JATROPHA SUPPORT PROGRAMME

Pipal Limited

THE ECONOMIC VIABILITY OF GROWING JATROPHA CURCAS AS A SUSTAINABLE BIOFUEL FEEDSTOCK IN EAST AFRICA

David Lebun and Joseph Kiptoo taking germination data at Saffron Energy Ltd., Laikipia, 2009

EXECUTIVE SUMMARY

MAY 2012

Background to the project

The Jatropha Support Programme (JSP) is a private public partnership project co-financed by Deutsche Investitions- und Entwicklungsgesellschaft (DEG) with funds from the German Ministry for Economic Cooperation and Development and nine East African companies. These parties found a complimentary set of interests. More details on the institutional arrangements can be found in Annex One of the separate Annexes document. The companies in East Africa continue to face the challenge of increasingly expensive and sometimes unavailable energy to power their farms, equipment, processing units and vehicles.

In 2007, when the project was conceived, jatropha was being lauded as a wonder biofuel crop that could grow on marginal soils in arid and semi arid areas. One of the main factors in its promotion remains the fact that the oleochemistry of straight and trans-esterified jatropha vegetable oil allows it to be used in a much wider range of temperature and engine conditions than many other primary and secondary biodiesel feedstocks and, along with camelina and algae, it is one of the main natural oils suitable for aviation kerosene.

The aim of the DEG Jatropha Support Programme has been to give an informed response to the question: 'Under what conditions is it economically viable to grow jatropha as a commercially sustainable biofuel feedstock in East Africa?' In line with conventional wisdom, the benefits of the DEGJSP project were anticipated to include 1) bringing potentially marginal land into cultivation, 2) developing optimal cultivation and production processes for jatropha, and 3) promoting low emission fuel that may contribute to mitigating climate change.

In this project, provenance, spacing and pruning, agronomy, micronutrient, economic, and pest and disease trials were conducted at nine agro-ecologically different sites located 2000 km apart. This fieldwork aimed to produce practical results that could guide future investments. The provenance trials used 22 different accessions planted in plots of 9 plants each, which were replicated five times. Most of the trials were planted in potentially limiting or fair agro-climatic conditions, both in terms of minimum temperatures and average rainfall patterns. Furthermore, initial growth at many of the sites was restricted by the 2009 drought. The establishment and performance of the trials was monitored over a three-year period. Some basic observations from the data collected are shared in this summary, as well as in the first half of the main report. Jatropha takes five to six years to mature, so any discussion of potential yields, harvesting, processing, commercial sustainability, and social, environmental and regulatory data rests on discussions and feedback with other practitioners and extensive background desk research.

The companies

The companies involved in this project were interested in discovering if a small- to medium-sized jatropha plantation could support their own energy needs. The pilot project targeted companies with which DEG either has a current relationship or may form a relationship to co-finance such investments in the future. In almost all cases, this meant that the 10 hectares of land the companies were able to dedicate to the project would be in close proximity to their existing operations, which were predominantly in Central Kenya.

Results from the project suggest that, at this point in time, the potential for commercial success rests on growing rain-fed jatropha under potentially optimal agro-climatic conditions. Very few such conditions exist naturally in East Africa, and thus have to be created by using adequate inputs and proper management. Reliable high-quality jatropha seeds are also required, planted at the right time and managed using appropriate agronomic practices. Temperatures, rainfall and atmospheric humidity, as well as altitude are all important factors to consider in deciding on site location. An informed choice of a plantation site will reflect a balanced set of cost-benefit risk assessments inclusive of a range of factors. As seen below, most of the DEGJSP sites were not in optimal agro-climatic zones for jatropha and so performed poorly during the period of observation.

Table 1 List of companies and lcoations of sites

Company Name and Location	Altitude masl.	Average Rainfall mm p.a.	Annual temperature Min	Max	Mean	Normal Commercial jatropha production potential.
Kenya						
REA Vipingo Plantations Ltd. -Kilifi	45	1200	22	37	24.5	Optimal/Fair
Kofinaf Company Ltd.-Thika	>600	970	8	31	25	Limiting – Dry/Cold
Tropical Farm Management (Kenya) Ltd. -Makuyu	1500-1750	900-1020	8	31	24	Limiting – Cold
Lesiolo Grain Handlers Ltd. (LGHL)-Nakuru	1950	700-965	18	30	21.5	Limiting – Dry
Small-scale extension in Bungoma	1400	1100-1300	11	32	21.5	Fair
Kordes Roses East Africa (Kenya)-Nairobi with Saffron Energy Ltd. Kenya- Laikipia	1850	525	12	32	16	Limiting – Dry/Cold
Vegpro Kenya-Naivasha	1750	450-770	6	32	24	Limiting – Dry/Cold
Economic trials in Kibwezi	1900	400	17.5	31	24	Limiting – Dry
Tanzania						
Minjingu Mines and Fertilizer Ltd.-Manyara	1200-1400	500-700	15	37	25	Limiting – Dry
Tanganyika Wattle Company Ltd.-Mbeya	1800	1100	-6	27	16.5	Limiting – Very cold, long dry season
Uganda						
Multiple Hauliers (EA) Ltd.-Masindi	1158	1100-1400	16.8	30.1	25	Optimal/Fair

A brief description of each site is given in the separate Annexes Document: Annex Two.

General East African agro-climatic conditions and potential

Maps based on average annual temperature and rainfall patterns do not capture the seasonality that limits the window for commercial jatropha establishment and long-term viability. Some potential was witnessed under normally limiting conditions related to East Africa's erratic weather, and a few well-funded and serious research companies are working hard on different ways to improve jatropha yields and 'stretch' the plant. As a result, very conservative variables were chosen to demonstrate the seasonality of planting windows, well aware that generic maps have very low actual predictive value.

1. Temperature:
   - Potentially optimum – 20° C - 32° C
   - Potentially fair – 16° C -22° C
   - Potentially limiting if less than 16° C and above 32° C for 8 months

2. Rainfall

Potentially optimum – >650 mm distributed evenly over at least 6-8 months
Potentially fair – 400-650 mm distributed over at least 6 months
Potentially limiting – <400 mm within the first 6 months

3. Altitude

Potentially optimum – 0-1200 masl
Potentially fair – up to 1500 masl
Potentially limiting – >1500 masl

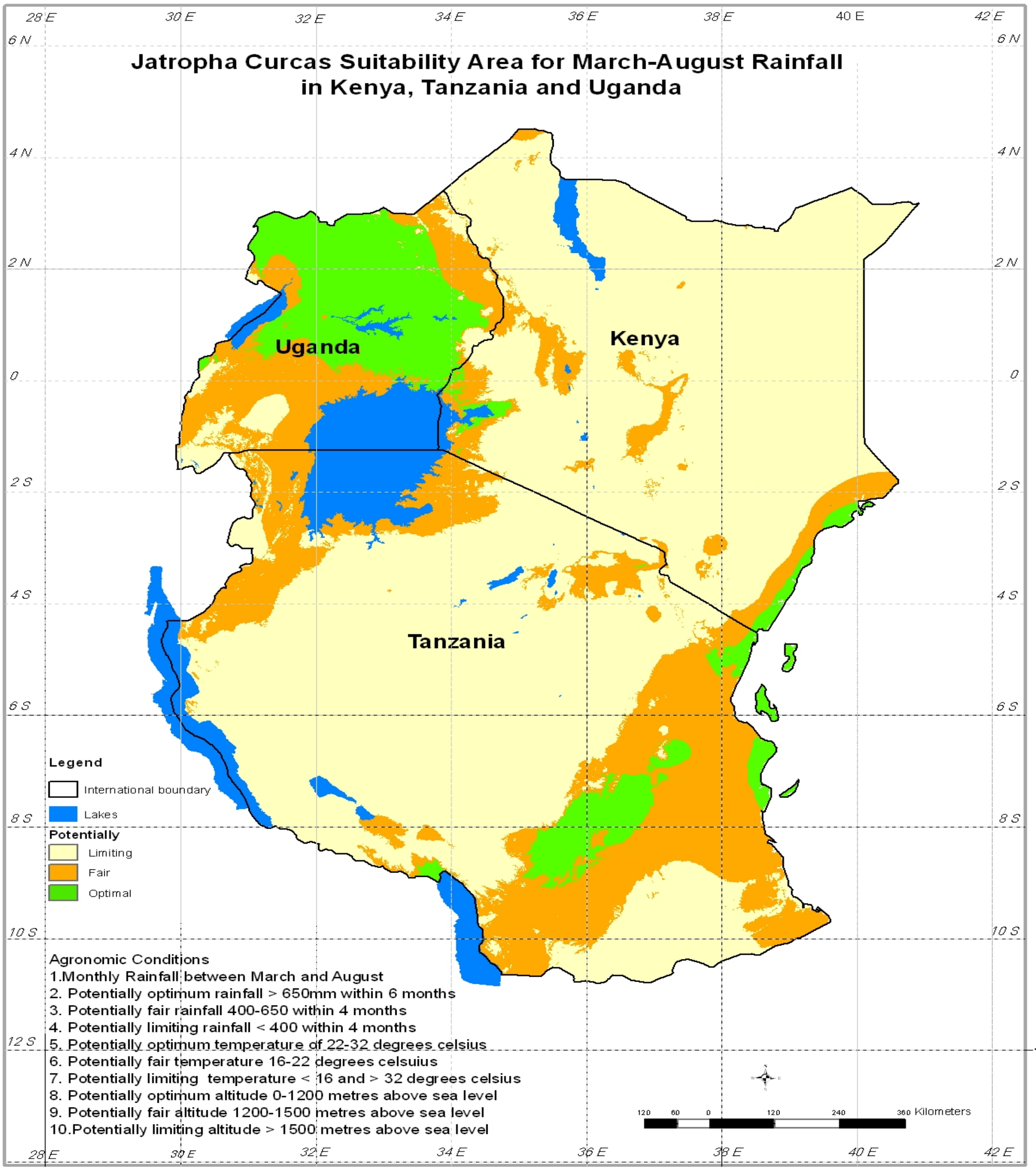

Figure 1. Map generated using monthly averages since 2000 showing levels of potential for jatropha in March.

Figure 1 illustrates the potentially limiting arid/semi-arid belt that runs from Northern Uganda across North and Northwest Kenya through to Southern Central Tanzania. It also indicates that jatropha could be grown in the region's high plateaus and mountainous areas. Moreover, it suggests there exists some optimal potential areas where the tropical coastal monsoons and tropical seasonal inland climates prevail.

The three maps available in Annex Three of the Annexes document, seek to highlight the small planting 'windows of opportunity' that exist within the increasingly erratic East African one- and two-season rainfall systems. Optimal potential depends on jatropha receiving at least 650 mm (optimally 800 mm) spread evenly over the first six months of plant growth. The combined project observations demonstrate that the 'margins of error' for establishing a jatropha plantation are very small in locations characterised by potentially limiting and fair conditions, and risk is still significant even in areas that have potentially optimal conditions. Small increases in rainfall at the right time can have a dramatically beneficial effect, while small decreases can lead to poor results. While temperatures and traditional rainfall patterns at the Kenyan coast are potentially optimal, increasingly unpredictable rainfall patterns make monoculture large-scale commercial production a high-risk business, especially if commercial sustainability depends on repaying initial loans within a certain plantation establishment time period.

As indicated in our original table of sites, the areas that remain potentially limiting whatever planting start date you choose, tend to be too dry and or have too many days and/or nights at less than 15^0 C, usually due to altitude and/or local conditions. With favourable water-retaining soils, jatropha can grow slowly in dry conditions, however it will not be commercially viable without proper water and nutrition management. In Kenya, even though Nakuru is at a higher altitude of 2000 metres, Thika and Naivasha have more frequent cold nights, which limit jatropha growth.

In summary, specific microclimates and local conditions aside, the general mapping of East Africa's average climates suggests there are very few areas within East Africa with optimal agro-climatic conditions for commercial jatropha production. Good varieties, management practices, soil nutrition and favourable erratic rainfall may increase the chances of success in certain areas. Some of the main observations are shared below.

Seeds

The 22 provenances collected germinated to different degrees and the first conclusion was that the seeds carry some adaptability to the agro-climatic conditions in which they matured. The same provenances performed differently in different locations, starting with germination, height, and also in architecture and branching, emphasizing jatropha's high environmental sensitivity.

Germination

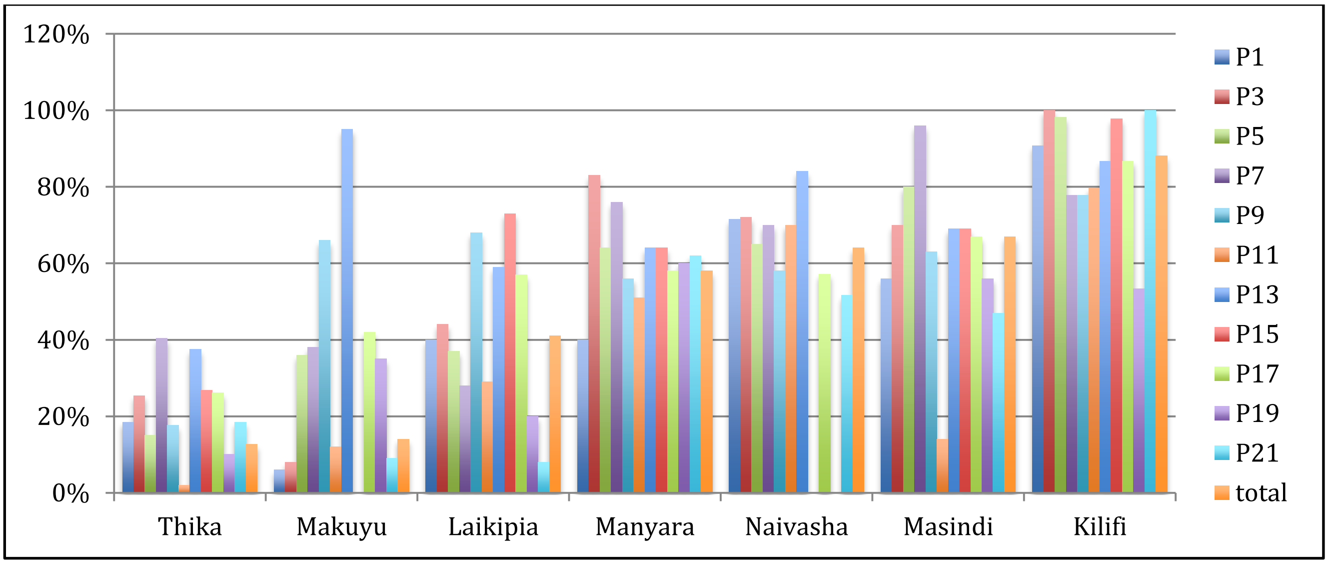

Figure 2. Percentage germination data of selected jatropha seeds at six different sites with different climatic conditions

A germination protocol was recommended and each company soon adopted their own approaches, such as seedbeds grown under sophisticated shade netting, poly bags and those in the warmer climates planting out into direct sand beds. Different provenances in different locations produced different germination rates. Full details are available in Annex Four of the Annexes document.

Germination under warm humid conditions at low altitudes (e.g., Kilifi) was close to 100% when freshly harvested seeds were used, and below 50% in areas were the average temperatures were lower (e.g., Thika). Even at sites in higher altitudes the germination was higher than 50% when the average temperatures were maintained by using plastic or other methods to keep the seeds warm, such as digging trenches and filling with compost mixed soil (e.g., Mbeya). These findings support others in saying optimal germination for jatropha occurs between 27-30^{0} C. Even with mitigation techniques, this temperature is hard to maintain under fair and limiting temperature conditions, except in specific seasons. Due to the 2009 drought, the project seedlings were either planted out to face drought or stayed for an overly long period in the nursery, both of which negatively affected initial growth.

The challenge for East Africa is that for optimal larger-scale germination of any direct field planting, the warmer months preceded the increasingly unpredictable long rains, and the months before the shorter August-October/November rains are cooler. More expensive nursery operations allow for a greater margin of unpredictability at the start of the rains, some degree of stronger seedling selection, and early pest and disease management. If fresh seeds are sown during seasons where ambient temperature are high and soil moisture can be maintained, direct sowing can be used. In such cases, the soils need to be deep, loose and fertile. Under these circumstances, 2-3 seeds may be sown per pit so that robust seedlings can be retained and others can be removed in due time.

Oil Content

The percentage oil content of the daughter seeds of a number of provenances, some over a 2-year period, was highly varied and no particular conclusions could be drawn at this point.

Variations in growth patterns between the provenances and the different sites

The growth patterns of the same provenances in different sites were very dependent on rainfall and temperatures, and to some extent soil fertility, humidity, management practices and pests and diseases.

Figures 3 and 4 show the average of data taken from 15 plants per provenance spread over 5 replicative blocks. By illustrating the average for each provenance, the tables do not show that, despite a certain amount of selection of seedlings in the nurseries, there was great variation also seen between individual plants of the same provenance in the same plot. This again emphasizes the need for true-to-type breeding and the high risks of using wild seeds in directly seeding large commercial plots.

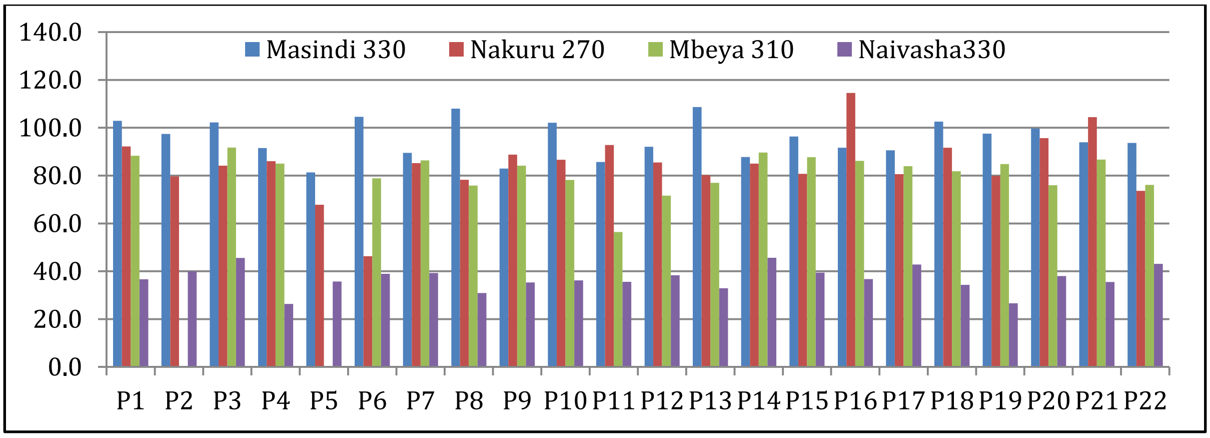

Figure 3. The averge height in cm of the provenances after 330, 270, 310, and 330 days in Masindi, Nakuru, Mbeya, and Naivasha, respectively

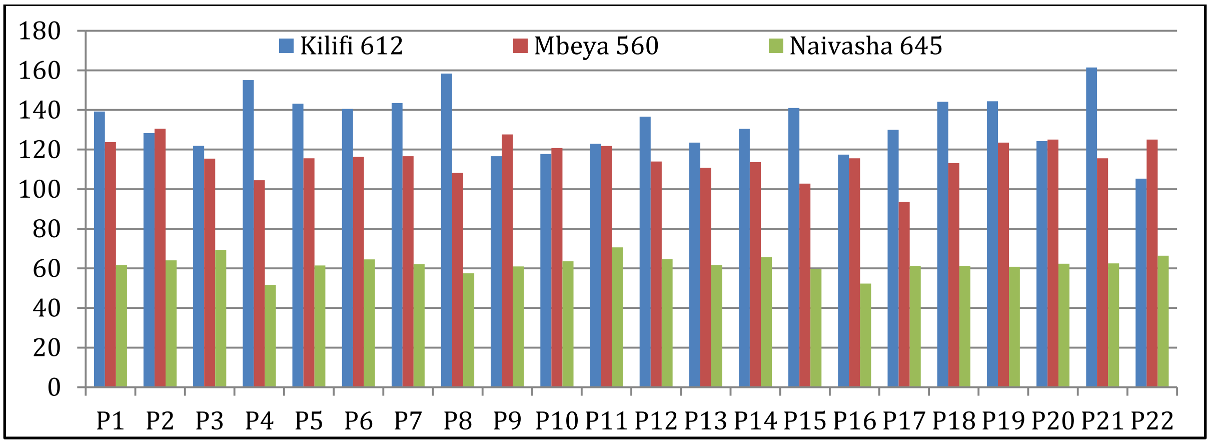

Figure 4. Average height in cm of each provenance, 612, 560, and 645 days after planting out in Kilifi, Mbeya and Naivasha, respectively

The different provenances showed differences in growth performances within and across sites. No correlation was found to initial seed weight. There also seemed to be some preliminary indication that provenances originating from high altitude regions, such as P11 (origin 1400 masl) and P16 (1300 masl) performed relatively better in high altitude regions, and those originating at lower altitudes did better in lower altitudes and worse in higher altitudes. However, with so many factors coming into play this has not been demonstrated definitively across all sites.

In some very limiting sites, it was clear that some seeds had impressive vigour compared with others. The results also suggest that within one site, the heights of each provenance at planting out were not a good predictor of the relative height of each provenance after 12 months. However, the heights of each provenance at 12 months were a good predictor of the relative height of each provenance at 20 months, especially after the second rainy season. One of the big challenges for commercial plantations is whether to leave or replant jatropha that starts slowly, perhaps due to late or erratic rains. The findings of this study concur that jatropha needs to grow smoothly and optimally in the first six months to have useful yields. The following charts show the meteorological conditions for the growth charts above.

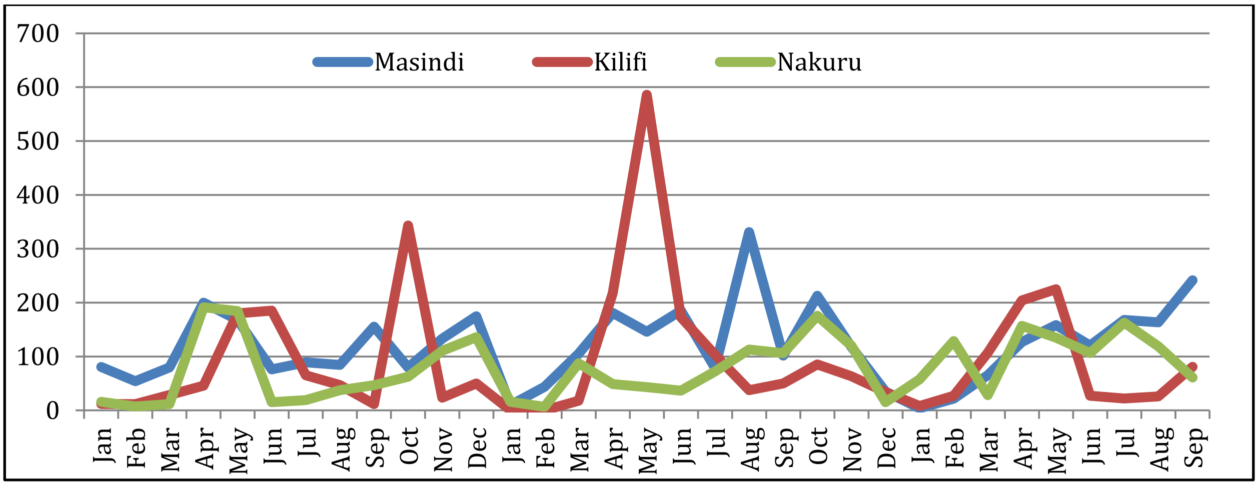

Figure 5. Average monthly rainfall in mm for Masindi, Kilifi and Nakuru Jan 2009-September 2011

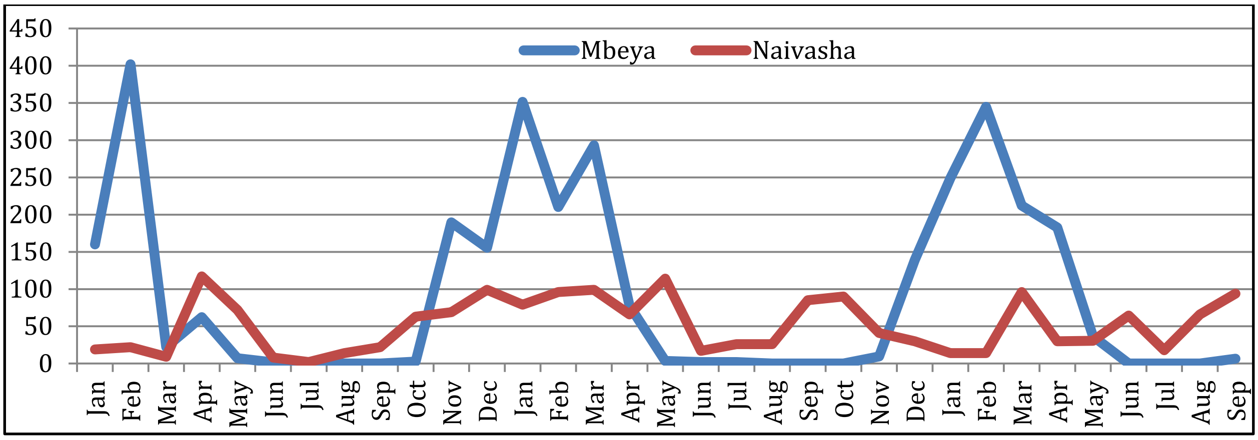

Figure 6. Average monthly rainfall in mm for Mbeya and Naivasha, January 2009-Septemeber 2011

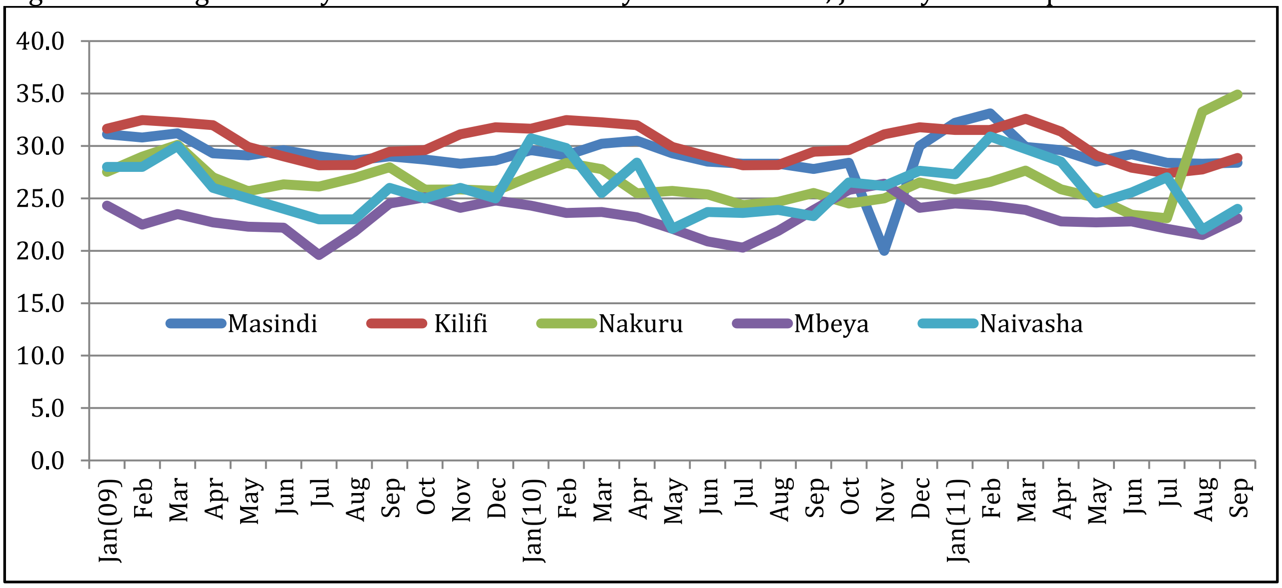

Figure 7. Average monthly maximum temperatures in degrees ^{0}C for Masindi, Kilifi, Nakuru, Mbeya and Naivasha

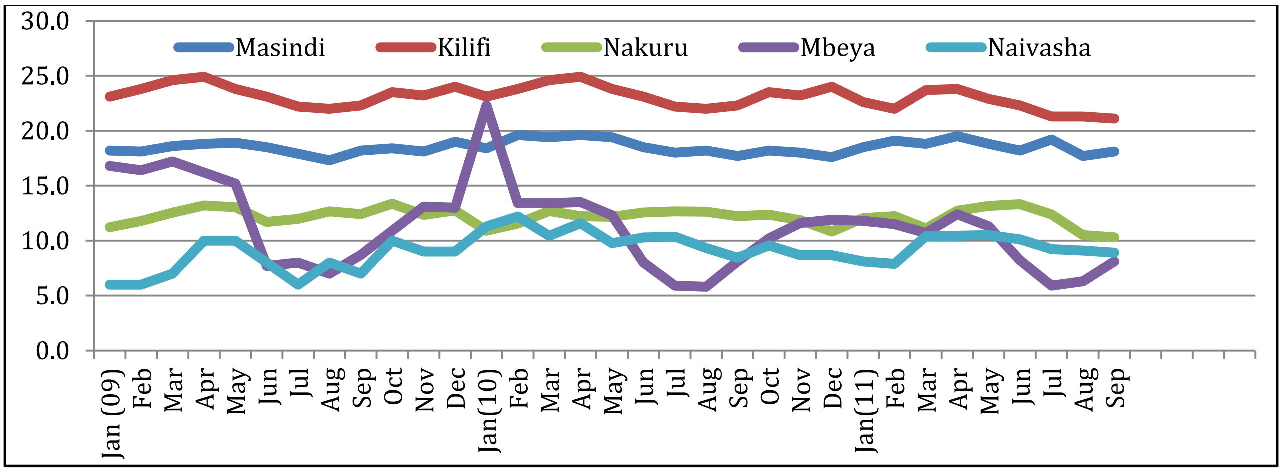

Figure 8. Average monthly minimum temperatures in degrees ^{0}C for Masindi, Kilifi, Nakuru, Mbeya and Naivasha

As seen from the charts above, the variations in minimum temperature is a much greater contributory factor to jatropha growth than maximum temperatures, especially the number of nights below 15^{0} C: lack of adequate rainfall is also a critical factor. The plants in Masindi continued to grow up to 1.8–2 metres high. They had few branches and tended to be tall and thin, probably due to lack of management and pruning. The lack of a distinct dry season may turn out to be a limiting factor in Masindi. In Kilifi, while the plants initially grew quite fast, few reached over 1.8 metres by the end of the project. This could have been due to the dry conditions in which they started, as well as a lack of adequate weeding and nutrition. The site was on a seaward exposed slope, which could have reduced humidity and increased wind exposure, unlike the previously planted and more sheltered cattle boma. Kilifi also experiences two dry periods each year and sudden, rather than evenly distributed, heavy rainfall. This pattern may not suit jatropha as well as a strong mono-modal rain system.

The fact that minimum temperatures in Nakuru, Mbeya and Naivasha dip below 15° C for many months of the year, as opposed to Kilifi and Masindi, will be a main factor affecting growth of jatropha at these sites. Nevertheless it seems that in Nakuru, there may have been a microclimate in which the day temperatures may have been higher than shown by the data from the (in this case) government meteorological station above. This, combined with the low but steady rainfall, allowed the jatropha to grow quite tall, even if the bushes had few branches and produced limited amounts of seeds. In the original 5-year-old plantation, one tree produced 327 fruits after heavy rain, about 0.6 kg, while most produced much less in drier years.

Similarly in Mbeya, despite one or two freezing nights of almost 3^0 C in June/July 2010, which killed all 7000 seedlings in the economic trials, the plants in the provenance trials had been set out three months earlier in a rich peat-like soil in a sheltered yet open place. The morning air in Mbeya has 80-90% relative humidity all year, dropping to between 50-70% towards evening. So, despite very unfavourable minimal temperatures, the 6-month rainy season of between 1100-1300 mm, combined with good soils, perhaps allowed jatropha to at least grow during the rains and use stored nutrients and hibernate during the dry periods. The seed productivity of the plants exposed to such low temperatures could, however, not be monitored during the project period. Only limited flowering was reported in plants that started to flower.

In contrast, the conditions in Naivasha remained too cold and too dry for the plant to grow. This was predicted and so the economic trials were set in Kibwezi, but there they suffered from weeds and poor rainfall. Small additional irrigated trials in Kibwezi fared much better and exhibited early flowering and fruiting in the warmer temperatures.

In summary, above frost temperatures, limiting minimal temperature conditions can be mitigated to an extent by suitable soils and rainfall. However, without compensatory high day temperatures, jatropha is unlikely to flower and fruit at high levels. The effect of limited rainfall (below 950 mm) depends on how and when it is distributed, which is why lower figures were chosen for the mapping. Even though the trial plantations were only beginning to produce seeds, different accessions have different growth potentials in different environments. Seeds from mother plants adapted to certain climatic conditions performed well under similar climatic conditions, as expected. It is important for any potential jatropha farmer to carefully select jatropha seed stock, especially since standard seeds are not yet commercially available. It is best to select seeds from locally adapted, healthy, and high-yielding accessions. If these are not available, seeds from accessions adapted to similar climatic conditions should be chosen. The seed stock should ideally have an average weight above 0.7 g per seed and an oil content of above 35% (w/w) on a dry matter basis.

Roots

The different impact on roots and growth of individual plants in deep and rocky soils, compared to better-aerated and nutrient-rich soils, was clear in Nakuru, Laikipia and Mbeya. Root structure is known to be highly dependent on propagation methods, followed by soil and water availability. Initial root development may have been stunted in quite a few trials by the plants staying too long in polybags before planting out. In Laikipia, directly planted seeds fared better than those long in the nursery. The topsoil in large-scale plantations is often cleared and compacted by earthmovers. This had happened in the agronomy trials in Mbeya. There was higher mortality and disease in the agronomy trials on compacted soils than in the looser soils of the provenance trials. Root rot was visible in an early trial in Naivasha in waterlogged clay soils. Trichoderma has been shown to assist root rot in very wet soils (Ochieng, 2011).

Soil

The myth that jatropha flourishes in marginal soils without additional care has been disproven and ‘marginal soils give marginal yields’ in almost all circumstances. This is perhaps a key factor that creates a push to use nutrient-rich soils for food and higher value cash crops rather than for biofuel production. The pH from the soils below the wild trees from which provenances were collected mirrored the more alkaline soils at the coast and more acidic soils inland, ranging from 8.18 to 5.42. Different pH levels have different consequences for nutrient availability and microbial activity.

Detailed soil analysis tables of all the sites showed that the range of soil fertility was very wide and that most soils had quite serious issues with nutrient availability. The tables of these analyses are available in Annex six of the separate Annexes document. One of the early soil reports from Thika showed the presence of acidic soils and lime was applied. However, the limiting night temperatures and other factors allowed only minimal growth of jatropha there, so no improvement due to liming was visible. As Thika and Makuyu sites are only approximately 30 km apart and had practically the same general agro-climatic conditions over the project period, one explanation for the almost double better growth in Makuyu may be the slightly better soils[1], also demonstrating the sensitivity of Jatropha to limiting or mitigating factors under very limiting conditions. Similarly, the ability of the plants to grow tall in Mbeya in very limiting temperature conditions was probably due to the quality of the soil and high morning humidity.

There was dramatic anecdotal and visual evidence of the positive impact of organic soil fertility. In Rea Vipingo in Kilifi, sisal waste had been dumped on a patch of soil in the middle of an economic trial field and plants located on the more nutritious patch reached up to 2 metres in height and had flowered and fruited with up to 9-10 fruits per bunch in the second year of fruiting. This compared with nearby plants that were a metre or less in height and had few branches and no fruits. Studies emphasize that, as inorganic fertilisers leach in heavy rain, jatropha responds well to a mixture of organic and inorganic fertiliser, but only up to a certain level, beyond which additional fertilization becomes inhibitory. As long as there is adequate soil depth for full taproot growth and suitable soil types containing sufficient nutrients, growth may depend more on adequate drainage and the amount of rainfall received.

Land preparation

While manual labour was used at quite a few sites to prepare holes for the jatropha plants, mechanical preparation was used at others. In Laikipia, the land was prepared by ripping with single tyne (a shank with a blade on the end) to a depth of 40 cm. This was not always easy. At times the tyne would hit hard spots and have to be lifted up and reset to go down the prescribed line. Based on the soil analysis, piles of nutrients at each station described below were placed on that line, so that they were mixed in up to 10 cm below surface. This was done with a two-disc mechanical harrow (powered), which breaks up all the clods and incorporates the nutrients in a single pass.

Branching and plant architecture

Whatever the most commercially viable dynamics of jatropha plantations turn out to be, high yields per hectare depend on optimising the number of branch endings the tree can hold so that each new branch ending produces fruit bunches with high averages of fruits per bunch. In this project, there were many examples of stressed jatropha plants growing with a single stem, and poor branching seems to be a function of limiting agro-climatic conditions. Some pruning was done in the DEGJSP project in the second year, but no effect was reported.

Leaf shedding

Across all sites, trees in the better soils still had leaves when those growing in poorer soils had already started to shed. This was particularly striking at Lesiolo, Nakuru, which is a dry limiting climate. Trees close to a water tap that often ran (providing extra moisture) still held their leaves while others were bare, to the extent that close to the pipe, one side of the tree had leaves and the other not. This pattern may suggest that there is a particular length of drier conditions and temperature drop that triggers leaf drop. Anecdotally, the agronomists in the project noticed that perhaps the longer and colder the dormant period was, the longer it could take for leaves to regrow once the rains come, so maybe regeneration is triggered more by temperature than moisture availability. One of the challenges noticed on the coast was that, due to flourishing golden beetle populations, small new leaves were quickly eaten, which did not give the first-year plants a chance to regenerate.

Flowering

	Kilifi	Masindi	Manyara	Nakuru	Makuyu
Reported number of days between transplanting and the first flowering on first provenance	132	145	326	450	564

[1] More detailed soils maps in the region are available at http://www.flowman.nl/kiogorokenyasoilsmap.htm

Across sites, the speed of first flowering of the first provenance was positively related to the average monthly maximum and minimum temperatures of each site, as well as the sequencing of adequate growth by the time the rains came. The first fruits were reported in Kilifi as early as November 2009 and small numbers of flowers and fruits reported consistently through to May 2010, a 7-month period. No consistent flowering was reported in Naivasha, Mbeya, Laikipia, Makuyu or Thika. Initial results do not show any consistency in flower ratios of the same provenance across different sites.

Fruiting

Compared to fruit bunches in favourable areas, most of the fruit bunches produced were small, although some did reach 12-13 fruits per bunch. In the mostly limiting areas that were planted in a drought year, this project was not established long enough to conclusively determine the difference between provenances or gauge annual change in fruiting that was more than minimally significant.

Pollination and beehives

Bees are the main known pollinators of jatropha and given the drastic global decline in bees, maintaining healthy populations for all bee-pollinated agriculture needs to be taken very seriously. Ten beehives were given to each site, except Masindi, as there was no one present to protect them. They were spread at varying distances and heights from the trials depending on the site, the main concerns being security from theft and protection from ants. One of the real threats to jatropha yields is the effect of glyphosate herbicides, used for the all-important initial weed control, on later pollination. Also, because jatropha is seasonal, providing year round flowering indigenous trees for forage in intermittent wildlife patches can help maintain healthy populations. Jatropha honey is said to be excellent and is a good way to involve surrounding communities in profiting from any plantation.

Figure 9. A beehive in Nakuru

Pests and diseases[2]

At the start of the project, there was limited study of the insect fauna of jatropha in East Africa. Jatropha is as vulnerable as any other crop, especially once it is removed from its original habitat and put into high density, intensive cropping systems. One aspect of keeping costs manageable is to not overreact to pests and diseases that will not be economically damaging to remain very informed and focused in pest management techniques. Surveys were conducted in Eastern, Western and Nyanza provinces, and in parts of Rift Valley, to study the diversity of insect fauna associated with jatropha, while scheduled field assessments were conducted in the plots set up in commercial and smallholder farms in Kenya.

The major pests identified from the study sites include flea beetles, leaf miners and leaf spots. Kilifi had the highest diversity of pests, while Naivasha had the lowest. The incidence of attack of flea beetles was highest in Kilifi and lowest in Naivasha, while leaf miners were highest in Kilifi and lowest in Thika. Once the plant has reached over 1-1.5 metres, in most cases the annual leaf shedding seems to take care of most leaf-eating pests. It is true that intense fruit-sucking beetle attacks will lower yields. Aside from occasional fatal termite damage, grasshoppers (Makuyu) or small herbivores like dik diks (Manyara), mealy bugs, powdery mildew and webbing insects seem to be of commercial note.

Some of the pests and diseases that have been identified have been found to probably have annual rhythms and so identifying these rhythms and spraying once at the right time could have a yearlong impact.

[2] This section is contributed by Beryn Otieno of KEFRI with additional comments from Dr George Francis

Table 2. Pest and natural enemy diversity in farmlands in Kenya

Pest/Location	Kilifi	Makuyu	Naivasha	Thika	Kajiado	Ngurumani	Kitui	Bungoma	Kibwezi	Mbeere
Beetle damage	+	+	+	+	+	+	+	+	+	+
Thrips	+	+	-	+	+	+	+	+		+
Red spider mites	+	+	+	+	-	+	-	+	+	
Broad mites		+	+	+		+	+		+	+
Blue bug	+	-	-	-	-	+	-	-	+	+
Leaf miner	+	+	+	+	+	+	+	+	+	+
Scale insects	+	-	-	+	-	-	-	-	-	-
Mealy bugs	+	+	-	+	-	+	+	-	-	+
Termites	-	-	-	-	+	-	-	-	-	-
Ladybugs	+	+	+	+	+	+	+	-	-	+
Spiders	+	+	+	+	+	+	+	+	+	+
Preying mantis	+	-	-	-	-	+	-	-	-	-
Leaf spot	+	+	+	+	+	+	-	+	+	+
Powdery mildew	+	+	-	+	+	+	+	+	+	+
Root rot	-	-	+	-	-	-	+	-	+	-
Stem cankers	+	-	-	-	-	-	+	-	+	-

(Key: +=observed, -=not observed

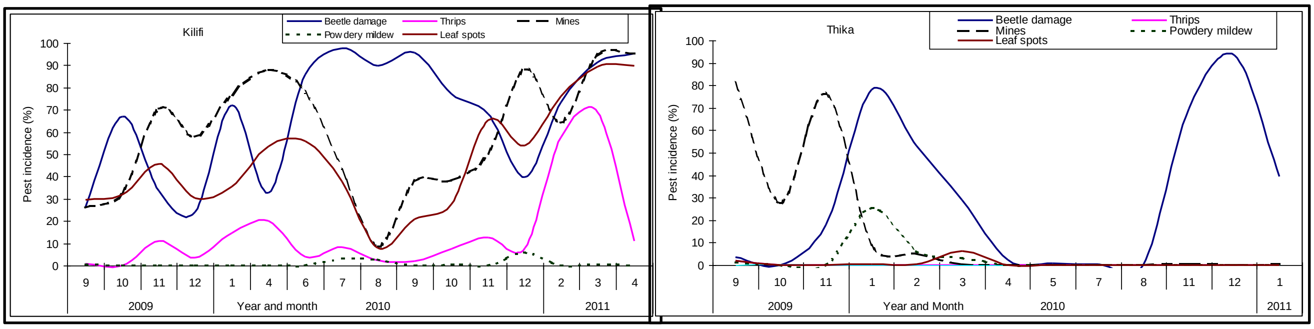

Figure 10. Seasonal trends of the damage incidences of pests on jatropha at Kilifi and Thika

The pattern of leaf-dependent beetles and leaf spots can be expected to follow leaf shedding and emerging cycles that follow the temperature and rainfall cycles. Removing early weed competition is crucial for strong jatropha establishment and will also lessen beetle populations. Once a tree is over 1-1.5 metres high with a full canopy, then damage is usually limited to the lower leaves and is seldom economically damaging. Ideally, planting jatropha in seasons when pest pressures are low will reduce the need for spraying, but given the usually short planting windows, this may not be practical. The presence, occurrence and cycles of the dominant pests and diseases of jatropha are likely to be quite site-specific.

Weeding and Intercropping

The impact of weeding cannot be overemphasized. No consistent data was collected to allow comparisons between weeded and non-weeded plots. There were instances in economic trials where the weeds took over and the plants were not large enough to compete and so mostly died or remained very stunted. Most sites did not intercrop the provenance trials. In Nakuru, at 2000 metres, the first-year seedlings were intercropped with maize. At that altitude, this seemed to create a warm microclimate and perhaps some moisture retention, so the jatropha did better than those left exposed. However, second-year growth seemed slower, perhaps because nutrients were not replenished. In the third year, perhaps because of fertiliser application, growth again improved. This is in comparison to neighbouring plants, which were not intercropped and maybe had to compete harder with the perennial grasses.

In Western Kenya, it was decided by Lesiolo to allow the surrounding smallholders to intercrop under the supervision of the local agronomist. In the process of planting their own crops, some of the leafless jatropha trees were damaged. This emphasizes the importance of the involvement of local smallholders in the trials and strong supervision and management of any site.

Good agronomy practices

The discussions above highlight some of the basic practices that are important for reaching targeted yields and approaching commercial sustainability. There is much advice now available on the Internet, as well as some useful, publically available documents from people with experience in East and Southern Africa. (e.g., Van Peer, *A Jatropha Manual* 2010; Volkaert, 2011; Jongschaap, in Van Eyck, et al., 2010). A brief smallholders 'Farmers Handbook' has been generated from this project and an interactive poster on the website can also be printed off for schools, community centres and churches[3]. While some basic understanding of soils, nutrients and management is essential, there will be much specificity for each site.

Brief conclusion

Achieving commercially viable yields of Jatropha fruit becomes a balancing act between the following factors and the cost of modifying those you can change in your favour.

- Enough days above limiting minimal temperatures
- Enough days below limiting maximum temperatures
- A seasonal rhythm and set of conditions that produce enough inputs, as well as stresses to create high oil yields
- Adequate and timely water
- Adequate soil nutrition and texture/composition
- Drainage, slope, sunlight, pollination, pest and disease pressure
- Using a true-to-type and well-adapted *Jatropha curcas* variety or standardized seed material
- Ability to implement good agro-economic practices

Set-up activities and costs are more likely to be less expensive if a project is started in optimal conditions than if it is started under fair or limiting conditions. At the same time, success in optimal conditions will depend on good management practices, as weed and pest intensity are also likely to be higher.

Four key issues for a commercially successful jatropha plantation

Four key issues for achieving commercial success are:

1. Achieving targeted yields per hectare
2. Choosing affordable harvesting techniques
3. Maximising oil extraction and quality
4. Profiting from the whole plant

The first part of this summary above described some of the findings of the project in regard to achieving targeted yields per hectare. The design of a plantation needs to be aligned with the expected harvesting technique (manual, semi-mechanical or mechanical harvesting). Manual harvesting requires a huge seasonal labour force, which will be a key cost component. Semi-mechanical harvesting will be needed on most plantations if the production model is to establish a long-lasting plantation. Mechanical harvesting will come into greater play if very high-yielding dwarf varieties are used.

Many commercial models rely on achieving an oil yield of 2 tonnes of oil per hectare, even though one tonne is probably more realistic at this time, even under optimal conditions. Some of the highest yielding individual plants have so far yielded between 5-6 kg of fruit per tree, which certainly does not necessarily extrapolate out to a whole plantation. Some project oil extraction rates of 30% and others project 25%. Most out-growers and other projects in Africa have struggled to exceed 21%. The DEG-supported 'Daimler'

[3] www.degjsp.com

project in India consistently achieved an average of 25% with Indian screw presses from seeds purchased from outside. Project experiments in Kilifi using a Chinese press were disappointing, mostly due to clogging the press with the cake. In the lab, oil tests using the original seeds achieved a 34% yield. The average oil production from the Chinese press was 13.48% and the average seed cake production was 63.75%. The chemical extraction oil tests done on the original provenances and their daughter seeds from some sites in this study proved very varied and are available in Annex Five of the separate Annexes document.

The case for jatropha plantations to be profitable producing jatropha oil is yet to be demonstrated, and producers also need to look at the uses of the bi-products. The cake can be used as a bio-fertilizer, a bio-pesticide, as a substrate for biogas production and, especially if high-yielding non-toxic varieties are bred, the cake (which is high in protein) could be suitable for poultry and animal feed.

Regulatory frameworks

A 'one stop' regulatory framework for biofuels was not in place when East Africa was subject to the jatropha hype and the sudden rush of Foreign Direct Investment into biofuels in Africa in 2006-2009. In all three countries, much policy work has been carried out over the last five years, such that drafts and guidelines are ready in each country. No specific biofuel policies are yet in place, however, so setting up a plantation comes under a number of different regulations. The project was able to contribute significantly to the Kenyan National biofuel policy/strategy, biodiesel strategy as well as the environmental zoning of Kenya for biofuels.

The lack of regulatory readiness and, in particular, the current lack of clarity in land use laws, led to a number of contentious issues that have been well documented and highlighted by many non-governmental organisations. These issues include 'land-grabbing', food for fuel, and indirect land use change. Biofuel production on a large scale in Africa is complex. Often the figures used have been inaccurate and not a faithful reflection of actual activities on the ground. Mistakes were made, and given so many failures there has been much to easily criticize. However, the underlying drivers of the need for a rural wood biomass replacement remain critically urgent to maintaining existing forest cover and improving rural health and livelihoods. There is still a need for in-depth debate in multi-stakeholder platforms, and evidence-based decision-making about ecosystem and natural resource management at national and regional levels.

Commercial models

Most smallholder jatropha plantations and out-grower schemes are not yet yielding significant income for rural populations and/or the 'hub' organisations are not yet commercially self-sustaining, despite significant set-up investments.

Set-up and management costs are highly dependent on the condition of the land to be used and the existing infrastructure that a company is using. In our study, a sisal farm with optimal conditions was able to set up a nursery and plant out well below a € 300 benchmark, which was exceeded by a coffee estate in much colder unfavourable conditions clearing scrubland. Clearing trees can cost up to US$ 1,400 per hectare[4], which is, in any case, usually self-defeating in terms of green house gas savings. With many unexpected and hidden costs, it is usually unrealistic to project 'cost per hectare'. What is true for most financial models is that the cumulative set-up expenditure tends to reach a peak by the third year, before significant oil and by-product yields start creating income. Notably, this is when many large-scale plantations in Africa have either gone bankrupt or sought reinvestment. The set up costs reported by some companies and financial models to replace current energy use are available in Annexes Seven and Eight in the separate annexes Document.

Jatropha straight vegetable oil and/or biodiesel is not traded openly in global markets, nor are there any established East African markets. Export potential is affected most by changing EU regulations, which most of all seek to ensure sustainable social and environmental production. Most of the companies in the project were interested in replacing existing fossil fuel use and reducing their energy costs. Financial modelling found that in order for a 28-hectare flower farm to substitute its energy demand using jatropha oil, 300 hectares of high-yielding jatropha planted with conservative cost inputs would be required. Even then it

[4] Shawn Botha: pers. Comm.

would take at least 7 years to start to make savings if the yield is 2 tonnes of oil/hectare, 10 years at 1.5 tons/hectare, and 15 years if the yield is 1.2 tonnes oil/hectare. With trees planted at 4 m x 3 m spacing, 1.2 tonnes of oil/hectare is equivalent to each tree yielding, on average, 5.7 kg per year, which is equivalent to the top individual yielding trees in optimal conditions in Indonesia, Zambia and Cape Verde.

Modelling also suggests that the break-even timing is the same for a 12,000-hectare sisal farm offsetting its current energy usage and costs with a 400-hectare jatropha plantation. For a sisal farm, it makes more sense to use its own biomass waste products to generate biogas and electricity. Flower and vegetable farms seldom have easy access to that much space and are often set up in areas that have cool nights, which does not suit jatropha. It should be noted that successful community level jatropha hedgerow systems, in optimal conditions, have the potential to greatly benefit the lives of women and children by providing clean lighting for household chores, economic activities such as weaving, school study using small jatropha lamps, and reducing the time needed for firewood collection (Boerstler, 2011).

The other two sources of possible income are by-products and carbon credits. Jatropha cake, especially from non-toxic varieties, can be used as a protein source for animal/fish feed, as a bio-fertiliser able to almost triple existing maize yields and, particularly important in rural Africa, as a wood biomass substitutes with 1 kg of cake briquettes able to replace 3.3 kg of wood fuel. The carbon markets currently offer two routes for earning credits, one as supplying carbon sequestration from increasing vegetative cover and existing land use and the other on replacing fossil fuel in transport use. Carbon earnings are currently more easily negotiated on the voluntary markets than under CDM schemes.

In conclusion, most of the East African agro-climatic conditions are not potentially optimal for using *Jatropha curcas* as a biofuel feedstock on any significant commercial scale at this time. *Jatropha curcas* has been in East Africa for centuries and is used in different ways by different people. That use and exploration as a potential input into rural energy supply will continue and hopefully, in some places, will yield sustainable results (e.g., Boerstler 2010). Given the on-going intense research in Brazil and India, as well as the recent upsurge of interest in jatropha in Southeast Asia (The Philippines and Indonesia) and China, a critical mass of examples of using *Jatropha curcas* as a commercially viable feedstock for biofuels may still emerge. Its development may fall into two types, anticipated by others (Fact Foundation, 2010).

One is the current model of low intensity widely spaced larger trees. The other model that may emerge as genetic modification and/or breeding progresses is the use of fast-growing, high-branching, quick-fruiting and high-yielding non-toxic dwarf varieties, planted by direct seeding at 10,000 plants per hectare (1 m x 1 m). Each plant may be able on average to yield 20 bunches of 15 fruit (@300fruits) within 6-9 months of growth. This could yield 5.5 tonnes of seed and 1.3 tonnes of oil per hectare. Breeders will continue to work for more. Adequate pollination not withstanding, the whole crop could be combine-harvested at an adequate height at the 10% yellowing stages, the biomass separated from the seeds and put back into the field, the seeds ripened off the tree, and the by-products developed into high-end poultry feed and protein products and/or used as fertiliser back on the same field. As one agronomist said looking at *Jatropha curcas* growing in Nakuru at 2000 metres, ‘If it grows, we can fix it’. Given the drivers for greater access to modern energy and alternatives to fossil fuel, it is likely that jatropha use and production techniques will continue to evolve in the years to come.

Contributors to the project, report and accompanying documents

The Partners and dedicated on-site agronomists laying out trials and taking measurements

Company and location	CEO/ MD and/or key people (November 2008)	On site Agronomists
Kenya		
REA Vipingo Plantations Ltd. -Kilifi	Neil Cuthbert	Samson Kimani.
Vegpro Kenya-Naivasha	James Cartwright	George Kyalo, Tariq Malik, Mercy.
Lesiolo Grain Handlers Ltd. (LGHL)-Nakuru	Carl Tundo	Daniel, Karanja, Spencer Mabonga.
Tropical Farm Management (Kenya) Ltd. -Makuyu	Jason Green Derek Harries	Patrick Mwangi, Sylvester Waita , Martin Mwambia.
Kordes Roses East Africa (Kenya)-Nairobi Saffron Energy Ltd Kenya-Laikipia	Bas Smit Barney Gasston	Esther Siphilah Wambui, Joseph Kiptoo, David Lebun.
Kofinaf Company Ltd.-Thika	Fabian Phillipart Jean Guy Cobbaert	Paul Njuguna.
Tanzania		
Minjingu Mines & Fertilisers Ltd.-Manyara	Vinod Dhall - Mac Group. Anup Modha	W. Msuya.
Tanganyika Wattle Company Ltd.-Mbeya	Bram Goswami	Aza Mbaga, Joseph Shirima.
Uganda		
Multiple Hauliers (EA) Ltd.-Masindi	Rajinder Baryan Clive Critchlow, Randeep Lochab	George Wanjala.

Agronomists:

Angela Kuthuku-Experimental design and initial laying out of early trials, early photos and reports.

Moses Wamalwa-Set up and data collection Lesiolo Western Bungoma, Data collection Masindi, Lesiolo, Vegpro Naivasha

Alex Nabiswa -East African provenance collection, Masindi, Minjingu, other site visits.

Dr. George Francis-Overall Jatropha *curcas* agronomy consultant, final analysis of available data.

Jatropha Pests and Diseases specialist, *Beryn Otieno* KEFRI – section on pests and diseases and pest identification cards

Beehives, pollination and bee keeping advice has been supplied by *Ernest Simeoni* of African Beekeepers with the support of *Tom Masao* in Tanzania.

Researchers:

Louise Nzomo-Background research and data compilation 2009–2010.

Eunice Kijiwanda- Background data, web site design and management, designing and formatting outputs and updates.

Seth Nyangara-SEIA and regulatory sections and accompanying jatropha poster and Farmer's Fieldbook.

Farid Mohamed- Director Pipal Ltd – Contribution to financial models.

Dr. Sue Canney Davison-Director Pipal Ltd –Project management, overall report writing and compilation.

Special thanks to:

DEG: In particular *Ricarda Horst* for being an insightful, patient and responsive project leader in the PPP section of DEG.

Dr Jacob Kithinji, Dr Kahiu Ngugi, Vishal Shah, Dr Jens Poestch, Martin Kaonga, Francis Xavier, Sue Hinson, Evelyn Nyambura, Tiffin Harris, Annalise Volse, Ab Van Peer, Vincent Volkaert, Ben Muok, Meshak Nyabenge, Tabeel Nandokha, Tameezan Gathui, Martina Otto, Lorna Omuodo, Faith Odongo, Mike Lu and in particular Nico Strydom, Shawne Botha, Peter Whitehead and Richard Morgan from Sun Biofuels and to the many others who supported the project and shared information freely.

Although this report is co-financed by DEG with public funds, the views expressed in this report are entirely those of the authors and do not necessarily represent DEG's own policies or views. Any discussion of their content should therefore be addressed to Pipal Ltd and not to DEG.

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Correct Citation: *Economic Viability of Growing Jatropha curcas as a Sustainable Biofuel Feedstock in East Africa.* Final Project Report to DEG. May 2012. Pipal Ltd. Nairobi.