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Redesigning oilseed tree biofuel systems in India

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ABSTRACT

Liquid biofuel production has been widely promoted as a rural development strategy in the South. Yet, the development of biofuel value chains faces many context-specific challenges. In this empirical study we use a labelled choice experiment to assess smallholder farmer preferences for alternative production systems, value chain organisations and market developments for a biofuel program using oilseed trees (neem (*Azadirachta indica*), pongamia (*Millettia pinnata*), mahua (*Madhuca longifolia*)) in Karnataka state, India. Our results demonstrate that biofuel programs can benefit from ex ante analyses to improve their design. We find that most farmers (71%) are likely to adopt biofuel trees in most scenarios, especially species with relatively high yields, low labour requirements and high oilseed prices. Nevertheless, value chain reorganization through contracting and labour provision proves to be the key lever to stimulate adoption. This calls for further research on effective contract design and implementation, and for developing alternative business models. Our results imply that next to high opportunity costs of land, also high opportunity costs of labour can be a barrier to biofuel tree adoption. If biofuel programs are to succeed, they have to move beyond the idea of smallholder biofuel production on marginal lands with surplus labour.

1. Introduction

In the past two decades, production of liquid biofuels has been widely promoted in developing countries as a clean energy source fostering rural development (Sorda et al., 2010). Liquid biofuels are argued to increase energy security, in particular in countries heavily depending on imported fuel (Sorda et al., 2010), and mitigate climate change (Fargione et al., 2008; Tilman et al., 2009). Furthermore, feedstock production, processing and marketing could serve as a source of income, employment, trade and technology spillovers for local communities (Ewing and Msangi, 2009; Riera and Swinnen, 2016). However, many concerns have been raised about the interference of biofuels with food production and markets (Koh and Ghazoul, 2008; Zhang et al., 2013), as well as about the inclusiveness and efficiency of biofuel value chains, and land grabbing (Arndt et al., 2011; Cotula et al., 2008; Lee et al., 2011). Production of non-food crops – predominantly jatropha (*Jatropha curcas*) – on wasteland plantations has been hyped as a solution to the food versus fuel debate. Yet, it is being contested whether such 'unproductive' and 'underutilized' lands effectively do not have any community functions and opportunity costs (Baka, 2014; Borras et al., 2011). Economic viability of such systems critically depends on seed yields, which proved to be lower than expected and highly variable (Achten et al., 2014; Ariza-Montobbio and Lele, 2010; Muys et al., 2014). In addition, there is no consensus on which value chain organisation and degree of (de)centralization lead to most welfare benefits (Altenburg, 2011; Negash and Swinnen, 2013; van Eijck et al., 2014b). In reality, many context-specific technical, ecological, socio-economic and institutional opportunities and constraints exist for a successful implementation of liquid biofuel programs, and these are often insufficiently understood (Florin et al., 2014; Muys et al., 2014; van Eijck et al., 2014a). Many biofuel projects have failed to gain momentum, and some large investment projects have not paid off (Sanderson, 2009; Singh et al., 2014; van Eijck et al., 2014a).

As jatropha wasteland plantations have not lived up to the expectations, alternative production systems have been explored (Altenburg et al., 2009; Faße et al., 2014; Sharma et al., 2016). Small-

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scale integration of multipurpose oilseed trees within the existing farming system, i.e., as agroforestry systems, might hold significant pro-poor potential (Achten et al., 2010; Muys et al., 2014; Sharma et al., 2016). In this low input – high diversity – high resilience system (Tilman et al., 2006), low production inputs are coupled to multiple products, uses and co-benefits,[2] thereby limiting investment risks for smallholder farmers. Nevertheless, also in these systems feedstock production entails land, labour and capital opportunity costs for farmers, while benefits and risks depend on the production system, value chain organisation and market conditions (Altenburg, 2011; Florin et al., 2014; van Eijck et al., 2014b). Understanding how these context-specific factors play a role in smallholders' decisions whether to cultivate feedstock or not, is crucial to the design and implementation of biofuel projects and the development of biofuel value chains (Achten et al., 2014; Florin et al., 2014). There is an emerging empirical literature on biofuel adoption by smallholders in developing countries, but studies mainly focus on jatropha and mostly investigate adoption through an ex-post evaluation of a single biofuel program (e.g., Axelsson et al., 2012; Goswami and Choudhury, 2015; Kuntashula et al., 2014; Montefrio et al., 2015; Mponela et al., 2011; Negash and Swinnen, 2013; Soto et al., 2015).

In this paper we take a different view to address both shortcomings. Starting from an existing biofuel program, we use an ex-ante approach to predict (the variability in) smallholder preferences for alternative production systems, value chain organisations and market developments. This allows us to assess the potential of hypothetical changes in these characteristics and the likelihood that alternative biofuel programs are adopted. We do this by conducting a discrete choice experiment (CE) with 396 farmers in Hassan district, Karnataka state, India. In this region, a small-scale decentralized model of biofuel development, where oilseed trees (including pongamia (*Millettia pinnata*), neem (*Azadirachta indica*) and mahua (*Madhuca longifolia*)) are cultivated in agroforestry systems, is being promoted since 2007 by the government through training and planting programs, marketing support, cooperative establishments and distribution of processing equipment. Oilseed trees have received little if any attention in the literature on biofuels (Achten et al., 2014). Yet, trees are inherently a long-term investment – because of their maturation period and long lifetime – requiring long-term commitments of land, and involving upfront investments as well as yield and price risks (Khanna et al., 2017). The latter holds in particular for biofuels, given substantial policy and market uncertainties (Chen and Önal, 2014; Kumar et al., 2012; Locke and Henley, 2013). This makes adoption studies, and ex-ante approaches in particular, all the more relevant. There is a large interest for biofuel production on marginal lands and for tree-based biofuel programs in India (Gunatilake et al., 2014), which makes this study directly relevant from a policy perspective.

While other papers have used CEs for ex-ante assessments of smallholders' technology adoption (e.g., Kikulwe et al., 2011; Lambrecht et al., 2015; Scarpa et al., 2003) or marketing and contracting preferences (e.g., Abebe et al., 2013; Schipmann and Qaim, 2011; Van den Broeck et al., 2017), this paper is to the best of our knowledge the first to address smallholders' adoption of alternative biofuel trees through a CE.

2. Methodology and data

2.1. Research area

Since the beginning of this century, the Indian government has expressed large interest in liquid biofuels (Gunatilake et al., 2014). This has been mainly driven by energy security concerns – currently 70% of the domestic oil demand is covered by imports; this share is estimated to increase to over 90% by 2040 (IEA, 2015) – as well as by the potential of biofuel production and consumption for rural development (Altenburg et al., 2009; Gunatilake et al., 2014). The government implemented various policies,[3] eventually setting an ambitious 20% blending target for bioethanol and biodiesel in gasoline and diesel, respectively, by 2017, supported by subsidized prices and fiscal incentives (Sorda et al., 2010). These policies require biofuels to be exclusively produced from feedstocks that limit competition with food production, such as molasses for bioethanol, and non-edible tree borne oilseeds produced on wasteland plantations of jatropha (and pongamia) for biodiesel (Biswas and Pohit, 2013). However, a variety of ecological (e.g., low yields on marginal soils, susceptibility to pests), socio-economic (e.g., lack of land, ownership and usufruct rights, economic unviability) and institutional (e.g., lack of research and extension, competing fuel subsidy schemes) constraints has resulted in slow progress towards the specified targets (Altenburg, 2011; Biswas and Pohit, 2013; Kumar et al., 2012). The 2013 level of blending was still below 1% (IEA, 2015).

Alternatives to large-scale wasteland plantations have been explored in India as well (Altenburg et al., 2009). Since 2007, such an approach is brought into practice in Hassan district, Karnataka state, India, through a government – university partnership.[4] The biofuel program in Hassan aims to integrate various oilseed trees (including pongamia, neem and mahua) in smallholder farms on field edges, in homegardens and on fallow land. They do so by (1) conducting awareness and training programs on oilseed tree cultivation and biofuels, (2) distributing high-yielding oilseed tree seedlings to farmers free of charge, (3) offering minimum support prices for oilseeds, (4) establishing biodiesel cooperatives within villages for streamlining biodiesel activities, and (5) distributing small-scale oil-expelling equipment for local processing. Pongamia, neem and mahua are native species whose wood, leaves, fruits and seeds have long been used for various purposes. Seed oil is traditionally used for pesticidal, medicinal, cosmetic and/or industrial purposes, while seed cake is used as an organic fertilizer, pesticide and/or fodder. Accordingly, oilseed collection from trees on community and private land is known as a traditional marginal activity, and oilseed value chains, involving middlemen and local oil mills, do exist, especially for neem and pongamia (Altenburg et al., 2009). In addition, seed oil can serve as a lamp fuel, as a small blend in (modified) diesel engines, and can be processed to biodiesel.

Hassan district has a population of about 1.8 million inhabitants, 79% of them living in rural areas, and comprises some 2600 villages, which are clustered into 38 administrative units termed *hoblis* (DCO, 2014). It is a geophysically diverse region containing three agro-ecological zones (dry, transition, hill) characterized by a distinct rainfall regime (Fig. 1). Correspondingly, a wide variety of crops are being cultivated, including several plantation crops such as coconut in the dry and transition zone, and coffee, pepper and cardamom in the hill zone (DES, 2016). The average farm size (2.02 ha) in the hill zone is considerably larger than the district's average (1.06 ha) (DAC&FW, 2017). Agricultural production is mostly done by smallholders, with landholding sizes below 1 ha for 65% of the farmers and below 2 ha for 89% of the farmers (DAC&FW, 2017). About 27% of the cultivated land is irrigated (DES, 2015).

[2] Co-benefits in agroforestry systems can include for example improved soil fertility, biodiversity and soil conservation, pest control, carbon sequestration, labour and income diversification, and increased farm resilience (Sileshi et al., 2007).

[3] This includes the Ethanol Blended Petrol program (2003), the National Mission on Biodiesel (2003) and the National Policy on Biofuels (2008) (Sorda et al., 2010).

[4] The Karnataka State Bio Energy Development Board and the University of Agricultural Sciences Bangalore.