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Cultivating clean energy in Mali: policy analysis and livelihood impacts of *Jatropha curcas*

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Cultivating clean energy in Mali: policy analysis and livelihood impacts of *Jatropha curcas*

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Contents

Abstract

Fossil fuel depletion, energy security and climate change concerns have precipitated recent investment in biofuels. However, empirical case study data on the benefits and drawbacks of biofuels is lacking. This paper presents new integrated mixed-method multi-level assessments of the potential for inedible biodiesel crop *Jatropha curcas* to diversify livelihood strategies and enhance energy access in rural Mali. A combination of questionnaires, interviews and participatory methods were utilised in data collection. Semi-structured interviews were undertaken with a range of stakeholders including government departments. Data show that households involved with NGO or private sector activities linked to *Jatropha curcas* cultivation gained financial capital and reduced household expenditure due to income from the sale of *Jatropha curcas* seeds and soap made from *Jatropha curcas* oil. Grown as a living fence, *Jatropha curcas* demarcates agricultural property, reducing land tenure conflicts and soil erosion. Projects focusing on *Jatropha curcas* use for rural electrification offer potential to improve fuel and energy access. However, current supplies of biodiesel remain insufficient for these benefits to materialise and gaps between policy targets and actual yields were identified. Ambitious land cover targets set within policy in relation to production could risk land use shifts away from food production and toward biofuels.

Keywords: *Jatropha curcas*, Mali, biofuel, energy security, sustainable livelihoods, policy implementation, participatory methods.

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1 Introduction

In recent years there has been growing interest in the use of more accessible alternative energy sources as a consequence of continuing increases in global oil prices, the scarcity of known petroleum reserves (Sorrell *et al.*, 2010) – most of them located in regions that are politically unstable (Charles *et al.*, 2007) – and the climate change arising from the intensive burning of fossil fuels (IPCC, 2007). Such interest has been further heightened by recent natural disasters such as the 2010 BP oil-spill in the Gulf of Mexico and Japan's 2011 nuclear crisis. As a development concern, the international community has widely recognized the importance of improving energy access for the rural poor in order to combat developing countries' major environmental threats (such as deforestation) and to accelerate achievement of the Millennium Development Goals (MDGs) (OECD/IEA, 2010).

The opportunities and impacts of biofuels as a viable option for enhancing access to energy, substituting imported oil, reducing CO_2 emissions and promoting sustainable development have attracted growing attention of policy (UNDESA, 2007), industry (Lengkeek, 2009), NGOs (Palliere *et al.*, 2009) and the academic research community (Raswant *et al.*, 2008). Great hopes have been pinned on the oil-bearing, "drought resistant" non-edible tree *Jatropha curcas* (hereinafter termed *Jatropha*) to help alleviate energy demands (Gilbert, 2011), restore degraded ecosystem services in drylands (Garg *et al.*, 2011), combat climate change (Ogunwole *et al.*, 2008) and generate income in rural areas of developing countries (Achten *et al.*, 2010). However, the *Jatropha* sector is still young and empirical analyses on the claims and potential impacts of this plant is largely lacking.

In this paper, we provide new case study mixed-method, multi-level analytical assessments of the potential of *Jatropha* to diversify livelihood strategies and enhance energy access in rural Mali, where roughly 99% of the population lacks modern energy services (COMPETE, 2009). Mali is one of the pioneers among dryland Sub-Saharan countries in the promotion of *Jatropha* cultivation aimed at fuel production, due largely to the initiatives supported across the country over the last decade by a variety of actors (*i.e.* development agencies, government, private sector and NGOs). Analysis of national policies and stakeholders in the *Jatropha* sector are

presented, together with detailed livelihoods assessments at community and household levels. Despite *Jatropha's* potential to deliver a variety of livelihood benefits, the gap between policy targets and actual cultivation remains.

2 Research design, field site and methodology

To analyze the complexity within which the Malian *Jatropha* sector operates, this research draws descriptive and explanatory dimensions from the conceptual frameworks of policy implementation (Knill *et al.*, 2007) and sustainable livelihoods literature (Chambers *et al.*, 1992; Scoones, 1998). The research design is divided into four stages. Stage one involved a review of the relevant literature on biofuels development with particular focus on *Jatropha*. The second stage involved an exploratory scoping study – carried out between March and May 2010 – which aimed to identify the main actors and issues of the Malian *Jatropha* sector as well as research gaps in literature. Stage three involved analysis of biofuels and energy policies at national and regional levels with particular focus on the role of institutions and policy implementation gaps. The fourth stage involved a detailed livelihoods assessment at household and community levels in rural regions of Mali, with particular focus on *Jatropha* and its role in livelihood diversification.

Case studies were selected based on data gathered during the scoping study in which expert and stakeholder interviews were undertaken together with exploratory household questionnaires. Three farming communities in the most environmentally stressed regions of Mali (Wong *et al.*, 2005) were selected, in which agro-ecological conditions are suitable for *Jatropha* cultivation (Diarra, 2010, FACT Foundation, 2009), population densities and poverty are high (Wong *et al.*, 2005) and where three of the four main *Jatropha* pilot activities – including one of the most relevant examples of *Jatropha* rural electrification projects discussed in the international arena (Gilbert, 2011; Practical Action Consulting, 2009) – are taking place.

Stakeholder, biofuel and energy policy analyses and identification of policy gaps were achieved through discourse analysis (Hewitt, 2009) and policy analysis (Shankland, 2000), semi structured interviews (n=36) (Hay, 2005) with government officials and relevant experts (identified in the scoping study in stage 2 of the research) and by using conceptual frameworks of policy outcome and impact

analysis (Knill et al. 2007). The use of these methods allowed assessment of: a) the energy policy targets in relation to on-the-ground *Jatropha* cultivation and its use to improve rural energy security and foster rural development in the country: and b) which stakeholders are involved in *Jatropha* cultivation in Mali.

At household and community levels, in-depth livelihood analysis was carried out with the aim of addressing the following research questions: (i) What are the kinds of livelihood goals that people aspire to achieve through cultivation of *Jatropha* and what is the relative emphasis that they place on different livelihood outcomes? (ii) To what extent do people actually achieve their livelihood goals, and what is preventing people from fully achieving them? Village level focus groups (n=31) and household questionnaires (n=120) identified key livelihood components.

Sampling was purposive and non-random (Wilmot, 2005) according to criteria including degree of project involvement (farmers potentially performing well), same maturity of plantations (three years old), income level, age and geographical distribution. Detailed livelihoods assessments used the Sustainable Livelihoods Framework (SLF) (DFID, 1999) to guide implementation of participatory methods, including in-depth semi-structured interviews (n=10/project area, total n=30), transect walks (n=30), wealth ranking and seasonal calendars (n=30) with farmers identified through the focus groups and preliminary questionnaires. Combining methods allowed triangulation of data. The SLF allowed analysis of the interaction of livelihood assets and household members, the factors affecting vulnerability of the household and the influence of different institutions and processes in relation to *Jatropha*.

3 Fuelling Malian politics with *Jatropha*: national energy policy and stakeholders

As part of the integrated multi-level analytical assessment, this section provides an overview of the main policy drivers and key players that are fostering the production and use of *Jatropha* within Mali, as identified through stakeholder and policy analysis.

Use of *Jatropha* oil has been fostered by several policy measures aimed at sustaining both rural and national energy development. The 2008 National Biofuels Strategy sets ambitious targets including the substitution of 20% of fossil fuel consumption with *Jatropha* biofuel by 2023, involving a production of 84,000,000 litres of refined oil and a total cultivated surface area of 50,000-70,000 hectares (MEME, 2008). Interviews with government officials revealed that the National Agency for Biofuels Development (ANADEB), created in 2009, will approve by early 2012 the elaboration of a $40 million national plan – funded by the World Bank (WB, 2010) – for the development of alternative energies. Roughly 30% of this funding will be invested in *Jatropha* biofuel development. Additionally, the Investment Promotion Agency of Mali (API-MALI) – a public agency under the supervisory authority of the Ministry of Industry, Investments and Trade – is elaborating a National Strategy of Foreign Investments Attraction, also due by early 2012. The specific role of biofuels has not yet been defined, but an interview with an API official acknowledged that *Jatropha* is likely to play a major role in energy development, as it is considered to be crosscutting in the development of other industrial sectors.

Driven by these measures, initial project activities have been undertaken in production, extraction, transformation, and utilization of *Jatropha* by different organisations with varying approaches and motivations including fossil fuel substitution, carbon credits commercialization and rural electrification. In 2009, *Jatropha* cultivated in Mali – excluding minor ongoing initiatives and the area covered by living fences – accounted for almost 4,576 hectares, involving the participation of approximately 5,500 smallholder farmers supported by four main initiatives (Figure 1).

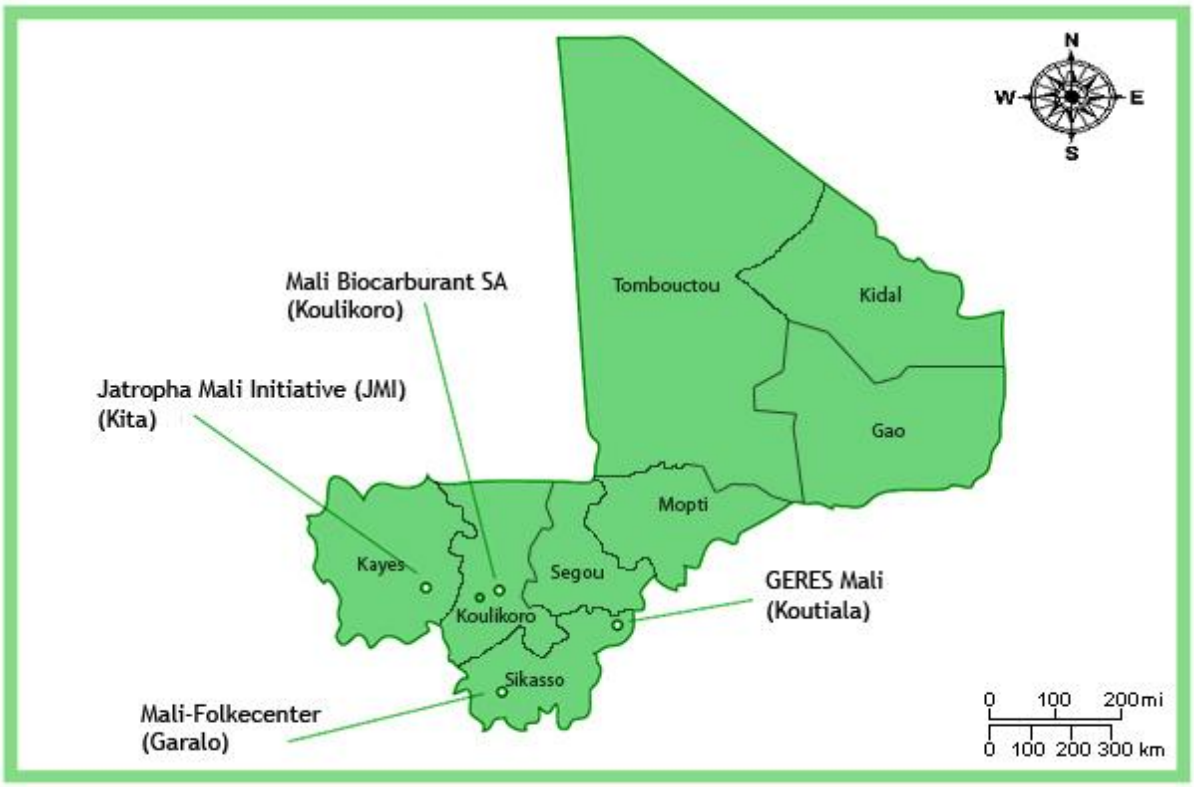

Figure 1: Location of the main *Jatropha* development projects in Mali

Source: Map created by the author

In line with observations at community and household levels validated through semi-structured interviews at regional level with the management and staff of each initiative, Table 1 outlines the main characteristics and key challenges of the major Malian *Jatropha* activities.

Table 1: Major *Jatropha* activities in Mali: characteristics and challenges

Initiative	Description	Main outcomes and challenges
The Jatropha Mali Initiative (JMI)	JMI is a French-Malian joint venture with the objective of producing pure *Jatropha* oil - promoting out-grower schemes - for local and national markets alongside the commercialization of seedcake, the pressing residue that can be used as organic fertilizer (JMI, 2008).	JMI trains the farmers to produce improved white soap from the commercialized *Jatropha* oil as well as black soap from the humid part of the pressing residue. Also, JMI sells the leftover seedcake at a preferential price - linked to the quantity of seeds that each farmer is able to harvest and sell - to its farmers, providing them a much cheaper source of organic fertiliser for their agricultural land. Challenges: limited oil extraction and production due to small yields is a relevant constraint to the increase of both fertilizers and village level soap production as well as to the commercialization of *Jatropha* biofuel.
GERES	GERES is a French non-profit NGO that promotes rural electrification. Its main goal is to facilitate establishment of a local *Jatropha*-based biofuel supply chain and produce the technical and organizational knowledge required for future replication (GERES, 2008).	GERES is providing decentralized oil extraction units – managed and owned by the villagers or local operators – which will substitute fossil fuel consumption and cover the energy needs of local power units and existing local energy services such as grinding engines. Challenges: due to limited feedstock availability and relatively young development, the extraction units are not yet fully operative or installed, and remain in a "learning-by-doing" phase.
Mali-Folkecenter Nyetaa (MFC)	MFC is a Malian NGO that targets the promotion of out-growers schemes for improvement of rural electrification through power generators that can run with pure *Jatropha* oil (MFC, 2006).	Farmers from MFC manage the centralized oil press installed by the project and the sales of the leftover seedcake. Since 2007, MFC has been providing rural electricity for 8 hours per day to the village of Garalo through a controlled power company called ACCESS. Challenges: despite rural energy provision perspectives look promising, relatively small quantities of seeds have been commercialized and transformed into oil. The MFC power generator, expected to be run on pure *Jatropha* oil in the future, is actually entirely fuelled by regular diesel and *Jatropha* biofuel has been mainly used only for testing and demonstration.
Mali Biocarburant SA (MBSA)	MBSA is a private Dutch company which aims to produce refined biodiesel for the domestic and international market sourcing its stock from smallholder-growers (MBSA, 2008).	The farmers, organized in cooperatives and represented by the Farmer's Union, own 20% of the shares of the company. Similarly to MFC, MBSA farmers manage the centralized oil press installed by the project, as well as the sales of the leftover seedcake and a soap production unit that uses glycerine, a *Jatropha* by-product. MBSA is testing the use of oil and biogas from *Jatropha* for fuelling Multifunctional Platforms (machines that provide rural energy). Challenges: limited feedstock availability. The feedstock used to fulfil the needs of the 2,000 litre/day MBSA biodiesel plant – which currently works at its full capacity – comes only in small part from *Jatropha* (detailed % are not available) while other vegetable feedstock (both produced locally and imported) is used.

Sources: (i) Descriptions: projects websites, (ii) Outcomes and challenges: semi-structured interviews and field observations.

The following sections integrate the descriptive and explanatory dimensions from the policy and stakeholder analysis at national and regional levels with the village-level perspectives.

4 Village-level perspectives: farmers' expectations, priorities and main difficulties

As identified through in-depth interviews at household level, farmers' uptake reasons and priorities (Table 2) as well as main difficulties with relation to *Jatropha* cultivation (Table 3) are presented. *Jatropha* is mainly grown for demarcating property (n=25), generating revenues (n=22) and producing soap (n=21). It is also seen as a potential substitute for cotton farming, which over the last decade has been experiencing a significant reduction of acreage and production due to institutional constraints, including low credit recovery rates and delayed payments to farmers (Theriault, 2011).

Table 2: *Jatropha* farmers uptake reasons as outlined in household-level interviews (n = 30)

Uptake reasons	No. of farmers	Illustrative quotations
Demarcating food crops property - avoiding land tenure conflicts - and excluding livestock	25	"Since 40 years ... (*Jatropha*) delimitates (cereal) crops in order to avoid conflicts among the farmers in the village" (male farmer, Karaya-Toumouba, May 2011)
Generating revenues	22	"In the future, when the price increases, revenues from *Jatropha* will pay food for my family" (male farmer, Garalo, April 2011)
Producing soap	21	"*Jatropha* soap plays a big role in reducing my family expenses" (female farmer, Karaya-Toumouba, May 2011)
Extracting fuel for fuelling local grinding machines and reducing grinding prices	18	"Even if my (*Jatropha*) field would produce only 1 litre of fuel, this would be worth it, it is for our future" (male farmer, Garalo, April 2011)
Substituting cotton farming (*Jatropha* is easier to grow, requires less labour and fertilizers and provides a more immediate source of liquidity compared to cotton)	12	"*Jatropha* is worth it 1,000 times much better than cotton... When the *Jatropha* price increases, I will quit cotton" (male farmer, Garalo, April 2011)
Producing fertilizer	11	"(*Jatropha* fertilizer) works better than the chemical fertilizer" (male farmer, Fakoumala, May 2011)
Stopping soil erosion (water flows during rainy season) and better management of less fertile land	11	"Hopefully *Jatropha* will stop the water flows on my crops, I have already seen the improvements" (male farmer, Karaya-Toumouba, May 2011)
Easy to grow (especially with respect to cotton farming), allows revenues diversification	11	"Me and my wife are too old and do not have enough energy anymore for growing cereals... I will further reduce the cereal surface in the future because *Jatropha* will be my source of retirement income" (male farmer, Garalo, April 2011)
Making traditional drugs	4	Seeds, boiled leaves and branches residues from *Jatropha* are used for treating malaria, sore throat, headache, wounds, skin diseases and intestinal worms (observations from in-depth interviews across different villages between February and May 2011)
Reducing deforestation	3	(observations from in-depth interviews across different villages between February and May 2011)
Fighting climate change	1	"Planting *Jatropha* trees can help to fight climate change" (male farmer, Bendougouba, May 2011)
Improving human capital	1	"The technical training provided to my children by the project is an added value for them" (male farmer, Douna, March 2011)

The main difficulties and concerns associated with *Jatropha* production at the local level focus on the low price of seeds sold (n=25) and the lack of fertilizers and agricultural equipment (n= 16). The role of extension networks plays a key role in the development of the *Jatropha* sector, with a lack of farmer support being identified as a key concern (n=11).

Table 3: *Jatropha* cultivation: main difficulties and concerns

Difficulties	No	Illustrative quotations
Price is too low	25	"Harvesting *Jatropha* requires time and labour... it is not worth it if the price does not increase" (male farmer, Sorona, April 2011), "At the beginning, with cotton there were only 4 producers in the village, but after the (cotton) price has increased all the farmers got involved... it will be the same with *Jatropha*... a poor farmer can do nothing without a revenue" (male farmer, Kouyou, April 2011)
Lack of agricultural equipment and organic fertilizer	16	(Providing fertilizers and equipment on credit) "would be a stimulus to take care of our (*Jatropha*) crops - even if we are not interested in that - and would also improve cereal production" (male farmer, Sorona, April 2011)
Young trees are attacked by termites	13	"The main problem are the termites, they eat the young trees... they (the project) should find a remedy for this" (male farmer, Karaya-Toumouba, May 2011)
Lack of communication, insufficient support from the project developer	11	"3 years ago they (the project) came promising things, now they do not even come to collect the seeds. So, last year I did not even harvest.... If they keep disregarding us, I will abandon *Jatropha*", (male farmer, Sorona, April 2011) "(the project) has informed the farmers about the several benefits including fuels, fertilizers, electricity, fight to climate change...if this is all true, why are they not supporting us?" (male farmer, Sorona, April 2011)
Lack of labour	7	"My main problem is that I lack of labour... most of my sons have left the village to work outside" (male farmer, Bendougouba, April 2011)
Wild fires	5	(observations from in-depth interviews across different villages between February and May 2011)
Lack of/difficult access to water for tree nursery	4	"Water is a problem, the well is too far and very deep" (male farmer, Karaya, May 2011)
The promised benefits have not yet materialized	4	"I do not harvest because it is not rentable. The project comes and promises gains, than the gains do not materialize" (male farmer, Zena, April 2011)

The majority of the *Jatropha* farmers initially identified by project lists and interviewed through focus groups were unsuccessfully cultivating the crop and only a small share of them (the ones selected for household questionnaires and in-depth interviews) had kept their crops alive in the first 3 years of plantation. Transect walks showed that there are significant differences in plant size and yields among different farmers (Figure 2). According to the farmers' perceptions assessed through in-depth interviews, size differences link to the fact that the young trees are often attacked by termites, while perceived soil fertility differences also play a role. In line with findings of Achten *et al.* (2010), Dyer *et al.* (2012) and Shanker *et al.* (2006), the results confirm that *Jatropha* yields are difficult to predict and the trees are subject to pests and diseases.

Figure 2: Differences in plant size among 3 years old plantations in the villages of Zena, Kita, Tandio and Douna. 2011. All photos taken by the author.

5 Land use, agroforestry and cropping calendar: beyond food versus fuel?

As of 2011, *Jatropha* is only grown at a small-scale in Mali: results from in-depth interviews indicate that the maximum individual surface area planted does not exceed 4 hectares and 77% of the plantations are smaller than 3 hectares. In line with Achten *et al.* (2010) and Dyer *et al.* (2011), results from in-depth interviews at household level indicate that smallholder farmers will not replace food production with *Jatropha* farming. While this is mainly due to the cultural importance of cereal production *"I always give priority to cereals because I have to feed my family*" (male farmer, Ngorola, March 2011), this is also linked to other reasons that are outlined below.

Living fences. When grown as a living fence – the most widespread existing use of *Jatropha* that farmers are aware of (83%) – *Jatropha* can reduce land tenure conflicts among farmers as well as protect their cereal crops from wind, water flows, soil erosion and trespassing wildlife. This supports findings from FAO (2010), GTZ (2009), Achten *et al.* (2010) and Dyer *et al.* (2011).

Previous land use, agroforestry and food security. Only 2 respondents (7%) are growing *Jatropha* on land not previously under agricultural use. In 93% of cases the land now dedicated to *Jatropha* was used – in rotation with cotton farming – for food cultivation such as sorghum, millet, peanuts, corn and beans. But *Jatropha* has not decreased food security in Mali. Indeed, 82% of the smallholder farmers interviewed intercrop *Jatropha* with peanuts, cowpeas, sesame, sorghum, millet, corn, sweet potatoes, beans and soya. The intercropping system guarantees the land used for food is not entirely shifted to biofuel production (Magcale-Marcandog, 2010) and according to the farmer experiences, *"(intercropping) is essential to avoid fires and weeds"* (male farmer, Garalo, April 2011) (Kumar, 2006). Observations from farming calendars indicate that, among the different tasks performed on the different crops during the year, there is a major trade-off between the labour required for harvesting *Jatropha* and the labour needed for hoeing and harvesting cereals and cotton (67%) *"In August I have postponed the Jatropha harvest because I was too busy with cereals"* (male farmer, Koury, March 2011). This suggests farmers prioritise food crops over *Jatropha* harvests. The role of intercropping is further highlighted as a

core strategy for reducing labour trade-offs: *"If you intercrop there is no problem (in terms of labour availability), otherwise it would be difficult to take care of it (Jatropha crop)"* (male farmer, Bendougouba, May 2011).

Intercropping for most farmers is possible only in the first 3 years of plantation due to the small distance between their *Jatropha* trees – mainly 3x3 or 4x4 metres (87%). 10% of interviewees already noted that by the third year there was not enough space in between the *Jatropha* lines to grow cereals: *"I do not do it (intercropping) anymore, Jatropha trees are too big now"* (male farmer, Kerekoumana, April 2011). This might lead to a land-use shift from food to non-food crops, therefore having implications for long term food security. But such a shift will be only partly explained by the introduction of *Jatropha*. Some farmers (17%) have been shifting their cereal cultivation to other land, which in some cases have better fertility: *"I choose this land (for Jatropha farming) because it is less fertile than other lands"* (male farmer, Fakoumala, May 2011). Also, in the future, the threat to food security will be overcome as the projects outlined in Figure 1 are now training their farmers to establish *Jatropha* agro-forestry systems. With larger cropping schemes – such as 2x2x8 metres – intercropping will be possible over the long-term, allowing permanent food production. This is in line with expectations of farmers who are planning to expand their *Jatropha* surface in the future (57%): *"There will be no problem for cereals because I will benefit from intercropping"* (male farmer, Karaya, May 2011).
In 10% of the cases the food vs. non-food land shift would have occurred independently from *Jatropha*, mainly due to the lack of labour and agricultural equipment: *"I have reduced the cereals surface but this is not due to Jatropha, my main problem is that I lack of labour... most of my sons have left the village to work outside"* (male farmer, Bendougouba, April 2011).

Large-scale developments. While as of 2011 no large-scale activities were reported to be taking place in the country, the National Strategy of Foreign Investments Attraction promoted by API-Mali and interviews with government officials show that large-scale plantations of *Jatropha* are foreseen in the future to allow the ambitious fossil fuel substitution objectives and targets set by the National Biofuels Strategy to be met. The energy policy and stakeholder analysis revealed that large-scale investments might lead to *Jatropha* being planted on productive agricultural lands,

confirming the concerns raised elsewhere by Achten *et al.* (2010). Discourse analysis and semi-structured interviews with government officials from the Ministry of Agriculture, Ministry of Mines, Energy and Water and UNDP informed that, prior to the creation of ANADEB, land acquisition pre-agreements between the Malian Government or local municipalities and foreign private investors have been signed with the aim to set up large-scale *Jatropha* plantations of 10,000-100,000 hectares (UNDP, 2010). Land used for such purposes was expected to be "marginal" but at that moment a specific regulatory framework was lacking. These investors have left the country and are not following-up with the expected activities due to unspecified reasons. The interviews also revealed that use of irrigation and fertilizers is envisaged in order to establish productive large-scale plantations.. This is in contrast with claims asserting that *Jatropha* flourishes in marginal land with limited water supply and poor soil (Francis *et al.*, 2005) and shows that the commercial viability of large-scale *Jatropha* activities depends on the use of irrigation and fertilizers (Patolia *et al.,* 2007). ANADEB envisages supervising future large-scale land acquisitions in order to guarantee the preservation of productive agricultural land as well as the socio-economic and environmental sustainability of these operations. Sustainability standards and a legal framework are being discussed amongst several stakeholders at various levels and should be approved by early 2012. Whether *Jatropha* will improve or threaten food security within the country will not depend on the development of small-scale agroforestry systems but on the establishment and enforcement of clear "sustainable" rules for setting up large-scale activities.

6 Local impacts: the seeds of an economy or plant of unfulfilled promise?

Evidence from this Malian case study shows that *Jatropha* has the potential to promote development at household and village levels in a variety of ways outlined below.

Revenue and cash liquidity generation. According to the farmers' perceptions, *Jatropha* can offer the potential to generate revenues, giving the households a regular income. However, economic benefits from *Jatropha* are strictly linked to the ones in the cotton market. To date, the rentability per hectare of *Jatropha* is lower

than for cotton *"The revenue from 1 hectare of cotton is bigger than the one coming from 5 years of work with Jatropha"* (in-depth interview, male farmer, Kerekoumana, April 2011) and priority to *Jatropha* in the future will be given as long as the price and yields increase. 17% of the interviewees argue that the immediate cash liquidity coming from *Jatropha* is a particularly important advantage compared to cotton as in recent years Mali's cotton farmers have faced several problems due to significant delays in the collection of their revenues and indebted cooperatives.

Revenues from *Jatropha* vary among the projects depending on variations of the seeds' purchase price – *e.g.* GERES pays a higher price compared to the standard one set by the other initiatives – and the level of support provided to the farmers. Extension networks are key elements to allow farmers to take advantage of the additional *Jatropha* utilities (others than seed sales) and enhance their livelihood outcomes. While income from seed sales has been mainly used among all the project areas for buying clothes for religious ceremonies (up to US$11) (n=5), repairing agricultural equipment (up to US$14) (n=2), buying school material (up to US$11) (n=2) and reducing the expenses for animals vaccinations and fertilizers (up to US$2) (n=2), bigger revenues have been generated by soap production. The households trained by JMI to transform the *Jatropha* oil into white soap for commercialization – in line with the project's goals identified in the stakeholder analysis – have been gaining up to US$94 net per year (n=3) *"(White) Soap production improved my life... if I want to borrow money, now it is easier because people know that I will be able to reimburse"* (in-depth interview, female farmer, Bendougouba, May 2011). On the other hand, Malian families have almost 40 years' experience with producing black soap – used within the household for laundry and showering – which plays a role in reducing the family expenses (of up to US$54 annually).

Improving rural energy security. At the village level, claimed potential benefits from *Jatropha* oil include substitution of diesel consumption and improvement of rural energy access as well as reduction of household expenses due to income generation through sale of the oil and/or the by-products (Achten *et al.*, 2010, Dyer *et al.*, 2011). The multi-level analytical assessments carried out through this research confirm that establishment of local *Jatropha* supply chains have the potential to generate such benefits, at the same time raising some concerns, particularly that there is a lag time

between initial investments and the derivation of benefits. While rural energy provision perspectives appear promising, to date, *Jatropha* oil has been mainly used in Mali only for testing and demonstration due to the limited feedstock availability. Plantations are relatively young and yields remain low. Since 2007, the MFC power generator has been delivering obvious benefits to the Garalo farmers thanks to the provision of rural electricity, though it is still run purely by regular diesel and estimates concerning the timeframe for substituting this with *Jatropha* oil are unavailable. This is in contrast with the outlook on biofuels published recently by Nature (Gilbert, 2011: S18), which asserts that *"(Jatropha in Garalo)...provides electricity to 350 homes"* and that *"The Garalo project is a testament to how biofuel production can greatly improve the lives of poor people in developing countries"*. Conversely, this study found that the local extraction units installed by GERES are not yet fully operative. Interviews with government officials from the Ministry of Agriculture informed that additional pressing units have been donated by the government to some villages. Data gathered at community level through focus group in the village of Bendougouba (May 2011) confirm this assertion but reveal that the donated press has not yet been installed. The positive soap production impacts delivered by JMI will remain limited if oil production does not increase and a more substantive share of farmers is not trained.

A plant for smallholders. In-depth interviews revealed that the substantive plant size differences outlined in the village-level analysis are not linked to the area planted (all the Malian *Jatropha* growers are smallholders) or farmers' income level. The wealth ranking showed that the poorest farmer out of all the interviewees – lacking access to basic agricultural equipment such as a donkey cart and oxen – performed better than some wealthier ones. According to his perceptions, this is due to the good soil fertility and his knowledge of farming techniques. This evidence is in contrast to the findings of Ariza-Montobbio *et al.* (2010): development impacts from *Jatropha* in Mali are not exclusive to farmers with larger landholdings or resource endowments, but rather to those who have access to fertile soil as well as information on farming and processing techniques.

7 Conclusions and contribution to energy policy

Case study research on *Jatropha curcas* uptake and benefits is much needed to better inform biofuel debates and inform local, national and international policy. By integrating participatory and scientific approaches and through mixed-method multi-level analytical assessments in Mali, this work addresses key policy and decision-making challenges related to biofuels development in dryland Africa.

Our findings show that at community and household levels *Jatropha* offers the potential to contribute to rural development and diversify farmers' livelihood strategies. In Mali, *Jatropha* is widely used to demarcate field boundaries and avoid land tenure conflicts, to produce soap and to reduce soil erosion. Local communities' expectations remain high with regards to future generation of revenues that would allow a shift between different capital assets and a diversification of farmers' livelihood strategies: such revenues can be used to buy cereals in times of shortage, clothes, school materials and to repair agricultural equipment. *Jatropha* is also perceived as an "easy-to-grow" crop that could substitute cotton farming, providing a diverse and more immediate source of liquidity to face the problems experienced in the past decade in the Malian cotton sector. The main barriers for *Jatropha* production at the local level have been shown to be the low price achieved for seeds that are sold, as well as a lack of organic fertilizers and agricultural equipment.

National and regional level analysis shows that potential of *Jatropha* oil to enhance rural energy access looks promising, especially when activities are adequately supported by institutions and practitioners. However, local-level benefits in terms of diesel substitution and revenues generation through sale of the oil and/or the by-products are still weak and current supplies of biodiesel remain insufficient for improving energy security. Project developers and policy makers need to acknowledge this issue and recognize that actual or potential growers may be reluctant to invest time and money in a crop that does not bring obvious, immediate livelihood gains. This has the knock-on effect of policy targets remaining unachievable. Some farmers have already abandoned their plantations and others have left their crops unharvested due to a perceived lack of support and insufficient financial returns. Extension networks, improved communication and farmer support at

the local level are key variables that require further investment and development in order to maximize the positive impacts of the *Jatropha* sector in Mali.

In moving forward, it is vital to recognize that *Jatropha* is not a wonder crop: yields are difficult to predict and the trees may be subject to pests and diseases. The establishment of productive plantations to allow the achievement of the ambitious targets set by national policies requires this crop to be grown on fertile land. While smallholder farmers look unlikely to replace food production with *Jatropha* farming at community and household levels thanks to the establishment of agroforestry systems, future large-scale investments fostered by policy drivers might lead to *Jatropha* being planted on productive agricultural lands. Policy makers should establish an adequate legal and institutional framework to avoid future land tenure disputes and threats to food security.

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