Ecological Economics 106 (2014) 155–166

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Surveys

Bioenergy and rural development: The role of agroforestry in a Tanzanian village economy

Anja Faße *, Etti Winter, Ulrike Grote

Institute for Environmental Economics and World Trade, Leibniz University Hannover, Königsworther Platz 1, 30167 Hannover, Germany

ARTICLE INFO

Article history:
Received 30 July 2013
Received in revised form 20 June 2014
Accepted 26 July 2014
Available online 17 August 2014

Keywords:
Natural resource management
Multiplier analysis
Agroforestry
Bioenergy
Village economy

ABSTRACT

Recent papers indicate that decentralized bioenergy crop production offers increased market access and income diversification strategies for the rural population. The analyses concentrate on the potential effects of newly discussed crops such as *Jatropha curcas*, cassava, and sugarcane on macro level. Thereby two aspects are neglected, the income effects on micro level, and the integration of traditional firewood production systems for comparison. To fill this gap, an Environmentally Extended Social Accounting Matrix (ESAM) at the village level is developed and applied to a rural village in Tanzania. The objective is first to explore the integration of agroforestry systems in rural smallholder systems and second to analyze income effects of agricultural biomass production for bioenergy purposes in comparison to firewood production. In order to distinguish the use of firewood from public and private tree resources, environmental accounts for changes in tree stocks (public and private) are included. Findings indicate the importance of including common firewood production as a reference point. The highest income effect for the poorest households derives from agroforestry, which households use as a source of firewood and fruits for sale or home consumption, followed by *J. curcas*, sugarcane and finally cassava. Agroforestry in general has been also found to substantially release the pressure on public forest reserves.

1. Introduction

Considerable debate exists about potential trade-offs emerging from establishing bioenergy production activities in developing countries (Karp and Halford, 2010). Governments in developing countries regard bioenergy as an opportunity to reduce the dependence on imported fuels, to stimulate economic growth through generating new job opportunities, and hence to increase households' incomes. However, the production of biomass for biofuel production is also viewed as a threat to social equity and environmental sustainability; particularly food security issues are addressed, in areas where overall food supply is inadequate (Maltsoglou et al., 2013). Therefore, effects on food crops have to be taken into account in the analysis of bioenergy.

In recent years, Tanzanian domestic energy needs have rapidly grown due to both the increase in economic development and population growth (Cleaver et al., 2010). Basic biomass-based fuels, particularly charcoal, firewood and crop residues, dominate the energy supply with about 90% of total use (Mshandete, 2011). The remaining energy consumption is composed of fossil fuels (6.6%), gas (1.5%), hydropower (0.6%), and coal and peat (0.2%) (Cleaver et al., 2010; FAO, 2010b). Tanzania imports fossil because it does not own any oil deposits, and alternative adequate energy sources are lacking (Amigun et al., 2008; van Eijck and Romijn, 2008). To ensure a sustainable and secure energy supply, as well as supporting environmental protection activities (Mshandete, 2011), two major strategies for the agricultural sector are promoted by the government: (a) bioenergy initiatives including *Jatropha curcas*, sugarcane, cassava, and sunflower production (Romijn and Caniëls, 2011), and (b) agroforestry implementation (Sonwa et al., 2011).

Agriculture-based economic growth has the largest impact on reducing poverty rates compared to non-agriculture growth in Sub-Saharan Africa including Tanzania (IFPRI, 2012). In Tanzania, the agricultural sector accounts for 25% of GDP, employs 80% of the workforce, and generates more than 50% of the total export earnings (Kaliba et al., 2008). Around 81% of the households living below the poverty line are rural households where the main income activity is small-scale agriculture (Cleaver et al., 2010). Hence, biofuel-crops are expected to provide new income possibilities for rural farmers and lessen the pressure on public forests, if the new energy sources are used locally (Arndt et al., 2011). In the African context, Tanzania is considered as a major forerunner in attracting national and international bioenergy investments (Romijn and Caniëls, 2011).

Addressing the national perspective, Arndt et al. (2012) and FAO (2010b) showed that large-scale production of bioenergy crops for export may generate larger increases of agricultural GDP than production

* Corresponding author. Tel.: +49 511 762 19966; fax: +49 511 762 2667.
E-mail address: fasse@iuw.uni-hannover.de (A. Faße).

http://dx.doi.org/10.1016/j.ecolecon.2014.07.018

through smallholder schemes. However, differentiated by the income level of households, the results indicate that lower-income households benefit more from smallholder schemes than high-income households, and vice versa (Arndt et al., 2012). In terms of pro poor strategies, decentralized bioenergy crop production has been evaluated to foster income growth since it offers increased market access and livelihood diversification strategies for the rural population (Arndt et al., 2010). Due to the additional income possibilities, the associated economic multipliers are expected to be high especially for energy net-importing countries, such as Tanzania (Amigun et al., 2008; Domac et al., 2005; Malik et al., 2009). The magnitude of the economic multipliers especially for poor households is assumed to vary regionally depending on crops, production and consumption pattern (Domac et al., 2005). It is therefore crucial that governments in countries such as Tanzania understand how different household groups are influenced at the micro level by proposed biofuel policies (e.g. supporting specific feedstock) to achieve national development objectives (Arndt et al., 2012). However, a regional multi-sectoral analysis of bioenergy has not been developed, yet (Allan, 2013).

In addition to bioenergy implementation, the Tanzanian initiative on agroforestry promotion aims to increase the availability of trees on private properties to reduce overexploitation of public forests due to firewood collection (Sonwa et al., 2011). Additional benefits of agroforestry come from ecosystem restoration and increased agro-biodiversity on private lands, namely soil improvement, erosion control, and risk mitigation due to more diversified food production systems (Beddington et al., 2012; De Groot et al., 2013; FAO, 2012b; Garnett and Godfray, 2012). Recommended concepts share their emphasis on pro-poor and smallholder oriented strategies, and focus on diversified farming systems that are supposed to increase yields with low external inputs and without adverse environmental impacts (Altieri et al., 2012; Bommarco et al., 2013; Brussaard et al., 2010; Tittonell et al., 2012).

No study is known to the authors, which includes and quantifies agroforestry cultivation within a multi-sectoral village model and compares it to other bioenergy crops (see also Allan, 2013; Alavalapati and Mercer, 2005). Our paper contributes to this research gap by developing a Social Accounting Matrix (SAM) at the village level. In order to include agroforestry, we extended the conventional economic accounting system by natural resource accounts, comprising firewood as the major reference point for rural energy production. The case study area is characterized by two firewood sources: a) private agroforestry including food and non-food trees and b) public areas including community and governmental forest. The paper analyzes the following two research questions: 1) How advanced is the integration of agroforestry systems in rural smallholder agricultural systems and 2) What are the household specific income effects of agricultural biomass production (*J. curcas*, sugarcane, cassava, maize) for bioenergy purposes in comparison to agroforestry.

The remainder of the paper is structured as follows: Section 2 reviews the empirical literature on the economic impact of renewable energy. Section 3 briefly describes the underlying data and the SAM framework applied in this study. The empirical results are presented in Section 4 including the discussion; Section 5 finally concludes.

2. Recent Research on Bioenergy Impact on Welfare

In 2005, the GTZ classified maize, cassava, sugarcane, *Jatropha*, and palm oil as the most promising for biofuel production in Tanzania (GTZ, 2005). Later FAO (2010a) conducted scenario analysis to evaluate the most promising agricultural crops for potential bioenergy development in Tanzania, Peru, and Thailand/Cambodia. The authors only considered the income effects through different scales of bioenergy production, but only for export use; national consumption and hence a change in behavioral energy use was not taken into account (Arndt et al., 2011; FAO, 2010b). In terms of food security, the most relevant crops in Tanzania were maize, cassava and rice, based on per capita calorie consumption (FAO, 2010b, 2012a,b). The results of a dynamic economy wide model for Tanzania developed by FAO revealed that cassava as a major food and staple crop has large production potential throughout Tanzania, which can be also utilized for ethanol production (FAO, 2010b). The analysis indicates that ethanol production schemes based on cassava would result in economic growth and support poverty reduction (FAO, 2010b).

From the macroeconomic perspective, several studies were conducted based on partial and Computable General Equilibrium (CGE) models (Arndt et al., 2010, 2011; Zhang et al., 2013). The findings of CGE models by Arndt et al. (2010) suggest that all biofuel production scenarios improve households' welfare, but it is also shown that "there are significant differences in the distributional impacts across household groups" (FAO, 2010b, p. 188). While all rural households would gain from a biofuel industry in Tanzania, higher-income rural households in large-scale production scenarios, such as sugar cane plantations may benefit more. Small-scale outgrower schemes, especially for cassava and *Jatropha*, are most effective in raising poorer households' incomes (FAO, 2010b). This suggests that the participation of smallholders in bioenergy value chains would contribute to poverty reduction, especially when additional agricultural investments were offered to improve the general productivity of smallholders (FAO, 2010b).

J. curcas was revealed to affect economic growth positively through a smallholder-based system (FAO, 2012a, 2012b). However, the results derived from *Jatropha* schemes only included harvested oil seeds. Joint-production schemes where *J. curcas* is utilized as a host plant for the production of high value black pepper and vanilla plants are less explored and have not yet been considered in a multi-sectoral model. GTZ (2009) recommends further analysis of such joint-production schemes.

In terms of sugarcane, Tanzania is among the significant producers in the east African region supplying 187,000 tons of sugar (Hassan, 2008). The cultivation of sugarcane in Africa is mainly rainfed however higher productivity is reported from irrigated production schemes (Hassan, 2008). FAO (2010b) suggests that the sugarcane potential for bioenergy production under rainfed conditions is limited; irrigation could significantly change this. Although sugarcane-ethanol is competitive in Tanzania, it requires a large-scale industrial production scheme. Although this type of biofuel supply chain could lead to more economic growth, it is doubtful whether it has a poverty reduction effect (FAO, 2010b). In contrast, bioenergy investments in small-scale agriculture along with the target of increasing yields of food crops could be economically viable and help reduce poverty (FAO, 2010b).

3. The Model Framework and Underlying Data

3.1. Underlying Data

This environmentally extended village SAM is based on primary data collected from an own household survey (see also Faße and Grote, 2013a,b). Therefore the results can be directly linked to information from the household-level data set.

In order to identify an appropriate study site, a village scoping study was carried out. The selection of the village is based on certain requirements including the existence of *Jatropha* shrubs on plots of mainly small-scale farmers, and at least two other potential bioenergy crops. Furthermore, the level of transaction costs and the heterogeneity among households played a critical role. High transaction costs may lead to isolation from outside markets (evolvement of endogenous prices) often resulting in non-separability of production and consumption. Low transaction costs rather result in exogenous prices channeled via distant markets outside the village (Taylor and Adelman, 1996).

Within this context, Tandai, a village located in Kinole ward, Morogoro district was identified as an appropriate study location. The main outside markets are the Morogoro (capital city of the district) and Dar es Salaam (capital city of Tanzania). The village borders the governmental forest reserve considered as a biological hotspot (Finch et al.,