CHALMERS

# Socioeconomic and environmental effects from sugarcane expansion in to the Pontal do Paranapanema region (state of São Paulo, Brazil)

A model-based analysis

*Thesis for the Degree of Master of Science in Industrial Ecology*


ANDREA EGESKOG, STINA GUSTAFSSON

Department of Energy and Environment
*Division of Physical Resource Theory*
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2007

Thesis for the Degree of Master of Science in
Industrial Ecology

# Socioeconomic and environmental effects from sugarcane expansion in to the Pontal do Paranapanema region (state of São Paulo, Brazil)

A model-based analysis

ANDREA EGESKOG, STINA GUSTAFSSON

Department of Energy and Environment
Division of Physical Resource Theory
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2007

Socioeconomic and environmental effects from sugarcane expansion in to the
Pontal do Paranapanema region (state of São Paulo, Brazil)
A model-based analysis

Thesis for the Degree of Master of Science in Industrial Ecology

ANDREA EGESKOG, STINA GUSTAFSSON

Supervised by Gerd Sparovek, Göran Berndes, Julia Hansson

Department of Energy and Environment
Division of Physical Resource Theory
CHALMERS UNIVERSITY OF TECHNOLOGY
SE-41296, Göteborg, Sweden, 2007
www.chalmers.se

Telephone +46(0) 31 - 772 10 00

Printed by Chalmers Reproservice
Göteborg, Sweden, 2007

## Abstract

Pontal do Paranapanema is the only region in São Paulo state where a large scale sugarcane expansion can take place. Such expansion is expected and will likely affect the rural family farmers in the region. Without regulations, the expansion might negatively affect the income of family farmers who start to grow sugarcane. Some family farmers already grow sugarcane and it has been shown that their average income from sugarcane is sometimes less than 3 times the average income from sugarcane in the rest of the state. The same is expected to be the case for all family farmers who start to grow sugarcane if no regulations are added. The family farmers have such small properties that it is not profitable for them to buy all necessary equipment for growing sugarcane. They rent some services from the sugarcane industry leading to lower net incomes. The sugarcane expansion can lead to increased socioeconomic benefits for the family farmers if the expansion is done in combination with changed cattle farming. Family farmers can have a combined production system where they grow sugarcane on parts of their property and in exchange for the delivered sugarcane to the sugarcane industry they could receive nutritious cattle feed made from sugarcane residues. If the cattle stock is changed and feed with the cattle feed this can lead to large increases in milk production and hence large income gains. To evaluate the socioeconomic and climate impacts of expanding ethanol sugarcane production in conjunction with this combined production system, two models were created: one for calculating income growth of family farmers when a combined sugarcane and milk production system is introduced and one for calculating energy and emissions from a sugarcane expansion when coupled with the combined production system.  The model analyses indicate that income could 10-fold for family farmers if a combined sugarcane and milk production system is introduced. At the same time, the global emissions of greenhouse gases could be significantly reduced if the ethanol from such production replaced gasoline used for transportation in the EU. If a sugarcane industry wants to run in Pontal regulations could state that they then have to produce cattle feed of some of the sugarcane residues in order to promote the combined production system.

## Acknowledgements

First of all we would like to thank our supervisors Gerd Sparovek and Göran Berndes for good ideas and help through out the work. We would also like to thank Julia Hansson for help with organizing the report.

We would like to thank for financial support from
SIDA through the MFS scholarship from Geovetarcentrum and Karlstads universitet
Anna Whitlock's memory foundation
STEM
Tall Oil
CF's environmental scholarship
Thank you for believing in our project!

We would also like to thank our good friend Flavio Luiz Mazzaro de Freitas without whom we would never had learned this much. Thank you Flavio, both for helping us with the project and learning about Brazil!

Bruno Souza, thank you for helping us with the interviews and giving us a good time in Piracicaba. Thank you also Vanessa Schmitz, Gláucia Siqueira Gonçalves and Josimar da Silva Santos for helping us conduct the interviews.

Thank you Ricardo Burgi, Alberto G de O Pereira Barreto, Marcelo Valadares Galdos, Carlos Eduardo P Cerri, Stefan Wirsenius and the sugarcane law man for helping us with specific data.

André Luiz Couto Assunção and the rest of the students in the office, many thanks!

Thank you Konrad Görg for helping us take the first step towards learning to fly ☺

Also big thanks to Márcia Kagohara and Luiza Montoya Raniero, obrigada!

And finally Jens and Mattias, muito obrigada e lembremos, nós amamos você para sempre!

An article based on the work performed for the master thesis was accepted for an oral presentation at the 15th European Biomass conference and exhibition in Berlin, spring of 2007. Gerd Sparovek held the presentation as a step to spread the idea and get funding to test the model in Pontal.

# Table of content

# 1 Introduction

In the EU, ethanol has been put forward as one alternative to fossil fuels in the transportation sector. The main strategy for the introduction of alternative transport fuels has been low-level blending of biofuels[1] in gasoline. The blending of biofuels in gasoline has increased due to recent policy initiatives. The so called biofuel directive (EC, 2003) proposes that biofuels should constitute 2 % (energy content basis) of the total amount of transportation fuels sold in the individual EU countries in 2005. The goal is to increase this amount to 5.75 % in the year 2010 (EC, 2003). In January 2007 the European Commission made proposals for a new Energy Policy for Europe. These included a renewable energy roadmap proposing a binding 10% target for the share of biofuels in petrol and diesel in each Member State in 2020, to be accompanied by the introduction of a sustainability scheme for biofuels (EC, 2007).

Brazil is the worlds' largest exporter of sugarcane based ethanol (Jagger, 2007) and is expected to increase its production as import demand increases in the EU, the USA, Japan and other nations. This can lead to both expansion of total cropland and intensified production in agriculture in general (including, e.g., improved yields and changes in crop production patterns). Depending on the specific land-use changes, resulting from the increased sugarcane production, biospheric C-stock changes can substantially influence the climate benefit of replacing gasoline with ethanol. Also the specific design of the ethanol plant (e.g., whether and how the by-product bagasse is used for process heat and electricity generation at the ethanol-plant) influences the total climate performance of the sugarcane ethanol system. Since ethanol use for transport in the EU is partly motivated by the desire to reduce emissions of greenhouse gases (COM, 2006) it is important to investigate whether the common understanding – that the use of Brazilian ethanol has a great positive impact on greenhouse gas emissions– holds also in the context of a substantially expanding sugarcane ethanol production. Besides green house gas emissions reduction benefits also socioeconomic effects of expanding sugarcane ethanol production need to be assessed.

A survey conducted at USP[2] considering socioeconomic effects from an introduction of commercial sugarcane into small-scale family milk farms in the region of Pontal do Paranapanema, São Paulo state, Brazil, shows that families starting to grow sugarcane experience economic stagnation (F. Freitas, personal communication, October, 2006). Following this study an idea was formed at USP to investigate the possibilities to make the introduction of sugarcane more favourable for the small-scale farmers (settlers) of Pontal by launching a combined production system with sugarcane and milk cattle. By producing cattle feed from sugarcane residues milk production and thereby income could be increased.

This master thesis is performed in cooperation between USP and Chalmers and forms a part of USP's existing research regarding sugarcane expansion in Pontal. The thesis aims at two main questions; (1) investigating the possibility of an improved socio-economic situation among settlers

[1] The term biofuels will be used to represent biomass based transport fuels
[2] University of São Paulo, division Escola Superior Agricultura Luiz de Queroz, Piracicaba, Brazil

of Pontal and also (2) investigate the possibility of reducing green house gas emissions, following a sugarcane expansion in the Pontal do Paranapanema region.

## 2 Scope of the study

The major share of the Brazilian sugarcane cropland areas is located in the state of São Paulo (SP) and sugarcane is the largest crop in the state. Approximately 60 % of Brazil's total sugarcane production comes from SP (IBGE, National Institute for Geography and Statistics, 2006). Figure 1 illustrates the growth of the five largest crops in SP considering number of harvested hectares (ha). Between 2001 and 2004 the area of harvested sugarcane grew more than any other crop in the state. In 2006 IEA (Institute of agrarian economy in the state of SP) forecasted that the sugarcane areas in Brazil will further increase from 6 Mha in 2006 to 12 Mha 2016. 3 Mha of this expansion is expected to take place in the state of SP. This forecasted expansion would lead to a doubling of harvested sugarcane both in Brazil and the state of SP.

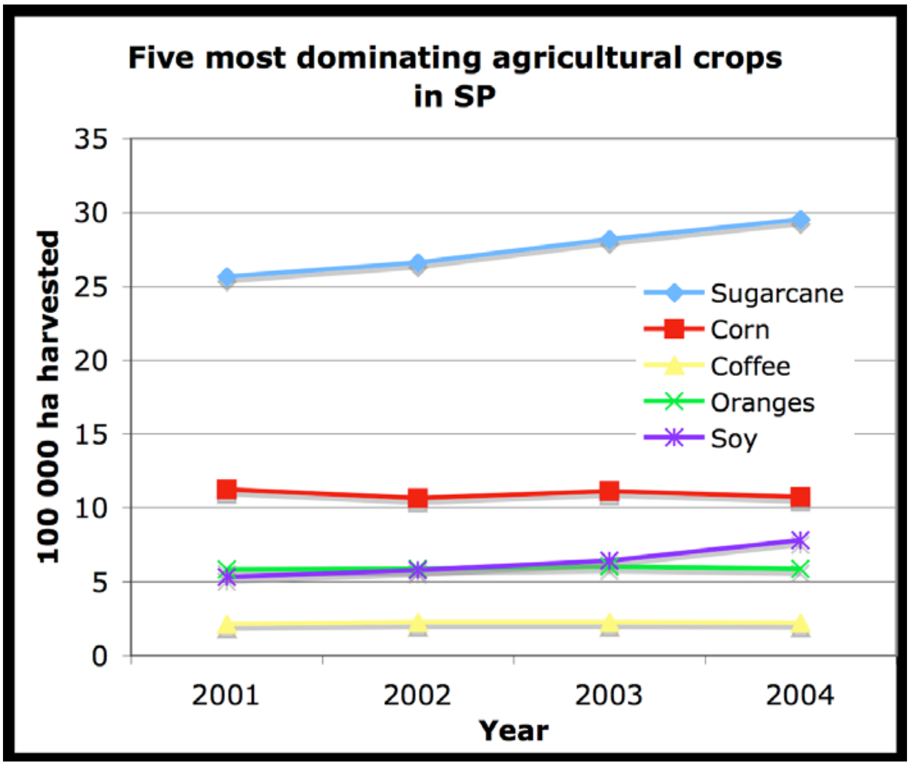



**Figure 1** Increase in harvested area for the five most harvested crops in the state of São Paulo between 2001 and 2004 (IBGE).

Due to physical conditions for growing sugarcane, such as climate, soil and slope, as well as present land-use, the areas for expanding sugarcane plantations in SP are limited. Figure 2 gives an overview of the SP state. Sugarcane areas as well as forests and groups of rural small scale family farms (settlements) are shown. In the state there are large sugarcane plantations in the north regions. The forest in the east parts is remaining parts of the Atlantic rain forest and protected by law from deforestation (G. Sparovek, personal communication, September, 2006). Sugarcane is not intensively grown in the north-west parts due to the dry winter climate. South of the large existing sugarcane area the climate is too wet for sugarcane plantations. Hence, the only areas remaining in SP state where sugarcane can expand in a large scale is the most western parts. Here lies the Pontal do Paranapanema region (Pontal). Research performed at USP show that Pontal is the most likely region for sugarcane to expand in to (Freitas, 2005).

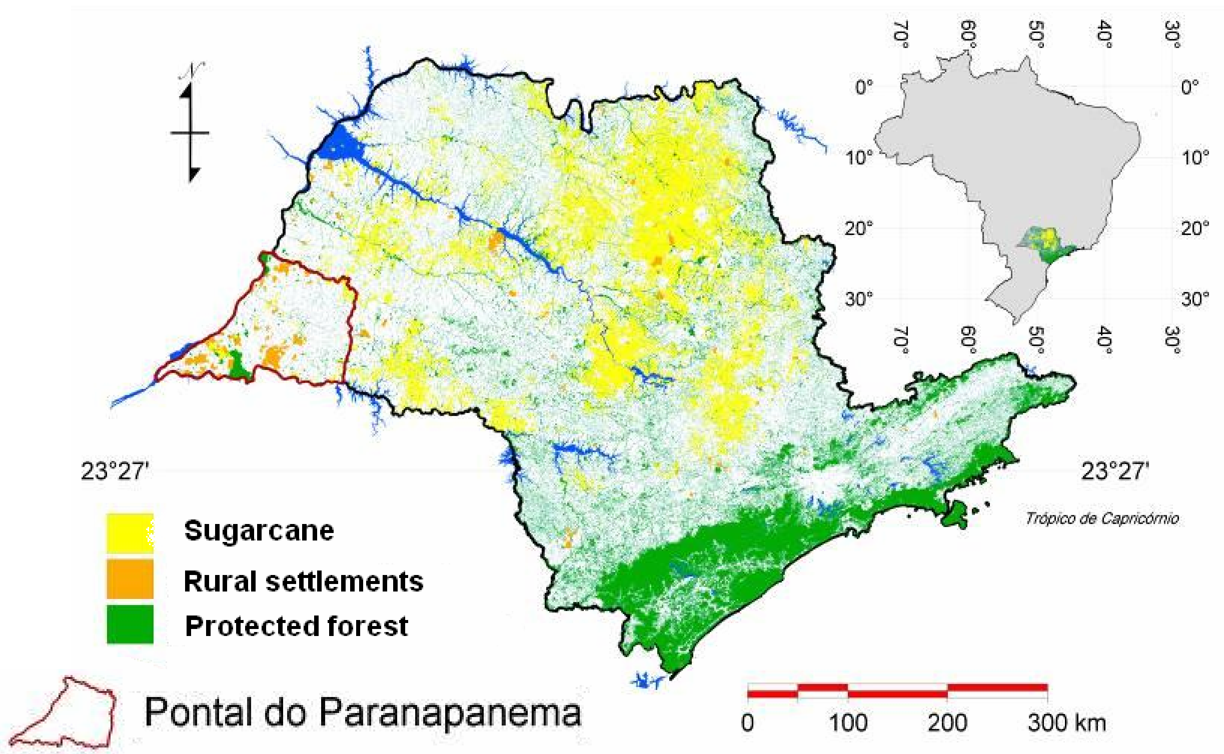



**Figure 2** Sugarcane, forests and rural settlements in SP state (Freitas, 2005)

Pontal, with an area of 1,4 million ha[3], located in the west of the SP state between the rivers Paranapanema and Parana, is the second poorest region of SP. Figure 3 illustrates different land use in Pontal. Cattle farming is dominating and 55 % of the area holds pasture whereas only 4 % holds sugarcane (all numbers exclude settlements) (Freitas, 2005).The forest is remaining Atlantic rainforest and protected by law from deforestation.

[3] This is the same size as the sum of the two most south counties of Sweden, Skåne and Blekinge

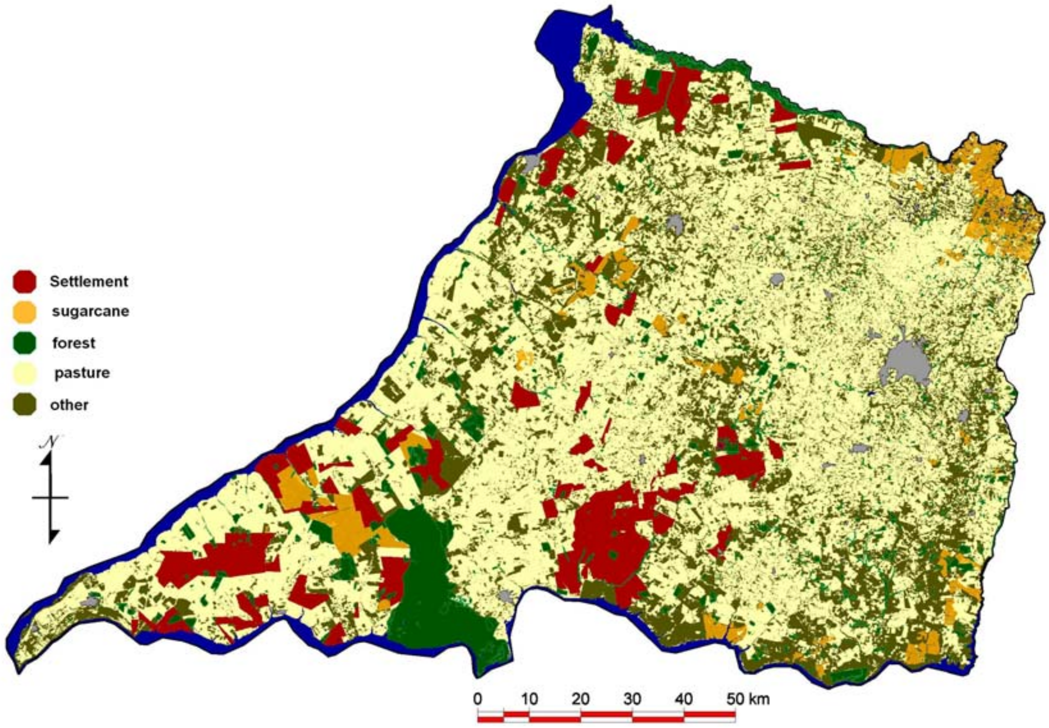



**Figure 3** Land-use in Pontal (Freitas, 2005)

**Picture 1** Pontal do Paranapanema seen from Morro do Diablo, a peak in the remaining Atlantic rainforest. The rainforest shows in the foreground of the picture, the large light green area to the right is a sugarcane field and the area in the centre and to the left are different rural settlements.

There are two types of farmers in Pontal.

- *Settlers*, who live in the settlements, received their land through agrarian reforms[4] helped by the local MST[5] (Brazil´s Landless Workers Movement). The settlers often own properties with around 20 ha of land. Most settlers in Pontal use their land for milk production and the main income comes from selling milk and livestock (F. Freitas, personal communication, October, 2006). The prevailing low-productive and extensive milk production system in the settlements in Pontal (i.e., low-productive cows and limited pasture management) restricts income growth for the settlers (R. Burgi, personal communication, October, 2006).

**Picture 2** To the left shows the house of the Freitas family. The typical Pontal house is often built from re-used billboard (as this one) or bricks. To the right are some of the Freitas family's cows.

- *Ranchers, who* often own properties larger than 1 000 ha own all areas outside of the settlements. Cattle-farming is the most common use of land for ranchers today in Pontal (F. Freitas, personal communication, October, 2006).

Almost half of the total area in Pontal is suitable for growing sugarcane (Freitas, 2005) and approximately 12 % of the suitable land is located within the settlements (F. Freitas, personal communication, October, 2006). Some settlers in Pontal already grow sugarcane for local industries(from now on these settlers will be called sugarcane sellers, SCS) but the possibilities for settlers to rent out or sell their land to e.g. the sugarcane industry is regulated and limited by ITESP[6], the institute managing the land-reform in SP state. The contracts present in Pontal between SCS and the sugarcane industry bind the SCS to a fixed price for sugarcane for a three-year period. A common circumstance is that the SCS lack capital to invest in equipment for sugarcane production and have to pay the sugarcane industry to take care of large part of the production cycle.

---

[4] One goal with the agrarian reforms is that each settler shall be self-sufficient by growing their own food on their own land. This restricts the area possible to produce other goods, e.g. cash crops.

5 MST, Movimento dos Trabalhadores Rurais Sem Terra, is a social movement with an estimated 1.5 million landless members organized. MST carries out land occupations as a way to bring about redistribution of land. In Brazil, 3% of the population owns two-thirds of the arable land (Körling, 2004).

[6] Fundação Instituto de Terras do Estado de São Paulo

The contracts between SCS and the sugarcane industry in Pontal generates around 110 €[7] per ha sugarcane (F. Freitas, personal communication, October, 2006). The average income from sugarcane in the state of SP (excluding Pontal) varies from 144-360 € per ha (F. Freitas, personal communication, October, 2006). A majority of the settlers in Pontal that today grow sugarcane and sell it to the local industry experience economic stagnation soon after starting the production (Freitas, 2005). The contracts present in Pontal today are not believed to be favourable for the settlers in general (F. Freitas, personal communication, October, 2006) (See Appendix A, Contracts with the sugarcane industry, Pontal 2006)

Five sugarcane companies have at present received the environmental licence to operate in Pontal (G. Sparovek, personal communication, September, 2006). This together with the forecasted expansion of sugarcane in the state of SP makes a near expansion very probable. If the sugarcane expansion took place on a large scale with the present contracts in the settlements, there is a risk that the socioeconomic situation for the settlers would stagnate or deteriorate (F. Freitas, personal communication, October, 2006).

At USP an idea was formed to investigating the possibilities to make the introduction of sugarcane more favourable for the settlers in Pontal by launching a combined production system with sugarcane and milk cattle. This master thesis report will present results from a study of socioeconomic and climate effects[8] of realizing such a sugarcane expansion strategy in Pontal. The expansion strategy has been developed at USP based on a similar project in the Orlândia region in SP. The project in Orlândia is based on researched performed by Burgi R. (1985).

The central questions for this thesis are:

- What are the opportunities for beneficial socioeconomic effects for the settlers in Pontal if they were to grow sugarcane to sell to the local sugarcane industry and at the same time intensify their milk production system?
- How would the GHG emissions change if pastures were converted to sugarcane plantations, milk production in the settlements was intensified, and the ethanol produced from the sugarcane was substituting gasoline in the EU transportation sector?

[7] 1 Brazilian real (R$) = 0,36 €

[8] Local environmental aspects such as fire, pesticide use and soil erosion are important issues to consider when looking at climate effects but will not be considered in this thesis

# 3 Methods

The study is based on combining interviews with scenario-construction and modelling (see Figure 4). Two different models were developed to analyse the effects of realizing the studied expansion strategy, one model for socioeconomic change in the settlements (the CoC model) and one model for related GHG emissions and energy flows (the GHGE model). There is very little written information about the conditions and occurrences of Pontal in general and the settlements in particular. An important basis for the construction of the scenarios was obtained from interviews with settlers and experts and study visits at an ethanol-plant producing also cattle feed.

Two scenarios were created, one where the settlers expand their milk production system helped by the sugarcane industry to which they deliver sugarcane, the *integrated production scenario*. In the other scenario, sugarcane is the settlers' only source of income and called the *sugarcane scenario*. The net GHG emissions and energy flows from the two scenarios are tested in the GHGE model and income-development from milk and cattle is examined for the integrated production scenario in the CoC model. The scenarios are based on information collected from the different interviews and the results from them will be presented before the scenarios and models are described.

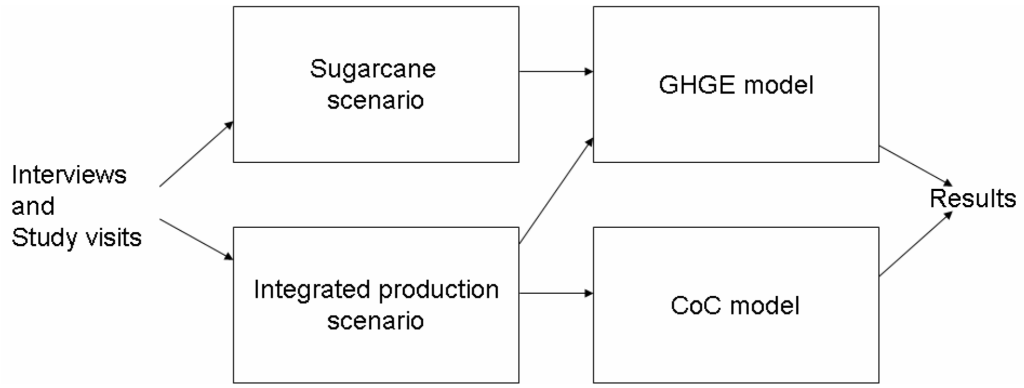



**Figure 4** Description of methodology used in this report

## *3.1 Interviews*

At present, Pontal holds approximately 60 % of the settlements in the state of SP, with 4823 families living in 84 different groups of settlements (Freitas, 2005). To collect site specific data regarding the conditions in Pontal, interviews were made with SCS settlers and those that do not sell sugarcane to the industry (non-sellers, NS). In total 74 interviews were conducted during two weeks in the autumn of 2006. The questions concerned the settlers' income, cash crop production, milk production system and opinions regarding sugarcane (see appendix B, Questionnaire). The method used for the interviews was a fixed questionnaire using quantitative questions.

Interviews were also performed with experts on settlements, milk-cattle farming and sugarcane.

### 3.1.1 Interviews with settlers

Previous surveys have been performed with SCS in Pontal. To be able to compare conditions and broaden the analysis also NS were included in this study. Of the 74 performed interviews 25 were made with SCS and 49 interviews were made with NS. The age of the interviewed ranged from 17 to 79. Due to the nature of the questions only persons who could have sufficient knowledge about the family-income and production at the settlement were included in the interview-study. Interviews would be biased since only settlers who were home and settlers willing to answer the questions were interviewed. It has to be taken into consideration how this will affect the answers given in the interviews. However, there will be no modification of the data or results where the potential biases are taken into account. The possible biases are only to be taken into consideration by the reader.

**Picture 3** Vanessa Schmitz walking in Pontal from one interview to another, some settlers in this part of Pontal already grows sugarcane as can be seen to the right in the picture.

When all interviews were performed they were analysed with help of Microsoft office access and Microsoft office excel in order to make assumptions regarding the settlers income, number of cattle and area of property. Results will be presented in chapter 3.1.3.

### 3.1.2 Interviews with experts

In order to create two possible scenarios for Pontal information additional to the interviews in settlements were needed. For this five different experts were consulted.

- **Gerd Sparovek**, professor of soil science, USP, working mainly with poverty reducing projects. Sparovek provided general information about the conditions in Pontal as well as basic information about sugarcane in the state of São Paulo.

- **Flavio Luiz Mazzaro de Freitas**, student in agronomy, USP with family living in the settlements in Pontal. Mazzaro provided information about farming in Pontal as well as general information about living conditions there.

- **Alberto G de O Pereira Barreto**, agronomy PhD student, USP and also a part time farmer. Provided information about farm management and cattle breeding.

- **Carlos Eduardo P Cerri**, PhD in soil science and specialised in soil C sequestration, and post-doc at USP, provided information about management of sugarcane in general and harvest management of sugarcane in particular.

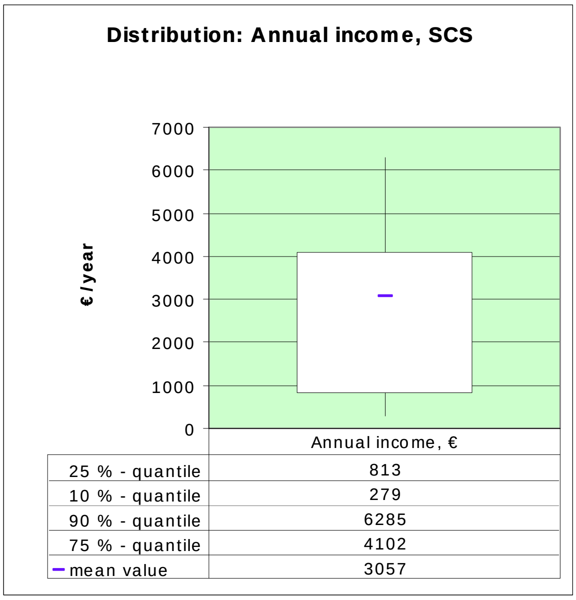
- **Ricardo Burgi**, Master of Science in agronomy, specialized in pasture management from USP, now working as a consultant in cattle feed and pasture. Burgi has developed a sugarcane-based cattle feed, which is being produced at an ethanol-plant in the northern parts of SP state. This feed is used in one of the scenarios. Burgi also works with models on how to change and breed cattle. One of his models, Family milk Production Systems (FPS, 2006), and information from him was used in the construction of the change of cattle model created for this report.

### 3.1.3 Results from interviews

Some of the result from the interviews were used as input for the creation of the scenarios and thus presented in the following sections. The results presented regarding the settlers are chosen with the objective to primary describe NS settlers.

**Income, 2006**

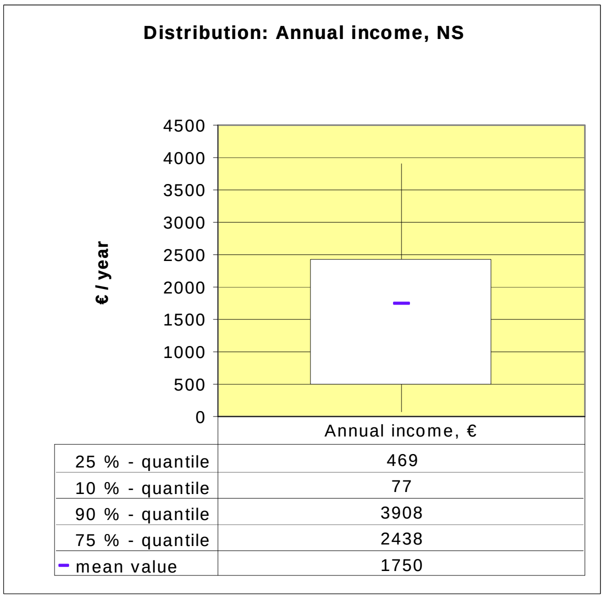
The interviews in Pontal provided information about socioeconomic conditions in the settlements. Income from milk and cattle is a large part of the total income for almost all settlers. The total annual income varies between 80 € to 6 300 € and Figure 5 and 6 shows the total annual income for SCS settlers and NS settlers. The annual income for SCS settlers is almost twice the income for the NS settlers.




| | Annual income, € |
|---|---|
| 25 % - quantile | 813 |
| 10 % - quantile | 279 |
| 90 % - quantile | 6285 |
| 75 % - quantile | 4102 |
| mean value | 3057 |

**Figure 5** Total income among SCS settlers

Freitas (2005) conclude that the entrance of sugarcane in to Pontal led to economic stagnation among SCS settlers and hence was bad for the settlers. Figure 5 and 6 shows that SCS settlers have a higher annual income than NS settlers, pointing somewhat in the other direction. It could be that only the settlers with relatively high incomes start to grow sugarcane but since no studies have been made investigating total annual income among setters in Pontal over a longer time period, there are no numbers confirming impact on economy from sugarcane or income of SCS before they grew sugarcane.




| | Annual income, € |
|---|---|
| 25 % - quantile | 469 |
| 10 % - quantile | 77 |
| 90 % - quantile | 3908 |
| 75 % - quantile | 2438 |
| mean value | 1750 |

**Figure 6** Total income among NS settlers

One reason for SCS settlers to experience stagnation in income-growth could be that their area to grow sugarcane on is limited and restricted. The properties are quite small and some of it has to be used for domestic food production. The results presented in Figure 5 combined with Freitas (2005), SCS have higher annual income than NS settlers but they still experience economic stagnation points to that sugarcane alone can not raise the income levels appreciably.

**Area, settlements Pontal**

Figure 7 shows the distribution of area within the settlements among both NS and SCS settlers. Three of the total 74 answers were excluded since they were either unreasonable or not possible to interpret.

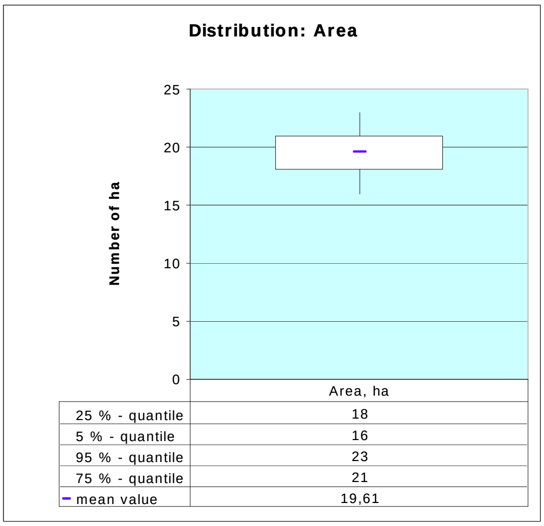



**Figure 7** Area of property among all settlers in Pontal

90 % of the interviewed settlers possess an area between 16 and 23 ha. The mean property in the settlements is 19,6 ha, and the median property is 20 ha. The white box holds the 50 % mid-range values ranging from 18 to 21 ha. Considering the fact that land was distributed in land reform could explain the relatively small spread of size of property.

**Number of cattle, 2006**

Figure 8 represents the distribution for number of cattle among the 49 NS settlers excluding the minimum and maximum 10 %. The median value for number of cattle in this group is 22 cattle. The correlation coefficient between number of ha and number of cattle was investigated to be 0,009 and hence not relevant for this study. Due to the week correlation it will not be considered when identifying relevant characteristics of the settlements. The area of the lot will only be stated as an eventual limiting factor.

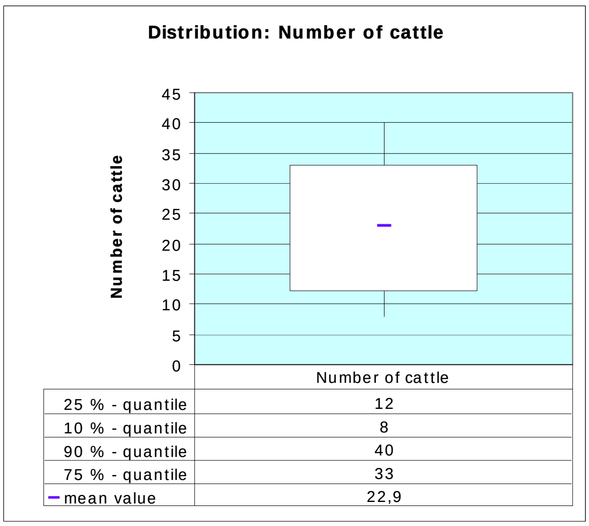



**Figure 8** Number of cattle owned by NS settlers

### Number of cattle in lactation, October 2006

Since all NS settlers are milk farmers the amount of cows in lactation are of great importance. Figure 9 shows the relation between number of cattle in lactation and the total amount of cattle for all NS settlers. The regression coefficient is 0.23 cattle in lactation per cattle. The correlation coefficient is 0.49.

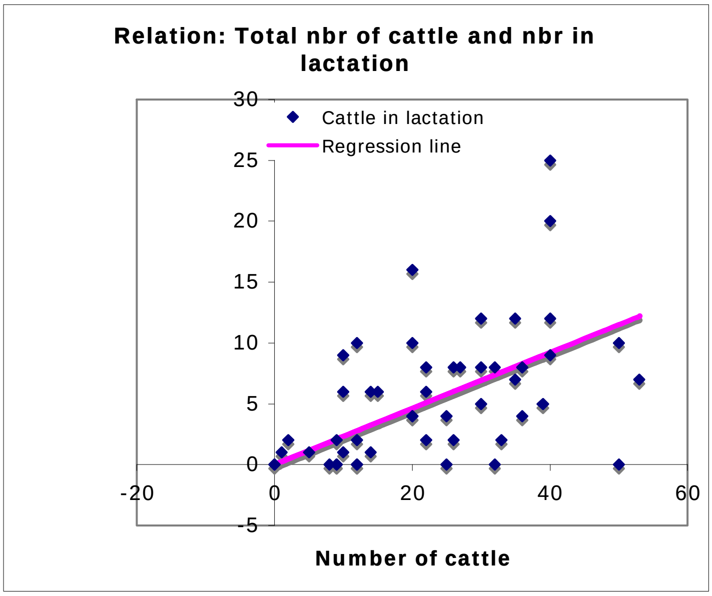



**Figure 9** Total number of cattle in relation to number of cattle in lactation

Figure 10 shows the daily milk production over the number of cattle in lactation for all but one NS settler. The value for the excluded settler was assumed to be unreasonable. Regression coefficient is 3,6 litres of milk per day per cattle. The correlation coefficient is 0.90.

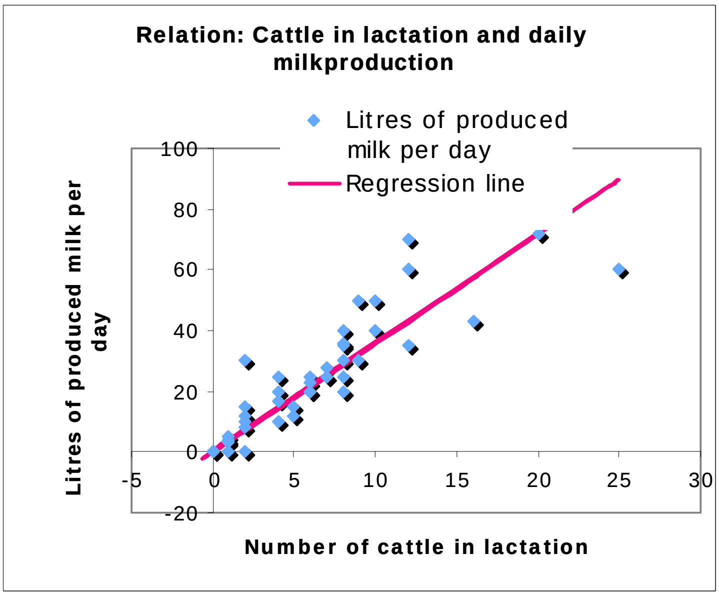



**Figure 10** Number of cattle in lactation in relation to daily milk production.

No questions where asked regarding amount of cows and hence no values could be calculated regarding lactation periods for the settlers cows. Values used in the CoC model regarding lactation are taken from the FPS model (Ricardo Burgis model) and are presented in Table 1. The low producing cows are the cows today present in Pontal and their milk production is based on the interviews. The medium producing cows are the cows that the settlers are assumed to change to in the study.

**Table 1** Groups of animals used in the CoC model

| Type of animal | Years old | Milk production (partly based on the interviews) | Annual milk production per animal | Annual lactation |
|---|---|---|---|---|
| Male calves | Sold immediately | | | |
| Female calves | 0-1 | | | |
| One year old heifers | 1-2 | | | |
| Two year old low producing heifers | 2-3 | 3,6 litres / day | 329 litres | 25 % |
| Low producing cows | 3-8 (sold at eight years old) | 3,6 litres / day | 657 litres | 50 % |
| Medium producing two year old heifers, bread from low producing cows | 2-3 | 10 litres / day | 913 litres | 25 % |
| Medium producing two year old heifers | 2-3 | 12 litres / day | 1095 litres | 25 % |
| Medium producing cows, bread from low producing cows | 3-8 (sold at eight years old) | 10 litres / day | 2920 litres | 80 % |
| Medium producing cows | 3-8 (sold at eight years old) | 12 litres / day | 3504 litres | 80 % |

The low producing cows for example are in lactation for 50% of the year. In other words this means that if a settler has 10 cows, 5 cows will produce milk daily.

**Typical settlers**

The median value for number of cattle owned by a settler in Pontal is 22. With cows being in lactation 6 months per year and 23 % of one settler's cattle in lactation one month gives an average herd of 0.46 cows per cattle. This assuming that only cows are included (H2 excluded) in the answers from the interviews (when asked amount of cows in lactation) and that any other month of the year would have given the same value for cattle in lactation in the heard. Hence an average small-scale farm in Pontal holds 22 cattle of which 10 are cows.

Assumptions, based on gender and probability, were made considering the composition of the rest of the herd, see *Median settler –cows* in Table 2. Two other types of settlers are also shown in the table. The *Median settler –cattle* has the same size of heard as *Median settler –cows* but this settler has no special focus on milk cattle. The *Small settler –cows* has basically the same composition of animals as *Median settler –cows* but the heard is half the size. These three types of settlers where used and examined in the modelling.

**Table 2** Three types of settlers in Pontal

| Characteristics[9] | Median settler-cows | Median settler- cattle | Small settler-cows |
|---|---|---|---|
| Number of cattle | 22 | 22 | 10 |
| Number of cows | 10 | 5 | 5 |
| Cows and H2 (heifers, 2 years old) in lactation | 5 | 3 | 3 |
| Number of H2 | 2 | 3 | 1 |
| Number of H1(heifers, 1 year old) | 3 | 2 | 1 |
| Female calves | 3 | 2 | 1 |
| Male calves | 3 | 2 | 1 |
| Male cattle | 1 | 8 | 1 |
| Milk-production, l/day/cow | 3,6 | 3,6 | 3,6 |
| Income from milk, €/l | 0,14 | 0,14 | 0,14 |

All cows and H2 will produce 3,6 litre of milk per day and the income from the milk will be 0,14 € per litre milk (R. Burgi, personal communication, October, 2006). The values from Table 2 are used in the CoC model.

## *3.2 Scenarios*

Information from the interviews was examined and then used to build the integrated production scenario as well as the sugarcane scenario. In the integrated production scenario the settlers focus on increasing gains from milk cattle farming by growing sugarcane. In the sugarcane scenario sugarcane is the only source of income and all milk cattle are sold. Above information from the interviews also a land suitability assessment analysis was made to, among other things, find out how much of the area in Pontal that can be used for sugarcane cultivation.

### 3.2.1 Land suitability assessment

A survey considering suitable areas for expanding sugarcane production in Pontal has been made by Freitas (2005) using the Geographical Information System, GIS (see Table 3 for some of the findings). Suitable in the context of sugarcane expansion is in this thesis only referring to physical conditions for growing sugarcane, such as climate, soil and slope, as well as present land-use. Economic, environmental or social parameters are not considered. 94 % of the suitable areas for sugarcane are found within a distance of 30 km from the settlements. Considering the sugarcane-industries need for large concentrated areas of land, presence of sugarcane within the settlements is likely to increase if a sugarcane expansion in Pontal were to take place (Freitas, 2005).

**Table 3** Areas planted or suitable for planting sugarcane in Pontal (Freitas, 2005, F. Freitas, Personal communication, November, 2006)

| | |
|---|---|
| **Area suitable for sugarcane *expansion* (outside settlements)** | ***609 000 ha (46 % of total area outside settlements)*** |
| Area suitable for cultivating sugarcane (in settlements) | *78 699 ha (66 % of total in settlements)* |
| Area already used for sugarcane production (in settlements)* | *4756* ha* |
| **Total area suitable for sugarcane expansion** | ***(609 000+78699-4756) ha = 682 943 ha*** |
| Total area of Pontal | *1 400 000 ha* |
| *Total area of settlements in Pontal* | *118 908 ha* |

* This number is based on the assumption that the presence of sugarcane is the same within the settlements as without them. That is 4 %.

[9] Divisions of animals based on information from Barreto (Personal communication, October, 2006)

The total area of cultivated sugarcane in Pontal will be the same in both scenarios after full expansion. Values can be found in Table 4.

**Table 4** Area on which sugarcane will be cultivated when the scenarios have reached their full expansion

| | |
|---|---|
| Outside settlements | 487 200 ha (80 % of suitable) |
| Inside settlements | 22 200 ha (30 % of suitable) |

The land outside the settlements will be used identical in both the scenarios. It was assumed that 80% of the suitable area for growing sugarcane was used for sugarcane plantation when the expansion had reached its culmination[10]. The value was not set to 100% since an expansion of sugarcane also includes an expansion of roads and ethanol-plant areas. It was assumed that infrastructure and capital connected to the sugarcane industry would need approximately 10% of the suitable land. Additional to this the remaining land is used for planting ecological corridors of forests. According to Brazilian environmental legislation all farms must have 20 % forest on their land (F. Freitas, personal communication, October, 2006) and it was assumed that half of the forests were planted on areas suitable for sugarcane and half on non-suitable land. The ranchers are assumed to either rent out their land or sell it to the sugarcane industry. Either way they were assumed to move with their cattle to areas where the land was cheaper (G. Sparovek, personal communication, September, 2006). The number of ranch cattle was assumed to remain the same.

Inside the settlements the production system differs in the two scenarios but still the same amount of ethanol is assumed to be produced. This is a theoretical assumption made with an intension of comparing the scenarios, both from an emission and socioeconomic perspective. A specific number of ethanol plants are assumed to be built and this number will be the same for both scenarios, hence the same amount of ethanol will be produced. When the sugarcane system is fully expanded close to 25 % of the settlers in the sugarcane scenario will cultivate sugarcane on 80 % of their land. In the integrated production scenario the settlers will cultivate sugarcane on 30 % of their land and hence almost 65 % of the settlers will be included in the scenario.

In this thesis the socioeconomic and climate effects from the two different sugarcane expansion scenarios will be modelled, see Table 5 for assumptions regarding the scenarios. The integrated production scenario was created to investigate an option for the settlers to increase their income continuing with milk cattle, which they are accustomed to, and adding some sugarcane production. The sugarcane scenario was created as a prototype for a conventional sugarcane expansion system and is used as a reference to compare the integrated production scenario with.

[10] It is assumed that the ethanol-plants will exclusively produce ethanol. This is made even though a majority of the ethanol-plants in Brazil produce both sugar and ethanol. The assumption was made based on an increased demand for ethanol. To fully investigate the potential for ethanol production and thereby the avoided emissions of greenhouse gases the plants built in Pontal were assumed to be pure ethanol-plants.

The climate effects will be calculated for both scenarios and represented by the total avoided GHG emissions that the different scenarios give raise to each year. The scenarios stretch from year 2007 to 2032. The expansion of sugarcane is growing linearly and starts in 2008.

**Table 5** Overview of the two scenarios created and tested in this report in 2032 when the expansion has reached its culmination

| In 2032 | Sugarcane scenario | Integrated production scenario |
|---|---|---|
| Total sugarcane expansion outside the settlements | Yes (80 % of suitable land) | Yes (80 % of suitable land) |
| Area used to produce sugarcane on (per settler) | 80 % of premises | 30 % of premises |
| Area used for domestic production | 20 % of premises | 20 % of premises |
| Area used for cattle | 0 % of premises | 50 % of premises |
| Source of income for settlers included in the expansion | Sugarcane will be the only source of income | Milk production system and sugarcane will both contribute to the income |
| Settlers included in the scenario | ~ 25 % of all settlers | ~ 65 % of all settlers |

It was assumed that the only income parameters for all settlers will be livestock, milk and sugarcane. Therefore, in 2007 before the expansion begins, income from selling milk and livestock is the only share of income for the settlers as only NS settlers are included in the expansion.

### 3.2.2 The sugarcane scenario

In the sugarcane scenario, sugarcane is the only source of income for the settlers, 80 % of the premises will be used for sugarcane cultivation. The land not used for growing sugarcane will be used for cultivation of crops to stay self-sufficient and to keep some milk cattle for domestic milk and meat demand. The settlers not included in the sugarcane expansion will keep the present production system.

### 3.2.3 The integrated production scenario

In the integrated production scenario the settlers will allocate 30 % of their premises to sugarcane production. The premises not allocated for sugarcane will contain grass land (50 %) used as pasture for the milk cattle during summer and the remaining area (20 %) will be used for subsistence. The settlers not included in the sugarcane expansion will keep the present production system.

The ethanol-plants will provide cattle feed, based on the sugarcane residue bagasse mixed with nutritional compliments (in this report denoted full ratio feed[11]), to the settlers. The full ratio feed is important to increase milk production in the settlements.

[11] In the integrated production scenario there will be an increased demand for corn following the demand for full ratio feed. Land transformations following the increased demand are not considered.

**Picture 4** A cow eating the full ratio feed at a farm in Orlândia, state of São Paulo.

Milk cattle present in the settlements today are low producing (LP) (3 - 5 litres of milk/day/cow, 3,6 litres of milk/day/cow is used based on the interviews) milk cattle. This type of cattle will not increase milk production when given the full ratio feed (R. Burgi, personal communication, October, 2006). Changing the livestock is therefore a condition to increase milk production and income from it. In the integrated production scenario the settlers were assumed to change from LP to medium producing (MP) (12 l milk/day/cow) milk cattle. When a LP cow is bread with semen from a MP the born calve will grow up to be an MPmix cow producing 10 litres of milk per day. An inseminated MPmix cow will give birth to MP animals. The MP cattle as well as the MPmix cattle need nutritional supplements in order to produce 10-12 litres of milk per day. The supplements will be provided by the full ratio feed.

The settlers are assumed to form associations containing 100 settlers. The associations will employ technicians, preferably from within the association creating job opportunities that perform the artificial insemination.

The MP cattle need above the full ratio feed, better pastures in order to produce more milk than LP cattle. With the pastures present in Pontal today it is possible to keep 3-5 Animal Units (U.A.)[12] per ha during the wet summer and around half that during the dry winter. With fertilizers the amount of cattle during the summer can be increased to 5-6 U.A.'s per ha (R. Burgi, personal communication, October, 2006). If no additional feed is given to the cattle during the winter, the winter pasture will be the factor limiting the numbers of cattle. In the integrated

[12] Here, 450 kg cattle equals one unit of animal (U.A.), it is a measure.

production scenario fertilizers will be added to the pasture. Additional cattle feed, the full ratio feed, will be provided 180 days during the winter making the summer pasture limiting factor for number of cattle. This makes it possible for the settlers to increase the amount of cattle and the settlers were assumed to do so. The settlers are also assumed to keep milking by hand and this fact limits the possible increase of milk producing cattle. It was assumed that the settlers can manage a double of milk producing animals and still keep milking them by hand.

**Picture 5** Pasture at the Freitas family, Pontal do Paranapanema, November 2006. The cows grassing at this pasture produce less than 4 litres of milk per day when they are in lactation.

The change of cattle will be made through artificial inseminations (for assumptions regarding the change of cattle see appendix C Change). This will be a slower transition compared to just selling the LP cows and buying new MP cattle, but significantly less expensive. In order to get the change of cattle started, 12 MP heifers, four two year old heifers (H2) and eight one year old heifers (H1) are bought in the beginning of the first year of the change. To finance the change of livestock the settlers were assumed to take a specific loan offered to family farmers by the Ministry of Agrarian Development and operated by the Brazilian banc, Banco do Brasil (Pronaf).

As the number of milk producing animals increase and LP cattle are changed in to MP cattle the milk production will increase. To increase the income per litre milk, refrigerators to store the milk in are bought. Cooled milk pays more than non cooled milk and today milk is simply stored in buckets until collected.

The full ratio feed is vital for the MP cows increased milk production. It is assumed that the full ratio feed will be sold by the ethanol plants to the settlers at a price corresponding to the production cost, roughly half the market price for cattle feed. The low price can be considered a cost (no gain is made) for the ethanol-plant that they are willing to accept since it contributes to local support for the sugarcane for ethanol expansion and motivates the settlers to make land available for sugarcane production. The sugarcane industry will have to invest in full ratio feed processing machines and related capital[13]. The investments for the sugarcane industry will not be further investigated in this thesis; it is only stated as a condition for the integrated production scenario.

## *3.3 Change of cattle (CoC) model*

Through the interviews with settlers and experts the CoC model, describing all incomes and expenses connected to the change of cattle, was created. The model is used on the integrated production scenario for the three types of settlers presented in Table 2 (*Median settler – cows*, *Median settler –cattle* and the *Small settler –cows* ) in order to draw conclusions regarding change in the settlers' income as they go from present milk production systems to the integrated milk and sugarcane production system.

The three types of settlers, the *Median settler – cows*, *Median settler –cattle* and the *Small settler – cows* are tested in the CoC model. They bring two recourses in to the model, the agricultural loan and the number of held cattle. These parameters will constitute the characteristics of the settlers. Other incomes or possessions will not influence the possibility of changing cattle.

The settlers' restricted access to capital had to be taken in to account when creating the model. Amount of investments that can be made by the settlers are limited by the size of the loan[14] taken and the settlers annual income from selling milk and livestock. This model only includes incomes and expenses connected to the management of cattle and leaves out additional incomes and expenses such as pension, salary and income from other goods.

The CoC model is constructed to exchange the LP cattle to MP cattle and double the amount of milk producing animals. The CoC model also calculates a net income for the settlers as the livestock is changed and increased. As input to the CoC model the incomes and expenses below are provided. For more detailed information about the incomes and expenses see appendix D, Income and Expense

TI = Total income = SM + SC + L
SM –selling milk
SC –selling cattle
L –the loan

TE = Total expenses = A + AI + CF + PM + R + BC
A –amortization of the loan
AI –artificial insemination
FR-full ratio feed
PM –pasture management
R –refrigerators
BC –buying cattle

Net income = TI - TE

[13] The economy of the ethanol-plants is not considered in this thesis. Extra costs for the industry to access land in the settlements are assumed to be small and are therefore not considered.
[14] The loan has the intension of gain rural agricultural development and is provided by Brazilian bank "Banco do Brasil". The loan, 6 480 €, is given with an interest rate of 3 % and has to be repaid within eight years. 3% is a relatively low interest rate. To apply the model on other places an interest rate closer to 10 % might have been more realistic but since this model looks at the specific conditions in Pontal the interest rate of 3 % was used

## *3.4 GHG emission and net Energy (GHGE) model*

Ethanol is a renewable fuel and is, when used in a combustion engine, considered as climate neutral; it does not give rise to any additional emissions of CO2 to the atmosphere. Though, the production of ethanol requires energy and also produces emissions of GHG.

GHG emissions and energy flows in the production and use of ethanol in Brazil was calculated by de Carvalho Macedo, et. al (2003). From this study (UNI/Cop) the values for energy and emissions connected to the processes of producing sugarcane and ethanol was received and used in this thesis. UNI/Cop was performed for both average and best available technology (BAT) and this thesis use the BAT values considering the creation of future oriented scenarios. UNI/Cop is based on present values for mechanical and manual harvest of sugarcane. Values regarding harvest of sugarcane are therefore not based on UNI/Cop since harvest management will change in a future scenario towards increased mechanical harvesting. Additional, this thesis considers the losses of C from soil when pasture is transformed to sugarcane fields and the emissions and energy requirements when the ethanol is transported to Europe.

Harvest management of sugarcane are assumed to change in SP state due to the phase out law of the practice of burning the sugarcane fields before harvest. This state-law constitutes that the practice of sugarcane harvest preceded by burning should be totally phased out in year 2031. At present two harvesting managements are dominating; the most common is manual harvest preceded by burning and the other is mechanical harvest not preceded by burning. Choice of harvest management will affect the emission balance of sugarcane production and therefore the phase out of burning is considered in the model.

The average sugarcane yield in Brazil is 82,4 ton per ha (de Carvalho Macedo, et al, 2003). Assuming a six-year cycle containing five harvests this gives an average yield of 68,7 ton sugarcane per ha and year. This number is used in the modelling.

One metric ton of sugarcane (TC) was used as reference flow for the sugarcane and ethanol production and emissions per year was used as reference flow for land use changes. As functional unit avoided emissions per litre ethanol used as blend in the European transportation sector is used. The energy balance was only calculated for present situation due to very small variations over time. The emission balance on the other hand was calculated from 2008 to 2032 for both the sugarcane scenario and the integrated production scenario. A detailed analysis and all calculations are shown in Appendix E, GHGE model.

### 3.4.1 Energy calculations

The energy balance was calculated for both scenarios when fully expanded, 2032. The energy inputs used in harvesting is the only energy parameter that varies over time in the GHGE model and the variations of this will be small compared to other energy flows. The energy used in harvest will vary with less than 1 % of total energy input over the whole expansion leading to that the main result will not vary considerably over time, hence the energy balance is only calculated for fully expanded scenarios.

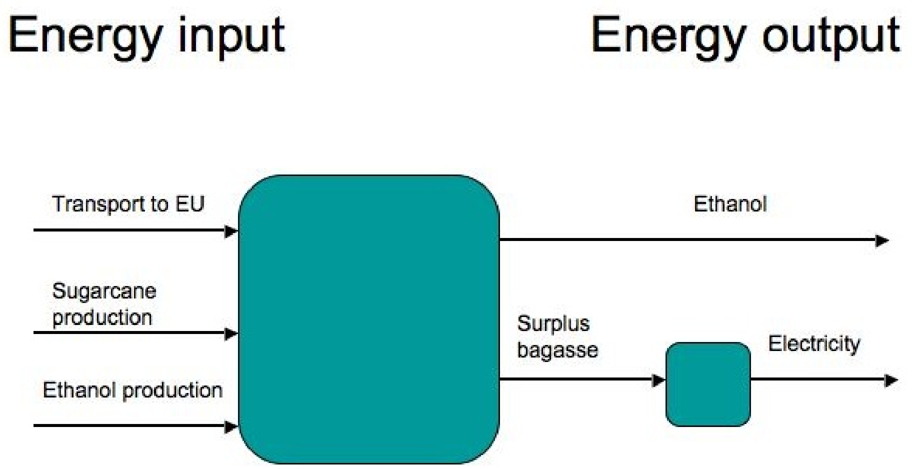



**Figure 11** Overview of the energy calculations

When calculating the energy balance all the inputs and outputs of energy connected to the manufacturing and distribution of sugarcane and ethanol, and also electricity generation, is taken in to consideration (see Figure 11). The total energy inputs and outputs were calculated to get the output/input ratio, units of energy gained for every unit of energy invested. Table 6 accounts for the energy using processes considered.

**Table 6** Processes in need of energy for sugarcane and ethanol production (values can be found in appendix E, GHGE model)

| | **Production of sugarcane** | **Production of ethanol** |
|---|---|---|
| **Energy is used for** | Agricultural operations | Electricity for processes |
| | Harvesting | |
| | Transportation of harvested sugarcane to the ethanol plant | Production of chemicals |
| | Production of fertilizers | |
| | Production of herbicides | Production of lubricants |
| | Production of pesticides | |
| | Production of seeds | Fabrication and maintenance of buildings and equipment |
| | Fabrication and maintenance of buildings and equipment | |

In both the sugarcane and the integrated production scenario, Brazilian ethanol is used in Europe, hence long distance transport of ethanol have to be taken in to account as an energy input. All of the produced ethanol was assumed to be transported from Pontal to Santos (with its international port), SP, Brazil, with truck and further to Europe on large ships over the Atlantic Ocean.

In Europe the ethanol is blended with gasoline and distributed is the same way that pure gasoline would have been. It was assumed that the distribution of the blended gasoline give rise to the same amount of energy use and emissions as the distribution of pure gasoline would have. Hence, the energy used and emissions from distribution are not taken in to consideration. The output of energy from the model comes from the produced ethanol and the electricity produced from the sugarcane residue bagasse. The energy content of the ethanol is calculated as the lower heating value.

### 3.4.2 GHG emission calculations

The GHGE model considers emissions connected to four different activities; 1) sugarcane and ethanol production and manufacturing, 2) transport to Europe, 3) reduction of soil C as a result of land use change from pasture to sugarcane and 4) avoided emissions from using renewable fuel in the transportation sector and the production of electricity from bagasse. The GHGE model only takes into account GHG emitted or avoided. The net emission balance was calculated for each year from year 2008 to year 2032, which also gives the accumulated GHG benefits during the period.

**1. Sugarcane and ethanol production and manufacturing**

The GHG emissions from the sugarcane and ethanol production and manufacturing could be divided in to two main groups; CO2 emissions from the use of fossil fuels and other emissions.

Fossil fuels are used in:

- Agricultural operation at the sugarcane field e.g. harvesting.
- Production of agricultural inputs such as fertilizers, seeds, herbicides, pesticides, lime, etc.
- Production and maintenance of agricultural equipment.
- Production of industrial inputs, lime, lubricants etc.
- Manufacturing of equipment, construction and maintenance of industrial area and buildings.

Other activities that give rise to GHG emissions are:

- Release of CH4 when sugarcane is burned before harvest.
- Release of N2O from fertilizer decomposition.
- Emissions of GHG (non CO2) from combustion of bagasse at the ethanol-plant.
- Emissions of GHG (non CO2) from the combustion of ethanol in engines.

All figures and relations for these emissions where taken from de Carvalho Macedo, et al (2003). The system in de Carvalho Macedo, et al (2003), is based on present Brazilian averages considering harvesting and therefore emission figures have been modified according to the approaching phase out of burning practices in sugarcane harvest. In 2002 the Brazilian averages considering harvesting was 35 % mechanical harvest, 65 % manual, 80 % burned sugarcane and 20 % non-burned sugarcane. In this study all mechanical harvest is assumed to be non-burned sugarcane and all manually harvested sugarcane assumed to be burned before harvest, with 20 % mechanical and 80 % manual harvest.

**2. Transport to Europe**

All of the produced ethanol was assumed to be transported from Pontal to Santos with truck and to Europe on large ships over the Atlantic Ocean. As the ethanol is blended in to gasoline in Europe the distribution do not create any additional emissions as distribution of fuels would have taken place anyway.

**3. Reduction of soil C as a result of land use change from pasture to sugarcane**

The land transformation from pasture to sugarcane will give rise to different emissions depending on what type of harvest that is practiced. There are two main types of harvesting systems. Manual harvest preceded by burning of the sugarcane field to get rid of residues and mechanical harvest where the residues are separated from the sugarcane at the field and left on the soil. Combinations of the two systems also exist but in the creation of the scenarios only the two main types are considered.

Brazilian law regarding SP state states that the practice of burning the sugarcane leaves before harvest should be totally phased out by year 2031 (see Table 7). Today it is not possible to mechanically harvest sugarcane on slopes steeper than 12 °. Therefore the phase out law has two different criteria, one for areas with larger declivity than 12 ° and/or are smaller than 150 ha, and one for areas larger than 150 ha. Due to large extra costs for mechanical harvest compared to manual harvest areas smaller than 150 ha are included in the less strict regulation.

**Table 7** Specific law in the state of SP regarding phase out of burning practices. The percentage represents area allowed to keep on harvest by burning. (Ministry of justice, Brazil, 2006)[15]

| | More than 150 ha | Less than 150 ha or slope steeper than 12° |
|---|---|---|
| 2006 | 70% | 90% |
| 2011 | 50% | 80% |
| 2016 | 20% | |
| 2021 | 0% | 70% |
| 2026 | | 50% |
| 2031 | | 0% |

A change in harvesting based on the phase out law of burning was assumed to take place in Pontal. 13 % of the suitable areas for sugarcane have a declivity above 12° and 10 % of the suitable areas for sugarcane are within the settlements where all settlers have less area than 150 ha (C. Cerri, personal communication, November, 2006 and F. Freitas, personal communication, October, 2006). At least 23 % of the areas fall under the looser regulation. An assumption was made that 70 % of the sugarcane expansion in Pontal would follow the stricter regulation and 30 % the less strict regulation.

The change from burning to non-burning practices was assumed to take place so that a maximum of possible ha were harvested with burning every year. If harvesting by non-burning is taking place from the beginning, no C will be lost from the soil. If harvesting was done by burning, year for land transformation and which cycle the ha was in was kept track of. The approximation was made that the emissions from soil took place evenly distributed during the sugarcane cycle so that if an area went from a burning management to a non-burning one in the middle of a cycle the emissions were assumed to stop that year (for more information regarding the sugarcane cycle, see Appendix F, The sugarcane cycle). The non-burning management was not assumed capable of raising the C level in the soil from one year to another.

Pontal used to be covered by the Atlantic rain forest but most of the forest is gone today. Data on soil C content in pastures in Pontal are not available. Based on information from Cerri (Personal communication, November, 2006) it was assumed that pastures in Pontal have the same C content as pastures in the Amazon region. Soil organic C stocks in the 0-30 cm soil layer range from 30-50

[15] For example, Law nº. 11.241 of September 19, 2002 of São Paulo state, which hosts the vast majority of ethanol mills in Brazil, contemplates a continuous ratcheting down of the percentage of harvested area subject to burning, with a complete phase out in flat areas by 2021, and in areas not suitable for mechanized cultivation by 2031. A protocol just signed by Unica (União da Indústria de Cana-de-Açúcar, the influential São Paulo-based sugar cane industry trade association) and the Governor of São Paulo state, commits sugar cane growers to end the practice of burning flat fields by 2014, and sloped areas by 2017. Although compliance with the protocol is voluntary, the state government contemplates legislation to render it law. (Alves and Del Duca, 2007)

ton C/ha under well-managed pasture for the Amazon. The number of 30 ton C/ha is for a young pasture (10-20 year old) and the higher values of 50 ton C/ha are related to old pastures (40-60 year old) (C. Cerri, personal communication, November, 2006). The pastures in Pontal are old pastures and they are assumed to have a soil C stock of 40 ton C/ha.

When pasture is converted into sugarcane plantations, either with burning or non-burning harvest system, there will be losses in the soil C stock due to preparation and cultivation procedures. The tillage operations (e.g. ploughing) that are used to prepare the soil for planting sugarcane will release C as CO2 and the consequence is a reduction in the soil C stocks. Estimates show that about 10-15% of the soil C stock is lost each sugarcane cycle due to these tillage practices (C. Cerri, personal communication, November, 2006). The losses were assumed to be 10 % over the six years that the sugarcane cycle lasts and continue until a new soil-C equilibrium is reached. Soil C levels are site specific and dependent on local circumstances. No numbers have been found for soil C levels of sugarcane areas in Pontal. Instead numbers from a study of soil C losses due to sugarcane cultivation performed in the State of Espirito Santo, Brazil, was used. Espirito Santo state is similar to Pontal in the way that it used to hold rainforest followed by 22 years of light grazing and no fertilizer input before sugarcane was planted. In the study made in Espirito Santo, after twelve years of sugarcane cultivation with burning management, the soil C content had decreased with 28 % in the first 100 cm depth (Lal et. al. 2006). It was assumed that a 30 % decrease of soil C would give rise to new soil C equilibrium for sugarcane areas in Pontal.

The difference between the two harvest systems, burning and no-burning is that under continuous burning procedure, the soil C stock will be reduced with time. When using the no-burning system, the decomposition of leaves will propitiate an accumulation of soil organic C and therefore, with good management, this could compensate the soil C lost during tillage practices (C. Cerri, personal communication, November, 2006). In this thesis it is assumed that the no-burning system fully compensates for the losses due to tillage. Figure 12 illustrates how the soil C levels changes under different harvesting practises and with the assumptions made in this thesis.

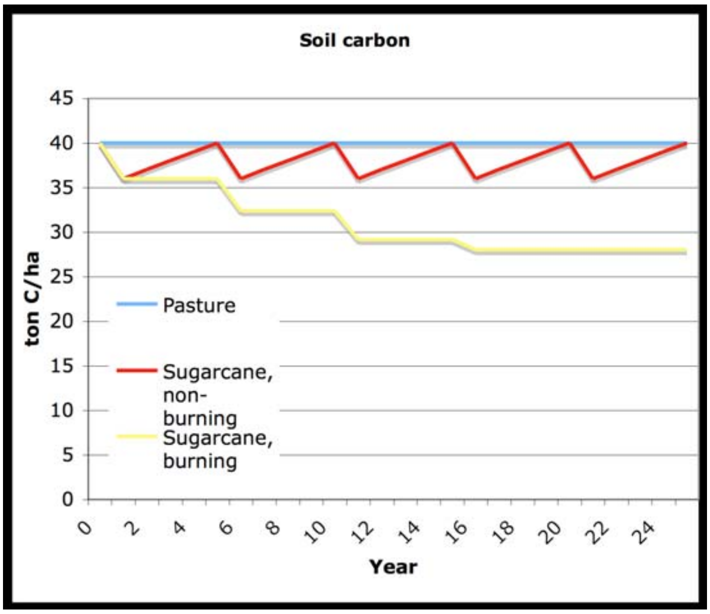



**Figure 12** Change in soil-C due to harvesting practices. The graph is produced based on (C. Cerri, personal communication, November, 2006 and Lal et. Al. 2006).

For non-burning practise the soil C stock will decrease by 10 % in the beginning of the cycle due to the tillage procedures but it will increase during the cycle due to the decomposition of the leaves left on the field. After each sugarcane cycle the soil C stock will be the same as it was before the cycle. For sugarcane harvested by burning the losses are 10 % of the stocks due to the tillage practises. Since no leaves are left to decompose on the field, there is no compensating soil C addition and the soil C stock will decrease with 10 % each sugarcane cycle until a new equilibrium is reached at 28 ton C/ha (70 % of the present day value).

**4. Avoided emissions from using renewable fuel in the transportation sector and the production of electricity**

The direct emissions from gasoline and oil that are replaced by ethanol and surplus bagasse are considered as avoided emissions. Emissions from the production and distribution of gasoline and oil are not included.

The ethanol produced in Pontal is used as a 5 % blend in gasoline (E05) in the European transportation sector. Each m3 of ethanol is replacing 0.66 m3 of gasoline.

It is probable that in a future oriented scenario the ethanol-plant would utilize the bagasse for power production. The ethanol-plant requires 85 % of the produced bagasse for domestic needs of heat and electricity (de Carvalho Macedo, et al, 2003). This leaves 15 % of surplus bagasse. The electricity generated from the surplus bagasse is assumed to be exported to the grid and replacing oil on the margin.

In the sugarcane scenario all surplus bagasse will be used in the production of electricity. In the integrated production scenario part of the surplus bagasse will be used for producing full ratio feed and the additional surplus bagasse will be used in the production of electricity.

## *3.5 Limitations*

In the assessment of the settlers' socioeconomic situation, focus is put on incomes and expenses from the milk production system. The effects on other interested parties of the region such as the ranchers or the sugarcane industry are not included in this thesis. Further, in the analysis of the effects on GHG emissions, only the choices and activities of the settlers and the sugarcane industry are affecting the model. Activities and choices of the ranchers are not included.

Due to lack of written site-specific information concerning the Pontal region alternative sources of information has been used in some cases. People with great knowledge about the area and/or great knowledge in a specific field have been consulted instead of making conclusions from general scientific information. Problems connected to this method such as lack of objectivity and relevance etc is acknowledged by the authors. Still, talking to people living and working in the region has been the most efficient way to state the conditions in Pontal. Information has been related to in a critical way and the ambition has been to confirm information with at least two sources before accepting it as relevant information.

# 4 Result and discussion

The main result from the modelling was that increased production of sugarcane ethanol from Pontal can decrease GHG emissions globally and at the same time improve income levels for the settlers.

## *4.1 CoC model*

The possible income increases for the three types of settles (*Median settler – cows*, *Median settler –cattle* and the *Small settler –cows*) tested in the CoC model are presented here. The *Median settles –cows* income is then compared with income from the sugarcane scenario.

### 4.1.1 Net income and milk production

The change of cattle will take place over 25 years. The first year when the settlers only have LP cattle their only expense originate from a test made on all cows to find and get rid of any disease before the inseminations start. Annual income for the three types of settlers before and after the change of cattle can be found in Table 8. Year 16 the income starts to stabilise for all three types of settlers as can be seen in Figure 14, 15 and 16. All three types of settlers have then had close to a 10 time increase of income.

**Table 8** Net income for all three types of settlers from the integrated production scenario investigated in the CoC model

| | *Median settler – cows* | *Median settler –cattle* | *Small settler –cows* |
|---|---|---|---|
| Income the first year | 1097 € | 638 € | 548 € |
| Income year 16 to 25 | ˜10 000 to 11 000 € | ˜6 000 to 7 000 € | ˜4 000 to 5 000 € |

In the integrated production scenario the settlers increase their amount of milk producing animals. If they where to make the same increase of animals but keep the LP cattle the income would increase with close to five times compared to the income they have today but with the change of cattle this income can be doubled, as can be seen in Figure 13 showing the income for a *Medium settler –cows*[16].

[16] This assuming that the only difference is the amount produced milk from the cattle and that the settler with the LP cattle do not have to buy the full ratio feed

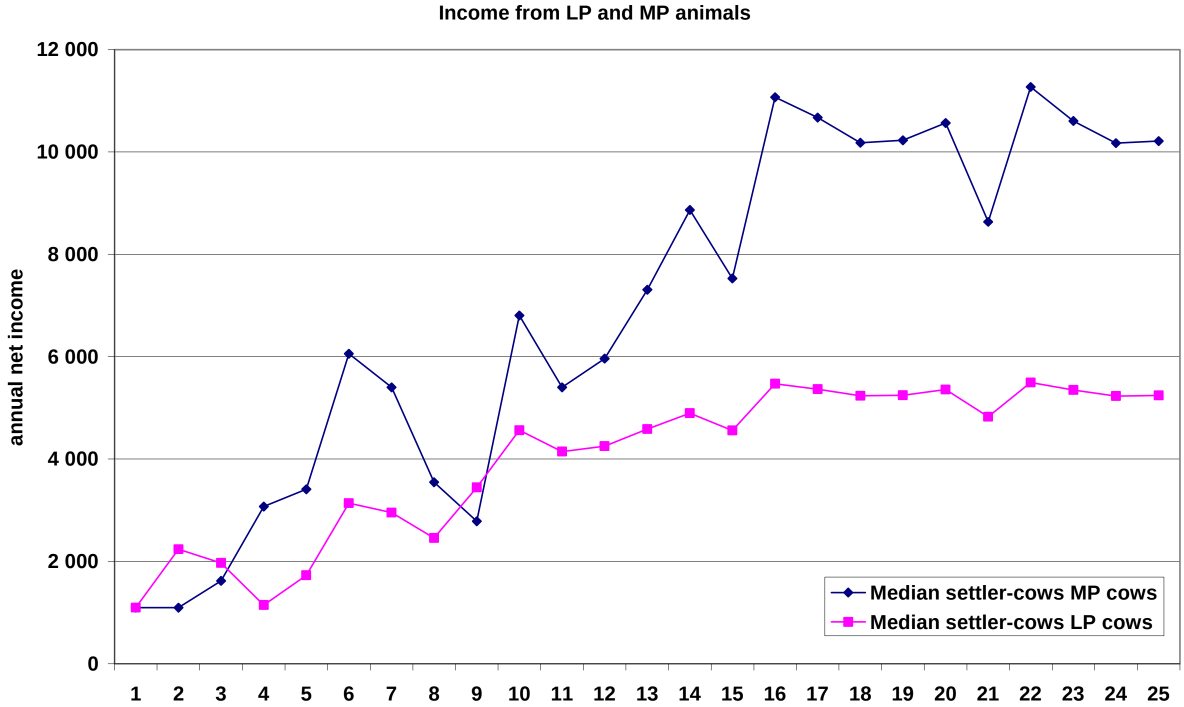



**Figure 13** Net annual income for a Medium settler –cows with low producing and medium producing animals respectively

For all three types of settlers both milk production and net income go up and down over all the years and net income follows milk production closely. The fluctuation decrease as time goes by and goes towards a stabile amount of cattle and the long time trend regarding net income is increasing. Income from milk is between 5 and 10 times as important as income from cattle, hence the close link between net income and milk production (the loan is only used year 2 and 3 when new cattle are bought and milk production has decrease due to sale of cows). To not exceed the doubling of milk producing animals, cows and H2 are sold. The fluctuation in income and produced milk is a result from the change in number of milk producing animals and is model specific. The amount of cows and H2 can together not exceed a sat number and since H2 produces less milk than cows, when more H2 are sold of than cows, more milk will be produced. This could have been implemented so that a specific number was sat for cows and H2 separate, in that case the fluctuations would have been smaller/non-existing.

Figure 14 to 16 show net income and expenses for the different types of settles. Annual net income is shown in the bottom of each stack. The costs are put on top of the net income hence each bar represents total income. The annual milk production shown as a line in the figures follows annual total income closely.

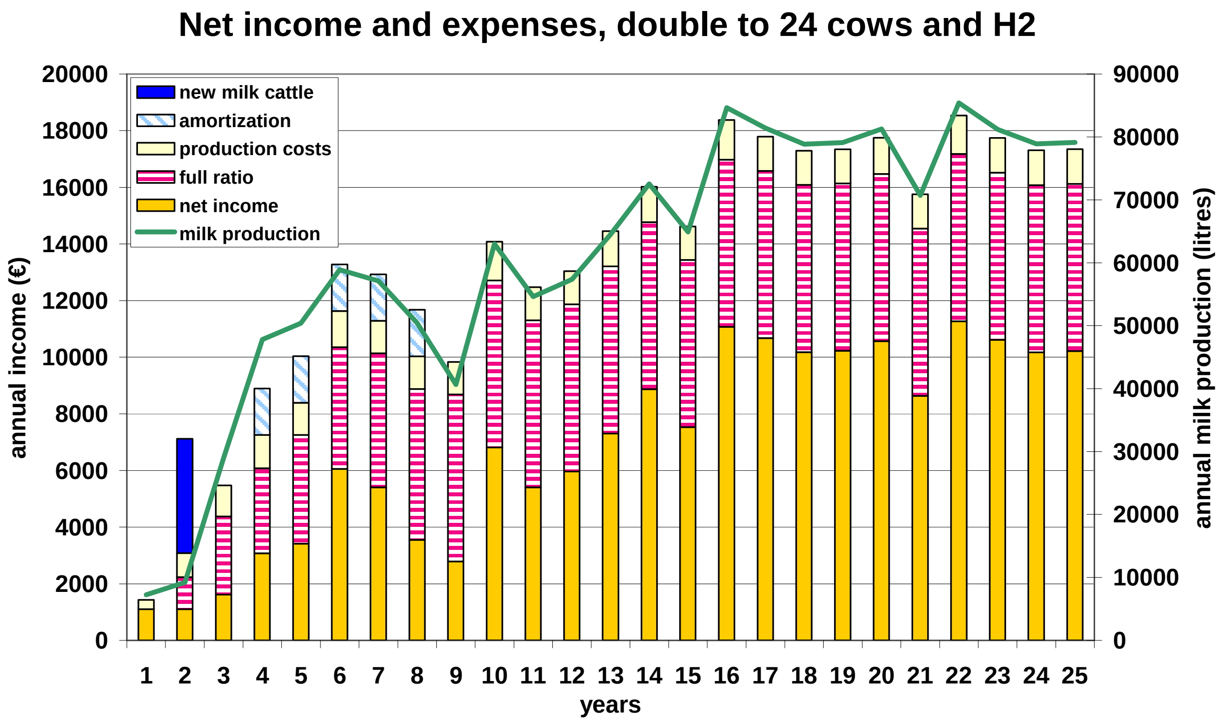



**Figure 14** Net income, expenses and milk production for the *Median settler – cows*, after a doubling of cows and H2

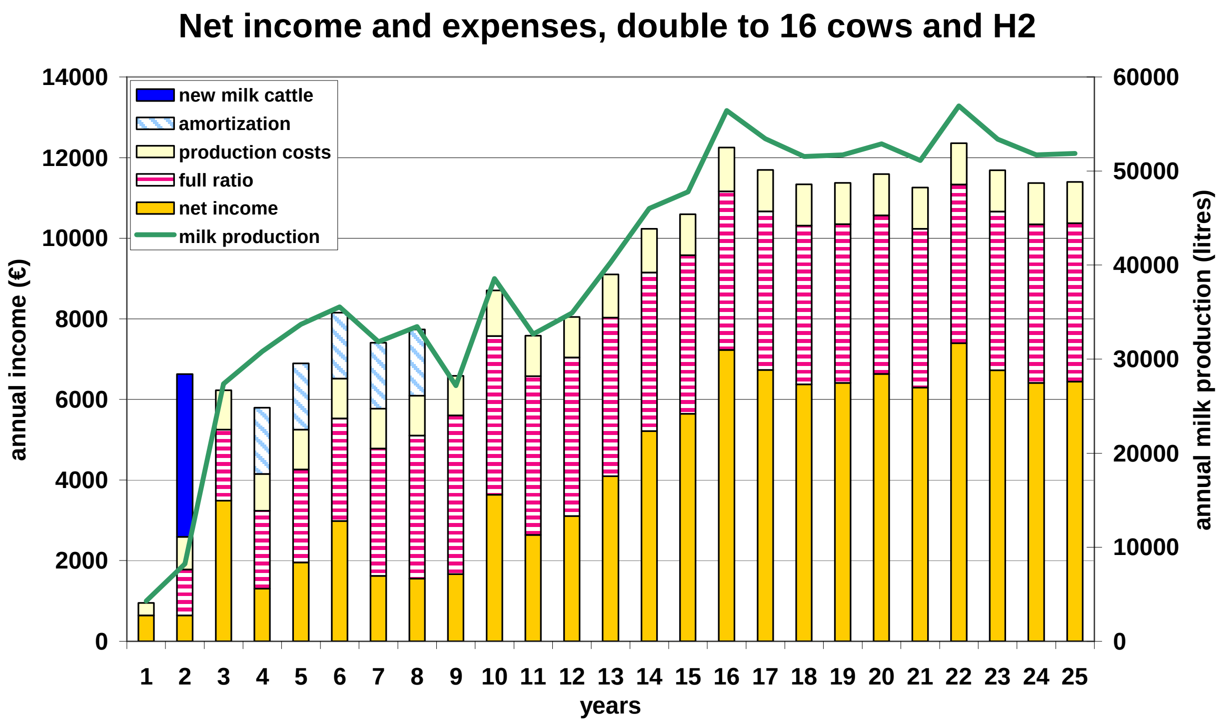



**Figure 15** Net income, expenses and milk production for the *Median settler –cattle*, after a doubling of cows and H2

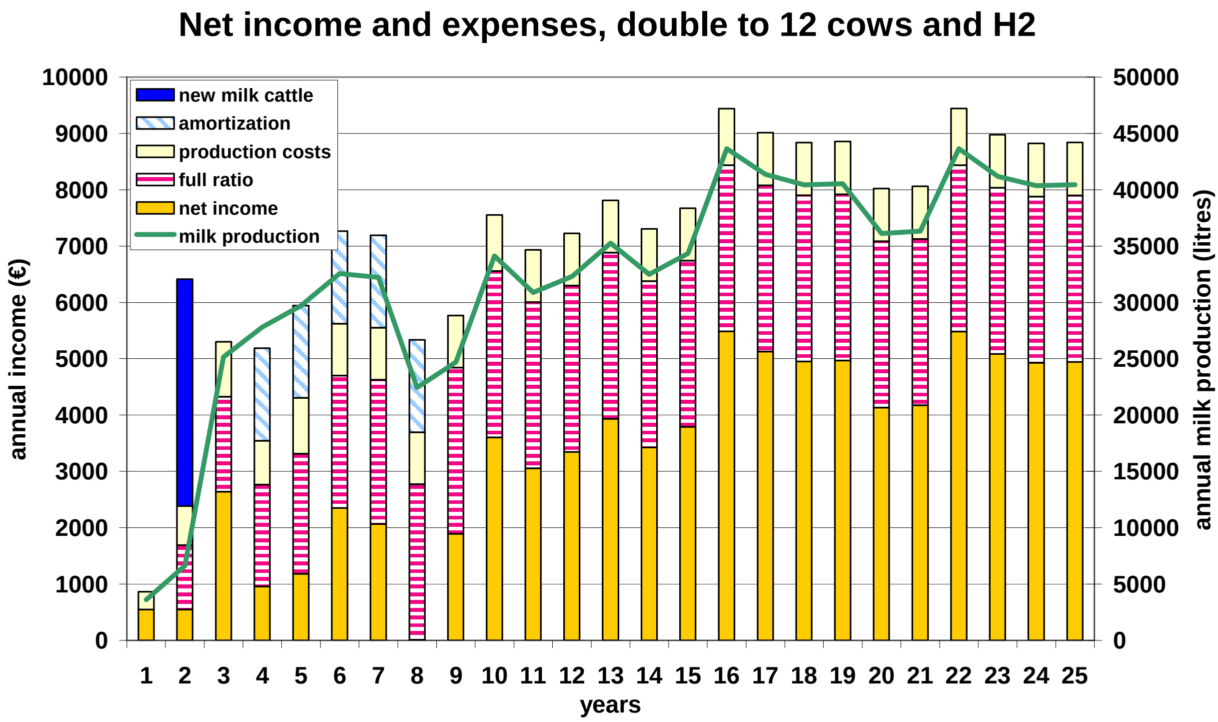



**Figure 16** Net income, expenses and milk production for the *Small settler –cows*, after a doubling of cows and H2

All three types of settlers manage to almost 10-fold their income with the integrated production system. Except the small decrease in income year 2 for all settlers and the *Small settler –cows* dip in income to 12 € in year 8 the income stays above the starting income from year 1 for all years. The decrease in income year 2 is caused by selling of LP cattle leading to less milk production and at the same time buying MP H2 and H1. The dip for the *Small settler –cows* is caused by selling of cows and H2 the years before to stay at the 12 milk producing animals. The dips can be avoided or at least reduced by using the loan and paying back the amortizations in a different way. In the CoC model the loan is used only in year 2 and 3 and thereafter paid back evenly year 4 to 8. This is model specific and does not have to be the way the loan is used. As long as the loan is paid back within eight years it can be used whenever.

The settlers were assumed to not more than double their amount of cattle to be sure that a manual milk production can be kept. It can be discussed though that the *Small settler –cows* had the amount of cattle they have due to lack of capital to invest in more cattle or just bad management and very well could manage an increase of cattle to 24 cattle, an increase by 4 times, when given the loan and some information. And regarding the *Median settler –cattle* the same argument can be applied. Since the area of property is assumed to be the same for all three types of settlers there are no area restrictions hindering all settlers to increase amount of milk producing animals to 24. Around 24 milk producing animals in a heard the number of total U.A will restrict further growth due to pasture limitations, 6-7 ha will be used for pasture. Figure 17 and 18 shows net income, expenses and milk production for the *Small settler –cows* and *Median settler –cattle* when allowed to increase number of milk producing animals to 24. When an increase in milk producing animals is sat to 24 instead of double present day values all three types of settlers will be able to reach an income between 10 000 and 11 000 € annually.

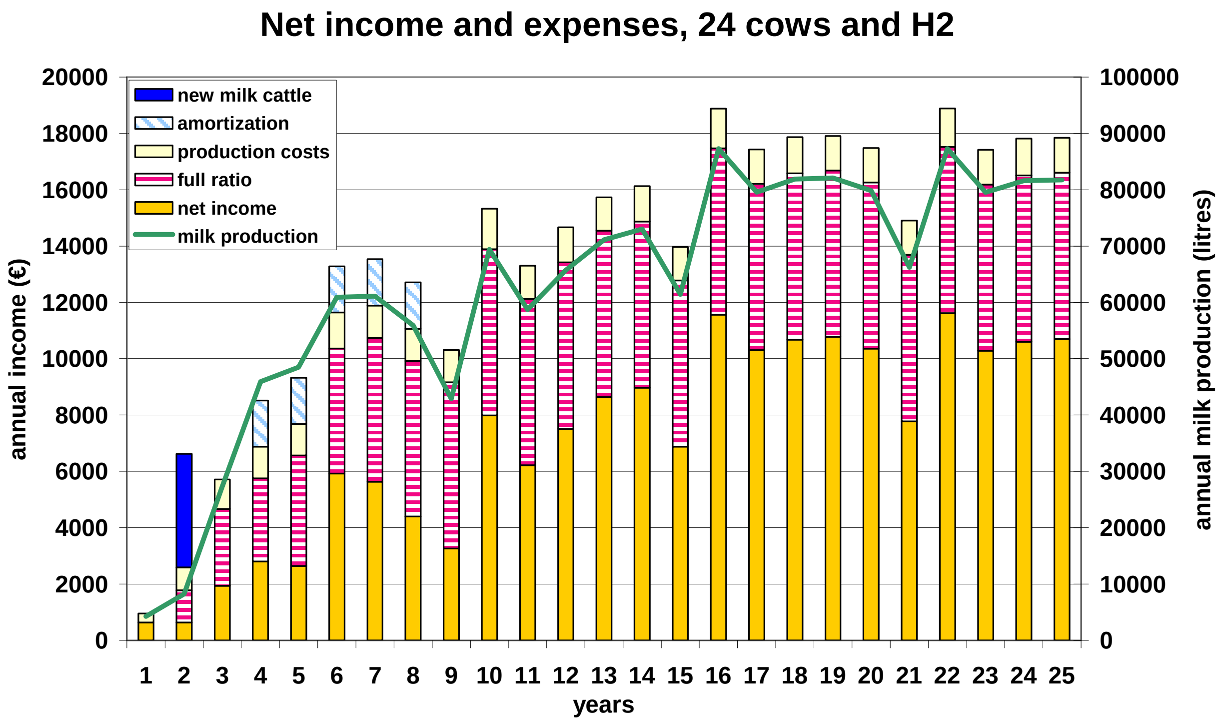



**Figure 17** Net income, expenses and milk production for the *Median settler –cattle*, after an increase to 24 cows and H2

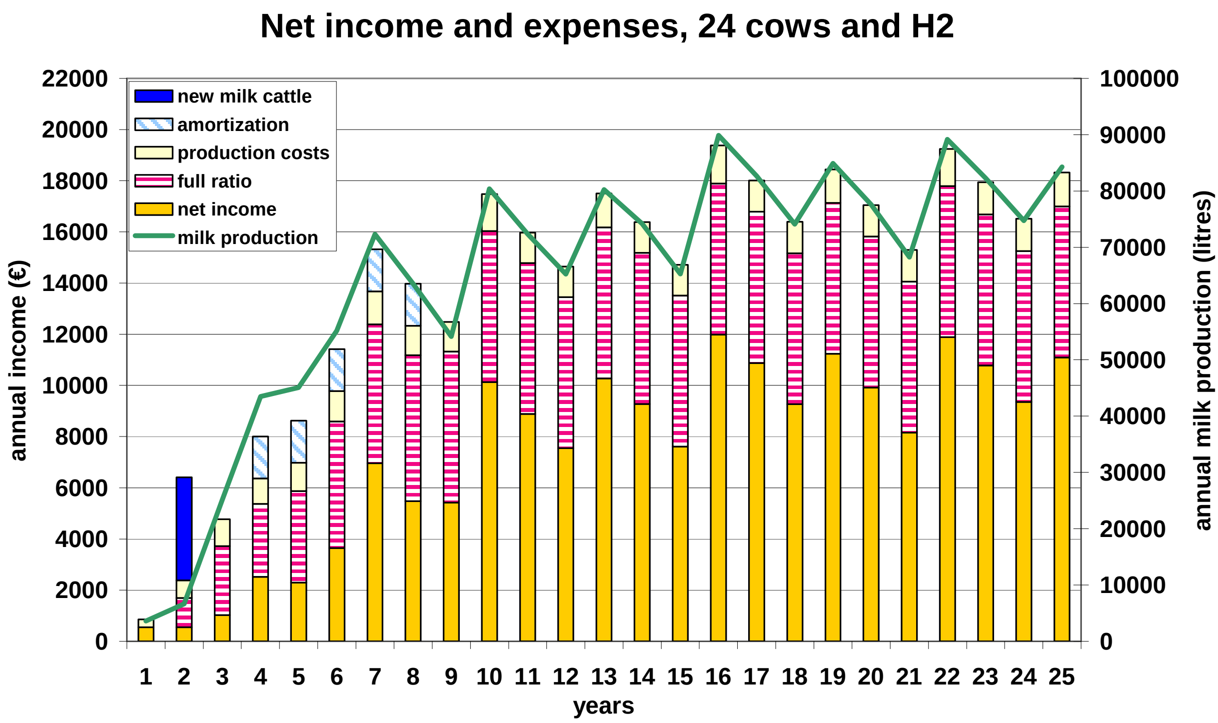



**Figure 18** Net income, expenses and milk production for the *Small settler –cows*, after an increase to 24 cows and H2

The CoC model is constructed in a way that keeps the amount of milk producing animals steady. There is no rule regarding how many of these animals that should be H2 and how many that should be cows. These amounts will change and since cows and H2 produce different amounts of milk, the milk production will fluctuate and hence so does the net income (as can be seen in Figures 14 to 18). The amounts of cows and H2 will not only vary over the years but also between the three types of settlers, assuming an increase of milk producing animals to 24. The net income however moves towards an annual income around 10 000 € for all three types of settlers.

The CoC model is partly based on the FPS model (R. Burgi's model)[17]. Figure 19 shows the settlers net income based on the FPS and the CoC model. All settlers increase their amount of milk producing animals to 25 since this is the number used in the FPS model. As can be seen the results are similar between the models and among the settlers in the CoC model.

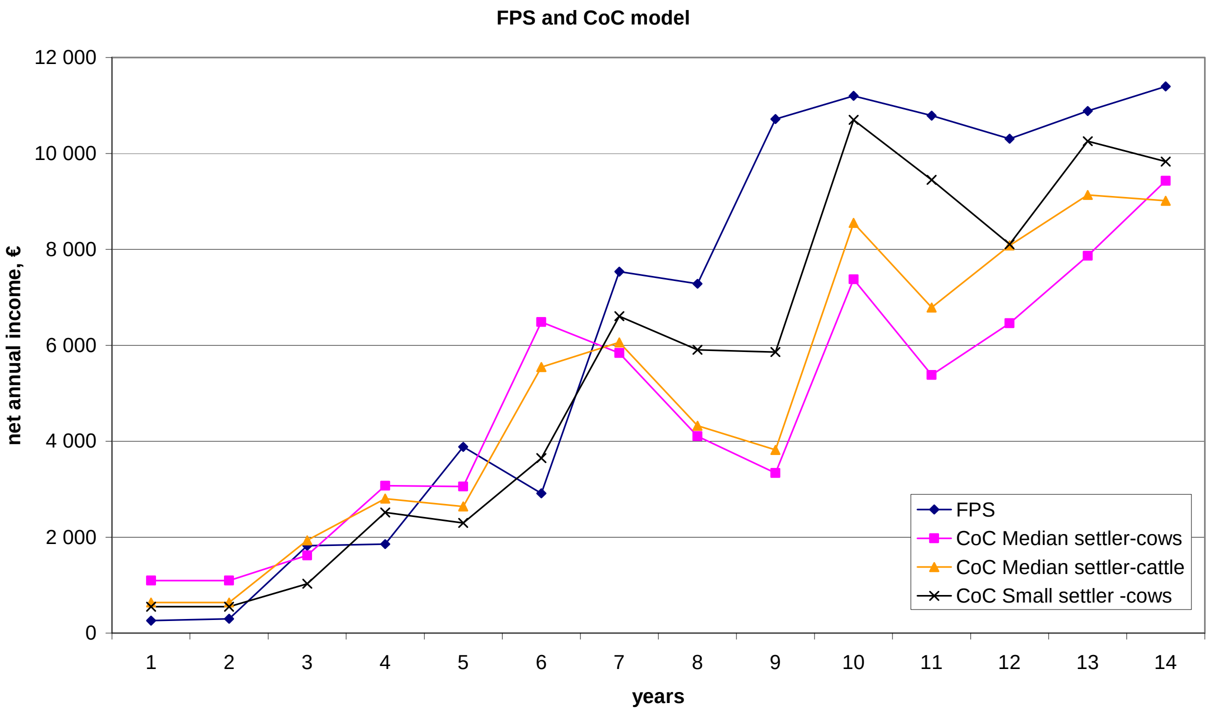



**Figure 19** Net income from the milk production system in the integrated production scenario. The CoC models results are compared to the results from the FPS model

The first seven years the net income based on the different models follow each other closely. The larger difference in net income at the end of the 15 years basically comes from the fact that the FPS model has a different way of selling of animals. In the FPS model the price for animals increase over the years but in the CoC model the prices remain the same. The flat price for animals was used to get a conservative increase of income. Another difference of the two models is that in the CoC model, associations are used to perform the artificial inseminations and in the FPS model the service of getting artificial inseminations are bought from an outside company. The associations are more expensive but are used in the CoC model since they produce jobs among the settlers, the technicians performing the artificial inseminations are supposed to come from within the settlements.

[17] All values for pasture management are taken from the FPS model

### 4.1.2 Full ratio feed

As the amount of produced milk increases so does the net income. Cost for full ratio feed is the largest expense and for all three types of settlers the cost for the full ratio feed stays between 30 and 45 % of the gross annual income. Having in mind that the full ratio feed used in the model is sold to the settlers at a non profit price, half of what is expected to be the market price, an important conclusion is that the low price for full ratio feed is a necessity for the model to give good incomes to the settlers. If the price for the full ratio feed were to increase by around 3 times there would not be any gains when the system is stabilising. Thus, the support to the settlers from the ethanol-plants – in the form of cheap cattle feed – is crucial. If the feed price was raised to the market price level, double the price for the full ratio feed assumed in the CoC model, much of the net income would disappear as can be seen in Figure 20. There would even be some years with negative incomes.

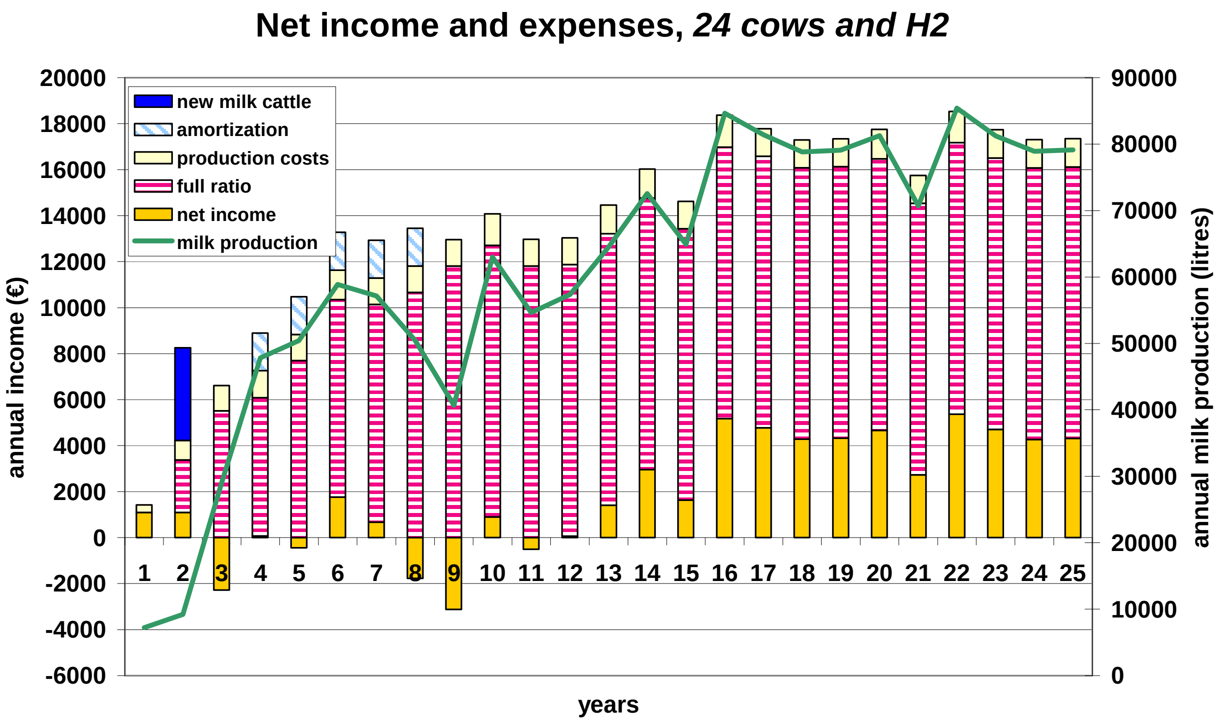



**Figure 20** Net annual income for the Median settler –cows with market prices for the full ratio feed

## *4.2 Integrated production scenario vs. sugarcane scenario*

The median property among settlers in Pontal is 20 ha. Assuming that when the expansion has reached its culmination the *Median settler –cows* make 10 500 € annually, the *Median settler –cattle* make 6 500 € and the *Small settler –cows* make 4 500 € comparisons with the settlers in the sugarcane scenario can be made. All three types of settlers in the integrated production scenario plant sugarcane on 30 % of their land (6 ha). The settlers in the sugarcane scenario plant sugarcane on 80 % of their land (16 ha).

Assuming that the settlers in the integrated production scenario receive half of what the settlers in the sugarcane scenario does per ha sugarcane. The lower price based on the fact that the settlers in the integrated production scenario not only sell their sugarcane but also buy the full ratio feed to a non profit price from the ethanol-plants. In order for the settlers in the two different scenarios to have the same annual income from milk, cattle and sugarcane (the settler in the sugarcane scenario only have income from sugarcane) the ethanol-plants will have to pay the settlers prices according to Table 9.

**Table 9** Income per ha sugarcane to make total income equal

| | Integrated production scenario (€/ha sugarcane) | Sugarcane scenario (€/ha sugarcane) |
|---|---|---|
| *Median settler –cows* (total income 10 500 €) | 404 | 808 |
| *Median settler –cattle* (total income 6 500 €) | 250 | 500 |
| *Small settler –cows* (total income 4 500 €) | 173 | 346 |

The best prices paid today in the state of SP are 360 €/ha sugarcane and prices in Pontal are closer to 110 €/ ha sugarcane. If the conditions and incomes from sugarcane in Pontal would rise it is possible for a settler from the sugarcane scenario to compete with the *Small settler –cows* from the integrated production scenario and maybe even with the *Median settler –cattle*, implying that the price for sugarcane would rise to 346 and 500 €/ha respectively. This conclusion is based on income for the settlers in the integrated production scenario if they are only allowed to double their amount of cattle. It is probably more realistic that a larger increase of animals will take place and then all settlers in the integrated production scenario will have an annual income around 10 000 € and sugarcane would have to pay around 800 €/ha to be equally profitable. Even if the settlers in the integrated production scenario did not have any income from sugarcane at all, the settlers in the sugarcane scenario would have to get more than 625 €/ha to have the same annual net income.

## *4.3 Results from the GHGE model*

### 4.3.1 Energy calculations

Figure 21 and 22 shows the relative size of the different energy inputs invested and energy outputs gained per processed ton of sugarcane (TC).

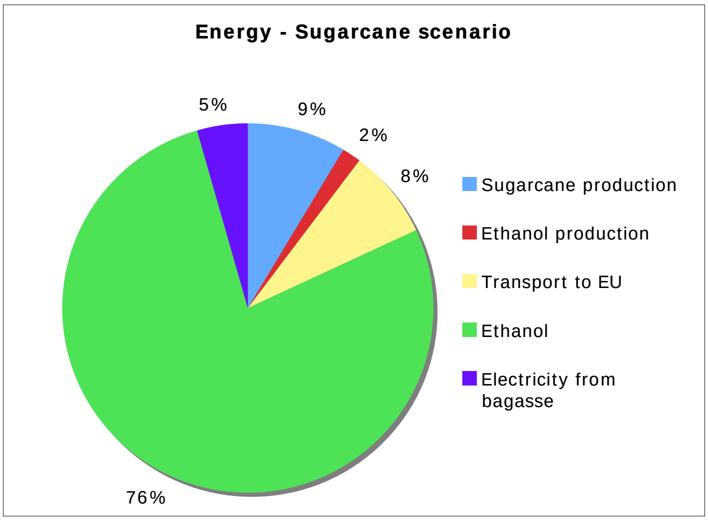



**Figure 21** Energy input and output regarding ethanol production and transport to EU, sugarcane scenario

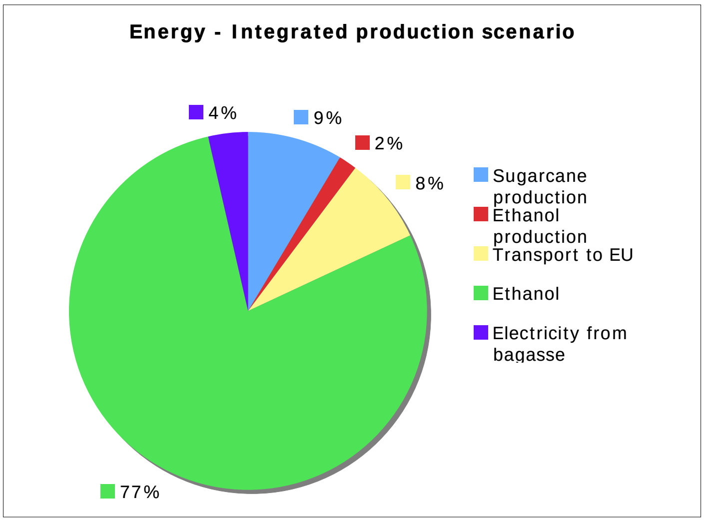



**Figure 22** Energy input and output regarding ethanol production and transport to EU, integrated production scenario

The absolute numbers in MJ/TC for the sugarcane scenario can be found in Table 10. For the integrated production scenario the posts are identical with exception for the output electricity from bagasse (88 MJ/TC) and total energy output (1 984 MJ/TC). The output over input ratio for the sugarcane and integrated production scenarios respectively is 4,55 and 4,50 leading to the conclusion that it is energy efficient using Brazilian ethanol in the European transportation sector.

**Table 10** Energy input and output for the sugarcane scenario

| Sugarcane scenario (MJ/TC) | | |
|---|---|---|
| | Energy input | Energy output |
| Sugarcane production | 211 | |
| Ethanol production | 40 | |
| Transport to Europe | 190 | |
| Ethanol | | 1896 |
| Electricity from bagasse | | 111 |
| Total | 441 | 2007 |

Figure 21 and 22 shows that the transport with large ships to Europe is representing a major part of the energy inputs, 35 %, which corresponds to 8 % of the total energy (input and output). If the ethanol were used in Brazil instead, domestic distribution transport included, the energy output over input ratio would be close to 7 for both scenarios (compared to around 4). It is 36 % less energy efficient to use Brazilian ethanol in the European transportation sector than on the domestic market. Still it is more efficient using Brazilian ethanol than ethanol produced in Europe which has a transportation fuel output divided by total energy input ratio of about 2 (Börjesson , 2004) and the north American corn ethanol with a ratio of 1,24 (Corn ethanol, 2007), transport to Europe not included.

## 4.3.2 Produced ethanol

Figure 23 shows how the scenarios perform during the five first years when it comes to output of ethanol. This is compared with the amount of ethanol (248 302 m3 ethanol) that was required in Sweden 2006 for 5 % blend in gasoline (Statistiska Centralbyrån, 2006). If Sweden will have the same ethanol demand it could be covered by ethanol produced in Pontal in year 2009, by then 252 000 $m^3$ ethanol will be produced.

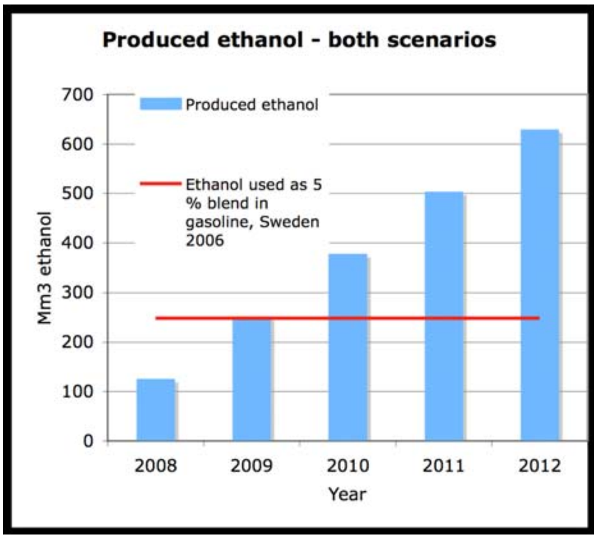



**Figure 23** Possible ethanol production, both scenarios, in Pontal during the five first years of production.

Figure 23 shows that the possible production of ethanol in Pontal is significant in size. In 2032 when the sugarcane production is fully expanded the annual potential ethanol production is 3 149 620 m³. This could cover more than 1 % of EU's demand for biofuels if following the biofuel directive and blending 25 % biofuels in all transport fuel by 2030. In this study a 5 % blend of biofuel in transport fuels is assumed and then close to 7 % of EU's demand for biofuels could be covered by ethanol from Pontal[18].

One question could be raised about the relevance of a 5 % ethanol blend in gasoline in year 2032, which is the year when the scenarios end. It is reasonable to believe that gasoline would not be used in the same extent in the European transportation sector. If also ethanol will be phased out from the transportation sector it could be used as refined ethanol or directly (as sugarcane) in other sectors such as heat and electricity. The climate benefit would then depend on what kind of fuel the ethanol/sugarcane replaces.

### 4.3.3 Net avoided emissions – comparing the scenarios

Figure 24 shows the net avoided emissions for both scenarios per litre used ethanol. The figure shows that performance is increasing over time, with approximately 40 %, for both scenarios and that the sugarcane scenario has a slightly better performance than the integrated production scenario. As production outside the settlements are identical in both scenarios the difference is all due to the different production systems within the settlements.

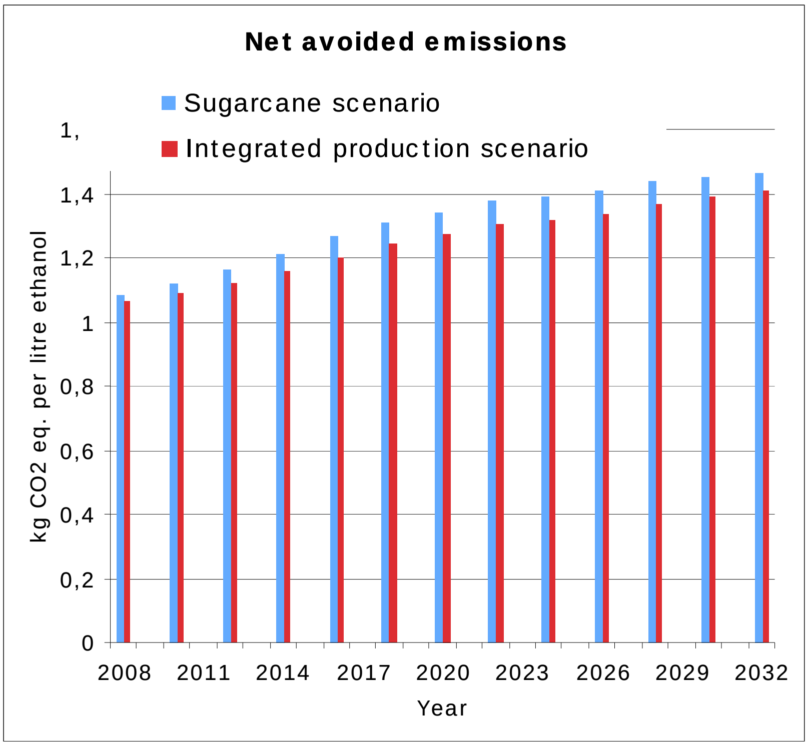



**Figure 24** Net avoided kg CO2 eq. per litre ethanol blended into gasoline in the European transportation sector.

[18] Assuming the total need for transport fuel in 2030 is 19,2 EJ (J. Hansson, personal communication, April, 2007) and 3 149 620 m³ ethanol equals to 0,066 EJ

Figure 25 shows how the different scenarios perform, only including ethanol produced within the settlements. The weaker performance for the integrated production scenario is all due to that surplus bagasse is used to produce the full ratio feed and hence not used for electricity production which replaces oil on the margin. The bagasse produced within the settlements is not sufficient to supply the demand of full ratio feed in a fully developed integrated production scenario. Also bagasse produced outside the settlements is required.

The emissions gained by producing ethanol from sugarcane grown within the settlements are to a large part consumed because less oil is replaced by bagasse outside the settlements. But what should not be forgotten is that also more milk is produced, see next paragraph. If the bagasse was not used as a replacement for fossil fuels, producing heat or electricity, there would be no difference between the two scenarios.

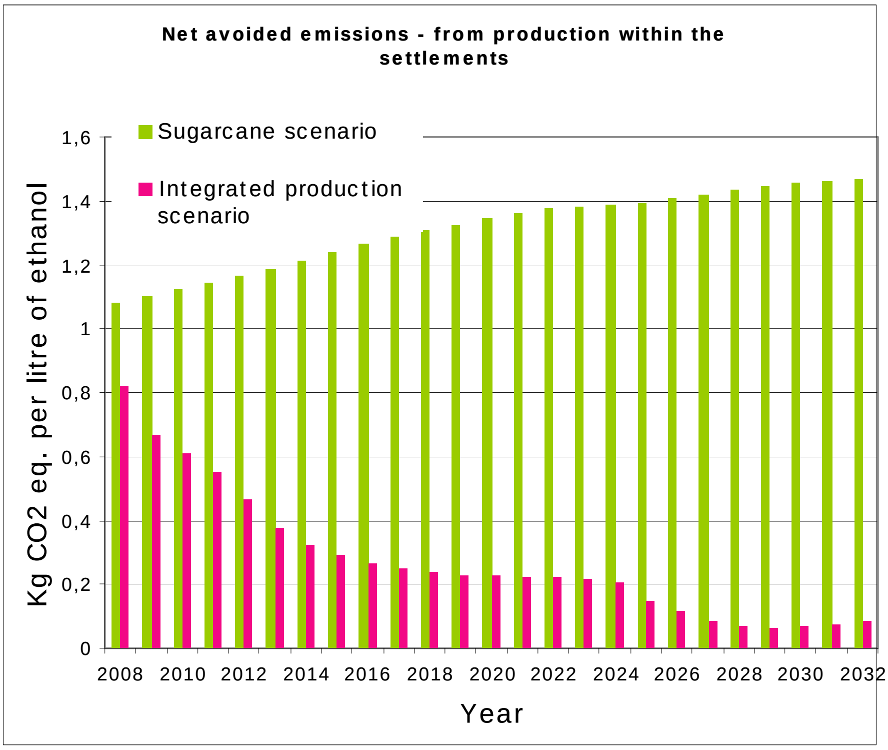



**Figure 25** Net avoided emissions, kg CO2eq. per litre ethanol produced in the settlements in Pontal

**Emissions connected to milk production**

The integrated production scenario has a significantly weaker net climate performance per produced and exported litre of ethanol than the sugarcane scenario but on the other hand it leads to an intensified milk production within the settlements. In the integrated production scenario more than 225 million litres of milk could be produced annually in the settlements when the expansion has reached its culmination. Approximately 50 000 ha used for both pasture and sugarcane cultivation are included in the scenario. To produce this amount of milk with present production system, using LP cows, would require an area of approx. 175 000 ha for pasture, 3.4 times more land than in the integrated production scenario.

Cattle emit $CH_4$ during their food processing and additional to this, other processes connected to cattle management such as manure, fertilizers and pasture emits GHG. The LP cows and present production system gives rise to higher GHG emissions per litre of milk produced than the MP cow in the integrated production scenario. 3 kg CO2 eq./litre milk for the LP cow and 1,3 kg CO2 eq./litre milk for the MP cow (ALBIO). Production of 225 million litres of milk with present milk production system (LP milk cattle) would give rise to approximately 687 kton CO2 eq. while the integrated production scenario with MP cows would give rise to 298 kton CO2 eq.

Assuming a constant demand for milk and that the same amount of milk, 225 million litres, were to be produced with the two different scenarios 389 kton CO2 eq. more would be emitted from the milk production in the sugarcane scenario. This is more than two times the difference between the two scenarios when it comes to net climate performance within the settlements. The difference in annual avoided CO2 eq. from use of ethanol produced within the settlements is 190 kton.

### 4.3.4 Production and use of ethanol – Integrated production scenario

Figure 26 shows that avoided emissions due to ethanol use in the integrated production scenario is constant over time and that avoided emissions due to bagasse use for electricity is slightly changing due to requirement of cattle feed within the settlements (per litre of ethanol).

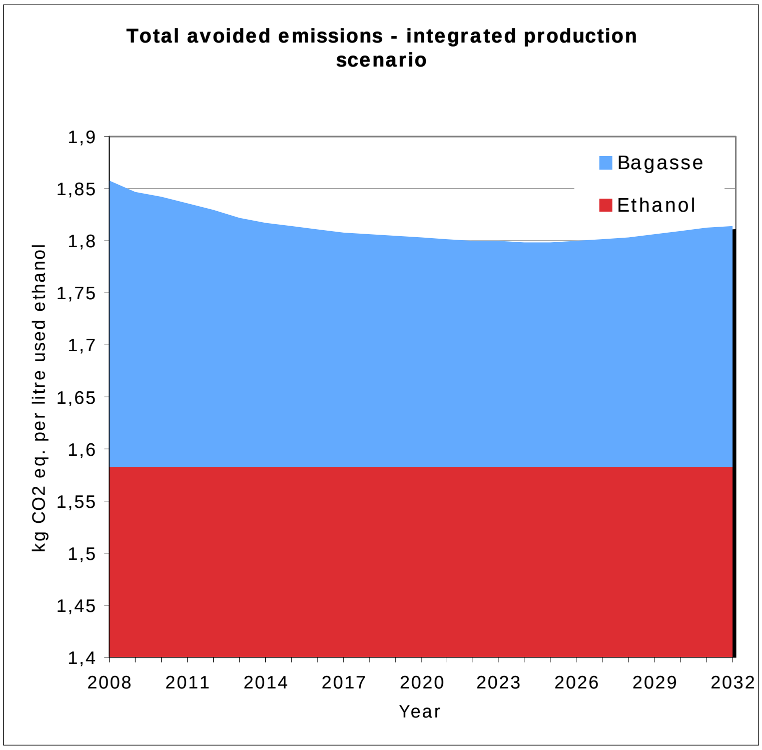



**Figure 26** Total avoided emissions from using ethanol produced in integrated production scenario.

Figure 27 shows that emissions from transport to Europe are constant while emissions from production slightly decrease over time. Use of fossil fuels in harvest management increase over time and the decrease in emissions from production are linked to the phase-out burning sugarcane before harvesting which leads to a decrease in GHG emissions. Emissions from land transformation also decrease significantly over time following the phase-out of burning management before harvest. Emissions from land transformation are not only larger but also take place to a greater extent in the earlier years of the sugarcane expansion.

This is both due to the fact that the regulation is allowing less land to be harvested by burning for every year and that C loss from soil decreases when the C stock decreases.

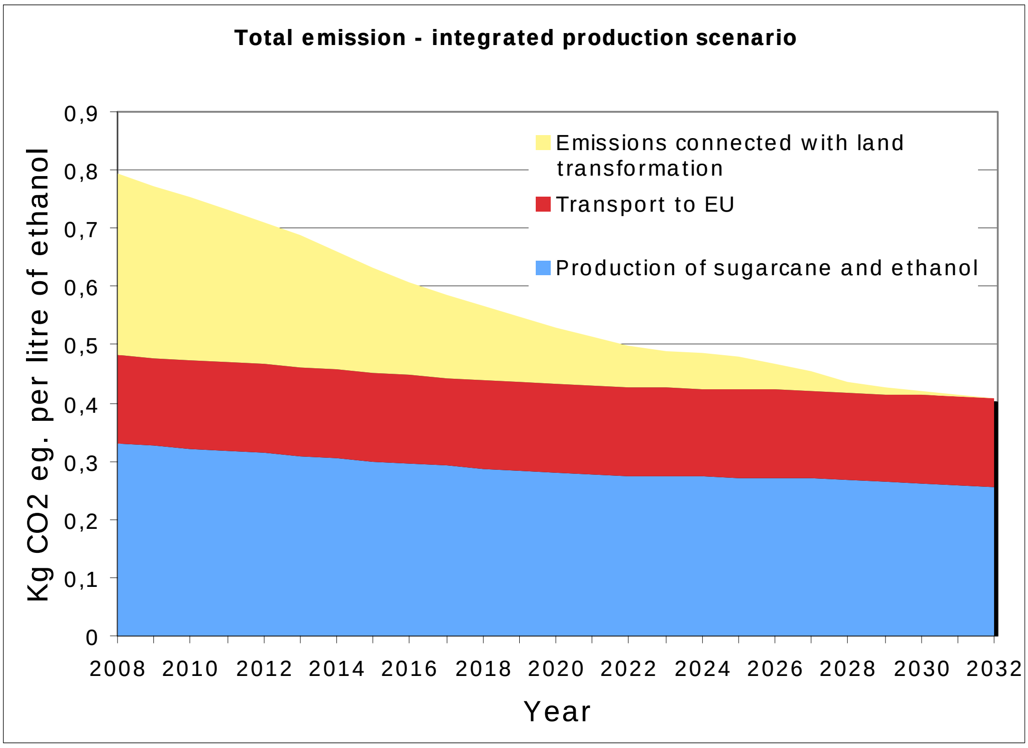



**Figure 27** Emissions from the production of ethanol in Integrated production scenario.

Figure 27 illustrates the emissions from land transformation with the prerequisites that the soil loos 10 % of soil C each sugarcane cycle and that a new soil C equilibrium is reached 30 % below the present soil C level of 40 ton C/ha. All assumptions are made based on that Pontal could be compared to he Amazon region when it comes to soil C stocks and the referenced survey performed in the State of Espirito Santo, Brazil, when it comes to soil C losses.

The data are based on conditions for rainforest areas transformed to well-managed, which is a relative concept, pasture. The pastures are in general not overgrazed and therefore they where classified as well managed pastures in this thesis. Also type of pasture affects the soil C content. The conditions of the compared areas might differ significantly in other aspects that make a direct comparison less adequate. For example, the Espirito Santo survey was taking place during twelve years and it is uncertain if this is enough time to reach new soil C equilibrium. This survey was also performed in another state, on a greater depth and nothing is said about the length of the sugarcane cycles, which will also affect the outcome.

Assuming that a new equilibrium is reached, 20 or 40 % below present soil C stock gives that total soil C losses becomes 11 % less or 2.2 times more than total losses shown in Figure 27. This report assumes that the sugarcane expansion in Pontal takes place linearly over a 25 year long time span. The calculated GHG emission benefits are based on the stated Brazilian law considering phase out of burning before harvest, presented in Table 7. A more rapid sugarcane expansion in the early years would give rise to larger losses of soil C as less area is under restriction then. If the growth would have a slow start it would be the other way around. How the law is implemented will therefore affect the outcome. Graphs illustrating different implementations of the law are shown in appendix G, Harvest management.

Assuming that with the change of harvest method from burning to non-burning management it is possible to gradually increase the soil C to at least the original level, would decrease the total soil C losses by 7.8 % during the time span 2008 to 2032. Eventually all C losses would be restored in to the soil. Graph illustrating this condition is shown in appendix G, Harvest management.

### 4.3.5 Net avoided emissions -Integrated production scenario

Figure 28 shows the net avoided emissions from the integrated production scenario per litre of used ethanol. The performance is increasing mostly due to decreasing emissions from land transformation.

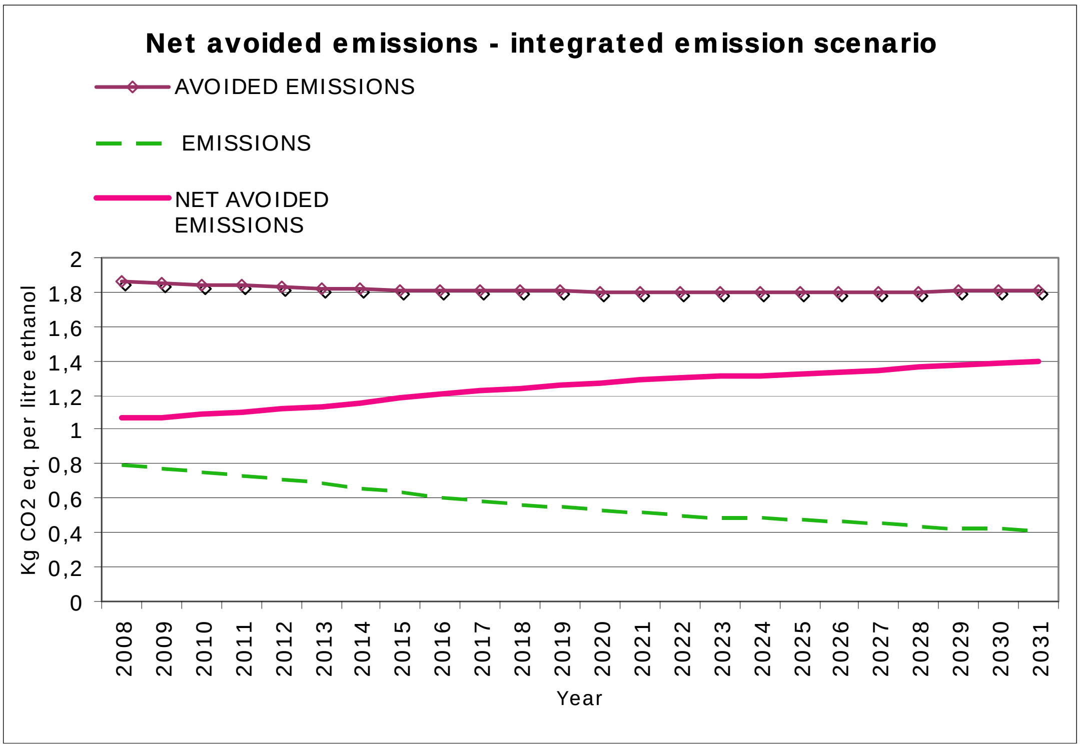



**Figure 28** Net avoided emissions. Soil C losses are allocated to the year they are physically taking place

How the emissions from land transformation are allocated is also important when estimating the climate benefits of a sugarcane expansion. In the GHGE model the emissions are allocated to the year when they are physically taking place. It could be argued that these land emissions should be evenly distributed over the years sugarcane is cultivated on the area since emissions are phasing out when a new equilibrium is reached. Figure 29 shows the result if land emissions are allocated evenly over 50 years of sugarcane cultivation.

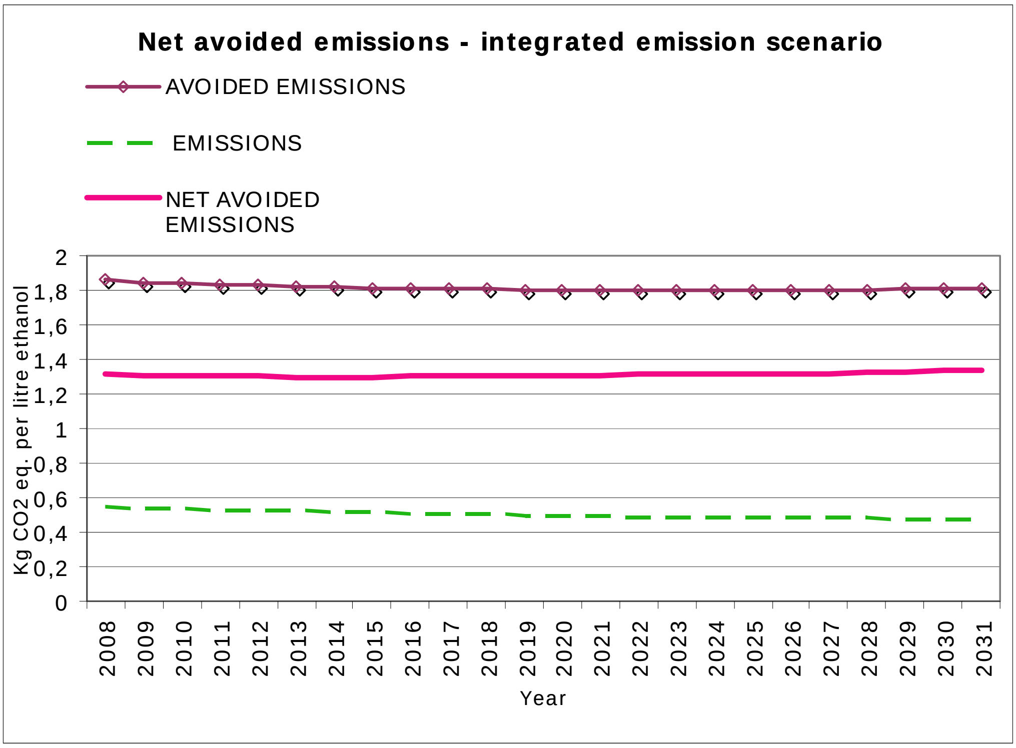



**Figure 29** Net avoided emissions when soil C losses are distributed evenly over 50 years

### 4.3.6 Ranchers

In both scenarios the ranchers are assumed to move to other areas and keep the same amount of cattle. The settlers on the other hand were assumed to stay on their settlements.

In the GHGE model it is assumed that when sugarcane plantations replace cattle ranching, this does not lead to any "leakage", e.g. that the cattle ranchers in Pontal establish themselves elsewhere and during that process induce GHG emissions. The empirical basis for linking sugarcane expansion in Pontal with land use change in the Amazon region is very weak. But the emission gain of expanding sugarcane ethanol production in Pontal is highly sensitive to the occurrence of such second order effects.

For example, assuming that cattle ranchers leave Pontal and establish new ranches in the Amazon region, claiming an area corresponding to 14% of the pasture land converted to sugarcane outside the settlements in Pontal (i.e. 14% of 609 000 ha). If this would be done by clearing forests with a mean C content of 177 ton C per ha (mean C in biomass according to Houghton et al), all estimated emission gains from the sugarcane expansion in Pontal, during 2007 to 2032, would disappear. Clearly, the possibility of leakage warrants close attention and strategies for expanding sugarcane production on pasture land may need to include instruments countering such land use change effects.

### 4.3.7 Summary, avoided emissions

Table 11 shows that even though the same amount of ethanol from both scenarios is identical the sugarcane scenario performs slightly better when it comes to net climate performance. The difference is all due to how the surplus residue bagasse is used in the scenarios. In the sugarcane scenario all is used for producing electricity, replacing oil on the margin. In the integrated production scenario part of the bagasse is used for producing the full ratio feed.

**Table 11** Ethanol production and net climate performance from an expansion of sugarcane in Pontal.

| 2032 when sugarcane is fully expanded | Sugarcane scenario | Integrated production scenario |
|---|---|---|
| Annual production of ethanol (million m3) | 3.15 | 3.15 |
| Annual avoided emissions (million ton CO2eq.) | 4,62 | 4,43 |
| Total accumulated avoided emissions (million ton CO2eq.) | 56.4 | 53.7 |
| Avoided kg CO2 eq emissions/ litre ethanol | 1.47 | 1.41 |
| Annual avoided ton CO2 eq emissions/ ha grown sugarcane | 9.07 | 8.70 |

Looking exclusively at the production of ethanol in the settlements the difference between the scenarios is more significant. Still the production of ethanol is identical and the difference in performance is also here due to the different use of the surplus bagasse. The bagasse requirements are larger in relation to total amount produced ethanol.

**Table 12** Ethanol production and net climate performance from an expansion of sugarcane in Pontal within the settlements.

| 2032 when sugarcane is fully expanded | Sugarcane scenario | Integrated production scenario |
|---|---|---|
| Annual production of ethanol (million m3) | 0.137 | 0.137 |
| Annual avoided emissions (million ton CO2eq.) | 0.201 | 0.011 |
| Avoided kg CO2 eq emissions/ litre ethanol | 1.47 | 0.082 |
| Annual avoided ton CO2 eq emissions/ ha grown sugarcane | 9.07 | 0.51 |
| Annual production of (m3) ethanol per settlement producing sugarcane | 113* | 43.4* |
| Annual avoided ton CO2 eq emissions/ settlement | 166* | 3.6* |

*Based on the assumption that 25 respectively 65 % of the settlers producing sugarcane.

# 5 Conclusions

The central questions for this thesis have been to look at what the opportunities for beneficial socioeconomic effects for the settlers in Pontal are if they were to grow sugarcane to sell to the local sugarcane industry and at the same time intensify their milk production system (the integrated production scenario). The integrated production scenario was compared with a scenario where the settlers' only income originates from sugarcane (the sugarcane scenario). The GHG emissions change if pastures are converted to sugarcane plantations, milk production in the settlements is intensified and the ethanol produced from the sugarcane substitutes gasoline in the EU transportation sector. The change of GHG emissions has been studied for both scenarios. Even though more GHG emissions are avoided in the sugarcane scenario than in the integrated production scenario (excluding the fact that more milk is produced), the integrated production scenario is assumed to be the better scenario. This since the integrated production scenario provides the settlers with a much higher possible annual income than the sugarcane scenario. It is likely to assume that more settlers will start to grow sugarcane if they can get the benefits from the integrated production scenario than if they can only receive money from sugarcane. Hence, the integrated production scenario might lead to more avoided GHG emissions than the sugarcane scenario as totally more sugarcane might be grown.

Based on the calculations in chapter 4.2 regarding income for settlers in the integrated production scenario and the sugarcane scenario, it can be concluded that the integrated production scenario have better chances of increasing income for the settlers in Pontal than the sugarcane scenario does. In the integrated production scenario income from milk is the largest contributor to the increased income. The increase comes from an increase of milk producing animals but also from the change of cattle from LP to MP cattle. As can be seen in Figure 13 (chapter 4.1.1) the settlers could increase their income without changing their livestock but only to about half of what is possible with changed livestock.

The MP cattle need the full ratio feed in order to produce more milk than the LP cattle and the price for the feed is very important for the CoC model to give good incomes for the settlers. As can be seen in Figure 20 (chapter 4.2.1) a doubling of the price for full ratio feed would lead to a decrease of income with around 60 %, when the system stabilises, compared to what is possible.

The change of cattle to MP cattle and the price for the full ratio feed, half of the expected market price, are the two most important factors for the integrated production scenario to give good results for the settlers' income. For the settlers to be able to invest in new cattle and get the change started the loan that they are offered plays an essential role. The change could have taken place without the loan but it would have been much slower since no MP cows could have been bought, inseminations would have been the only way to change cattle.

To be able to increase the amount of milk producing animals the whole heard will increase. A settler will need 6-7 ha for pasture to keep the increased heard corresponding to 24 milk producing animals. The settlers in Pontal have properties between 16 and 23 ha and since they will use 50 % of their properties the area of the property is not a problem even for the settlers with smaller holdings.

The results of this thesis show that it would be energy efficient and profitable from a GHG emissions perspective to produce ethanol in Pontal for use in the European transportation sector. Four times the energy added to the system is gained when sugarcane is produced in Pontal and shipped as ethanol to Europe.

Results also show that the net climate performance is improving significantly during the scenario time span most due to decreasing emissions from land transformation and that choice of harvesting management could significantly affect the net climate performance of sugarcane ethanol. Harvest by burning will give rise to losses of C from soil at least until a new soil C equilibrium is reached. Changing pastures to sugarcane fields will in the long run give rise to new soil C equilibrium. If the new equilibrium is 40 % instead of 20 % below present soil C level the total losses of C will be affected with close to 14 %. Not only the new soil C equilibrium is closely linked to losses of soil C. The rate of which burning practices are phased out, there is no soil C loss when sugarcane is harvested without burning, also has a large impact. Present soil C levels and new soil C equilibriums should therefore be investigated additionally with the attempt to minimize soil C losses.

How the phase out law is implemented will significantly affect the net climate performance. Emissions from land transformation are 312 % larger if all sugarcane areas would follow the looser implementation of the regulation than if all areas would follow the stricter. It is uncertain to which extent a heavily C depleted soil could be restored by changing harvest management and the emissions from soil followed by land transformation are largest during the first years of sugarcane cultivation. Hence, from an emission perspective the expansion situation makes it even more important to consider the choice of harvest management. This could also be recognized in European policy making considering ethanol technologies and creating possibilities for an earlier phase out of burning practices. Effects on soil C should be considered when calculating the net climate benefit following the replacement of gasoline for ethanol.

The sugarcane scenario performs slightly better than the integrated production scenario considering net avoided GHG emissions, this is all due to different uses of surplus bagasse. In the sugarcane scenario all surplus bagasse is used for electricity production replacing oil on the margin and in the integrated production scenario a large part of the surplus bagasse is used for full ratio feed production and only small shares are used for electricity production. If the surplus bagasse is not replacing fossil fuels for producing heat or electricity there would be no difference between the scenarios considering emissions connected to the production and use of ethanol. Both scenarios produce the same amount of ethanol while the integrated production scenario produces significantly more milk than the sugarcane scenario. If the increased milk production in the settlements following the integrated production scenario replaces milk production from a production system similar with the system present in Pontal today, the integrated production scenario would have a superior net climate performance compared to the sugarcane scenario.

As seen in the results for income, the integrated production scenario offers an opportunity to a significant improvement in income among the settlers. Considering relatively low income in the area at present the integrated scenario appears to be more sustainable in the long-term, both gaining the small-scale farmers and avoiding emissions of GHG.

What should not be forgotten are the ranchers in Pontal! If only 14 % of the ranchers move their cattle to rainforest areas, all estimated emission gains from the sugarcane expansion in Pontal, from 2007 to 2032, disappear. Considering this, a scenario where sugarcane is integrated with cattle instead of a replacement scenario should be investigated and made valid also for the ranchers.

It is important for both the settlers and the industry with long term cooperation between each other. The industry invests in full ratio feed machines under the condition that they will be provided with sugarcane from the settlements and the settlers invest in new cattle under the condition that they will be provided with low cost full ratio feed. With long term cooperation and an integration scenario also for the ranchers Pontal could become a good example for the rest of the world considering socioeconomic and environmental work.

## Reference list

*Articles and books*

Alves R., Del Duca P., 2007: The National Year Of Clean Development For Brazil, 2007, Latin American Legal Developments Newsletter. American Bar Association Section of International Law

Bauman H., Tillman A-M., The Hitch Hiker's guide to LCA, 2004, Studentliteratur

Burgi, R. 1985, Produção do bagaço de cana-de-acúcar (*Saccharum sp.*L.) auto-hidrolisado e avaliação de seu valor nutritivo para ruminantes (Hydrolyzed bagasse from sugarcane and its nutritional value for ruminants. In Portuguese),1985, master thesis work performed at Escola Superior de Agricultura "Luiz de Queiróz"/USP, Piracicaba, São Paulo, Brazil

Börjesson P, 2004, Energianalys av drivmedel från spannmål och vall, http://www.miljo.lth.se/svenska/internt/publikationer_internt/pdf-filer/Etanolochbiogas.pdf, 2007-08-20

de Carvalho Macedo, et al 2003, Greenhouse gas (GHG) emissions in the production and use of ethanol in Brazil: present situation (2002), (2003), UNICAMP/Copersucar

Freitas 2005, F. Luiz Mazzaro de Freitas, Avaliação dos efeitos da entrada da cana-de-açúcar em áreas de assentamentos da região do Pontal do Paranapanema – SP (Evaluation of the effects from an entrance of sugarcane in to the settlements in the Pontal do Paranapanema region, São Paulo, Brazil. In Portuguese), 2005, accepted for publication in "Scientia Agricola, Piracicaba, Brazil" http://www.scielo.br/scielo.php?script=sci_serial&pid=0103-9016&lng=en&nrm=iso

Houghton et al, The spatial distribution of forest biomass in the Brazilian Amazon: a comparison estimate, R.A. Houghton, K.T. Lawrence, J.L. Hackler, Sandra Brown, Global Change Biology (2001) 7, 731-746, Blackwell Science Ltd

Jagger 2007, A. Jagger, Viva bio-Brazil, Chemistry and Industry, p.22-23, 15 January 2007

Körling 2004, L. Körling, Så länge det finns hunger – de jordlösas rörelse i Brasilien, 2004, Ordfront förlag

Lal et al, 2006, R. Lal, C. C. Cerri, M. Bernoux, J. Etchevers, E. Cerri, Carbon Sequestration in Soils of Latin America, Food Products Press®, an imprint of The Haworth Press, Inc., New York, 2006

*Web pages*

Corn ethanol 2007,
http://www.ethanol-gec.org/corn_eth.htm, 2007-08-20,
Corn ethanol energy ratios

IBGE, Instituto Brasileiro de Geografia e Estatística,
http://www.ibge.gov.br/home/, 2006-10-03

IEA, Instituto de Economia Agrícola, http://www.iea.sp.gov.br/out/verTexto.php?codTexto=7448, 2006-11-15

Ministry of justice (Secretaria de justice), http://www.mj.gov.br/, the phase out law

Pronaf, (http://www.agronegociose.com.br/agronegocios/coringa.agr?opcao=paginaCoringa&numeroRegistro=14), Banco do brasil 2006-10-17
Agronomic loan to family farmers in Brazil

Statistiska Centralbyrån, http://www.scb.se/templates/tableOrChart____24338.asp, 2006-01-01
Ethanol blend in gasoline in Sweden

Minimum wage, 2006, http://www.planetark.com/dailynewsstory.cfm/newsid/36292/story.htm, 2007-08-20, Minimum wage in Brazil 10th of May 2006

http://abspecplan.com.br,
Information regarding artificial insemination, costs for semen and equipment

Google earth,
http://earth.google.com/ ,
Distance between the cost outside São Paulo and Amsterdam

*Other*
ALBIO, a model created by Stefan Wirsenius, Chalmers

COM 2006, 34 final, An EU strategy for biofuels

EC 2003, European Parliament and Council, Directive on Biofuel for Transport 2003/30/EC, 2003

EC 2007, European Parliament and Council, 2007

FPS, 2006, PROJETO DE SISTEMA DE PRODUÇÃO DE LEITE FAMILIAR, a model created by Ricardo Burgi, (BOVIPLAN CONSULTORIA AGROPECUÁRIA, Piracicaba, Brazil), 2006

# Appendix A. Contracts

**Contracts with the sugarcane industry, Pontal 2006**

The farmers and the ethanol-plant are in a partnership together where the ethanol-plant provides the technology and also acts as guarantor towards the Bank of Brazil in order for the farmer to get started with the plantation. A loan of than 5040 € is given to the settlers. This amount goes directly to the factory that purchases the raw material and normally also caries through the plantation. . The ethanol-plant is guaranteeing security for the loan and also handles amortizations. The settler can chose to do all or some of the work connected to the sugarcane cycle and will then get paid for the work by the ethanol-plant. The extents to which the settler can do this work is often restricted due to limited access to capital The financial payments are made annually and subtracted from the harvest in the following way: the settlers deliver the produced sugarcane to the factory that pays the amortization to the bank with the money from production. What is left after amortization are paid to the settlers in 4 month parcels. The settlements generally do not have any infrastructure for sugarcane production and normally they do not form associations or cooperatives for production. Since the settles do not have the appropriate machines for cultivating sugarcane the factory handles everything.

# Appendix B. Questionnaire

Questions asked to settlers in Pontal during autumn 2006.

Dados da Entrevista /Data about the interview

| a. Nome do entrevistador / Name of the interviewer |
|---|
| |

| b. Data e horário do início da entrevista /Date and place of the interview | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ______/______/_____________ | (dd/mm/aaaa) | Hora início/time of start: | | | hh | | | Mm | (formato 24h) |

| c. Coordenada geográfica /geographic coordinates | | |
|---|---|---|
| Latitude | Longitude | Número do ponto/ number of points |

Localização e município de referência/ localization of the town in question

| a. Município e UF do imóvel/ Town and UF (?) of the property |
|---|
| UF |

| b. Nome do assentamento ou localidade /name of settlement or village |
|---|
| |
| c. Identificação do lote (n°, setor, etc.)/ Identification of the lot (number, sector etc.) |
| |

| d. Município de referência do imóvel/ city reference of the property |
|---|
| Qual é o município de referência, aquele em que você mais vai e utiliza serviços, faz compras e vende produtos?/ To which town do you go for services and to buy and sell products?<br>☐ Mesmo município do imóvel/ the same town the property belongs to |
| ☐ Outro ( Nome do município)/ another town (name of this town): |

| e. Acesso mais usual ao município de referência/ how the reference town is accessed | | | | | | |
|---|---|---|---|---|---|---|
| **Qual é o meio de transporte mais usado por você para ir ao município de referência?/ how do you usually go to the reference city?** Marque somente um tipo de transporte relacionando com o tempo que se gasta para chegar ao município de referência /only mark the transportation that is used to reach the city | | | | | | |
| ☐ Ônibus/ bus | ☐ Carro/ car | ☐ Trator/ tractor | ☐ Moto/ motor cycle? | ☐ Bicicleta / bicycle | ☐ Cavalo/animal /horse or other animal | ☐ A pé/ walking |
| ☐ Outros, qual/ other, what: | | | | | | |

| f. Qual é à distância do município de referência?/ How far is it to the reference town? | | | | Km |
|---|---|---|---|---|

| | | Horas/ houres | | | Minutos/ minutes | **Quanto tempo demora para ir ao município de referência?** (utilizando o meio de transporte assinalado acima)/ **How long time does it take to go to the reference town?** ( using the choice from above) |
|---|---|---|---|---|---|---|

**Perfil do entrevistado/ Profile of the interviewed person**

**a. Nome do entrevistado/ Name of the interviewed**

**b. Idade /Age**

| | |
|---|---|

**c. Escolaridade do entrevistado /Education of the interviewed**

☐ Não lê e não escreve, ou apenas assina o nome /Can not read or write, maybe the signature

☐ Lê e escreve/ Can read and write

☐ Fundamental incomplete/ First grade incomplete

☐ Fundamental em andamento/ In the middle of first grade

☐ Fundamental complete/ First grade completed

☐ Médio incomplete/ Second grade incomplete

☐ Médio em andamento /In the middle of second grade

☐ Médio complete/ Second grade completed

☐ Superior incompleto: Qual ______________________ / Third grade incomplete, what was studied?

☐ Superior em andamento: Qual____________________ In the middle of third grade, what is studied?

☐ Superior completo: Qual______________________ /Third grade completed, what was studied?

☐ Técnico: Qual___________________________ /Expert, on what?

**d. Qual sua posição no imóvel?/ What do you do on the property?**

☐ Proprietário/ Owner

☐ Cônjuge/ husband or wife

☐ Filho do proprietário /child of the owner

☐Outro parente /relative ☐Empregado/ employee ☐Arrendatário/ leaseholder

☐Sócio/ Partner ☐Outros, qual: Other, what

---

**Caracterização socioeconômica da família/ Socioeconomic characterization of the family**

a. **Você possui casa própria na cidade? Do you have a house in the town?** ☐Sim*/ Yes* ☐Não /No

***Quantas?** __________ / How many? ***N° de cômodos?** __________**/ How many rooms?**

***Qual o material de construção?/ Which material is the house built from?**

☐Alvenaria/ Masonry ☐Tábua/ Board (paper or wood?) ☐ Lona/ Canvas (tent?)

☐Alvenaria e tábua/ Masonry and board ☐ Outros, qual:______________________ /Something else, what?

b. **Casa no imóvel.** * House on the property*

***Quantas?** __________(caso tenha mais de uma casa, considerar a casa do titular do lote) /How many? (in case of more houses than one, consider the house of the property holder) ***N° de cômodos?** __________

***Qual o material de construção?**

☐Alvenaria ☐Tábua ☐ Lona

☐Alvenaria e tábua ☐ Outros, qual:______________________

***Presença de acabamento**

☐Bem acabada ☐Semi-acabada ☐Sem acabamento

***Estado de conservação**

☐Bom ☐Médio ☐Ruim

***Cobertura da casa?**

☐ Telhas de barro (sem laje) ☐ Brasilit (cimento amianto) ☐ Laje (sem telhas)

☐ Laje (com telhas) ☐ Lona ☐Outros, qual:_________________________

c. **Possui automóvel?** ☐Sim* ☐Não

***Quantos?** __________ Modelo e ano do mais novo: ________________________________________________

d. **Possui motocicleta?** ☐Sim* ☐Não

***Quantas?** __________ Modelo e ano do mais novo: ________________________________________________

e. **Eletrodomésticos**

| | | | | | |
|---|---|---|---|---|---|
| TV | ☐ Sim* | ☐ Não | *Quantas polegadas:________ | | |
| DVD | ☐ Sim | ☐ Não | Aparelho de som | ☐ Sim | ☐ Não |
| Vídeo cassete | ☐ Sim | ☐ Não | Maquina fotográfica digital | ☐ Sim | ☐ Não |
| Computador | ☐ Sim | ☐ Não | Máquina de lavar roupa | ☐ Sim | ☐ Não |

f. **Número de pessoas da família por faixa etária? (pessoas que moram com a família)**

| | | | |
|---|---|---|---|
| 0 – 4 | | 20 – 24 | |
| 5 – 9 | | 25 – 39 | |
| 10 – 14 | | 40 – 59 | |
| 15 – 19 | | Acima de 60 | |

g. **Quantas pessoas da família trabalham fora do lote?**

| _ | _ | **Onde trabalha**

h. **Quantas pessoas da família são deficientes ou incapacitadas para o trabalho?**

| _ | _ | **O que ela (s) tem:**

**Informações sobre o imóvel**

a. **Área total do imóvel**

| _ | _ | _ | **Hectares** (preencha somente com números inteiros)

b. **Desde que ano você possui esse imóvel?**

| _ | _ | _ | _ | ☐ Não lembra

c. **Qual o órgão responsável pelo assentamento?**

| | | |
|---|---|---|
| ☐ ITESP | ☐ INCRA | ☐ Outros*, *qual:________________________________ |

**Informações sobre a produção do lote**

a. **O que você produziu em sua propriedade nos últimos 3 anos?(prestar atenção nas unidades de área) (considerar as três culturas de maior área para cada ano)**

| | | | | | | |
|---|---|---|---|---|---|---|
| **2004** | Cultura 1: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | ☐ Não produziu nada |
| | Cultura 2: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | ☐ Não produziu nada |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Cultura 3: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | ☐ Não produziu nada |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | |
| 2005 | Cultura 1: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | ☐ Não produziu nada |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | |
| | Cultura 2: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | ☐ Não produziu nada |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | |
| | Cultura 3: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | ☐ Não produziu nada |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | |
| 2006 | Cultura 1: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | ☐ Não produziu nada |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | |
| | Cultura 2: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | ☐ Não produziu nada |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | |
| | Cultura 3: | Área: | | | | ☐ Não lembra |
| | Finalidade: | | | | | ☐ Não produziu nada |
| | Como foi a sua produção? | ☐ Boa | ☐ Média | ☐ Ruim | ☐ Ñ lembra | |

Produção leiteira

**b. ►Quando você começou a ( [1] arrendar suas terras) ou ( [2] produzir cana para a usina)?**

Ano de: | | | | |  ☐ Não lembra

**c. Qual a distância da usina até a sua propriedade?**

| | | | km

| | | | |
|---|---|---|---|
| d. **As propriedades vizinhas a sua também foram arrendadas?** | ☐ Sim* | ☐ Não | ☐ Não sei |
| ***você sabe quais os motivos?** | ☐ Sim** | ☐ Não | |

****Quais?**

| | |
|---|---|
| ☐ Falta de incentivo para a produção | Obs: |
| ☐ **Imóvel com baixa rentabilidade** | |
| ☐ Atrativos oferecidos pela usina * | |
| *quais atrativos | |
| ☐ Falta de aptidão para o trabalho rural | |
| ☐ **Solos inaptos para o sistema de produção que você têm aptidão** | |

| | | | |
|---|---|---|---|
| e. **Você acha que a cana de açúcar é a melhor opção para suas terras?** | ☐ Sim* | ☐ Não* | ☐ Não Sei |

***Por que?**

Evolução do uso de agrotóxicos e produtos químico na área da propriedade

Assistência Técnica

**Renda**

a. ►Quanto você ganha com (*o arrendamento das terras) (**a produção de cana para a usina)?

| | | | |
|---|---|---|---|
| , 0 0 | R$/Mês | , 0 0 | R$/Ano |

b. ²◙ Qual é a sua produção de cana-de-açúcar

| | | | | |
|---|---|---|---|---|
| | Ton/ha | Ou | | Ton/alq |

c. **Renda média (somando todas as rendas e excluindo o consumo da produção)**

**Qual é a renda média da família (sem contar o consumo daquilo que é produzido no imóvel) ?**

Valor em R$/mês ____ , 0 0

d. **Quais as fontes renda (exceto arrendamento de terras ou produção de cana)?**

| | Valor em R$/mês | Valor em R$/ano |
|---|---|---|
| ☐ Venda de leite | , 0 0 | , 0 0 |
| ☐ Venda de novilhos | , 0 0 | , 0 0 |
| ☐ Produção agropecuária (exceto cana e leite e novilhos) | , 0 0 | , 0 0 |
| ☐ Salário | , 0 0 | , 0 0 |
| ☐ Diárias de serviços | , 0 0 | , 0 0 |
| ☐ Auxilio desemprego | , 0 0 | , 0 0 |
| ☐ Aposentadorias | , 0 0 | , 0 0 |
| ☐ Pensões | , 0 0 | , 0 0 |
| ☐ Bolsa escola | , 0 0 | , 0 0 |
| ☐ Bolsa família | , 0 0 | , 0 0 |
| ☐ Bolsa alimentação | , 0 0 | , 0 0 |
| ☐ Prog. De erradicação do trabalho infantil | , 0 0 | , 0 0 |
| ☐ Vale-gás | , 0 0 | , 0 0 |
| ☐ Parcerias de produção (meeiro) | , 0 0 | , 0 0 |
| ☐ Aluguel de máquinas | , 0 0 | , 0 0 |
| ☐ Cesta básica | , 0 0 | , 0 0 |
| ☐ Doações | , 0 0 | , 0 0 |

| | | |
|---|---|---|
| ☐ Venda de produtos não agrícolas | _ _ _ _ _ , 0 0 | _ _ _ _ _ , 0 0 |

☐ Outra*____________________________________________________________

| | |
|---|---|
| e. ►Sua renda em relação à situação anterior ao ( [1]arrendamento do imóvel)( [2] plantio da cana) | |
| **Na média, a renda familiar em relação à situação anterior à entrada da usina em seu imóvel?** | |
| ☐ Melhorou muito | ☐ Piorou |
| ☐ Melhorou | ☐ Piorou muito |
| ☐ Ficou na mesma | ☐ Não sabe |

Contrato (procurar descrever em obs. o tipo de contrado)

| | | |
|---|---|---|
| a. Você tem algum tipo de contrato com a usina? | ☐ Sim* | ☐ Não |

| | |
|---|---|
| *Qual | |
| ☐ De fornecimento | ☐ De parceria |
| ☐ De arrendamento de terras | ☐ Outros** |
| **Outros | |
| | |
| | |

| |
|---|
| b. Quem realiza as atividades necessárias na produção da cana-de-açúcar na sua propriedade? |
| **Quem realiza:** |

| | Família | Usina | Outros (quem) |
|---|---|---|---|
| Cultivo das soqueiras | ☐ | ☐ | ☐ __________ |
| A aplicação de inceticidas | ☐ | ☐ | ☐ __________ |
| A aplicação de herbicidas | ☐ | ☐ | ☐ __________ |
| A reforma e plantio | ☐ | ☐ | ☐ __________ |

| | | | |
|---|---|---|---|
| O corte | ☐ | ☐ | ☐ ______ |
| O carregamento | ☐ | ☐ | ☐ ______ |
| O transporte | ☐ | ☐ | ☐ ______ |

**c. Forma de pagamento adotado pela usina**

| | |
|---|---|
| ☐ Valor fixo especificado no inicio do contrato | ☐ Salário mensal |
| ☐ Por hectare arrendado | ☐ Pela produção, mas não através do sistema consecana |
| ☐ Sistema consecana | ☐ Outros* |
| *Outros | |
| | |
| | |

**d. Tempo de duração do contrato**

☐☐ Ano(s)

Variação do patrimônio

**a. Comparando a situação antes e após a cana.**

►Compare a situação da época em que você começou a ( [1] arrendar) ( [2] produzir cana-de-açúcar para vender a usina) sua propriedade com a de hoje, considerando seus bens.

| Número | | |
|---|---|---|
| Inicial | Atual | Item |
| | | Tratores |
| | | Animais de tração |
| | | Implementos de tração mecanizada |
| | | Implementos de tração animal |
| | | Sistemas de irrigação |
| | | Veículos de transporte de carga (caminhão, caminhonete) |
| | | Bovinos de corte |
| | | Bovinos de leite |
| | | Bovinos mistos |
| | | Ovinos e caprinos |
| | | Pequenos animais (aves, suínos) |
| | | Outro** |

| | |
|---|---|
| Outros (completar) | |
| | |

**Avaliação geral da relação usina – fornecedor**

**a. ◙Como é hoje a relação sua com a usina?**

- ☐ Vantajoso só para a usina
- ☐ Vantajoso para a usina e para o fornecedor
- ☐ Vantajoso principalmente para o fornecedor

Por que?

**b. ◙Quais são os principais problemas que há na relação entre você e a usina?**

- ☐ Não é possível mais produzir outra coisa na propriedade
- ☐ ►Dificuldade de negociação dos contratos de (*arrendamento ou de parceria) (**fornecimento)
- ☐ Depois que cessa a produção de cana a terra não produz mais outra cultura
- ☐ A cana degrada o meio ambiente
- ☐ Dificuldade de receber da usina
- ☐ A usina paga muito pouco
- ☐ Intoxicação de pessoas e/ou animais
- ☐ Outros:

| c. Como você acha que seria sua situação se a usina não tivesse se implantado nessa região? | |
|---|---|
| ☐ Muito Melhor | ☐ Pior |
| ☐ Melhor | ☐ Muito Pior |
| ☐ Mesma Coisa | ☐ Não sabe |

| | | | |
|---|---|---|---|
| **d. Você acha que a usina traz algum benefício para você?** | ☐ Sim* | ☐ Não* | ☐ Não Sei |

* Por que?

**e. Você acha que houve impactos ambientais (como morte de animais silvestres, intoxicação dos solos e da água etc). Após o início do plantio da cana-de-açúcar?**

| | | |
|---|---|---|
| ☐ Sim* | ☐ Não* | ☐ Não Sei |

* Por que?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Hora final:** | | | hh | | | Mm | (formato 24h) |

# Appendix C. Change

Here the costs and incomes regarding the change of cattle used in the CoC model are presented (in €). Also numbers for e.g. mortality and lactation rate are presented in the following tables. Values taken from Burgi (personal communication, October, 2006) and Freitas (personal communication, October, 2006)

| | | |
|---|---|---|
| **nbr of bought MP cattle:** | | **cost per MP cattle (€):** |
| cows | | |
| heifer 2 | 4 | 432 |
| heifer 1 | 8 | 288 |
| | | |
| **nbr of U.A per:** | | |
| cow | 1 | |
| heifer 2 | 0,8 | |
| heifer 1 | 0,6 | |
| female calve | 0,25 | |
| bull | 1,2 | |
| male calve | 0,3 | |
| | | |
| **lactation rate:** | | |
| LP cow | 0,5 | |
| LP H2 | 0,25 | |
| MP cow | 0,8 | |
| MP H2 | 0,25 | |
| | | |
| insemination rate | 0,8 | |
| mortality | 0,98 | |
| share female calves of all newborn calves | 0,5 | |
| natality | 0,8 | |
| price for testing a cow | 3,6 | |
| share of sick cows | 0,1 | |
| | | |
| **Milk production:** | | |
| milk from a LP | 3,6 | |
| milk from a MPmix | 10 | |
| milk from a MP | 12 | |
| | | |
| **income from milk (€)** year 1-3 | 0,1368 | |
| 4-5 | 0,18 | |
| 6- | 0,198 | |
| | | |
| **income from selling:** | € | |
| LP cow | 144 | |
| bull | 180 | |
| LP female calve | 54 | |
| LP male calve | 64,8 | |
| MPmix and MP cow | 147,6 | |
| MPmix and MP heifer 2 | 118,8 | |
| MPmix and MP male calve | 57,6 | |
| sick cow | 108 | |

**Articficial insemination**

| cost per 100 settlers | nbr of | Á (€) | investment cost need maintenance | yearly cost | investment cost, no maintenance |
|---|---|---|---|---|---|
| motor cycles (need maintenance) | 3 | 1080 | 3240 | | |
| education | 4 | 180 | | | 720 |
| computer (need maintenance) | 1 | 720 | 720 | | |
| printer (need maintenance) | 1 | 144 | 144 | | |
| telephone (need maintenance) | 1 | 720 | 720 | | |
| house (need maintenance) | 1 | 1800 | 1800 | | |
| desks (need maintenance) | 4 | 72 | 288 | | |
| chairs (need maintenance) | 4 | 18 | 72 | | |
| desconador de semen (new every 5th year) | 5 | 275,4 | 1377 | | |
| bag for visits (new every 5th year) | 5 | 16,2 | 81 | | |
| butilion (need maintenance) | 1 | 1134 | 1134 | | |
| superior tehcnichian (yearly cost) | 1 | 10800 | | 10800 | |
| technichian in farming (yearly cost) | 4 | 4045,5 | | 16182 | |
| fuel (yearly cost) | | 2160 | | 2160 | |
| phone bill (yearly cost) | | 259,2 | | 259,2 | |

| cost for settlers (abspecplan.com.br) | | yearly cost | cost per insemination |
|---|---|---|---|
| liquid nitrogen (yearly cost) | 67,32 | 67,32 | |
| thermometer (yearly cost) | 16,2 | 16,2 | |
| semen (per insemination) | 14,4 | | 14,4 |
| gloves (per insemination) | 0,252 | | 0,252 |
| applicator (yearly cost) | 29,16 | 29,16 | |
| tweezers (yearly cost) | 8,28 | 8,28 | |
| pipette (per insemination) | 0,92 | | 0,9216 |
| maintenance costs (of invetsment cost) | 10% | | |

| | |
|---|---|
| **Feed (full ratio)** | |
| *MP and MPmix cow and heifer 2* | |
| kg feed per day | 23 |
| days per year | 180 |
| price for feed €/day | 1,224 |
| *MP and MPmix heifer 1 and female calve* | |
| kg feed per day | 2 |
| days per year | 150 |
| price for feed €/day | 0,216 |
| **Milk system** | |
| price for freezer (€) | 7200 |
| capacity (litres of milk per day) | 2000 |
| maintenance costs (of invetsment cost) | 10% |
| **The loan** | |
| size (€) | 6480 |
| interest | 1,03 |
| payback time (years) | 5 |
| payback max time (years) | 8 |

# Appendix D. Income and Expense

Incomes

A short explanation and discussion of each major source of income is given in the following paragraphs.

Selling milk

The milk price will increase during the transition 0,14 to 0,2 €/litre (for exact price changes see appendix C, Change). This quite large growth in price is caused by two things. First, more milk is assumed to be produced in the area and this larger scale will motivate a higher price. Second the treatment of the milk will improve with the investments in refrigerators, which also will generate a higher price. 0.38 is the price given for milk in Pontal today and 0.55 is given to well-managed small scale farms in the state of Sao Paulo.

Selling cattle

Just before the transition period, all cows will be tested for disease. This is done to maximize the chances of successful inseminations later on and also to decrease risk of transmission of diseases. 10% of the cows are assumed to be sick and immediately sold. In the first year the cows that are six and seven years old are also sold in order to make room for the new MP heifers. From the second year of transition cows that reach their eight year are sold. The price for selling of the MP cows was assumed to be only slightly higher than the price for LP cows to make the analysis more conservative (for exact prices see appendix C, Change). The male calves are always sold as soon as they are born (for exact prices see appendix C, Change). In the tenth year when the number of milk producing animals has doubled some of the H2 are sold before insemination. This is done to stabilise the model.

The loan

A loan of maximum 6480 € can be taken. The loan has the intension of gain rural agricultural development and is provided by Brazilian bank “Banco do Brasil”. The loan is given with an interest of 3 % and has to be repaid within eight years (Pronaf). The capital will be used in the first two years to cover investment cost in cattle, full ratio feed, artificial inseminations, change in pasture management and refrigerators.

Expenses

Short explanation and discussion of each major source of expense is given in the following paragraphs.

Amortization

Amortizations of the loan are annualized and made from the third to the eight year of the transition period.

Artificial insemination

Changing the livestock can be done in at least two different ways. Either the livestock could be exchanged by an immediate process of buying and selling or the change could take place with a more time consuming process of artificial insemination. In this model transition is made through artificial inseminations when the longer transition period is compensated by the fact that it is considerably less expensive (R. Burgi, personal communication, October, 2006).

*Associations*
The service of having someone performing the artificial inseminations can be bought from different companies (this is the case in the change model made by Ricardo Burgi). But in this model technicians employed by associations within the settlements will perform the artificial inseminations. These associations will be created during the first year and groups consisting of 100 settlers will form an association. Creations of associations are encouraged by the local MST (F. Freitas, personal communication, October, 2006) and would also create local jobs within the settlements. The associations will handle the artificial inseminations and take care of within the settlements concerning cattle and pasture management. External education for the employees of the associations is also taken into account in the model.

*Costs regarding the associations and artificial inseminations*
Investments regarding the associations are made in the first year, starting by building a head quarter for the technicians. One house will be constructed for each association. Four desks, four chairs, one computer and one printer will be bought to the house. One telephone will be installed and three motorcycles will be bought for the technicians to use when they go around performing the inseminations and education. One technician and four technicians in farming will be employed during the second year and they will perform educations within associations on how to perform inseminations. This will take place four times. Instruments and tools used when performing artificial inseminations are listed in Appendix C, Change. In the model the costs are annualized. Every year the members of the associations will split the cost for the salary for the superior technician and the four technicians in farming. They will also divide the cost for fuel to the motor cycles and the phone bill.

All cows up to the age of seven years will be inseminated. All H2 will be inseminated up to year ten of the transition, after that only five H2 will be inseminated per year, the rest will be sold.

Each year the members of the associations share costs not directly connected to each number of inseminations, such as cost for fluid nitrogen, thermometer etc. Cost directly connected to number of inseminations, like gloves, seamen and pipettes, are paid by each settler. These costs are all specified in Appendix C, Change.

Full ratio feed
During the transition period, the typical settler will double their amount of milk producing cattle at the same time as 30 % of the farmers land will be allocated for sugarcane. Only 50 % of the land will be used for pasture. In addition to this the MP cattle requires more feed than the present LP cattle. To meet the increased demand of feed, fertilizers are used on the pasture to increase its productivity. This will increase the capacity of the pasture to holding 5-6 U.A. per during the summer, which is approximately 200 days of the year.

To feed the cattle during the winter and to provide nutritional supplements to the MP cows, required to make them produce 12 litres of milk per day, additional feed is needed. The full ratio feed made from sugarcane residues is a full good supplement for the MP cattle (R. Burgi, personal communication, October, 2006). The cows and the MP H2 were given 23 kg/day during 180 days each year and the younger animals were given 2 kg each day during 150 days each year. The LP cattle would not increase their milk production if given the full ratio feed and therefore only fed by grazing. Costs are provided in Appendix C, Change.

Pasture care

In order to get as good pasture as possible it needs to lie fallow for a month when the livestock have eaten from it (F. Freitas, personal communication, October, 2006). The pasture will be split into five pieces and the livestock is assumed to be moved around on the pieces. When cattle are allowed on large areas they tend to only graze what they prefer and therefore it is easier for bushes and other grass-sorts to grow on the pasture. When the cattle are kept on smaller areas they eat everything more even and when the pasture is left in fallow the preferred grass can re-grow (S.Wirsenius, Personal communication, January, 2007). The costs of this pasture management and the costs for fertilizers are taken from a model constructed by Ricardo Burgi (FPS). The four first years the pasture is not fertilized but after that fertilizers are applied on 2 ha each year.

Refrigerators

At present in Pontal the milk is stored in buckets until it is sold (F. Freitas, personal communication, October, 2006). A task within the associations will be the investment in milk refrigerators and management of centralised milk storage. The milk gets a higher quality when it is kept cool and the price per litre of milk will increase. Each refrigerator can store 2 000 litres of milk per day. The total milk produced within each association was calculated and then the number of needed refrigerators was planned using this value. The cost are annualized and shared among the 100 settlers in each association. Costs are specified in Appendix C, Change.

Buying cattle

The first year is the only year when cattle will be bought. Four H2 that immediately can be inseminated and eight H1 are bought. The H1 can be bought at a price of 2/3 the price for H2. The settlers lack investment capital and because of this, more H1 than H2 are bought in order to minimize expenses.

# Appendix E. GHGE model

Presenting all assumptions and calculations connected to the GHGE model.

### Energy calculations

**Table E1** Net energy balance.

| | Input (kcal/TC) | Output (kcal/TC) |
|---|---|---|
| Sugarcane production * | 45 861 | |
| Ethanol production * | 9 510 | |
| Ethanol produced | | Ep |
| Surplus bagasse | | Sb |
| Transport to EU | T | |
| TOTAL | totI | totO |
| Output/Input | totO/totI | |

* ( de Carvalho Macedo, et al, 2003)

Density of ethanol: 0,789 ton/m3 = x1
Ethanol per Ton of sugarCane (TC): 0,09 m3/TC = y1
Energy requirements for transport: 0,216 kJ/kg,km = x3 (Bauman H., Tillman A-M.2004)
Distance: 10 000 km = y3
Lower heating value of ethanol: 26,7 GJ/ton = z1
Lower heating value of bagasse: 1800 kcal/kg = z2
Surplus bagasse per TC: 42 kg / TC = x2
Electricity conversion factor: 0,35 = y2
1 kcal = 4,184 kJ

ep = x1*y1*z1/4,184*10^-6
sb = z2*x2*y2
t = x3* y3*x1*1000*y1/4,184

In sugarcane milling an average of 280 kg bagasse/TC with 50 % moisture content, 50 % dry matter and the lower heating value (LVH) of 1800 kcal/ kg is produced (de Carvalho Macedo, et al, 2003). It is probable that in a future oriented scenario the ethanol-plant would utilize the bagasse for power production. The ethanol-plant requires 85 % of the produced bagasse for domestic needs of heat and electricity (de Carvalho Macedo, et al, 2003). This leaves 15 % of surplus bagasse. The bagasse requirement for the full ratio feed is annually 4140 kg/UA.

## GHG emission calculations

**Table E2** Emissions connected to the ethanol life cycle. Model taken from de Carvalho Macedo, et al, 2003.

| Type | kg $CO_2$ eq. /TC | |
|---|---|---|
| Fossil fuels | $F_i$ | |
| Methane and N2O from trash burning | $M_i$ | |
| Soil N2O * | 6,3 | |
| Transport to EU | T | |
| Avoided emissions | | |
| Surplus bagasse use | SB | |
| Ethanol use (EU) | Eu | |

* ( de Carvalho Macedo, et al, 2003)

**Table E3** Emissions connected to land use change.

| Type | kg CO2 eq. /year |
|---|---|
| Changed emissions from cattle | $CC_i$ |
| Emissions from land transformation | $LT_i$ |

Index indicate year: i = 1,2,…,25

Number of produced ton sugarcane each year (TC/year): $X_i$ (For calculations see 2.8.)

This gives annual avoided emissions ($AE_i$) (kg CO2 eq./year):
$(SB+EU-F_i-M_i-6,3-T)*X_i-CC_i-LT_i=AE_i$

### *Transport to EU (T)*

Distance (D), km: 10 000
Emissions from ship (E), g CO2/kg,km: 0,0154 g (Bauman H., Tillman A-M.2004)
Density of ethanol (DE), kg/litre: 0,789
Production efficiency (PE) litres/TC: 90 (de Carvalho Macedo, et al, 2003).

This gives, (g CO2 /TC): E*D*DE*PE = T

Transport from mill to port in Santos, Brazil.
Average distance: 800 km
Truck with draw bar: (Bauman H., Tillman A-M.2004)
Energy: 0.65 MJ/tkm
CO2: 48 g/tkm

### *Fossil fuels (F)*

Total emissions from using fossil fuels in the production of sugarcane ethanol today is 17,7 kg CO2 eq. /TC (de Carvalho Macedo, et al, 2003) and a part the emissions included comes from the process of harvesting sugarcane. 17,7 is based on a harvesting mix of 35 % mechanical harvest (ME) and 65 % manual harvest (MA). The different harvesting methods do not give rise to an equal amount of fossil fuel emissions. To be able to this assumptions have to be made about harvesting mix. ME and MA were calculated for year 2008 to year 2032. Index indicates year one to 25. Methods for calculating the harvesting mix is presented in 2.10.

de Carvalho Macedo, et al, uses equation (1) for calculating the annual diesel consumption (Cac) in agricultural operations and in harvesting.

(1) $Cac\ (l/TC) = (1/Y) *0,83*(ME_i*(Ccc+Ctr)+MA_i*(Ccm+(2/3)*Ctr)$

**Table E4**

| | |
|---|---|
| Y= annual sugarcane yield | 68,7 TC/ha.year * |
| Ccc = consumption in mechanical harvest | 74 l/ha * |
| Ctr = tractor hauler consumption | 12,7 l/ha * |
| Ccm = consumption in manual harvest | 21,2 l/ha * |

* (de Carvalho Macedo, et. al, 2003)

Total C emissions from diesel, kgC/m3: 908
This was assumed to only give rise to $CO_2$: 1 kg C → (44/12) kg $CO_2$
This gives emission from diesel, ED: 908*44/12 kg $CO_2$ /m3 diesel = 0,908*44/12 kg $CO_2$/l diesel.
This gives emissions from fossil fuels, (kg $CO_2$ eq./ TC):

$$17,7 + (1/Y) *0,83*((ME_i-0,35)*(Ccc+Ctr)+(MA_i-0,65)*(Ccm+(2/3)*Ctr))*ED = F_i$$

Index i, indicates year one to 25.

***Methane and N2O from trash burning (M)***

When the sugarcane leaves are being burned before harvest methane and $N_2O$ are emitted. de Carvalho Macedo, et al, suggests 9,0 kg $CO_2$ eq. /TC. This is calculated in the article for an assumption of harvest management with 80 % burning (B) and 20 % non-burning (NB). For calculating emissions when burning is phased out assumptions had to be made considering the velocity of phase out in Pontal. This is calculated in ***Land transformation.***

Methane and $N_2O$ from trash burning, (kg $CO_2$ eq. /TC): $(9/0,8)*B_i = M_i$
Index i, indicates year one to 25.

***Surplus bagasse (SB)***

In sugarcane milling an average of 280 kg bagasse/TC with 50 % moisture content and 50 % dry matter is produced. The surplus is 15 % and the lower heating value (LVH) is 1800 kcal/ kg of the bagasse (de Carvalho Macedo, et al, 2003).
1 kcal = 4,184 kJ

This gives; (kg surplus bagasse/ TC): 280 *0,15 = 42
( kJ /TC): 1800*4,184*42 = 316310,4
Electricity, produced from bagasse with an efficiency of 35 %.
This gives surplus bagasse electricity, SBE: (MJ electricity /TC): 0,35*316,3104

**Table E5** 1 TJ net electricity from oil (Bauman, 2004)

| GHG outputs to air | Kg | GWP (100 years) | CO2 eq. kg |
|---|---|---|---|
| CO2 | 229380 | 1 | 229280 |
| CH4 | 307 | 21 | 6447 |
| N20 | 5,53 | 310 | 1714,3 |
| Total | | | 237441,3 |

Avoided emissions due to surplus bagasse use, (kg $CO_2$ eq. /TC): 237441,3*10^-6*SBE = 26,29 = SB

The sugarcane scenario:
All the surplus bagasse was used for production of electricity, replacing oil on the margin.
This gives avoided emissions per year from surplus bagasse, kg $CO_2$ eq. /year: $SB*X_i$

The integrated production scenario:
A part of the surplus bagasse is used in the production of the full ratio feed the rest was used to produce electricity that replaces oil on the margin.
This gives avoided emissions per year from surplus bagasse: SB*( $X_i$ – $CF_i$)/year,
where $CF_i$ is the amount of sugarcane required for producing the necessary amount of full ratio feed.

CF
Annual requirement of bagasse for full ratio feed, ton/farmer: 103,5
Number of farmers cultivating sugarcane: 4100*y, y=year=1,2,…,25
Annual requirement of bagasse for full ratio feed, ton: 103,5*4100*y, y=year=1,2,…,25

*Ethanol use (EU)*
Ethanol is assumed to have a LHV that is 66% of LHV of gasoline.
Production efficiency ethanol (PE): 90 litres ethanol/TC (de Carvalho Macedo, et al, 2003).
This gives that 90*0,66 litres of gasoline is replaced per TC.
Emitted CO2 from gasoline (kg CO2/l gasoline): 2,4
This gives, EU (kg CO2/TC): 90*0,66*2,4

*Number of ha and ton sugarcane*
The sugarcane expansion in Pontal is assumed to be linear and taking place during 25 years in both scenarios.
Expansion area, the sugarcane scenario, ha: 546 400
Expansion area, the integrated production scenario, ha: 509 400

Every ha has an average yield of 68,7 TC/year (de Carvalho Macedo, et al, 2003).
This gives number of TC/year:
The sugarcane scenario: (546 400/25)*68,7*year X; where X=1, 2,…, 25
The integrated production scenario: (509 400/25)*68,7*year X; where X=1, 2,…, 25

***Land transformation***

Expanded area, (EA) ha:

The sugarcane scenario: (546 400/25)*X,  X=1,2,…,25

The integrated production scenario: (509 400/25)*X,  X=1,2,…,25

$Y_i = EA_x * B_i$ ; $B_i$ see 2.10.

$Z_i = Y_{i+1} - Y_i$ ; i=0 → 0; i=1,2,…,25

| i | Burning (ha) $Y_i$ | Expanded area (ha)(burning) $Z_i$ |
|---|---|---|
| 2008 | 16097,04 | 16097,04 |
| 2009 | 30462,12 | 14365,08 |
| 2010 | 43095,24 | 12633,12 |
| 2011 | 53996,4 | 10901,16 |
| 2012 | 63165,6 | 9169,2 |
| 2013 | 69930,432 | 6764,832 |
| 2014 | 74739,168 | 4808,736 |
| 2015 | 77591,808 | 2852,64 |
| 2016 | 78488,352 | 896,544 |
| 2017 | 77428,8 | -1059,552 |
| 2018 | 77551,056 | 122,256 |
| 2019 | 76287,744 | -1263,312 |
| 2020 | 73638,864 | -2648,88 |
| 2021 | 69604,416 | -4034,448 |
| 2022 | 64184,4 | -5420,016 |
| 2023 | 64551,168 | 366,768 |
| 2024 | 64428,912 | -122,256 |
| 2025 | 63817,632 | -611,28 |
| 2026 | 62717,328 | -1100,304 |
| 2027 | 61128 | -1589,328 |
| 2028 | 51347,52 | -9780,48 |
| 2029 | 40344,48 | -11003,04 |
| 2030 | 28118,88 | -12225,6 |
| 2031 | 0 | -13448,16 |
| 2032 | 0 | -14670,72 |

Emissions 1st cycle: 7,5 t C/ha

Emissions 2nd cycle: 6,4 t C/ha

Emissions 3d cycle: 5,4 t C/ha

Emissions 4th cycle: 4,6 t C/ha

Emissions 5t cycle: 3,9 t C/ha

***Harvesting management***

70 % of expansion area was assumed to follow the stricter regulation and 30 % the looser.

Burning (B) is equal to Manual harvest (MA)

B = S*0,7+L*0,3

NB=1-B

| Year | Strict regulation (S) | Loose regulation (L) | Burning ($B_i$) | Non-burning (NB) |
|---|---|---|---|---|
| 2008 | 0,7 | 1 | 79,0% | 21,0% |
| 2009 | | | 74,8% | 25,3% |

| | | | | |
|---|---|---|---|---|
| 2010 | | | 70,5% | 29,5% |
| 2011 | | | 66,3% | 33,8% |
| 2012 | 0,5 | 0,9 | 62,0% | 38,0% |
| 2013 | | | 57,2% | 42,8% |
| 2014 | | | 52,4% | 47,6% |
| 2015 | | | 47,6% | 52,4% |
| 2016 | | | 42,8% | 57,2% |
| 2017 | 0,2 | 0,8 | 38,0% | 62,0% |
| 2018 | | | 34,6% | 65,4% |
| 2019 | | | 31,2% | 68,8% |
| 2020 | | | 27,8% | 72,2% |
| 2021 | | | 24,4% | 75,6% |
| 2022 | 0 | 0,7 | 21,0% | 79,0% |
| 2023 | | | 19,8% | 80,2% |
| 2024 | | | 18,6% | 81,4% |
| 2025 | | | 17,4% | 82,6% |
| 2026 | | | 16,2% | 83,8% |
| 2027 | 0 | 0,5 | 15,0% | 85,0% |
| 2028 | | | 12,0% | 88,0% |
| 2029 | | | 9,0% | 91,0% |
| 2030 | | | 6,0% | 94,0% |
| 2031 | | | 3,0% | 97,0% |
| 2032 | 0 | 0 | 0,0% | 100,0% |

# Appendix F. The sugarcane cycle

The sugarcane is neither an annual nor a perennial plant but is cultivated in four to eight year cycles. First seed canes of sugarcane is grown and planted in the sugarcane fields. This plant will be harvested for the first time after 12-18 months. After harvest the plant produces a new stalk, called ratoon, and the plant is harvested again after 12 months. The re-growth from the ratoon usually produces a smaller yield. One cycle contains of 4-6 harvests and then there is a reform, preparation of the land before next cycle, and new seed canes are planted. Tilting during the reform gives losses of C in the soils.

As a generalization there are two types of sugarcane harvests. The manual cutting of sugarcane which is preceded by burning (burning) and the mechanical harvesting, not preceded by burning (non-burning). When sugarcane is cut manually the fields are burned to get rid of the dry matter/residues/leaves in order to make it easier for the workers to cut. This timesaving by burning first reduces the price of harvest with approximately one third and improved the safety for the workers considering snakes and cuts from the dry matter. When sugarcane is harvested mechanically the residues are separated from the sugarcane and left on the ground to decompose.

Production of sugarcane

Today the most common way of producing sugarcane in the settlements in Pontal is that the settlers takes care of the basic steps in the production and the ethanol-plant handles the rest, typically the ethanol-plant handles the parts where machinery and chemicals are needed. It is possible for the settlers to handle all the steps in the production but it is not common. To be able to do everything the settler will need a lot of tools, chemicals and a tractor, most of the settlers today do not have these kinds of resources. It is possible for the ethanol-plant to handle all the steps but this is not common either (G. Sparovek, personal communication, September, 2006). If the ethanol-plant does all the steps the settler will make less money and so they are assumed to perform the steps they are able to do.

Burning

When fields are burned before harvest there is a loss of quality in the sugarcane. Still it is cheaper to cut sugarcane manually than mechanically (Sparovek, 2006). The manual cutting of sugarcane is a very physically hard job. Sugarcane workers usually manage to work only around eight years with cutting. Manual cutting is on the verge to a phase out, mainly due to health considerations. The burning is creating ash that gives rise to major health problems in sugarcane areas. Manual cutting of sugarcane creates a lot of jobs in Brazil and this is the reason to why it is not forbidden at once. An abrupt phase out would create massive unemployment.

Non-burning

When sugarcane is harvested mechanically the residues are left on the ground. The residues are decomposed and this management is contributing to increasing the C content in the soil. During reform when the soil is being tilted C is lost from the soil and with non-burning management it is possible to make up for the losses made during reform (C. Cerri, personal communication, November, 2006). One problem with mechanical harvest is that it, at present, is impossible to harvest sugarcane that grows on land steeper than 12%.

Sugarcane products

A lot of different by-products arise from the sugarcane when sugar and or ethanol are produced (Figure A). Depending on the end-of-line product that is produced the amounts of the different by-products vary.

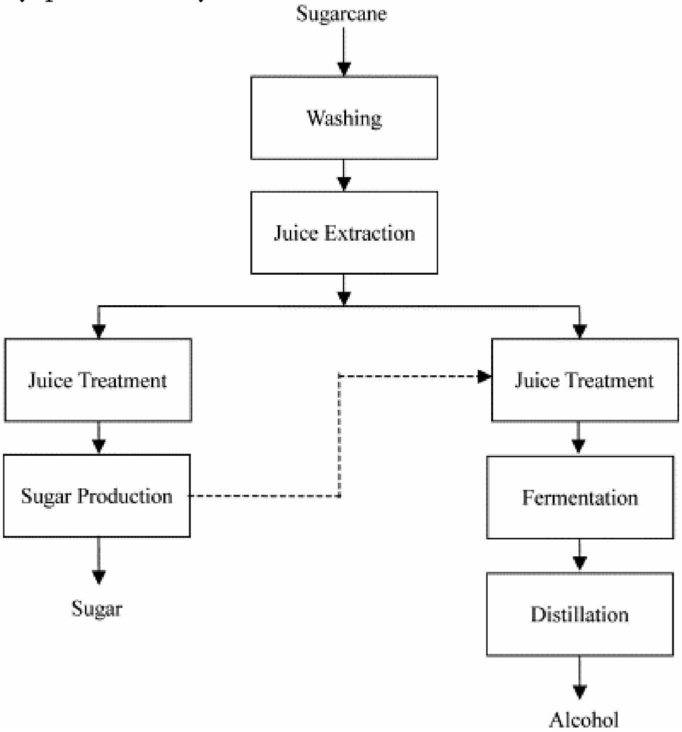



**Figure F1** The sugarcane flow

Sugar

Ethanol –two forms of ethanol are produced in the Brazilian sugarcane industry, anhydrous and hydrous ethanol. Anhydrous ethanol is close to pure alcohol and used as blend-in in gasoline. Hydrous ethanol contains approximately 5 % water and is used directly as fuel in Brasil (and elsewhere?).

Filtercake –industrial residue from sugar production. The filtercake contains several nutrients and is therefore used on the sugarcane fields when the seed cane is planted.

Vinasse –liquid industrial residue from the molasses' fermentation in the alcohol production. Also this is rich in nutrients and used as a fertilizer.

Bagasse –fibre residue left over from when the juice is pressed out of the sugarcane. The bagasse is used for providing needed electricity and heat at the ethanol-plant. The surplus bagasse can be used for producing additional electricity for the grid or sold to other industries.

# Appendix G, Harvest management

Sensitivity analysis of C losses from soil.

Figure G1 and G2 show emissions from land transformation with the assumption that a new equilibrium is reached, 20 % or 40 % below present soil C stock.

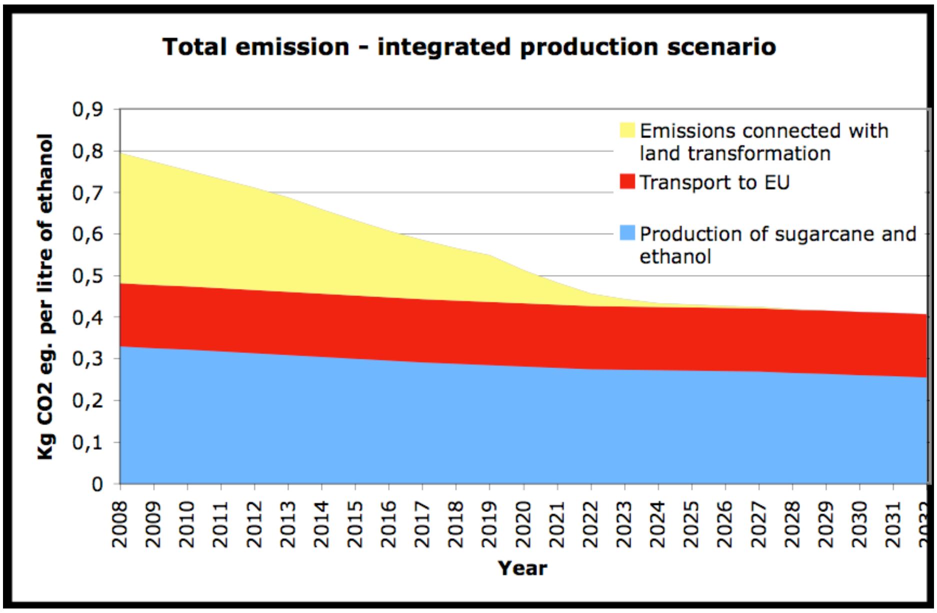



**Figure G1** New soil C eq. 20 % below present

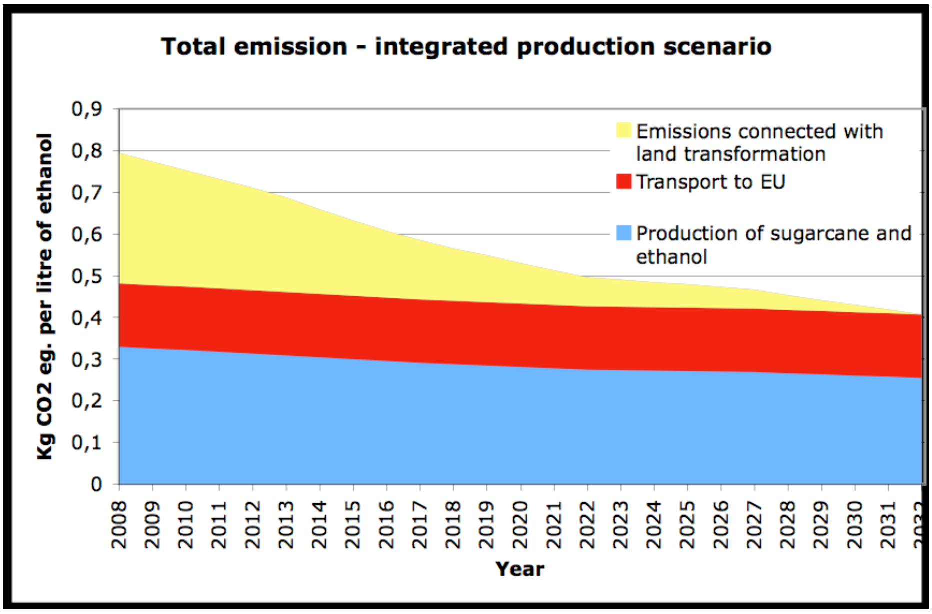



**Figure CG2** New soil C eq. 40 % below present

Figure G3 and G4 illustrates the emissions if all the area would follow the strict and the loose regulations respectively.

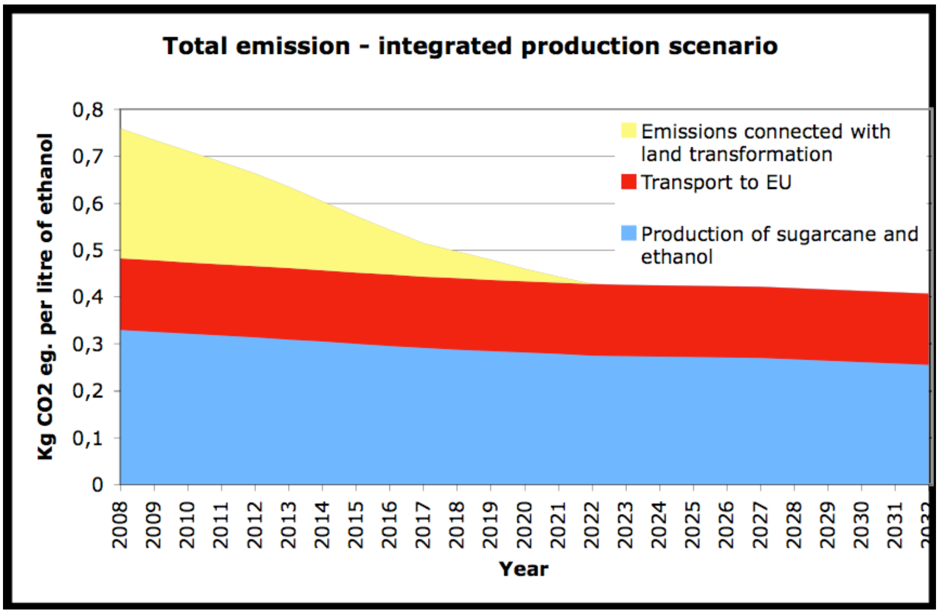



**Figure G3** Expansion following strict regulation

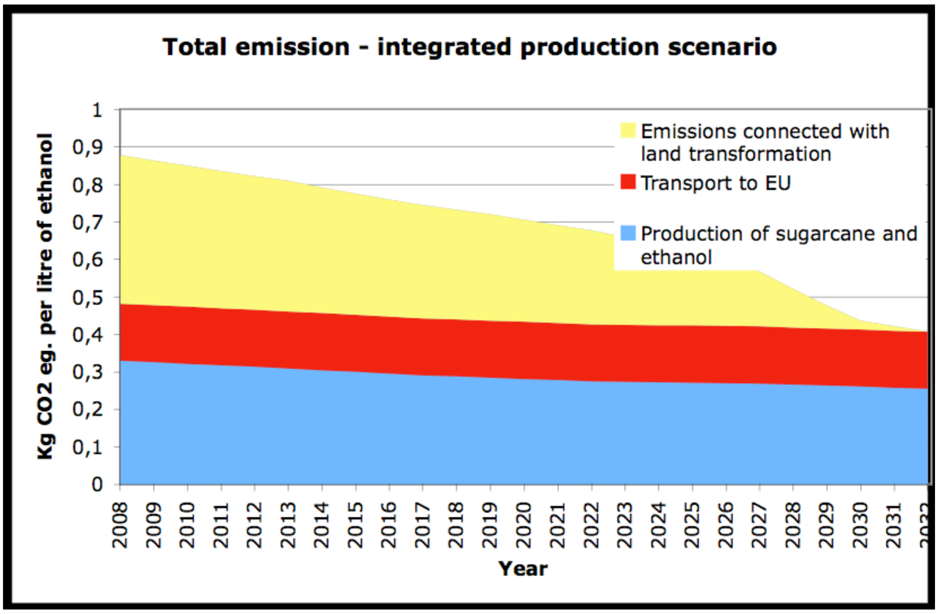



**Figure G4** Expansion following loose regulation

Figure G5 illustrates what could happen if C levels in the soil increase when burning practice is changed to non-burning practise. Eventually all lost soil C would be brought back to the soil.

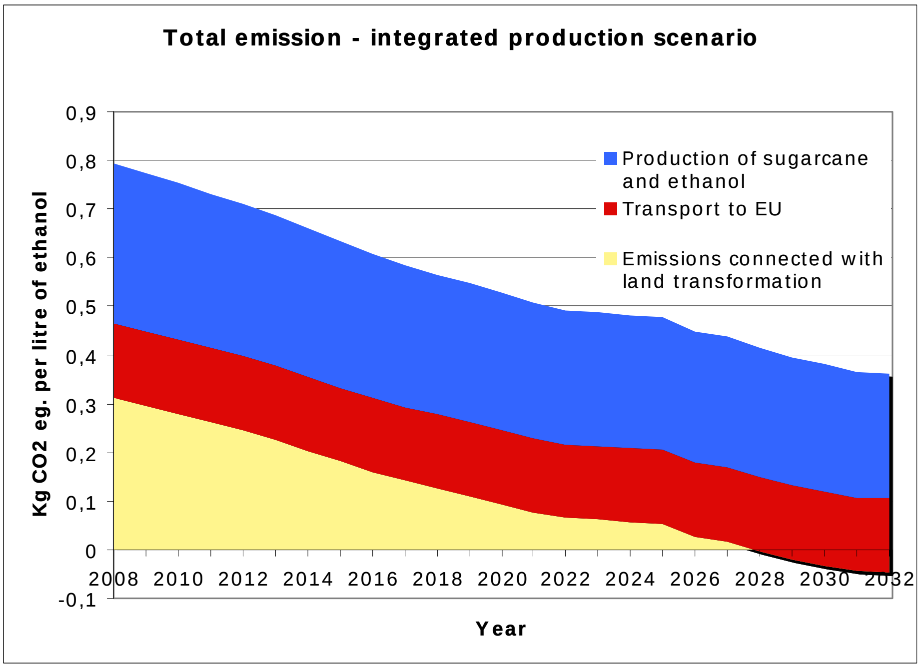



**Figure G5** Change of harvest method will be able to raise C stock to original level.