TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Civil Engineering and Architecture

A COMPARATIVE ANALYSIS ON BEEF PRODUCTION IN CONFINED VS FREE-ROAMING PRODUCTION SYSTEM USING THE TOOLS OF LCA AND FOOTPRINT ANALYSIS TO ASSESS THE DAMAGES TO THE ENVIRONMENT

VEISELIHA TOOTMISE VÕRDLEV ANALÜÜS PIIRATUD JA VABAPIDAMISEGA TOOTMISSÜSTEEMIS, KASUTADES ELUTSÜKLI (LCA) JA JALAJÄLJE ANALÜÜSI TÖÖRIISTU, ET HINNATA MÕJU ÖKOSÜSTEEMIDELE

MASTER THESIS

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AUTHOR’S DECLARATION

Hereby I declare that I have written this thesis independently. No academic degree has been applied for based on this material. All works, major viewpoints, and data of the other authors used in this thesis have been referenced.

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The thesis is in accordance with terms and requirements

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THESIS TASK

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Thesis topic:

A comparative analysis on the beef production in confined vs free roaming production systems to assess damages to the environment.

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Thesis main objectives:

1. To investigate the different beef production systems
2. To compare and analyze confined vs free roaming production system
3. To assess the damages to environment using the tools of LCA

Thesis tasks and time schedule:

No:	Task Description:	Deadline:
1	Literature Review	1st June 2021
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3	Thesis Finalization	22nd June 2021

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PREFACE

The comparative analysis of confined vs free roaming beef production system is an insightful analysis on traditional beef production systems. The study provides insights and statistical findings on product systems and provides strategies which enable the systems to become more efficient and sustainable. The thesis is based on the comparison of two chosen two beef production systems, confined and free roaming. The data utilized for analysis were from 'Ecoinvent databases' developed and assessed by more than 1000 researchers from leading universities.

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List of Abbreviations

FAO	Food and Agricultural Organization
OECD	Organization for Economic Cooperation and Development
FAOSTAT	The Food and Agriculture Organization Corporate Statistical Database
EPD	Expected progeny differences
BCS	Body Condition score
BSE	Breeding soundness Examination
LW	Live weight
SOC	Soil Organic C
EEA	Extracellular Enzyme Activity
GHG	Greenhouse gases
HPG	Holistic Planned Grazing
AMP	Adaptive Multi Padlock Grazing
FC	Field Capacity
PWP	Permanent Wilting Point
SPS	Silvo Pastoral Systems
ISPS	Intensive silvopastoral systems
ART	Assisted Reproductive Technology
C	Carbon
N	Nitrogen
P	Phosphorus
LCA	Life Cycle Analysis
EF	Ecological Footprint
EPD	Environmental Product declarations
LCI	Life Cycle Inventories
USD	US Dollar
DALY	Disability Adjusted Life year

INTRODUCTION

In the world of agriculture, livestock production is the major contributor to economic growth (World Bank 2009). Meat production will face a huge demand in the forthcoming decades (de Vries, van Middelaar, and de Boer 2015). In OECD (Organization for Economic Cooperation and Development) countries, livestock products account for about 58 percent of total protein, with beef accounting for about 12% (OECD 2016). According to Eurostat (Meat productions statistics archives, no 1165/2008) the EU production system contributes to around 13.0% of beef production in the world.

Urbanization and industrialization indicate a greater demand for beef, especially in developing countries (de Vries et al. 2015). This surge puts a greater strain on the natural sources for production (Hole et al. 2005). Especially in terms of energy, water, and land (van Zanten et al. 2016). The other components which also play a crucial role in sustainability would be the welfare of the animals and humans utilized, and the environmental impacts including those on biodiversity, pollution, and climate change (Giraldo et al. 2011).

A system or process can be defined as sustainable, if and only if it is sustainable in the present and will be sustainable for the anticipated future implications (Jorgensen, S. E., & Fath, B. D. 2014). Especially in terms of resource availability, operational implications, and morality of the actions (Broom D.M,2014). Industrialized intensive livestock operations in developed and developing countries are a major source of environmental pollution (Glatzle 2014). Beef production to be precise has significant environmental impacts (de Vries et al. 2015). It is one of the primary causes of deforestation and land degradation (et al 2011). It accounts for about 41% of global greenhouse gas emissions (de Vries et al. 2015).

The thesis will further explore and investigate the current beef production practices and suggest the most resilient and sustainable one, accounting for its environmental implications. Significant contamination in terms of Land-Energy-Water nexus, discerned during the production were:

1. Land: Livestock production occupies up to 50-75 percent of agricultural land (van Zanten et al. 2016). Beef production occupies about 60% of the world's agricultural land, while it only accounts for about 2% of total calories consumed (GRAIN, I.2018).
2. GHG: The livestock industry is responsible for 18% of anthropogenic greenhouse gas emissions, in CO2 equivalents (Liu et al. 2012). According to Animal production FAO 2018, feed production, enteric fermentation, animal waste, and land use alteration were the significant contributors to emissions. Cattle (beef, milk) account for almost two-thirds of the total methane emissions.
3. Energy: Livestock production is energy intensive. An average of 25kcal of fossil fuel is required

to produce 1Kcal of meat. Which is 10 times more than the 2.5 Kcal of energy for plant protein (Liu et al. 2012).

4. Water: According to Hoekstra et al.2011, around 30 percent of the water footprint of humanity is related to livestock production. The average amount of water utilized to produce one kg of beef is 15,414 liters (Mekonnen, M. M., & Hoekstra, A. Y. 2012).

A pattern of interdependencies between the synergies of 'land-water- energy' emerges. Apart from the interdependencies, cases of pollution as a by-product of their interactions are also observed. To gain a better understanding of the synergies, we have to consider the 'supply chain thinking' (Hoekstra et al. 2011).

Keywords: Sustainability, methane emissions, land occupied, energy intensive, water footprints, beef production, land-water-energy pollution.

1. THE SYSTEM

A system can be defined as a well-organized collection of components (or subsystems) that strive to achieve a core objective. The system accepts a variety of sources, which are processed to produce specific outputs (McNamaraC.2017). Depending on the level of technology utilized, the established systems employ either intensive or extensive exploitations. In addition to these two production methods, there are sustainable production systems that prioritize environmental conservation while still having beneficial effects on agricultural ecosystems (Reganold et al.2016).

Figure 1.1 gives the pictorial representation of the beef production system. It comprises 3 major subcomponents, such as cow- calf operations, backgrounding and finishing. The system begins at the cow calf operations and commences at finishing. During the cow calf operations, the calves are impregnated either through natural mating or through artificial insemination. Following a cycle of 9 months pregnancy, the calf is supplemented and natured under the maternal care of its mother. Succeeding periods of 7-8 months the calf is weaned and prepared for backgrounding (Herring et.al 2014) The backgrounding process occurs either in a confinement or on pasture depending on the type of production system. The final stages of the system are finishing off, where feed of a high grain diet is fed to cattles (Herring et.al 2014) The thesis will further explore the widely recognized methods of beef production with their significant impacts on the 'Land, water and energy'. The general process of the system is explained in the following sections.

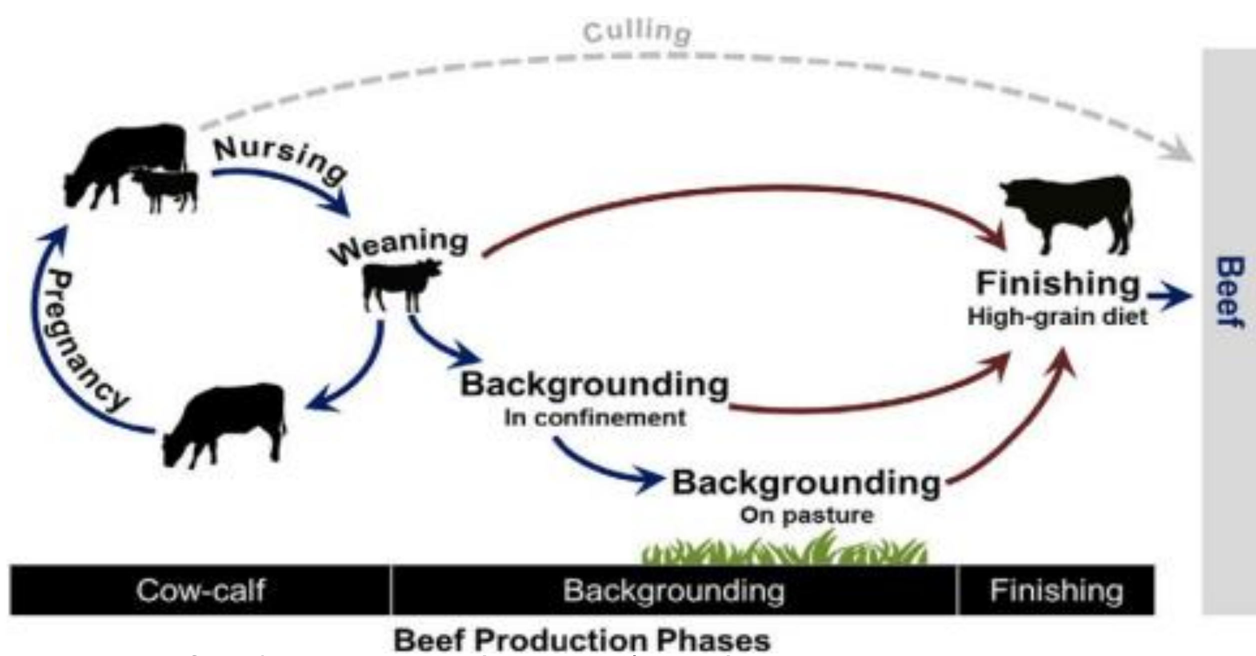

Figure 1.1 Beef production systems (Pogue et al. 2018).

1.1 Cow-Calf operations

The impregnation of the calves was observed through two breeding techniques:

- Selective breeding techniques
- Artificial insemination

Selective breeding techniques:

Selective breeding of cattles can be achieved through the selection of desirable genes of the livestock. According to Ben J. Hayes et.al 2013, the profitability performance traits for selection would be fertility, maternal ability, growth rates, feed efficiencies, body measurements, longevity, carcass merit, conformation, or structural soundness. One of the crucial instruments in the hands of beef cattle producers would be the utilization of genetic prediction (EPD's). Expected Progeny Differences (EPD) can be utilized to test the genetic viability of the parental genes, before implanting to its offspring. The test is assessed based on the data submitted by the cattle associations accounting the animal performance, progeny performance and DNA analysis. Depending upon the end production goals (milk, meat) EPD can be utilized to selected the respective bulls and cattles (Eenennaam and Drake, 2012, Rolf et al.2014).

After the application of EPD, the gestation of calves is observed. The ending of gestation indicates the beginning of the calving phase. After the calving, the bull is usually released into a cowherd within 55 days, depending on the cows' Body Condition Score (BCS). The BCS can be defined as the visualization technique for measuring body fat reserves that is unrelated to body weight or frame size. BCS, which is a 5-point scale with 0.25-point intervals. Cows with a score of 1 are emaciated, whereas cows with a score of 5 are obese. (Rodríguez Álvarez et.al .2019).

In case of its first calving, it can take a minimum of 10 days or longer to re-breed. Examination used to determine the quality of the bull is coined as 'BSE' or 'Breeding Soundness Examination'. The examination is carried out in the genital organs of the claves to determine their productivity (Pleasants 1997). Selective breeding can also be achieved through Artificial insemination which will be further explored in the next subsections.

Artificial Insemination:

Artificial Insemination (AI) is a form of Assisted Reproductive Technology (ART) which involves injecting the stored sperm directly into the uterus of a cow or heifer. It's a vital tool for enhancing livestock's reproductive efficiency and genetic consistency. This method is commonly used in the dairy and beef cattle industries to improvise the desirable characteristics more rapidly through intense genetic selection (Rocha et al. 2020). However, there are several ethical issues on the utilization of these breeding technologies. One of them would be the intrinsic values of the cows and their significant impacts on the wellbeing of animals, agro-biodiversity and on the environment. Three major theories were taken into consideration with regards to animal's ethics and AI: Animal rights, utilitarianism, and biocentric answers. All the theories point out the intrinsic or sentient nature of animals, which should be the crucial point of focus in large scale animal production (Rutgers et.al 1999).

1.2 Backgrounding and fed lotting operations

Backgrounding commences when calves are weaned and terminated when they are placed in the finishing systems. The process aims to increase the calf's weight by several hundred pounds. Depending upon the production system, backgrounding either can be concentrated feedlots or pasteurized systems. It aids in building up tolerance to diseases and until the cattles reaches the feedlot by relying more heavily on forage. Examples of forages are grass, hay in conjunction with grains. Beef calves can gain up to 800 pounds of weight with a solid backgrounding program. Much of the weight gained is in the form of muscle and frame growth. In addition to pasture feeding, these gains can be made as cost-effectively as possible by maximizing the use of forages such as hay and silage in the feed (Pogue et al. 2020).

1.3 Finishing

After the backgrounding process, cattles are further fed a highly intensive diets before finishing off. According to Kamilaris et al. 2020, the finishing is the termination of the beef production process. As the process differs significantly from one system to another, the respective greenhouse emission varies significantly according to the process selected. According to Cassy and Holden, 2006 the shorter the duration, enhanced efficiencies and significantly minimized carbon footprints.

2. CLASSIFICATION OF SYSTEMS

Based on the literature review, the above beef production systems are selected for further exploration.

A) Confined beef production systems

B) Semi-intensive beef production systems

C) Free roaming beef production systems

2.1 Confined beef production systems

Confined production is defined as, the systems in which cattle are confined and are fully dependent on humans for the provision of basic needs such as food, shelter, and water (Gollehon et al. 2001). The system concentrates the feed and nutrients to cattle's during the backgrounding process and is finished off in the industry.

Nutrients requirements for cattle growth:

According to the (Robinson et al. 2006), cattle require nutrients in the form of daily supplements to support their growth and development. The nutrients are usually taken in the form of carbohydrates, proteins, minerals, vitamins and fats (Van Saun 2006). The water consumed during a calf's lifetime is also relatively high. The water consumption also depends upon several factors such as the temperature, age, size and body weight of the cattle's (Parish and Rhinehart 2008). The amalgam of the feed intakes gives a clear overview of the backgrounding process. The feeds usually consist of

- Proteins
- Grasses and legumes hay
- Alfalfa Hay
- Wheat pastures
- Vitamins and minerals
- Corn silages

Proteins:

Proteins are the building blocks of life. They are necessary for animals to perform various functions which are crucial to survival. For calves under 600 pounds and cattles starting out on feed, plant protein supplements usually outperform urea or other non-protein nitrogen supplements. Since light-weight cattle have a lower rumen capacity to produce microbial protein, they need more protein in their diet than older, heavier cattles (Parish and Rhinehart 2008).

Table 2.1 Protein requirements per TDN added (Tylutki, Fox, and Anrique 1994)

Ration energy level	Maximum ration protein percent attained with added urea
Percent TDN	Percent of Protein
50-59	7 to 8
60-74	10
75-100	11-12

The energy level in the ration provides a rule of thumb for the level of crude protein equivalent that can be achieved with non-protein nitrogen additions. Several studies indicate that urea in combination with slowly degraded protein sources can be significantly beneficial for cattle growth. It includes distiller byproducts and blood meal and has proven to outperform soybean meal in young calves' rations. The Table 2.1 indicates the urea trials for proteins. These nutrients are termed as High Bypass proteins (Tylutki et al. 1994)

Grasses and legumes hays:

Hay quality varies greatly, so a feed test should be performed to determine the amount of protein, energy, and minerals in the hay. For example, to achieve 1.5 pounds of daily gain on weanling calves, late-cut grass hay or those with a lot of weather damage would be crucial. When 5 pounds of feed containing a protein-mineral mixture of 2/3 ths of corn fed regularly, a sustainable weight gain of 1.69 pounds was observed (Parish and Rhinehart2008).

Alfalfa:

Calves' rations may be supplemented with alfalfa or other high-quality legume such as hay, silage, or haylage to supplement corn silage for protein. To get the same amount of protein as 1.2 to 1.5 pounds of soybean meal, the approximation would be 3.5 to 4.5 pounds of alfalfa hay. When alfalfa is substituted for soybean meal in corn silage rations for rising 500- to 700-pound cattle, the rate of benefit decreases slightly. Alfalfa hay contains less energy than the soybean meal and corn silage. However, it will lower the cost of growth gains because it is a cheaper source of protein and energy than silage and oil meals (Anon 2020).

Wheat pastures:

Wheat pasture contains 20 to 30% of crude protein, On a dry matter basis. Wheat pasture has a low calcium content (0.02%), high phosphorus content, and a marginal to low magnesium content. Hence, the calcium and magnesium levels in mineral supplements for calves on wheat pasture should be accentuated. Bloating can be a crucial problem on the wheat pastures. Regular feeding of 50 to 200 mg of Rumensin or Bovatec will guard against bloating and aid in weight gain of cattles (Tylutki et al. 1994)

Mineral and vitamins:

Vitamins, minerals, and trace elements are dynamic nutrients that are commonly included in the complementary feed rations of all ruminants. However, purity and bioavailability are important factors in efficacy. Supplementing the diets of cattle and goats with vitamins, minerals, and trace elements (in the form of a premix) are critical because they improvise maintenance, growth, health, and lactation. To enhance the immune system, combinations of intake such as micro (mg/kg dry matter) and macro (g/kg dry matter) components are essential. They support the bone growth, enzymatic functions of the various cell membranes in the system of organisms. They enable and assist in the regulation of alkaline and acidic conditions of the systems.
Examples of vitamins and minerals in the feed would be Vitamin A, phosphorus inclusion in hay due to lack of potassium in the feed (Anon 2020)

Corn silage rations:

According to Tylutki et al. 1994, increments of 3 pounds of high moisture corn per head daily to full-fed corn silage calves have improvised benefits. For a 400- to 500-pound calf, a good quality full feed of corn silage supplemented with protein, minerals, and Vitamin A can yield up to 1.5 to 1.8 pounds gain. To gain 2.0 pounds per day, some grain additions are essential. 400- to 500-

pound calves require around 1.1 to 1.3 pounds of 40% protein supplement in combination with corn silage intake per head per day. However, in regard to the Kentucky experiments, for a 400-pound steer calves, 1 pound of soybean meal appeared to be sufficient. Silages have to be treated with nitrogen in order to have higher protein concentrations (Tylutki et al. 1994).

2.2 Semi intensive beef production systems

In a semi-intensive production system, cattles are raised and cultivated in pastures. The limitations of pasture supply during the dry periods are often supplemented with mineral salts to enable weight gain. The figure 2.2, represents the 'Semi intensive systems', where the pastures are often divided into smaller pickets. Utilization occurs in a sequential manner to ensure plant recovery from grazing. The semi-intensive system enables faster acquisition of animals for slaughter than the comprehensive systems (Willers et al. 2017).

Case Study of Bahia, Brazil:

The system layout indicated in figure 2.2, is based on a case study from Brazil, Itapetinga micro-region. It was located in the central south meso part of Bahia. It consists of nine towns with excellent soil and climatic conditions. It is termed as one of the most important agricultural and livestock areas in Bahia. The micro region accounts for the largest cattle population in Bahia. The entire system is divided into 2 farms. Pasture cultivation and breeding usually takes place in Farm 1 and the fattening, backgrounding and finishing takes place in Farm 2. The characteristics of both farms are described below to get a clear overview of the process (Willers et al. 2017).

Farm 1: It comprises an area of 267.9 ha with 14 ponds, and 1 creek for livestock irrigation. As well as an access road connecting the property, a silo, corral, stable, administration house, and workers housings.

Farm 2: It comprises a 200-hectare grazing field with eight ponds, and one creek for livestock irrigation. As well as an access road connecting corral, administration house, and worker housing. While the foreground system provides pasture cultivation, mineral salt processing, animal transportation, breeding, and fattening (Willers et al. 2017).

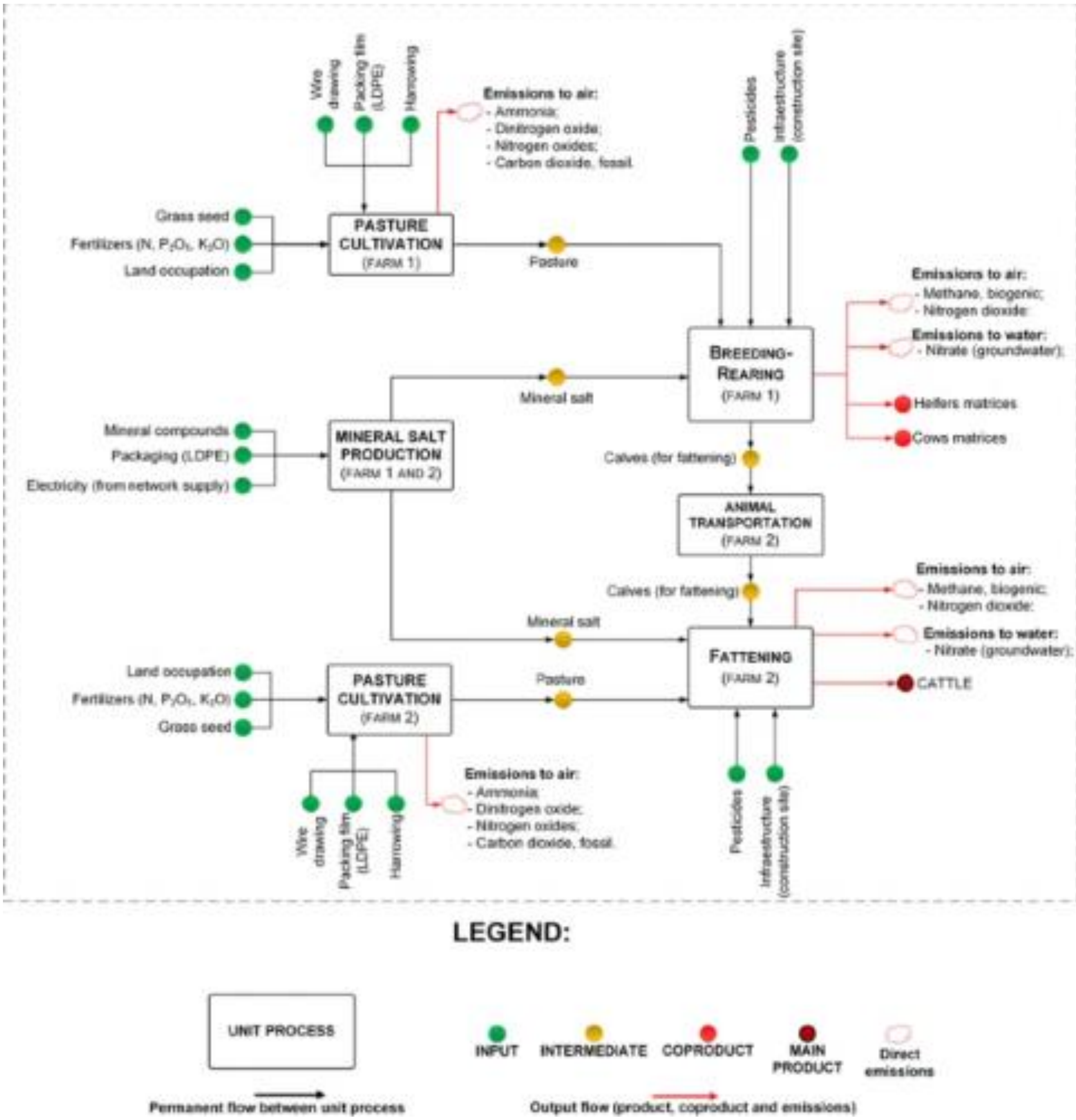

Figure 2.2 Semi intensive beef production systems (Willers et al. 2017)

To get a clear overview of the Semi intensive beef production, we further explore the calving and feed management phases. The breeding and rearing are usually observed in farm 1, whereas the fattening and the pasture cultivation is observed in farm 2. The mineral salt production to enable the weight gain is manufactured in farm 1 and farm 2.

Cattle and calves:

The calves are produced with the aid of AI or through natural mating. The reproduction cycle typically lasts upto 9 months. When the calves are born, a 60-90-day wait is observed before the next fertilization. Following six months, the calves are weaned, and the bull calves are sent to fattening systems. A few of the heifers will be slaughtered, while the remainder will be held on farm 1, to replace mature breeding cows. During the first 20 months of their lives, bull calves are fattened. They are then sold to slaughter with a life weight of about 480 kg (Willers et al. 2017).

Feed Management:

Unlike extensive farming, where cattles are allowed to roam freely to get their supplies. In Semi intensive farming, the cattles are supplied with all the essential nutrients for growth and development. Feed management with the supply of all the vital nutrients occurs at the fattening stage and backgrounding stage. The feed usually consists of Goosegrass (Eleusine indica), nutgrass (Cyperus rotundus), buffelgrass (Cenchrus ciliaris), and bahiagrass (Paspalum notatum). Corn, wheat bran, soybean meal, molasses, palm oil, essential amino acid, essential minerals, premix, and vitamins are also included in the concentrate. These forage foods are often dewy and smelly during the rainy season, hence the supplies would be out of stock. To compensate for the supply of the feed in that season, farmers usually provide elephant grass (*Pennisetum purpureum*) or paddy straw and concentrates. The source for the semi- intensive system is typically from shrubbery, uncultivated land, and uncultivated paddy fields. (Dedeh et al. 2016)

2.3 Free roaming beef production systems

According to Teague, Grant, and Wang, 2015, free roaming beef production can be defined as the system where the cattles are allowed to roam freely for a minimum of half day in comparison to fenced in counterparts. The cattles are often allowed to roam freely to get their supplies. The various forms of free roaming beef production systems assessed during the literature review are as follows:

i) Adaptive Multi Padlock grazing
ii) Holistic Planned Grazing
iii) Silvopastoral Systems
iv) Extensive unmodified Pastures & Fertilized Irrigated Pastures

2.3.1 Adaptive Multi Padlock grazing (AMP)

AMP catalyzes rapid grass growth, by employing high livestock densities for shorter periods in the intervals of longer forage rest. This method is neither prescriptive nor planned but rather moves the animals in accordance to how the land and life respond. Thus, AMP grazing is extremely observant and adaptive. It has been documented that the AMP grazing improves soil's physical, chemical, and biological properties. These systems propose different ways to boost soil organic C (SOC) and macronutrients (Teague, Grant, and Wang 2015). They further enhance the soil function and health and mitigate climate change through increased C storage (Byrnes et al. 2018). This is done by increasing atmospheric C fixation into plant biomass. The system is built to replicate the natural pattern of dense herds of wild ruminants that are continuously moving due to predation and food availability. The system is mostly regenerative and produces methane relatively less in comparison to its counterparts (Shrestha et al. 2020).

Alberta Case Study:

The Alberta case study was conducted in Alberta, Canada. The aim of the study was to ascertain the soil properties and CH4 uptake as a result of AMP grazing. The participants were the farmers of grasslands. The participants' of were selected based on a series of questionnaires. These questionnaires were verified through telephone interviews. A total pair of 11 grasslands were selected for this study. However, there were certain requirements to be qualified as a participant for the study. Such as the number of paddocks used per herd (>10), the minimum size of the ranch (>65 ha), the frequency of cattle rotation, and the use of versatile stocking density adjustment in response to climatic variation. Soil samples were collected if the requirements were met. A randomized collection of soil samples at 22 sites were further analyzed for testing (Shrestha et al. 2020).

EEA (Extracellular Enzyme Activity):

EEA is one of the crucial activities that enhances AMP. Soil Extracellular Enzyme Activity (EEA) influences the GHG fluxes from the soil by regulating soil organic matter (SOM) decomposition and nutrient cycling. During the decomposition of SOM, plants and microbes release enzymes that catalyze the decomposition of target molecules. Plethora of enzymes are responsible for decomposing a single biopolymer in SOM. Hence, multiple enzymes must be calculated at the same time to fully comprehend the function of EEAs in I and nutrient cycling (N). Soil EEAs can change as a result of biotic (e.g., vegetation, faunal influences) and abiotic (e.g., temperature and moisture) conditions in the soil. The knowledge of EEA is crucial in understanding how the grazing induced environments affect GHG fluxes in the soil (Shrestha et al. 2020)

Results:

To comprehend the effect of AMP, we further explore and compare the Net GHG flux, CH$ flux, N2O flux and CO2 flux to the non-AMP. AMP soils emitted 17 percent more CO2 than non-AMP soils at 25 degrees Celsius, while non-AMP soils emitted 18 percent less CO2. CO2 fluxes from soils at FC (Field Capacity) were 2.1 and 2.7 times higher than those from soils at PWP (Permanent Wilting Point) and 0.4FC, respectively. The illustration of the results are indicated in figure 2.3.1.

Interestingly, both the grazing systems' responses to moisture remained similar. Soils at 25 degrees Celsius provided 3.4 times more N2O than soils at 5 degrees Celsius. Soil N2O fluxes at FC were 1.5 and 3.1 times higher than those at PWP and 0.4FC, respectively. When comparing AMP grazing to non-AMP grazing, N2O emissions were unaffected by grazing, and grazing interactions with temperature to affect CO2 flux. With increased moisture levels and soil temperature, CH4 absorption and CO2 and N2O emissions increased. For the first two weeks, grazing affected CH4 absorption, but after that, the grazing effect faded, and N2O emissions were indirectly influenced by grazing by affecting NAG (Non-AMP Grazing). In comparison to non-AMP-grazed soils, we conclude that AMP grazing has the ability to mitigate the impact of a warmer soil on GHG emissions by consuming more CH4 (Shrestha et al. 2020)

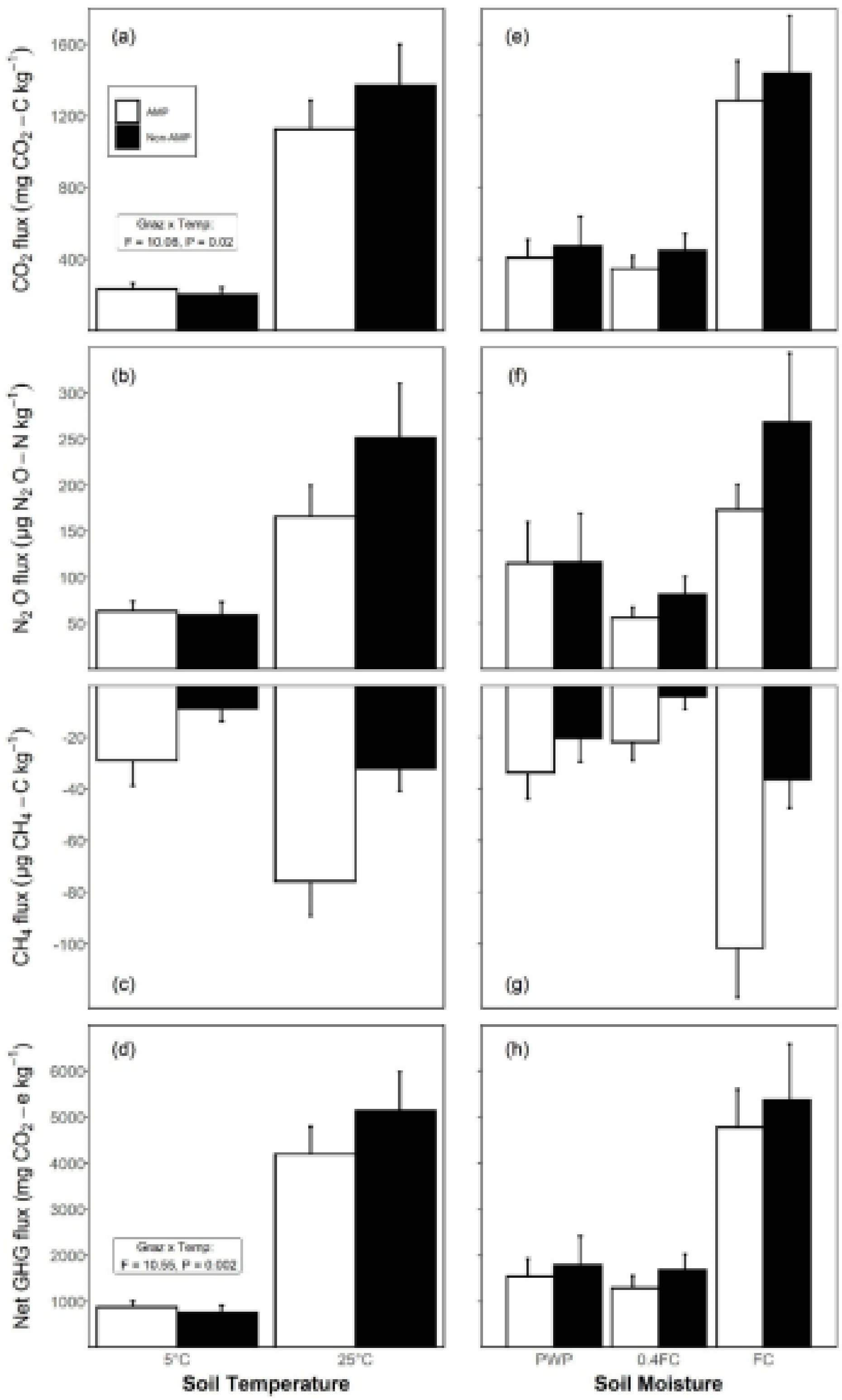

Figure 2.3.1 Results of AMP grazing (Shrestha et al. 2020)

2.3.2 Holistic Planned Grazing (HPG)

Holistic Planned Grazing (HPG) is a form of rotational grazing. It has been claimed to increase rangeland productivity and reverse climate change while doubling stocking rates, primarily due to the effect of densely bunched animals on primary production (Hawkins 2017). There are several reinforcing camps enforcing shorter durations of grazing. The higher intensities combined with shorter periods of grazing ensure long periods of return for the vegetation regrowth and reproduction. Due to the time control intervention, the herd effect is observed where the topsoil is mulched due to the grazing activities of the cattle. However, several critics claim to question the reliability and positive impacts during the grazing practices. There are several other constraints such as the above grazing is either restrictive or constrained to non-anthropogenic rangelands. The other outcomes observed during the study were the positive relationship between the size of the soil cover and the animal densities, depending on whether the weight of the animal did or did not exceed. Since the above grazing practice is relatively new, much research is needed to analyze and comprehend the synergies and the tradeoff between the systems (Hawkins 2017). The literature review indicates that either one or the combination of two can be utilized to reduce the impacts on the ecosystem. Hence the combination of both AMP and HPG can be further experimented.

2.3.3 Silvopastoral Systems

Silvopastoral systems (SPS) are agroforestry structures that combine fodder plants like grasses and leguminous herbs with shrubs for animal nutrition (Cardona et al. 2014). They permit the intensification of cattle production through natural processes. SPS is recognized for its integrative approach to sustainable land use (Nair et al. 2009). The figure 2.3.2, provides a pictorial representation of silvopastoral systems. It facilitates ecologically beneficial interactions, such as increased yield per unit area, improvised resource efficiency, and environmental service provision. SPS results in increased farm income directly through increased sales of wood, cattle, and animal products, or indirectly through soil conservation, livestock shelter, and improved animal welfare. Thus, these systems are more productive, profitable and sustainable than the specialized forestry and individualized animal production systems.

According to Chará et al. 2017 systems usually comprise of

- ➔ Dispersion of trees among pasturelands,
- ➔ Timber plantations along the livestock grazing areas,
- ➔ Pasteurized grasslands along the tree alleys, windbreaks, live fences, fodder banks with shrubs and
- ➔ Intensive silvopastoral systems: Intensive silvopastoral systems (ISPS) combine high-

density fodder shrubs (4000–40 000 plants ha-1) with improved grass cultivation, at the densities of (100–600 trees ha-1). These systems operate under rotational grazing with occupational periods ranging from 12 to 24 hours along with rest periods ranging from 40- 50 days. In addition, inclusion of adlibitum clean water and mineralized salt in each paddock (Giraldo et al. 2011).

To better understand the ecological benefits of the silvopastoral system we further explore the benefits of the systems, with a distinctive focus on the carbon sequestration and reduction in GHG emissions after its application.

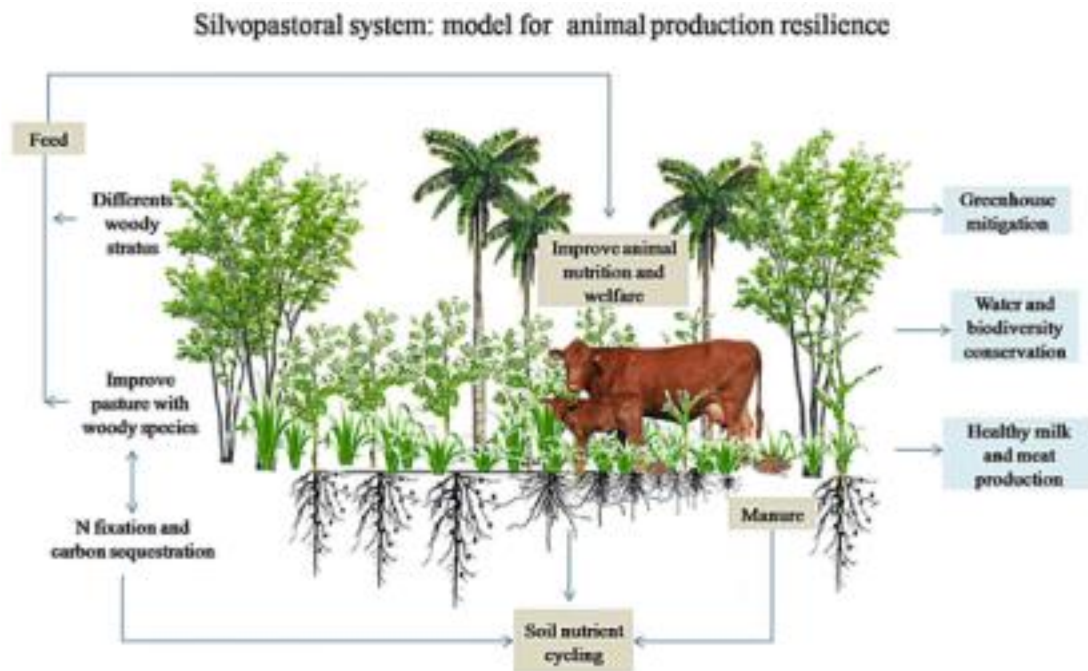

Figure 2.3.2 Silvopastoral system model for animal production resilience (Solorio, S. F. J, Wright, 2017)

- **Benefits:**
  - ➔ Increased outputs of higher-quality forages, which in turn reduces the need for external forage supplementation (Chará et al. 2017)
  - ➔ Increased cattle production per hectare, by up to fourfold (Thornton and Herrero 2010).
  - ➔ Increased carbon storage in the systems above ground and underground compartments (Bonsignore and Vacante 2018).
  - ➔ Improved soil properties due to increased nutrient absorption from deeper soil layers,

increased nutrient availability from leaf litter, and increased nitrogen intake from N2-fixation trees (Aryal et al. 2019).

➔ Improved soil resistance to erosion, nutrient depletion, and climate change (Aryal et al. 2019).

- **Carbon sequestration and GHG emissions:**

Increased net C storage above and below the soil is achieved through planting trees in croplands and pastures. The 'Carbon sequestration capacity' of agroforestry systems is estimated to range from 0.29 to 15.21 Mg ha-1 yr-1 above the ground and 30 to 300 Mg C ha-1 in the soil up to 1 m depth (Nair et al. 2009). The estimated sub soil carbon sequestration capacity of SPS ranges from 1.5 Mg ha-1 yr-1 to 6.55 Mg ha-1 yr-1. (Nair et al. 2009)

2.3.4 Extensive unmodified Pastures & Fertilized Irrigated Pastures

Extensive unmodified pastures, includes raising cattle on pasture throughout their lives, first with the maternal figures and then in the significant age groups. A common practice considered here is to leave animal manure on land, that which has not yet been fertilized and irrigated artificially. The cattle selected for the systems were Bos taurus, zebu (Bos indicus), or zebu-cross beef breeds. When zebu or zebu-cross animals were slaughtered at 30 months of age, their average live weight would be 468 kg, which translates to a 255 kg hot carcass weight (Roça, R.O, 2000). Fertilized irrigated pastures on the other hand, utilize fertilizers as a crucial part of pasture management. The possibilities of concentrated feeds were minimal. The cattle utilized for these production systems were usually B. taurus breeds, zebu and zebu-cross breeds. In these systems, cattles of 30 months of age reached a weight of 468 kg, equivalent to those on extensive unmodified pasture. However, the density of animals was higher due to greater food availability (Roça, R.O, 2000). As the land and water consumption are significantly higher in the extensive unmodified pastures, we further explore in the next subsections.

Land and water consumption:

Extensive systems with unmodified pasture utilize most land per kg of meat processed. It equals to 2.7–12.3 times more land use than its counterparts. If the land is degraded or the conditions on extensive unmodified pasture were extremely dry, more land is required to produce a kilogram of beef. When the animals are reared on fertilized or irrigated pasture, the amount of land required for the feedlot method is comparable to all the required inputs from pastures. The land use for beef cattle held solely on fertilized pasture is doubled if they are thoroughly reared before being placed in the feedlot.

In terms of water usage, extensive unmodified beef systems utilize 89% of total water for cattle consumption. The cattle's water consumption was 12 percent of the total water used in feedlot systems, when animals were reared on irrigated pasture and fed concentrates irrigated during harvest. Whereas this percentage increased to 21 percent when fertilized irrigated pasture systems were used throughout. In conclusion, feedlots have the highest water consumption. Water use in fertilized pastures is comparatively high. While it is significantly lower in extensive unmodified pastures and the lowest in the semi-intensive silvopastoral method (Ogino et al. 2016).

3. IMPACTS OF BEEF PRODUCTION ON ECOSYSTEM

In Livestock production, ruminant systems account for the significant amount of GHG emissions (Nguyen et al. 2013). It contributes significantly to global environmental concerns such as climate change, deforestation, land degradation and pollution of water systems. Life cycle Analysis (LCA) estimates the beef supply chains to emit around 2.9 gigatons of CO2-eq globally. It accounts for about 40% of all livestock emissions. Figure 3 distinctively indicates the CO2 emissions from beef cattle production are significantly higher to its counterparts. However, the actual impacts on the ecosystems can only be determined based upon the animal management practices and technologies utilized (Gerber et al. 2015). The production system takes place in a variety of agro-ecological conditions. It relies on various breeds to produce a variety of goods and services. Understanding these differences in production practices is essential for assessing the impacts of various systems and unraveling environmental interactions, as well as proposing new developmental pathways (Bouwman et al. 2005).

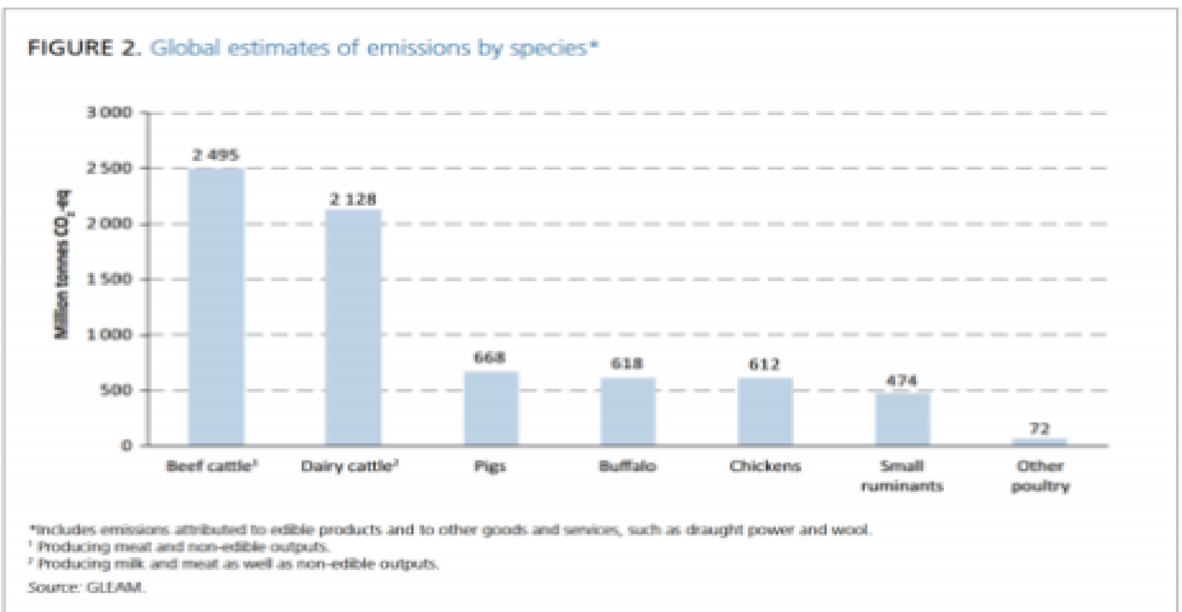

Figure 3 Global estimates of Co2 emissions by species (Gerber et al. 2015)

3.1 Land and Water

Land occupancy related to the production of materials (for all ruminants) is estimated at about a quarter of emerging land surfaces (Glatzle 2014). In regard to the management practices ranging from intensively managed pastures (planted and fertilized) to rangeland that are used occasionally depending on rainfall. The remaining 40% consists of crop residues (about 30%), crop products and its by-products. It is estimated that global feed crop production (for all livestock species) will mobilize roughly one-third of global cropped area.

According to de Vries et.al 2015, in OECD countries, the production of 1 kg of beef requires 30 to 50 m2 of land. In comparison to other livestock production (such as poultry and dairy), the area occupied is less than 15 m2 to produce 1 kg of meat. Though it should be noted that the way the land is used is not similar.

According to Gerbens-Leenes, Mekonnen, and Hoekstra 2013, beef cattle accounted for 33% of the global water footprint of animal production and nearly 10% of total agricultural production. The figure 3.1 is a combination of grey, green and blue water footprints. The blue water footprints include surface water, groundwater and other irrigation services. Whereas the green footprints represent the rainwater evaporated from soil and plants. Whereas the gray water is the assimilation of loads of pollutants such as manure and waste emitted to streams and rivers.

The gray water footprint ranges from 0 m3 per ton (Grazing systems in India) to 1234 m3 per ton (Industrial systems in China) and green water footprints ranges from 2949 m3 per ton (Industrial systems in the United States) to 25,913 m3 per ton (Industrial systems in China) (Grazing systems in India). The on-farm cropland utilized for beef production is significantly higher than its counterparts and indicated in figure 3.1. The variability at the farm level will be even greater than the variability at the country/system level (Gerbens-Leenes et al. 2013). Further exploration on land use and water consumption with the tools of LCA will be carried out.

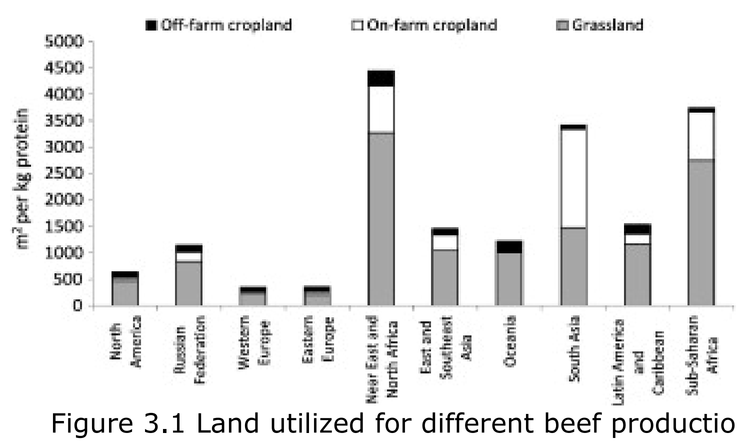

Figure 3.1 Land utilized for different beef production systems (Gerber 2013)

3.2 Nutrient cycles

According to Sommer et al. 2006, cattles were estimated to contribute 56-60% of the annual 75-138 Tg N excreted by all livestock species. Generally, 55 to 95 percent of the nitrogen (N) and approximately 70 percent of the phosphorus (P) consumed by livestock are excreted in the form of urine or feces. A portion of this manure is recycled and used as fertilizers for pastures and crops (Menzi et al. 2010). However, a large portion is still lost to the environment in the form of gaseous emissions, leaching, and runoff (Castillo et al. 2000). The utilized manure's efficiencies for N ranges from 15- 35%, in comparison P efficiencies are generally higher. Hence, P ranges from 19-60% for milked cows and 14-28% for fattening systems. The illustrative representation of percentage of N and P in feed recovered in edible products, at animal level is indicated in figure 3.2. According to Gollehon et al. 2001, N losses per ha increases with the transition from grazing systems to mixed systems.

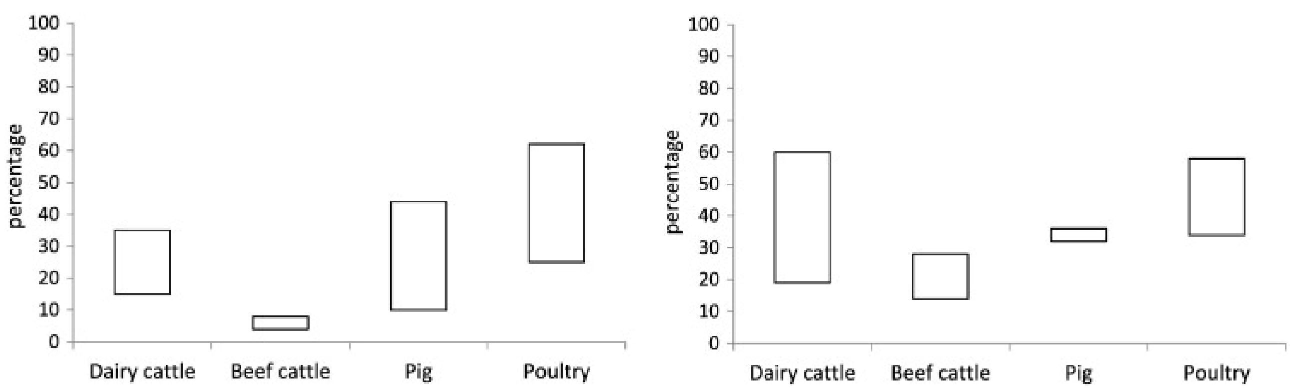

Figure 3.2, Percentage of N (left) and P (Right) in feed recovered in edible products, at animal level. (Gerber et al. 2013).

3.3 Greenhouse Gas Emissions

Livestock contributes to climate change by emitting greenhouse gases (GHGs) either directly (from enteric fermentation and manure management,) or indirectly (from other sources) (e.g., from feed-production activities, conversion of forest into pasture). According to Gerber et.al 2013, the sector emits approximately 7.1 gigatons of CO2 equivalent, or about 14.5 percent of total anthropogenic GHG emissions.

Cattle are the largest source of pollutants in the industry, accounting for about 4.6 gigatons of CO2-eq, or 65 percent of total emissions. Beef cattle (which produce meat and non-edible byproducts) and dairy cattle (which produce both meat and milk, as well as non-edible byproducts) emit equal quantities of greenhouse gases.

Beef accounts for 2.9 gigatons of CO2-eq, or 41%. Cattle milk on other hand accounts for 1.4 gigatons of CO2-eq, or 20%, of total sector emissions. Beef has the highest emission intensity which is indicated in figure 3.3 (the amount of GHGs emitted per unit of production produced) when expressed per protein, with an average of over 300 kg CO2-eq per kg of protein, followed by meat and milk from small ruminants, with averages of 165 and 112 kg CO2-eq per kg of protein, respectively.

According to Gerber et al, there is a significant difference in emission intensity between beef produced by dairy herds and beef produced by specialized beef herds. The emission intensity of beef produced by specialized beef herds is nearly four times that of beef produced by dairy herds (68 vs. 18 kg CO2-eq per kg carcass weight). The observed differences are since one produce beef and milk, whereas the other focuses on meat production. In this thesis, we will further investigate the GHG emission for the selected production systems in terms of meat production (Gerber et al. 2013).

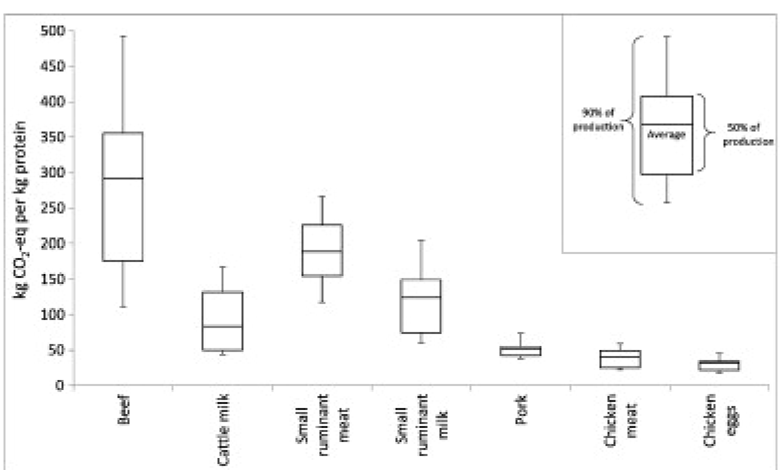

Figure 3.3 GHG emissions for various production systems (Gerber et al. 2013).

3.4 Biodiversity

Biodiversity is considered to be the endpoint of environmental mechanisms. It indicates the interactions between beef production and various environmental categories – GHG pollution, nutrient cycles, land and water usage – and its effect on biodiversity. Many mechanisms have an impact on biodiversity, and they vary from negative to positive results. Here, we explore 3 types of habitat modifications due to beef production.

Beef processing alters many ecosystems due to its significant land use. The degradation of undisturbed ecosystems, such as the conversion of the Amazonian rainforest to pastures and feed crops, is one form of habitat modification (soybean in particular).

For example:

Amazonian rain forests are biodiversity hotspots, containing up to a quarter of all terrestrial species on the planet (Dirzo et al. 2003). This habitat's degradation resulted in significant biodiversity losses.

The second type of habitat loss would be land degradation. It is caused by a combination of inadequate grazing management (particularly overgrazing) and climatic factors. Land degradation can result in desertification or woody encroachment, both of which are associated with biodiversity losses (Asner et al. 2004).

The third observes a positive impact on biodiversity termed as 'Extensive grazing'. For example, Grassland ecosystems in Europe have the highest biodiversity levels, owing to a long history of livestock farming that enabled a diverse range of species to adapt and specialize (Bignal and McCracken 1996).

Maintaining these habitats and their rich biodiversity needs extensive and effective grazing management. When they are abandoned, they "close-in" on shrubland and eventually trees, which have lower conservation value. Beef production contributes significantly to this form of extensive management, and its positive impact on biodiversity has been demonstrated in other areas (e.g., China, USA) (Bignal and McCraken1996)

Mixed and industrial beef production systems could have a positive impact on biodiversity if intensifying production allowed for the preservation of undisturbed ecosystems. Specific intensification practices, on the other hand, will be needed to reduce the other types of negative effects that these processes can have on biodiversity, especially pollution. Furthermore, since intensification does not always result in more land available for biodiversity conservation, strong policy mechanisms are required (Ewers et al. 2009).

However, there are several downsides to beef production as well. An example would be direct pollution resulting in nutrient loading. ‘Nutrient loading in the Mississippi River’, a result of widespread fertilizer uses in central US croplands (primarily for animal feed), causing hypoxia and “dead zones” in the coastal ecosystem.

Biodiversity decline due to eutrophication can also be traced back to the farm level, where high livestock density and large amounts of nutrients excreted make manure management difficult (Carpenter et al. 1998). The transformation from natural to fertilized grasslands causes a significant loss of biodiversity in mixed systems. Manure excreta in pastoral systems, on the other hand, can be beneficial to biodiversity and play an important role in nutrient cycling (Gerber et al. 2013).

4. STRATEGIES AND MODELS DEVELOPED

The strategies and models developed in the EU and in various countries to minimize the environmental impacts of livestock production systems are explained in table 4. Here we explore 4 selective strategies that are well suited to the chosen production system. The classification is made based on the year it came into force and strategies implemented.

Table 4 Strategies & Models Developed

YEAR	EVENT/DECLARATION:
2001	ErhaiSD-A system dynamics approach for regional environmental planning and management
2008	The hard path and the soft path approach for the allocation of environmental flow requirements
2012	Land-Water-Energy-Nexus – Rio+20 conference
2012	LEAP – Livestock Environmental Assessment and Performance Partnership

4.1 ErhaiSD- A system dynamics approach for regional environmental planning and management

It consists of dynamic simulation models that explicitly consider the information feedback that governs interactions within the ecosystem. Such models are capable of synthesizing component-level knowledge into a system behavior simulation at an integrated level. (Guo et al. 2001). It aims to analyze and synthesize policy decisions based on the complex interactions of systems. The ErhaiSD is made up of dynamic simulation models that take information input into account when governing system interactions. Such models are capable of integrating component-level information into integrated system behavior simulation. The above model can be implemented to understand the complex interaction of the ecosystem with the livestock production sector and to come up with a solution. (Guo et al. 2001).

4.2 Hard and soft path of water allocation for environmental requirements

Increased agricultural production has major environmental implications, especially on environmental flow requirements (Khan and Hanjra 2009). In case of water withdrawals from an aquatic ecosystem, a major portion of it should be allocated for the welfare and preservation of the ecosystem. (Yang et al. 2009).

Hence there are two methods of allocation:

- The hard path
- The soft path approaches.

The soft path approach combines a multitude of factors of efficiency, equity, and environmental protection goals. Whereas the hard path approach focuses more on the advancements in agricultural biotechnologies, to reduce the external dependencies of pesticides and fertilizers (Khan and Hanjra 2009).

4.3 Land- Water- energy Nexus (LWE)

According to OECD 2017, Land-Water- Energy is strongly interlinked in biophysical and economic terms. The bottlenecks in one will significantly threaten the other. The nexus provides a crucial platform for policymakers to connect the interlinkages since the negligence and bottlenecks in one are bound to affect the other. It also provides the synergies, tradeoffs between the sectors. The objective of OECD, 2017 would be to understand the multifaceted nature of bottlenecks and synergies and to provide global economic consequences of the nexus.

4.4 LEAP (2012)

LEAP was developed as a part of the sustainable development goals of 2018. The Livestock Environmental Assessment and Performance (LEAP) Partnership is a first-of-its-kind multi stakeholder collaboration between governments, the private sector, non-governmental organizations, and civil society organizations. International, inclusive, consensus, transparency, science, systematic, quality improvement, and adoption are among the LEAP guiding principles. The objective would be to achieve global agreement on science-based methodology, metrics, and databases for analyzing the environmental performance of livestock supply chains to shape evidence-based policy initiatives and business strategies which is indicated in figure 4.4 (Mehrabi and Gill 2020)

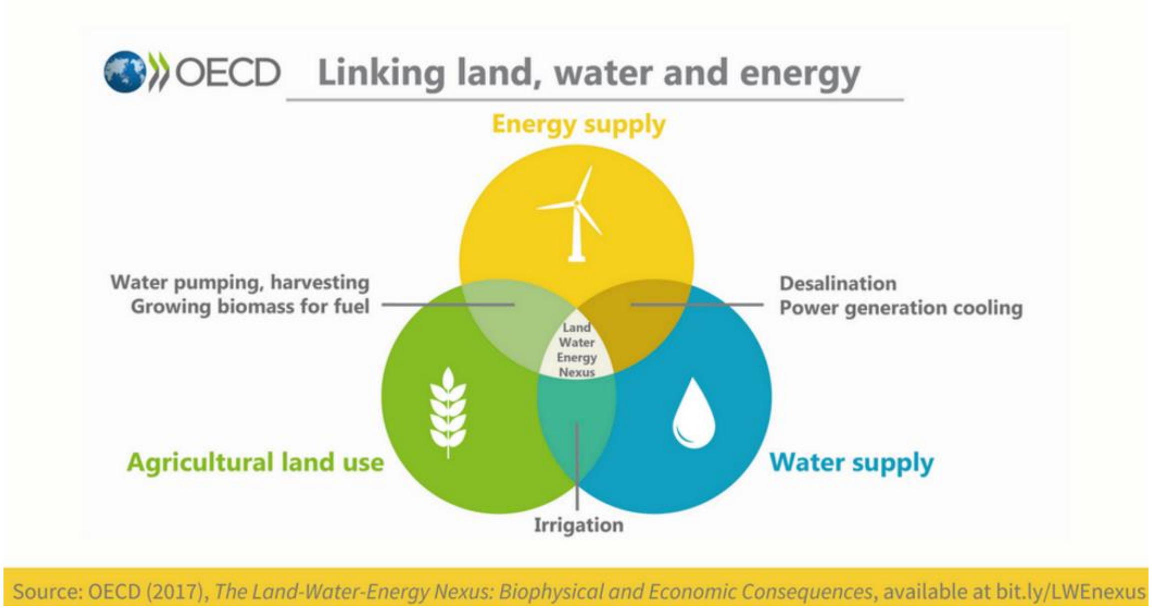

Figure 4.4 The Land- Water and Energy Nexus: Biophysical and Economic Consequences (OECD,2017)

5. METHODOLOGIES

The thesis implements two methodologies in the experimentation phase to explore the impacts of beef production on the ecosystems. One of the major grounds for choosing the LCA approach would be, the approach is iterative, integrative and enables us to understand the complex interactions between the ecosystem and product while accounting for the impacts on human health and resources utilized. It also accounts the impacts from the production of the raw material till the disposal of the finished product to the environment, (i.e a cradle to grave approach). On other hand, Ecological Footprint (EF) focuses on the 'Land resources utilized' during the production phases.

- LCA (Life Cycle Analysis)
- Ecological footprint (EF).

Both the methodologies have a common goal to identify the environmental impacts. However, the approach utilized to calculate the impacts is quite different (Boulay, Hoekstra, and Vionnet 2013). Application of both might result in extensive and thorough outcomes, which in turn would support a greater decision-making process (Wiedmann and Barrett 2010). As the strength of one system's approach complements the weaknesses of another, it is wise to utilize both for enhanced outcomes. Table 5 further explores the strength and the weakness of both methodologies.

Table 5 Comparison on the strength and weakness of LCA and EF into understandable and usable policy indicators (Castellani and Sala 2012)

Strengths:	Weakness:
The significant feature of EF would be the ability to directly present the result while accounting for a specific physical threshold. Example: Amount of land on the earth (Castellani and Sala 2012).	On the other hand, EF does not account for all environmental impacts, such as those caused by acidification, eutrophication, ecotoxicity, or human toxicity. These effects imply processes that may have irreversible consequences for bio productive capacity. Examples: Limitation in ecosystem services, interfering in nutrient cycles, and adversely impacting biodiversity. (Castellani and Sala 2012)

Table 5 Comparison on the strength and weakness of LCA and EF into understandable and usable policy indicators (Castellani and Sala 2012) (continued)

The EF methodology was created specifically to provide a picture of the sustainable or unsustainable nature of consumption patterns in terms of resource availability. It assists the decision-makers to identify the activities which are responsible for the most relevant impacts in terms of resource consumption and land use (Castellani and Sala 2012).	LCA results can be difficult to translate into understandable and usable policy indicators (Castellani and Sala 2012).
LCA was designed to provide a comprehension assessment and the potential environmental tradeoffs in the systems (Curran et.al 2014).	LCA has to be supplemented by other tools in the decision-making process (Curran et.al 2014)

LCA:

LCA (Life Cycle Assessment) is a measurement technique that has been utilized to examine the environmental impacts of products or services produced. Exploration of Life Cycle assessments in the forms of literature from renowned authors states that the principles are iterative and envelop either cradle- cradle(C2C), cradle to gate, or cradle to grave approach (Olivier Jolliet and Shaked 2015). In the thesis, we further explore the system boundaries, assumptions, and limitations of confined vs free-roaming beef production systems in four phases (Olivier Jolliet and Shaked 2015). The pictorial representation of all the 4 phases of the LCA is depicted in figure 5.1.

- Phase 1: Goal and scope definition, which includes a statement of the system boundary, functional unit, and aspects of the inventory and its corresponding environmental impacts.
- Phase 2: Inventory analysis, which includes identification and description of the network of unit processes and flows that make up the product's life cycle.
- Phase 3: Impact assessment, in which the environmental significance of inventory flows is estimated.
- Phase 3: And finally, the 'Interpretation of the results' in correspondence to its impacts

on the ecosystem.

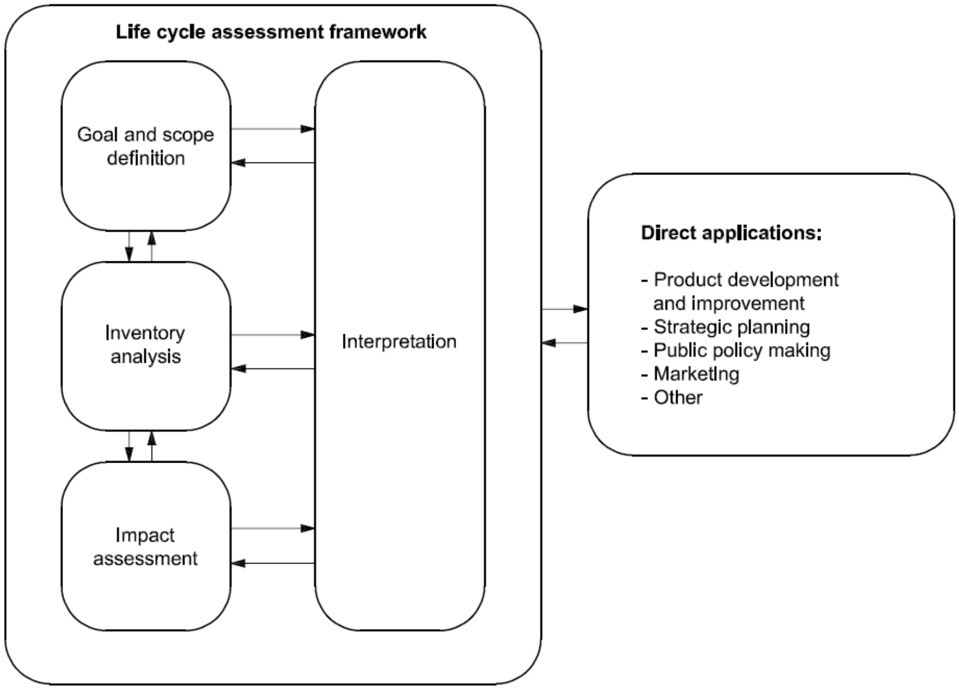

Figure 5.1 Life cycle assessment Framework (Olivier Jolliet and Shaked 2015)

5.1 Phase 1: Goal and scope definition

The goal and scope definition of LCA describes the product system in terms of the system boundaries and a functional unit. The functional unit is the important basis that enables alternative goods, or services, to be compared and analyzed (Kuczenski, Geyer, and Boughton 2011). The table 5.1 gives us a clear overview of the purpose of carrying out the analysis.

Table 5.1 Goal and scope definition

Goal/Purpose:	Evaluation of LCA for the environmental impacts of confined vs free-roaming beef production systems
Application:	The basis for deciding the most eco-friendly beef production systems.
Functional Unit:	500 kgs of beef produced (E.g:500 kgs)

5.2 Phase 2: Inventory Analysis

Life cycle inventory (LCI) focuses on the methodology for estimating the consumption of resources and the quantities of waste flows and emissions caused by or otherwise attributable to a product's life cycle (G. Rebitzer et.al 2004). The 5.2.1 inventory tables were generated with 'Eco invent' Databases. The raw materials required for the production of 500 kgs beef were quite similar for both the systems (confined vs free roaming production systems) with only a difference in feed rations. The respective differences were soybean meal, maize silage, maize grain in rations supply for confined beef production, whereas for free roaming smaller quantities of mineral supplements were provided. However, there are several limitations to the models which will be further elaborated in the next section.

5.2.1 Free roaming beef productions

The pictorial representation of the inventory analysis provides an overview of the processes and product systems included within the system boundaries. In the case of free roaming beef production systems, the boundaries begin with the grasslands and end at the fattening of the calves. The emissions to the environment within those durations were only considered. The thick black arrows indicate the emissions to the Air, water and soil and other arrows indicate the process flow within the systems indicated in figure 5.2.1. The production process before, which includes maintenance of grasslands, applications of fertilizer, transportation and electricity consumed where not included. The after-production stages, which include transportation of the produced meat and end of life cycle of the beef product is not included in the system.

Free roaming beef productions

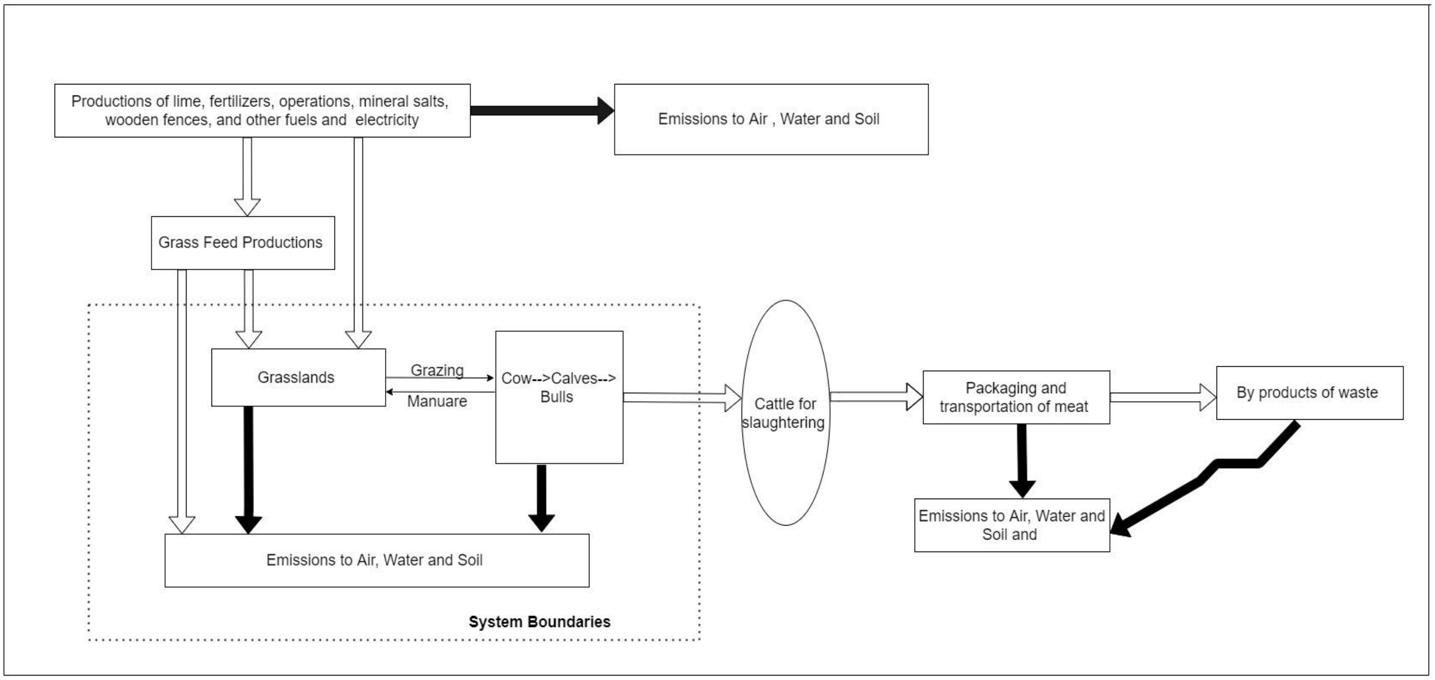

Figure 5.2.1 Flow process of free roaming production systems generated, with the aid of 'Ecoinvent' from environment data.

Limitations:

The limitations of the systems would be the following:

1. The data utilized is from "Eco-invent databases" and the data is obtained from the beef cattle production systems, pasture in Brazil.
2. The system considers the fattening of the calves in the grasslands and pastures and their respective emissions to the air, water and soil during the process.
3. The system commences at the grasslands and terminates at the fattening of heifers at the farm gate. Hence, the emissions after the fattening are not included in the boundaries. This indicates that the system boundaries do not include the slaughtering, packaging, and the transportation of the beef and their respective emissions after the farm gate.
4. Only mineral supplement and mineral salt are provided to the cattle for the purpose of fattening.
5. Grass seeds of 3% product mass are not included in the system.

6. The maintenance of the pastures with the aid of fertilizers, inorganic fertilizers and their respective market is omitted in the calculations. The other pasture maintenance activities

such as the weed control, harrowing, fertilizing by broadcasters are also considered to be out of the system boundaries.

7. The mating and the production of young calves are not included in the system.
8. The end of emissions such as the manure of the cow, and waste after slaughtering the heifers and cattle's are out of the system boundaries.
9. As there was no accurate data on the water requirements for the maintenance of cattle. The miscellaneous water supply for maintenance is omitted. Whereas, the water supply of unspecified origin, which mentioned in the database of the 'Eco invent' for the drinking purposes of the cattle is included in the system.
10. The values lesser than 10^-10 in the impact categories were omitted due to minimal mathematical insignificance.

Assumptions:

The assumptions of the models would be:

1. The free-roaming beef production model is quite similar to the 'beef production on pastures' model in the ECO- invent database.
2. The average size of the farm is based on the data obtained from the 'Eco invent databases and the average size of the cattle population in the farm is 150 cattles.

Table 5.2.1 provides a clear overview of the resources utilized during the production and the fattening of the cattles. The values in the Table 5.2.1 have been re-estimated and recalculated to the values to produce half a ton of beef (500kgs).

Table 5.2.1 Inventory Analysis table- Free Roaming production

From Environment:	Amount	Unit:
Land use change, pasture, man made	0.6283	ha
Mineral supplement, for beef cattle	53.295	kg
Salt	53.295	kg
Energy, gross calorific value, in biomass	7993.5	MJ
Occupation, pasture, man made	78540	m2*year
Transformation, from pasture, man made	3927	m2
Transformation, to pasture, man made	3927	m2

5.2.2 Confined production systems

The pictorial representation of the inventory analysis provides an overview of the processes and product systems included within the system boundaries. In the case of confined beef production systems, the boundaries begin with the usage of crops, rape meals, corn silage rations and end at the fattening of the calves. The emissions to the environment within those durations were only considered. The thick black arrows indicate the emissions to the Air, water and soil and other arrows indicate the process flow within the systems indicated in figure 5.2.2. The production process before, which includes the production of crops, maintenance, transportation and the associated emissions to (air, water and soil) where not included. The after-production stages, which include transportation of the produced meat and end of life cycle of the beef product is not included in the system.

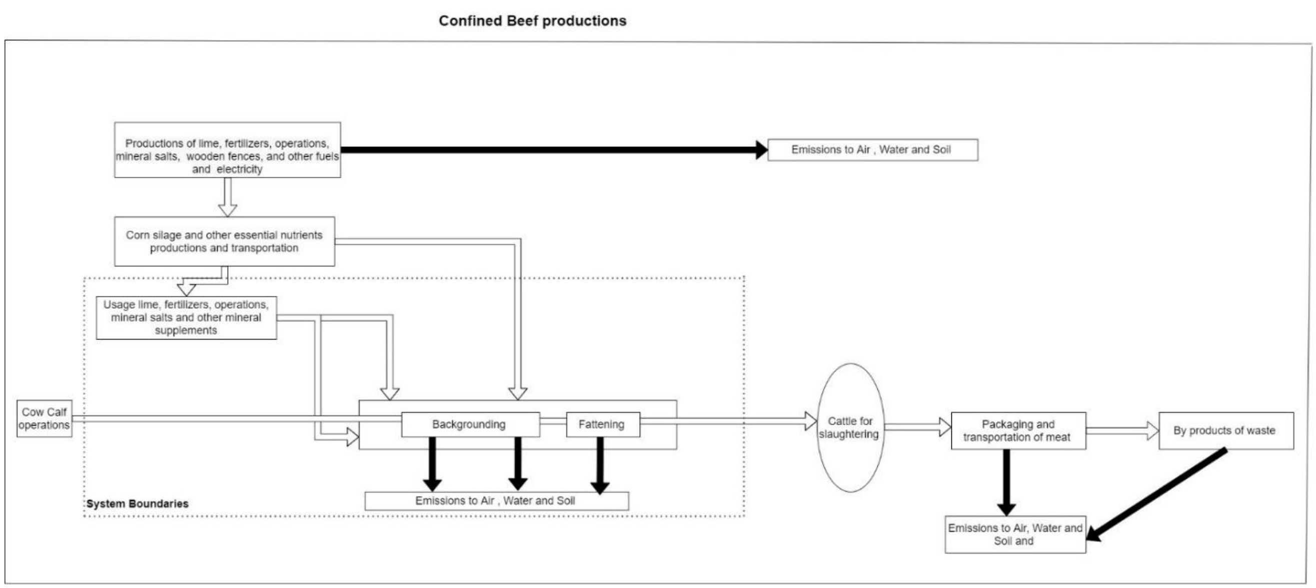

Figure 5.2.2 Flow process for confined beef production system with the aid of 'Ecoinvent' from environment data

Limitations:

1. The feeding and fattening of the respective feed rations would occur in a confined space for confined beef productions, with an occasional pasture feeds in a week.
2. The data utilized is from "Eco-invent databases" and the data is obtained from the beef cattle production systems in South Africa.
3. The system commences when the cattle's enters the feedlot and terminates at the fattening

of heifers at the farm gate. Hence, the emissions after the fattening are not included in the boundaries.

4. Production of Lime, Urea, fertilizers, mineral salt, soybean meal, maize grain, maize chop, maize silage, sodium chloride powder, rape meal were considered out of the system boundaries. This further indicates that the associated emission to air, water, and soil are of the system boundaries as well. However, the market and the utilization of those feed is included in the system.
5. The system boundaries do not include the slaughtering, packaging, and their respective emissions to air, water and soil.
6. Transportation of the beef and their respective emissions after the farm gate.
7. The mating and the production of young calves are not included in the system.
8. Farm manure is considered the only organic manure whose emissions are not included.
11. As there was no accurate data on the water requirements for the maintenance of cattle. The miscellaneous water supply for maintenance is omitted. Whereas, the water supply of unspecified origin, which mentioned in the database of the 'Eco invent' for the drinking purposes of the cattle is included in the system.
9. The values lesser than 10^-10 in the impact categories were omitted due to minimal mathematical insignificance.

Assumptions:

- The confined beef production system model generated is remarkably like the model of the Eco invent database 'Beef production in pasture and feedlots. The only difference would be the fattening and supply of the essential nutrients such as maize grain, maize silages, soybean meals. The feed ration supply would occur in a confined land area. Accounting for a reduction of land space and the modification of pasture will also be significantly lesser.

Table 5.2.2 provides a clear overview of the resources utilized during the production and the fattening of the cattle. The values estimated in the table 5.2.2 has been re estimated and recalculated to the values to produce half a ton of beef (500 kgs) to be exact.

Table 5.2.2 Confined production systems inventory table

From Environment:	Amount	Unit
Alfalfa-grass silage	17.55	kg
Electricity, low voltage	1.725	kWh
Energy feed, gross	947500	MJ
Irrigation	3.705	m3
Lime	13	kg
Maize chop	311	kg
Maize grain	287.5	kg
Maize silage	345	kg
Rape meal	68.5	kg
Sodium chloride, powder	6.05	kg
Tap water	148	kg
Urea	16.7215	kg
Weaned calves, live weight	238	kg
Wheat bran	97	kg
Occupation, grassland, natural, for livestock grazing	94.2	m2*year
Occupation, pasture, man made	22.9	m2*year
Occupation, unspecified	2.25	m2*year
Transformation, to grassland, natural, for livestock grazing	254.65	m2
Transformation, to pasture, man made	61.95	m2
Transformation, to unspecified	6.05	m2

5.3 Phase 3: Impact Assessment

Impact assessments are utilized to assess the environmental consequences of the inventoried emissions (Olivier Jolliet and Shaked 2015). They are based on the emissions from the air, water, and soil. The impact categories were generated with the aid of the LCA analysis method. Based on the classification from the inventory analysis, with the aid of 'Recipe 1.11' further categorization of emissions to impact categories. Midpoint categories represent the characterization of impacts. The end point categories represent the impacts on ecosystems, human health, and resources.

5.4 Phase 4: Interpretation of Results

The results obtained so far are interpreted and the uncertainties are evaluated. The key parameters and improvement options can be identified using sensitivity studies and uncertainty propagation, and a critical analysis evaluates the influence of the chosen boundaries and hypotheses. Finally, the environmental impacts can be compared with economic or social impacts (Olivier Jolliet and Shaked 2015).

5.5 Ecological Footprint

Ecological footprint is defined as the amount of cropland, grazing land, forest area, and fishing grounds required to meet the needs of a population for food, clothing, shelter, products, and services, as well as the amount of land required to absorb wastes. The impact metric is measured in the terms of, 'Land and resources used' (Pelletier, Pirog, and Rasmussen 2010). Footprint is an important ecological indicator of indirect accumulation of greenhouse gases such as methane and nitrous oxide due to the production activities (Pelletier, Pirog, and Rasmussen 2010). The ecological footprint is modeled with the aid of literature reviews from renowned authors.

Limitations:

- The cited model utilizes the Cradle to farm gate approach (Pelletier, Nathan, Rich Pirog 2020). Whereas the impact categories generated in the study included the system process only during the production stages.
- The cited literature utilized the data from the United States, upper Midwestern to be. Specific.
- The system does not account for the birthing of calves and associated emissions.

Assumptions:

The assumptions of the model would be as follow:

- The literature utilizes three beef production systems, two of which are of the similar model utilized in this study. The first system is similar to the confined beef production system and the other one is similar to the free roaming production system. The feed lotting and fattening of the calves in a confined and concentrated system represent the confined production system, whereas those attain weight gain through pasture feed without other mineral supplements represent the free roaming beef production systems. Hence, the results cited are a more or less an accurate representation of ecological impacts due to the beef production system.

6. RESULTS

The results were generated with the aid of the open LCA software and were based on the ecoinvent databases termed as" ecoinvent_371_cutoff_unit_20210104_1_". From the inventories database, both the inflow (resources utilized) and the outflow properties (emissions to air water and soil) of the systems have been recalculated for the values of half a ton (500kgs). The model graph of both the systems (confined and free roaming beef production system) gives a clear overview of the inflows in the system. The midpoint and endpoint categories give a tangible evidence of impact on the ecosystem, human health and resources as a result of beef production systems.

6.1 Model Graph

The model graph gives a pictorial representation of resources utilized during the production process. As the confined beef production utilizes much more resources to fatten the cows within shorter duration such as corn silage, maize, rape meal, protein supplements. Whereas free roaming beef production system solely relies on the grass feed with occasional mineral supplements. Hence, the inflow of the confined production system are greater in comparison to the free production systems. The inflows of both the beef production system are represented in figure 6.1, a and figure 6.1, b.

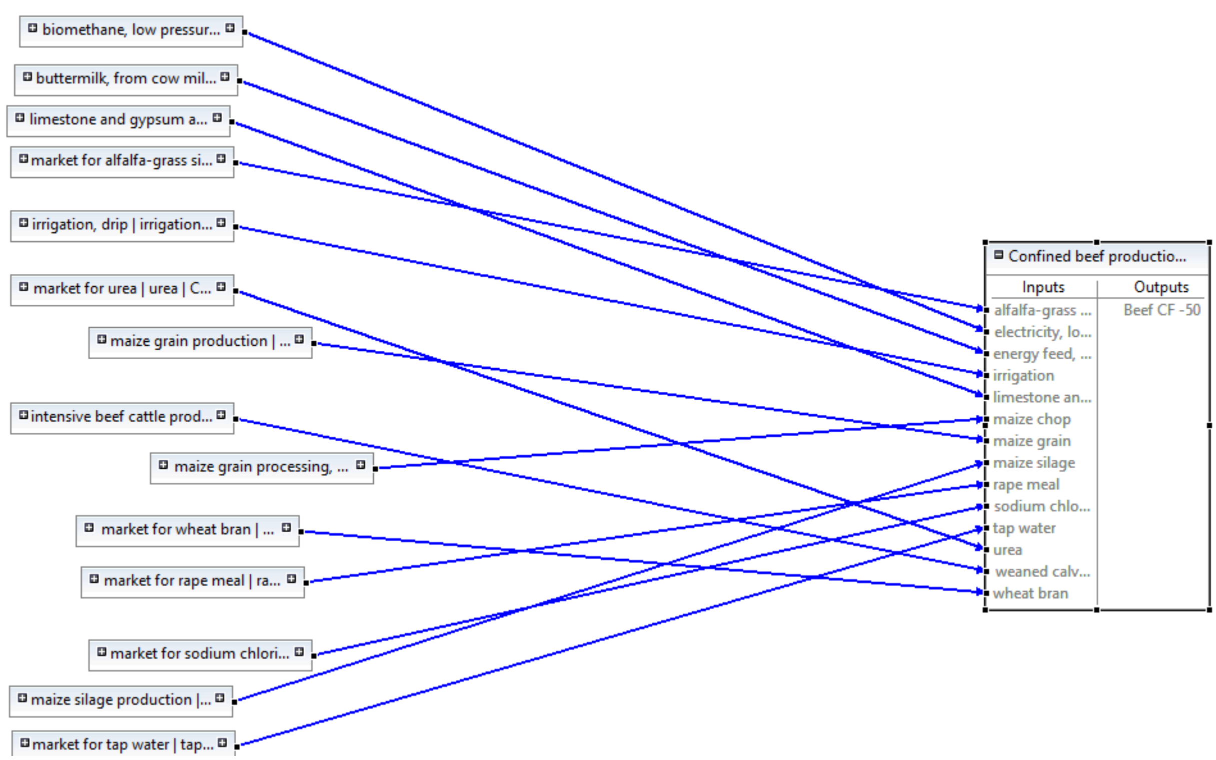

Figure 6.1, a Confined beef production system model graph

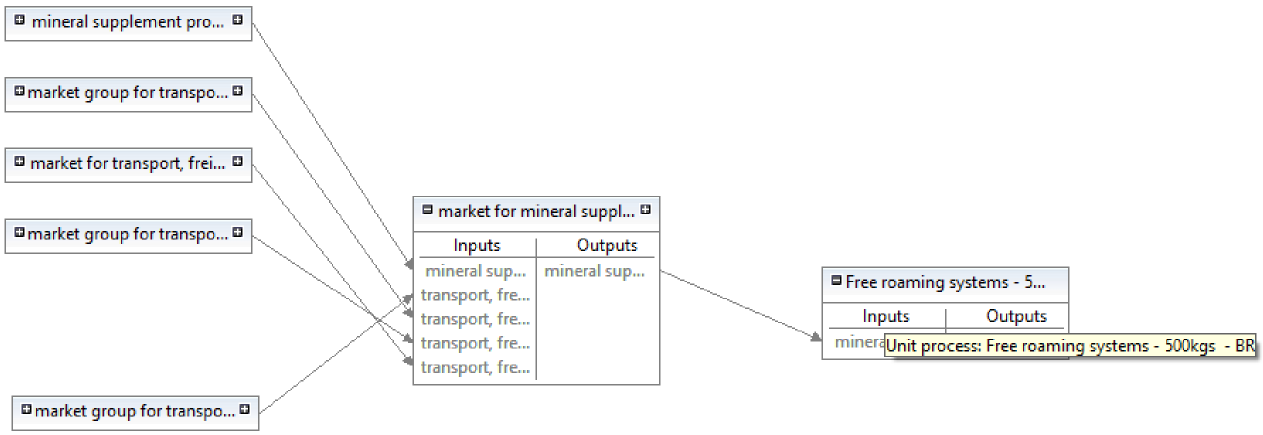

Figure 6.1, b Free roaming beef production system model graph

6.2 Mid-point categories

The midpoint categories have been calculated from the open LCA software under the cateogy of 'ReCiPe Midpoint (H) [v1.11, December 2014]' . The values have been estimated based on the respective emissions (to air, water and soil) cateogries. One of the major critera for utilizing recipe 1.11 in comparion to its counterparts is the ability to clearly differnate and determine the signifcant emissions in various cateogries such as the agriculatural land occupation, climate change, freshwater ecotoxicity and much more . There are around 18 midpoint impact cateogries out of which 8 were selected to based on the signifcance of the emissions and impact toe the ecosystem.

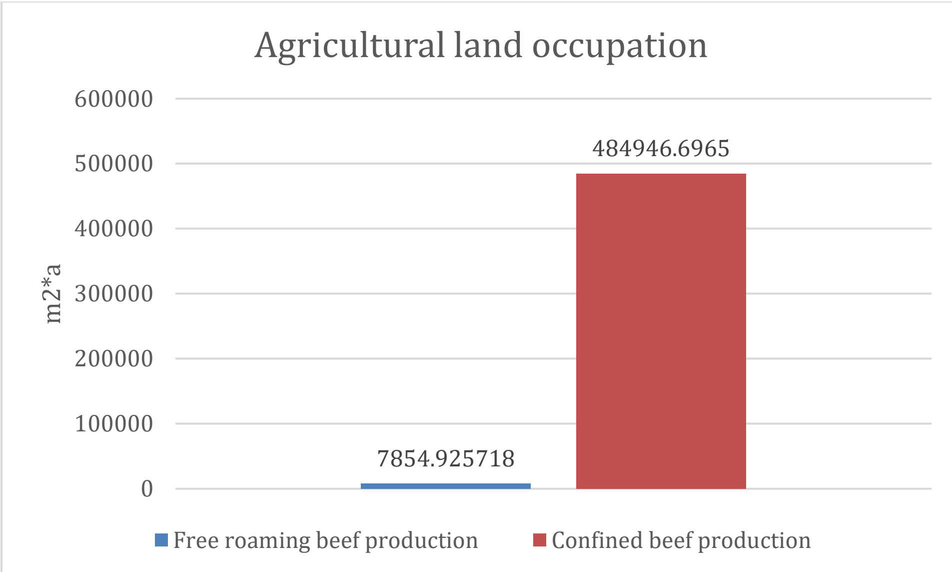

Figure 6.2, a Agricultural land occupation

The agricultural land occupation is represented in terms of m2*a. The free roaming beef production occupies around 7854 m2*a whereas the confined beef production utilizes much more land for production (484946.9 m2*a) which is indicated in figure 6.2, a. The reason being the utilization and storage of several resources such as the corn silage, hay, grass, silage and rape meals.

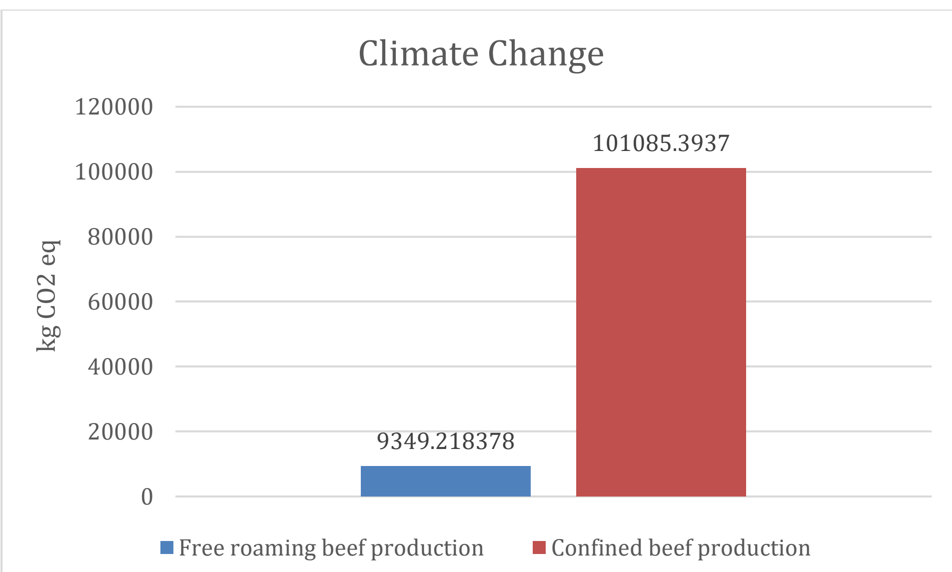

Figure 6.2, b Climate change

The climate change is indicated in terms of kg C02, eq. The climate change emissions from confined beef production systems are significantly ten times higher than the free roaming beef production systems which is indicated in figure 6.2, b.

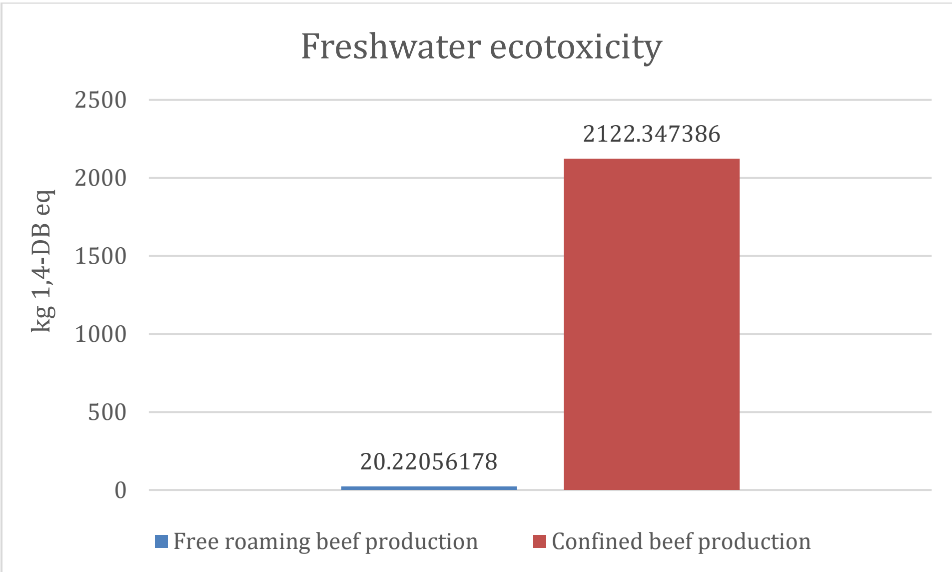

Figure 6.2, c Freshwater ecotoxicity

The freshwater ecotoxicity is represented in terms of kg1,4-DB eq. The values for confined beef production systems are significantly higher than the free roaming production systems for freshwater ecotoxicity indicated in figure 6.2, c.

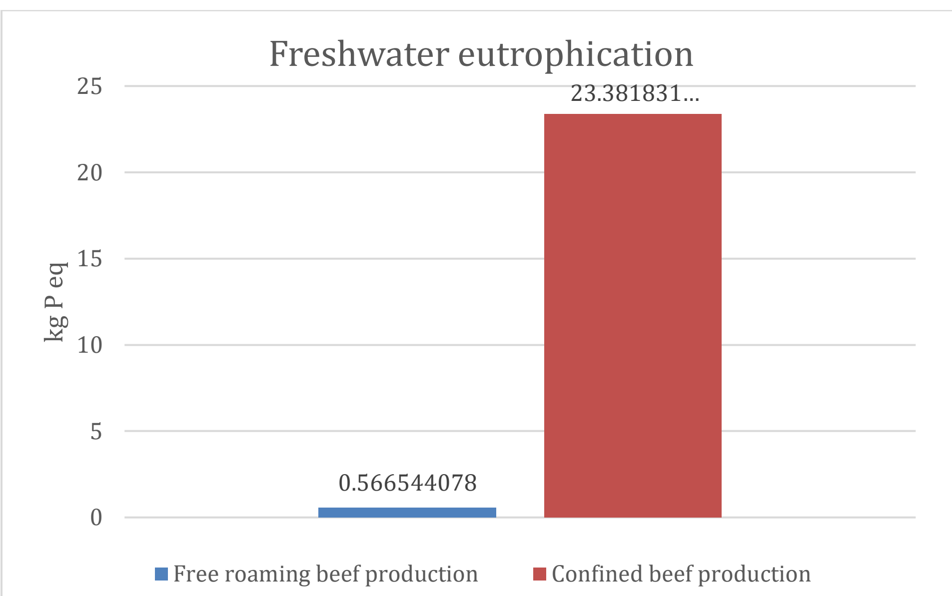

Figure 6.2, d Freshwater eutrophication

The freshwater eutrophication is measures in the terms of Kg P eq. The values for confined beef production systems are 23 times higher than the free roaming production systems for freshwater eutrophication indicated in figure 6.2, d.

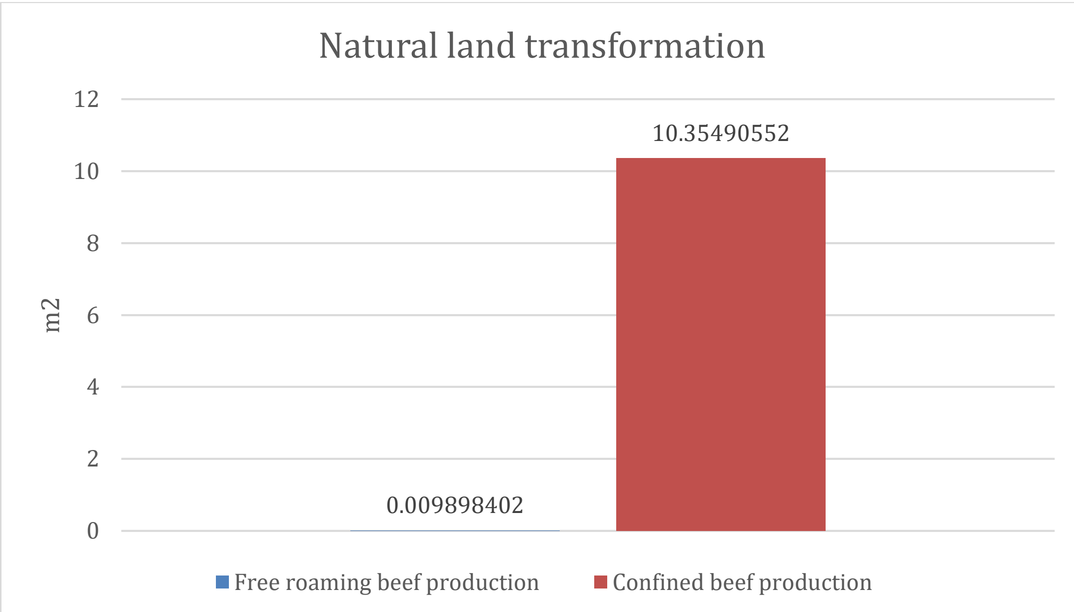

Figure 6.2, e Natural Land transformation

Natural land transformation is measured in the terms of m2. The land occupation for the confined beef production systems is 10 times higher than the free roaming beef production system which is indicated in figure 6.2, e.

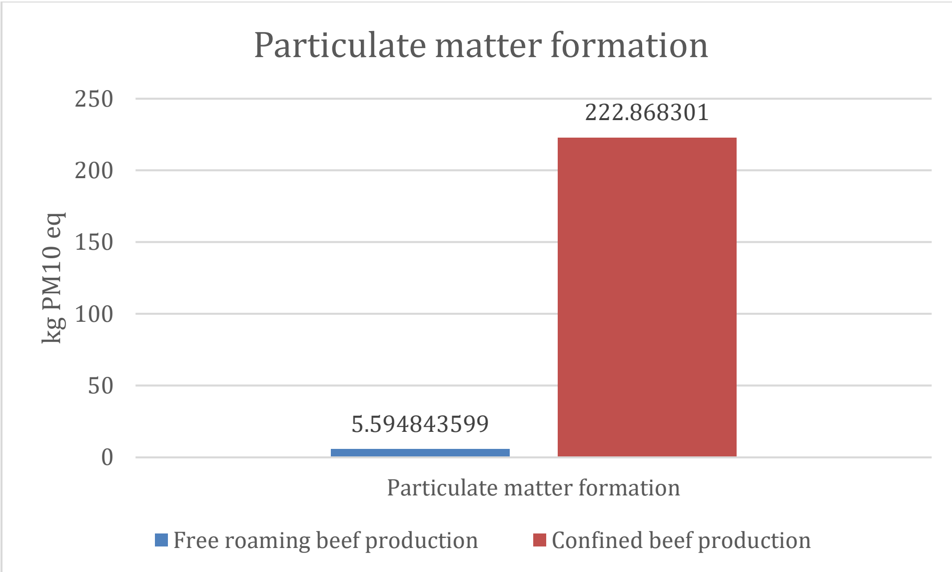

Figure 6.2, f Particulate matter formation

The particulate matter formation is measured in the terms of kg PM 10 eq. The confined beef production similar to the other categories, has a 100 times significant impact in terms of particulate matter formation, which is indicated in figure 6.2, f.

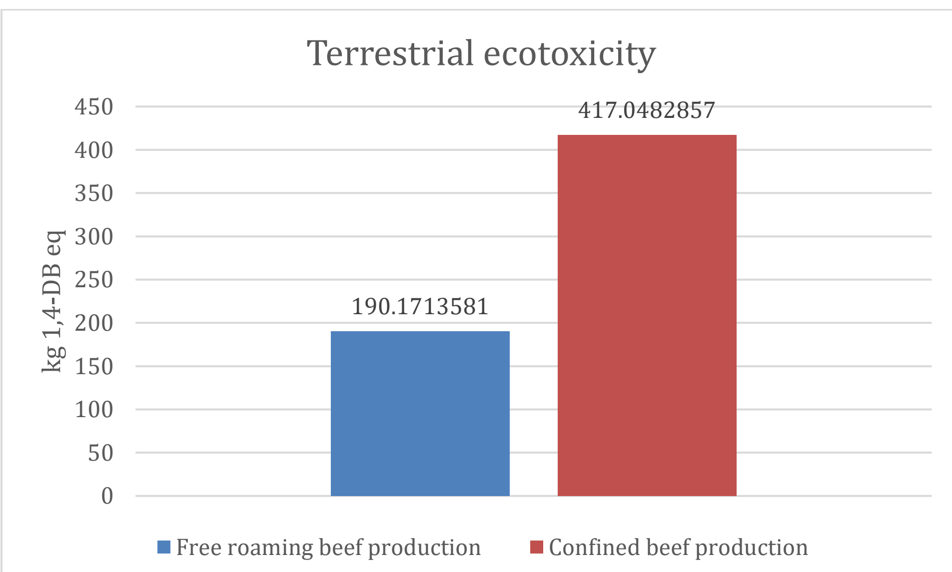

Figure 6.2, g Terrestrial ecotoxicity

The terrestrial ecotoxicity is measured in the terms of kg1,4DB-eq similar to the freshwater ecotoxicity. The impact caused to the terrestrial ecosystem is significantly higher for confined beef production systems which is indicated in the figure 6.2, g.

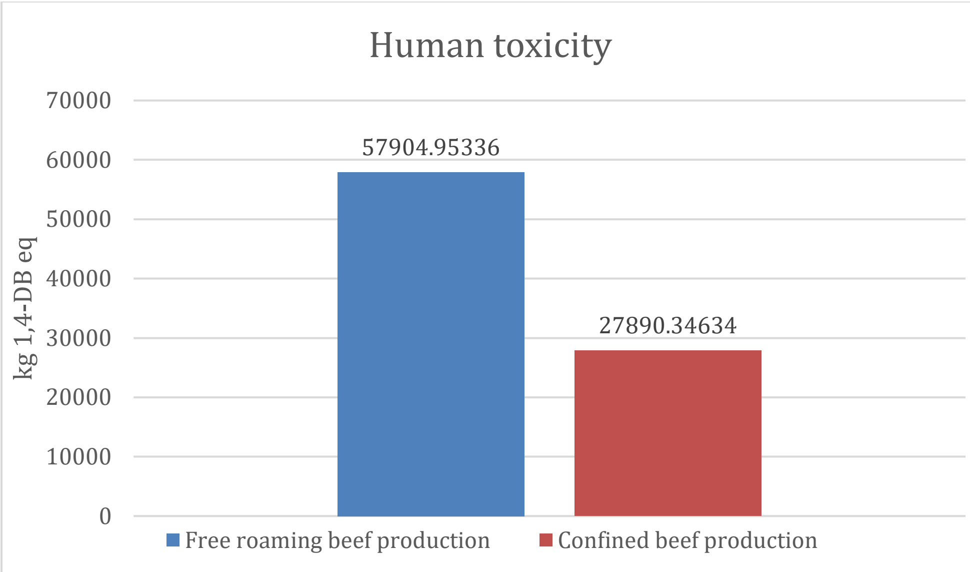

Figure 6.2, h Human toxicity

The Human toxicity is measured in the similar terms to the freshwater and terrestrial ecotoxicities. The values are significantly higher for the free roaming beef production system in comparison to the confined beef production system which is indicated in figure 6.2, h .

6.3 End point categories

The end point categories were analyzed on similar bases to midpoint categories. The impact category selected were 'Recipe Endpoint (H) [v1.11, December 2014]'. A major focus is given to impacts in three categories impact on human health, ecosystem and resources.

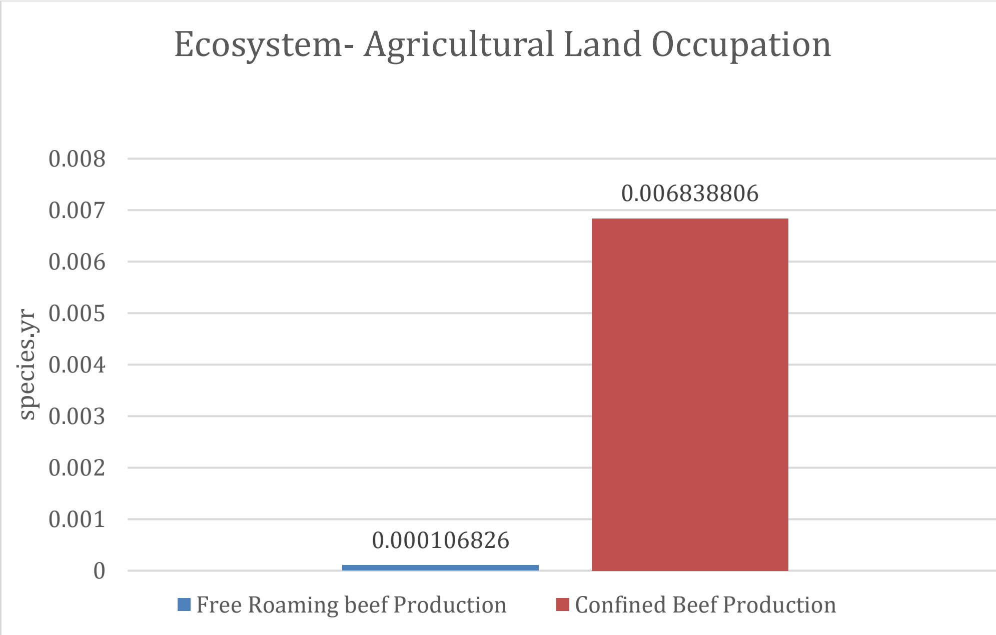

Figure 6.3, a Ecosystem- Agricultural Land occupation

The Ecosystem category measures the impact in terms of species.yr. The impact on ecosystem in terms of agricultural land occupation is significantly higher for confined beef production systems which is indicated in figure 6.3, a.

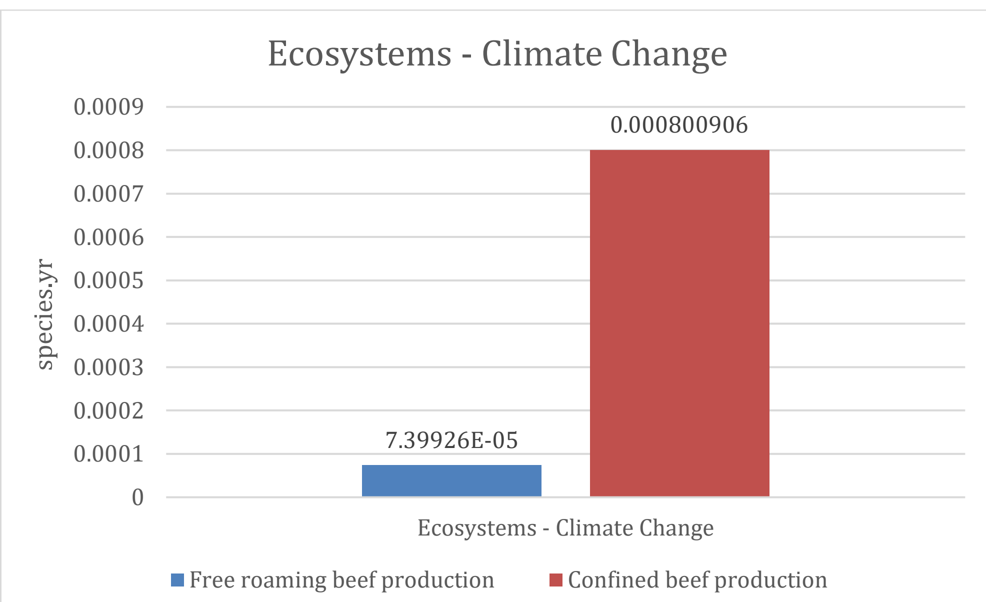

Figure 6.3, b Ecosystems- Climate change

Climate change especially in terms of impact to the ecosystem, is one of the important categories for assessing the damages to the environment. The confined beef production system has a significantly higher value than the free roaming beef production system indicated in the figure 6.3, b.

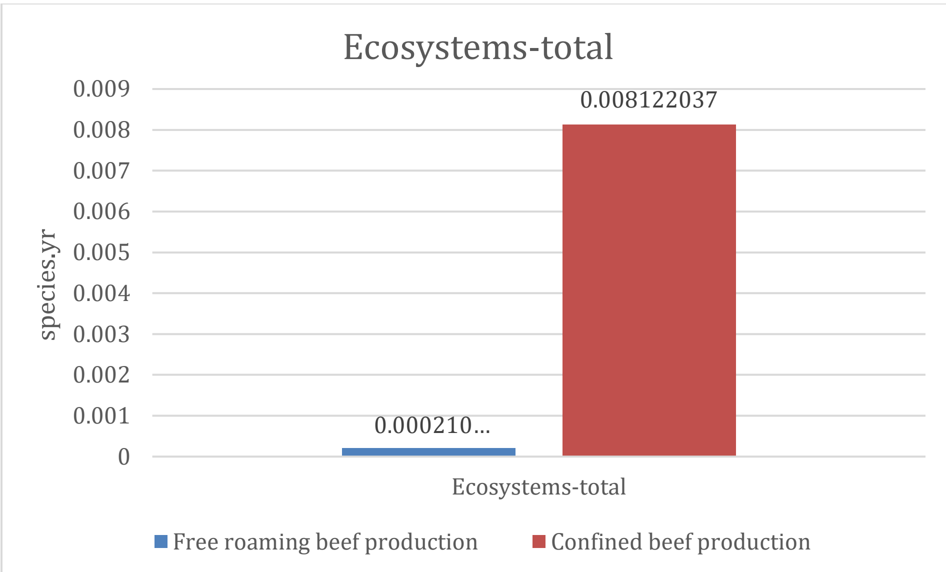

Figure 6.3, c Ecosystems – Total

The total impact to the ecosystems is significantly higher for the confined beef production system indicated in the figure 6.3, c

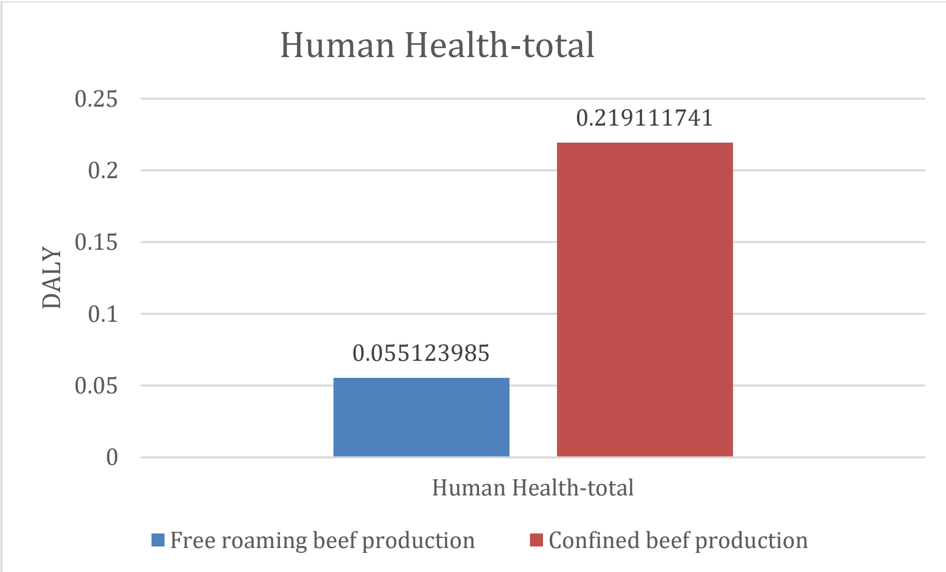

Figure 6.3, d Human Health- Total

The impact on human health is calculated in terms of DALY (Disability Adjusted Life Years). The impact on human health is significantly higher for confined beef production system indicated in the figure 6.3, d.

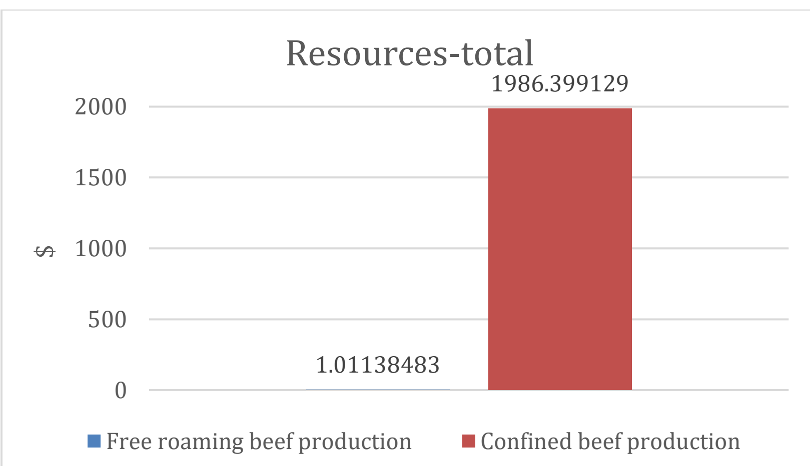

Figure 6.3, e Resource –total

The resources used is indicated in terms of $. The confined beef production system clearly utilizes significant amount of resources in comparison to the free roaming systems indicated in the figure 6.3, e.

6.4 Ecological Footprint:

Based on the study conducted by Pelletier, Nathan, Rich Pirog 2020 the ecological indicator of the beef production system has been estimated. The study provides the estimation of the 'Land resources utilized' for the various system. Based on the assumption and limitations indicated in the subsections of chapter 5.2, the ecological footprint estimation has been indicated in the figure 6.4. The pasture operations have significant ecological impacts in comparison to feedlot and backgrounding operations. The values have been calculated in the terms of m2 based on the land occupation.

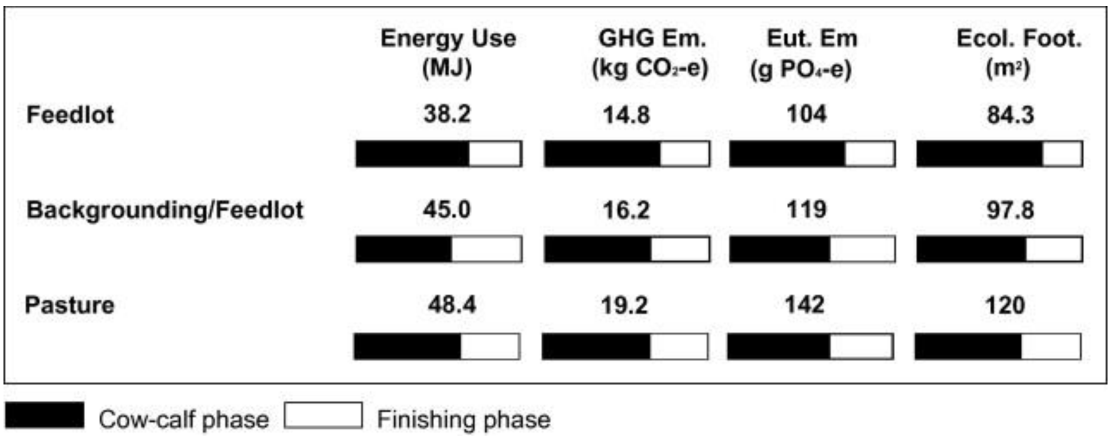

Figure 6.4 Ecological Indicator for beef production system

7.CONCLUSION

The confined vs free roaming production systems aims to analyze and categorize the impacts to the ecosystem in terms of mid-point and end point categories. The systems have several assumption and limitations which were further discussed in detail under the methodology section of chapter 5. The emissions categories were significantly higher for the confined beef production system. The higher emission categories were due to significant number of resources utilized from ecosystem to produce beef. In confined beef production, several proteins and nutrients were fed to build up the muscular volume and weight of the cattle within a shorter period. The resources utilized in terms of land (occupational transformation of the pastures and storage of the resources) to electricity and water consumed were also significantly higher than its counterpart. Whereas the free roaming beef production utilized the grass feed as a major source of nutrition. In case of protein deficiency, mineral supplements were provided in liquid. As the resource utilized is significantly less, the emission due to the production, manufacturing and transportation of the same are also significantly less. In free roaming, duration for the gestation and the maturing of the cow is longer than confined production. The results of midpoint and end point impact categories indicate confined beef production to highest impact to the environment. In terms of human health and resources utilized, confined beef production has greater impacts. Several studies, similar to the conditions and limitations discussed in chapter 5 of the thesis that the confined or the industrialized form beef production to the least environmentally friendly system. A remarkable number of emissions contributing to climate change, acidification, eutrophication and ecotoxicity were methane, dinitrogen monoxide, copper ion, cadmium ion, zinc and Nickel. The analysis provides us an overview of where to apply mitigation measures to combat the impact. The results were generated from the open LCA software and data was utilized from ecoinvent databases. The analysis produced similar results to the literatures published by (Ogino et al., 2016), (Pelletier et al., 2010) and (Broom, 2019).

When pointing out the alternatives, there are several ecosystems which utilize integrative approaches such as the Silvo Pastoral system, AMP and Holistic planned grazing which have shown to sequester carbon and methane in soil. Silvo Pastoral on other hand, ecologically modifies the environment in a beneficial manner (Nair et.al 2009). Studies also indicate that semi-intensive beef production system has lesser emissions in comparison to its counterparts in terms of acidification potential, global warming and impacts on human health. The major contributor of methane from ruminants is during the production and manufacturing process. Hence, it would be crucial to sequester the carbon during the process.

SUMMARY

The overall goal outcome is to choose the best available method of cattle production system that is beneficial to the human health and the ecosystems. The number of resources utilized, and the associated emissions produced as a byproduct is observed to one of the significant contributors to impacts on the ecosystem and human health. During the analysis it was also observed that confined beef production systems had a significant impact on the ecosystem in comparison to its counterpart free roaming production system. In both the systems, the production process has been analyzed until the farm gate, hence the emissions after the production stage and the disposal of the waste to the ecosystem is not considered. The thesis aims to compare the impacts of two beef production process and explore the alternatives. In doing so we analyze the possible mitigation strategies.

The overgrazing of cattle in grass feed agriculture is one of the major reasons for desertification.

One of the crucial ways to reduce the impact would be cut the resources feed to the cattle in the feedlot and backgrounding process. As most of the resources fed are not primarily produced in the region of beef production, they usually have to be transported. Hence, the associated emission from transportation is also a major contributor. Mitigation of waste after the production in the form of refining and filtration of the waste from waterways. Others, include reducing overgrazing and overfeeding of cattle's. An integrative approach which holistically sequences carbon such as the silvopastrol systems can also be adopted. Another strategy by (Capper, 2011) would be the 'dilution of maintenance' . It indicates, the minimization in daily maintenance, reduction in time period to slaughter. In doing so, we save energy and water, which are vital resources. As the energy utilized varies from gestation to slaughtering. The earlier the slaughter, the greater the possibility to minimize the energy utilized. In free roaming productions system, the ruminants produce significant quantities of methane during the digestion, which in turn is a major contributor to climate change. Hence, by reducing the duration of the animal on farm we significantly reduce the associated emissions.

Several authors such as(Mekonnen & Hoekstra, 2012) and (Pimentel & Pimentel, 2003) have indicated that reducing the meat consumption would decrease the hunger of the world to signifiable levels. Hence, reducing the meat consumption in our daily diets and opting for vegan or vegetarian diets would be a sustainable alternative.

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