Jatropha facts

Can jatropha curcas contribute to climate change mitigation?

Climate change mitigation is one of the key arguments for promoting biofuels. It has been claimed that cultivating jatropha increases the carbon stock when grown on marginal land, and additional GHG reductions are possible by replacing fossil diesel with biofuels. We have shown that bioenergy from jatropha can generate GHG savings of more than 40% compared with fossil fuels. However, jatropha can also create a carbon debt, delaying net savings for more than 50 years. The potential for climate change mitigation depends on where and how the value chain is established and is particularly sensitive to the initial soil and vegetation carbon stocks, land preparation, crop management and use of by-products.

Policy message

- Jatropha value chains can potentially enable more than 40% savings in greenhouse gas (GHG) emissions relative to a fossil reference. Climate change mitigation can only be achieved, however, if jatropha is cultivated on land with initially low carbon stocks and if no trees are cut.
- The carbon sequestration potential of jatropha is limited, due to its low growth rate and continuous pruning. It is only possible to achieve a relatively low carbon stock, which is comparable to fallow land. Consequently, cultivating jatropha solely for carbon payments is inadvisable.
- The cultivation of jatropha as a living fence allows maximum greenhouse gas savings due to low resource inputs and minimal land use transformation.

Figure 1: Kenyan farmer in Kibwezi showing her one year old jatropha plantation. Growth rate is low and carbon sequestration potential is limited. (©Gmuender)

Jatropha's mitigation potential and emission risks

Over the past five years, jatropha has been promoted in sub-Saharan Africa as a crop that is well-adapted to the semi-arid conditions, able to enhance rural development and reduce the dependency on fossil fuels, and as a climate change mitigation strategy (Mogaka et al, under review).

Several studies have underscored the potential for jatropha bioenergy to contribute to climate change mitigation by increasing carbon stocks when grown on marginal land and reducing GHG emissions compared to the use of fossil diesel. However, most studies are based on estimates rather than measured data, and the results vary widely because the climate change mitigation potential is highly dependent on where and how the jatropha value chain (Figure 1) is established.

This study's main objective was to assess the variance in GHG emissions across different jatropha systems in East Africa (Kenya, Tanzania and Ethiopia) and West Africa (Mali). Using the life cycle assessment (LCA) approach according to ISO standards 14040/44, specific biomass and soil carbon stocks were measured and the carbon emissions across the whole value chain were estimated and benchmarked against fossil fuel values.

We have shown that the climate change mitigation potential of jatropha bioenergy includes GHG savings of more than 40% compared to fossil fuels (Gmünder et al, in prep.). However, cultivating jatropha can also cause significant carbon debts. The capacity for jatropha value chains to mitigate climate change is particularly dependent on: i) selection and preparation of land, ii) crop management and iii) use of by-products.

Selection and preparation of land

Optimal site selection is key to establishing sustainable jatropha production systems, because the relevant factors are site-specific: crop growth rates, economic viability, social acceptance and environmental impacts. The carbon balance of jatropha bioenergy is also heavily influenced by the amount of carbon emitted due to direct or indirect changes to the biomass and soil carbon stock (Figure 3).

Direct land use change effects
Generally, establishing jatropha on natural areas has caused a significant loss of carbon stored in the biomass and an initial loss of soil carbon (observed in 3-4 years

Featured case studies

Carbon debt from jatropha cultivation: A case study in Mali showed that in 10% of the cases, jatropha was established on former fallow land with an average biomass carbon stock (above and below ground) of 25 Mg carbon per hectare. The biomass carbon stock (above and below ground) of four year old jatropha plantations, however, is only 2.3 Mg carbon per hectare, resulting in a significant increase in net carbon emissions.

Jatropha as a multipurpose crop mitigating soil erosion and climate change: In Ethiopia, approximately 90% of the population lives in areas marked by land degradation and reduced agricultural productivity. A case study in Ethiopia showed that planting jatropha can be an effective prevention and mitigation measure against soil erosion (Bach 2012). The build-up of biomass and collection of seeds to secure local energy needs also allows for GHG savings. Thus, jatropha has the potential to alleviate soil degradation, increase carbon stocks and contribute to energy security.

Integrating jatropha into existing cropping systems as hedges or fences: In Tanzania, a private company linked jatropha out-growers to a centralized press. jatropha is cultivated in fences, and the seeds are processed in a large-scale oil press, allowing maximum GHG savings due to low resource inputs during cultivation, minimal land use transformation and efficient co-product use. After ten years, however, the business is still not economically viable.

old plantations; soil carbon Stock might, however, increase again in the longer term). A case study in Mali showed that more than 10% of the jatropha plantations were established on former savannah land, where it takes several decades to pay back the carbon emitted due to the land transformation (Degerickx et al. in prep.). Similarly, the conversion of Miombo forest in East Africa led to a carbon debt of more than 30 years (Romijn 2011).

In Kenya and Tanzania, more than 80% of the smallholder farmers established jatropha monocropping or intercropping systems on agricultural land that in most cases had previously been used to cultivate maize (Mogaka et al. under review). If such relatively low carbon stock areas are transformed into jatropha plantations, the carbon stock generally increases. Nevertheless, the potential for carbon sequestration is low due to limited biomass build-up caused by continuous pruning and short rotation length (Figure 1).

Indirect land use change effects

The transformation of arable land into jatropha plantations might cause indirect land use change effects, as the replaced crops are likely to be produced elsewhere. This mechanism might lead to either agricultural intensification or to the expansion of production activities into protected areas or natural ecosystems. The introduction of jatropha on arable land may therefore indirectly increase pressure on natural forest systems, which, in the worst-case scenario, would result in more than twice the GHG emissions of fossil fuels.

Crop management from a greenhouse gas perspective

Significant GHG emissions during crop cultivation are often related to the use of machinery and irrigation systems, the production of fertilizers and pesticides, and the field emissions generated when applying fertilizer (e.g. nitrous oxide). The extent to which these emissions contribute to the overall GHG balance is mainly determined by the chosen cropping system and how efficiently the resources are used.

Optimal crop management practices for jatropha currently remain undetermined. In East Africa, this was one of the key factors leading to poor yields and inefficient use of inputs, especially in the case of block plantations, whether commercial or smallholder monocropping and intercropping systems. Fencing systems and hedges, however, are often not managed and therefore generate minimal GHG emissions during cultivation (Figure 2).

Figure 2: In Bati (Ethiopia) jatropha is used as fences around plots and as a soil and water conservation structure. The build-up of biomass and collection of seeds to secure local energy needs also allows for GHG savings. (©Gmünder)

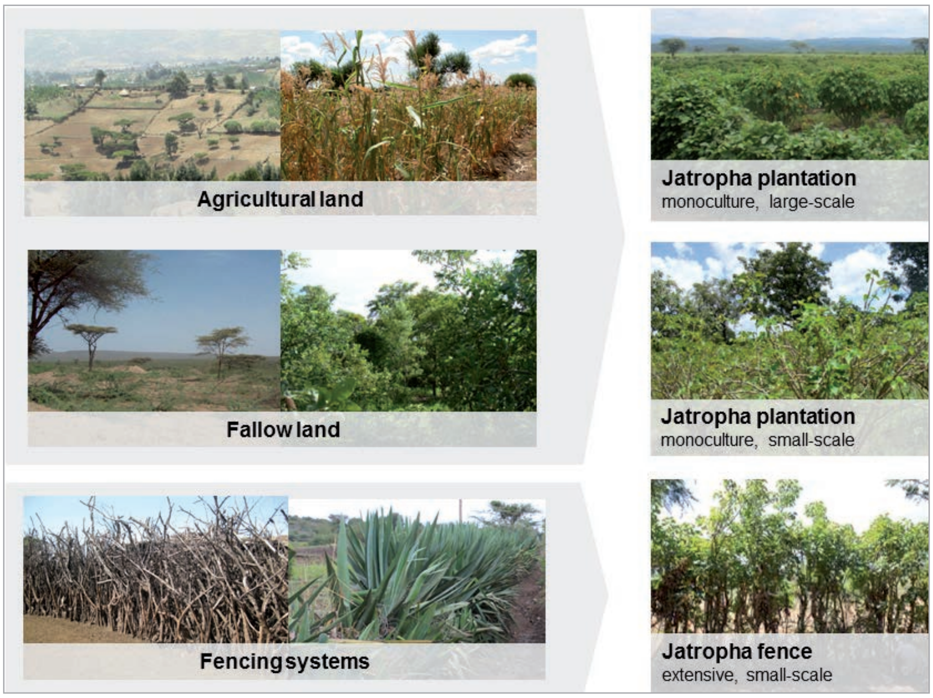

Figure 3: Establishing jatropha plantations causes direct and indirect land use changes. Biofuels' greenhouse gas balance is greatly determined by the net impact of land use changes on the extent of biomass and soil carbon pools.

Optimizing the use of by-products

The average oil content of a jatropha seed is about 35%, and depending on the extraction technology, about 75% of this oil can be collected. For each kilogram of straight jatropha oil that is collected, about 2.8 kilograms of press cake are therefore produced. The press cake contains several toxic compounds and therefore cannot be used as animal feed without first undergoing detoxification. It does, however, have high nutrient levels and can be used directly as a fertilizer to close the nutrient cycle (substituting fertilizer).

The press cake fraction also contains more energy than the oil fraction and therefore great potential exists for using the press cake as a biogas feedstock (substituting natural gas) or for direct combustion as briquettes or pellets (substituting charcoal or firewood). GHG emission reductions will generally be lower if by-products remain unused (Figure 4).

Further research needed

Participatory data acquisition is needed to build up a consolidated and reliable database that includes documented metadata along the entire land use system. The focus should be primarily on yield data, carbon stock data and non-CO_2 GHG emissions, which typically show large variations and are highly context specific. It would also be useful to consolidate knowledge related to land use dynamics across both croplands and their surrounding areas.

In addition, most studies about the potential for climate change mitigation focus on established jatropha value chains and therefore updated models are required to understand the impact of future jatropha systems.

Definitions

Carbon debt: The amount of biomass and soil carbon released due to land conversion.

Carbon sequestration: The uptake and storage of carbon containing substances, in particular carbon dioxide, is often called (carbon) sequestration. (source: www.ipcc.ch)

Carbon payback time of biofuels: The number of years needed to produce carbon savings from burning biofuels instead of fossil fuels to offset the carbon debt incurred by clearing land to grow biofuel crops.

Greenhouse gas (GHG): Gaseous constituents of the atmosphere that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour, carbon dioxide, nitrous oxide, methane and ozone are the primary greenhouse gases in the Earth's atmosphere. (source: www.ipcc.ch)

Life Cycle Assessment (LCA): The compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040).

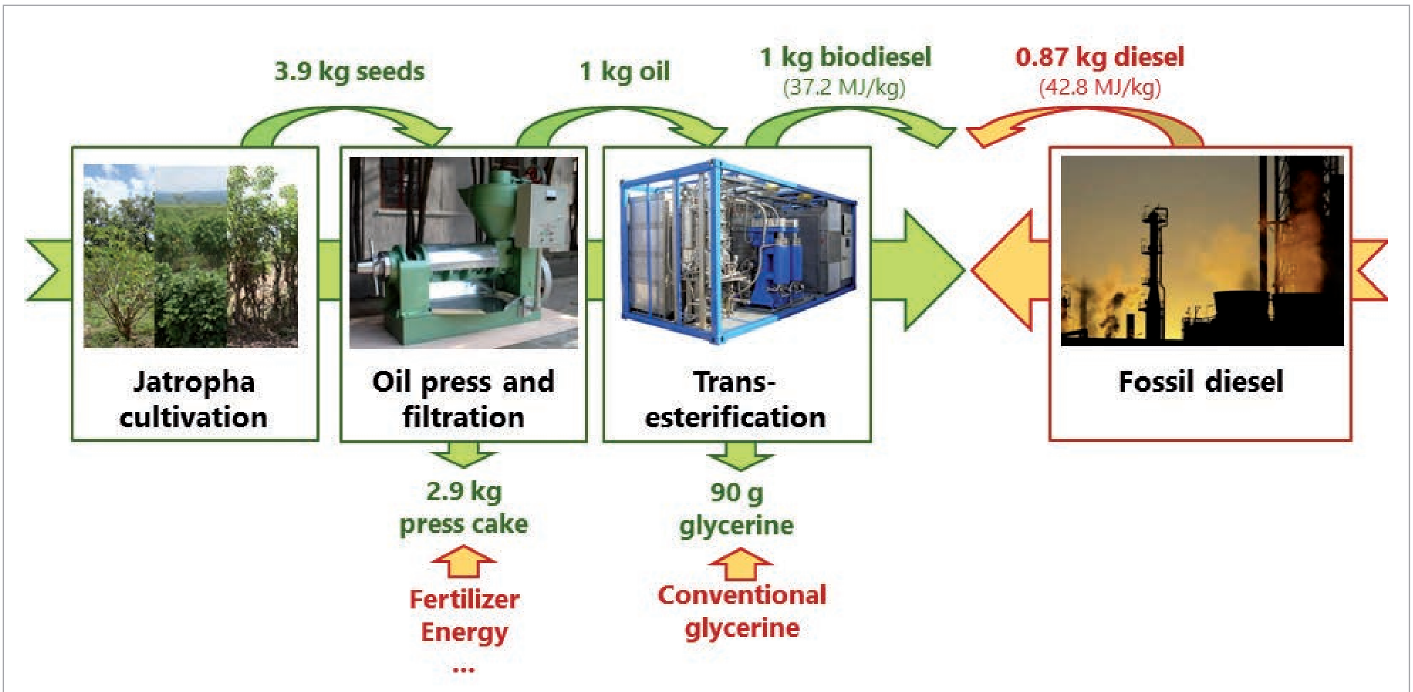

Figure 4: Schematic overview of a typical jatropha biodiesel value chain (green) including substituted products (red). Efficient use of resulting by-products is crucial to reduce environmental impacts and increase economic viability.

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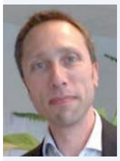

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Policy implications

Jatropha bioenergy is not per se climate friendly
jatropha can, but not necessarily does contribute to climate change mitigation and the mitigation potential is highly dependent on where (previous land use) and how (crop management, processing efficiency and use of by-products) the jatropha value chain is established. Regulations aiming to promote biofuels should therefore include a context-specific assessment of net GHG savings in order to assure climate change mitigation. In various national regulations (e.g. of the EU and USA) and certification standards (e.g. Roundtable on Sustainable Biofuels) the GHG emissions related to bioenergy production and use are calculated based on life cycle assessment.

Integrated land use planning is key
Jatropha's carbon balance is highly sensitive to direct and indirect GHG emissions from land use changes. Jatropha plantations should therefore only be established on low carbon stock land. Indirect effects, in particular, are complex and highly dependent on local conditions, so an in-depth study (e.g. land use modelling or displacement risk assessment) should be conducted for planned biofuels plantations providing details about the local land use change mechanisms, and a land use plan should be developed, including mitigation measures.

Income from carbon payment is highly limited
The carbon sequestration potential of jatropha is limited, due to low growth rate and continuous pruning. Only a relatively low carbon stock may be reached, which is comparable to fallow land. It is therefore not advisable to cultivate jatropha for afforestation and reforestation carbon payments either through the Clean Development Mechanism or on the voluntary carbon market.

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Jatropha Facts *Jatropha Facts* is a series of five policy briefs providing research insights on important issues of jatropha and bioenergy. Each policy brief addresses a specific, policy-relevant aspect: (1) jatropha growth and oilseed production in Africa; (2) the potential of jatropha for climate change mitigation; (3) the potential of jatropha for rural energy supply in Africa; (4) the economic feasibility of biofuels in Africa; and (5) the food security implications of jatropha and other biofuels.

ERA-ARD
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