Working Paper

Jatropha curcas biodiesel production in Kenya

Economics and potential value chain development for smallholder farmers

Yuka Tomomatsu and Brent Swallow

Eastern and Central Africa

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Jatropha curcas biodiesel production in Kenya

Economics and potential value chain development for smallholder farmers

---

Yuka Tomomatsu and Brent Swallow

World Agroforestry Centre

TRANSFORMING LIVES AND LANDSCAPES

Tomomatsu, Yuka and Swallow, Brent. 2007. *Jatropha* curcas biodiesel production in Africa: economics and potential value chain development for smallholder farmers. WP 54. Nairobi. World Agroforestry Centre. 33 pgs.

Titles in the Working Paper Series aim to disseminate interim results on agroforestry research and practices and stimulate feedback from the scientific community. Other publication series from the World Agroforestry Centre include: Agroforestry Perspectives, Technical Manuals and Occasional Papers.

Published by the World Agroforestry Centre
United Nations Avenue
PO Box 30677, GPO 00100
Nairobi, Kenya

Tel: +254(0)20 7224000, via USA +1 650 833 6645
Fax: +254(0)20 7224001, via USA +1 650 833 6646
Email: icraf@cgiar.org
Internet: www.worldagroforestry.org

Working Paper # 54

About the authors

Yuka Tomomatsu is a Masters degree student at the Graduate School of Agriculture and Life Sciences at the University of Tokyo. As a Research Fellow of the Japan International Research Center for Agricultural Sciences (JIRCAS), she conducted the research underlying this paper while attached to the ASB Partnership for Tropical Forest Margins (ASB) at the ICRAF offices in Nairobi, Kenya. She is currently working on her MSc thesis on the traditional tree management systems and agroforestry policy in Northern Ghana. Her email address is: aa66250@mail.ecc.u-tokyo.ac.jp.

Brent Swallow is the Leader for Policy Options and Incentives and Global Coordinator of the ASB Partnership for the Tropical Forest Margins, World Agroforestry Centre, Nairobi, Kenya. His email address is: B.Swallow@cgiar.org.

Abstract

In recent years, the production of *Jatropha curcas* has been widely promoted by private enterprises, non-governmental organizations and development agencies as one of the most viable candidates for biodiesel feedstock in Africa. While multiple benefits of jatropha production such as a petroleum product substitute, greenhouse gas mitigation and rural development are emphasized, the viability of production at farm level is questioned. By examining the initial production experiences that have taken place in Kenya since 2005 and analysing Indian experiences with production and processing, this study reveals that the profitability of jatropha production for smallholder farmers is expected to be minimal unless farm-level production is accompanied by investments and policies promoting decentralized oil extraction and transesterification. While the study largely rules out jatropha as a plantation type of crop under current economic conditions, the opportunity for smallholder farmers in value chain development are discussed.

Keywords

Jatropha curcas, biodiesel, Kenya, Clean Development Mechanism, biofuels, value chains, Africa

Acknowledgements

This study was made possible through the CGIAR-JIRCAS research fellowship program funded by Japan International Research Center for Agricultural Sciences (JIRCAS). The project was supported by the Global Coordination Office of the ASB Partnership for Tropical Forest Margins and the Environmental Services Theme at the World Agroforesty Centre (ICRAF) in Nairobi. We would like to thank especially Ms. Sandra Velarde at ASB for her support to complete this research. We also appreciate the valuable inputs provided by the many stakeholders in jatropha production and biodiesel development in Kenya.

Contents

Currency Exchange Rates

The following yearly exchange rates provided by Oanda Corporation currency database are used for currency conversation between Kenyan Shillings and US dollars, and Indian Rupees and US dollars as average. Unless the year of the data is specified in the paper, the exchange rate of year 2006 (Kshs.72.62/US$1.00) is applied for currency conversion.

Year	Kshs./US$
1996	57.17
1997	58.92
1998	60.54
1999	70.42
2000	76.28
2001	78.75
2002	79.15
2003	76.32
2004	79.55
2005	75.72
2006	72.62

Indian Rupee to US dollar is calculated by applying average exchange rate in 2006: US$1.00 = Rs.45.31.

Introduction

The biofuels industry is growing rapidly as a result of high petroleum prices and increasing concerns about global climate change. Ethanol from sugarcane in Brazil and corn in the United States, and biodiesel from rapeseed in European Union countries have been successfully commercialized as petroleum product substitutes with government support. In Africa, Jatropha curcas (jatropha) is considered to be one of the most viable candidates for biodiesel feedstocks mostly due to its adaptability to semi-arid lands. Biodiesel promoters regard this “low productive land” (or often called “marginal” or “waste” land) to be largely available for new agricultural development.

Jatropha is a large shrub or small tree reaching a height up to 5 meters (Heller, 1996). After having been introduced to Africa centuries ago, it is now widely observed in semi-arid lands throughout the drier area of continent. In Kenya, it is naturalized in bushlands and along rivers in the western, central and coastal parts of the country in altitudes of 0-1,650 meters above sea level (Maundu and Tengnäs, 2005). Planting of jatropha has been taken place in some locales across Africa. For example, around the N’gurmani area of Kajiado District in Kenya, the local population has extensively planted jatropha as a hedge and boundary marker. In Tanzania, Uganda and Madagascar, jatropha is intercropped with vanilla (*Vanilla planifolia*) to serve as a pole for vanilla vines and to provide shade for vanilla leaves. In these and other African countries, the extracted oil from jatropha seeds has been used for soap making. In the 1990s, GTZ (German Technical Cooperation) conducted experiments in Mali on the use of jatropha oil as a renewable fuel for powering diesel engines (Henning, 2002). However, it is only recently that the production of jatropha as a biodiesel feedstock has been widely promoted by private enterprises, non-governmental organizations and overseas development assistance agencies working in Africa, including Kenya.

Jatropha production has been promoted for its perceived economic and ecological advantages. From the perspective of private investors, it is a newly available energy crop that is expected to be less expensive to produce than other energy crops such as rapeseed and soybeans. This argument is based on the availability of low-cost labour and land in Africa. Like other energy crops, jatropha’s contribution to mitigation of greenhouse gas (GHG) emissions is strongly emphasized, with the assumption that new regulations and carbon offset markets will provide price premiums for renewable sources of energy. The Clean Development Mechanism (CDM) of the Kyoto Protocol is expected to promote investment in renewable energy supplies by Annex I developed countries in non-Annex I developing countries with potential to produce biofuel feedstocks. If the acquisition of Certified Emission Reductions (CERs) is assured, the

CDM would give additional investment incentives for investors in developed countries who otherwise would not invest in biofuel projects due to the high risk of return.[1]

Not only private enterprises, but also non-governmental organizations and development agencies are interested in supporting jatropha development in Africa as a means for rural development and poverty alleviation. Jatropha biodiesel production is expected to contribute to the improvement of rural livelihood because the main production location for jatropha is in semi-arid lands where poverty levels are high and land productivity low.

Thus jatropha appears to be the potential crop that enables "win-win" relationship among all the actors in the value chain– the biofuel industry to gain profit, society as a whole to achieve GHG mitigation and energy security, and the producers to improve their livelihoods. However, our analysis shows that current conditions are not consistent with this win-win outcome. From the investor perspective, it may not be worthwhile to invest in jatropha biodiesel production under a large scale of operation can be achieved. For the society as a whole, the larger the production scale, the greater the benefit generated by newly available bio-energy. However, smallholder farmers may receive minimal benefits from large-scale jatropha biodiesel production if they simply compete for jobs on large plantations or produce seeds under contract to private processors. In other words, the desired rural economic benefits may not be achieved by through the simple introduction of jatropha production to local communities. Unless farmer groups are able to operate small-scale oil extraction operations (preferably with transesterification), the rural economic benefits are likely to be absorbed by the bigger entities in the industry.

Our argument on the minimal benefit to local farmers in large-scale jatropha biodiesel production is based on the profitability of jatropha seed production as a farm enterprise. The biofuel industry is interested in jatropha production because it is expected to be less expensive feedstock. The cost of feedstock production largely determines the viability of biodiesel production where the feedstock cost is calculated to be 65-78% of overall production expense depending on the size of the facility (Pruszko, 2006). In India, where commercial jatropha production has taken place since 2003, concerns about the possibility of over-estimation of yield and profitability are being raised among project developers (Singh, Swaminathan and Ponraj, 2006).

1 As of the end of 2006, none of the CDM methodologies using biofuel for energy use had been approved (UNFCCC, 2007). The clarification of double-counting of CERs that could occur at different points in the production chain is required for methodologies to be approved (UNFCCC, 2006). In the thirtieth meeting held on 23 March 2007, the CDM Executive Board agreed not to approve two proposed methodologies on biodiesel production projects: "biodiesel production and switching fossil fuels from petro-diesel to biodiesel in transport sector - 30 TPD biodiesel CDM Project in Andhra Pradesh, India (NM0108-rev)" and "Sunflower methyl-ester biodiesel project in Thailand (NM0129-rev)." The Excecutive Board has further clarified the guidance provided in annex 12 of the twenty-sixth CDM Executive Board meeting report that project activities claiming CERs from the production of biofuel are eligible for the CDM but not CERs from consumers (end-users) of these biofuel (UNFCCC, 2007). If and when methodological problems are solved, the investment is expected to expand.

The current discussion on bio-energy is dominated heavily by the energy and climate change perspectives. However, what is missing in the bio-energy debate a discussion of the viability of feedstock production from the perspective of smallholder farmers in developing countries. These farmers are expected to engage in the feedstock production at the first stage of biofuel value chain, whether it is jatropha, palm oil or other crops. As controversies arise about the promotion of jatropha biodiesel production arise between conservators and enthusiasts in other parts of the world, more investments are turning to Africa.[2] There is therefore an urgent need to examine the viability of jatropha production and value chains, focusing on the economic incentives and socio-economic impacts on smallholder farmers who engage in the production. The objectives in this paper are to determine if it is a rational choice for smallholder Kenyan farmers to engage in jatropha production and to discuss the potential for jatropha to contribute to the improvement of local livelihoods.

This paper consists of two parts. The first part discusses the viability of biodiesel value chain in current Kenyan market conditions by examining the price competitiveness of biodiesel in the Kenyan market and the profitability of jatropha production as a biodiesel feedstock in terms of expected yield, revenue and opportunity cost of production. After presenting the results of the analysis, the second part of paper discusses how jatropha could positively be introduced to local communities for improvement of rural livelihoods. Possible value chain channels based on the scale of production and operating actors are identified, and according impacts to local communities are discussed. While the quantitative results are specific to Kenya, there are implications of general relevance to other parts of Africa.

Method of Study

Data and information for this study were collected through interviews with stakeholders and visits of jatropha production sites in Kenya. The stakeholders who are engaged in initial experiments of jatropha and biodiesel production in Kenya include project developers such as consultants, NGOs and private companies, policy makers at relevant government ministries, research and academic institutions, and local farmers and extension officers. The production sites that were visited include the villages of Kaveta and Wikililye, Central Division, Kitui District; the villages of Malaika, Nthunguni, Mtito-Adei, and Mangelete in Mtito-Andei Division, Makueni District; the Ngurmani area in Kajiado District, and the village of Gede in Malindi Division, Malindi District. Jatropha production has started since 2005-2006 in Kenya.

[2] The Bank for Investment and Development (EBID) of the Economic Community of West African States has decided to provide US$35million for a *jatropha* biodiesel project in Ghana in conjunction with the country's commercial banks and financial institutions (Santuah, 2006). Senegal, with cooperation of Brazil and India, is launching a biofuel production programme by planting *jatropha* on 4,000 hectares of land in Touba (Africa Research Bulletin, 2006).

Thus the literature on other countries' experiences, especially in India where commercial production started around 2003, is extensively reviewed. Some production data from India are also used in the analysis.

Viability of biodiesel value chain

Biodiesel production is considered to be economically viable when it is price competitive with petroleum products. The cost of biodiesel production is greatly affected by the cost of feedstock production. As the feedstock for biodiesel could be any vegetable or animal fat, jatropha oil is only economically viable when it is price competitive with available alternative oils. This section first examines the viability of biodiesel production in the current Kenyan market, analyzing the competitiveness of biodiesel with petroleum products and the market price of jatropha oil and seeds in Kenya. It then examines the profitability of jatropha production as biodiesel feedstock for smallholder farmers.

Price competitiveness of biodiesel

Jatropha was first introduced in Kenya in 2005, when local farmers started small-scale production in the Districts of Kitui, Makueni and Malindi. Whereas in India the sales price of jatropha biodiesel to oil companies may vary between US$ 0.68 (Rs.31) and US$ 0.90 (Rs.41) per litre (Tewari, 2007),[3] there had been no actual sales of jatropha oil in the Kenyan market at the time of this study. In order to estimate the price of biodiesel in Kenya, the price of alternative vegetable oils that are available was used as an indicator. Palm oil is assumed to be the main alternative to jatropha. [4] Crude palm oil has been the major imported vegetable oil into Kenya for the past decade in terms of both quantity and value. The commercial price of jatropha oil is thus expected to be less than that of crude palm oil. In 2005, the landed price of crude palm oil was US$0.46 per litre (Kshs.34.68), with the total quantity of 338,731 tons, comprising 97 % of total imported vegetable oils (Figure 1). The average landed price from 1996 to 2005 was US$0.51 per litre (Kshs.35.97). Depending on the size of the facility, the cost of feedstock consists of 65-78% of overall biodiesel production expense including feedstock, chemicals, energy, labour, depreciation and overhead and maintenance (Pruszko, 2006). Applying the cost of imported crude palm oil in 2005, US$0.46 (Kshs.35) per litre as feedstock, the total production cost of biodiesel derived from palm oil is calculated to be US$0.70-0.89 (Kshs.53-67).

[3] The biodiesel purchase policy of the Ministry of Petroleum and Natural Gas is that oil companies should purchase biodiesel for US$0.55 (Rs.25) per litre (Tewari, 2007).

[4] Kenya exports oil seeds as well, and the average export price of major oil seeds such as castor, sesame and sunflowers in 2005 was US$0.51(Kshs.39) per kg (Kenya, 2006d).

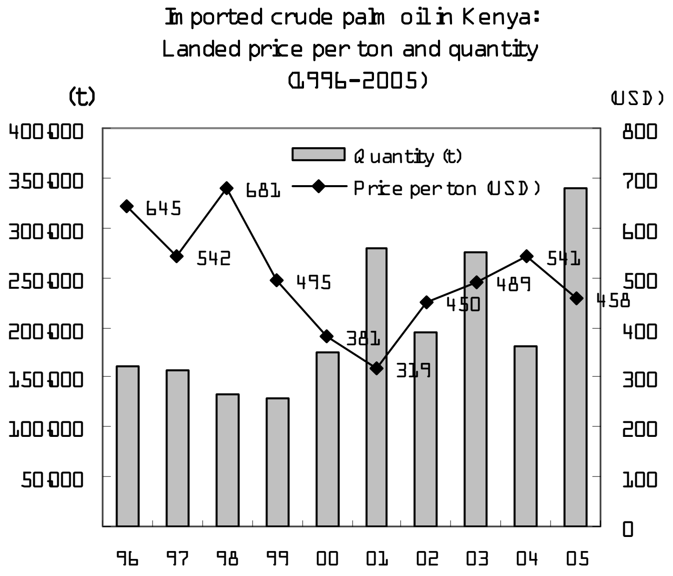

Figure 1. Yearly quantities and landed prices per ton of crude palm oil imported in Kenya

Source: Kenya Export Promotion Council (data provided in February, 2007)

Note: This information was compiled and provided by Kenya Export Promotion Council (KEPC). The raw data is supplied by the Customs and Excise Department of the Kenya Revenue Authority (KRA) who are responsible for the accuracy of the data.

In Kenya where no government intervention exists, the ex-factory price of biodiesel has to be competitive with the landed price of petroleum diesel oil in order for oil companies to purchase biodiesel as an alternative to petroleum diesel oil. As seen in Figure 2, the average landed price of diesel products in 2005 was US$0.37 (Kshs.28) for automotive gasoil (light diesel) and US$0.40 (Kshs.31) for industrial diesel (heavy diesel). In the above scenario of biodiesel production where the ex-factory price, including the value-added tax (VAT) was US$0.81-1.32 per litre, biodiesel was not price competitive with petroleum automotive gasoil in 2005, which landed price with tax and levies, is US$0.68 (Table 1). However, the worldwide experiences with biofuel manufacture to date is that biofuel development has required active government support in the form of tax exemptions, mandates, and direct subsidies (Kojima,2006). If biodiesel was exempted from VAT in Kenya, it would have been almost competitive with the petroleum-based product. In addition, the landed price for automotive gasoil has been increasing since 2005. The average retail price of automotive gasoil for the year 2006 excluding December was US$0.94 (Kshs.68) per litre, increasing from US$0.82 (Kshs.62) in 2005 (Kenya, 2006b). If the price of petroleum products increases without corresponding increases in the price of vegetable oils, biodiesel will become more and more price competitive with petroleum diesel.

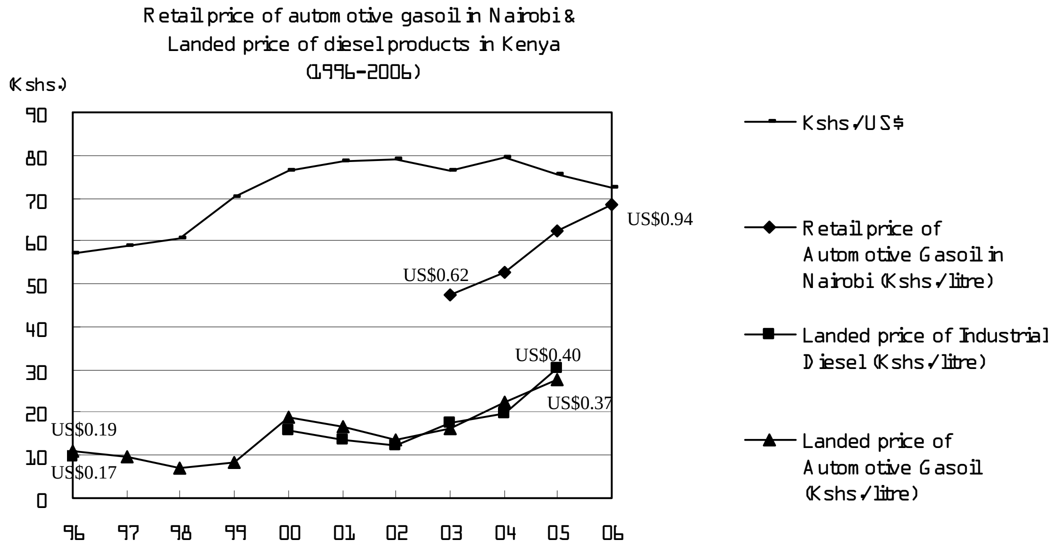

Figure 2. Landed prices of diesel products in Kenya (1996-2005) and retail price of automotive gasoil in Nairobi (2003-2006).

Source: Landed prices provided by KEPC in February, 2007; retail prices in 2003-2005 (Kenya, 2006a); and retail prices in 2006(Kenya, 2006b)

Note: Automotive gasoil refers to light diesel oil for high speed engines; industrial diesel refers to heavy diesel oil for low speed marine and stationary engines. The annual average retail price of automotive gasoil in Nairobi was calculated by monthly data from January, march, June, September and December. The data of December 2006 is not included in the average for 2006.

Table 1. Price Comparison of Palm Oil Biodiesel and Automotive Gasoil (2005)

Price components – Automotive gasoil	Automotive Gasoil US$/litre (Ksh/litre)	Price components – Biodiesel	Biodiesel US$ / litre (Ksh / litre)
Ex-factory Price (Automotive gasoil)	0.43 (33)	Landed price (Biodiesel)	0.70-0-.89 (53-67)
Taxes and levies: excise duty, petroleum development levy	0.25 (19)	VAT of 16%	0.11-0.43 (8-32)
Landed with taxes and levies	0.68 (52)	Ex-factory with VAT tax	0.81-1.32 (62-100)

Source: Authors' calculations

Price of jatropha seeds and oil

In Kenya the average landed price of imported crude palm oil at the port in 2005 was US$0.46 (Kshs.35), which implies that the market price of crude jatropha oil could be no higher than $0.46 (Kshs.35) per litre. Although there had not been any market transaction of jatropha oil and seeds for biodiesel production by the time of this study, the recommended producer price for one kilogram of jatropha seeds is said to be around US$0.10-0.12 (Kshs.7-9) (Personal communication with experts in biodiesel industry).[5] Assuming a 90% extraction rate in the relatively inefficient mechanical oil press, 3.5 kilograms of jatropha seeds with 32% oil content would be required to produce 1 litre of jatropha oil (assuming the actual extraction rate from seeds to be 29%). Without adding oil extraction processing costs such as labour, energy, depreciation, overhead and maintenance, the oil would cost US$0.35-0.42 per litre (Kshs.25-31) , which is US$0.11-0.04 less that the price per litre of crude palm oil in 2005.

Feedstock comprises 65-78% of the overall costs of biodiesel production (Pruszko, 2006), suggesting that biodiesel processors have strong incentives to produce or purchase feedstock at the lowest possible cost.[6] In India, the price of jatropha seeds varies around US$0.13-0.18 (Rs.6-8) per kilogram, while the sales price of jatropha oil varies around US$0.41-0.56 (Rs.19-25) per litre (Tewari, 2007). The target landed price of jatropha oil in Northern Europe is reported to be US$0.48-0.50 per litre by a multi-national biodiesel enterprise which specializes on jatropha, compared to other major biodiesel sources: US$0.63 for palm oil, US$0.80 for soya oil, and US$0.94 for rapeseed oil (D1 Oils, 2007).[7]

Francis, Edinger and Becker (2005) conducted an analysis of the jatropha biodiesel value chain for a small-scale processing facility in India that yields 2,000 tonnes of raw vegetable oil per year. He assumed a price of jatropha seeds of US$0.11 per kilogram and the cost of seed to produce one litre of oil to be US0.39, assuming that 3.57 kilograms of seeds is required to yield 1 litre of oil. The facility could cover its additional costs at a sales price of US0.41 per litre of raw oil. Transesterification would increase the cost to US0.50 per litre and the minimum sales price would be US0.53 per litre (including marketing costs and profits). The transesterification process would generate 0.095 litre of glycerol for every litre of biodiesel. Francis, Edinger and Becker assumed a glycerol price of US$0.08 per litre of biodiesel. However, Kojima (2005) argues that the value of glycerine should not be included in cost / benefit analysis. As production increases, the price of glycerine is expected to fall.

[5] Since there is no established market for *jatropha* yet, the price of *jatropha* varies between producers and buyers in different region. For propagation purposes, seeds are purchased at Ngurmani for an average price of Kshs.25 (US$0.34), which is about three times higher than the recommended price of seeds for oil. The high price for *jatropha* seed is due to the current high demand for seed for propagation purposes.

[6] The cost of oil is affected by the percentage of oil contents as well. D1 oils (2007) set different purchasing prices for seeds with different oil contents.

[7] The prices of *jatropha* oil were reported to be US$0.60 per litre in Mali (Henning, 2002) and US$1.50 in Madagascar (Freudenberger, 2006) where the main use of oil is for soap-making.

Profitability of jatropha production as biodiesel feedstock

Currently three different modes of jatropha production are taking place in Kenya: monoculture, mixed intercropping, hedges and intercropping with vanilla. In Makueni District where jatropha production has been introduced by non-governmental organizations, some farmers are converting their farms into jatropha plantations, although they intercrop jatropha with other food crops for the first year when jatropha is relatively small. Some farmers with limited landholdings have decided to experiment with growing jatropha as a hedge. However, the majority of farmers in the area are observing their neighbours' production of this new crop to see how profitable it will be. The intercropping of jatropha with vanilla was started in the coastal zone of Kenya since 2005. At this moment, there is neither biodiesel production nor purchase agreements between farmers and buyers. This section estimates the yield and expected revenues of jatropha production and analyzes the potential economic returns of adopting jatropha production by smallholder farmers.

Expected Yield

Different yields of jatropha are reported and estimated by different authors (Table 2). There has been neither a long history of production nor systematic data collected in different production conditions with varying climate, soil fertility, landform, altitude, water and fertilizer inputs etc. Francis, Edinger and Becker (2005) estimates the annual seed production per plant to range from about 200 grams to more than 2 kilograms. Yield varies significantly depending on the water input, which determines the number of fruiting period per year, which can vary from one to three. From the early experience of jatropha production by research institutes, private enterprises and local farmers in Maharastra state, Rao (2006) estimates that the average yield of jatropha seeds in drylands is unlikely to exceed 400 kilograms per acre per year. Prajapati and Prajapati (2005) estimated jatropha yields in rainfed and irrigated conditions in India. After 5 years, the production per tree ranged from 1.2 kilogams under rainfed conditions to 3.2 kilograms under irrigated conditions. The yield in rainfed conditions is around 40% as high as under irrigation, implying that jatropha can be grown in semi-arid lands but requires certain level of rainfall to produce high yields. In other words, the plant can survive but not give high yields under conditions of stress (Kureel, 2006). In Mali where jatropha was planted as a hedge by GTZ in the 1990s, the production of seeds was calculated to be about 0.8 kilograms per meter of hedge (Henning, 2002). Table 2 summarizes the yield levels estimated by different authors.

Table 2. Yield estimates of jatropha seeds by different authors

Mode of production	Condition	Year after planting	Annual yield	Yield per tree	Sites	Author
Monoculture	Unknown	Unknown	-	0.2kg to more than 2 kg	Unknown	Francis, Edinger and Becker (2005)
		5th & onwards	-	2-4kg	Unknown	Singh, Bargali and Swamy (2006)
	Rainfed	3rd year	400 kg /acre	0.4kg [a]	Maharastra (dryland), India	Rao (2006)
		Not indicated	400 kg/acre[b]	0.4kg [a]	North East Hill region (dryland), Raipur, India	Singh, Bargali and Swamy (2006)
		Not indicated	400-440 kg/acre[c]	0.4kg [a]	Chatrapati, India	Gour (2006)
		5th & onwards	1,200 kg/acre[d]	1.2kg	India	Prajapati (2006)
		8th & onwards	1,500kg/acre	1.5kg	India	Tewari (2007)
	Irrigated	Not indicated	600 kg/acre [e]	0.6kg[a]	North East Hill region (dryland), Raipur, India	Singh, Bargali and Swamy (2006)
		6th & onwards	1,000 kg/acre[f]	1kg[a]	India	Ministry of Agriculture, India (n.d.)
		8th & onwards	2,500kg/acre	2.5kg	India	Tewari (2007)
		5th & onwards	3,200 kg/acre[g]	3.2 kg	India	Prajapati (2006)
Hedge	Unknown, probably rainfed	Not indicated	1kg/meter	-	North East Hill region (dryland), Raipur, India	Singh, Bargali and Swamy (2006)
		Not indicated	0.8 kg/meter	-	Mali	Henning (2002)

Note: [a]The yields per tree are calculated as1,000 trees planted per acre by spacing 2 meter by 2 meter. [b]The yield was originally given as1000 kg /ha. [c] The yield was originally given as1000-1100 kg /ha. [d] The yield was originally given as 3,000 kg/ha with 2,500 plants. [e]The yield was originally given as 1500kg/ha. [f]The yield was originally given as 2,500 kg /ha. [g]The yield was originally given as 8,000 kg/ha with 2,500 plants.

Differences in seedling development are also observed according to the different agro-ecological conditions such as in Kitui, Makueni and Malindi Districts, where farmers have started growing jatropha recently (Table 3). The plants of jatropha are placed at 1.5-2.0 meter intervals in all of the sites. The growth of plants in Kitui (2) is observed to be significantly less than Kitui (1): in Kitui (1) the seedlings were planted at the beginning of rainy season and soil is relatively fertile. Makueni (1) had the worst growth among the sites, perhaps due to neglect of clearing weeds and waterlogging around the seedling. The largest difference of growth is observed in the Makueni sites. The height of Makueni (3) is 3 times greater than the height of Makueni (1), with Makueni (3) having the most fertilie soils and year-around irrigation.

Table 3. Difference of seedling development in Kitui, Makueni, and Malindi District

No.	Height (cm)	Date & method of planting	Agro-ecological condition observed	Date observed	Site
Kitui (1)	120-160	Early November 2006, 1 month old seedling	Rainfed Low-land Relatively fertile soil	Late-Jan. 2007	Kaveta, Central Division
Kitui (2)	40-70	Late November, 2006, 1.5 month old seedling	Rainfed Upland, on the slope	Late-Jan. 2007	Wikiliye , Central Division
Makuen i (1)	30-60	April, 2006, Directly sown by seeds	Rainfed Low-land Intercropped: maize and cowpea	Early Feb. 2007	Malaika, Mtito-Andei Division
Makuen i (2)	80-100	April, 2006, Directly sown by seeds	Rainfed Low-land Intercropped: maize and green-gram	Early Feb. 2007	Nthunguni, Mtito-Andei Division
Makuen i (3)	180-210	April, 2006 Directly sown by seeds	Irrigated (once a week) Low-land Fertile soil Intercropped: maize	Early Feb. 2007	Mangelete, Mtito-andei Division
Malindi (1)	180-220	Late January, 2006 Cuttings	Irrigated (once a week) Low-land Sandy soil, fertilized with organic manure Intercropped: vanilla	Late Feb. 2007	Gede, Malindi Division

Note: There are two rainy seasons in Kenya, and the seasons and periods varies in each region. The average annual rainfalls during two rainy seasons are 800mm (April-May) and 500mm (November-December) in Kitui District, 329.3mm (April-June) and 372.4mm (October-December) in Makueni District and 1,200mm (April-July) and 1,400mm (January-March) in Malindi District. The altitude is 400m-1,800m in Kitui, 600m-1,900 in Makueni, and 0m-418m in Malindi (Kenya, 2002a,; 2006b, 2006c, 2006d).

A wide range of genetic variation has been observed for different provenances but not yet fully explored. Country-wide studies have been undertaken in India, identifying superior jatropha provenances with higher yield and oil content (Kureel, 2006). Among twelve provenances tested in 8 regions of Chhattisgarh, Madhya Pradesh, Andhra Pradesh, Orissa, Tamil Nadu, Uttaranchal, Rajasthan, and Uttar Pradesh in India, oil content ranged from 30.5% in Tamil Nadu to 42.3% in Uttar Pradesh (Tewari, 2007). The yield and growth of jatropha varies by agro-ecological condition. In Malindi town, the average height of 30 jatropha plants of 13 years of age is reported to be only around 2 meters, while jatropha can reach a height of up to 5 meters. The yield per year of these plants in Malindi is less than 1 kilogram with only one fruiting season in July / August, which is the end of long rains that start in April.[8] Heller (1996) suggests the cause of low yields observed in several projects is the use of unadapted provenances. Francis, Edinger and Becker (2005) highlight the need for careful selection and improvement of suitable germplasm before mass production is undertaken. The low height and low yield of the jatropha planted in Malindi could also be due to the unsuitability of the variety for the agro-climatic conditions of Malindi. Further research on yield, oil content and growth of different provenances under different agro-ecological conditions region is required before large-scale production could be recommended in Kenya.

[8] However, for the first time in 2006, where the short rainy season lasted longer than usual, the second fruiting was observed for the first time. In Malindi, the average amount rainfall is 1,200mm (April-July) during the long rains and

Revenue and opportunity cost of jatropha production

Farmers' decisions about starting jatropha production depend upon the returns that they expect to generate. In this section we compare the revenues that Kenyan farmers are likely obtain by growing jatropha with the revenue streams and profit margins of other crops they can grow on the same land. Other production cost such as labour and agricultural inputs are not considered. There is an indication that maintenance cost might be substantial as Rao (2006) reports that Jatropha has turned out to be as vulnerable as any other crop to pests and diseases once it is removed from its original habitat and put under high density and intensive cropping systems (Rao, 2006). However, in the absence of comparable data on the costs of production, comparisons of revenue streams provides a first approximation of the relative economic attractiveness of the different crops. Table 4 presents estimates of the gross revenue that farmers in Kenya may generate from jatropha production, assuming a producer price of US$0.10-0.12 (Kshs.7-9) per kilogram and the highest yields that have been recorded in India under rainfed conditions (Tewari, 2007) and irrigated conditions (Prajapati, 2006). Under these very favourable circumstances, smallholder farmers are likely to generate US$150-180 of revenue per acre after the 8th year under rainfed conditions and US$ 320-384 per acre after the 5th year under irrigation.

Table 4. Average expected yield of seeds with good care and revenue

Year after planting	Per Acre (kg)		Per Tree (kg)		Revenue per acre			
	Rain-fed	Irrigated	Rain-fed	Irri-gated	Rainfed		Irrigated	
					US$	Kshs.	US$	Kshs.
1st	0	100	0.00	0.1	0	0	10-12	726-871
2nd	50	400	0.05	0.4	5-6	363-436	40-48	2,905-3,486
3rd	100	1,000	0.10	1.0	10-12	726-871	100-120	7,262-8,714
4th	250	2,000	0.25	2.0	25-30	1,816-2,179	200-240	14,524-17,429
5th	500	3,200	0.50	3.2	50-60	3,631-4,357	320-384	23,238-27,886
6th	1,000	3,200	1.00	3.2	100-120	7,262-8,714	320-384	23,238-27,886
7th	1,250	3,200	1.25	3.2	125-150	9,078-10,893	320-384	23,238-27,886
8th & after	1,500	3,200	1.50	3.2	150-180	10,893-13,072	320-384	23,238-27,886

Source: Tewari (2007) for rainfed conditions and Prajapati (2005) for irrigated conditions.

At this level of likely revenue, jatropha would not be an attractive crop to grow for smallholder farmers. Table 5 compares the revenue from jatropha with major cash crops in Gede, Malindi District where jatropha is currently introduced as an intercrop with vanilla. Mango is more

1,400mm (January-March) during short rain. The second fruiting in 2006 may imply that *jatropha* fruits as long as it gets enough water to keep developing continuously.

attractive to grow than 8th year of jatropha, generating revenue of US$167-197 (Kshs.12,128-14,307) per acre, while the revenues from cashew and coconuts are lower than those generated by jatropha. To minimize risks, most farmers currently grow a mixture of mangos, cashews and coconuts. Another possible production system is the intercropping of jatropha with vanilla. The intercropping of jatropha with vanilla has been researched by private enterprises, NGOs and the governmental organizations in Kenya (Muchiri, 2007a). [9]

Table 5. Comparison of revenue per acre with cash crops in Gede, Malindi

Crop	No. of trees per acre	Annual yield per tree	Producer's Price	Revenue per acre	Revenue from 8th year of jatropha per acre
Mango	28	300 fruits	US$0.04 (Kshs.3) / fruit	US$347 《Kshs.25,200》	US$150-180 (Kshs.10,893-13,072)
Cashew	28	15 kg	US$0.34 (Kshs.25) / kg with shell	US$145 (Kshs.10,500)	
Coconuts	40	50 nuts	US$0.03 (Kshs.2) / nut	US$55 (Kshs.4,000)	

Note: All the trees are expected to be 10 years old. The information on mangoes, cashews and coconuts were provided by local farmers.

Table 6 presents estimates of the gross margins (revenues less costs) that farmers can generate by growing selected food crops in the semi-arid area of Kenya's Machakos District. The results indicate that farmers might be better off producing food crops rather than jatropha. The gross margin of potatoes, cassava, and green grams are US$698 (Kshs.50,667), US$257 (Kshs.18,666), and US$115 (Ksh.8,327) respectively. In the case where farmers are able to grow crops for two seasons in the year of good rain, the gross margin may be doubled. An added financial advantage of these annual food crops is that they can be expected to generate positive revenue from the first year of production, while jatropha will not yield any return in the first years after planting.[10] Comparing the annual revenue of US$ 150-180 per acre from the 8th year of jatropha produced in rainfed condition (which does not consider the production costs of jatropha), the planting of jatropha on farms where potatoes, cassava, or green grams could be grown would be an irrational choice for the farmers.

[9] Learning from neighbouring country's experience such as Uganda, vanilla production is promoted as high value crop in Kenya for flavouring food products such as coca-cola, chocolate, yogurt, cakes and also as fragrance in cosmetics and perfumes industry (Kigomo et al., 2006)

[10] *Jatropha* is considered to be a less labour intensive crop, with low production costs than the cash crops described below. However, pest and disease control could add to the cost of production if necessary. The early production experiments in Kenya suggest problems with red mites and fungus.

Table 6. Gross Margins of major food crops in Machakos (per acre)

Crop	Farmer's level in US$ (Kshs.)			Optimal level in US$ (in Kshs.)		
	Cost	Revenue	Gross Margin	Cost	Revenue	Gross Margin
Potatoes	561 (40,833)	1,260 (91,500)	699 (50,667)	1,089 (79,092)	2,086 (151,500)	997 (72,408)
Cassava	473 (35,334)	744 (54,000)	257 (18,666)	922 (66,924)	1,432 (104,000)	510 (37,076)
Green Grams (N26)	83 (6,073)	198 (14,400)	115 (8,327)	126 (9,167)	347 (25,200)	221 (16,033)
Beans	93 (6,728)	155 (11,250)	62 (4,522)	140 (10,179)	248 (18,000)	108 (7,821)
Cow peas (K80)	76 (5,487)	116 (8,400)	40 (2,913)	88 (6,417)	182 (13,200)	94 (6,783)
Pearl Millet	100 (7,254)	112 (8,100)	12 (846)	210 (15,257)	335 (24,300)	125 (9,043)
Pigeon Pea	106 (7,722)	113 (8,200)	7 (478)	166 (12,033)	267 (19,400)	101 (7,367)
Sorghum	95 (6,915)	99 (7,200)	4 (285)	198 (14,356)	297 (21,600)	99 (7,244)

Source: Machakos District Resource Management Guidelines, Eastern Province, Horticulture and Traditional Food Crops Project, Ministry of Agriculture (2006)

Note: The cost includes seeds, seed dressing, plough, weeding, manure, fertilizer, pesticides, bags, storage, transport, labour (land preparation, planting, fertilizer and pesticide application, weeding and thinning, harvesting, drying etc.) etc. as well as interest on working capital (17%).

The above comparison of jatropha revenue with other food crops in Malindi and Machakos District indicates that the production of jatropha is not a rational choice under current economic and policy conditions. For smallholder farmers with limited land sizes, conversion of land into jatropha production is risky. The average farm size cultivated by smallholder farmers is, for example, 5 acres in Kitui, 6 acres in Makueni, 2 acres in Kajiado, 20 acres in Malindi (Kenya, 2002a; 2002b; 2002c; 2002d). It is important for farmers to make a rational choice in using their limited land; farmers should engage in jatropha production only after a purchasing agreement is made between farmers and buyers at a satisfactory price.[11] Under those conditions, farmers would be able to avoid the risks of poor future market conditions and being exploited by market intermediaries.

[11] D1 oils (2007) engages in contract farming in Swaziland for 17,316 hectares, while managed plantations for 3,288 in Zambia and Swaziland, and seed purchase and oil supply agreements for 11,895 hectares in Zambia and the rest of Africa as of 15 March 2007.

However, if the production of jatropha becomes attractive for smallholder farmers with subsidies or large increases in petroleum and oil palm prices, more farmers will convert their land into jatropha production. Everything else equal, shifting land from the production of food crops into jatropha production will lead to a reduction in the supply of food crops and subsequent increases in the local price of food crops. In this sense, the production of jatropha cannot be justified as having “no competition with food.” The recent increases in the prices of major agricultural products such as sugar and cereals in the world market due to increased biofuel production is an indication of the potential effects of large-scale jatropha on local food prices in Kenya. The crop change from food crop to energy crop should especially be avoided in semi-arid areas that experience production declines due to unpredictable and unstable rainfall.

In Kenya, there currently is experimentation with other feedstocks for biodiesel production. The economic case for these crops may be stronger than for jatropha. For example, the production of canola as a biodiesel feedstock is being undertaken by a private enterprise in Nyeri District, where it appears to be more promising than jatropha due to its value as both a high-quality edible oil and potential biofuel source, and the high value of its by-product, edible seedcake which is used for animal feed. The current market price for canola seeds in Nyeri is Kshs.12.50 (US$0.17) per kilogram, which is US$0.05-0.07 higher than the most likely producer price of jatropha seeds. The seedcake of canola is sold for Kshs.12 (US$0.17) per kilogram. Assuming a 90% extraction rate, 2.8 kilograms of canola seeds are required to make 1 litre of crude canola oil from seeds with 40% oil content. The by-product of about 1.8 kilograms of seedcake generates extra revenue of Kshs 21.6 (US$0.30) per litre in addition to the revenue from extracted oil (Personal communication with Bioenergy Ventures). Although jatropha seedcake could be used as organic fertilizer, it has a relatively low market value. Other candidates for biodiesel feedstock are forest species such as croton (*Croton megalocarpus*), cape chestnut (*Calodendrum capense*), and yellow oleander (*Thevetia peruviana*). These species are currently being grown experimentally around the Mount Kenya region, although they are already abundant in the forest area and grown on farm. Compared with jatropha that is currently introduced as a new “farm crop,” the production of biodiesel from indigenous tree species might be less risky and more sustainable. The seedcake of croton can be used for animal feed as well, and thus is more valuable than the non-edible jatropha seedcake. However, there is a challenge to overcome with croton. Due to the hardness of its kernel, deshelling is required before oil can be extracted. The additional processing step adds the extra costs and difficulties in production (Muchiri, 2007b). More research and development are necessary to make it economically viable.

How jatropha could contribute to improvement of local livelihoods

The results presented in the previous part of this paper show that current market conditions do not make jatropha production an attractive investment for smallholder farmers in Kenya, despite heavy promotion by several private firms and some non-governmental organizations.

The above conclusion was based on a key assumption about the value chain: that smallholder farmers would engage in jatropha seed production in order to sell to private biodiesel enterprises that would compete with wholesale supplies of diesel. However, other value chains exist for jatropha biodiesel production in which smallholder farmers might be able to obtain more attractive outcomes. After identifying the different value chain channels based on the scale of production and operating actors involved, this section discusses how jatropha production could contribute to the improvement of rural livelihoods and the kind of policy changes that might contribute to the achievement of that goal.

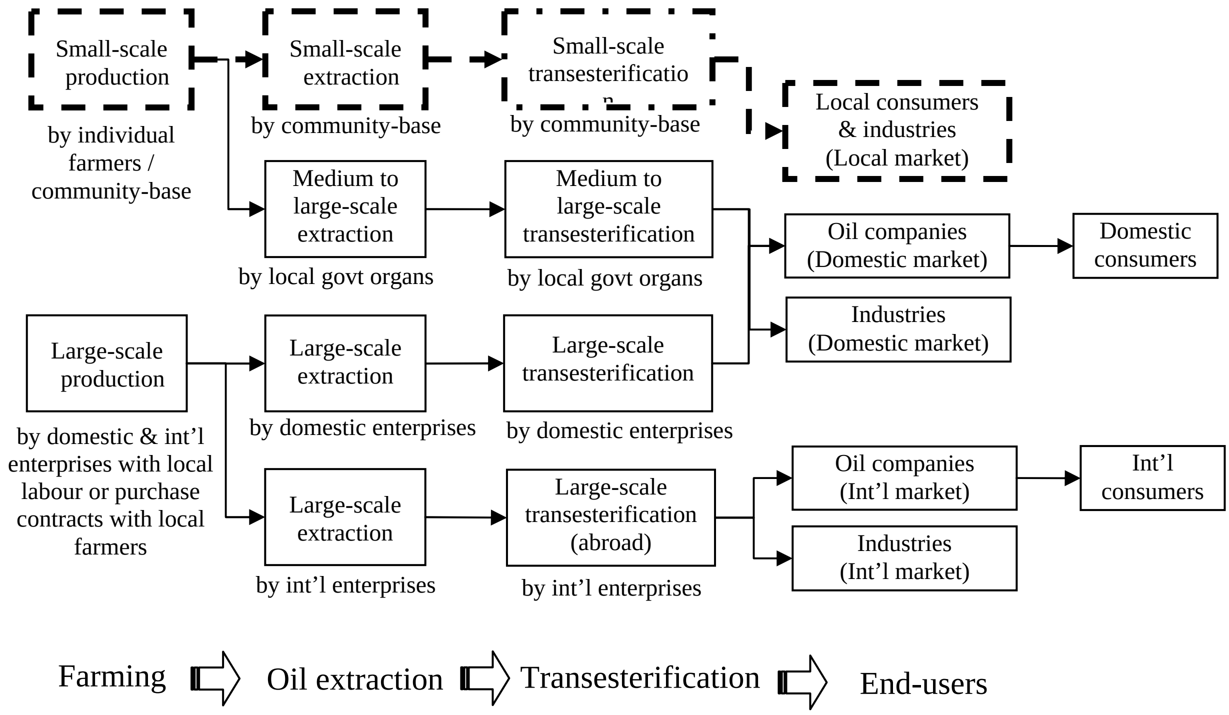

Figure 3. Scale-based analysis of value chain channels for Jatropha curcas biodiesel production

Source: Authors

Alternative value chains and potential impacts on local livelihoods

The different value chain channels based on current production cases are displayed in Figure 3. The value chain consists of four stages: production of feedstock (farming), oil extraction (first processing), transesterification (second processing), marketing to end-users, and distribution of products that connect each stage. The actors in the value chain include local farmers, domestic and international private enterprises, government agencies and national and international end-users, depending on the local context.

For commercial investors interested in selling biofuel to wholesale or international market outlets, large-scale production is likely to generate greatest profits. For society as a whole, large-scale production will provide greatest benefit in terms of increased access to a renewable source of energy. However, for smallholder farmers in local communities, small-scale production and processing may bring more benefits.

There are two scenarios for introducing jatropha production to local communities shown in the first stage of the value chain. The first scenario is large-scale production where private enterprises take initiatives to produce large amounts of biodiesel and local populations are incorporated into the production process as wage labourers on plantations or contract suppliers of seed. There is little data available on the possible economic impacts of large plantations of jatropha, although the maximum wages for employees would be determined by the international price of jatropha oil, which is not particularly attractive at present. As a vegetable fat, jatropha will be subject to price fluctuations in international agricultural products. As the degree of integration between local communities and the corporate production system increases, this dependency may increase the vulnerability of local communities to market fluctuations and other external shocks.

An analysis of the benefits and limitations of jatropha production should take account of the social and environmental impacts on local communities, in addition to the economic impacts. Large-scale monoculture production systems rightly raise criticism and concern, and jatropha production should be no exception. If large-scale plantations are established to satisfy the demands for growing bio-energy in the world market, the accompanying land use change could well bring unfavourable social and environmental changes in the affected communities.

Project developers highlight the fact that jatropha can be grown on "marginal" or "waste" land, a claim which must be tested for validity. While there may appear to be a great amount of underused marginal land in developing countries where jatropha could be grown, most of these lands are currently used for communal livestock grazing (Benge, 2006). However, for outsiders, the importance of grazing activity by local pastoralists and argo-pastoralists has not been obvious. Land that is not farmed may be considered to be "idle," producing little economic value. However, replacing pastoralism with farming activities could lead to degradation of natural resources. Van Noordwijk, Ni'matul and Lusiana (2006) raise concerns about the damage to local ecosystems brought by a large-scale monoculture mode of production. Pastoralists have evolved sound ecological strategies to enable them to live in harmony with their environment by keeping different livestock species and practicing small-scale crop production on a sustainable basis (Barrows, 1996). The land use change brought by the introduction of large scale plantations could undermine the sustainable management of land. Another issue is availability of labour. Even if lands without farming or grazing are available for producing jatropha, the availability of adequate labour will become an issue since such land is likely to be located far away from settlement areas. Labour migration, and its attendant challenges, might therefore become an issue.

A second scenario is the case of small-scale decentralized biodiesel production. Local populations grow jatropha seeds which are collected through local collection systems, and jatropha biodiesel produced in small oil pressing and processing facilities. Facilities could be operated by community groups, cooperatives or private enterprises. Provided that transesterification is included in the biodiesel production process, the product can be sold in local retail markets as a substitute for imported petroleum-based diesel. Francis, Edinger and Becker (2005) emphasizes the need for establishing seed collection and oil pressing centres close to production sites in villages to encourage investment in remote areas. Small-scale expellers with capacity of up to four to five tonnes / day are available in India, some of which are operated by local government agencies (Mohan, Phillippe and Shiju, 2006). The lack of availability of these expellers in local markets, and the lack of finance for their purchase, is a major constraint on decentralized production in Kenya. It is uncertain what combination of private, cooperative or public action might overcome these constraints in the Kenya context.

Potential of jatropha “oil” for the improvement of local livelihood

From the above discussion, it appears that the opportunity for local populations to maximize benefits from jatropha is to engage not only jatropha production but also in oil extraction. Even if transesterification is not realistic, locally extracted oil can be directly used in diesel engines or as a kerosene substitute for lamps and stoves (Heller, 1996). The direct use of pure jatropha oil for lister-type diesel engines has been experimented by GTZ in Mali (Henning, 2002). The direct use of oil in these engines is limited to areas with warm climates due to the viscosity of jatropha oil (Benge, 2006).

Experiments are also under way to use jatropha oil as a substitute for kerosene in lamps and stoves. Jatropha oil is much less expensive than kerosene so its use could contribute to savings for local communities and poor urban households. According to a survey administered to 2,300 households in 15 rural districts and five urban centres in Kenya by the Ministry of Energy in 2000, 82% of urban and rural households used kerosene for lighting in lanterns, tin lamps and pressure lamps, and 88% used kerosene for domestic cooking. The kerosene consumption per household in urban areas was an average of 90 litres/year compared with 41 litres/year in rural areas, while per capita consumption was an average of 23 litres/year in urban areas and 8.6 litres/year in rural areas. Kerosene is mainly used for lighting in rural areas and for both lighting and cooking in urban areas (Kenya, 2002e). Despite the reliance on kerosene by low income households, kerosene, like other petroleum products, has become less affordable for low income population in recent years. The landed price of kerosene has gone up by 3.5 times from 1996 to 2005 (Figure 4) and the average consumer retail price for kerosene has gone up for 2.5 times from US$0.36 (Kshs.22.03) per litre in 1998 to US$0.77 (Kshs.56.16) per litre in 2006 (excluding December) (Kenya, 2006b). This compares favourably with the cost of producing biodiesel from imported palm oil (see Figure 1). Jatropha oil might be most competitive with kerosene when produced in rural areas close to the source of seed supply and far from the source of kerosene production.

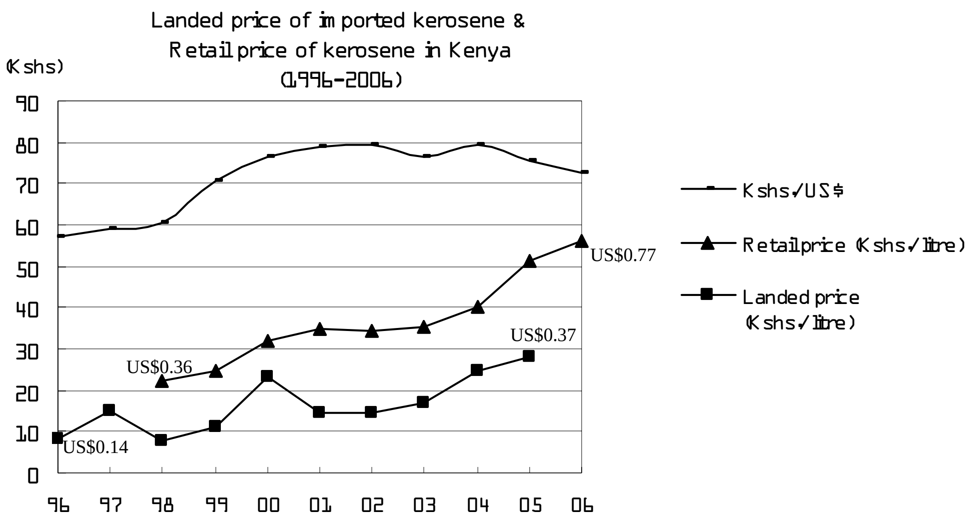

Figure 4: Landed price (1996-2005) and average retail price (1998-2009) of kerosene in Kenya.

Source: KEPC for Landed prices, provided in February, 2007; retail prices in 1988-2005 (Kenya, 2006d) and in 2006(Kenya, 2006b)

Note: The data of December 2006 is not included in the average for 2006.

Constraints on the promotion of jatropha oil for lighting and stoves are discussed by van Eijck (2006) for the case of Tanzania. Using jatropha oil for lighting and cooking requires different equipment than that used for kerosene. Lamps need to be modified to account for the high viscosity and low absorbance of jatropha oil in the wick. Special lamps and stoves designed for jatropha oil have been developed and tested by NGOs in Tanzania. However, there is not yet a good network to widely distribute that equipment. The successful promotion of jatropha oil for cooking depends on the availability and affordability of other energy sources (eg fuelwood, charcoal, liquid natural gas, etc.) in the local context. Early project developers are aware of the difficulty of introducing new sources of energy in communities where kerosene has been used for a long time and families may be slow to adopt new fuels and equipment (Mbola, 2004).

Currently, the most promising and well developed uses of jatropha are for soap and candle making (Tigere et al, n.d.). Soap production with jatropha oil has been promoted in Mali, Tanzania and Madagascar where it has gained recognition in the market as an anti-septic natural soap. However, the market for jatropha soap may not expand much beyond its current size due to the high price compared to ordinary soaps (van Eijck and Romijn, 2006).

Government policy on jatropha biodiesel production for the improvement of local livelihood

Government policy plays an important role in fostering growth of the biodiesel industry. Active government support has been essential in every country where biodiesel and other biofuel industries have been successfully established. The previous analysis of value chain channels discussed different production options to generate different beneficial outcomes for the industry and smallholder farmers. For the industry and society as a whole, larger production scales bring more benefit, while the benefit to smallholder farmers may remain minimal if local farmers are employed in large plantations as wage labourers or if they engage in production independently and sell seeds to large-scale private processors seeking to compete with wholesale diesel. Government policy influences the returns that can be generated from different value chains and thus the potential returns to different types of actors.

By supporting the biodiesel industry, governments of oil-importing countries accrue benefits such as increased energy self-sufficiency, foreign exchange savings, and income from the growth of agricultural sectors and new biodiesel industries. The impact of foreign exchange savings may be substantial. Brazil, which has directly invested the total of US$4.92 billion in the agricultural and industrial sectors for the production of ethanol for vehicle use during the period 1975-1989, reduced oil imports by a total of US$52.1 billion (US$, January 2003) during the 1975-2002 period (Coelho, 2005). In Africa, South Africa has been most active in promoting biofuels through their biodiesel support program. The South African Treasury approved the implementation of a fuel levy exemption for biodiesel, beginning at 30% in 2003 and increasing to 40% in 2005 (South Africa, 2006).

As a country without proven petroleum resources, Kenya’s economy is vulnerable to increases in the prices of petroleum products. The total import value of crude petroleum and petroleum products in 2005 was US$1,288,933,291 (Kshs. 97,598,000,000), which accounts for 23% of the country’s total import expenditure of US$5,688,589,540 (Kshs.430,740,000,000) (Kenya, 2006a). Governments must make careful decisions on whether the benefits from supporting the biofuel industry would exceed the loss of government tax revenue that would result from lower imports of petroleum products (Kojima, 2005). As in other oil importing countries, biofuel policy is under discussion in Kenya. Interestingly, Kenya has a history of blending petroleum with ethanol made from sugarcane. Between 1983 and 1993, the government required oil companies to sell a petroleum blend composed of 65% super petroleum, 25 % regular petroleum, and 10 % of ethanol made of sugarcane. The blending requirement was discontinued due to unsustainable pricing and extensive lobbying by oil companies. The government has an interest in reintroducing power alcohol as a motor fuel in its long-term policy to enhance security of supply if it could overcome the problem of competitiveness in the market place (Kenya, 2004). However, the government has taken a cautious approach towards reconsidering support for the biofuels industry, due to the experience of previous policy failures. In Kenya, various stakeholders in biodiesel industries formed the national biodiesel committee in January 2006 under the Ministry of Energy to have a collective voice in promoting policies such as blending mandates, tax mandates and production subsides (Kituyi, 2006; Kituyi 2007).

Policy support is a not straightforward issue. Different government policies affect different stages of the value chain for different actors. Tax reductions or exemptions, low-interest loans, and tax holidays to biofuel producers could produce a competitive margin for firms involved in the oil extraction and transesterification processes. Meanwhile, only direct subsidies to producers will affect the viability of feedstock production. However, it is likely that direct subsidies will be of much greater benefit to large-scale producers than smallholder farmers (Kojima, 2005). India began its current biodiesel programme, the “National Mission on Biodiesel,” in 2003. The programme focuses primarily on production and processing of feedstock from jatropha and pongamia. The national biodiesel programme encourages states to adopt different combinations of policies to meet targets for increased biodiesel production, including subsidising water and electricity to set up plants, allowing companies to lease government wasteland, and undertaking state-owned jatropha plantations (Mohan, Phillippe and Shiju, 2006). However, the main government support has focused on large-scale production, rather than production by smallholder farmers.

If the Government of Kenya does support the large-scale development of the biodiesel industry, it must consider the likely conflict of interest between local communities and the biodiesel industry concerning the “actual outcome” brought from different production channels in the jatropha biodiesel value chain. The pastoralist community living in the Tana Delta, the largest and most ecologically and biologically diverse wetland in East Africa, filed a suit in court to bar two organisations from setting up a Sh24 billion 12,000 hectares sugar project in the area. The pastoralist communities feared that they could lose their homes and that there would be damage to the ecosystem (Machuhi, 2007). The government should analyze the socio-economic impact on local communities of potential land use changes, and base its policy decisions on the need for equitable benefits among different stakeholders. The government must propose a clear policy vision on the direction of jatropha biodiesel industry, whether focusing on the improvement of local livelihood by setting up small-scale processing facilities, or supporting the large-scale production by private enterprises.

Conclusions

The global rise in the price of petroleum prices and interest in renewable energy sources has resulted in increased interest in all types of biofuels across the developing world. Like other African countries, Kenya has seen a great increase in promotion of *Jatropha curcas*, a naturalized shrub that produces a non-edible oil suitable for biodiesel. Both private companies and non-governmental organizations are involved, claiming potential benefits for energy security, GHG mitigation and rural development.

Biodiesel production could become economically viable through a combination of higher petroleum oil prices, government waiver of the value added tax (VAT), and / or if the government established and maintained subsidies for a minimum purchasing price for jatropha seeds that considered farmers' opportunity costs of producing other cash crops. In order for processors of biodiesel to have secure sources of feedstock from smallholder farmers, they would need to make proper long-term purchase agreements with local farmers, offering attractive prices. Otherwise at the current recommended price of jatropha seeds, the profit that farmers are likely to obtain from producing jatropha is expected to be unattractive for smallholder farmers to start the production, compared with investing in other cash crops. Therefore, smallholder farmers should make a rational choice on whether or not to introduce jatropha and the mode of production on their limited land.

This paper also assessed the case for jatropha and biodiesel production from the prospective benefits for each actor: the production of biodiesel with less expensive feedstock for private enterprises, access to alternative clean energy sources for the society as a whole, jatropha as an alternative income source for smallholder farmers, and lastly the national policy perspective on biodiesel as an alternative energy source and on policy equitability among different stakeholders. Unless large-scale production is achieved, it is not worthwhile for the private enterprises to launch the jatropha biodiesel production. The more that alternative clean energy is generated through large-scale production, the more the society as a whole will benefit. However, unless farmers are able to engage in oil extraction process through decentralized small-scale production, the benefit to local communities will be minimal. Further analysis is needed of the economic case for decentralized production of biodiesel and substitutes for kerosene.

There is some potential for the Clean Development Mechanism (CDM) to provide enough additional incentives to make jatropha economically viable, and a trial to promote jatropha production as a CDM project has been developed for Kenya (ECM, 2005). However, it is important to note that many African countries, including Kenya, have relatively poor investment climates with considerable risk of project implementation failure. Under such conditions, attractive CDM projects will be large-scale ones that generate big volumes of Certified Emission Reductions, preferably implemented by a single corporate entity, not by the bundle of smallholder farmers (Balint, 2006). In this sense, unless a jatropha project that substitutes fossil fuels is large-scale, the project is unlikely to attract CDM financing. On the other hand, if the jatropha biodiesel industry grows and becomes very profitable, the scenario of business as usual (BAU) will apply. Project proponents would need to demonstrate that the biofuel project would not occur in the absence of CDM project activity.

Considering the uncertainties around large-scale jatropha production, van Noordwijk (2006) explores the possibility of safely integrating jatropha as a biofuel crop into agroforestry systems that can minimize risks to local farmers. In terms of income generation from jatropha, at this moment it may be better to promote the production of jatropha as a live fence for marking boundaries between houses and farms. In that farm niche, jatropha could generate small amounts of revenue that could be relatively steady if there was a vibrant market.

References

Africa Research Bulletin, 2006. Power Africa. *Africa Research Bulletin* 17203. November 16th-December 1st 2006. Blackwell Publishing Ltd. Available at http://www.blackwell-synergy.com/doi/pdf/10.1111/j.1467-6346.2007.00652.x?cookieSet=1. Accessed 14 February, 2007.

Balint, J., 2006. Financing the development dividend. In: Cosbey, A., Murphy, D., Drexhage, H. Balint, B., 2006. *Making development work in the CDM: Phase II of the development dividend project*. Pre-publication version. International Institute for Sustainable Development.. Available at: http://www.iisd.org/pdf/2006/climate_cdm_phase2.pdf. Accessed 25 January 2007. p.100-156.

Barrows, E.G.C., 1996. *The drylands of Africa: local participation in tree management.* Nairobi: Initiatives Publishers. p.3.

Benge, M., 2006. Assessment of the potential of *Jatropha curcas*, (biodiesel tree,) for energy production and other uses in developing countries. Posted on ECHO's website with permission of the author. July 2006 and updated August 2006. Available at:

http://www.echotech.org/mambo/index.php?option=com_docman&task=doc_view&gid=179&Itemid=68. Accessed 10 February 2007.

Coelho, S.T., 2005. *Biofuels: Advantage and Trade Barriers.* United Nations Conference on Trade and Development. Available at: http://www.unctad.org/en/docs/ditcted20051_en.pdf. Accessed 5 February 2007.

D1 oils plc, 2007. Preliminary result for year ended 31December 2006. Available at: http://www.d1plc.com/pdf/analyst_28_03_07.pdf. Accessed 13 April 2007.

Francis, G., Edinger, R., and Becker, K., 2005. A concept for simultaneous wasteland reclamation, fuel production, and socio-economic development in degraded areas in India: Need, potential and perspectives of *Jatropha* plantations. *Natural Resources Forum,* 29:12-24.

Freudenberger, M., 2006. Comments from the field. Added to ECHO Websites 19 August 2006. p.17. In: Benge, M., 2006. Assessment of the potential of *Jatropha curcas*, (biodiesel tree,) for energy production and other uses in developing countries. Posted on ECHO's website with permission of the author. July 2006 and updated August 2006. Available at: http://www.echotech.org/mambo/index.php?option=com_docman&task=doc_view&gid=179&Itemid=68. Accessed 10 February, 2007.

Gour.V.K., 2006. Production Practices Including Pest Harvest Management of *Jatropha curcas*. In: Singh, B., Swaminathan, R., Ponraj, V. (eds), 2006. *Boidiesel Conference Towards Energy Independence – Focus on Jatropha.* Papers presented at the Conference Rashtrapati Nilayam, Bolaram, Hyderabad on 9-10 June, 2006. pp.223-251. Available at: http://presidentofindia.nic.in/presentation/splang189PDF%20Format786.pdf. Accessed 9 February, 2007.

Heller, J., 1996. Physic nut. *Jatropha curcas* L. Promoting the conservation and use of underutilized and neglected crops. 1. Institute of Plant Genetics and Crop Plant Research, Gatersleben / International Plant Genetic Resources Institute, Rome.

Henning, R.K., 2002. Using the Indigenous Knowledge of *Jatropha*. The use of *Jatropha curcas* oil as raw material and fuel. Local Pathways to Global Development. *Indigenous Knowledge Notes*, 47, August. The World Bank, Washington, D.C. Available at: http://siteresources.worldbank.org/EXTINDKNOWLEDGE/Resources/iknt47.pdf.

India, n.d.. *Jatropha*. National Oilseeds and Vegetable Oils Development Board, Ministry of Agriculture, Government of India. Available at: http://www.novodboard.com/Jatropha.pdf. Accessed 15 April 2007.

Kenya, 2002a. *Kajiado District Development Plan 2002-2008*. Effective Management for Sustainable Economic Growth and Poverty Reduction. p.10. Ministry of Planning and National Development, Government of Kenya, Nairobi.

Kenya, 2002b. *Kitui District Development Plan 2002-2008*. Effective Management for Sustainable Economic Growth and Poverty Reduction. pp.9-10. Ministry of Planning and National Development, Government of Kenya, Nairobi.

Kenya, 2002c. *Makueni District Development Plan 2002-2008*. Effective Management for Sustainable Economic Growth and Poverty Reduction. pp.8-9.Ministry of Planning and National Development, Government of Kenya. Nairobi.

Kenya, 2002d. *Malindi District Development Plan 2002-2008*. Effective Management for Sustainable Economic Growth and Poverty Reduction. pp.8-9. Ministry of Planning and National Development, Government of Kenya, Nairobi.

Kenya, 2002e. Study on Kenya's energy demand, supply and policy strategy for households, small scale industries and service establishments. Final report, September. p.16. Ministry of Energy, Government of Kenya, Nairobi.

Kenya, 2004. *Sessional Paper No. 4 of 2004 on Energy*. October. p.16. Ministry of Energy, Government of Kenya, Nairobi.

Kenya, 2006a. *Economic Survey 2006*. p.121; pp.162-167. Central Bureau of Statistics, Ministry of Planning and National Development, Government of Kenya, Nairobi.

Kenya, 2006b. *Key Highlights on Leading Ecopnomic Indicators*. December. pp.28-29. Central Bureau of Statistics, Ministry of Planning and National Development, Government of Kenya, Nairobi.

Kenya, 2006c. *Machakos District Resource Management Guidelines.* Eastern Province Horticulture and Traditional Food Crops Project, June. pp.40-48. Ministry of Agriculture, Government of Kenya, Nairobi.

Kenya, 2006d. *Statistical Abstract 2006*. p.101, p.307. Central Bureau of Statistics, Ministry of Planning and National Development, Government of Kenya, Nairobi.

Kigomo, J.N., Oyugi, J.O., Muturi, G.M., Cheruiyot, H.K., Esilaba, A.O. and Ogamba, J., 2006. *Promotion of Vanilla planifolia and Jatropha curcas in Turkwel Irrigation Scheme – Experiences of DMP-Kenya*. Nairobi: Kenya Forestry Research Institute.

Kituyi, E., 2006. Towards Sustainable Production and Consumption of Biofuels in Kenya: Some Issues to Consider. *Discussion paper*, Vol. 1 No.1. November, Environmental Chemistry Division, University of Nairobi, Nairobi.

Kituyi, E., 2007. National Biofuel Strategy (Draft). National Biofuel Committee, Ministry of Energy, Government of Kenya, Nairobi.

Kojima M., 2005. Potential for Biofuels for Transport in Developing Countries. UNDP/World Bank Energy Sector Management Assistance Program. Washington, DC: The World Bank Group.

Kureel, R.S., 2006. Prospects and Potential of *Jatropha curcas* for Biodiesel Production. . In: Singh, B., Swaminathan, R., Ponraj, V. (eds), 2006. *Boidiesel Conference Towards Energy Independence – Focus on Jatropha.* Papers presented at the Conference Rashtrapati Nilayam, Bolaram, Hyderabad on 9-10 June, 2006. pp.43-74. Available at: http://presidentofindia.nic.in/presentation/splang189PDF%20Format786.pdf. Accessed 9 February, 2007.

Machuhi, E., 2007. Pastoralists oppose Sh24bn sugar plan. *Daily Nation*, 30 Janurary, 2007. Nairobi: Nations Media Group Limited. p.25.

Maundu, P. and Tengnäs, B., 2005. *Useful tress and shrubs for Kenya*. Technical Handbook No. 35. International Centre for Research in Agroforestry (ICRAF), ICRAF-ECA, Nairobi. p.269.

Mbola, W.K., 2004. *Vanilla Jatropha Project*. Malindi: High Value Crops and Victoria Vanilla Project.

Mohan, M.P.R., Phillippe, G.T.T.,Shiju, M.V., 2006. Biofuel Laws in Asia: Instruments for Energy Access, Security, Environmental Protection and Rural Empowerment. *Asian Biotechnology and Development Review.* 8:2.51-75.

Muchiri, B. , 2007a. *Biodiesel production for poverty alleviation in coast province*. Feasibility Study for UNDP/SGP. Nairobi: Tree Crops Network Africa.

Muchiri, B. , 2007b. Cape chestnut: potential to alleviate poverty among forest adjacent communities. Nairobi: Bioenergy Ventures.

Prajapati, N.D. and Prajapati, T., 2005. *A hand book of Jatropha curcas Linn. (Physic nut).* Jodhpur: Asian Medical Plants & Health Care Trust.

Pruszko, R., 2006. Rendered fats and oils for biodiesel. *Oils and Fats International.* Volume 22, No. 5: 23-24, September 2006.

Rao, V.R., 2006. The *Jatropha* Hype: Promise and Performance. In: Singh, B., Swaminathan, R., Ponraj, V. (eds), 2006. Boidiesel Conference Towards Energy Independence – Focus on *Jatropha*. Papers presented at the Conference Rashtrapati Nilayam, Bolaram, Hyderabad on 9-10 June, 2006. pp.16-19. Available at: http://presidentofindia.nic.in/presentation/splang189PDF%20Format786.pdf. Accessed 9 February, 2007.

Santuah, N., 2006. India gives West Africa US$250m to develop biofuels. *Science and Development Network*. 23 November 2006.

Singh, L., Bargali, S.S. and Swamy, S.L., 2006. Production Practices and Post-Harvest Management in *Jatropha.* In: Singh, B., Swaminathan, R., Ponraj, V. (eds), 2006. Boidiesel Conference Towards Energy Independence – Focus on *Jatropha*. Papers presented at the Conference Rashtrapati Nilayam, Bolaram, Hyderabad on 9-10 June, 2006. pp.252-267.

Singh, B., Swaminathan, R., Ponraj, V. (eds), 2006. Boidiesel Conference Towards Energy Independence – Focus on *Jatropha*. Papers presented at the Conference Rashtrapati Nilayam, Bolaram, Hyderabad on 9-10 June, 2006. Available at: http://presidentofindia.nic.in/presentation/splang189PDF%20Format786.pdf. Accessed 9 February 2007.

South Africa, 2006. Draft biofuel industrial strategy of the Republic of South Africa. Department of Minerals and Energy, the Government of South Africa. Available at: http://www.dme.gov.za/pdfs/energy/renewable/Biofuels_Strategy_SA.pdf. Accessed 8 February 2007.

Tewari, D.N. 2007. *Jatropha & Bio-Diesel*. Delhi: Narula Printers.

Tigere, T.A., Gatsi, T.C., Mudita, I.I., Chikuvire, T.J., Thamangani, S., and Mavunganidze, Z., n.d.. Potential of *Jatropha curcas* in Improving Smallholder Farmers' Livelihoods in Zimbabwe: An Exploratory Study of Makosa Woard, Mutoko District. Available at: http://www.jsd-africa.com/Jsda/Fall2006/PDF/Arc_Potential%20of%20JC%20in%20Improving%20Smallholder%20Farmers's%20livlihoods%20in%20Zimbabwe.pdf. Accessed 12 February 2007.

UNFCCC, 2006. The Executive Board of the Clean Development Mechanism Twenty-sixth Meeting Report. 29 September. United Nations Framework on Climate Change Convention (UNFCCC). Available at: http://cdm.unfccc.int/EB/index.html. Accessed 20 January 2007.

UNFCCC, 2007. The Executive Board of the Clean Development Mechanism Thirtieth Meeting Report. 23 March. United Nations Framework on Climate Change Convention (UNFCCC). Available at: http://cdm.unfccc.int/EB/index.html. Accessed 19 April 2007.

van Eijck, J. and Romijn, H., 2006. Prospects for Jatropha Biofuels in Developing Countries: An analysis for Tanzania with Strategic Niche Management. An earlier version presented at the 4th Annual Globelics Conference "Innovation Systems for Competitiveness and Shared Prosperity in Developing Countries" in Thiruvananthapuram, India, 4-7 October 2006. Available at: http://fp.tm.tue.nl/ecis/Working%20Papers/Ecis%20wp151.pdf. Accessed 10 February 2007.

van Noordwijk, M., Khasanah Ni'matul and Lusiana, B., 2006. Preliminary exploration of agroforestry options with *Jatropha curcas L*: applications of the WaNuLCAS model. DRAFT ICRAF Southeast Asia Working Paper, October. International Centre for Research in Agroforestry (ICRAF). Bogor: ICRAF-S.E. Asia.

WORKING PAPERS IN THIS SERIES

1. Agroforestry in the drylands of eastern Africa: a call to action

2. Biodiversity conservation through agroforestry: managing tree species diversity within a network of community-based, nongovernmental, governmental and research organizations in western Kenya.

3. Invasion of *prosopis juliflora* and local livelihoods: Case study from the Lake Baringo area of Kenya

4. Leadership for change in farmers organizations: Training report: Ridar Hotel, Kampala, 29th March to 2nd April 2005.

5. Domestication des espèces agroforestières au Sahel : situation actuelle et perspectives

6. Relevé des données de biodiversité ligneuse: Manuel du projet biodiversité des parcs agroforestiers au Sahel

7. Improved land management in the Lake Victoria Basin: TransVic Project's draft report.

8. Livelihood capital, strategies and outcomes in the Taita hills of Kenya

9. Les espèces ligneuses et leurs usages: Les préférences des paysans dans le Cercle de Ségou, au Mali

10. La biodiversité des espèces ligneuses: Diversité arborée et unités de gestion du terroir dans le Cercle de Ségou, au Mali

11. Bird diversity and land use on the slopes of Mt. Kilimanjaro and the adjacent plains, Tanzania

12. Water, women and local social organization in the Western Kenya Highlands

13. Highlights of ongoing research of the World Agroforestry Centre in Indonesia

14. Prospects of adoption of tree-based systems in a rural landscape and its likely impacts on carbon stocks and farmers' welfare: The FALLOW Model Application in Muara Sungkai, Lampung, Sumatra, in a 'Clean Development Mechanism' context

15. Equipping integrated natural resource managers for healthy agroforestry landscapes.

16. Are they competing or compensating on farm? Status of indigenous and exotic tree species in a wide range of agro-ecological zones of Eastern and Central Kenya, surrounding Mt. Kenya.

17. Agro-biodiversity and CGIAR tree and forest science: approaches and examples from Sumatra.

18. Improving land management in eastern and southern Africa: A review of polices.

19. Farm and household economic study of Kecamatan Nanggung, Kabupaten Bogor, Indonesia: A socio-economic base line study of agroforestry innovations and livelihood enhancement.

20. Lessons from eastern Africa's unsustainable charcoal business.

21. Evolution of RELMA's approaches to land management: Lessons from two decades of research and development in eastern and southern Africa

22. Participatory watershed management: Lessons from RELMA's work with farmers in eastern Africa.

23. Strengthening farmers' organizations: The experience of RELMA and ULAMP.

24. Promoting rainwater harvesting in eastern and southern Africa.

25. The role of livestock in integrated land management.

26. Status of carbon sequestration projects in Africa: Potential benefits and challenges to scaling up.

27. Social and Environmental Trade-Offs in Tree Species Selection: A Methodology for Identifying Niche Incompatibilities in Agroforestry *[Appears as AHI Working Paper no. 9]*

28. Managing tradeoffs in agroforestry: From conflict to collaboration in natural resource management. *[Appears as AHI Working Paper no. 10]*

29. Essai d'analyse de la prise en compte des systemes agroforestiers pa les legislations forestieres au Sahel: Cas du Burkina Faso, du Mali, du Niger et du Senegal.

30. Etat de la recherche agroforestière au Rwanda etude bibliographique, période 1987-2003

31. Science and technological innovations for improving soil fertility and management in Africa: A report for NEPAD's Science and Technology Forum.

32. Compensation and rewards for environmental services.

33. Latin American regional workshop report compensation.

34 Asia regional workshop on compensation ecosystem services.

35 Report of African regional workshop on compensation ecosystem services.

36 Exploring the inter-linkages among and between compensation and rewards for ecosystem services CRES and human well-being

37 Criteria and indicators for environmental service compensation and reward mechanisms: realistic, voluntary, conditional and pro-poor

38 The conditions for effective mechanisms of compensation and rewards for environmental services.

39 Organization and governance for fostering Pro-Poor Compensation for Environmental Services.

40 How important are different types of compensation and reward mechanisms shaping poverty and ecosystem services across Africa, Asia & Latin America over the Next two decades?

41. Risk mitigation in contract farming: The case of poultry, cotton, woodfuel and cereals in East Africa.

42. The RELMA savings and credit experiences: Sowing the seed of sustainability

43. Yatich J., Policy and institutional context for NRM in Kenya: Challenges and opportunities for Landcare.

44. Nina-Nina Adoung Nasional di So! Field test of rapid land tenure assessment (RATA) in the Batang Toru Watershed, North Sumatra.

45. Is Hutan Tanaman Rakyat a new paradigm in community based tree planting in Indonesia?

46. Socio-Economic aspects of brackish water aquaculture (Tambak) production in Nanggroe Aceh Darrusalam.

47. Farmer livelihoods in the humid forest and moist savannah zones of Cameroon.

48. Domestication, genre et vulnérabilité : Participation des femmes, des Jeunes et des catégories les plus pauvres à la domestication des arbres agroforestiers au Cameroun.

49. Land tenure and management in the districts around Mt Elgon: An assessment presented to the Mt Elgon ecosystem conservation programme.

50. The production and marketing of leaf meal from fodder shrubs in Tanga, Tanzania: A pro-poor enterprise for improving livestock productivity.

51. Buyers Perspective on Environmental Services (ES) and Commoditization as an approach to liberate ES markets in the Philippines.

52. Towards community-driven conservation in southwest China: Reconciling state and local perceptions.

53. Biofuels in China: An Analysis of the Opportunities and Challenges of Jatropha curcas in Southwest China.

54. Jatropha curcas biodiesel production in Kenya: Economics and potential value chain development for smallholder farmers

Who we are

The World Agroforestry Centre is the international leader in the science and practice of integrating 'working trees' on small farms and in rural landscapes. We have invigorated the ancient practice of growing trees on farms, using innovative science for development to transform lives and landscapes.

Our vision

Our Vision is an 'Agroforestry Transformation' in the developing world resulting in a massive increase in the use of working trees on working landscapes by smallholder rural households that helps ensure security in food, nutrition, income, health, shelter and energy and a regenerated environment.

Our mission

Our mission is to advance the science and practice of agroforestry to help realize an 'Agroforestry Transformation' throughout the developing world.

United Nations Avenue, Gigiri - PO Box 30677 - 00100 Nairobi, Kenya
Tel: +254 20 7224000 or via USA +1 650 833 6645
Fax: +254 20 7224001 or via USA +1 650 833 6646
www.worldagroforestry.org