The impact of Brazilian livestock production on global warming

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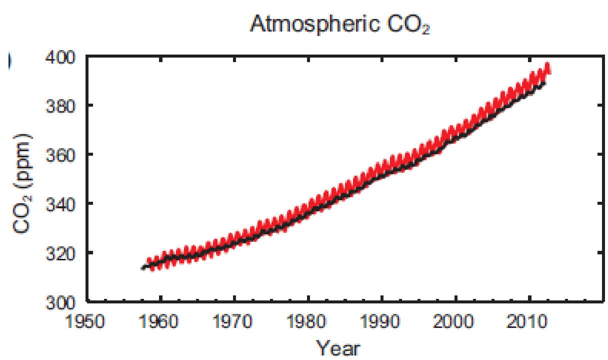
The global scenario

The 5th assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2013) reported that warming of the global climate system is unequivocal and that many changes have already been observed since the 1950s, including warming of the atmosphere and oceans, reductions in quantities of snow and ice, rising sea levels and increased concentrations of greenhouse gases. Figure 1 shows the increase in the concentration of CO_2 in the atmosphere from 1958 until 2010. In May 2014, atmospheric CO_2 concentrations reached the historical level of 400ppm for the first time on record (NOAA, 2014).

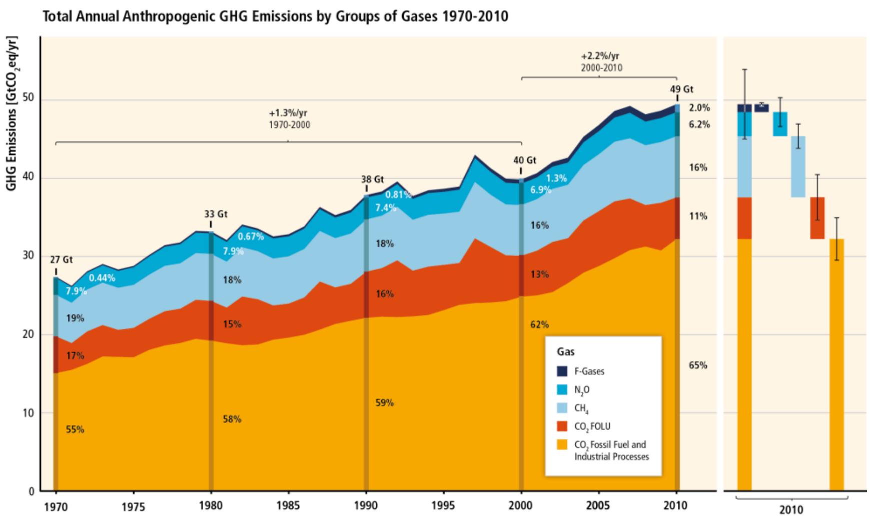
Figure 1. Atmospheric concentrations of carbon dioxide (CO_2) from Mauna Loa (19º32´N, 155º34´W – red) and South Pole (89º59´S, 24º48´W – black) since 1958. (IPCC, 2013)



The global demographic scenario indicates continued population growth, with a corresponding increase in demand for food. Total production of meat and milk is expected to increase by 73% and 58% respectively to meet this demand, in relation to the base year of 2010, mainly as a result of improvements in extensive production systems based on efficient use of tropical pastures and the application of fertilization and intensive management techniques.

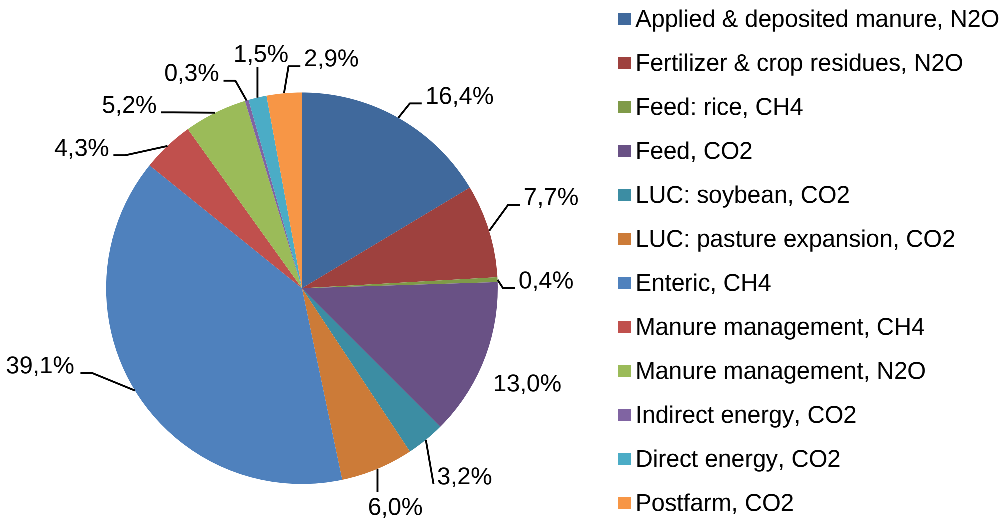
Recently, was published in IPCC Report the distribution of groups of gases and also the changes in the land use during the last 40 years (Figure 2).

Figure 2. Total Annual Anthropogenic GHG Emissions by Groups of Gases 1970-2010. (IPCC, 2014).



Of the productive industries, the livestock industry contributes to climate change with estimated emissions of 7.1 gigatonnes of CO_2-eq per year, representing 14.5% of the total of human induced greenhouse gas emissions (FAO, 2013a). Production of meat and milk contribute to 41% and 20% of emissions from the industry, respectively. The two main sources of emissions are the production and processing of feed and enteric fermentation, corresponding to 45% and 39%, respectively. Management of manure represented 10%, and the remainder is attributed to the processing and transport of animal products (FAO, 2013a), as displayed in Figure 3.

Figure 3. Global emissions from livestock supply chains by category of emissions (FAO, 2013a).



The Brazilian scenario

Brazil is a country of continental dimensions and contains diverse livestock production systems displaying varying degrees of intensification. The national herd is basically raised in its natural habitat, with the main food source consisting of pastures occupying huge expanses of land, approximately one quarter of the country according to data from the Brazilian Institute of Geography and Statistics´ (IBGE) Agriculture and Livestock Census 1970/2006 (Oliveira et al, 2014).

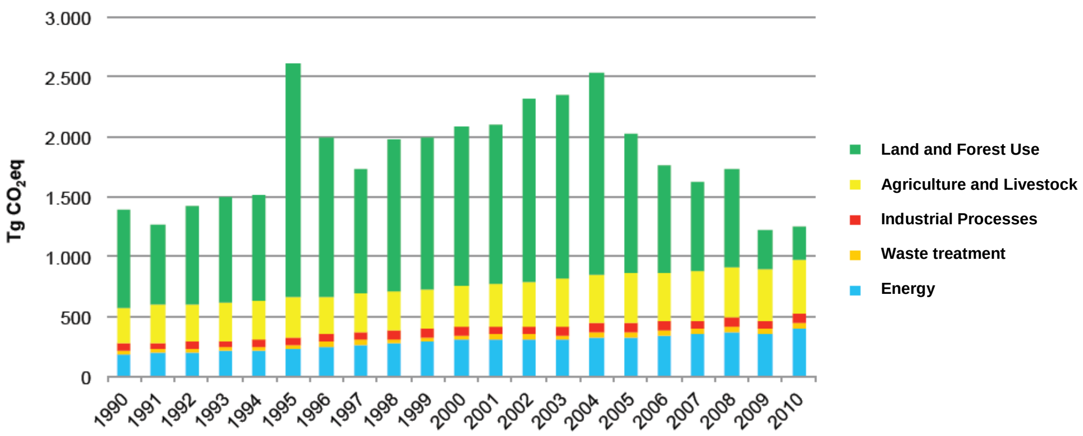
Considering that Brazil possesses the largest commercial herd in the world, of approximately 170 million heads of cattle and utilizes 172 million hectares for its production (IBGE, 2006), we can estimate an average stocking rate of one animal per hectare. Over the past thirty years there has been a notable shift, with livestock gradually occupying less area with greater production and productivity gains (IBGE, 2007). In 1970 the stocking rate was 0.51 livestock units per hectare and by 2006 the rate had more than doubled to 1.1 animals per hectare (Oliveira et al, 2014). Although the average national stocking rate is considered to be low, there are also extremely intensified systems with intensive pasture management and confinement, especially those with high rotation, completing up to three cycles per year and those which utilize waste products from agro industry as the feed base for cattle. This performs an important environmental service by correctly disposing of agro-industrial waste, as well as reducing the consumption of grains, a type of food which could be destined for human consumption. Livestock raising interacts with the environment in various ways, occupying land which was originally covered by native vegetation, emitting and removing greenhouse gases (GHG), participating in the use of water and cycling of nutrients and providing environmental services (Oliveira et at, 2014, *Personal Communication*).

In Brazil, cattle represent 83.9% of all livestock production (of which 89% is beef cattle and 11% dairy cattle). Extensive production systems predominate and the majority of the national herd is composed of Zebu cattle, of which Nelore is the most numerous breed (80%) (MCT, 2010).

Enteric methane emissions, which are the result of a process which is natural and intrinsic to ruminants, tend to increase with the size of the national herd. The 1st Brazilian Inventory of Anthropogenic Greenhouse Gas Emissions (MCT, 2004), estimated total enteric methane emissions at 184,800 Gg of CO_2-eq/year, however, the 2nd Brazilian Inventory of Anthropogenic GHG Emissions and Removals (MCT, 2010) indicated methane emissions of enteric origin at 241,227 Gg of CO_2-eq/year, while the report of Estimated Annual GHG Emissions in Brazil (MCTI, 2013; Figure 4) presented emissions of 246,569 Gg of CO_2-eq/year in 2010. The three corresponding estimates for the cattle population in these publications were 158,243,229; 207,156,696; 209,541,109 animals, respectively.

Information presented in the Estimated Annual GHG emissions in Brazil (MCTI, 2013) indicated that agriculture and livestock farming were responsible for 35.1% (437,226 Gg CO_2-eq) of national emissions in 2010 and changes in land use were responsible for 22.4% (279,163 Gg CO_2-eq). In Figure 3 we can observe Brazilian GHG Emissions in CO_2-eq from 1990 to 2010. From 2005 onwards there is a decrease in the percentage from land and forest use and as a consequence agriculture and livestock farming becomes the largest single factor in emissions statistics.

Figure 4. Brazilian GHG Emissions in CO_2-eq between 1990 and 2010; Tg = millions of tonnes (MCTI, 2013).



With this scenario in mind, the importance of understanding the mechanisms of methane synthesis and the factors which affect its production becomes increasingly apparent. The most recent challenge in the ruminant production system is to develop diets and management strategies which minimize the relative production of methane

(methane/kg of meat or milk), allowing greater production efficiency and reducing the negative impact of livestock production on global warming.

Greenhouse gas mitigation strategies for livestock production

According to the FAO (2013a), emissions could be reduced by between 18 and 30% (or from 1.8 to 1.1 gigatonnes CO_2-eq) if producers in a given system, region and climate adopted the practices currently applied by the 10 to 25% of producers who present lower emissions intensities from their properties.

Mitigation of methane emissions from cattle, that is, the use of strategies to reduce the impact of Brazilian livestock production on global climate change, constitutes part of a voluntary commitment to reduce emissions. Reducing methane production by cattle also provides improvements in the efficiency of energy use by the animals, resulting in improved productive and economic performance. It is fundamental that Brazil demonstrates sustainability in livestock production, favors debate on the subject and allows for the possibility of technical questioning of environmentally based non-tariff barriers, considering that production which respects the environment is one of the demands of the consumer, especially in the European market (Berndt, 2010).

Enteric fermentation is responsible for the production of methane gas in the animal´s rumen, which is released by eructation. The production of this gas is closely linked to the quality of food that the animal consumes, the greater the digestibility of the food, the lower the daily methane emission. Improvements to the quality of feed and the alteration of ruminal microflora permits greater energy retention, reducing losses through methane, and therefore results in lower methane production per unit of product (methane/kg meat, milk, etc.). In the case of animals destined for slaughter, with improvements in performance and reduced length of the productive cycle, the total methane emitted during the life of this younger animal will be less than from an animal slaughtered later.

Studies show that the first step in the attempt to reduce the effect of cattle production on global warming is to increase productivity by supplying better quality food. Beauchemin et al. (2011) estimated that implementing a diet based on forage for the growth of beef cattle increased the intensity of GHG emissions by 6.5%. Pelletier et al. (2010) found an increase of 30% in total GHG emissions from cattle finished on pasture compared to cattle in a confined system.

Although the intensification of livestock farming can increase gross daily emissions, it also shortens the lifespan of the animal and consequently reduces Emission Intensity by around 10% in kg CO_2-eq/kg meat produced (Berndt and Tomkins, 2013). This demonstrates the importance of intensifying the adoption of more intensive production systems, for example: pasture improvement and implementation of rotational systems; semi-confinement and confinement; and alternatives such as integrated crop-livestock or silvipastoral systems.

The main strategies for reducing GHG emissions involve: improving productive and reproductive indexes (reducing age on slaughter, age at first calving and calving interval); reducing the quantity of replacement animals; increasing the longevity of reproductive cows; improving the genetic merit of both animals and forage plants; utilizing additives and supplements; improving food conversion efficiency; optimizing the supply of good quality water; improving management of both animals and pasture; enhancing animal health (control of parasites, diseases and vaccines); and looking to improve animal well-being (Boadi et al., 2004; Hegarty et al., 2007; Beauchemin et al., 2008; Perdok and Newbold, 2009; Berndt, 2010; Smith et al., 2011). In terms of nutritional management and manipulation of the rumen, three specific strategies should be considered: reduce H_2 production, look for other alternative sinks for H_2 produced by enteric fermentation and reduce populations of methanogenic microorganisms – *Archaea* (Joblin, 1999). Grainger and Beauchemin (2011) elaborated a revision of nutritional strategies and management processes to reduce enteric methane and assess the potential effects on animal production. The strategies include intensive pasture management, use of grains and concentrated food, processing and conservation of forage to reduce particle size and increase digestibility, use of legumes, presence of tannins, saponins, secondary compounds, essential oils, addition of oils and saturated and unsaturated fats, ionophores, nitrate, yeasts, malate and fumarate.

Improvements in the efficiency of the use of resources entering the production system should be sought as one pathway for improving the sustainability of livestock production by implementing new technologies which permit satisfactory productivity based on “lowest cost” to the environment.

Within the context of the various different strategies to reduce greenhouse gases, it is important to highlight the factors which have a direct influence on fermentation, such as nutritional factors. Various strategies have been developed by nutritionists from around the world to reduce energetic losses in the form of methane. Factors such as dietary improvements with the use of additives (probiotics, ionophores, yeasts, essential oils and tannins), polyclonal antibodies or supplementation with fats, principally unsaturated, are being used as alternatives for reducing methane production, with these being the main direct methods for reducing methanogenesis (Steinfeld et al., 2006). However, indirect factors such as those mentioned by the US Environmental Protection Agency (USEPA, 2000) should also be taken in to account, these include improving pastures by conducting soil analysis and taking corrective measures, improving the health and genetic and reproductive efficiency of the herd to increase productivity and reduce the amount of gas released in relation to the final product, the use of vaccines, and also the use of confinement strategies which result in a reduction of the age on slaughter (Primavesi et al., 2012).

Innovative strategies can be applied in the production system to reduce emissions of methane and other GHGs by adopting a broader, sustainability-based approach. Cattle production in confinement became significant in Brazil from the 1980s onwards, based on supplying water, food and supplements to the animals in the dry season due to the seasonality of forage availability (Moreira et al, 2009). It should be emphasized that intensive cattle production in confinement is growing in Brazil, with greater density in the Center-West region due to the logistics of food production, lower land costs and a more accessible labor supply. The technique of confinement provides certain advantages, such as alleviating pressure on pastures, programmed slaughter, freeing-up of pasture areas for planting other crops, reduction in the age of slaughter or shortening of the cycle and improved meat quality (Peixoto et al, 1989). Recently, increasing production per area has become fundamental to the profitability of the activity, with extensive production becoming less and less profitable and competitive. In relation to GHG emissions, principally of methane, O´Hara et al. (2003) advise that the more productive the animal, the lower emissions of the gas will be. This affirms similar findings reported by Moss and Givens (2002) who cited that elevated animal performance can reduce methane emissions as a result of the reduction in the number of animal in the production system, considering that in meat production systems, increases in animal performance result in the animal remaining in the system for a shorter period of time, thereby reducing the production of gas during its life cycle. Therefore, as technologies are adopted to improve animal performance, it indirectly aggregates value to the product from an environmental and sustainability viewpoint. This concept is called emission intensity (EI) which is equivalent to the number of kilograms of CO_2 equivalent emitted to produce one kilogram of carcass equivalent (kg CO_2-eq/kg CE).

Studies show that the first step to reducing the contribution of cattle farming to global temperature increases is to increase productivity by supplying better quality food. Despite the potential increase in daily emissions, this action will reduce the lifespan of the animal, which, according to Monteiro (2009) could reduce emissions of methane per kilo of meat produced by approximately 30%. This goes to show the importance of adopting more intensive production systems, improving pastures and implementing rotational, confinement and semi-confinement systems. With the development and application of efficient production technologies it is possible to reduce GHG emission from livestock farming, implementing changes which favor the sustainability of the industry. One of the most efficient ways of increasing the productivity of a system is to increase the stocking rate, which essentially depends on suitable pasture management. Improved and well managed pastures, as well as supporting a larger number of animals, also permit improved animal performance, reducing the age on slaughter and consequently GHG emissions per kilo of meat (Alves, 2003). Furthermore, in beef cattle farming, anticipating the age of the first mating and therefore the first calving is an important factor in reducing the herd of heifers on the property to replace discarded cows in the future. With this reduction in the number of heifers necessary for replacement it is possible to select the most efficient animals, keeping only the most productive and as a result contributing to reduce total methane emissions (Rovira, 1996).

Improved management in beef cattle farming will make it more sustainable by avoiding major waste of concentrated feed, reducing costs and time of production, improving the efficiency of processes and the activity as a whole and consequently increasing productivity by maximizing the potential of the animals. In a study conducted by Monteiro (2009), which simulated a model of the beef production process, the author cited a total methane production (53.1 kg of CO_2-eq/year/animal) in the intensive system of pasture with confinement, with the confinement period responsible for around 6.5% of the total methane produced. The total quantity of CH_4 emitted in this system was only 2.2% greater than on intensive pasture alone. The confinement provided a reduction in CH_4 emissions of 57% from the steer in finishing phase category, and also eliminated GHG emissions from the unfinished steer category, considering that this category ceased to exist as a result of the 6 month reduction in the age on slaughter. The reduction in the emission intensity for the intensive pasture system with finishing in confinement was 38% (kg CO_2-eq/kg CE), when compared to the Brazilian average from extensive systems. The efficient use of pasture and adequate nutritional management allows for mitigation of methane emissions, slaughtering animals at a younger age and therefore reducing the length of stay in the pasture.

Conscious of the importance of GHG dynamics, the Brazilian government and scientific community are expanding considerable effort to understand the processes of emission and removal of these gases. In 2011, the PECUS Research Network was launched with the objective of assessing the livestock production systems representatives of the six Brazilian Biomes: Amazon, Cerrado (savannah), Atlantic Forest, Pantanal (wetlands), Caatinga (semi-arid forest) and Pampa (grasslands). The network has the objective of measuring emissions of methane (CH_4), nitrous oxide (N_2O) and the removal of carbon by the soil, generating specific data to form a national baseline. The network also studies different strategies for mitigation of GHGs in the search for more sustainable production systems. The data generated by the network will supply the National Emissions Inventories and governmental Public Policies to incentivize sustainable production. The PECUS Network possesses 25 data collection sites, distributed across the country. One of the collection sites is located at the Embrapa Southeast Livestock Experimental Farm.

Applying strategies to Brazilian livestock farming

Some studies have already been conducted in Brazil with the aim of finding alternatives for mitigation of enteric methane emissions in different production systems, using different breeds of animals and different diets.

In a study carried out by the PECUS Network at Embrapa Southeast Livestock, in São Carlos/SP, in 2012 and 2013, methane emissions per animal per day were similar for the four different treatments: intensive irrigated pasture with high stocking rate (IHS), intensive pasture without irrigation with high stocking rate (DHS), pasture in recuperation with moderate stocking rate (DMS) and degraded extensive pasture (DP) (152.35±19.18 g-CH_4/d). The animals were exclusively grazing tropical forage grasses of the genus *Panicum* in the IHS and DHS systems and the genus *Brachiaria* in the DMS and DP systems. Corrected DM availability for 36 days, taking into account the season in which the enteric methane emissions were measured (summer; December/2012 to March/2013), was 3395±1332a, 1962±567b, 1338±1098b, 1488±1369b kg of DM for the different treatments, respectively. The values obtained for emissions were similar to the IPCC´s (IPCC, 1996) default values for beef cattle in Latin America (153.4 gCH_4/animal.day) and the values obtained by Demarchi et al. (2003), Fontes et al. (2011) and Berndt and Tomkins (2013) in Australia.

The daily weight gain (summer; December/2012 to March/2013) was also similar for the four treatments (0.407±0.16 kg/day, P=0.18), indicating the availability of forage per animal was sufficient, even in the system considered degraded, due to the daily adjustments in the stocking rate in response to the quantity of forage available in the area of the four treatments. The assessments occurred during the wet season, when the photoperiod is long and temperatures are high, favoring the growth of tropical grasses. In this season, in the degraded system with continuous grazing it is easier for the animal to select plants or parts of plants which are more digestible, while in the IHS and DHS systems the rotational grazing with high stocking rates offers more homogenous forage mass in a short period of time, restricting selection on the part of the animals.

The variable most affected by the treatments during this period (December/2012 to March/2013) was the stocking rate, which was significantly different ($P<0.05$) for all of the grazing systems. The IHS system presented an average of 11.56 Animal Units - AU/ha while the DP presented only 1.71 AU/ha, 85% less. Despite each of the systems providing the same average daily weight gain and the same methane emissions, the more intensive systems (IHS and DHS) supported a larger number of animals. Consequently the weight gain obtained in the same area of 1 hectare was 6.8 times higher in the IHS (4684 gLW/ha.day) in relation to the DP (861 gLW/ha.day). The intensification of production systems utilizing intensive rotational grazing techniques, fertilization with N and irrigation permitted the production of more meat in the same area, or alternatively, the production of the same quantity of meat in a much smaller area.

Mandarino et al. (2014) measured enteric methane from Nelore heifers at Embrapa Cerrados in three different integrated systems: pasture with six years of formation (ICLS6), pasture with one year of formation (ICLS1) and pasture with one year of formation established under *Eucalyptus urograndis* trees with a north-south orientation and spaces of 22 meters between lines (ICLFS1) (417 trees/ha), all consisting of *Brachiaria brizantha*. They reported enteric methane emission values for ICLS1, ICLFS1 and ICLS6 of 112.4; 96.6 and 88.5/animal/day, respectively. There was no significant difference (P>0.05). There were differences in the Dry Matter Intake (DMI) and DM digestibility (DMD). It was concluded that the age of the pasture, that is, the time after planting, affects the DMD and the DMI, but not the enteric methane emissions in integrated crop-livestock-forestry systems during autumn in the Cerrado.

Additionally, Andrade et al. (2013) permitted 20 young Charolaise bulls to graze areas of dwarf elephant grass (*Pennisetum purpureum* cv. BRS Kurumi) with or without access to an area of pinto peanut (*Arachis pintoi* cv Amarillo), and observed that daily methane emissions were greater (P<0.05) for animals grazing legumes, while methane emissions per kg of dry matter consumed did not vary from one treatment to the other. Therefore, it was concluded that young bulls grazing areas of dwarf elephant grass with access to an area of pinto peanut can increase their performance without increasing the production of methane per kg of dry matter consumed.

Furthermore, recently Fiorentini et al. (2014) hypothesized that by adding and/or modifying the profile of fatty acids in the diet of 45 young Nelore bulls it would be possible to influence their feed ingestion, performance, ruminal fermentation and the emission of enteric methane. The animals were distributed between five experimental groups to receive concentrate: 1) without additional fat (27.9g/kg of ether extract); 2) with palm oil; 3) with linseed oil; 4) with protected fat - Lactoplus® - Dalquim group, Itajaí, SC, Brazil; 5) with soy bean. At the end of the experiment, it was observed that the animals in groups 1) and 4) presented greater CH_4 emissions from enteric fermentation (P<0.05).

Conclusions

It is important to develop and apply alternative mitigation technologies in livestock production to avoid losses and reduce enteric methane emissions from these ruminants. The implementation of strategies developed in the research mentioned in this review could make cattle farming using technified systems more efficient and productive, with greater profitability and sustainability, principally in relation to greenhouse gas emissions which have an impact on global warming.

References

Andrade, E.A.; Ribeiro Filho, H.M.N.; Liz, D.M.; Almeida, J.G.R.; Miguel, M.F.; Raupp, G.T.; Ramos, F.R.; Almeida, E.X. 2013. Herbage intake, methane emissions and animal performance of steers grazing dwarf elephant grass with or without access to *Arachis pintoi* pastures. Proceedings of the 22nd Internacional Grassland Congress. 15-19 September 2013, Sydney, Australia.

Alves, D.D. 2003. Crescimento compensatório em bovinos de corte. Revista Portuguesa de ciências veterinárias. 98 (546):61-67.

Beauchemin, K.A.; Janzen, H.H.; Little, S.M.; McAllister, T.A.; McGinn, S.M. 2011. Mitigation of greenhouse gas emissions from beef production in western Canada – Evaluation using farm-based life cycle assessment. Animal Feed Science and Technology. 166-167: 663-677.

Beauchemin, K.A.; Kreuzer, M.; O´Mara, F.; Mcallister, T.A. 2008. Nutritional management for enteric methane abatement: a review. Australian Journal of Experimental Agriculture. 48:21-27.

Berndt, A. 2010. Impacto da pecuária de corte brasileira sobre os gases do efeito estufa. Paper presented at the III International symposium of beef cattle production, 03-05 July

2010, Viçosa, Brazil, 122-143.

Berndt, A. and Tomkins, N.W. 2013. Measurement and mitigation of methane emissions from beef cattle in tropical grazing systems: a perspective from Australia and Brazil.Animal. 7:s2, 363-372.

Boadi, D.; Benchaar, C.; Chiquette, J.; Masse, D. 2004. Mitigation strategies to reduce enteric methane emissions from dairy cows: update review. Canadian Journal of Animal Science 84, 319–335.

Demarchi, J.J.A.A.; Lourenço, A.J.; Manella, M.Q.; Alleoni, G.F.; Friguetto, R.S.; Primavesi, O.; Lima, M.A. 2003. Preliminary results on methane emission by Nelore cattle in Brazil grazing *Brachiaria brizantha* cv. Marandu. Proceedings of the Third International Methane and Nitrous Oxide Mitigation Conference, 17-21 November 2003, Beijing, China, 80-84.

FAO. 2011. World Livestock 2011- Livestock in food security. Rome, FAO, 115p.

FAO. 2013a. Tackling climate change through livestock. A global assessment of emissions and mitigation opportunities.Rome, FAO, 115p.

Fiorentini, G.; Carvalho, I.P.C.; Messana, J.D.; Castagnino, P.S.; Berndt, A.; Canesin, R.C.; Frighetto, R.T.S.; Berchielli, T.T. 2014. Effect of lipid sources with different fatty acid profiles on the intake, performance, and methane emissions of feedlot Nellore steers. Journal of Animal Science. 2013-6868.

Fontes, C.A.A.; Costa, V.A.C.;Berndt, A.; Frighetto, R.T.S.; Valente, T.N.P.;Processi, E.F. 2011. Emissão de metano por bovinos de corte, suplementados ou não, em pastagem de capim mombaça (*Panicum maximum* cv. Mombaça). Proceedings of the 48th Reunião Anual da Sociedade Brasileira de Zootecnia, 18-21 July 2011, Belém, Brazil.

Grainger, C.; Beauchemin, K.A. 2011. Can enteric methane emissions from ruminants be lowered without lowering their production?. Animal Feed Science and Technology, 166-167, p.308-320.

Hegarty, R.S.; Goopy, J.P.; Herd, R.M.; Mccorkell, B. 2007. Cattle selected for lower residual feed intake have reduced daily methane production. Journal of Animal Science. 85: 1479-1486.

IBGE. 2006. Censo Agropecuário 2006, Brasil, Grandes Regiões e Unidades da Federação. Rio de Janeiro, Brazil.

IBGE, 2007. Censo Agropecuário 2006: Resultados Preliminares. IBGE: Rio de Janeiro, p.1-146.

IPCC. 2006. IPCC guidelines for national greenhouse gas inventories. Vol 4. Agriculture, forestry and other land use, Hayama, Japan.

IPCC. 2013. IPCC: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Johnson, K.; Huyler, M.; Westberg, H.; Lamb, B.; Zimmerman, P. 1994. Environmental Science and Technology. 28, 359-362.

IPCC. 2014. IPCC: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and

J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Joblin, K.N. 1999. Ruminal acetogens and their potential to lower ruminant methane emissions. Australian Journal Agricultural Research, v. 50, n. 8, p. 1321-1327.

Mandarino, R.A.; Pereira, L.G.R.; Barbosa, F.A.; Santos, D.C.; Vilela, L.; Maciel, G.D.A.; Barioni, L.G.; Guimarães Junior, R. 2014. Methane Emissions from Nellore Heifers under integrated Crop Livestock Forest Systems. Livestock, Climate Change and Food Security Conference. In: Conference abstract book. Madri, Spain. 156p.

MCT. 2004. Ministério da Ciência e Tecnologia.Brazil's Initial Communication to the United Nations Framework Convention on Climate Change, Brasília, MCT. 271p., 2004.

MCT. 2010. Inventário Brasileiro de Emissões Antrópicas por Fontes e Remoções por Sumidouros de Gases de Efeito Estufa não Controlados pelo Protocolo de Montreal - Parte II da Segunda Comunicação Nacional do Brasil. Retrieved from http://www.mct.gov.br/index.php/content/view/310922.html.

MCTI. 2013. Estimativas anuais de emissões de gases de efeito estufa no Brasil. Ministério da Ciência, Tecnologia e Inovação, Brasília, MCTI. 81p., 2013.

Monteiro, R.B.N.C. Desenvolvimento de um modelo para estimativas da produção de gases de efeito estufa em diferentes sistemas de produção de bovinos de corte. 2009. 75 p. Dissertação (Mestrado em Agronomia com área de concentração em Ciência Animal e Pastagens) - Unidade, Escola Superior de Agricultura "Luiz de Queiroz" Universidade de São Paulo, Piracicaba. 2009.

Moreira, S.A; Thomé, K.M; Ferreira, P.S.; Botelho Filho, F.B. 2009. Análise econômica da terminação de gado de corte em confinamento dentro da dinâmica de uma propriedade agrícola. Custos e Agronegócio online – v. 5, n. 3, p. 132 – 152. Set/Dez - 2009.

Moss, A.R.; Givens, D.I. 2002. The effect of supplementing grass silage with soya bean meal on digestibility, in sacco degradability, rumen fermentation and methane production in sheep. Animal Feed Science and Technology.v.97, n.3, p.127-143.

NOAA, 2014. Retrieved from http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html (acess 02 june 2014).

O'Hara, P.; Freney, J.; Uliatt, M. 2003. Abatement of agricultural non-carbon dioxide greenhouse gas emissions: a study of research requirements. Report prepared for the Ministry of Agriculture and Forestry on Behalf of the Convenor, Ministerial Group on Climate Change, the Minister of Agriculture and the Primary Industries Council. Crown Copyright – Ministry of Agriculture and Forestry, New Zealand, p. 170.

Oliveira, P.P.A.; Bernardi, A.C.C.; Alves, T.C.; Pedroso, A. de F. 2014. Evolução na recomendação de fertilização de solos sob pastagens: eficiência e sustentabilidade na produção pecuária. SIMPÓSIO INTERNACIONAL DE PRODUÇÃO DE GADO DE CORTE, IX, 2014, Viçosa... Anais, (*in press*)

Peixoto, A.M.; Haddad, C.M.; Boin, C.; Bose, M.L.V. 1989. O confinamento de bois. 4. ed. São Paulo: Globo, 1989.

Pelletier, N.; Pirog, R.; Rasmussen, R. 2010. Comparative life cycle environmental impacts of three beef production strategies in the Upper Midwestern United States. Agricultural Systems. 103, 380-389.

Perdok, H.; Newbold, J. 2009. Reducing the carbon footprint of beef production. Nutrition for Tomorrow. ProvimiNutron, December 2009.

Primavesi, O.; Berndt, A.; Lima, M.A.; Frighetto, R.T.S.; Demarchi, J.J.A.A.; Pedreira, M.S. 2012. Produção de gases de efeito estufa em sistemas agropecuários, p 239-270.

In: Estoques de carbono e emissões de gases de efeito estufa na agropecuária brasileira. Magda A. Lima; Boddey, R. M.; Alves, B. J. R.; Machado, P. L. O. de A.; Urquiaga, S., editores técnicos. – Brasília, DF: Embrapa, 2012. 347 p.

Rovira, J. 1996. Manejo reproductivo de los rodeos de cria en pastoreo. Montevideo: HemisferioSur, p.288.

Smith, P.; Martino, D.; Cai, Z.; Gwary, D.; Janzen, H.; Kumar, P.; Mccarl, B.; Ogle, S.; O'Mara, F.; Rice, C.; Scholes, B.; Sirotenko, O. 2011. Agriculture. In: Metz, Davidson, Bosch, Dave, Meyer (Eds.), Climate Change 2007: Mitigation. Contribution of working group III, 4th Assessment report of the Intergovernmental Panel on Climate Change.Cambridge University Press, Cambridge, United Kingdom.

Steinfeld, H.; Gerber, P.; Wassenaar, T.; Castel, V.; Rosales, M.; De Haan, C. 2006. Livestock's long Shadow. Environmental issues and options, LEAD-FAO.Roma.390 p.

USEPA – United States Environmental Protection Agency. 2000. Evaluating Ruminant Livestock Efficiency Projects and Programs. In: Peer Review Draft. Washington, DC: USEPA. p.48.