Towards a low carbon emissions agriculture sector: the case of Costa Rican Coffee NAMA

Abstract

This paper discusses the best on-farm practices for low GHG emissions coffee growing. The relevance of this issue arises in the context of the Costa Rican Coffee NAMA development. Costa Rican coffee plantations data shows an inverse relationship between intensive farming management and coffee GHG emissions. A production function was derived to find those agronomic practices that enable a more intensive management without increasing the use of fertilizers. As a closing discussion, the authors highlight the importance of analyzing market variables that may affect the implementation of suggested practices.

1.Introduction

Costa Rican Coffee is certainly a fine and consistent quality product. Coffee profiles originated in different growing regions of Costa Rica are highly sought after by the world market, particularly differentiated specialty markets. Coffee from Costa Rica is, in itself, an element for which the country is recognized globally and a key part of the modern economic history of the country.

Despite having lost prominence in recent years, coffee production is still an important activity within the agricultural sector in Costa Rica along with bananas and pineapple. According to Costa Rican Coffee Institute (ICAFE) figures for 2012, the coffee industry is comprised of more than 52,000 farmers who grow just over 93,000 hectares of coffee throughout the country. The next link in the value chain benefits is also relevant: 192 coffee mills, 57 exporters and 37 roasters are reported. It is estimated that the coffee sector emissions account for 25% of emissions in the agricultural sector and 9% of the total emissions of Costa Rica (Zamora, 2013), accounting for the second largest emission amount -after cattle- in country's agriculture.

These cultural, economic and environmental factors are the most relevant on the decision of creating a Costa Rican coffee NAMA. According to the United Nations Framework Convention on Climate Change (2014), a National Apropiate Mitigation Action (NAMA) is "refer to any action that reduces emissions in developing countries and is prepared under the umbrella of a national governmental initiative. They can be policies directed at transformational change within an economic sector, or actions across sectors for a broader national focus.

Costa Rican Coffee NAMA comprises three main areas of emissions reduction: reduction of nitrogen fertilizers, water and energy use in coffee processing and fostering agro-forestry systems (Zamora, 2013). Within this framework, the focus of this paper is to adress the more accurate and monitorable emission reduction measures at farm level, given the challenge of owenership fragmentation of costa rican coffee plantations –more than 23000 farms are less than 1ha (INEC, 2007).

1.1. Costa Rican Coffee: Production methods and productivity

Many of the coffee production systems observed in Costa Rica show the typical limitations of a tropical low crop productivity. It is common to identify deficiencies in terms of processing and labor inputs into the final product. Inefficient processing resources is a key element in greenhouse gases emissions, since in most cases, resources that are not incorporated into the production flow will end becoming agents generating GHG emissions.

Moreover, it is clear that there are also systems in which improved efficiency is observed in the resource allocation and transformation. Such systems usually content a number of practices and activities that promote a better agronomic, economic and environmental performance; with notable positive social externalities from improved performance in these areas. The identification and dissemination of practices or activities that positively impact the productivity of farms is particularly important in the quest for reducing emissions of greenhouse gases in the sector.

1.2. Contribution of the coffee sector in the country's carbon emissions: key emission sources in production

In recent years there have been efforts to estimate the amount of carbon emissions in coffee. Information about it this topic still limited –due to uncertainity and data collection complexities-. Altough there is inherent variability in the absolute magnitude of emissions according to the characteristics of the production systems, relative emissions at each stage of the value chain and their main sources remain constant regardless of the system being analyzed. Thus, we can conclude that on-farm activities contribute between 50-55% of total emissions; meanwhile, processing and transportation of the product represent between 30-35% and 10-15% of emissions, respectively (Navichoc, Kilian and Rivera, 2012; Noponen et al 2013; PCF, 2008).

The analysis of the underlying processes in farm emissions, primarily involves discussion on inputs and agronomic practices used in the field. Navichoc, Kilian and Rivera (2012) found that in Costa Rica, the footprint of the farm stage reaches 1.02 CO_2eq / kg green coffee, representing 53% of total emissions considering a farm system, milling and oceanic exports (excluding toasting process, distribution, packaging and consumption).

Like in many other crops, fertilizers appear to be the protagonists when emission sources are assessed in farm (Table 1). 95% of on-farm emissions are due to the use of fertilizers, including chemical fertilizer production, transport and direct and indirect emissions of nitrous oxide (N_2O mainly). Table 1 also points out that the farms studied were low-intensive in terms of fossil fuels, electricity, and pesticides; so the contribution of these items in emissions is relatively limited.

Table 1. Farm level Carbon Footprint in Costa Rica

Emission Source	Emissions	
	kg CO_2eq/kg Green coffee	%
Fertilizers	0,96	94%
Fossil fuels	0,03	3%
Electricity	0,02	2%
Pesticides	0,01	1%
Total	**1,02**	**100 %**

Source: Adapted from Navichoc, Kilian and Rivera (2012)

The vigor and productivity of coffee plants shows a direct and significant correlation with the application of nitrogen, and not coincidentally is the element that is used most in the coffee plantations. Consequently nitrogen fertilizers also have the greatest share of responsibility for emissions from fertilizers.

Regardless of its origin (organic or inorganic), Nitrogen is subject of biological conversion in soils, which favors volatilization (releases to air) as nitrous oxides. Meanwhile, leaching (nitrogen loss because water influence) is a phenomenon that is affected by soil physicochemical such as structure and pH conditions; added to the effect that intensity and frequency of rainfall can have in relation to the application of nitrogen fertilizer (Nielsen, 2006).

It is clear that –in both cases- when nitrogen is applied, a part is absorbed by plants and some is lost in the environment. Therefore, reducing this loss seems to be essential to reduce the potential nitrogen emissions of a coffee plantation. The rate of absorption of nitrogen is mainly influenced by the health of the plant, in terms of rate of photosynthesis and plant pathology condition, but also by the frequency and severity of leaching and volatilization (De Klein et al., 2006).

Clearly, the existence of these phenomena implies a significant carbon footprint impact of fertilizers. However, it must be emphasized that the emissions from the production of the fertilizer itself represent the most important contribution, representing up 80% of the total fertilizers-sourced emissions (Navichoc, Kilian and Rivera, 2012).

2. Methodology

Given the proposed action scheme proposed within the Costa Rican Coffee NAMA, this paper aims to spotlight a discussion on the most carbon-efficient farm practices, giving the local economic, social and environmental context. The statements made in the precedent section will be matched with primary sourced data with the purpose of finding significant relations between farm conditions, productivity and agronomical practices, specially fertilizing.

Primary farm data was collected as part of a precision agriculture project developed by ICAFE-CIMS between 2009 and 2012, in the following regions: Los Santos, Valle Central y Valle Occidental. The sample comprises 323 observations and were selected according to the arrangement of producers to join the project. Given that the sample is considerably robust in terms of size, number of crops and involves the major growing regions of the country, it is very possible that emission distribution pattern shown in Figure 1 has a high inference potential of the national coffee plantations emission pattern.

One could affirm –given the statements cited in section 1.2- that the intensity of fertilization in a coffee farm emissions can reasonably be inferred by the intensity of fertilization. The histogram showed in Figure 1 depicts the emissions distribution (kg CO2 / kg green coffee / harvesting) of the mentioned sample, which calculated from the reported fertilization intensity, and yield for each production unit[1].

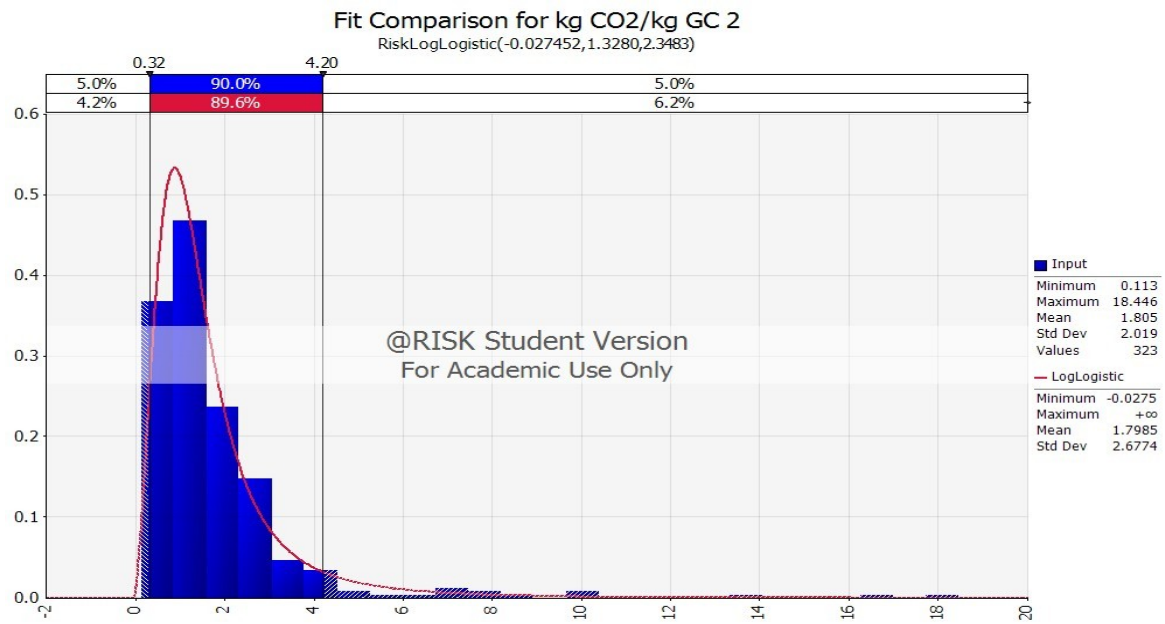

Figure 1. Emissions distribution (kg CO2 / kg green coffee / harvesting) in three coffee regions of Costa Rica 2010-2013.

Source: Based on data from 2009-2012 CIMS-ICAFE project.

As seen in Figure 1, approximately 70% of the sampled production units emit less than 1.5 kg CO2 eq / kg green coffee / harvest. The remaining 30% of the observations presented higher emissions ranges than this limit, with outliers as 18 kg CO2 / kg green coffee / harvest. High rates of emissions exist in productive units in which there was very little yield per unit of fertilizer, however it must be stressed that this does not necessarily mean that the unit is inefficient in terms of processing

1 Production unit is defined as a Coffee land with an specific área, for which labor, materials and the corresponding yield was recorded.

resources, which may correspond to particular situations such as early phenological stages of plantation (production unit under renovation).

Given the emission distribution of the farms. Correlation analysis were run to caracterize the relations between emissions, output and area of the production units. With those relantionships understood, linear regression tecnique was applied to develop a production function, adressing which variables are associated with higher productivity levels are on a coffee farm.

3. Results

3.1. Best practices in the coffee sector:

Can intensifying systems reduce carbon emissions and promote sustainable agriculture in low emissions?

The observations reflect different management intensities within Costa Rica coffee farms (ie with maneuvers that represent the full spectrum of population variability). Thus, they sample can demonstrate a number of interesting relationships that occur in the dynamic productivity-emissions.

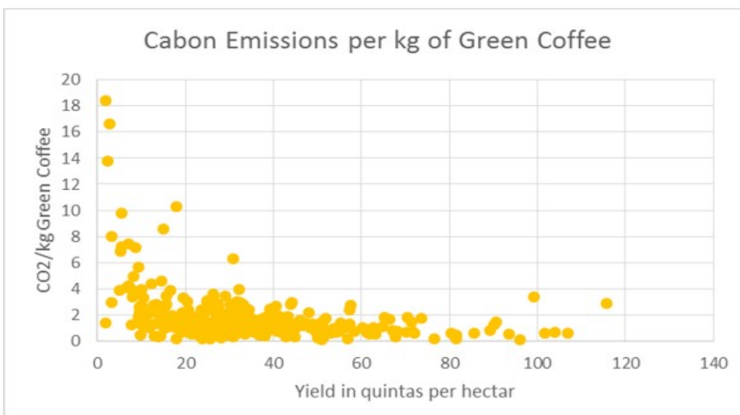

Figure 2. Relationship between farm productivity and emissions per unit of output.

Source: Based on data from 2009-2012 CIMS-ICAFE project.

Productive units analyzed show an inverse (R = -0.51) and significant (p-value <0,01, see Appendix 1) correlation between yields and emissions per unit of output. This means each kilogram of coffee tends to present lower emissions when the yield of a production unit is greater per unit area.

In contrast, when per-hectare emissions are analyzed in terms of yield per-hectare (Figure 3), it is noted that the behavior is reversed.

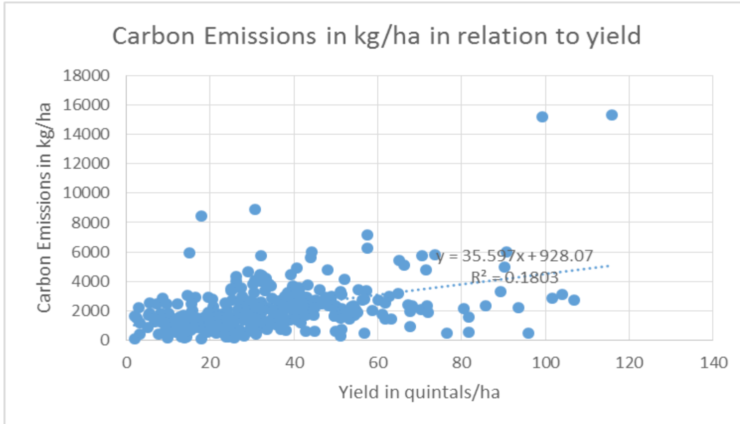

Figure 3. Relationship between farm productivity and emissions per unit area.

Source: Based on data from 2009-2012 CIMS-ICAFE project.

In this case, the production units were directly correlated (R = 0.425) and significant (p-value <0,01) between carbon emissions per unit area and the corresponding yield. Put differently, one hectare of plantation has higher emission levels at higher yields for that same hectare.

Up to this point, there seems to be a paradox: the more productive is a farm, each kilogram of coffee produced in it tend to emit less greenhouse gases, but in turn, the more hectares of high returns exist, the greater the carbon footprint of the cultivated area. However, if one consider that the alternative to at least maintain domestic production of coffee -using systems with lower productivity and therefore lower emissions per unit of area-, it would be necessary to expand the coffee frontier in areas currently covered by forest, the paradox seems to be resolved. In this regard, Noponen et al. (2013) indicate that the extension of the production area to land with forest cover would mean more than 5,000 kg CO2eq / increase ha / crop, thereby resulting in systems that exceed 8,000 kg CO2e / ha / crop.

The results suggest the way forward would be to increase yields in low-productivity units without changing the extension of the existing coffee plantations, ensuring that this enhancement does not depend solely on an increase in fertilizer consumption.

This raises the question of which variables are associated with higher productivity levels in local coffee farms. The estimation of the production function (Table 2) can answer this question with statistical robustness.

Table 2. Production function for productive units in three coffee growing regions in Costa Rica, 2009-2012

Source: Based on data from 2009-2012 CIMS-ICAFE project.

The effect of fertilization intensity parameter is clearly the most important and significant to the variable "production" of production unit. Meanwhile investment of labor in pruning and herbicide application are the second and third most significant parameters respectively, with greater effect in herbicides application. Finally, with lower levels of significance, it shows the variety and labor investment in desuckering, in this case the selection of the variety has a greater effect on the production function.

Thus, we can conclude that increasing investment in pruning work and desuckering, and the use of an appropriate variety (Catuai) may intensify the productive units without necessarily changing the levels of fertilization present in the sample universe.

In Figure 4, three scenarios are described for the cases of not compromising nitrogen levels for fertilization, since it is clearly a key productivity factor.

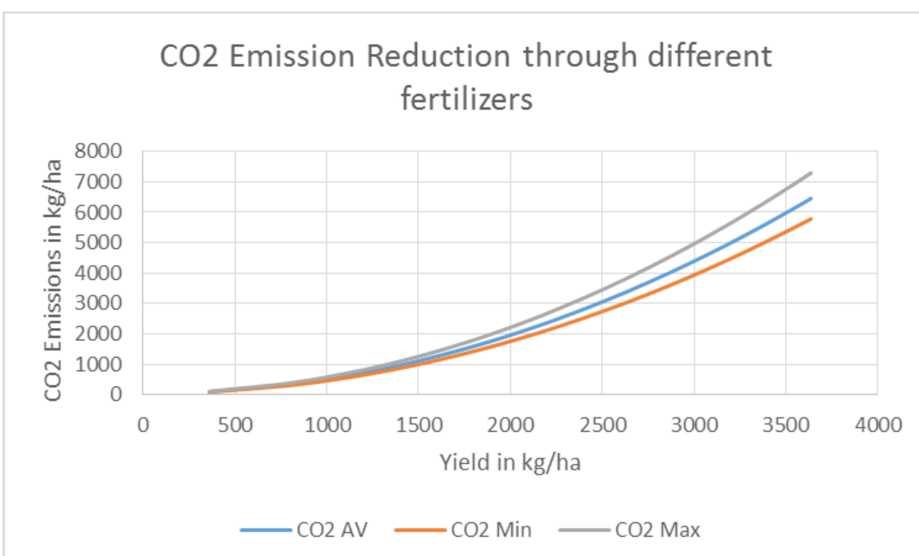

Figure 4. Evolution of emissions as using different fertilizers

Source: Based on data from 2009-2012 CIMS-ICAFE project.

The CO2 AV scenario describes the evolution of usual emission levels according to the productivity of the system, based on the typical usage of common nitrogenous sources, namely, urea and different types of nitrates. The other two scenarios show what would happen if only high emissions nitrogen sources (CO2 Max) or only lower emissions sources (CO2 Min) were used. In units producing 3,000 kg / ha of green coffee, the choice of a nitrogen source of high emissions per unit of item (urea, for example) could represent an increase of up to 1,000 kg CO2e / ha compared to a system using sources lower nitrogen emissions per unit of element (ammonium nitrate or other nitrates, for example)

3.2 Potential impact of good practices

The application of good practices altogether undoubtedly brings benefits in terms of productivity and, therefore, in terms of emissions. Wheater it is consider (or not) the effect of agronomic practices in determining the production function, it is posible to generate scenarios describing the evolution of emissions for different productivity levels (Figure 5).

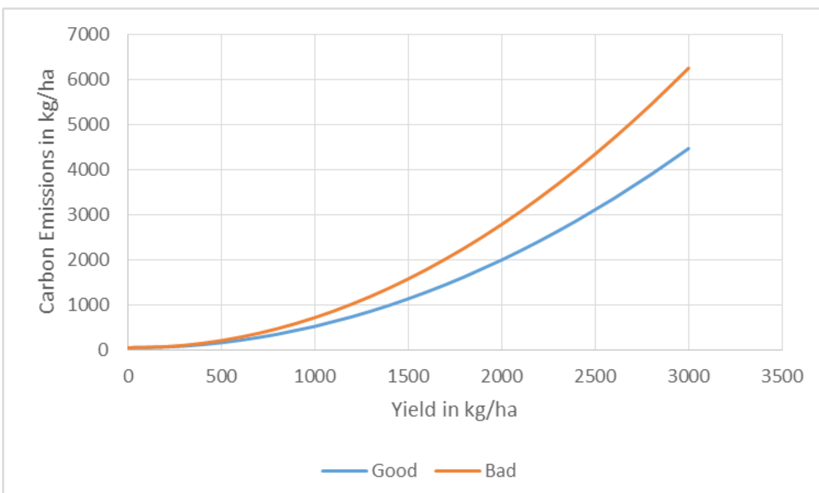

Figure 5. Evolution of Emission productivity

Source: Based on data from project CIMS-ICAFE 2009-2012

From the observation of the respective scenarios, one may denote that the difference in emissions broadens as yields increase in productive systems, ie, a production system that applies malpractice is more emission-intensive than a more productive one. For example, at levels of 3.000 kg / ha a system applying good practices might avoid the emission of CO2 eq 1800-2000 kg / ha compared to a system that do not apply them.

4. Conclusions

The efficiency in transforming inputs into outputs (productivity), is a key element in emissions management for the agricultural sector, since usually the resources or inputs that are not incorporated into the production flow will end up becoming generating agents of GHG emissions. Thus, the increase in productivity should be widespread when designing policies towards a low emissions agricultural sector, as well as being a factor in the reduction and control of emissions, it is also in itself an incentive for the adoption of policies and practices at the producer level.

In the coffee sector, the analysis of emissions per unit of output and per unit area seems to generate a paradox on the decision whether or not to commit to increase productivity in the coffee fields. However, it is clear that production volumes must inevitably increase as the market demand and population increase. Thus, the alternative to productivity growth then involves the extension of the agricultural frontier, which results in degradation or destruction of forest systems and this event per se, has a greater impact in terms of emissions rather than the intensification of productive systems.

The increase in productivity should focus on maximizing the factors that impacts yields the most significantly coupled with less impact on the product carbon footprint. In the case of coffee, agronomic practices such as pruning and desuckering, coupled with selection of more productive varieties suggest to be the most relevant. Evidently, specific fertilization to crop needs, coupled with the use lower emission potential fertilizers are essential actions in the pursuit of maximizing production with low impact on emissions. The joint implementation of these actions shows potential emissions savings between 30-50% depending on the levels of productivity.

Additionally, these actions conduct to a range of co-benefits for producers, such as higher net income and lower vulnerability of plantation both to environmental and Phytopathological adverse conditions. In this regard, the guidelines and policies set by the NAMA Coffee precisely focus the essential points discussed throughout this document, therefore represent an excellent roadmap to follow to achieve low emissions coffee culture.

The accurate identification of the determinants of productivity requires the existence of robust data originated from the populations of interest to generate the estimation of the corresponding production functions. Thus it is advisable to regularly rise field data (agronomic, economic and environmental) in key management issues for the different agricultural subsectors.

5. Discussion

There is a range of factors that may underpin or constrain the proper implementation of measures contained within an agricultural sector NAMA. The case of Costa Rican Coffee NAMA allows to visualize a set of market variables that can affect the successful implementation of the measures proposed in this sectoral plan on the the production stage, guided by the principles identified in this paper.

The case of Specialty Coffee market was selected to raise the discussion on how to market trends and its underlying signals (such as price) should be considered when evaluating the feasibility of measures wanted to implement throughout the sector. This is due to the (favorable to the development of NAMA or no) incentives that generate these market conditions on management and investment decisions made by the producers, who are mostly small farmholders in the case of Costa Rica.

Specialty coffees are grown in special and ideal climates. Acording to Specialty Coffees Asociation of America, they must possess at least one distinctive attribute in the body, flavor, aroma, or acidity, and be free of faults and taints (Barker, 2004). Market for Specialty Coffees has grown significantly in recent decades. In the US alone, Specialty Coffees represent about 37% of the market in volume and nearly 50% of the value (SCAA, 2012). An important portion of the Costa Rica coffee would be supplying this growing demand –sold at prices about 4 times higher than the world price benchmark (Wall Street Journal, 2014) - and for this reason it is important to delve into the dynamics that this consumption trend generates for producers.

It was found that some Specialty Coffee profiles are produced under low productivity schemes, both because of agronomic practices as for the use of certain varieties. Moreover, these come largely from small producers, who have a more limited capacity to increase labor in some GHG reducing measures, as outlined in this paper. These characteristics of production, -coupled with rising global demand reflected in prices- could generate conflicting signals to small producers when implementing sectoral measures included in NAMA. Thus, the entities involved in implementation of the Coffee NAMA should consider a differentiated approach and generate discussion about action varies given this and other market trends.

Moreover, the growth of Specialty Coffees market could be a major driver to enhance climate change adaptation. This is due to the possibility of small farmers of gaining better access to Specialty Coffee category prices and thereby, increase their capacity to invest in adaptation measures. These factors emphasize the importance of further investigation of the identification of adaptation measures in coffee production, characterizing its cost and ease of implementation as well as their contribution to reducing the vulnerability of farms.

References

Barker, R. 2004. Green coffee grading part II. Tea & Coffee Trade Journal. May-June, 2004. Available at http://www.teaandcoffee.net/0504/coffee.htm. Accesed on October, 2014.

Chacón, A., Montenegro, J., Sasa, J. (2009). Inventario nacional de emisión de gases con efecto invernadero y absorción de carbono en Costa Rica en el 2000 y 2005. MINAE. Costa Rica.

De Klein, C., Novoa, R.S.A., Ogle, S., 2006. N2O emissions from managed soils and CO2 emissions from lime and urea application. In: IPCC Guidelines for National Greenhouse Gas Inventories. IGES, Japan (Chapter 11)

FAO. (2013b). Climate-Smart Agriculture Sourcebook. http://www.fao.org/docrep/018/i3325e/i3325e.pdf

Instituto Nacional de Estadística y Censos. 2007. Censo Cafetalero: Turrialba y Coto Brus 2003, Valle Central y Valle Central Occidental 2004, y Pérez Zeledón, Tarrazú y Zona Norte 2006: Principales resultados. Instituto del Café de Costa Rica. -1. ed.--San José, C.R.

Josephs, L. 2014. Coffee Prices Soar at Online Auctions. The Wall Street Journal. Updated Oct. 27, 2014. Available at http://online.wsj.com/articles/coffee-prices-soar-at-online-auctions-1414428118. Accesed on October, 2014.

Nielsen, R. 2006. N Loss Mechanisms and Nitrogen Use Efficiency. Available at: http://www.agry.purdue.edu/ext/pubs/2006NLossMechanisms.pdf. Revisado en junio 2014.

Navichoc, D., Kilian, B. and Rivera, L. 2012. Carbon Footprint Across the Coffee Value Chain: The Case of Costa Rican Coffee. Paper presented at the annual meeting of the BALAS Annual Conference, Universidad ESAN, Lima, Peru. Disponible en: http://www.balas.org/BALAS_2013_proceedings_data/data/documents/p639212.pdf. Accessed on December, 2013

Noponen, M., Haggar, J., Edwards-Jones, G., Healey, J. 2013. Intensification of coffee system can

increase the effectiveness of REDD mechanisms. Agricultural Systems 119: 1-9. DOI:10.1016/j.agsy.2013.03.006

PCF (Pilotprojekt Deutschland). 2008. Case study tchibo private kaffee: rarity machare by tchibo

GMBHD. Disponible en : <http://www.pcfprojekt.de/files/1232962944/pcf_tchibo_coffee.pdf>

Secretaría Ejecutiva de Planificación Sectorial Agropecuaria (SEPSA). (2012). Boletín Estadísitico Agropecuario N°22. San José: Secretaría Ejecutiva de Planificación Sectoria y Agropecuaria.

United Nations Framework Convention on Climate Change. 2014. FOCUS: Mitigation - NAMAs, Nationally Appropriate Mitigation Actions. Available at: http://unfccc.int/focus/mitigation/items/7172.php. Accesed on October, 2014.

Specialty Coffees Association of America. 2012. Specialty Coffees Fact & Figures. Statistical bulletin. Available at: http://www.scaa.org/PDF/resources/facts-and-figures.pdf

Zamora, L. 2013. NAMA Agrícola Costa Rica. Ministerio de Agricultura y Ganadería de Costa Rica. Presentación en UNFCCC regional workshop for Latin American and the Caribbean regions.

Acknowldgement

This document was elaborated upon request of "Programa Acción Clima" (Climate Action Program), of the Gesellschaft für Internationale Zusammenarbeit (GIZ-Germany), asd financed by the Federal Ministry of Environment, Nature Protection, Infraestructure and Nuclear Security of the Federal Government of Germany.

Appendix A. Correlation matrices

i. Correlation matrix: productivity and emissions per product unit

Correlation Matrix

	Yield	*Emission*
Yield	1.000	
Emission	-.501	1.000

323 sample size

± .109	critical value .05 (two-tail)
± .143	critical value .01 (two-tail)

ii. Correlation matrix: productivity and emissions per area unit

Appenndix B. Regression Analysis

Appendix C. Emissions from agriculture

From 1990 to 2005, total emissions from other agricultural sources decreased from 1,283 million tonnes of CO2 equivalent to 1.165 million tons (US-EPA, 2012 p. 75), corresponding to 20.1% of total emissions of agriculture.

Other sources of non-CO2 agricultural emissions (CH4, N2O)

Type of emission	**Total emissions 1990 ($MtCO_2e$)**	**Total emissions 2005 ($MtCO_2e$)**	**Total emissions 2030 (projection) ($MtCO_2e$)**
	(million tonnes of CO_2 equivalent)		
Agricultural soils (N_2O)	1,658 (29.5%)	1,840 (31.7%)	2,483 (35.8%)
Enteric fermentation (CH_4)	1,763 (31.4%)	1,894 (32.7%)	2,320 (33.4%)
Rice cultivation (CH_4)	480 (8.5%)	501 (8.6%)	510 (7.3%)
Manure management (CH_4, N_2O)	436 (7.8%)	398 (6.9%)	466 (6.7%)
Other emissions (CH_4, N_2O)	1,283 (22.8%)	1,165 (20.1%)	1,165 (16.8%)
Total non-CO_2emissions	5,620 (100%)	5798 (100%)	6944 (100%)