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Abbreviations and acronyms

ABIEC	The Association of Brazilian Beef Exporters
AgraFNP	Agribusiness Institute
ANDA	Brazilian Fertiliser Association
ANUALPEC	Annual Livestock Statistics
ASSOCON	The Association of Brazilian Feed-lot Producers
AU	Animal Unit
BFB	Bone free beef
BSE	Bovine spongiform encephalopathy (mad cow disease)
CH_4	Methane
CNPC	Brazilian National Beef Cattle Council
CNT	Brazilian National Transport Confederation
CO_2	Carbon-dioxide
CWE	Carcass weight equivalents
EMBRAPA	The Brazilian Agricultural Research Institute
FAO	Food and Agriculture Organization
FMD	Foot-and mouth disease
FVO	Food and veterinary office in the EU
GHG	Greenhouse gas(es)
IBGE	Brazilian Institute of Geography and Statistics
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
Mha	Million hectares
MT	Million tonnes
N_2O	Nitrous oxide
SECEX/MDIC	External Trade Secretary (SECEX) of the Ministry of Development and
SISBOV	The Brazilian identification and certification system for cattle
USDA	United States Department of Agriculture

Summary

Goal and Scope
The goal of this study was to estimate the life cycle greenhouse gas (GHG) emissions and the use of energy and land from beef produced in Brazil and exported to Europe (Stockholm, Sweden). A national top-down model approach of Brazilian beef production was applied in the analysis and LCA methodology was used as the primary method. The functional unit is the reference basis in analyses applying LCA methodology, here we used two functional units:

1) one kg of Brazilian beef at the farm-gate, as carcass weight equivalent
2) one kg of Brazilian beef exported to Europe (Stockholm, Sweden), as bone-free beef

Functional unit no 2 (bone-free beef) was calculated as: 1 kg carcass weight (meat with bone) = 0.70 kg bone-free meat

This study includes biogenic emissions of methane and nitrous oxide (from livestock, soil and manure) and emissions from production and use of materials and energy. GHG emissions from land-use transformation caused by the expansion of pasture into forestland were also included; this is however not reported here but in a coming paper. Transports and slaughter processing are also included in functional unit no 2. Here, use of energy as well as production of infrastructure (capital goods) was taken into account.

Cattle and pasture in Brazil
The cattle population is approximately 175 million head of which only a small share (~10 %) are dairy cows. Over the last decade there has been a rapid expansion of cattle herds in the northern and north-eastern regions of Brazil towards the Legal Amazon region. The Legal Amazon is an administrative unit (5.5 million km^2) which include the nine Brazilian states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins, Maranhão and Mato Grosso. In this part of Brazil, expansion of pasture land and cattle production is identified as the key driver of deforestation.

Beef production in Brazil is based on continuous grazing all year around. Apart from a very small share of the cattle being held in feed-lot systems and fed mostly with silage, grass from cultivated and native pastures is the predominant feed source. There are more than 170 million ha pasture in the Brazilian agriculture, of which approximately 100 million hectares are planted and 70 million are native pastures (rangeland). Pasture productivity in Brazilian beef production is increasing considerably and this intensification is the major cause of recent production growth. In the Legal Amazon, pasture expansion also contributes to the increasing production, during the last decade pasture area increased by 20 % here.

Overgrazing and lack of nutrient replacement leads to pasture degradation, which is a severe problem in Brazilian agriculture. There are contradictory sources on the extent of degradation, but is possible that around half of the cultivated pastures are in some form of degradation caused by poor management methods, insufficient maintenance fertilisation and high stocking rates.

Production and exports of Brazilian beef
During the past decade there has been a strong increase in beef production in Brazil, from 6.44 to 8.6 million tonnes (MT) carcass weight equivalents (CWE) between 1997 and 2006. During this ten-year period, production in the nine states of Legal Amazon increased from 1.1 to 2.16 MT CWE, i.e. almost a doubled production. In the rest of Brazil, beef production increased by from 5.4 to 6.4 MT CWE, an increase of 20 % between 1997 and 2006. Approximately half of the production increase during the last decade has occurred in the nine states of the Legal Amazon and half in the rest of Brazil.

The domestic consumption of beef in Brazil has been relative stable during the past decade. In 1997, almost the total beef production (97 %) was consumed within Brazil, while in 2006, ~75 % of

production was consumed internally. The overall production increase over the past decade (approximately 2.16 MT CWE) is driven by increased demands on the export market, not by domestic demands. The most important beef-exporting states of Brazil are situated in the southern and central-western parts of the country. These states have an advantage on the export market compared with states in the Amazon region due to better infra-structure, more modern slaughterhouses and a longer period of foot-and mouth-disease free status.

Emissions of methane and nitrous oxide
Emissions of methane from enteric fermentation were calculated with emission factors (EFs) according to the IPCC guidelines and with EFs developed from research in Brazil; there are only small differences in estimated methane emissions between these two sources. Emissions of nitrous oxide from manure dropped during grazing were calculated with EFs according to the IPCC.

Results
The GHG emissions from primary production (not including emissions from land use changes) were estimated at approximately 28 kg CO_2-equivalents per kg CWE at the farm-gate. Methane (CH_4) from enteric fermentation makes up ~ 76 % of these emissions, and nitrous oxides (N_2O) approximately 22 %. CO_2 emissions from the use of fossil fuels are of little significance to the result.

The overall life cycle of Brazilian beef, from primary production via slaughterhouse and transports to Europe (Stockholm) generates a GHG emission of about 41 kg CO_2-equivalents per kg bone-free beef (BFB). NB., it is not the transport that is responsible for the higher number here, it is the choice of functional unit (reference base). Here we used the factor 0.7; i.e. from 1 kg CWE, 0.7 kg bone-free beef is produced. Similarly, as when the emissions are related to carcass weight, methane from enteric fermentation is the pre-dominant source and make up to approximately 75 % of total emissions. Emissions of fossil CO_2, even when transports of the beef to Europe (Stockholm) are included, are still of very little significance (around 2.5 % of total emissions).

The energy use in the primary production was calculated to be very low, close to 4 MJ per kg carcass weight at the farm-gate. When considering the whole life cycle of bone-free beef exported to Europe, the overall energy use is roughly17 MJ per kg bone-free beef. Non-renewable fossil energy is around 80 % of this, and the rest is renewable, consisting mostly of hydro power for electricity used in the slaughterhouses. The use of energy in the whole life cycle up until the bone-free beef is transported to Europe can be divided up as ~30 % livestock production (farms), ~35 % transports and ~ 35 % slaughterhouses.

Land used for beef production in Brazil in 2005 was calculated at approximately 175 m^2 per kg carcass weight*yr and ~250 m^2 per kg bone-free beef*yr for beef exported to Europe.

Conclusions
The GHG emissions in the primary production of Brazilian beef production (not including land-use changes) are at least 30-40 % higher than current European production. High emissions of methane is the main cause and explained by high slaughter ages and long calving intervals, and also that the majority of beef is produced in cow-calf systems, not as by-products from milk production. The use of energy in Brazilian beef production is very low, approximately a tenth of European production. Land use in beef production is considerable higher than in European production.

Improved land management is a necessary measure to take in order to substantially reduce and halt the on-going land expansion into natural ecosystems. Pasture degradation can be prevented by maintenance fertilisation and avoidance of high stocking rates, especially in dry periods. Methane emissions can be reduced by improving livestock performance, e.g. by shortening calving intervals and lowering slaughter age but also by improved pasture management.

Sammanfattning

Mål och omfattning
Målet med denna studie är att beräkna utsläppen av växthusgaser samt användning av energi och mark i produktionen av brasilianskt nötkött som exporteras till Europa (Stockholm). Köttproduktionen studerades ur ett nationellt ”top-down” perspektiv med hjälp av metodiken för Livscykelanalys (LCA). Funktionella enheten är jämförelsebasen i analyser som tillämpar denna metod, i studien användes två funktionella enheter:

1) ett kg brasilianskt nötkött vid gårdsgrinden, som slaktad vikt (vara med ben)
2) ett kg brasilianskt nötkött exporterat till Europa (Stockholm), som benfritt kött (vara utan ben)

Funktionell enhet nr 2 (benfritt kött) beräknades enligt: 1 kg slaktvikt (kött m ben) = 0.70 kg benfritt kött.

Studien inkluderar biogena emissioner av metan och lustgas (från nötkreatur, mark och stallgödsel) samt emissioner från produktion och användning av material. Estimat av utsläpp av växthusgaser orsakade av förändrad markanvändning när skogsmark omvandlas till betesmark ingick i studien, detta rapporteras i en kommande publikation och inte i denna rapport. Transporter och processning ingår i funktionell enhet 2 och här är även produktion av infrastruktur inkluderat.

Nötkreatur och betesmark
Det finns ca 175 miljoner nötkreatur i Brasilien och endast en mindre del (ca 10 %) är mjölkkor. Under de senaste tio åren har nötkreaturen förflyttats mot den norra regionen i Brasilien vilken benämns ”Legal Amazon”. Detta är en administrativ enhet om 5,5 miljoner km^2 som består av de nio staterna Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins, Maranhão and Mato Grosso. Det är i denna del av Brasilien som expansion av betesmark och nötkreatur bedöms vara den största drivkraften till avskogning.

Nötköttsproduktionen i Brasilien baseras på betesdrift året runt. Det är endast en mycket liten del av djuren som hålls i så kallade ”feed-lots” där olika ensilagetyper är dominerande foder, i övrigt är betesgräs från kultiverade samt naturliga betesmarker som är det helt dominerande fodret. Det finns drygt 170 miljoner ha betesmark, av detta är ca 100 miljoner ha insådda med gräs och 70 miljoner är ursprunglig gräsvegetation. Avkastningen på betesmarken har ökat väsentligt under de senaste 10 åren, d v s mera kött produceras per hektar betesmark, och detta är den viktigaste förklaringen till den ökade köttproduktionen under det senaste decenniet. I Legal Amazon sker dessutom en areal-expansion, under det senaste decenniet har betesmarksarealen ökat med ca 20 % här.

Överbetning och brist på växtnäring leder till att betesmark degraderas, detta är ett allvarligt problem i brasilianskt jordbruk. Det finns motstridiga källor till hur stor omfattningen är av detta problem i Brasilien i dag, men det är möjligt att åtminstone hälften av den kultiverade betesmarken är i någon form av degradering orsakat av bristfälliga skötselmetoder, liten eller ingen gödsling samt för högt betestryck.

Produktion och export
Under den senaste 10-årsperioden har nötköttsproduktionen ökat kraftigt i Brasilien, från 6,44 till 8,6 miljoner ton (MT) slaktvikt (1997-2006). Under detta decennium ökade produktionen i Legal Amazon från 1,1 till 2,16 MT, d v s nästan en fördubbling. I övriga Brasilien ökade produktionen från 5,4 till 6,4 MT, en ökning med 20 % under 10 år. Ungefär hälften av produktionsökningen under det senaste decenniet har skett i de nio staterna i Legal Amazon och hälften i övriga Brasilien.

Den inhemska konsumtionen i Brasilien har varit relativt stabil under de senaste 10 åren. 1997 så konsumerades nästan hela produktionen (97 %) inhemskt, och 2006 konsumerades 75 % av produktionen inom landet. Den totala produktionsökningen (motsvarande ca 2.16 MT slaktvikt, vara

med ben) har således drivits av ökande efterfrågan på exportmarknaden och inte av inhemsk efterfrågan. Nötköttet som går på export kommer framförallt från staterna i södra och syd-östra Brasilien. Dessa stater har en fördel på exportmarknaden jämfört med staterna i Legal Amazon p g a bättre infrastuktur, moderna slakterier och framförallt så har de har varit fria från mul- och klövsjuka under en längre tid.

Utsläpp av metan och lustgas
Emissioner av metan från nötkreaturens fodersmältning beräknades med olika emissionsfaktorer (EFs); dels från IPCC:s riktlinjer, dels med EFs som har utvecklats med hjälp av nyligen avslutad forskning där emissioner har mätts på betande djur i Brasilien. Det var dock små skillnader i beräknade utsläpp med de olika emissionsfaktorerna. Emissioner av lustgas från betesgödsel beräknades enligt IPCC:s riktlinjer.

Resultat
Utsläppen av växthusgaser från primärproduktionen (icke-inkluderande emissioner från förändrad markanvändning) beräknades till ca 28 kg CO_2-ekvivalenter per kg slaktvikt (vara med ben) vid gårdsgrinden. Metan från djurens fodersmältning utgör drygt 75 % av de totala utsläppen, lustgas ca 22 % medan CO_2-utsläpp från användning av fossil energi har en mycket liten andel av de totala utsläppen.

Livscykeln som omfattar benfritt nötkött processat, transporterat och färdigt att konsumera i Europa (Stockholm) visar ett totalt utsläpp om ca 41 kg CO_2-ekvivalenter per kg benfritt kött. Observera här att det inte är transporten som gör skillnaden till resultatet för funktionell enhet 1, utan att det är den annorlunda funktionella enheten; det beräknas att 0,7 kg benfritt kött erhålls från 1 kg kött med ben. Likadant som vid beräkningen av utsläpp per kg vara med ben, så är metan från djurens fodersmältning den helt dominerande källan och står för nära 75 % av de totala utsläppen. De totala utsläppen av fossil CO_2, även när transporterna av köttet till Europa är inkluderade, är fortfarande av en mycket liten betydelse (ca 2,5 % av total utsläpp).

Användningen av energi i produktionen av brasilianskt nötkött är mycket låg, beräknad här till ca 4 MJ per kg slaktvikt vid gårdsgrinden. När hela livscykeln t o m transporten till Europa är inkluderad är energianvändning ca 17 MJ per kg benfritt kött. Fossil energi utgör ca 80 % av användningen och resten är förnyelsebar, företrädesvis el från vattenkraft som bedömdes användas i slakterierna. Den totala energianvändningen till och med transporten till Europa kan fördelas till ~30 % i primärproduktionen, ~35 % transporter och ~35 % i slakterier.

Markanvändningen i nötköttsproduktionen i Brasilien beräknades till ca 175 m^2 per år och kg slaktvikt (vara med ben) eller ca 250 m^2 per år och kg benfritt kött exporterat till Europa (år 2005).

Avslutande kommentarer
Utsläppen av växthusgaser i primärproduktionen av brasilianskt nötkött (förändrad markanvändning inte inkluderad) är runt 30-40 % högre än nuvarande europeisk produktion. Skillnaden kan framförallt förklaras med höga utsläpp av metan vilket förklaras med hög slaktålder, långa kalvningsintervaller och även att en mycket stor andel av nötköttet är producerade i ”rena” köttsystem, d v s inte som biprodukter från mjölkproduktion. Energianvändningen i brasiliansk nötköttsproduktion är mycket låg, endast ca en tiondel jämfört med europeisk produktion. Markanvändning är i gengäld väsentligt högre än i europeisk produktion.

Förbättrad användning av befintlig betesmark är en nödvändig åtgärd för att stoppa den pågående omvandlingen av skog till ny betesmark. Degradering av betesmarker kan motverkas av bl a underhållsgödsling och undvikandet av för högt betestryck, särskilt under torrperioder. Metanutsläpp kan minskas per kg kött genom att förbättra djurens produktivitet (lägre slaktålder, förkortade kalvningsintervall), även här är förbättrad betesstatus en viktig åtgärd.

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1 Introduction

During the past years there has been a rising awareness of the many environmental impacts caused by a rapidly growing global production and consumption of animal products. According to the FAO-report "Livestock´s Long Shadow" (Steinfeld et al., 2006), the global livestock sector is one of the top two or three most significant contributors to some of the most serious environmental problems of today, at every level, from local to global. The production of meat, milk and eggs has major impact on land degradation, climate change, air pollution, water shortage, water pollution and loss of biodiversity according to this FAO-study. There are also health aspects connected to the rapid worldwide growth of meat production and McMichael et al. (2007) discuss the uneven global consumption of meat and the need for an international contraction and convergence strategy to combat health problems as well as environmental impacts caused by present meat-consumption patterns. The current global meat consumption is 100 g per capita and day in average, with about a ten-fold variation between high-consuming and low consuming populations. McMichael and colleagues (2007) suggest 90 g per day and capita as a working global target, shared more evenly than today, and with no more than 50 g per day coming from red meat from ruminants.

This study of Brazilian beef production is a part of the research project "*Greenhouse gas emissions from production and consumption of animal products in Sweden 1990 and 2005"* carried out at SIK, the Swedish Institute for Food and Biotechnology. In Sweden, there has been a significant increase of meat consumption between 1990 and 2005 (from 60 kg to 82 kg meat per person and year), and since this consumption increase is almost solely based on imported meat, the environmental effects of this changed consumption pattern have not been analysed; focus on government´s assessments of the environmental impact of food has so far been very much on domestic production, not consumption. Several environmental assessments of animal products clearly show that the predominant impact is in the primary production part, not in the transport-, process- and consumer part of the life cycle. The environmental impact of this significant increase in meat consumption during the past two decades in Sweden is therefore far from fully known.

Most of the meat import is sourced from neighbouring countries in northern Europe with production systems similar to Sweden´s. However, when it comes to beef, Brazil has become increasingly important during the first years of the 21st century and was in 2007, the fourth largest beef exporter to the Swedish market. There is a lack of environmental assessments of meat production in tropical countries (almost all studies are done for temperate conditions) and this knowledge gap is a motive for this study. Brazilian beef production is growing very fast and in only one decade, Brazil has become the major beef exporter of the world.

The overall aim of this study was to quantify the total greenhouse gas (GHG) emissions from Brazilian beef production with a product perspective, and for this, life cycle assessment (LCA) methodology is used. LCA is the most common tool used today for assessing environmental impact (defined as resource use and emissions) of products and the basic principle is to follow the product throughout its entire life cycle. Brazilian beef production was analysed with a top-down national perspective. The potential impact on global warming was analysed, as was the use of resources land and energy.

Greenhouse gas emissions from land use changes have also been analysed in the project; this will be reported in a coming paper and is therefore not discussed in this report.

Data on resource use and emissions from Brazilian beef production were collected from statistical sources, recently published scientific literature and through frequent contacts with Brazilian researchers in the fields of agriculture and environment.

1.1 Structure of the report

In Section 2 (Goal and scope definition) the aim and the range of the study is defined. Decisions made concerning the definition of functional unit (i.e. the reference unit) are motivated and allocation procedures, system boundaries etc are presented. Sections 3 – 4 (Livestock production and trade and Export of beef) give a background description of the production of Brazilian cattle (beef and milk), as well as presenting information on the growing importance of Brazilian beef to the global trade. In Section 5 an overview of land use in Brazilian agriculture with emphasis on pastureland is provided, and inventory data on inputs of resources into pasture production are given. In Sections 6 and 7, the biogenic emissions of methane and nitrous oxide are estimated. In Section 8, data on use of resources and fossil fuels in the beef chain are presented. The results are presented in Section 9 and discussed in Section 10.

1.2 Acknowledgements

Frequent contacts with Brazilian researchers via telephone and mail have been absolutely necessary for the inventory of data for this study. We are very grateful for this help and want to thank: Prof. Frederico Brandini, Universidade Federal do Paraná – UFPR; Prof. Geraldo Tadeu dos Santos, Universidade Estadual de Maringá – UEM; Prof. Domicio do Nascimento Jr., Universidade Federal de Viçosa – UFV; Prof. Luís Otávio Bau Macedo, União das Instituições Educacionais do Estado de São Paulo, UNIESP; Prof. Everaldo Zonta, Universidade Federal Rural do Rio de Janeiro – UFRRJ; Prof. Victor Cruz Rodrigues, Universidade Federal Rural do Rio de Janeiro – UFRRJ; Prof. Gaspar Korndorfer, Univeridade Federal de Uberlândia – UFU; Dr Peter May, Universidade Federal Rural do Rio de Janeiro – UFRRJ; Prof. Lincoln de Camargo Neves Filho, Faculdade de Engenharia de Alimentos -UNICAMP-FEA; Dr Tania Lyra, Universidade Federal de Minas Gerais – UFMG; Dr Angélica Simone Cravo Pereira, Universidade de São Paulo –USP; Resercher Juliana de Oliveira, Universidade Federal do Paraná –UFPR; Researcher Robert Michael Boddey, Embrapa Agrobiology; Researcher Odo Primavesi, Embrapa Environment; Researcher Magda Aparecida de Lima, Embrapa Environment; Researcher Rosangela Zoccal, Embrapa Milk Livestocking; Researcher Judson Ferreira Valentim, Embrapa Acre; Researcher Diego Campana Loureiro, Universidade Federal Rural do Rio de Janeiro – UFRRJ; Veterinary Roberto de Oliveira Roça, Universidade Estadual Paulista Júlio de Mesquita Filho – UNESP; Researcher Augusto Landim, Associação Brasileira dos Criadores de Zebu – ABCZ.

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2 Goal and scope definition

2.1 Goal and purpose of the study

The goal of this study was to assess the life cycle greenhouse gas (GHG) emissions and the use of energy and land from beef produced in Brazil and exported to Europe (Stockholm, Sweden). A national top-down perspective of the Brazilian beef production was applied in the analysis and LCA methodology was used as the primary method.

The purpose of the study was to gain increased knowledge of the environmental impact of beef production under tropical conditions where pastureland is the main resource used. There have been several environmental system analyses of animal production under temperate climate conditions; these production forms are characterised by keeping the livestock stabled during a large part of the year, and providing the animals with mechanically harvested forage and feed. These livestock production systems form a sharp contrast to systems in the tropics which are based on continuous grazing all year around.

Since land use changes are of great importance for GHG emissions and habitat destruction caused by the livestock sector in South America, according to Steinfeld et al. (2006), a deeper analysis of deforestation related to Brazilian beef production was performed. One important purpose of this research was to estimate the GHG emissions from deforestation caused by pastureland expansion in the Legal Amazon and relating these emissions to the product beef and not only to the land area or the livestock sector which has often been done in other studies. This will be reported in a coming paper and not in this report.

2.2 Functional unit

The functional unit is the basis for the analysis according to LCA methodology, and it must be a relevant and well defined, strict measure of the function that the system delivers (user function). In this study we used two functional units:

1) one kg of Brazilian beef as carcass weight, at the farm gate

2) one kg of Brazilian beef exported to Europe (Stockholm, Sweden), as bone-free meat

The motive for choosing two functional units is that in the international literature, production, consumption and trade of beef meat is often presented as carcass weight equivalents (CWE) (i.e. meat with bone), and consumption data are given as meat including bones. However, the consumer often buys meat as unprocessed bone-free meat or processed meat in different meat products (e.g. sausages), and conversion factors are used to re-calculate these consumer products into CWE. We therefore choose to present the GHG emissions and resource use both in relation to meat with bone (CWE) which is used in the international meat statistics, as well as bone-free meat exported to Europe (Stockholm) which is the major beef product imported to Sweden from Brazil.
According to ABIEC (the Association of Brazilian beef exporters), the conversion of metric tonnes boneless meat into CWE tonnes is done by multiplying with the factor 1.3[1]. This means that one kg of CWE equals 0.77 kg bone-free meat. The Swedish National Board of Agriculture uses the conversion factor of 1.429 when recalculating imported bone-free meat into CWEs (Jirskog, E pers. comm., 2008). In this study, we used the Swedish conversion factor for imported meat. Therefore, functional unit two (bone-free meat) was calculated as:

1 kg carcass weight (meat with bone) = 0.70 kg bone-free meat

[1] www.abiec.com.br/eng_version/faq.asp

2.3 The scope of the study

The study dealt with all the phases as shown in Figure 2.1, including production of materials and energy used. GHG emissions from land-use transformation caused by the expansion of pasture into forestland were also included; this is however not reported here but in a coming paper. Production for the year of 2005 was studied.

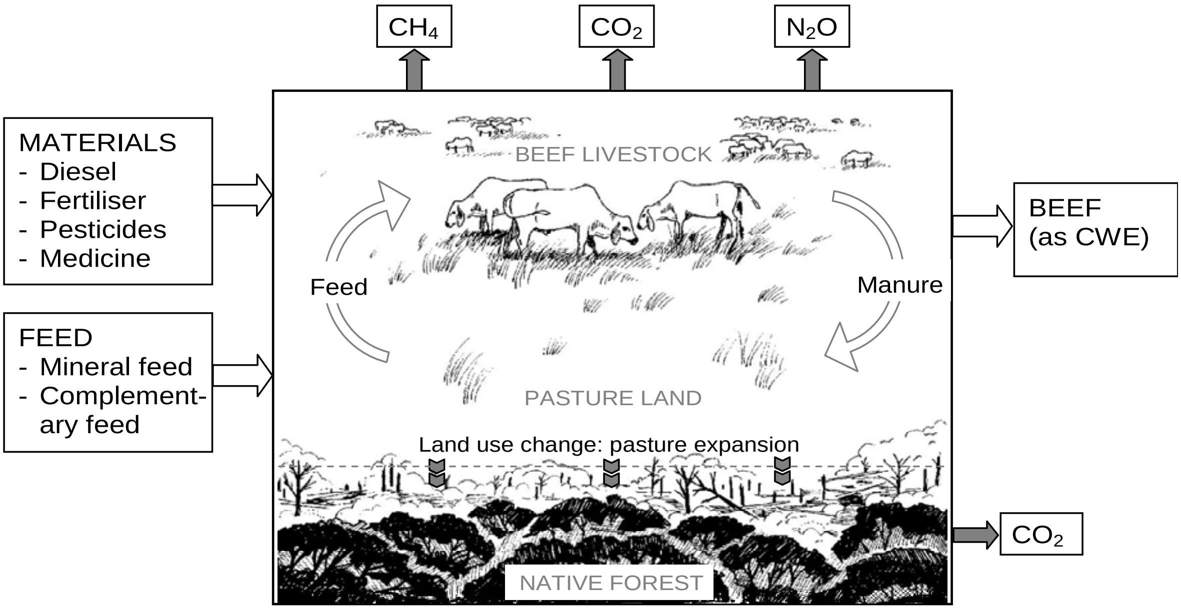

Figure 2.1 The production system studied for the analysis of the first phase of Brazilian beef production ending up as CWE at the farm-gate

When the beef cattle are ready for slaughter, they are transported to a slaughter house and then follow the part of the life cycle that deals with the slaughter, processing and transport of the beef product to its final consumption in Europe (Stockholm).

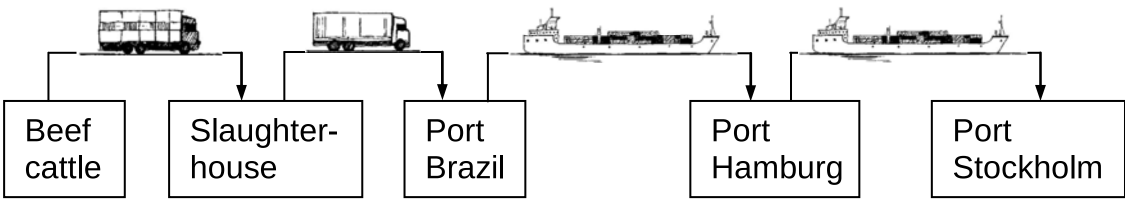

Figure 2.2 The production system studied for the second phase of Brazilian beef ending up as one kg of bone-free meat exported to Europe

In the analysis of transports, use of energy as well as production of infrastructure (production of capital goods) is included.

2.3.1 Delimitations

Production of farm buildings and machinery was excluded in the study, but this should be insignificant to the results as the beef production studied is based on all-year grazing and thereby has a very small use of capital goods in production.

The production, use and emissions from medicines and pesticides were excluded. It is known from other studies of animal production that energy use and GHG emissions from the production of these input goods in livestock production are almost non-significant. However, the environmental impact of medicine and pesticide residues emitted to the natural ecosystems might be of substantial significance, but this environmental interference was not considered in this study.

Production of seed for renewing pastures was not included because it was assumed that there are only small amounts used in the overall production.

2.4 Allocation

The beef production system studied generates more products than only meat, most important are hides and intestines. None of the calculated environmental impacts were allocated to these by-products, i. e. the beef carries the whole potential environmental burden from the production.

Beef and milk production are closely interlinked as milk production gives rise to by-products that end up in the beef production. Surplus calves not needed for replacement on the dairy farms (mostly bull calves) are raised as beef cattle. After the dairy cows´ lives as milk producers are ended, they are in most cases slaughtered and meat is produced, or they go can into a beef system to produce calves.

In this study, we have tried to avoid allocation between milk and beef production and instead divided resource use and emissions as close to the mode of production as possible. In the 1990s, it was estimated that milk production used 20 million hectares (Mha) pasture in Brazil (Wada & Ortega, 1996) which corresponds to slightly more than 10 % of the total pasture area. For example, this area was not included when estimating resource use and emissions from beef.

When calculating emissions of methane and nitrous oxide, emission factors per cattle head were used. In these calculations, the dairy cow population was not included, which is easily done since the statistics report dairy cows and beef cows separately. However, replacement heifers headed for the dairy sector are included in the overall category of young female animals in the statistics, and it was not possible to exclude the dairy sector´s young animals. All young cattle (beef and dairy) were therefore included when calculating the emissions of methane and nitrous oxide for the beef sector. On the other hand, the dairy cows end up as meat when slaughtered, and this meat is included in the overall beef production statistics. So the allocation between beef and milk production was avoided by distributing all environmental impact from the dairy cows to milk production and none of the impact from the dairy cows to the meat production. In contrast, the environmental impact from the rearing of the replacement heifers headed for milk production was only distributed to the meat production and nothing to the milk production.

2.5 Environmental impacts considered

The main focus in this study is GHG emissions from Brazilian beef, and the environmental impact category *climate change* is therefore prioritised. Land management and land transformation are major sources of GHG emissions in South America (Steinfeld et al., 2006; McAlpine et al., 2009), and land use in Brazilian beef production was more deeply analysed. The environmental impact category *use of the resource land* was estimated *quantitatively* and quality aspects were not possible to include. In this aspect, impact on biodiversity caused by land transformation is of major importance, and hopefully this environmental intervention can be considered in future studies of beef production in Brazil. Use of *energy resources* were also considered in the study. The environmental impact categories eutrophication and acidification were not considered, since up to this point in time they have not been recognized as major environmental impacts caused by livestock production in Brazil.

2.6 Data gaps

This study shows that Brazilian beef production is now undergoing substantial changes that improve animal productivity. Feed-lot systems have been introduced where the cattle are fed with mechanically harvested fodder, complementary feed is given in dry periods to avoid weight loss and systems that integrate crops and livestock have been introduced. It has not been possible to collect trustworthy data on the amounts of feed and fodder used in these improved systems or on how the fodder is cultivated (fertilisation, yields, use of diesel etc). Therefore, the production and use of this complementary feed (in addition to pasture) are not included in the study. Still today, a minor fraction of the beef is produced in these more intense systems (see section 5.3), but these production systems will most probably increase in the future. For upcoming studies, it is essential that resource use and emissions from complementary feed production are also included.

3 Livestock production

Beef and milk production in Brazil are based on continuous grazing all year around. Apart from a very small share of the cattle being held in feed-lot systems and fed mostly with silage, grass from cultivated and native pastures is the predominant feed source.

Over the last 35 years, the Brazilian cattle herd has more than doubled (IBGE 2007) see Figure 3.1. Following India, Brazil is the second nation in the world when it comes to the size of cattle population. Faminov (1997) explains the rapid herd growth up until 1995 by pointing out two principal causes: *i)* high inflation over much of this time period in combination with imperfect financial markets that stimulated the use of cattle as an inflation hedge and *ii)* expansion of the agricultural frontier in the Central-Western and Northern regions, where extensive cattle production is the primary land use.

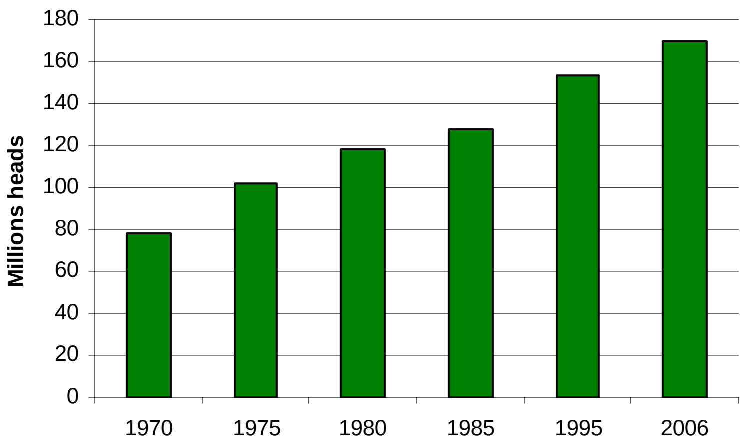

Figure 3.1 Growth of the Brazilian cattle herd 1970 – 2006 (million head)

Over the last decade, the rapid expansion of cattle herds in the northern and north-eastern regions has modified the dynamics of beef production, i.e. in the direction towards the Legal Amazon. The Legal Amazon is an administrative unit (5.5 million km^2) which include the nine Brazilian states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins, Maranhão and Mato Grosso (Barreto et al., 2006). According to Margulis (2004) cattle ranching enterprises now occupy ~75 % of the converted lands in the Amazonia region. Fearnside (2008) concludes that cattle ranchers are key actors in Amazonian deforestation and responsible for most of the clearing.

Figure 3.2 shows a map of Brazil and its states. Brazil is divided into five regions and agricultural statistics are often aggregated for these regions. In Table 3.1, the five regions and the states belonging to each region are listed, as well as the number of cattle per region in 1995 and in 2006. The numbers are based on preliminary results from the Brazilian Agro Census for 2006 (IBGE 2007). Since 1995, there has been a very strong increase of cattle in the northern region (the Amazonia forest region) while in the south-eastern and southern regions, cattle population has decreased. The increase of livestock in the northern region over the past decade is a combined effect of an overall total increase in cattle (approximately + 10 %) and a shift in location. Also see maps in Appendix 1.

Figure 3.2 Regions and states in Brazil. Green=northern region, orange=north-eastern, yellow=central-western, blue=south-eastern and red=south

Table 3.1 Geographical distribution of Brazilian cattle population 1995 and 2006

Region	States	10^6 head		% change 1995 – 2006
		1995	2006	
Northern	Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins	17.3	31.3	+ 80
Northeastern	Alagoas, Bahia, Ceará, Maranhão, Paraíba, Piauí, Pernambuco (including the State District of Fernando de Noronha Island), Sergipe and Rio Grande do Norte	22.8	26	+14
Central-western	Mato Grosso, Mato Grosso do Sul, Goiás and Distrito Federal	50.8	53.8	+ 6
Southeastern	São Paulo, Minas Gerais, Rio de Janeiro and Espírito Santo	36	35	- 3
South	Paraná, Santa Catarina and Rio Grande do Sul	26.2	23.9	- 9
Total		153.1	169.1	+ 10

Source: IBGE (2007)

Macedo (2006) also discusses the geographic redistribution of the cattle population and has analysed the changes between 1980 and 2004 (Table 3.2). The most significant change in absolute numbers during this time period took place in the northern and central-western regions, where in 2004 more than half of the cattle population was situated, compared with less than a third of the population in 1980. The southern and south-eastern regions are now of less importance, and during the period, pastureland has been transformed into arable land in these southern regions. According to Macedo (2006) the same development is now taking place in the states of Mato Grosso, Mato Grosso do Sul and Goiás where the expansion of soybeans and cotton has transformed pasture into arable land.

Table 3.2 Geographical distribution of Brazilian cattle population in 1980 and 2004

Region	1980		2004	
	10^6 heads	% of total	10^6 heads	% of total
Northern	4	3.4	28.2	16.6
Northeastern	21.5	18.2	25.1	14.8
Central-western	33.3	28.2	58.8	34.5
Southeastern	34.8	29.5	33.3	19.6
Southern	24.5	20.7	24.8	14.6
Total	118	100	170*	100

* Macedo (2006) has used and combined statistics from AgraFNP and IBGE before the preliminary results of the 2006 Agricultural Census was published and therefore the total number differs somewhat between Tables 3.1 and 3.2

The rate of growth in the total number of cattle has decreased during the last decade. In 2006, the total number was estimated at close to 170 million head, corresponding to a 10 % increase during the ten year period from 1997 – 2006. The increase in cattle herd has only occurred in the nine states of the Legal Amazon, while cattle population in the rest of Brazil has stabilised (see Figure 3.3).

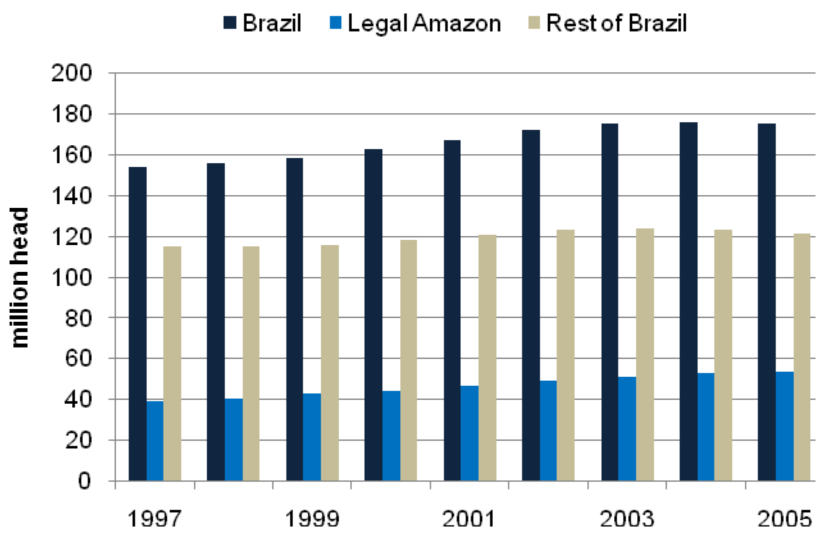

Figure 3.3 Development of cattle herd 1997 – 2006 in the whole of Brazil, the nine states of Legal Amazon and in rest of Brazil (ANUALPEC/FNP 2008; 2006)

3.1 Categories in the cattle population

There are two major sources for statistics on Brazilian agriculture: IBGE (Brazilian Institute of Geography and Statistics) and AgraFNP, which is a private agribusiness institute. The IBGE previously estimated the total number of cattle at 207 million head in 2005, this was based on data from Municipal Livestock Production[2], which is a yearly data source from IBGE based on information

[2] www.sidra.ibge.gov.br

from the main producing municipalities and regions. AgraFNP, on the other hand, presented considerably lower numbers, 175.1 and 169.9 million head in 2005 and 2006 respectively (ANUALPEC/FNP 2008). In 2006, the IGBE carried out a census of Brazilian agriculture (which is done approximately every tenth year) and this is a more exact method for estimating the cattle population. The preliminary results from this census now gave an estimation of a cattle population close to 170 million heads in 2006 (IBGE 2007), i.e. very similar to the statistics given by the AgraFNP. In the census of 1995/96, the AgraFNP and IBGE also had similar data for cattle population and statistics from FNP are often used by Brazilian experts and researchers. Since the AgraFNP provides detailed data on the number of livestock in different categories which is needed for estimations of emissions and resource use, we used the AgraFNP data in this study

The cattle population in Brazil is dominated by animals producing beef. The number of dairy cows is estimated at approximately 16 million head which is less than 10 % of the total population and approximately 25 % of the total cow population (ANUALPEC/FNP 2008). In Table 3.3, the total number of cattle in 2005 according to the FNP-statistics (175 million head) is presented in different livestock and age categories. The total number of 61.6 million cows in 2005 is divided into 16.6 million dairy cows and 45 million beef cows.

Table 3.3 Distribution of the Brazilian cattle population in different livestock categories in 2005 (ANUALPEC/FNP 2008)

Category	Age	10^6 head
Cows*		61.6
Bulls		2.3
Calves (heifer)	0-12 months	24
Calves (bulls)	0-12 months	23.8
Heifers, younger	1-2 yrs	20.5
Heifers, older	2-3 yrs	13.1
Bulls and steers, younger	1-2 yrs	17
Bulls and steers, older	2-3 yrs	9.2
Steers, older animal	3-4 yrs	2.9
Steers, older animal	> 4 yrs	0.6
Total		175

* dairy cows included which are estimated at 16.5 million head leaving approximately 45 million beef cows

3.2 Beef production

Beef production in Brazil takes place mainly under tropical conditions and most cattle are purebred zebu or mixed zebu-European or zebu-criollo-European blood (Faminov 1997, Landers 2007). According to Faminov (1997), animal output in tropical regions depends on three critical factors:

- grass growth is heavily influenced by water availability, and in periods with high temperatures, forage grass can be stressed; this can even happen in shorter periods without adequate rainfall;
- warm and humid conditions reduce the cattle´s appetite so forage intake, and thereby growth, are lowered at high temperatures;
- the genetic potential is lower for producing beef and milk under tropical conditions because the animals are smaller (adaptation to heat) compared with temperate conditions.

Animal health management is also affected by tropical conditions, e.g. insect attacks are a problem all year around. In free-range grazing systems it is more difficult to have regular monitoring of animal health and feed intake; Tokarnia et al. (2002) report that plant poisoning, rabies and botulism are main causes of death in adult cattle in Brazil.

It has been very difficult to find information on the major production systems of beef in Brazil. In Table 3.4, we have put together information and data from various sources (de Moura Zanine et al., 2006; Martins Cezar et al., 2005; ASSOCON 2008). As shown in Table 3.4, it is estimated that the predominant production still is carried out in extensive systems with low animal density per hectare of land. Further on in the report, pasture types and productivity will be more discussed.

Table 3.4 Survey of beef production in systems in Brazil

	Extensive				Semi-intensive (rotation)			Intensive
% of farms	80				15			5
% of production	No data				No data			5
Location*	All regions				C-W, S-E (80 %), small areas in S, N and N-E			C-W, S-E (90 %)
Pasture type	Native		Planted		Native	Planted	Suppl Feed	Mostly feed-lots
	Various ecosystems, mainly C-W, S, N, N-E		Mainly Brachiaria and Pancium grass, planted in all regions		Various eco-systems Mainly C-W, E, S, N, N-E	See: planted in exten-sive systems	Creep feeding, protein salt and various concentrate	Planted pastures, silage 60 % and concen-trates 40 %
Produc-tivity (head ha^{-1})	Climate zone				Climate zone		Climate zone	Climate zone
	Tro-pical	Sub-tropic al	Tropical	Sub-tropic al	Tropical and Sub-tropical		Tropical and Sub-tropical	Tropical Sub-tropical
	0.1-0.3	0.5-1	0.5-2.5	0.5-2.5	2.5-3		2.5-3	4 - 10
Production phases	Cow-calf		Cow-calf, rearing and finishing		Cow-calf, rearing and finishing		Cow-calf, rearing and finishing	Cow-calf, rearing and finishing (each isolated)
Grazing periods	Whole year				Whole year		Whole year	Whole year, but mainly during dry season

*N north, N-E north-east, C-W central-west, S-E south-east, S south

According to Landers (2007), the livestock sector in the tropical zones of Brazil is now at an end of a phase where the solution for growth has been expansion onto newly cleared land. Landers cites Macedo (1999), who presents some indicator values for the performance of the cattle herd in Brazil today, and potentials in improved systems (see Table 3.5). Grass production and quality are key factors not only for growth but also for reproduction rates. Late weaning, often an effect of poor pasture and nutrition, leads to longer inter-calving intervals, thereby reducing the overall calf production of breeding cows in the herd (Faminov 1997). ANUALPEC/FNP (1999) provides data on an average calving interval of 20 months, and Oliveira et al. (2006) estimate it to be 21 months, i.e. well in agreement with indicator values in Table 3.5. Another important indicator for herd productivity is the age of the first breeding which in extensive cattle production systems in Brazil tends to be high. According to Zylberstein & Filho (2000), the age for the first calving of the heifer (young cow) is four years in traditional areas and around three years in areas with improved technology. Finally, low mortality of calves is important for the overall herd performance and today an average of eight percent of calves die before weaning (Table 3.5). High mortality of calves and cows can be a significant problem when pasture conditions are poor. According to Faminov (1997) there are regions in Brazil where toxic plants have invaded poorly managed pasture resulting in an increase of death losses of mature cows by up to 10 % in some herds. Tokarnia et al. (2002) estimate that up to one million cattle die annually in Brazil due to plant poisoning and that this cause of cattle death is more common in northern region than in the south and south-east regions.

Table 3.5 Indicator values for cattle herd performance

	National average	Improved system	High technology system
Calving rate, %	60	>70	>80
Calving interval, months	21	18	14
Weaning rate, %	54	65	75
Mortality to weaning, %	8	6	4
Age at slaughter (years)	4	3	2,5
Herd off-take (%)	17	20	22
Carcass weight, kg	200	220	230

Source: Macedo (1999) cited by Landers (2007)

In purely grass-based beef production systems, long growth periods are often necessary for the animals to be ready for slaughter. Zylberstein & Filho (2000) give information that the average slaughter age has been reduced from 42 – 48 months to 32 – 40 months. It has not been possible to get verified data on what the average slaughter age is today but different experts and researchers interviewed estimate it at 36 – 42 months. This is an important improvement achieved in the beef sector during the last decade and an effect of different production improving measures, such as rotational grazing, feed supplements in the dry periods, better mineral additives and improved genetics in the breeding program. Lowered slaughter age is a very important parameter for improving productivity and leads to a higher turnover of the cattle herd (herd off-take increases).

3.3 Milk production

Milk production is mainly localised in the south and the south-east of Brazil. According to the IBGE (2007), total milk production in 2006 was 21.43 million tonnes (MT), two thirds of which were produced in the southern part of the country (Table 3.6). FNPs data for milk production is ~21 MT in 2005 (ANUALPEC/FNP 2006). FAO (2005) reports the annual Brazilian milk production at 22.45 MT in 2002.

Table 3.6 Milk production 2006 in Brazilian regions (IBGE 2007)

Region	10^6 ton	Share of milk production
North	1.2	0.06
Northeastern	2.9	0.13
Central-west	3.0	0.14
Southeastern	8.1	0.38
Southern	6.2	0.29
Total	21.4	1

With a dairy cow population of approximately 16 million head (ANUALPEC/FNP 2008), the average milk production is around 1 350 kg milk per cow in 2005. FAO (2005) reports of a milk yield of 1 174 kg per cow in 2002, so the yields per cow are of the same magnitude.

There are around 1.3 million farms with dairy cows in Brazil (IBGE 2007) and there is a large variety of production forms. De Assis *et al* (2005) have identified four milk production systems in Brazil, see Table 3.7. The predominant volume of milk is produced in extensive or semi-extensive systems, but in the southern and southeastern regions more intensive milk production now is developing. According to de Assis *et al* (2005), surplus calves in extensive and semi-extensive systems are mostly sold for further rearing as beef cattle, while it is more common that the surplus bull calves from the more intensive systems in the south are slaughtered as calves.

Table 3.7 Characteristics of milk production systems in Brazil

	Extensive	Semi-extensive	Intensive pasturing	Intensive in confinement
% of dairy farms	89.5	8.9	1.6	<0.1
Location, regions*	N, N-E, C-W	S-E, C-W, N-E (S)	S-E, S	S-E, S
Productivity, litre cow^{-1} yr^{-1}	<1 200	1 200 – 2 000	2 000 – 4 500	>4 500
% of production	32.8	37.7	25	4.6
Pasturing	All year	All year	All year	Not, conserved forage
Weaning age	6-8 months	8 – 10 months	2-3 months	2 – 3 months

* N north, N-E north-east, C-W central-west, S-E south-east, S south

3.4 Recent changes in beef production

During the past decade there has been a strong increase in beef production in Brazil. Statistics according to AgraFNP show that production increased from 6.44 to 8.6 MT CWE between 1997 and 2006 (33 %), see Figure 3.4 (ANUALPEC/FNP 2008; 2006). During this ten-year period, production in the nine states of Legal Amazon increased from 1.1 to 2.16 MT CWE, i.e. almost a doubled production. Production data are also summarised in Appendix 2.

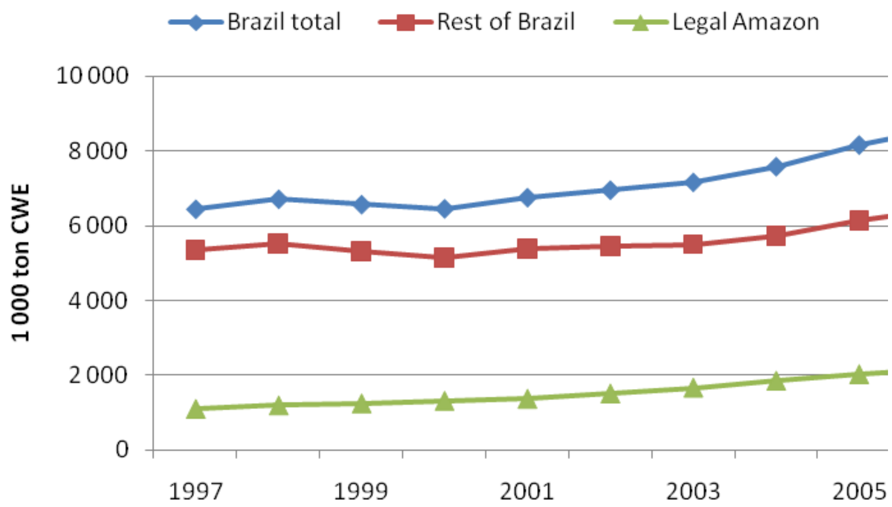

Figure 3.4 Changes in beef production 1997 – 2006 in the whole of Brazil, the nine states of the Legal Amazon and the rest of Brazil, data from ANUALPEC/FNP (2008; 2006)

In the rest of Brazil (not including the nine states of the Legal Amazon) beef production increased by from 5.4 to 6.4 MT CWE, an increase of 20 % between 1997 and 2006. During the past decade, Legal Amazon has taken an increasingly larger share of Brazil´s total beef production and in 2006, approximately 25 % of the Brazilian production came from the nine states of the Amazonia region.

In Table 3.8, changes in beef production over the past decade are analysed using the ten-year period 1997-2006. From the calculations we conclude that approximately to half of the production increase during the last decade has occurred in the nine states of the Legal Amazon and half in the rest of Brazil.

Table 3.8 Increase of beef production (MT CWE) in different parts of Brazil 1997 – 2006

	Brazil total	Legal Amazon	Brazil except the nine states of Legal Amazon
1997	6.444	1.095	5.349
2006	8.6	2.155	6.445
Increase, 1997-2006	+2.156	+1.060	+1.096
Share of increase, 1997-2006		0.49	0.51

Source: ANUALPEC/FNP 2008; 2006

3.4.1 Causes for increased production

An increase of beef production is an effect of higher volumes (more animals) and/or improved productivity. Productivity can be improved in different manners: higher CWE per slaughtered cattle, lower slaughter age (i.e. higher production CWE/lifetime), improved reproduction parameters (e.g. shorter calving intervals, earlier first breeding).

The growth rate in total number of cattle in Brazil has decreased during the last decade (see Figure 3.1). In 2006 the total number was close to 170 million head according to the IBGE (2007), which corresponds to an increase of ~ 10 % during the last decade. The increase in cattle population has only taken place in Legal Amazon, while cattle population has decreased in the rest of Brazil (compare Figure 3.3). With the help of FNP statistics, we calculated some indicator-values to better understand the causes for the production increase during the last decade.

The average slaughter weight per cattle was calculated by dividing the total beef production by the number of slaughtered cattle (ANUALPEC/FNP 2008; 2006), see Figure 3.5 and also Appendix 2. No significant differences in the indicator-value "*kg CWE per slaughtered cattle*" were found during this time period, but there is a trend towards lower average slaughter weights for the total Brazilian production in the end of the period. There is a tendency towards higher carcass weights in the Legal Amazon but this must be interpreted with caution, due to uncertainties in the statistics or with natural explanations, for example that fewer cattle are slaughtered as calves in the northern region. In 2003-2006 there was a trend towards decreasing carcass weights in overall Brazilian production except Legal Amazon, which might have been an effect of the booming export market with high demands leading to slaughter at lower weights.

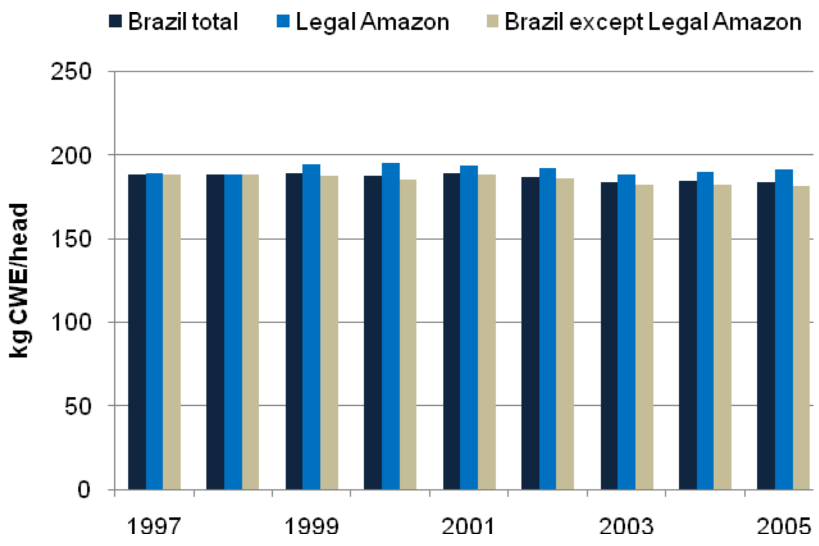

Figure 3.5 Average slaughter weight, kg CWE per slaughtered cattle, 1997 – 2006, in the whole of Brazil, in the nine states of Legal Amazon, and rest of Brazil

The share of slaughtered cattle related to the total population (herd take-off) is lower in the Legal Amazon, but there was a clear increasing trend during 1997 – 2006 (0.15 – 0.20), see Figure 3.6 and Appendix 2). For Brazil except Legal Amazon, this indicator is around 0.25 in 2005. There are several possible explanations to why a smaller share of the total cattle population is slaughtered in Legal Amazon than is the case in the rest of Brazil. Beef production in the Legal Amazon can have a higher slaughter age, lower calf-production per cow during a given time-period and a higher mortality rate. Moreover, the ongoing increase of the cattle population can lead to more young females being used for replacement instead of being available for producing beef. Also, fewer industrial slaughterhouses in the northern region plus an inferior infrastructure can be a reason for having fewer animals in the official statistics. In an article published in 1997, Faminov discusses the high frequency of clandestine slaughter in Brazil in the 1990s and it is possible that this unofficial slaughtering today is more common in the Legal Amazon than in the southern and south-eastern regions.

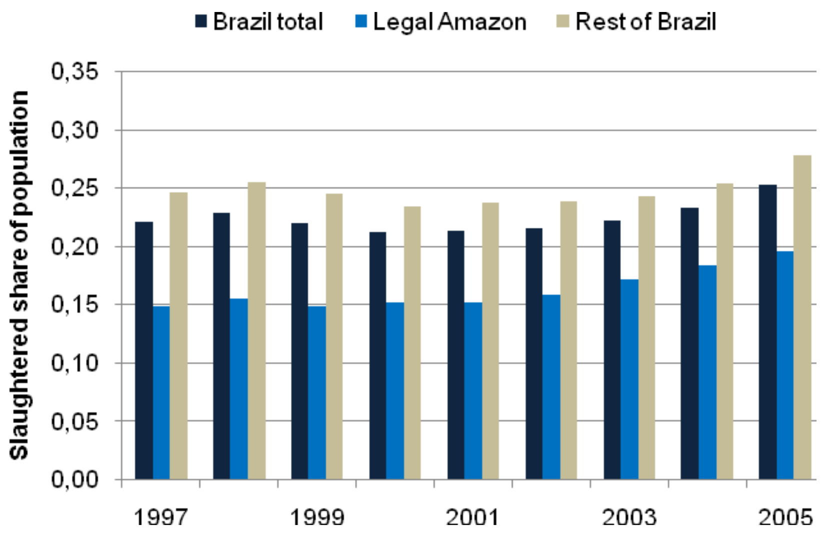

Figure 3.6 Share of total cattle population that was slaughtered 1997 – 2006 in the whole of Brazil, the nine states of Legal Amazon and the rest of Brazil

This analysis implies that approximately half of the production increase in Brazil during the time period 1997-2006 has taken place outside the Legal Amazon where it has been done without increasing the number of cattle (Table 3.8; Figure 3.3). Increased animal productivity, with lowered slaughter age, is the most plausible explanation for this positive development. Approximately half of the production increase (see Table 3.8), has occurred in the nine states in the Legal Amazon and here the increase seems to be an effect of improved animal productivity as well as an increase of the total cattle population. The total number of cattle increased from 39 million head in 1997 to 53.5 million head in 2006 in the Brazilian Amazon (ANUALPEC/FNP 2008; 2006).

3.4.2 Causes for cattle growth in the Legal Amazon

Arima et al. (2006) have analysed the cattle growth in the Amazonian region and conclude that it is mainly motivated by higher rates of return on investment, compared to other producer regions of Brazil. This is caused by lower land prices, favourable agro-climate, subsidised credits in the Amazon region and extra income from timber sales which provide a basis for capital investment. Control of foot-and-mouth disease (FMD), reduction of pasture area in the central and southern parts of Brazil and infrastructure investments have also been important for the Amazonia cattle growth.

Real land price for pasture was 1 200 – 1 300 R$[3] per hectare in 2002 in major cattle regions of Amazonia compared with 3 300 R$ per hectare in ranching regions in São Paulo (Arima et al., 2006). Different pasture prices in different regions reflect the alternative agriculture use of land. São Paulo is the leading state for bio-ethanol production and because of the large interest in producing ethanol, the value of land has increased considerably over the last years. Martines-Filho (2006) report that price of land more than doubled between 2002 and 2005 in the western part of São Paulo ($US 1 350 to 3 070 per hectare). The closeness to consumer market in the southern region is another factor that contributes to a higher pasture price in this region, even when there is no alternative use than the ranching of the land. The cattle prices were 10 – 20 % higher in São Paulo compared with the main producing regions in the Amazonia 1998-2002, and the higher income is transformed into the price of land (Arima et al., 2006).

The most productive beef production region in the Amazon tends to be located in the zones where the yearly precipitation is between 1 600 – 2 200 mm, which is higher than in the Cerrado region (Arima *et al* 2006). For example, southern Pará has a dry winter season of 2-3 months compared to 4-6 months in the Cerrado (Landers 2007). Provided that the pasture is of good quality (not degraded), forage grass growth is vigorous under these climate conditions, making it possible to maintain a high stocking rate and to lower the slaughter age.

There are public funds for rural development in the Amazon region and a substantial part of these funds goes to cattle ranchers. FNO (Fundo Constitucional de Financiamento do Norte) is the main fund in the northern region and it gives loans at much lower interest rates than the market rates. Borrowers that pay on schedule are given a discount on the rate. Between 1989 and 2002, the Banco da Amazonia (Amazon bank) lent $US 5.8 billion under the Rural FNO in the Amazon (excluding Mato Grosso and Maranhão); around 40 % if this was directly aimed at cattle ranching (Arima et al., 2006). These funds are financed from 0.6 % of the income tax and industrialised product tax collected throughout Brazil.

Revenues from timber sales in the Amazon are invested in cattle ranching but there is a lack of information on the quantity of the investments. Arima et al. (2006) refer to a survey in 2004, stating that 20 % of the loggers interviewed invested in cattle and beef production. Also, timber harvesting establishes infrastructure that facilitates the development of cattle ranching.

[3] R$=Brazilian Real. During 2002, the price of $US 1 in Brazil varied from 2.2 – 3.9 ending the year on R$ 3.5

4 Trade and export of beef

The USA, Brazil, the EU-25, China and the Argentine are the five largest beef-producing nations (see Figure 4.1). In the first year of the 21st century, Brazil and China had the fastest expansion, each of these showing increases in production of almost 40 % between 2000 and 2006 (USDA 2008a).

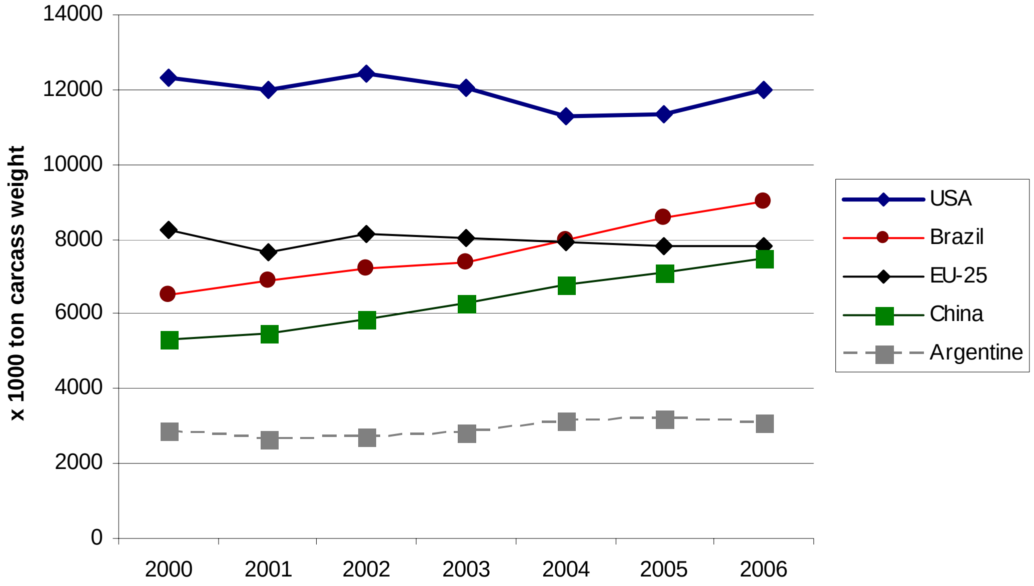

Figure 4.1 Beef production in the five major beef- producing nations (regions) 2000 – 2006, data from USDA (2008a)

A decade ago, Australia, the USA and the EU were the major beef exporters, but a significant shift has taken place on the global beef market and in 2004, Brazil became the largest exporter of beef (Figure 4.2). In 2003, BSE (Bovine spongiform encephalopathy) was discovered in the USA and Canada and these nations, then supplying one-quarter of the world beef trade, faced bans on export of certain beef qualities in 2004 - 2005. In 2004, global poultry trade was also adversely affected when it experienced outbreaks of avian influenza (AI). These outbreaks of diseases led to increasing global meat prices between 2004 and 2005, and the global meat price index rose by 15 – 20 % (Morgan & Prakash, 2006).

The USA lost its dominant role in the export market after the outbreak of BSE in 2003, and Brazil has taken over the role of the world´s number one beef exporter. Brazil´s growing importance for the global beef market in recent years is exceptional, and its total export increased 7.5-fold during the last decade. In this period, the EU lost 75 % of its export and is now barely self-sufficient on beef; in 2006 the EU`s production was 8 MT CWE and its consumption was 8.5 MT. Australia has had an on-going and steady growth, increasing their export by 40 % during the last decade (USDA 2008a), see Figure 4.2.

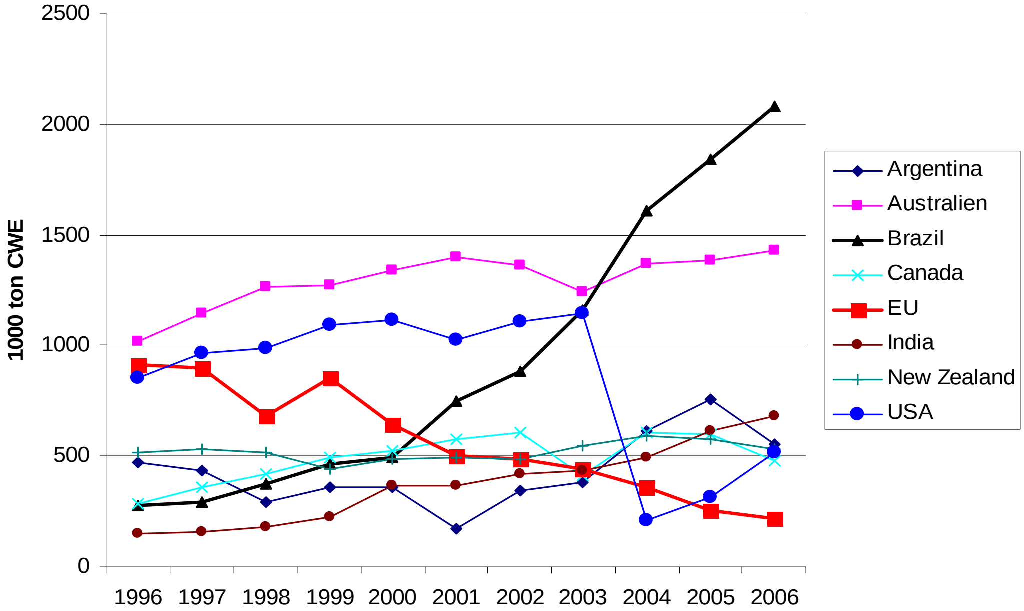

Figure 4.2 Beef export (1000 tonnes CWE) 1996 – 2006 from the major exporting nations (USDA 2008a)

In economic value, the growth of Brazilian beef exports has been extraordinary. The export value in 1997 was approximately $US 440 million which increased to $US 3.24 billion in 2006 (Figure 4.3). In later years, exports from the nine states of the Legal Amazon are of growing importance to the total exports of Brazil. In 2006, 22 % of total beef export value came from the Legal Amazon and this share increased to 24 % in 2007 (SECEX/MDIC)[4].

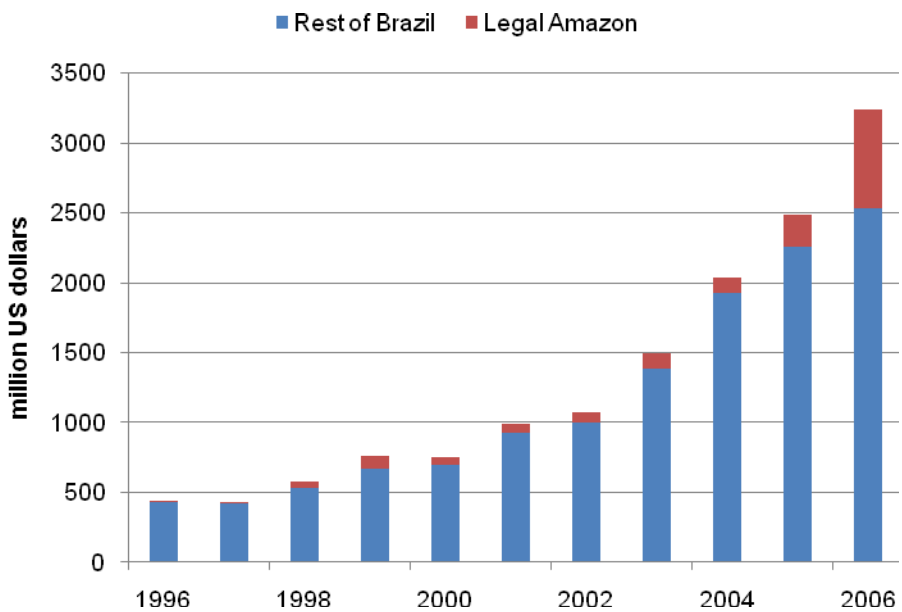

Figure 4.3 Value of exports of Brazilian beef 1996 - 2006

[4] External Trade Secretary (SECEX) of the Ministry of Development, Industry and Trade (MDIC): www2.desenvolvimento.gov.br/sitio/secex/depPlaDesComExterior/indEstatisticas/balComercial.php.

During the past ten year period, the domestic consumption of beef in Brazil has been relative stable, despite its growing population (see Appendix 2). In 1997, almost the total beef production (97 %) was consumed within Brazil, while in 2006, ~75 % of production was consumed internally (ANUALPEC/FNP 2008; 2006). Obviously, the overall production increase over the past decade (approximately 2.16 MT CWE, see Appendix 2a) is driven by increased demands on the export market, not by domestic demands, see Figure 4.4.

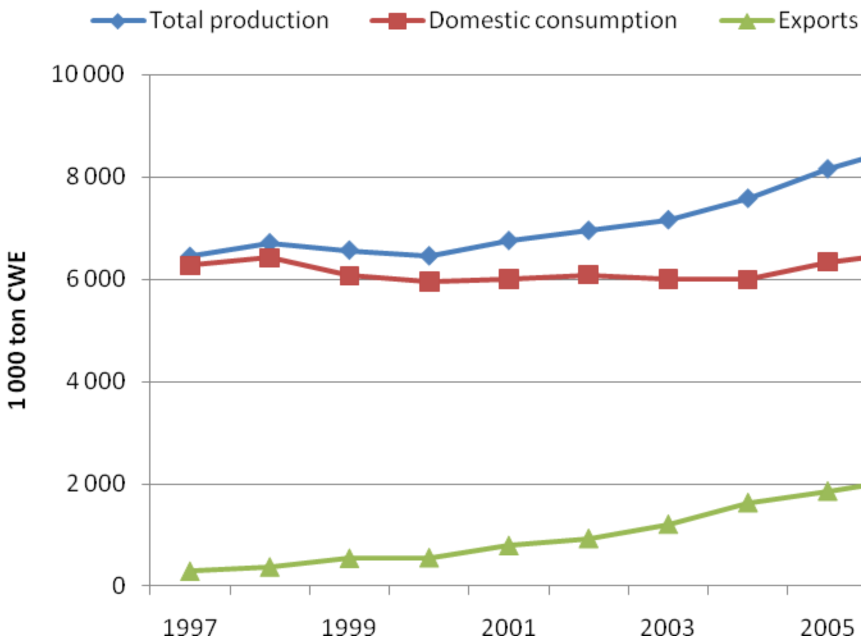

Figure 4.4 Development of production, domestic consumption and exports of beef in Brazil (1 000 tonnes CWE), 1997 – 2006

The most important beef-exporting states of Brazil are situated in the southern and central-western parts of the country. These states have an advantage on the export market compared with states in the Amazon region due to better infra-structure, more modern slaughterhouses and a longer period of FMD-free status (see next section). This has better enabled them to build up beef exports to the EU and other important markets. However, the fast growing production in the nine states of the Legal Amazon, now representing approximately 25 % of Brazil´s total production, is to a very large extent exported from the Amazon region to other parts of Brazil. Arima et al. (2006) give an account of a survey from 2001, the purpose of which was to increase the knowledge of meat trading in the Amazon. The survey was based on interviews with 21 slaughterhouse managers in the Legal Amazon (representing a third of the slaughterhouses at the time in the region), and 28 cattle buyers in 27 municipalities. On average, 87 % of the meat produced by the surveyed slaughterhouses was destined for states outside of the Amazon, while 13 % was sold on the regional market. The most important market for the surveyed slaughterhouses was the southeast of Brazil. Most of the meat produced in Pará was sold to the north-eastern and south-eastern regions, while those in Mato Grosso were mostly sold to the southern and south-eastern. Since the time of this survey (2001), Mato Gross has also received FMD-free status and has been qualified for meat export. Already in 2006, Mato Grosso had become the third largest exporting state in Brazil.

4.1 Export restrictions caused by FMD

World beef markets have long been divided into disease-restricted and disease-free countries (USDA 2005). The most important disease affecting beef trade is foot-and-mouth disease (FMD[5]) and because of its virulence and speed, an outbreak can lead to substantial economic costs and animal suffering. Countries that have eradicated FMD put strict sanitary barriers on imports of animal products.

FMD has been a problem for beef production in South America for a long time. In Brazil, control efforts have been concentrated to the livestock regions in the southern, south-eastern and central-western parts of the country. A combination of contact slaughter, movement controls and vaccination has been the traditional strategy to deal with outbreaks. According to Rich (2005), Brazil has been very successful in combating FMD on a regional basis and FMD-free status in Brazil is given to regions, not to the entire country. Until the early years of 2000, FMD control was more effective in the states of southern, southeastern and central-western regions. These regions were recognized by the World Organization of Animal Health (OIE) as FMD-free, and could therefore export meat to the EU and other countries requiring this accreditation. Mato Grosso became a FMD-free zone in stages between 2000 and 2001 and the states of Rondônia, Tocantins and Acre obtained this status with vaccination in 2001, 2003 and 2005 and thus were allowed to export.

In October 2005, several outbreaks in Mato Grosso do Sul were discovered, this state then holding the largest cattle herd and being responsible for 20 % of Brazil´s beef export (Arima et al., 2006). As a consequence of the FMD outbreaks in late 2005, imports of fresh meat into the EU from the states of Paraná, São Paulo and Mato Grosso do Sul were suspended for animals slaughtered from October 1st 2005. Imports of de-boned meat, produced and certified according to EU requirements, were permitted from the remaining areas of Brazil approved for EU export (EC 2007). The EU has adopted a regionalization approach for permitting import of fresh meat from Brazil as opposed to the USA, which has imposed a total ban on all fresh beef imports from Brazil.

The consequences of the 2005 FMD outbreak for Brazil´s overall beef export were, however, small, and despite export restrictions to the EU and Russia, beef export continued to grow in 2006 (see Figure 4.2). Production from other states compensated for the export loss from the banned regions and this take-over of export markets can be one explanation for the rapid increase in the share of beef from states in Legal Amazon in relation to the total of Brazil´s exports between 2005 and 2006, see Figure 4.3.

In 2006, almost 95 % of Brazil´s total export value of beef was generated from six states (São Paulo, Goiás, Mato Grosso, Minas Gerais, Rio Grande do Sul and Rondônia), see Figure 4.5 (SECEX/MDIC)[6].

[5] FMD is an easily transmitted virus affecting clover-hoofed animals (cattle, sheep, buffalo, goats, pigs and deer). FMD results in significant production losses in terms of weight gain and milk production. Young pigs have a high mortality rate when affected by FMD.

[6] Information about the beef export from separate states in Legal Amazon were taken from a data-base/information system called AliceWeb (in SECEX/MDIC see note 5). Available at: http://aliceweb.desenvolvimento.gov.br/

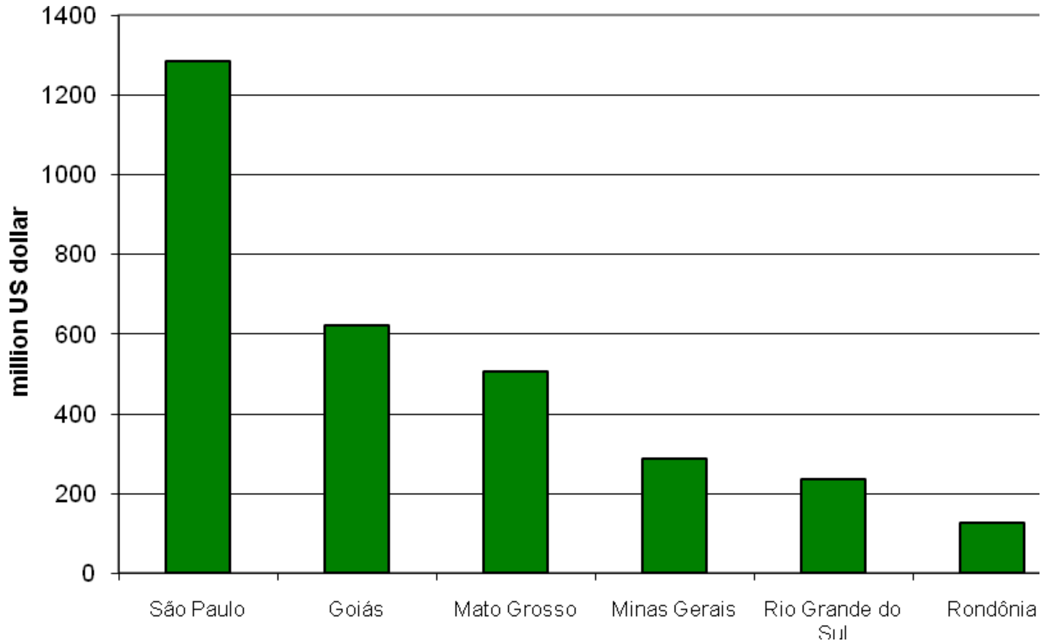

Figure 4.5 Beef export value in 2006 (million $US) of the six most important exporter states in Brazil

4.2 Destinations for exports

Russia is the single most important receiver of Brazilian beef exports, generating slightly more than 20 % of the export value in 2005 – 2007, see Appendix 3. Egypt is another important importer but has not shown as strong a growth rate as Russia during the last years. The United Kingdom, the Netherlands, Italy and Germany are the major European markets but also smaller countries such as Sweden and Switzerland are found among the top 20 countries buying Brazilian beef. When the European countries are presented as EU-25, this constellation becomes a larger importer than Russia during 2005 – 2007, see further Appendix 3. The top 20 countries for the Brazilian beef export generated approximately 85 % of the total export revenue (ABIEC 2008)[7].

In 2008 export restrictions in the EU market changed the scene. Since 2003 audit reports from the EC FVO (Food and Veterinary Office) have reported deficiencies in the Brazilian cattle identification and certification system SISBOV, as well as in the Brazilian government oversight and testing. SISBOV comprises measures and procedures to characterise the origin and production of the Brazilian beef sector to ensure safe food. The aim of the system is to individually identify, register and inspect all bovine and buffalo cattle in Brazil[8]. After a FVO inspection in March 2007, assessing in particular the FMD situation (including regionalisation controls), the implementation of the vaccination program and the surveillance program and controls and records of animals moving, the Standing Committee on Food Chain and Animal Health (SCFCAH) approved a Commission decision that imposed stricter traceability requirements for Brazilian beef exports to the EU (USDA 2007). DGSANCO then suspended all Brazilian beef imports from 31 January 2008 because they did not approve a list of eligible Brazilian cattle farms that had been audited by the Brazilian Ministry of Agriculture, Livestock and Food Supply. The list contained 2 681 cattle farms designated as eligible to export to the EU and this far exceeded the EU`s recommendation and expectations of a few hundred farms only. The result of this decision was that Brazilian meat inspection services could no longer sign any beef

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[7] Statistics on exports are official data from the Ministry of Development, Industry and Foreign trade – MDIC presented on ABIEC´s homepage www.abiec.com.br/estatisticas_relatorios.asp
[8] www.abiec.com.br/eng_version/faq.pdf

export certificates from 1 February 2008. However, products that were certified before this suspension date could enter the EU until 31 March 2008 (USDA 2008b).

During the first half year of 2008, FVO has permitted export of beef for some one hundred Brazilian cattle farms to the EU market and this is only a small fraction of the 6 780 farms that were certified during 2007. As a consequence, the EU fresh beef import declined by 40 %, frozen beef by about 30 % and processed beef by about 10 % during the first five months of 2008. The overall beef import declined by about 25 % during this period (see Table 4.1) (USDA 2008c).

Table 4.1 EU imports of Brazilian beef 2005 - 2008, 1 000 tonnes CWE (USDA 2008c)

	2005	2006	2007	Jan – May, 2008
Fresh beef	109	102	112	11
Frozen beef	232	266	140	32
Processed beef	199	193	220	86
Total beef imports	540	561	472	129

Despite the export restrictions to Europe, the overall value of Brazilian beef export has continued to grow in 2008. Up until August 2008, the value of the beef export to Russia is over 1 billion $US and for example export to Hong Kong, Venezuela, Iran, Algeria and Saudi Arabia is of increasing importance for the total export value.

5 Land use

5.1 Overall land use in agriculture

Land use in Brazilian agriculture is reported in three different categories (IBGE 2007):
Crops: Permanent and temporary crops, cultivation of flowers etc, greenhouses, cut fodders
Pasture: Natural and planted pastures (degraded and in good condition)
Bush and forests: Bushes and/or natural forests intended for permanent preservation or legal reserve forests, forests with essence and forest areas also used for crops and grazing of animals.

Figure 5.1 shows the development of land use in the different categories according to the agriculture census from 1970 until the most recent one in 2006 (IBGE 2007). Cropland area has shown a very strong increase between the last census in 1995 and the newly reported census in 2006 when 77 Mha croplands were reported. The pasture area seems to have stabilised or even decreased slightly since 1985; - from 178 to 172 Mha. The area of bush and forest has shown an ongoing and steady increase and 100 Mha were reported in this land use category in 2006.

Bush and forest is a broad land use category including areas with some kind of environmental legacy or protection status. Also included are areas used for extraction of non-planted vegetation (covered with bushes and natural forest), and they can also be used for animal grazing. This land use category also includes planted forest and bush used for wood production and its derivations, or for environmentally aim (for example CO_2 uptake). Finally, the category also includes forest areas used for cropland and animal grazing, i.e. agro-forestry systems. It is reasonable to assume that areas of secondary forest (i.e. re-growth forest on degraded pasture) to some extent are included in this land use category. Also, cerrado vegetation is included in the definition, provided that it is under some agricultural activity or has as environmentally-protected status.

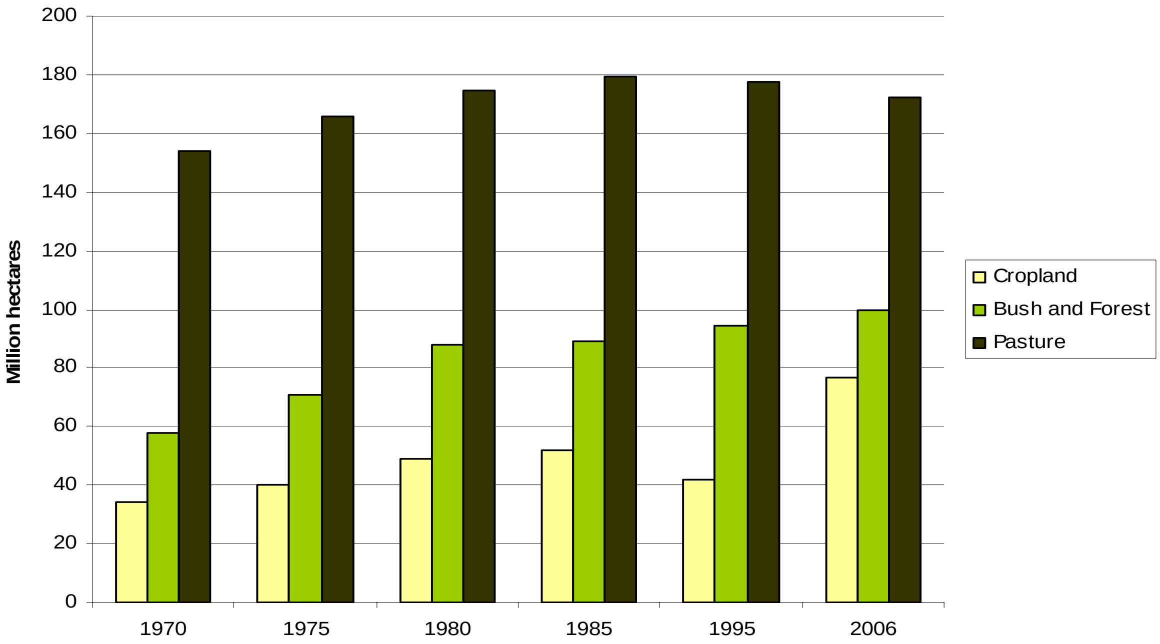


Figure 5.1 Land use in Brazilian agriculture 1970 – 2006 (IBGE 2007)

Total area of pasture is divided into natural and cultivated (planted) pasture. In 1970, ~20 % of the pasture area was planted and in 1995 this share had increased to 55 %.

Over the last 30 years an increasingly larger share of pastureland is situated in the nine states of the Legal Amazon and in 2006, 35 % of the pasture area was grown in this area (Table 5.1)

Table 5.1 Development of pasture areas (million hectares) 1970 – 2006 in the whole of Brazil, the nine states of the Legal Amazon and the rest of Brazil

	Brazil, total	Brazil, except the Legal Amazon	Legal Amazon (nine states)
1970	154.1	115	39.4
1975	165.6	145	20.3
1980	174.5	147	27.4
1985	179.2	136.5	42.7
1995	177.7	126.5	51.2
2006	172.3	110.7	61.6

Source: IBGE 2007

Today, the pasture area is mostly found in the central-western and northern regions (Table 5.2). Less than 30 % of the total pasture area is grown in the south and south-eastern regions.

Table 5.2 Areas of pasture in Brazilian regions in 2006

Region	Pasture, Mha	Share of total
Northern	32.63	0.19
Northeastern	32.65	0.19
Central-west	56.84	0.33
Southeastern	32.07	0.19
Southern	18.15	0.1
Total	172.3	1

Source: IBGE 2007

5.2 Land use changes between 1995 - 2006

Behind the gross land use changes shown in Figure 5.1, there are significant land use shifts within the country. Table 5.3 presents changes in cropland and pasture area between 1995 and 2006 for each of the five Brazilian regions (see Figure 3.2 for a map of the states in Brazil). As described previously, the cattle population has transferred north and northeast (Table 3.1 and 3.2); in only a ten-year period the cattle population has had a very strong increase (+80 %) in the northern region (Amazonas forest region). Consequently, a strong increase has also been noted in the region´s total area of pastureland, approximately 8.3 Mha between 1995 and 2006 (Table 5.3). Cropland area has also increased strongly during this time period in the northern region; according to IBGE (2007) this is due to soybean expansion.

For the nine states of the Legal Amazon, the total agricultural area increased from 57 Mha in 1995 to 70 Mha in 2006 (IBGE 2007). Pasture area increased from 51.2 Mha to 61.6 Mha, and when comparing this with the statistics of land use in the different regions (Table 5.3), it is obvious that the seven states in the northern region are responsible for the dominant increase of pasture area in the Legal Amazon between 1995 and 2006; this is apparently coupled to the strong growth (+ 80 %) of the cattle herd in the northern region during this time period (compare Table 3.1).

Table 5.3 Land use changes between 1995 and 2006 in the five different regions (IBGE 2007)

Region	States	Pasture, 10^6 ha		Change pasture 95-06 10^6 ha	Crops, 10^6 ha		Change crops 95-06 10^6 ha
		1995	2006		1995	2006	
North	Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins	24.4	32.6	+8.3	2.0	7.4	+5.4
North-east	Alagoas, Bahia, Ceará, Maranhão, Paraíba, Piauí, Pernambuco (including the state District of Fernando de Noronha Island), Sergipe and Rio Grande do Norte	32	32.6	+0.6	10.3	22.2	+11.8
Central-West	Mato Grosso, Mato Grosso do Sul, Goiás and Distrito Federal	62.8	56.8	-5.9	6.6	12.9	+6.3
South-east	São Paulo, Minas Gerais, Rio de Janeiro and Espírito Santo	37.8	32	-5.8	10.6	15.9	+5.3
South	Paraná, Santa Catarina and Rio Grande do Sul	20.7	18.1	-2.6	12.3	18.3	+6
Total		177.5	172.1	-5.4	41.8	76.6	+34.8

Soybean, maize and sugar cane are the dominating crops and especially the area of soybeans has shown a very strong growth recent years, having expanded by a third during the last decade (see Table 5.4). All other crops show minor area changes during this period but the soybean crop is singled out by a very strong area expansion. The total crop areas shown in Table 5.4 for 2006 differ from the statistics of IBGE (2007), and it has not been possible to find out the reason for this. It is possible that the crop area of 77 Mha in 2006 according to the preliminary results from IBGE (2007) is too high. Irrespective of statistical source, it is obvious that cropland area has increased significantly between 1995 and 2006.

Table 5.4 Changes in cropland areas from 1995/96 until 2006

Land use	1995/96[a], Mha	2006[b], Mha
Soybeans	16.4	22.1
Corn	12.3	13
Sugarcane	5.2	6.2
Beans (Phaseulus sp)	4.3	4.2
Rice	3.2	3
Coffee	2.4	2.3
Wheat	2.2	1.8
Cassava	1.7	2
Orange tree	0.8	0.8
Cotton	0.8	0.8
Other agricultural use	4.7	5.9
Total	54	62.2

a) Sparovek et al. (2007) whose source is Municipal Agricultural Production
b) Municipal Agriculture Production IBGE (2006)[9]

[9] //www.sidra.ibge.gov.br

The overall change in agricultural area during the last decade, including both pasture and cropland, shows a remarkable change of almost 30 Mha (219 Mha to 249 Mha) increase. Approximately 75 % of this growth of agricultural land area has taken place in the nine states in the Legal Amazon (IBGE 2007), see Figure 5.2.

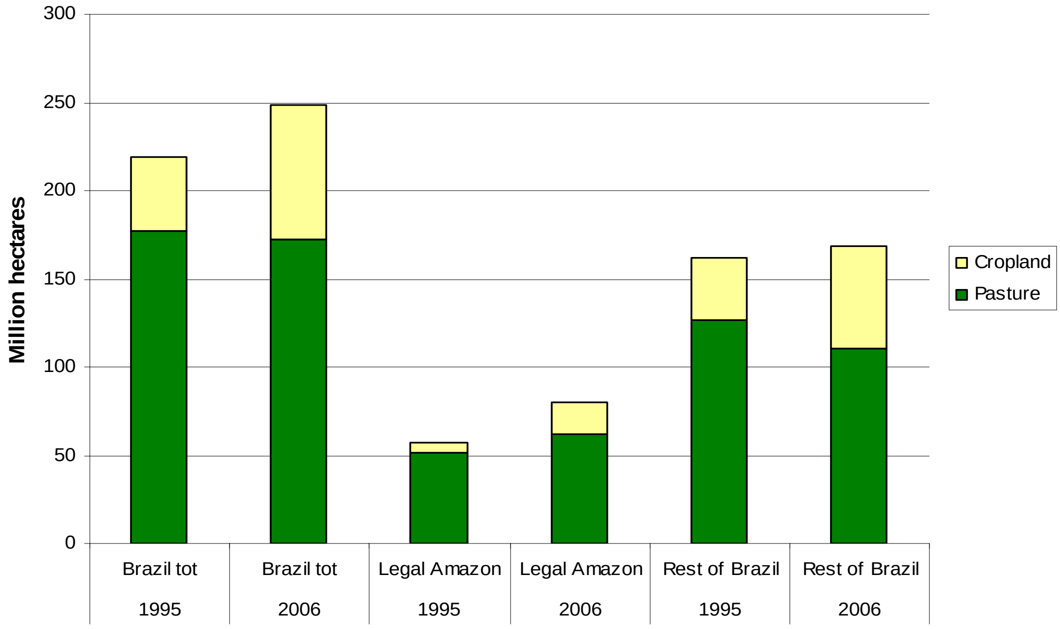


Figure 5.2 Changes in total agricultural area (million hectares pasture + cropland) between 1995 and 2006 in Brazil, the nine states of the Legal Amazon, and Brazil except the Legal Amazon

5.3 Pasture

Pasture is the overall dominant feed in Brazilian beef production. Only five percent of the slaughtered animals in 2006 were raised in feedlots, with the remaining 95 % of production coming from grazing livestock. According to ASSOCON[10] (the largest association for feed-lot producers) this production system is mainly found in the states of Goiás, São Paulo and Mato Grosso do Sul.

Of the total pasture area of approximately 178 Mha, 100 Mha is planted grass and 78 Mha is native vegetation (so called rangeland) (Sparovek et al., 2007). This information on area of planted and native pastures is however, based on 1995/96 data and due to agricultural intensification, planted pasture area may now have expanded. Boddey et al. (2004) cite different sources estimating the distribution of planted pasture as ~50 Mha on the Cerrado, ~20 Mha in the Amazonia and > 20 Mha in the Atlantic forest region, i.e. a total of approximately 90 Mha.

Grasses from Africa have long been used for beef and milk production. Seeds of *Panicum maximum* (Guinea grass) came to Brazil in straw bedding on slave ships, and this species now covers vast areas in the southern states (Boddey et al., 2004). Cultivated pastures are now dominated by *Brachiaria spp* which is planted in different species (de Oliveira et al., 2004). The *Brachiaria* grasses were introduced on a large scale in the 1970s with the opening of the Cerrado region. Cultivation of pasture has led to a drastic change in land use over only 25 to 30 years and exotic African grass now covers around 10 % of the total Brazilian land area of 850 million ha (Boddey et al., 2004).

5.3.1 Carrying capacity

It is the dry season that is the bottleneck for pasture production, and the supply of grass during this period determines a farm´s yearly carrying capacity, i.e. the number of livestock that it is possible to

[10] Associação Nacional dos Confinadores, www.assocon.com.br

feed per hectare. Landers (2007) defines the carrying capacity as the stocking rate of dry season. The winter (dry season) carrying capacity of native pasture is around 0.05 – 0.1 animal unit (AU[11]), with annual burning to generate re-growth at the height of the dry season. Introduction of planted grass such as *Brachiaria spp* in the Cerrado raised average year carrying capacity from 0.3 to 1.0 AU/ha (Landers 2007). This is in agreement with the information of Cantarutti et al. (2002), which states that during the first years after pasture establishment with cultivated grass species, animal live weight gain is at least ten-fold higher than those from native grassland areas. De Oliveira et al. (2004) cite Zimmer & Euclides Filho (1997), reporting that newly established pasture in the Cerrado is able to support 1 – 2 AU per hectare and year.

Arima et al. (2006) report varying stocking rates in the Amazon region, which are explained by pasture productivity that can vary considerably due to pasture management, regional climate differences and the genetic quality of the cattle. The most productive pastures in the Amazon, corresponding to 20 % of the total area, had in the 1990s an average stocking rate of 1.38 head per hectare, while the average stocking rate in the rest of the Amazon was 0.5 head per hectare. According to Arima et al. low productivity in cattle ranching is probably associated with the following:

- speculative occupation of land in new agricultural frontiers through pasture planting with inadequate technique for plantation and low use of animal husbandry technologies;
- settlement on low-potential agricultural land, especially in regions with high rainfall and poor soil;
- pasture degradation from soil compaction, overgrazing and nutrient depletion.

5.3.2 Changes in pasture productivity 1995 – 2006

Indicator values for pasture productivity, defined as meat production per hectare of pasture, were calculated using the most recent statistics, see Table 5.5. In the late 1990s, it was estimated that milk production used 20 Mha pasture (Wada & Ortega, 1996). Since beef production has grown substantially more than milk production in Brazil since the 1990s, and total pasture area has shown a small decrease, it is not likely that milk production uses more than 20 Mha today, which is roughly 10 % of the pasture area. In 1995, there were approximately also 1.6 million buffalos, 18 million sheep, 11 million goats, 6.4 million horses and 3.3 million donkeys and mules (EMBRAPA, 2002 b). These animals are also grazing and users of the pastureland but it has not been possible to find any data on how much pasture they consume. Therefore, we made an assumption they use half the area of the dairy cow population of ~16 million head, i.e. 10 Mha. When beef production per hectare of pasture was calculated, the area for milk production (20 Mha) and other grazing livestock (~10 Mha) was deducted (Table 5.5).

Table 5.5 Indicator values for production of beef (kg CWE) per hectare of pasture, Brazil total

Year	Mha pasture, total	Mha pasture, beef	Mtonnes CWE	Kg CWE ha^{-1} pasture***
1995*/97**	177.7*	148	6.444**	44
2006	172.3	142	8.600	60

* ha pasture, data from 1995 (IBGE 2007), ** MT CWE, data from 1997 (ANUALPEC/FNP 2006)
*** calculated after ~30 Mha of the pasture area was deducted for milk production and other livestock, see text

These calculated indicator values indicate that pasture productivity has increased from ~44 to 60 kg CWE per hectare, i.e. an increase by approximately 35 % in ten years. Some technologies have been introduced during the period that influences this indicator value. In feedlot systems, crops or by-products from cropland are used and this system was rare in Brazil in the 1990s. The cropland area used for feed production in 2006 should be added to the pasture area for completing the picture of the

[11] One AU (Animal Unit) in Brazil corresponds to one cattle with a live weight of 450 kg (one cow). A heifer with a live weight of 225 kg is 0.5 AU

overall land use for beef production. However, only 5 % of the slaughtered cattle in 2006 were reared in feed-lots so this is of minor impact for the calculated indicator values in Table 5.5. Systems integrating crops with livestock have also been introduced in recent years to avoid soil degradation and increase land productivity, for pasture as well cropland. There are different modes on how to integrate crop and livestock production; Landers (2007) describes some integrated systems that have crops and a pasture in rotation and they are comprised of: *i*) winter stubble grazing on summer cropland; *ii*) summer crops with winter pasture (undersown or oversown) for grazing; *iii*) summer crop plus second crop plus stubble grazing in the winter; *iv*) crop production for feed supplement on pasture (silage, sugar cane, grass etc) usually on minor cropland and/or *v*) some combination of these. However, all in all, feed crops from cropland area supporting beef production are still far much smaller than the overall, dominating land use, pasture, and it is clear that the use of pasture has been intensified over the last decade.

The same indicator values were calculated for the pasture area in the Legal Amazon (Table 5.6). Since milk production has a relative smaller share of cattle production in the Legal Amazon compared with the south and south-east of the country, we assume that in total, 10 % of the pasture are used of other production than beef. Beef production per hectare is lower in Legal Amazon than the average value for the whole of Brazil (compare Table 5.5) which is reasonable since this region is less developed in terms of management, breeding, advisory service etc. However, beef production per hectare pasture has shown a strong increase in the Legal Amazon over the ten year period.

Table 5.6 Indicator values for production of beef (kg CWE) per hectare of pasture, Legal Amazon

Year	Mha pasture, total	Mha pasture, beef	Mtonnes CWE	Kg CWE ha^{-1} pasture***
1995*/97**	51.2*	46	1.095**	24
2006	61.6	55	2.155	39

* ha pasture, data from 1995 (IBGE 2007), ** MT CWE, data from 1997 (ANUALPEC/FNP 2006)
*** calculated after ~10 % of the pasture area was deducted for milk production and other ruminants

5.3.3 Pasture establishment and renovation

The establishment of new pastureland in the north region (with information from the states of Pará, Rondônia and Mato Grosso) is fully described by Barros et al. (2002). Initially, the forest areas are cleared using a process called “drill and overturning” (in Portuguese: *broca e derrubada*). Drilling is the construction of access roads that are made for the entry of equipment, making it possible to remove trees that have a commercial value (logging). Overturning is the cutting of smaller trees, vines and foliage that are left to dry on the ground and serve as fuel for burning. Then next step is the burning of the forest, performed at the peak of the drought season in each region. After the burning of the forest, grass seeds are applied on the larger properties using aircraft and using a normal seed drill on the smaller properties. In some regions a mixture of 80 % Brachiaria and 20 % Tanzania grass is used because this seed mixture with Tanzania grass makes better use of the high fertility of ash aggregated to the soil after the fire. The Tanzania grass prevails for approximately a year, as the fertility from the ash is still high. When the direct fertility effects from the ashes decline, Brachiaria becomes the dominant forage grass. In the second year after fire, a complementary clearing (in Portugese: *roçada*) usually takes place in order to control undesirable plants in the newly established pasture. If there are many weeds and other alien plants, e.g. tree stumps, one more burning may be called for.

In the maintenance of the pasture, control of alien plants is essential, which also can be done with herbicides. According to Barros et al. (2002), a renewal of pasture is generally needed after twelve years in places where the soil has low fertility and/or when the pasture has been badly managed during the first ten years. Pasture renewal is achieved with harrowing, sowing and by the general application of phosphorous and lime, depending of the type and fertility status of the soil.

According to Arima et al. (2007) fire is a land management tool today used by around four million Amazonian farmers for land clearing and for the control of grasses and shrubs that compete with the crops for nutrients. Primary burning after deforestation cleans up the areas, the fields are prepared for sowing and the ashes provide the soil with an important amount of nutrients. In addition, burning organic matter releases the mineral nutrients as oxides or carbonates, having alkaline reaction and reducing soil acidity, which is important for phosphorous availability (Müller et al., 2004).

Arima et al. (2006) argue that inadequate forest clearance prior to pasture establishment is one major cause of low productivity in some cattle ranching in the Amazon region. In some cases, the first settlers that clear and burn the forest do not put enough effort into clearing the land, and the first pastures have to compete with forest re-growth and stumps. Inadequate establishment methods are due to a lack of capital for clearance and/or because the settlers only want to establish a possession of the land so they can sell it to larger ranches in the future.

Morton et al. (2006) studied cropland and pasture establishment after deforestation in the southern Brazilian Amazon (Mato Grosso) using satellite data. This study shows that the transition from forest to cropland was very rapid and that >90 % of the land was planted the year immediately after forest clearing. Conversions of forest to pasture occurred more slowly, and 72 – 86 % of the land was planted the year after forest clearing while the remainder required more than two years to develop a full grass vegetation over the majority of the deforested area.

In other regions than the Amazonia forest region, mostly Cerrado, pastures were established after a pioneer crop of rice or other grain. Natural soil fertility was low and the burning of sparse scrub gave limited nutrient effect compared with the Amazon forest; pasture productivity therefore relied on the residual fertiliser applied to the pioneer crop (Boddey et al., 2004).

Sparovek et al. (2007) estimate, based on expert opinion, that cultivated pastures are reseeded every ten years corresponding to approximately 10 Mha pasture renewal every year. In annual crops, there has been a shift towards no-tillage systems, in order to present soil erosion. When pastures are renovated, soil over vast areas is left bare before the seed has sprouted and the new grass is established. According to Sparovek et al., (2007) there is too little knowledge of the methods used in pasture re-seeding and also of the environmental impact of soil erosion on tilled pasture.

Estimations of the use of diesel for yearly pasture renewal were done using data from a database of feed production in Sweden (Flysjö et al., 2008). Sowing (drilling) the seed, and cultivation (harrowing) before this, require approximately 8 l diesel ha^{-1} for each machine operation according to this database. We assumed that cultivation before sowing was done in half of the area and that the rest was planted directly, resulting in an average yearly use of 12 litre diesel per hectare of pasture area being renovated. This is probably a conservative estimate, since diesel for fertiliser application and herbicide spraying should also be added; however, it is difficult to estimate to what extent these operations are practised. For the estimations of use of fossil fuels in pasture renovation it was assumed that 10 Mha pasture was reseeded yearly requiring 12 litre per hectare of diesel, which makes a total consumption of 120 000 m^3 diesel.

5.3.4 Use of synthetic fertilisers

The use of synthetic fertilisers in Brazilian pastures is very low. In 1990, around 100 000 tonnes of fertilisers for pasture were sold, the number growing to 570 000 tonnes in 1999 and then falling back to around 500 000 tonnes in 2001 (Bueno & Corsi 2001; Aguiar et al., 2002; Vilela et al., 2004). Dividing these figures on the area of planted pastures (100 Mha) gives an average fertiliser rate of 5 kg ha^{-1} of cultivated pasture. Statistics from the Brazilian Fertilizer Association show that Brazilian cultivated pastures received an average quantity of NPK-fertilisers of 4 kg ha^{-1} yr^{-1} between 1994 - 2002 (ANDA 2008).

According to agricultural experts, phosphorous is the most common nutrient applied in pastures. We estimate an annual average use of 4 kg single superphosphate per hectare on cultivated pastures (~100 Mha) corresponding to 400 000 tonnes per year.

5.3.5 Pasture degradation

Overgrazing and lack of nutrient replacement leads to pasture degradation, which is a severe problem in Brazilian agriculture. De Oliveira et al. (2004) estimate that degraded *Brachiaria* pastures now occupy over 25 Mha in the tropical regions of Brazil, i.e. more than a forth of the area categorised as cultivated pasture. Cerri et al. (2005) cite different sources estimating than more than 10 Mha of the pastures in Brazilian Amazon in the 1990s had some level of weed infestation, which characterises a high degree of degradation. Landers (2007) cites Sano et al. (1999) and Vilela et al. (2004) stating that of the 80 Mha cultivated pasture grown today in the Amazon and Cerrado biome, 70 – 80 % are classified as degraded.

After pasture establishment, productivity is high, but after some years grass production declines and weed species invade the pasture. This leads to a significantly lower carrying capacity, and the stocking rate can decline from 2 AU/ha to less than 0.5 AU/ha. This loss in carrying capacity represents a value loss of more than $US 10 billion in terms of beef production (de Oliveira et al., 2004). In order to compensate for the production loss, farmers usually incorporate new areas of native vegetation into pasture production.

Landers (2007) describes the process of pasture degradation, which includes several steps, beginning with N and P deficiencies and ending up in soil degradation (Figure 5.4). A number of poor pasture management activities are driving the process and overgrazing is the most important one. The first step in the process is loss of forage yield, as well as lower quality. This is followed by weed invasion and termite wounds. The trampling of cattle in combination with a diminishing grass cover leads to compaction and bare soil. Finally, the land has a very low productivity and is exposed to wind and water erosion.

Müller et al. (2004) investigated the soil properties in degraded pastures in the state of Pará, in eastern Amazonia. The pastures had been planted after deforestation approximately 15 years ago, and were now maintaining low productivity, supporting only 0.2 – 0.25 AU/ha. The results of this study show that pasture decline, quantified by the decrease of forage production and the increase of weed invasion, is accompanied by a decrease in root biomass and by a concentration of the root system closer to the soil surface. In an area deforested over the last 30 years in the Atlantic forest region and planted with pastures, nitrogen (N) circulation at stocking rates of 2, 3 and 4 animals per hectare were studied by Cantarutti et al. (2002). In extensively managed tropical pastures herbage utilisation is generally low (10 – 40 %) so it is the nutrient cycling through the litter[12] pathway that dominates. The study of Cantarutti et al. (2002) showed that at high stocking rates (4 AU/ha) a much greater proportion of N and other nutrients recycled through the animal. Unlike nitrogen deposited in plant litter, N in animal excreta is not distributed uniformly across the pasture but much of it is concentrated around drinking stations and shaded or rest areas where, owing to severe trampling, there is little grass to benefit from the nutrients. The results presented by Cantarutti et al. (2002) suggest that it is due to the fact that at high stocking rates most nitrogen is inefficiently recycled via animal excreta, while at more modest stocking rates (typically 1-3 AU/ha) a large proportion of the nutrients are efficiently recycled via plant litter, and plant productivity can be maintained for many years.

[12] Litter: dead plant material on the surface of the soil no longer attached to the plant

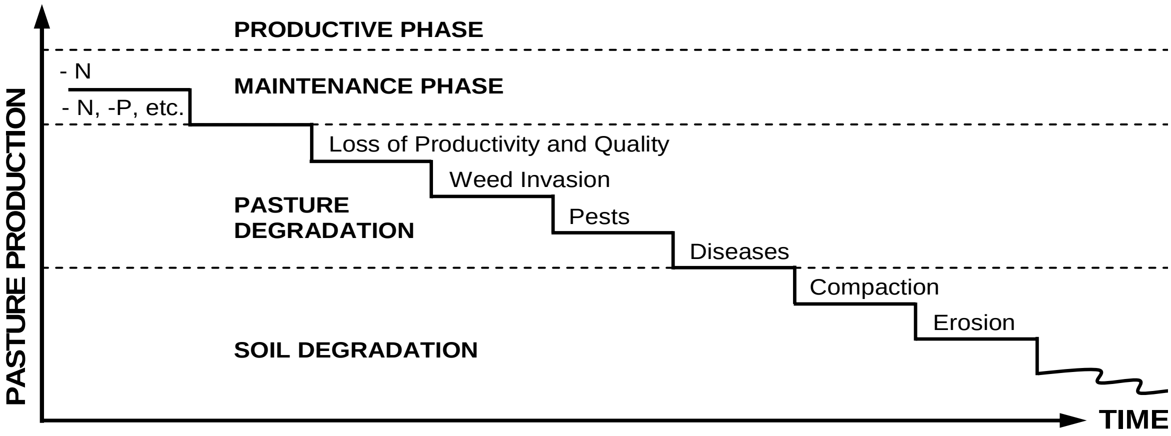


Figure 5.4 Schematic illustration of the process of pasture degradation (from Landers 2007)

5.3.6 Carbon storage in soils under pasture in the Cerrado

On a global scale, permanent grassland is a carbon sink. Studies on temperate grassland ecosystems in Europe and North America show a carbon sequestration of 200 – 600 kg C ha^{-1} yr^{-1} (Jones & Donelly, 2004). Recent studies on European grasslands reveal an even higher carbon sink capacity, around 1 t C ha^{-1} yr^{-1} (Soussana et al., 2007).

Da Silva et al. (2004) conducted a study in the Cerrado region of Brazil, where data on soil carbon storage under six different cultivated pastures were measured through soil sampling, and compared with native grassland. The purpose was to estimate carbon gains and losses under different grassland regimes, some of them representing the common pattern of pasture management in the region. Four of the studied sites were cultivated grassland (all grazed), with pasture of various quality (different capacities to produce biomass) and the other two were sown grassland used for seed production (no grazing).

The total carbon storage was around 100 t C ha^{-1} at 1.0 m depth on the native grassland of the Cerrado soil investigated which differed considerably from storages found in the Colombian Savannas of ~200 t C ha^{-1}. There was a strong correlation between total accumulated soil carbon and above ground forage biomass. Since different land use management methods mostly affect soil carbon in the surface layer, it was mainly in this layer (0-20 cm) that differences in carbon stocks were registered. Native pasture land held ~31 t C ha^{-1} in this surface layer as opposed to one site of well managed cultivated pasture and two sites of grassland for seed production (no grazing) where carbon storage in the surface layer were in the magnitude of 37 – 40 t C ha^{-1}. Sites with pasture in some degraded condition had carbon storage similar to those of native grassland or even slightly lower (da Silva et al., 2004).

The conclusion of the study of da Silva et al. (2004) is that carbon accumulation in soil above the previous native stocks in the Cerrado was found only in areas with fertilisation inputs, and the magnitude of that carbon accumulation was low, compared with the stocks under native pastures. The authors inferred that, since most of the pastures in the Brazilian Cerrado region are in some process of degradation (caused by poor management methods, low input fertilisation, no maintenance fertilisation and high stocking rates), it is questionable to consider the area of ~50 Mha cultivated pastures in this region as a sink for atmospheric CO_2.

Based on the finding published by da Silva et al. (2004), no carbon sink was estimated for the pasture land used in Brazilian beef production. The main motive for this is that a significant share of the cultivated pasture lands are in some phase of degradation and therefore have a low potential for carbon sequestration.

6 Methane emissions

6.1 Enteric fermentation

6.1.1 Emission factors

In the IPCC guidelines, emission factors (EFs) are given for estimating CH_4 emissions from enteric fermentation (IPCC 2006). The EFs are given for different production and feeding praxis globally. For Latin America, the EFs are based on estimates for Brazil. Table 6.1 presents the EFs for the categories "other cattle than dairy cows" in Latin America according to IPCC Tier 1.

Table 6.1 Emission factors for methane due to enteric fermentation in Latin America (IPCC 2006)

Category	LW*, kg head^{-1}	EF, kg CH_4 head^{-1} yr^{-1}	Population mix, %
Mature female	400	64	37
Mature male	450	61	6
Young	230	49	58

* = Live weight

The feeding situation for all the animal categories in the IPCC guidelines are described as large areas, which we interpret as grazing pastures. Mature females are beef cows where two thirds of the population is pregnant according to the guidelines and their production is in average of one kg milk per day, which we assume is consumed solely by its calf, i.e. they produce no milk for human consumption. Mature males are older steers or bulls with a live weight around 450 kg which implies that this livestock category is soon ready for slaughter. Young livestock with a given live weight of 230 kg is a broad definition for growing cattle and almost 60 % of the non-dairy cattle in Brazil are in this category according to IPCC (2006), see Table 6.1.

One national greenhouse gas inventory of the Brazilian agriculture has been published with data from the early 1990s. In one of the background reports, details are given on the input data for estimations of methane emissions from livestock and in this inventory, IPCC guidelines from 1996 were used (EMBRAPA 2002a). Here it was concluded that there is a lack of basic data necessary for an adequate characterisation of the cattle population in means of distribution of livestock categories, live weights, food consumption, feed digestibility, etc when estimating methane emissions from the livestock. In this inventory, EFs were estimated at 65-73 kg CH_4 hd^{-1} yr^{-1} for grown females, 62 – 73 kg CH_4 hd^{-1} yr^{-1} for grown males and 47-56 kg CH_4 hd^{-1} yr^{-1} for young cattle. The variation in EFs in respectively livestock category was mostly explained by different live weights and also different feed digestibility in different regions.

In recent experiments in the state of São Paulo, the CH_4 emission rates of grazing steers were measured with the SF_6 (sulphur hexafluoride) tracer technique (Lima et al., 2007). This technique is based on inserting a calibrated source of SF_6 into the rumen of each participating animal. The technique can detect gas samples at very low levels (parts per 10^{12}) (Lassey, 2007). For measurements of grazing livestock the SF_6 tracer technique is uniquely appropriate.

Sixteen steers of the breed Nelore, with a live weight of 300 – 600 kg, participated in the experiment and emission rates were measured when non-fertilised pasture (*Brachiaria)* was the only feed intake and also when the cattle were given supplements of different feed rations to increase live weight gain during the dry season. The average emission, calculated on a yearly basis, was 156 g CH_4 day^{-1} which corresponds to 57 kg CH_4 head^{-1} yr^{-1} for cattle with the average live weight of 375 kg.

Table 6.2 shows the emission factors based on the experiments suggested by the researcher group, expressed as kg CH_4 per head^{-1} year^{-1} for different livestock categories (Lima et al., 2007). No data were given for calves in this reference. Before the rumen is developed, during the suckling period, the young cattle´s methane emissions are fairly small and slowly grow as they starts to eat grass. Embrapa (2007) gives data that the calf, in extensive systems, is normally weaned at the age of 6 – 8 months with a life weight of 150 – 200 kg. Lima et al. (2007) set an EF for the young animal from 7 months of age, which in practice means that during the first year of the cattle´s life, its CH_4 emission is half of that of its second year (46.7 kg CH_4/2 = 23.4 kg CH_4, see Table 6.2).

Table 6.2 Preliminary estimations of methane production of cattle herds (Nelore / Zebuínos), in the southeast region of Brazil (tropical climate) according to Lima et al. (2007)

Category	LW*, kg animal^{-1}	Winter	Spring	Summer	Autumn	kg CH_4 head^{-1} yr^{-1}
		CH_4, g day^{-1}				
Bulls	> 500	131	192	274	168	69.7
Cows	350-450	116	150	198	161	57
Young females, 7 months - 2 yr	180-250	95	99	159	159	46.7
Young females, 2-3 yr	250-351	103	114	194	130	49.3
Young males, 7 months - 2 yr	180-250	95	99	159	159	46.7
Young males, 2-3 yr	230-351	103	114	194	130	49.3
Males, 3-4 yr	350-450	116	150	198	161	57
Males, 4 yr	>450	131	192	274	161	69.1

* Live Weight

6.1.2 Calculated emissions top-down

Total CH_4 emissions due to enteric fermentation from the Brazilian beef cattle population were calculated with emission factors according to IPCC (2006), Table 6.1, and Lima et al. (2007), Table 6.2. Input data for the number of cattle in different age- and weight classes were statistics from FNP for the year of 2005, see Table 3.3 (ANUALPEC/FNP 2008). All calculations are shown in Appendix 4. The dairy cow population (~16 million animals) was not included in the calculations but in the categories for heifers at different ages, replacement animals from the dairy sector are included. It was not possible to exclude dairy heifers from the total number of young heifers in the statistics. However, dairy cows have dual purposes since they are also meat producers when they are culled, and because the bull calves they give birth to will go into beef producing systems. Therefore it is justified that a share of the emissions from the milk producing system must end up in the beef system. Here, we use a straightforward and simple method for dividing the calculated CH_4 emissions between beef and milk. The dairy cows are not included in the beef system, even though they produce surplus calves (bull calves) and meat when they are slaughtered. Instead, emissions from the young females that are going to replace the culled dairy cows are included in the emissions from the beef system, since the number of all growing livestock was considered in the calculations (see Appendix 4).

The methane emissions due to enteric fermentation from beef cattle in 2005 were estimated at approximately 6.9 – 7.3 million tonnes CH_4 (Table 6.3 and Appendix 4), i.e. there are only small differences in EFs from the IPCC guidelines and EFs suggested by Lima et al. (2007).

Table 6.3 Calculated methane emissions due to enteric fermentation from beef cattle in Brazil 2005 using two different sets of emissions factors (EFs)

Source of EF	10^6 tonnes CH_4
Lima *et al* (2007)	6.9
IPCC (2006), Tier 1	7.3

In the inventory of GHG emissions in Brazil, methane from enteric fermentation from the beef cattle population was estimated at ~$7.84 \cdot 10^6$ tonnes CH_4 in 1995 (EMBRAPA 2002a). The calculated emissions for 2005 in this study are thereby lower, despite a larger cattle population in 2005 compared to the one in 1995. One explanation for the discrepancy is how emissions from the livestock category young calves (0-12 months) are calculated since they include many heads in the total livestock population (see Table 3.3). Here we halved the EF for young cattle since there is very little methane production from a calf during its first months. A lower EF for young cattle (calves) is also used in the inventory report of GHG emissions from agriculture in Ireland where a young cattle <1 year has an EF of 28 - 29 kg CH_4 hd^{-1} yr^{-1} and a cattle age 1 – 2 year has an EF of 46 – 60 CH_4 kg hd^{-1} yr^{-1} (EPA Ireland, 2008).

In the calculations of total GHG emissions from the beef production in 2005, the calculated estimate according to EFs presented of Lima et al. (2007) was used as input data, i.e. $6.9 \cdot 10^6$ tonnes CH_4.

6.2 Manure management

Methane emissions for manure management are mostly connected to anaerobic conditions, for example slurry systems. When the manure is dropped directly on pasture, the methane emissions from the manure are normally small.

In the IPCC Guidelines Tier 1 method for estimating methane losses from manure management an EF of 1 kg CH_4 hd^{-1} yr^{-1} is suggested (IPCC 2006). This is calculated according to the equation:

$EF_{hd*yr} = VS * B_o * 0.67 \text{ kg } CH_4/m^3 * MCF$[13]

VS = volatile solids in manure, for cattle (non-dairy) in Latin America with a live weight of 305 kg; VS-production is 2.5 kg per head and day, i.e. 910 kg VS per year and cattle;
B_o = maximum amount of methane able to be produced from the manure, m^3 CH_4 kg VS^{-1}, B_o is 0.1 for non-dairy cattle in Latin America;
MCF= Methane conversion factor which is determined by a specific manure system (for example, anaerobic or non-anaerobic) and temperature is also of significance. MCF for cattle manure dropped on pasture in warm climate is 2 %.

A beef cattle with a live weight of 305 kg is thus calculated to have an emission of 1.2 kg CH_4 yr^{-1}.

Methane emissions from manure management (all manure dropped on pasture) were calculated with the simplified EF of 1 kg CH_4 hd^{-1} yr^{-1}. For cattle less than one year old (lower live weights=less VS-production) the EF was halved. The number of livestock shown in the different categories was based on ANUALPEC/FNP (2008) for the year of 2005, see Table 3.3. As can be seen in Table 6.4, methane emissions were calculated as 135 000 tonnes CH_4 for the beef cattle population of 2005. This is only a small fraction of the methane emissions from enteric fermentation (compare Table 6.3).

Table 6.4 Calculated methane emissions from manure management 2005

Livestock category	Million head	Kg CH_4 hd^{-1} yr^{-1}	CH_4 emission from manure management, tonnes
Beef cows	44	1	45 015
Calves, 0 – 12	47.8	0.5	23 910
All other beef cattle	66.6	1	65 650
Total	158.4		134 575

[13] IPCC (2006). Volume 4, Chapter 10.4 and Annex 10A.2

7 Emissions of nitrous oxides

7.1 Direct emissions

Calculations of emissions of nitrous oxide from manure management are based on data on the nitrogen (N) excreted by livestock. When calculating production under controlled conditions in stables, e.g. when the feed is analysed and weighed and the N output in products (milk, meat, eggs) is relatively well registered, a nitrogen balance for the single animal or the herd can be estimated with reasonable accuracy. Estimating N production in manure for grazing livestock is much more uncertain, since it is difficult to control forage intake and production of manure (dung and urine). Also, the N content in pasture and manure can vary during the year, due to climate conditions and stages of the grass development. However, it is known from many sources that beef production has a very low N efficiency, i.e. only a small share of the nitrogen consumed by the animals is retained in the body. Van der Hoek (1998) calculated the global N efficiency in cattle production (calculated as the ratio between N in animal products and N input in feed) at 7.7 % including both meat and milk. IPCC (2006) suggests a default value of 0.07 kg N retained per kg N in feed intake for the livestock category “other cattle than dairy”. The default value is 0.20 kg N/kg N in feed intake for dairy cattle and 0.30 for pigs. Boddey et al. (2004) estimated that 5.5 – 8.5 % of N in forage consumed by grazing steers on *Brachiaria* pasture in Brazil was retained in the animals as live weight gain.

Since it was not possible to find data on N excreted in manure for different beef cattle categories in Brazil, IPCC’s default values[14] were used for nitrogen excretion rate (IPCC 2006). For the livestock category “other cattle” in Latin America, the value is 0.36 kg N/day for 1 000 kg animal mass, i.e. a beef cattle with a live weight of 500 kg excretes 0.18 kg N day^{-1} corresponding to 66 kg N year^{-1}.

Table 7.1 Calculated default values for N excretion in manure (dung and urine) in different livestock categories

Livestock category/age	Average, kg LW* animal^{-1}	Kg $N_{excreted}$ head^{-1} yr^{-1}
Beef cow	400	52
Calves, 0-12 months	100	13
Young cattle, 1-2 years	230	30
Young cattle, 2-3	310	40
Steers, 3-4 years	400	52
Steers, bulls >4 years	>450	59

* LW=live weight

A calf weighs around 40 kg when born, and in extensive systems the calf is normally weaned from the cow at the age of 6 – 8 months (EMBRAPA 2007). According to Gottschall (2003), the life weight of a weaned calf should be around 150 - 200 kg. To calculate the average $N_{excretion}$ in manure during the first year, an average of 100 kg weight was used (Table 7.1). The livestock category from one to three years of age is large, including > 55 million heads in 2005 in Brazil (see Table 3.2). Depending on the intensity of the production system, the livestock reach a higher live weight at a lower age. The average live weight used for calculating the N production in manure for these categories was estimated from live weight intervals at different ages as provided by Lima et al. (2007) and IPCC guidelines for calculations of CH_4 from enteric fermentation from cattle in Latin America, see Table 6.1-6.2. It was estimated that the N excreted is between 30 – 40 kg N head^{-1} year^{-1} for cattle within the age 1 – 3 years (Table 7.1). Boddey et al. (2004) investigated nitrogen cycling in *Brachiaria* pastures and concluded that dung production decreased as stocking rate increased, because the cattle consume less forage at higher stocking rates. In a field experiment presented by Boddey et al. (2004) steers’ forage consumption and manure production were measured. The initial live weight was approximately 250 kg head^{-1} and depending on the stocking rate in the experiment, the live weight gain varied between 120 –

[14] IPCC (2006): Chapter 10, table 10.19

153 kg animal^{-1} yr^{-1}. The N production in manure (dung+urine) was measured at between 28 – 42 kg N head^{-1} yr^{-1} with the highest figures for the fastest growing animals (lowest stocking rate). Compared with the results from Boddey's field experiment, our estimate of $N_{excretion}$ at 30 – 40 kg N head^{-1} yr^{-1} for cattle between one and three years of age seems reasonable.

With a beef cattle herd of approximately 158 million head (dairy cows excluded), total annual N excreted was calculated at around 5.3 million tonnes N, when using the default factors presented in Table 7.1. The emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing cattle is 0.02 kg N_2O-N per kg $N_{excreted}$. Total direct N_2O emissions from manure management (manure on pasture) are estimated at close to 106 000 tonnes N_2O-N or 166 500 tonnes N_2O: calculations are shown in Appendix 6.

7.2 Indirect emissions

Indirect N_2O emissions occur after volatilisation of N as NH_3 and oxides, and the deposition of these gases as NH_4^+ and NOx in adjacent ecosystems (IPCC 2006). Gas emissions of nitrogen oxides from manure are minor and are not included here. Ammonia emissions from dung, and especially from urine, can be considerable, and increasing losses are found at high temperatures and high soil pH. There is not much data available on ammonia losses from urine and dung under grazing in tropical regions. Boddey *et al* (2004) reports of trials with ^{15}N-labelled urine that was applied to bare soils and Brachiaria grass over a period of 150 days. In these experiments 24 – 34 % of N in the applied urine could not be found in either plant or soil; the highest number of losses in these experiments was in bare soil, suggesting that at least a forth of the N applied in the urine had been lost, probably mostly as ammonia. In other experiments referred to by Boddey et al. (2004), even higher losses of ammonia from urine applied to grass and soil were found, also indicating significantly higher volatilisation from bare soils.

An often used emission factor for ammonia volatilisation from manure deposited by cattle on pasture is 7 – 8 % N excreted (Cederberg & Nilsson, 2004; Hutchings et al., 2007); this factor has been developed for temperate regions. Since there is not enough knowledge of the losses of ammonia from urine and dung from cattle grazing in tropical regions, this EF were used in this analysis. This is probably an underestimation of the losses of ammonia. Higher temperatures under grazing conditions in the tropics are beneficial for ammonia volatilisation. Also, grazing on pastures in different stages of degradation (it is impossible to estimate to what extent such grazing regimes occur) means that the manure is dropped on bare soils, which increases the risk of ammonia losses to the air.

Seven percent of the N in the manure of the cattle was estimated to be lost as ammonia, leaving a total of close to 350 000 tonnes NH_3-N from the beef cattle herd. The EF for indirect emission of nitrous oxide from losses of ammonia from manure is 0.01 kg N_2O-N per kg NH_3-N (IPCC 2006). From this, the indirect N_2O emission from ammonia volatilisation from urine and dung was calculated at close to 5 800 ton N_2O, see Appendix 6.

Indirect losses of N_2O caused by leaching/runoff are calculated as 0.0075 kg N_2O-N per kg $N_{leaching/runoff}$. It has not been possible to get any data on leaching/runoff from pasture area, which is why this post has been omitted in this study.

8 Use of resources and fossil fuels

8.1 Feed production

Brazilian beef is produced in a system that is almost solely based on the resource land. Pastureland in Brazil provide the feed for the cattle as well as their daily living conditions – as opposed to livestock production in temperate regions where there is a need for some sort of stables and for the harvesting of winter forage. This land-based production system in Brazil leads to a small input of external resources, with the exception of the use of land.

8.1.1 Mineral feed

Tropical and sub-tropical grasses are often poor in essential macro- and micro-nutrients for cattle, and mineral feed supplements are therefore important for herd productivity. To estimate the potential overall consumption of mineral feed, data from recommended daily intake were obtained for cows from Nicodemo (2001) and for growing cattle from Ortolani (1999).

A daily intake of ~55 g mineral supplement per cow was discussed by Nicodemo (2001) from a product containing 514 g dicalcium phosphate and 450 g NaCl per kg. In addition, minor amounts of Cobalt, Copper, Iodine, Selenium and Zink were suggested to be included in a cow mineral feed. In a field experiment with two-year-old growing steers (320 kg LW), a daily intake of 27 g (hard block minerals) – 56 g (loose minerals) per head was tested, and showed more positive weight gain when minerals were loose, so the steers could consume more. The formula of the mineral feed in the experiment was: dicalcium phosphate 486g, sodium chloride 400g, elemental sulphur 20g, magnesium oxide 30g, Zinc 3,600ppm, Copper 1,500ppm, Iron 1,800ppm, Manganese 1,300ppm, Cobalt 200ppm, Iodine 150ppm, Selenium 12ppm. In another field experiment, growing steers (LW 266 kg) and finishing steers (LW 377 kg) had a daily intake during the dry winter season (140 days) of 42 and 57 g head^{-1} day^{-1}, respectively (Moreira et al., 2003).

There seems to be large variations in mineral consumption between farms. This depends on a number of factors, such as quality and quantity of grass, animal productivity, number, type and location of mineral blocks, mineral mixture composition (especially the percentage of NaCl) etc. Ortolani (1999) describes excessive feeding of minerals on many Brazilian farms when mineral supplement is deposited in the feed trough on one occasion. During the rainy season the minerals become a hard block when exposed to moisture and less accessible to the livestock.

Based upon these data of daily intake of minerals and the number of cattle in different categories (see Table 8.1), a rough estimate of the total mineral-feed consumption was made. Calves (young cattle up to 12 months) were assumed to have been fed from cows' mineral ration, and were therefore not included. Approximately 1 660 kilotonne mineral feed in 2005 was calculated to have been consumed in beef production.

Table 8.1 Estimation of consumption of mineral feed in the beef production in 2005

Livestock category	Million head, 2005	Estimated mineral feed consumption, g hd^{-1} day^{-1}	Estimated mineral feed consumption, kg hd^{-1} year^{-1}	Total consumption, mineral feed, ktonne
Cows	45	55	20	900
Cattle, 1- 2 years	37.5	25	9	338
Cattle, 2 – 3 years	22.3	40	15	334
Older cattle	5.8	40	15	87
Total				~1 660

The two major components in the mineral feed were identified as dicalciumphosphate and sodium chloride. The production of other elements was excluded due to small flows. As an estimate, one kg of mineral feed was assumed have a content of 500 g di-calciumphosphate and 450 g NaCl per kg. Data for production of these two components were taken from the Ecoinvent database[15]. It was assumed that the mineral feed is transported 400 km from production site to the farm.

8.1.2 Complementary fodder (feed-lots)

In Brazilian beef production, the use of feed-lots is still rather uncommon, and according to ASSOCON, 5 % of the slaughtered cattle in 2006 were raised in intensive systems where mechanically harvested fodder is given to the livestock. ANUALPEC/FNP (2006) provides information that in 2006 approximately 2.5 million cattle were held in feed-lots; according to ASSOCON, silage of corn, durra, sugarcane, grass and bagasse are the most common feed in these production systems. Approximately 2.7 million cattle were kept in “semi-feedlots”; we interpret this as a system, in which the final fattening is carried out in feed-lots using mechanically harvested fodder (ANUALPEC/FNP 2006). Finally, there are also cattle farmers that give complementary feed during the dry season, when grass growth is insufficient in order to reduce the slaughter age.

It has not been possible to collect reliable data on the amount of complementary fodder used, nor on how this fodder is produced. In an analysis of the total beef production in Brazil, the resources used for growing, harvesting and transporting this complementary fodder should be included, as well as the emissions from these operations. However, it is still only around 5 % of the total beef -cattle population that is raised under these more intense conditions, so this data gap should be of minor importance for the final results. However, as more intense production systems for beef production are becoming more common, it is of great importance to include these systems in future environmental system analysis of Brazilian beef.

8.1.3 Summary of external resources used in production

The estimated use of input resources in the overall beef production that is considered in this study is summarized in Table 8.2.

Table 8.2 Summary of input of resources in beef production considered in this study

Activity	Amount	Source	Comment
Fertiliser application	400 000 tonnes P_2O_5 as single superphosphate	Fertiliser production according to Ecoinvent database	90 % of this is allocated to beef production*
Mineral feed	1 660 000 tonnes mineral feed	Production of mineral ingredients according to Ecoinvent database	
Pasture renovation	120 000 m^3 diesel	Ecoinvent database	90 % of this is allocated to beef production*
Production of silage crops as feed complements	No reliable data could be found		

* ~10 % estimated to be allocated to milk production

[15] No LCA-data for production of dicalcium phosphate were avialable in Ecoinvent´s database, instead LCA-data for the production of natrium phosphate were used

8.2 Transports and slaughterhouses

From ranch to slaughterhouse

The most common way to transport cattle from the ranch to the slaughterhouse is by using trucks of different sizes, the most common being the *caminhão trucado* (also popularly called *caminhão boiadeiro*). Each truck carries an average of 16-20 animals, depending on the weight and size of the animals. Here we assume 18 bovine animals per truck, and given that each animal weighs ~450 kg, the total weight is around eight tonnes for the animals per truck. An average load when transporting cattle has been calculated as 390-410 kg m^{-2} (Roça, 2001; Joaquim 2002). In a study of Pigatto (2001), the distance between farm and slaughterhouse was investigated by interviews at 19 slaughterhouses in São Paulo, see Table 8.3. This state is one the largest beef producers in Brazil, and has the largest share of exports (see Figure 4.4). The infrastructure is well developed, and it is reasonable to assume that the transport distances of cattle to the slaughterhouses in this state are shorter than average for the whole of the Brazil. We estimated an average distance from ranch to slaughterhouse at 200 km, which is slightly higher than the average distance recorded for slaughterhouses in São Paulo.

Table 8.3 Distance from farms to slaughterhouses in São Paulo

Distance, km, from farm to slaughterhouse	Share of cattle transported to slaughterhouse
<50	0.27
51 – 100	0.37
101 – 300	0.24
301 – 500	0.10
501 - 1000	0.02

The road system in Brazil encompasses 1.6 million km. According to the National Transport Confederation (CNT) there are 1.3 million km municipal roads, 210 000 km of state roads and 73 000 km of federal roads[16]. We estimate that at least 70 % of the roads in the most intense cattle producing regions are in regular, poor or very poor conditions, according to CNT's yearly evaluation. São Paulo is an exception, with 50 % of the roads labeled as being in "perfect" condition, and less than 10 % in "poor" and "very poor" condition. In the states of Mato Grosso and Rondônia, 30 % and 40 %, respectively, of the roads are labeled as being in "poor" or "very poor" condition.

Data for emissions from truck transports (lorry 16-32 ton, EURO3) were taken from the Ecoinvent database (Ecoinvent 2003). Due to the generally poor conditions of the roads where cattle are transported from farm to slaughterhouse, the use of diesel was estimated to be 25 % higher than under normal road conditions.

After the arrival at the slaughterhouse, the cattle must have a certain amount of time to recuperate. According to Brazilian law[17], the cattle must be able to rest for 24 hours prior to slaughter.

Slaughterhouse

Data for energy use at the slaughterhouse is taken from a Swedish study on LCA of beef (Anonymous, 2002), where 2.4 MJ electricity and 2 MJ fossil fuel were used per kg of bone free meat. Brazilian electricity mix and natural gas were used as energy sources in the calculation.

From slaughterhouse to port

From the slaughterhouse the meat is generally transported to the ports in trucks with refrigeration systems, and around 45 % are owned by the slaughterhouses themselves in São Paulo (Pigatto, 2001). Each truck can transport around 20 to 30 tonnes (here 25 tonnes are assumed) of meat per load, and data for emissions of GHG for the transport (Transport, lorry >32t, EURO3) are taken from the

[16] Numbers available on the homepage of the Brazilian National Transport Confederation www.cnt.org.br

[17] Article 110 of RIISPOA, Regulamento de Inspeção Industrial e Sanitária de Produtos de Origem Animal

Ecoinvent database (2007). Since the trucks are equipped with refrigerant or freezing systems, an extra energy use of 30% is added.

The Port of Santos stands for almost 50 % of meat exports and over 95% of all exported meat goes through ports located along the eastern coast of Brazil (Santos, Itajai, Rio Grande, Antonina, Ibituba, Paranagua, Rio de Janeiro São Fransisco do Sul, Vitoria, Sepetiba and Salvador). The distances from slaughterhouses to ports on the east coast were estimated as ~900 km from the central-western region, ~250 km from the southeastern region, ~300 km from the southern region, ~1 800 km from the northern region and ~600 km from the northeastern region. The average distance from slaughterhouse to the port of Santos was estimated at close to 400 km for slaughterhouses in the state of São Paulo. In this study, we estimate the distance from slaughterhouse to exporting port at 500 km.

The Brazilian port of Santos has experienced rapid growth, which has resulted in long queues/traffic jams at the port. Because of this, an additional energy use is added for the refrigeration systems, even when the trucks are not moving. The estimated amount of diesel used is 2.8 litre per hour, and we assume the extra waiting time to be two hours per truck.

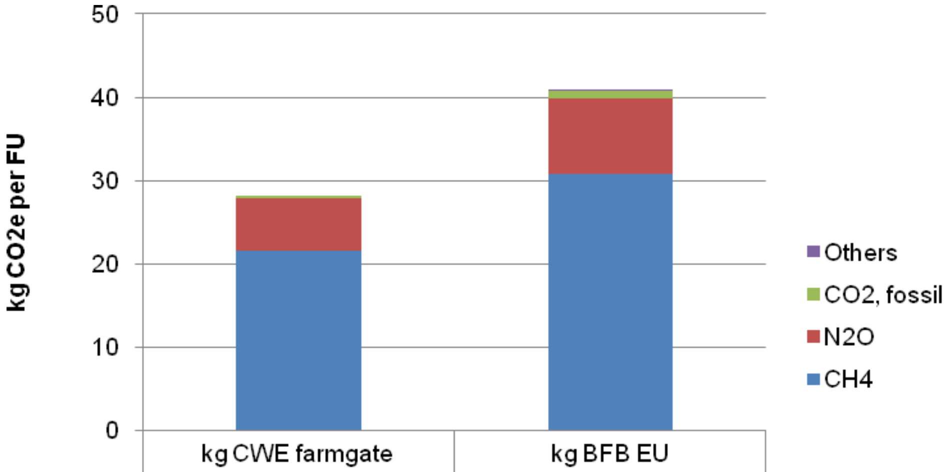
Port to Europe
From the Port of Santos the meat is transported in containers to Hamburg/Rotterdam by large freight ships, which use refrigeration (or freezing); this is a distance of 10 080 km. In Hamburg/Rotterdam the meat is reloaded, and for transports to Stockholm, Sweden, a smaller freighter is used (distance 1 000 km). Data for boat transports (transoceanic freight ship and barge for large and smaller ship) were taken from the Ecoinvent database (2007). Due to the refrigeration (or freezing) equipment on the boat transport, an extra 40 % energy use was added.

9 Results

As described in Chapter 2.2, the results are presented for a reference base, i.e. a functional unit (FU), which describes the function of the system studied. In this study, two different FUs were used; 1 kg carcass weight equivalent (CWE) meat at the farm-gate and 1 kg bone-free beef (BFB) exported to Europe (Stockholm).

9.1 Emissions of greenhouse gases

The emissions of GHGs for the average Brazilian beef production in 2005 were calculated ~28 kg CO_2e per kg CWE at the farm-gate and ~ 41 kg CO_2e per kg BFB exported to Europe, se Figure 9.1. The greenhouse gases are weighted into CO_2-equivalents by the factors 1 kg CO_2 = 1 kg CO_2e, 1 kg CH_4 = 25 kg CO_2e and 1 kg N_2O = 298 kg CO_2e (IPCC 2007).



	kg CWE farmgate	kg BFB EU
Others		0,2
CO2, fossil	0,3	1
N2O	6,3	9
CH4	21,6	30,8

Figure 9.1 Greenhouse gas emissions per i) kg CWE at the farm-gate, and ii) kg BFB exported to Europe

The total primary production (except emissions from land use changes) of beef cattle is included in the functional unit 1 kg CWE at the farm-gate, and GHG emissions total at 28.2 kg CO_2e CWE^{-1}. Methane (CH_4) from enteric fermentation makes up ~ 76 % of these emissions, and nitrous oxides (N_2O) approximately 22 %. CO_2 emissions from the use of fossil fuels are of minor significance for the Brazilian beef´s carbon footprint.

The overall life cycle of Brazilian beef, from primary production via slaughterhouse and transports to Europe (Stockholm) generates a GHG emission of about 41 kg CO_2e per kg BFB. When the emissions are presented in relation to the consumer product bone-free beef (BFB), a conversion factor from CWE must be used. Here we used 0.70, i.e. from 1 kg CWE, 0.7 kg BFB is produced (see section 2.2). Similarly, as when the results are related to CWE, methane from enteric fermentation is the pre-dominant source and make up to approximately 75 % of the total emissions. Emissions of CO_2 from the use of fossil fuel in transports are included in this functional unit; when this part of the production chain is considered, fossil CO_2 emissions from the whole life cycle are still of very little significance (around 2.5 % of total GHG emissions).

The data-gap for the production of supplementary fodder (cultivation, harvesting, transports) used in the more intensive beef production systems is very likely to be of minor importance in terms of the results for GHG emissions, since the use of fossil fuels in the overall production is so limited, being only about 5 % of the beef livestock that is raised in these systems.

9.2 Energy use

Energy is presented as Cumulative Energy Demand (CED), or primary energy. The energy use per kg CWE at the farmgate was calculated at close to 4 MJ kg^{-1}, of which non-renewable fossil fuel is the dominant source, see Figure 9.2. Production of mineral feed is the major part of the energy use in the primary production while diesel (for re-planting pastures) and fertilisers are of less significance.

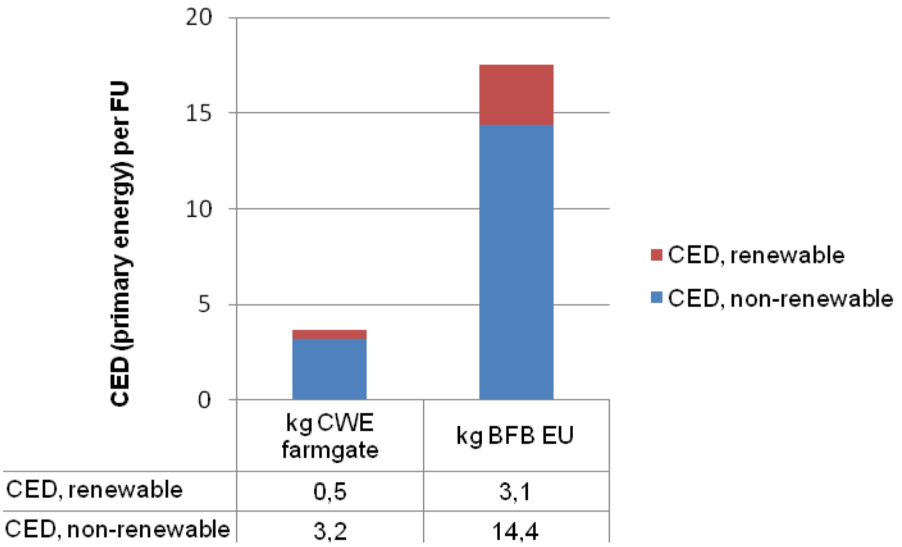


Figure 9.2 Primary energy (CED) MJ per i) kg CWE at the farmgate, and ii) kg BFB exported to Europe

For the whole life cycle of bone-free beef exported to Europe, the overall energy use is roughly17 MJ kg^{-1} BFB. Non-renewable fossil energy is around 80 % of this, and the rest is renewable, consisting mostly of hydro power for electricity used in the slaughterhouses. The use of energy for the life cycle up until the bone-free beef is transported to Europe can be divided up as ~30 % livestock production (farms), ~35 % transports and ~ 35 % slaughterhouses.

The data gap of inputs in the production of supplementary feed used in the more intensive systems results in an underestimation of energy use in primary production at the farms. However, even if this is underestimated by as much as 50 % (which is hardly the case since only 5 % of the livestock are raised under these conditions), the overall energy cost for the life cycle of one kg BFB exported to Europe would still not be more than 20 MJ kg^{-1} BFB.

9.3 Land use

Man´s use of land is an environmental intervention and in the LCA-methodology it is usually described as the occupation of a piece of land for a certain man-made purpose (in this study beef production) over a certain period of time. Here we calculated the land use for beef production in Brazil in 2005 at approximately 175 m^2 $year^{-1}$ for 1 kg CWE meat at the farm-gate and ~250 m^2 $year^{-1}$ for 1 kg of bone-free beef exported to Europe, see Figure 9.3.

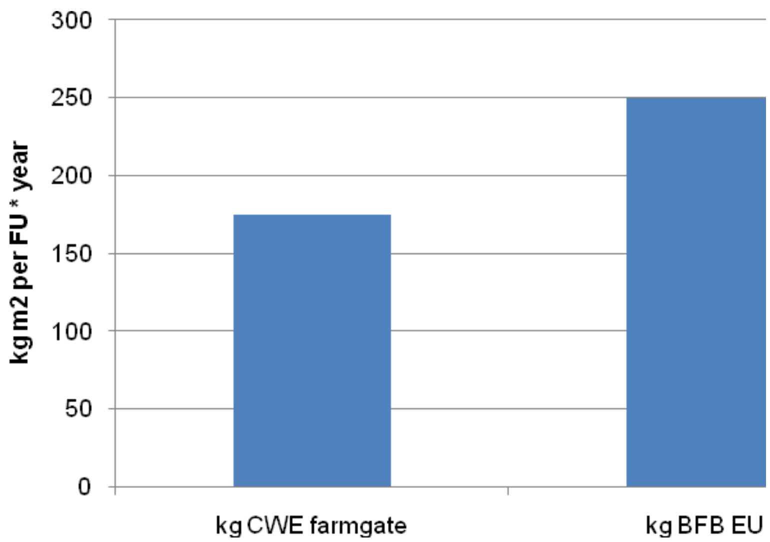


Figure 9.3 Land occupation m^2 per year for i) kg CWE at the farmgate; and ii) kg BFB exported to Europe

The estimate of yearly land occupation was based on statistics stating that there were ~172 Mha pastureland in Brazil in 2006 (IBGE 2007), and that around 20 Mha of this land was used for milk production (Wada & Ortega, 1996), i.e. not allocated to the production of beef. There are also other grazing livestock, such as buffalos, sheep and horses, and it was not possible to find data on the yearly land occupation for these animals. We assumed that those other grazing animals make use of ~10 Mha grasslands annually (which is half of the pasture area used by dairy cows).

It could be argued that of the pasture area reported, there is a significant share of land that is idle; native pasture (rangeland) with very low animal density and/or pastures in various degraded conditions. However, the official statistics from IBGE report all of the 172 Mha pasturelands as agricultural land, and as such, it is correct to include all of it since in some respect it is needed for the grazing animals. Also, the results for land occupation of beef production in Brazil shown in Figure 9.3 can be underestimated. According to the statistics, there are also around 100 Mha of the land category “bush and forest” (see section 5.1), which were reported as agricultural land in 2006 (IBGE 2007). According to the description in the official statistics of this land category, it can, to some extent, be used by grazing animals. No occupation of the land category “bush and forest” were included in our calculations. It is, however, interesting that this land category is steadily increasing (see Figure 8.1), and in 2006 it comprised as much as 100 Mha. Obviously, it provides some support function for Brazilian agriculture, including its grazing animals.

10 Discussion

10.1 Methane

The methane emissions caused by enteric fermentation for the year 2005 were calculated with FNP statistics on cattle population (~158 million heads, dairy cows not included, see Table 3.3). Using the most recent emission factors (EFs) suggested by Lima et al. (2007) results in an average emission of 0.85 kg CH_4 CWE^{-1}, and the EFs according to IPCC's guidelines of 2006 (Tier 1) gives an average emission of 0.9 kg CH_4 CWE^{-1} with the 2005 years production (8.152 MT) as denominator. If we instead use the EFs suggested in the first Brazilian inventory of GHG emissions from the early 1990s, approximately 67, 64 and 48 kg CH_4 hd^{-1} yr^{-1} for cows, adult males and young cattle, respectively, (EMBRAPA 2002a), and only consider calves as emitting methane from 7 months of age, the average emission is 0.91 CH_4 CWE^{-1}.

Emissions from enteric fermentation can also be estimated the other way around, by analysing the beef production system from a bottom-up perspective (see Figure 10.1). The young beef cow gives birth to her first calf at approximately four years of age (Zimmer & Euclides Filho, 1997). The calving interval is ~20 months (see Table 3.5), so when the cow is around ten years old, she has produced four calves. The average lifetime of a suckler cow is 10 – 12 years and this gives a life-time production of four to five calves per cow (EMBRAPA 2007). One of the calves replaces the beef cow to keep the cattle population intact, while three-four calves per beef cow are raised for meat production. The average age at slaughter is three years (see section 3.2).

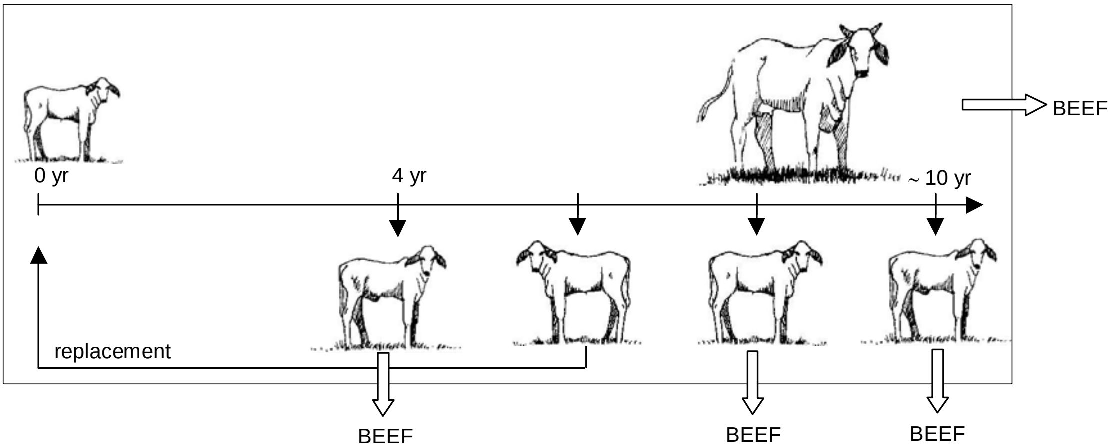


Figure 10.1 Approximate life time production of one beef cow

In Table 10.1, the total meat production from this beef cow - calves system is calculated with reasonable carcass weights per animal category; total meat production from the system is 860 kg CWE

Table 10.1 Approximate meat production from the system "one beef cow and her calves", raised until 36 months of age

Category, number	Production, kg CWE $head^{-1}$	Production, kg CWE total
1 beef cow	200	200
3 beef producers (2 bulls, 1 heifer)	220	660
1 heifer for replacement	-	-
Total		860

The total enteric fermentation CH_4 emissions from all the cattle in this beef cow – calves production system were calculated with EFs according to Lima et al. (2007), and they totalled approximately 875 kg CH_4, see Table 10.2.

Table 10.2 Methane production from the system "one beef cow and her calves", raised until 36 months of age

Category, number	Age	Average, kg CH_4 head^{-1} yr^{-1}	Total kg CH_4 during time period	Comment
1 heifer to cow	0 – 4 yr	44	176	47/2+47+49+57
1 beef cow	4 – 10 yr	57	342	57 x 6
3 beef producers	0 – 3 yr	40	357	(47/2+47+49)x3
1 replacement heifer*			0	
Total			875	

* Emissions from the heifer production are included in the beef cow above

This bottom-up approach for calculating CH_4 emissions from a pure beef system gives an estimate of approximately 1 kg CH_4 CWE^{-1}, i.e. approximately10 - 20 % higher than the top-down approach based on the total number of beef cattle according to statistics and total beef production in 2005. There are several explanations for divergent estimates in both directions. In the top-down calculation, the positive benefits of the by-products from dairy cows (surplus calves for meat production and meat from culled cows) are considered, and this lowers the average emission per kg meat produced. Beef produced in suckler cow systems has higher emissions per produced unit than beef produced as a by-product to dairy systems (Cederberg & Stadig, 2003). On the other hand, the example of the pure beef system illustrated in Figure 10.1 is idealised, since there is no correction for mortality, which is considered in the top-down calculation for the whole country since the calculated emissions are distributed on the reported meat production (CWE) solely. Finally, errors in the statistics can have great impact, e.g. Faminov (1997) reported on prevailing clandestine slaughter in the 1990s, and it is uncertain to what extent this still is an existing phenomenon. Also, the number of cattle varies in different sources of statistics, and there are probably errors in how the cattle are distributed in different age- and weight categories.

Lassey (2007) discussed the estimations of enteric fermentation emissions at different scales and concluded that an assessment of an enteric methane inventory requires that the livestock population and its feed intake are well characterised. In some countries, climatic extremes and variability (and regional variations of these) affect diet quality and availability, and impose changes in animal husbandry that are difficult to characterise. In addition, livestock population censuses may be too infrequent and/or unreliable, or fail to capture seasonal variations. According to Lassey, national enteric fermentation inventories rarely have less than ~20 % uncertainties.

In a country the size of Brazil, with its large and growing livestock production, which in only a decade has developed into the world´s largest beef exporter, there is an urgent need for more detailed basic data on beef production systems in different climatic regions. This was already concluded when the first inventory report on GHG emissions was compiled back in 2002 (EMBRAPA 2002a), and is even more inquired about today in light of Brazil´s increasing importance to global beef exports.

10.2 Nitrous oxide

In the first Brazilian inventory of greenhouse gas emissions, direct soil emission of N_2O from grazing animals was calculated at close to 142 000 tonnes N_2O-N, see Table 10.3. According to this inventory, beef cattle (non-dairy) make up close to 75 % (105 000 tonnes N_2O-N) of the total N_2O-emissions from grazing animals (EMBRAPA 2002b).

Table 10.3 Direct soil emissions of N_2O from manure from grazing animals in 1995 according to the first Brazilian Inventory of anthropogenic GHG emissions (Embrapa 2002b)

Livestock category	Tonnes N_2O-N	Share of total
Dairy cattle	14 300	0.10
Non-dairy cattle	105 000	0.74
Sheep	4 400	0.03
Buffalo, horses, goats, mules etc	17 900	0.13
Total	142 000	1

We estimated that the direct N_2O emissions from grazing beef cattle corresponded to a little more than to 100 000 tonnes N_2O-N in 2005, i.e. very similar to the Brazilian inventory results for 1995. There are, however, some disparities in the modes of calculation that influence these two estimates in both directions. We used the number of 158 million head corresponding to the cattle herd not including dairy cows for the year of 2005 (ANUALPEC/FNP 2008). In the Brazilian GHG inventory for the year of 1995, a total number of 161.2 million cattle were used, of which 140.6 million head were non-dairy cattle (EMBRAPA 2002b); and this number of total cattle population actually differs from the statistics in the latest Agro Census, which gives an estimate of a total cattle population in 1995 of 153.4 million head (IBGE 2007).

Here, we used the most recent IPCC guideline (IPCC 2006) for estimating the nitrogen content in dung and urine dropped in the pastures, and did a division in default values for different livestock categories of N excretion based on age and weights (see Table 7.1). In the Brazilian inventory, a fixed default value of 40 kg N $head^{-1}$ $year^{-1}$ was applied for all non-dairy cattle, which originated from the older IPCC guidelines from 1996. In this study, we calculated that all manure was dropped in pasture, although a small share of the livestock were kept in feed-lots. In the Brazilian inventory, it was estimated that around 20 % of the manure from non-dairy cattle in the southern region of Brazil were spread on arable lands as solid manure, which is probably a truer picture of reality than ours. Nonetheless, it is still a very small share of the total cattle population that are kept in feed-lots/paddocks, so our assumption that all manure is dropped in pastures should be of minor significance.

The indirect N_2O emissions in this study were calculated using conservative estimates. Ammonia emissions from manure dropped in pastures were calculated as 7 % of N in manure, which is an EF often used for this manure type under temperate conditions. The IPCC guidelines give a default value for estimates of ammonia losses from manure, stating 20 % of N for all types of manure with a very wide range of uncertainty (5-50 %). We did not calculate any indirect N_2O emissions caused by leaching of N from the pastures; this is motivated with the knowledge that non-fertilised pastures under temperate conditions have low N-leaching, and this should be valid for pastures in tropical areas as well.

All in all, estimates of N_2O emissions from agriculture in general, and grazing animals specifically, are afflicted with substantial uncertainties. The cattle population must be numbered correctly and characterised in different categories depending on age and weight. The nitrogen production in the dung and urine dropped in the pasture must be estimated, which is a difficult task when pasture is the overall dominant feed intake. It is difficult to assess the intake of nitrogen in the feed, and this N intake can vary considerably during a year due to changing climatic conditions. Finally, when having established the total amount of N in manure that is deposited on pastures from the cattle, a default emission factor according to the IPCC guidelines is used for calculating the total direct N_2O emissions from the grazing cattle. This default value is that 0.02 kg N_2O-N are emitted per kg N in manure that is applied in pastures by grazing cattle, but the range of uncertainty for this emission factor is large, ranging from 0.007 – 0.06 kg N_2O-N per kg N applied.

The direct N_2O emissions from grazing cattle calculated in this study is an estimate with a large range of uncertainty. However, the estimate is in good agreement with the results published in the first Brazilian inventory of GHG emissions from agriculture. To improve these estimates, we need better characterisation of the livestock population in Brazil, as well as their feed intake, and also more research on the processes of N_2O-emissions from soils, so that the emission factor can be set with a lower range of uncertainty than is the case today.

10.3 Land use

The total land area of Brazil is ~850 Mha and, of this, close to 250 Mha (approximately 30 %) was registered as agricultural land (cropland and pasture) in the latest preliminary Agro Census (IBGE 2007). Since approximately 100 Mha out of a total of 172 Mha pastureland is planted, there is still a substantial share of native pasture (so-called rangeland) with low carrying capacity. This, in combination with the fact that a significant share of the planted pastures are in some form of degraded condition, leads to that large area of the agricultural land has low productivity.

Two primary biomes are important for providing land area for Brazil´s beef production, the *Cerrado* (the central savanna region) and the Amazonas forest region. The *Cerrado* encompasses around 200 Mha and it is estimated that more than half of this area has been transformed into pasture, cash-crop agriculture and other uses in a time-period of only 35 years. Cultivated pastures (planted mostly with the grass *Brachiaria spp* in monoculture) cover around 50 Mha of the Cerrados, approximately a forth of the area (Klink & Machado, 2005). The land transformation of the Cerrado region in recent years has had a high environmental cost: loss of biodiversity, invasive species, soil- and water erosion, not to mention emissions of carbon dioxide; although one should bear in mind that the carbon emissions are much less than those stemming from land transformation in the Amazon region. Today most of the cultivated pastures in the Cerrado region experience some degree of degradation, which means that they have lost some of their capacity to produce biomass (da Silva et al., 2004). It is noteworthy that the deterioration of the pastureland as a resource has become large-scale, after only a few decades of man’s activity and that overgrazing is the predominant cause of this. Costa & Rehman (2005) investigated farmers´ motives to uphold high stocking rates in the Cerrado region, despite the negative effects on pasture productivity. They showed that farmers regarded their cattle as a very valued asset and that in some cases, the benefits of holding more cattle could compensate for the increasing costs of pasture recovery and/or maintenance. Costa & Rehman (2005) therefore argue that when the problem of pasture degradation is to be addressed, merely giving farmers advice not to overgraze is an incomplete solution to the problem.

Brazil´s Legal Amazon covers approximately 500 Mha of which 400 Mha was originally forested. Up until 2003, ~65 Mha of this native forest had been cleared, which corresponds to roughly 16 % of the original forest (Fearnside 2005). Soares-Filho et al. (2006) estimate that if current trends in agricultural expansion continue, as much as 40 % of the forests in the Amazon basin could be eliminated by 2050. Such a development would have severe impacts not only on the rate of carbon emissions, but also for loss of biodiversity and sustaining water cycling in the Amazonas. It is estimated that more than 70 % of the forest cover of Amazon landscapes may be necessary to maintain the forest-dependent rainfall regime (Soares-Filho et al., 2006).

Pastureland makes up the principal use of cleared land in the Brazilian Amazon. According to Cerri *et al* (2005), five to ten years after they are established, many pasture areas begin a process of degradation that is characterized by a decline in grass productivity and an increase in the cover of weeds. As previously described, cattle farmers holding livestock levels above the pasture´s carrying capacity is the core reason for this. But Arima et al. (2006) also point to the fact that cattle ranchers start operations in regions of the Amazon that are non-suitable for agriculture, due to high rainfall and poor soils. Thus, poor land management and the establishment of beef production in regions of low agricultural potential are important causes for the ongoing land transformation in the Amazon; this results in carbon- and species rich forests being replaced by a cattle production system with an extremely low production per area unit. Nepstad et al. (2008) suggest that this can even be said to violate Brazil's own constitution, which stipulates that the social function of the land is to provide maximum socio-economic benefits to society. Current expanding beef production in the Legal Amazon is yielding an extremely low output per area unit, in terms of beneficial products, at a very high social and environmental cost.

The necessity of urgent improvements of land management methods in the beef production in the Brazilian Amazon is obvious. Environmental legislation states that cattle ranchers must set aside 80 % of their land holdings as forest reserves, and according to Nepstad et al. (2006), the profits of cattle producers can decline to nearly zero when complying with this regulation. Nepstad and colleagues therefore argue that one way to compensate beef producers for the costs of complying with environmental regulations is to establish a system of environmental certification recognised by markets in Brazil and abroad, and thereby possibly achieve higher beef prices on world market.

10.4 Comparisons with beef production in Europe

In Table 10.4, the results of GHG emissions per kg CWE at the farm-gate are compared with some European studies. Results on emissions from European beef production are based on data from the EU study "Environmental Improvement Potentials of Meat and Dairy Products" (IMPRO-meat and dairy) (Nguyen et al., 2009) and in Table 10.4 results are presented for one "pure" beef production system (cow-calf) and two production systems of bull calves from dairy cows with slaughter age at 16 and 24 month respectively. Approximately two-thirds for beef production in the EU has its origin as by-products in milk production (surplus calves, mostly bulls and culled cows) and a rough estimate of the average emissions from EU beef production is ~19 kg CO_2e kg^{-1} CWE (Hermansen J E., pers comm. 2009). The Swedish results presented in Table 10.4 comes from a study of organic beef production on a big farm (1700 cattle, 2 275 ha, mostly pastures) with a suckler cow-calf system and the livestock kept outdoors all year around, fed with silage during the winter (Cederberg & Nilsson, 2004). A top-down analysis of the whole Swedish beef production in 2005 where approximately 65 % of the beef is derived from dairy sector (i.e. by-products) gives an estimate of close to 19 kg CO_2e kg^{-1} CWE at the farm-gate (Cederberg et al., 2009), very close to the estimate for the average European beef production.

The GHG emissions in the primary production (not including land-use changes) are at least 30-40 % higher in Brazilian beef production compared to European. High emissions of methane is the main cause and explained by high slaughter ages and long calving intervals, and also that the majority of beef is produced in suckler cow-calf systems. The very low use of fossil energy (fertilisers, diesel, feed) in Brazilian leads to very low emissions of fossil CO_2 per kg beef while emissions of nitrous oxide (mostly direct emissions from manure dropped in grazing) are in the same range as European production.

Table 10.4 Emissions of GHGs in primary production, kg CO_2e per kg carcass weight at the farm-gate, for Brazilian and European beef production. Land use changes not included.

	Brazil top down national average	**EU** beef production systems			**Sweden*** cow-calf, organic ranching 26 m slaughter
		Cow-calf, 16 months slaughter	Dairy bull calves, 16 m slaughter	Dairy bull calves, 24 m slaughter (steers) grassland	
CO_2	0.3	4.1	2.9	3.3	0.6
CH_4	21.6	12.1	7.1	10.1	15.6
N_2O	6.3	10.1	4.7	9.1	4.2
Total	~28	~27	~15	~22	~21

* In this study, the original functional unit was bone-free meat, by-products hides were considered and GWP were weighted with 21 kg CO_2e per kg CH_4. Here the results are re-calculated to CWE at farm-gate, no allocation for hides are accounted for and weighting factor is 25 kg CO_2e per kg CH_4 to make the results comparable.

The results for GHG emissions shown in Table 10.4 do not include effects of land use and land use changes. Croplands in Europe (arable farming) are known to be a carbon source while permanent grasslands act as carbon sinks. Studies on temperate grassland ecosystems in Europe and North America show a carbon sequestration of 200 – 600 kg C ha^{-1} yr^{-1} (Jones & Donelly, 2004). Recent studies of European grasslands reveal an even higher carbon sink capacity, around 1 t C ha^{-1} yr^{-1}, when well-managed (Soussana et al., 2007). European beef production based on grazing permanent grasslands and a large share of grass/clover fodder in the winter feed ration provide a land use that benefits carbon sequestration. One example of such a production system is the Swedish suckler cow-calf system in organic ranching, see Table 10.4. This production system is almost exclusively based on permanent grasslands and if the annual carbon sink capacity is around 500 kg C ha^{-1} yr^{-1} on this land, a considerable share of the estimated emissions of ~21 kg CO_2e kg^{-1} CWE is compensated due to this positive land use. Due to the problems with degradation of many pasturelands in Brazil, the conditions are low for a similar carbon sink capacity. Furthermore, the on-going pasture expansion into Amazon forest, corresponding to an increase of close to 19 Mha pastures in the nine states of the Legal Amazon between 1985 and 2006 (IBGE 2007), leads to additional emissions of CO_2 from the land transformation process, this is discussed in a coming paper.

Table 10.5 Use of primary energy, MJ per kg carcass weight at the farm-gate, for Brazilian and European beef production

	Brazil top down national average	**EU**, different production systems (Nguyen et al, 2009)	**Sweden** cow-calf, organic ranching,
MJ, primary energy	~4	39 – 49	~9

The use of energy in Brazilian beef production is very low. The estimate in this report is around 4 MJ per kg CWE at the farm-gate, although this can be slightly underestimated due to data gaps on the production of supplementary feed. In average, European beef production (as seen in Table 10.5) has a use of energy that is around ten times as high as this. Generally, the more intense the system is (which often is the fact in European production), in terms of use of concentrates and time in stable, the higher is the use of energy. The study of a Swedish organic suckler cow-calf system (Cederberg & Nilsson, 2004) is an exception; this is a beef production system seldom found in northern Europe, in which the cattle herd are hold outside in pastures all year around (no stables), and fed only with organically grown clover/grass silage during the winter. It should however, be emphasised that there are not many of this kind of system, and that it is a rare exception from standard northern European beef production systems.

Table 10.6 Yearly use of land, m^2 per kg carcass weight at the farm-gate, for Brazilian and European beef production

	Brazil, top down national average	**EU**, different production systems (Nguyen et al, 2009)	**Sweden** cow-calf, organic ranching,
m^2 per kg CWE and yr	~175	17 - 43	~130

The EU study shows a land use in different beef system in range of 17-43 m^2 kg CWE^{-1} yr^{-1}, see Table 10.6. The results in this study of Brazilian beef, estimating a land use of approximately 175 m^2 CWE^{-1} yr^{-1}, is substantially much higher than the European production, and this fact further underscores the discussion in previous sections of the lack of efficient land use in current beef production in Brazil.

A comparison with land use in the Swedish organic ranching system (Cederberg & Nilsson, 2004) is interesting. This is one of very few farms in Sweden that has cattle ranching with outdoor grazing all year around, and where supplementary fodder (organic grass/clover silage) is given outdoors in the winter. This farm is located close to valuable bird habitats, including lakes and wetlands near a densely populated urban area[18] and the positive landscape effects from grazing cattle are much appreciated by the public. The ranch receives substantial environmental subsides from the government for producing other services than beef, such as biodiversity and a beautiful landscape, and therefore the farm´s primary strategy is not to optimise (minimise) the land use per produced beef unit. This is in sharp contrast with most European meat production systems, where optimising land use is of great importance since the land resource has a high price. Despite the fact that this organic ranching production, producing beef as well as biodiversity, and being subsidised for these environmental services which requires an extensive use of the land resource, the land use is still lower than average Brazilian beef production. This is another example of the land-inefficiency in the Brazilian beef production of today.

10.5 Conclusions

It would have been preferable to have conducted this study using a bottom-up perspective, analysing the environmental impact of some of the different basic Brazilian beef production systems that were well defined, with data on production of feed and animal productivity. Unfortunately, such data are not available. In the Brazilian inventory of GHG emissions (EMBRAPA 2002a), a discussion was included on the problematic issue of the non-availability of systematic data on animal weights, food consumption, production of residues and energy consumption, and that this, in turn, can lead to uncertainties in the estimates of methane emissions from Brazilian agriculture. The same goes for this study, that lack of basic data on production systems makes it necessary to exercise great caution when interpreting the results.

Not being able to find unambiguous clear-cut data on the number of livestock is troublesome. We have used the AgraFNP data of 175 million head of cattle (dairy cows included) in 2005, and this source gives the number of 170 million head in 2006, in good agreement with the preliminary results from IBGE census in 2006. However, there are also numbers presented showing a total cattle population of around 200 million heads in 2005, for example, by the CNPC on the official home page of the Brazilian beef association. It is obvious that the calculation of methane emissions is very dependent on a reasonably correct number of cattle, since the emission factor is set per animal head and it underscores the need for more detailed basic data on different beef production systems in Brazil.

The Brazilian Ministry of Agriculture is forecasting a 93 % increase in beef exports in the coming decade, requiring increase of production of close to 50 % in 2019. How this projected Brazilian beef expansion will turn out is of major importance for the overall GHG emissions from global livestock production, today amounting to ~18 % of the world´s total emissions of which land use changes due to pasture expansion in south America is a major source (Steinfeld et al., 2006; Wassenaar et al., 2007, McAlpine et al 2009). Improved land management is the first and absolutely necessary measure to take in order to substantially reduce and halt the on-going land expansion into natural ecosystems. Pasture degradation can be prevented by maintenance fertilisation and avoidance of high stocking rates, especially in dry periods. Methane emissions can be reduced by improving livestock performance, e.g. by shortening calving intervals and lowering slaughter age but also by improved pasture management. Overall productivity would benefit from using more supplementary feed as complement to pasture in dry periods and also by increasing the use of more intense production forms, such as feed-lots and integrated livestock-cropping systems.

[18] Lund-Malmoe region in the SW of Sweden
[19] www.meatinternational.com/news/brazilian-beef-exports-to-nearly-double-by-2018-19-id1129.html

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Appendix

Appendix 1

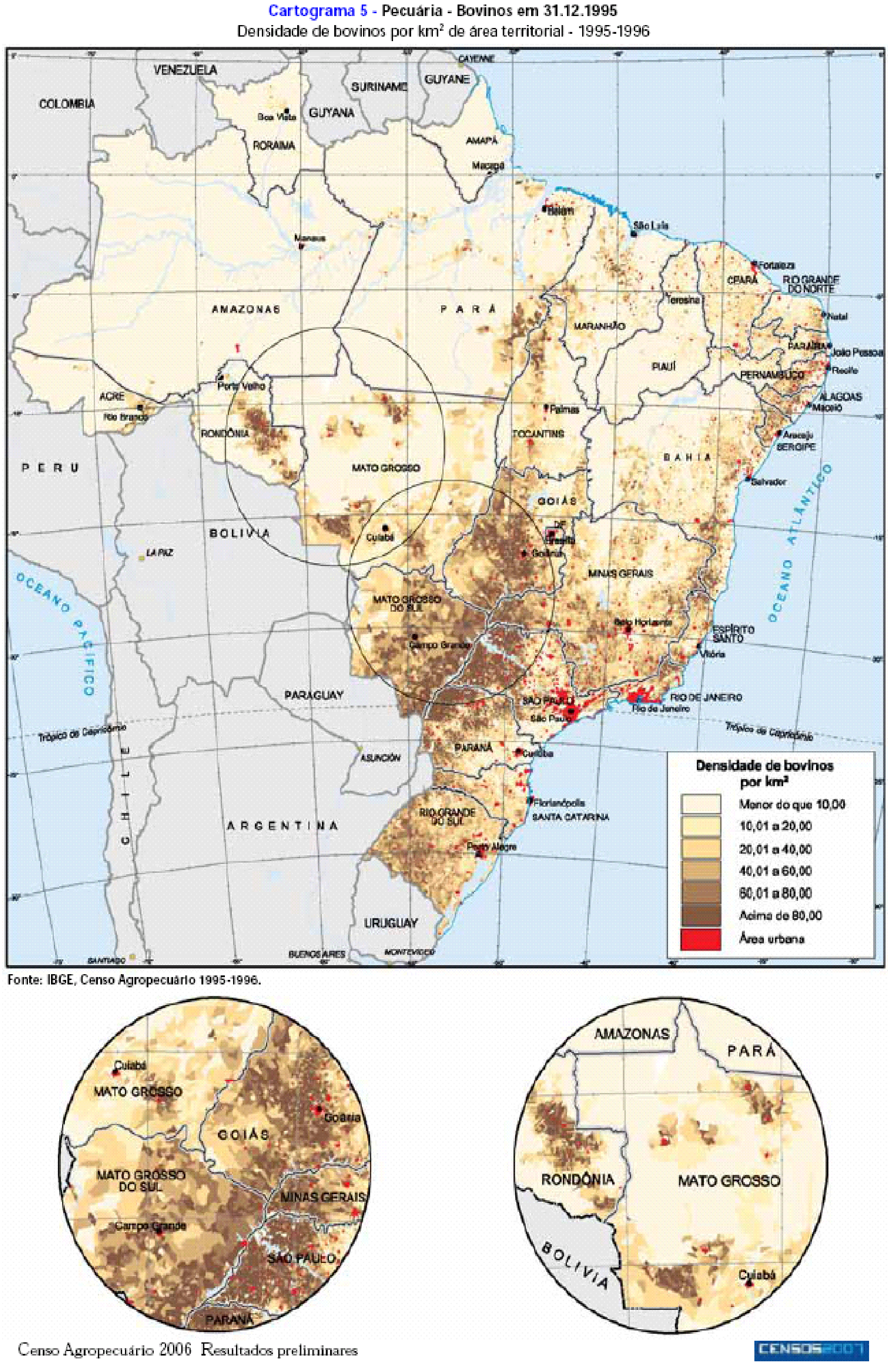

Figure 1 Density of cattle in Brazil per km2 1995. Red = urban areas, white areas <10 head/km2, dark brown> 80 head/km2. Source: IBGE (2007)

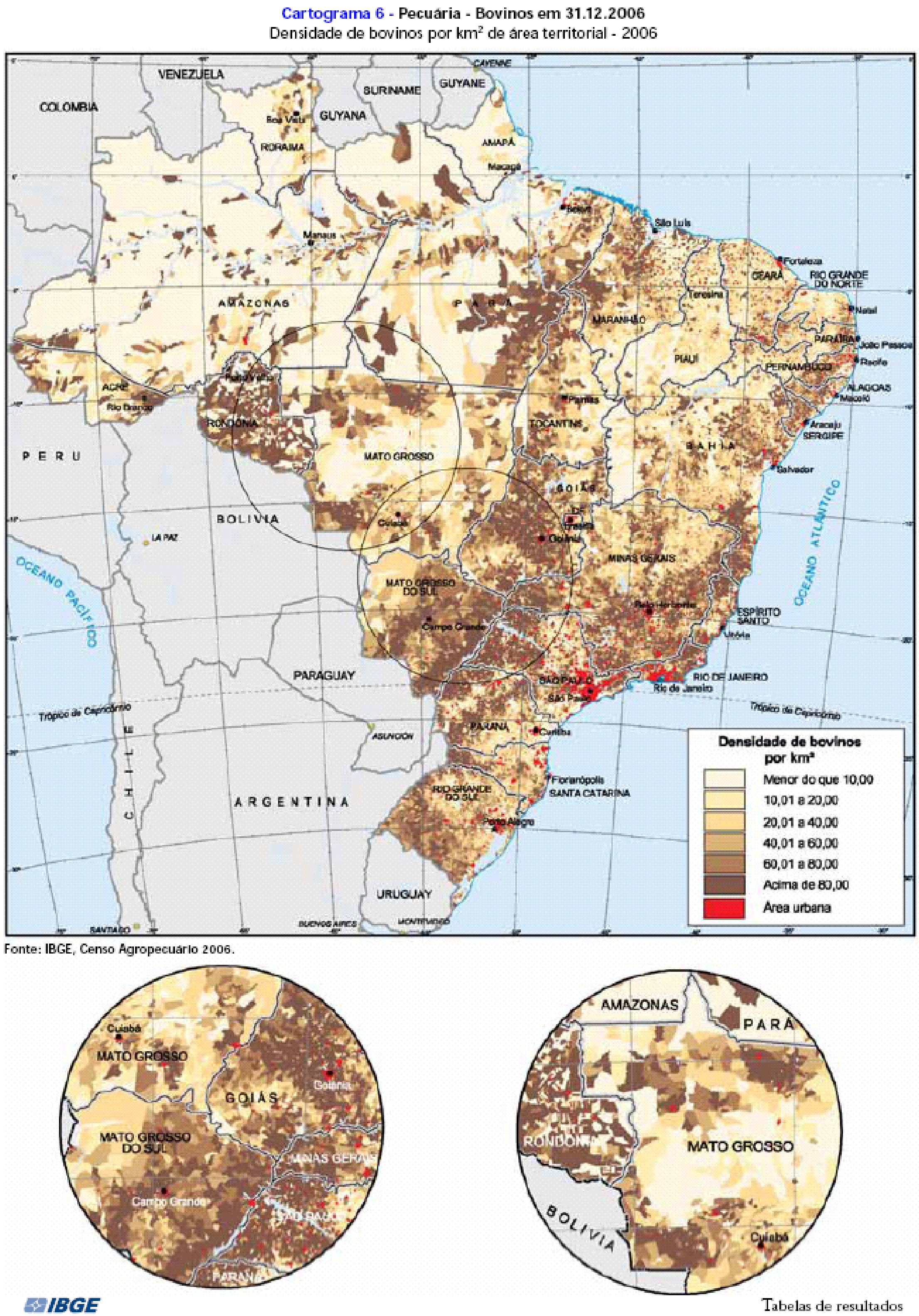

Figure 2 Density of cattle in Brazil per km2 2006.. Red = urban areas, white areas <10 head/km2, dark brown> 80 head/km2. Source: IBGE (2007)

Appendix 2

Table 1 Production data and export, Brazil

	Source	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total cattle population, million head	1)	n. d.	n. d.	154,2	155,8	158,3	162,6	167,2	172,2	175	176,1	175,1	169,9	167,5
Slaughtered cattle, million head	2)	n. d.	n. d.	34,2	35,6	34,8	34,4	35,7	37,1	38,9	41,1	44,3	47,1	42,1
Slaughtered share of total cattle population	3)			0,22	0,23	0,22	0,21	0,21	0,22	0,22	0,23	0,25	0,28	0,25
Production, x 1 000 ton CWE	4a)	6077	6372	6444	6709	6567	6456	6754	6952	7159	7577	8152	8600	7783
Production, x 1 000 ton CWE	4b)	5251	5977	5867	6196	6396	6682	7151	7540	7792	8488	8778	9053	9298
Average kg CWE/slaughtered cattle	5)			188	188	189	188	189	187	184	184	184	183	185
Domestic consumption, x1000 ton CWE	6)	n. d.	n. d.	6269	6418	6086	5959	6003	6089	6009	5994	6337	6525	5615
Import, x1000 ton CWE	7)	n. d.	n. d.	112	79	42	57	38	66	58	48	43	25	26
Total population, million	8)	154,9	157,1	159,6	161,8	163,9	169,8	172,4	174,6	176,9	181,6	184,1	184,0	184
Average consumption, kg CWE/cap	9)			39,3	39,7	37,1	35	34,8	34,9	34	33	34,4	35,5	30,5
Export, x 1 000 CWE,	10a)		280	287	370	541	554	789	929	1208	1630	1857	2100	2194
Export, x 1 000 CWE	10b)		278	287	377	560	592	858	1066	1301	1854	2198	2200	2350
Export, million US$	11a)		431	428	573	762	755	991	1075	1493	2410	2944	3789	4180
Export, million US$	11b)		440	436	588	785	786	1022	1107	1510	2452	3033	3800	4500

1) ANUALPEC/FNP (2006): 1997-1998; ANUALPEC/FNP (2008): 1999-2007
2) ANUALPEC/FNP (2006): 1997-1998; ANUALPEC/FNP (2008): 1999-2007
3) Own calculation: Slaughtered cattle divided by total cattle population
4a) ANUALPEC/FNP (2006): 1997-1998; ANUALPEC/FNP (2008): 1999-2007; www.bndes.gov.br/conhecimento/bnset/carne.pdf: 1995-1996
4b) CNPC (National Beef Council – Brazil): www.abiec.com.br/estatisticas
5) Own calculation, total CWE production according to ANUALPEC/FNP (4a) divided by number of slaughtered animal (2)
6) ANUALPEC/FNP (2006): 1997-1998, ANUALPEC/FNP (2008): 1999-2007
7) ANUALPEC/FNP (2006): 1997-1998, ANUALPEC/FNP (2008): 1999-2007
8) www.ibge.gov.br/home/estatistica/populacaol/estimativa2008/default.htm: 1995-2006; ANUALPEC/FNP (2008): 2007
9) Own calculation, total domestic CWE consumption (6) divided by total population (8)
10a) ANUALPEC/FNP (2006): 1996 – 1998; ANUALPEC/FNP (2008): 1999-2007

10b) CNPC (National Beef Council – Brazil): www.abiec.com.br/estatisticas data sources:MDIC/SECEX)
11a) ANUALPEC/FNP (2006): 1996-1998, ANUALPEC/FNP (2008): 1999-2007
11b) CNPC (National Beef Council – Brazil): www.abiec.com.br/estatisticas (data sources: MDIC/SECEX)

Table 2 Production data and export, Legal Amazon

	Source	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total cattle population, million head	1)	n.d.	n.d.	39,0	40,6	42,8	46	48,2	51,6	54,1	55,9	56,9	56,5	56,8
Slaughtered cattle, million head	2)	n.d.	n.d	5,8	6,3	6,4	6,7	7	7,8	8,8	9,7	10,5	11,3	10,5
Slaughtered share of total cattle population	3)	n.d.	n.d	0,15	0,16	0,15	0,15	0,15	0,15	0,16	0,17	0,18	0,20	0,18
Production, x 1 000 ton CWE	4)	n.d.	n.d	1095	1190	1241	1311	1366	1505	1661	1843	2016	2155	2026
Average CWE/slaughtered cattle	5)			189	189	194	196	195	193	188	190	192	191	193
Export, million kg as meat products, **PWE**	6)	n.d.	1,1	4,1	14,8	31,5	23	34,7	43,2	63,1	59,7	115	277	349
Export, million US$	7)	n.d.	1,0	11,5	44,7	90,6	59,1	67,4	74,4	111,9	114,8	231,2	704,0	881

1) ANUALPEC/FNP (2006): 1997 – 1998; ANUALPEC/FNP (2008): 1999-2007
2) ANUALPEC/FNP (2006): 1997 – 1998; ANUALPEC/FNP (2008): 1999-2007
3) Own calculation. Slaughtered cattle divided by total cattle population
4) ANUALPEC/FNP (2006): 1997-1998; ANUALPEC/FNP (2008): 1999-2007
5) Own calculation. Production CWE (4) divided by number of slaughtered cattle (2)

6) SECEX/MDIC, External Trade Secretary (SECEX) of the Ministry of Development, Industry and Trade (MDIC). 1996-2003: http://aliceweb.desenvolvimento.gov.br (only Brazilian citizens have access to this homepage); 2004-2007 http://to.gov.br/redirect.php?url=http://www.sefaz.to.govbr/ (data on export compiled by the state of Tocantins, Department of Finance Management Oversight of Tax) that refer to SECEX/MDIC

N. B: Export figures for Legal Amazon are given as product **meat products**, not as CWE

7) Same as 6

Appendix 3

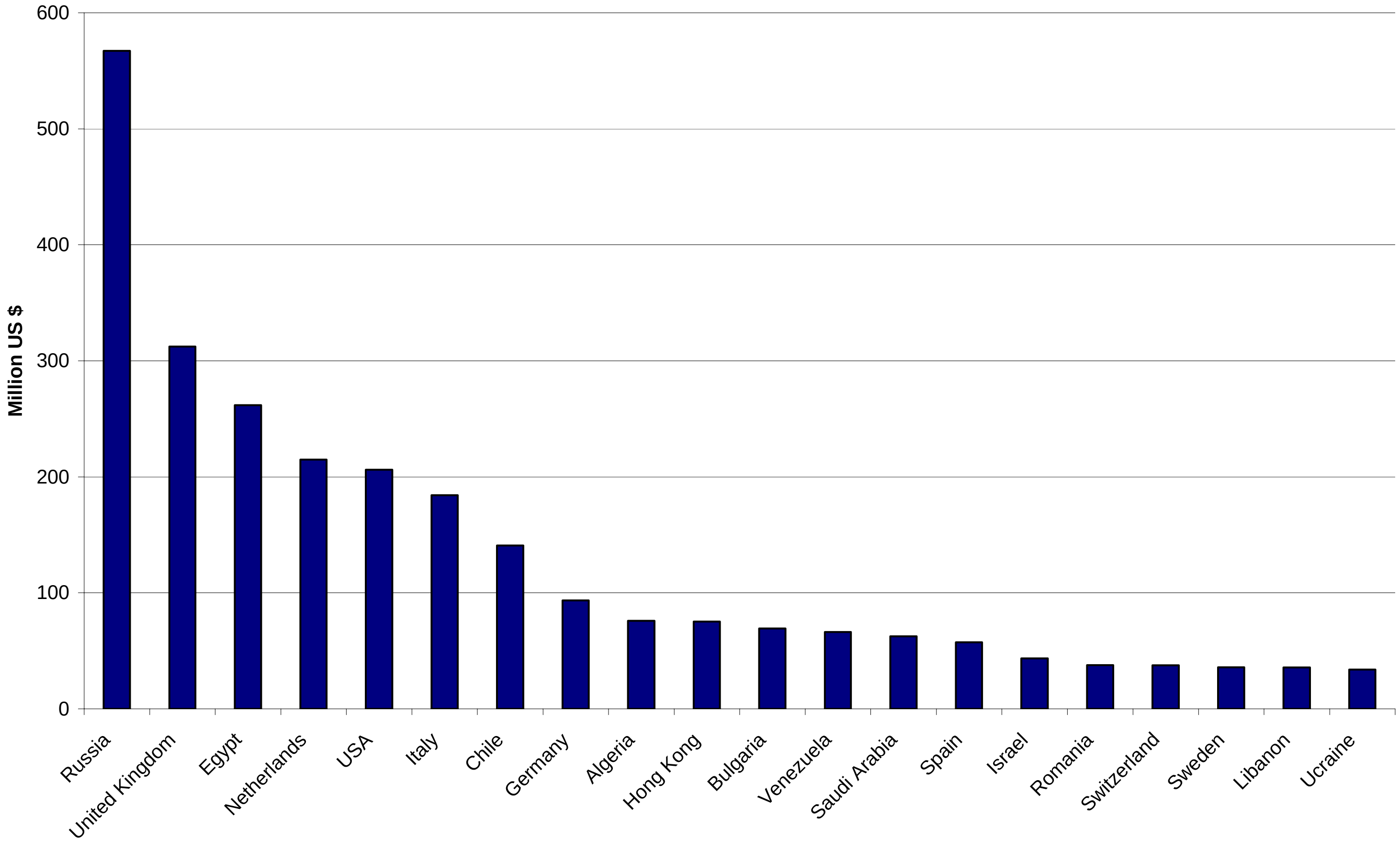

Figure 1 Destination of exports, top 20 nations, 2005
(www.abiec.com/estatisticas_relatorios.asp, with data on exports from MDIC/SECEX)

Appendix 3

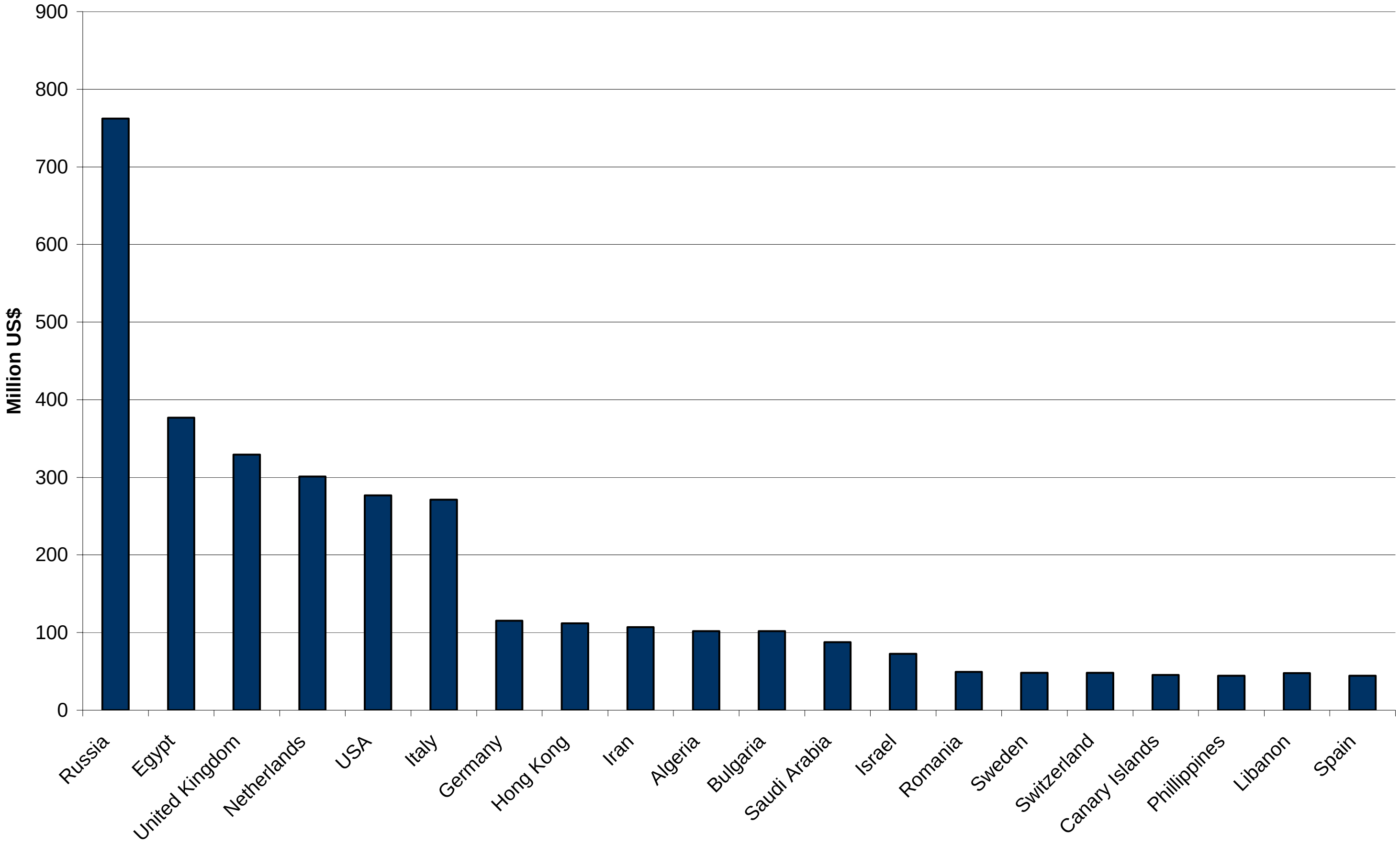

Figure 2 Destination of exports, top 20 nations, 2006
(www.abiec.com/estatisticas_relatorios.asp with data on exports from MDIC/SECEX)

Appendix 3

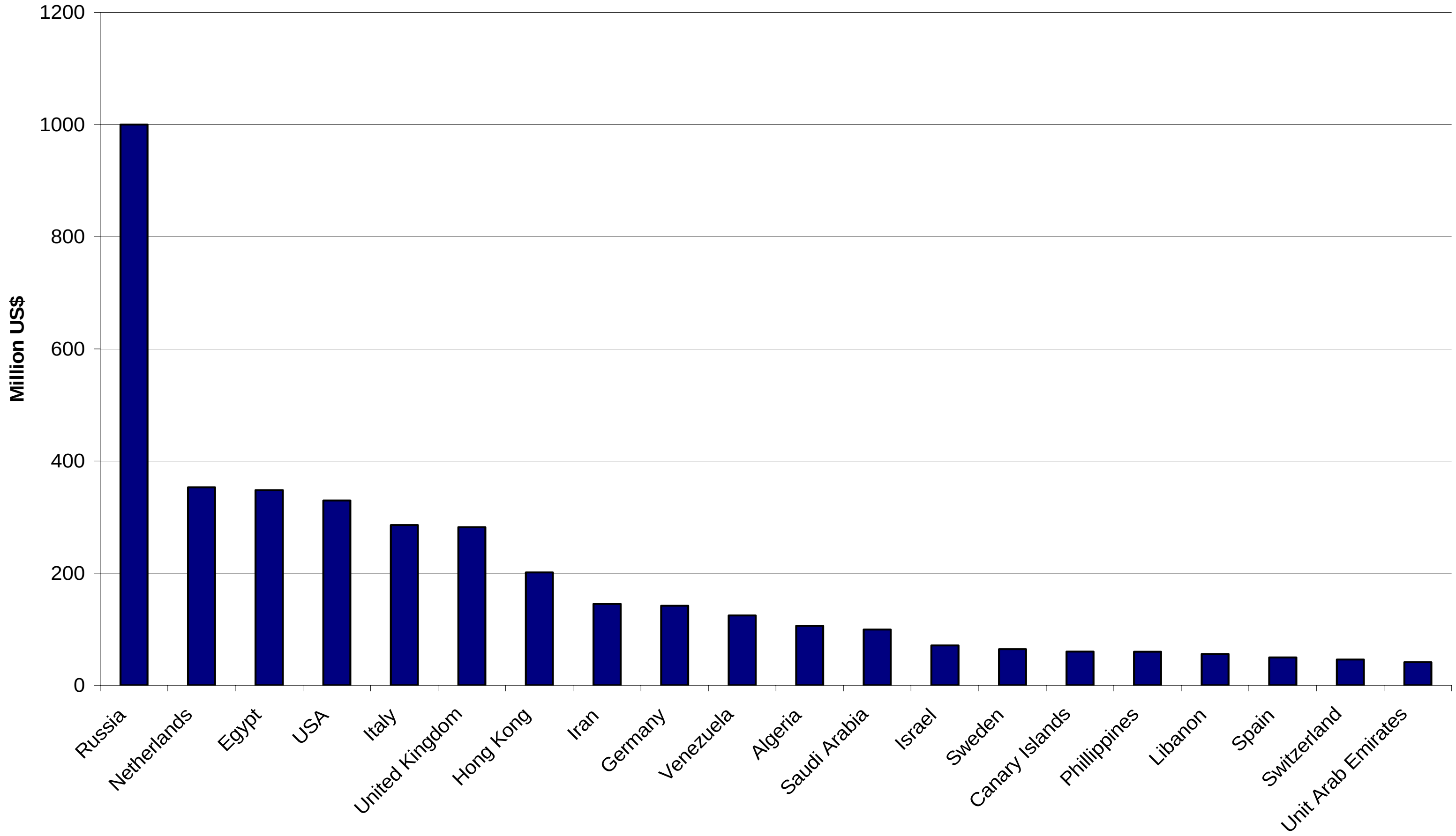

Figure 3 Destination of exports, top 20 nations, 2007
(www.abiec.com/estatisticas_relatorios.asp with data on exports from MDIC/SECEX)

Appendix 4

Table 1 Calculations of CH_4 emissions 2005 due to enteric fermentation from beef cattle, emission factors IPCC 2006

Livestock cat	Livestock, cat	Age	Live weight, kg	Number	kg CH_4/head * yr	Ton CH_4
Touros	Bulls		450	2 317 980	61	141 397
Vacas	Cows (a)		400	45 016 120	64	2 881 032
Bez. (a)	Calves (heifer) (b)	0-12 months old		23 985 041	23,4	561 250
Bez. (o)	Calves (bull) (b)	0-12 months old		23 835 775	23,4	557 757
Novilhas	Heifers	1-2 years old	230	20 487 811	49	1 003 903
Novilhas	Heifers	2-3 years old	230	13 136 849	49	643 706
Garrote 1 – 2	Bulls, Steers	1-2 years old	230	17 018 164	49	833 890
Machos 2 - 3	Bulls, Steers	2-3 years old	230	9 181 984	49	449 917
Bois 3-4	Castrated Bulls	3-4 years	450	2 918 103	61	178 004
Bois >4	Castrated Bulls	> 4 years	450	589 894	61	35 984
Total				158 487 721		7 286 839

a) From the total number of cows, 16 567 949 dairy cows are deducted

b) EF for calves are estimated at half of the EF for the second year (see text)

c) estimated live weight according to IPCC 2006

Table 2 Calculations of CH_4 emissions 2005 due to enteric fermentation from beef cattle, emission factors Lima et al (2007)

Livestock cat, port	Livestock, cat	Age	Live weight, kg	Number	kg CH_4/head * yr	Ton CH_4
Touros	Bulls		>500 c	2 317 980	69,7	161 563
Vacas	Cows (a)		350-400	45 016 120	57	2 565 919
Bez. (a)	Calves (heifer) (b)	0-12 months old		23 985 041	23,4	561 250
Bez. (o)	Calves (bull) (b)	0-12 months old		23 835 775	23,4	557 757
Novilhas	Heifers	1-2 years old	180-250	20 487 811	46,7	956 781
Novilhas	Heifers	2-3 years old	250-350	13 136 849	49,3	647 647
Garrote 1 – 2	Bulls, Steers	1-2 years old	180-250	17 018 164	46,7	794 748
Garrote 2 - 3	Bulls, Steers	2-3 years old	230-350	9 181 984	49,3	452 672
Bois 3-4	Castrated Bulls	3-4 years	350-450	2 918 103	57	166 332
Bois >4	Castrated Bulls	> 4 years	>450	589 894	69,1	40 762
Total				158 487 721		6 905 430

a) From the total number of cows, 16 567 949 dairy cows are deducted

b) EF for calves are half of the EF for the second year (see text)

c) estimated live weight according to Lima et al (2007)

Appendix 5

Table 1 Calculations of N2O, direct emissions, in 2005

Livestock cat	Livestock, cat	Age	Est average LW, kg	Number	kg Nexcre/head*yr	Ton N	Ton N2O-N	Ton N2O
Touros	Bulls		> 450	2 317 980	59	136 761	2 735	4 294
Vacas	Cows (a)		400	45 016 120	52	2 340 838	46 817	73 502
Bez. (a)	Calves (heifer)	0-12 months old	100	23 985 041	13	311 806	6 236	9 791
Bez. (o)	Calves (bull)	0-12 months old	100	23 835 775	13	309 865	6 197	9 730
Novilhas	Heifers	1-2 years old	230	20 487 811	30	614 634	12 293	19 300
Novilhas	Heifers	2-3 years old	310	13 136 849	40	525 474	10 509	16 500
Machos 1 – 2	Bulls, Steers	1-2 years old	230	17 018 164	30	510 545	10 211	16 031
Machos 2 - 3	Bulls, Steers	2-3 years old	310	9 181 984	40	367 279	7 346	11 533
Machos	Castrated Bulls	3-4 years	400	2 918 103	52	151 741	3 035	4 765
Bois + 4	Castrated Bulls	> 4 years	>450	589 894	59	34 804	696	1 093
				158 487 721		5 303 747	106 075	166 538

a) From the total number of cows, 16 567 949 dairy cows are deducted

Table 2 Calculations of N2O, indirect emissions, in 2005

N in excrements	EF, NH3-loss	Ton NH3-N	E-fakt N2O-N	Ton N2O-N	Ton N2O
5 303 747	0,07	371262	0,01	3 713	5829