**Trade-off between GHG emissions and economic performance of the Brazilian Agriculture: an environmental input-output analysis**

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**Abstract**

The aim of this paper is to analyze the relationship between the Brazilian Agriculture sector GHG emissions and its potential for fostering employment, income and sectoral linkages. In this regard, data from World Input-Output Database (WIOD) were used to construct an environmental input-output model for Brazil. The main results indicate that this sector is responsible for the highest emission rates in the Brazilian economy. Nevertheless, such environmental cost is not converted into economic benefits, given that this sector has generated a below-average number of jobs, income and linkages.

Keywords: Input-output; GHG emissions; Agriculture; Brazilian economy.

**1 Introduction**

Global warming has raised the attention of the international community for the development of climate policies and adaptation to the effects of the extreme weather. The greenhouse gas (GHG) emissions caused by anthropogenic activities is one of the main cause of these problems. According to Magalhães and Domingues (2013), the rise in the average temperature observed since the mid 20th century is largely caused by the increase of GHG concentration in the atmosphere.

There are three main sets of air pollutants, which are Greenhouse Gases (GHG) that contribute to global warming, pollutants that contribute to acidification (ACID), and Tropospheric Ozone Forming Potential (TOFP). For the purpose of this paper, we only used data related to GHG emissions, constituted by Carbon dioxide (CO2), Methane (CH4), [Nitrous oxide](http://en.wikipedia.org/wiki/Nitrous_oxide) (N2O), Sulfur hexafluoride (SF6), Chlorofluorocarbon (CFCs) and Hydrofluorocarbons (HFCs) (Moll et al., 2006; Genty et al., 2012).

The main source of GHG in almost all economic activities is the consumption of fossil fuels (IPCC, 2001). However, in the agriculture and forestry sectors, emissions are in most cases the result of: biotic processes inherent to the development of plants and animals; of some methods used in this sector; and of changes in land use, especially deforestation (Janzen 2004; Mosier et al., 1998; Smith e Conen, 2004). The heterogeneity of economic activities interferes in the elaboration of transversal climate policies. On the other hand, direct and indirect emissions throughout the productive chain may be assessed by using extended input-output models which incorporate environmental aspects.

The traditional input-output models reflect the economic structure of a given country/region through the representation of monetary trades of goods and services among its many sectors of economic activity (Miller and Blair, 2009). Environmental components such as emission of pollutants, for instance, may be easily incorporated within these models and assessed by different techniques and analytical perspectives.

The international literature presents many studies about the intensity of CO2 or GHG emissions in economic sectors for different countries/regions from an environmental input-output framework. Studies by Carvalho et al. (2013), Rhee and Chung (2006) and Su et al. (2013), based on international trade's perspective, evaluated CO2 emissions of Minas Gerais (Brazilian state), between Korea and Japan and China, respectively. Brizga et al. (2014), Butnar and Llop (2011), Silva and Perobelli (2012) and Yamakawa and Peters (2011), used the structural decomposition analysis (SDA) to evaluate CO2 or GHG emissions of The Baltic States, Spain, Brazil and Norway, respectively. Cristóbal (2010; 2012), Hristu-Varsakelis et al. (2010) and Hristu-Varsakelis et al. (2012), used an environmental input-output linear programming model to minimize GHG emissions subject to environmental and economic constraints.

All those studies have used input-output models that somehow cover the intensities of emissions. None of them, however, has been concerned with specifically analyzing the role of the agriculture sector as an important generator of GHG emissions and its relationship with its weak economic performance regarding its employment and income generation and linkages effects, which can be defined as the intermediate relations between sectors in terms of purchases and sales. This topic gains even more relevance when related to the reality in Brazil, as it is home to the biggest primary forest in the world (the Amazon rainforest). Besides, this country owns comparative advantages in the agriculture sector due to the pressure this activity exerts on deforestation.

Specifically, this paper aims to calculate the GHG emissions multipliers of the Brazilian economy in 2009 and associate these results with the employment and income multipliers, specially of the Agriculture sector. In this regard, data from World Input-Output Database (WIOD) were used to construct an environmental input-output model for Brazil. To achieve the proposed objectives, Section 2 presents data about the GHG Brazilian emissions. Section 3 presents the input–output (IO) model incorporating GHG emissions and some IO indicators. Section 4 describes the database. Section 5 presents and discusses the empirical results and Section 6 presents the conclusions.

**2 GHG Brazilian emissions**

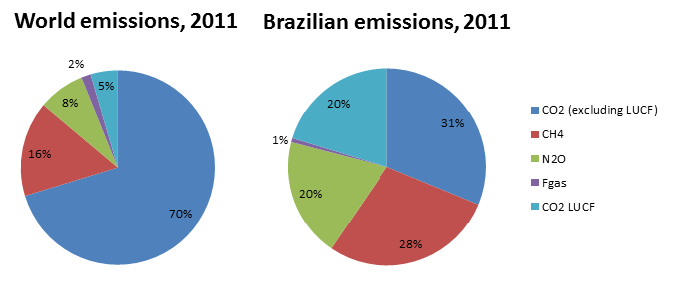
According to the World Resources Institute (2014), world GHG emissions reached 45,766 MtCO2eq (CO2eq = CO2 equivalent) in 2011 and carbon dioxide reached 31,854 Mt, most of that due to the consumption of fossil fuels (30,451 Mt). The increase in the total emissions compared to the year 1990 has been 37%. Brazil was the sixth largest GHG emitter (1,419 Mt), responsible for 3% of the total, preceded by China (20%), USA (14%), India (5%), Russia (5%) and Indonesia (4%). The 27-country EU block was responsible for 9%.

As for the accumulated emissions since 1990, the global emission has had a few changes. The USA has emitted 16%, followed by China (15%), EU (12%), Russia (6%) and Brazil (5%). The highest variations are in the per capita values. In such case, the annual emissions in Brazil (7.21t) have been close the world per capita values (6.59t), the French per capita values (7.08t), the Chinese (7.63t) and the Mexican (6.06t), and way below the G8 countries (14.23t), the USA (19.89t) and Russia (15.50t).

The coefficient of emissions per monetary unit of GDP was of 505tCO2eq and for each million dollars of the world GDP, adjusted by purchasing power parity. In Brazil it was 503tCO2eq, above the USA (394tCO2eq), G8 (366tCO2eq) and Europe (328tCO2eq), and below China (760tCO2eq), Russia (689t CO2eq) and most of the least developed countries.

The Brazilian electricity matrix is more concentrated in hydroelectric generation; the intensity of CO2 per unit of energy is much lower here than in most major emitters. The low carbon-intensity of the energy is due to the high share of hydro in the electricity and biomass in transportation and in sugar and biofuels industry. They are 35g CO2/MJ in Brazil, compared with 85g in China and India, and between 50 and 55 in the United States, Japan and Germany (Lenzen et al., 2013). The economy has comparative advantages in agriculture. The result is a unique emissions profile. There is a strong presence of methane as well as nitrous oxide gases related to agriculture and waste generation. Carbon dioxide amounted to 58% of GHG in Brazil and 77% in the world in 2011. Figure 1 compares the profile between Brazilian emissions and global emissions.

Figure 1 – Profile of Global and Brazilian GHG emissions.



a) Emissions in CO2eq.

b) “Fgas” include HFC’s, CF’s e SF6.

Source: World Resources Institute*,* 2014.

Although it may rely on its recent good performance in controlling total emissions with the lowest responsibility in per capita terms, Brazil, alongside other emerging countries, will play an important role regarding its contributions to global warming in any future scenario. Moreover, if deforestation rates continue to decrease, Brazil's emissions will become more adherent to the economic cycle. According to the Brazilian Panel on Climate Change, the growth in emissions rate will resume from 2021, due to a trend of increase in emissions from burning fossil fuels, and in expected limits for the expansion of renewable energy sources (PBMC, 2014b) .

Figure 2 shows GHG emissions in Brazil between 1990 and 2010, based on the annual estimates of greenhouse gases, published by Brazil's Ministry of Science, Technology and Innovation (MCTI, 2013). Brazilian estimates have followed the methodology recommended by the IPCC for the elaboration of national inventories of GHG emissions.

Figure 2 – Greenhouse gas emissions in Brazil between 1990 to 2010.



a) The gases listed in these estimates were carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluocarbonos (FC's), and sulfur hexafluoride (SF6). Emissions in CO2eq.

b) LUCF is the Land Use Change and Forestry.

Source: MCTI (2013).

The Energy sector comprises emissions from fossil fuel combustion related to the oil, gas and coal production. In the case of industrial processes, emissions arise from the production processes themselves, exclusively those resulting from fuel combustion, which is accounted for in the energy category. In agriculture, emissions from enteric fermentation of herds, rice cultivation, animal waste management, agricultural land and burning of agricultural residues were considered. In LUCF the balance between removals and emissions between different land uses, in addition to liming and biomass burning (MCTI, 2013).

Two movements have been quite prominent in the evolution of Brazilian emissions: the change in total due to the behavior of LUCF, with progressive decrease since its peak in 2004, and the continued increase in emissions by other sources, notably agriculture and energy generation.

Agriculture has emitted 437 MtCO2eq in 2010, that is, 35% of total emissions. In this sector, methane from enteric fermentation in ruminants accounted for 56.2% of emissions, and agricultural soils by other 35.2%, mainly by animal manure on pasture and nitrogen fertilizer use. Animal waste management, especially with respect to herds raised in intensive confinement, which favors anaerobic decomposition of waste, has emitted 4.9%; the cultivation of rice, 2%; and burning waste from sugar cane and cotton, 1.5%. Since 1990 emissions growth in agriculture has been of 43%.

Beef cattle totaled almost 90% of the methane from enteric fermentation in 2005 (MCTI, 2010). The prospect in this segment is of an emissions increase in the medium-term. There is an increasing global demand for beef and the country has comparative advantage in its production. Furthermore, since it is the second largest exporter, after Australia (Loyola, 2013). Currently, domestic demand represents 84% of production and per capita consumption is 40kg/year, surpassed only by Argentina, 51Kg. Slaughter grew at 5.1% per year between 2000 and 2011.

According to the Municipal Livestock Production Research from IBGE (Brazilian Institute of Geography and Statistics, 2009), Brazil has an estimate of 190 million head cattle herd in 2009, being the second largest slaughterer country, only behind China. Ranching occupies 199,000 hectares (73% of the area), the largest area among all agricultural activities in Brazil. Livestock market also has lower employment generation per occupied area, that translates into one job per 500 hectares. In addition, there is a high informality in the sector. In 2006, the livestock market generated only 440 thousand formal jobs, 43% of which were generated in the Southeast, a region that corresponds to only 19% of the Brazilian cattle herd.

Net emissions of LUCF were 279 MtCO2eq, or 22% of 1,246 Mt emitted in 2010. Almost all of these emissions have been caused by deforestation, except 10 Mt which was due to the application of Calcium (liming). The main gas was carbon dioxide (90%). Among the Brazilian biomes, the Amazon and the Cerrado together accounted for 93% of net emissions of LUCF (MCTI, 2013).

To Houghton (2005) the emissions of carbon from tropical deforestation are determined by two factors: rates of land-use change (including harvest of wood and other forms of management) and per hectare changes in carbon stocks following deforestation (or harvest). The amount of carbon held in trees is 20-50 times higher in forests than in cleared lands, and changes in carbon stocks vary with the type of land use (for example, conversion of forests to croplands or pastures), with the type of ecosystem (tropical moist or tropical dry forest), and with the tropical region (Asia, America, or Africa).

In the past two decades, Brazil has been the world leader in tropical deforestation, clearing an average of 19,500 km2/year from 1996 to 2005. This forest conversion to pasture and farmland released 0.7 to 1.4 GtCO2eq per year to the atmosphere. According to the FAO (2001), the highest rates of deforestation (in 106 ha/yr during the 1990s) occurred in Brazil (2.317). These rates are higher than the reported net changes in forest area.

The main causes of deforestation in Brazil, specifically in the Amazon, are its exploitation for timber, agriculture and the opening of new roads (Fearnside, 2005; Margulis, 2003; Nepstad et al 2001; Rivero et al., 2009). Even with the supervision of the federal government, there is illegal large-scale harvesting of timber, especially the most profitable species (mahogany and ipe).

A reduction in deforestation has been achieved after the year 2004, when The Action Plan for Prevention and Control of the Legal Amazon Deforestation (PPCDAM) and analogue plans for the *Cerrado* and *Caatinga* regions were released. Through such measures, the Brazilian government took the responsibility to control deforestation and reduce it to a minimum rate by the year 2020 (MMA, 2013). In the Amazon biome the annual rate dropped from 27,772 km² in 2004 to 6,418 km² in 2011. In 2012, the figure of 4,571 km² was the lowest ever recorded by the Project of Deforestation Monitoring in the Legal Amazon, and in 2013, 5,891 km² have been deforested (PRODES/INPE, 2014). In the *Cerrado*, the drop was from the average of 14,179 km² in the period 2002-2008, to the average of 6,469 km² in the period 2009-2010 (MCTI, 2013). In 2010, the GHG annual emissions were 65% lower than those registered in 1990.

Between the years 2004 and 2010 the Brazilian economy registered strong growth in production, more than 4% per year. The decoupling of LUCF emissions from the economic cycle and reveals the advantage that the country had to reduce its emissions, compared to other emerging countries whose GHG releases are most associated with energy generation, such as China or Russia.

Although it is a multidimensional phenomenon, the deforestation of the Amazon is largely attributed to the clearance of land for livestock, and then for agriculture (Diniz et al., 2009; Margulis, 2003).

Despite Brazil's participation as a non-Annex 1 in the Kyoto Protocol, therefore without having adopted emission reduction targets, the country has established its National Policy on Climate Change (NPCC) through Law 12,187/2009, which defines the voluntary national commitment to the adoption of mitigation actions in order to reduce its emissions of greenhouse gases (GHG) between 36.1% and 38.9% compared to projected emissions by 2020. This projection was estimated in 3,236 GtCO2eq. In that account, for the year in question, the corresponding reduction in the percentages established was between 1,168 GtCO2eq and 1,259 GtCO2eq, respectively. In the 21st century, especially due to the increased demand for commodities from China, the Brazilian agriculture gained new momentum and started to increase production in order to meet international demand.

In this context, new areas are being used for large-scale agriculture, especially the states of Maranhão, Piauí, Tocantins and Bahia, which form the region of MAPITOBA. In addition to these regions, the Legal Amazon has had an increased use of land for agriculture, especially lands that were formerly used as pasture. According to Aguiar *et al.* (2007), the area that has been converted to pasture corresponds to 70% of the total deforested area.

The advance of agriculture in the amazon region has contributed to the deforestation in the forest, mainly for corn and soybeans. Castro (2005) and Fearnside (2005) show that crops has advanced faster than livestock, and it also expands to states that have a well-structured agribusiness such as Mato Grosso and Tocantins. In the 1990s, according to Costa (2000), tax incentives from the federal government for ranchers through Finam (Amazon Fund), rural credit and FNO (Constitutional Fund for the development of the North region) may have encouraged deforestation in the Amazon.

To assess the economic and environmental performance of the agriculture sector, the input-output model was used. This framework allow us to have an integrate perspective in terms of sectoral relations. Next section presents the model and also some methods of analysis.

**3 The input-output model incorporating emissions**

The input-output model traces the trade between industries and the final demand of the economy in an integrate perspective. More specifically, according to Leontief (1941, p.3): "An attempt to apply the economic theory of general equilibrium - or better, general interdependence - to an empirical study of inter-relations among the different parts of a national economy as revealed through covariations of prices, outputs, investments, and incomes". This model may be represented by the following system of matrix equations:

 (1)

 (2)

In which *x* and *f* are respectively the total output and final demand;  is the Technological Matrix defined as quantity of intermediate input used by sector *i* to produce an output unit of production sector *j* (in monetary terms), for *i, j =* 1,…, *n*; and  is the Leontief Inverse Matrix.

To incorporate emissions associated with the production of inter-sector activities, according to Miller and Blair (2009), we consider a matrix of direct emissions coefficients , wherein each element indicates the amount of pollutants of the type *k*, generated per unit of production of industry *j*. Therefore, the level of emissions associated with the vector of total output can be expressed as:

 (3)

In which is a vector that represents the level of emissions per economic activity. Combining equations 2 and 3, we have:

 or  (4)

The result of the multiplication represents a matrix of total coefficients of environmental impact, that is, the elements of this matrix represent the total emissions impact generated per unit of final demand.

There are several Methods of analysis that can be calculated from the input-output tables. For the present article, we calculate the multipliers for emissions employment and income. Furthermore, to measure the linkages effects, it is also calculate the traditional field of influence and the field of influence that incorporates emissions.

3.1 Input-output indicators

Input-output multipliers are overall used to evaluate the impact of exogenous changes on the product, income, employment, value added, among other variables. The simple output multiplier of sector *j* *()* can be defined as the total required emissions from all sectors, to meet the variation in a monetary unit of the total demand of sector *j* (Miller and Blair, 2009), and can be expressed by:

 (5)

Wherein *lij* are the elements of Leontief Inverse Matrix. It is important to highlight that the simple multiplier is calculated from a model with household exogenous. According to Miller and Blair (2009), the analysis becomes more interesting when is measured by jobs creation and income effects, for instance. In this regard, the simple income multiplier is defined (*Mej*) as follows :

 (6)

Where *an+, i* is the labor-input coefficient of sector *j* measured in monetary terms, i.e, wages earned per unit of output. We can use the same equation (6) to calculate also the simple employment multiplier. In this case, the Leontief Inverse elements will be weighted by the employment coefficient, i.e, number of jobs per unit of output. These multipliers can be defined also in physical terms (persons-year, for example) which are called as Type I multipliers, that is:

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In order to identify the strongest linkages that may cause greater impacts on the Brazilian economy, the field of influence developed by Sonis and Hewings (1992) is presented. From it, it is possible to view the sectors that exerted greatest influence, from their intersectoral relationships, on the rest of the economy. To evaluate the impact of these variations on each element of the Technological Matrix (*A*), a small change ()[[4]](#footnote-4) must occur, on each isolatedly, (i.e.), is a matrix . If the change occurs in location (*i1*, *j*1) i.e.:

(7)

In this case, a variation of magnitude  in the coefficients of Matrix  results in a new Technological Matrix: . Accordingly, Leontief Inverse Matrix may be rewritten as: . The field of influence (F) of each coefficient is approximately equal to:

 (8)

The total influence of each technical coefficient of the input-output matrix is given by equation (9). The higher the  the larger the field of influence of coefficient  on the productive structure.

 (9)

To incorporate the emissions, a new matrix *G* is used, in which  and , therefore equation (8) may be rewritten as:

 (10)

To calculate the new field of influence that incorporates the direct coefficients of GHG emissions, it is simply necessary to use the result obtained by equation (10) in equation (9).

**4 Database**

The input-output matrix used in this paper was taken from the World Input-Output Database (WIOD). This database was built from official information of national accounts, international trade statistics, and comprises a set of annual input-output tables from 40 countries for the period 1995-2011, consisting of 35 sectors and 59 products. In addition, this database provides information regarding various pollutants by sector (Dietzenbacher et al, 2013; Timmer, 2012;).

The WIOD only provides information of the CO2 CH4 and N2O due to missing data related to the SF6, CFCs and HFCs. However, Genty et al. (2012) says that the last three gases generate a weak impact on global warming. Furthermore, agriculture emits significant quantities of CO2,CH4 and N2O (Janzen, 2004; INCC, 2007; Mosier et al., 1998)[[5]](#footnote-5).

The choice of conducting the study for the year 2009 is justified by the fact that the most recent data of WIOD regarding emissions are only available until 2009, despite the availability of input-output matrices by 2011.

**5 Results and discussion**

According to the World Bank data, in 2009 Brazil was ranked as the world's tenth largest economy in terms of GDP. However, such economic performance has generated a high cost to the environment. In the same year, according to WIOD, the country emitted 820.1 million tCO2eq, accounting for 2.39% of global emissions. Other emerging countries like China, India and Russia emitted, in the same year, more GHG than Brazil: 24.02%, 6.75% and 5.8%, respectively (Timmer, 2012). Figure 3 represents the Brazilian GHG emissions per major economic sectors and per pollutant type.

Figure 3 - Percentage of GHG Brazilian direct emissions per pollutants and Macro-Sectors - 2009



Source: Own elaboration based on Timmer (2012).

Agriculture, Hunting, Forestry and Fishing, in 2009, accounted for 62% of total GHG emissions in Brazil, followed by Industries (21%) and Services (17%). It is observed that CO2 is more concentrated in industries (56%) and services (34%), while CH4 and N2O are concentrated in agriculture, with rates of 78% and 96%, respectively. The share of 14% of services in the total CH4 emission can be justified by the disposal of solid waste and the treatment of domestic and residential sewage, see Figure 3.

Except for Agriculture, Hunting, Forestry and Fishing, which was responsible for 62% of the Brazilian GHG direct emissions in 2009, Figure 4 shows the percentage of direct emissions from the other sectors. The second largest share, 7%, is related to sector Other Community, Social and Personal Services, which includes the treatment of solid waste. Other activities that stand out in terms of emissions are:

Inland Transport (4%), Mining and Quarrying (4%), Basic Metals and Fabricated Metal (3%), Other Non-Metallic Mineral (3%) and Coke, Refined Petroleum and Nuclear Fuel (3%). The remaining segments total 13%.

Figure 4 - Percentage of GHG Brazilian Direct Emissions per Sectors - 2009



Source: Own elaboration based on Timmer (2012)

It is clearly visible through the result displayed in Figure 3 (on the right) that the GHG emission is highly concentrated in the first sector. This is justified due to enteric fermentation of livestock, animal waste management, agricultural soils, rice cultivation, burning of agricultural wastes and, especially, by the change in land use and forests (Janzen, 2004;. Mosier et al., 1998; MCT, 2010, Smith and Conen, 2004). Is this environmental cost generated by agriculture reversed in economic returns through the generation of employment and income, for instance? To answer this question, the results of the emissions multiplier reported in Table 1 have been confronted with the results of traditional employment and income multipliers.

Sector 1 - Agriculture, Hunting, Forestry and Fishing is the one that presents the greatest emissions multiplier, 4.21 – well above the average of the Brazilian economy (0.57). This means that for every US$ 1,000 of variation in demand from this sector, the entire economy produces 4.21 tCO2eq to meet this demand. It is noteworthy that 87.8% (3.7t/CO2eq.) of such emission is generated directly and only 12.2% is generated indirectly (0.51 tCO2eq.). The largest indirect effect of emissions (1.6) is activity 3 - Food, Beverage and Tobacco, which depends on several agricultural products (see Figure 5).

Table 1: Multipliers of GHG emissions, employment and income - 2009



Source: Own elaboration based on Timmer (2012).

On the other hand, concerning the generation of employment and income, it is visible that Sector 1 - Agriculture, Hunting, Forestry and Fishing is much below the Brazilian economy average (3 and 1.96, respectively). For every job created in this sector, only one job is generated, while for every US$ 1 of income created in this sector only about $ 1.51 of additional income in the economy is generated. Moreover, as will be seen later, Sector 1 has shown few important linkages with the other sectors of the production structure.

Despite these results, we highlight the importance of agriculture for the Brazilian economy, as in 2009 it presented the sixth highest gross value of production (GVP) and value added, and the highest number of employed workers: 5%, 5.6% and 21.9% respectively. The coefficient of employee per generated GVP (E/GVP), however, demonstrates that agriculture is more intensive in the use of workforce than the rest of the economy, since it uses almost five times more workers per million dollars (120) than the average in economy (25). This explains, in part, the low multiplier effect on job creation from exogenous shocks to the total demand of this sector.

Figure 5 depicts the field of influence calculated in its traditional fashion, (i.e.), without the incorporation of the vector of GHG emissions intensity. This analysis defines the importance of each of the intersectoral relations of purchase and selling. In order to facilitate interpretation, the results for each production link were highlighted in color scales[[6]](#footnote-6) indicating the above-average fields of influence, that is, the most important linkages for the economy as a whole. Reading is similar to the input-output matrices, in other words, the lines are formed by input seller sectors, while the columns are input buyer sectors.

It is noticed that sector 1 - Agriculture, Hunting, Forestry and Fishing presents few important linkages when compared to other activities. The relations with the following sectors stand out due to their demand: 3 - Food, Beverage and Tobacco; 4 - Textiles and Textile Products; 6 - Wood and Products of Wood and Cork; and 15 - Transport Equipment. Their links are classified as very strong.

Figure 5: Brazilian Economy Field of Influence - 2009



Source: Own elaboration based on Timmer (2012).

Figure 6 shows the result of the field of influence of sectoral GHG emissions. It can be observed that the most intensive sectors in GHG emissions (see column 1 of Table 1) 1 - Agriculture, Hunting, Forestry and Fishing, 3 - Food, Beverage and Tobacco (indirectly intensive) 11 - Other Non-Metallic Mineral and 24 - Water Transport, form the only important sectoral connections, especially sector 1 which showed very strong linkages. It is important to stress that linkages are established on the supply side, which highlights the greater intensity of emissions during the supply (production) of inputs and outputs. It is noteworthy that these three sectors accounted for 62.3%, 0.74%, 2.85% and 0.89%, respectively, of Brazil's GHG emissions in 2009.

Figure 6: Field of Influence weighted by GHG emissions - 2009



Source: Own elaboration based on Timmer (2012).

The share of agriculture in GHG generation is proportionally higher than its contribution to its generation of employment and income. Nevertheless, one must consider this activity as the basis of the so-called agribusiness[[7]](#footnote-7). For instance, Montoya et al (2013) estimated the contribution of agribusiness to the Brazilian GDP at 21% and the contribution to employment generation at 32% in 2009. Taking into account emissions from energy consumption only, the sector was responsible for 40% of the generated CO2 (Montoya et al. 2013).

Nevertheless, when Brazil's emissions are taken into perspective, although the CO2 resulting from the consumption of fossil fuels presents a growth tendency (EPE, 2012; Montoya et al, 2013), methane from enteric fermentation and carbon dioxide from slash-and-burn are the greatest part of GHG emissions and are heavily concentrated in agriculture. For Bustamante et al. (2013) more than 50% of GHGs are directly or indirectly related to agriculture. Thus, it is relevant to note that although investments in other sectors of the economy generate greater impacts in the productive structure, they have lower GHG emissions levels. The same applies to exports. Indeed, the increase in exports of higher added-value food products over the exports in agriculture can decrease the intensity of emissions from foreign trade (Perusso, 2012).

**6 Conclusion**

The present article has examined the contribution of agriculture to the release of GHG in Brazil, taking into account the influence of these emissions on emissions from other sectors, and vis-a-vis their contribution to the generation of employment and income. To do so, we have used the methodology of the field of influence and impact multipliers applied to the input-output analysis weighted by the coefficients of GHG emissions.

The result indicates that this sector has decisive contributions to the emissions, while its impact on the economic activity is less pronounced. In reality, such impact is smaller than the average of the economy in terms of generation of employment and income. The immediate implication is that investments in other sectors of the economy would result in better economic and environmental performance.

Nevertheless, it is important not to lose sight of the overall importance of agribusiness to the Brazilian economy and of the role that this country shall play in the world's food supply, given its comparative advantages and the growing demand from emerging countries. In this sense, the largest share of higher value-added food in the exportation agenda as substitute for agricultural products may not only favor the generation of employment and income, but also decrease the intensity of emissions from foreign trade.

With the objective of bringing new results to the literature, we intend to perform similar exercises to the ones applied here in future works, but this time considering the economic relations in agribusiness given its relevance to the Brazilian economy.

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4.  [↑](#footnote-ref-4)
5. To make the three gases compatibles in t/CO2 eq., we used the equation (11) proposed by Hristu-Varsakelis et al. (2010) and Hristu-Varsakelis et al. (2012):  [↑](#footnote-ref-5)
6. The lighter color represents the coefficients above the average; intermediate color refers to the coefficients above the mean plus one standard deviation; and darker color refers to the coefficients above the mean plus two standard deviations. [↑](#footnote-ref-6)
7. The delimitation of agribusiness was accomplished "considering the profound technological, productive, financial and business relationships that agriculture has with industry and other economic activities, the measurement of the agribusiness, must be implemented from a systemic view, in which input and output flows and transfers from one sector to another are integrated" [Own translation] (Montoya et al., 2013, p.6). The aggregation of activities in agribusiness considers the participation of agricultural inputs, agricultural products, agroindustry products and services related to agriculture, see Finamore and Montoya (2003). [↑](#footnote-ref-7)