Renewable and Sustainable Energy Reviews 27 (2013) 30–42

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

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

Second generation biofuels and bioinvasions: An evaluation of invasive risks and policy responses in the United States and Canada

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ARTICLE INFO

Article history:
Received 14 January 2013
Received in revised form
7 June 2013
Accepted 16 June 2013

Keywords:
Biofuels
Biological invasion
Invasive species
Second generation
Policy
Risk

ABSTRACT

Biofuels are being embraced worldwide as sustainable alternatives to fossil fuels, because of their potential to promote energy security and reduce greenhouse gas emissions, while providing opportunities for job creation and economic diversification. However, biofuel production also raises a number of environmental concerns. One of these is the risk of biological invasion, which is a key issue with second generation biofuel crops derived from fast-growing perennial grasses and woody plant species. Many of the most popular second generation crops proposed for cultivation in the U.S. and Canada are not native to North America, and some are known to be invasive. The development of a large-scale biofuel industry on the continent could lead to the widespread introduction, establishment, and spread of invasive plant species if invasive risks are not properly considered as part of biofuel policy. In this paper, we evaluate the risk of biological invasion posed by the emerging second generation biofuel industry in the U.S. and Canada by examining the invasive risk of candidate biofuel plant species, and reviewing existing biofuel policies to determine how well they address the issue of invasive species. We find that numerous potentially invasive plant species are being considered for biofuel production in the U.S. and Canada, yet invasive risk receives little to no attention in these countries' biofuel policies. We identify several barriers to integrating invasive species and biofuel policy, relating to policy analytical capacity, governance, and conflicting policy objectives. We recommend that governments act now, while the second generation biofuel industry is in its infancy, to develop robust and proactive policy addressing invasive risk. Policy options to minimize biological invasions include banning the use of known invasive plant species, ongoing monitoring of approved species, and use of buffer zones around cultivated areas.

Contents

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1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2013.06.013

1. Introduction

In an era of rising oil prices and growing concerns over climate change, biofuels are receiving increasing attention from governments worldwide as alternatives to fossil fuels [1]. Unlike gasoline and diesel, biofuels (which are derived from biological material like carbohydrates and lipids) are renewable resources, and theoretically carbon-neutral, since greenhouse gases emitted when they are burned may be offset by those absorbed when growing biofuel crops [2,3]. Biofuels thus offer the promise of energy security, and reduced greenhouse gas emissions. Additionally, biofuels could create jobs and promote economic diversification, especially in rural areas [4]. As a result, many governments have enthusiastically supported the development of the biofuel industry in recent years through financial subsidies, regulatory mandates, and research [5,6].

The rush to embrace biofuels, however, may be premature and misguided. The strong desire to mitigate greenhouse gas emissions and strengthen energy security has meant that the environmental and socio-economic sustainability of biofuels has been subject to limited scrutiny [6–9][1] . Yet the large-scale production of biofuels required to shift from our current dependence on fossil fuels brings with it a suite of potential problems. For example, widespread conversion of forest, grasslands and peatlands to bioenergy plantations would lead to increased carbon emissions as a result of burning or decomposing biomass, and to loss of habitat and biodiversity [10]. Intensive agricultural practices could increase pollution, as well as soil erosion and depletion [11,12]. Furthermore, first generation liquid biofuels are derived from crops also used for animal or human food (e.g., canola, corn, soy, sunflower, sugarcane, oil palm and wheat) and thus can displace food production, driving up food prices and exacerbating food insecurity [13–15].

Second generation biofuels derived from ligno-cellulosic plant material (e.g., perennial rhizomatous grasses and woody plant species) are increasingly attractive to the biofuel industry because they are expected to be more efficient (i.e., have higher energy yields) than first generation crops and will not compete directly with food production [1,14][2]. However, many of the most popular second generation crop species are not native to North America, and some are known to be invasive (e.g., giant reed, *Arundo donax*; false flax, *Camelina sativa*) [16], raising the specter of the introduction and spread of invasive species across the continent (Table 1) [6,16]. Indeed, the sheer scale of biofuel cultivation envisioned worldwide (estimated to reach 1.5 billion ha by 2050, which would equal all agricultural areas now under production) will increase the propagule pressure of invasive plant crops, thereby boosting invasion success [8,17,18]. However, the risk of plant invasions and the subsequent potential for economic and ecological damage are rarely considered in the appraisal, development and regulation of different biofuel feedstocks [1,8–20].

An additional threat is posed by the development of genetically modified (GM) second generation feedstocks. At present no GM crops have been designed specifically for biofuel production worldwide [21], but modification of second generation plant species could prove desirable if it improves production and conversion processes (e.g., by increasing biomass yield and reducing lignin content respectively) [22]. Such introduced traits could make GM biofuel crops invasive, particularly if modified genes spread to native plant populations [23–25].

The second generation biofuel industry is still in its infancy in North America, as the commercialization of cellulosic feedstocks currently faces technological and financial barriers [15,26–29]. Nonetheless, several commercial-scale production plants are already under construction (e.g., biorefineries run by Blue Sugars, Dupont, POET, and ZeaChem in the United States) [30–33]. Governments in both the United States and Canada are supportive of the biofuel industry, and have been creating policy in recent years to promote its development. Yet a comprehensive review of the risk of biological invasion posed by this nascent North American second generation biofuel industry has not yet been undertaken. In this study we evaluate this invasive risk and our preparedness to address it in both the U.S. and Canada. We first identify the plant species proposed for use as second generation feedstocks, and review the scientific literature to assess which of them are considered invasive risks. We then review biofuel policies in the U.S. and Canada to determine whether and how they address the issue of invasive species. Next, we identify major barriers to the integration of biofuel and invasive species policies. We close by recommending steps to strengthen governmental responses to this important issue.

2. Biofuels and invasive species

Many of the traits that make ideal biofuel crops are common to invasive plants, including rapid growth, high yields, perennial growth form, adaptability to a variety of habitats and climatic conditions, and resistance to pathogen or insect pests [8,34]. In North America, a variety of grass and woody plant species are being touted as the next generation of plants for bioethanol and biodiesel production, even though they are considered invasive or potentially invasive (Table 1). The Global Invasive Species Programme (GISP), a partnership of leading international scientific and conservation organizations, identified 20 plant species that have been recommended for biofuel production in North America despite being known to be invasive either there or elsewhere [16]. These include non-native species, such as miscanthus (*Miscanthus spp*.; native to Asia) [19], false flax (native to central Europe) [35], and Chinese tallow tree (*Sapium sebiferum*; native to Asia) [36]. Plants native to regions of North America, such as switchgrass (*Panicum virgatum*; native to eastern North America), could also become invasive if cultivated beyond their range [19]. Switchgrass has broad environmental tolerances and is a fast-growing, highly productive species, making it a prime biofuel candidate [37].

The use of established invasive plants as sources of biofuel has also been proposed as a way to control their populations while taking pressure off agricultural land for bioenergy production [38]. For example, invasive plants such as purple loosestrife (*Lythrum salicaria*), European common reed (*Phragmites australis*) and reed canarygrass (*Phalaris arundinacea*) could be harvested from wetlands as part of habitat restoration efforts [38]. Similarly, the

[1] Although Ref. [9] does go into greater detail on the environmental and socio-economic sustainability of biofuels.
[2] Another potential feedstock is algae, considered a third generation biofuel. Since the focus of this paper is on second generation biofuels derived from ligno-cellulosic material, algae will not be evaluated here.