Retrospective: bottlenecks to *Jatropha curcas* bioenergy value-chain development in Africa – a Kenyan case

Miyuki Iiyama[1*], Steven Franzel[1], Navin Sharma[2], Violet Mogaka[1], Jeremias Mowo[1], Ramni Jamnadass[1]

[1]World Agroforestry Centre (ICRAF), United Nations Avenue, Gigiri, Nairobi, Kenya.
[2]ICRAF, Dev Prakash ShastriMargPusa, New Delhi, India.
*corresponding author: m.iiyama@cgiar.org

Introduction

Jatropha curcas (*Jatropha*), a shrubby tree native to Central America, thrives in many parts of the tropics and sub-tropics in sub-Saharan Africa (SSA) and Asia. Though an essentially undomesticated shrub, *Jatropha* suddenly emerged as a promising biodiesel feedstock during the period 2003-2009, when rising petrol prices fuelled global interests in bioenergy crops. *Jatropha* was claimed to produce high-quality oil, and had a wide adaptability to diverse climatic zones and soil types, minimum input requirements, short gestation period, easy multiplication, drought tolerance, pest and disease resistance and an ability to grow under marginal conditions without competition for resources for food production. It was considered a 'silver bullet' to solve energy insecurity in low-income countries and to support economic development. Similarly, investors from developed nations were eager to grow it in large commercial plantations in SSA and elsewhere for export.

However, many claims made regarding *Jatropha* have proven highly exaggerated (GTZ, 2009). After some years of plantation, the *Jatropha* boom halted. By 2009, many media reports revealed disillusioning episodes across the developing world. Academics also began to question its commercial viability as a bioenergy feedstock, with low yields (if no inputs) being a significant concern (GTZ, 2009; Ariza-Montobbio and Lele, 2010; Iiyama *et al.*, 2013; NL Agency, 2013). In SSA, the *Jatropha* hype left many affected smallholder farmers confused and disillusioned. Yet few assessments (NL Agency, 2013) have critically examined the crop's rather disorganised promotion and analysed failures on the ground from the value chain (VC) perspective.

Considering a Kenyan case, we examine the following hypothesis: the recent *Jatropha* boom failed to deliver the claimed benefits for energy security and economic development, because (i) the bioenergy VC remained under-developed in SSA, and/or (ii) lacked the enabling environment present in other bioenergy VCs, e.g. India.

The Jatropha VC in Kenya

Oilseed bioenergy VC

A VC describes all activities required to bring a product or service from conception, through production, to consumption, and final disposal after use (Kaplinsky and Morris, 2002). Oilseed bioenergy production essentially involves a three-stage VC: (i) procurement of inputs and cultivation of plants to produce oil-bearing fruits; (ii) extraction and processing of oil; and, (iii) marketing of end products (Messemaker, 2008). Stage one (i) involves preparation of ecologically suitable land, the procurement or collection of high-quality planting material, crop establishment by direct seeding or by the planting of cuttings or nursery seedlings, the application of fertiliser, irrigation and pest and disease control, weeding, pruning and harvesting. Farmers require knowledge on appropriate farm management practices to carry out these activities adequately. In stage two (ii), straight vegetable oil (SVO) contained in the seeds is expelled or extracted either mechanically or chemically. SVO can be used directly as fuel or processed through a trans-esterification process (which reduces viscosity and increases combustion quality) into biodiesel. SVO can also be used in soap manufacturing. Seedcake residues after extraction can be used directly as a fertiliser or for the formation of fuel briquettes, or in biogas production. Processors also need adequate technical knowledge and equipment for producing high-quality oil. In stage three (iii), SVO may be consumed locally as fuel for modified stoves and lamps or marketed for use in modified diesel engines, while biodiesel may be sold for direct use in regular, unmodified diesel engines, either pure or blended with regular diesel. Government policy should favour use of SVO and biodiesel to support the needed investments for production and processing and to encourage local use.

The need for closely coordinated steps to develop a well-functioning VC poses significant challenges in infrastructure development (Messemaker, 2008; van Eijck and Romijn, 2008) as can be seen from the Kenyan *Jatropha* case.

Promotion of Jatropha – emphasis on production

While *Jatropha* is not an indigenous crop in many parts of Kenya, farmers have been growing it for many decades for fences, windbreaks, medicines and support for vanilla vines. Only in 2006-2009 did *Jatropha* become widely known as a potential bioenergy feedstock, and unlike Tanzania, where large European companies drove bioenergy projects involving various stakeholders from rural communities and ministry officials (Van Teeffelen, 2013), in Kenya, such investors initially played a minor role. Only after 2009 did some foreign companies try to get access to land for large-scale *Jatropha* plantations in the coastal province, but largely unsuccessfully. In Kenya, initial enthusiasm was driven by promoters, such as non-governmental organisations (NGOs) and adopters, mainly individual farmers and groups (GTZ, 2009; Figure 1). Several NGOs promoted *Jatropha* primarily as a new source of income generation for the rural poor, and for mitigating climate change impacts through substituting fossil fuel and unsustainable woodfuel use (Mogaka, 2010; Mogaka *et al*., in press). Promoters sought to convince as many farmers as possible to adopt *Jatropha*. Some promoters redistributed seeds from wild/semi-wild plants and/or raised seedlings, selling those as certified material to farmers, promising them high investment returns (GTZ, 2009). Some sold *Jatropha* planting materials to farmers for US$12.5-25/kg of seeds, exceeding the price of planting materials for tree species whose

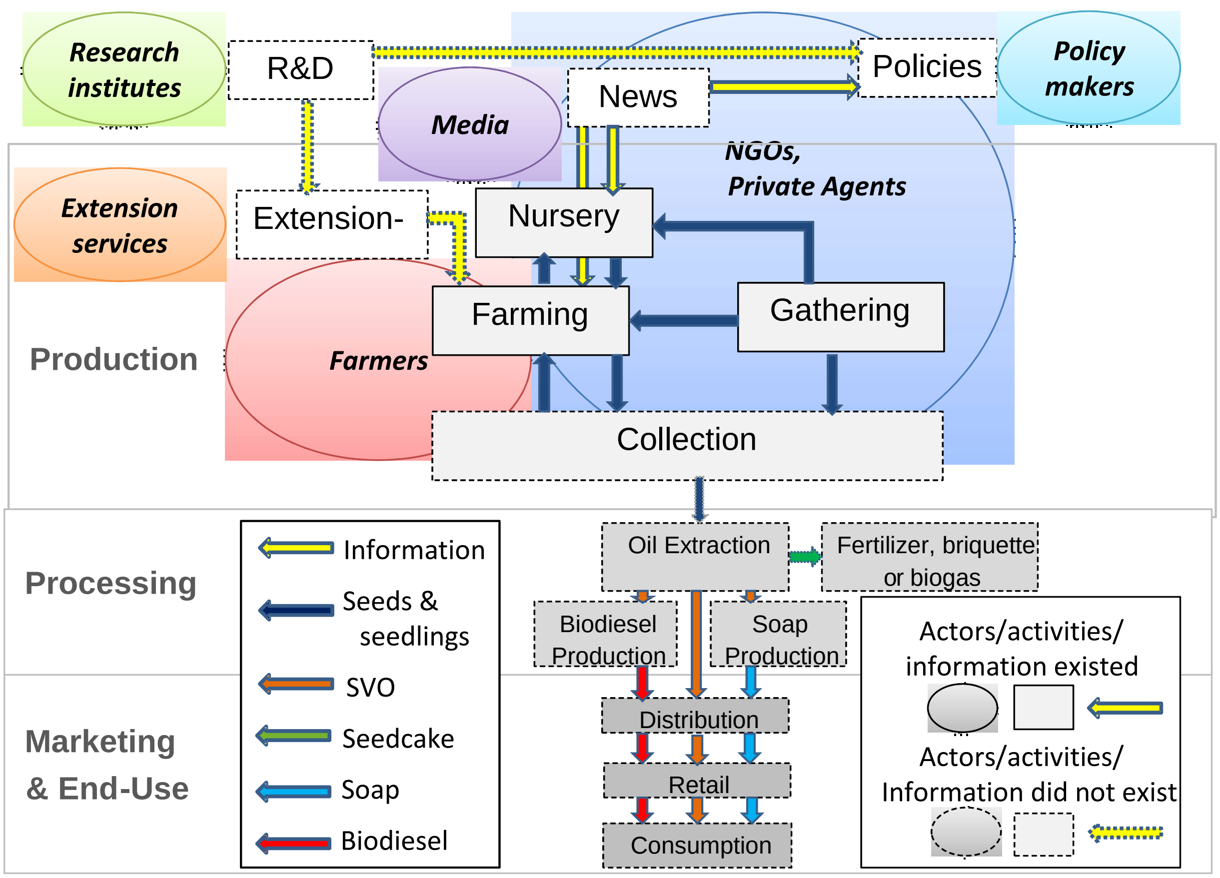
Box 1: **Farmers' reactions to the Jatropha hype**

In early 2009, a group of farmers from Mumias in the Western Province of Kenya, a major sugarcane-producing zone and agriculturally fertile area, was interested in obtaining *Jatropha* planting materials. Via their community members in Nairobi, who had heard about it on the radio, these farmers learnt that *Jatropha* was a miracle crop. They had suffered from low sugarcane prices, low salaries, and high taxes and were desperately looking for alternative high-value cash crops which would transform their livelihoods. They were convinced that *Jatropha* would be a good investment opportunity. Yet, they were advised not to replace sugarcane with *Jatropha* but rather do small experiments because they lacked agronomic knowledge about the plant and there was no predictable market for its products.

products already had established markets and were more lucrative. Farmers were encouraged by the promise of additional income and locally produced affordable fuel (Box 1).

In Kenya, the emphasis was on production and there was a clear disconnection from the processing and marketing stages. The only existing market was an unstable one for seeds and other propagation materials, and a limited market for the purchasing back of seeds from contracted farmers. Oil extraction only took place for demonstration purposes (Mogaka, 2010). There was no market for end-products of *Jatropha*, e.g., SVO, soap, biogas, fertiliser and briquettes, unlike in neighbouring countries such as Tanzania where markets for SVO and soaps existed (Messemaker, 2008; Struijs, 2008). The main challenge was the lack of infrastructure and manpower. Although the technology to produce biodiesel in Kenya was known e.g., through the Kenya Industrial Research and Development Institute (KIRDI), local equipment producers were lacking; hence processing equipment had to be imported.

Figure 1: The actors, activities and flows of the information in the *Jatropha* VC in Kenya



R&D status and capacity

High and stable yields are essential for the economic feasibility of any plantation. The yield of tree crops is a function of genetic material, climatic and soil conditions, age, management and competition for resources, but their relative importance is largely unknown (Jongschaap *et al.*, 2007; Achten *et al.*, 2008).

Irrigation, fertilisation, intercropping, pruning and spacing significantly affect *Jatropha* growth and biomass production under controlled conditions (Kheira and Atta 2009; Maes *et al.*, 2009; Achten *et al.*, 2010; Behera *et al.*, 2010).The depth of planting holes and spacing are key to drought tolerance (Githunguri *et al.*, 2012). However, smallholder farmers cannot always afford to optimise portfolios of technology to maximise yields (Iiyama *et al.*, 2013).

In Kenya, when the *Jatropha* hype started, there were limits to the response of government, universities, and national and international agricultural research institutions in filling the knowledge gap regarding *Jatropha* production, processing and marketing, although the University of Nairobi was conducting breeding trials. The extension service was unable to provide adequate support to guide farmers. Moreover, many of the early promoters had not conducted multi-year research trials under local conditions to verify their claims for *Jatropha.* Many relied on information available from the Internet instead. Consequently, farmers had to apply sub-optimal management practices (GTZ, 2009), which may have significantly affected yield potentials, and they had few buyers for the small quantities of seeds that were produced. As farmers got near-nil yields of *Jatropha* seeds in the first 2-3 years and estimates were very low for 4-6 years (<1.0 kg/tree), many abandoned the crop (GTZ, 2009).
A survey conducted in different agro-ecological zones of Kenya in 2009 indicates that proper management during the establishment phase could be critical for survival and might have cumulative effects on potential yields of *Jatropha* under smallholder conditions (Iiyama *et al*., 2013). High yields were not achieved partly because growers were still using unimproved germplasm, management practices were sub-optimal, and the biophysical boundaries of high *Jatropha* yield were poorly defined (Iiyama *et al.*, 2013).

Complexity and maturity of the *Jatropha*/oilseed bioenergy VC in Kenya

Comparison of oilseed bioenergy VCs with other agricultural commodity VCs

Most Kenyan farmers primarily grow food and cash crops, mainly maize, but also horticulture crops in favourable agro-ecological regions. Drought-tolerant pulses and grains such as green gram and pigeon peas are grown in drier regions. Oilseed bioenergy VCs may be more complicated than VCs of other agricultural commodities and agroforestry products, as they cannot be high value despite intensive management requirements: they also cannot directly serve immediate food security needs. Processing is seen as more technically complex and needs higher economies of scale than other commercial crops that only need post-harvest attention (Figure 2).

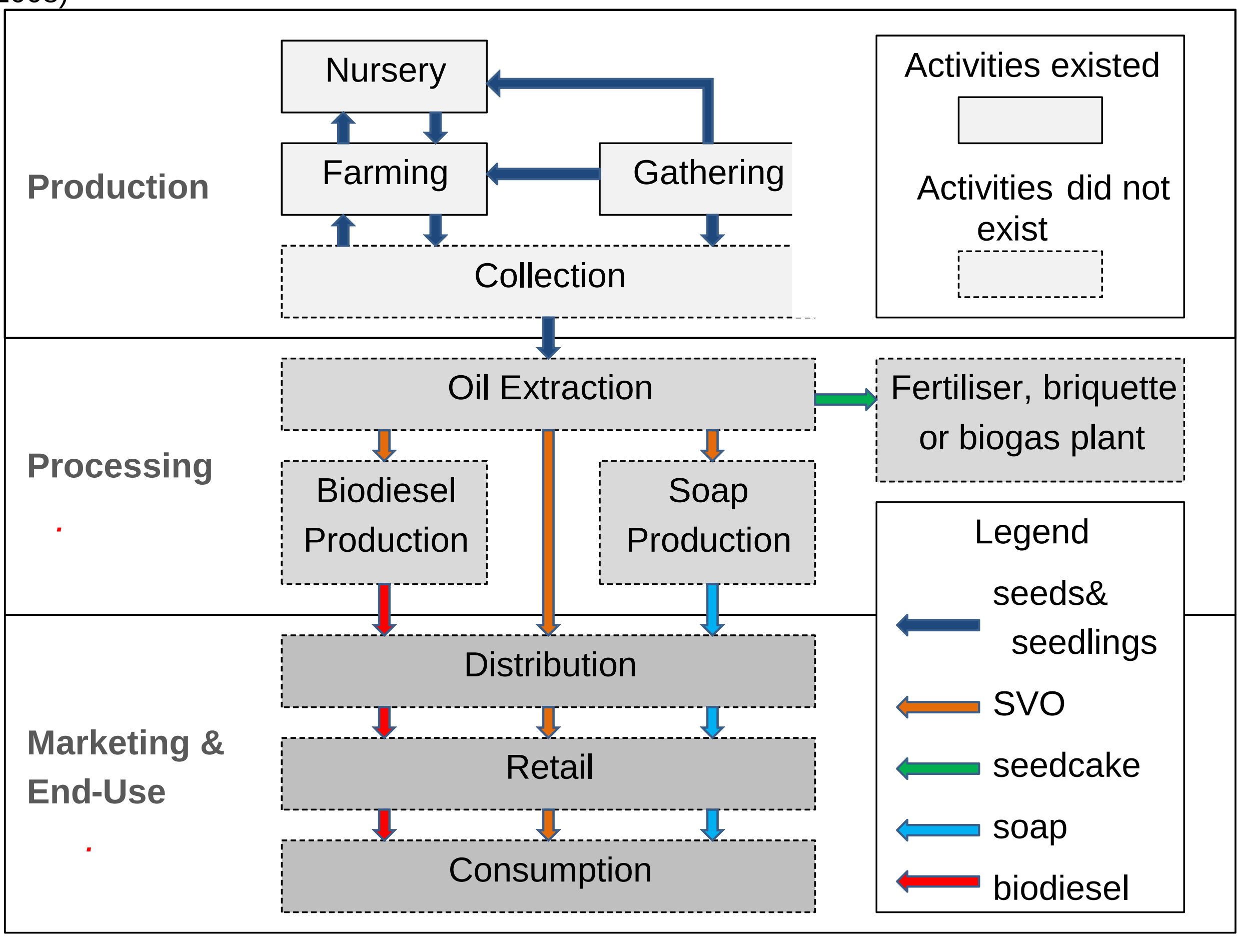
Firstly, *Jatropha* as a bioenergy feedstock is a low-value crop when compared to traditional cash crops. In Kenya, inflated prices for planting materials confused many farmers about its value. If *Jatropha* oil is to substitute for diesel it needs to be priced competitively (NL Agency, 2013; Box 2). Secondly, *Jatropha* is a non-food crop with high risks and low returns, requiring intensive management like other high-value crops (GTZ, 2009). Growing *Jatropha* could require replacing land for primary crops and/or reallocating limited family labour. Current *Jatropha* yields would not

Box 2: **Hypothetical pricing**

In a scenario of diesel priced at US$1/litre, a maximum price for *Jatropha* seed of 33 cents per kg is required assuming 30% oil content and not accounting for other costs in production. This is a tiny fraction of the amount of $12.5-25/kg that farmers paid for planting material. Under scenarios of yields per tree of 0.25 kg to 1 kg per year, a 0.25 ha *Jatropha* plantation at 2 × 2 m spacing (625 trees) will yield only $50-200 net revenues. Considering the rather significant cost requirements, especially in the initial years before *Jatropha* yield enough seeds, growing this crop is highly unlikely to be economically viable for smallholders.

realise positive returns, especially considering the opportunity costs of land and labour. Thirdly, efficient bioenergy processing requires purpose-built equipment because the oil is highly viscous. Presses for oil extraction are generally not locally available and most farmers are unfamiliar with *Jatropha* in liquid oil form. In our survey, farmers did not have functioning stoves for cooking with *Jatropha* oil and very few had appropriately designed lamps (GTZ, 2009). Efficient processing also requires sufficient seed quantity to achieve economies of scale; most growers in Kenya are geographically dispersed and thus are challenged to produce in sufficiently large enough quantities (GTZ, 2009). Without general access to appropriate technology for local use, and with no evident market available, many Kenyan *Jatropha* farmers abandoned the trees.

Figure 2: The *Jatropha* VC and status of activities in Kenya, with reference to Messemaker (2008)



Comparison of the R&D and policy environments surrounding Kenyan Jatropha VC with those for the bioenergy VC in India

The Kenyan government became interested in substituting *Jatropha* oil for fossil fuels, especially in dryland regions, to create income opportunities while reclaiming marginal lands (GoK, 2008). The Ministry of Energy, in particular, facilitated knowledge-sharing among key stakeholders, including promoters, farmers, and national/ international research institutes, to develop a supportive policy environment. In 2008, a few leading Kenyan NGOs tried to set up a National Biodiesel Committee with participants from private, public sectors and NGOs, and produced a draft biodiesel strategy in 2009 to provide guidelines on production that complied with existing policies. The plans and strategy, however, never materialised and interest faded after the collapse of the boom.

In contrast, bioenergy in India was considered an important component of energy security, and universities and national agricultural institutes studied non-edible-oil-bearing species for bioenergy well before the recent boom. Policy promoted bioenergy from non-food crops grown from marginal land (GOI, 2009), despite concerns about competition with food crops. A minimum support price for farmers was key to attracting them to grow these crops. However, although India has 400 non-edible-oil-bearing tree species, *Jatropha* alone was pushed for large-scale farming operations as the most suitable, high-yielding tree species in marginal lands. The promotion of plantations proceeded without proper domestication and use of superior planting materials, before researchers were confident of its yield potentials on marginal land or under farmers' field conditions. *Jatropha* subsequently failed to deliver against optimistic projections and its economics remain unattractive, given low yields (Shinoj *et al.*, 2010; Box 3).

> Box 3: **India: *Jatropha* boom and bust**
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> In India, around 17.4M ha was identified as suitable marginal land to grow *Jatropha* to meet 20% blending target, and by 2011, nearly 900,000 hectares were under cultivation (Gunatilake, 2011). However, *Jatropha*'s economics remains unattractive for farmers due to its low yields (Shinoj *et al.*, 2010) – ₹ 7,560-15,125 per hectare.

Meanwhile, Karnataka State is preeminent in using oil-bearing tree species for local energy provisions and for improving livelihoods of smallholder farmers. An innovative agroforestry model of growing multiple tree species (including *Pongamia, Neem, Mahua, Simarouba, Callophyllum* and *Innopylum*) on farm fences has proved successful. The development of VCs has been crucial, starting from nurseries for planting material to co-products generation and many options of local energy, e.g., biogas and SVOs for transport (http://www.biofuelkarnataka.com/; http://biofuelpark.org/).

Conclusion

There is a need for adequate research and development (R&D) to support all stages of VC development from production to processing to markets and this was inadequate in the Kenya case. The policy instruments to support the local market development for alternative fuels e.g. biodiesel, including the R&D and extension and business development services, must be established to encourage investment and sustain industry development. Success in VC development in one industry or even one country cannot be transported to another environment without adequate investments in R&D.

Acknowledgements

The oilseed baseline survey and analyses in Kenya in 2009 was funded by GTZ, while the Japanese Government contributed to the lead authors' engagement in the follow-up analysis. We appreciate the valuable inputs of World Agroforestry Centre colleagues and Kenyan bioenergy stakeholders.

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