Jatropha Biofuels Developments 2003-2013 An Industry Perspective from Ghana Emergence, and Potential

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Abstract

Over the past decade, Biofuels has been seen as 'the answer' and as a curse. From the perspective of the popular media in Europe and West Africa, Biofuels have been highly fashionable and worthy of support as a more sustainable fuel; whilst to others, as a toxic socially destructive activity. It is the view of the authors that substantial social, environmental and and economic benefits are available from the well managed development of biofuel sectors. Others are doubtful, envisaging large trade-offs between the pursuit of social, environmental and economic objectives, particularly in poor countries in the tropics. This paper explores these issues in Ghana, which has been a leader in West Africa in the cultivation of the bio-oil producing tree called Jatropha curcas L. We detail how early Jatropha biofuel experiments or pilots, developed from a field trial planned in 2003, led to the growth of Ghana based Jatropha growers. We identify gaps that remain to be bridged, before the young Jatropha industry in Ghana, can develop to the next stage of significant growth, whilst profits and other benefits are shared to the advantage of Ghana.

Innovation and conflict around Jatropha production in Africa have both informed the development of the sector. There have been lessons to be learned from other parts of Africa. These lessons are available to spur evolution of the plant, of the management of cultivation, of relationships between the young Jatropha industry, governments and people with a stake in appropriate land. In Ghana there has been much well intentioned innovation, and to the credit of the country, there has been no destructive conflict as this has been avoided through dialogue.

These processes of innovation and dialogue have resulted so far in a partial development of a young Jatropha production industry. There remains much to be done for crop processing and storage to be developed and installed. Only then would a mature Jatropha industry develop that enabled value to be added beyond agricultural production and the farm gate. The Jatropha industry (beyond agriculture) in Ghana has yet to emerge, so it remains too soon to claim that it is a sector with a strong contribution to people, profit and the environment. However with informed local, national and global governance many potential hurdles to achieving social, environmental and financial benefits, could be reduced.

Keywords :

Biofuels
Jatropha
Sustainability
Ghana

This section is organised into four phases exhibited in the development of most industry sectors (Abernathy and Utterback, 1978). The industry life-cycle of Jatropha is considered under the four headings:

- Proto or embryonic stage;
- introduction;
- growth,
- maturity

1. The 'Proto' Stage: landscape and regime dynamics and sector emergence around 2003

1.1. Background conditions

The background against which the Ghanian Jatropha sector emerged around 2006 was one of increasing concerns about global warming. It was 2006 in which Jatropha Africa was formed and it began preparations for its first plant nursery to start the cultivation of Jatropha. Within months we were aware of about four other Jatropha farming companies starting cultivation activity on a scale that was larger than the research stage. Unknown to these new entrants, there had been a Jatropha growing research project, that took the step from breeding activity in 2003 to seeds being handed to farmers in 2005, to plant in a trial in the Brong Ahafo Region. This trial had the support of the Regional Chief Executive who allocated land, and found 12 farmers to cultivate the crop. The plants provided by the researcher grew vigorously and produced high yields in their first 2 years. However during 2005, there was no evidence of demand for the seed crop, from the perspective of the farmers. With no revenue being produced from this early Jatropha cultivation activity, the farmers pulled up almost all of these Jatropha plants and resumed their normal practice of growing short rotation cash crops, which yield revenue within 3 to 6 months of planting.

The researcher died in 2006, and knowledge of the development of this high yielding Jatropha variety was lost. Interest from the regional government and from research bodies in this trial in the Brong Ahofo region waned.

Good Fortune In the Proto Stage

In 2007 that Ohene Akoto and I visited the Regional Chief Executive, saw the remains of the trial, which was are area of less than one hectare with Jatropha plants that were about 8 months old. It was clear to our eyes that these plants were significantly more vigorous than wild Jatropha found across West Africa. We also had the good fortune that these remaining plants were in fruit, so it was easy to see that these were indeed high yielding, and the seeds were slightly larger than wild Jatropha. We bought a few kilograms of seeds from the farmers who were thinking of uprooting these remaining plants. Since then the majority of the 100,000 Jatropha trees planted so far by Jatropha Africa, have derived from the plants left over from the Brong Ahafo Jatropha trial.

Jatropha Africa benefited in two ways from the research work undertaken in Ghana. The fast growing, high seed yielding plants derived from the trial resulted in earlier and larger yields than would have been the case from the use of wild Jatropha seed. This was clear to us from a comparison of the Standard plants we planted in late 2006, and the Improved plants we planted in late 2007. The two sets of plants were planted in the same soil, raised in the same nursery, given the same treatment in terms of fertiliser and water. They were planted in similar soil, in plots next to each other.

It is the adoption of high seed / oil bearing variants of Jatropha that are well suited to the climate of central Ghana, that we count to be one of the major factors, contributing to the growth of the company.

Fig. 1 The plant nursery of Jatropha Africa – a significant investment step during the proto stage of the company and Jatropha sector in Ghana.

Responses to Global Warming and Green House Gases

The Kyoto Protocol came into force on 16 February 2005, focusing public attention on the global warming and steps to reduce the burning of fossil derived carbon based fuels. The ratification also created possibilities to offset carbon emissions in developed countries through trade in carbon credits with developing countries under the CDM mechanism, which raised high expectations of profitable investments in renewable energy schemes in poor countries (although to my knowledge not one Jatropha project had been CDM-funded in Ghana by 2012).

Other important landscape pressures were an increasing awareness of the limited availability of fossil fuels, fast rising energy demand from emerging African and Asian economies, and the logistical unreliability of Middle Eastern oil supplies due to political problems. High and rising prices of fossil fuels were an important manifestation of these rising concerns.

These factors have been major drivers of recent investments in, and official promotion of biofuels around the world (Rajagopal and Zilberman, 2008; Hazell and Pachauri, 2006). For example, the 2006 EU strategy document concerning biofuels states:

"..The EU is supporting biofuels with the objectives of reducing greenhouse gas

emissions, boosting the decarbonisation of transport fuels, diversifying fuel supply sources and developing long-term replacements for fossil oil." (European Commission, 2006, p. 3).

Statements such as this encouraged the more adventurous investors to start Jatropha cultivation. Jatropha Africa was founded in October 2006. At the start of the 2005 there were no commercially minded Jatropha farmers, cultivating areas of greater than one hectare. By the end of 2006 there were five commercially minded Jatroph farming companies operating in Ghana with cultivated areas of over 10 hectares per company. These very early stage investors where mostly from an agri-business background, drawn from the UK, Norway, the USA, and Japan.

Potential investors in biofuels began to perceive the attractiveness of vast areas of uncultivated land in Africa that could possibly be exploited for biofuel cultivation. Such biofuels were seen to hold promise of generating energy from biodiesel with a substantially lower greenhouse gas footprint than conventional fossil diesel and petrol. Many observers

considered biofuels to be the only feasible option for the substitution of fossil fuels in the transport sector (Peters and Thielmann, 2008).

A remarkable U turn was being adopted by the environmental lobby around 2007. From 2005 to 2006 most European based environmental lobby groups had a very favourable stance on biofuels. At that time major oil companies where not known to have made significant investments into biofuels and not into Jatropha. In early 2007, BP invested in a joint venture with the UK based company D1 Oils. This JV was established to cultivate Jatropha on an unseen scale of tens of thousands of hectares in the countries in which it operated, including Tanzania, Mozambique, India. In 2007 it was reported that D1 Oils had planted over 150,000 hectares of Jatropha. This figure is widely considered amongst Jatropha industry executives to be greatly inflated. The figure may have derived from a total of the areas written into farm management or out-growers agreements. Such figures were not an accurate record of the number of hectares on which Jatropha was being farmed.

Once it became clear that oil majors were starting to invest in bio-oils including Jatropha, then the environmental lobby changed it pro-biofuels stance. The BP – D1 joint venture was a turning point. When speaking in Europe at biofuels or investor conferences, I would regularly have to counter ill informed comments about toxicity, land shortages linked to food shortages, and high water consumption. The environmental lobby had shown no interest in these issues when they were pro-biofuels and anti oil major.

Factors Favouring Investment in Ghana

Ghana, began to attract much investor attention between 2006 and 2009. The characteristics found attractive by international investors generally included:

- The climate was well suited to the cultivation of Jatropha. Ghana benefits geogpraphically by being in one of the best areas for Jatropha cultivation in the world. The following conditions are particularly favourable to Jatropha: Latitude 6% to 12 % North, with rainfall between 800mm and 1100mm per year, with this rainfall occurring mostly in two periods per year, and with an altitude between 0 – 500 metres.
- Land with suitable climatic conditions can be found across large areas across the central belt of Ghana. The Atlantic coastal belt is too humid, and the northern border with Burkina Faso is too dry. The presence of suitable of land which is not taken up with food cultivation is not a significant a limiting factor in much of central Ghana.

  With reference to the EU ACP project to support non-food bio-oils, Ghana was the country with the best combination of climate factors that favoured the cultivation of Jatropha. Most of South Africa and Namibia suffer from occasional minimum temperatures that are too low for Jatropha to tolerate without retarding growth.
- political stability, democracy, relatively low violent crime, treaties to protect foreign investment, Foreign investment is actively facilitated by the Ghana Investment Promotion Centre (GIPC).
- A large workforce which is relatively well trained due to prioritisation of education during the past decades. The proportion of its GDP which Ghana allocates to eduction, was a significant indicator, which influenced my personal decision to invest in the country. At the time Ghana ranked 2nd to South Africa in the league table of African nations.
- Ghana government departments appeared to have a neutral to positive stance towards the cultivation of Jatropha. By 2008 South Africa had labelled Jatropha to be an alien invasive species. On the other hand some African countries such as

Mozambique were offering incentives to attract companies to invest in Jatropha cultivation.

- Road transport in Ghana has been costly for goods haulage, however road building projects were in construction, and it was clear that journey times from farming areas to the coast and export markets were on a reducing trend.
- Unlike South Africa, legal hurdles to the establishment of Jatropha farms, were not thrown in the way in Ghana. During 2008, Jatropha was designated as an alien invasive species in South Africa.

These factors have influenced investors' choices over recent years. However as yet insufficient investors (international or Ghana based) to bring about a balanced or mature Jatropha industry. By this I consider that there is a lack of supply of oil expelling facilities or services available to Ghana based Jatropha growers. When this gap is addressed, then so to should the issue of dedicated Jatropha oil storage. To prevent contamination, with fossil fuels or other vegetable oils, dedicated storage facilities will be required to maintain the quality standards required by biodiesel refining companies.

1.2. Regime Conditions – Energy, Supply Chain Processing, Agriculture and Land

Regarding the energy regime, Ghana has a high import-dependence on fossil fuels and an underdeveloped modern energy supply system. There is a significant long term programme of electrification with the national grid being extended to larger rural communities. However many of the smaller rural communities are likely to remain unconnected to the national grid over the next decade.

Traditional sources of biomass fuel – charcoal and firewood – are becoming increasingly scarce and expensive. Amongst the biofuel plants which could be grown in Ghana, Jatropha was seen to be particularly promising, because early publications noted its potential for marginal land regeneration and erosion prevention alongside energy provision (Openshaw, 2000).

The national economy of Ghana has been supported by subsidised fossil fuel costs, so it is not yet clear that the introduction of new competing energy sources would face a level playing field for competition.

Ghana's agricultural sector is dominated by large numbers of traditional smallholders. These are mostly poor marginal farmers, who have been suffering from structurally low prices of staples such as maize and cassava. They may have been interested in switching over to a new crop such as Jatropha. However this crop is seen as being too slow to produce revenues, because the maturation time of 5 years compares unfavourably with food crops.

Small farmers tend to be sceptical about becoming outgrowers with new crops.

Oil Expelling

Another factor that is relevant to the establishment of a mature Jatropha biofuel sector is the post-harvest oil processing technologies. The extraction of Jatropha oil from Jatropha seeds

requires high pressure presses. Basic technological knowledge about low pressure press manufacturing and use exists in Ghana, due to widespread use of vegetable oil presses for crops such Palm oil. However there is little advanced knowledge about efficient high pressure, high-capacity presses in the country. Suitable reliable machines are commercially available. A number of the better engineered machines are manufactured in Germany and the UK. Lower cost, less reliable machines are also available however for high pressure oil expelling the less well engineered components often fail and operating costs are high.

Alongside the Oil Expelling Issue, the storage of Jatropha Oil will have to be addressed.

Land

Land in Ghana can be leased for up to 50 years, but the acquisition of land is difficult, procedurally complex and time consuming. Obtaining such leases will require local knowledge, negotiating expertise, respect for local customs, patience and funding from a risk accepting source.

Some Ghanian citizens and local and international NGOs oppose large-scale land acquisition by foreigners. However many traditional holders of land of modest value, are open to discussions with developers of farms and plantations.

Fig. 2 Finalising a land, labour and profit sharing agreement with leaders of rural communities with traditional land rights.

1.3. Sector Processes

It is against this background that the first activities towards the development of a Jatropha sector in Ghana began to take shape. In 2006, we saw just a few unconnected experiments or pilot farms founded by entrepreneurs. The government of Ghana was notably absent from taking a view of Jatropha. There was no regulation of Jatropha farming, and no stimulation or support, no guidelines as to where to plant or where not to plant. It was unknown if there would be any financial support or bureaucratic or perhaps legal hurdles associated with this crop.

Two ways of operating as a Jatropha producer :

Informal outgrower model, buying seeds from farmers on an irregular basis (including seeds from wild Jatropha plants already growing in the region). Production takes place on a small scale.

Encouraging Signals For Ghana from Tanzania

Just ahead of our formation in Ghana, Diligent had just begun operations in Tanzania in 2005, trying to contract small farmers as outgrowers to supply its prospective oil pressing facility in Arusha with seeds from small plants supplied by the company, which the farmers plant around their small plots as hedges. No large plantation cultivation was noted, and no special plant material developed from research was known of by potential inward investors considering large scale Jatropha cultivation in Ghana or Tanzania.

Although there were at this proto stage a small scale local farmers involved in the cultivation stage, the oil pressing stage was being set up and the end-use stage almost non existent. This order of development makes sense, as a full value chain can only be built up once sufficient oilseeds are available to be processed and based on known varieties in 2006, it takes 2 to 4 years for new plants to start yielding sufficient seeds to justify harvesting.

By the end of 2006, the numbers of small farmers involved in cultivation in both Tanzania an Ghana was expanding quickly. Several agronomic learning processes had already occurred, for example concerning ways of propagation of seed, irrigation, and planting distances. However, these lessons had not yet been shared among all the relevant actors in African nations.

Over-optimistic Figures Distort Expectations of Investors

During the period 2006 to 2008, people's expectations about Jatropha's viability were generally highly positive. With hindsight (from the perspective of late 2009 onwards) people's seed yield estimates of 5–10 t/ha/yr have proved to be completely unrealistic, a clear sign of the underdevelopment of the sector, and the hype promoted by some researchers and middle men involved in seeking funds for large scale Jatropha plantation projects.

Other over optimistic figures associated with Jatropha that was promoted in some business plans, was the oil yield figure. We work on the assumption that a modern mechanical press can extract 23% of the weight of a seed, as Crude Jatropha Oil (CJO). I have seen plans stating that the seeds they were going to grow were made up of 60% oil and that they would extract over 40% of the weight of the seed as CJO.

In oil pressing, we saw a few small groups involved. Early experiences were gained by Diligent and based on basic mechanized Sayari oil expellers made in Tanzania by a German aid-supported NGO, and on manual ram presses. From a commercial perspective, we observe that the ram press is inefficient and unwieldy for producing larger quantities – sufficient to fuel a small community, electricity generator. Regardless, we saw ram presses being promoted by NGOs as the way forward for rural communities in Ghana during 2006 and 2007.

At the end of 2006, there was little more than a group feeling that Jatropha oil had technical advantages (low plug point) over other biofuel feedstocks e.g. Palm Oil. Other factors that appeared to be in favour of Jatropha were that it was not a food crop. By the end of 2007,

the non-food character of Jatropha was seen as a differentiator that made it more acceptable than Palm Oil as a biofuel feedstock. However by 2009, the fact that Jatropha needed land to be grown on was enough for it to blamed for displacing the cultivation of food.

In Ghana there remain few lessons yet about the infrastructure and storage requirements of seeds and oil, although this aspect is important because seeds and oil are natural products and degrade over time.

People's expectations about viable business models varied widely: some mentioned small pressing units in several rural places, from where the oil could be collected and distributed. Others envisaged a small number of large central pressing unit, with the seeds being transported many tens of miles. High transport costs and inefficiency of equipment are seen as barriers to the development of the industry. However the road network of Ghana has been improving, so journey times and reliability are not unreasonable. However the costs of haulage from the centre of Ghana to the coast are high by world standards.

Usage of Jatropha

At the end use stage of the production chain, the installations are embryonic because a smoothly operating commercial market for Jatropha oil and its co-products does not yet exist. Demand appears to exist, from the evidence that we regularly handle enquiries for Jatropha seed and oil, in quantities stated in the 10's of thousands of tons. However such enquiries are usually from middle men trying to buy contracts for Jatropha being produced, and then sell the contracts on to biodiesel refiners or electricity generators. Such enquirers had no understanding that there would be a lag of 4 to 5 years from funds invested in Jatropha oil production (cultivation) and Jatropha oil lying in suitable oil storage depots, ready for shipping.

Early stage entreprenuers had identified Jatropha oil as a potentially good diesel substitute, particularly in remote locations or for use in tractors on farms. The behaviour of the pure plant oil (PPO) in car engines by converting one car engine to enable it to run on pure Jatropha oil had been studied at Eindhoven University of Technology (TUE) in the Netherlands, where an MSc project had started about the behaviour or Jatropha oil in diesel engines (Rabé, 2004).

The successful flight of an Air New Zealand Boeing 747 with one engine converted to run on 50% blend of Kerosene and Jatropha Oil, boosted interest in Jatropha production.

A second set of applications that was beginning to be investigated was the use of Jatropha seedcake for biogas production, as fertilizer, and as stove briquettes. There were no experiences with Jatropha as fertilizer or briquettes. The research in 2005 concluded that seed cake applications (as a fertilizer or as briquettes) had been explored only very marginally. This was identified as a major weakness for the development of the Jatropha innovation system, because productive use of the seedcake (which makes up about 70% of the seed weight after oil extraction, is crucial for making Jatropha biofuels profitable.

A third possible application concerned the use of the pure plant oil (PPO) in oil lamps and cooking stoves. Kerosene lamps are widely used in the villages, but using Jatropha oil is expensive because a separate lamp with a thicker wick is required than what is normally used.

Finally, Jatropha gave rise to some non energy-related byproducts, notably medicinal soap, which is made by Kakute in Tanzania on a small-scale basis. The soap commands a small niche market. We have not seen a regular supplier of Jatropha soap which showed the capacity to satisfy the requirements for an export market.

During the early years, people's expectations about possible end-uses varied widely in the absence of developed end-markets and developed oil expelling and storage infrastructure. Sadly this situation with the absence of dedicated modern Jatropha oil extracation facilities and Jatropha oil storage capacity continues in Ghana.

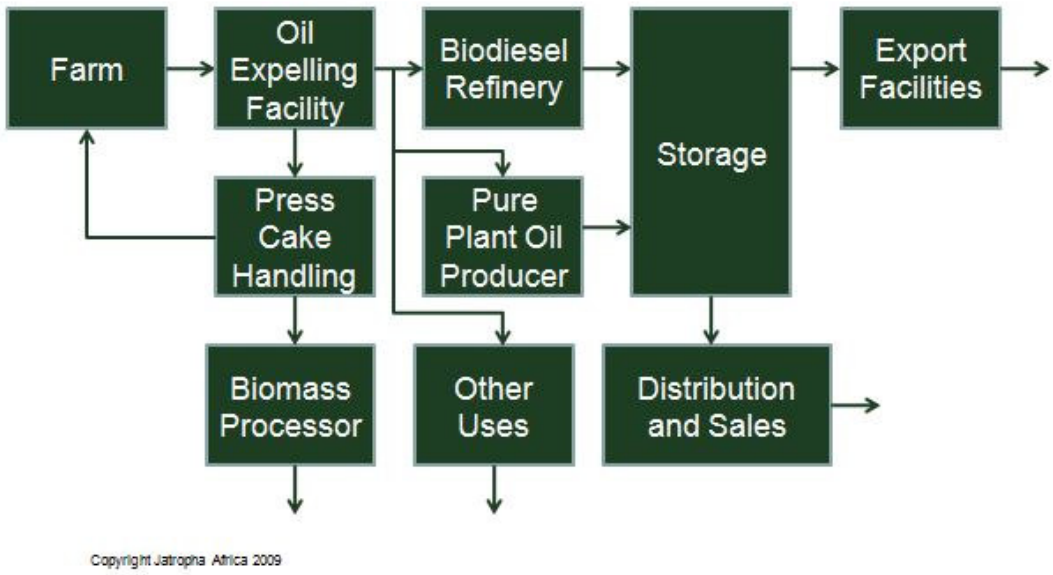

Fig 3. Product supply chain for the Jatropha sector as proposed by Jatropha Africa.

In the early years 2003 to 2006 we could not find significant differences in beliefs and expectations among stakeholder groups (farmers, early stage investors, biodiesel refineries, many researchers in developing nations and rural development NGOs) they all expressed great optimism. This state of affairs is reflected in all the different potential Jatropha applications. This stage between 2003 and 2006 was largely driven by individual / entrepreneurial (rather than research group informed) vague beliefs and expectations, rather than facts and experiences.

1.4. Evolutionary Drivers

In particular we see evolutionary variation emerging in the technologies used, e.g. different agronomic practices for propagating Jatropha in the cultivation stage. Jatropha Africa adopted the planting of seedlings raised in our own nursery. Some other Ghana based Jatropha farmers favoured the use of Jatropha cuttings. Another example of variation is oil use, where participants had identified many different possibilities of using Jatropha or its by-products.

We did not yet witness any evolutionary selection in terms of cultivation and pressing technologies, business practices, and business models. Learning has still been insufficient for lessons and experiences to accumulate to the point where people can make informed

selection decisions. This stage is characterised by what Kempf (2007) has called 'limited first order learning' which is basically just technical learning about the key technical processes in the value chain. There are no wider lessons yet about the impact of the processes: about user acceptance, logistics, or possible toxicity. There are also no documented evidence (audited accounts) confirming the commercial profitability of Jatropha, although this now receives much attention during the due diligence stage prior to investments being made. During the years upto 2007, the process of sector development as a whole was largely fueled by highly optimistic yield expectations.

The second driver of change in our analytical framework, socio-political contestation and conflict, is not yet operating. We still see a reasonably harmonious process led by few individual actors with plenty of space in Ghana to pursue their own interests without having major effects on each other. At this proto / embryonic stage there is no large influx of big investors whose activities could potentially have major effects on the rural ecological and socialeconomic scene. The public at large – both within Ghana and abroad – is at this proto stage, at best vaguely aware of Jatropha's emergence. To the extent that people are aware of it, there is just a vague sense, mostly based on heresay, that social and environmental impacts will be positive.

2. 'Introduction Stage ': mounting landscape pressures and evolutionary variation in 2006–2007

2.1. Background Conditions

The favourable expectations generated in the early years of the Jatropha sector development in Ghana – as well as in other tropical countries such as Tanzania, Mozambique and India – fostered an international climate of great optimism regarding investment possibilities. This was simultaneously being stimulated by developments in the landscape: the IPCC published a report stating that it is 90% certain that the increase of CO2 in the atmosphere over time is induced by human activity. It also stated that if the combustion of fossil fuels would not be reduced significantly within the next decades, a temperature increase of over 2 ◦C will cause climate change with catastrophic consequences (IPCC, 2007). In its summary report for policy makers, the IPCC recommends the use of biofuels in several sectors (including dedicated liquid energy crops for the transport sector), and discusses several policy measures to boost investments and use, such as mandatory blending targets and subsidies (IPCC, 2007).

The film 'An Inconvenient Truth' produced by Al Gore also did much to enhance global public awareness of the dangers of human-induced climate change (http://en.wikipedia.org/wiki/An Inconvenient Truth;

These global landscape developments were accompanied by a growing interest in western developed countries to utilise biofuels to combat climate change and enhance energy security. The EU adopted Directive 2003/30 (RED), in which it set indicative targets for biofuel consumption as road transport fuel of 5.75% by 2010, and 10% by 2020. In the US, a target was set of 7.5 billion gallons by 2012. Thus, policy-induced market creation and subsidies for biofuel investment in the developed world became major inducements for expansion of Jatropha activities in tropical countries, including Ghana. However in practice few of these subsidies were invested in Ghana to support the large scale cultivation of scale oil seed bearing plants like Jatropha.

2.2. Regime conditions

Energy regime conditions, both globally and in Ghana, were favourable to early biofuel industry growth. Fossil oil prices in this period rose to around US$ 55–75 per barrel, which was much higher than the average price experienced in the previous two decades (see Fig. 2). This raised expectations among investors that the production of biofuels like Jatropha could actually become competitive under market conditions.

2.3. Sector processes

The combined occurrence of these landscape and regime trends heralded the second major phase in the industry's development, which is characterised by global hype.

A major influx by western transnational corporations (TNCs) happens, into tropical

countries in Asia, Africa and Latin America. However Ghana does not see their presence. This may be, because the governments of other countries, offered greater incentives to attract investors. Such incentives may have been required to overcome some barriers to inward investment, e.g. political instability, remoteness from developed nation markets.

These international companies were intent on the large-scale commercial cultivation of Jatropha predominantly for western markets of transport fuel and electricity-generation feedstocks, taking advantage of favourable market prospects created by the biofuel targets set in these countries as well as their lavish investment subsidies (e.g., ABN, 2007;

Beattie, 2008; Knaup, 2008; FAO, 2008; GEXSI, 2008). Within just a few years, the stream of these investments had grown to such an extent that it began to attract considerable attention in the press in developed and developing countries alike. One CNN report estimated (greatly over estimated in our view) that more than 720.000 ha had been planted by spring 2008, expected to rise to over 21 million ha in 2014 (Whiteman, 2008), out of an achievable total potential of around 30 million ha (Wille, 2008).

For evidence that Jatropha was hyped, see Achten et al. (2010, 2007), and Fairless (2007).

In Ghana, the combination of the various global landscape pressures and positive expectations gave rise to a period of about 3 to 5 years of modest foreign investments into the fledging Jatropha sector. Most of this investment went into establishing farms. Very little went into oil expelling, or Jatropha oil storage. Some investment went into seed storage in Accra to support the export of unprocessed seeds.

It should be noted, however, that the export orientation of these international Jatropha growing firms was also induced by the evident difficulties involved in developing a domestic market owing to landscape factors discussed earlier, namely bad infrastructure, bureaucratic government, and low purchasing power. The same argument can be made in relation to their choice for a vertically integrated supply chain. In a poor country, central plantations afford much easier and better control over feedstock supply than decentralised outgrower-based systems dependent on poorly educated and widely dispersed smallholder farmers.

2.4. Evolutionary Drivers

Summing up the main developments during 2006–2007, we see a continuation of the evolutionary variation motor of change. Compared with 2005, the learning in the sector is broadening from purely technical aspects to business organisation and coordination.

While three distinct business models begin to crystallise out, we cannot yet identify any evolutionary selection in the sense of failing alternatives falling by the wayside, or any of the three emerging models being clearly preferred over the other(s).

Upto 2007 we do not yet see fullblown conflict, but we can discern the first signs of these in early publications by NGOs such as the ABN.

3. Frustrated early growth: to mid 2008

3.1. Background Conditions

The first half of 2008 is marked by major changes in the global and Ghanain landscape, which have had dramatic effects on the development of the Jatropha sector. These developments coincided with significant learning, due to the accumulation of experiences from the cultivation of Jatropha as a managed agricultural crop. Since Jatropha takes 18 months to 3 years to start yielding seeds, the earliest Jatropha projects around the world were beginning to get their first results around this time. From these results, it was becoming increasingly clear that although Jatropha is indeed able to survive under hostile environmental conditions, its seed and oil yields are much higher in conditions where the plant has adequate access to soil nutrients and water (FAO, 2008; Achten et al., 2007, 2008; The Guardian, 2009).

At around the same time, global food prices began to climb to the highest levels since the 1970s. The FAO (2008) gave warning about serious implications for food security among poor populations around the world. It forecasted global food-import expenditures to reach US$ 1035 billion in 2008, 26% higher than the previous peak in 2007. These emerging facts intensified and expanded a debate, until then limited to the USA and Brazil, about competition between food and fuels (Rathmann et al., 2010).

The World Bank (Mitchell, 2008a) and the OECD (2008) came out with reports claiming that biofuel production, spurred by attractive subsidies, minimum blending requirements, and skyrocketing fossil oil prices in an overheating global economy (see under ‘regime’, below), had been one of the main reasons for the increasing food prices. This, coinciding with a drought in Eastern Africa, caused great concern in the region, where periodic food shortages have been an issue for a long time.

Another major global landscape factor that began to come into play was that several bodies began to raise questions whether biofuels were really as GHG-friendly or -neutral as they were initially claimed to be. In January 2008, two articles in Science caused a worldwide stir, pointing out that biofuel environmental life cycle studies so far had neglected GHG emissions due to land conversion prior to start of cultivation. Palm oil plantations established on former tropical forest lands in Malaysia and Indonesia would need to run for over 300 years for the initial carbon debt to be repaid (Fargione et al., 2008).

Although Jatropha was not yet included in these initial studies, they raised worldwide doubts about the desirability to promote biofuel investments of any sort. It did not take long before these concerns began to include Jatropha. Achten et al. (2008) worldwide Jatropha survey asserts: “The caused emission due to removal of (semi-) natural forest is a heavy burden on the initial GHG investment, which will take a significant time span before it is paid back with the GHG emission reduction of the use of the bio-diesel.”

3.2. Regime conditions

Steadily climbing fossil oil prices (see Fig. 4) were the major energy regime feature in this period, both globally and locally. For the first time ever, the oil price broke through the US$

100 mark, and then continued to rise even further to US$ 147 per barrel during the 2nd quarter of 2008 (Bloomberg, 2008). This trend boosted large-scale biofuel energy investments, by fuelling widespread expectations of structurally high energy prices. The realisation was dawning worldwide that the era of cheap oil had come to a definitive end.

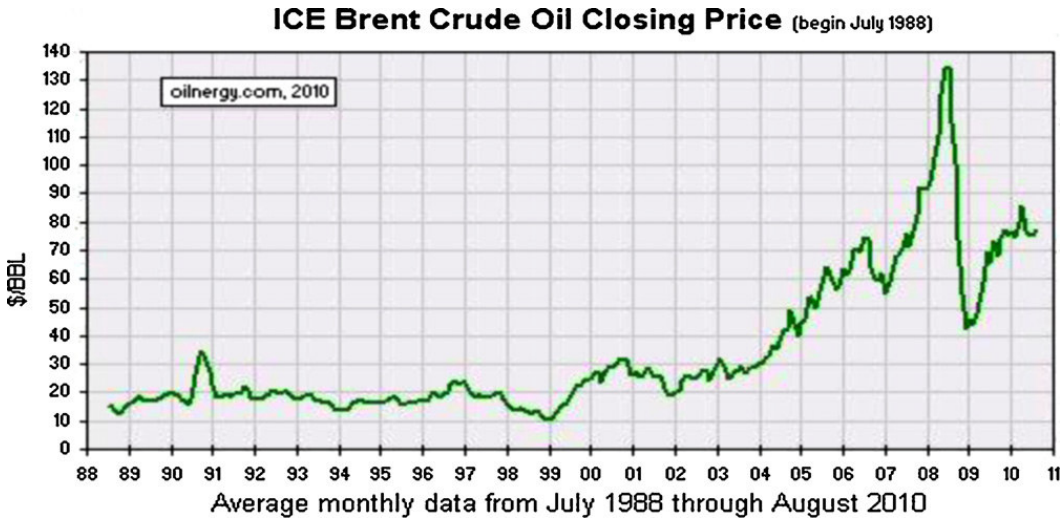

Fig 4. Fossil oil price 1988–2010. Source: http://www.oilnergy.com/1obrent.htm#since88.

However, we also see negative pressures relating to land use. While plantation investors often claimed land abundance, others began to point out that land that might seem unused at first sight can yet be valuable for its provision of durable ecosystem services, as a resource of various forest products, as spiritual places, and as roaming places for nomadic people and cattle.

In response, several countries, regional groupings, and organisational networks stepped up efforts to institute committees to develop social and environmental sustainability criteria that biofuels must meet to ensure responsible practices (Lerner, 2008). The best-known national initiatives include: the RTFO (UK), the Cramer initiative (The Netherlands), the Social Biodiesel Schemes and Programme for Certification of Biofuels (Brazil) and the South African biofuel standard. Three international institutional initiatives were also started: The GBEP (G8 + 5, UN agencies), the BEFS and BIAS (FAO), and the EU Biofuels Directive. In addition there is an international voluntary initiative, the Roundtable on Sustainable Biofuels (RSB), which initiated a specific working group devoted to standard setting for Jatropha by mid 2009.

3.3. Sector Processes

Due to these combined and cumulative landscape and regime pressures, the Jatropha sector in Ghana as in other countries comes under pressure to prove its environmental and social sustainability to various local and global stakeholders in order to avoid losing their public support base and their reputation (and access to finance to boot). At a biofuel conference in Accra at which the authors were speaking, we were faced with a group of about a bus load of vocal protestors chanting ‘no to biofuels’. On speaking with the

protesters it was clearly organised by a local NGO looking for concessions for its own benefit, from companies that had already started investing in the young Jatropha sector of Ghana.

The critical focus is mainly on large plantation projects connected to international investors, and on the government whose regulatory oversight of these schemes is seen to be inadequate. Global, Pan-African and local NGOs are among the first to become restive. The ABN flags potential threats to land, livelihoods, food security, biodiversity and water. The positive effects of jobs, increased food production from intercropping where land unused for food, is brought into use for Jatropha cultivation, does not get promoted with as much noise.

By 2008 we recognise about 5 companies establishing large scale (or pilot scale in preparation for large scale) Jatropha farms in Ghana. We estimate the total area under Jatropha cultivation at this point to be about 1,500 Hectares. By comparison the Jatropha farming operations in Tanzania had grown to approximately 38.

In 2008, Oxfam issued a highly critical report claiming that the EU biofuel target could actually increase carbon emissions by 70 times by 2020, because of the required changes in land use (Oxfam International, 2008). We were amongst the companies which took part in phone interviews as part of the research for this report. It was obvious from the phone interview that the questions were designed to collect quotes that could be used to tarnish the reputation of the Jatropha growers. An anti biofuels bias was evident – in contrast to the pro-biofuels bias evident from Oxfam and Friends of the Earth upto 2006.

In retrospect, this brief period was a particularly tumultuous one in the biofuel development trajectory, both in the world at large and in Ghana.

The global landscape in particular contributed through enormous spikes in food prices, leading to social unrest in many countries. However, the energy regime also contributed through unprecedentedly high fossil oil prices and high fertilizer prices. This boosted vast renewable energy investments by fuelling widespread expectations of structurally high energy prices. Whether or not biofuel investments indeed played a truly dominant role in causing these food price rises has remained a matter of some debate. However, a more important lesson that sunk in during this episode was that some of the major drivers of the food price hike constitute major structural developments—especially the steadily rising purchasing power in large emerging economies in Asia. The public support base for large-scale plantation investments in biofuels began to erode.

3.4. Evolutionary Drivers

Around 2008 we now begin to perceive results from Jatropha cultivation in different climates. The vital agronomic lesson emerging at this stage is that Jatropha is no different from any other wild crop: it can survive in drought-prone conditions and poor soils, but it cannot be commercially attractive and reliable under those conditions. The ‘selection’ we observe is that this caused investors to scout for land with higher rainfall than previously, further inflaming the food versus fuel debate.

This happens globally in Jatropha-producing regions, as well as in the local Jatropha sector in Ghana.

For Jatropha Africa, the lower oil prices, the negative messages from the environmental lobby contributed to the environment in which investment into the young Jatropha industry dried up. At this point the Jatropha trees planted in 2006 / 2007 were producing sufficient fruit to be harvested, and indications that the next logical stage of investment in oil expelling facilities in Ghana, was approaching. With potential new investors in Jatropha being influenced by negative messages from environmental groups, before revenues from

Jatropha had matured to break even level, physical development of the next key part of the Jatropha production line came to a halt.

In all this upheaval and contestation, it is hard to find evidence of additional evolutionary variation processes such as oil pressing and user applications, which along with agronomic learning had been the dominant drivers of progress in the sector until then. Undoubtedly these processes went on as before, but became eclipsed by the concerns with major unresolved issues relating to environmental and social sustainability. Still, in this period we cannot yet see any effects from the second (contestation and conflict) change driver on the nature and direction of the innovation process in the sector.

4. Interrupted early growth: instability from 2008 onwards

4.1. Landscape and regime conditions

The start of the final period in the development of the Jatropha sector so far is marked by the global financial crisis causing major energy regime instability. The recession is associated with dramatically plunging oil prices and falling oil demand. The oil price plunged by US$ 115 from its peak of US$ 147 at the end of July 2008 to its lowest point of US$ 32 in December, the most precipitous fall the world had ever seen (The Economist, 2009a,b, p. 69). Although long-term oil price projections point upwards again, the large swing caused major problems for renewable energy programmes worldwide, including those based on Jatropha bio-oil. By way of example, in October 2008 the fossil diesel CIF price at Dar es Salaam harbour had declined to US$ 0.80 per litre (US$ 127.20 per barrel), whereas the cost of producing a litre Jatropha biodiesel excluding taxes was US$ 0.74 (or US$ 117.66 per barrel) (van Eijck, personal communication). This demonstrates how high the fossil diesel price has to be in order for Jatropha biodiesel to be able to be competitive under current conditions (assuming similar domestic taxes for both). It is interesting to compare these figures with the US$ 56 per barrel provided by Goldman Sachs in 2007, as the cost of production of Jatropha oil, once the sector had matured.

Recently established EU biodiesel factories suddenly experienced dramatic overcapacity. By early 2009, only 60% of the German biodiesel production capacity was still in use, and several factories had closed down (MVO Magazine, May 2009). Producers of Jatropha feedstocks – particularly large export-oriented firms – had to revise their expectations about market prospects.

4.2. Sector processes.

Since 2008, at least two of the 5 companies actively expanding Jatropha cultivation in 2007, were in liquidation. At least two other companies had ceased expansion of their Jatropha farms. Two new internationally funded Jatropha farm projects have started in Ghana.

Jatropha Africa continues to operate, and reached the milestone of exporting its first 10 tonne shipment of seeds to Japan in 2011. This was achieved by combining 6 tonnes of seeds from our self managed farm in the Brong Ahafo Region, with 4 tonnes sourced from out-farmers.

The EU/ACP Non-Food Biofuels Programme conference in Accra during this period, enabled considerable learning between industry, research and funding bodies. At this valuable conference, we learned much about the potential of soil improvement and options for food intercrops, to improve the viability of Jatropha farms. However investment into the Jatropha growing companies of Ghana was reducing or coming to a halt following banking sector instability in the US and EU. Without funds for R&D activity, Jatropha Africa had to shelve its plans for development and focus on its core activity of Jatropha seed production.

By 2013 we can speak of the formation of a Jatropha sector, however it is premature to consider this as mature as there is little more than Jatropha farming with little oil expelling beyond that required to produce Jatropha oil samples for export. The supply chain for products shown in Figure 3 remains largely non existent in Ghana despite significant demand for cold pressed, filtered, Crude Jatropha Oil (CJO). It is too soon to claim that an innovation system involving organisations involved in plant R&D, farm manangement, oil expelling, oil storage and transport, is forming in Ghana.

We present some brief information about the developments on the ground in Ghana, that are important for understanding the nature and direction of learning over the years since 2009. In particular, the future outlook for Jatropha looks more mixed than was the case during the early fast growth of the sector suggests. Despite increasing international landscape pressures favoring renewables for environmental and energy security reasons, local user preferences in Ghana are primarily based on price because of the poverty. Remarkably little Jatropha oil is sold for end use in Ghana. It remains the case that most of the Jatropha product that is exported is seed, not in the higher added value form of oil.

The fall of the fossil fuel price in the fall and winter of 2008 was, on the whole, a bad thing for the development of an economically viable local Jatropha sector that would cater to local needs. This is especially true for the national regime-competitive applications, such as Jatropha fuel for transport fuel or oil lamp fuel for lighting. The outlook is better for local Jatropha applications that do not aim for substitution of an existing energy regime. For example, some projects aim for rural electrification in places where the fossil based regime is not yet present. Prospects in these local sheltered spaces continue to appear to be somewhat promising, also because the desirability of local applications for Jatropha – as opposed to export to western markets – is increasingly being emphasized in international publications (Tilman et al., 2009; Vilt, 2009).

The learning in the sector is still mostly supplier-driven (about costs, technical performance, etc.). End user involvement is still limited. At the same time, learning mechanisms have expanded from trial and error in 2005 to systematic search, use of test plots, use of literature, internet use and participation in international conferences.

Technological learning is also still ongoing, e.g. experiments with biodiesel through transesterification and blending yield new facts and possible practical lessons around this new product. Also, in order to extract more value from the Jatropha seeds, actors continue to search for, and experiment with ways of using the seed cake. Stimulated by user preferences and possible future regulation (potential taxation of fossil derived aviation fuel), some interest in the properties of Jatropha oil continues.

In Ghana Jatropha was transported as seed (typically in 80 kg sacks) from the farms to be packed into 20 foot ISO containers for export (in our case to the US and 10 tons to Japan). We also exported our Improved Jatropha seeds to Mozambique, Portugal and Italy, though these seeds for planting were in smaller batches of upto 500kgs. We received many enquiries for Jatropha oil, but could only provide small samples (upto 50 litres) as we only had access to one inefficient oil expeller on the outskirts of Accra (a 10 hour truck journey from our self managed farm and our associated out-grower farmers.

As Tanzania had efficient oil expelling facilities operated by Diligent, distribution was of Jatropha oil in plastic barrels from Tanzania delivered to specialist refining companies, eco-

safari companies, a local soap producer and Boeing (15,000 l in 15 barrels exported by air) which used the oil for a successful test flight in a Air New Zealand plane in December 2008. Local usage of PPO in older vintage stationary diesel engines—as designed for the rural LMPs, is also being considered. Different applications for the seed cake, such as briquetting and charcoal making, already mentioned as possibilities in the 2005 survey, are now being tried out. Many projects have not settled on the main type of end-use that they will go for, but socio-political pressures against large-scale (raw seed) export for western markets are mounting.

The overall balance of all the emerging pros and cons associated with the different business models have the effect of putting the Jatropha plantation model under a lot of pressure towards more environmentally responsible practices. The same holds for recently started higher rainfall or irrigation than is required by Jatropha.

Learning about ecological sustainability occurs through literature search, limited data collection, and simple tests performed on small samples, e.g., about poisonous qualities, effects of Jatropha on soil quality, and the effect of Jatropha on nitrogen depletion and how to prevent this through intercropping with leguminous plants or feeding back the seedcake. Regarding the impact on global warming, some lessons are being learnt through monitoring in ongoing projects.

A need for clear rules about Environmental Impact Assesments, Water Extraction Permits, and taxation of biofuel producers would provide firm information of relevance to future investment in the development of the Jatropha sector in Ghana. But perhaps the most important issue which international investor seek knowledge of, is guidelines on ensuring food security and preventing exploitation of villagers, e.g. in the form of rules on how to acquire land, and a statement on the introduction or not of zones for biofuel feedstock farming.

Pressures is emerging with respect to international norms and standards currently under development, include the Dutch NEN NTA8081 (currently in the trial stage), the GBEPGHGguidelines (GBEP, 2009), the UK RTFO standard and the EU RED (McGregor, 2008).

In connection with this development, worldwide efforts to define truly sustainable biofuels are being stepped up (see, e.g., Tilman et al., 2009). The formation and introduction of trade standards, certification, and carbon trading are widely being seen as suitable and necessary instruments for market regulation and promotion of sustainable practices by investors: the idea is that they can only earn carbon credits and market access in major western markets when they are able to prove that they meet certain social and environmental requirements.

Another major expectation is that by-products must be used for the achievement of financial profitability for investors; and that in addition, seed yields can and must also be increased through improved crop management, better seed varieties, etc. Actors generally expect that the financial feasibility of Jatropha projects can and should be improved strongly for the sector to become economically sustainable in the longer term.

5. Conclusions

From this review about the development of the Jatropha biofuels sector in Ghana and lessons we learned from other countries e.g. Tanzania, we can conclude that the sector has

evolved from an embryonic state in early 2005 to an early-stage sectoral system of innovation and production by the end of 2009.

Notably, there were a number of powerful investment drivers in the landscape and regime, such as rising awareness about dangers of climate change, temporary high and low energy prices, and subsidies for biofuels with unclear rules regarding eligibility of Jatropha.

The fast pace of investment in 2006 established farms and started the 'learning by doing' phase of the development of a Jatropha sector. Most investors piled into the country in a great rush, without much regard to possible longer term effects of an as then little known, wild tree. Many investors did not take time to start experimenting on a small scale, so that the puncturing of the hype of Jatropha as a reliable and viable oil crop for marginal soils gave many large investors a particularly hard hit from which some may not recover. Added to this were major landscape and agricultural-regime instabilities that led to an unprecedented spike in worldwide food prices, igniting a worldwide food versus fuel debate (even if the extent to which the biofuel rush actually contributed to the food price rises has remained unproven).

Promises of new economic opportunities voiced by proponents stand against the adverse impacts on the loss of sovereignty and domestic food security stressed by others (e.g., The Economist, 2009a,b). The large controversies, conflicting interests, and power inequalities between the key parties, have hindered effective and speedy policy action.

As a result, the Jatropha sector – still barely out of its embryonic stage in Ghana - is still facing an uncertain future. While economic viability is still not assured, and much further experimentation and learning is required to raise yields and efficiency (particularly the mechanisation of harvesting). Another factor which inhibited growth of the sector has been the absence of well equipped and well-funded national R&D institutions with a focus on non food biofuels.

Overall, we conclude that although the sector has become sizeable in terms of the number of, and variety in participating parties, in terms of key capabilities it is still in the early stages of innovation system development.

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