



Environmental Impacts of Bovine Meat Production



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Abstract

Climate change threatening the well-being of current and future generations. Livestock sector plays an important role in climate change. Beef and cattle milk production account for most of the emission. The objective of this article was to provide an overview of the bovine meat production environmental impact. Especially, the main greenhouse gases (GHG) emitted by this subsector, the main GHG emissions sources and some mitigation strategies. Methane CH₄ (the greenhouse gas related to animal emissions), Nitrous oxide N₂O (the most powerful greenhouse gas) and Carbon dioxide CO₂ are the main GHG emitted by beef cattle. The main emission sources considered include enteric fermentation, manure management, nitrogen inputs, direct energy, inputs used within the farm. Levers for mitigation strategies include animal feeding, productivity and flock management, nitrogen fertilization, management of rejections, energy reduction and carbon storage.

Keywords: Beef; Production-greenhouse gases; Emissions-Methane-Nitrous; Oxide-Carbon dioxide

Introduction

Now a days global warming is the most dangerous environmental problem that human can faces it. It represents a threat to the living being. Most people are still unaware of global warming and do not consider it to be a big problem in years to come. What most people do not understand is that global warming is currently happening, and we are already experiencing some of its withering effects. It is and will severely affect ecosystems and disturb ecological balance. However, 97% of climate scientists and researchers agree that humans have changed the Earth's atmosphere in dramatic ways over the past two centuries, resulting in global warming [1].

The mainly cause of global warming is the continuous rise in planet's temperature. And small changes in that temperature correspond to enormous changes in the environment [1,2] affirm that this rise in planet's temperature causes by increasing of greenhouse gases rate in atmosphere such as carbon dioxide CO₂, methane CH₄ and nitrous oxide NO₂. Therefore more, Steinfeld et al (2006) state that three of the most important greenhouse gases; carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), are emitted largely due to livestock activities. Also, according to the FAO report livestock production contributes to 18% of total anthropogenic greenhouse gases emissions.

In the other hand, in European Union livestock sector is major of agricultural economy and its land use. There is

a different subsector and within each subsector a range of different production systems, we note a rise of intensification, larger farm units and more diversity of farming systems [3]. Andrien [3] note that according to the CAPRI model calculations agriculture sector emit 49% of total GHG emissions, 21% from energy sector, 2% from industrial sector and 29% from land use and land use change. About the livestock sector, European livestock production emit a total GHG fluxes of 661 Mio tons of CO₂-eq, which is distributed as follows: 29% are coming from beef production, 29% from cow milk production, 25% from pork production, 17% are coming from all other animal products.

Therefor more, Pelletier et Tyedmers report that by conjunction, in 2050 direct GHG emissions from meat, milk and egg production are projected to increase by 39% over the year 2000. So, meat beef production one of the major sub-sectors of livestock sector that contributes to GHG emissions. We focus in this study on beef production GHG emissions and mitigation strategy applied to mitigate this environmental impact.

Environmental Impact of Meat Production: Greenhouse Gases Emissions

Overview of the Meat Production Sector

According to Steinfeld [4] because of the increase of the population and the rise of the standard of living between 2000

and 2050 the demand of meat will split of 229 million tons per year to 465 million tons per year. According to Table 1 the largest quantity of beef is produced by the USA in 2012. In the other hand beef cattle is one of the most species which emit GHG (Figure 1).

Table 1: Production and consumption of beef worldwide in 2012 (La viande.fr).

Country (2012)	Production (thousands of tons)	Consumption (thousands of tons)	Consumption (kg eqc/inhabitant)
UE at 27	7760	7760	15
USA	11855	11744	37
Brazil	8669	7045	36
Argentina	2620	2458	59
Australia	2152	745	33
New Zealand	615	110	25
Russia	1380	2395	17
China	5540	5600	4
India	3460	2050	2

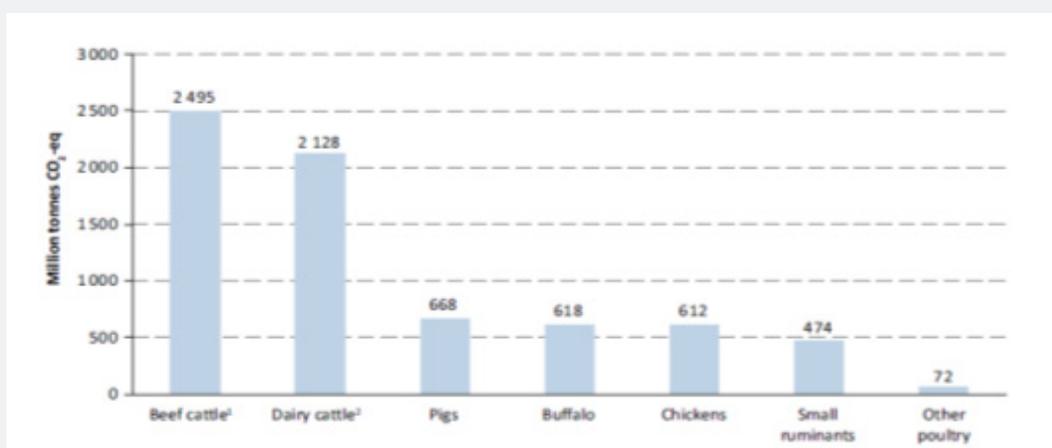


Figure 1: Global estimates of emissions by species (FAO 2013).

The main Gases emitted by Cattle

The greenhouse gases comprise only about 1% of the total gases in the earth’s atmosphere. The predominant gases are oxygen (21% of the total) and nitrogen (78% of the total). The primary greenhouse gases are carbon dioxide, methane, nitrous oxide, ozone and water vapor. These gases trap infrared

energy that contributes to higher atmospheric temperatures. It is important to remember that carbon dioxide, methane and nitrous oxide are continuously emitted and removed from the atmosphere by natural processes. In addition to these natural processes, anthropogenic activities also cause emissions of some of these gases [5].

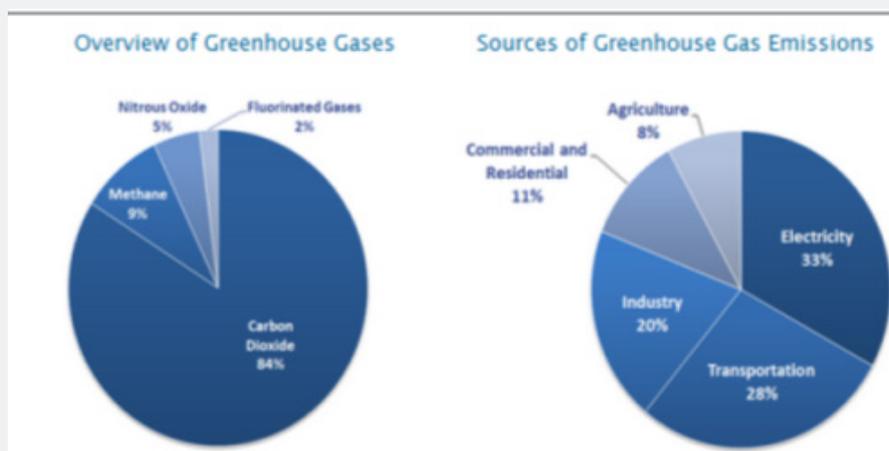


Figure 2: Overview of greenhouse gas and sources of greenhouse gas emissions in U.S in 2013.

There are mainly CO₂, CH₄ and NO₂. But there are also other gases such as fluorinated gases (CFC, HFC, PFC, SF6) that do not concern the agricultural field. Each gas is characterized by their global warming potential, it is the cumulative heating forcing over a defined period. It is measured in relation to CO₂ and is expressed in kg CO₂ equivalent [6]. The main gases emitted by beef cattle are: Methane CH₄, Nitrous oxide N₂O and Carbon dioxide CO₂. As an example, Figure 2 shows an overview of greenhouse gases and sources of greenhouses gas emissions in US in 2013. This figure is from the Environmental Protection Agency website characterizes US greenhouse gas production. According to Figure 2: Methane represents 9%, Nitrous oxide represents 2% and Carbon dioxide represents 84% of total US greenhouse gases. While, agriculture is responsible for 8% of the total US greenhouse gas emissions.

Methane: CH₃

Methane is the greenhouse gas related to animal emissions [5]. Their warming potential is 25 kg CO₂/Kg of CH₄. The plant diet of cows and other ruminants is high in cellulose, which cannot be digested by the ruminant itself. However, ruminants have a symbiotic relationship with colonies of microorganisms, called methanogens, which live in their gut and break down the cellulose into carbohydrates. These carbohydrates provide both the microbial community and the ruminant with an energy source. Methane is produced as a by-product of this process. Machen & Mccollum [7] says that methane is a loss of dietary energy during digestion by microorganisms in the rumen.

Nitrous oxide: NO₂

Nitrous oxide warming potential: 298 kg CO₂/kg of NO₂. Nitrous oxide is a very sensitive greenhouse, it has a 296 times higher impact than CO₂. One of important sources of N₂O emissions is agricultural activities such as: The use of nitrate fertilizers, livestock production, and manure management. N₂O is generated as an intermediate product or by-product of nitrification and denitrification processes. Their emission is very complex [8]. NO₂ issues from nitrogen fertilizers (organic manures or inorganic fertilizers) or by manure storages and by deposition by grazing animals [9,10]. 50% of NO₂ emissions is form animal agriculture [11]. The nitrogen excreted more in the urine whereas the nitrogen excreted in the dung is constant [12,13].

Carbone Dioxide: CO₂

Carbone dioxide CO₂ has a lower warming potential then CH₄ and NO₂, but it has the most emitted gas especially from industrial sector. The use of fossil fuel is the most important emissions source of CO₂, it can be also emitted by from land use, degradation of soil [14].

Sources of GHG emissions from Bovine Meat Production

Dollé [5] have defined 5 mainly sources of emissions:

- Enteric fermentation: CH₄ emissions from animal biological activity of cattle: Enteric fermentation is a process that characterizes ruminants. It occurs at the rumen level. It produces methane as a byproduct of a microbial fermentation of carbohydrates into simple molecules [15].
- Manure management: CH₄ and NO₂ emission from the management of rejections (pasture, building, storage).
- Manure contains two chemicals components: Organic matter converted to CH₄ by anaerobic decomposition, mostly when manure is managed in liquid form, Nitrogen leads to nitrous oxide emissions by indirect transformation of nitrogen released in the atmosphere to ammonia NH₃ and then to N₂O.
- Nitrogen inputs: NO₂ emission resulting from the nitrification and denitrification phenomena of direct nitrogen inputs through organic and mineral fertilization and indirect nitrogen inputs by nitrate leaching and ammonia volatilization.
- Direct energy: CO₂ emission from fossil fuels consumed on the farm (electricity and fuel).
- Inputs: CO₂ emission from transport of cattle feed, NO₂ emission from fertilizer manufacturing.

Table 2: Emission source of GHG emitted by beef.

Emission Source	Compounds
Use of fertilizers (pastures and feed production)	N ₂ O, NH ₃
Manufacturing of fertilizers	CO ₂ , N ₂ O
Land-use change due to grasslands expansion/ cropland expansion for feed production	CO ₂
On-farm energy use	CO ₂
Enteric fermentation	CH ₄
Manure deposition by grazing animals	NH ₃ , N ₂ O, CH ₄
Indirect N2O from leaching and runoff	N ₂ O
Indirect N2O from deposition of NH3	N ₂ O
Transport of animal products	CO ₂

Therefore more, Andrian cited different emissions sources of beef which are illustrated in Table 2: Andrian considered CH₄ from enteric fermentation is the important GHG source. While Gerber his model GLEAM (Global Livestock Environmental Assessment) ranked the sources of GHG emissions as shown in Table 3

- The greenhouse gases emissions variation factors
- Rumen activity and Animal feed
- Rumen activity

The rumen is home to millions of microorganisms that digest food into co-products. Methane production in the rumen is related to the size of the protozoa. If the size of protozoa increases methane production also increases. It is also related to the percentage of hydrogen used to make methane [16].

Table 3: Sources of GHG emissions considered on the GLEAM model (FAO 2013).

Supply chain	Activity	GHG
Upstream	Feed production	<p>NO₂: direct and indirect from:</p> <ul style="list-style-type: none"> -Application of manure. -Application of synthetic N. <p>-Direct deposition of manure by grazing animals and scavenging animals.</p> <p>-Crop residue management.</p>
		<p>CO₂, NO₂, CH₄:</p> <ul style="list-style-type: none"> -Energy use in field operations. - Energy use in feed transport and processing. -Fertilizer manufacture. -Feed blending. -Production of non-crop feedstuff. -Land use change related to soybean cultivation.
	Non-feed production	<p>CO₂: -Embedded energy related to manufacture of on-farm buildings and equipment.</p>
Animal production unit	Livestock production	<p>CH₄:</p> <ul style="list-style-type: none"> -Enteric fermentation. -Manure management. <p>NO₂: -Direct and indirect NO₂ from manure management.</p> <p>CO₂: -Direct on-farm energy use for livestock (ventilation, heating.)</p>
Downstream	Post farmgate	<p>CO₂, CH₄, HFCs:</p> <ul style="list-style-type: none"> -Transport of live animals and products to slaughter and processing plant. -Transport of processes products to retail point. -Refrigeration during transport and processing. -Primary processing of meat into carcasses. -Manufacture of packaging.

Animal feed

Fibrous and poorly digestible diets cause an increase in CH₄. In the other hand According to Machen et Mccollum diet influences the amount of methane. Cattle that consuming stem forage (high fiber) emit more methane then cattle that consuming concentrate (low fiber). They add that when highly available carbohydrates are fed at limited intakes, high fractional methane losses occur. At high intakes of highly digestible diets, low fractional methane losses occur.

Productivity and Herd Management

There is a relationship between productivity and GHG emissions intensity, when productivity and yields increase GHG emissions intensity decreases. According to Gerber poorer animal husbandry, lower slaughter weights and higher age at slaughter leading to higher GHG emissions. An increase in productivity without an excessive reliance on inputs that allows for an increase in the average daily gain, this leads to a reduction in the fattening time, and consequently a reduction in GHGs emissions associated with production. Guickshank assert that a good herd management: an adequate diet, a good reform of unproductive animals, an effective health management capacity to adapt to environmental changes, leads to a reduction of 2 to 5% of GHGs emitted by cattle farming.

Carbon Storage/Restorage

Soil change is reflected in a change of carbon flux in the soil, it is carbon storage and restorage. This can lead to GHG emissions of carbon sequestration. Any conversion of a forest or grassland into a crop induces GHG emissions (from 4 to 6 tonnes of CO₂ / ha / year). Conversely, any conversion from a crop to a grassland induces sequestration of carbon in soils (from 0.84 to 2.75 tonnes CO₂ / ha / year) [17]. According to Table, soil change from crop to grassland is better than soil change from grassland to crop because it mitigates CO₂ emission and capture CO₂.

Nitrogen Fertilization

Proper nitrogen management can reduce 90% of CO₂ emissions [18]. Much of the nitrogen management is evident in the management of N input at the farm level. Moderate nitrogen fertilization reduces the purchases of synthesized fertilizers and consequently reduces carbonic gases emissions associated with their manufacture and transport (5.3 to 6.1 kg of CO₂/kg of nitrogen).

Energy Consumption

Energy consumption within a farm is the major factor for CO₂ emission. Dollé assert that the consumption of fuel and electricity causes the direct emission of CO₂. So, any reduction

in energy consumption will reduce the CO₂ emission (mitigation strategies of energy consumption are more detailed in the third party).

Mitigation Strategies

Technologies and practices that help reduce emissions exist but are not widely used. Their adoption and use by the bulk of

the world's producers can result in significant reductions in emissions. Dollé summarize action levers that can reduce GHG emissions from cattle (Table 4) it's through means that act on Animal feed, productivity and herd management, nitrogen fertilization and manure management, reduction of energy consumption and carbon storage. Table 5 shows this means and their effect on CH₄, NO₂ and CO₂ emissions.

Table 4: Impact associated to soil change between crop and grassland Arrouays et al. (2002).

Soil Conversion	Average Annual Additional Flow T C/ha/year	CO ₂ Equivalences Emitted or Captured (T CO ₂ eq/ha/an)
Crop ↘ grassland	Carbon storage 0.49 +- 0.26	CO ₂ capture 0.84 to 2.75
Grassland ↘ crop	Carbon Destorage -0.95 +- 0.3	CO ₂ emission 2.4 to 4.6

Table 5: Potential effects of the main levers of action on GHG emissions.

Action Lever	CH ₄	NO ₂	CO ₂	Potential Effect on Reducing the Net Carbon Foot Print of Products
Animal Feed				
Increase in the Share of Concentrates	↓	-	↓	0 to 5%
Fat Intake	↓	-	-	3 to 7%
Food Additives	↓	↓	-	?
Optimization of the nitrogen content of the Ration	-	↓	↓	2%
Replacement of Soybean Meal with Rapeseed Meal	-	-	↓	3 to 7%
Protein Autonomy	-	-	↓	2 to 5%
Productivity and herd Management				
Productivity	↓	↓	↓↑	-5 to 10%
Renewal	↓	↓	↓	0 to 5%
Health optimization	↓	↓	↓	2 to 5%
Genetic Improvement	↓	↓	↓	2 to 10%
Nitrogen Fertilization				
Reduction of Nitrogen Intake	-	↓	↓	2 to 5%
Introduction of legumes	-	↓	↓	2 to 5%
Nitrification Inhibitor	-	↓	↓	0 to 5%
Manure management				
Optimization of pasture	↓	↓	-	3 to 5%
Optimum recovery of manure	-	↓	↓	3 to 5%
Methanation	↓	↓	↓	5 to 7%
Reduction of energy consumption				
Electricity	-	-	↓	<1%
Oil	-	-	↓	1 to 2%
Carbon storage				
Increase the proportion of permanent grasslands	-	-	↓	3 to 10%
Implement hedges	-	-	↓	3 to 10%

Mitigation strategy of CH₄ emissions

Focusing on animal feed (Table 4), we can use additives to limit enteric fermentation [19]. Or changing animal diet for example changing grass to maize can reduce methane from enteric fermentation [20]. Also, increase the part of concentrate in the ration, which replaces cellulose by starch, so it can reduce enteric methane. To reduce the production of methane in the

rumen we can decrease the population of the protozoa by the ingestion of rations very rich in cereals. Or redirect the hydrogen used in the manufacture of methane in other biochemical pathways such as the sulphate or nitrate reductant route. Similarly, polyunsaturated fatty acids represent hydrogen sinks (capture hydrogen) so they try to reduce methagenesis.

Concerning mitigation strategy applied to reduce methane and other GHG emissions from manure management we can site:

- a. Composting, by aerating and ventilating stored manure, this decrease CH₄ emission but increase NO₂ emission from manure [21].
- b. Excessive use of straw in litter can reduce GHG emission from manure [22].
- c. -Manure compacting and coverage by plastic sheeting reduce CH₄ but may increase NO₂ according to climatological conditions [23].

In the other hand, according to Weske [24] more lactations per cow, less enteric methane emission. Because without producing milk there is more GHG emissions.

Mitigation strategy of NO₂ emissions

As example of mitigation strategy of NO₂ emissions from agriculture soil is nitrification inhibitors which can reduce roughly 30% of NO₂ emission from soil [25]. Nitrification inhibitors can reduce losses by leaching and consequently reduce emissions, by slowing the production of nitrate nitrogen resulting from the transformation of the ammoniacal nitrogen of pissats and manure. This reduction can reach 60 to 68% of GHG emissions. This strategy is very much studied in New Zealand [26]. According to Soussana [27] reducing grazing intensity or overgrazing, reduce both NO₂ emissions and soil organic carbon.

In the other hand, the division of ploughing grassland in several times per year instead of ploughing permanent grassland can reduce NO₂ emissions from the soil. Or reducing ploughing area by leaving areas un-ploughed and sowing new seed under a no-till system [28]. According to Wulf [29] most effective way to reduce NO₂ and CH₄ both emissions from manure management is trail hose application in combination with immediate shallow, but that can increase NH₃ emissions. Therefore more, the use of cropped crops, such as energy crops as buffer strips along open streams in order to mitigate nutrient leaching, so reducing NO₂ in the atmosphere [30-32]. Focusing on manure biosolid management strategies such a: compacting and coverage, increasing straw content for composting, covering manure storage, no manure application in autumn, mitigates both NO₂ and CH₄ emissions gases. Also, the use of legumes reduces NO₂ emissions, thanks to symbiotic fixation that dos nit emits GHGs.

Mitigation strategy of CO₂ emissions

There are two main levels of CO₂ mitigation strategies:

- a. Carbon storage

Extensification can reduce CO₂ emissions from soil by turning grassland into a carbon sink instead of a source. So, increase the proportion of permanent grassland. Implementation of hedges.

- b. Energy use

Practice grazing instead of the installation of cultures has end of underestimate the consumption of fuel for harvesting,

distribution of forage, spreading of droppings, reduce CO₂ emissions from fuel use [33-35]. On the other hand, checking the tractors, good economic driving, reducing transport, simplifying farming practices..., can significantly reduce CO₂ emission from energy use [5].

Conclusion

Methane CH₄, Nitrous oxide NO₂ and Carbone dioxide CO₂ are the main GHGs emitted by beef cattle. NO₂ is the most powerful GHG, which retains more heat than CH₄ and CO₂. Enteric fermentation, manure management, energy use and nitrogen inputs are the main GES emissions sources from bovine meat sector. Cattle is the agriculture sector that emits the most GHGs. So the aim is not only to encourage and support research and GHG abatement strategies, but also to popularize and raise awareness among all members of agricultural sector, especially producers, in order to highlight the seriousness of this situation, to find viable and achievable solutions.

More communication with farmers is needed, new policies and investments that facilitate the use of mitigation solutions. Meat production increases as demand increases. Therefore, adequate strategies are needed to limit GHG emissions while guaranteeing food safety, the state of the animal and avoiding any undesirable effects. We must strive for sustainable agriculture that preserves our natural and environmental resources.

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