Biomass and Bioenergy 114 (2018) 157–173

Contents lists available at ScienceDirect

Biomass and Bioenergy

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

Research paper

Mechanisms and indicators for assessing the impact of biofuel feedstock production on ecosystem services

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ARTICLE INFO

Keywords:
Impact mechanism
Ecosystem services
Indicators
Landscape conversion

ABSTRACT

Biofuel feedstock production can be a significant driver of landscape modification, ecosystem change and biodiversity loss. There is growing body of literature that shows how biofuel landscapes provide various ecosystem services (e.g., feedstock for fuel, carbon sequestration) and compromise other ecosystem services (e.g., food, freshwater services). These effects are context-specific and depend largely on prior land use conditions and feedstock production practices. Changes in the flow of ecosystem services due to the conversion of natural and agricultural areas can have ripple effects on human wellbeing. Despite some recent attempts to apply to biofuel settings concepts and methods rooted in the ecosystem services literature, this is the exception rather than the rule within both the biofuel and the ecosystem services research communities. This paper synthesizes the current knowledge about the impact of biofuels on ecosystem services. It focuses especially on the feedstock production phase and outlines the main mechanisms through which landscape conversion affects the provisions of ecosystem services. It proposes conceptually coherent indicators to reflect these mechanisms and offers a critical discussion of key issues at the interface of biofuels and ecosystem services.

1. Introduction

The sustainability impacts of biofuels depend on the cultivation and harvesting of the biofuel crops (referred to as feedstock in this paper). Knowledge syntheses conducted by the Scientific Committee on Problems of the Environment (SCOPE) have outlined some of these diverse social, economic, and environmental impacts around the world [1]. Studies have analyzed the potential conflicts of biofuel production with food production and food security [2,3], while others have addressed concerns over land-grabbing [4,5]. Impacts related to deforestation, biodiversity loss and Greenhouse Gas (GHG) emissions, including those from direct and indirect land use and cover change (LUCC), have also been prevalent [6–8]. While most studies have focused on negative impacts, there is a growing body of literature outlining possible positive impacts on energy security, economic development and climate change mitigation among others [9–15]. Given the diversity of these sustainability impacts, it is challenging to develop a unified framework for biofuel impact assessment and knowledge synthesis [16] [20].

Some recent studies have applied concepts and methods rooted on ecosystem services to synthesise the current knowledge and identify the impacts/trade-offs of biofuel production (see below). The basic premise of the ecosystem services perspective is that ecosystems provide directly and indirectly various benefits to humans (i.e. ecosystem services) [17–19]. For biofuel systems these trade-offs can relate to provisioning ecosystem services (e.g. fuel, food), regulating services (e.g. carbon sequestration, water purification) and cultural services (e.g. religious values) [17,18].

Changes and trade-offs in the flow of these ecosystem services can have important ramifications for human wellbeing (Fig. 1), whether positive or negative [17,18]. Yet there are multiple ways to catalyze these changes in ecosystem services. For example they can be directly

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https://doi.org/10.1016/j.biombioe.2018.01.024
Received 12 January 2018; Accepted 31 January 2018
Available online 13 February 2018
0961-9534/