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A conceptual approach tackling the question: Can "bio"-fuels[1] become a synonym for social progress in remote areas in Brazil?

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Abstract: In Brazil, the inclusion of family farmers into the biodiesel production chain is one major goal of the National Program for the Production and Use of Biodiesel (PNPB) implemented in December 2004. Seven years after the start of the program, several obstacles remain and the social sustainability of the measures can be questioned. To understand the dynamics and interdependencies of the complex system of biodiesel production in rural areas, a case study is conducted in the North of Minas Gerais, a dry and poorly developed rural area characterized by smallholders. Several workshops and interviews will take or have already taken place over a four-year period to involve stakeholders in the process of identifying problems and planning future land cultivation scenarios. To get an understanding of the stakeholders' views on the system of biodiesel production cause maps were constructed together with them. The analysis shows that the perspectives vary quite a lot between them which is probably one of the reasons for the partly failure of the goals of the program. Despite the differing views an aggregated cause map could be drawn and the most important key variables could be identified. The final aim is a system dynamics model which simulates – based on the current situation – actual and future socio-economic impacts of the biodiesel production. The model can help stakeholders to understand the crucial dependencies of the biodiesel system and their possibilities to act.

***Keywords**: Biodiesel, family farmers, cause maps, system dynamics, Brazil*

1. INTRODUCTION

1.1 Bioenergy development

Concerning energy supply it becomes more and more evident that the world is facing several serious challenges in the future. Rising oil prices already led to some serious crises in the past. The overall tendency is that oil prices will stay volatile but will constantly rise because of rising demand, higher extraction costs and a continuing unstable political situation in the most important export countries. This also makes the energy supply more insecure. Another challenging topic is the mitigation of climate change which highly depends on the reduction of CO_2 emissions from fossil energy sources [International Energy Agency (IEA) 2011].

These are the reasons why many countries have started to look for alternative energy sources. They are fostering production and use, as well as research and de-

[1] The prefix "bio" has a positive connotation and suggests that fuels derived from renewable resources are at least ecologically correct. As this is not unquestioned we put it in quotation marks.

velopment of alternative energies like wind and solar power and biofuels. But it is not only energy security and the mitigation target to climate change that push bioenergy on the political agenda. There is also the hope that by supporting (for example) biofuel production another goal can be achieved: providing the poor with a new income source, jobs and energy [Wissenschaftlicher Beirat Globale Umweltveränderungen 2009].

1.2 Biodiesel production in Brazil

In Brazil biofuel production has a long tradition. Since the late 1970's bioethanol production from sugar cane has been strongly supported through the PROALCOOL program (Programa Nacional do Álcool). The latest initiative is the promotion of biodiesel production through the National Program for the Production and Use of Biodiesel – PNPB (Programa Nacional de Produção e Uso de Biodiesel), which was launched in December 2004 by the Brazilian Government. Beside the aims to increase the biodiesel production and to produce biodiesel from different oil crops in various regions in Brazil, the social inclusion of smallholders[2] through involvement into the biodiesel value chain is for the first time enforced as a major goal [Ministério de Minas e Energia 2012]. To reach these goals several policy tools have been applied: tax reduction and access to auctions based on the compliance with the newly implemented "social seal" on the industry side, technical assistance (in form of provided seeds, logistics, and advisory assistance), formal contracts and price and loan incentives for family farmers.

Seven years after its implementation several studies point out difficulties in implementing this top down developed program successfully [Brune 2011; da Silva César and Otávio Batalha 2010; Faria and Jerneck 2009; Garcez and Vianna 2009; Watanabe and Zylberstajn 2010].

2. OBJECTIVES OF THIS STUDY

The implementation of the biodiesel program is driven by the motivation to overcome the poverty in the countryside through agricultural occupation. Based on this assumption the main research questions are:

- Can the production and use of biodiesel in Norte de Minas contribute to social progress?
- Who benefits?
- What impacts does the biodiesel program bring to rural areas?

Objective of the presented research project is to deliver an approach to understand and evaluate the dynamics and interdependencies of the complex system of biodiesel production in a rural area in a systematic way. Aspects and variables important in this context will be identified and a first conceptual model will be presented.

3. THE REGION OF NORTE DE MINAS

To get an in-depth understanding of the situation in a rural area in Brazil a case study is being conducted in the northern part of the state Minas Gerais (Norte de Minas). This area is characterised by a very dry climate and poor soils. The overall socioeconomic conditions are very unfavourable. Smallholders mainly raise meat

[2] Who is a smallholder (*agricultor familiar* in portugues) in Brazil is defined in Law No. 12.512 of 2011. Smallholders or family farmers (these terms are used synonymic in this paper) must not own land lan area larger than a certain area (depending on the region), have to use mostly hand labor of his own family, their income must predominantly be originated from economic activities linked to their own establishment, and head of the establishment has to be a family member. Who complies with these rules can get a certain document called DAP (Declaração de Aptidão ao Pronaf). This document allows access to different governmental programs and fair loans.

and dairy cattle and grow various food and oil crops. For this region, the guidelines of the biodiesel program state that a minimum of 30% of the total industry agricultural expenses have to be related to family farmers in form of raw material purchase (oil seeds or vegetable oil), technical advisory service, seed distribution or transportation costs [Ministério do Desenvolvimento Agrário 2009].

The main raw material for the biodiesel production grown by family farmers in Norte de Minas is castor bean. This crop was chosen as favourite crop to be purchased by the parastatal oil company Petrobras which has a biodiesel plant in the city of Montes Claros. Castor bean is a rustic plant and relatively resistant to drought periods. Moreover it allows the simultaneous cultivation of other crops (i.e. beans) which makes it very interesting for family famers because it favours subsistence farming.

4. METHODOLOGY

To get a holistic view, a system thinking approach was chosen. Thereby the whole system can be described by its elements (variables) and their reciprocal interaction. This description serves as a basis for the subsequent system dynamics model. As a system dynamics model can represent the real world including its complexity, interdependency, nonlinearity, and feedback loop structures [Forrester 1994] we will gain knowledge about the structure of the system and the possible behaviour it can produce. Moreover this method gives us the opportunity to build the model step by step and to integrate local stakeholders in the process by developing a causal loop diagram with their help.

Causal loop diagrams as part of system thinking are a valuable tool to display the structure of a system by showing the variables, their interaction and most important the feedback loops which are created by the interrelations. This allows a better understanding of the system for the modeller as well as for the stakeholders [Sendzimir et al. 2010].

During a field stay in November 2010, guided interviews were conducted with family farmers in the municipalities Matias Cardoso, Rio Pardo de Minas and Montezuma, as well as with representatives of the local agricultural advisory services, cooperative members, and Petrobras officials. After the interview, the interviewees were asked to draw individual ‘cause maps’ as described in [Vennix 2001].

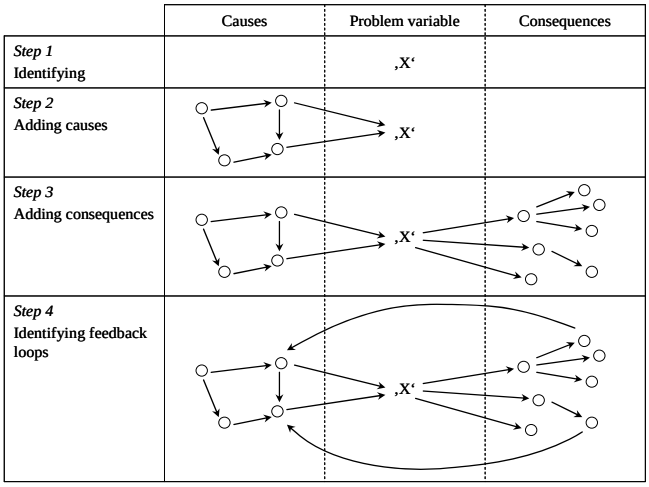

Figure 1. Building a Causal Loop Diagram in an interview [Vennix 2001]

The topic for this 'cause map' was chosen from the previous interview and the problem variable was defined accordingly. The focus was either on the main problems associated with the production of biodiesel and castor beans, the preconditions to join the program by growing castor beans or the possibilities to have a higher regional value creation in the region. These maps represent the respondent's view on the problem in a structured manner and the goal was to get a first preliminary and qualitative model [Vennix 2001]. During the interview aspects named by the interviewees were written as variables on small post-its either by themselves or by the interviewer. Afterwards they were asked to connect the variables to the problem and to draw any interconnections they would see [Vennix 2001]. Some unclear interrelations were clarified by asking back to the interviewee with a 'why'-question. Because some interviewees were not always easily familiar with the method, the cause maps were compared with the interviews done before and missing variables were added to the diagrams.

Afterwards the diagrams were analysed in a semi-structured manner to find out which variables matter in the system. First an aggregation and simplification of variable names was necessary because the interviewees did not always use the same wording but from the context it could be known that they meant comparable aspects. The mentioned frequency of these variables was counted within the stakeholder groups and if the respondents emphasized the importance of certain variables this was taken into account as well. The outcome is a table which shows the ranking of three different stakeholders (or groups): Petrobras, the agricultural advisory service and the family farmers.

5. FIRST RESULTS

During the interviews and especially through the cause maps it became obvious that the opinions about the favourable development and the most pressing problems concerning biodiesel production from castor beans differ widely among the stakeholders. The analysis of the mind maps showed, that they have an overlapping but not identical view on the system. Table 1 gives a differentiated picture and shows the ranking of the importance of the aggregated variables.

Table 1. Importance of variables according to stakeholder groups

Petrobras		**agricultural advisory service**		**family farmers**	
production of castor bean	***	production of castor bean	****	production of castor bean	*****
technical assistance	***	machinery	****	machinery	*****
mobilization	**	tradition/experience	****	soil quality	****
machinery	**	income	***	fertilizer	****
cooperative	**	guaranteed price	***	weather/climate	****
infrastructure	*	assured profit	***	infrastructure	****
assured profit	*	financing	***	transport/logistics	****
transport/logistics	*	soil quality	***	financing	***
contracts with Petrobras	*	availability of seeds	***	credits	***
trust	*	trust	***	availability of seeds	***
weather/climate	*	other markets	***	contracts with Petrobras	***
fertilizer	*	technical assistance	***	technical assistance	***
workers		transport/logistics	**	income	**
education		contracts with Petrobras	**	assured profit	**
soil quality		fertilizer	**	sowing date	**
bureaucracy		weather/climate	**	material aid	**
attributes of castor bean		breach of agreement	*	workers	**
income		bureaucracy	*	education	**

Petrobras	agricultural advisory service	family farmers
external support	credits *	tradition/experience *
financing	risk of overindebtedness *	bureaucracy *
guaranteed price	attributes of castor bean *	risk of overindebtedness *
credits	external support *	external support *
quality of life	infrastructure *	attributes of castor bean *
material aid	cooperative *	cooperative *
sowing date	quality of life *	quality of life *
availability of seeds	workers	mobilization *
tradition/experience	education	breach of agreement *
risk of overindebtedness	material aid	trust *
breach of agreement	mobilization	other markets *
other markets	sowing date	guaranteed price

Petrobras primarily looks at the economics and organisational part of the castor bean production and use. It takes the perspective of a big industrial company that wants to have as little effort and costs with the purchase from family farmers. From the perspective of Petrobras the main obstacles of an economically functioning biodiesel production chain are: the distribution of the farmers over a large area, their low mechanization degree, their unwillingness to organize themselves in co-operatives and the resulting difficulties in organizing logistics, technical assistance, contract closing and support supplemented by an insufficient infrastructure. Of foremost importance here is the technical assistance service, which acts as a middleman between Petrobras and the family farmers.

The representatives of the technical assistance service look at the topic from an expert point of view but as they advise the farmers and deal with their everyday problems they are closer to the farmer's point of view. This is confirmed as the variables mentioned by the technical assistance service equal those listed by the family farmers (see Table 1). They emphasize the economic benefit for the farmers but also underline the preconditions that must be fulfilled in order to take part in the program successfully (i.e. sufficient machinery, experience, financing possibilities, a reasonable soil quality, availability of seeds, trust and technical assistance).

For the family farmers the most essential variables in the system are related to their every day practical work. They emphasize the importance of having the possibility to borrow machinery when needed, because they cannot afford to buy them. Other important variables concern the ecological attributes of their region (i.e. soil quality, weather), but also commercialising, financing and supporting aspects. All in all their focus is more at the local farming practise. For some family farmers the biodiesel program provides the first opportunity to gain a regularly income which they use to improve their quality of life. Both the technical assistance service and the assured contracts are judged as positive. The most urgent problems of the farmers relate to the weak soil quality, unpredictable weather conditions, insufficient machinery, delayed seed delivery, difficulties to get a loan from the bank and a poor infrastructure. But the horizon within this group differs as well. Some farmers had a quite narrow view on the system, which ended so to say at their farm gate, while others had a much wider understanding which included possibilities to get further external support and to gain more profit by organizing themselves and processing the castor beans collectively.

6. CONCLUSIONS AND RECOMMENDATIONS

During the research process it has become apparent that each stakeholder has a distinct view on the system of biodiesel production. This reflects the gap between the top down approach of the biodiesel program and the local conditions of actors

who should benefit from it. On the local level other aspects matter than at the level above. Furthermore there seems to be a clash of two different cultures, which are not easily conformable: family farming tradition versus agro-industrial development. These findings correspond with the experiences [Brune 2011] made in a case study conducted in Piauí. In her opinion the implementation of the biodiesel program failed because the culture and context of smallholders were neglected. The opinion shared by Petrobras and the Agricultural Ministry is that smallholders just need technological development to be able to participate in the biodiesel value chain. This is a reductionist view as smallholders are more than just a smaller version of large scale agriculture [Brune 2011]. Beside profit maximization they are led by additional objectives such as minimizing the risk of over-indebtedness, diversification of production, risk management, food security, orientation towards local markets, continuing tradition, and possibility to work with existing resources. Moreover, some farmers are not used to contracts and hence are not fully aware of the importance of a signature. This can result in contract breaches or distrust. Even if farmers value the contracts as security this could be deceptive in the future. As at the moment no biodiesel is produced from castor beans yet (because of a higher value of the oil at the pharmaceutical market) the continuation of the facilitation of castor bean production through the biodiesel program may be questioned.[3]

7. CHALLENGES FOR IMPLEMENTING A SYSTEM DYNAMICS MODEL

Due to some particularities of the research area and the research topic several challenges exist in terms of creating a quantitative model. First of all it is difficult to understand the system and to give advice as an outsider. Even with the best understanding many uncertainties remain (policies, market trends, personal interrelations between stakeholders, corruption).

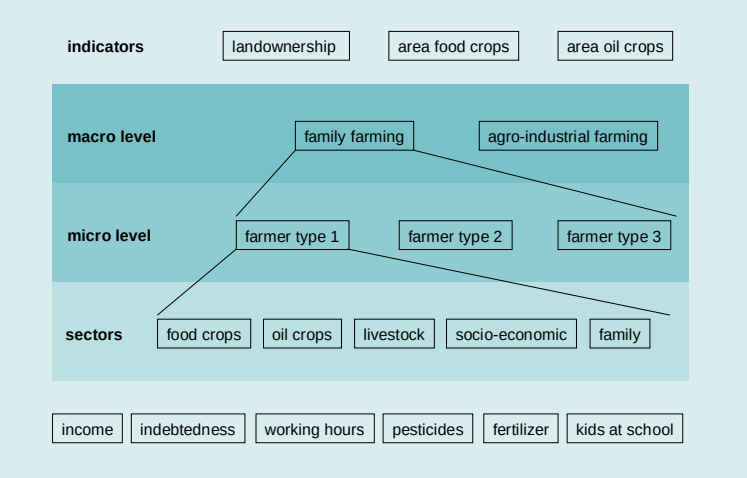

Figure 2. Model structure

Nevertheless, a first conceptual model was built. The model will be structured in different levels (see Figure 2). This allows the evaluation of changes over time on the micro level in the farming households as well as on the regional level where the aggregated effects of changing agrarian structure will be seen.
The variables which were identified before, build the core of the model. A literature review identified some additional variables. All variables could be grouped into five sectors (food crops, oil crops, livestock, socio-economic factors and family). Each sector consists of variables and their (at this stage) qualitative interrelations. The

[3] Currently soy beans provide 70-85% of the raw material for the production of biodiesel. Despite the presently unfavorable conditions to use castor bean in the biodiesel production Petrobras as well as research institutions keep investing in technology, breeding and integration of more family farmers. Castor bean might be used as raw material for biodiesel in the future.

sectors are interrelated between each others as well via information links or material flows. The idea is to model different farmer types as it seems that for instance risk awareness and farm size will be essential for the performance of the farm. Three different farmer types will be created. Family farmers, as the focus of this study, will be modelled in more detail than agro-industrial farmers. On the macro level, family farming and agro-industrial farming will be displayed including their areas for food and oil crops and the landownership.

Indicators such as income, indebtedness, working hours, pesticides, fertilizer and kids at school will show the behaviour of the system over time. Some of these indicators will be specified to the farmers' type, others will show the aggregated development of all family farmers. Through these indicators it shall be represented how the different behaviour of the farmers affects the outcome. Aggregated indicators will display the effects of raw material production for biofuels on the environment.

Another challenge lies in the lack of proper statistical data. As the biodiesel program only started in 2005, there is no long-term data available to calibrate the model. Moreover geographically specific data are not always available in the required high resolution and sometimes numbers vary a lot. Especially data concerning reasons for decision-making, costs, profit, prices, and working hours are needed. Such data is required on the micro level to feed the model with mathematical interrelations and to create a reference mode by asking for the historical development in the region. Moreover some interrelations between identified variables are difficult to quantify.
One possibility is the collection of statistical data during a survey. But as family farmers often do not keep accounts and are not used to quantitative surveys, they might give numbers of questionable quality because, as they tend to always give an answer even if the question has not been fully understood. Besides it is difficult to get a representative sample because the universe is not known. Another difficulty is posed by the fact that interviewees have to be interviewed personally, because a high percentage is illiterate and/or not familiar with questionnaires. This is very time consuming and costly as farmers are spread out over a large area.
All in all, these problems are not Brazilian specific: a lack of statistical data is a common problem in developing countries [cf. Vermeulen and Cotula 2010; Skutsch et al. 2011]. Also data collection and participative modelling is described as difficult by other authors [Mitchell 2008; German et al. 2011].

8. OUTLOOK

Although it will be challenging, a data collection survey is planned. But instead of interviewing a large number of respondents, we will focus on a smaller number (20-30) in depth. Therefore, we will conduct expert interviews to cluster the farmers into groups and then interview some representative farmers of each group. We will have to rely on the expertise of local experts from research projects and the agricultural advisory service to help us with the sample. Farmers will be questioned concerning agricultural practice, historical development of castor bean production, decision making, income, working hours, technical assistance, contracts, loans and quality of life. Moreover we will expand our search for existing data from other studies to decrease uncertainties. This will be the basis for an attempt of quantification.

In addition we will conduct a scenario workshop with representatives from agriculture, agricultural advisory service, unions and cooperatives to create possible future scenarios. During this workshop model uncertainties shall be identified and addressed and the scenarios shall be used to feed the model.

Of course, a system dynamics model is just one way to understand the system and to evaluate the success of top-down agro-programs and to find ways to improve the situation. One could also think of an agent-based model to test the effect of

communication between the stakeholders. This could be important as well, but problems such as data availability would remain. To display different stakeholder types in the system dynamics model different farm types (e.g. small farmer, larger farmer, indebted farmer, risk avoiding farmer) will be created to feed the model with different parameters and to evaluate the outcome under such different assumptions. During the oral presentation, some more details of the conceptual model will be shown including more feedback loops extracted from a literature review.

Later on, we intend to compare our case study with other top-down implemented programs e.g. the bioethanol program in Brazil and also programs in regions outside Brazil to evaluate the outcomes and to search for learning processes.

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