

The Jatropha biofuels sector in Tanzania 2005-9 : evolution towards sustainability?

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The Jatropha Biofuels Sector in Tanzania 2005-9: Evolution Towards Sustainability?

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**The *Jatropha* Biofuels Sector in Tanzania 2005-9:
Evolution Towards Sustainability?**

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Abstract

Biofuel production has recently attracted much attention. Some anticipate substantial social and environmental benefits, while at the same time expecting sound profitability for investors. Others are doubtful, envisaging large trade-offs between the pursuit of social, environmental and economic objectives, particularly in poor countries in the tropics. The paper explores these issues in Tanzania, which has been an African forerunner in the cultivation of a bio-oil shrub called *Jatropha curcas* L. We trace how isolated *Jatropha* biofuel experiments developed since early 2005 towards a sectoral production and innovation system, and we investigate to what extent that system has been capable of developing and maintaining sustainable practices and producing sustainable outcomes. The application of evolutionary innovation theory allows us to view the developments in the sector as a result of evolutionary variation and selection on the one hand, and revolutionary contestation between different coalitions of stakeholders on the other. Both these processes constitute significant engines of change. While variation and selection are driven predominantly by localised technical and agronomic learning, the conflict-driven dynamics are highly globalised and occur primarily as a result of reflexive learning about problematic sustainability impacts. The sector is found to have moved some way towards a full sectoral innovation and production system, but it is impossible to predict whether a viable sector with a strong “triple bottom line” orientation will ultimately emerge, since many issues surrounding the social, environmental and financial sustainability still remain unresolved, especially relating to local and global governance.

Key words: biofuels, evolutionary theory, innovation systems, sustainability, stakeholder conflict, learning, Tanzania.

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1. Introduction

Biofuel production from the tropical plant *Jatropha curcas* L. has recently attracted much attention. It has been widely claimed to be the only early biofuel that is not a food crop and can grow on marginal lands, thereby avoiding competition with food production and even helping in soil regeneration and erosion prevention (e.g., Jongschaap et al., 2007; Achten et al., 2007, 2008, ProForest, 2008; IFAD, 2010). Tanzania – along with India – have been major forerunners in attracting initiatives in this line of business (GEXSI, 2008). A survey of emerging *Jatropha* biofuels activities conducted in March-June 2005 uncovered a number of recently-started experiments (van Eijck, 2007; van Eijck and Romijn, 2008, Caniëls and Romijn, 2008). A second survey carried out in Sept-Dec 2008 (Roks and van Vlimmeren, 2009) revealed a veritable explosion of activities, organised in a variety of business models.

The aims of this paper are to: (1) explore to what extent, and how the *Jatropha* biofuel experiments in Tanzania have developed towards a fully fledged sectoral production and innovation system; and (2) investigate whether that system has developed and maintained sustainable practices and produced sustainable outcomes.

Following the UN World Commission on Environment and Development (1987) and the United Nations 2005 World Summit, sustainable development is referred to as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. In general terms, this implies the creation and maintenance of a good balance between economic, environmental and social/equity considerations. In this paper we will refer to these as “People, Planet, Profit”, or PPP. Obviously, each of the three generic PPP dimensions consists of various sub-dimensions, but unlike the main dimensions, the characteristics of the sub-dimensions are largely specific to time, place and sector. The *Jatropha* biofuels sector in Tanzania has been widely pushed because of its alleged potential to mitigate global warming and restore degraded tropical ecosystems (two environmental sub-dimensions), avoid competition with food production and create reliable opportunities for boosting local livelihoods (two social sub-dimensions), alongside promising a sound economic boost at the macro and local micro level (two economic sub-dimensions).

Our methodology is grounded in evolutionary innovation theory, and combines two different types of analysis. The first type concerns the question of how technologies and associated organisational forms and business practices have arisen and evolved over time through evolutionary variation and selection. The second type is a study of how different

stakeholders have attempted to safeguard their interests in processes of debate, coalition formation, power play and conflict. This highly globalised process of contestation is found to be a key driver of sectoral development alongside more locally-based evolutionary variation and selection. Stakeholders differ predominantly in terms of the importance they attach to the various (sub-)dimensions of sustainability, which is reflected in their actions. We show that in a newly emerging sector such as this one, where so many contentious issues are at play, the sustainability performance and outcomes of the sector as a whole arise from the co-evolution of technology and organisation through gradual learning on the one hand, and opposing societal forces on the other. Thus, the paper also seeks to make an innovative theoretical contribution by expanding the role of societal contestation and conflict in evolutionary innovation systems research.

In section 2 and 3 we outline the theoretical framework. Section 4 describes the data gathering. In section 5 we apply the framework to the *Jatropha* case in Tanzania. Our own two surveys constitute the main sources, supplemented with secondary sources such as press reports, NGO studies, company reports, reports from other researchers, etc. Section 5 comes into four parts, which trace sequentially how the sector evolved from early 2005 to late 2009. Section 6 teases out the key stumbling blocks and unresolved sustainability issues in the sector that arise from the analysis in section 5, and reflects on the merits and possible limitations of our methodology.

2. Conceptual starting point: Systems of innovation

A logical point of departure for addressing our objectives is the innovation systems literature (e.g., Edquist, 1997; Lundvall, 1992), in which innovation is seen as a collective process driven by learning, involving a wide variety of interacting agents. The systems perspective also points us towards the importance of sectoral structures and institutions, and how they impact on learning and innovation. It allows for a holistic interpretation of economic development as driven by co-evolving technologies and societal factors (Malerba, 2004).

There are several distinct sub-sets of innovation systems literature, not all of which are suitable for analysing the dynamics of newly emerging systems and analysing PPP-sustainability issues and how these interact with systems development. Only the more recently developed systems approaches include an explicit focus on societal and environmental sustainability. These approaches address the question how, and under what conditions, more ‘environmentally friendly’ innovations can emerge, develop and be broadly accepted in

society to the point where they can begin to offer superior performance characteristics over extant unsustainable practices, thus enabling a so-called socio-technical 'transition' to occur (for a good review, see Coenen and Díaz López, 2010). One of these approaches is Strategic Niche Management (SNM), which has its roots in evolutionary transition studies (e.g., Hoogma *et al.* 2002; Kemp *et al.* 2001, 1998; Weber *et al.* 1999; Elzen *et al.* 2004; Raven, 2005). SNM posits that successful radical innovations with environmentally sustainable characteristics emanate from socio-technical experiments in which various stakeholders collaborate and exchange knowledge and experience, thus embarking on an interactive learning process that will facilitate the incubation of new technologies. This occurs in a protected space called a 'niche' (Hoogma *et al.* 2002, 30).

In a later refinement of the SNM framework, which we also follow in this study, SNM writers have made a distinction between two types of interlinked niche-levels in which technological development and diffusion processes take place: the so-called 'global' niche level and the local niche level. The global level is where the emerging technological trajectory can be seen. It consists of accumulated, global, abstract and generic knowledge. Local niches (which are for instance national or regional) feed new knowledge into the global niche, and can also tap into the accumulated knowledge that is available at the global niche level. In this paper, the global niche level primarily refers to the international level. The local niche level consists of the set of projects and experiments carried out by actors in Tanzania, using their own networks and knowledge, and a specific configuration of the technology that is locally relevant.

Niche experiments take place in the context of a 'socio-technical regime', which essentially defines the established way of doing things in a particular sector. It comprises "... the whole complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures" (Hoogma *et al.* 2002, 19). There can even be more than one relevant regime for a radically new innovation. Radical innovations often require the building of entire new value chains, which may cut across different sectors of economic activity (e.g. Raven, 2007). In our biofuels case, no less than four regimes come into play, namely (fossil) energy, agriculture, oil processing, and land use & ownership customs and practices.

In turn, the regime(s) is (are) embedded in a contextual 'landscape' – a set of structural societal factors such as demographics, political system, cultural patterns and lifestyles, and macro-economic conditions (Raven, 2005, 31-32). The landscape is beyond the direct influence of niche and regime actors. Changes at the landscape level most often take place

very slowly, but sudden changes have also been known to happen (as in the case of the oil crises in the 1970s, political coups, or unexpected natural disasters).

Another line of innovation systems research with a strong sustainability focus is the Technological Innovation System (TIS) approach (e.g., Hekkert et al., 2007), which - compared to SNM - is more narrowly focused on the development of technological systems, and hones in on the critical functions that have to be fulfilled in these systems in order to generate truly sustainable innovations. Both SNM and TIS focus on newly emerging innovation systems that generate innovations with environmentally promising characteristics. They try to analyse the socio-economic and environmental learning trajectories involving incubation and commercialisation, and the outcomes of these processes.

Major differences between stakeholder priorities and agendas are recognised in these approaches. These problems are explained in terms of tensions between progressive innovation-promoting (niche) actors and conservative actors in the established regime or technological-system context, who try to oppose promising novelties to safeguard their vested interests (see, e.g., Smith, 2007). For example, the TIS framework speaks in terms of the need to engage in struggle for legitimation of sustainable radical innovations in renewable energy and transport, because incumbent technologies, actors and institutions in these sectors have had many decades to secure their powerful and organised positions. Not only may they be hesitant to embrace radical innovations in their area, but they may actively try to block their progress. Much of the early efforts of an emerging technological innovation system thus have to be spent on legitimation – activities aimed at increasing social acceptance and establishing compliance with relevant institutions (Bergek et al., 2008). There is a very similar argument underlying the dynamics of the multi-level framework upon which SNM has been crafted. As Geels (2004) explains, there are various organisational commitments and vested interests of existing organisations and commitments by people to the continuation of existing systems. “Powerful incumbent actors may try to suppress innovations through market control or political lobbying. Industries may even create special organisations, which are political forces to lobby on their behalf” (p. 911).

While this ‘niche-regime translation’ (or ‘technological system – context’) perspective on actor contestation is probably an accurate representation of reality in many cases, it is too restrictive for contentious new sectors such as biofuels. Stakeholders with opposing (or aligned, or complementary) interests can pop up anywhere in society – not only in the regime (or context). The potential social and environmental consequences are expected to be so dramatic that many groups and individuals from all walks of life want to engage in the debate

about where the new sector should go, if anywhere. Relatedly, the societal and environmental sustainability of the new technologies in question themselves become an issue of contention. As their impacts begin to crystallise out in practice, they seem to fall short on several initial promises, or at least their performance becomes open to multiple interpretations.

In other words, in these cases we do not have a clear scenario of progressive and genuinely sustainability-focused niche players versus defenders of interests vested in incumbent technologies with non-sustainable characteristics. This type of situation has been captured well in a recent paper by Sengers et al (2010), who deliberately put the word sustainability between inverted commas to indicate the growing debate about the supposed beneficial qualities of biofuels fed by experts, NGOs, and even corporate actors. They note that “... not much is known about the dynamics of these radical shifts in depicting sustainable technologies, and how this kind of criticism, especially as ventilated through the media, affects biofuel practices” (p 5013). In an analysis of distributed generation technologies based on the SNM perspective, similar patterns of growing contestation and confusion about the sustainability performance of the new technologies are observed (van der Vleuten and Raven, 2006). The authors conclude that “...technological change as well as technological stability should be analysed as potentially contested processes.” (p. 3747). Similarly, Hård (1993) criticized the socio-technical system concept for one-sidedly emphasising harmonious interactions between components whilst silencing processes of conflict and dysfunctionality. We concur with these studies in the sense that when we want to study the emergence of radical ‘sustainable’ technologies such as biofuels, contestation and conflict need to be an integral – and often constructive – part of the innovation process itself, rather than merely forming a contextual drag on it by hampering progressive innovation forces in the niche.

Thus, what we require for a comprehensive analysis of the evolution of the *Jatropha* sector is an analytical tool that is capable of integrating a focus on gradual variation and selection in a newly emerging innovation system, with a more explicit analysis of human controversies and actions around PPP issues as a second dominant driver of change. This approach is more comprehensive than what has been done so far in innovation systems frameworks such as SNM and TIS, because contestation processes will be endogenised comprehensively within the framework itself. Only then can we understand how evolutionary variation and selection on the one hand, and conflictuous inter-stakeholder dynamics on the other influence each other over time, and how sustainability-related outcomes are co-produced by these two motors of change.

3. Sectoral evolution & sustainability: A contestation-augmented systems framework

Our starting point for developing such a framework is Greiner's (1972) model of organisational development. The essence of this model is the interspersing of periods of incremental learning and adaptation with upheaval and turbulence, in his case in one organisational entity. The model consists of a number of stages, each of which represents a different developmental form of the entity. During each stage, gradual incremental change and adaptation processes are at work. This is first-order change that remains within an existing framework, producing variations on the same theme (Van de Ven and Poole, 1995: 522). However, there comes a time when people working in the entity begin to encounter fundamental misalignments between the requirements of good organisational functioning and existing organisational routines. As Greiner puts it: "During such periods of crisis, ... those companies] that are unable to abandon past practices and effect major organizational changes are likely either to fold or to level off in their growth rates." (p 401). Adjustments during these periods constitute second-order change, because they tend to involve discontinuous and unpredictable departures from past patterns (Van de Ven and Poole, 1995: 522).

Greiner's explanation of his model is worth quoting:

"... variation, selection ... explains the form of the stages, while the dialectics explain the underlying dynamics of movement [from one form to the next]. ... I put the crises in the model because I could not find data showing the stages as naturally and automatically evolving one after the other. This is not a model where a future life or end stage is assured. ... there is no envisioned end state that pulls the process – for me it is the current dynamics within the organisation that are driving it forward – convergence around the thesis of each stage and then running into resistance (antithesis) and requiring re-orientation for the conflict to be resolved. The model in fact has no ending and concludes with a question mark." (Interview with Greiner, as quoted in Van de Ven and Poole, 1995: 530).

Greiner's model was designed in a period when social and environmental sustainability issues were still primarily subservient to the pursuit of profit for commercial gain. Back then, the key contentious issue concerned the different ways in which economic efficiency could be increased and competitive advantage ensured, while the primacy of those aims themselves was not questioned except by a fringe minority. The current challenges raised in relation to recently emerged sectors such as biofuels, nanotechnology and biotechnology are more

fundamental. Societal values have evolved to reflect broader environmental and equity concerns (e.g., Korten, 2009), while those new technologies also have the potential of generating dramatic societal impacts. These concerns are reflected in different stakeholder experiences, interests, and perceptions with respect to the profound environmental and social/ethical sustainability implications that a sector may give rise to, in its pursuit to become economically viable. This insight is reflected in more recent 'conventionalist' sociological works about technological change at the sectoral level, such as Kaplan and Murray (2010). They posit that the financial profits pursued by Schumpeterian entrepreneurs are only one among many interpretations of the value of a new technology. Other parties can have different values, such as civic duty, attainment of fame, technological excellence, creativity, ecological consciousness, etc. Such value differences can lead to contestation and conflict, which can even lead to moments of crisis and breakdown when a given technological trajectory fails to mobilise sufficient societal support. These breakdowns create new opportunities for entrepreneurs to find alternative ways of exploiting their new knowledge. Thus, in these sociological models, too, we recognise the alternation of periods of incremental progress along a given technological trajectory with moments of turmoil, which was also a defining characteristic of Greiner's early model.

We introduce these concepts into a multi-level sustainability-focused innovation systems perspective. In this paper we choose SNM as our systems approach because of its multilevel perspective, which constitutes a convenient way to express and order the dynamics of a newly emerging innovation system. This is needed here, since we want to explain the *emergence* of a *new* sector. This is hard to do without studying the contextual forces in the 'landscape' and the 'regime' that give rise to its birth.

In the SNM perspective, evolutionary variation and selection mechanisms are commonly analyzed as three interrelated and mutually reinforcing niche processes (Geels and Raven, 2007; Raven, 2005, p. 43):

- (1) Voicing and shaping of people's expectations concerning the innovation. This is necessary in order to match the promises held out by the innovation and the stakeholders' expectations about it, with the needs in society that the innovation is meant to satisfy.
- (2) Experimentation-based learning about the possibilities and constraints of the innovation, specific application domains, its acceptability, suitable policies to regulate or promote it, and so on.
- (3) The constitution of a co-operating actor network, especially to enable early feedback from users and for the actors to develop a common core vision ('alignment').

The main effect of integrating sociological models of conflictuous change into an SNM perspective is a more distinctive phasing of the system's innovation development trajectory. The essential difference with the conventional SNM framework is that at certain points in time gradual variation and selection become insufficient vehicles for solving certain emerging problems and contradictions. Conflict then becomes a *necessary condition* for further sectoral development. Conversely, the original SNM approach (and other innovation systems models) predicts the fastest progress in the *absence* of conflict, because of easy alignment of expectations and efficient collaborative learning.

The empirical analysis in section 5 is structured as indicated in Figure 1. The first three rows constitute the three main conceptual levels in the multi-level SNM framework. In our analysis we fit the processes represented by these concepts onto a time line, on which we distinguish four distinct stages in the evolution of the *Jatropha* sector, as indicated in the columns of the table. By analysing the three SNM innovation drivers at the niche level, networking, learning and voicing and shaping of expectations, we can deduce to what extent these are being driven by evolutionary variation and selection and/or by revolutionary contestation and conflict in each period. In the first three periods we are able to adopt a clear sequential approach. From the analysis of the three SNM processes we are able to distil the change motors in operation. In the fourth period the cause and effect relationships between SNM processes and change motors become more complex due to the emergence of broad reflexive learning about societal impacts in the (global and local) *Jatropha* niche, which is both cause and effect of the operation of the change motors. This complex co-evolution is best shown through a joint discussion of the niche processes and the evolutionary drivers in their mutual interaction. The feedback loop from the change motors to the SNM niche processes is indicated with an upward pointing arrow in Figure 1.

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4. Data collection methodology

In the two surveys in early 2005 and late 2008, we tried to identify all significant socio-technical experiments (as defined in SNM terms) with *Jatropha* in Tanzania by talking to local people who were knowledgeable about the budding sector, primarily Ministry officials and members of the National Biofuels Taskforce (started in 2006), NGO representatives, academics and private entrepreneurs. We relied on the snowball method, starting with a few

known experts, and identifying others through these people. An "experiment" is understood as an activity undertaken by an individual or a group aimed at growing *Jatropha*, seed pressing, or developing end-use applications for the oil or the seedcake. Most of the experiments took the form of development projects led by local NGOs and governmental agencies, but there were also some for-profit ventures. Most had foreign connections involving financial support or knowledge transfer. In the first survey, 17 experiments were found, while the second survey uncovered close to 40. The great majority of these were visited and a few were contacted by e-mail. Most early experiments were situated in the Arusha and Kilimanjaro regions in the northeast. Others were situated in Morogoro and along the coast. Later experiments were also found in western Tanzania. Participants located outside Tanzania (such as international donors and car manufacturers) were not interviewed.

The interviews with the representatives of the *Jatropha* experiments were held face to face, with the help of a detailed checklist of open-ended questions. Each interview covered information about the goal, history and nature of the *Jatropha*-activities undertaken. The respondents were asked to provide details about the development trajectory of their *Jatropha* activities, covering actor network activities, people's learning processes, and the dynamics of their expectations. Considering the complexity of the processes, the experimental nature of the research, and the low level of literacy and capacity for abstract thinking among some respondents, we confined ourselves to gathering mostly qualitative information through informal discussions, loosely guided by our checklist.

5. The *Jatropha* biofuels sector during 2005-9: Emergence, evolution and conflict

The discussion in this section is organised into four time periods. For this purpose we follow the concept of the industry life-cycle model with an embryonic/proto stage, introduction, growth, maturity and decline (Abernathy and Utterback, 1978). An overview of the key SNM processes and the two drivers of change is presented in Table 1 at the end of section 5, which is a filled-out version of Figure 1.

5.1 The 'proto' stage: landscape & regime dynamics and niche emergence in 2005

Landscape conditions

The 'landscape'-canvas against which the Tanzanian *Jatropha* sector emerged in 2004-5 was one of increasing concerns about global warming. The Kyoto Protocol came into force on 16

Feb 2005, focusing public attention on the issue. 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 only one afforestation project and not a single *Jatropha* project had been CDM-funded in Tanzania by 2010). Other important landscape pressures were an increasing awareness of the finiteness of fossil fuels, fast rising energy demand from emerging Asian economies, and structural 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. All 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). Meanwhile, 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 (Mercer, 2003). Such biofuels were seen to hold promise of generating energy for biodiesel and bio-ethanol 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).

Tanzania began to attract much investor attention in an early stage for several reasons that have to do with its national 'landscape'-characteristics. Foreign investors generally find it an attractive country because of its political stability, democracy, relatively low violent crime, treaties to protect foreign investment and recent economic liberalisation (CIA Factbook, 2008). Foreign investment is actively facilitated by the Tanzanian Investment Center. There is also a large workforce which is relatively well trained due to prioritization of education during the past decades. Likewise, many aid organisations find Tanzania a good place to execute projects and programmes (CIA Factbook, 2008; van Eijck and Romijn, 2008).

However, there have also been unfavourable factors: Tanzania suffers from all kinds of problems associated with poverty. Its policymaking and implementation capacity is limited, its degree of industrialization low, and its infrastructure network inadequate. Road transport is time-consuming, difficult and costly. As we shall note later, these factors have influenced investors' choices about the set up of their biofuel supply chain.

Regime conditions

At the level of the 'regime', we have to consider the energy regime as well as the agricultural regime, the oil pressing regime, and the land regime. Regarding the energy regime, we can say that Tanzania has a high import-dependence on fossil fuels and an underdeveloped modern energy supply system. The electricity grid reaches just 11 % of the total population (EWURA, 2007), and frequent blackouts and power drops occur. Rural electricity coverage is estimated to be no more than 4% at best. Traditional sources of biomass fuel – charcoal and firewood – are becoming increasingly scarce and expensive. There is increasing deforestation due to land clearing for fuel and agriculture for an expanding population. Among different biofuels, *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). On the other hand, Tanzania's government budget has been highly dependent on import duties from fossil fuels, so that the introduction of new competing energy sources could face opposition. Also, in 2005 there was no renewable energy policy that could stimulate, facilitate and assist orderly market development of biofuels.

Tanzania's agricultural regime also influences the prospects for the development of a viable biofuel niche. Tanzania's agricultural sector is dominated by vast numbers of traditional smallholders. These are poor marginal farmers, who have been suffering from structurally low prices of staples such as maize and cassava. They might be interested in switching over to a new cash crop such as *Jatropha*. Cash crop agriculture is already well established in Tanzania. However, no policy support for smallholders exists to make this happen. There are no micro credit programmes, or well-running extension services through which peasants can learn to cultivate new crops. Moreover, local farmers tend to have low faith in becoming outgrowers with new crops. Past experiences such as with the Moringe tree – promoted by the government some years ago – have been disappointing because of market collapse (Roks and van Vlimmeren, 2009).

Yet another regime that is relevant to the establishment of a biofuel niche concerns post-harvest oil processing technologies. Basic technological knowledge about press manufacturing and use exists in Tanzania, due to widespread use of vegetable oil presses for crops such as sunflower and castor; however there is no advanced knowledge about efficient high-capacity presses in the country.

The fourth regime that needs to be discussed here is the land regime. Land can be leased by foreigners for up to 99 years, but acquisition of land is difficult, procedurally complex and

time-consuming. Furthermore, many Tanzanian citizens and local and international NGOs oppose large-scale land acquisition by foreigners. This opposition goes back to colonial times and is mainly based on negative experiences in the past with different crops and resources. Some valuable resources, e.g. Tanzanite and gold, have been exploited by foreigners while Tanzanians have hardly benefited. There is considerable public fear that the same will happen when large patches of land will be exploited for biofuels (Odgaard, 2006; Laltaika, 2008; Sulle and Nelson, 2009).

Niche processes

It is against this landscape and regime background that the first activities towards the development of a *Jatropha* niche in Tanzania began to take shape. In 2005, we see just a few loosely connected single experiments. Network density is low, and the government is notably absent from it. There is no regulation, and no stimulation (van Eijck, 2007: 87), so we cannot yet speak of an innovation system in the sense of a set of interacting and interconnected learning agents with an accompanying institutional infrastructure and governance, as it is commonly defined by authors such as Malerba, Lundvall, and so on.

There are just two key players, one NGO (Kakute), and one subsidiary of a small Dutch TNC (Diligent Energy Systems). Their business models are not yet clearly articulated. Kakute started its *Jatropha* activities with funding from the Mc Knight Foundation in 2000. It is pursuing an informal outgrower model, collecting seeds from farmers on an irregular basis (including seeds from wild *Jatropha* plants already growing in the region). These are pressed manually with a ram press. Production takes place on a small scale. 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.

Although there were already a diversity of actors in the cultivation stage, the oil pressing stage was incipient and the end-use stage almost non-existent. This makes sense, since a full value chain can only be built up once sufficient oilseeds are available, and it takes 3-4 years for new plants to start bearing fruit. In the cultivation stage, the *actor network* was also found to be expanding quickly and becoming more diverse, with research institutes beginning to be involved. Several agronomic *learning processes* had already occurred, for example concerning ways of propagation of seed, irrigation, and planting distances. However, these learning processes had not yet been synthesized or shared among all the relevant actors.

People's *expectations* about *Jatropha*'s viability were generally highly positive. On hindsight (from the perspective of late 2009) people's seed yield estimates of 5 to 10 t/ha/yr have proved to be completely unrealistic, a clear sign of the underdevelopment of the sector.

In oil pressing, we see a small but diverse *actor network*, mostly linked through Kakute which effectively acts as a channel for transfer of new information and effective practices among different stakeholders. Early technical *learning* by Diligent and Kakute was based on basic mechanized Sayari oil expellers made in Tanzania by a German aid-supported NGO in Morogoro, and on manual ram presses. There were no lessons about profitability of different press techniques yet, although some actors observed that the ram press is inefficient and unwieldy for producing larger quantities. There were no ideas either about what press capacity would ultimately be used, because of complete lack of information about market acceptability and suitability of the oil. There were also no lessons yet about the infrastructure and storage requirements of seeds and oil, although this aspect was expected to be important because seeds and oil are natural products. 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 one central pressing unit, with the seeds being collected from various places. Transport difficulties due to poor roads, and unreliability and inefficiency of equipment are seen as barriers to the development of the industry.

At the usage-stage of the production chain, the *network* is embryonic because a commercial market for *Jatropha* oil and its by-products does not yet exist, while there is also no developed seed and oil supply system. However, actors had by then identified several different possible uses for *Jatropha* and were just beginning to engage in *learning*. First, actors had identified *Jatropha* oil as a potentially good diesel substitute in remote locations within Tanzania, or for export. Diligent was also exploring 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. Diligent's experiments were to some extent supported by research at Eindhoven University of Technology (TUE) in the Netherlands, where an MSc project had started about the behaviour of *Jatropha* oil in diesel engines (Rabé, 2004). However, since *Jatropha* had never been used as a diesel substitute, lessons on acceptance by users and car manufacturers were still lacking.

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. Kakute had already conducted an experiment with a small biogas plant, which yielded mixed results because of unreliable gas pressure. There were no experiences with *Jatropha* as fertilizer or briquettes. Clearly, much technical (and societal) learning was still required here. The research in 2005

concluded that seed cake applications 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 still contains about 50% of the oil) 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. Kakute has a small *Jatropha*-oil lamp factory, but no widespread market for this new lamp was found. Kakute has also experimented with a cooking stove prototype, but there has been no sharing of lessons and no continuous learning due to shortage of *Jatropha* oil. The stove prototype was not yet functioning properly and there were many complaints about fumes.

Finally, *Jatropha* gave rise to some non energy-related by-products, notably medicinal soap, which is made by Kakute on a small-scale basis. The soap commands a small niche market. Users are happy but there is no clear strategy for upscaling and more systematic marketing.

In sum, individual people's *expectations* about possible end-uses varied widely in the absence of developed end-markets. We could not find any systematic differences in beliefs and expectations among stakeholder groups; they all express great market optimism at this stage. There is no communication with potentially interested users who could provide useful information about their preferences and needs. This state of affairs is reflected in all the different potential *Jatropha* applications. This stage is driven by individual (rather than group-based) vague beliefs and expectations, rather than facts and experiences.

Evolutionary motors

We now spell out the findings from the 2005 situation for the two transition drivers discussed in the previous section. At this early stage, it is evident that *evolutionary variation* is the dominant mode of progress. In particular we see variation emerging in the technologies used, e.g., three different agronomic practices for propagating *Jatropha* in the cultivation stage. Another example of variation is oil use, where participants had identified many different possibilities of using *Jatropha* or its by-products. We also see the early beginnings of what were later to become two distinct business models: (1) Diligent's commercial outgrower model, which combines contracting from many small-scale outgrowers located in different regions with centralised factory oil pressing in Arusha, with the aim to develop a national or even an international supply line; (2) Kakute's less commercially oriented outgrower model,

with prime emphasis on empowerment of rural women through local income generation and local use of *Jatropha* 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 lessons yet about economic viability of *Jatropha*, although this is receiving everyone's attention and is subject to much speculation. The process of niche development as a whole is pulled mainly by highly optimistic yield expectations.

Major social or environmental sustainability issues are not yet in view. In SNM terminology, there has been no reflexive societal learning. The second motor 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 this vast country to pursue their own interests without having major effects on each other. At this embryonic stage there is no large influx of big investors whose activities could potentially have major effects on the rural ecological and social-economic scene. The public at large – both within Tanzania and abroad – is still hardly 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.

5.2 'Introduction': mounting landscape pressures and evolutionary variation in 2006-7

Landscape conditions

The favourable expectations generated in the early years of *Jatropha* niche development in Tanzania - as well as in other tropical countries such as 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 degrees Celsius 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; Kolk and Pinkse, 2008; Sampei and Aoyagi-Usui, 2009).

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. In addition, according to the OECD, annual financial support given by the US, EU and Canada to stimulate the supply and use of biofuels had risen to US\$ 11 billion in 2006 and was expected to rise further to approximately US\$ 25 billion by 2015 (Hauwermeiren, 2008). 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 Tanzania.

Regime conditions

Energy regime conditions, both globally and in Tanzania, were equally 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 Figure 2). This raised expectations among investors that the production of biofuels like *Jatropha* could actually become competitive under market conditions. Conditions in the other three regimes essentially remained as in the earlier period.

PLEASE INSERT FIGURE 2 ABOUT HERE

Niche 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.ⁱ There occurs a major influx by western transnational corporations (TNCs) into tropical countries in Asia, Africa and Latin America. These 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 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).

In Tanzania, the combination of the various global landscape pressures and positive expectations gave rise to a virtual deluge of foreign investments into the fledging *Jatropha* sector. A survey undertaken in the spring of 2008 identified a whole range of different initiatives and scales of production, varying from very small-scale production activities to extremely large plantations (or sets of plantations) exceeding 50,000 ha (Martin et al., 2009). In our own second survey, all these initiatives were found to be linked to foreign investors or aid donors (Roks and van Vlimmeren, 2009).

At this stage we can also begin to differentiate between more or less distinct business models with distinctive technologies (Martin et al., 2009; Roks and van Vlimmeren, 2009): Local Multifunctional Platforms (LMPs); Large Plantations (LPs); and decentralised Outgrower-based Models (OMs).

LMPs are established in rural areas, motivated by the potential for improving livelihoods through collective utilisation of local resources (Appropriate Technology, 2007). Two LMPs were set up in the remote Maasai villages of Engaruka and Leguruki. Designed to promote local economic development through community self-sufficiency, LMPs consist of a set of three basic interlinked machines placed behind one another: a small oil expeller, a generator set, and a maize mill. The idea is that local farmers will cultivate the plant as hedges round their fields and/or intercropped with food crops, and that the oilseed harvest would be sufficient in due course to substitute for fossil diesel as a feedstock for locally generated electricity (Wijgerse, 2007). The LMPs should stimulate activities such as maize milling, lighting, radio services and mobile phone charging. The LMPs are preferably run by local women's groups, and are meant to contribute to their empowerment. The model was copied from projects in Mali, where it was reportedly highly promising (UNDP, 2004).

The LP side of the business-model spectrum consists of a number of western investors, mostly from EU countries, attracted by the Tanzanian government's welcoming attitude to large scale agricultural initiatives and backed up by a favourable biofuel investment climate

and lavish subsidy schemes in their home countries. Since these projects are required to go through lengthy land acquisition procedures, they were still in their infancy during this stage, but their plans were grandiose. In one case, a company wanted to lease 81,000 ha of village land for conversion into 200 ha estate plots of *Jatropha* monoculture. It planned to remove existing vegetation using heavy duty imported machinery. It was also planning to conduct systematic agronomic experiments in collaboration with local and foreign universities to optimise *Jatropha* yields by means of pruning, mulching, and introducing pest and disease controls, and it wanted to introduce mechanical harvesting, never tried before with *Jatropha* (Romijn, 2008). Many of the LP schemes were being established in Tanzania's coastal zone, in view of their ambitions to export (Martin et al., 2009), in many cases through shipping out the raw agricultural product (Romijn, 2008). In 2007 the African Biodiversity Network (ABN) noted that

"...the Tanzanian government is evidently committed to fast-tracking agrofuel initiatives, and switching over vast areas of land to sugar cane, palm oil and *Jatropha*. The most fertile lands, with best access to water are being targeted, even though these lands are already used for food production by small-scale farmers. Any talk of biofuel production for local energy consumption is undermined by the obvious intent of international investors to target foreign markets ... Also, there are no plans to invest in infrastructure in Tanzania to process agrofuels for local use" (ABN, 2007: 12).

It should be noted, however, that the export orientation of these 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.

The OM business model constitutes the middle ground in the business spectrum. OM projects do not acquire own land (Sulle and Nelson, 2009), but source their seed supply from independent farmers. The OM thus affords a more gradual growth trajectory, enabling firms to start experimenting with oil pressing on a small scale, growing gradually by extending their contract farmer network over time. They also utilise well-established *Jatropha* plants that are already growing wild in some areas, such as Shinyanga and Singida. These companies were not established with a definite plan where their main market should be. Exports as well as

domestic and even local sales (for instance, to a soap producer and to local eco-safari companies) were being targeted, depending on the economic viability. In any case they plan to utilise the *Jatropha* by-products (hulls and seedcake) locally, so their market strategy is more mixed than that of the LMPs and the LPs (Roks and van Vlimmeren, 2009).

Evolutionary motors

Summing up the main developments during 2006-7, we see a continuation of the *evolutionary variation* motor of change. Compared with 2005, the learning in the niche 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).

As far as *antagonistic processes* go, we cannot yet see full-blown conflict, but we can discern the first signs of these in early publications by NGOs such as the ABN. Interestingly, the ABN actually operates from within the African *Jatropha* niche, since it is a regional network promoting sustainable biofuel practices involved in collecting and disseminating lessons from project experiences in different African countries to relevant niche stakeholders.

5.3 Frustrated early growth: Landscape instability and seeds of conflict during the 1st half of 2008

Landscape conditions

The first half of 2008 is marked by major instabilities in the global and local Tanzanian landscape, which have had dramatic effects on the development of the Tanzanian *Jatropha* niche. These developments coincided with significant learning in the niche, due to the accumulation of experiences from the cultivation of *Jatropha* as a managed agricultural crop. Since *Jatropha* takes about 3 years to start yielding seeds, the earliest *Jatropha* projects in Tanzania and in other countries such as India 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 percent higher than the previous peak in 2007. It also pointed out that the bulk of the anticipated growth in the world food import bill would come from higher expenditures on rice (77 percent), wheat (60 percent) and vegetable oils (60 percent) (Ibid, p. 107). 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 (The Citizen, 23 July 2008). In Tanzania it began to spur major controversies over the large scale biofuel plantations that had recently been established in the country, for example in the form of press articles, parliamentary & academic debates and NGO activity (see 'niche' discussion below).

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.'s (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." A survey of environmental life cycle studies about *Jatropha* biofuels concluded that all of them were deficient in their treatment of land use change and thus too optimistic about the crop's GHG mitigation effects. Its own preliminary estimations of GHG emissions associated with the conversion of Miombo Woodlands – the dominant Sub-Saharan African ecosystem – into *Jatropha* plantations support Achten's qualitative conclusions (Romijn, 2010).

Regime conditions

Steadily climbing fossil oil prices (see Figure 2) 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.

However, we also see negative pressures beginning to emanate from Tanzania's dominant agricultural regime: 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. A World Bank report estimated that informal uses of local forests account for US\$ 35-50 in generally unaccounted-for per capita income in Tanzania (Sulle and Nelson, 2009, p. 4). Also, the argument is surfacing that future land requirements for food crop cultivation restrict its availability for biofuel production, for example in traditional rotational agricultural schemes that are still widely practiced in Tanzania. Similar arguments are surfacing in relation to other countries, e.g. India.

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.

Niche processes

Due to these combined and cumulative landscape and regime pressures, the Tanzanian *Jatropha* niche 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). 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, and notes that the government of Tanzania has already surveyed many fertile regions with the best access to water, which also happen to be the regions where farmers are already growing food. It warns that Tanzania's main rice areas could be given over to biofuels production and that production of maize, wheat, beans and cassava may also be affected. The NGO accuses the government of having few qualms about evicting smallholders from their land. Perhaps worst of all, it predicts increased conflicts over already problematic water access when this resource will be diverted for biofuel irrigation (ABN, 2007).

The biofuel sector in Tanzania had grown so large (approximately 38 leading actors in early 2008) that it also began to draw the attention of the international press. In May 2008, the *Financial Times* reported that the food versus fuel debate and associated turmoil had led to disarray in the Tanzanian government about how to proceed, "blowing hot and cold" depending on who's asking, and dithering over the introduction of effective regulation. A national biofuels policy was called for by concerned donors and investors who dearly desired more clarity about future prospects and land acquisition procedures, but so far divided politicians and the 'creaky government machinery' had not made much progress (Beattie, 2008). The *East African* regional newspaper adds further inflammatory details about one 8000 ha plantation scheme close to Dar es Salaam implemented by Sun Biofuels (UK), especially about its alleged lack of prior consultation with local affected villagers, the low wages on the plantation (\$3 per day), the long land lease (99 years), and the danger that Tanzania might soon be overrun by similar investments, which would cause a major threat to its already precarious food security situation (Redfern, 2008).

Further details about latent and rising inter-stakeholder contentions related to this case are given in Habib-Mintz (2010), based on stakeholder interviews. She found that one village had expressed reservations and had filed a formal objection that the company had earmarked more land than permitted by the village. While this was still being processed by the bureaucratic legal system, clear-cutting of forest began without completing village consultations, demarcations, and district level government approval. Problems were also found in relation to compensation payments. Some of the affected villagers only knew their name was on a list but did not know any details about the allocated land size. No contracts were drawn up and discussed with the village council and there had been no possibility to negotiate over payments. The district agricultural officer indicated that the actual per ha compensation paid

was to the tune of one seventh of the estimated commercial value of the land lease. Contentions also arose over the magnitude of promised employment. Whereas the company gave out estimates ranging from 1000 to 4000 jobs per village at an annual wage of \$1095 per person and promised to spend 5% of its annual budget on ‘social infrastructure’, it became increasingly obvious that this would not be financially feasible due to the marginal profitability of *Jatropha* oil production when the fossil oil price would dive below US\$ 100 again (which it did very soon) with no likely repeat of the 2008 oil price spike any time soon (Habib-Mintz, 2010).

Similar experiences have been reported in relation to EABD, an investor in remote Bahi, which bypassed the formal land acquisition procedures, instead approaching the local government directly. When the Regional Commissioner publicly denounced EABD activities as illegal, villagers got confused since they did not receive the information through the usual local government channel. In one village, fertile land was allocated to the investor without owner consent, or any formal notification to the district. When pressed about it, the investor threatened to move to another village, which upset villagers who were expecting major benefits promised by EABD. In one instance, one village gave away land legally belonging to another village. This transaction induced conflicts between food versus fuel crop cultivation involving neighbouring communities. EABD did not offer to pay any land compensation, instead promising large numbers of jobs, free local supply of *Jatropha* oil and by-products for lighting, cooking and so on, improved water distribution and substantial investments in community development projects. Several villagers were taken in by these promises (which were not backed up by written contracts) while others were doubtful or angry with the investor. Thus we see local conflicts emerging within village communities, as well as conflicts between communities, and between villagers and the investor. We also see that the government is also a multi-layered actor, whose employees can take different sides in the debate. Some take advantage of opaque procedures and institutional weaknesses to attract investors, whereas others try to uphold the law (Habib-Mintz, 2010).

A few weeks after the *East African* article referred to above, the same newspaper hones in on a highly critical new report by Oxfam International (2008) 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). The same article reports on a Tanzanian Member of Parliament (MP) cum environmentalist who takes the government to task over its rush to embrace biofuels without proper consideration. In reply, the Prime Minister announces that the Ministry of Energy and Minerals and the Ministry of Agriculture, Food and

Cooperatives have been tasked to come up with policy regulation, but that investments that are already underway in the country cannot be halted (Afandi, 22 July 2008). Just two days later, a local paper adds to the heat with an editorial stating that another concerned MP spoke in parliament about a Dutch investor acquiring long leases over very large tracts of fertile land directly from villagers in the Kilwa area, which it is not allowed to get without prior government permission under the 1999 Village land Act. The journalist laments that the government has remained silent, in spite of more and more reports and statements from local watchdogs, NGOs, university researchers and MPs expressing great concerns over the large-scale allocation of fertile land (estimated by the Land Research and Resources Institute to amount to 641,170 ha by then) and the uncertainties hanging over the supposed benefits of biofuels like *Jatropha*. It is urged to act immediately to put regulatory and legislative mechanisms in place (*The Citizen*, 24 July 2008).

An interesting example of academic voices in the debate is a presentation given in a biofuels conference in Dar es Salaam, which reported on survey findings from a multidisciplinary study group from Tanzania's three best known universities. The group noticed that the country's coastal regions top the investment list because of port facilities, a factor indicating that the biofuel business is mainly for export. This, they say, raises concern about benefit sharing for improved local livelihoods. Long term attractiveness of the current crops is also no certainty, in view of intensive ongoing research for more efficient biofuel crops. Will the costs of the loss in biodiversity and land degradation caused by these developments not outweigh short term financial gains? And finally, they draw attention to the need to build better national capabilities, research and transport infrastructure. In the absence of these assets, foreign investors will be induced to keep relying on foreign partners for key services and collaborations, thus contributing to exclusion of national parties and lost knowledge accumulation and local development opportunities (Mwamila, 2008).

In retrospect, this brief period was a particularly tumultuous one in the biofuel development trajectory, both in the world at large and in poor developing countries like Tanzania, with the tumult mainly emanating from developments in the landscape and in the niche. 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. 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. Hence, the world can ill afford to devote vast tracts of arable land to the cultivation of biofuels. The public support base for large-scale plantation investments in biofuels began to erode, both globally and within Tanzania itself.

Evolutionary motors

This lesson began to sink in just as the first results of significant progress in learning in the emerging global *Jatropha* biofuel niche began to circulate. First of all, in addition to ongoing *evolutionary variation* we now begin to perceive *evolutionary selection* in *Jatropha* cultivation. 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 possibly be financially attractive and reliable under those conditions. The ‘selection’ we observe is that this caused investors to scout for cultivable land, further inflaming the food versus fuel debate. This happens globally in *Jatropha*-producing regions, as well as in the local *Jatropha* niche in Tanzania. This dawning reality therefore also marks the start of ‘reflexive learning’, i.e. second-order learning about the desirability or otherwise of *Jatropha* biofuels, driven by sustainability impacts. In Tanzania, the accumulation of problems with large plantations such as those detailed above for the cases of Sun Biofuels and EABD was beginning to cause disillusionments about the much hyped developmental benefits of the crop for poor developing countries. For many, this effectively punctured the overblown expectations that had been built up.

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 motor on the nature and direction of the innovation process in the sector. At this stage, all we can see is fermentation, but no outcomes. This was to change in the next period (discussed in section 5.4 below).

Seen through the lens of Greiner's framework, this is a period in which it is discovered that major parameters governing the future operation of the sector would need to be reset for further progress to be able to take place. We also see different parties mobilizing to make this happen, by doing research, writing reports, begin work on regulatory institutions, forming

stakeholder forums, and striking up informal alliances (e.g., by supporting each other on blogsites and in the local press) to put pressure on other parties, especially large plantation investors, investment subsidy agencies and policy makers. Some of these parties form part of the (local or global) *Jatropha* niche itself, while others are more loosely connected to it, or form part of the contextual landscape. In any case, it is clear that the sources of contestation are not limited to regime or landscape domains, as the consensual SNM perspective assumes. We begin to discern the first *selection* results from these societal pressures and power strugglesⁱⁱ in late 2008/early 2009, to which we now turn.

5.4 Interrupted early growth: landscape & regime instability and niche conflict from mid 2008 onwards

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 – both at the global level and locally in Tanzania. 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*, 23 May 2009, 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, 2010, Table 5). 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).

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.

Meanwhile, the severe food shortages and high food prices (national landscape factors) that are also experienced in this period begin to spur major concerns about the state of Tanzania's agricultural regime – the backwardness of the massive domestic agricultural

smallholder sector and its inability to provide food security. One finds increasingly vociferous criticisms by actors such as NGOs, academics and journalists in the press and on blogs, about the neglect of these issues by the government (Godoy, 2009; Kamata, 2009). One journalist also criticises the wishy-washiness of a recent FAO report about the consequences of the large scale acquisition of African land by foreign investors. The FAO report emphasises the potential for macro-economic developmental benefits arising from this development, while underplaying the regulatory and legal requirements that need to be in place and to be enforced in order to guarantee the safeguarding of local Tanzanian interests. The journalist points out that African countries lack the required governance capacity. In these circumstances, a foreign investor can strike deals with corrupt representatives of the host state or local elites to get its way, while displaced smallholders do not have the wherewithal to negotiate fair deals, nor are they able to enforce agreements when the foreign party fails to deliver promised services such as employment or public services (Godoy, 2009).

Another piece suggestively titled “Imperial Projects and the Food Crisis in the Periphery” reports on a seminar held at the University of Dar es Salaam by concerned academics. It draws attention to the long historical neglect of Tanzania’s agricultural smallholder sector and its colonial history, when rulers gave preference to cash crops for export, or to the modern food sector. The biofuel wave is feared to be a continuation of these past policies (Kamata, 2009). Similar sentiments are expressed in international publications (e.g., Dauvergne and Neville, 2009). Another local academic details the impacts of advancing *Jatropha* cultivation on Maasai pastoralists, including loss of grazing lands and spiritually significant places. It also cautions NGOs that try to involve Maasai in cultivation of *Jatropha* themselves. Many Maasai apparently experience it as upsetting their traditional ways of life and culture, though they might not say so openly (Laltaika, 2008).

Niche processes and evolutionary motors in mutual interaction

The main developments in the Tanzanian *Jatropha* niche at this stage are detailed in our second survey in sept-nov 2008. Looking first at the *network dimension of niche development*, we note that the network has expanded exponentially. In addition to the two original lead players in 2005 (Kakute and Diligent Tanzania Ltd) there is a raft of major new players, many of them large plantation investors. At the same time, the original incumbents continue to play a core role in the expanding network because of their experience, accumulated knowledge and contacts with farmers. Diligent is the first to start oil pressing on a commercial scale, and new start ups in the sector are keen to absorb these lessons, as well as its experiences with

managing a decentralised supplier network and cultivation-related lessons. The company becomes flooded with curious visitors almost on a daily basis, to the point where it has to appoint a public relations officer in order to regain control on the public dissemination of information. In terms of organisation, we note considerable development associated with increasing specialisation of functions driven by growing volumes of production and trade. The different stakeholders were found to execute a number of increasingly differentiated roles, including: cultivation; processing; knowledge and consultancy; financing; purchasing of end products; special interest group promotion and lobbying; regulation; machinery supply and new equipment development (Roks and van Vlimmeren, 2009, pp 47-49). There is also some progress in terms of institutional development. In mid 2009, a number of private biofuel producers formed an association for the purpose of collaboration on research and lobbying for coherent and transparent policies (ProBEC, 2009). The network is thus developing considerable specialisation and gaining more depth in its functions, as well as growing fast in terms of sheer size. There are clear connections between the early projects and later ones, in terms of involved parties, cumulateness of learning (see below for more details) and logical progression in the emergence and organisation of different functions. Thus, we can justifiably begin to speak of the maturing of a cohesive niche, the first step towards the emergence of a full-fledged innovation system.

Next, we consider some important *niche learning processes*. The stellar growth, combined with the adverse landscape constellation and the absence of effective regulation, conspire to feed worries about the current and future impacts of the sector, fed by frequent articles in the local and international press and parliamentary debates. Several leading NGOs start investigating. One study by the WWF Tanzania chapter with support from WWF Sweden in 2008 contains damning findings regarding the location decisions, investment procedures and operations of some of the foreign plantation investors (WWF-Tanzania Programme Office, 2009). Another study by the Tanzania National Research Forum's Forestry Working Group and the International Institute for Environment and Development, estimates that a total of 640,000 ha had been allocated for biofuel investments, with approximately 4 million ha being requested by investors. It also estimates that between 5000 and 10000 local people have been affected so far, leading to the alienation of their rights over customary lands (Sulle, 2009). More examples of critiques are given in the analysis below.

Before delving further into the learning details, we first present some brief information about the actual developments on the ground that are important for understanding the nature and direction of learning in this period. In particular, the future outlook for *Jatropha* looks

more mixed than the recent fast growth of the niche suggests. Despite increasing international landscape pressures favoring renewables for environmental and energy security reasons, local user preferences in Tanzania are primarily based on price because of the poverty. Hence, the crash 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 transportation or lighting. However, since the quantities of *Jatropha* oil that are actually reaching these markets are still minimal in any case, there was not much short-term negative impact there.

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, 2009, Vilt, 2009). It has become easy for NGOs to acquire donor finance for such applications because their multipurpose functions, including a focus on Millennium Development Goals such as poverty alleviation, gender equity, and environmental protection, and their potential to foster local democracy and decentralized development fit well with the dominant priorities in the extant development discourse, or ‘international aid landscape’ (Nygaard, 2010). A local technology development organisation, TaTEDO, announced that it had received funding from Dutch parties to implement 100 additional LMPs along the lines of the two experimental ones installed earlier, even though these were not yet functioning adequately. A recent review of LMPs in West Africa has shown their financial viability to be quite bad when they are run on *Jatropha* oil, which have caused many to revert to fossil diesel, and others to shut down completely (Nygaard, 2010). Unless *Jatropha* is introduced on a commercially sound basis and accompanied by strong local capacity building for project management and maintenance, the biofuel-based LMP concept will not be sustainable after the donors pull out (Trondsen, 2009; Wijgerse, 2007). If things don’t improve fast enough, we expect that the LMP model might become subject to negative selection.

The learning in the niche is still mostly supplier-driven (about costs, technical performance, etc). 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, participation in international conferences, etc. in 2008/9. As a result,

enough lessons have accumulated for local actors to agree that the technology functions well enough. Further learning is geared towards overcoming problems in other dimensions, e.g., to improve alignment in preferences between users and suppliers, or to minimize ecological impact. 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, some actors also investigate properties of the *Jatropha* oil. One company installed its own laboratory facilities to do this. This company also assists the government with the drawing up of national technical standards, since the government's own facilities and capabilities are insufficient (Romijn, 2008). Actors also continue to learn about the agronomical properties of *Jatropha* and conditions affecting plant growth and yield. A new experience concerns bottlenecks with seed supply logistics. These begin to be seen as a barrier for the further development of the *Jatropha* technology particularly by OM companies. One project is setting up an efficient supply chain for large scale decentralized production involving thousands of outgrowers, based on regional collection centres that are also hubs for training and extension work.

Early learning on the user-side gets also under way at last. There are different experiments related to different end uses (Roks and van Vlimmeren, 2009). Here we see a new instance of *evolutionary variation* occurring. So far, distribution has been done with barrels delivered to special user categories, including eco-safari companies, a local soap producer and Boeing (15,000 litres 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. Another promising end use is biodiesel for clients like eco-safari companies. 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.

We also begin to see the first instance of (negative) *evolutionary selection*. One project being pursued was the use of PPO in the Protos, a cooking stove developed by BSH Bosch und Siemens Hausgeräte GmbH. However, an experiment with local users failed because of fast clogging of the pipes, high oil costs, and unreliable supply of *Jatropha* oil. The experiment was discontinued, and so far no new cooking oil experiments have taken place,

although the Protos design has since been improved and the clogging problem has been solved. The stove is now being successfully mass-marketed in Indonesia, but its market potential in Eastern Africa remains to be assessed.

All the learning processes detailed up to now in this paper can be mainly associated with the *first change motor* in our framework, i.e., evolutionary variation and selection. At this point in time, however, the influence on the sectoral innovation process from the *second change motor* - contestation and conflict - becomes evident as well. This happens under the influence of reflexive impact learning which is picking up speed as a result of the accumulation of results by various studies and press reports.

One major aspect of impact learning concerns environmental sustainability effects of *Jatropha* investments. It is becoming increasingly evident that these effects differ markedly across different business models. Some large plantations are found to be infringing on ecologically rich areas (such as Tanzania's coastal forest belt) and these are thought to have invasive effects on flora and fauna. These projects are not necessarily favorable in terms of GHG emission reductions either, because they cause carbon emissions from clearing vegetation and disturbing soils that have never been tilled before (Dehue and Hettinga 2008, Reinhardt et al. 2007; Romijn, 2010; Veen and Carrillo, 2009). The OM and LMP models are emerging as the ecologically soundest options, because *Jatropha* is generally not planted on uncultivated land (it is rather intercropped with food crops, or planted as hedges around crop fields because of the better fertility of the land in those conditions, see: Wahl et al., 2009; Wiskerke et al. 2010; Messemaker, 2008; Kempf, 2007; Mitchell, 2008), while it also does not compete much with food production (Struijs, 2008; FAO, 2010; Gordon-Maclean et al. 2008; Mitchell 2008; Loos, 2008).

On the social dimension, the three business models are more competitive. Large plantations offer much short term wage employment, although longer term employment is uncertain, and plantations use a lot of village land. Longer term implications for local food security are also still questionable. The OM and LMP models offer much less full-time employment, and only limited supplementary income to poor smallholder farmers (Loos, 2008; Mitchell, 2008b), but their labour/capital ratio tends to be higher than those of plantations because they can make do with much smaller fixed capital investments (AgentschapNL, 2010, forthcoming). Their impact on food security is expected to be minimal, as investors do not acquire land. The LMP schemes are expected to have the best social results, because they are designed to combine benefits for local growers with benefits

for local energy users, although there are many problematic economic and organizational aspects associated with these schemes, as noted before.

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 LMP schemes, which tend to be NGO-financed, are still left off the hook for the time being. The pressure on the LPs comes in the form of *societal contestation* from a range of actors including NGOs, anti-biofuel government representatives, critical journalists and newspapers, and academics, in turn aided by international stakeholders of similar stripes. The same holds for recently started palm oil and sugar cane plantations.

This is beginning to have effects on the nature and direction of the innovation process in the sector as a whole. Such effects can take place through various mechanisms, including exit of firms with characteristics that are widely considered to undesirable and entry of more firms with more desirable characteristics. It can also manifest itself through an organizational reorientation of operations in ongoing companies, e.g. making increased efforts to serve local/national (rather than international) oil markets, experimenting with local-foreign partnership arrangements, and using less mechanized technologies in order to generate more employment.

A third selection pressure mechanism could be purposive investments by companies in reflexive learning through technical experimentation. However, despite the mounting societal pressures and contestation, we have found only limited experiments set up for the sole purpose of broad social and ecological sustainability-related learning. Learning about ecological sustainability occurs through literature search, limited data collection, and simple tests performed in the projects, 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. One investor is beginning to measure carbon sequestration in its growing *Jatropha* plants.

The first consequence of selection pressure through the exit mechanism comes in the form of the withdrawal of a Swedish ethanol producer from sugarcane. SEKAB received a great deal of adverse publicity in the Tanzanian press and on environmental blog sites related to its water use, its adverse impacts on the valuable local ecosystem and its dubious social effects (a good example is Madoffe et al., 2009). When the news reached the Swedish parliament and the Swedish public, SEKAB found it impossible to raise the additional funds it needed to

make its plantations operational. It announced its withdrawal from Tanzania in January 2009 (although it seems to be trying to restart under a different name).

A second victim in the making – through exit or organisational re-orientation – is the Dutch Kilwa-based *Jatropha* producer Bioshape that had set its sights on 80,000 ha of ‘degraded Miombo’ that turned out to include sections of valuable coastal forest according to the WWF (WWF-Tanzania Programme Office, 2009). One of the investors in the company got cold feet and halved its share, leaving the firm with an acute cash flow problem. This company has not withdrawn from Tanzania, but the Dutch mother company has been declared bankrupt in 2010, and a new owner is being sought for the Tanzanian subsidiary. If this happens, the company will have to reorient its operations in order to show – to future investors and others – that it is capable of developing truly sustainable operations.

Another aspect of sustainability-related learning that puts special selection pressure on the plantation investors concerns the formation and implementation of rules, regulations and standards. Within Tanzania, this issue came to the fore after the National Biofuel Taskforce – constituted by the government in 2006, but initially not quick-acting – finally came with its first results in August 2008 in the form of a Draft National Biofuel Guideline. The task force includes a representative selection of industry stakeholders, who debated and helped to set the definition of national standards for the quality of biodiesel and bioethanol (now completed, with the help of the one firm with a laboratory), and how the government should enforce these standards (still ongoing). A need for clear rules about taxes on *Jatropha* biofuels was also voiced during the consultation process. But perhaps the most important issue tackled by the Taskforce has been the formulation of guidelines on respecting biodiversity, ensuring food security and preventing exploitation of villagers, e.g. in the form of rules on how to acquire land, and introducing land zoning. A revised/improved guideline was issued in November 2008 which has been passed by parliament. However, in 2010, the guideline had still not been approved by the Cabinet. The delay has attracted severe criticism from the local media (Mngazija, *Daily News*, 12 Oct 2009; Kandoya, *Daily News*, 4 Oct, 2009). Even villagers had become so politically aware by this time that they refused to sign a recent land lease contract with a major investor Sun Biofuels, for its expanding plantations in Kisarawe district (Lugungulo, *Daily News*, 12 October 2009).

Worse than the pressures from within the Tanzanian system are those emerging with respect to international norms and standards currently under development, such as the Dutch NEN NTA8081 (currently in the trial stage), the GBEP GHG guidelines (GBEP, 2009), the UK RTFO standard and the EU RED (McGregor, 2008). As stated earlier, biofuels are also

approved for inclusion into the Kyoto Clean Development Mechanism (CDM), which generates high expectations of gaining carbon credits among investors. For the actors targeting international markets, learning had to begin about how to match their practices to these new standards and potential opportunities. The standardization and certification efforts are clearly linked to *landscape pressures*: negotiations are underway to create a successor treaty to Kyoto, which ends in 2012, and to the implementation of RED in early 2011. New binding commitments on the part of member countries towards reducing GHG emissions are obviously expected to be included. 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.

The third niche process, *formation and evolution of stakeholder expectations*, suggests that the sector is still very much in a flux and expectation-alignment among stakeholders is only just beginning, and covers only a few broad areas. No dominant design is being foreseen yet, although the stakeholders observe that the OM has achieved the most stable situation in respect of supply and demand and public acceptance. Tanzanian *Jatropha* insiders also expect the OM model to top the list in terms of market size and surface area in future years (Roks and van Vlimmeren, 2009, p. 64). However, the logistics, extension, and certification requirements of this model will become highly complex and costly when OM companies grow large, encompassing thousands or even tens of thousands of small contract farmers. We also see ongoing *evolutionary variation*: some OM investors are now considering hybrid business models, comprising a core plantation supported by a sizeable outgrower system (Vermeulen en Cotula, 2010). Other ideas include hiving off all the labour-intensive training, extension, standards monitoring and seeds collection activities into a separate non-profit foundation that may qualify for carbon credit funding and can attract socially ethical investors who cannot involve themselves as co-owners in a commercial entity. This could be a way to cover the structurally high costs of working with smallholders (van Eijck, 2009; van Eck, 2009).

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. This requirement is likely to drive some convergence between the dominant LP and OM models. For the OM businesses this will likely involve some sacrifices in terms of social and environmental sustainability in order to improve their financial profitability, e.g., through adding central plantations alongside their expensive and complex outgrower systems; whereas the LP companies could improve their performance on the environmental and social scores to some extent by adopting locally less invasive arrangements, e.g., in the form of partnerships with co-operations of local farmers who cultivate adjoining plots of land ('block plantations') without acquiring their land (Vermeulen and Cotula, 2010).

However, it is still an open question to what extent an acceptable balance between the three PPP-sustainability elements (and their sub-elements) will be achieved in this way. Significant trade-offs between them have emerged, and it remains to be seen if the sector will ever get the opportunity and time to work out compromises that are broadly acceptable for all stakeholders. In October 2009, the *East African* reported that the Tanzanian government was finally giving in to the public pressure by suspending all new investments and acquisition of new lands by investors already in the country, until it had reviewed the selection criteria for each investment and drawn up clear policies and procedures. This followed a report in the same newspaper a few days earlier, in which an academic from Sokoine University of Agriculture accused the government of treating the biofuels sector as a 'bottomless pit' at the expense of local farmers after it had emerged that 5000 rice farmers were being evicted to pave the way for plantations (Mande, 5 October 2009). In this latest development, then, we recognize the question mark indicating the undefined end stage in Greiner's model.

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6. Conclusions

From this review about the development of the *Jatropha* biofuels sector in 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 in late 2009. That is to say, in 2009 it had grown into a network consisting of well over 40 lead actors, each with their own local and global network, which are undertaking different functions covering the entire supply chain as well as

involving various chain-supporting organisations and many thousands of outgrowers and wage workers. This is in itself a remarkable achievement.

Our analysis with the multilevel SNM framework provides good insights into why the sector developed so quickly. 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 energy prices, and mandatory blending requirements and subsidies overseas.

At the same time, the fast pace of investment has had its clear downsides. Most investors piled into the country in a great rush, without much regard to possible longer-term effects of an as yet unknown wild crop. This bandwagon effect is at least in part responsible for the major social and the environmental sustainability problems that soon began to emerge. 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 contentious).

Although many in the industry are drawing lessons in hindsight, it is doubtful whether the boom-bust phenomenon and its fallouts could have been prevented through more pro-active policies and better regulation and enforcement, involving more attention to social and environmental sustainability impacts of projects. Policy institutions in most African countries have weak capabilities for pro-active decision making. At the time the biofuel boom began, some countries – including Tanzania – did not even have a renewable energy policy in place that could have provided guidelines for regulating investment and facilitating orderly and sustainable market development. But weak institutions are only partly to blame. Even leading international aid institutions full of experts were taken by surprise over the ‘third globalisation wave’, due to the suddenness and unprecedented scale on which foreign investments for large-scale fuel (and food) production in Africa occurred. Furthermore, much international (and local) disagreement over the desirability of these developments has arisen. Many governments in the South are essentially still groping in the dark about the best way forward, trying to weigh the pros and cons. Promises of new economic opportunities (and warnings about missing out on them through restrictive policies) voiced by proponents stand squarely against the adverse impacts on local livelihoods and ecosystems, and loss of sovereignty and domestic food security stressed by others (e.g., *The Economist*, 21 May 2009). The large controversies, conflicting interests, power inequalities between the key parties, and

uncertainties over long-term outcomes have hindered effective and speedy policy action, along with lack of governance capability.

As a result, the sector – if we can call it that – is still highly unstable and its future is uncertain. Whilst economic viability is still not assured, and much further experimentation and learning is required to raise yields and efficiency, the general public and many interest groups – both in Tanzania (and many other African countries) and abroad – may not have enough patience to wait for these outcomes because of their urgent concerns over food security, adverse ecological impacts and socio-economic marginalisation of vulnerable groups. In that sense, our analysis confirms Greiner's idea of an open-ended process which is driven by its own internal dynamics without being pulled by a defined end state, and which does not follow a strict sequence of prescribed evolutionary stages.

One problem is that the sector's development into a full-fledged innovation system still requires considerable technological capability building, and this requires sustained efforts, investments and time, as well as facilitative government. The need for capability building has been emphasized by a raft of publications about technology and development, mainly drawing on successful development in East Asia where the sustained acquisition of technological, managerial and organisational skills and knowledge by industry was supported by stimulating government policies and gave rise to durable dynamic competitiveness (e.g., Ernst et al., 1998, Lall, 1992). There is an equivalent literature dealing with best practices in development projects and programmes, which concentrates on addressing issues such as feasible business models, innovation for cost-reduction, market development, standards development and enforcement, development of appropriate credit mechanisms and technology support services, and the role of R&D and how it should link to market parties, and so on (e.g. Martinot et al, 2001; Brew-Hammond et al., 2008). These lessons are clearly relevant for *Jatropha* in Tanzania. In this case, important missing or weak capabilities include, among others, the absence of a well-equipped and well-funded national R&D institutions, the absence of micro-credit facilities that can fund innovative smallholder farmers in rural areas, rudimentary standardisation and metrology services, grossly underfunded agricultural extension services, and the lack of objective intermediaries who can assist between foreign and local parties in negotiating fair and transparent land deals. 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.

In addition to gaps in technological capability, our analysis has thrown up additional essential functions that are still underdeveloped. These include systematic reflexive (impact)

learning and inter-stakeholder conflict-management capabilities. In the literature about technological capability building there has been little (if any) attention for the need to develop these broader societal capacities. This is most likely caused by a key limitation in that literature, namely its concern with economic competitiveness and its neglect of the imperatives of environmental and social/ethical sustainability issues. However, current-day technological developments and economic pressures in many sectors are so far-reaching, conflicting interests so powerful, and societal uncertainties about impacts so great, that social and environmental sustainability will and do increasingly come to the fore alongside economic competitiveness concerns. Our *Jatropha*-Tanzania case is just one particular example of how these concerns can impose themselves on the development of innovation systems, but there are likely to be many others (think, e.g., of nanotechnology or genetic engineering applications). It is therefore encouraging to note that recent development literature is beginning to make forays into the exploration of capacity/capability requirements to address these wider issues. E.g., the capacity development approach championed by the UNDP points towards the need to grow local capacities for designing suitable institutional arrangements, growing leadership capacity, developing accountability and promoting transparency, and promoting knowledge accumulation by different stakeholders (UNDP, 2008). Such capacities are important elements of what we would like to single out as key concerns based on our case evidence, namely, the development of capacity of individuals, organisations, innovation systems and countries to manage resource-related contentions and conflicts. The development of innovation systems such as *Jatropha* biofuels thus requires a combination of supportive reflexive innovation system policies and evolving systems of regulation and control to contain side-effects and transfer of problems. This conclusion fits with the SNM perspective on the stimulation of innovation through balancing of protection and selection pressure.

We were unable to explore the suitability of Greiner's model to the full in our analysis, because of the very recent emergence of the *Jatropha* biofuels industry. Our timeline covers just four years and a few stages, including only one stage of contestation and conflict, which has not reached any acceptable compromise at the time of writing. Yet we are convinced that a combination of two evolutionary drivers of change, consisting of gradual evolutionary variation and selection and more discontinuous processes of conflict driven by performance trade-offs between core sustainability dimensions, is required to explain the evolution of the sector. An analysis of dialectic stakeholder relations and how these shape sectoral development represents a significant advance on earlier studies about innovation systems,

especially where it concerns sectors that generate radically new technologies. The development of these sectors raises many contentious issues that are relevant to many different stakeholders, whether they live close to the implementation scene or thousands of miles away. In that sense, it is hard to separate the influencing factors that drive the sector into "local" and "global". Stakeholders near and far strike up alliances, for instance through research collaborations, financing, trade linkages, and so on, and it is impossible to determine who is influencing whom. The local-global interface is likely to be an intricate two-way process. Further field research on this global local interface could shed more light on its causalities and drivers.

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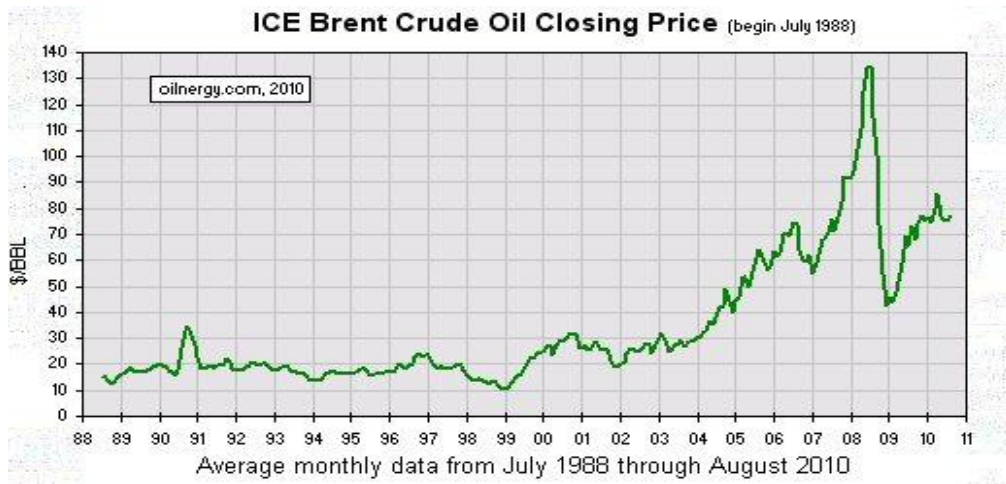
Table 1: Summary of the establishment of a Tanzanian *Jatropha* innovation system, 2005-9

	'Proto-stage' 2005	'Introduction' 2006-2007	'Frustrated early growth' early 2008	'Interrupted early growth' late 2008 - 2009
Landscape	Increasing international concerns about greenhouse effect -> intensifying search for renewable energy techs Kyoto ratified: carbon market trading starts (CDM) Perception about Africa: vast empty lands Tanzania: politically stable, welcomes TNCs,NGOs. But: ineffective political governance, poverty, weak infrastructure & institutions	Further international concerns about GHGs (IPCC report, 2007; An Inconvenient Truth, etc.) Mandatory biofuel blending targets introduced by EU,US, Brazil, India, etc. Subsidies & investment inducements for western investors through directives to create markets in developed economies	Huge spike in world food prices and drought in East Africa Tanzanian public wakes up to structural neglect of smallholder agriculture and food security issues Global food versus fuel debate ignited	Global recession: food prices come down Overcapacity in western biodiesel factories, some keel over Global credit crunch -> hard to boost cash flow in LP investments East African drought continues. Food vs fuel debate, and debate about neglect of agricultural smallholder sector continues.
Regime	High dependence on imported costly fossil fuels. Poor peasant farmers Basic capacity in oil pressing technologies Complex land acquisition procedures and latent public opposition towards land acquisition by foreigners due to bad historical experiences	Rising fossil oil price: increasingly heavy pressure on balance of payments of oil-importing developing countries; favourable market situation for developing renewables	Continued rising fossil oil price: favourable for renewables. But also: emerging evidence that 'non-arable lands' are often not empty wastelands, they are utilised and valuable for local populations	Fossil fuel prices crash from US\$ 147 (July) to US\$ 32 per barrel (Dec), causing the short/medium outlook for renewables to look less rosy.
<i>Jatropha</i> niche development	Vastly optimistic expectations esp. about yields and economic benefits drives growth Technical / agronomic learning only , mostly about cultivation, no lessons about possible end-uses. No societal impact learning. Incipient network with just two small lead players: NGO and a small TNC, absent government	Hype formation (shared beliefs based on rumours, not experiences -> <i>Jatropha</i> takes minimum 3 years to yield first harvest Growing network: Tanzania deluged by western TNCs	Puncturing of the hype Global niche development: work on biofuel standards stepped up (Cramer, RTFO, EU, Brazil, GBEP, FAO, RSB...): Science publications: Biofuel LCAs neglect land use change: possibly long 'carbon debts' <i>Jatropha</i> global & local niche developments: Early learning experiences show: <i>Jatropha</i> ≠ wonder crop: profitable yields incompatible with cultivation on wastelands - > pressure to scout for fertile croplands or forests, danger of displacing people, fauna & flora, carbon debt (early NGO, press reports). Growing network continued	Expectations become increasingly realistic (yields, cultivation, financial viability) Learning is widespread in technologies, agronomy & production; starting in end-use & logistics; taking off fast in social & environmental impacts; search for innovative hybrid business models Start of selection in business models (some LPs keel over). Large network , many specialised functions, draft national biofuel guideline adopted, but government still too slow-acting.
Change motor 1: Evolutionary variation & selection	Limited evolutionary variation, no selection No clear business models , just some loose experiments	Evolutionary variation in tech & organisation ; no selection yet Emerging variation in business models : 1. Local Multifunctional Platform (LMP, copied from Mali); local rural markets 2. Decentralised Outgrower Model (OM): local/national / international markets 3. Centralised Large Plantations (LP): western markets	Start of 'reflexive' learning Selection pressures are building , but no selection results yet.	Much progress in evolutionary variation & selection , but swamped by conflicts reported in media.

<p>Change motor 2: Contestation & conflict</p>	<p>No conflicts: plenty of space for each small actor to operate in</p>	<p>First critical remarks being made about LP practices (a few local press & NGO statements)</p>	<p>Growing contestation: Pressure on investors to address social & environmental sustainability problems and to address concerns about economic viability at the same time</p>	<p>Further growing contestation: Stream of NGO investigations (local-global alliances), esp. aimed at LP model Barrage of local, regional and western newspaper articles critical of LPs and inaction by govt Flood of internet blogs, local & western contributors Many presentations at regional / local conferences and workshops esp. by Tanz. academics, attacking government for neglecting smallholder agriculture and pushing neo-colonial raw material exports Western funding of stakeholders consultation for drafting government biofuel policy guideline. Exposure of malpractices: forced displacement, improper land lease negotiations, inadequate compensation, land conversion in wrong places, GHG emissions from virgin land conversion, etc. In Nov 2009 the governments halts all new investments in biofuels. Conflict is glo-cal: Global and local cannot be disentangled.</p>
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Figure 1: Structure of empirical analysis in section 5

	Proto-stage 2005 Section 5.1	2006-2007 Section 5.2	Early 2008 Section 5.3	Late 2008 – 2009 Section 5.4
Landscape				
Regime				
<i>Jatropha</i> niche development 1. networking 2. learning 3. expectations				
Change motors 1. Evolutionary variation & selection (in terms of technology and business organisation) 2. Contestation & conflict between stakeholders	↓	↓	↓	↓ ↑



Source: <http://www.oilnergy.com/lobrent.htm#since88>

Figure 2: Fossil oil price 1988-2010

Notes

ⁱ For evidence that *Jatropha* was indeed a hype, see Achten et al, 2010 and 2007, and Fairless, 2007. A general treatment of the phenomenon of hype in new technologies can be found in Ruef and Markard (2010).

ⁱⁱ In evolutionary theory, selection pressure is defined as “the intensity with which an environment tends to eliminate an organism, and thus its genes, or to give it an adaptive advantage” (International Society for Complexity, Information, and Design Encyclopedia of Science and Philosophy, http://www.iscid.org/encyclopedia/Selection_Pressure).