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Unpacking livelihood challenges and opportunities in energy crop cultivation: perspectives on *Jatropha curcas* projects in Mali

NICOLA FAVRETTO, LINDSAY C STRINGER AND ANDREW J DOUGILL

Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds LS2 9JT

E-mail: n.favretto@see.leeds.ac.uk; nicola.favre@libero.it

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This study contributes to global debates on biofuels and rural development, providing insights into the role of *Jatropha curcas L. (Jatropha*) in addressing global poverty and promoting sustainable energy. *Jatropha* energy crop investments have proliferated as a means to substitute imported oil, foster rural development and reduce poverty. This paper presents new mixed-method assessments of the potential for, and initial impacts of, *Jatropha* projects that aim to improve livelihoods and energy security in rural Mali, a leading proponent of *Jatropha* cultivation. Factors affecting the socio-economic and environmental vulnerabilities of smallholder farmers are assessed and capital assets available for different livelihood strategies are identified and evaluated. Comparative analysis of information gathered through participatory methods allows evaluation of the role played by *Jatropha* cultivation in the determination of different livelihood outcomes. Data show that households involved with NGO or private sector activities linked to *Jatropha* can gain financial capital from the sale of *Jatropha* seeds and soap. Findings also show that small-scale cultivation does not threaten food security. When grown on a small scale as a living fence, *Jatropha* demarcates property, and reduces land tenure conflicts and soil erosion. Projects focusing on *Jatropha* use for rural electrification offer potential to improve energy access. However, current supplies of *Jatropha* oil remain insufficient for these benefits to materialise. On-the-ground challenges were identified, along with opportunities to better link policies to local-level practices.

KEY WORDS: Mali, biofuel, sustainable energy, food security, rural livelihoods, participatory methods

Introduction

At the beginning of the twenty-first century biofuel projects proliferated as a means to enhance access to energy, foster rural development and reduce poverty (Gasparatos *et al*. 2012; Diaz-Chavez 2010). Several guidelines have been developed to ensure that biofuel operations promote rural and social development (Diaz-Chavez 2012; Duvenage *et al*. 2012). Despite this, concerns have been raised regarding impacts on food security ('food versus fuel' debates), with the concern that biomass previously destined for human consumption is being diverted to fuel production (Rosillo-Calle and Johnson 2010), and the ability of biofuels to enhance rural energy and deliver development benefits has also come into question (ActionAid 2012; Nuffield Council on Bioethics 2011).

In contrast with these concerns largely based on large-scale biofuel plantation projects, small-scale cultivation of the oil-bearing, 'drought resistant', non-edible tree *Jatropha curcas* (hereinafter termed *Jatropha*) has been identified as a promising livelihood diversification strategy for the rural poor and a route to help alleviate energy demands (Gilbert 2011; Palliere and Fauveaud 2009), restore degraded ecosystems (Garg *et al*. 2011) and generate income (Achten *et al*. 2010; Dyer *et al*. 2012). This paper provides new empirical evidence on the role of *Jatropha* at village and household levels in rural Mali, paying particular attention to how it supports livelihoods.

Jatropha cultivation is only part of the diverse portfolio of livelihood activities managed by farming households. Initial research has been carried out at the local level across Asian, African and Indian

farming systems, but claims on the impacts of *Jatropha* cultivation for improving livelihoods remain contrasting (Hodbod and Tomei 2013). More empirical data and case study analyses are urgently needed.

Sustainable livelihood approaches can play a role in targeting this knowledge gap as a route to understanding and enhancing the livelihoods of the rural poor (e.g. Scoones 2009; Morse and McNamara 2012). In this paper we refer to a livelihood as the ensemble of the 'capabilities, assets . . . and activities required for a means of living' (Chambers and Conway 1992, 10). According to Scoones (2009, 175): 'a livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base'. Based on this conceptualisation, the Sustainable Livelihoods Framework (SLF) has been developed as an analytical tool to assess major livelihood components and the key vulnerabilities (shock, trends and seasonality) and transforming structures and processes (e.g. laws, policies and institutions) that affect the achievement of livelihood outcomes (DfID 1999). Research in dryland Africa (e.g. Dyer *et al*. 2012; Brock 1999) and India (Vaidyanathan 2009) shows that the SLF can be a powerful analytical tool in providing an objective assessment of the local-level impacts of biofuel projects.

This paper provides a new case study assessment 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 sub-Saharan countries in *Jatropha* cultivation aimed at fuel production, due to pilot initiatives supported over the last decade by a variety of development agencies, government, private sector enterprises and NGOs. A range of government policies in the fields of energy, environment, agriculture and rural development support the use of *Jatropha*, including a National Strategy for Biofuels Development approved in 2008 which sets quantitative targets for *Jatropha* biofuel production (Favretto *et al*. 2012). Mali thus provides a suitable country context in which the challenges and opportunities associated with *Jatropha* can be explored.

After assessing the key socio-economic and environmental vulnerabilities of smallholder Malian farmers, comparative aspects of each pilot activity are drawn out in the analysis in order to answer the following research questions:

1. What are the opportunities offered by small-scale *Jatropha* agriculture to improve livelihoods and rural energy security?
2. Does small-scale *Jatropha* farming compete with land, labour and food production at the household level?
3. To what extent do people achieve their livelihood goals, and what barriers do they face?

Research design and methods

Mixed-method approaches were used to assess the potential of *Jatropha* to improve livelihoods and expand access to energy in rural Mali.

A desk-based literature review allowed identification of the vulnerability context in which household livelihood activities were operating. A scoping study was then carried out between March and May 2010 to identify the main actors and issues associated with the Malian *Jatropha* sector and to identify research gaps. Semi-structured interviews were undertaken with informants from government, international organisations, the private sector and NGOs. Forty exploratory questionnaires were carried out at the household level and 17 focus groups at the community level in four project areas.

As of 2011, with a total cultivated surface accounting for roughly 5000 ha, four main *Jatropha* pilot activities operated with approximately 5000 smallholder farmers in the southern regions of Sikasso, Koulikoro and Kayes. These activities are led by different stakeholders: two private companies – the Dutch Malibiocarburant SA (Koulikoro) and the French-Malian joint venture Jatropha Mali Initiative (JMI) (Kita); both of these target oil extraction and sale to local and national markets; and two NGOs – the Malian Mali-Folkecenter (MFC) (Garalo) and the French GERES Mali (Koutiala), both of which promote *Jatropha*-fuelled rural electrification for local communities (Favretto *et al*. 2012).

Livelihoods assessment (n = 30) at household level was carried out between January and June 2011, with particular focus on *Jatropha* and its role in livelihood diversification. Three of the four main *Jatropha* pilot activities were selected as study sites encompassing 14 villages. Selected pilot activities were MFC (a *Jatropha* rural electrification project widely discussed in the international arena; Gilbert 2011; Practical Action Consulting 2009), JMI and GERES. These are operating in locations where important ecosystem services for human wellbeing are most critically stressed (Wong *et al*. 2005), agro-ecological conditions are suitable for *Jatropha* cultivation (Diarra 2010), and population densities and poverty are high (Wong *et al*. 2005).

Village-level focus groups (n = 1/village, total n = 14) were undertaken with *Jatropha* cultivators to discuss issues and concerns about *Jatropha*-related activities based on key themes identified in scoping study. Household questionnaires (n = 80 in total: 30 in Garalo, 25 in Kita and 25 in Koutiala) identified key livelihood assets. Sampling was purposive and non-random according to criteria including degree of project involvement (farmers potentially performing well), same maturity of plantations (three years old),

age and geographical distribution. Livelihood assessments used the SLF (DfID 1999) to guide the implementation of participatory methods, including in-depth semi-structured interviews (n = 10/project area, total n = 30), transect walks (n = 10/project area, total n = 30) and seasonal calendars (n = 10/project area, total n = 30) with farmers identified through focus groups and preliminary questionnaires. By complementing the information on land tenure, and agricultural and income generating activities collected in household questionnaires, seasonal calendars allowed insight into the seasonality of agricultural and non-agricultural workloads (Chambers 1994). Transect walks allowed observation of the extent and condition of the cultivated crops, to verify the *Jatropha* acreage and environmental context.

Interview and transect walk notes were analysed to identify emerging issues for field discussions and as themes for semi-structured interviews. The data generated by all research methods were analysed by reviewing the questions, categorising the information through tables and matrixes to highlight similarities and contrasts, carrying out numerical calculations and creating graphs with electronic spreadsheets, and integrating and synthesising the findings (Slocum 2005).

Wealth ranking was conducted according to the Malian Company for Textile Development (CMDT) definitions (Nubukpo and Keita 2005), where farmers were placed into one of four categories based on the type and quantity of agricultural equipment owned: 'A' better off, 'B' medium, 'C' basic and 'D' poor.

How do smallholder Malian farmers sustain their living? Illustrative livelihood portfolios

This section outlines the livelihood strategies pursued by case study households in light of the varied combinations of capital assets available. Household-level data are grounded in questionnaires, in-depth semi-structured interviews and seasonal calendars.

Crop production is the main livelihood activity pursued, and is strictly dependent on access to land. The average land area owned by interviewees – including abandoned, fallow and cultivated land – was 19 ha (30 ha in Koutiala, 16 in Kita and 10 in Garalo). Only 4 of 30 households (13%) were able to farm all the available land, while in the other cases, the actual cultivated surface was notably smaller than the total land area available, accounting for 18 ha (Koutiala), 10 ha (Kita) and 6 ha (Garalo)[1]. Limits in expanding the farmed land area are due to the insufficient labour, farm equipment, fertilisers and seeds.

Differences in total cultivated land size are related to the household wealth status. The wealthiest households (category A) cultivate a larger average area of land (21 ha) than categories B (7 ha), C (6 ha) and D (5 ha).These observations highlight the importance of physical capital, on which the wealth ranking categorisation is based, in sustaining livelihoods by allowing a larger acreage of land to be cultivated.

These differences arise as wealthier households have more financial capital to hire labour, buy farm equipment and fertilisers. This translates into higher food production, therefore improved food security and the possibility to sell the surplus offering an important diversification activity. Poorer households have less capacity to absorb labour shortages, and this negatively affects their other capitals. For example, this translated into lower attendance at school and higher vulnerability to child labour (human capital): 'I cannot afford to send my kids to school, fees are too expensive and I need to feed my family . . . who is going to work on my land?' (Male farmer, Zena, MFC, 2011).

Labour and agricultural equipment are often shared among relatives or neighbours to address this situation, with group work carried out with tools such as oxen and ploughs in rotation across different fields. This highlights the key role played by social capital in sustaining livelihoods of poorest households.

Resource-poor Malian famers rely on rainfed agriculture and traditional farming techniques (Fofana *et al*. 2011). Compost production is a common practice and access to chemical fertilisers is limited. Cotton is popular because it is perceived not only as a good source of financial capital but also of physical capital: at the beginning of each sowing season, cotton growers receive fertilisers on credit, with the promise of repayment at harvest time (Theriault 2011). This has positive impacts on other forms of capital (particularly human), by increasing food security: 'Cotton farming gives me access to fertilisers . . . this has improved my cereal yields' (Male farmer, Douna, GERES, 2011). Nevertheless, cotton farming is labour intensive and differences in uptake were observed. In Koutiala – where the overall wealth status is higher – 100% of the respondents grow cotton, while in Kita 60% and in Garalo (lowest wealth ranking) only 30%. This reiterates that wealthier and resource-rich households have access to a wider range of livelihood activities.

Livestock production is the second major livelihood activity. Livestock are mainly used within the household with livestock being sold only in exceptional circumstances, when immediate liquidity is needed. Households also pursue a variety of off-farm activities aimed at generating financial capital. These include seasonal labour, fruit sales, household manufacturing, handicrafts, micro to small-scale business (e.g. welding, tailoring and grocery sale), gold mining and remittances. When liquidity is urgently needed, interest-free money is borrowed from family, neighbours and friends, while microcredit is perceived as a less accessible option due to the limited capacity to provide a reimbursement guarantee.

The activities pursued vary across different wealth-ranking categories. Wealthier households can afford higher financial investments, which allow the establishment of small-scale businesses. Diversification options for poorer households are more limited, with the most common off-farm activities mainly being seasonal labour and remittances. While seasonal labour offers a source of income, it also reduces availability of labour on the farmer's own land, which means reduced human and natural capitals. This suggests that a smaller range of diversification options is available to poorer households to break their cycle of poverty (cf. Sallu *et al*. 2010).

This section has shown that the livelihood portfolios of the study households are highly variable and capitals are interlinked. While a high dependence on natural capital is evident, limited availability of human and physical capitals limits the capacity to make effective use of natural capital and to cope with major shocks.

Social, economic and environmental vulnerabilities of Malian *Jatropha* farmers

Household questionnaires, semi-structured interviews and seasonal calendars allowed assessment of the vulnerability context, which is outlined in Table 1.

Table 1 Key social, economic and environmental vulnerabilities of rural households in Mali

Key vulnerability factor	Description
Trends	
Increase in population	Total population: 15.8 million people. Average annual rate of population change in the period 2005–2010: +3.1% (UNDESA 2011)
	Strong increase in energy needs due to growing population (WB and GoM 2011)
Increasing pressure on natural resources	Caused by: growing population, declining amount – and increased intensity – of rainfall, and delay in rainy season (GoM 1998 2012)
	Growing scarcity and degradation of natural resources translate into reduced soil fertility and a high susceptibility to soil erosion and desertification (GoM 1998 2012)
Increasing prices of oil and food	The Malian energy sector is fully dependent on imported oil (GoM 2007). Increases in oil prices affect food production and prices (AfDB *et al*. 2012)
Increasing difficulties in cotton agriculture	Significant reduction of acreage and production due to institutional constraints, including low credit recovery rates and delayed payments to farmers (Theriault 2011)
Shocks	
Political instability	Security threats in the North – including rebellious uprisings and terrorist activity –and military coup in March 2012. Reduced access to food and fuel (AfDB *et al*. 2012)
Climatic shocks	Uneven and delayed rains, droughts and water flows (GoM 1998 2012)
Crop failures and drops in food production	Sharp fall in agricultural production in 2011, caused by climatic shocks (AfDB *et al*. 2012)
Pests and diseases	These are one of the major causes of crop failures (GoM 1998)
Loss of physical and human capitals	Death or loss of livestock and illness of family members negatively affect agricultural productivity (Fofana *et al*. 2011)
External shocks	Libyan war, post-elections crisis in Ivory Coast, rising prices of oil and food (AfDB *et al*. 2012)
Vulnerability of the energy sector to climate change	Climate change impacts on the production of hydroelectricity, which accounts for 55% of the energy mix (WB and GoM 2011)
Seasonality	
Labour shortages	Mainly experienced between June and November (cropping calendars and semi-structured interviews, 2011)
Poor harvests	Linked to lack of labour and major environmental shocks
Food shortages	Lowest food availability in August/September (cropping calendars and semi-structured interviews, 2011)
High variability of food prices	Highest picks in September (cropping calendars and semi-structured interviews, 2011)

National-level data on the trends and shocks that globally affect the agricultural activities of all the Malian farmers are linked to the local-level data to show the relevance of these issues to the *Jatropha* farmers.

Trends

Mali is amongst the countries with the highest rate of population change and lowest per capita energy consumption in Africa (GoM 2007). It is one of the world's least developed countries (UNDP 2011) and growing population places additional pressure on energy production.

From a climatic perspective, reduced annual rainfall since the 1970s (GoM 1998), together with dramatic spatial variations and prolonged dry spells, have enhanced land degradation (Wong *et al*. 2005) and disrupted the cropping schedule. Increased rainfall intensity was observed by 5 of 30 interviewees (17%), who reported substantial food crop damages caused by heavy rains, particularly since the mid 2000s: 'In the past 3 years the rain was more intense than usual and it has destroyed some of my crops' (Male farmer, Kona, GERES, 2011). Ten farmers (33%) reported a delay in the rainy season compared with 10 years before. To adapt to these changes, the sowing period has been gradually postponed: 'Every year I start sowing at a later date because the rain comes too late' (Male farmer, Kala, JMI, 2011). As a consequence of postponed sowing, seasonal vulnerabilities linked to pre-harvest food shortages are exacerbated.

Over the last decade cotton farmers have experienced increasing difficulties which have reduced their capacity to generate cash. The functioning of local cotton cooperatives has been hampered by increasing levels of debt. Delayed payments to farmers have hampered their capacity to reimburse creditors. This has had negative repercussions on successful farmers, who were responsible for reimbursing not only their own loan but also the overall debt of the cooperative. Many producers have therefore abandoned the cooperatives and cotton farming with *Jatropha* has gained increasing relevance.

Shocks

The Malian economy's growth has been threatened by various shocks even before the major conflict since March 2012 (post data collection). From an international perspective, the country suffered from the post-election crisis in the Ivory Coast, the Libyan war, and a rise in oil and food global prices. In 2011, this situation was worsened by a sharp fall in agricultural production due to drought. At the national level, increased climatic vulnerability exacerbates shocks in the energy sector, dominated by hydroelectricity.

Seasonality

Figure 1 outlines the agricultural annual workload of a typical interviewee, as assessed through farming calendars.

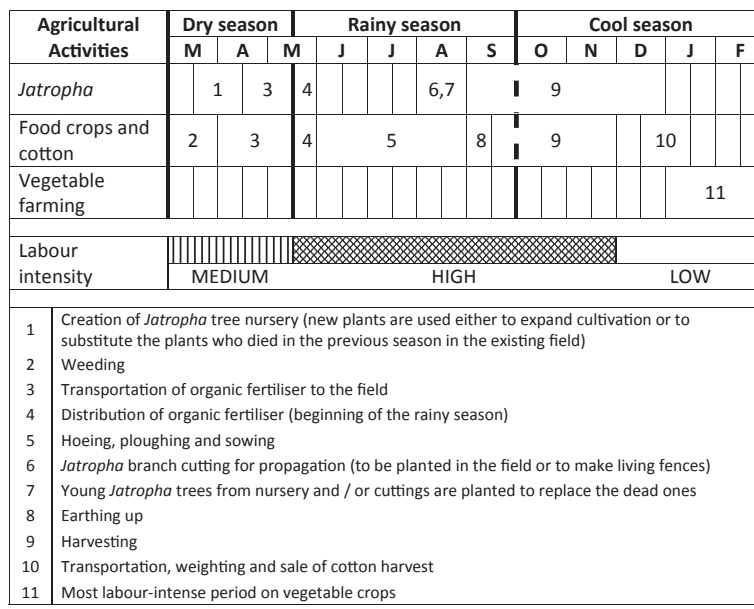

Figure 1 Example farming calendar, semi-structured interview, Kita (JMI), 2011

Cropping calendars reveal that labour shortages occur between June and November, during the ploughing, sowing, and harvest periods of cereals and cotton. Labour shortages, together with a limited access to farming equipment and fertilisers, limit the capacity to cultivate more land and diversify livelihood activities.

According to focus groups and household interviews across the three case studies, food shortages are a major seasonal stress. This situation is exacerbated by poor and postponed harvests, which increase the gap between cereal production and consumption needs. There is a high variability of food prices, which peak in September at the beginning of the harvest season. While the livelihoods of the less wealthy households are most vulnerable to these shocks, wealthier households are able to generate profits: 'I normally wait until September to sell my cereals surplus . . . food availability is very low at that time and I can sell at much higher prices' (Male farmer, N'gorola, MFC, 2011). The poorest are often obliged to sell livestock or borrow money to afford food while waiting for the next harvest.

While *Jatropha* cultivation and sales offer new opportunities to reduce the farmers' seasonal vulnerabilities by diversifying access to capital assets, knowledge of the trade-offs that might arise is still limited.

Farmers' uptake reasons: expectations and priorities

Farmers' uptake reasons and priorities in relation to *Jatropha* cultivation are now assessed using the findings from SLF interviews and questionnaires. Findings are grouped according to the perceived contribution of *Jatropha* uptake to each of the five capital assets. *Jatropha* is mainly grown as a means for improving physical and financial capitals, while a smaller impact is perceived on natural and human capitals. No claims that social capital has been improved through *Jatropha* uptake were made.

Physical capital

Jatropha has been traditionally used as a living fence in Mali (n = 25, 83%) to demarcate property and manage environmental vulnerabilities by protecting food crops from water flows, soil erosion and grazing animals: 'For 50 years, Jatropha had delimited [cereal] crops in order to avoid conflicts among the farmers in the village' (Male farmer, Karaya-Toumouba, JMI, 2011). Given promises made by the pilot activities established in 2007 high expectations are also put on the use of *Jatropha* oil to substitute diesel consumption and improve electrification (n = 18, 60%). With regards to productivity improvements, 11 interviewees (37%) hope to benefit from access to cheaper organic fertiliser produced by the pressing residue of *Jatropha*.

Financial capital

Twenty-two interviewees (73%) plan to generate revenues due to their involvement with *Jatropha* activities and the sale of seeds. The expected improvement in financial capital was seen as a strategy to secure cereal provision in periods of shortage: 'The project told us that we will gain a lot of money from Jatropha . . . In the future, revenues from Jatropha will pay food for my family' (Male farmer, Garalo, MFC, 2011). Twenty-one interviewees (70%) have been using Jatropha seeds since the 1970s to produce black soap and reduce household expenses.

Jatropha is also perceived as easier to grow and less labour intensive compared with cotton. Twelve interviewees (40%) hope to substitute cotton farming with *Jatropha*: 'When the Jatropha price increases, I will quit cotton' (Male farmer, Garalo, MFC, 2011). Only one interviewee has reported replacement of cotton with *Jatropha*. Five interviewees (17%) noted that the immediate cash liquidity coming from *Jatropha* can reduce the problems faced by the highly indebted cotton cooperatives. *Jatropha* cultivation is therefore a strategy to diversify livelihood strategies and is perceived as a new source of household income.

Natural capital

Growing *Jatropha* as a living fence is seen as a livelihood activity that can reduce environmental vulnerabilities by reducing soil erosion and restoring degraded land (11 interviewees, 37%). Only one farmer noted that 'Planting Jatropha trees can help to fight climate change' (Male farmer, Bendougouba, MFC, 2011). These data show that the environmental reasons related to *Jatropha* uptake play a less relevant role than those linked to enhancing physical and financial capital.

Human capital

Jatropha is perceived to contribute to human capital in terms of healthcare improvement, supporting findings in the wider literature (cf. Sabandara *et al.* 2013). Four interviewees (13%) reported the use of *Jatropha* for making traditional medicines.

Social capital

Despite none of the interviewees reporting perceived benefits from *Jatropha* uptake in this regard, the analysed pilot project activities have fostered social capital improvements. In three villages, women have formed collective *Jatropha* farming groups. Such reinforced interaction among villagers can strengthen their negotiating power and generates a common financial interest based on cooperation.

Lessons learned in small-scale *Jatropha* projects: key opportunities and challenges

This section outlines the opportunities and challenges related to *Jatropha* as a rural development tool. The lessons learned provide valuable perspectives on future *Jatropha* development, but it should be noted that projects remain relatively young and are still in a 'learning-by-doing' phase. Operations of the pilot activities examined started in 2007 and have been constantly evolving.

Revenue generation: the seeds of an economy or plant of unfulfilled promise?

Household-level interview data show that *Jatropha* offers potential to generate revenues through the sale of seeds and soap. The major barriers described below need to be overcome in order to achieve more substantial impacts.

Sale of Jatropha *seeds* All of the *Jatropha* pilot activities operate in collaboration with farming communities in establishing small-scale *Jatropha* plantations. Technical support on farming techniques is provided, with a guarantee that seeds will be purchased at a fixed price. Revenues from *Jatropha* vary among projects depending on variations in the seed purchase price, for example, at the time of field observations GERES paid a higher price (US$0.17/kg) compared with the standard price set by other initiatives (US$0.1/kg).

Income from sales of seeds has been mainly used by households in all project areas for buying clothes for religious ceremonies (n = 5, 17%), repairing agricultural equipment (n = 2, 7%), buying school material (n = 2, 7%) and reducing the expenses for animal vaccinations and fertilisers (n = 2, 7%). Nevertheless, revenues through seed sales remain low and farmers' perceptions of the viability of income from the plant remain negative (n = 25, 83%).

While the production and sale of seeds alone are not yet profitable, they are seen as a potential source of diversification, as long as communities can benefit from other uses of *Jatropha* such as soap production. This creates a safety net in relation to shocks and stresses and adds a new option to the array of coping strategies traditionally used, such as selling livestock, working as seasonal labour and borrowing money.

Economic benefits from *Jatropha* are linked to those in the cotton market. To date, profitability per hectare of *Jatropha* is lower than for cotton but priority will be given to *Jatropha* in the future as long as prices and yields increase: 'Last year Jatropha was replacing cotton, but this year in light of the increased cotton price to US$0.5, Jatropha will not be competitive anymore' (Male farmer, Bendougouba, MFC, 2011).

These findings suggest that to replace cotton and succeed as a livelihood diversification strategy, *Jatropha* cultivation must be accompanied by benefits other than the sale of seeds (i.e. soap production and energy generation).

Soap production Larger revenues than seed sales have been generated by *Jatropha*-derived soap both in terms of reduced outgoings and enhanced income.

Malian families have 50 years of experience with black soap production (derived from the crushed seeds) which can contribute to reduce family expenses of up to US$48 annually. Findings show that further revenue generation opportunities come from production and commercialisation of improved-quality white soap (derived from processed *Jatropha* oil) (n = 3, 10%). Production requires a pressing infrastructure and basic tools to allow the household to cut the soap into pieces of equal shape and weight. The soap is sold to local markets at the competitive price of US$0.24 per unit, which according to the interviewees makes the product easily saleable. One interviewee reported that due to her involvement with the soap business her capacity to borrow money has increased: '[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' (Female farmer, Bendougouba, JMI, 2011). This improves not only the household's social capital (credibility and reputation within the community) but also access to financial capital.

The scale of such success stories remains small, with only 10% of the interviewees able to produce and sell white soap. However, they do show that *Jatropha* offers promising potential to increase financial capital through the sale of soap. To achieve this goal, it is vital to provide adequate farmer support and training, otherwise expected benefits will not materialise. This mirrors findings from Basinger *et al*. (2012), who highlight the key role played by information provision in determining farmers' *Jatropha* uptake.

Improving rural energy security with Jatropha *oil*

At the village level, potential benefits from *Jatropha* oil include substitution of diesel consumption and improvement of rural energy access (Achten *et al*. 2010). The analytical assessments carried out here confirm that establishment of local *Jatropha* supply chains can generate such benefits.

Increases in physical capital fostered by improved access to *Jatropha*-fuelled decentralised electricity grids for energy supply (as promoted by MFC and GERES) favour income generation opportunities through the establishment of small-scale businesses. It can also improve human capital through better access to health: 'Since we have electricity, the pharmacy has been able to keep medicines cool in a refrigerator' (Male farmer, Garalo, MFC, 2011) and education: 'Thanks to public lighting, our kids can now study after dusk' (Male farmer, Garalo, MFC, 2011). *Jatropha* oil can potentially substitute diesel consumption in local grinding machines and fuel

multifunctional platforms[2] to provide mechanical power for agriculture and energy generation.

However, concerns were raised, particularly that there is a lag time between initial investments and the derivation of benefits. Challenges faced by farmers in *Jatropha* agriculture translate into low availability of feedstock on the market, which limits capacity to produce sufficient quantities of *Jatropha* oil. To date, *Jatropha* oil has been mainly used only for testing and demonstration.

The MFC power generator has been delivering electricity to Garalo farmers since 2007; however the generator is diesel powered and estimates concerning the timeframe for substituting this with *Jatropha* oil are unavailable. This is in contrast with the positive outlook on biofuels (Gilbert 2011, 18), which asserts that '[Jatropha in Garalo] . . . provides electricity to 350 homes'. Our study found that local extraction units installed by GERES are not yet fully operational. Interviews with government officials suggested that additional pressing units have been donated by the government to some villages. Data from focus groups in Bendougouba (May 2011) confirm this assertion, but reveal that the donated press has not yet been installed. Similarly, feedstock used to meet the needs of the Malibiocarburant SA biodiesel plant comes only in minor part from *Jatropha* (Malibiocarburant SA, interview data, 2011). Similar challenges are faced in the implementation of the Multifunctional Platforms National Programme. After 15 years of experience gained in the implementation of multifunctional platforms where 1000 units were installed by 2011 (UNDP 2012) but less than 30 are operating on *Jatropha* oil (UNDP interview data 2011).

These findings show that win–win opportunities for fuel production and rural development are yet to be realised. It remains vital to remove the barriers to cultivation faced by smallholder farmers and to improve yields. Facing these challenges would allow *Jatropha* to contribute to the expansion of rural energy security and generate greater livelihood gains. Increases in physical capital (through expanded access to electricity and mechanical power for agriculture) would allow transfers to other forms of capital: access to mobile phones improves communications (social and physical capital); public lighting promotes after-dusk study (human); use of refrigerators allows medicines to be kept cool and improves health and food storage (human); business activities benefitting from electricity can generate increased revenues (financial); energy used for agriculture increases productivity (financial), food security (human) and reduces the time spent by women on domestic chores (human).

Beyond food versus fuel?

As of 2011, *Jatropha* is only grown at a small scale in Mali. Results from household interviews indicate that the maximum individual surface area planted does not exceed 4 ha and 77% of the plantations are <3 ha. Focus group discussions indicate that smallholder farmers will not replace food production with *Jatropha*. While this is mainly due to the cultural importance of cereal production, it also links to the use of *Jatropha* as a living fence and the establishment of agroforestry systems.

Use of Jatropha *as a living fence* When grown as a living fence *Jatropha* can also reduce land tenure conflicts among neighbouring farmers as well as protect their cereal crops from wind, floods, soil erosion and grazing animals. This supports findings from FAO (2010), GTZ (2009) and Achten *et al*. (2010). In a transect walk, one farmer reported that the use of a *Jatropha* living fence allows him to grow food on land that would otherwise be flooded and damaged during the rainy season. This suggests that *Jatropha* cultivation can be a successful land management strategy that improves natural capital and food production.

Land use and labour trade-offs Only two 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 cultivation of food. But small-scale *Jatropha* agriculture has not reduced food production in Mali. Indeed, 82% of the farmers interviewed intercrop *Jatropha* with peanuts, cowpeas, sesame, sorghum, millet, maize, sweet potatoes and cowpea beans. Two respondents (6.7%) intercrop *Jatropha* with cotton, in rotation with other edible crops. Intercropping guarantees the land used for food is not entirely shifted to biofuel production (Lengkeek 2009) and according to the farmer experiences: '[intercropping] *is essential to avoid fires and weeds*' (Male farmer, Garalo, MFC, 2011).

Jatropha plant size is not affected by the farmers' income level. The wealth ranking showed that the poorest farmer out of all the interviewees performed better than some of the wealthier ones. This evidence is in contrast to the findings of Ariza-Montobbio and Lele (2010) in India, suggesting that 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 and information on farming and processing techniques. This suggests that availability of natural and human capital plays a dominant role in the achievement of satisfactory livelihood outcomes. It also confirms that *Jatropha* can offer valuable diversification alternatives to poorer households.

Labour competition, particularly between the months of September and November (Figure 1), currently limits the expansion of *Jatropha* as farmers prioritise food and cotton. This is partly due to the cultural importance of food production, and partly to

the fact that, at present, both cereals and cotton are more profitable than *Jatropha*. The establishment of agroforestry systems can reduce these problems, where the role of intercropping is highlighted as a core strategy for reducing labour trade-offs: 'If you intercrop there is no problem, otherwise there would not be enough labour to take care of Jatropha' (Male farmer, Bendougouba, JMI, 2011).

Farmers' perceptions of difficulties surrounding *Jatropha* agriculture and measures proposed

This section describes the main difficulties and concerns associated with *Jatropha* production at the local level (Table 2), as identified through household-level interviews.

Financial unprofitability of *Jatropha* production is a major concern reported by 25 (83%) interviewees, together with the lack of fertilisers and agricultural equipment ($n = 16$, 53%). The majority of the *Jatropha* farmers initially identified by projects and interviewed in focus groups were unsuccessfully cultivating the crop and only a small share of them (the ones selected for in-depth interviews) had kept their crops alive in the first three years of plantation. This links to the fact that young trees are often attacked by termites, as confirmed by 13 interviewees (43%). While water requirements are perceived as a minor issue at the household level, with difficult access to water for tree nurseries being reported by four (13%) respondents, considerations at the national level might differ. Literature indicates that water demands of *Jatropha* may intensify competition over water access, particularly when large-scale operations are established (Ariza-Montobbio and Lele 2010).

Measures proposed by farmers to foster *Jatropha* production at the household level are outlined in Table 3 and include providing agricultural equipment on credit, improving communication, increasing the price of seeds, and establishing a credit system for fertilisers.

Improving farmer support at the local level, facilitating access to credit and reinforcing extension networks are also required to address difficulties in *Jatropha* cultivation and would bring livelihood benefits.

Discussion and conclusions: what future role can *Jatropha* play in fostering rural development?

Case study research on *Jatropha* uptake and benefits is needed to better inform ongoing academic debates (cf. Hodbod and Tomei 2013), biofuel policymaking and project implementation. By integrating participatory approaches and through mixed-method analytical assessments in Mali, this work addresses key challenges related to biofuels development in dryland Africa.

Limited availability of human and physical capitals (in the form of labour shortage and limited access to farming equipment and fertilisers) are key barriers that translate into a limited capacity of poorer households to diversify their livelihoods. In line with Achten *et al*. (2010), FAO (2010) and Dyer *et al*. (2012) our findings show that at community and household levels, *Jatropha* offers the potential to contribute to rural development and diversify farmers' livelihood strategies to face key socio-economic and environmental vulnerabilities. *Jatropha* cultivation offers an alternative source of liquidity that can create a safety

Table 2 Main difficulties and concerns of *Jatropha* farmers in rural Mali ($n = 30$ household-level semi-structured interviews)

Difficulties	No.	Illustrative quotations
Price is too low	25 (83%)	'Harvesting Jatropha requires time and labour . . . It is not worth it if the price does not increase . . . The promised gains are not materialising' (Male farmer, Sorona, MFC, 2011)
Lack of agricultural equipment and organic fertiliser	16 (53%)	'We need fertilisers . . . they are more important than fuel' (Male farmer, Tandio, GERES, 2011)
Young trees are attacked by termites	13 (43%)	'The main problem are the termites, they eat the young trees . . . they [the project developers] should find a remedy for this' (Male farmer, Karaya-Toumouba, JMI, 2011)
Lack of communication, insufficient support from the project developer	11 (37%)	'3 years ago they [the project developer] 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, MFC, 2011)
Lack of labour	7 (23%)	'I have left my Jatropha [mono]-crop unharvested because I had too much work on my cereal and cotton crops' (Male farmer, Zena, MFC, 2011)
Wild fires	5 (17%)	(observations from semi-structured interviews across different villages, 2011)
Lack of/difficult access to water for tree nursery	4 (13%)	'Water is a problem, the well is too far and very deep' (Male farmer, Karaya-Toumouba, JMI, 2011)

Table 3 Measures proposed by *Jatropha* farmers to foster production in rural Mali (n = 30 household-level semi-structured interviews)

Measures	No.	Illustrative quotations
Provide agricultural equipment on credit	16 (53%)	'In order to gain a donkey cart, people would do everything possible, including increasing the Jatropha surface' (Male farmer, Kona, GERES, 2011)
Improve communication between farmers and project	11 (37%)	'If the project comes regularly to see the farmers, we would never disregard the Jatropha crops' (Male farmer, Fakoumala, JMI, 2011)
Increase the price of seeds	10 (33%)	'At the beginning there were only 4 cotton producers in the village, but after the 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, JMI, 2011)
Establish a credit system for fertilisers similar to the one introduced in the cotton market	9 (30%)	'We do not want fertilisers for free, donation is not good. We need a transparent mechanism of credit, with clear access conditions and eligibility criteria' (Male farmer, Zena, MFC, 2011). This would increase farmers' motivation in growing successful Jatropha crops. In a intercropping system, both Jatropha and food crops would benefit from the inputs provided, which might improve cereal yields and, hence, food security: 'The credit system would be a stimulus to take care of our [Jatropha] crops and would also improve cereal production' (Male farmer, Sorona, MFC, 2011)

net in relation to a variety of shocks and stresses, allowing a shift between different capital assets and helping to make livelihoods more sustainable. *Jatropha* is 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 cotton sector (Theriault 2011).

Nevertheless, the harvest and sale of seeds alone is not perceived as profitable. The lack of human and physical capital, together with a high incidence of pests and diseases, hamper achievement of optimal yields. Seed sale prices remain low. 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. It must also be considered that the evolution of the cotton market, in which revenues are currently higher than those from *Jatropha*, plays an important role in determining the uptake of *Jatropha*. Bigger revenue generation potential is currently offered by production and commercialisation of soap, a *Jatropha* by-product. Household-level analysis indicates that provision of adequate farmer support, training and improved communication are vital to allow the expected benefits to materialise (as per Achten *et al*. 2010; Garg *et al*. 2011) and to enhance livelihood outcomes. These key concerns need particular attention in the initial phase of implementation of pilot project activities, when the trees have not yet reached maturity. Project developers and policy-makers need to acknowledge this issue and recognise that potential growers may be reluctant to invest in a crop that does not bring obvious, immediate livelihood gains.

Community-level analysis shows that projects promoting the use of *Jatropha* oil offer potential to enhance rural energy. Project developers in Mali attempt to achieve this goal by providing local pressing facilities, power generators and multi-functional platforms, yet these are not currently powered by *Jatropha* oil. Increases in both physical and financial capitals derived by promotion of *Jatropha*-fuelled energy could favour transfers to other forms of capital and offer new opportunities to reduce seasonal vulnerabilities. However, local-level benefits in terms of diesel substitution and energy generation are still lacking and the potential has not been realised. It is vital to recognise that *Jatropha* is not a wonder crop: adequate support from project developers and extension networks is required to expand access to electricity and mechanical power for agriculture.

Our study shows that smallholder farmers look unlikely to replace food production with *Jatropha* farming at the household level thanks to the establishment of agroforestry systems. No land trade-offs were observed. While productive plantations require this crop to be grown on fertile land, *Jatropha* cultivation is widely used as a land management strategy to reduce soil erosion, demarcate field boundaries and avoid land tenure conflicts. Farming calendars indicate that labour trade-offs occur as the harvest period of *Jatropha* overlaps with that of cereals and cotton. Labour competition limits the expansion of *Jatropha* agriculture. Promotion of intercropping is essential to allow the minimisation of labour trade-offs with food crops. It should be recognised that availability of natural and human capital (e.g. fertile soil and knowledge of farming techniques) plays a

dominant role in the achievement of satisfactory livelihood outcomes with relation to *Jatropha* cultivation. These factors are more important than farmers' income levels, suggesting that *Jatropha* can offer valuable diversification alternatives to poorer households who have limited capacity to expand their livelihood portfolio.

This study has outlined key aspects that should be considered in the establishment of small-scale *Jatropha* supply chains. Despite the promising claims surrounding *Jatropha*, there are a variety of barriers that project developers and policymakers need to overcome in order to achieve successful outcomes. The paper provides empirical evidence on the role that *Jatropha* cultivation can play in fighting poverty and fostering rural development if locally appropriate support is provided by local and national institutions.

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Notes

1 The average cultivated land in sparsely populated semi-arid areas of Africa accounts for 10 ha (Salami *et al*. 2010).

2 The multifunctional platform consists of a source of mechanical and electrical energy provided by a diesel engine. It can power various tools, such as a cereal mill, husker, welding equipment, alternator, battery charger and water pump (UNDP 2004).

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