Technological, Social and Institutional Interactions in the Design Process of Eco-Engineered Wastewater Systems in Matagalpa, Nicaragua

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Final Report, June 2011

Department of Communication & Innovation Studies,
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MSc Minor Thesis in Communication & Innovation Studies (COM-80418)

June 2011

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Opgesteld door : S.M. (Stefan) de Wildt
Datum : 09/06/2011
Versie : 1.1, Final

In collaboration with:

Abstract

This study is about the influence and importance of inclusion of local knowledge and weighty organisational and institutional arrangements in the design process of eco-engineered wastewater treatment systems in Matagalpa, Nicaragua. As a technological niche and its innovation process are dependent on the co-evolution and interaction between the technology itself, the involved people, and the institutional arrangements and conditions, i.e. the hardware, software and orgware components of innovation. As scientists frequently still draw a straight and one-directional line between science and practice, the inclusion of local, specific knowledge in design processes of socio-technological innovation is often overlooked. In this study research the perspectives of three distinguished stakeholder groups – Dutch engineers, Nicaraguan engineers of the municipal environmental department and local coffee farmers – in relation to the hardware, the software as well as the orgware have been compared and analysed thanks to long-term observations and in-depth interviews over a period of four months. The most prominent result would be the difference between the initial, rather interactive and cognitive organisational arrangements on paper and the linear, one-directional implementation of the technological innovation (i.e. the hardware) in practise, without providing and developing the necessary institutional arrangements and involving the beneficiary people effectively. Because of the lack of profound stakeholder interaction, exchange of generic versus local, specific knowledge was obstructed, while capacity building among the Nicaraguan engineers and coffee farmers did not lift-off. Besides the additional functions of the 'ecological' treatment of coffee wastewaters, such as the production by-products like biomass, and the amplification of financial value and activities, were not fully inquired and employed. Consequently, the importance of local, specific knowledge, early and effective stakeholder inclusion and collaboration, and well considered and established institutional arrangements were revealed as indispensable in the process and evolution of socio-technological innovations.

Keywords: *socio-technological innovation, hardware, software and orgware interactions, eco-engineered wastewater treatment systems, innovation brokers*

Specific pre-reading recommendations

This study is mainly based on stakeholder observation and interview analysis. Part of the persons interviewed asked for a certain confidentiality knowing the underlying conflictive or mutual dependent relationships and the risks of misunderstanding.

As a result, I have used several tools to guarantee a maximum confidentiality:

- The interviews' transcriptions will not be published in the annexes of this report;
- Fictive names have been used and no original names will appear on purpose.

Acknowledgement

I would like gratefully to acknowledge my thesis supervisor, Cees Leeuwis, whose wise advices and support were essential for me. He has shown deep patience by supervising a student from a not communication-related study, with a technical background and a tendency to appear suddenly after weeks of radio-silence. I have really appreciated our valuable and fruitful discussions which have guided me toward this, in my humble opinion, interesting and structured study research.

I am also very grateful to the persons I met during my time in Nicaragua. Their support and patience in teaching me the Spanish language, their availability and their common interest and involvement in combating the pollution of rivers by coffee wastewaters were invaluable for me. I would like to greatly thank and mention especially: Roger of DIMGARENA, Floris for our impassioned discussions during coffee breaks, Odelba for patiently teaching me Spanish, Luisa for introducing me to Matagalpa and its inhabitants, family Montenegro for their hospitality – Alicia, you were like a mother to me! -, and Joost of LeAF and Oscar of waterschap De Dommel for their guidance during the internship.

I can not close this acknowledgement without expressing my special gratitude to my family for unconditionally supporting and encouraging me, especially during the tough start in Nicaragua were my motivation dropped to almost zero. They never stopped believing in me and provided me with the psychological support I needed. I also want to say a word of thanks to my friends in the Netherlands for their help, understanding and encouraging support in moments of doubts and discouragement.

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List of Abbreviations and Definitions

Abbreviations

ApT-ApS	*Agua para Todos – Agua para Siempre*; cooperation and development programme between a Dutch consortium and the Municipality of Matagalpa
BOD	biological oxygen demand
CECOCAFEN	Coffee Cooperatives Central Association in the Northern Regions of Nicaragua
COD	chemical oxygen demand
DIMGARENA	*Direccíon Municipal para la Gestión Ambiental y los Recursos Naturales*; environment and natural resources department of the Municipality of Matagalpa
GDP	gross domestic product
LAM	*Laguna Anaerobica Mejorada*; improved anaerobic lagoon system
LeAF	Lettinga Associates Foundation; knowledge centre on development and implementation of environmental protection technologies
MAGFOR	*Ministerio de Agricultura y Forestal*; the Nicaragua Ministry of Agriculture and Forestry
MARENA	*Ministerio de Ambiental y los Recursos Naturales* ; the Nicaragua Ministry of Environment and Natural Resources
MLP	multi-level perspective
MN	*Molino Norte* river; tributary of the *Río Grande de Matagalpa*
NGO	non-governmental organization
O&M	operation and maintenance
SF	*San Francisco* river, tributary of the *Río Grande de Matagalpa*
SNM	Strategic Niche Management approach
SSF	subsurface flow system

WH	Water Harmonica; a natural or constructed wetland that fills the gap between pre-treated wastewater and surface water
WTS	wastewater treatment system

Definitions

finca	a rural property, especially a large farm or ranch in Latin America. In the context of this research a coffee plantation is meant
cuencas	watersheds

1. Introduction

In the central highlands of Nicaragua, coffee plantations (*fincas*), located in the mountain area, discharge wastewater from wet coffee processing in the rivers *Molino Norte* (MN) and *San Francisco* (SF) running towards the city of Matagalpa (Jacobi, 2004). Plantations are taking most of their processing water from streams contributing to these rivers. These practices pose serious threats to the environment and the drinking water situation of Matagalpa. The wastewater is characterized by high levels of biological and chemical oxygen demand and low pH levels.

To tackle the highly polluted wastewater, to increase water quality and quantity for the drinking water situation of the city Matagalpa and to minimize negative environmental impacts of coffee processing a low technology solution is needed, adapted to the local conditions. A system which purifies water efficiently and cheap with a low demand of operation and maintenance. According to recommendations of Jacobi (2004) and Sas (2006), a combination of an improved anaerobic lagoon (LAM) system and the Water Harmonica (WH) concept – together referred as an eco-engineered wastewater treatment system (WTS) – seems to be a suitable technology to tackle this problem.

However, during the design process of eco-engineered WTSs by the *Agua para Todos – Agua para Siempre* (ApT-ApS) programme, local and social knowledge, interests, perceptions and contexts of local parties, as well as their potential active and creative role, seems not to be fully taken into account.

Objective of this research is therefore to acquire insight into local knowledge in order to improve the current technological as well as the social, and institutional design of eco-engineered WTSs. Gained social, institutional and technological contextual knowledge can lead to modifications in the design and innovation process of technological niches.

2. Background

In order to get familiar with the project region and the policy background of the same project, the regional background and coming into existence of the *Agua para Todos – Agua para Siempre* (ApT-ApS) programme will be elaborated in the following paragraphs.

2.1. Regional background

The municipality Matagalpa, capital of the equally named province in the central highlands in the north of Nicaragua, is situated next to *Rio Grande de Matagalpa* at 700 meters above sea level (Figure 1). More than half of the population of the province lives in the city Matagalpa, which counts an estimated 160,000 inhabitants. Shortage of water ration forces rural people to move to (the slums of) Matagalpa. The city of Matagalpa obtains its drinking water from the watersheds (*cuencas*) MN and SF. The total extension of these basins is 32.2 km². The *cuenca* MN is located in the north of the city Matagalpa and its river travels about 12 kilometres from the head until its outlet meets the river SF, giving origin to the *Rio Grande de Matagalpa*.

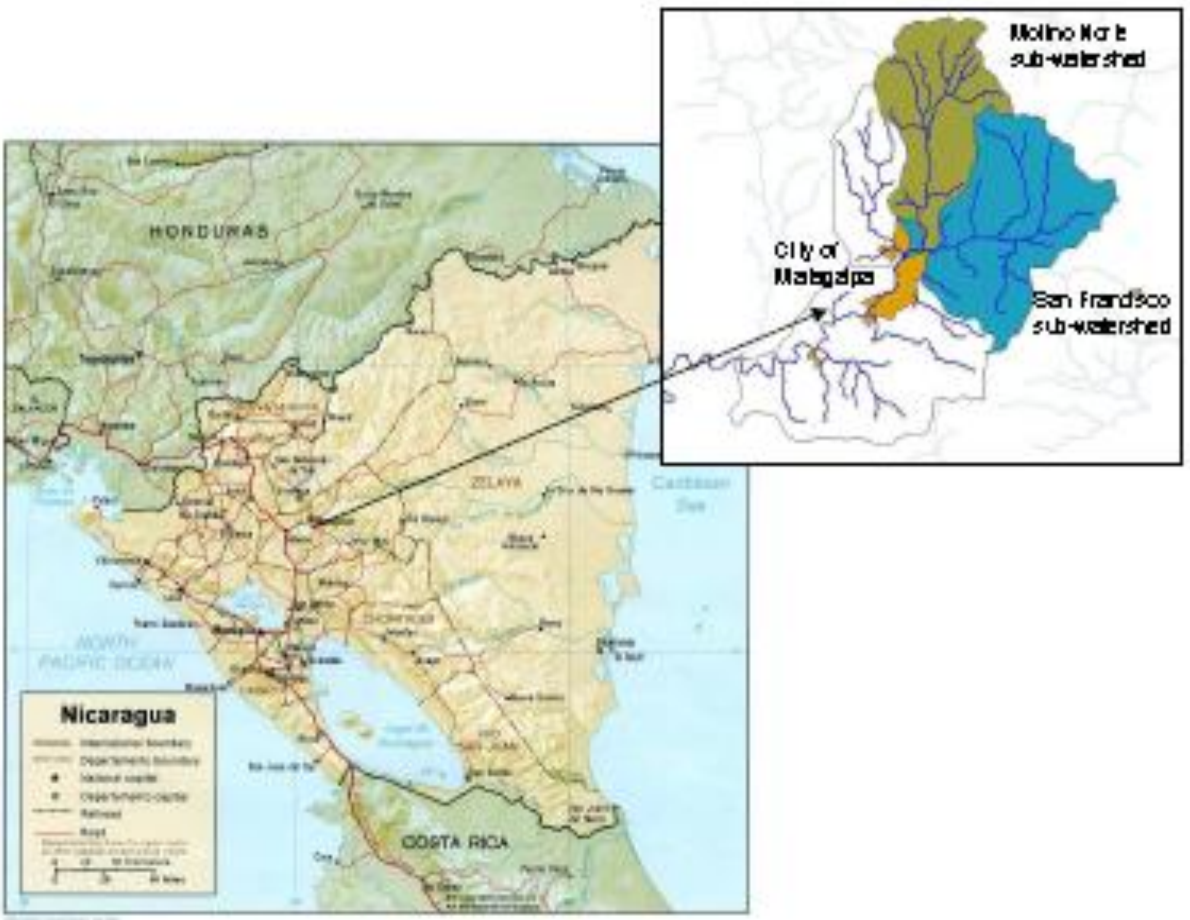

Figure 1: Location of the *Molino Norte* and *San Francisco* watershed (ApT-ApS, 2007)

The climate of Matagalpa is subtropical, and has temperatures between 18-26° C. The average annual precipitation is 1550 mm, and the annual evaporation is 1215 mm. The main agricultural activity is coffee production, but also elementary products are cultivated for own consumption such as corn and beans. For the export vegetable and ornamental ferns are grown in the area. Besides that, the area is covered with pastures and forest. The inclination of the slopes varies between the 4 and 75% and at some steep slopes mudflows occur, caused by erosion.

After tourism, coffee is one of the most important export products of Nicaragua. The counties Matagalpa and Jinotega of this Central American country produce together 80% of the total Nicaraguan harvest (1993-2003). The region is therefore economically highly dependent on coffee. The decrease of the international coffee-price had major consequences for the profits. In the period 2001-2003 the coffee business in Nicaragua generated an average of 87.4 million dollars annually, representing six percent of Nicaragua's gross domestic product (GDP) (Sas, 2006, p.10). Prior to coffee exportation, considerable processing takes place in order to prepare dried green coffee beans. In Matagalpa most plantations or *fincas* take their water for wet coffee bean processing from streams contributing to MN and SF. These practices pose serious threats to the environment and the drinking water situation of Matagalpa. The wastewater is characterized by high levels of biological and chemical oxygen demand and low pH levels.

The rugged mountainous terrain of Matagalpa province is composed of ridges 900 to 1,800 meters high and a mixed forest of oak and pine alternating with deep valleys that drain primarily toward the Caribbean Sea. Very few significant streams flow west to the Pacific Ocean. The relatively western slopes of the central highlands, protected by the ridges of the highlands from the moist winds of the Caribbean, have drawn farmers from the Pacific region since colonial times and are now well settled. The eastern slopes of the highlands are covered with rain forests and are lightly populated with pioneer agriculturists and small communities of indigenous people.

2.2. Policy background

ApT-ApS is a three year cooperation programme between the Dutch water boards *Waterschap De Dommel* and *Hoogheemraadschap de Stichtse Rijnlanden*, Lettinga Associates Foundation (LeAF), and the Municipality of Matagalpa, which started in July 2007. LeAF is an "independent knowledge centre on the development and implementation of sustainable environmental protection technologies, with the object of (re)utilizing valuable compounds in waste and wastewater" (LeAF, 2010). The foundation has close connections with Wageningen University & Research Centre in the Netherlands. The two Dutch water boards and LeAF together will be mentioned as 'the Dutch consortium' in this report.

The Dutch consortium and the Municipality of Matagalpa support the programme by putting on 'in-kind' hours. Aqua for All and the Foundation of Dutch Water Boards (*Stichting Nederlandse Waterschap*) finance the programme with approximately a half million Euros. The programme was extended in 2010 with one more year.

The main aim of the programme is to make the SF river feasible for drinking water use by reducing the pollution to this river and focuses on three main topics, namely (1) drinking water and sanitation, (2) eco-engineered treatment of wastewater from coffee processing, and (3) integrated water resource management.

There is, however, little local experience with eco-engineered wastewater treatment for the sizes of wet-mills in the SF watershed. This is because each *finca* processes coffee in individual wet-mills. There is a lack of feasible available WTSs and there is not much experience with eco-engineered wastewater treatment technology by the ApT-ApS programme (Zuijderhoudt, 2008). In the programme proposal it is stressed that local parties should be able and willing to continue the programme independently. The programme is looking for local parties that can take up part of the programme work and is looking as well to increase the number of coffee farmers who will replicate and implement an eco-engineered wastewater treatment.

Currently, five pilot projects are indicated in the SF watershed; one large *finca*, two middle-sized *fincas* and two small *fincas*. For each *finca* a tailor-made eco-engineered WTS will be designed. However, calculations and design was done by the Dutch consortium in the Netherlands. Intention of the programme is to transfer knowledge of the design process to the environment and natural resources department of the Municipality of Matagalpa (DIMGARENA), as this is the direct partner of the Dutch consortium in the ApT-ApS programme, to design and implement eco-engineered WTSs in the future. DIMGARENA (*Direccíon Municipal para la Gestión Ambiental y de los Recursos Naturales*) is established in 2007 and is responsible for the protection of the watersheds in the Municipality of Matagalpa, reduction of the nuisance as a result of the discharge of coffee wastewaters, and the decrease of deforestation. The department concerns about conservation and protection of the environment and natural resources within the Municipality of Matagalpa. There is institutional coordination with National Ministries to resolve environmental problems. As little experience and knowledge with eco-engineered WTSs is locally available nor within DIMGARENA, this knowledge and experience needs to be shared with and transferred to them.

3. Theories and Concepts

Analyzing the development policy and political background, it can be said that the innovation of eco-engineered WTSs originates from (Dutch) scientists and engineers. The project strives that the innovation will be transferred by intermediaries, and applied by the coffee farmers. This mode of thinking is called 'the linear model of innovation' as it draws a straight and one-directional line between science and practice, with a clear task division between various actors (Leeuwis, 2004a, p.135). However, analyzing historically the successfulness of such implementations of innovations it appeared, for example, that farmers made significant adaptations to the packages developed by scientists (Ibid.). Based on such findings it was concluded that innovation requires stakeholder interactions who all contribute to the generation and transfer of knowledge (Ibid.).

Based on the outcomes of innovation diffusion literature Panebianco and Pahl-Wostl (2006) listed technology features, technology dependencies and effects, characteristics of the potential adopter, social and institutional interrelations, and decision stages as the determining factors in transformation processes in wastewater treatment and the socio-technical determinants of the decision-making processes. In relation to the five determining factors listed by Panebianco and Pahl-Wostl, innovation is considered a complex, interactive process in which there is a large amount of co-evolution of technological, institutional and societal developments, in which cause and effect are often difficult to distinguish (Smits, 2002 cited in Klerkx and Leeuwis, 2007, p. 365). A socio-technical innovation process therefore requires deliberate efforts to create effective linkages between the technology itself, people, and organisational and institutional arrangements, i.e., between *hardware*, *software* and *orgware* (Smits, 2002). The *software* can be seen as the knowledge and skills of people which are needed to develop, produce and use the hardware. The *orgware* are the needed organisational and institutional arrangements and conditions under which the technology can be applied and adopted.

Gandarillas (undated, p.3) describes institutional arrangements as "the forms of contract or arrangement that are set up for particular transactions between contracting parties, governing the way that these parties cooperate or compete". This includes issues like the way of financing the eco-engineered WTS, the provision of labour and milestones in the project.

As described by Smits (2002), the co-evolution of the *hardware*, *software* and *orgware* can be seen as the innovation process of technological niches. A successful design and implementation of a technological niche, like the eco-engineered WTSs in the ApT-ApS programme, thus is dependent on the interaction between technology, involved knowledge and skills, and institutions, finances and acceptation. In other words: it is dependent on the interaction between hardware, software and orgware on multiple levels. Therefore, technological development (*hardware*) should go hand in hand with institutional development (*orgware*) for an optimal evolution of an innovation (Figure 2). The *software* component could have been added to Figure 2 as the third determining factor of evolution of innovation. As shown in Figure 2, the development of every individual component as well as the interaction between the components brings forth a gradual evolution of the innovation process. In the context of this research, the innovation process can be seen as the design and implementation process of the eco-engineered WTSs and the collaboration between the Dutch consortium, DIMGARENA and the coffee farmers.

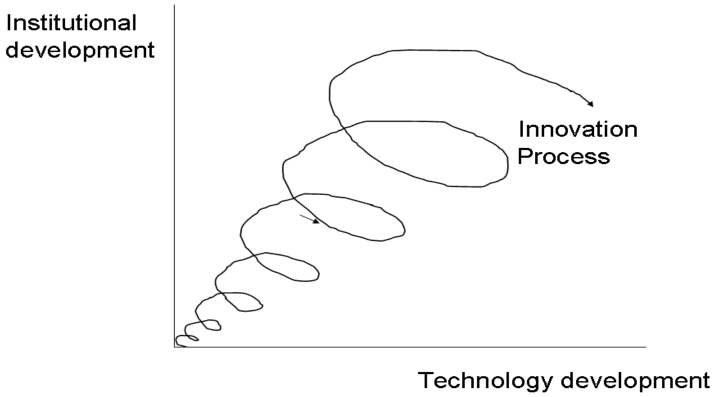

Figure 2: Co-evolution of Innovation (after IMCDD session 1, 2009)

Another helpful tool to analyse the evolution of innovation could be the strategic niche management (SNM) approach. "The SNM approach suggests that sustainable innovation journeys can be facilitated by creating technological niches, i.e. protected spaces that allow the experimentation with the co-evolution of technology, user practices, and regulatory structures" (Schot and Geels, 2008). In other words, their theory presumes that innovation involves change and selection of *hardware*, *software* and *orgware* at multiple nested levels. Therefore, a socio-technical regime, like the current polluting coffee production system with the eco-engineered WTS as the experimental niche, evolves (1) in the form of practices, procedures, standards and modes of thinking, but is (2) also embedded in institutions and infrastructures.

Schot and Geels' (2008) of many years' standing SNM research showed that experimentation with a technological niche and "internal analysis of crucial niche processes (expectation dynamics, learning, network building) contributes to learning" regarding different issues – such as: technology, skills and knowledge of the involved parties, and institutional arrangements – including change and expectations. Experimentation of the niche also serves to build networks and create alignment among the involved stakeholders, horizontally as well as vertically (Ibid.). Furthermore, the multi-level perspective (MLP) of SNM proved to "led to modifications in claims about the breakthrough of sustainable innovation journeys" (Ibid.). The MLP which leads to modifications in claims can be seen as a cognitive or learning process – or as Grin and Van de Graaf (1996 cited in Schot and Geels, 2008) called it *second-order learning* –, where "the involvement of relative outsiders may be particularly important to broaden cognitive frames" (Schot and Geels, 2008, p.541) which contributes more to niche development. In this particular case there are besides the technological niche – the eco-engineered wastewater treatment system – other niche-innovations needed to co-evolve and determine the failure or success of the technological niche (Figure 3). The production of biomass, like duckweed, vegetables and fish, from wastewater nutrients, development of eco-tourism and upgraded environment and water quality coffee certificates are such niche-innovations. Therefore, to achieve a shift from technological niche to market niche, and eventually to a total regime shift, understanding the complex, interactive process of the large amount of co-evolution between *hardware*, *software* and *orgware* (Smits, 2002) and the *second-order learning* (Schot and Geels, 2008) is indispensable. In conclusion, the SNM approach can be seen as an analytical tool for the interactive and evolutionary processes of technical niches, where the focus is rather on the cognitive process than successful technological substitution (Ibid.).

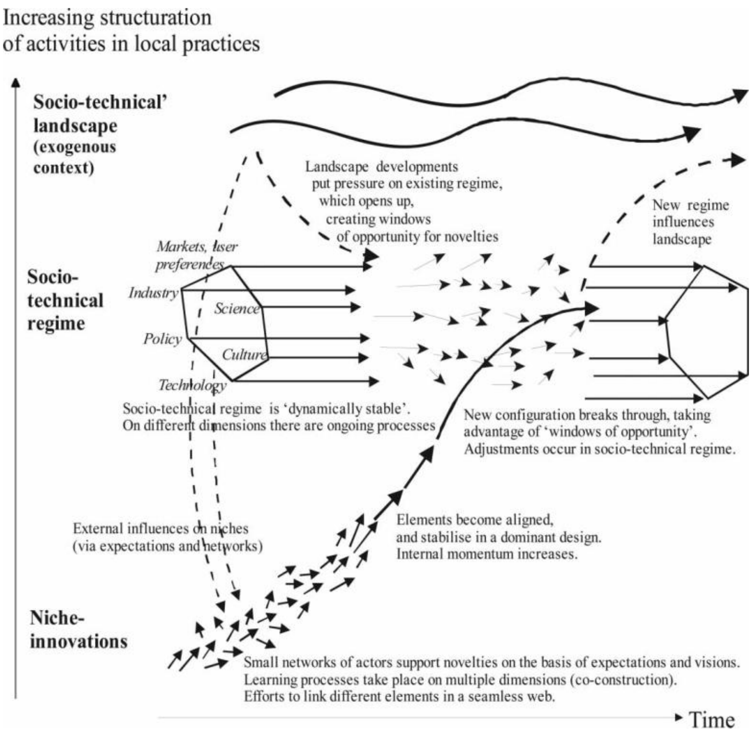

Figure 3: The needed learning process and development of niche-innovations in order to achieve a shift from technological niche to eventually a regime shift (source: Schot and Geels, 2008, p. 546)

Rethinking of the conventional 'top-down' wastewater system design and management is therefore required. According to Grendelman and Huibers (2010) inclusion of local parties in design and operation processes is always necessary, while Hall *et al.* (2001; 2006) states that *local, specific knowledge* is indispensable in technological innovation systems. In these systems "flows of knowledge between actors and institutions in the process, and the factors that condition these flows, are central to innovative performance" (Hall *et al.*, 2001, p.794).

Considering the importance of the interaction between *hardware*, *software* and *orgware* in the innovation process (Smits, 2002; Schot and Geels, 2008), this research will focus on how the interaction between these components as well as the stakeholders was organised. In order to analyse this interactive innovation process I would argue that a constructivist research approach (Zwarteveen and Wester, 2009) is required. The (social-) constructivist research culture is based on its hybrid concepts and is highly socio-technical. For me, as an engineer with a technical educational background, this means I have to change from analyzing technical problems to analyzing socio-technical problems (Grendelman and Huibers, 2010). This includes the investigation of how different interests can be translated into design, what the management demands of the wastewater system are as well as the societal effects are.

4. Research Questions

The Dutch consortium seems to lack farmer interaction and insight in farmer's local, specific knowledge, demands and constraints. These factors seem not to be fully taken into account within the highly technocratic design and implementation process of the eco-engineered WTSs. The main objective of this research is thus to acquire insight into the current local stakeholder interactions and the knowledge deficiency. The aim is to create insight into interests, perception and contexts of local parties, especially those of coffee farmers.

Therefore, the following **main research question** was formulated:

> "What were the knowledge, interests, perspectives, perceptions and interactions of the various involved parties towards eco-engineered WTSs, and what were the implications of these for the technological as well as institutional implementation of the WTSs in the *San Francisco* watershed, Matagalpa, Nicaragua?"

Starting this study research it was expected that the three distinguished stakeholder groups had different perspectives concerning the hardware, software and orgware components of the project, while they were involved in different phases of the design and implementation process. Based on the main research question and the aforementioned issues the following **sub research questions** were formulated:

1. What was the exact problem definition and the objectives of the ApT-ApS programme – i.e. what was the background of the of the project and its technology – as defined by the project management?

2. How was the overall design process of the eco-engineered WTSs organised and what were the major events in this process?

3. What were the perspectives of the Dutch engineers, DIMGARENA as well as the coffee farmers in relation to the hardware, software and orgware components of the eco-engineered WTSs?

5. Methodology

In first instance I would go to Nicaragua from July to November to supervise and coordinate the construction of five eco-engineered WTSs as part of an internship for Lettinga Associates Foundation (LeAF). Simultaneously, I would transfer knowledge concerning design processes to DIMGARENA and practices concerning O&M to the coffee farmers. As the urgency of understanding local perceptions towards the socio-technical design came forward, the idea rose to interview and observe the involved actors at the same time for the duration of four months.

Within the research the following activities can be identified:

1. Literature review and stakeholder identification;
2. Semi-structured interviews with the major stakeholders;
3. Participant observation;
4. In-depth interviews with selected stakeholders;
5. Analysis.

Considering the described research topic, employees of DIMGARENA and the coffee farmers involved in the pilot project are, logically, the main and central units of research. This includes their social networks, institutional relations and practices. The research is executed for and in close cooperation with the ApT-ApS programme. At various times in-between results of research activities will be presented and discussed with DIMGARENA and the Dutch consortium personally.

5.1. Research methods

The methods identified for the research are based on the content and requirements of the main research and sub research questions, and according to methods used in studied literature. Since required information and data – such as identification of local and social knowledge and perceptions – is highly tacit, implicit as well as contextual of nature, use of quantitative research methods is not so sensible, and makes the use of qualitative methods, like interviews, necessary.

5.1.1. Literature review and stakeholder identification

Within this step available literature will be reviewed. This will be an inventory and analysis of existing documents of the ApT-ApS programme, the Dutch consortium and DIMGARENA. Useful and relevant data will be filtered out, to identify the stakeholders and get a clear insight into the problem.

5.1.2. Semi-structured interviews with the major stakeholders

In order to answer the sub research questions, semi-structured interviews will be used to acquire insight in local and social, knowledge, interests, perceptions and contexts of the major identified stakeholders. It is expected that during fieldwork, the supervision and coordination of the construction of eco-engineered WTSs, sufficient interaction with the stakeholders is available to have semi-structured interviews and ask exhaustive/detailed questions (grill).

5.1.3. Participant observation

During the supervision and coordination of the construction of eco-engineered WTSs observations of participants (daily) behaviour, customs and operations can be closely followed. This can give additional information of why they execute things in a certain way, and can give a deeper insight and understanding in their level of local and social knowledge, perception and context. The infrequent participant observations have been documented in 'day' reports.

5.1.4. In-depth interviews with selected stakeholders

More in-depth interviews have been held at the end of the period in Nicaragua (October) with pre-selected stakeholder. Selection of interviewees is based on their importance, crucial position in social and institutional relations, and possession of valuable knowledge towards the research topic. Results of the semi-structured interviews also led to new insights and the desire to interview new or other stakeholders later on.

5.1.5. Research analysis

Within the analysis the outcomes of the research activities have been analysed. From the stakeholder interviews responses and answers to certain questions have been encoded and divided according to one of the three components of innovation: *hardware*, *software* or *orgware*. From there, there has been searched for patterns in the responses and perspectives among the stakeholders towards one of the three components of innovation. This gave me information about perspectives concerning the *hardware*, *software* and *orgware* of the technological innovation as well as information towards the co-evolution and interactions between those three components in the innovation process itself. Technological as well as social-institutional conditions and arrangements will be reflected on, while suggestions to adapt and re-consider some of those conditions in the design and design process of eco-engineered WTSs will be made in the discussion part of this report.

5.2. Methods of recording

Outcomes and data of semi-structured interviews, on-site observations and in-depth interviews were documented by note taking and/or audio recording. In all cases permission of the interviewee for documenting and audio recording has been asked on forehand, while notes and audio records have been digitalized, summarized and documented.

6. The Design Process of the Eco-engineered WTSs

This research intends to analyse the perspectives of the different stakeholder groups in relation to the *hardware, software* and *orgware* components of the design and implementation process of the eco-engineered WTSs as well as giving an analysis of the interactions between these components as well as the stakeholder groups in the project. In order to achieve this the background of the project, its technology and the major formal project events in the design process – in other words: the design process of the eco-engineered WTSs –will be clarified in this chapter.

6.1. Coffee wastewaters discharged on rivers

The coffee sector is the main polluter of the *Molino Norte* (MN) and the *San Francisco* (SF) watersheds, but is simultaneously of significant importance for the regional as well as national economy (Jacobi, 2004). The main problem is that the coffee plantations discharge wastewater form wet coffee processing in the two rivers towards the city of Matagalpa. During the harvest season, plantations are taking most of their processing water from streams contributing to the MN and SF rivers. These practices pose serious threats to the environment and the drinking water situation of Matagalpa. The coffee wastewaters are characterized by high levels of biological and chemical oxygen demand (BOD & COD respectively), high nutrients and low pH-values (Ibid.). The standard for the maximum content of organic material of discharge water on rivers, as imposed by the Nicaraguan Ministry of Environment and Natural Resources (MARENA) (ANN, 1996; ANN, 2000), is nowhere met on coffee plantations in the SF watershed. Incidentally this leads to the cease of intake of waters from the San Francisco river as it is too contaminated to use as a drinking water source (Zuijderhoudt, 2008, p.9).

6.2. Dutch consortium combats environmental issues in the San Francisco watershed

The environmental issues in the San Francisco watershed were recognized in a preliminary study by J. Jacobi in 2004. This formed a reason for the LeAF and two Dutch water boards (*Waterschap De Dommel* and *Hoogheemraadschap de Stichtse Rijnlanden*), together collaborating as ‘the Dutch consortium’, to assist the Municipality of Matagalpa in Nicaragua. This Dutch consortium developed a three year programme, called the *Agua para Todos – Agua para Siempre* programme (APT-APS, 2007), which started in July 2007 and was extended in 2010 with one more year.

The main objective of the ApT-ApS programme is to combat untreated discharges of agricultural wastewaters (coffee wastewaters in particular) and insecticides on both rivers, and its consequences for the quality of the river water and related drinking water collection of the city of Matagalpa.

6.3. Eco-engineered WTSs as most desirable technology

The engineers of the Dutch consortium were involved as firsts in the ApT-ApS programme, and particularly in the design process of the eco-engineered WTSs. According to them, and in order to increase the water quality and quantity for the drinking water situation of the city of Matagalpa and to minimize negative environmental impacts of coffee processing, a low technology solution was needed. A system that could purify water efficiently and cheap with a low demand of operation and maintenance, and which is adapted to the local conditions was regarded as the most desirable solution (Jacobi, 2004; Sas, 2006).

A WTS consisting of an improved anaerobic lagoon pre-treatment facility (LAM system) and a post-treatment based on the Water Harmonica (WH) principle (Sas, 2006; Heller, 2008) was proposed in the ApT-ApS programme proposal (APT-APS, 2007). In the WH system nutrients (or coffee) wastewater is treated, while its nutrients are reused at the same time by the growing of biomass in the form of plants or fish. According to various authors (Jacobi, 2004; Heller, 2008; Zuijderhoudt, 2008) this type of WTS also seems to be the most suitable technology to tackle the problem of highly polluted coffee wastewaters in a developing country with restricted capital, like Nicaragua.

In the next sub-paragraphs the functioning of an anaerobic pre-treatment system and a post-treatment based on the WH principle will be explained.

6.3.1. LAM system (Improved anaerobic lagoon)

The LAM system is a covered anaerobic biogas reactor based on a pond in a conventional *pond system* (Zuijderhoudt, 2008, p.55). This primitive, but dominant system in Matagalpa makes use of several infiltration pits or ponds in sequence where the coffee wastewater can infiltrate in the soil and evaporate. The LAM system, however, was designed by Daniël Paudriet of SOLAMSA, a local NGO in Costa Rica, and adapted by Seghezzo (2007 cited in Heller, 2008, p.53). This system is a concrete dug pond that has a smaller surface on the bottom than on the top, which allows better mixing of the effluent water (Figure 4). Before the wastewater flows into the reactor, alkalinity, phosphor and little micronutrients need to be added, while the incoming wastewater needs to be pre-treated by sedimentation and sieving as well (Zuijderhoudt, 2008, p.58). The wastewater flows via pipes to the bottom of the reactor to guarantee a good mixture from where it flows up. Wastewater flows out of the reactor by overflow on the top and is directed to the WH system. The reactor is covered with a special geo-membrane to collect biogas. The hydraulic residence time should be about six days which ensures a COD removal efficiency of 50% - 70% (Heller, 2008, p.53).

Figure 4: concrete reactor of the LAM system at *finca Cueva del Tigre* under construction (source: author, 2010)

6.3.2. Water Harmonica system

After the LAM system wastewater is directed to the WH system. The WH system could be defined as "a surface water constructed and managed in such a way that the self-purifying and ecology improving processes, that also take place after discharge of wastewaters in natural surface water, take place in a controlled environment on a smaller surface with greater efficiency" (Schomaker, 2005, p.11 cited in Sas, 2006, p.4).

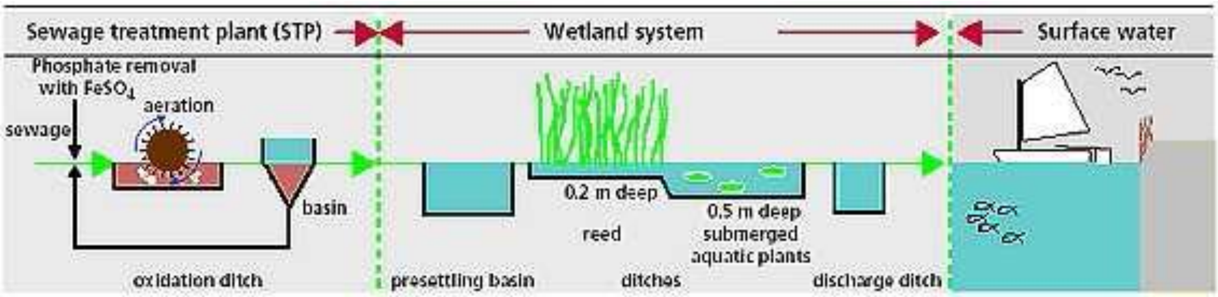

Figure 5: An example of an eco-engineered treatment system between wastewater treatment plant and surface water (source: Schomaker, 2005, p.1 cited in Sas, 2006, p.4)

The natural self-purification processes are accelerated by a tailor-made design, where the wetlands can be natural, constructed in a subsurface or surface scheme, or a combination of these three (Figure

5). After removal of sediments, lifting of pH and pre-treatment in the LAM system, the wastewater can be led to a subsurface flow system (SSF) including plant filter (Figure 6 [1]). Aquatic plants and sandy substrate create a suitable environment for water purification bacteria converting wastewater nutrients into biomass. A further treatment occurs in a surface flow system where more nutrients are translated into biomass through, for example, duckweed (Figure 6 [2]). An open pond provides the last polishing step (Figure 6 [3]). Under certain conditions it is even possible to grow fish, which is correlated to the food-chain approach of the principles of the WH system (Martijn and Mels, 2003). Finally, water can be directed to open waterways without any consequences for human and environment (Heller, 2008, p.18).

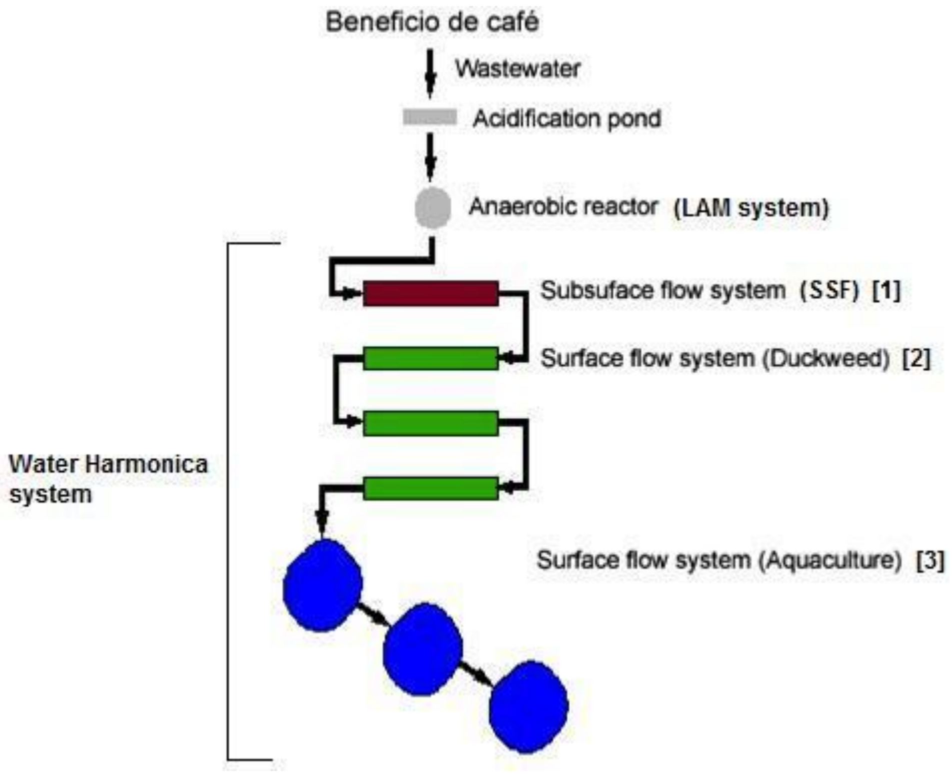

Figure 6: Layout of the eco-engineered WTS for coffee wastewater treatment (source: adapted from Sas, 2006)

Schomaker (2005 cited in Sas, 2006) as well as Martijn and Mels (2003) are concluding that the characteristics of an eco-engineered treatment system fit well within the constraints for wastewater treatment in the developing world. These characteristics are the possibility to produce biomass, a low or absent energy requirement, easy operation with low skilled operators, and easy to construct with locally available materials. On the other hand the WH system needs more space compared to conventional wastewater treatment systems. Furthermore, an organic system is always vulnerable to changing environmental conditions and can break down completely, for instance after an overload, changed temperatures or insufficient operation and maintenance.

Especially the possibility to use the treatment system as a production system make them suitable for use in developing countries and can determine the success of eco-engineered WTSs in countries with limited resources (Martijn and Mels, 2003; Schomaker, 2005 cited in Sas, 2006, p.4). For this reason an eco-engineered WTS was considered by the Dutch consortium as the base of the coffee wastewater treatment systems in Matagalpa. The other units of the treatment system will be designed with the goal to make the wastewater suitable for a biomass producing eco-engineered WTS (Sas, 2006, p.4).

As the technology of a constructed wetland is fairly new and not a fully investigated and developed concept it can be considered as a *niche* (Levinthal, 1998 cited in Schot and Geels, 2008, p.539) or *innovation* (Leeuwis, 2004b; Hall, 2005; Hall *et al.*, 2006). There are many pilot projects implemented for different types of wastewater, but under diverse conditions (e.g. design, climate, wastewater quality and quantity, plants) and often with "a missing long-term monitoring" (EPA, undated cited in Heller, 2008, p.18).

6.4. Organisational arrangements of the project

The ApT-ApS programme initially intended to realize six eco-engineered WTSs (in 2010 reduced to the realization of five WTSs) at coffee plantations as a pilot and in order to reduce the contamination on the SF river with coffee wastewaters substantially (i.e. > 40%). Point of departure in the programme was that coffee farmers have and take own responsibility in the procedure of operation of this issue. They have to be prepared to invest in and maintain the WTSs. *Finca El Salvador* was selected as the first pilot project. Based on an extensive study by M. Heller (2008) on the design and implementation of an eco-engineered WTS on this specific coffee plantation, a first design was made in May 2008. As *El Salvador* was selected as the first coffee plantation for the implementation of this innovative eco-engineered WTS in Matagalpa, it received extra financial support by the Dutch consortium; 70% of the total costs were financed by the ApT-ApS programme.

In 2007 there was a first open plenary meeting with interested coffee farmers. Coffee farmers could voluntary enter the project or DIMGARENA came to them (J. van Tilburg, 2010, pers. comm., 10 November). The owner of *finca El Salvador*, for example, is a friend of one of the engineers of DIMGARENA. An informative workshop led by LeAF in October 2008 presented the different technology options to pre-selected coffee farmers, although the focus was already on a combination of the LAM and the WH system. The selected coffee farmers pronounced again (depending on the costs and economic developments) to be prepared to invest in the treatment of coffee wastewaters. Furthermore, the basic principles of wastewater treatment have been endorsed to the coffee farmers, while designing a WTS and technology- and site-selection were trained to the engineers of DIMGARENA. The following actual selection of the coffee plantations was facilitated by DIMGARENA at the beginning of 2009, and was based on the criteria and outcomes as presented in a study executed by Zuijderhoudt (2008). The participation of a coffee farmer in the implementation of an eco-engineered WTS is partly financially as well as the provision of labour.

Subsequently, the programme proposed to realize the following activities:

1. implementation of a show project in the *San Francisco* watershed;
2. an awareness campaign;
3. one or more technical trainings concerning the treatment of coffee wastewaters;
4. financial contribution in the construction of the eco-engineered WTS.

In relation the implementation of five pilot project, or eco-engineered WTSs, five coffee plantations were selected (Table 1).

Table 1: Names of coffee plantations, plantation owners, plantation sizes of wet-mills of the involved coffee farmers and their cost-allocation keys

Nº	Name of plantation	Name of plantation owner	Size	Cost-allocation key
1	***Aztecas***	Roberto Zanetti	Medium	50%
2	***El Nido del Condor***	Freddy Pescador	Large	90%
3	***El Salvador***	Fidel Hierro	Medium	30%
4	***Virgin Magdalena***	Rodrigo Obispo	Small	50%
5	***La Hacienda***	Tatiana Montenegro	Small	50%

The activities related to the implementation of five eco-engineered WTSs will be shown further below. It must be mentioned that the activities were not executed for all five coffee plantations at the same time, but rather independent from each other. The construction of the eco-engineered WTSs at *finca La Hacienda* and at *finca El Salvador* started, for example, already in May 2009, while others only started in July 2010. The activities consist of:

1. a preliminary survey and participative technology selection (from May 2004 till 2009);
2. the design (May 2008 – July 2010);
3. the construction (May 2009 – October 2010);
4. the drawing up of instructions for maintenance and operation, and announce among the coffee farmers (July 2010 – November 2010);
5. training of local engineers (various moments within the four year ApT-ApS programme);
6. monitoring (from November 2010 onwards).

All ten aforementioned activities were the initial concepts for the Dutch consortium and the Municipality of Matagalpa to start the design and implementation of five eco-engineered WTSs.

Nevertheless, construction of the WTSs was twice aborted in November 2009 and November 2010 as the picking of the coffee berries and the wet processing of coffee beans already started. As the original or WTSs under construction are needed for this process, construction could not continue from November until late April. In the following Chapters the underlying reason of the abortion of construction as well as other failures and constraints in this design process will be analysed and discussed on the basis of the perspectives of the three distinguished stakeholder groups. Based on the historical analysis of the design process in the previous paragraphs, a timeline with the major formal project events is presented in Figure 7.

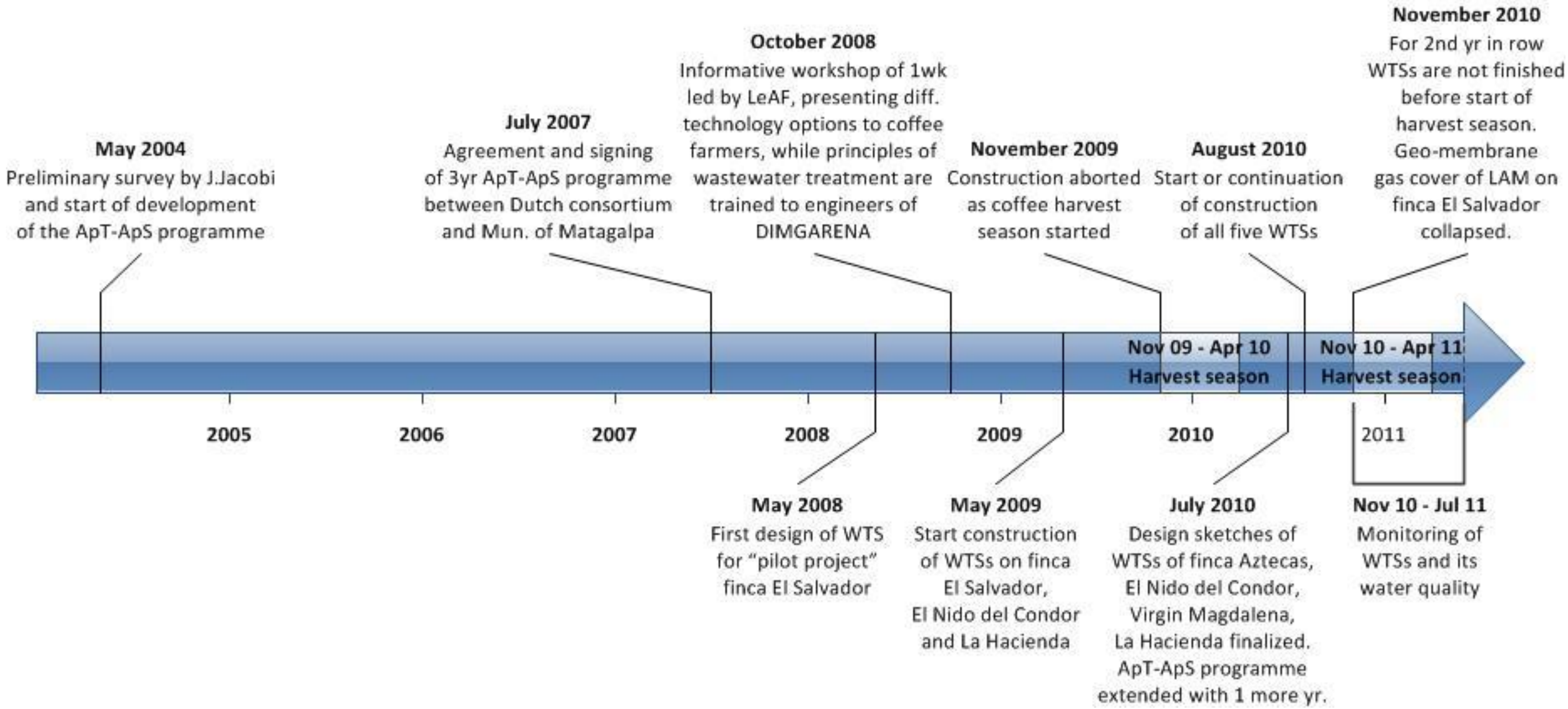

Figure 7: Timeline with the major formal project events of the design and implementation process of the eco-engineered WTSs in the ApT-ApS programme

7. Perspectives Concerning the Hardware

In this chapter the different perspectives of the three distinguished stakeholder groups will be analysed concerning the hardware component of innovation in the design process of the eco-engineered WTSs.

7.1. Conceptions of the Dutch engineers

As mentioned in paragraph 6.3, a WTS consisting of an improved anaerobic lagoon pre-treatment system (LAM system) and a post-treatment based on the Water Harmonica principle – both adapted and developed by LeAF – seemed to be the most desirable technology to combat the untreated discharges of coffee wastewaters. As they are the highest qualified persons and master the most advanced knowledge of the three distinguished groups, the Dutch engineers applied “the linear model of innovation” (Leeuwis, 2004a, p.135). Besides, there is a strong impression that the implementation of this particular type of WTS was the leading goal for them, leaving the involved coffee farmers without any other option than selecting this proposed eco-engineered WTS.

7.2. Conceptions of DIMGARENA

The engineers of DIMGARENA had a high trust in the advised and prescribed project technology by the Dutch engineers, its activities and the overall process. Nevertheless, they did not fully understand the functioning of the system as they lacked profound education or training in environmental technology and wastewater treatment systems and management themselves (R. Yvan Fernandez, 2010, pers. comm., 22 October; E. Dulzón Cuzco, 2010, pers. comm., 3 November).

Another remark by the engineers of DIMGARENA was the fact that several Dutch engineers of LeAF, *Waterschap De Dommel*, and of *BZ Innovatiemanagement*, a Dutch environmental consultancy, were advising or calculating different things concerning required dimensions and specifications of the systems, which confused the employees of DIMGARENA.

In an interview on 22 October 2010, R. Yvan Fernandez, the Project Manager of DIMGARENA, gave several comments in relation to the design of the eco-engineered WTSs. The interview was taken in a hectic period with significant adversity in the implementation phase of the WTSs. Rodrigo looked frustrated during the interview, which is reflected in some of his pronunciations:

> *“Dutch partners come and go! A big part of the available money is going to their [work] hours, but they are almost never here! And the eco-engineered WTSs lack specific final designs and dimensions!”*

Dutch engineers advised DIMGARENA that for a robust WTS better materials are needed. However, according to Rodrigo, farmers do not want to pay for these extra costs, while the eco-engineered WTS is already too expensive in his opinion. Continuing, the Dutch engineers only send sketches without clear specifications and prescribed adequate materials. Furthermore, some of these prescribed materials are common in the Netherlands, but are not always available in Nicaragua. The dismay of only having sketches resulted in a chaotic and unstructured implementation of the WTSs. In his opinion the WTSs also need a lot of surface, which is not always available on the coffee plantations. Moreover, Rodrigo does not believe that the WTS will bring notable (financial) benefits to the coffee farmers, meanwhile he supposes that farmers are actually only interested in what can bring them higher coffee prices, rather than a cleaner river. Finally, "coffee farmers lack the specific technical knowledge to truly understand, operate and maintain the treatment systems" (Ibid.).

E. Dulzón Cuzco's (2010, pers. comm., 3 November), director of DIMGARENA, perceptions are somewhat similar to the ones of Rodrigo. Not having a fixed, final design with a planning and specifications which explain how to execute the design in the field, was lacking the most according to him. Something he definitely wants to improve for the implementation phase of WTSs in the future is the conclusion of contracts with constructors. Now, Rodrigo and his team were most of the time in the field constructing the eco-engineered WTSs with their own hands themselves. In the director's opinion (and according to the ApT-ApS programme) constructors should have constructed the eco-engineered WTSs, in order that the engineers of DIMGARENA can focus on their actual task: coordinating and supervising. Argumentation of Rodrigo to construct the WTSs with his own hands was the fact that he believed that local constructors do not have the knowledge and experience to build this type of WTSs. This extended the total implementation phase of the five eco-engineered WTSs from just 10 weeks to more than 20 weeks.

7.3. Conceptions of the coffee farmers

In the period when the interviews with the coffee farmers were held (12th of October till 15th of October 2010) construction of the eco-engineered WTSs was still in progress and none of them were completely finished, while the picking of coffee berries already was started. Although it was intended and promised by the project management of the ApT-ApS programme (the Dutch consortium and DIMGARENA) to finish the WTSs already in 2009, and later postponed to before the harvest season of 2010 (F. Pescador, 2010, pers. comm., 13 October), the coffee farmers still had to discharge coffee wastewaters directly on rivers and streams. Therefore, when asking the opinions concerning the implementation of the WTSs, the pronunciations given by Fidel Hierro (2010, pers. comm., 14 October), owner of *finca El Salvador*, express the living feelings the best:

> *"Everything goes wrong, because until now nothing has been finished yet! Where do I leave the wastewater!?"*

And:

> *"In the initial stage and still sometimes a Dutch delegation passes by and takes pictures, but in the end my promised eco-engineered WTS is still not finished! I trusted the foreign engineers! But in the last years I only saw Dutch students passing by!"*

Frustration was partly fed by the slow construction process as DIMGARENA was only provided by the Dutch engineers with rough sketches of the WTSs without specifications and prescribed adequate materials, which resulted in a chaotic and unstructured implementation of the WTSs. As the Project Manager of DIMGARENA believed that coffee farmers did not have the availability over sufficient financial resources he decided that more cheap, but also more fragile materials would be applied.

The collapsing of the geo-membrane gas cover of the LAM system on *finca El Salvador* on Wednesday the 13th of October in the implementation phase is a striking example of the shortcoming of only rough design sketches and the use of cheap and more fragile materials. The owner of *finca El Salvador* (Ibid.) states, however, that he could and rather would have applied for an extra loan or credit in order to buy better materials to build a more robust system, hereby contradicting the Project Manager of DIMGARENA.

Another often heard comment was the fact that parts and details of the designs of the LAM and the WH systems kept on changing, while the coffee farmers were never really consulted in the changes being made (R. Zanetti, 2010, pers. comm., 12 October; F. Pescador, 2010, pers. comm., 13 October). In relation to the design, some coffee farmers did not expect that the eco-engineered WTSs consumes such a lot of land (i.e. approximately 10% of the total plantation surface), and thereto the loss of area with coffee plants. This loss accounts especially for the smaller *fincas Aztecas*, *La Hacienda* and *Virgin Magdalena*.

Finally, and although not all WTSs were yet finished, some coffee farmers wanted something on paper to read about the functioning and managing of the LAM and WH system (R. Obispo, 2010, pers. comm., 14 October; T. Montenegro, 2010, pers. comm., 15 October). They especially liked to receive more information concerning operation and maintenance (O&M) activities. A workshop given by LeAF concerning this issue was on the planning for November 2010.

7.4. In sum

Misunderstanding between the stakeholders, uncertainty and improvisation as a result of a lack of fixed, final designs including planning and specifications were one of the most prominent findings in this chapter. Also the collapsing of the geo-membrane gas cover on *finca El Salvador* is a clear indication of a lack of consultation between the stakeholders. From the mentioned issues in this chapter we can conclude that there was a significant lack of stakeholder interaction on multiple levels and between all involved stakeholders throughout the design and implementation process of the eco-engineered WTSs.

8. Perspectives Concerning the Software

The lack of *local, specific knowledge* (Hall *et al.*, 2006) by the Dutch engineers and on the other hand the lack of knowledge and experience in wastewater treatment systems and management among the engineers of DIMGARENA as well as the coffee farmers – as mentioned in the previous chapter – is a good example of the interdependent interaction between hardware and software. Panebianco and Pahl-Wostl (2006) already identified that innovation is an interaction between technology (hardware), knowledge and skills needed to develop, produce and use the technology (software) and the necessary organisational and institutional arrangements and conditions (orgware).

8.1. Conceptions regarding the Dutch engineers

The Dutch engineers and experts involved in the "participative technology selection" during the informative workshop in October 2008 and in the design process between 2004 and 2010 are all highly educated and qualified experts in the field of environmental technology and wastewater treatment systems. They master the most advanced knowledge and skills of the three distinguished stakeholder groups to develop and produce and eco-engineered WTS. Because of this knowledge advantage, the Dutch engineers drew a straight and one-directional line between science and practice for selecting, according to them, the most appropriate WTS system (a combination of the LAM and the WH system). This mode of thinking could be referred as "the linear model of innovation" (Leeuwis, 2004a, p.135). Furthermore, the combination of a LAM system and a WH system is an innovation developed by the ApT-ApS programme itself; especially by engineers of LeAF. Against this background the selection of the technology gives the appearance that the wish of implementing one type of system was the leading and foremost goal, rather than the reasons and importance of the coffee farmers and their plantations.

As technical trainings concerning the treatment of coffee wastewaters and of local engineers were initially integral activities of the ApT-ApS programme, LeAF had the intention to focus on capacity and knowledge building there where necessities were within DIMGARENA or among coffee farmers. This, however, turned out to be too time-consuming and costly for the Dutch engineers and therefore received less attention during the execution of the programme (J. van Tilburg, 2010, pers. comm., 10 November). This had as effect that the few organized workshops were rather informative and one-way-oriented. In other words, information was merely disseminated from the Dutch engineers to DIMGARENA and the coffee farmers.

Furthermore, the Project Manager of LeAF (2010, pers. comm., 10 November) admits that there is already a knowledge and communication gap between the Dutch engineers and the engineers of DIMGARENA, and again between DIMGARENA and the Nicaraguan coffee farmers. As there is no real direct interaction between the Dutch engineers and the coffee farmers, he considers the knowledge and communication gap as "huge". The employment of technically highly competent

Dutch experts in Nicaragua was in that sense not contributing to an environment where mutual learning should have been stimulated and where *local, specific knowledge* and *generic knowledge* (Hall *et al.*, 2006) should have been exchanged.

8.2. Conceptions of DIMGARENA

The engineers of DIMGARENA admit themselves that they lack profound knowledge and experience in wastewater treatment systems and management (R. Yvan Fernandez, 2010, pers. comm., 22 October; E. Dulzón Cuzco, 2010, pers. comm., 3 November). Most of them regard the organized workshop in October 2008 led by engineer Lucas Seghezzo (LeAF) as the only wastewater treatment training they have ever attended (Ibid.). It can thus be said that the engineers of DIMGARENA are in fact not competent persons to coordinate and supervise a project and technology in which they have no expertise and experience.

DIMGARENA also identified communication as an issue that is currently lacking, while cultural differences hinder the working process and atmosphere. The director as well as the Project Manager of DIMGARENA mention that Dutch employees who come to Nicaragua do not all master the Spanish language. On the contrary, Spanish is the only spoken language by the engineers of DIMGARENA. In relation to language issues, Rodrigo indicates that currently information in Spanish concerning the design, operation and maintenance (O&M) activities, and a plan how to monitor the five WTS locations is lacking. When this information was or is available in Spanish he says he and the other local engineers could increase their knowledge and expertise themselves, which is related to 'activity 5. Training of local engineers'. He also says that "the Dutch need to realize that times and activities are not always punctual, fixed an planned", as unplanned and accidental means occur more often in Nicaragua. It was observed, for example, that the one, old company car needs to be shared daily by various people who generally need to go to different locations around Matagalpa. Moreover, the car is occasionally without gasoline as there are not always funds available which are directly ready for use in order to buy new gasoline.

8.3. Conceptions of the coffee farmers

The educational levels of the coffee farmers are differing between not even finished Primary School (2 coffee farmers) and accomplishing the study Agronomic Engineering on a Polytechnic School (also 2). Furthermore, two coffee farmers are stating that they have little knowledge concerning wastewater treatment (R. Zanetti, 2010, pers. comm., 12 October; F. Hierro, 2010, pers. comm., 14 October). Knowing that the coffee farmers have little affinity with wastewater treatment, while some even lack basic education, it may not be surprising that the Dutch consortium received little to no comments and criticism while presenting the combination of a LAM and WH system as eco-engineered WTS as the most desirable technology. It thus can be said that the decision to choose for this particular wastewater treatment technology was made by the Dutch engineers. Therefore, the technology selection lacked stakeholder interaction and involvement of local knowledge on agricultural, natural and social demands. Further on in this research we will show that this *local, specific knowledge*, like which materials are available for construction in Nicaragua, the available land on the plantations and preferences for future activities as a result of the eco-engineered WTS and its by-products, is possessed by the coffee farmers.

Nevertheless, the coffee farmers all have at least 10 years of working experience on a coffee plantation, of which a great part as owner. Besides, *finca Aztecas, El Nido del Condor* and *El Salvador* already made use of the conventional and primitive *pond system*; the dominant treatment system used in Matagalpa consisting of one or more dug ponds in a row where the coffee wastewaters can precipitate, infiltrate in the soil and evaporate (Zuijderhoudt, 2008, p.55). Because of this working experience, their potential contribution in the innovation process seems to have been overlooked (Röling, 1988; Röling, 1994), while “inclusion of their knowledge appears to be indispensable” (Grendelman and Huibers, 2010) for a local desired and accepted coffee WTS.

According to the coffee farmers a more protected and better conserved environment is the main expected benefit by the implementation of eco-engineered WTSs. Especially people downstream of the coffee plantations will benefit from the improved water quality in rivers and streams. Surprisingly, the coffee farmers do not see so much advantages for themselves. Three coffee farmers expect less contaminated and more worthy properties, while the owner of *finca El Nido del Condor* also expects better coffee prices. Re-use of the water after the treatment process for washing purposes of the coffee berries was also mentioned as a benefit. Nevertheless, the coffee farmers expect that these benefits and advantages will be marginal in relation to the high initial costs of the eco-engineered WTSs.

8.4. In sum

From this chapter it can be concluded that there is a great lack of overall coordination from the Dutch consortium on the local situation in Nicaragua. Besides, there is a significant difference in education and knowledge level between the three distinguished stakeholder groups, while knowledge captured within one stakeholder cannot be exchanged as there is a lack of interaction and opportunities to exchange either their *generic* or *local, specific knowledge* in order to enhance mutual learning.

9. Perspectives Concerning the Orgware

Analysing the *orgware* component of the technological innovation process, the "institutional and organisational arrangements under which the technology could be developed and adopted" (Panebianco and Pahl-Wostl, 2006) is meant. Institutional arrangements could be seen as "the forms of contract or arrangement that are set up for particular transactions between contracting parties, governing the way that these parties cooperate or compete" (Gandarillas, undated, p.3). In relation to this particular technological innovation and project, the way the eco-engineered WTSs are financed, the provision of labour and the agreed milestones in the project are relevant issues. Besides, through the 'ecological' treatment of coffee wastewaters the WTSs can have additional functions such as the production of by-products, like biomass, and the amplification of financial value and activities, which also received attention in this study.

9.1. Conceptions towards the additional functions of the WTSs

The initial idea of the Dutch consortium with the eco-engineered WTSs was to convert wastewater nutrients into biomass, like duckweed, while under certain conditions fish can be grown in open ponds at the end of the system (Heller, 2008). These positive characteristics were incorporated by the Dutch engineers to provide the coffee farmers with alternatives to earn a little extra money by implementing this particular type of WTS. In other words, the Dutch consortium found that this niche innovation should be adopted from the start to cover the high initial costs of the eco-engineered WTSs and generate extra income (Raven, 2006 cited in Schot and Geels, 2008, p.547). However, only Tatiana Montenegro and Rodrigo Obispo have concrete plans to plant fruit and vegetables plants in the subsurface flow system (SSF), which can convert wastewater nutrients into biomass. Rodrigo intends to start cultivating *Xanthosoma* (also known under the names *Malanga*, *New Cocoyam* or *Tannia*). It is a vegetable that is not yet sold and consumed a lot in Nicaragua, but shows high potentials as it grows fast and does not need a lot of nursery. Nevertheless, the coffee farmers expect the returns from growing fruits, vegetables, duckweed and fish *in* their eco-engineered WTS to be marginal in relation to the high initial costs of the eco-engineered WTS. They also say that the harvested fruits, vegetables and fish will mainly be for auto-consumption. Thus, according to farmers' expectations and visions as well as external influences (e.g. lack of profitable markets), the niche innovation of using wastewater nutrients for the cultivation of fruit and vegetable plants is unlikely to link up with ongoing processes at the existing regime and landscape levels in society (Schot and Geels, 2008, p.547).

Turning their coffee plantation into an *eco-finca* or *eco-farm* for eco-tourism seems to be much more promising to the coffee farmers, as this additional activity is growing rapidly in Nicaragua. However, this potential future activity as part of implementing an eco-engineered WTS received none till little attention from the Dutch consortium in the ApT-ApS programme. Having an eco-engineered WTS on your plantation contributes to and emphasizes the ecological and sustainable way of producing coffee.

According to the Project Manager of DIMGARENA (2010, pers. comm., 22 October) this ambition requires yet another investment capital which most of these coffee farmers do not possess. Nonetheless, this small group of farmers apparently support this novelty on the basis of expectations and visions. With support of external financers and organizations or NGOs who support small coffee-producers (e.g. *Solidaridad CSN*), the niche innovation of developing an *eco-farm* can diffuse more widely.

However, and according to Schot and Geels' (2008, p.546) (Figure 3) 'niche-innovations perspective on transitions', niche innovations do better co-evolve and mutually adapt on multiple levels when diversity is created and competition encouraged (Shove and Walker, 2007 cited in Schot and Geels, 2008, p.547). In other words, it might be better when different niche innovations are developed – such as the use wastewater nutrients for cultivations of fruits and vegetables, the transformation of coffee plantations into *eco-farms* and the certification of produced coffee (paragraph 9.3.) – and compete with each other in an initial stage of the innovation process. Its further learning processes may eventually lead to more substantial reconfigurations of these niche innovations, until elements become more aligned, and stabilise in a dominant design (Schot and Geels, 2008, p.546-547).

9.2. Transactional arrangements between the parties

Starting the ApT-ApS programme, transactional arrangements have been made between the initiators of the project (the Dutch consortium and DIMGARENA) and the coffee farmers. The five selected coffee farmers pronounced to invest in the treatment of coffee wastewaters. Participation was partly financially, according to a cost-allocation key (Table 1), as well as the provision of labour.

However, from the ApT-ApS programme and from interviews it could not be discovered which rules concerning division of costs were agreed upon or if there was a maximum financial contribution for the coffee farmers. As changes of the design kept on being made by the engineers of DIMGARENA (R. Zanetti, 2010, pers. comm., 12 October; F. Pescador, 2010, pers. comm., 13 October), the WTSs also became more expensive as more construction materials were being used (F. Pescador, 2010, pers. comm., 13 October; R. Obispo, 2010, 14 October). This all caused vagueness and frustration among the coffee farmers, also because the delivery of the WTSs exceeded the set target-date. One coffee farmer (F. Hierro, 2010, pers. comm., 14 October) also refused to provide DIMGARENA with labourers of his own coffee plantation, as he said that this never was the agreement. Although the provision of labourers by the involved coffee farmers is mentioned in the ApT-ApS programme (ApT-ApS, 2007), it appears that clear, written transactional agreements have been absent. Aforementioned issues and events damaged trust and jeopardized relations in this project significantly, particularly those of the coffee farmers towards the other two stakeholder groups. As especially trust and reciprocity has been fallen, it has been observed that shared norms, values and beliefs and the sharing of information and collective action and decision making was below optimal.

9.3. Certification of produced coffee

During several coffee plantation visits and from the interviews with the coffee farmers it was noticed that certification of the produced coffee is an important asset for Nicaraguan coffee farmers to distinguish themselves on the competitive coffee market. However, only two coffee farmers produced certified coffee. The large coffee plantation *El Nido del Condor* is certified by *RainForest Alliance* and *Starbucks* for producing its coffee in a socially, economically and environmentally sustainable manner. *Finca La Hacienda* is *"Por Biolatina"* certified for its biological coffee production. The three other coffee producers are not certified yet, but all have plans to certificate their coffee production in the future.

Although certifications for produced coffee also have environmental criteria, no distinctions are made by the certifying authority between conventional ways of water treatment (e.g. the *pond system*) or improved wastewater treatment systems, like the eco-engineered WTS, as long as national obliged water quality standards are been met. Also the environmental criteria required by the certifying authority remains rather general and vague, such as: "minimize water usage and environmental pollution", "treatment of contaminated water" and "protecting water sources"[1]. This superficiality creates no incentive or enforcement for the coffee farmers for implementing an improved WTS. Besides, R. Pasveer of *BZ Innovatiemanagement* (2010, pers. comm., 23 November) says it is difficult for certifying authorities to distinguish different certificates according to particular determined WTSs. This has to do with the fact that the primary focus of the certifying authorities remains on cultivation of coffee (e.g. minimized use of agrochemicals) and protection of the livelihoods of coffee farmers and their employees (e.g. protection of labour rights and access to health care and education), while precise rules and best ways for treating coffee wastewaters are still under exposed.

9.4. In sum

In conclusion, institutional dimensions and arrangements have been greatly overlooked or were not clearly embedded in the project. The Dutch consortium fully putted all their cards on the cultivation of vegetables and fruits as by-product of the 'ecological' WTS as a financial incentive to implement this particular WTS, while development of other niches and their mutual co-evolution and adaptation through competition has been neglected. Also the possibilities for advanced coffee certificates and cooperation with certifying authorities received little attention in the ApT-ApS programme.

[1] http://www.utzcertified.org/index.php?pageID=114 [latest update: 2006, accessed on: 20 April, 2011]

10. Reflection on the Process of the Eco-engineered WTSs

During interviews with the several stakeholder groups, disappointment, frustration and interesting pronunciations in relation to the organisational arrangements and process became apparent. However, most of these comments are not directly related to the technology but are more referring to the collaboration between the different stakeholder groups and its process. This will be discussed in this chapter.

10.1. Conceptions of the Dutch engineers

In an interview with the Project Manager of LeAF (2010, pers. comm., 10 November) the institutional and organisational arrangements in the design and implementation process of the eco-engineered WTSs were evaluated. He declares that (1) an environmental engineer with high facilitating abilities and intercultural communication skills, (2) the limited human (available man-hours) and financial capital in the programme, especially within DIMGARENA, and (3) a good network and relation with constructors for construction of the WTSs, were the most important organisational conditions lacking.

Continuing on the essential orgware part of technological innovations, LeAF admits that the relation between the three counterparts of the Dutch consortium were not always constructive (Ibid.). It seems that especially the two Dutch water boards had other obligations and priorities (i.e. their businesses in the Netherlands). There are three major reasons why these water boards, as Dutch governmental institutions, participate in the ApT-ApS programme:

1. “Exchange of knowledge and experience. Not only bringing knowledge, but also experiencing how others, in much simpler ways have organised their water management[2];

2. Source of inspiration for their employees. Experience learns that foreign activities are inspiring for employees as they get in touch with other cultures and learn that having basic services are not always self-evident;

3. Strengthening of collaboration between regional partners (like the three Dutch partners who all have their head office, main activities and roots in the Netherlands) through special foreign activities.”

The three mentioned reasons to participate in the programme are, however, totally different objectives than the main objective of the ApT-ApS programme (paragraph 6.2.) and its sub-objective to tackle the highly polluted coffee wastewaters. Aforementioned reasons of the Dutch water boards to participate in the project degrades the interactive design and implementation process of the eco-engineered WTSs, although maybe unconsciously, immediately to a side issue and one of secondary importance. Moreover, the water boards fundamentally do not invest own money in foreign activities.

[2] http://www.dommel.nl/projecten/internationale [latest update: April 2011, accessed on: 11 May, 2011]

Their support originates from the provision of human capacity and expertise (J. van Tilburg, 2010, pers. comm., 10 November). One could also say that, through this way, the water boards have no financial solidarity or risk of financial losses in this project, making them less 'attached' with the project, while the motivation and pressure to achieve set goals is also lower.

In the same interview with the Project Manager of LeAF (2010, pers. comm., 10 November), Van Tilburg mentions that the communication with DIMGARENA is "a super important" issue. On the contrary, he accede later on in the interview that the Dutch experts and engineers who go on mission to Nicaragua "are not [all] able to speak Spanish" (Ibid.). Also some cultural differences made it difficult to establish optimal organisational arrangements and conditions under which the technology could be applied and adopted. Planning of (long-term) activities, being punctual as well as the presence of high qualified labourers are not self-evident issues within DIMGARENA. The programme also tried an open forum in Spanish on their website[3] to discuss the implementation and elaboration of the ApT-ApS programme between the Dutch engineers and DIMGARENA in 2007. This worked quite well in the beginning but doze off after a while (Ibid.).

10.2. Conceptions of DIMGARENA

According to several authors in the field of technological innovation systems, (Hall *et al.*, 2001; Hall *et al.*, 2006; Grendelman and Huibers, 2010) inclusion of local parties and the flow of knowledge between other actors and institutions in crucial niche processes is indispensable. However, in the interview with Rodrigo on the 22nd of October, 2010, the Project Manager of DIMGARENA believes that the relation and collaboration between his organization and the Dutch consortium is still marginal.

One of the first conditions that have been mentioned by both the director and the Project Manager of DIMGARENA is the slow and inefficient way of transferring project money from the Netherlands to Nicaragua. When DIMGARENA makes a tender offer at a hardware store in order to buy materials they have to send the tender first to the Netherlands for approval and authorisation, and only then the necessary money will be transferred to the bank account of DIMGARENA. This process takes between two and three weeks. As the Nicaraguan currency (Córdoba) is linked to the American Dollar, prices fluctuate heavily. In the period of time between the request of DIMGARENA and transfer of money by the Dutch consortium, the available amount of money frequently does not meet the new price levels anymore.

In general, the department depends a lot on the Dutch consortium concerning decisions needed being made and necessary money. The latter makes these decisions based on the information provided by DIMGARENA or, when present, a Dutch student without knowing the exact situation in Nicaragua as

[3] http://www.aguaparatodos.nl/forum/index.php [Accessed on: 20 April, 2011]

there is no general ‘Dutch’ coordinator or assessor in Nicaragua. It is suggested that it sometimes would be better when the department could make decisions themselves (R. Yvan Fernandez, 2010, pers. comm., 22 October; E. Dulzón Cuzco, 2010, pers. comm., 3 November).

Related to the educational level and capacity of DIMGARENA-personnel and based on comments made by the Project Manager of LeAF, the capacity and potential of a student as coordinator for the implementation of the eco-engineered WTSs has been highly overestimated. According to R. Yvan Fernandez (2010, pers. comm., 22 October) a Dutch assessor or coordinator with various years of experience in the field of potable water and wastewater treatment should have been more appropriate for the successful implementation of the WTSs. According to Rodrigo there should also be more frequent direct contact with the Dutch engineers; i.e. contact with the Dutch engineers in Nicaragua at the location of issue. Rodrigo reminds the interviewer that he is only an agronomist, not an environmental engineer.

10.3. Conceptions of the coffee farmers

All coffee farmers mention DIMGARENA, or the Municipality of Matagalpa in general, as the (only) institution with whom they are collaborating. More striking is the fact that the Dutch consortium is by some coffee farmers not mentioned as one of the collaborating partners. Some farmers admits that the Dutch consortium is somehow involved, but that their personal names and their exact role in the project are unknown (F. Pescador, 2010, pers. comm., 13 October; F. Hierro, 2010, pers. comm., 14 October; T. Montenegro, 2010, pers. comm., 15 October). This remarkable outcome has to do with the lack of *visibility* of the Dutch consortium and, resulting from that, the lack of direct interaction between the Dutch consortium and the Nicaraguan coffee farmers.

Also when describing the way of collaboration with DIMGARENA and the Dutch engineers a one-way communication process becomes apparent. Fidel Hierro (*finca El Salvador*), Rodrigo Obispo (*finca Virgin Magdalena*) and Tatiana Montenegro (*finca La Hacienda*) are all indicating that “*’they’* [DIMGARENA and the Dutch consortium] wanted to implement an eco-engineered WTS” and that ”*’they’* started executing their own plan”. The fact that DIMGARENA and the Dutch engineers were able to employ this one-directional line of implementation without consulting or receiving criticism from the coffee farmers is linked with the attitude of the farmers towards the engineers. Three coffee farmers did not want to interfere and discuss with the engineers concerning the design and implementation phase of the eco-engineered WTSs, because they respected and trusted the ‘highly educated engineers and experts’ (R. Obispo, 2010, pers. comm., 14 October; F. Hierro, 2010, pers. comm., 14 October; T. Montenegro, 2010, pers. comm., 15 October).

11. A Similar Project, Another Approach

In the same region of the ApT-ApS programme, the Dutch organization *Solidaridad CSN* support Nicaraguan coffee co-operatives and farmers active in this sector. Three of their supported coffee plantations were visited on the 12th of August, 2010, while the project was discussed with R. Pasveer of *BZ Innovatiemanagement* in an interview on the 23rd of November, 2010. This two parameters are however insufficient to analyse this project profoundly and to make a one-on-one comparison with the ApT-ApS programme. Nevertheless, as the project seems to make use of the strategic niche management (SNM) approach (Schot and Geels, 2008), the project is particularly interesting to compare the approaches of both projects.

Solidaridad CSN assist coffee producers who work on a sustainable development of their income and economy, they involve local inhabitants and consumers, and create support in society for sustainable economic development within globalizing economic, political and cultural relations, through an information policy which is focused on realization and change of attitude on the long-term.

R. Pasveer (2010, pers. comm., 23 November) gave insight to the approach of this project, which uses a totally different point of departure in comparison to the ApT-ApS programme. *Solidaridad CSN* works closely together with the Nicaraguan Ministry of Agriculture and Forestry (MAGFOR), coffee co-operations and buyers (*CECOCAFEN, El Polo, CISA*), *UTZ Certified*, a Dutch-based certifying authority, and *BZ Innovatiemanegement*, which functions as the Project Management in this project. R. Pasveer is married to a Nicaragua and resides therefore several months per year in Nicaragua, while mastering the Spanish language fluently. Although these organizations all are working in the coffee sector, they all are fulfilling other specialities. *Solidaridad CSN* has long-term contracts and long-running collaboration with coffee co-operatives and farmers, support them in a broad process of improvement on all aspects of coffee production and management. One could say that all involved parties are sharing the same vision, “networks, norms and trust that enable [them] to act together effectively to reach shared objectives” (Putnam, 1995, p.67). In other words: the *social capital* is strong.

Nevertheless, according to the principles of the *Solidaridad CSN* project, coffee farmers should initiate the collaboration for this broad and long-term support as well as the implementation of a WTS, not the other way around as in the ApT-ApS programme. R. Pasveer (2010, pers. comm., 23 November) also argues that the improvement of the environmental and water quality goes gradually. First the production quantity (kegs per ha.) needs to be improved, than progress can be made in the quality of the coffee beans (through good and strict management of the plantation and better coffee processing) and only than bonification of quality of other aspects, like social and environmental issues, can be attained. This projects’ approach stimulates a development process through which coffee co-operatives and individual farmers can professionalize themselves bit by bit; a process that seems more sustainable than the one applied by the ApT-ApS programme. As shown in the previous chapters the latter lacks a clear, shared vision.

Coordinating local organizations, like *CECOCAFEN*, have technicians who have a clear picture on the developments on each plantation and know which ones are open and ready for improvements in the field of environment as well as in setting-up eco-tourism activities. Experiences learned Pasveer (Ibid.) that these plantations experience faster and more advantages of (the by-products of) the WTSs, which makes it more likeable that these systems remain well maintained and in operation.

The success of the approach of the project of *Solidaridad CSN* is reflected by the growing number of members of *CECOCAFEN* – from 1200 members in 2002 to 1500 in 2005 – and the relationship of trust established between them and coffee producers. In return, *CECOCAFEN* organizes capacity-building trainings in terms of encouraging income generation through *diversification* (eco-tourism initiatives), helping farmers develop new skills and knowledge of quality production (i.e. *software*) through workshops and technical assistance, and "increasing access to international markets by promotional activities" (Utting-Chamorro, 2005, p.596).

The selection procedure of the type of WTS also occurs differently from the ApT-ApS programme. According to Pasveer (2010, pers. comm., 23 November) it is important to first get the boundary conditions clear. When the boundary conditions are clear a highly qualified engineer can make the selection and a specific design himself. Exclusion of plantation owners in the technical design is than possible, as long this is in line with the boundary conditions and this is looped back to the plantation owner.

R. Pasveer (Ibid.) concludes by saying that "sometimes the wish to implement one particular type of system is the leading goal. Though it is not wrong to have development goals yourself. But when a project is not above all approached and implemented with the interests of the coffee plantation in mind, one will never receive the collaboration and support of the plantation owner which is needed" and goals will not be reached.

12. Analysis and discussion

The most prominent result from the previous chapters would be the difference between the initial organisational arrangements on paper and implementation of these in practise. A significant part of the proposed activities in the ApT-ApS programme were initially rather interactive and cognitive, including an awareness campaign, a participative technology selection and the training of local engineers. In reality the process was, however, quite linear, one-directional and with a strong focus on the technological innovation (i.e. the *hardware*) and its implementation, without providing and developing the necessary institutional arrangements and conditions (e.g. unclear financial and labour support, additional functions of the WTS, coffee certificates) and neither involving the beneficiary people (i.e. the coffee farmers) effectively, including their *local, specific knowledge*. Because of the lack of profound stakeholder interaction – with an aim to develop a process of mutual understanding and learning –, exchange of *generic* versus *local, specific* knowledge was obstructed. Furthermore, training of and capacity building among the engineers of DIMGARENA and the coffee farmers did not take place or lift-off.

Besides, there were some specific interesting issues that became apparent after analysis of the research result which will be discussed in the next paragraphs.

12.1. Employment of an innovation broker

From the interaction between the hardware and software components in the design process of the eco-engineered WTSs it appears that the employment of an expert with more facilitating abilities and (intercultural) communication skills would have been more appropriate. It should have been a prescribed institutional condition in the ApT-ApS programme under which co-ordination and integration of the project would have been more successful (Margerum and Born, 1995, p.386), rather than the employment of technocratic Dutch experts or students in Nicaragua. This research proved that the employment of the latter two is not contributing to an environment where mutual learning is stimulated and where local, specific knowledge and generic knowledge can be exchanged. Therefore, the employment of an *innovation broker* (Batterink, 2009; Klerkx and Leeuwis, 2009) would have been more appropriate. Despite some terminological redundancy in literature, an innovation broker has three main functions. Firstly he or she articulates "innovation needs and corresponding demands in terms of technology, knowledge, funding and policy" (Klerkx and Leeuwis, 2009, p.851). Secondly, he or she facilitates effective linkages between the involved stakeholders as well as achieve "adequate combinations of hardware, software and orgware" (Ibid., p.850), and finally he or she enhances mutual alignment and learning through facilitating learning and cooperation in the innovation process (Ibid.). The underlying assumption of the research executed by Batterink (2009) is that "innovation brokers must have excellent practices for these three functions when they want to orchestrate innovation networks successfully" (p.81). Furthermore is an impartial and independent position a key premise of this facilitator role (Isaksen and Remøe, 2001 cited in Batterink, 2009; and Klerkx and Leeuwis, 2009). Nevertheless, when such an intermediary is employed he or she also should have experience in environmental technology or wastewater treatment systems, master the Spanish language and understand the cultural differences between the stakeholder groups. These arrangements seems to be covered in the *Solidaridad CSN* project where R. Pasveer of *BZ Innovatiemanagement* was acting as the Project Manager, while speaking Spanish fluently and residing in Nicaragua for several months per year.

12.2. Transformation of environmental criteria of certificates

Concerning certification of produced coffee there is much to gain for environmentalists and the wastewater treatment sector to collaborate with certifying authorities. Involving these authorities as one of the main stakeholders in a project, like in the project of *Solidaridad CSN*, is recommendable, as they can fulfil their own speciality and can support the farmers in a broad process of improvement of their coffee production and management (R. Pasveer, 2010, pers. comm., 23 November). Simultaneously, transformation of environmental criteria of certificates should be discussed. All should contribute to more strict and clear rules concerning ways and efficiency of treating coffee wastewaters. Marketing a new, more environment and water quality friendly label or different degrees in certificates distinguishing between conventional, low efficient WTSs and eco-engineered, high efficient WTSs are possibilities interesting to investigate. The issue of and link with coffee certificates as part of 'ecological' coffee WTSs was ignored in the ApT-ApS programme.

12.3. Competing niche innovations

Besides the primary function of the eco-engineered WTS – the treatment of coffee wastewaters – the system may have some additional functions, or niche innovations, of which the aforementioned environment and water quality friendly coffee certificate could be one of them. Other niche innovations are the use of wastewater nutrients as biomass for cultivation of fruits and vegetables, which is recommended by the Dutch consortium, while coffee farmers have higher expectations from turning their coffee plantations into *eco-farms*. The recommended niche innovation of the Dutch consortium is justified by themselves as the growing and selling of fruits, vegetables, duckweed or fish *in* their eco-engineered WTS generates extra income. Though, market research for these products has never been executed, while farmers themselves do not expect the production of fruits and vegetables from the eco-engineered WTS as being a reliable source of income; the cultivation would be for auto consumption at the utmost.

Turning their coffee plantation into an *eco-finca* or *eco-farm* creates higher expectations among the coffee farmers, as the eco-tourism sector is growing rapidly in Nicaragua. However, this potential future activity as part of implementing an eco-engineered WTS received none till little attention from the Dutch consortium in the ApT-ApS programme, while on the contrary it is uncertain whether the eco-tourism market around Matagalpa is significant enough for several *eco-farms* in a rather small area. Nonetheless, this small group of farmers apparently believes more in the novelty of *eco-farms* on the basis of expectations and visions. External financers, coffee co-operations and supportive organizations of small coffee-producers (e.g. *Solidaridad CSN* and *CECOCAFEN*), could undertake and support such capacity-building activities which encourages income generation through *diversification* (e.g. eco-tourism activities). In this way developments of niche innovations may diffuse more widely (Schot and Geels, 2008, p.547).

Nevertheless the preference of some stakeholder groups for particular niche innovation, it is believed that creation of niche diversity and competition may lead to more substantial co-evolution and mutual adaptation of the niche innovations on multiple levels (Shove and Walker cited in Schot and Geels, 2008, p.547). The learning process and its multi-level perspective of the SNM approach in which this co-evolution of innovation may occur, is proven to lead to the breakthrough and, eventually, the alignment and stabilisation of one final, dominant niche innovation.

13. Conclusion

In this study research it has been indicated that there was a great lack of stakeholder interaction on multiple levels and between all involved stakeholders throughout the design and implementation process of the eco-engineered WTSs. In contrast, Leeuwis (2004a, p.135) argues that innovation precisely requires stakeholder interaction who all contribute to the generation and transfer of knowledge – the cognitive component of evolution of innovations. Inclusion and direct implication of local parties in the design and implementation phase should have been ensured, as their local knowledge is indispensable for a local desired and accepted wastewater system (Grendelman and Huibers, 2010). Although words like "interaction" and "cognitive" have been used in the ApT-ApS programme proposal and its proposed activities, the actual process was rather linear with a strong focus on the technological niche and its implementation. Continuing, the projects' transactional arrangements have never been clearly documented or developed, and neither fully complied with in the execution phase.

Besides, the lines between *hardware*, *software* and *orgware* are sometimes unclear as they are thin and interlinked. Although the theory developed by Smits (2002) proved to be applicable and useful in this study, it remains sometimes arbitrary to place certain perspectives of a stakeholder under one single box. For example, the selection of a certain wastewater treatment technology is much dependent on the knowledge level and capacity of the one who makes the selection. Does one consider this than *hardware* or *software*? Further research reconsidering this theory or defining better the inter-linkages between the three innovation components is recommended.

Finally, the project lacked early and effective stakeholder interaction and the inclusion of *local, specific knowledge*, as the coffee farmers were marginally approached and involved. All aforementioned issues, as described in the previous chapter, were revealed as indispensable factors in the process and evolution of socio-technological innovations.

More related to the co-evolution of innovation and its process, it gives the impression that focus was more on the technological development of the niche – despite of the absence of final designs and specifications – than on the institutional developments. However, according to Smits (2002) and Schot and Geels (2008) technological development should evolve together and hand-in-hand with institutional development, not to mention the skills which need to be evolved in order to develop, produce and use the technology. No competent environmental technology experts within DIMGARENA, lack of adequate materials and no qualified contractors in Nicaragua, are a few of the most obvious examples of missing links in the institutional development.

In a more integrated approach and environment, guided by the proposed experienced *innovation broker* (Klerkx and Leeuwis, 2009), objectives and tradeoffs could simultaneously have been determined by the involved stakeholders. Margerum and Born (1995, p.386) are stating that "in this process of co-ordinating actions, stakeholders should constantly review and improve upon their own approach. They should also consider whether they have examined the full scope of the issues, recognized the important interconnections, and developed appropriate goals and key actions". Perhaps most importantly, when the next eco-engineered WTSs are being implemented, stakeholders should assess whether they are successfully moving towards meeting the goals for the system and adapting accordingly, because ultimately the success of and support for integrated management will be judged by the ability to demonstrate that integration is producing desired outcomes (Ibid.).

14. Reflection on own research

When reflecting on this study research, my first comment would be the conflict between the internship activities, which I executed for the Dutch consortium, and the need for data collection during my time in Nicaragua, which both fought for supremacy. Actually, the internship activities – the design, supervising and realization of the five eco-engineered WTSs – asked most of my time, as I felt responsible to deliver these systems before the coffee harvest season of 2010 started. Therefore, the data gathering for this research suffered a bit; only in the last 3 weeks of my period in Nicaragua I did in-depth interviews. Though, reports of remarkable and interesting events, quotes and observations were documented throughout the four months period of research.

As already said in the conclusion, the lines between hardware, software and orgware were sometimes thin and unclear to me. Due to this it can happen that the reader can be confused with the event described under a certain innovation component during reading, which I consider as a flaw in this research.

Genuinely, writing down my results and analysis of the data I also occasionally mixed up terminology. Especially the difference between orgware and process as well as the *orgware* of the technology and the *orgware* of the stakeholders' collaboration were hard for me to distinguish, particularly during the start of writing this report. Nonetheless, and after comments from my supervisor, I think I corrected and improved these terms and their position in the report well in the end.

Lastly, I realize I miss profound and advanced understanding of communication and innovation theories, concepts and literature. This can be explained, as I am an International Land and Water Management student with a highly technical and practical background, and only followed one course provided by the Department of Communication & Innovation Studies. Nonetheless, I gained significant more insight in its theories and concepts because of this study research and through the literature I read as a result of that, which again is related to and I can apply in my major specialization, Integrated Water Management.

References

ANN, 1996. *Asamblea Nacional de la República de Nicaragua*. 'Ley 217 "Ley General del Medio Ambiente y los Recursos Naturales"', published in *La Gaceta* No. 105 of 6 June 1996 and its regulation, decree No. 9-96, published in *La Gaceta* No. 163 of 29 August 1996. Available at: <http://legislacion.asamblea.gob.ni/Normaweb.nsf/($All)/1B5EFB1E58D7618A0625711600561572?OpenDocument> [Accessed on: 21 March 2011].

ANN, 2000. *Asamblea Nacional de la República de Nicaragua*. 'Dispociones para el Control de la Contamincacion Proveniente de las Descargas de Aguas Residuales Domesticas, Industriales y Agropecuarias'. Decree No. 33-95 of 14 June 1995, published in *La Gaceta* No. 118 of 26 June 1995.

APT-APS, 2007. *Agua para Todos, Agua para Siempre.* 'Verbeterd stroomgebiedsbeheer en verbeterde en duurzame drinkwater- en afvalwatervoorzieningen voor de regio en stad Matagalpa, Nicaragua. Voorstel voor een 3-jarig samenwerkingsprogramma tussen de Nederlandse watersector en waterpartners in Matagalpa, Nicaragua' (CONCEPT).

BATTERINK, M.H., 2009. Profiting from external knowledge: how firms use different knowledge acquisition strategies to improve their innovation performance. PhD-thesis Wageningen, Wageningen Academic Publishers. *Innovation and sustainability series*, Vol. 3, pp. 1 – 195.

BLAIKIE, P. M., 1996. Post-modernism and global environmental change. *Global Environmental Change*, Vol. 6, no. 2: pp. 81-85.

GANDARILLAS, E.G., UNDATED. Institutional Arrangements to Improve the Responsiveness of Agricultural Innovations Systems to the needs of the Poor: An Investigation of Participatory Monitoring and Evaluation in Bolivia, pp. 1 – 34.

GRENDELMAN, R., AND HUIBERS, F., 2010. Governing Peri-Urban Wastewater Used by Farmers: Implications for Design and Management. Irrigation and Water Engineering Group, Wageningen University, The Netherlands.

HALL, A., SIVAKOHAN, M.V.K., CLARK, N., TAYLOR, S., AND BOCKETT, G., 2001. Why Research Partnerships Really Matter: Innovation Theory, Institutional Arrangements and Implications for Developing New Technology for the Poor. *World Development*, Vol. 29, No. 5, May 2001, pp. 783 – 797.

HALL, A., 2005. Capacity development for agricultural biotechnology in developing countries: an innovation systems view of what it is and how to develop it. *Journal of International Development* 17, pp. 611 – 630.

HALL, A., W. JANSSEN, E. PEHU AND R. RAJALATHI, 2006. Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Sytems. Chapter 1 & 2, pp.1-26.

HELLER, M., 2008. Eco-Engineered Treatment of Coffee Wastewater according to the Water Harmonica Concept: Design of a Pre- and Post-Treatment-System for the Mid-Sized Finca *El Salvador* in Matagalpa, Nicaragua. Internship Report, Wageningen University, November 2007 – March 2008, pp. 1 – 78.

JACOBI, J., 2004. The potential of eco-engineered wastewater treatment for improvement of the drinking water quality of Matagalpa, Nicaragua. Inventory research on water quantity and quality of two watersheds. MSc Thesis, Wageningen University.

KLERKX, L.W.A., AND C. LEEUWIS, 2007. Balancing multiple interests: Embedding innovation intermediation in the Agricultural knowledge infrastructure. *Technovation*, Vol. 28, No. 6, June 2008, pp. 364 – 378.

KLERKX, L.W.A. AND C. LEEUWIS, 2009. Establishment and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector. *Technological Forecasting and Social Change*, Vol. 76, No. 6, July 2009, pp. 849 – 860.

LEAF, 2010. *Lettinga Associates Foundation*, Wageningen UR, 2011. Available at: < http://www.leaf-water.org/UK/> [Accessed on: 21 March 2011].

LEEUWIS, C., 2004a. Communication in Rural Innovation: Rethinking Agricultural Extension. Third edition, Blackwell Science Ltd.

LEEUWIS, C., 2004b. Innovation as a process of network building, social learning and negotiation – Implications for transdisciplinary research collaboration. Trans-KARST 2004 – International Transdisciplinary Conference on Development and Conservation of Karst Regions, Hanoi 13-18 September 2004.

MARGERUM, R.D., AND BORN, S.M., 1995. ‘Integrated Environmental Management: Moving from Theory to Practice’, *Journal of Environmental Planning and Management*, Vol. 38, No. 3, pp. 371 – 392.

MARTIJN, E.J., AND MELS, A., 2003. Waterharmonica in Developing Countries. Use of the Waterharmonica for conversion of treated waste water into a natural resource in the developing world. Project 03-136. LeAF. Wageningen, the Netherlands.

PANEBIANCO, S., AND PAHL-WOSTL, C., 2006. Modelling socio-technical transformations in wastewater treatment – A methodological proposal. *Technovation* 26 (2006) 1090-1100.

PUTNAM, R., 1995. Bowling Alone: America's declining social capital. *Journal of Democracy*, Vol. 6, No. 1, pp. 65 – 78.

RÖLING, N.G., 1988. Extension Science: Information Systems in Agricultural Development. Cambridge University Press, Cambridge.

RÖLING, N.G., 1994. Platforms for decision-making about eco-systems. In: L.O. FRESCO, L. STROOSNIJDER, J. BOUMA AND H. VAN KEULEN (Eds), The Future of the Land: Mobilising and Integrating Knowledge for Land Use Options, pp. 386-93. John Wiley & Sons, Chichester.

SAS, M.J., 2006. Eco-engineered treatment of coffee wastewater according to the waterharmonica. A case study in Matagalpa, Nicaragua. Aqua for All & LeAF, Wageningen, the Netherlands, March 2006 – May 2006.

SCHOT, J., AND GEELS, F.W., 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, Vol. 20, No. 5, September 2008, pp. 537-554.

SMITS, R., 2002. Innovation studies in the 21st century: questions from a user's perspective. *Technological Forecasting and Social Change*, Vol. 69, No. 6, pp. 861 – 883.

UTTING-CHAMORRO, K., 2005. Does fair trade make a difference? The case of small coffee producers in Nicaragua. *Development in Practice*, Vol. 15, No. 3&4, 2005, pp. 584 – 599.

ZUIJDERHOUDT, B.N., 2008. Development of a methodology for choosing most feasible systems for the treatment of wastewater from coffee processing in Matagalpa, Nicaragua. Minor Thesis, Wageningen University, pp. 1-80.

ZWARTEVEEN, M., AND WESTER, F., 2009. Knowing Knowledge. *Lecture Notes Research Approaches in International Land and Water Management.*

Annex I: Stakeholders Interviewed

Dutch consortium: 1 person

- J. van Tilburg, Dutch Project Manager of LeAF for the ApT-ApS programme, date of interview: 10 November, 2010

DIMGARENA: 2 persons

- E. Dulzón Cuzco, director of DIMGARENA, date of interview: 3 November, 2010
- R. Yvan Fernandez, Project Manager of DIMGARENA for the ApT-ApS programme, date of interview: 22 October, 2010

Local coffee farmers: 5 persons

- R. Zanetti, owner of coffee plantation *Aztecas*, date of interview: 12 October, 2010
- F. Pescador, owner of coffee plantation *El Nido del Condor*, date of interview: 13 October, 2010
- F. Hierro, owner of coffee plantation *El Salvador*, date of interview: 14 October, 2010
- R. Obispo, owner of coffee plantation *Virgin Magdalena*, date of interview: 14 October, 2010
- T. Montenegro, owner of coffee plantation *La Hacienda*, date of interview: 15 October, 2010

Other useful complementary interview: 1 person

- R. Pasveer, Dutch Project Manager of *BZ Innovatiemanagement* for the *Solidaridad CSN*-project, date of interview: 23 November, 2010