncertainties surrounding the effects of biofuels/bioenergy production on ILUC (GBEP Task Force, 2011, Scarlat and Dallemand, 2011) as well as general concern among stakeholders about the benefits of bioenergy to sustainability (McBride et al., 2011).

Agro-ecosystems can meet the rising demand in renewable energy by providing suitable biomass for bioenergy production. Due to the their increasing importance, Biomass-Based Energy Sources (BBES) have been included in the Common International Classification of Ecosystem Services (CICES, Haines-Young and Potschin, 2011) as Provisioning ES.

Since relationships between ESs are complex and change in space and time (Bastian et al., 2012), the exploitation of BBES can result in trade-offs with other services (e.g. Verkerk et al., 2014), which are not currently taken into account in either the feedstock analysis or certification schemes. Meyer and Priess (2014) proposed an analysis of selected certification schemes at National and International level using the ES cascade model, to test the comprehensiveness and quality of environmental indicator sets. They classify indicators according to their significance and representativeness with respect to ecological processes and structures, as well as to ecological functioning. As a result, the authors report that certification schemes are unable to address fully all aspects of ESs and trade-off between them, as they are sensitive to neither interactions within the different components of the ESs cascade, nor to feedback on the use of ESs on ecosystem structures, processes, and therefore they are unable to identify the environmental impacts of different types of feedstock.

Proper management of agro-ecosystems (and feedstock) is critical to developing BBES, by allowing the management of trade-offs among ESs and optimizing the provision of ES from agro-ecosystems by ensuring the integrity of ecosystem functions and processes.

When calculating energy potentials, Angelis-Dimakis et al. (2011) propose a rationale to categorize the analysis of energy from renewable sources: potential energy is understood as the gross energy of the source, based on land area per productivity rate according to land use type; theoretical energy is the fraction of PE that can be harvested by the energy conversion system, according to legal and technological limitations; finally, the exploitable energy is the fraction that can be used, taking into account the criteria of sustainability in terms of logistic, environmental and economic issues.

This paper proposes an extension of the rationale of Angelis-Dimakis et al. (2011), introducing the concept of "sustainable potential", applying the recent notion of sustainability from Müller et al. (2007:11). Sustainability has been intended as keeping "available the ecosystem services on a long-term, inter-generational and a broad scale, intra-generational level", sustainable potential is understood as the fraction of energy potential whose exploitation cause no harms to other ESs delivered by the sources of renewable energy.

This paper proposes a method of identification of sustainable potential energy from Biomass Based Energy sources, by analyzing and discussing trade-offs between ESs. The aim is to evaluate suitable areas for biomass production considering interactions and trade-offs between BBES and other ESs. Certain ESs, relevant to bioenergy, are selected to be evaluated together with feedstock production within a specific area. The sustainable energy potential is calculated and discussed in the case of the Province of Rovigo, in the Region of Veneto of Italy, to highlight how the proper management of agro-ecosystems is critical to developing BBES, by allowing the management of trade-offs among ESs and optimizing the provision of agro-ecosystem services by ensuring the integrity of ecosystem functions and processes.

2. Case study area

The territory of the Province of Rovigo is located between the Po River (to the south) and Adige River (to the north) (Fig. 1). It is a totally flat land that extends for about 100 km and has an area of 1.789 km^2.

The type of land cover of the study area (Fig. A1.1) shows that most of the land is destined for agricultural use (75%) and that the forested and semi-natural areas are limited to small and fragmented pockets of land. Water ecosystems are scattered in the plain as far as the area of the Po River Delta, forming part of a delicate environmental mosaic (Viaroli et al., 2006, Ludovisi et al., 2013).

A more detailed analysis of the agricultural area's composition shows that 67% of arable land is used for cereal production. Of this, maize crops cover more than half of cereal crop land (Table A1.1), common wheat is the second cereal crop in terms of land area, while others crops show just marginal percentages.

The Region of Veneto has been the subject of a rapid increase in demand for permits for bioenergy plants, as a result of current National incentives. In the Province of Rovigo, 28 bioenergy plants are currently registered, with a total energy supply of 114 MWe (data recorded and mapped by the Environmental Offices of the Province of Rovigo). Among these, 19 of the 28 plants use biogas technology (68%), but supply just 17 MWe (15%). This is due to the fact that all biogas plants declare power of < 1 MW, so that they are not subjected to any certification schemes, nor monitored by the Regional Plant Register, which records only plants which produces more than 1 MW.