WORKING PAPER

This review is associated with the Evidence-Based Forestry initiative, a collaboration between CIFOR and partner institutions supporting systematic reviews of evidence to enable better-informed decisions about forests and landscapes.

Does production of oil palm, soybean or jatropha change biodiversity and ecosystem functions in tropical forests?

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Working Paper 167

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Photo by Jeff Walker/CIFOR
The Miombo woodlands in northern Zambia are the site of a number of large-scale biofuel investments.

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1 Background

During the past decade there has been a growing interest in bioenergy, especially biofuels, driven by concerns about global climate change, growing energy demand and depleting fossil fuel reserves (Rajagopal and Zilberman 2007). Energy derived from plant material, such as sugarcane and oil palm, offers, at least in theory, a promising way to answer part of our energy demand without increasing our greenhouse gas (GHG) emissions. In addition, biofuel production can create additional income for the rural poor and advance economic development (Feintrenie et al. 2010).

Nevertheless, biofuel-based opportunities do not come without concerns. Direct or indirect land-use change due to a wide expansion of biofuel cultivation can result in deforestation and destroy natural habitats (Lewandowski and Faaij 2006; Koh and Ghazoul 2008) which in turn may lead to the loss of biodiversity (Danielsen et al. 2009; Phalan 2009). Other environmental concerns include soil degradation and erosion, water pollution and scarcity, and species' potential to invade natural ecosystems (Lewandowski and Faaij 2006). Furthermore, biofuel production can cause greater GHG release than the use of fossil fuels depending on the feed stock, energy intensity of the production process and land type converted to biofuel cultivation (Fargione et al. 2008; Gibbs et al. 2010). Potential negative social aspects include rising food prices and shortages of food supply, land tenure conflicts and insufficient production remuneration (Naylor et al. 2007; Feintrenie et al. 2010).

The debate surrounding biofuel production, especially in the tropics, has been highly polarized (Koh and Wilcove 2009). In this review, we intend to assess objectively the current state of knowledge of the impact of three first generation biofuel crops (oil palm, soybean and jatropha) on biodiversity in the tropics. We use the broad definition of biodiversity as defined in the Convention of Biological Diversity: "Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." Thus, we will assess the effects of biofuel crops on three different levels: landscape, ecosystem and species level. First, we will study the direct impact of crop plantations due to forest fragmentation and deforestation (i.e. forest conversion) on species abundance, diversity and composition. We will also include studies on ecosystem functions, as these reflect changes in the ecosystem. Second, as the impact on biodiversity may differ under different production models, we will also compare industrial plantations and smallholder plantations. If we find negative impacts of biofuel crop cultivation on biodiversity, we will study different standards related to oil palm, jatropha and soybean to find out how well these standards mitigate the impacts.

We recognize that biofuel production is currently not the main use of palm oil and soybean and, hence, has so far contributed largely in an indirect way on the observed land-use change patterns (Rajagopal and Zilberman 2007; Phalan 2009). However, as biofuel production is likely to grow significantly (FAO 2008), it is important to know what the potential consequences of an expansion of biofuel cultivation for biodiversity are in order to provide informed policy guidance.

1.1 Objective of the review

1.1.1 Primary question

Does production of oil palm, soybean or jatropha change biodiversity and ecosystem functions in tropical forests?

1.1.2 Secondary questions

Is there a difference in the impact on biodiversity between industrial plantations and smallholder plantations per volume of fuel produced?

Do different standards related to oil palm, jatropha and soybean mitigate the negative impacts?

2 Methods/Design

2.1 Searches

The search aims to capture a comprehensive as possible sample of literature published in peer-reviewed journals and other relevant literature. The following literature databases will be searched: Biofuels Abstracts database by CABI, Web of Science, LAN TEEAL (Agriculture and natural resource management), and Directory of Open Access Journals.

In addition, the following internet search engines will be used in order to maximize coverage: Google, Google Scholar and Scirus. Literature will also be searched on the websites of relevant organizations such

as the Food and Agriculture Organization (FAO), the International Finance Corporation (IFC), the United Nations Framework Convention on Climate Change (UNFCCC), the World Resources Institute (WRI), the International Institute for Environment and Development (IIED), the International Union for Conservation of Nature (IUCN), the Rights and Resources Initiative and the World Wildlife Fund (WWF). Bibliographies of articles included in the review and previously published reviews will be checked for references. Recognized experts and key stakeholders will be contacted to provide further recommendations and information. The protocol will be updated if any additional source of information outside those listed is used.

The following search strings and their translations in French, Spanish, German, Swedish and Finnish will be used: (oil palm OR soybean OR jatropha) AND tropic* AND "species diversity" OR "species richness" OR "species abundance" OR "species similarity" OR "species composition" OR "community composition" OR deforestation OR "land use change" OR fragmentation OR "habitat loss" OR connectivity OR "functional diversity" OR ecosystem OR displacement. Variation in spelling of search terms will be checked. All returned hits from academic databases will checked for relevance. When searching the internet, only the first 50 hits will be checked.

2.2 Study inclusion criteria

The criteria listed below will be used to assess the title, keywords, and the abstract for relevance. If there is uncertainty whether an article should be included or not based on the title, keywords, and the abstract, the article will be read in full to determine suitability. Studies that have data about a relevant subject, intervention and outcome, along with a valid comparator will be included if they fulfill the quality criteria listed in Table 1.

2.2.1 Primary study question: Does production of oil palm, soybean, or jatropha change biodiversity and ecosystem functions in tropical forests?

Geographical location: Study area should be within the tropics (23.438°S to 23.438°N).
Relevant subject(s): Faunal and floral species.
Types of intervention: Conversion of the land to cultivate oil palm, soybean, and jatropha for any purpose.
Types of comparator: Other land use or land cover (primary forest, logged over forest, secondary forest (*i.e.* regrowth forest), shrub land, grassland, cropland). Ideally a study would compare current land use with previous land use but as those types of studies a rare, we will accept studies that have a reference site close enough to the converted site so that ecological conditions in study sites remain similar.
Types of outcome: Change in biodiversity indicators (relative species richness and abundance, species composition) and ecosystem functions.
Types of study: Qualitative and quantitative primary studies as well as descriptive studies and reports.

2.2.2 Secondary study question 1: Is there a difference in the impact on biodiversity between industial plantations and smallholder plantations per volume of fuel produced?

Geographical location: Study area should be within the tropics (23.438°S to 23.438°N).
Relevant subject(s): Faunal and floral species.
Types of intervention: Conversion of the land to industrial plantations to cultivate biofuel crops.
Types of comparator: Smallholder plantations.
Types of outcome: Change in biodiversity indicators (relative species richness and abundance, species composition) and ecosystem functions.
Types of study: Qualitative and quantitative primary studies as well as descriptive studies and reports.

2.2.3 Secondary study question 2: Do different standards related to oil palm, jatropha and soybean mitigate the negative impacts?

Geographical location: Study area should be within the tropics (23.438°S to 23.438°N).
Relevant subject(s): Different standards related to biofuels.
Types of intervention: Standard in place should mitigate the impact of crop cultivation on biodiversity.
Types of comparator: Standards will be compared against each other to clarify how they mitigate the impact on biodiversity.
Types of outcome: Preferable outcome of any given standard is that it will mitigate any negative impact and enhance positive impacts within and nearby production area.
Types of study: Standards related to oil palm, jatropha and soybean, i.e. international legislation, industry standards, ISO management standards, NGO standards.

3 Potential effect modifiers and sources of heterogeneity

Spatial and temporal scales can affect study outcomes as can different environmental conditions of the study sites. Hence, potential effect modifiers and sources of heterogeneity are listed below. Furthermore, surrounding landscape can influence the direction and intensity of a change.

Temporal and spatial scale
Altitude
Soil properties
Surrounding landscape
Original vegetation
Hunting intensity
Herbicides
Insecticides
Rodenticides
Fertilizers
Rotation time
Plantation management (industrial vs. smallholders)
Plantation size
Plantation type

4 Article screening

First reviewer will check all hits for relevance based on the title and keywords. After the first selection, abstracts of the remaining articles will be read to further determine the suitability of the articles for the review. The selected documents will then be read in full to determine their suitability for the review. At the beginning of the literature selection phase, kappa analysis will be undertaken to assess reviewer bias in the selection phase and to assure that study inclusion criteria are used consistently.

5 Study quality assessment

An ideal study for this review would have sampled the area before and after the land conversion. The sampling would have been long enough to take into account seasonal variation and it would have been spatially extensive. However, as such studies are not common, we will include all studies that fulfill the inclusion criteria. To avoid misleading conclusions due to the variation in the general study design, the studies will be weighted according to the hierarchy of quality of evidence (Table 1). Studies that fall into the category VI will be excluded from the analysis.

Table 1. Hierarchy of quality of evidence based on the information provided in the documents.
Modified after Pullin and Knight (2013).

Category	Quality of evidence presented
I	Randomized controlled trials of adequate spatial and temporal scale for the study species
II	Controlled trials without randomization with adequate spatial and temporal scale for the study species
III	Comparisons of differences between sites with and without controls with adequate spatial and temporal scale for the study species
IV	Evidence obtained from multiple time series or from dramatic results in uncontrolled experiments
V	Opinions of respected authorities based on qualitative field evidence, descriptive studies or reports of expert committees
VI	Evidence inadequate owing to problems of methodology e.g. sample size, spatial or temporal scale

6 Data extraction strategy and synthesis

For the analysis we will categorize the data using the following five categories: mammals, birds, amphibians and reptiles, invertebrates and plants. If we find enough studies on plants they will be classified according to plant functional groups.

The estimates of species richness and abundance and their means and standard deviations will be extracted to a spreadsheet. Also, species similarity indices will be extracted. If information about the type of species that cause dissimilarities in the species composition, e.g. forest, edge or light-demanding species, is available, it will be extracted and categorized accordingly. In regard to ecosystem functions the change and its direction (negative or positive changes) will be recorded. Finally, information about the potential sources of heterogeneity will be included in the spreadsheet and if enough data for any of the categories is found it will be taken into account in subsequent data analyses. Where insufficient data is provided for extraction, we will contact authors to acquire additional data.

If there is insufficient data to perform meaningful statistical analyses on biodiversity indicators or ecosystem functions, we will summarize the data narratively. At a minimum, we will present narrative synthesis tables that will list all included studies together with key characteristics, including critical appraisal of methodology.

The data will be categorized according to the subject, comparator and outcome. We will also summarize the requirements to mitigate impacts related to biodiversity in different standards.

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CIFOR Working Papers **contain preliminary or advance research results on tropical forest issues that need to be published in a timely manner to inform and promote discussion. This content has been internally reviewed but has not undergone external peer review.**

Background: Biofuels, or fuels derived from transformation of biological matter, are hailed by some as a promising source of renewable energy potentially reducing greenhouse gas emissions. A widespread adoption of biofuels will, however, present its own set of challenges and consequences. Direct or indirect land-use change due to expansion of feedstock cultivation can cause deforestation and forest degradation leading to biodiversity losses and other environmental concerns like soil degradation and erosion, water pollution and scarcity, and the risk of crop species invading natural ecosystems.

Although biofuel production is currently not the main use of palm oil and soybean and, hence, has so far contributed only little to the land-use change patterns, it is predicted to grow. Therefore, it is important to know the potential consequences of the expansion of biofuel cultivation may have for biodiversity in order to provide policy guidance.

Methods/design: In this review, we will assess the current state of knowledge of the impact of three first generation biofuel crops — oil palm, soybean and jatropha — on the biodiversity and ecosystem functions of the tropical forests. We will look at the additional comparison of impacts from industrial versus smallholder plantations, and will compare the mitigation potential of different standards related to biofuel production. We will consider both qualitative and quantitative primary studies as well as descriptive reports that compare land conversion for target crop production with other land uses or land-cover types. Both before/after and site comparison studies will be included. Biodiversity indicators to be assessed are species richness, abundance, and plant and animal community composition. If there is enough data, quantitative meta-analysis will be performed. Otherwise, results will be summarized narratively.

BioMed Central

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