Most current biofuels are produced from food crops that are well understood and have been domesticated for centuries. However, many plant species which are currently being developed or considered for biofuels for their potential efficiency gains (including better GHG balance, reduced competition for land, etc.) are potentially invasive. Invasive species can cause serious harm to the environment, local livelihoods and economies. Prevention and mitigation measures at the national and project level can help to minimize the risk of invasion of species used for biofuel production and their impacts. Using risk assessments and monitoring systems including indicators to reflect potential impacts on biodiversity is considered an important step to identify where special care or urgent action is needed. So far, in the rush to pursue benefits of biofuels, the risk of invasion by species developed or introduced for biofuel production has received little attention.

UNEP WCMC IUCN

GAIN OR PAIN? BIOFUELS AND INVASIVE SPECIES

WHY IT MATTERS: RISKS AND OPPORTUNITIES

Most current biofuels are produced from food crops that are well understood and have been domesticated for centuries. However, many plant species that are currently being developed or considered for biofuels are potentially invasive. Whether species that are used, considered or developed as biofuel crops will become invasive depends on their ability to grow and spread in the conditions where they are used, hence the risk of invasiveness has to be determined on a local, eco-system level.

Several features have been found to be typical of crops that are invasive (source: IUCN, 2009):

- Fast growth and ability to outcompete local vegetation
- Large and abundant seed production
- Tolerance to wide range of soil and climate conditions
- Adaptability to a wide range of soils and climates
- Resistance to pests and diseases
- Lack of predators in the recipient ecosystem

It is exactly for these features that potentially invasive species are being considered as biofuel feedstocks as they may make them more resource efficient, which may ultimately result in economic and to some extent environmental benefits linked to reduced competition for land and other resources.

This is of particular relevance to advanced biofuels – including so called second generation biofuels – as they can be produced from biomass from a wide range of fast growing ligno-cellulosic feedstocks and inedible plant oils, many of which featuring on the list of potentially invasive species, such as *Arundo donax, Panicum virgatum,* and *Prosopis spp.* (GISP 2008, see Box 1). Potential benefits in terms of productivity and profitability gains need to be weighed against the greater risk of becoming invasive and causing damage to ecosystems, livelihoods and the economy.

Genetically modified crops are often developed specifically to target some of the features that are typical for invasive species. To reduce competition for land with food crops, genetic modification of advanced biofuel species may promote drought tolerance and low nutrient requirements to allow the species to grow on degraded land. Traits such as resistance to pests and diseases may be promoted as well, and thus the potential invasiveness of the resulting crop may be greater. This is of special concern in the development of advanced biofuels, but can be an issue as well in the genetic modification of food crops used for biofuel production (first generation biofuels).

For example, canola (*Brassica napus*) and its relatives are known for their potential weediness (e.g. GISP 2008). Its seeds and pollen are highly mobile and can outcross and hybridize with wild relatives. Through genetic modification, insect-resistant and herbicide-tolerant canola varieties have been developed. The species' prominence as a source for biodiesel may lead to larger areas planted with canola and potentially also its genetically modified varieties (McGeoch 2009 for South Africa). Another species which is prominent for biofuel production but has a history of invasion in some places is J*atropha curcas*. The species originates from tropical regions in the Americas but has been found to become invasive in parts of Australia, South Africa, India, and the Galapagos Islands, among other places (GISP 2008).

It is considered likely that the cost of an invasion by a biofuel feedstock or associated pest would, in the long-run, outweigh any economic benefit offered by biofuel development (IUCN 2009). The potential benefits of introducing new species as biofuel feedstocks should thus be weighed against the potential of those species to cause serious harm to biodiversity, local livelihoods and national economies.

While this paper has focused on feedstock for biofuels, it is important to consider that potential invasiveness may also be an issue for species considered for bioenergy more generally, such as fast growing trees and shrubs. Measures to prevent invasion and mitigate impacts will be similar to those discussed here.

Box 1: Example of a potentially invasive bioenergy crop

Prosopis spp. are a group of species that might initially appear to be ideal feedstocks for second-generation biofuels. Native to Central and South America, the species are fast growing, have low nutrient requirements and are able to access deep sub-surface water sources in dry areas. They are also nitrogen fixing and can improve soil fertility. These characteristics led to a number of Prosopis species being introduced to Australia, Asia, and dryland Africa for fuelwood, fodder, shade, to improve soils and reduce soil erosion. However, it quickly became apparent that Prosopis was invasive due to traits such as rapid growth, abundant seed production, the tendency to form impenetrable thickets and stop other plants from growing, the ability to thrive in dry, saline soils, and foliage that is unpalatable to livestock.

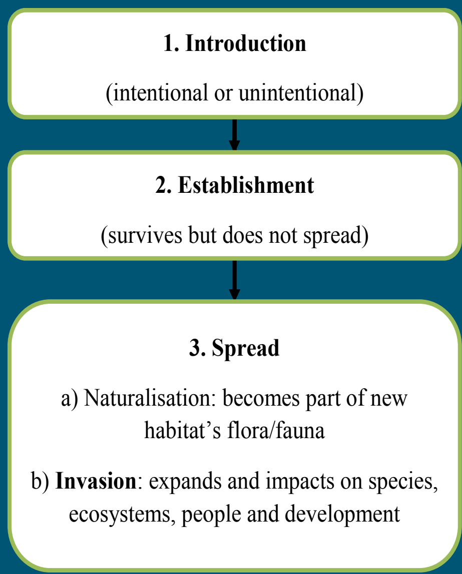
Following the collapse of demand for Prosopis, many plantations were abandoned, without adequate management and eradication. Prosopis now covers millions of hectares in many countries in Africa and is severely impacting on grazing and traditional pastoralist livelihoods. The dense thickets have outcompeted local species and lowered ground and stream flow levels in many watersheds. Despite these negative effects, some positive benefits from Prosopis include wood and charcoal so there is often conflict over plans to control or eradicate it.

Current efforts to control Prosopis involve a mix of chemical, mechanical and biological control methods. Two biological control agents from the US (*Algarobius prosopis* and *Neltumius arizonensis*) have been used to reduce seed production with some success in South Africa, however more options such as fungi are being explored. (Source IUCN 2009)

Invasive species: Definition and Impacts

An invasive species is defined as a species that has become naturalized in a new ecosystem and causes (or has the potential to cause) harm to biodiversity, the environment, economies and/or human health (see figure 1, adapted from IUCN 2009). Some species become invasive after introduction into environments where they do not naturally occur either intentionally, e.g. for agriculture, forestry and horticulture, or accidentally in association with international trade and tourism. Other species become invasive because factors that naturally control their populations, such as pathogens or predators, change or disappear. The phenomenon of "biological invasion" results from a combination of the characteristics of the introduced species and the recipient ecosystem.

Figure 1: The process of invasion (adapted by IUCN, 2009)



Invasive species can out-compete other species and irreversibly alter ecosystem composition and functioning. In addition, they can introduce new pathogens that can harm ecosystems and affect human health. The Millennium Ecosystem Assessment (2005) considers biological invasions brought about by alien species to be among the most important direct drivers of biodiversity loss and degradation of ecosystem services. They are especially important on islands, where they represent the leading cause of species extinctions.

Apart from their impacts on biodiversity and the environment, invasive species can have significant impact on local people's livelihoods that depend on natural resources (such as the alien Larger Grain Borer in Africa which can spoil more than half a year's harvest of stored grain), and the economy. For example, the total cost of introduced weeds to the United States economy was estimated to be around $27 billion per year (Pimentel et al. 2005). In India, economic loss due to introduced weeds was estimated at $37.8 billion per year (Pimentel et al. 2001).

Although countries are establishing stricter rules for the introduction of new species, and national invasive species' management systems are improving, evidence suggests that the magnitude of the threat to biodiversity posed by biological invasions is increasing globally (Hulme 2009). Developments in the biofuels sector have the potential to contribute to this trend (IUCN 2009).

PREVENTION AND MITIGATION OPTIONS

The risk of invasion by biofuel crops and resulting environmental, social and economic impacts can be minimized through prevention and mitigation measures. Guidance exists for measures at every stage in the supply chain and for governments as well as developers and investors (see figure 2).

International initiatives to enhance the sustainability of the biofuels sector have been established targeting the national level through partnerships between governments and a number of intergovernmental agencies, such as the Global Bioenergy Partnership (GBEP). Targeting the project level, initiatives have been created through partnerships between producers, NGOs, intergovernmental agencies, banks and investors and other stakeholders, as in the Roundtable on Sustainable Biofuels (RSB), the Roundtable on Sustainable Palm Oil (RSPO), and the Better Sugarcane Initiative (BSI). Awareness of the potential invasion risk of species used for biofuel production is clearly increasing throughout these initiatives, and is reflected in the sets of standards, principles, criteria and/or indicators they have developed.

Monitoring systems are of crucial importance to detect the escape as well as impacts of potentially invasive crops; and direct control can be applied on the project level. For example, Criterion 7.e of the Version One of the Roundtable on Sustainable Biofuels (RSB) addresses invasive species and currently states the following: *Biofuel operations shall prevent invasive species from invading areas outside the operation site.* Operators who must comply are Feedstock Producers and Feedstock Processors.

Calotropis Gigatean

Minimum requirements stipulated in the RSB standard are: Operators shall not use any species officially prohibited in the country of operation. Whenever the species of interest is not prohibited in the country of operation, operators shall seek adequate information about the invasiveness of the species to be used for feedstock production, e.g. in the Global Invasive Species Database (GISD). If the species is recorded as highly invasive under similar conditions (similar climate, and similar local ecosystems, and similar soil types), this species shall not be used. If the species has not been recorded as representing a high risk of invasiveness under similar conditions (climate, local ecosystems, soil type), operators are required to follow steps to prevent the invasion and mitigate potential impacts of the species. (For more information see www.rsb.org)

On a national level, one option to monitor risk potential is by observing some indicators: the number of species used for biofuel production that have a potential for invasiveness in the country, the area on which these species are grown and existing, and newly arising information on impacts that they can cause or are causing in other places. This will help identify areas where special care or urgent action is needed to prevent or mitigate potential impacts on the environment, local people's livelihoods and economies. The end of the paper presents some tools and resources that are readily available to assess the potential risk of invasiveness of species and find more information about their history and potential impacts (Box 2).

Figure 2: Stages in the biofuel supply chain and steps that can be taken by governments, as well as developers and investors to prevent and mitigate impacts of potentially invasive species used for biofuel production

Stage in supply chain	Guidance for governments	Guidance for developers & investors
1. Crop selection	• Conduct Strategic Environmental Assessment (SEA) to identify suitable crops and plan zoning to ensure cultivation areas are sensibly sited. • Plan for mitigation in case needed.	• Conduct Environmental Impact Assessment (EIA) to accompany SEA, incl. a Weed Risk Assessment of potential crops. • Include cost of eradication, containment, management and restoration in economic assessment.
2. Importation of crops	• Develop and strengthen quarantine regulations that meet the International Standards for Phytosanitary Measures (ISPM) and allocate resources to National Plant Protection Organisations (NPPOs) for monitoring and enforcement.	• Comply with national regulations relating to the introduction of live plants or propagules during the importation phase. • Consider support of voluntary standards for best practice. • Support quarantine measures.
3. Feedstock production	• In line with the 'Polluter Pays' principle, develop regulations that enable the polluter to be pursued for compensation in any case of negligence, thereby encouraging the developer or producer to follow best practices.	• Submit Environmental Management Plan (EMP), including a) a contingency plan for action in the event of an escape, b) the provision of a fund for action needed after an escape, c) the development and implementation of a monitoring system.
4. Harvesting, processing, transport and trade	• Promote conversion of feedstocks at or near the production site • Ensure that quarantine procedures monitor movement of high-risk crops • Develop communication and education programs for stakeholders	• Ensure propagules are contained in appropriate manner on site • Prevent spread of seeds, pests, etc. during transport and monitor transport corridors • Convert crops on or near cultivation areas • Raise awareness of stakeholders

AVENUES FOR SUSTAINABLE BIOFUEL PRODUCTION

LOOKING AHEAD:

- Raise awareness of the potential risk of invasiveness of some species currently cultivated, considered or developed for biofuel production and of impacts they can cause to the environment, local people's livelihoods and economies.

- Use existing guidance for governments, as well as developers and investors and establish measures to prevent and mitigate any potential risk for species to become invasive and cause harm.

- Use existing information sources for regular updates on potentially invasive species, impacts they may cause and options for preventing invasion and mitigating potential impacts. Develop a mechanism for collating experience of invasiveness in biofuel crops and channeling it to the updating processes of relevant global information sources.

- Develop and use indicators to monitor the cultivation of potentially invasive species at the national level and escapes at the project level to allow for early identification of species of potential concern and escapes of propagules, and establish appropriate mitigation measures.

Box 2: Tools and resources

There are a variety of tools and resources that can aid in the planning process to avoid the use of invasive species for bioenergy projects. Below is a list of some tools/resources that are available for project developers:

Weed Risk Assessment (WRA): WRA is a question-based scoring system used to assess the likelihood of a species for becoming invasive. The system was developed in Australia and has been endorsed by the Australian Government to assess all new plants before entering Australia. It is transferable to other contexts and can be used before introduction of a new species as well as at a later stage to identify whether species in cultivation have the potential for becoming invasive by substituting the scores 'accept', 'evaluate' and 'reject' with 'low risk', 'medium risk' and 'high risk'.

CABI International Invasive Species Compendium: The Compendium is an encyclopedic resource that brings together a wide range of different types of science-based information to support decision-making in invasive species management worldwide. It comprises detailed datasheets that have been sourced from experts, edited by an independent scientific organization, and enhanced with data from specialist organizations, images, maps, a bibliographic database and full text articles.

Global Invasive Species Database: The Global Invasive Species Database (created by the Invasive Species Specialist Group - IUCN Species Survival Commission) is a global database that is regularly updated by experts with species information on alien species from all taxonomic groups in all ecosystems. It is utilized to increase awareness about invasive species in an effort to promote better management practices.

IABIN's Invasives Information Network (I3N): The Invasives Information Network of the Inter-American Biodiversity Information Network (IABIN) integrates information from Western Hemisphere countries to support the detection and management of invasive species. I3N provides capacity building, electronic tools and support for database development and increased access to information.

References

GISP (2008) Biofuels run the risk of becoming invasive species. Global Invasive Species Programme (GISP), available at http://www.gisp.org/whatsnew/docs/biofuels.pdf, accessed 19/04/2010.

Hulme, P.E. 2009. Trade, transport and trouble: managing invasive species pathways in an era of globalization. Journal of Applied Ecology 46, 10-18.

IUCN (2009) Guidance on Biofuels and Invasive species. IUCN, Gland, Switzerland.

McGeoch, Kalwij, J.M., Rhodes, J.I. 2009. A spatial assessment of Brassica napus gene flow potential to wild and weedy relatives in the Fynbos Biome. South African Journal of Science 105, 109-115.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

Pimentel, D., Zuniga, R., Morrison, D. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52, 273-288.

Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'Connell, C., Wong, E., Russel, L., Zern, J., Aquino, T., Tsomondo, T. 2001. Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, Ecosystems & Environment 84, 1-20.

For more information on the Bioenergy Issue Paper Series, please contact Punjanit Leagnavar at: punjanit.leagnavar@unep.org, or visit our website at http://www.unep.fr.