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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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Driven by growing constraints on energy supplies and the fiscal burden of fossil fuel imports, a number of Sub-Saharan African countries are looking more closely at the use of biofuels for transportation and domestic purposes. They also view biofuels as a potential option for improving rural incomes. Senegal, Tanzania, Mozambique, and Ethiopia are a few of the countries considering--and already engaging in--the development of biofuels feedstock production and processing capacity. Because these countries include the developing world's poorest and least food-secure countries, some observers are concerned about the implications for local-level land use availability and communal rights and national-level food security. Biofuel projects in many sub-Saharan African countries such as Ethiopia, Kenya, Madagascar, Mozambique, and Tanzania are export-driven and prompted by investment from such external agencies as European companies (Bekunda et al., 2009). At present, there are two jatropha production models in Africa: commercial production on estates (plantation) and an outgrower model, which involves farmers growing Jatropha on smallholder lands and using family labor to collect seeds for sale to local processors. This paper focuses on the outgrower model to assess farmers' production decisions with respect to growing jatropha, specifically seed production to supply to the foreign companies. We do not consider jatropha oil production for local use.

The question we consider in this paper is what conditions need to be met in order for smallholder farmers to enter into and benefit from an expanding jatropha market. Most commercial jatropha production is currently undertaken by large-scale farms, with smallholder farmers planting it as a hedge plant. A number of studies assume that jatropha can be a smallholder crop;

in this paper we undertake a simple thought-experiment to consider under onditions smallholder farmers are likely to enter jatropha production. We take the case of Mozambique, where smallholder jatropha production has been suggested and promoted (Arndt et al 2009, Nielsen and de Jongh 2009).

JATROPHA: A GOOD FIT FOR FOOD-INSECURE COUNTRIES IN AFRICA?

- Used to produce biodiesel or as straight vegetable oil in diesel engines
- Drought resistant and grows on degraded land, making it suitable to Africa's waterscarce climate and abundant "marginal" or under-utilized land¹
- Produces inedible oil; doesn't compete with food crops
- As improved varieties and technologies are developed, smallholder farmers can potentially benefit from the this new cash crop's income opportunities
- As jatropha is more closely studied, its desirability as a biofuels feedstock is increasingly questioned
- Its yields under marginal conditions are low and its need for more intensive production practices on better-quality soils risk competition with food crops²
- Realization of its potential requires a number of economic and agronomic condi-

tions to be met, and may prove to be elusive for some regions.

1Ambiental and UNAC,, 2009; Field et al. 2008

IMPORTANT GENDER CONSIDERATIONS

- We can also examine some interesting aspects of gender that enter into the picture when we consider:
- Men –whose opportunity cost is related to cash crop farming or other off-farm labor

Women – who are mostly involved in food production (like in the case of Mozambique) and for whom a diversion of labor towards jatropha production means exposing the household to volatility in prices as the household goes to the food.

Due to the difference in the role men and women playing in household production, investment in jatropha may have indirect implications on labor allocation to food versus fuel crops. Traditionally, men are more engaged in cash crop farming or other off-farm labor, as compared to women who are predominately involved in food production (like in the case of Mozambique) (Arndt et al., 2010; Asbjørn Eide, 2008). As women divert labor towards jatropha production (cash crop production), food crop production is expected to reduce and food prices are likely to go up. As a result the conditions under which cash crop producers (more likely men) will switch into Jatropha might be quite different from the conditions under which food crop producers (more likely women) will switch into Jat-

Due to the traditional role women play in food production, some are concerned about the risks that women will face if large-scale production of feedstock for biofuel goes ahead, due to, for instance, constraints of resources such as water and other inputs, and the loss of common property resources available to female farmers existed on the marginal land (Asbjørn Eide, 2008). For smallholder biofuel crop production, however, the pathways of impact on women could be different and very much depend on the production model adopted. Let's consider this in light of some alternative cases:

• In the case when farmers bring marginal land into jatropha production, women may be involved by providing the labor needed. While increasing cash revenue, women would have to extend their working hours beyond their labor input for food crop production. • In the case of switching from one cash crop to jatropha, the impact on women is likely to be small, unless the cultivation of jatropha is more labor intensive than the displaced cash crop, which is very likely as jatropha seed harvest has been shown to be very labor intensive.

• In the case of switching from food production to cash production, women's labor input is indeterminate, although it is possible that more labor is required for a more profitable cash crop than food crop. While the household may be earning more income as a result of jatropha production, they are also more exposed to the food price volatilities.

The gender dimensions of biofuels and their economic impacts are often not well-addressed in the literature, and should be explored further as issues of high importance and relevance when considering household-level decisions and welfare.

Understanding smallholder contraints to jatropha investment Ruth V. Hill, Siwa Msangi & Wei Zhang

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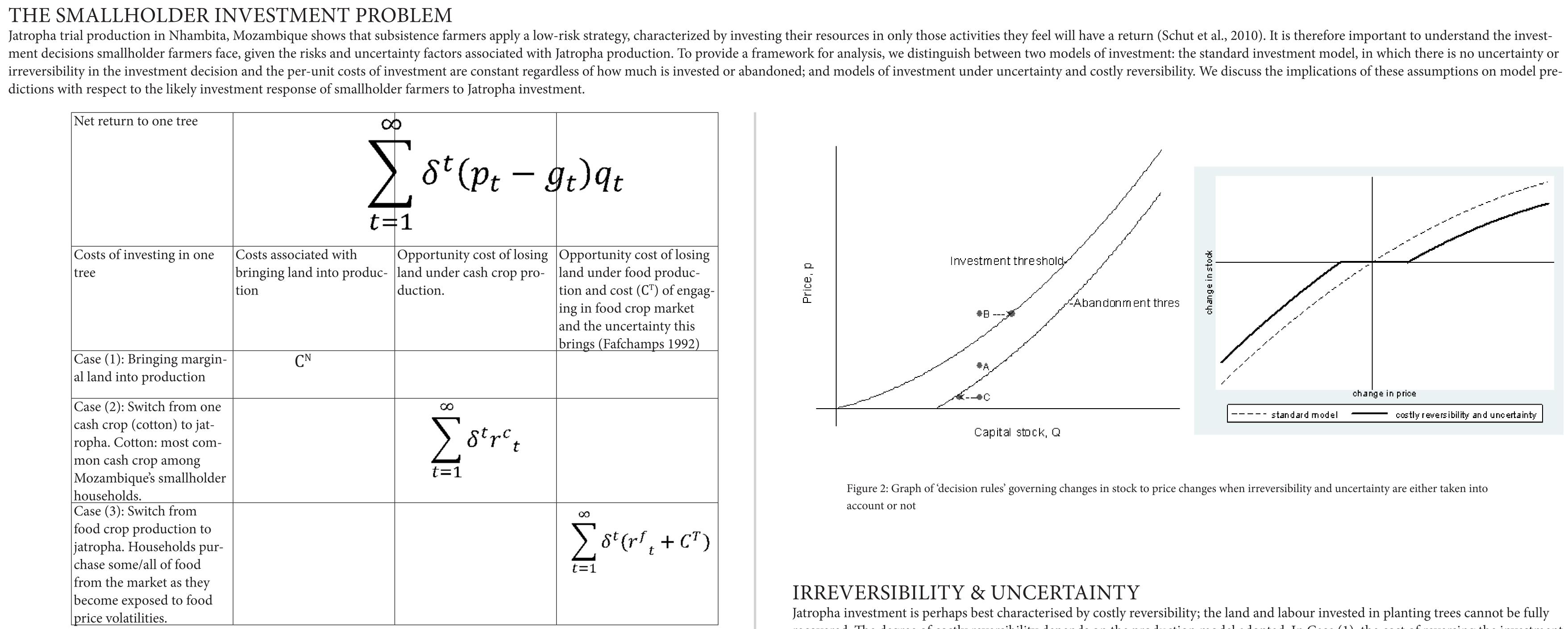


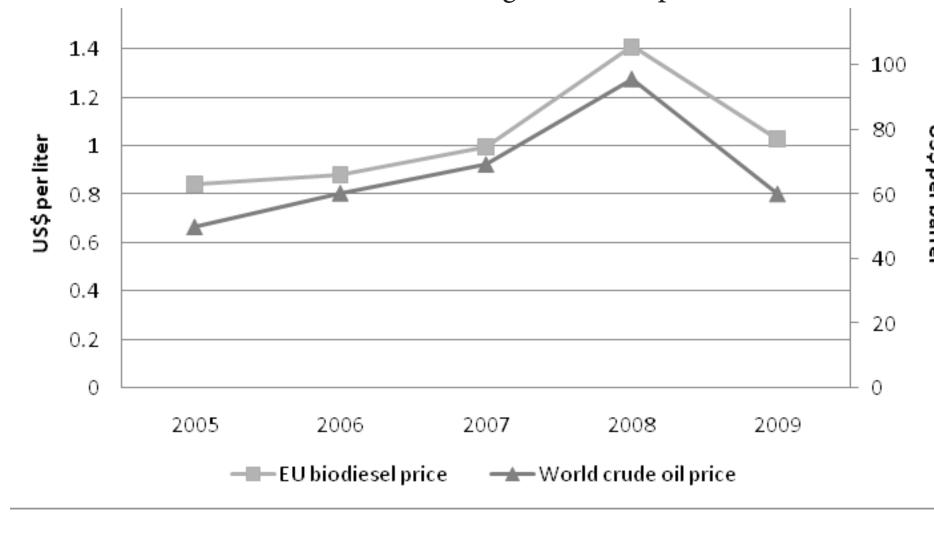
Table 1: Three cases of the standard investment model

Jatropha also faces uncertain returns. Uncertainty results from: Uncertainty over yields; uncertainty over the price; and uncertainty over THE STANDARD INVESTMENT MODEL the price of food in C (3). Uncertainty over yields and prices may fall over time as knowledge about jatropha increases and the market Under a standard investment model (Jorgenson 1963; Tobin 1969), jatropha investment will occur whenever the present value of develops. However, quite some uncertainty will remain to the extent that the biodiesel price is integrated with the oil price – which may the stream of profits resulting from investing in one tree, V_t, is greater than the unit cost of investing in that tree, C. The present or may not translate directly to the dynamics of jatropha prices, depending on how integrated the value chain of production becomes. value of the stream of profits resulting from investing in one tree is given in Table 1 (where p is the unit price and g the unit cost of We thus turn to models of investment under uncertainty and costly reversibility (Dixit and Pindyck 1994, and Abel and Eberley 1994). production of one unit of output, q (we could think of this as being one kilogram of jatropha seeds). To consider the costs of in-To the extent that we can consider Jatropha prices as being characterised by a Wiener process (or at least perceived as such by smallvestment in one jatropha tree, we consider three distinct cases, as described in the following paragraphs and summarized in Table holder farmers), the investment models of Abel and Eberly and Dixit and Pindyck provide some insight into the production behaviour that is likely to result.

Unlike other cash crops, jatropha can grow on marginal or wasted land with little or no input, although yield under good soil and input conditions is substantially higher. This unique feature offers farmers the option to bring marginal land into production, making Jatropha a unique case to study smallholder's investment decisions. In this case (Case 1), the costs of investing in one jatropha tree include costs associated with bringing land into production (labor and necessary inputs) as well as the labor and other cultivation costs.

In Cases (2) and (3), we address the food-cash crop interactions. In Case (2), farmers switch from one cash crop to jatropha. In addition to labor and cultivation costs, there is also an opportunity cost of losing land under cash crop production. The switch is triggered by the expectation that the expected return of planting jatropha trees is greater than expected return of growing other cash crops. The proportion of purchased food in all food consumption remains the same, while the household's cash revenue may be different from before. In Case (3), farmers switch from food crop production to jatropha. Costs related to Jatropha investment therefore include the opportunity cost of losing land under food production and the cost of engaging in a food crop market and the uncertainty this brings (Fafchamps 1992), in addition to the labor and cultivation costs.

EMPIRICAL EVIDENCE: THE EXPECTED VALUE OF JATROPHA PRODUCTION Since a Jatropha market still does not exist, information on producer price is rare, and the few estimate the domestic market price in Mozambique to be \$278/ton, assuming the market value is about twice of the produc-



might also be exposed to volatility in the prices they receive for jatropha seed. farmers are earning about one-third (33%) of the EU biodiesel price. et al., 2007)

Published yield estimates range from 0.4 to 12 tons of seed per hectare per year (Jongschaap, et al., 2007) with little evidence to explain the large differences. D1 Oils, a UK company which has extensive planting programs in East and South Asia and Africa, expects oil production under the best conditions to be 1.7 tons of oil per hectare from wild jatropha plants and 2.7 tons of oil per hectare from selected varieties on well managed plantations (D1 Oil, 2009). Econergy et al. (2008) report a low seed yield of 3 ton/ha and a high yield of 4 ton/ ha for Mozambique. A generally accepted expectation is that seed yields will be 3.0 tons per hectare initially and higher yields will be 3.0 tons per hectare

If we assume yields of 3 tonnes per hectare, and a conversion rate of 1 kilo of seeds to 4.5 litres of biodiesel (Nielsen and de Jongh 2009) then one hectare can be expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and an expected life of a discount rate of 0.8 and a discount 40 years, the net present value (gross) of investing in a Jatropha plant is \$372. To the expected present value under uncertainty. However under uncertainty, this expected present value will need to exceed the costs of investment by a factor of $\beta/(\beta-1)$.

Jatropha investment is perhaps best characterised by costly reversibility; the land and labour invested in planting trees cannot be fully recovered. The degree of costly reversibility depends on the production model adopted. In Case (1), the cost of reversing the investment is likely to be small if farmers simply abandon the trees on the otherwise unproductive lands or leave them as unharvested farm hedges. There may, however, be some cost in abandoning the land if the farmers had previously invested other capital in addition to their own labor when converting the land For Cases (2) and (3), however, the costs of reversing investment involve uprooting the Jatropha trees and restoring the soil when necessary to a suitable condition for growing food or cash crops.

The investment models of Abel and Eberly and Dixit and Pindyck predict that an investor may choose to wait to invest even if $V_t > C$ on account of the additional option value of the investment, $F(V_{t})$, that is lost when the investment is made. Investment only takes place when V_{t} - $F(V_{t})$ >C, i.e. when $V_{t} \ge \beta/(\beta-1)$ C where β (the solution to the fundamental quadratic) is greater than 1 and decreasing in uncertainty, σ . Figure 1, below, shows that the decision rule for how an investment stock should be managed differs from the standard model, when irreversibility and uncertainty are taken into account. The 'flat' spot in the decision rule curve that accounts for irreversibility and uncertainty represents the magnitude of the quantity V_{t} - F (V_{t}) in the decision problem.

To summarize, we can argue that models that account for irreversibility and uncertainty in the decision process have the following implications for the investment behaviour of rural smallholder households.

• Prices will have to be higher than needed for net revenue for households to invest in jatropha.

- Jatropha price increases will need to be large to result in large new investments in tree stocks.
- Once planted, farmers may be reluctant to uproot jatropha even when the price falls.

tion cost. However, Nielsen and de Jongh (2009) report that, in 2009, smallholders in Mozambique were commonly paid \$75 per ton for Jatropha seeds, and this is quite consistent with evidence from Tanzania. In Tanzania, foreign companies typically pay about \$100/ton for Jatropha seeds, but most outgrowers only get about \$70/ton, with the middlemen earning the \$30/ton margin (Thornhill, 2010).

Given biodiesel is a substitute for petroleum, biodiesel prices are driven, in part, by world oil prices. This is indicated in Figure 2, which shows that the annual EU biodiesel prices and world crude oil prices are highly correlated 2005–2009. Given the considerable volatility in world crude oil market, we expect that biodiesel prices would more or less track oil prices, and therefore, remain highly volatile. If the value chains of biofuel production within the country are closely linked to these markets, and transmit the world price movements strongly, then smallholder jatropha farmers

Taking a conversion rate of 4.5 kg of seeds to 1 litre of biodiesel (Nielsen and de Jongh 2009), when we combine the data on farm-gate prices in Mozambique with the EU biodiesel price, we see that

While at present there is no information available on the value of jatropha oil meal, the by-product will likely have some value as a boiler fuel or fertilizer (Cargill, 2009; Econergy et al., 2008). For smallholder farmers, the meal as fertilizer can be used for the continued cultivation of jatropha (therefore reducing the cost of production if it displaces existing fertilizer input or increasing yield if there is no fertilizer being applied) or sold for cash. By-product values may be important contributors to revenue, but market tests are needed.

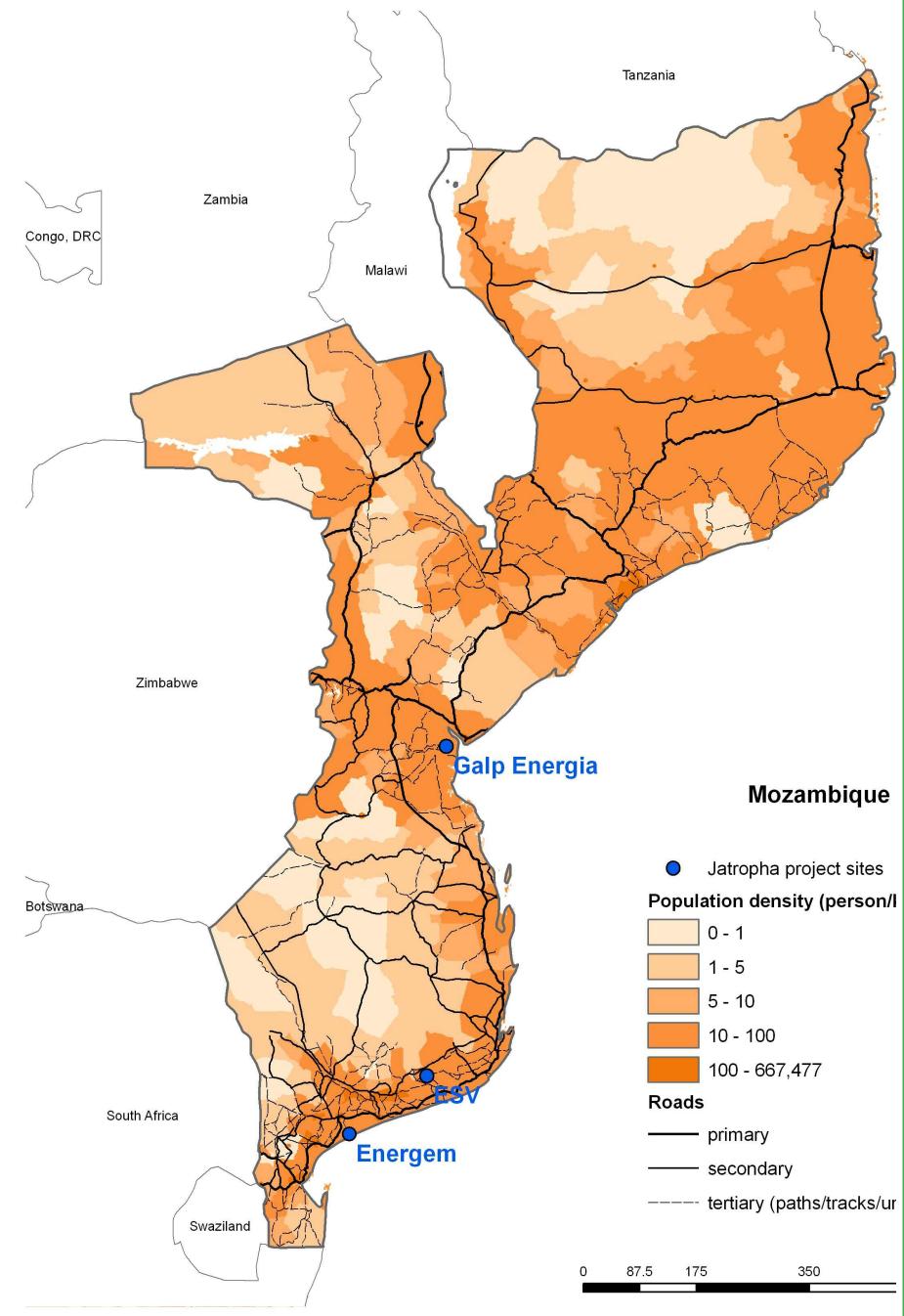
Very little reliable information is available about jatropha yields and oil production. In addition, there is little information on the yield potential under different agro-climatic zones (Bekunda et al., 2009). Significant seed production typically does not establish until the third year and it takes about 4 to 5 years for jatropha trees to reach maturity. Yield is also highly corrected with agronomic conditions. Yield on marginal and degraded lands is very little. However, it grows well on good soils, with adequate moisture of 600 mm or more per year, and it responds well to fertilizer (Ghrosh,

INVESTING IN JATROPHA UNDER THREE STANDARD INVESTMENT MODEL SCENARIOS¹

Case 1: Converting marginal land to jatropha production

The opportunity cost of land is low if farmers use marginal or degraded land. The only opportunity cost is labor and input that would otherwise be used for other activities. Arndt et al (2009) assume the cost of bringing in nonfarmed land to be zero, based on the assumption that it is off-season labor will be used to cut-down existing growth and cultivate the land. Whilst this is certainly a lower bound, it may be that the costs of bringing land under production are low. However, it is worth considering the extent to which farmers actually are able to bring non-cultivated land into production. Whilst it is a well-known fact that very little of Mozambique is farmed and many districts have low population densities (Figure 3), the rural population is concentrated in a few areas within districts. The large tracts of uncultivated land are often areas of dense forest and with little infrastructure. Even if land is going to be cleared for Jatropha production, it is not clear that it is going to be smallholder farmers that are doing this. This may require large-scale operation to invest in clearing the land and building infrastructure. There are a number of indicators that in those areas where land is cultivated, land is under pressure and there may not be large amounts of new land that can be brought under cultivation by smallholders (Strasberg and Kloeck-Jenson 2002):

• There is significant fragmentation of household's land holdings, such that 95% of households cultivate three or more parcels. The average number of parcels is 5, and they appear to be geographically dispersed in that 59% of parcels are 31 minutes or more from the homestead.



- Fallow periods have declined in recent years and sampled Figure 3: These are the 12 ongoing project sites in Mozambique. Source: Stephen Thornhill, University College Corkhill households attribute this to growing land scarcity
- 83 percent, or over four of five rural households sampled, perceive that land conflicts are a problem within their communities and 23 percent of sampled households reported having had a land dispute at some point.

Cases 2 and 3: Land is converted from other uses

If farmers grow jatropha on existing crop land, there is opportunity cost of land in terms of forgone return from cash crop or cost of purchased food if the household would otherwise use the land for subsistence farming. We can relate the opportunity cost to the value marginal product of an alternative crop that could have been grown on the land used for Jatropha or some other resource that has gone into jatropha production (labor, capital, yield-enhancing input).

Traditionally, Mozambique's most important cash crop is cotton; this is the case we consider here. Cotton yields a gross return of \$100 per hectare on average (Benfica et al 2005) and has a net present value of \$400. Assuming maize and cassava prices of 20 cents and x cents per kilo this gives returns of \$200 and x per hectare respectively.

• The two most important cereal crops are maize and cassava (3 and 2.3 million hectares of land planted to maize and cassava respectively in 2006/7). The average yield of these crops is about 1 and 7 tons per hectare respectively (all data from the Crop and Early Warning Department, Ministry of Agriculture, Mozambique). Taking the example of maize and assuming maize prices of 20 this gives a return of \$200 per hectare. Taking the return to maize production, and again assuming a discount rate of 0.8, this would give a net present value (also assuming constant prices) of \$800

Comparing costs and prices, we can see that at current prices farmers will not choose to plant jatropha, even though it's yearly return is higher (this is driven by the 5 year maturation period).would result in investment under a higher level of volatility in jatropha prices

The opportunity cost depends on the alternative use of the land the labor required to cultivate Jatropha

CONCLUSIONS

Our analysis shows that the decision that small-holders are likely to adopt when deciding whether or not to plant jatropha is highly dependent on the forgone returns to other alternative agricultural activities and the level of uncertainty associated with jatropha yields and prices. In the numerical example we have used, farmers would not forgo their food or current cash crop activities to plant jatropha, based purely on expected returns. We have not exhaustively identified the range of contractual arrangements that companies might offer to smallholders, though, in order to encourage outgrower participation. So there might be a set of contracts that would prove more favorable, especially if they were able to offset some of the risk and uncertainty. We have likely under-stated the consumption-side risk to farmers, as we have treated their production and consumption decisions as separable, and have not brought in some considerations of household utility and aversion to risk in consumption that might further raise their threshold to participate. The gender dimensions of the problem are also striking, as men and women are known to have significantly different distributions of their labor in agriculture (Arndt et al. 2010). Much depends, however, on the labor intensity of jatropha relative to other alternative activities, as there could be a net savings of labor (and time for other market or non-market activities) for women, if jatropha is less labor-intensive for them. Since there is a wide heterogeneity of household types, it would seem advantageous for biofuels companies to offer a menu of contracts to smallholder farmers, so that they can select the terms of their payment and contract based on household characteristics that they themselves have better information on than the contract principal. For example, some might prefer partial payment in food goods or vouchers to offset the risk they may face in food markets, whereas others might prefer all-cash payments. The design of such contracts should be guided by empirical evidence of farm household characteristics, perhaps even using in-field experiments, and is being considered for an ongoing program of research in this area.