REGIONAL DIFFERENCES OF COFFEE CULTIVATION IN BRAZIL

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ABSTRACT: Brazil is one of the major coffee producers in the world, because of this, the goal of this study was to assess the regional differences of coffee cultivation for the reference crops 2001/2002 and 2002/03 by means of a life cycle assessment (LCA) in order to generate detailed production inventory data as well as quantify the potential environmental impacts of this crop. All information considered in this study (use of water, fossil based energy, fertilizers, pesticides and correctives) was taken from data collected from the producing farms. Four Brazilian coffee producer regions located at the Southeastern region were evaluated: Sul de Minas Gerais and Cerrado Mineiro in Minas Gerais State, and Mogiana and Alta Paulista regions in São Paulo State. The data refer to a production of 25.2 million kg of green coffee. Depending on the considered region, the production of 1,000 kg of green coffee requires, on average, approx. 9,300 to 13,000 kg of total energy, 70 to 130 kg of diesel, 6,500 to 12,700 kg of process water, 270 to 340 kg of fertilizers (NPK), 2.0 to 13.0 kg of pesticides, 230 to 600 kg of correctives, and yield around 1,600 to 1,900 kg/ha. Despite 20% of the coffee growers showing a good environmental performance, i.e. consumption of pesticides, fertilizers and correctives lower than the regional averages, this study has also identified some farms that can probably reduce the amount of some inputs and enhance their environmental performance.

Key words: Coffee, tropical product, LCA, ecolabelling, Brazilian farms.

DIFERENÇAS REGIONAIS DO CULTIVO DE CAFÉ NO BRASIL

RESUMO: *O Brasil é um dos maiores produtores mundiais de café. Assim, objetivou-se, neste estudo avaliar as diferenças regionais do cultivo de café das safras de 2001/02 e 2002/03 por meio da avaliação do ciclo de vida (ACV) com a finalidade de gerar um inventário de dados de produção detalhado, bem como quantificar o impacto ambiental potencial desse cultivo. Todas as informações consideradas nesse estudo (uso de água, energia de fonte fóssil, fertilizantes, pesticidas e corretivos) foram obtidas por meio de coleta de dados nas fazendas produtoras. Foram avaliadas quatro regiões brasileiras produtoras de café localizadas na região sudeste: Sul de Minas e Cerrado Mineiro, no estado de Minas Gerais e Mogiana e Alta Paulista no estado de São Paulo. Os dados referem-se à produção de 25,2 milhões de kg de café verde. Dependendo da região considerada, a produção de 1.000 kg de café verde requer, na média, cerca de 9.300 a 13.000 kg de energia total, 70 a 130 kg de diesel, 6.500 a 12.700 kg de água de processo, 270 a 340 kg de fertilizantes (NPK), 2,0 a 13,0 kg de pesticidas, 230 a 600 kg de corretivos e têm um rendimento de 1.600 a 1.900 kg/ha. Apesar de 20% dos produtores de café terem apresentado um bom desempenho ambiental, i.e. consumo de pesticidas, fertilizantes e corretivos inferior aos valores médios regionais, esse estudo também identificou algumas fazendas que, provavelmente, podem reduzir o consumo de alguns insumos e melhorar seu desempenho ambiental.*

Palavras-chave: Café, produto tropical, ACV, rotulagem ambiental, fazendas brasileiras.

1 INTRODUCTION

Coffee is one of the largest consumed internationally traded commodities. Approximately sixty countries produce coffee in the world. Brazil and Colombia together command approximately half of the world market, while the remaining countries have small market shares. In 2006, Brazil produced 2.6 million tons of coffee in a total cultivated area of 2.32 million hectares, obtaining an average yield of 1,115 kg/hectare. Brazil is also a great consumer of coffee, having consumed approx. 40% of its production in this same year (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE, 2007).

In 2005, three states produced approx. 92% of green coffee exported by Brazil: Minas Gerais (71%),

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São Paulo (11%) and Espírito Santo (10%). Coffee is also produced in smaller amount in the states of Paraná and Bahia (BRASIL, 2006).

1 Specific requirements of coffee cultivation

1.1 Fertilizers

Coffee plants have high N and K requirements (CATANI et al., 1967; CATANI; MORAES, 1958; CORREA; GARCIA; COSTA, 1983; MALAVOLTA et al., 1963). There is a close relationship among nitrogen supply, number of leaves and number of bud (DIERENDONCK, 1959). Whereas adequate tissue N levels are favorable for starch and other carbohydrate production needed for fruit formation and growth, in deficient plants symptoms develop particularly during the berries grow (MALAVOLTA, 1986).

Potassium also plays a major role in coffee plant physiology especially during fruit growth and maturation. The K quantity exported at harvest exceeds that of N, which helps to explain why it can become limited after a few years (MITCHELL, 1988). A good correlation exists between the K status, as measured by leaf content, and stored starch and yield. When tissue K is adequate the proportion of floats and branches with symptoms of overbearing decreases (LIMA; MALAVOLTA, 2003).

1.2 Pesticides

The correct and appropriate safe use of pesticides is a topic of great attention. It has important implications for three basic areas in the general context of agricultural sustainability: preservation of the environment, health and safety of farmers, and food safety. Pesticides are necessary to control the main coffee pests: cicada, coffee berry borer – CBB, leaf miner and rust, the main disease. Plagues and diseases can cause losses of up to 30% in the production of the coffee grain (ALMEIDA et al., 2003). The *Xylella fastidiosa* bacterium causes problems to coffee cultivation because of a relationship with various stress factors, leading to reduction on coffee production by decreasing fruit number and size, as well as senescence of branch (QUEIROZ-VOLTAN et al., 2005).

1.3 Soil Correctives

Limestone is the most usual Ca and Mg source. These elements have a significant participation in the coffee grain composition besides their use for correction of the soil acidity.

2 Main Brazilian Coffee Growing Regions

Four Brazilian coffee producer regions were evaluated in this study: Sul de Minas Gerais and Cerrado Mineiro regions in Minas Gerais State (MG), Alta Paulista and Mogiana regions in São Paulo State (SP). There are several differences in all the production aspects among them as size of the coffee production areas, edafoclimatic differences, cultivated varieties, adopted spacer, crop management, local topography and processing technology conditions (AGUIAR et al., 2001; FAZUOLI et al., 1999; IGREJA; BLISKA, 2002; VERDADE et al., 1996).

2.1 Sul de Minas Gerais Region

The Sul de Minas Gerais is the largest area producing coffee in Brazil, responsible for 25% of all national production and approx. 80% of the production of Minas Gerais State. It is a traditional coffee plantation area, which has being cultivating coffee since 1870, being the unique region that never abandoned this crop. The mountainous relief is ideal for the production of coffee, with altitude that varies from 900 to 1300 m and an annual average temperature between 22 and 24ºC. The coffees of this area stand out due to their fruity aroma and notable acidity, producing an excellent drink.

2.2 Cerrado Mineiro Region

The Cerrado Mineiro is an ideal area for cultivation of natural and special coffees. The plantation areas are located in altitudes above 1,100 m, with Xanthic soil predominance, with annual medium temperatures of 19ºC, with well-defined rain periods. The sun drying in yards is favorable for this area, being a method that allows the migration of the sugars from the pulp to the grain, providing a more sweetened drink. The coffee of the Cerrado Mineiro has chocolate aroma, with medium body and medium acidity.

2.3 Alta Paulista Region

The Alta Paulista region has approximately 1,300 coffee producing properties divided in an estimated area of 27,500 hectares, which means an arithmetic average of 21 hectares per property. The total area with perennial crop is approximately 34,600 hectares in this same region (ALVES, 1999). The region has an average altitude of 600 meters and produces Arabic coffee. The Novo Mundo is the more cultivated cultivar, but there is a strong tendency to substitute it by Obatã cultivar, mainly due to its superior quality, resistance to the rust, and the short plant that facilitates the harvesting.

In the Alta Paulista Region the hard drink is obtained predominantly. The use of agricultural machinery for harvesting and some crop treatments is usual in this region, mainly due to the favorable topography of the soil. The technology of irrigation, however, is not usual. In spite of the water to be a scarce natural resource in this region, the hydro-deficit is not too large, which happens in occasional dried periods. The frosts are even more sporadic. The great problem of the Alta Paulista Region is the occurrence of plagues and diseases.

2.4 Mogiana Region

Mogiana Region is split in Alta Mogiana and Média Mogiana Regions. The Alta Mogiana is one of the most traditional areas producing coffee in the São Paulo State, located at the Northeast of the State. In this region, the coffee crop was introduced approximately 200 years ago. It has an altitude that varies between 900 and 1,100 m and quite interesting annual average temperature, about 20ºC, favorable to the coffee plantation, characterizing the area as excellent for the production of special coffees. The produced drink has high body with fruity aroma. The coffees of Alta Mogiana are marked by the balance between sweetness and acidity.

Média Mogiana Region has a climate with characteristics of hot and dry, with annual average temperature of 22ºC. The pluviometric index of this area reaches to the annual average between 1,200 and 1,600 mm. The altitudes range from 700 to 1,300 m. The region is considered appropriate to the coffee production, mainly due to its nutrient-richness, deep reddish purple soil, that characterizes this region by its excellent fertility, and also an appropriate climate with low risk of occurrence of frosts. Média Mogiana is an excellent region for the production of special coffees, with high body and fruity aroma.

Besides the above geographical factors influencing the coffee quality, the preparation process also directly affects the product quality. There are two coffee preparation methods: the dry method and the wet method. Both methods have the following common stages: cleaning, separation, drying, storage, processing and classification. Additionally, the wet method includes the separation of red coffee berries, pulp remotion, mucilage removal and product washing (LIMA FILHO; MALAVOLTA, 2003; MALAVOLTA, 1986; MITCHELL, 1988).

GOAL AND SCOPE

The goal of this paper is to present some aspects of the life cycle inventory - LCI of green coffee produced in different Brazilian coffee grower regions for the reference crops 2001/02 and 2002/03.

The scope of this work was to qualify and quantify the main environmental aspects of the green coffee production in the main Brazilian coffee producer regions in order to establish parameters for the sustainability and a future ecolabelling program for the Brazilian green coffee.

The adopted functional unit was the production of 1,000 kg of green coffee destined for exportation. This unit is not related to the function of the green coffee since the use stage was not included in the system. So, the cradle to gate LCI basis was adopted.

2 MATERIAL AND METHODS

This study has been conducted in accordance with the recommendations of the International Standard ISO 14040 (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION - ISO - 2006) – Environmental Management - Life Cycle Assessment - Principles and Framework (ISO, 2006). The following impact categories were selected for the study: depletion of fossil energy resources, depletion of natural resources; climate change; acidification; eutrophication; human toxicity; ecotoxicity and land use. The data collection for the LCI of green coffee was carried out taking into account the impact categories selected for the study. Data storage and modeling were performed by means of the PIRA Environmental Management System – PEMS4 software purchased from Pira International.

The system evaluated includes crop cultivation at commercial farms, harvesting, storage and transport by trucks until the exportation harbors (Figure 1). The cultivar of coffee beans considered in this study were Mundo Novo, Catuaí (yellow and red), Icatu (yellow and red), Catucaí (yellow and red) and Obatã.

The selection of the studied regions was done taking into account the geographical boundaries. The four main Brazilian coffee producer regions included were: Sul de Minas Gerais and Cerrado Mineiro regions in Minas Gerais State, and Mogiana and Alta Paulista regions in São Paulo State.

All information considered in this study was taken up in-depth data collection by means of specific questionnaires applied on farm level and/or sent by mail considering the inputs of water, fossil based energy, energy consumption, fertilizers, pesticides, correctives and residue disposal. Only the inputs and outputs relative to the coffee crop were considered in this study as a cradle-to-gate system. The production of fertilizers, correctives and pesticides were not included in the boundary, but only their amount and the transportation of them until the farms. The detailed methodology employed in this study was published previously (MOURAD et al., 2006).

3 RESULTS AND DISCUSSION

The data refer to a production of approx. 25,200,000 kg of green coffee and a productive area of approx. 14,300 ha, supplied by 56 coffee growers grouped in 28 questionnaires (named farms hereafter) and separated in the four main Brazilian coffee regions. The present work shows the main inputs by farm of each Brazilian coffee grower region evaluated. The final LCI was previously published in the paper Environmental Profile of Brazilian Green Coffee (COLTRO et al., 2006).

The total energy consumed per farm of each evaluated region is shown in Figure 2. The figure also presents the weighted average per region, i.e. the productive contribution of each cooperative and/or each farm to the average of the evaluated regional sample. Three of the total evaluated farms (2, 7 and 25) consumed much higher energy than the others and higher than the regional averages, being farms 2 and 7 located at the same region (Sul de Minas Gerais) while farm 25 is located at Mogiana region. It was found no relationship between the energy input and the adopted method (wet or dry) since the farms 2 and 25 adopted approx. 35% wet method while the farm 7 employed the dry method. On the other hand, the farms with lower energy consumption adopted 70 to 100% dry method. Some harvest characteristics adopted by the evaluated farms are presented in Table 1. Besides, the farms adopted the following agricultural practices: use of other species, subsoil, brush management, level curves, retention box, terrace, levelly plantation, etc.

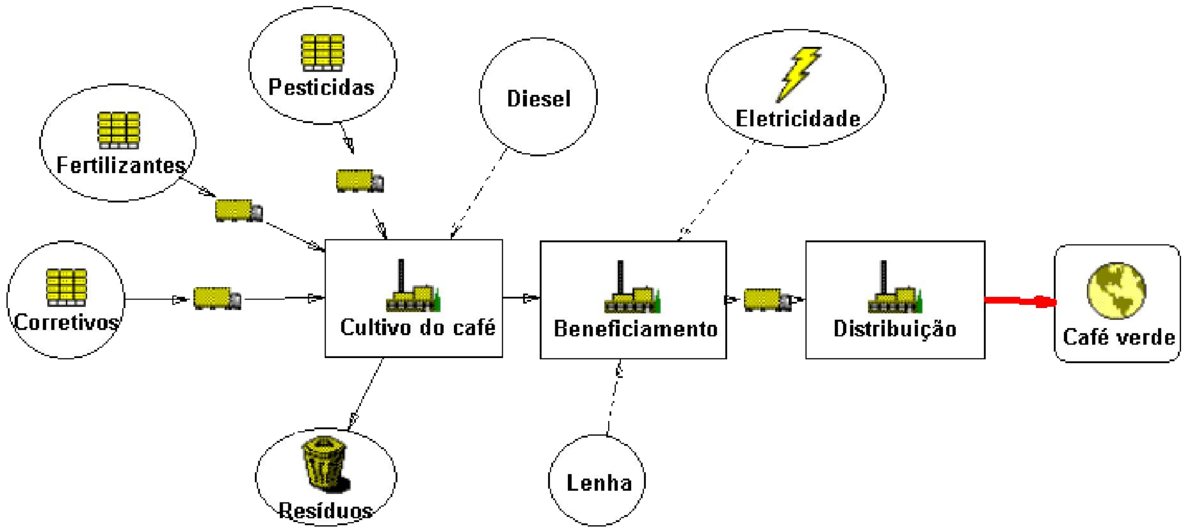

FIGURE 1 – Flowchart of the coffee production system.

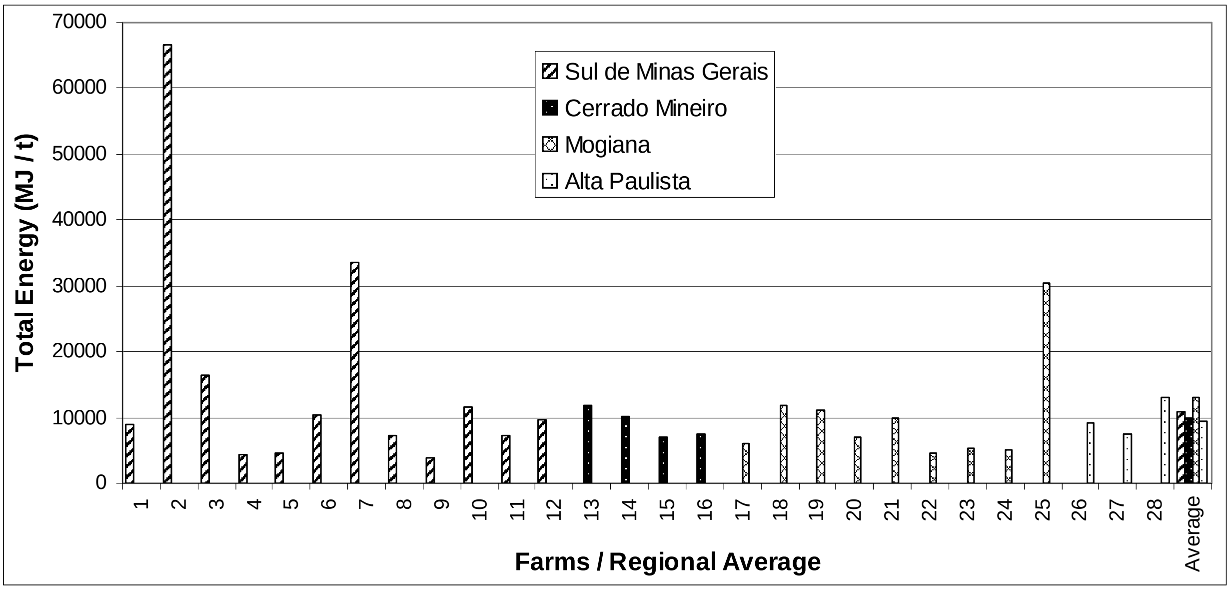

FIGURE 2 – Total energy input by farm for the four coffee producer regions (MJ / 1,000 kg green coffee): 1 to 12 - Sul de Minas Gerais region (MG); 13 to 16 - Cerrado Mineiro region (MG); 17 to 25 - Mogiana region (SP) and 26 to 28 - Alta Paulista region (SP).

TABLE 1 – Harvest characteristics of the evaluated farms per region.

Coffee Region	Harvest		Processing Method		Cultivated Area (ha)
	Manual (%)	Mechanical (%)	Dry (%)	Wet (%)	
Sul de Minas Gerais	20 – 100 (A = 75)	0 – 80 (A = 25)	50 – 100 (A = 81)	0 – 50 (A = 19)	90 – 3100
Cerrado Mineiro	0 – 60 (A = 28)	40 – 100 (A = 73)	40 – 100 (A = 69)	0 – 60 (A = 31)	90 – 2600
Mogiana	40 – 100 (A = 82)	0 – 60 (A = 18)	70 – 100 (A = 83)	0 – 30 (A = 17)	30 – 430
Alta Paulista	0 – 30 (A = 10)	70 – 100 (A = 90)	80 – 100 (A = 93)	0 – 20 (A = 7)	100 – 600

A = Arithmetic average

Both regions located at Minas Gerais state showed similar regional averages for the total energy consumed while Mogiana, at São Paulo state, showed 20% higher energy consumption than Minas Gerais regions (Table 2). On the other hand, the Alta Paulista, also at São Paulo state, was the region showed lower average total energy consumption. Thus, the energy input is much more related to the production management than the cultivation method adopted by the farm.

The consumption of diesel by agricultural machinery and coffee processing is shown in Figure 3. The farms located at Alta Paulista region have showed high consumption of diesel (near or above the regional average) while the other regions showed a dispersion profile with both farms with high and very low or absence of diesel consumption. This input profile probably is due to the appropriate topography of the soil for using mechanical harvesting techniques

TABLE 2 – Summary of the regional weighted average for the main inputs of the Brazilian life cycle inventory for 1,000 kg of green coffee production for the reference crops 2001/02 and 2002/03.

Coffee Region	Total Energy (MJ)	Diesel (kg)	Water (kg)	Fertilizers (kg)	Pesticides (kg)	Correctives (kg)	Yield (kg/ha)
Sul de Minas Gerais	10,926	67.3	12,759	266.3	4.7	226.8	1,811
Cerrado Mineiro	10,017	115.1	10,894	286.9	3.0	237.6	1,874
Mogiana	13,138	127.6	10,614	276.9	2.4	607.6	1,682
Alta Paulista	9,302	116.0	6,556	339.6	13.0	344.7	1,587
Total average	10,846	106.5	10,206	292,4	5.8	354.2	1,738

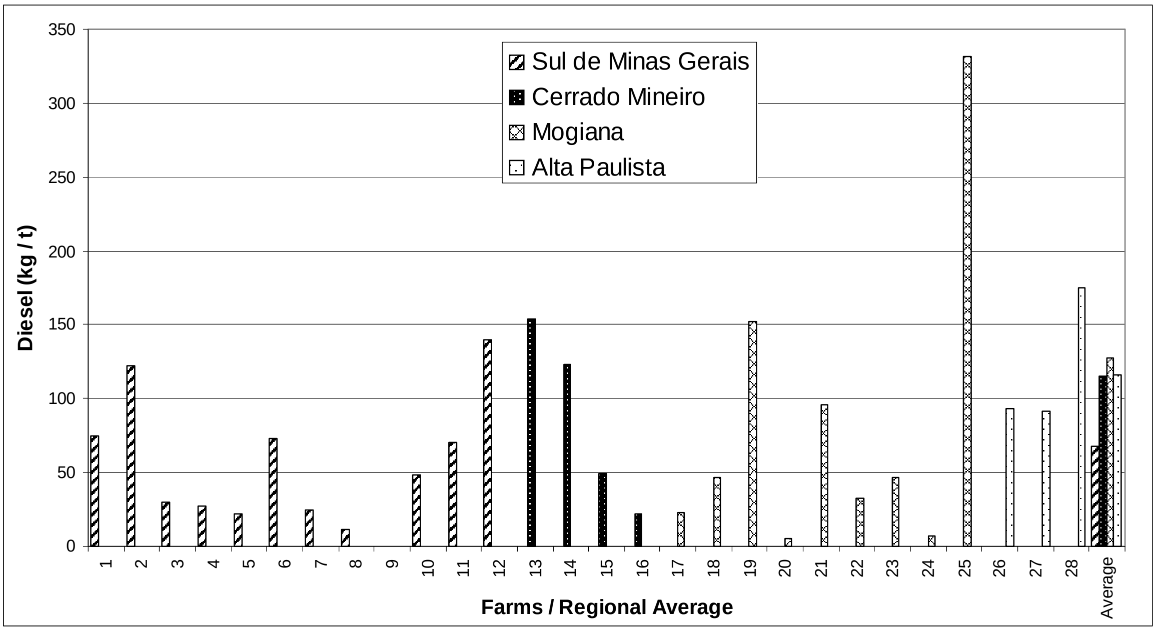

FIGURE 3 – Consumption of diesel by farm for the four coffee producer regions (kg / 1,000 kg green coffee)): 1 to 12 - Sul de Minas Gerais region (MG); 13 to 16 - Cerrado Mineiro region (MG); 17 to 25 - Mogiana region (SP) and 26 to 28 - Alta Paulista region (SP).

of the Alta Paulista region and local topography of the farms at the other regions. The lower average consumption of diesel was observed for the Sul de Minas Gerais region probably due to the mountainous relief of it (Table 1).

Despite the Sul de Minas Gerais region has showed the farm with the greater amount of the total energy input, the farm with the higher consumption of diesel was located at the Mogiana region.

Approximately half of the sample evaluated in each region adopted the dry method for coffee processing, even the two farms (18 and 23) with higher consumption of water (Figure 4), being the water consumed for coffee washing (i.e. process water) since the evaluated farms do not adopt irrigation techniques. Then, the results showed that the quantity of process water consumed was more related to the process management than the type of method adopted for coffee processing.

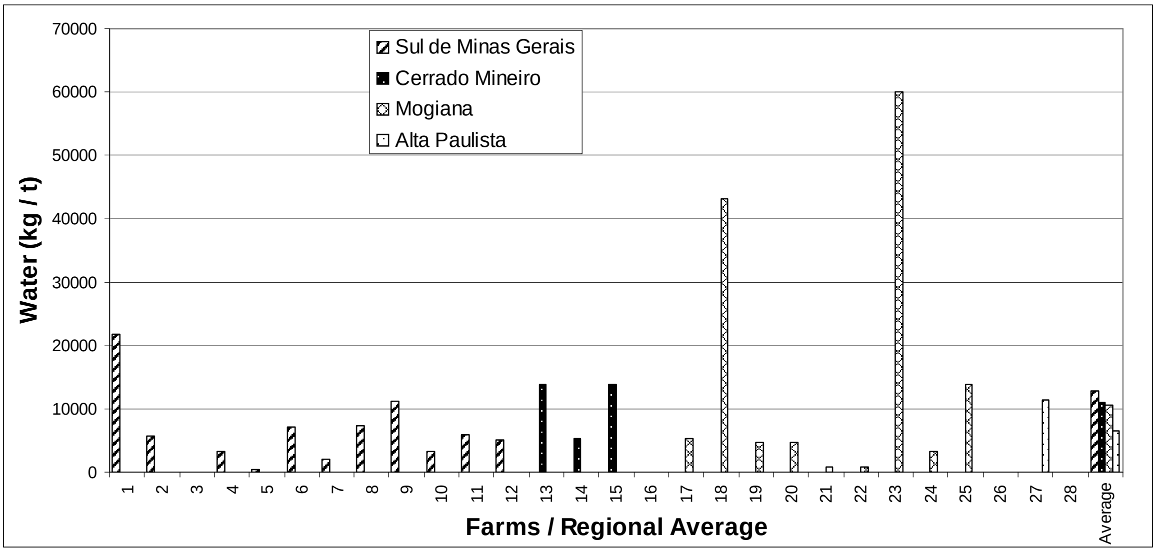

FIGURE 4 – Consumption of water for processing by farm for the four coffee producer regions (kg / 1,000 kg green coffee)): 1 to 12 - Sul de Minas Gerais region (MG); 13 to 16 - Cerrado Mineiro region (MG); 17 to 25 - Mogiana region (SP) and 26 to 28 - Alta Paulista region (SP).

The main inputs as fertilizers, pesticides and correctives of the life cycle inventory of the coffee growing in Brazil are shown in Figures 5. The fertilizers, that include mainly macro-nutrients as nitrogen, phosphorus and potassium and can be supplied by several sources, organic and inorganic, were the input that showed the larger variation for the total quantity added to the crop among the evaluated farms. This larger variation was observed in Sul de Minas Gerais and Mogiana regions, traditional coffee producer regions, being the farm with the greater consumption of this input located at the former region. The mountainous relief, characteristic of these two regions, probably is the reason for this great variation. Many of these farms have extensive planted areas in lands with accentuated decline, demanding larger amounts of this input due to natural loss that happens in the rain periods.

Although the number of questionnaires evaluated by region is quite different, it was observed that the farms of the Alta Paulista Region exhibited the largest consumption of pesticides per ton of produced coffee (Figure 5), which is a consequence of the high incidence of plagues and diseases that occur in this region. It was also observed that 3 among the 25 evaluated farms from the other three regions consumed more pesticides than the weighted regional average (Table 2), what can be probably associated to an excessive usage of pesticides. Nevertheless, approximately half of the evaluated sample showed a maximum consumption of 2 kg/t, lower than the regional average.

The soil acidity did not seem to be very different among the farms evaluated in this study since the amount of correctives used per ton of produced coffee showed small variation (Figure 5). Nevertheless, farm 25 probably used correctives in excess and needs a new soil acidity analysis for checking the proper consume of this input. That is why the Mogiana region showed the higher average correctives consumption (Table 2).

The salts added to the crop derive from natural resources as rocks and ores being the mining processes very intensive in energy consumption. Nevertheless, the stage of fertilizers and correctives production was out of the boundaries of this study.

The continuous agricultural cultivation in the same area for many years causes a progressive and significant soil mineralization. The impact caused by the addition of these salts to the crop is sometimes forgotten and eventually discussed. But certainly it alters the original fauna of existing microorganisms. Also the use of agricultural machinery and the practice

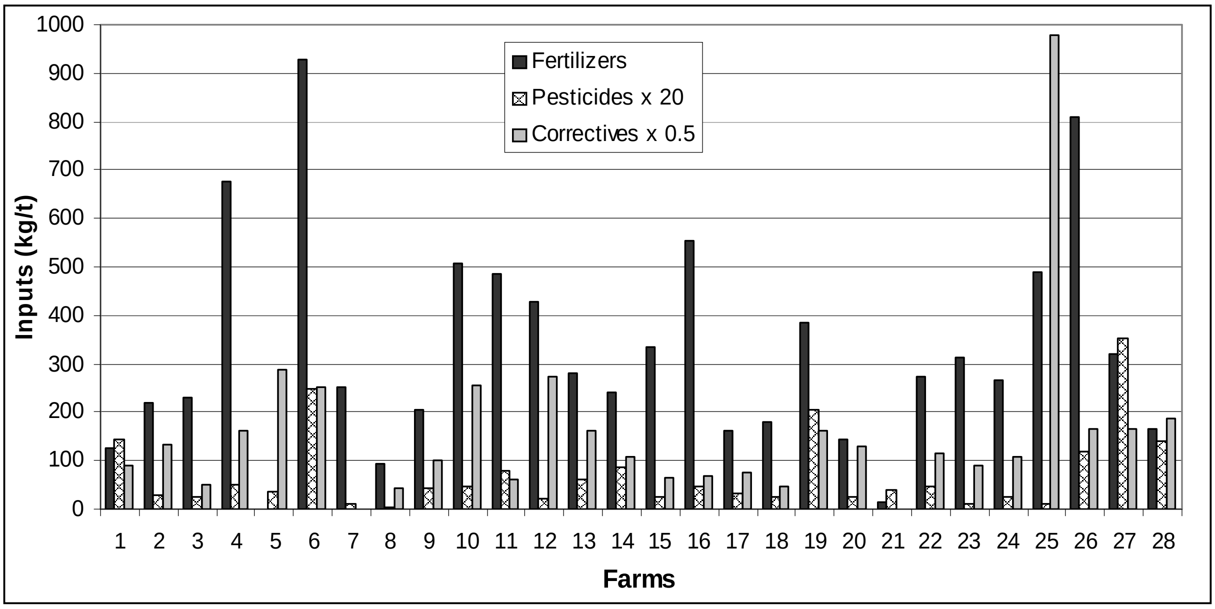

FIGURE 5 – Consumption of fertilizers (N, P, K and other elements), pesticides (only actives) and correctives (Ca and Mg) by farm for the four coffee producer regions (kg / 1,000 kg green coffee)): 1 to 12 - Sul de Minas Gerais region (MG); 13 to 16 - Cerrado Mineiro region (MG); 17 to 25 - Mogiana region (SP) and 26 to 28 - Alta Paulista region (SP).

of low plant densities without shade trees increase the erosion potential of the soil.

These salts are sources of phosphates, nitrates and sulfates that are carried by the rainwater to the rivers or the groundwater courses. The evaluated regions include areas in Minas Gerais and São Paulo States with pluviometric indexes ranging from approx. 1200 to 2000 mm/year. This high amount of rainwater is typical from tropical regions and elevates the eutrophication potential of the Brazilian rivers.

The actual technology for coffee production in tropical regions is intensive in pesticides usage being these products applied in order to control disease propagation. More than half of these pesticides are classified as elevated toxicity product. Although the pesticides are added in smaller amount than the fertilizers and correctives their environmental persistence degree is much higher.

The main categories of environmental impact determined in a life cycle assessment study for coffee in the stage of cultivation were found as Eutrophication and Terrestrial Ecotoxicity [22]. In this study, it was included the effects of energy, fertilizers and pesticides available in commercial databases. Considering 1 kg of packed coffee as a functional unit, a contribution of 320 grams equivalent of phosphates and around 6 terrestrial m^3 were found using CML method, considering cultivation, processing, transport, consumption and final disposal stages.

In general the land use ranged from 0.4 to 0.8 ha/t. The land use per ton of produced coffee is an indirect measure of the yield of the farm (Figure 6). Although the Sul de Minas Gerais region has showed the farm with the highest yield (approx. 2,500 kg/ha) it has also showed the farm with the lowest yield (approx. 800 kg/ha). Nevertheless, the regions located at Minas Gerais state showed the higher average yield (approx. 1,800 kg/ha).

Although Brazil is the 5th larger country in the world and the land usage is not a key issue as in smaller countries, the majority of the coffee cultivation regions are located in states with high demographic density. Besides the land transformation caused by the cultivation, land use should be considered since a significant portion of the population lives close to the planted areas and is subjected to the environmental impacts caused by the fertilizers and pesticides.

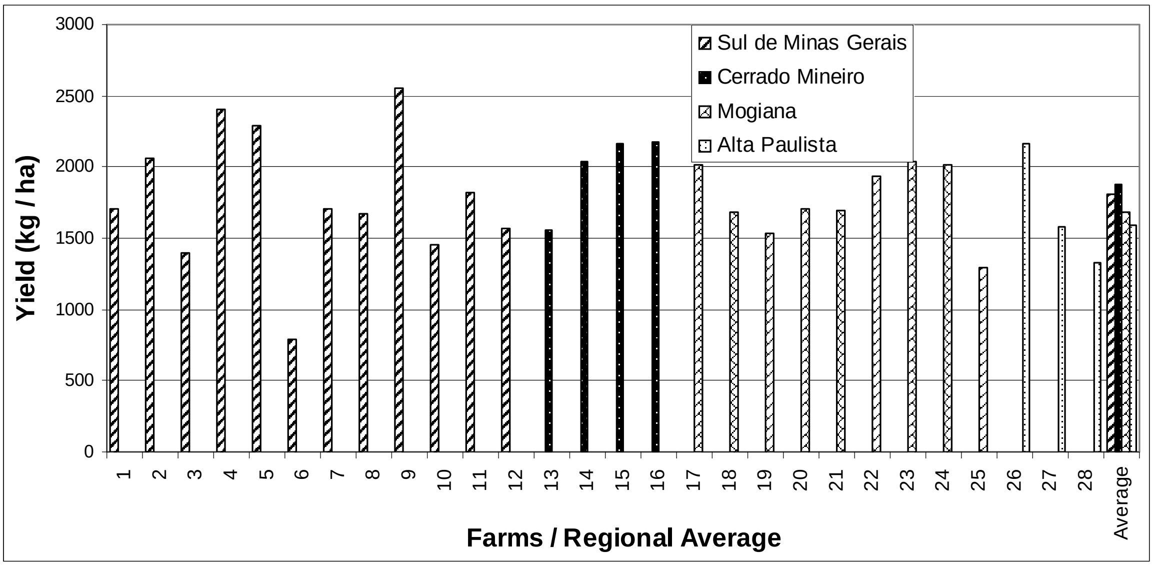

FIGURE 6 – Yield by farm for the four coffee producer regions (kg / ha)): 1 to 12 - Sul de Minas Gerais region (MG); 13 to 16 - Cerrado Mineiro region (MG); 17 to 25 - Mogiana region (SP) and 26 to 28 - Alta Paulista region (SP).

Surprisingly, farm 6 was the one with the smallest yield while showed the highest fertilizer consumption and one of the largest pesticides users. On the other hand, farm 9 showed the best environmental profile since presented the highest yield among the evaluated farms with minimum consumption of energy besides consumption of the other inputs lower than the regional average.

Besides the variations among the regions, in general it was also observed a great dispersion of these data among the farms located at the same region.

Taking into account all the inputs discussed previously (total energy, diesel, water, fertilizers, pesticides and correctives) and comparing each farm with the weighted regional average of these inputs, it was observed that depending on the region:

- Up to 90% of the evaluated farms showed total energy consumption lower than the regional average;
- Up to 80% of the evaluated farms consumed lower diesel than the regional average;
- Up to 92% of the evaluated farms showed water consumption lower than the regional average;
- Up to 70% of the evaluated farms showed fertilizer consumption lower than the regional average;
- Up to 90% of the evaluated farms consumed lower pesticides than the regional average obtained for this input;
- Up to 90% of the evaluated farms consumed lower correctives than the regional average.

From the evaluated sample, the farms 9 and 20 (7% of the sample) showed the best environmental profile since their inputs were lower than the weighted averages. Besides these properties, the farms 7, 8 and 17 (11% of the farms) showed consumption of pesticides, fertilizers and correctives lower than the averages. So, considering the aspects evaluated in this study, approx. 20% of the coffee growers showed a good environmental performance.

4 CONCLUSIONS

Although the inputs are directly related to the specific characteristics of each farm and the climatic conditions of its location, this study has identified some farms that can probably reduce the amount of some input and enhance their environmental performance.

The farmers knowledge on other farms in the same coffee growing region showing lower consumption of some inputs than their management will be a driving force for trying to reduce the consumption of these inputs too, both for environmental and economical reasons.

Besides the total amount of these inputs, good agricultural practices should also be considered for having a good yield and improving the sustainability of coffee production.

One of the main goals for conducting this study was to measure the actual environmental profile of coffee cultivation sector in order to establish a scientific basis for the implementation of a future environmental label for this product.

Considering the aspects evaluated in this study, 20% of the coffee growers showed a good performance, i.e. consumption of pesticides, fertilizers and correctives lower than the weighted averages.

The authors suggest the weighted average determined for each region as the maximum allowed value for the start up of the discussion on a process for the establishment of the environmental label for the coffee sector. Besides the total amount of these inputs, for the establishment of an environmental label it should be considered also all the good agricultural practices for improvement of the sustainability of the coffee production.

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