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Environmental Impacts of Cattle Production

Bachelor Thesis

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2017

Declaration

I declare that the Bachelor Thesis "Environmental impacts of cattle production" is my own work and all the sources I cited in it are listed in the Bibliography.

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Summary

Agriculture was the key for the development of the human civilization. Although, nowadays it needs to keep up with the increasing human population in the world. While doing so, agriculture has many impacts on the environment. Many of these impacts come from livestock production, specifically that of cattle production. Cattle originated from India and were first domesticated 10,000 years ago in the Middle East. They were, and still are used, for their meat, milk and hide and also for draft power. Throughout history, their populations expanded all over the world, typically to anywhere that grass can be grown. Cattle are ruminant animals that utilize vegetation on marginal land where the cultivation of other crops is not possible. At any given time, the world population of cattle is 1.4 billion head. There is increasing demand for beef and dairy products coming from developing counties with a rising economy. For the supply chain, there are three types of cattle production systems: cow-calf operations, indoor/outdoor rearing with grazing and intensive. The environmental effects of each system will vary on water and land resources and GHG emissions. Out of all agricultural products bovine meat has the largest water footprint, 15,415 L/kg. A substantial portion of this, is the water used to grow feed crops. There is also water pollution that comes from growing the feed, such as fertilizer, pesticides and sediment. Where cattle manure is applied as fertilizer, water can be contaminated by pathogens, drug residues and heavy metals found in cattle excreta. Water cycles are affected by the grazing behavior of cattle. Deforestation to create pasture and land for soybean production is rampant in the Amazon rainforest, which has the largest drainage basin in the world. Much of GHG emissions in Brazil comes from the burning of biomass to clear the land. GHG emissions from cattle represent 65% of all livestock emissions, which is 14.5 % of all anthropogenic emissions. Much of cattle GHG emissions is CH_4 produced by enteric fermentation. There are also emissions from cattle manure, which emit both CH_4 and N_2O. Water seems to be the most affected by cattle production. There is a clear connection between water availability and land-use conversion. If demand for beef is reduced, the same will happen for cattle populations and, consequently, CH_4 emissions. Less cattle means that more food will be available to people in poverty-stricken countries where hunger is a major issue.

Keywords: **cattle production, environment, pollution, greenhouse gases, water footprint**

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1. Introduction

Agriculture is the basis of civilization. The main turning point for agriculture occurred around 9500 B.C. in the Levant, an area in the eastern Mediterranean (New World Encyclopedia, 2015). It was then that the eight founder crops of agriculture appeared: emmer and einkorn wheat, barley, peas, lentils, bitter vetch, chick peas and flax. The transition to agriculture allowed people who were previously hunter-gatherers to allocate their time to other activities, instead of gathering food. This, in turn, allowed human populations to flourish and the advancement of societies. However, it worked too well and caused an exponential increase in the human population, especially after the industrial revolution, growing to seven times its size in a period of two centuries. In order to sustain more people, there was a need for intensive agriculture. It involves using high inputs of capital and labor to achieve high crop yields per unit area of agricultural land. There is a high level of mechanization which makes it very efficient. Inputs such as genetically modified organisms (GMO) and artificial fertilizers are used to ensure high outputs. Chemical agents are applied to eliminate weeds, pests and fungi. The utilization of various synthesized elements would have a negative effect on the environment. There are already several issues on the environmental impacts of agriculture. From the global sum of all freshwater withdrawals, agriculture takes up 69% (FAO, 2016). Another issue is the eutrophication of lakes and rivers caused by runoff from farm land carrying excess nitrogen and phosphorus fertilizer. According to a report by the Intergovernmental Panel on Climate Change (IPCC), in 2010 agriculture, along with forestry and other land use (AFOLU), contributed 24% to global greenhouse gas emissions (Smith et al., 2014). A large portion of greenhouse gas emissions from AFOLU are from livestock (18%), of which cattle are a major contributor. This statement brings us to the topic of the thesis: the environmental impacts of cattle production. Compared to other livestock, cattle production consumes the most resources. For example, as much as 20,000 L of water can be used to produce 1 kg of beef (Gerbens-Leenes, et al., 2013), whereby the same amount of chicken meat only require one-fifth as much water (Institution of Mechanical Engineers, 2013). Cattle also require large areas of land for forage and feed production. This literary review will discuss in detail the environmental implications of cattle production, both beef and cow milk, in its exploitation of natural resources and the pollution that comes from its management practices.

2. Objectives of work

In these times, with the threat of climate change, it is popular to adopt a lifestyle that is environment-friendly. Common practices include using LED (light-emitting diode) lightbulbs, driving electric cars and recycling. However, people often overlook the effects of food production on the environment, especially that of cattle. It consumes the most water and is a significant source of greenhouse gases. The objective of this work is to review the scope and intensity of the environmental impacts of cattle production, explaining its characteristics and mechanisms. We hope that this compilation work can help people make informed decisions to reduce their burden on the environment more effectively.

3. Literature Overview

3.1 History of cattle domestication

A brief overview, summarized from C.J.C. Phillips' *Principles of Cattle Production* (2001), will be given on the history of cattle domestication. Cattle originated from India and dispersed to throughout Asia, northern African and Europe after the Great Ice Age, about 250,000 years ago. Their domestication from the now-extinct aurochs (*Bos primigenius*) began 10,000 years ago in the Middle East (Gotherstrom et al., 2005). Similar to today, cattle were used for the production of meat and milk and as beasts of burden. From their carcasses, their hides were used for clothing and tents and their bones were made into tools, such as fishhooks and spears. They are effective in converting fibrous grasses into food for human consumption in areas where the land is not suitable to grow food crops. The bull became a symbol of power and fertility because of their strength, aggression and its ability to serve a large number of females. Cows are an important figure in the religions of Middle East, North Africa and India. The main difference in that of India is that they were considered sacred and their slaughter and consumption is forbidden. Cattle farming was introduced to India by nomadic herdsman from the Asian steppes. At first, the low population allowed for the consumption of beef, but as it grew, more cattle had to be allocated to crop production for their draught power. Only the higher classes had the privilege of eating beef. Eventually, the population increased until it could not sustain beef consumption and it was prohibited altogether. In Africa, the Maasai tribes have practiced nomadic pastoralism for a thousand years to this day. This system of husbandry developed because grazing lands are not regularly available throughout the seasons. The tribe keeps moving within Kenya and Tanzania in search of pasture to support their herd. For the Maasai, their herds are their primary source of food. The village council manages the balance between food availability and stock numbers. An imbalance would lead to tribal wars, where people and cattle are killed until the balance is restored.

Cattle are an important aspect in Spanish culture. It was introduced to Spain, initially, by the Celts, then by the Romans. For a long time, the cattle were raised in the arid plains of Spain, until Christopher Columbus discovered the New World in 1492. The Americas provided cattle ranchers with vast areas of pasture, which were of better quality than that of Spain. Longhorn cattle were shipped across the Atlantic to ranches in South America and colonization soon followed. By 1870, about 13 million Longhorn cattle occupied the Pampas in Argentina. The British were responsible for the expansion of cattle farming into North America. The wealth brought by the industrial revolution created a new British middle class, who could afford beef on a regular basis. This new demand for beef prompted two things: the creation of new cattle breeds which were smaller and quicker to finish, such as the Hereford and the westward exploration of the United States for more pasture land. The development of cattle ranching in the American west was funded mainly by the British. Their investment went into the purchase of cattle stock, expansion of railways and refrigerated transport. Soon, the Americans became wealthier and with it, like the British, grew a demand for beef. Afterwards, for the sake of efficiency, the cattle were no longer finished on pasture, but instead in feedlots where they are given a cereal-based diet. This gave way to the intensification of cattle farming.

As more farms became under control of private companies, with the help of modern technologies, herd sizes and production increased. We take an example from the UK, where the average herd size of dairy cows grew from 30 in 1970 to 72 in 1998 and the milk produced by each cow increased from 3750 L to 5790 L. The public became concerned about the safety of consuming products from these intensive systems which focused on profitability. The responsible and informed consumer would only accept products from farms whose practices were ethical and environment-friendly. Consequently, there came to be organic farms, which minimize artificial inputs. Different systems of cattle production exist depending on the needs of the consumer, the economy, the climatic conditions, the terrain and the availability of resources.

3.2 Production systems

For our purposes, a concise explanation of the commercial production systems of cattle will be given. Most of the stock in beef production comes from suckled calf operations. A suckler herd is mainly raised on pasture, where the land is low in fertility and cannot be utilized for other crops. When a cow is in estrus, which occurs every 18-24 days, conception is achieved either by being served by a bull or through artificial insemination. The gestation period is 280-285 days (UNL Beef, 2017). After calving, cows go through postpartum anestrous, which should optimally be within 85 days if the manager wants to achieve a 1-year calving interval (Bischoff et al, 2012). Once the calves are weaned at 7-8 months old, they are either raised to slaughter weight or sold to be finished elsewhere (Gillespie & Frank, 2009).

Indoor/outdoor rearing systems are used in countries where the cold in winter would reduce the cattle's growth if they are outside, so they are kept inside over winter. Here they are fed conserved forage of good quality, such as hay and silage, and a limited amount of concentrates (oats, barley, wheat), up to 2-3 kg per head per day. In this stage of production, beef cattle are finished in 18 months; 24 months for late-maturing breeds, such as Charolais and Limousin (Phillips, 2001). The ideal growth rate for an 18-month finishing period is 0.8 kg per day, but in winter it is reduced to 0.5 kg per day. The cattle are fed on pasture in the summer. Generally, feeding cattle in a housed system is more efficient than grazing. When cattle are fed indoors, the quality of forage is controlled. When grazing, cattle consume 65% of the grass grown, whereas for silage it is 75%. In addition, a cow's energy requirement increases by 25% when it is grazing. Despite the efficiency of housed feeding, keeping cattle inside all year would have a negative effect on their welfare and, consequently, on their performance. The stockperson should take into account the welfare benefits and the costs of letting the herd out to pasture and make a compromise. In the case of intensive beef production, the cattle are kept indoors throughout their life, where they are given either concentrates or conserved forage. The feeding period in intensive systems is reduced to less than one year due to a growth rate of 1.1 kg per day. Grain-fed cattle are quicker to finish, but some metabolic disorders may arise, such as laminitis and liver abscesses due to rumen acidosis caused by "rapid degradation of cereals by bacteria"(Philips, 2001).

The standard cattle breed for dairy farming is the Holstein-Friesian. Dairy cattle can live to about 20 years, but they are culled at 6 years old (Compassion in world farming, 2012). To produce milk continuously, cows need to give birth, ideally, every year. The calf should receive the mother's first milk (colostrum) as it contains immunoglobulins which are important for the calf's immune system. They are separated from the mother after a few days and are fed milk replacers. Lactation usually lasts 305 days after calving (Phillips, 2001). From the animal's perspective, we are taking milk that rightfully belongs to the calf, but in a commercial context the cattle and calf are assets and the milk is the product. Yearly output of milk per cow depends on the feed that is given. These figures are taken from a report by Compassion in World Farming (2012). A cow fed entirely on grass produces 4,000 liters per year. If concentrates are added, it can produce 5,000 liters per year, while medium-high yielding cows, with the same diet, can produce 8,000-14,000 liters per year. Cows that are fed total mixed ration (hay, silage, concentrates) produce more than 12,500 liters per year, without weight loss.

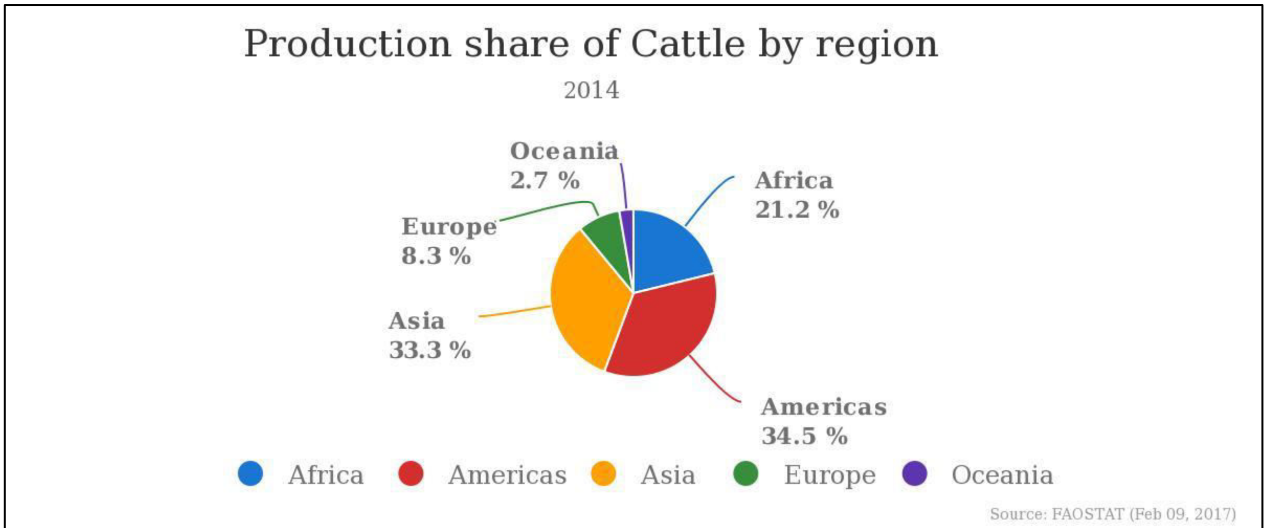


Figure 1. Asia and the America's have an almost equal percentage of cattle production

3.3 Current situation and trends

For 2014, FAO put out the figure for the world population of cattle as 1,474,526,581 (FAOSTAT 2017). The top countries having the most cattle are, in descending order: Brazil, India and China. United States comes fourth in population of cattle, but it is the first in production followed by Brazil, which makes the Americas have the largest share of cattle production, as seen in Figure 1. We raise cattle mainly for the consumption of their meat and the milk that they produce. The consumption of dairy products is higher in developed countries and beef was always considered a commodity exclusive to people with relatively high income. However, there is an increasing demand for beef and dairy products in developing countries. This is due to their growing populations and an emerging consumer class with higher income (McAlpine et al., 2009). In fact, the level of income and consumption of animal protein has a positive correlation (WHO, 2017). People with more money feel entitled to a better quality of life and consuming animal protein is one aspect of that. Uruguay and Argentina are the top consumers of beef with 46.7 and 41.4 kg per capita, respectively (OECD, 2016). From 1961 to 2005, world beef production more than doubled from 30 million to 64 million tons and is expected to be 106 million tons in 2050 if current trends continue. The projected demand for beef cannot be met without severe environmental consequences, as there would be an increase in feedlots and expansion of grazing lands (McAlpine et al., 2009).

3.4 Environmental impacts

Speaking objectively, an environmental impact is anything that comes about because of human activity and alters the natural world, whether it is beneficial or detrimental. It has several connotations, one of which is pollution, and is usually associated with opportunity costs. Something can be considered an environmental impact if it disrupts an ecosystem and poses a health hazard to living beings. Cattle production has consequences on three aspects of the environment: aquatic, terrestrial, and atmospheric. As livestock production is a part of agriculture, they would have the same environmental issues in addition to the ones that relate to animal husbandry. They can be directly caused by the activities in cattle production itself or indirectly, through inputs such as feed or land. This review will be written from a global perspective, taking examples from different countries. Despite all the evidence about the negative environmental impacts of cattle production, there are some positive ones, which we will discuss here. The grazing behavior of cattle improves the composition and maintains the diversity of plant species in grasslands (Marty, 2005; de Haan et al., 2002). Cattle are less selective when grazing compared to other ruminants because their muzzles are bigger and further from the ground. Excess vegetation would be regulated and shrubs are controlled, while seeds are dispersed through their hooves and manure. Trampling may seem damaging, but it induces grass tillering, seed germination and disintegrates hard soil crusts. Their manure is used to fertilize the land and is important in the cattle farms of desert reclamation programs as it stabilizes the sandy soil and improves water retention (Phillips, 2001).

3.5 Water

Water covers 71% of the planet's surface. It is found in all known living things and they need it to survive. More than half of the human body consists of water. We will discuss the aquatic aspect of the environmental impacts first because of water's importance in agriculture and that it is essential for life. In the past, droughts had a severe impact on a society. Agriculture predominates global freshwater consumption at 69%. Livestock production, especially that of cattle, uses the most water, with regard to feed production. Agriculture is also a known cause of water pollution and in some cases a victim of it. Developing countries are more vulnerable to agricultural water pollution as the lack of infrastructure make it possible for contamination of drinking water.

3.5.1 Water consumption

Water has always been the limiting factor for any agricultural activity. The Dublin Principles, which recognizes the scarcity of water is as relevant today as it was when formed in 1992, if not, even more. Clean fresh water is a scarce resource and for that reason should be treated as an economic good (IHE-Delft, 2003). Water scarcity has now become a global issue due to international trade of agricultural products (Hoekstra, 2012). Through that trade, there is an exchange of virtual water, which is the water consumed to make a certain product. A country with relatively low rainfall would still be able to consume water-intensive products, such as beef, by importing them. To correctly quantify and understand water consumption in cattle production, we need to apply the concept of water footprint. In this context, it is the volume of all the water that is consumed (evaporated) or polluted throughout the supply chain of the animal product until it ends up with the consumer. Most consumers do not realize the staggering amount of water that is used to produce that piece of steak on their plates. Hoekstra (2012) distinguish three types of water footprint: blue, green and gray. Blue water represents water resources from the surface and groundwater. Green water is rainwater stored in soil. Grey water is polluted water, as in the volume of water needed to dilute the pollutants so that the ambient water is above water quality standards.

	Water footprint per unit of weight, L/kg				Nutritional content			Water footprint per unit of nutritional value		
Food item	Green	Blue	Gray	Total	Calories, kcal/kg	Protein, g/kg	Fat, g/kg	Calories, L/kcal	Protein, L/g of protein	Fat, L/g of fat
Sugar crops	130	52	15	197	285	0.0	0.0	0.69	0.0	0.0
Vegetables	194	43	85	322	240	12	2.1	1.34	26	154
Starchy roots	327	16	43	387	827	13	1.7	0.47	31	226
Fruits	726	147	89	962	460	5.3	2.8	2.09	180	348
Cereals	1,232	228	184	1,644	3,208	80	15	0.51	21	112
Oil crops	2,023	220	121	2,364	2,908	146	209	0.81	16	11
Pulses	3,180	141	734	4,055	3,412	215	23	1.19	19	180
Nuts	7,016	1,367	680	9,063	2,500	65	193	3.63	139	47
Milk	863	86	72	1,020	560	33	31	1.82	31	33
Eggs	2,592	244	429	3,265	1,425	111	100	2.29	29	33
Chicken meat	3,545	313	467	4,325	1,440	127	100	3.00	34	43
Butter	4,695	465	393	5,553	7,692	0.0	872	0.72	0.0	6.4
Pig meat	4,907	459	622	5,988	2,786	105	259	2.15	57	23
Sheep or goat meat	8,253	457	53	8,763	2,059	139	163	4.25	63	54
Bovine meat	14,414	550	451	15,415	1,513	138	101	10.19	112	153

Table 1. Global-average water footprint of crop and animal products. Taken from Hoekstra, 2012.

The global water footprint related to animal production is 2,442 billion m^3/year (Hoekstra, 2012). Beef cattle take up one-third of this amount, while dairy cattle take up 19% (Mekonnen & Hoekstra, 2010). Out of all agricultural products, beef has the largest water footprint at a global average of 15,415 L per kilogram. This value consists of the water used to grow the feed and to mix it, service water and drinking water for the cattle. The water requirements of cattle depend on their size, their management and the climatic conditions of the environment. Service water refers to water for cleaning production units, to wash the animals and cool the facilities, animals and their products (Steinfeld et al., 2006). Intensive systems typically use more service water. In a temperate climate, feedlot beef cattle weighing 364-636 kg need to drink, on average, 41 L of water a day (Ward, 2016). Dairy cows that are milking typically consume 115 L of water per day. Water requirements for each cattle would increase with higher temperatures. Of global freshwater uses, water for servicing and drinking in livestock production represents 0.6 % (Steinfeld et al., 2006). In cattle production, the total water used for drinking (1.1%), service water (0.8%) and water for mixing the feed (0.03%) is, similarly, a very small portion of the whole water footprint. Water consumption does not end after the animal has been slaughtered. There is significant water usage in processing the carcass, which range from 6 to 15 liters per kilo (Steinfeld et al., 2006). The process steps in abattoirs generate a lot of waste, such as blood, viscera and manure, which must be disposed of with water. The portion of water footprint that takes the brunt, at 98%, is water used to grow feed crops (Hoekstra, 2012). It can be said that the water footprint of cattle production is virtually the water used to grow feed. Thus, the type of feed has a significant effect on water footprint.

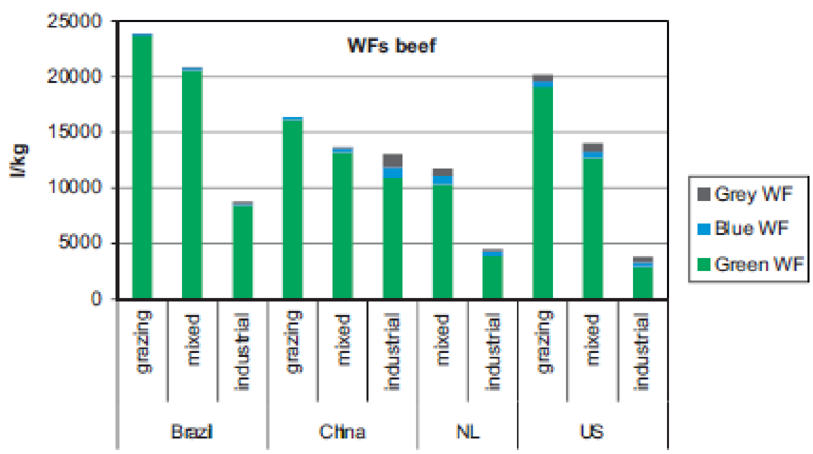


Figure 2. Comparison of water footprints of production systems in different countries. Source: Gerbens-Leenes et al. 2013.

Feed is mainly composed of roughages and concentrates, which, as Gerbens-Leenes et al. (2013) indicate, have an average water footprint of 203 m^3/ton and 1048 m^3/ton, respectively. The authors state that the three types of beef production systems: grazing, mixed and industrial, use different percentages of concentrates from 2%, 4% and to 18%, in that order. In the case of feed conversion efficiency, industrial systems are the best. They use 3.7 times less feed than grazing systems to produce the same amount of beef (Gerbens-Leenes et al., 2013). The reason for this is that the cows move a lot more in grazing systems, thus expending more energy from the feed that would otherwise have been allocated to fattening. To summarize, the water footprint of feed depends on two things: feed composition and feed conversion efficiency. With these two factors combined, as seen in Figure 2, the general trend is that water footprint increases from industrial systems to mixed systems and then to grazing systems. The different components of the water footprint relate to the different feeds that are used. Pastures have a green water footprint, since it uses rainwater. A blue water footprint indicates that the feed is from a crop that was irrigated. If fertilizer was used to grow a crop, it would have a grey water footprint, since the nitrogen and phosphorus can pollute water resources. Grazing systems in the U.S. as well as industrial systems in China feed their cattle concentrates which are predominantly corn that was irrigated and fertilized.

3.5.2 Water pollution

Given that agriculture is the largest user of freshwater in the world, it would, to some degree, be a contributor to water pollution. Though, not solely for that reason, agriculture is one of the leading causes of water pollution. The Green Revolution between the 1960's and 1970's became possible through the manufacture and increasing use of fertilizers and pesticides, though it heavily contributed to water pollution. Through the agricultural activities, water pollution comes in the form of phosphorus, nitrogen, metals, pathogens, sediment and pesticides (Ongley, 1996). Pollution is classified into two types: point source and nonpoint source. An example of point source water pollution in agriculture is the wastewater discharge from feedlots. It can be pinpointed to one source. Nonpoint source water pollution comes from many diffuse sources. The water pollution from crop production is only attributable to cattle production if those crops were grown exclusively for cattle feed.

Chemical fertilizer

Fertilizers in agriculture are a major culprit of environmental damage. Today, Asia uses the most fertilizer, accounting for 57% and 54.5% of global consumption of nitrogen and phosphorus, respectively (Steinfeld et al., 2006). As necessary as they are, nitrogen and phosphorus fertilizers are infamous pollutants of water. In European waters, half of phosphorus pollution comes from agriculture (EEA, 2005). One of the effects that nitrogen and phosphorus have on water is eutrophication. Taken from Schrimpf et al (2003), eutrophication means the anthropogenic enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life to produce undesirable effects. In freshwater, phosphorus is the limiting factor for eutrophication, while in marine water it is nitrogen, however both elements are necessary. In most cases, fertilizer is applied in excess to the plant's needs. The nutrients are transported to water bodies through runoff, where erosion is involved, and leaching. There are more losses of phosphorus from runoff water because its compounds bond stronger with soil particles (Steinfeld et al., 2006). Nitrogen is more soluble in water, so it is lost more through leaching (Ongley, 1996). Trophic states of freshwater bodies become higher as the concentration of phosphorus increase. Table 2 shows the classification of trophic states and its relationship with other characteristics. Algal blooms occur because of eutrophication. They disrupt aquatic ecosystems in that they block sunlight from reaching plant life residing at the bottom of the water body. Rapid growth of algae means that decay that is just as fast. The bacteria that decompose the dead organic matter use up the oxygen in the water, consequently killing other life forms, such as fish. There is also a loss of recreational function because of an influx of slime and weed and noxious odor from decaying algae (Ongley, 1996).

Trophic status	Organic matter mg/m^3	Mean total phosphorus[1] mg/m^3	Chlorophyll maximum[1] mg/m3	Secchi depth[1] m
Oligotrophic	low	8.0	4.2	9.9
–				
Mesotrophic	medium	26.7	16.1	4.2
–				
Eutrophic	high	84.4	42.6	2.45
–				
Hypertrophic	very high	750-1200		0.4-0.5

Table 2. Trophic states and their relationship to lake characteristics. Secchi depth is a measure of turbidity; the depth of water that is visible from the surface. Source: Ongley, 1996.

Nitrogen, in the form of nitrate, also contaminates groundwater through leaching, and therefore can leak into wells. Elevated levels of nitrate in drinking water can be hazardous to human health, causing abortions, stomach cancers and methemoglobinemia in infants (Steinfeld et al., 2006). Reported by Lawrence and Kumppnarachi (1986), concentrations of nitrate in groundwater near irrigated rice paddies in Sri Lanka reached 45 mg/l, grossly exceeding the WHO limit of 10 mg/l.

Pesticide

The intensification of food production observed during the Green Revolution would not have been possible without pesticides. We take an example from India, where food grain production rose almost fourfold 50 million tons in 1948-1949 to 198 million tons in 1996-1997 (Aktar et al., 2009). The application of pesticides reduced the loss of harvestable produce due to weeds, diseases and insects (Aktar et al., 2009). Agriculture is one of the few activities where toxic chemicals are intentionally released into the environment (Ongley, 1996). Over time, people became aware of the harmful effects of pesticides, such as DDT (dichloro-diphenyl-trichloroethane) on the environment. Their use in agriculture was completely banned in developed countries, while developing countries could not afford to ban them (Ongley, 1996). As an agro-chemical, pesticides contaminate water resources via runoff and leaching. It is through water that pesticides cause ecological damage.

The U.S. Geological Survey took samples of water and fish from all the major river basins across the country and found that more than 90 % of them contained one or more pesticides (Kole et al., 2001). In the FAO report by Ongley (1996), he explains the way in which pesticides affect an ecosystem: that is through bioconcentration and biomagnification. Bioconcentration is how a chemical from the surrounding medium, in this case water, gathers inside an organism. Lipophilic pesticides, like DDT, accumulate in the fatty tissue of fish and its concentration exceeds that of the water. In biomagnification, the concentration increases further as we go up the food chain, resulting in top predators having very high concentrations of pesticides. Some of the effects pesticides have on organisms are cancers, tumors and lesions, cellular and DNA damage, suppression of immune system, reproductive inhibition and, of course, death.

In humans, the effects of pesticides are linked to “oncological (cancer), pulmonary and hematological morbidity, as well as on inborn deformities…and immune system deficiencies” (UNEP 1993). The Center for Science and Environment of New Delhi made a shocking discovery when they found residues of organochlorine and organophosphorus pesticides in 17 brands of bottle water (Agrawal et al., 2010). They were above permissible limits set by the European Economic Society (EEC). There are two possible reasons as to how pesticides got into the drinking water. First, the treatment process of the raw water is not thorough. Second, there is no regulation restricting where bottled water may be extracted, so the companies pump out groundwater that lies beneath industrial and agricultural land.

Sediment

Again, we take from Ongley's (1996) report to explain about the role of sediments in agricultural water pollution. Although it is not quantified, it is most probable that much of global sedimentation of water bodies is caused by agriculture. The global sediment load to oceans in the middle of the 20th century was estimated to be 20 billion tons/year. It is believed that 30% of this comes from rivers of southern Asia and 50% is attributed to the mountainous islands in Oceania. Erosion and sedimentation is the process by which water transports soil particles from land to water bodies, so it is strongly linked to hydrological processes.

Sediment pollution has both a physical and chemical aspect. As a physical pollutant, sediments cause turbidity in water bodies which reduces penetration of sunlight. This, in turn, limits or stops the growth of algae and rooted aquatic plants. High turbidity also prevents fish from spawning by covering the gravel beds, where the eggs are laid, with sediment. High levels of sedimentation can raise the stream bed of channels which causes flooding and disrupts navigation of ships. The chemical properties of sediment are responsible for the transfer of phosphorus, metals and pesticides into water. Phosphorus and metals are highly attracted to the ion exchange site of the clay fraction of soil particles smaller than 63 µm. Regarding pesticides, they have a strong affinity to the organic carbon fraction of sediment.

Cattle manure

Cattle manure is applied to crops and pastures as a cheaper alternative to mineral fertilizer or where the latter is not available. It is also a way to economically dispose of animal waste from intensive production systems. In regard to water pollution, cattle manure can be considered as both point source, where cattle excreta is directly discharged into waterways, and non-point source where it is used as fertilizer. Water polluted with cattle excreta exerts a biological oxygen demand (BOD), where decomposing bacteria will compete for oxygen with other living things. Since they are used as fertilizer for its nitrogen and phosphorus, it is also responsible for the water pollution mentioned in section 4.2.1, but not limited to those. Cattle excreta carry pathogens, drug residues and heavy metals into water by runoff and severely affects the living things that live in and depend on water.

Pathogens that are found in cattle feces include bacteria, protozoa and viruses. They originate from the gastrointestinal tract and other systems of the animal and can be shed asymptomatically (Manyi-Loh et al., 2016). There are countless microbial pathogens that exist in a cattle's gut; we will only mention those listed by Kirk (2013) which have a reputation for causing disease in humans as well as cattle, as seen in Table 3. Their transmission to humans by water can be through drinking, bathing, or food that have been irrigated with contaminated water (Ramos et al., 2006). The fact that these pathogens are the most prevalent reflects their ability to survive in the environment, which depend on several factors: exposure to sunlight, extreme temperatures, high or low pH and exposure to oxygen and ammonia (Kirk, 2013). Not all the pathogens are zoonotic, such as the viruses causing Bovine Viral Diarrhea and Foot and Mouth Disease. The protozoans *Cryptosporidia parvum* and *Giardia spp.* cause gastrointestinal illness in humans (Steinfeld et al., 2006)

Causes disease in…	**Bacteria**	**Protozoa**	**Virus**
Humans	Escherichia coli O157		
Cattle			Bovine Viral Diarrhea Virus, Foot and Mouth Disease Virus
Both	Salmonella spp., Listeria monocytogenes Mycobacterium paratuberculosis	Cryptosporidia parvum, Giardia spp.	Coronavirus

Table 3. List of potential pathogens found in bovine manure affecting both humans and cattle. Source: Kirk, 2013

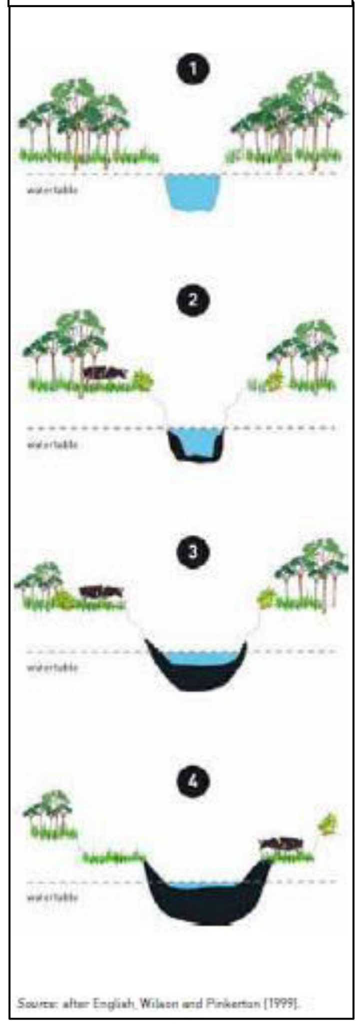
To guard against infection by these pathogens, cattle are given antibiotics extensively through their feed, water and injections. Antibiotics are used more in intensive systems where large numbers of animals live in close proximity to each other and the resulting stress make them more vulnerable to infection. Most antibiotics are given routinely at sub-therapeutic levels as prophylaxis. Additionally. they are most needed during transport and weaning, when the risk of infection is higher (Steinfeld et al., 2006). Antibiotics also serve as growth promoters, though the exact mechanism is not known. The normal gut flora in cattle compete with the host for nutrients, while harmful bacteria reduce the animal's performance. Wegener et al. (1999) suppose that the resulting effect of their reduction by antibiotics improves growth. Hormones are also administered to improve feed conversion efficiency (Steinfeld et al. 2006). However, these drugs are only partially metabolized and the rest, 30-90% for antibiotics, are excreted through feces or urine, which eventually end up in water resources (Zhao et al., 2009). According to Morse and Jackson (2003), residues of antibiotics and hormones have been found in surface water, groundwater and tap water. Bacteria that are exposed to antibiotics in the aquatic environment will develop strains that are resistant to them. This presents a threat to human health since those antibiotics target bacteria that affect both humans and cattle. There is increasing evidence of the effects of water contaminated by hormones. Fish have been found to exhibit masculinization or feminization and there are several cases of breast and testicular cancer in mammals (Steinfeld et al. 2006). The use of hormones in farm animals for growth promotion is banned in the EU with Directive 81/602/EEC (European Commission, 2017).

Low concentrations of heavy metals are given to cattle in their feed for health and as growth promoters (Steinfeld et al., 2006). In the UK, Nicholson et al. (1999) learnt that the highest metal concentrations in cattle feed were for zinc and copper in feed pellets/nuts/cakes for dairy and beef herds. For dairy cattle, they were 130 mg Zn/kg of dry matter (dm) and 40 mg Cu/kg dm while for beef cattle, the values were 190 mg Zn/kg dm and 35 mg Cu/kg dm. Only 5-15 % of the metals are absorbed when the animal ingests them, so much of it is excreted and returns to the environment (Steinfeld et al. 2006). The toxicity of these metals depends on their concentration, since they are necessary elements for the metabolic functions of living organisms. Copper has "a very narrow range of concentrations between beneficial and toxic effects" and high levels causes cellular damage in humans, leading to Wilson disease (Tchounwou et al., 2012). It also causes anemia and stomach and intestinal irritation (Singh et al., 2011). As for zinc, excessive exposure increases the risk of prostate cancer and can cause focal neuronal deficits (Plum et al., 2010).

3.5.3 Water cycles

Livestock grazing can disrupt water cycles, depending on its intensity, frequency and duration (Steinfeld et al., 2006). Hydrological cycles are dependent on the interaction of water with the soil and vegetation and the balance between infiltration and runoff. Any alterations to these components will have consequences on the flow of surface water and groundwater. Steinfeld et al. (2006) describe the mechanism of the impact that livestock grazing has on water cycles. Vegetation maintains water flows by reducing erosion and sedimentation and improving infiltration of rainwater by slowing down runoff, thereby aiding groundwater recharge. When the normal vegetation is replaced by less effective plant species, due to grazing pressure, the infiltration capacity is reduced. Light to moderate grazing reduces infiltration capacity by three-fourths while heavy grazing reduces infiltration capacity by half. Infiltration is also reduced by soil compaction caused by cattle with their hooves, especially when the soil is wet. These factors cause the water table to lower and its impacts are most severe in riparian ecosystems. Livestock prefer to graze in riparian zones where it is cooler, close to a water source and has forage of better quality. The effects of extensive grazing on a riparian environment can be seen when the elevation and water flow of a channel is reduced. A lowered water table around a channel eliminates the vegetation which protects the banks. Over time, the banks collapse and sediment fills the channel, which reduce its depth. The result is a low-flow channel with a lower elevation and the floodplain becomes a dry terrace as seen in Figure 3.

Figure 3. Progression of the degradation of a stream. Source: English et al. 1999



3.6 Land

The issue of land use in cattle production is mostly involved with grazing systems and more so because industrial systems are also called landless systems. For agriculture land in which 33% is reserved for livestock feed production, there is an indirect land use (Steinfeld et al., 2006). Much of the deforestation in Central and South America is driven by expansion of pasture for cattle ranching. Overgrazing in the past is one of the main causes of land degradation and the subsequent desertification of the arid regions in the world. In this section, we will discuss the land use and land use changes associated with beef cattle and the ways in which its production may cause land degradation.

3.6.1 Land use

Grazing systems contribute 9% to the world's production of beef (de Haan et al., 2002). According to FAO's Statistical Yearbook (2013), the area of permanent meadows and pasture for grazing is about 34.4 million km^2, which is 26% of the world land area. Another study by Ramankutty et al. (2008) claims that the area is 28 million km^2. The discrepancy is due to the inclusion of grazed forestland and semiarid land in FAOSTAT. It seems that FAOSTAT has a broader definition for "pasture" and each country obviously has its own definition. In most cases, the authors decided to trust the national data when the difference was too large and did not make sense and we will do so too. Notwithstanding, the data on pasture area does not indicate the intensity of grazing or even if there are any domestic ruminants occupying an area. Only when it is combined with livestock density can it be representative data for the land use of cattle production. One thing that is certain is the conversion of the planet's forests into pasture.

In the 1990's, 94,000 km^2 of forest land were being cleared every year (FAO, 2006). A prominent example of forest conversion into pasture is in the Amazon rainforest, where, from 1990 to 2005, 420,00 km^2 of forest was cleared in the Brazilian region (FAO, 2005). The Amazon rainforest spans nine countries in South America and most it (60%) lies within Brazil. Forest conversion in Brazil occurs mostly in the "arc of deforestation", depicted in Figure 4, which runs along the eastern and southern edges of the rainforest. Pacheco et al. (2017) asserts that pasture expansion is the cause of more than two thirds of the deforestation in Brazil's part of the Amazon. As for the whole Amazon rainforest, pastures account for 80% of all cleared lands (Arima et al., 2014). Since 2015, the number of cattle in the Brazilian Amazon was at 83 million head, which is 39% of Brazil's total herd (Pacheco et al., 2017). The stocking rate for Brazilian cattle in 2010 was 1.2 head/ha (McManus et al., 2016). Cattle ranching is popular in this area because of the low variability in prices, due to efficient production and marketing chains, and very low production costs; it is a safe investment (Veiga et al. 2002). However, the productivity of Brazil's forest-converted pastures usually does not last for more than ten years and the degraded land is abandoned (FAO, 2006). It has been suggested that there are 36 million ha of degraded pastures in Brazil (Merten & Minella, 2013). This is mostly due to overgrazing as a result of poor management and lack of knowledge (Costa & Rehman, 1999). To begin with, tropical soils are of inferior quality. They are acidic, highly weathered, have a high concentration of aluminum and deficient in phosphorus (Fonte et al., 2014). The loss of phosphorus is evident in the soil of degraded pastures, which contain less macroaggregates that protect organic phosphorus (Nesper et al., 2015).

The next leading, if not, well known, cause of deforestation in the Amazon rainforest is soybean production. Brazil is the second largest producer of soybean in the world. As of 2013, soybean cultivation covered an area of 27.6 million ha (Raucci et al., 2014). Much of Brazil's soybean production comes from the state of Mato Grosso. It produced 23.5 million tons, 29% of the country's production, in the 2012-2013 agricultural year (Fearnside & Figueiredo, 2015). Although soybean production only represents 5% of the causes of all deforestation in the Amazon (Arima et al., 2014), its importance in this context is reflected by its link to cattle production. The world demand for livestock products is one of the drivers of soybean production in Brazil. Soy is a major component in animal feed and its distribution has 17% in dairy cattle and 9% in beef cattle (Dei, 2011). Feedlot operations in China and countries in East Asia, where there is little land to grow crops, rely on imported feed from countries with abundant land such as Brazil (FAO, 2006). Apparently, in 2009, 56% of Brazil's soybean exports went to China, the world's largest importer of soybean (Brown-Lima et al., 2010). Interestingly, the profitability of soybean production is spurring its encroachment into pasture land, particularly in Mato Grosso (Barona et al., 2010). Consequently, cattle ranchers are displaced further into the forest's frontiers, causing more deforestation.

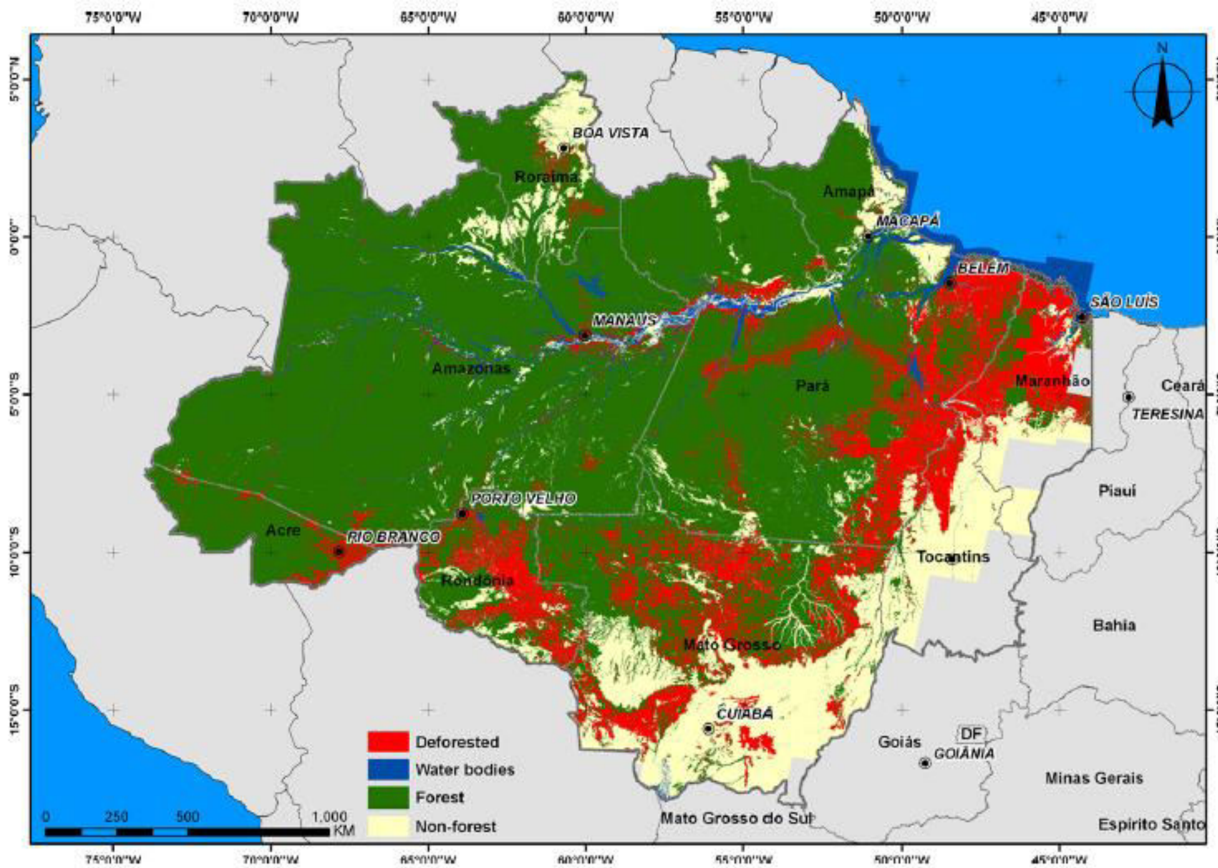


Figure 3. Deforestation in the Brazilian Amazon in 2001. Source: McAlpine et al. 2001

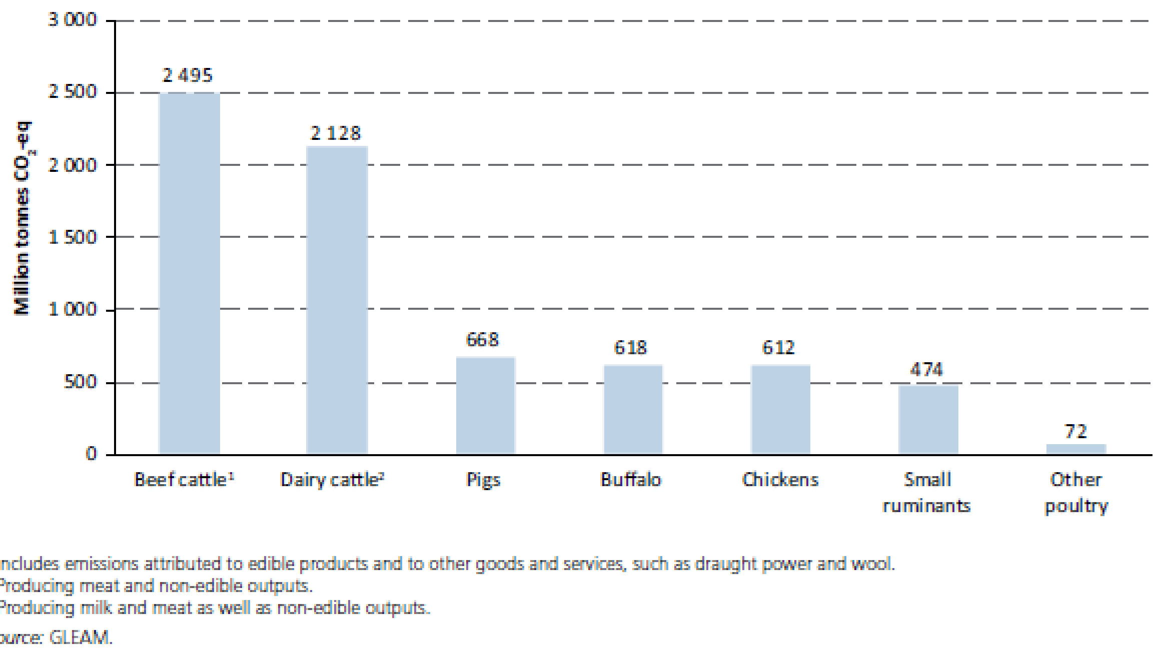
The impacts of deforestation on the environment have been discussed at length in journals and reports. Besides the loss of biodiversity, deforestation has similar environmental impacts to agriculture, namely soil erosion and disruption of water cycles. But, perhaps the most relevant one would be greenhouse gas (GHG) emissions. Burning is a cheap method for farmers to clear the land and it also adds nutrients to the soil, however it releases millions of tons of carbon dioxide into the atmosphere. Brazil's GHG emissions in the year 2005 was 2.2 million Gg (gigagrams) CO_2 equivalent, with 60% attributed to land-use change and forestry (UNFCCC*b*, 2014). In addition, deforestation reduces CO_2 sinks. It is worth mentioning that the cattle, for which forests are converted to pasture, are also a major contributor to global greenhouse gases.

3.7 Greenhouse gas emissions

GHG's are essential for keeping a warm temperature in the earth's atmosphere that sustains life. Solar radiation that warms the earth's surface is emitted back to space as infrared radiation. In what is known as the greenhouse effect, gases such as CO_2, CH_4 and N_2O, absorb the infrared radiation and warms the lower atmosphere. The concentration of GHG's has always been stable until about a century ago, which saw an unprecedented rise along with global average temperature. Human activity is thought to be responsible for this increase in GHG concentration, which is the cause of global warming. According to the UNFCCC (2014), CH_4 has a global warming potential (GWP) of 21 and N_2O has a GWP of 310. GWP relates to the potency of the gases as a GHG using CO_2 as the base and a time frame of 100 years. Since 1880, the earth has become warmer by 0.8°C (Carlowicz, 2014). Apart from a rise in sea level, the effects of global warming include more extreme weather events like hurricanes and droughts, more occurrence of disease from tropical pathogens and a change in animal and plant behavior. Agriculture will be severely affected, due to the increased variability of weather patterns, and, in fact, it is a notable source of GHG emissions.

Livestock production accounts for 14.5% of anthropogenic GHG emissions for 2005 at 7.1 giga-tonnes CO_2-eq per year (Gerber et al., 2013). Beef and cow milk production are the greatest contributors of GHG emissions, representing 65% in the livestock sector. This amount includes indirect emissions within the livestock sector which follows. In Gerber's et al. (2013) report, he states that CO_2 is emitted as a result of conversion of forested land for agriculture, either for pasture or to grow crops for feed, such as the case in the Brazilian Amazon. This land-use-change contributes 9% of anthropogenic CO_2 (Gerber et al, 2013). CO_2 emissions also come from activities like feed processing, transport and fertilizer and herbicide manufacture (Beauchemin et al., 2009). CO_2 exhalation from the animals is also evident, but is negligible and not taken into account. The two most important GHG that come from cattle production are CH_4 and N_2O. CH_4 emissions come from enteric fermentation and manure, while N_2O emissions come from fertilization of feed crops as well as manure (Gerber et al, 2013; Schwarzer et al, 2012). Fertilizer, manure and urinary deposits cause denitrification, which is the main cause of N_2O emissions (Beaeuchemin et al., 2009). Leaching, runoff and herbicide volatilization make up the rest of N_2O emissions (Beauchemin et al, 2009). Emissions from cattle far exceed that of other livestock, as seen in Figure 4.

Figure 4. Global estimates of emissions from livestock. Taken from Gerber et al. 2013.



3.7.1 Greenhouse gas emissions from enteric fermentation

Most methane emissions in the livestock sector are caused by enteric fermentation, which is an integral part of digestion in cattle and other ruminants. The digestive system of cattle has four compartments which are involved in a gradual process that digests tough plant matter. Food first enters the rumen in which there are up to 200 microbes, 10 to 20 of which are responsible for ruminant digestion (US EPA, 1998). These microbes, which include bacteria, protozoa and fungi, break down the plant carbohydrates into volatile fatty acids, mainly acetate, butyrate and propionate, which are the cow's main energy source (Beauchemin & McGinn, n.d.). Hydrogen gas is an end product of fermentation and it inhibits digestion in the rumen. To counter this, methanogenic archaea use H_2 to reduce CO_2 into CH_4 (Broucek, 2014). Enteric fermentation also occurs in the hindgut, where it handles 10 to 30% of digestion, usually of organic matter that bypass the rumen or aren't completely digested (Moss et al., 2000). CH_4 is expelled from the animal mostly by belching and only 5% is from the anus (Aguirre-Villegas et al., 2016). Where CH_4 is produced by digestion in the hindgut, it is emitted mostly (89%) by exhalation (Broucek, 2014).

Besides the environmental implications, CH_4 production represents a loss of productivity in the animal. 5.5-6.5% of the energy from feed intake is used for ruminant methanogenesis (US EPA. 1998). Factors that influence the production of CH_4 are feed characteristics and feed rate. Beauchemin and McGinn (n.d.) state that a diet with <90% grain reduces the energy consumed by methanogenesis to 3%. Forage-based diets with high-fiber content would increase CH_4 production (Broucek, 2014). The statements above agree with the findings of Beauchemin and McGinn's (2005) study on methane emissions of feedlot cattle fed on corn and barley. Cattle on a backgrounding diet with 70% corn silage emitted 170.6 g CH_4/cow/day while those that were finished on a diet with 81.4% corn grain emitted 62.1 g CH_4/cow/day (Beauchemin & McGinn, 2005). Higher CH_4 output from forage-based diets has some correlation as to why cattle in grazing systems take longer to finish, due to energy consumption for methanogenesis. Moreover, CH_4 emissions are a function of the animal's lifetime, so production systems that are quicker to finish cause less CH_4 emissions.

3.7.2 Greenhouse gas emissions from manure

Emissions from manure represents 28.2% in that of milk production and 23.1% in that of beef production (Gerber et al., 2013). Cattle excreta produce the GHG's CH_4 and N_2O. CH_4 from manure is the product of anaerobic decomposition of organic material by bacteria. A list of factors influence the amount of CH_4 produced: composition of manure, amount of volatile solids, availability of nutrients, water content, pH level and temperature (Jun et al., 2000). In the same report, Jun et al. (2000) explains the formation of N_2O in manure. Most of the nitrogen content is in in the form of NH_3, which is converted to nitrate through nitrification in an aerobic environment. After that, denitrification occurs anaerobically, converting the nitrate to N_2O. Parameters that affect N_2O production are temperature, pH and BOD.

Overall, GHG emissions from manure largely depend on its management, specifically those that affect temperature and water content. Comparisons were made on three types of manure storage, compost, stockpile and slurry, on an experimental farm in Ottawa, Canada (Pattey et al. 2005). Stockpiled manure was covered with polyethylene sheeting held down with chicken wire to keep moisture. As seen in the results in Table 4, the general trend was that GHG emissions increased from compost to stockpile and then to slurry. It tells us that manure from dairy cattle produce more GHG's than that of beef cattle. Composting manure seems to be the most favorable option in reducing GHG emissions. Because composted manure is the most exposed to air, there is a reduced chance of anaerobic conditions being met, thereby inhibiting CH_4 and N_2O production.

Table 4. Comparison of GHG emissions of cattle manure with three different storage methods. Data taken from Pattey et al., 2005

Dairy cattle manure	CH_4+N_20 gCO_2-eq kg DM^{-1}
Compost	207.2
Stockpile	301.4
Slurry	397.0
Slurry (5-month estimates)	599.7
Beef cattle manure	
Compost	51.2
Stockpile	75.6
Slurry	229.5
Slurry (5-month estimates)	353.5

4. Conclusion

Cattle production has a negative impact on the environment that we and other living things inhabit, affecting water, land and GHG's. It is a global issue that affects everyone on this planet. It does not matter how far away people live from areas of cattle production. The range of the dispersion of pollutants can be thousands of kilometers, moving through water cycles and the air, like the case of GHG's. The following conclusions were made:

- Based on the length of a section, it seems that water is the most affected by cattle production. In addition to the water consumption to grow feed crops, there is the water pollution from it and from the animal waste. From a human standpoint, the issue of water is crucial, as clean drinking water is a basic human need.
- There is a connection between water and the impacts of land conversion. Water cycles are dependent on vegetation and soil water characteristics. Conversion of forests into pasture or cropland alters the vegetation significantly. Consequently, the soil is more prone to erosion as there is more runoff water.
- If the one third of world's cropland that is used for animal feed production is allocated for human consumption, world hunger can be solved. For this assumption to occur, we would have to gradually reduce our consumption of meat. If a vegetarian diet is out of the question, the least we can do is eliminate beef from our diet, as it consumes the most resources to produce.
- Reducing CH_4 emissions is an effective way to reduce overall GHG concentration in the short term. CH_4 has a lifetime of about 10 years in the atmosphere, much shorter than CO_2, and has GWP 21 times that of CO_2. Reducing the population of cattle by reducing demand for beef is one way to achieve this.

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