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Review

A review of the sustainability of Jatropha cultivation projects for biodiesel production in southern Africa: Implications for energy policy in Botswana

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ABSTRACT

Jatropha curcas L. biofuel development is considered a strategy for achieving energy security, climate change mitigation, foreign exchange savings and economic development. This paper reviews the experiences of some southern African countries with the impacts of Jatropha biofuel development on sustainability, with a view to providing lessons for biofuel development policy for Botswana. The review has shown that most of the large commercial plantations planned to produce jatropha seed for home consumption and export were not economically viable mainly due to low seed yield, high cost of production, delayed production and uncompetitive feedstock prices. On the other hand, smallholder-based jatropha biofuel projects were economically viable due to their low input costs. Analysis of social impacts showed that jatropha production has been associated with loss of rights to land, low compensation levels, and compromised food security where land and other production inputs were diverted from food crops to jatropha production. Positive social impacts in some countries included increased employment opportunities and incomes. Jatropha production is associated with environmental impacts such as loss of biodiversity, high water requirements and high carbon debts resulting from conversion of land. Positive environmental impacts included high energy return on investment and high GHG savings when Jatropha is cultivated on abandoned agricultural fields as revealed by research in some parts of West Africa. Policy considerations for the Government of Botswana include: providing support to biofuel projects at their early stage of development, discouraging large plantation business models until such time that research in Botswana produces high seed-yielding Jatropha varieties, introducing legal safeguards for protection of land rights of local communities, and ensuring that land-use change and high carbon debts are minimized as they have adverse impacts on biodiversity and climate change.

1. Introduction

Biofuel development is considered to be an important strategy for energy security, climate change mitigation, foreign exchange savings, economic growth and rural development, (Gasparatos et al., 2015). Energy security is a key driver for biofuel development in countries such as USA, China and some EU member states, whereas climate change has been a major driver in the EU (Commission of the European Communities, 2009). Rural development, economic growth and energy security are key drivers of biofuel development in sub-Saharan African countries, where poverty and shortage of foreign exchange are major challenges. For instance, the key drivers of the pre-2000 biofuel projects in Kenya, Malawi, South Africa and Zimbabwe were energy security and foreign exchange savings (Dufey, 2006; Gasparatos et al., 2015; Von Maltitz et al., 2016).

The potential of biofuels to achieve the above-mentioned development goals is increasingly being questioned, mainly because their production and use is associated with social, economic and environmental risks. Economic risks include high food prices and perverse effects associated with subsidies, and high opportunity costs of land use. Although the production of biofuels may not necessarily compete with food products, the inputs used in their production may compete with those for food production, and this may ultimately lead to an increase in food prices. Social risks associated with production and use of biofuels includes food insecurity, displacement of small-scale farmers and employment associated with poor health and safety (FAO, 2008). Environmental risks include biodiversity loss, climate change and degradation of ecosystem services (Searchinger et al., 2008; Gasparatos et al., 2011).

To avoid these risks, the development of biofuels needs to be guided

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by comprehensive national policies with legal and regulatory frameworks. As clearly articulated by Janssen and Rutz (2012), regulatory frameworks for biofuels include legislation for the establishment of institutional structures (e.g. committees for regulation of standards), regulation of biofuel markets, creation of incentives, regulation of trade, introduction of sustainability certification schemes and promotion of research and development. In sub-Saharan Africa, South Africa and Mozambique are among the countries which have produced comprehensive policy strategies for guiding biofuel development (Janssen and Rutz, 2012). In South Africa, the policy document for biofuels called "National Biofuels Industrial Strategy" was introduced in 2007, whereas in Mozambique the biofuel policy was introduced in 2009. Other sub-Saharan African countries (including Botswana, Zambia, Tanzania, Mali, and Ghana) have introduced policy statements on biofuel policy or are in the process of drafting detailed legal and regulatory frameworks for biofuel development (Janssen and Rutz, 2012).

The *Jatropha curcas* L. plant (hereafter referred to as Jatropha) is being promoted by developing countries, international organisations and NGOs as potential feedstock for the production of Jatropha straight vegetable oil (SVO) which could be directly used as a household energy source or transesterised to biodiesel (Openshaw, 2000). Jatropha is native to Mexico and Central America but it is widely grown in the tropics of Central America, Africa and Asia (Contran et al., 2013). In Asia, cultivation of Jatropha is being tried in the large and rapidly growing economies of China and India, where there are mandates for the use of biofuels (Contran et al., 2013). In southern Africa, several countries, including Mozambique, Malawi, Zambia and Tanzania are growing Jatropha. However, the crop has been banned in South Africa based on perceived invasiveness, mainly because it has been listed as a potential noxious weed in Australia (von Maltitz et al., 2014). Gasparatos et al. (2015) contend that this ban of Jatropha was not based on any scientific proof, hence these authors quote studies in Zambia and Burkina Faso which suggest that the fear of invasiveness could have been overhyped. In Botswana, the Ministry of Minerals, Energy and Water Resources assessed the potential for the production and use of biofuels through a feasibility study undertaken in 2007. The study recommended Jatropha as a suitable feedstock for the production of biodiesel in Botswana (EECG, 2007). Currently, Jatropha is only grown for research purposes in Botswana and there are no commercial plantations (Kgathi et al., 2011; Von Maltitz et al., 2014).

The literature on Jatropha biofuels in sub-Saharan Africa suggests that the global potential of Jatropha biofuel production was greatly exaggerated during the period 2000–2008. This is referred to in this paper as the "global Jatropha biofuel hype" (Von Maltitz et al., 2014). Biofuel production was a new phenomenon in most countries of southern Africa during this period; Zimbabwe, South Africa and Malawi were the only countries in the region which had produced biofuels (sugarcane-based bioethanol) before this time period (Von Maltitz et al., 2014). In addition to the biofuel development drivers of energy security, climate change, foreign exchange savings and rural development, the Jatropha biofuel "boom and bust" was also driven by the following factors (Von Maltitz et al., 2014): 1) the belief that the crop could restore degraded lands, 2) the belief that the crop had high yields even in semi-arid conditions, 3) the belief that Jatropha production had no adverse impacts on food security, and 4) the creation of a biofuel market in the European Union, stimulated by European Union Directives, which encouraged biofuel investment in developing countries (Commission of European Communities, 2012). These factors have been revisited later in this paper. This paper builds on the previous studies on Jatropha biofuels in sub-Saharan Africa (Gasparatos et al., 2015; Von Maltitz et al., 2014; Romijn, 2011; Romijn., 2011, 2014; Achten et al., 2015), assessing the implications of the experiences of Jatropha biofuels on biofuel development and policy in Botswana. The general objective of this study is the assessment of the sustainability of Jatropha biofuels in southern Africa in social, economic and environmental terms. The following research questions are critical in understanding this general research objective: 1) What are the key Jatropha biofuel business models in southern Africa and how are they interlinked? 2) What are the environmental, social and economic impacts of Jatropha biofuels on sustainability and their associated trade-offs? 3) What are the implications of the results of this study for biofuel policy in Botswana? The rest of this paper is organised as follows: Section 2 presents a conceptual framework for analysing the sustainability of biofuel projects in southern Africa. Section 3 describes the study area and methods used in this paper while Sections 4–7 discuss the results of the literature review. Sections 8 and 9 suggest policy recommendations and conclude the paper.

2. Sustainability and biofuel development: a conceptual framework

The Brundtland Commission defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987:57–9). In economics, issues of sustainability are clearly articulated in the context of "capital theory approach", and scholars on this subject have two approaches of "weak sustainability" and "strong sustainability" (Stern, 1997). The "weak sustainability" approach is based on the neo-classical assumption that all forms of capital are substitutable, so it is indifferent about the forms in which capital bequests are passed to future generations (Pearce et al., 1994). Advocates of the "strong sustainability" approach, embraced mainly by some ecological economists and ecologists, contend that different forms of capital are not substitutable for each other and therefore they should not be depleted. For instance, "critical natural capital" which is crucial for human survival, does not have any substitutes, hence it may not be replaced when depleted. This paper adopts a meso-sustainability approach which permits the application of the weak sustainability approach up to a point where certain depletion rates and thresholds of the degradation of vital ecosystem services may not be exceeded (Hardi, 2007). This approach plays a mediating role between different forms of capital and it is conceptually situated between the two extremes of weak and strong sustainability (see Victor, 1991; Stern, 1997).

Fig. 1 provides a simple conceptual framework utilised in this paper to analyse impacts of the production and use of biofuels on sustainability. Biofuels are considered sustainable if their production and use do not have adverse effects on environmental and social sustainability and at the same time satisfy the criterion of economic sustainability. These three concepts of sustainability are multidimensional and also interlinked (Fig. 1). Economic sustainability of Jatropha biofuel projects is mainly determined by factors such as seed yield of the tree, oil market price, production costs, types of business models used and the global prices of crude oil. In the long run, the economic viability of Jatropha projects may be improved by reducing production costs or by increasing the yield by plant breeding. As Fig. 1 indicates, the key considerations of social sustainability of biofuels include access to land, food security, rural livelihoods, impacts on gender and distributive justice (Blaber-Wegg et al., 2015). These considerations are driven by factors such as type of land use, land tenure and transfer procedures, business models used, and biofuel policies adopted.

The key environmental sustainability issues of concern include greenhouse gas balances, impacts on biodiversity, energy balances, pollution and water resources (Van Eijck et al., 2014). Impacts of Jatropha production and use on environmental sustainability depend on type of land used, type of the business models used (refer to Section 4) and biofuel policies adopted (Gasparatos et al., 2015). For instance, the plantation business model is associated with negative or low greenhouse gas savings because it tends to clear original vegetation when cultivating biofuel crops. If biofuel crops are cultivated on former agricultural lands, they significantly contribute to savings on greenhouse gases.

In summary, the sustainability assessment explores the inter-