Biofuels and Invasive Species

Exploring the links between biofuel production systems and invasive species

A background paper prepared by John Mauremootoo for the IUCN Workshop on Biofuels and Invasive Species – Nairobi, Kenya, 20th-22nd April, 2009

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1. Introduction

MOTIVATION BEHIND THE SEARCH FOR ALTERNATIVE SOURCES OF ENERGY

Increasing oil and gas prices, diminishing supplies of fossil fuels, a growing energy demand coupled with climate change and greenhouse gas emissions targets - as well as policies to promote rural development - have contributed to the reassessment of energy policy in countries worldwide, and the pursuit of alternative energy options.

While traditionally biomass is the energy option of more than 2.5 billion people worldwide, more advanced forms of bioenergy are being explored for power generation, and increasingly biomass is being converted into liquid fuels suitable for power motors, whether in stationary machinery or in vehicles, ships and aircraft.

The European Union, for example, has set a renewable fuels target of 10%, including a target of 5.75% of total transport fuel consumed by the end of 2010[1]. This target cannot be met without significant imports and so developing countries are increasingly being targeted as potential sources of land for biofuel export, by both public and private sector organisations. Many developing countries are also pursuing small-scale biofuel developments to improve access to energy in rural communities and reduce the burden of imported fossil fuels. Increasingly, the environmental, social and true greenhouse gas benefits of such initiatives is being brought into question and are being explored in the European Union and the Roundtable on Sustainable Biofuels, for example. Yet in such discussions, very little attention has been given to the plants used as biofuel feedstocks and the possibility that these plants, or the production systems of which they are part, could lead to invasive alien species (IAS) problems.

As background to the upcoming workshop on Biodiversity Risks of Biofuels[2] this paper will examine the invasive species risks posed by an expanding biofuel industry, through both the type of feedstock and the production methods chosen. It will also outline measures that could be used to mitigate these risks.

INVASIVE SPECIES AND THEIR IMPACTS

Introduced or alien species are the mainstay of our food production and forestry systems. Common food species, like rice, wheat, maize, chicken and cattle have been introduced around the world. Other alien species are used in forestry, landscaping, biological pest control, for sport, as pets and in food processing. A small proportion of alien species have become invasive, i.e. spreading extensively and causing major economic, environmental and health problems. Invasive species risks are increasing in line with growing and more rapid global travel and trade (Bright 1998, Mack *et al.* 2000). By one estimate, invasive alien species (IAS) cost the global economy $1.4 trillion per year which represents 5% of global production (Pimentel *et al.* 2001).

Invasive species can change recipient ecosystems through processes such as competition with resident species for resources such as space, light, nutrients and water; utilisation of resources previously unavailable to resident species; predation, parasitism or pathogenicity; interference with mutualisms such as pollination and by hybridisation with resident species. -6 (r) -.9858c

2. The Invasion Process

INVASIVE SPECIES PATHWAYS AND VECTORS

Invasive species can be introduced intentionally or unintentionally. The means or route by which a species is moved from one location to another is known as the invasion pathway. This term covers both physical routes such as shipping and air transport networks, and activities which result in species movement such as trade in used car parts, trade in forest products and tourism. Biofuel feedstock production systems could constitute an invasive species pathway.

Vectors are the means by which a species can move along a pathway. A vector along the used car part trade pathway could be used tyres which can serve as breeding (and transport) habitats for mosquitoes. A vector along the forest products trade pathway could be timber which is infected by wood boring beetles. The tourist who smuggles plant mat

The likelihood of an introduced species becoming invasive

For a variety of groups of animals and plants introduced to the United Kingdom, Williamson and Fitter (1996) estimated that approximately 10% of introduced species will become established and approximately 10% of these will ‘spread to become pests’. Nonindigenous plants in different parts of the world vary in the degree to which they strictly adhere to this “tens rule” (e.g. Lockwood *et al.* 2001) but the point remains that only a small percentage of introduced species will go on to become invasive. However, this statement does not help us to predict which species are likely to become invasive.

3. Causes of Invasion Success – Why some species become invasive and some ecosystems become invaded

Scientist have attempted to explain biological invasions by identifying the traits of species that make them invasive (*invasiveness*), the characteristics of recipient ecosystems that make them vulnerable to invasion (*invasibility*) and historical factors (introduction effort and time since introduction) that facilitate invasion.

There is no universal trait that can be used to predict whether a particular plant will invade a particular ecosystem but there are at least certain factors that appear to render a plant species more or less likely to invade a recipient ecosystem. These factors have been used as the building blocks for the production of risk assessment tools to screen for invasiveness of proposed introductions (Kolar and Lodge 2001). These tools can help to identify the small fraction of species that could go on to become invasive, reducing costs of invasions by preventing importation. A summary of some of the factors that appear to facilitate plant invasions and their relevance to biofuel feedstock species is given below.

Traits of invasive plants

Invasion success elsewhere

It is often stated that the best predictor of invasiveness in a recipient ecosystem is the species’ record as an invasive species elsewhere (e.g. Panetta 1993, Scott and Panetta 1993, Mack 1996, Reichard and Hamilton 1997, Caley and Kuhnert 2006). Though apparently self-evident, this statement does indicate that a good invader possesses traits that make it successful across a wide range of sites. With this information it should be possible to reject imports of potentially invasive species (prevention) and prioritise control for already established plants (early detection and rapid response, containment and long-term control). Proposals for the use of species with a history of invasion as biofuel crops should be treated with extreme caution and should consider mitigation measures. For example, jatropha *gossypifolia* was banned in Western Australia as invasive which raised alarm bells world wide when jatropha *curcas* started to be promoted as a potential biodiesel feedstock, though this is a different variety.

Of course *invasiveness elsewhere* is irrelevant if the species in question has no prior history of

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been selected as promising biofuel crops can reproduce vegetatively as this may facilitate agronomic procedures and prevent the need for seed production and harvesting while retaining the same phenotype.

Traits of invasible ecosystems

Ecosystem disturbance

The vast majority of plant invasions take place in human- and /or naturally-disturbed habitats (Rejmánek 1989, 1996, Hobbs 1991, Whitmore 1991). Disturbance, for example through fire,

TIME SINCE INTRODUCTION

The idea that the longer the time since introduction, the more likely it is that a species will become invasive is linked to the notion of lag times and propagule pressure. Evidence to support this idea, however, is inconsistent. Scott and Panetta (1993) found invasiveness to be greater for longer-established plant species in Australia. In contrast Carpenter and Cappuccino (2005) in a study in Ottawa, Canada, found that recently arrived plants tended to be more invasive than older introductions. Time since introduction alone, therefore is difficult to use as a predictor of invasion success for introduced plants – including biofuel feedstock species.

4. Potential Invasions of Plants in and around Biofuel Production Systems

FIRST GENERATION BIOFUEL FEEDSTOCKS

First generation (1G) biofuels are biofuels produced from existing food and feed crops using simple and well established processing technologies. Nearly all biofuels are currently 1G. Biodiesel is derived from plant oils such as rapeseed, palm oil and soy and bioethanol is a petrol replacement produced from sugar or starch crops such as sugarcane, sugarbeet, maize and wheat.

1G BIOFUEL CROPS - TRADITIONAL ANNUAL FOOD CROPS

Traditional food crops grown for ethanol (e.g. sugarcane, soya and maize) and biodiesel (e.g. sunflower and peanuts) have been selected to respond to high inputs of water, fertiliser and pesticides and typically grow on prime agricultural land. These highly domesticated annual crops are dependent on human activities and are unlikely to become invasive (Baker 1974).

Some other cultivated plants such as oilseed rape (*Brassica napus*) and sunflower (*Helianthus annuus*) are closely related to weedy species. It is conceivable that certain kinds of genetic modifications of such species might cause invasiveness (Keeler, 1989). Many candidate biofuel feedstocks are the focus of well-funded genetic modification programmes (Burke 2007). Genetic modification of crop plants, either by traditional or molecular techniques, has rarely resulted in them becoming invasive because most modifications have been for traits such as genetic uniformity for ease of harvest, high fertiliser and irrigation uptake, and low seed dormancy (DiTomaso *et al.* 2007). In contrast, biofuel feedstocks are being modified to increase their environmental range (through traits such as drought or salt tolerance and enhanced nutrient-use efficiency) and aboveground biomass, both of which could increase invasiveness.

1G BIOFUEL CROPS -

Low and Booth (2007): jatropha (*Jatropha curcas*), Chinese tallow tree (*Triadica sebifera*), neem (*Azadirachta indica*), olive (*Olea europaea*), castor oil plant (*Ricinis communis*), Chinese apple (*Zizyphus mauritiana*), moringa (*Moringa pterygosperma*), calotrope (*Calotropis procera*), giant milkweed (*Calotropis gigantea*), caper spurge (*Euphorbia lathyris*) and pongamia (*Milletia pinnata*).

With the exception of pongamia, all of these species are known to be invasive somewhere in the world. Other traits of these species that make them high risk include rapid growth and establishment rates, large propagule production, broad environmental tolerance and few natural enemies in the recipient ecosystems. The scale of many proposed planting schemes is likely to exert major propagule pressure increasing the risk of invasions on adjacent protected areas, forests and agricultural land.

Jatropha and Jatropha *curcas* in particular has been heavily promoted in many countries as a source of biodiesel, especially in developing country contexts.. For example, by 2012, under an official biofuel development strategy, India aims to have planted jatropha on about 13.4 million ha of land classified as marginal (GoI 2003). This represents an area slightly larger than the size of Greece.

SECOND GENERATION BIOFUEL FEEDSTOCKS

Second generation (2G) biofuels are produced from a wider range of cellulosic biomass including agricultural wastes and plant species grown specifically for their biomass and converted to biofuels using advanced thermo-chemical or bio-chemical processes. A great deal of excitement is being generated by the prospect of 2G biofuels. Not only are they more efficient in terms of energy generated per hectare and equivalent greenhouse gas emission reduction, they open up the possibility of utilising a wide range of feedstock plants adapted to a range of environments, of utilising more marginal land for biofuel feedstock production, flexible harvesting times and the prospect of integrating biomass production into sustainable forest

Third generation biofuel feedstocks

Third generation (3G) biofuels are potential future biofuels produced from "energy-designed" feedstocks with much higher production and conversion efficiencies than other biofuels. One promising line of research is to reengineer easily cultured organisms such as the bacterium *E. coli*, yeast and algae to convert sugars from agricultural waste and other cellulosic materials to compounds that are essentially identical to today's fossil fuels. Other research efforts are focusing on engineering algae so that they can absorb sunlight to produce fuel directly.

Even if the technology to convert sugars and biomass to biofuels using reengineered organisms becomes economically viable in the near future, it will still largely depend on cropping systems to generate sugar and biomass. The invasive species implications of an species becoming invasive but it does mean that, other things being equal, the new crop is of ecosystem changes. However, the likelihood of this is much lower than it is for introduced species. On the other hand, if native species are bred especially to improve certain traits, there

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