Systems of innovation and cleaner technologies in the palm oil sector, Costa Rica

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Abstract

The main objective of this paper is to asses the relevance of systems of innovation for the firms´ environmental performance. The analysis is based on a case study in the co-operative palm oil sector in Costa Rica.

The core argument is that both the introduction of cleaner technologies and the use of environmental management systems are determined by the quality of the systems of innovation. Most of the factors that determine the environmental performance and the introduction of cleaner production are directly or indirectly affected by the factors facilitating or hindering innovation. At the same time, the improvements of environmental performance strongly depends on the innovative capabilities as well as the capacity to orient institutional and technological change, which also depends on the performance of the systems of innovation.

The analysis is based on an operative approach to evaluate the performance at firm and sectoral levels. This approach is based of the definition of critical variables. Such variables are the core issues defining the performance of a specific sector or firm.

A relevant idea is that the performance of the systems of innovation can be evaluated by studying the quality of the interaction in the system. More concretely, the quality of interaction is assessed with respect to its contribution to solve the critical variables of performance.

The paper is based on a historical approach. The hypothesis developed is that the critical variables determining the performance of the co-operative sector have been continuously changing, in three development stages of the sector, but the system of innovation has changed at a slower pace. In spite of a clear need for new interactions, the system of innovation have evolved to slowly. Old interactions are less useful in order to solve the new relevant variables of performance, specially for environmental issues. These interactions are then more superficial and there are no new actors contributing to improve the environmental performance. As a result, the performance of the systems of innovation has become worse, affecting the performance of the firms.

The paper argues that the introduction of cleaner technologies is a special kind of innovation, following incremental processes and clear trajectories. The barriers and motivators for the introduction of cleaner production are considered as “factors” facilitating or hindering the environmental innovation.

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Introduction

This paper is a result of the research project "Learning and collaboration processes for the introduction of cleaner technologies", SUDESCA.

The document presents the case of the co-operative palm oil sector in Costa Rica. The core argument is that both the introduction of cleaner technologies and the use of systems of environmental management are determined by the quality of the systems of innovation. Most of the factors that determine the environmental performance and the introduction of cleaner production are directly or indirectly affected by the factors facilitating or hindering innovation. At the same time, the improvements of environmental performance strongly depend on the innovative capabilities as well as the capacity to orient institutional and technological change, which also depends on the performance of the systems of innovation.

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The paper is very much related with the literature about environmental management, specially the one related to the introduction of cleaner technologies. The analysis is focused on the study of barriers and motivators for the introduction of cleaner technologies. These barriers and motivators can be considered "factors" facilitating or hindering the introduction of cleaner technologies. The argument is that such kind of "factors" are normally closely related to the factors explaining the innovation processes. The paper also argues that the introduction of cleaner technologies is a special kind of innovation, following incremental processes and clear trajectories.

The paper is organised in two parts. The first one presents the theoretical and methodological framework, developing the following points: a summary of methods and

principles for the introduction of cleaner technologies with a description of alternative environmental strategies (chapter 1); a discussion about the role of systems of innovation for cleaner production, including an analysis of the factors facilitating or hindering the cleaner production (chapter 2). The methodological framework (chapter 3) is based on four instruments: an environmental mapping; an organizational and institutional mapping; a network mapping; and a mechanism for the evaluation of the environmental strategies.

The second part presents the results of the case study. There is a description of the main processes of productions and sources of pollution (chapter 4). The study includes an analysis of the collaboration networks, considering the quality of interactions in terms of solving the critical variables of performance (chapter 5). From the study of barriers and motivators for cleaner productions the paper considers the role of the system of innovation for the environmental performance (chapter 6).

I Part: Theoretical and methodological framework

1. Methods and principles for the introduction of cleaner technologies

The definition of cleaner technology is based on the principle of pollution prevention. In this paper cleaner technology means "that pollution and waste as consequences of the production, use, and disposal of products are eliminated or limited as much as possible so close to the source as possible. This implies that the product or production process is altered so that the accumulated effect on the environment from the cycle of substances and materials is limited as much as possible" (The Danish Environmental Protection Agency, 1990, p. 2).

A detailed definition sustains that cleaner technologies refer to the "direct application of an environmental preventive strategy, applied to the processes, products and services, with the goal of incrementing the eco-efficiency and reducing the human and environmental risks" (UNEP). Cleaner production holds out the promise of improving the environmental performance of industry while at the same time improving a firm's bottom line (Gunningham and Sinclair, 1997).

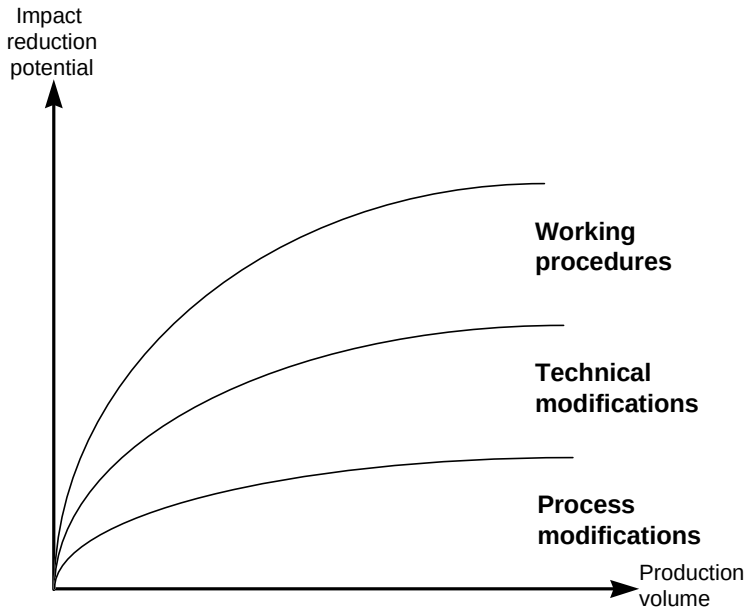
The concept of cleaner production is related with the concept of eco-efficiency used by World Business Council for Sustainable Development (1992). That means “creating value for society and business by doing more with less over the full life-cycle by: reducing the energy inputs to, and requirements of, goods and services; reducing toxic dispersion; enhancing material recyclability; maximizing sustainable use of renewable resources; extending product durability, and enhancing the functionality of goods and services” (p.11).

A definition of environmental policies is necessary for the introduction of cleaner technologies. Firms utilise environmental management systems in order to facilitate the application of environmental policies. An environmental management system (EMAS) is "the organisational structure of responsibilities, practices, procedures, processes and resources in order to determine and apply the environmental policies" (British Standard Institute, 1994: 46).

According to Gilbert (1993) the basic elements of an EMAS are:
· A declaration of policies indicating the commitment with the environmental improvement and the conservation and protection of resources;
· a group of plans and programs for implementing the policies inside of and outside the organisation;
· the integration of those plans within the daily activity and within the organisational culture;
· the measuring, auditing and revision of the performance of the environmental management of the organization, concerning the policies, plans and programs;
· the provision of education and training in order to increment the understanding of the environmental topics within the organisation; and
· the publication of environmental reports about the performance of the organisation.

Some of the advantages associated to the environmental management are (European Environment Agency, 1998):
· Cost saving;
· Ensuring legislative compliance;
· Anticipating future legislation;
· Meeting supply chain requirements;
. Reduction of environmental risks;
· Improved relations with regulators;
· Improved public image and community relations;
· Increased market opportunities;
· Employee enthusiasm.

Figure 1. Three aspects of cleaner technology



Source: Danish Engineering Association, 19??

There are a number of pollution abatement principles which may be applied to all food processing companies. These are:
- to reduce resource consumption (water, energy, chemicals, etc.)
- to decrease emissions (wastewater, smoke, noise, solid waste, etc.)
- internal recycling of water, etc.
- to separate the organic waste and to re-use it for other purposes (e.g. animal food)
- to use raw materials more effectively
- substitution of toxic chemicals, dangerous materials, etc.

Cleaner technologies are referring to these principles, which may be accomplished by:
- changing work routines (production planning, cleaning procedures, etc.)
- technical solutions (nozzles, automatic stop, dry transport of organic waste)

- process changes (fundamental changes in raw materials, production lay-outs, new machines or new products)

Table 1: Differences between command and control regulation and Environmental Management Systems.

Command and control regulation	**Environmental Management Systems**
Instituted by government	Instituted by private sector
Enforced by government	Enforced by companies themselves with some third-party verification
Compliance mandatory, with direct sanctions	Compliance voluntary, with indirect sanctions such as peer pressure
Places emphasis on product and process standards	Place emphasis on management systems
Defines standards for emissions or technology	Lets each company define own performance, with requirement for continuous improvement
Provides public access to information on compliance	Provides public access to information only in selected cases

Source: Smink, 1998, adapted from Nash and Ehrenfeld, 1996.

Table 2: Environmental strategies of companies

Roome (1992)	**Hunt and Auster (1990)**	**Remmen and Nielsen (1994)**	**Characteristics**
• Non-compliance	• Beginner	• Inactive	• 'We have no problems' • Environmental management is unnecessary • No reactions to new environmental standards
• Compliance	• Fire fighter	• Reactive	• 'We obey the law' • Environmental management should be addressed if necessary • Compliance position driven by legislation
• Compliance plus	• Concerned citizen	• Proactive	• 'We are ahead' • Environmental management is a worthwhile function • Willingness of senior management to use management systems and policies to encourage organisational change
• Commercial and environmental excellence • Leading edge	• Pragmatist • Pro-activist	• Interactive	• 'We define the agenda' • Strive to be environmental leaders in their industries • Environmental management is a priority item

Source: Remmen 2000, adapted from Henriques and Sadorsky, 1999.

There are three aspects of cleaner technology (see figure 1): the ***working procedures,*** which encompass optimisation of the "good house-keeping", maintenance, cleaning routines, handling of chemicals and hazardous substances, etc. as well as technical and process modifications. ***Technical modification*** comprises technical optimisation of a production line, installation of equipment for enabling recycling, reuse or recovery (heat, metal salts or others). ***Process modification*** might result in substitution of hazardous materials, change of fuel for heat production, etc. in practice, cleaner technologies solutions will often emerge from a combination of the three aspects.

Table 1 distinguishes the differences between command and control regulation and environmental management systems.

Four environmental strategies can be distinguished: the interactive strategy, the proactive strategy, the reactive strategy and the inactive strategy (Nielsen, 1994; Remmen, 1994). Differences in environmental strategies and environmental attitudes are illustrated in table 2.

2. The role of systems of innovation for cleaner production

A fundamental argument of this document is that the introduction of cleaner technologies is a particular form of innovation. The introduction of cleaner technologies is a process of innovation derived from a direct application of environmental preventive strategies. Such kind of strategies transform the processes, products and services, with the objective of incrementing the eco-efficiency and reducing the human and environmental risks.

In a similar way, Lundvall (1992) defines innovation in wide terms like on-going processes of learning, searching and exploring, which result in new products, new techniques, new forms of organization and new markets.

As a particular form of innovation, cleaner technologies are generated in interactive processes of learning, where several pieces of knowledge are combined in new forms, generating knowledge that is translated into new products or processes. The challenge is to improve the environmental performance, but contributing simultaneously to improve the competitiveness of firms.

The environmental management systems establish that as a first step it is necessary to generate the environmental policy. After that firms must define goals and design a program in order to reach them. The next step is the implementation of the programs and the posterior evaluation and application of corrective actions. The adjustment actions are followed by new revised program that restart the cycle in a philosophy of continuous improvement (European Environmental Agency, 1998). The core characteristic of cleaner technologies is the nature of continuous improvement. In this aspect the concept is related to incremental innovations. But even when cleaner technologies imply radical change for a specific firm, as for example the total substitution of machinery and equipment, most of the benefits come along the time. This is clear in the following argument:

"Most of the productivity gains associated with the diffusion of new technology do not come as an immediate consequence of the first radical innovation. On the contrary, they usually are only achieved as a result of a fairly prolonged process of learning, improving, scaling up and altering the new products and processes. This involve many follow-through inventions and innovations throughout the commercial life of the product or system" (Freeman 1991: 305).

The introduction of cleaner technologies is affected by several internal and external factors. There are barriers and motivators to the introduction of cleaner production that could be evaluated as a particular group of factors facilitating or hindering innovation. Such barriers and motivators can be studied within a wider list of factors, as those that are mentioned in the following paragraphs.

As Dosi (1988) points out, typically, the search, development, and adoption of new processes and products are the outcome of the interaction between two main groups of factors:

(a) capabilities and stimuli generated within each firm and within industries; and
(b) broader causes external to the individual industries, such as:

- the state of the science in different branches;
- the facilities for the communication of knowledge;
- the supply of technical capabilities;
- skill, engineers, and so on;
- the conditions controlling occupational and geographical mobility and/or consumer promptness/resistance to change;
- market conditions, particularly in their bearing on interfirm competition and on demand growth;
- financial facilities and patterns and criteria of allocation of funds to the industrial firms;
- macroeconomic trends, especially in their effects on changes in relative prices of inputs and outputs;
- public policies (e.g., tax codes, patent laws, industrial policies, public procurement).

Dosi also argues that historical evidence strongly suggest that a major impulse to innovation has derived form *imbalances* between the technical dimensions that characterise a 'trajectory'. He mentions as an example the imbalance between cutting speed and tool resistance in machine tools or shuttle speed in eighteenth century looms and spinning speed in spindles.

In another paper Dosi (1988b) affirm that in general, technological progress proceeds through the development and exploitation of both public elements of knowledge, shared by all actors involved in a certain activity, and private, local, partly tacit, firm specific, cumulative forms of knowledge.

Among the factors which induce, stimulate or constrain technical change from the outcomes of the changes themselves, Dosi points out:

- technological bottlenecks in interrelated activities;
- scarcities of critical inputs or conversely
- abundance of particular inputs (e.g. energy, raw materials, etc)
- composition, changes and rates of growth demands
- levels and changes in relative prices (first of all, as mentioned, the relative price of machines to labour)
- patterns of industrial conflict

Lundvall (1992) points out the relevance of several factors for the systems of innovation:

- the internal organisation of firms. The interaction between different departments is crucial. It becomes important because most innovations are developed by firms.
- Interfirm relationships

- The public sector (support of science and development; regulations and standards; as user of innovation developed by the private sector).
- The financial system (as early stressed by Schumpeter)
- The R&D system (its resources, competencies, organisation)
- The national education and training system

Innovation is influenced by the appropriation of benefits of innovation. The distribution of benefits, cost and opportunities and risks between the people interacting, influence the processes of innovation. It will influence the information communicated, the interaction undertaken and the efforts put in these activities (Johnson, 1997). “In the most general terms, private profit-seeking agents will plausibly allocate resources to the exploration and development of new products and new techniques of production if they know, or believe in, the existence of some sort of yet unexploited scientific and technical opportunities; if they expect that there will be a market for their new products and processes; and, finally, if they expect some economic benefit, net of the incurred costs, deriving from the innovations. In turn, the success of some agents in introducing or imitating new products and production processes changes their production costs, their markets competitiveness and, ultimately, is part of the evolution of the industries affected by the innovations”. (Dosi, 1988 Journal: 1120). These arguments are also valid for studying the introduction of cleaner technologies

Innovation and technical progress are the result of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge. The innovative performance of a country depends to a large extent on how these actors relate to each other as elements of a collective system of knowledge creation and use as well as the technologies they use. These actors are primarily private enterprises, universities and public research institutes and the people within them. The linkages can take the form of joint research, personnel exchanges, cross-patenting, purchase of equipment and a variety of other channels. (OCDE, 1997).

The existence of uncertainty associated with innovation and with the introduction of cleaner technologies is clear. It involves not only lack of knowledge of the precise cost and outcomes of different alternatives, but often also lack of knowledge of what the alternatives are. (see Freeman, 1982; Nelson 1981a; Nelson and Winter, 1982; and Dosi, 1988).

Dosi distinguishes between uncertainty and strong uncertainty. The first as considered by economic analysis is defined in terms of imperfect information about the occurrence of a known list of events. With strong uncertainty neither is the list of possible events known nor are the consequences of particular actions for any given event. The presence of strong uncertainty in most innovative search makes the firm tend to work with relatively general and event-independent routines. This also points at the importance of particular organisational arrangements for the success or failure of individual innovative attempts. (Dosi, 1998: 1135).

Innovation is shaped by institutions and institutional change. Relations between institutions and innovation can change, sometimes fundamentally, over time. But it is

clear that institutions have a strong impact on technical change although institutions normally are quite rigid and do not change easily. More concretely, institutions influence change through their impact on learning. They influence the growth of knowledge in many ways and on many levels (Johnson, 1992). Or as Hodgson wrote "information is culturally processed: it is never transmitted raw but is selected, arranged and perceived through institutions (Hodgson, 1988)".

There are some formal institutions influencing the innovation processes: 'in-house' R&D departments; extramural R&D organisations; universities and other organisations for basic research. Bridging mechanism between science and technology are of crucial importance (Dosi, 1988b). These kinds of institutions are also very relevant for the introduction of cleaner technologies.

Institutions have to change in order to stimulate technical change over longer stretches of time. It seems as if rigid habits and routines, and rigid patterns of interaction inside and between firms, can seriously hurt the ability of an economy to introduce and diffuse new technologies. A flexible institutional system might bring the skills, experience and knowledge of different people, organisations and government agencies together, and get them to interact in new ways, stimulating innovation processes (Johnson, 1986, 1988). "Institutional restructuring of an economy to preserve, reshape or strengthen its technical learning ability in a period of radical technical change is certainly not an automatic or costless process" (Johnson, 1992: 43).

Institutions are important both inside and outside firms. For example, communication and interaction inside firms depends on many institutional factors like quality control, job training, job rotation, communication between different departments, norms and habits of workers, trust and legitimacy, and supervision. But there are also many factors in the institutional system outside the enterprise sector which are important for learning. This is the case of the institutional infrastructure, as for example the educational infrastructure, the communication infrastructure and many social norms. (Johnson, 1992).

The analysis of factors facilitating or hindering the introduction of cleaner technologies gives additional arguments to conclude that cleaner production is a specific kind of innovation. Actually, most of the factors can be organised in the categories we mentioned in the previous paragraphs. For Gunningham and Sinclair (1997), it is clear that the majority of barriers to cleaner production confronted by firms could be placed into one of two categories: those that were internal to the firm and those that were external to the firm. Their report identifies the main barriers to cleaner production as follows:
Internal barriers:

- A lack of information and expertise
- A low awareness of environmental issues
- Competing business priorities, in particular, the pressure for short term profits
- Bounded rationality in decision making processes
- Financial obstacles
- Lack of communication in firms
- Middle management inertia

- Labor force obstacles
- Difficulty in implementing cleaner technology

External barriers:
- The failure of existing regulatory approaches
- Difficulty in accessing cleaner technology
- Difficulty in accessing external finance
- Perverse economic incentives
- An absence of markets for recycled goods
- Economic cycles

Primary motivators and drivers identified by Gunningham and Sinclair (1997) were: government regulation; the ability to share information through networking and business partnerships, and access to external expertise, particularly for smaller firms; the desire to maintain good community relations, particularly for larger firms; the convergence of more efficient production processes with sophisticated cleaner production processes, such as environmental management systems; and access to financial incentives for investment in new, cleaner technology.

The strategies for the management of the factors facilitating or hindering innovation and cleaner productions is determined by the performance of the systems of innovation. The better and solid the systems of innovations the better the way of solving the factors facilitating or hindering innovation. So, the quality of the interactions within the systems of innovation is a fundamental factor that explains the innovative performance in countries and firms. The efficiency of the introduction of cleaner technologies is also explained by the performance of the systems of innovation.

3. Methodological framework

The methodology of the research project was based on a case study, using four main instruments: an environmental map; institutional and organisational maps; collaboration networks maps; and evaluation of environmental management systems of the firms.

The objective of the environmental map is to determine the main environmental impacts at firm level. The mapping was developed by means of a reference analysis as well as interviews with internal and external experts, including a revision of previous auditing reports and a field study by specialized engineers.

The core objective of the institutional and organisational mapping is to study the impact of internal organisation on the introduction of cleaner technologies. It is studied the environmental management systems as well as the resources for improving the environmental performance. The information was generated by interviews with internal responsible people in the firms.

The networking mapping is an instrument for studying the role of several stakeholders collaborating with firms in order to improve environmental performance. Savage (1991:

61) defines stakeholders as ‘those individuals, groups, and other organisations who have an interest in the actions of an organisation and who have the ability to influence it’. To understand the interactions between a company, the authorities and other stakeholders we use the network model. From a company’s point of view there are at least three networks, (RUC, 1997):

- the *business* network: suppliers, competitors, buyers, consumers, investors, etc.
- the *regulation* network: national, regional and local authorities, standardisation organisations, etc.
- the *knowledge* network: consultants, business associations, universities, NGOs, etc.

The networking mapping is based on a revision of documents and on interviews with internal authorities as well as external advisors.

II Part: Systems of innovation and cleaner technologies in the co-operative sector

4. Processes of production and sources of pollution[2]

Following paragraphs describe the main extraction processes of crude palm oil (CPO) and sources of pollution.

- Reception, transfer and storage of fresh fruit bunches (FFB)

The fresh fruit bunches are harvested in the plantations and soonest transported to the palm oil mills for immediate processing.

In the studied region the more common forms of transport within the plantations are small carts drawn by horses, mules or oxen. These carts carry the FFB to roads, where they are picked up by trucks.

It is important to be careful in these processes of transport and storage, so that the FFB is not damaged. Damage of FFB will affect the quality of the crude oil due to increased free fatty acid (FFA).

- Sterilization

The FFB are loaded in sterilizer cages and then subjected to steam-heat treatment in horizontal sterilizers. The FFB is usually steamed for 75 to 90 minutes at a pressure of 3 kg/cm2 and a temperature of 140°C.

The objectives of the sterilization are to prevent the future formation of fatty acids, to facilitate stripping of fruits, to prepare the fruit mesocarp for subsequent processing, and pre-conditioning of the nut to minimise kernel breakage during the phases of pressing and nut cracking.

- Stripping

After sterilization the FFB are fed to a rotary drum-stripper. With this action the fruits are separated from spikelets of bunches stalks.

- Digestion

Digestion involves mashing of the palm oil fruits under steam heated conditions. The digester consists of vertically arranged cylindrical vessel fitted with a rotating shaft carrying a number of stirring arms.

- Crude palm oil extraction

Twin screw presses are utilized to press out the oil from the digested mash fruit under high pressure. Hot water is added to enhance the flow of the oils. The crude oil carries off to a process of clarification that permit the purification and separation of oil. The fibre and nut are conveyed to a depericarper for separation.

[2] This section is based on Department of Environment. Ministry of Science, Technology and the Environment, 1999.

- Clarification and purification of the crude palm oil

The crude palm oil (CPO) from the presses is a mixture of palm oil (35%- 45%), water (45%- 55%) and fibrous material in varying proportions. This is pumped to tanks of clarification and separation with a temperature that stays on 90°C in order to increase the oil separation. The clarified oil is continuously skimmed-off from the top of the clarification tank. It is then passed through a high speed centrifuge and a vacuum dryer before it is sent to the storage thanks.

The secondary flows from the clarification tanks still contain some quantities of oil and this is recovered by passing the underflow through a sludge separator. The recovered oil is returned to the clarification tanks.

- Depericarping and nut fibre separation

The press cake coming from the screw press contains a mixture of fibre and nuts (including broken ones and kernels). These are conveyed to a depericarper for nut and fibre separation. A strong current of air in form of suction is used for this task. The fibre is sent to the boiler house and is used as boiler fuel. The nuts are sent to a rotating drum in order to eliminate any remaining fibre and afterwards to the nut cracker.

- Nut cracking

A conventional centrifugal type of nut cracking is utilised in this process.

- Separation of kernels and shells

The method employed to separate the kernels and shells are based on the differences in specific gravity between both. A suspension of clay or a solution of salt is utilised for this separation. The selection of the method depends on the availability, costs and maintenance of the materials and equipment.

- Palm kernel drying

The palm kernels have to be dried to below 7% of humidity. This in order to prevent the growth of mould and to increase the storage time. Palm kernels are commonly dried in a silo drier. It is fundamental to avoid over-heating or over-drying in order to prevent a premature liberation of the kernel oil.

The main sources of waste generation are studied in the following paragraphs. Waste consists of liquid effluents, gaseous emission and solid waste materials, including some by-products.

- Sources of liquid effluent

Large quantities of water are utilised during the process of extraction of crude palm oil. About 50% of the water results in palm oil mill effluents (POME). The other 50% is lost in form of steam, mainly through sterilizer exhaust, piping leakages and wash water.

The waste water deriving from the extraction process is generated as follow:

- Sterilization of FFB (36%)
- Clarification of the crude palm oil (60%)
- Hydrocyclone separation of cracked mixture of kernel and shell (4%)

- Sources of gaseous emission

There are two principal sources of gases emissions in the palm oil mills: boilers that use the waste fibre and shell material; and incinerators that burn the empty fruit bunches for recovery the potash.

Smoke and dust emissions are the main problems due to incomplete combustion of the solid residuals. Palm oil mills are generally self-sufficient in terms of energy requirements due to the availability of adequate quantities of the fibre and shell materials that are used as solid fuel in the steam boiler.

- Sources of solid waste material and by-products

Solid waste materials and by-products generated in the palm oil extraction process are: empty fruit bunches (23% of FFB); potash ash (0.5% of FFB); palm kernel (6% of FFB); fibre (13.5% of FFB); and shell (5.5% of FFB)

The empty fruit bunches may be incinerated to produce potash which is applied in the plantation as fertiliser. The fibre and shell materials are utilized as boiler fuel. The palm kernel is sold to palm kernel oil producers or used in the same firm in order to extract kernel oil.

In general the method of incineration of the empty fruit bunches is not recommended, in order to reduce air pollution. The best practice is to deposit them in the plantations in order to take advantage of nutrient elements. This practice is much more environmentally friendly.

In summary, the environmental issues in palm oil mills are:

- Large quantities of oily effluent with extremely organic content;
- Smoke and particulate air emissions;
- Odour; and
- Noise

In that sense, the main environmental issues of the crude palm oil industry are primarily related to:

- Water pollution due to indiscriminate discharges of untreated or partially treated effluents;
- Improper interim storage of solid waste materials, including boiler and incinerator ash, spent bleaching earth and sludge separator residue;
- Improper land application techniques or practices for solid and/or liquid wastes;
- Air pollution due to the use of solid fuel fired boilers and incinerators for empty bunches;

- Odour emission from poorly managed effluents treatment systems, especially if they are located in close proximity to neighbouring residential areas;
- Some noise from the milling processes.

Untreated POME from an average-sized palm oil mill, i.e. processing capacity of about 30 tonne FFB per hour, has an organic content equivalent to raw domestic sewage from a population of 300.000 persons. Thus, the impact of the raw POME discharge to a relatively small river can be devastating to eco-systems.

5. Institutional and organisational mapping

In this section the focus is on the role of the internal organisation on the introduction of cleaner technologies. The main issues in the analysis are: the environmental management system, the resources for environmental management, the decision making processes on environmental topics and the main features of the organisational culture.

- Environmental management system

Strictly speaking, the company does not have an environmental management system. But there are some features that could facilitate the introduction of an environmental management system. For example: clarity about the environmental issues for the industry; knowledge about the concrete environmental impacts by the firm; opening for external advisory in order to improve the environmental performance; the strategic planning considered necessary fro improvement of the environmental performance; some actions have been implemented in order to diminish or mitigate impacts; some resources have been destined to environmental issues.

The lack of a environmental management system is clear. There are no permanent groups or teams attached to environmental issues. Most of the urgent tasks have been assigned to external advisory companies. Siel & Siel is the formal environmental responsible for the regulatory authorities. For some specific demands by the environmental authorities they have looked for support by other external firms or independent advisors. Within the company only concrete tasks have been assigned to some employees. But the task of coordination is carried out by the external advisors.

Using the definition by Gilbert (1993) for assessing, the conclusion is that the firm does not have an environmental management system:

- Although the strategic planning introduced goals of environmental improvement, a policy declaration does not exist;
- There are no plans and programs for policy implementation but only very specific actions to satisfy demands by environmental authorities;
- Environmental issues are not integrated within the daily activity and within the organisational culture;
- There is no system of assessing, auditing and revision of environmental performance
- There are no education or training mechanisms to increase the understanding of environmental issues;

- There are no published reports about environmental performance.

- Resources for environmental management

As it was mentioned the co-operative does not have an environmental management system. However, they have used some resources in order to improve the environmental performance, but only because of the authorities` pressure.

Some effort was put into investigation about alternatives for solid waste treatment. Improvement in treatment of liquid effluents has been possible because of investment for this purpose. The same applies for control of gaseous emissions. The major part of the money has been used to the pay advisory. However, the firms did not invest for change the productive processes in order to improve the environmental performance. However, the co-operatives are not stimulating the use of organic inputs. Most of the investments were made on treatment plants for liquid effluents, but as end of pipe technologies.

- Decision making processes

Responding the demand by regulatory authorities, an advisory company was put in charge of environmental matters. This firm is responsible for coordination with the regulation authorities. But inside the co-operatives there is no any employees working directly on environmental issues. Most of the decisions related with coordination with advisory companies are made by the board without participation of employees.

- Organisational culture

The organisational culture of the palm oil co-operatives is hindering the environmental management. There is a weak tradition of participatory processes, and the normal way of decision making is a vertical approach. Some times they work in teams, but such kind of team work may suddenly stop because of change of priorities or a lack of resources. Uncertainty about the continuity of projects or work teams is a strong factor hindering efficiency.

There is a similar kind of uncertainty about the continuity of policies. Several workers consider that board policies change very easily. This has happened in some programs. For example the process toward ISO 9000 suddenly stopped due to a change of priorities. This situation generated uncertainty among the personnel and now new board initiatives are received without enthusiasm.

Another feature of organisational culture that blocks the introduction of environmental management is the deficiency on processes for knowledge generation and transmission. In general, the internal flows of information and flows of knowledge do not respond to a clear strategy. The interaction with external actors neither generates complete information nor the necessary knowledge for improving environmental performance.

Actually, the cooperatives do not have a developed system for education and training, but only isolated courses. There are no mechanisms for assessing the contribution of isolated courses to the companies` performance. The implicit strategy is learning by doing, but without clear mechanisms for sharing individual knowledge. In the case of the

environmental issues this deficiency is more notorious: not even isolated courses have been imparted.

6. Collaboration networks and quality of interactions

Some external collaboration does take place among the co-operatives regarding environmental issues. Different stakeholders in the business, knowledge and regulation networks give some support to palm oil co-operatives.

- Business network

Business networks, with the aim of supporting environmental improvements, are very weak in the co-operative sector. The main actors with a relevant role are suppliers of equipment for catching oil in liquid effluents and suppliers of treatment plants for palm oil mill effluent. Some other firms, such laboratories, specialists in air emissions and in noise control have given some support for environmental matters.

The demand for by-products by some firms in the sector has increased, especially for fatty acids. The advantage for the co-operatives is that they can sell these products instead of through them as part of the waste water.

Banks have included some regulation for loans, by asking for an environmental impact assessment for any new project. However, banks have not financed investments that directly lead to improvement of the environmental performance. Part of the regulation is to have a deposit of guarantee in any bank in case of environmental damage.

There are no collaboration mechanisms with other actors in the business network (competitors and consumers).

- Regulation networks

Normally, regulation networks include national, regional and local authorities as well as organisations of standardisation. In the co-operative sector the national authorities with some role for environmental issues are the Health Ministry and the Environmental Ministry, with its regulatory agency SETENA.

SETENA is the organisation that approves environmental impact studies and asks firms for specific tasks. By demand of SETENA, co-operatives have a deposit of Environmental Guarantee in a bank. They also asked a firm responsible for environmental matters (the firm Siel & Siel). One more demand is the presentation of a plan for environmental management, including a declaration of environmental commitments and periodic reports of environmental performance. The local Municipality is supporting a study for the disposition of solid waste generated by the co-operatives while the Labour Ministry regulates the use of dangerous equipment. But the co-operatives` argument is that regulation authorities demand several tasks, but that they do not give any support in order to improve environmental performance.

- Knowledge network

Normal actors in this kind of network are advisories; associations of businesses; universities and NGOs. In the palm oil co-operative sector the knowledge network has given the most relevant support for environmental issues. But the problem is that external actors function as substitutes for internal employees and not as complementary support. Besides Siel & Siel who support the relationship with regulation authorities, the co-operatives have received support by other firms for research about the use of solid waste as organic fertiliser. There is also an agreement with an university concerning research into the alternative uses of potash. Another firm is giving support tor the design of environmentally efficient boilers, trying to reduce gaseous emissions.

7. Role of the systems of innovation for environmental performance

7.1. Evolution of the system of innovation and critical variables

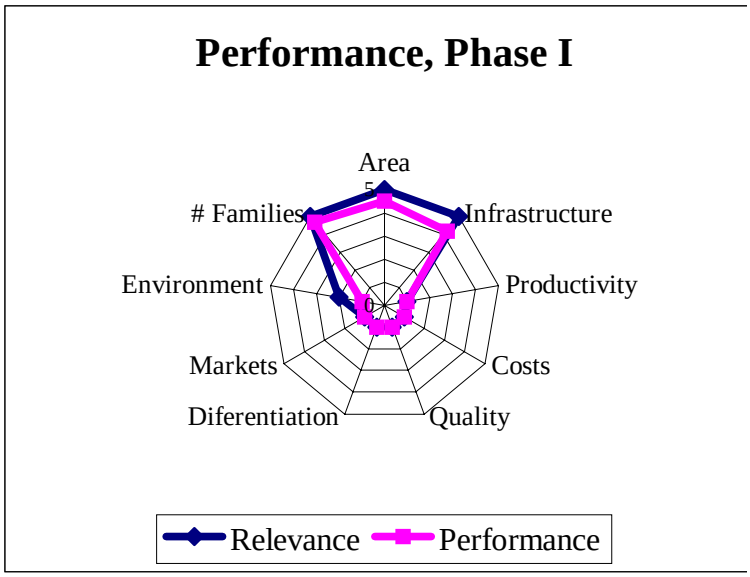
A relevant argument in this section is that it is possible to distinguish several stages in the process of development of the palm oil co-operative sector. The hypothesis is that in different stages of development of the sector the relevance of interactions with the actors is changing. So, the quality of interaction must be assessed by considering both the relevance of the specific interactions and their contribution to solve the critical variables of performance. The general argument is that the performance of the system of innovation has become worse, because interactions are not contributing to solve the critical variables of performance in the sector.

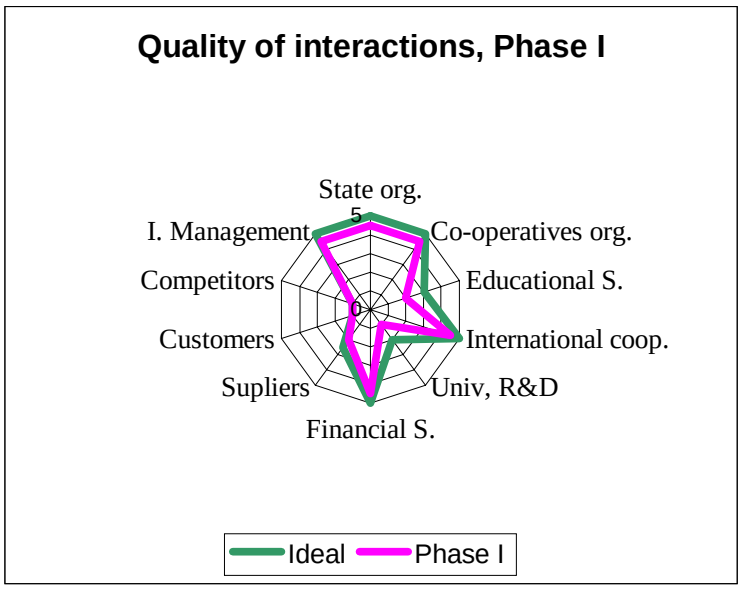
By studying innovation we can distinguish three main stages in the development of the sector. The first phase was the process of plantation, that incorporated the installation of the palm oil extraction mill for Coopeagropal. The second phase started when the palm oil extraction mill started working. The main product was crude palm oil. The third phase began with the challenge of generating products with more value added. This introduced a strategic change toward the innovations in products and markets. This phase still is not completely mature, but some advances have been achieved.

The development of the palm oil co-operative sector was oriented by the interaction among several groups of actors. The participation of the small farmers asking for development options was combined with the involvement of several state sector institutions. The institutions of the co-operative sector helped to define necessities and forms of organisation, orienting it toward a contribution in human development terms by an equal distribution of the value added. The financial component was achieved starting from the combined engagement of the Inter-American Development Bank, the Commonwealth Development Corporation of England and the Costa Rican Government. Small farmers had access to credit because of innovation in financial forms.

The second phase was in the period 1993-1996. This phase marks the beginning of the crude palm oil industry. The co-operatives produced crude palm oil, a basic product in this agro-industry. During this stage co-operatives produced some other products, but most of the production was sold directly to only one company, which is now the main competitor. The co-operatives did not have their own marketing and distribution systems. During this stage the main indicator of performance was the quantity and quality of crude palm oil and there was not many innovations in this phase. Actually, this phase is only the transition toward more ambitious challenges in terms of value added products.

Figure 2.
Performance and quality of interactions in phase I

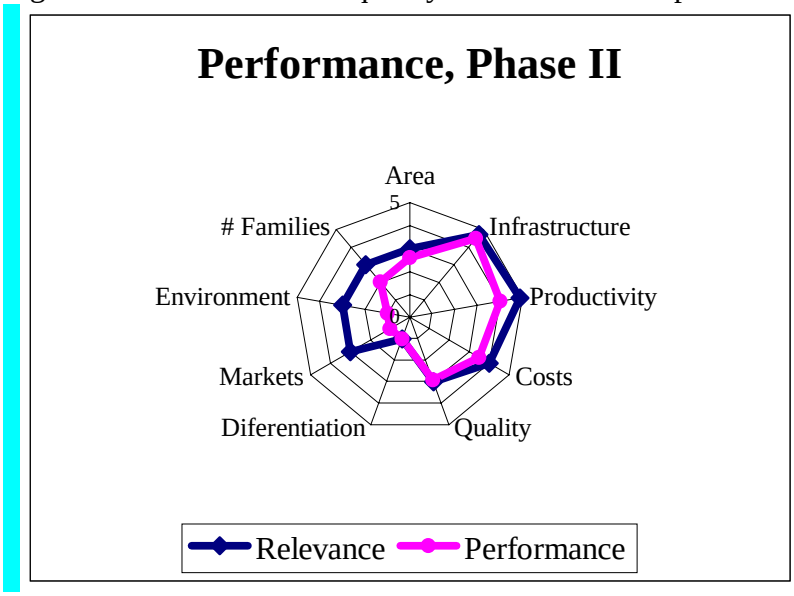


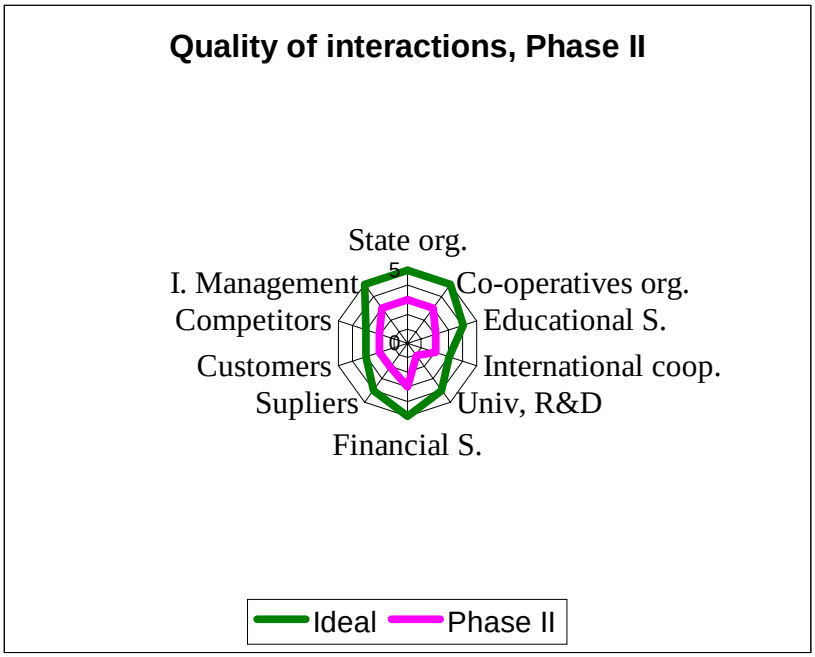


The third phase is characterised by the challenge of explicit establishment of sales structure with more emphasis on value added products. This introduces the challenge of innovation in products and markets, and in trading mechanisms. Environmental and social issues became relevant. This phase started in 1996 when the co-operatives sold crude palm oil in new markets, generating some other products with basic value added. However, the main change came in early 1999, when the co-operatives introduced their own branch of palm oil for cooking. Very relevant was the process for strategic planning from November 1998 to February 1999.

As part of the strategy in this third phase the sector, including the cooperatives in the Central Pacific Zone as well as Coopeagropal and the consortium CIPA, participated in a process of strategic planning. The core challenge was to design strategic alliances and actions in order to improve the performance of each firm, looking for a bigger share of the market. But the process never finished. Because of a strong crisis in the sector, each group had to design their own strategies, but recently they are working together again in order to continue with the strategic planning.

Figure 3. Performance and quality of interactions in phase II





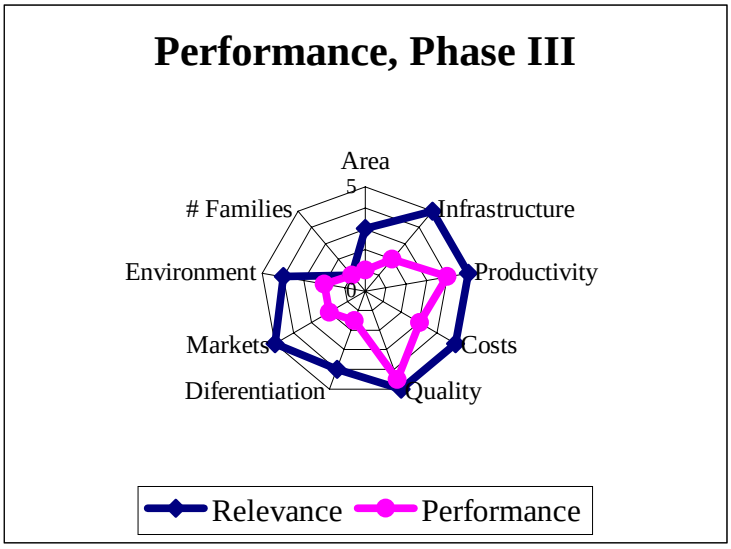
The nature of the business has changed in each stage, transforming the critical variables of performance. During the first phase the critical variables of performance were: to increase the number of families growing oil palm; to increment plantation areas; and installation of the basic infrastructure for plantations, i.e. drainages, internal roads and bridges. Environmental issues were not very relevant in this stage.

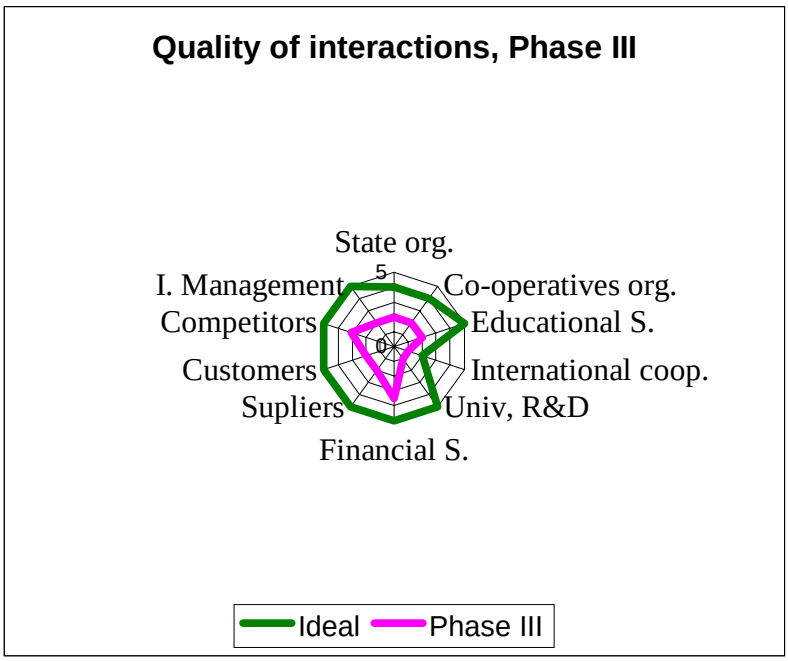
The collaboration networks conforming the system of innovation contributed very satisfactorily to solve the critical variables in the first stage. There was adequate coordination between the state agencies and the organisations in the co-operative sector.

Some of the support activities were training of producers, technological transfer and adequate financial mechanisms. Figure 2 shows these arguments.

During the second phase the nature of the business changed and new critical vvariables of performance became relevant. Productivity and the costs were critical variables in this stage, as well as the generation of industrial infrastructure. Environmental issues also became important. However, some critical variables of performance became less important, in this case the increase in the number of families and the plantation areas. But this change in the critical variables was not accompanied by transformations of the collaboration networks. The system of innovation that was utilised for the installation of the project did not work efficiently for solving the new critical issues.

Figure 4. Performance and quality of interactions in phase III





In this stage some of the interactions with state agencies became less relevant to solve the new critical variables of performance. That because the nature of such agencies is not related with the new challenges for the sector. Instead some other interactions became more relevant. However, the system of innovation did not change in that direction, becoming a little obsolete. In that sense, the performance of the system of innovation became worse. This is showed in figure 3.

During the third phase the nature of the businesses changed again. Once more the critical variables of performance evolve. Productivity and costs become more relevant. Other important variables in this phase are quality, differentiation of products and capacity to compete in new markets. Environmental issues also become very relevant, specially because regulation authorities and the community are more aware of this topic.

Growing the plantation areas and incrementing the number of families in the activity recover importance. But performance is bad even with respect to these variables. Collaboration networks used during the first phase weakened during the second and third phase. Public policy changed and the state agencies lost the mechanisms of coordination in order to foment new plantations. There are no new actors in the system of innovation with capacity of collaboration for solving critical variables. The quality of interaction with the relevant actors is not very high. Actually, some of the relevant interactions are inexistent or very weak. This is the main cause of non-satisfactory performance of the sector.

The evolution of the critical variables of performance was not accompanied by significant transformations of the system of innovation. There is deterioration in quality of the interactions, and critical variables are not adequately solved. This evolution is presented in figures 2 to 4. The figures show the evolution of performance with respect to ideal performance of critical variables. The figures also show the kind of relevant interactions in each stage and the real quality of interactions. The conclusion is that the gap with respect to ideal performance is growing in the second and third stages, due to a deterioration in quality of interactions for solving critical variables.

7.2. Barriers for cleaner production

Deterioration in quality of interaction is also a major barrier for cleaner production in the sector. There are both internal and external barriers. Main internal barriers are studied in the following paragraphs.

- Access to information

According to the interviewed people an important barrier is lack of information and expertise. There is a lack of information about environmental impacts, regulations, options for cleaner technologies, mechanisms of mitigation of the environmental impacts, costs, and proceeds for the introduction of cleaner technologies. This partly justifies a strong dependence on external advisers. But it is also an indicator of the failure of advisers in transmitting relevant information.

- A low awareness of environmental issues

It is clear that environmental issues still are less important for the co-operatives than competitiveness or related issues. The recent crisis because of low prices of crude palm oil forced a more marginal attention on environmental issues. The re-active environmental strategy is another obstacle for cleaner production.

Most actions are for mitigating the impacts but not preventive strategies. Little stability of managers and policies generates uncertainty and provokes resistance to change. The main goal is to avoid problems with regulatory authorities.

- Pressure for short term profits

Very low prices of crude oil generated a financial crisis. This has been a factor hindering the introduction of cleaner technologies because of the pressure for recovering short term profits. But even under normal conditions, environmental issues are not a priority with respect to profits.

- Financial obstacles

There are no programs for funding the introduction of cleaner technologies in Costa Rica. For the co-operative palm oil sector there are financial obstacles for any investment, because of the price crisis.

- Lack of communication in firms

The vertical form of decision making hinders communication and the introduction of cleaner technologies in the palm oil co-operatives. There are also problems in the processes of generation and transmission of knowledge. Internal flows of information and knowledge do not respond to an explicit strategy. The co-operatives do not have an adequate system for education and training. This is evident for environmental issues.

- Middle management inertia

Middle management inertia in the sector is due to distrust in continuity of policies and projects. Actually, several projects were suspended due to changes in board policies. Therefore, the lack of enthusiasm for new projects is caused by this uncertainty about continuity.

- Labour force obstacles

There are several labour force obstacles: lack of capable personnel for environmental issues; a lack of personnel for designing, controlling and implementing environmental projects; reticence of the personnel to environmental projects for distrust about its continuity; the personnel does not have time enough for environmental issues; a lack of clear instructions by the board and superior management; difficulty of developing a systems of knowledge management.

- Difficulties in implementing cleaner technologies

Difficulties in implementing cleaner technologies in palm oil mills are related to financial obstacles and not to technical problems. But in plantations there is some reticence for the substituting of chemical with organic fertiliser.

The analysis of the external barriers for cleaner production is presented in the following paragraphs.

- The failure of existing regulatory approaches

The co-operatives have a reactive environmental strategy. The main characteristics of the strategy are: actions only to obey the law, environmental management is addressed if

necessary, compliance position driven by legislation. The problem is that existing regulations have not implicated fundamental transformations. The co-operatives have reached the parameters of pollution having no incentive for additional improvement.

An additional problem is that the auditing systems by regulation authorities is very complex and expensive. The regulation authorities has put emphasis on mitigation of damages but not on a prevention approach.

- Difficulty in accessing cleaner technologies

Although there are cleaner technologies in leader countries, there is a failure in the system of technology transfer. The main obstacle is that the collaboration networks are very weak for transferring cleaner technologies.

- Difficulty in accessing external finance

There are no programs funding the introduction of cleaner technologies. Actually, banks do not have experience in assessing this kind of projects.

- An absence of markets for environmentally friendly goods

The existence of markets for environmentally friendly palm oil is not obvious. The normal argument for not stimulating organic production in co-operatives is that crude palm oil is a generic good without a possibility of differentiation for environmental reason. But there are no studies in the co-operatives about that.

- Economic cycles

Economical cycles in the palm oil activity are perceived by strong prices fluctuations. Uncertainty about prices is normal, affecting wiliness to invest in projects with profits only in the long term.

Conclusions: Some policy implications

There are several policy implications related to the important role of systems of innovation on the introduction of cleaner technologies. The main ones are studied in the following paragraphs.

- Strengthening systems of innovation: toward more efficient collaboration networks

Most barriers for introduction of cleaner technologies in the co-operative sector are related to a weak system of innovation. It is then necessary to strengthen this system. The main challenge is to recover a systemic approach for solving critical variables of performance. The strategy is based on improving quality of interactions. An important issue for consideration is the development of mechanisms for knowledge generation and transmission. Three areas of action would be: resolving problems of institutions for technology transfer; improving mechanisms of communication; and improving firm capabilities for absorbing cleaner technologies.

One important task is to promote joint research collaboration with the participation of firms and state agencies as well as universities. An useful mechanism is the exchange of

workers between national and foreign firms. It is necessary to research about the nature of informal flows of knowledge in the sector with the objective of improving flows of information and communication channels.

- National research policy

State agencies should promote agreements for research projects involving state and private research centres, universities and other stakeholders in the palm oil sector (co-operatives, suppliers, clients, competitors). The challenge is the generation and diffusion of knowledge and technologies. A fundamental objective is to increment capacity of technology adaptation in order to fit specific needs of co-operatives. The institutional framework for research and development should be transformed in order to facilitate processes of innovation.

- Policies for stimulating innovation and technology transfer

A basic challenge is improvement of co-operatives` capabilities of having access to adequate collaboration networks and for identifying relevant information. Projects for training and better systems of communication would be useful.

Three different types of programs for technology transfer would be very useful: sharing research outputs from state agencies and universities; identification of concrete technology necessities in the sector; and improving communication systems with research centres.

- Information and communication systems

It is important to improve the canals and codes of communication between producers and users of technology. The exchange of experiences, opinions and practical advice between firms would be very useful for stimulating technological development. One important project is the development of a bank of technologies for the palm oil activity.

Some changes of the organisational culture in cooperatives may be useful. The focus should be on stimulating more efficient processes of communication and on a strong role of labour teams instead of vertical structures for decision making.

- Policies for education and training

Policies for education and training are of vital importance. The objective is to improve leaders`, workers` and associates` capacity of generating and adapting useful knowledge. The mechanism is the development of training programs with periodic evaluation. The programs must incorporate the necessary knowledge for solving critical variables of performance and the most effective mechanisms in order to transmit the relevant knowledge.

- Transformation of the institutional framework

Part of the problem of having weak collaboration networks is caused by an inefficient institutional framework. There are no direct regulations or incentives promoting cleaner

technologies or other kinds of innovation processes. No programs or policies are stimulating collaboration networks.

- Financial mechanisms

Financial mechanisms are critical aspects for promoting innovation and technological transfer and it also applies for the introduction of cleaner technologies. State agencies and firms should spend more money both in programs of research and development and on the introduction of cleaner technologies.

References

Arocena, R and Sutz J (1999). *Looking at National Systems of Innovation from the South*. Paper presented in the Conference on National Innovation System, Industrial Dynamics and Innovation Policy, Danish Research Unit for Industrial Dynamics (DRUID), June 9-12 Rebild, Denmark.

Blumberg, Jerald; Blum, Georges and Korsvold, Åge. *Environmental Performance and Shareholder Value*. World Business Council for Sustainable Development.

Bozeman, Barry (2000). *Technology Transfer and Public Policy: a review of research and theory*. Research Policy 29, 627-655.

Carlsson, B., ed. (1995): *'Technological Systems and Economic Performance - The Case of Factory Automation'*, Kluwer Academic Publishers, Boston, Dordrecht and London.

Carlsson, Bo, Staffan Jacobsson, Magnus Holmén, Annika Rickne (1999). *Innovation Systems: Analytical and Methodological Issues*. Paper presented in the Conference on National Innovation System, Industrial Dynamics and Innovation Policy, Danish Research Unit for Industrial Dynamics (DRUID), June 9-12 Rebild, Denmark.

Centre for Corporate Environmental Management (CCEM), (1998). *Environmental Management Tools for SMEs.* A handbook. Environmental Issues series. No. 10. Edited for the European Environmental Agency by Richard Starkey.

Den Hond, Frank (1996). *In Search of a Useful Theory of Environmental Strategy: A Case Study on the Recycling of End-of-Life Vehicles from the Capabilities Perspective*. Ph. D. Thesis, Vrije Universiteit Amsterdam.

Department of Environment. Ministry of Science, Technology and the Environment**,** ***(1999).*** *Industrial Processes and The Environment**.** Handbook No.3.Crude Palm Oil Industry. Malaysia**.***

Dosi, G (1988). "The nature of the innovative process". In G.Dosi *et al* (eds.).

Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G., and Soete, L. (eds.), (1988): *Technical Change and Economic Theory*, London, Francis Pinter.

Edquist, Charles (ed) (1997). *System of Innovation: Technologies, Institutions and Organizations*. Pinter, London and Washington.

Eliasson, G. (1997): *Competence Blocs and Industrial Policy in the Knowledge Based Economy*, Stockholm, Department of Industrial Economics and Management, The Royal Institute of Technology.

Environmental Protection Agency By Local Sustainability (1996) . *Getting Ahead of the Game. An Anticipatory approach to Environmental Management* . Project, Centre for Resource and Environmental Studies. Australian National University and Deni Greene Consulting Services.

European Environment Agency (1998). *Envionmental Management tools for SMEs*. Environmental Issues series; No. 10.

Foster, Chris and Green, Ken, (1999). *Greening the Innovation Process*. Greeting of Industry Network Conference Best Paper Proceedings.

Freeman, C. (1987), *Technology and Economic Performance: Lessons from Japa*n, Pinter, London.

Fresner, Johannes, (1999). *Análisis del Flujo de Materiales*. Centro de Producción más Limpias. Managua, Nicaragua. Stenum – Unido – Ecoprofit.

Gu, Shulin (1999). *Concepts and Methods of NIS Approach in the Context of Less-developed Economies*. Paper presented in the Conference on National Innovation System, Industrial Dynamics and Innovation Policy, Danish Research Unit for Industrial Dynamics (DRUID), June 9-12 Rebild, Denmark.

Gunningham, Neil & Darren Sinclair (1997). *Barriers and motivators to the adoption of cleaner production practices*. Australian Centre for Environmental Law, The Australian National University.

Herrera, Almícar (1992). *Desarrollo, Medio Ambiente y Generación de Tecnologías Apropiadas*. En Sunkel y Gligo, Estilos de Desarrollo y Medio Ambiente en América Latina. Fondo de Cultura Económica.

Hughes, T. (1987) (eds.), *The Social Construction of Technological Systems*, MIT Press, Cambridge, MA and London.

Instituto Tecnológico de Costa Rica , (2000). *Plan Estratégico 2000-2005 para el sector Cooperativo Palmero*. Convenio INFOCOOP-ITCR. Sede Regional San Carlos. Costa Rica.

Johnson, Bjorn and Bengt-Ake Lundvall (1992). *National Systems of Innovation and Institutional Learning.*

Jørgensen, Tine and Remmen, Arne. *Implementation of Environmental Management Systems*. Departament of Development and Planning, Aalborg University, Denmark.

Lam, Alice (1999). *'Tacit Knowledge, Organisational Learning and Societal Institutions: An Integrated Framework*. Paper presented in the Conference on National Innovation

System, Industrial Dynamics and Innovation Policy, Danish Research Unit for Industrial Dynamics (DRUID), June 9-12 Rebild, Denmark.

Lindegaard, Klaus (1997). *State of the Art of Innovation System Analysis*. Sudesca Research paper No.7.

Lundvall, B.-Å. (1988): "Innovation as an Interactive Process: From User-Supplier Interaction to the National System of Innovation", in Dosi *et al.* (eds.), *op. cit.*, pp. 349-369.

Lundvall, B.-Å. (ed.) (1992): *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London, Pinter Publishers.

Malerba, F. and Orsenigo, L. (1990): "Technological Regimes and Patterns of Innovation: A Theoretical and Empirical Investigation of the Italian Case," in A. Heertje and M. Perlman (eds.), *Evolving Technology and Market Structure*, Ann Arbor, Michigan University Press, pp. 283-305.

Malerba, F. and Orsenigo, L. (1993): "Technological Regimes and Firm Behavior," *Industrial and Corporate Change* 2 (1), pp. 45-71.

Malerba, F. and Orsenigo, L. (1995): "Schumpeterian Patterns of Innovation," *Cambridge Journal of Economics*, 19 (1), pp. 47-65.

Metcalfe, S. (1995), “The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives”, in P. Stoneman (ed.), *Handbook of the Economics of Innovation and Technological Chang*e, Blackwell Publishers, Oxford (UK)/Cambridge (US).

Nelson, Richard R. (ed.) (1993): *National Systems of Innovation. A Comparative Analysis*. Oxford: Oxford University Press.

OECD (1996). *The knowledge based economy.* OECD paper.

OECD (1997). *National Innovation Systems.* OECD paper.

Organisation for Economic Co-operation and Development (OECD), (1995). *Promoting Cleaner Production in Developing Countries.* Paris.

Orozco, Jeffrey (1997). *Gestión Tecnológica y Desarrollo Sostenible: Deficiencias del Marco Institucional y de Políticas en Costa Rica*. En Economía y Sociedad. No. 3, Abril.

Orozco, Jeffrey (1999). *Innovación y Desarrollo Sostenible*. Ponencia presentada en el Seminario Innovación Tecnológica y Agricultura: los alimentos transgénicos, organizado por FUNDE, El Salvador.

Orozco, Jeffrey (2000). *Innovación en el Sector Cooperativo Palmero de Costa Rica.* Documento de trabajo. CONACOOP.

Orozco, Jeffrey (2000). *Marco teórico para el estudio de procesos de innovación en forma sistémica*. Documento de trabajo. CONACOOP.

Orozco, Jeffrey (2000). *Systems of Innovation and Sustainable Performance at Sector Level in Central America*. Paper presented in Rio 2000 Third Triple Helix International Conference. Brazil, April.

Patel, P. and K. Pavitt (1994), "The Nature and Economic Importance of National Innovation Systems*",STI Revie*w, No. 14, OECD, Paris.

Porter, M. (1990): *The Competitive Advantage of Nations*, The Free Press, New York.

Porter, M. (1998): "Clusters and the New Economics of Competition," *Harvard Business Review*, Nov.-Dec., pp. 77-90.

Remmen, Arne (1995). Pollution Prevention, Cleaner Technologies and Industry. In Rip, Arie

Thomas J Misa and Johan Schot (eds). *Managing Technology in Society. The Approach of Constructive Technology Assesment.* Pinter Publisher, London, UK.

Remmen, Arne (1999). *Greening of industry". Technological and Institutional Innovations*. SUDESCA, Conference, Costa Rica.

Remmen, Arne and Smink, Carla. *Reforming Environmental Regularion, New Ways to Accomplish Industrial appropriation of Pollution Prevention*. Aalborg University, Departament of Development and Planning. Denmark.

Segura, O (1999). *Sustainable Systems of Innovation: The Forest in Central America*. Ph.D Thesis. Aalborg University, Denmark.

Siel & Siel (2000). *Informe de Responsabilidad Ambiental No. 5* . Planta Extractora y Refinadora de Aceite, Coopeagropal R.L., Costa Rica.

Vickers, Ian and Cordey-Hayes, Martyn (1999). "Cleaner Production and Organizational Learning". *Technology Analysis and Strategic Management*, Vol. 11, No.1.

Welford, Richard and Starkey, Richard (1996). *Business and the Environment*. Earthscan Publications Ltd, London.

Welford, Richard, ed. (1998). *Corporate Environmental Management 1. System and Strategies*. Second edition. Earthscan Publications Ltd, London.