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Technological Implementation in the Brazilian Family Farming Context in Order to Minimize CO2 and CH4 Emissions, a Feasibility Analysis.

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Abstract

In Biguaçu County, State of Santa Catarina, traditional family farming represents most of the county's activity. These family farmers carry out a particular land use on which agriculture, forest and energy production are related. These farmers perform fallow agriculture in secondary subtropical forests (Atlantic Forest biome) where, energy production is made in the form of charcoal. As charcoal production is realized in traditional handcrafted kilns, gravimetric yield is meager and greenhouse gases emissions are high. In order to improve this scenario it has been experimentally installed in late 2014 a volatile recovery system (SRV). The SRV installation respond to three main characteristics: to be easily reproducible by others farmers, to have a low initial investment and to be locally adapted. The SRV allows the condensation of the gas fraction during production, obtaining pyroligneous acid (PA). Calculations indicate a PA production potential of about three thousand-liter year. Initial investment is reachable by local farmers and the investment recovery will take five years. The implementation results in a 30% increase in profits, a minimization of 1/8 of total emissions and 15% improve in gravimetric yield. With this basis, the SRV implementation can be considered as a feasible green infrastructure at regional scale.

Key-words: *Emerging Countries, SME, Technological innovations, Feasibility analysis, CO2 and CH4 emissions, Family Farming.*

1. Introduction

Greenhouse gases concentration in the atmosphere has grown exponentially in recent years as consequence of anthropic activities. Agriculture, like most of economic sectors, produces greenhouse gases and these emissions are generally related to agricultural soils management, livestock, rice production and biomass burning.

In recent years, aspects such as economic trends, regulatory instruments, farm management practices, and trends in the number of ruminant animals have influenced greenhouse gas emissions from agriculture. Most farm-related emissions come in the form of methane (CH4) and nitrous oxide (N2O). Sources include manure management, rice cultivation, field burning and fuel use on farms. At the farm level, the relative size of different sources will vary widely depending on the type of activities and products grown, farming practices employed, and geographical factors.

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In Brazil, agriculture importance is unquestionable as it counts for 1/3 of total commodities exportation, specifically 39% in 2014 (WTO, 2016) and represents a total area of almost 33% of the national territory, around 250 thousand Ha. (FAO, 2016). This economic sector counted for an average emissions of 450 thousand CO2 equivalent in 2012 and it is expected to raise around 12,5% by 2030 (FAO, 2016).

In southern Brazil, agriculture is highly related to family farming and in Biguaçu County, State of Santa Catarina, traditional family farming represents most of the county's activity. These family farmers carry out a particular land use on which agriculture, forest and energy production are related. These farmers perform fallow agriculture in secondary subtropical forests (Atlantic Forest biome) where, energy production is made in the form of charcoal.

Traditional charcoal production in Biguaçu is not different from the national production context, where, according to Sablowski (2008), charcoal is obtained with the use of rudimentary techniques, unskilled labor and small resource allocation. Charcoal from Biguaçu is aimed to domestic market, specifically to barbecue cooking. A great part of this charcoal is produced outlawed in brick beehive kilns under traditional practices of agriculture and forest management and its production control is made under subjective aspects, such as heat felt in the hands, smoke's color and smell and farmer's experience.

Recent studies, (ARAÚJO et al. 2013) (FANTINI et al. 2010) (ULLER-GOMES et al. 2015) have demonstrated that illegality because of traditional practices have shown to be a great threat to forests, traditional knowledge, environment, local farmers quality of life and governmental policies and accountability because of the lack reliable data from these activities. As a result, national statistics about charcoal production in the family farming context are not accurate, as they take into account only legal activities.

In addition, producers have not been able to access technical aid and consequently it is perceptible the lack of more efficient technologies in the field, which could make charcoal production effortless and environmentally friendly. It is estimated that for each kilogram of charcoal produced, it is emitted 1382 g of CO2, 324 g of CO and 47,6 g of CH4 (PENNISE 2003). According to Villazon, charcoal's production yield under this context is not as high as it should be, it is around 13% and environmental and health impacts are very high (VILLAZON, 2013).

In view of the explicit establishment by Brazilian authorities, in late 2009, in the urgency of accurate the national inventory of emissions, especially in the rural context; therefore, the importance of an accurate accountability of these activities in order to take proper actions to mitigate or adapt agricultural practices, specifically efficient environmental policies.

Considering that during wood carbonization process, charcoal is only a fraction of possible products that can be obtained; it is advantageous to adapt an appropriate technology in order to obtain co-products from the combustion gasses, improving production gravimetric yield and decreasing environmental impacts.

In this context, it has been experimentally installed in late 2014 a volatile recovery system (SRV) in Biguaçu/SC in order to obtain the pyroligneous acid as co-product by the time that production yield is also improved and emission factors are collected in order to accurate accountability emissions from Brazilian agriculture. The SRV installation responded to three main characteristics: to be easily reproducible by others farmers, to have a low initial investment and to be locally adapted.

This article aims to demonstrate that a feasible technology implementation is possible reaching the three sustainable pillars; environmentally correct, socially desirable and economically feasible.

2. Charcoal production in the family farming context

According to FAO, Brazil has been the world's largest charcoal producer and consumer in recent years (FAO, 2016). Charcoal consumption in the local scenario is mainly demanded as an energy and reducing supply, especially in the industrial sector for the manufacture of steel, pig iron and ferroalloys ((Bailis et al., 2013); (VITAL; PINTO, 2009); (JOAQUIM, 2009); (SEIXAS et al., 2006)). The activity supports a vast and diverse network of rural stakeholders, providing them jobs and livelihoods along the production chain (GHILARDI et al., 2013).

Brazilian extensive use of charcoal is a consequence of the Federal Government encouragement in many segments of the industrial sector after the oil crisis in 1973, and also as an alternative to replace fuel oil (ASSIS et al., 2008). Charcoal use was also extended after the Kyoto Protocol (1997), where it was agreed that developed countries should reduce emissions of greenhouse gases by replacing non-renewable energy (SABLOWSKI, 2008). Raw material that supports this production comes from planted forests (mainly eucalyptus) and native forests in a 50% proportion (CALAIS, 2009).

In southern Brazil charcoal comes from the family farming, which is predominant and, according to the agricultural census of "Instituto Brasileiro de Geografia e Estatística, IBGE"1 (IBGE, 2006), it represents 84% of farms in the region (86% in the State of Rio Grande do Sul, 87% in the State of Santa Catarina and 82% in the State of Paraná). This highlights the socioeconomic importance of this form of social organization in the occupation and development of rural areas.

The State of Santa Catarina is not a traditionally charcoal State producer; it does not appear among the main producing states in the country. Estimates of IBGE for the year 2011 indicate a production of almost 11 thousand tonnes, which represents less than 0.2% of national production (IBGE, 2011). Nonetheless, recent studies indicates that these numbers are being underestimated and charcoal signifies in most cases the most representative source of income (VILLAZON, 2013) (FANTINI et al., 2010). In Santa Catarina charcoal production is located in the Itajaí Valley, the North and South of the state and it is been estimated a wide large production of charcoal (STEENBOCK et al., 2011).

Santa Catarina's forests that supports this production are part of the Atlantic Forest biome (SCHAFFER, 2010), and studies by SOS Atlantic Forest / INPE (2011) show that there are about 102 thousands square kilometers of remaining forest which are larger than 100ha. The 2011 INPE report indicates that there are still 23% of remaining forests in Santa Catarina (INPE, 2011); and Siminski (2009) details that much of this proportion consists on secondary forest fragments and few areas of primary forests.

In Biguaçu County, charcoal is produced predominantly from native forest managed in a

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[1] The Brazilian Institute of Geography and Statistics.

fallow system, in a mountain and hill context. This land and forest management is also called swidden or slash and burn. Adams (2000) indicates that this is a complex land use system, which involves aspects such as cultural, traditional and indigenous heritage that have been adopted by today's immigrants during the civilizing process.

According to Araujo et al. (2013) and Siminski (2007), in this system, a secondary forest area of approximately one hectare, is cleared and cultivated with annual crops for a period of up to four years to leave then, to natural restoration. Fantini (2010) complements explaining that the products of this system are intended for the market or for consumption by families, and when the cycle finishes the area is left fallow to forest regeneration for periods of up to twenty years.

According to Villazon (2013) description, "charcoal production, in the region studied, is a traditional activity and it has a complex sequence of stages; from forest to charcoal." The day to day practical knowledge allowed farmers strengthening their technique on the process of charcoal production and the forest management, attribute which, enables them to elect the type of wood that offers higher calorific power or "calorie".

Charcoal production in the fallow system is an adaptation by local farmers, which signifies their will to maximize available raw material usage when performing the systems' first steps. They do not leave fire to burn the area up, it must be just enough to clear the underneath canopy from branches and grass. By this way, they allow wood availability to charcoal production.

3. Environmental concerns during charcoal production

Environmental aspects during charcoal production surpass aspects of forest management; they are highly related to the production process, the better the process the less polluting the activity is. Then aspects as technology adapted, quality of raw material, meteorological conditions, inter farm or propriety transport, storage of final product among others should be also considered.

Regarding production technology, Carvalho et al. (2005) indicate that it has been adopted, by most of the charcoal producers in Brazil, clay ovens (brick) kilns, which construction requires a low level of investment due to a lack of more efficient options. In this type of kilns, productive yield is expected to fluctuate between 10% and 30% of effective utilization of wood, thereby emitting a significant amount of substances through the smoke to the atmosphere. Alluding to the gaseous emissions from charcoal production process, in general, a large number of different chemical substances are emitted during the pyrolysis process in the form of gases or aerosols (liquid and solids in suspension).

According to Smith (1987) and de Koning (1985) these pollutants include carbon monoxide, nitrogen dioxide (largely of particles in the range below 10 μm in aerodynamic diameter) and other organic matter composed predominantly of polycyclic aromatic hydrocarbons (PAH) such as benzene-pyrene and other organic volatile compounds such as benzene and formaldehyde.

These pollutants are resulting from the incomplete combustion process, and its composition and concentrations vary depending on various factors. Smith (1987) indicates that the quantity and characteristics of the pollutants produced during combustion will depend on various factors such as the fuel composition (including moisture content), combustion conditions (temperature, air and moisture flow) and even the shape of the Kiln.

According to Pennise et al. (2001) the fact of better characterize emissions of incomplete combustions processes, as charcoal production, is crucial since CH4, NMVOC and CO have a higher Global Warming Potential (GWP) per mol kilogram of carbon, than CO2. It is also relevant to determine concentrations of particulate matter, CO, and hydrocarbons since they are air pollutants.

Pennises's research proposes emission factors to eucalyptus wood as raw material in kilns which are similar to those used in Biguaçu County.

Table 1. Emission Factors for selected Charcoal Kilns. Source: Pennise, 2003.

			[g of polltant/kg of charcoal produced)						
Kiln type	**Localization**	**Gravimetric Yield [%]**	**CO_2**	**CO**	**CH_4**	**TMVOC**	**N_2O**	**NO_X**	**TPM**
Hot-tail (brick-beehive)	**Brazil**	**34,1**	**1382**	**324**	**47,6**	**80,9**	**0,045**	**0,028**	
Surface (round-brick)	**Brazil**	**28,7**	**1533**	**373**	**56,8**	**45,9**	**0,051**	**0,014**	
Rectangular	**Brazil**	**36,4**	**543**	**162**	**36,5**	**23,9**	**0,011**	**0,005**	
Earth-Mound	**Kenia**	**22,6**	**1992**	**207**	**35,2**	**90,3**	**0,12**	**0,087**	**41,2**

4. Pyroligneous acid and the volatile recovery system

The pyroligneous fraction2 (PA) is possible to condensate from charcoal's smoke during the carbonization process and its main source is wood pyrolysis. Sablowski (2008) explains that pyroligneous liquid consists of water and chemicals such as acetic acid and formic acid, ether, the methyl and ethyl alcohols, acetone, tar, among others. Pyroligneous liquid, when diluted in water or bovine urine, finds wide application in the field of organic and conventional agriculture.

Tilikkala et al. (2010) indicate that the majority of the organic pyroligneous components of the PA are methanol and acetic acid. Also other compounds such as acetone, methyl acetone, acetaldehyde, alilálcool, furans, formic acid, propionic acid and butyric acids. Net tars can be fractionated into light and heavy fractions. The first consists of aldehydes, ketones, acids and esters. Various phenols, including a high proportion of tar and cresols, constitute the heavy fraction.

The use of pyroligneous acid in agriculture has a large potential as an insecticide,

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[2] Also known as pyroligneous liquid, pyroligneous extract, pyroligneous acid, wood vinegar, pyroligneous, liquid smoke or bio-oil

fertilizer, and for chemical industries, perfumes, food industry among others. In Brazil, its use in agriculture is recent, and according to Campos (2007) it has been released and encouraged a few decades ago and it has attracted the attention of researchers and technicians from various areas, mainly food and agronomy, as an alternative to a more natural product.

Obtainment of PA is not a recent fact, it has been well known, specially in Asia. There is available technology to maximize PA and charcoal yield for industrial and semi-industrial kilns in small, medium and large enterprises; nonetheless, there is lack of feasible technology options to adapt to traditional production.

The proposed volatile recovery system (SRV) consists of materials that do not differ from those employed in the traditional kiln construction. It was used bricks, clay, water, three 50 cm diameter concrete tubular sections and three Polyvinyl chloride tubes of 1 meter each. According to Campos (2007) material used in systems to obtain PA vary and will not directly influence the pyroligneous extract quality.

The SRV is adapted to current chimneys (see Figure 1) and its operation is based on pressure differential between environment and internal kiln conditions in order to allow gasses to pass through the whole system. Recovery of PA is based in the condensate of gases by temperature differential through the PVC tubes. The concrete sections serve as a pre-cooling chamber of gasses, and recovery of PA occurs when kiln's internal temperature is between 90°C and 130°C.

Figure 1. Volatile Recovery System

5. The feasibility analysis

In order to determine the impact on profits by obtaining PA, it was first necessary to determine the installed production capacity, as well as production yields in the county. Hence, the determination of productive capacity was made using a sample of fourteen kilns distributed in eight different properties. It was calculated in each kiln the maximum volume of wood capacity. Then, to determine kiln's production yield, it was tracked for six months the production process in a typical Kiln with a capacity of 12.65 m3 of wood in 2012.

In late 2014 a kiln with the SRV was built in order to determine the yield of PA per kg of charcoal produced. In both cases, wood and charcoal were also measured at the beginning and end of process. PA yield was corrected based on the Technical Report 264 by EMBRAPA[3](2011). In addition, for the determination of total gases emitted, emission factors described by Pennise (2003) were applied.

Finally, determining the impact on profits by obtaining PA was calculated based on the average production yields and average prices in the local market for charcoal and PA. The system's feasibility study was performed using the NPV and IRR based on the total value of investment and typical property costs.

In order to develop the cash flow to determine the NPV, it was used a reference prize of charcoal of R$ 12 per 7kg bundle and R$ 4 per liter of PA for the initial three years and R$5 for years four and five respectively. As for the SRV operation; there is no need of extra operator, then it was maintained a two persons working during charcoal process earning R$ 788 per month each. Regarding variables costs, it was considered the annual requirement of wood. It was also considered the SRV and kiln depreciation in a six years period and a safety margin of 5% over initial investment. As for net taxes it was used a 33% total net taxes over gross profit.

Conclusions

Results indicates that, in average for each typical kiln is demanded 14,5 m^3 of wood. It was also verified an average volumetric yield of 50% and approximately gravimetric yield of 14%. Consequently producing 7,22 mdc[4] of approximately 1 ton per kiln.

Data extrapolation to county's activity indicates an approximately 500 ton of charcoal being produced per year from the fallow system. The PA yield obtained was of 0.21 liters of P.A. per kg of charcoal produced; then, the county's potential production is about 7854 liters per month, or 94 thousand liters per year.

Table 2. County's PA production potential.

	Month	**Year**
Wood [Kg]	**400.395**	**4.804.741**
Charcoal [kg]	**37.700**	**452.394**
Pyroligneous Acid [L]	**7.854**	**94.249**

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[3] Empresa Brasileira de Pesquisa Agropecuária (Embrapa) is the Brazilian Public Agricultural Research Corporation

[4] Charcoal's meters

Applying emission factors previously described, the total gases and particles emitted without the SRV are around 900 000 kg per year. Mass balance calculus indicates that emissions post SRV implementation are minimized by 1/8 the amount of emissions. Improvements in production yield indicates a 32% positive impact on profits for county's family farmers.

Table 3. Impact on Profits Potential

	Mean	Profit
Expected Bundles [units]	138,00	R$ 828,00
P.A. potential [L]	223,23	R$ 267,88
Impact on Profits Potential [%]		+32%

Applying production yield and PA potential production in the county's it was calculated the cash flow for a period of five years. Initial investment for SRV implementation are not considerable, considering that bricks and clay are available in family farmer properties and acquisition of PVC and concrete tubes are no expensive. It is required an initial investment of R$ 2.300 in order to acquire materials and to construct the SRV.

Table 4. Cash Flow.

Year	*0*	*1*	*2*	*3*	*4*	*5*
Investment	R$ 2.300					
Income (+)		R$ 27.840	R$ 27.840	R$ 27.840	R$30.840	R$30.840
Fixed Costs (-)		R$ 18.912	R$ 18.912	R$ 18.912	R$ 18.912	R$ 18.912
Variable Costs (-)		R$ 7.200	R$ 7.200	R$ 7.200	R$ 7.200	R$ 7.200
Depreciation (-)		R$ 1.205	R$ 1.205	R$ 1.205	R$ 1.205	R$ 1.205
Gross profit (=)	-R$ 2.300	R$ 523	R$ 523	R$ 523	R$ 3.523	R$ 3.523
Taxes (-)	R$ ----	R$ 172,59	R$ 172,59	R$ 172,59	R$ 1.162,59	R$ 1.162,59
Net profit (=)	-R$ 2.300	R$ 350,41	R$ 350,41	R$ 350,41	R$ 2.360,41	R$ 2.360,41

The cash flow estimated after 5 years of SRV's operation is R$ 99,45; which represents that initial investment and costs are totally covered. Also a IRR (12%) calculated is 27%.

Conclusion

Initial investment is reachable by local farmers and the investment recovery will take five years. The implementation results in a 30% increase in profits, a minimization of 1/8 of total emissions and 15% improve in gravimetric yield. As consequence, the SRV is economically profitable, environmentally correct and socially desired; with this basis, the SRV implementation can be considered as a feasible green infrastructure at regional scale.

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