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Food Carbon Footprint Impact on Environmental Sustainability

Bachelor Thesis

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Declaration

I declare that the Bachelor Thesis Food Carbon footprint impact on Environmental Sustainability is my own work and all the sources I cited in it are listed in Bibliography.

Prague March, 2016 Signature___________

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Food Carbon Footprint Impact on Environmental Sustainability

Summary

Our increasing needs of the food products and the growing diversity modern lifestyle requested, the community farms are far behind to meet the requirements. Modern food supply chain is undergoing a way more complex system before they are served on the table, on-site farming operations, animal products management, and post-farm operations together with industrialized management impacts on environment directly and indirectly. Therefore, in some extent, end-users consumers' food consumptions patterns will influence food industries and farmers, as the same as 'supply and demand'.

Carbon footprint as an indicator to express the total amount of GHG is emitted by human activities and CF methodology indicated several advantages of a full life cycle assessment. A CF calculation can technically provide the information of environment friendly meals and the carbon labelling scheme gives a guideline how to consume eco-friendly. Even though, the uncertainty of food CF is arise from the difficulties in measuring GHG emissions from biological systems and the high variability in agriculture sector, especially in soil emissions. Nevertheless, it gives an evidence showing that in addition to technological mitigation it will also be necessary to shift patterns of consumption, and in particular away from diets rich in GHG intensive meat and dairy foods. This will be necessary not just in the developed but also, in the longer term, in the developing world.

Key words: climate change, diet patterns, GHG emissions, life cycle assessment, sustainable consumption

CONTENTS

1. Introduction

One of the reasons why food is such a compelling field of study and action is because it comprises pretty much all contemporary economic, environmental, social and political challenges. Regarding the environmental issues rising from agriculture, it is accounted for 43 % of the global methane (CH_4) emissions and 70 % nitrous oxide (N_2O) emissions in 2010, which the former is mainly from enteric fermentation and manure, rice cultivation and the latter is mainly result from synthetic fertilizers and agricultural waste burning.

In order to quantify the food supply chain from farm impacts on environment and affected the climate, carbon footprint has been taken use widely to estimate GHG emissions in agriculture On the aspect of diet patterns, carbon footprint is used as an indicator of the food items so that imply consumers' individual potential contributions to GHG emissions.

2. Objectives and Methodology

- This thesis investigated agricultural products with its carbon footprint methodology based on IPPC 2007 guidelines, as well as the available scientific literatures. Meanwhile, provide additional knowledge regarding the interrelation between the factors of GHG emissions on food products with its negative impacts on environment.
- Investigate contemporary food consumption patterns on local and global natural resources by tracing CF during a life cycle. Dietary patterns comparisons studies made between Czech Republic and China. To understand the resource intensive food environmental impacts.
- Through providing scientific knowledge and methodology regarding calculating the carbon footprint of food products. For consumers, facilitate their sustainable food consumption with considerable amount of meat and milk intake, the comparable results of carbon footprint value of different food items has been mentioned and dietary recommendations has been discussed; for farmers and commercial agriculture industries, carbon footprint value provides the way to rethink the farming operations so that raise the social responsibility for environment.

3. Theoretical Part

3.1 A global perspective of food system

"A healthy world through sustainable food system "

- World food system, ETH, Zürich

The term food system is frequently used in discussions about agricultural production, nutrition, and health. The food system nowadays on one hand as the function of feeding the world, on the other hand, it is ruled differently under international trade and varies from the countries' governmental policies and powerful economy tends.

When we walk into the supermarket with full of diverse products to choose with limitless consumption, few of us have questions or care about where are they from and how are they delivered. We have ignored the products' origins, Mulroy (2015) reported that 61 % of UK children have 'no idea' how the food they eat is grown, with one in ten not knowing an apple grows on a tree. The sushi soy source ingredients have travelled half hemisphere to be served in here was from Argentina and Brazil. To satisfy the global growing demand for soybeans at nearly 6 million tons per year, the Amazon is being cleared both by soybean growers (Hoefle, 2013). Reaching 100 million metric tons of soybeans imported to China, and the exporting accounted for 43 % of Brazilian and 25 % of Argentinean (WWF, 2012). The current trends of food choice towards to increase the environmental problems, and thus the more environmental diets need to be identified (Carlsson, 2001).The similar case happened in Europe too, and as well as other countries. Due to the restrict weather conditions, food products with special climate conditions are not able to plant in local, so they are from everywhere (BEUC, 2013). Food products comprises series of activities and equipment to complete this complex process from farm to table, including growing, harvesting, processing, packaging, transporting, marketing, consumption and disposal of food. The inputs and outputs operations to each of these steps are required. Food systems are either conventional or alternative according to their model of food lifespan from origin to plate (Simon et al, 2003). It can be influenced by policy, economic scales, environmental context, and social community. Convergent results are showing that climate change will fundamentally alter global food production patterns (Elbehril, 2015).

3.1.1 Factors influencing world food supply

When we are concerning about the excessive intake of food (over nutrition), another world is combating hunger. The latest statistics FAO (2015) showed there are 795 million people still don't have enough daily food, and 98 % of them are living in developing countries. The World population will be 9.1 billion by 2050, 34 % higher than today.

Agriculture is highly dependent on the climate; therefore, it's very sensitive to the changes. Extreme weather and natural disasters worried the farmers, as well as the agricultural markets (Gornall et al, 2010).Especially for the small-medium farm holders who is holding marginal lands are vulnerable to crisis (Easterling, 2007).Without proper income ,or not even basic food is causing migrate to cities rapidly, and continues the next problem of urbanization(Satterthwaite et al,2010).In some other countries, increasing incomes per capita are shifting people's diet to demand more meat based protein products, which indicates the more crops feedstuff and grassland for animal, and the consequence of natural ecosystems ecosystem service tend to decline (Kearney, 2010; Godfray et al, 2010).

Price volatility with uncertainties as the increasing demand of alternative energy sources like bio-fuel made from crops mainly from staple foods like i.e. wheat, maize (FAO, 2012). Inappropriate and unsustainable production system cause monumental impact on earth's finite resources (Moomaw, 2012).

We have benefit from modern agriculture with its advanced technology to produce more food, however, unfair trade is created by monopoly in food industries took advantages ahead of the market , and uneven distribution of rewards, technology accelerated the gap between rich and poor ,abundance and famine(Behnassi et al, 2014).

To cope with increasing population and make it more available for hanger population, meanwhile, minimize the environmental breakdown, the effective intergovernmental cooperation and regional agriculture policies are significant. When global food trade provided cheaper transport and reductions in agricultural tariffs will open up employment opportunities and economic growth for these regions (Bruinsma, 2003).The aggregation of efforts to reshape the conventional agro-food system that frames our conceptualization of the fight over the food (Wynne, 2007).

Future land use and food security will be determined largely by the dynamics and interactions of agricultural markets, climatic suitability, adaptive capacity and direct interventions along the supply chain (Elbehril, 2015).Many strategic researches on food security along with mitigating climate changes has been studied. Much work still need to cooperate with social–technical changes of agriculture development in the future, as D'Odorico (2014) concluded, "the world is more interconnected than ever, and the world food supply increasingly depends on this connection".

To sum up the main drivers to affect the future global food supply will depend on:

- Population growth and urbanization;
- Agriculture and climate change interaction;
- Ecosystem service and integrity;
- Availability of finite natural resources;
- Globalization of trade, economics and political change.

Understanding these factors is crucial to influence the future food system.

3.1.2 Sustainable food system

A sustainable food system was defined by high level panel of experts (HLPE) from FAO, is a food system that delivers food nutrition and security for all in a way that not harmful for economic, social, environmental aspects, yet able to generate food security and nutrition for the future generations.

Our current industrial agriculture food supply is different from conventional ones. From environmental point of view, a main contributor to GHG emissions, an estimated 25% of emissions of the total; from sustainability point of view, the available natural resources are threatened (Garnett, 2011).

The debate on food system sustainability is increasing by individual and experts, such as Jim Sumberg (2009) questioned 'What can be the best food system deliver fairness, economic, nutritional, rural development and environmental goals?' No matter distribute evenly, balance nutrition or environmental impacts reduction are all critically. Sustainable food will only be achieved only if these are re-oriented (Gomiero et al.,2011).

I highlight four values based on the research:

- Productivity and efficiency and Sustainability

Agriculture technology innovation brought us more diverse and quantity of food. Productivity can be achieved with approaches like to maximize yields through formulating practical nutrient based feedstuffs and enhance growth by improving conditions of animal housing systems. The efficiency of agriculture by optimizing the utility of technology and time, also cleaner energy options. For example, the usage of agriculture waste (crop residues) to make bio-gas fuel (Garnett et al, 2011).

External source of public service particularly can push the food system towards greater sustainability, such as 'sustainable catering' in campus provided 'climate-friendly' meals. The research proved that consumers' meal choices can be affected by offering meals with an intervention (Visschers et al, 2015). More details are presented in section 4.6.2.

- Excessive food consumption

Less is more .This problem is linked between consumers and food suppliers who is promoting unsustainable consumption patterns which are wasteful for natural resources (Reisch,2013). On the one hand, the 'less is more' approach could carry on in the ways like reducing consumption of dairy and bovine meat products, which has the most GHG emissions brings more benefits to ecosystem to future generation, on the other hand, reduce excessive food consumption will reduce the food gap (Lipinski, 2013).

- Food security

The security supply of food include both national and household levels to feed people adequately (Waterlow,1998).A resilient food system is essential overall would have the ability to continue providing sufficient quantities of food to face and sustain significant changes, i.e. prices, political ,and social changes (Sumberg, 2009).

- Ethical boundaries

Food Ethics Council (2009) 'Put fairness at the heart of efforts to promote sustainable food'. The challenge is to address uneven and resource-intensive consumption patterns, an enlightened analysis of how systematic imbalance should be addressed is absence, such as the feeding of grains to livestock is identified as a 'waste' since these could be more efficiently consumed directly by humans (UNEP, 2009). Other ethical and environmental concerns are added as well, i.e. water use and pollution, animal welfare (especially intensive breeding) and labour working conditions.

Table 1. Summary of four values:

	Productivity Sustainability	Food Security	Excessive food Consumption	Ethical Boundaries
Focus	Changes in production supply	resilient food system	Changes in consumption models	Fairness and social justice
GHG Approach	From producers to the end users-consumers with less environmental impacts	constraints on agricultural activities	Reduce environmental harmful products	Human maintain carefully ecosystem
Values	Ultimately green growth	Minimize hunger and malnutrition	Saved resources	Harmony for both nature and human

Challenges	How to better implement governance framework of sustainability with not less productive ?	Distribute food with nutritional values evenly in developing countries	How to change people's behaviour to reduce over consumption?	How to penetrate this ethic to commercial agriculture industries

For decision makers need to concern other social, cultural context, including human nutrition, biodiversity as well as animal welfare (Garnett, 2011). Sustainable food system will sustain when the overall economy is oriented to well-being, social justice, and system resilience. In other words, while a specific focus on food is certainly justified, and the food system itself can be an important step for the transit phase to sustainability.

3.2 Natural resources availability

International food research institute (Anderson, 1997) have pointed out if agriculture system is managed with efficient, environment friendly compatible with natural resources, then people will be able to access to sufficient food no matter economically or physically.

3.2.1 Agro-ecological footprint

Two mangoes with same colour, same nutrient content, even looked almost the same .But the one from Philippine and the one come from Taiwan are surely different farming systems, therefore must have different environmental impacts. How do we investigate and trace the impacts on agro-ecosystem? Scientist firstly took use of footprint, important quantitative methods. The concept of footprint, which was derived from ecological footprint, first introduced into the scientific community by Rees and Wackernagel (1996).The ecological Footprint is an effective tool for measuring human excessive demand on natural resources and monitoring environmental impacts on earth's system. It is an appropriate criterion for evaluating greenhouse gas emissions, usage of land and water in agriculture, also measure the nitrate from fertilizers and pesticides for assessing sustainability of agriculture. To calculate the ecological footprint, the most used method is Life Cycle Assessment (LCA) (Huijbregts, 2006). In this thesis CF calculation principle is based on it.

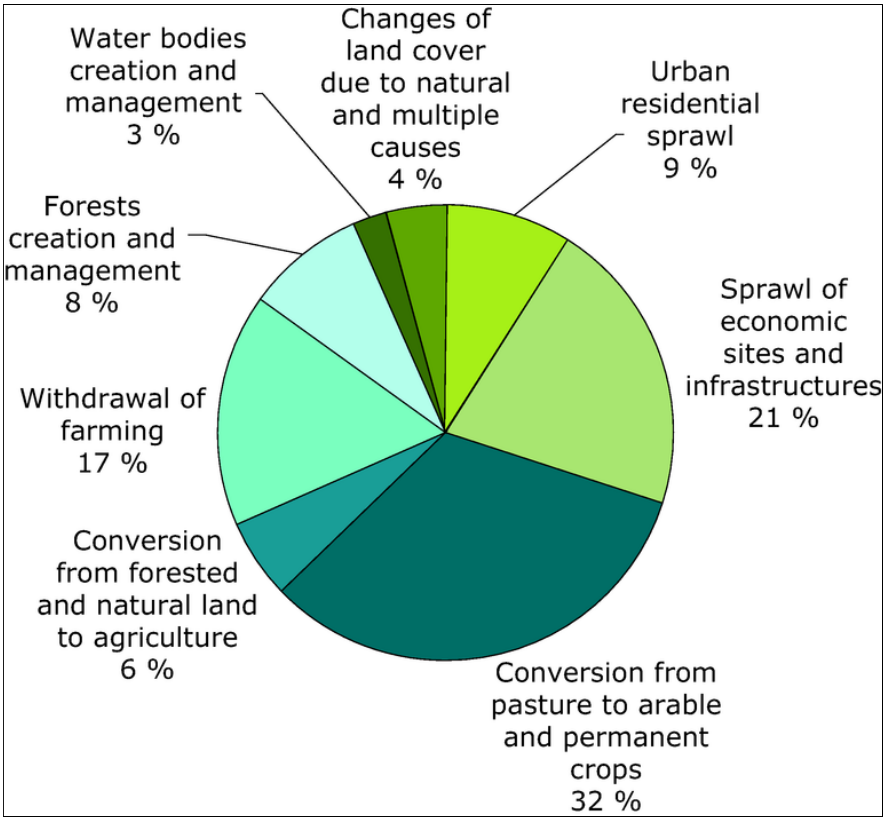
3.2.2 Anthropogenic Land Use Change

Land use change is defined by the United Nations Framework convention on climate change 'A greenhouse gas inventory section that covers emissions and removals of greenhouse gases resulting from direct human-induced land use change and forestry activities (UNFCC, 2009). It has been the subject of two major reports by the Intergovernmental Panel on Climate Change (IPCC, 2000).

Land-use changes directly affect the exchange of greenhouse gases between terrestrial ecosystems and the atmosphere. Emissions of CO_2 from deforestation arise mostly from the burning of trees and other vegetation in tropical forests cleared for industrial or agriculture use (IPCC, 2000).The losses increases in carbon storage and other ecosystem services.

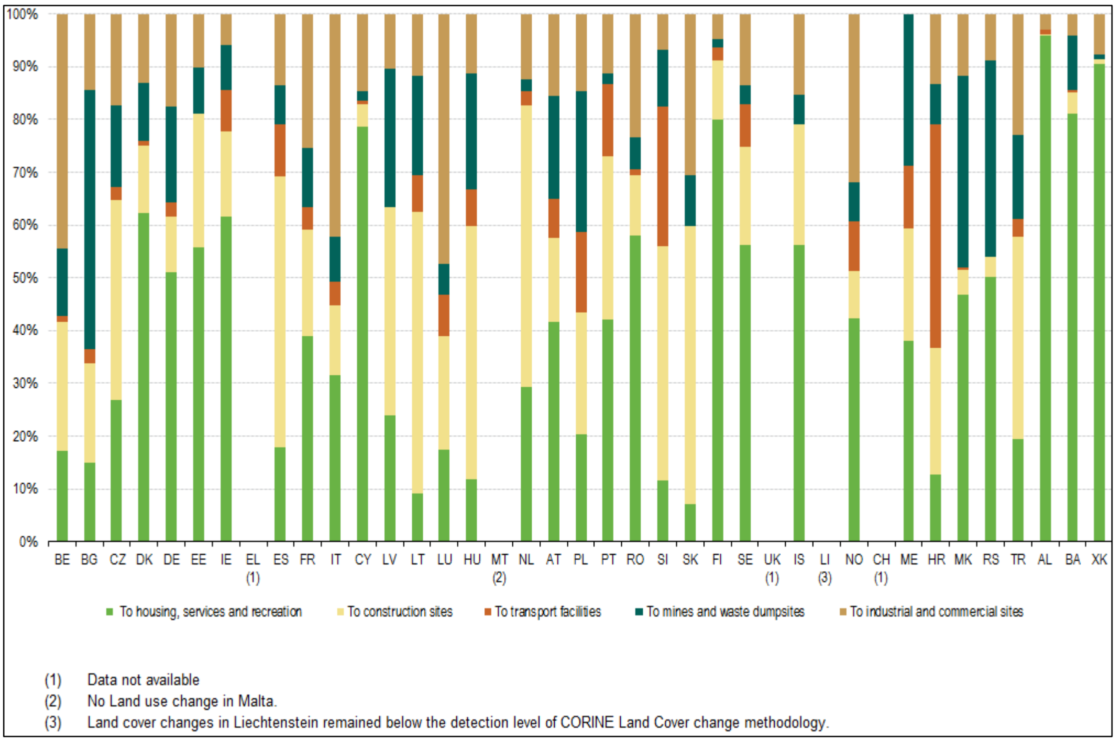
The below two graphs figure 1 showed the different purposes causes grassland reduction in EU-27 countries, and the figure 2 present the main changes of land use Data is collected from European Environmental Agency 2012.

Figure 1 Cause of loss of grasslands in Europe



(Source: EEA, 2012)

Figure 2 Land use change of agricultural land (ha and %) and conversion of agricultural land to artificial surfaces (ha and %), 2000-2006, EU-27&EU-Candidate



(Source: EEA,2012)

Figure 2 presents the reasons of grassland reduction in Europe. It is including the conversion for permanent crops, agriculture, for farming, residential urban sprawl, also for water body creation. So overall, the major purpose for conversion is that convert grassland into arable and permanent crops accounts for 32 % is the highest for usage change, followed by for the use of infrastructure usage with 21 % and withdraw of farming 17 %.

Figure 3 showed the EU-27 and EU-candidate countries land use change from 2000 to 2006 to commercial, agriculture, construction and infrastructures. In Czech Republic, the most change is used to create construction sites about 30 %; Belgium surprisingly almost 40 % used for mining or waste disposal; Luxembourg land change to use for industrial almost 50 %; Germany greatly over 60 % change for housing.

Europe is one of the most intensively used continents on the globe, with the highest share of land (up to 80 %) used for increasing demand for housing ,and the link between economic activity ,growth of transport infrastructure, and agricultural intensification as well. How the land is used constitutes one of the principal reasons for environmental change, with significant impacts on quality of life and ecosystems (EEA, 2013).

3.3 Carbon Footprint

3.3.1 History

The global constantly pay attention to climate change after the IPCC assessment climate change 2007 report released along with the international media reports, and spurred by blockbuster movies, organizations' awareness and interest (IPCC, 2007a). CF as the measurement is requested to restrict the industry, company, as well as the individuals GHG emissions. The concept name of the carbon footprint originates from ecological footprint, which was developed by Rees and Wackernagel in the 1990s which estimates the bio capacity that would theoretically be enough if everyone on the planet consumed resources at the same level as the person calculating their ecological footprint (Wackernagel, 1996). In 2007, carbon footprints was used as a measure of carbon emissions to develop the energy plan for City of Lynnwood, Washington (Mitra, 2007).Carbon footprint is one of a family of footprint indicators, which also includes water footprint and land footprint (Bastianoni, 2004).

3.3.2 Definition

The concept of carbon footprint has been in use since several decades but known differently as life cycle impact category indicator global warming potential. There is little uniformity in the definitions of carbon footprint within the available literature and studies (Finkbeiner, 2009; Wiedmann et al. 2007). Environmental Protection agency, U.S (EPA) defined carbon footprint is the total GHG are emitted by individuals, organizations, or company. Global Footprint Network (2007) presents the opinion that ‘footprints are spatial indicators’. Hence, the term commonly called as carbon footprint should precisely be called as ‘carbon weight’ or ‘carbon mass’ (Jarvis, 2007). It is complex to include all possible emissions ,and so there is a lack of uniformity over the selection, therefore, most studies report only direct or first order indirect emissions (Matthews et al,2008).. To identify the GHG emissions by estimate CF value have been studied and discussed broadly for several decades, also nowadays increasing attention in both politics and science. Lutter (2009) recognized tracing CF can support environment and economic policy making through quantifying natural resources supply.

3.3.3 Quantification

The global warming potential (GWP) of all tiers is calculated individually using the conversion factors of IPCC (2007) corresponding to a 100-year time horizon, which indicate the GHG released in a life cycle of a product (WRI/WBCSD, 2004; BSI, 2008). The GWP measures how much energy is consumed in the air by a certain relative amount of heat released by CO_2, and units expressed in kilograms or tonnes of carbon dioxide equivalent (CO2-eq.) (IPCC, 2007a), the formulation is given below:

$$\text{CF or } GWP_{total} \text{ (kg } CO_2\text{-eq) =}$$
$$\text{Amount of } CO_2 * 1 + \text{Amount of } CH_4 * GWP_{CH4} + \text{Amount of } N_2O * GWP_{N2O}$$

GWP_{CH4} refers to the global potential for CH_4

GWP_{N2O} refers to the global potential for N_2O

GWP is in kg CO_2-eq/ ha

The GWP of different gases depends on the time interval considered.

Table 2 GWP_{CH4} and GWP_{N2O} for different time perspectives

Gas	20 years	100 years	500 years
CH_4	72	25	7.6
N_2O	289	298	153

(Source: IPCC, 2007)

3.4 Life Cycle assessment

Life Cycle assessment (LCA) is a technique to assess the environmental impacts of a product, throughout its all stages from cradle to grave (i.e. from the inflows of raw materials, energy, land, water through processing, transport, use and disposal or recycling),and standardized by International Organization for Standardization (ISO 14040, 2006). It's a well-established method to quantify all steps in a life cycle, which focuses on the direct and indirect resource inputs and outputs emissions of products from the 'cradle to grave'. The philosophy indicates that all environmental impacts during the whole life cycle of products will be taken into account (Huijbregts, 2006).

It can be considered as the structure that describe how a LCA should be formed and what should it contain .It is carried out in following four main phases:

- Goal and Scope — explains clearly from start of the aim of study, also to whom and how the results are connected. Functional unit and system boundaries, assumptions and other critical technical details are defined in this phase.
- Life cycle inventory analysis — an inventory flow model is created based on the data of inputs (raw material, water, energy) and output(emissions release to the air, land, river). The data presented must relate to the previous goal and scope definition; also the quantity of data according to the system boundaries.

- Impact assessment — this step is aim to evaluate the environmental impacts based on the previous phase, classify inventory flows into impact categories and then characterize them into common equivalence units, for example, CO_2, CH_4 cause global warming in same category ,and commonly unit CO_2-equivalents.
- Interpretation — during this stage, the results are presented from the last two phases. The outcome then becomes a set of conclusions and recommendations for the study. The works involved identification of significant problems based on the results, considering completeness, sensitivity are evaluated, conclusions are drawn and recommendations are given. There can be two classes of LCA methods are identified for the interpretation of product life cycle. The first class of indicator methods commonly applied is eco-indicator99, which aims at analysing all potential environmental impacts occurring during the life cycle of a product and quantifying impacts on health, ecosystem, resources; the second class of methods produce input-related indicators, for instance based on the cumulative use of land, energy and materials (Goedkoop et al,1998; Goedkoop et al, 2000; Huijbregts, 2006).

LCA will be continuously improved, also can be combined with other tools such as tools for integrated waste management (EPA, 2006).It gives an effective approach to estimate GHG emissions during a product life cycle.

The phases of life cycle assessment described in graph Figure 3:

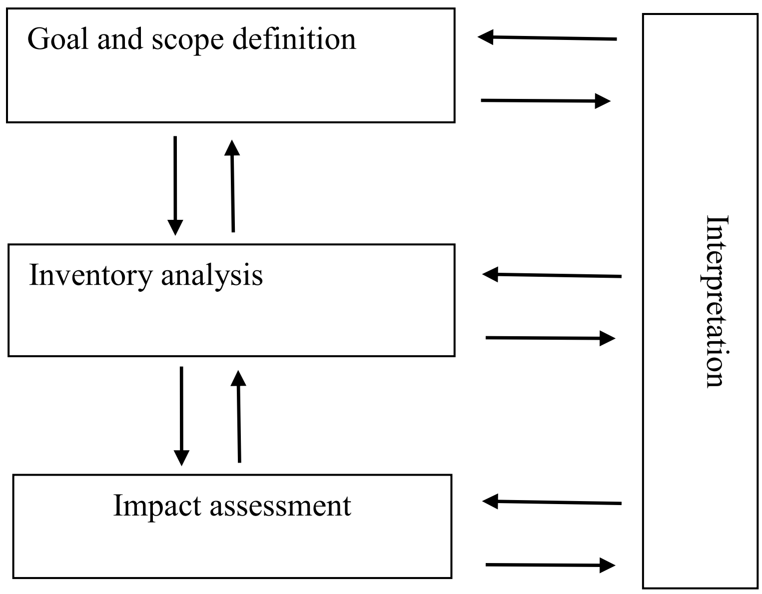


Figure 3 Life cycle assessment flow chart

4. Analytical Part

4.1 Food consumption patterns in the Czech Republic

Food consumption patterns can be variable, depend on such as specific history, regional variability, household income, and personal preference influenced by environmental and genetic (Logue, 1981). Some studies have shown that choice of food and diet can influence the energy requirements for the provision of human nutrition and the associated GHG emissions(Carlsson, 1998; Carlsson, 2003). In Europe, the contribution of GHG emissions from food and beverage consumption in EU-25 is consistently 20 – 30 % (Tukker, 2006). In this section Czech Republic main food consumption will be analysed based on the official statistics below.

Table 3 Consumption of food and non-alcoholic beverages (kg annual per capita averages) 2006-2014 Czech Republic

FOOD AND NON-ALCOHOLIC BEVERAGES (kg)	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cereals	136.5	147.6	133.7	144.7	138.6	151.7	145.1	143.4	140.8
Pork	40.7	42.0	41.3	40.9	41.6	42.1	41.3	40.3	40.7
Beef	10.4	10.8	10.1	9.4	9.4	9.1	8.1	7.5	7.9
Poultry meat	25.9	24.9	25.0	24.8	24.5	24.5	25.2	24.3	24.9
Aquatic products	5.6	5.8	5.9	6.2	5.6	5.4	5.7	5.3	5.4
cow's milk	239.3	244.5	242.6	249.6	243.9	227.6	234.2	234.0	236.4
Cheese, total	13.4	13.7	12.9	13.3	13.2	13.0	13.4	12.7	12.8
Fresh fruits	78.1	85.4	89.1	90.4	84.0	79.4	74.6	76.8	78.1
Fresh Vegetables	81.4	82.7	82.8	81.2	79.7	85.4	77.8	82.9	86.4
Edible vegetable oil	16.5	16.3	16.0	15.9	16.3	16.3	16.4	16.9	17.2
Sugar	95.1	39.0	32.5	36.7	36.0	38.6	34.5	33.4	31.7

(Source: CZSO, 2015.The Czech Statistical Office)

Table 3 presents 12 types of daily food products by Czech household per capita. The most consumed is for cow milk remain stable around 230-240 kg per capita from 2006 to 2014; while the least consumed is for aquatic products, more than 40 times less than milk .Cereals are the second largest group being consumed and tend to grow slightly since 2006. Among the beef, pork and poultry meat products, pork consumed the most around 40-41 kg per capita, followed by poultry ,which the figure stayed around 24-25 kg per capita during the right years. In contrast, beef consumption reduced from10.8 kg per capita in 2007 to 7.5 kg per capita in 2013. Sugar is the third biggest consumption group in 2006, however, a dramatic decrease since then, in 2014 to the smallest 31.7kg per capita from highest 95.1kg in 2006.

A basic summary from statistics above, the food consumption in Czech household is rather stay stable regarding the cereal, meat, fruits, diary and vegetables sections, although there was some slight growth or reduction, only sugar tend to decrease dramatically.

4.2 Food consumption patterns in China

Several studies have pointed out consumers notable changes towards food types and quantity in fast growing developing countries like China, India, Malaysia (Coyle et al.1998; Ishida et al, 2003). China's economic reform has brought significant changes in its food consumption patterns and consumes behaviours. In food consumption, there has been a significant transition from staple foods such as rice and wheat to high-value products (HVPs) such as meats, aquatic products, vegetable oils and dairy products (Zhang, 2003). In international trade, China was traditionally a major importer of only wheat and now increased its import of a wide variety of agricultural products such as poultry and edible oil.

In this section uses available data from National Bureau of China Statistics (NBSC) Household Survey to estimate urban and rural consumer demands for nine major food commodity groups (grain, vegetable oil, aquatic products, vegetables, fruits, meats, milk) from 1990 to 2012. The national sample contains a total of 36,000 households from 226 cities, our data set includes 3,600 3 households from 30 cities (NBSC, 2012).

Table 4 China Urban Areas Per Capita Purchases of Major Foods of Household (1990-2012, kg)

Item (kg)	1990	1995	2000	2005	2010	2011	2012
Grain	130.7	97.0	82.3	76.9	81.5	80.7	78.7
Fresh Vegetables	138.7	116.5	114.7	118.6	116.1	114.6	112.3
Edible vegetable Oil	6.4	7.1	8.2	9.3	8.8	9.3	9.1
Pork	18.5	17.2	16.73	20.2	20.7	20.6	21.2
Beef	3.3	2.4	3.3	3.7	3.8	3.9	3.7
Poultry	3.4	3.9	5.4	9.0	10.2	11.0	10.8
Aquatic Products	7.7	9.2	11.7	12.6	15.2	14.6	15.2

Milk	4.6	4.6	9.9	17.9	13.9	13.7	14.0
Fresh Melons and Fruits	41.1	44.9	57.5	56.7	54.2	52.0	56.0

(Source: 6-8. NBSC, 2012)

The table 4 presents the main categories food including staple food, fruits, meat products, and vegetable consumed in china urban areas household from 1990 to 2012. There was very noticeable decrease of grain per capita during this period of time, dropped from 130.7 kg in 1990 to 78.7 kg (a decrease of 67 %) in 2012. Fresh vegetable kept stable amount around 110-130 kg per capita. In the meat products section, pork is the most consumed since 1990 until 2012, approximately17-21 kg per capita. Poultry and aquatic products both are kept rising after 1990, the former increased rapidly, and the latter had an increase of 97 %.In the fruits section, the figure around 41-56 kg per capita during twelve years. Milk increased from 4.6kg to 13.9 kg per capita.

Table 5 China Urban Areas Per Capita Purchases of Major Foods of Household (1990-2012, kg)

Item (kg)	1990	1995	2000	2005	2010	2011	2012
Grain	262.1	256.0	250.23	208.8	181.4	170.7	164.2
Fresh Vegetables	134.0	104.6	106.7	102.2	93.2	89.3	84.7
Vegetable Oil	3.5	4.2	5.4	4.9	5.5	6.6	6.9
Pork	10.5	10.5	13.2	15.6	14.4	14.4	14.4
Beef	0.4	0.3	0.5	0.6	0.6	0.9	1.0
Poultry	1.2	1.8	2.8	3.6	4.1	4.5	4.4
Milk	1.1	0.6	1.1	2.8	3.5	5.1	5.2
Aquatic Products	2.1	3.3	3.9	4.9	5.1	5.3	5.3
Fruits	5.8	13.0	18.3	17.1	19.6	21.3	22.8

(Source: 6-15.NBSC, 2012)

Table 5 shows main food consumption household per capita in china rural areas from 1990 to 2012. Grain and fresh vegetables were ranked the highest consumption categories, even though it tended to decrease, the former from 262.21 kg per capita (1990) to 164.2 kg per capita (2012); the latter showed dramatic reduction from 134.0 kg per capita (1990) to 84.7 kg per capita (2012). In the meat products section, pork still the most popular one, stay quite stable figure around 11-15 kg per capita during this period of time; beef was the least consumed; poultry and aquatic products presented an increase. Milk increased mildly, while fruits increased rapidly.

Table 6 Comparison with China Urban and Rural Areas 6 types food consumption per capita (1990 and 2010, kg)

Year	1990		2010	
	Urban	Rural	Urban	Rural
Grain	130.72	262.08	81.53	181.44
Beef	3.28	0.4	3.78	0.63
Pork	18.46	10.54	20.73	14.4
Milk	4.63	1.1	13.7	3.55
Vegetable	138.7	134	116.11	93.28
Fruits	41.11	5.89	54.23	19.64

(Source: NBSC, 2012)

Table 6 compares both China rural and urban areas regarding the six food categories (grain, beef, pork, milk, vegetable, fruits) in 1990 and 2010, 10 years period.

Overall, grain and vegetable showed an obvious decrease, especially urban grain consumption decreased almost an half, whereas the rest presented growth, such as urban milk 3 times bigger than 1990; fruits in rural increased dramatically. Through a decade, we can see the trend of food consumption of consumers in both urban and rural areas tend to intake more protein rich milk and less vegetable.

The sheer size of China's population and different eating habits from north to south are leading the changes; the gap of income among households is leading the contents of nutrition food consumption difference; the living conditions led different consumption models between rural and urban consumers (Zhou et al 2012).

4.3 Comparison of main food categories in Czech and China Urban Areas

According to the statistics, comparison analysis is made between the Czech Republic and China urban areas. This study is motivated by the several previous studies on food sustainability in Czech, as well as in China (Vávra, 2013; Johns, 2004; Zhou et al, 2012).

Table 7 below is drawn out the major nine types of food consumption in the Czech Republic and China urban areas in 2010, 2012.We can see both countries have big difference in some items(cereal, milk, fresh vegetables),but shows similarity or small difference in some products(poultry meat, vegetable oil). The most noticeable was the consumption of milk in the Czech Republic, almost 20 times higher than in China; and followed by cereals consumption, in both years 2010 and 2012, the Czech Republic consumed 2 times higher, which is 138.6 kg (2010) compared with China 81.5kg(2010) .In contrast, fresh vegetables in China consumed about 2 times more than the Czech Republic; the aquatic products showed the same situation in both year 2010 and 2012 .

Table 7 Comparison Nine Types of Food consumption in Czech Republic and China (2010&2012, kg annual per capita averages)

Country / Year	Czech Republic	China Urban	Czech Republic	China Urban
Items	2010		2012	
Cereals	138.6	81.5	145.1	78.7
Pork	41.6	20.7	41.3	21.2
Beef	9.4	3.8	8.1	3.7
Poultry meat	24.5	10.2	25.2	10.8
Aquatic products	5.6	15.2	5.7	15.2
cow's milk	243.9	13.9	234.2	14
Fresh fruits	84	54.2	74.6	56
Fresh Vegetables	79.7	116.1	77.8	112.3
Vegetable Oil	16.3	8.8	16.4	9.1

(Source: NBSC&CZSO, 2010;2012)

we can conclude that time in 2010 and 2012 according to the statistics analysis, regarding these nine type of food products, majority of them consumed in both countries didn't change very much in this two years in each country, such as milk is still the dominant food products in Czech and aquatic products still the most popular out of these nine categories. However, this food patterns might changes influenced by national economy, political, social and environment under international context (Baker et al, 1998).

4.4 Carbon Footprint calculating methodology

For calculating carbon footprint, LCA estimates the amount of GHGs emitted or embodied in one life cycle of the product at each identified step, also called cradle-to-grave analyses. The GHG protocol acts as a common resource for CF calculation.

The collected GHG data is translated into CO_2-eq using global warming potentials (GWP) of different GHGs as provided by IPCC (2007). The final unit of the CF depends on the nature of the entity, which can be dynamic processes, one time emissions and combined process (Pandey et al. 2014). ISO (2013-14067) is under development to provide guidelines and principles of product CF. The following framework is suggested based on the research works (WRI/WBCSD. 2004; BSI, 2008).

a) GHGs Selection

b) System boundaries setting

c) Data Collection

d) Footprint calculation

Ad a) GHGs Selection, the need of carbon footprint calculation depend on the type of activity, which predominant emission is produced (i.e. cattle farm, CH_4, CO_2, and N_2O emission must counted, whereas from car mainly CO_2). All the guidance and standards direct to include all the general existing GHGs and not only CO_2 (Kelly et al.2009).

Ad b) System boundaries setting, a boundary refers to a production line being drawn in imagination involve the activities that will be used for calculating CF, which depends on the objective of footprints and characteristics of the entity for what kinds of footprint will be done (Pandey et al. 2014).In order to provide the convenience of accounting, the following tiers have been suggested .The principle to collect GHG data is translated into CO2-eq using global warming potentials(GWP) of all $tier_i$ (i=1,2or3) (WRI/WBCSD 2004;BSI,2008).

- $Tier_1$: All direct emissions, i.e., onsite emissions
- $Tier_2$: Embodied emissions by purchase of energy
- $Tier_3$: All indirect emissions not included in previous $Tier_1$ and $Tier_2$, such as delivery ,sold products etc. (WRI/WBCSD, 2004; Carbon Trust, 2007a; BSI 2008; CDP 2008; Matthews et al. 2008a, b).

In general, most CF studies limit up to $tier_2$ due to the increasing complexity and uncertainty in estimates if going beyond $tier_2$ (Matthews et al. 2008a). In order to make more clear definition of $tier_3$, Mathews et al. (2008) proposed that emissions exclusively related to delivery, and disposal of products also should be kept out of $tier_3$ .An additional $tier_4$ can be used for the same. In the Carbon Disclosure Project (CDP), 72 % of respondents among 500 companies reported their CF $Tier_3$, showed positive increase (CDP, 2009).

Ad c) Data Collection, to collect GHG data can take use of on-site direct measurements, or make emissions estimation based on the emission factors and models, which are the most used techniques. Emission factors are available for a wide range of industrial processes and land uses in GHG protocol, PAS-2050, IPCC (2006).Direct measurements include chemical, and optical instruments ,such as techniques like collecting gases in specially designed bottles and analysing through IR spectroscopy for CO_2 (Berg et al.2003).

Ad d) Footprint calculation, after the data collected will be translated into CO_2-e using GWP of different GHG is given by IPCC (2007). The final unit varies from different entities, such as dynamic process is calculated periodically, and some are one time emission, some are combination of both (Pandey, 2014).

4.4.1 Food footprint formulation

Food carbon footprint indicates the total GHG emissions during the entire food cycle, and our diet has significant environmental impact. It has been taken into account widely one of the reason cause climate change by emissions of greenhouse gases (GHGs) in term of pre-farm process that requires water, arable land, and post-farm process including the use of electricity, packaging, refrigeration, and the use of fossil fuels in transportation. Therefore, agriculture is certainly one of the main contributors for methane and nitrous oxide (Virtanen, 2011).

Use the conversion factors provided by IPCC(2007) to translate GHG data into CO_2-eq GWP of different GHG is given by IPCC(2007) (WRI/WBCSD 2004; BSI 2008). The time span to measure individual diet footprint is usually annually. With emission factors, calculations can be carried out, though there are uncertainties regarding the natural system and land use.

Figure 4 shows the LCA for common agricultural products, the basic steps to calculate emissions from each stage:

Figure 4 A life cycle of agricultural product

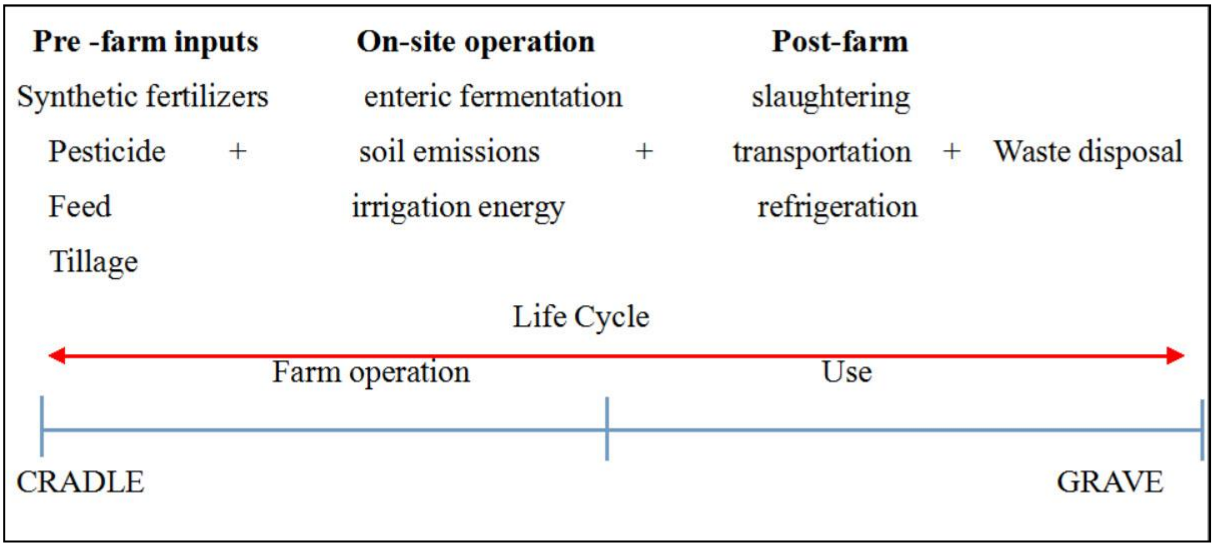


Figure 4 is a flow chart presents the main processes that are directly associated with food production and which contribute to emissions of GHG, inputs from pre-farm process like synthetic fertilizer and pesticide, machinery etc. On-site farm operations like soil emissions, and emissions from enteric fermentation in animals; Post farm processes including industrial packaging, refrigeration and transport to warehouse, etc. Unlike the GHG emissions from energy consumption and transports as well as the post-farm processes in food production, direct emissions from agriculture are not dominated by carbon dioxide (CO_2) from fossil fuel burning, but by emissions of methane (CH_4) and nitrous oxide (N_2O) from field and animal waste (Kelly et al, 2009).

4.4.2 Standardization

Nearly all GHG accounting guidelines, including ISO 14064 (2006a, b) and PAS 2050 of BSI (2008) based on GHG protocol of world resources institute.ISO14064 has developed this standard for determination of boundaries, quantification of GHG emissions, and removal (ISO 2006a, b), it has provided a substantial amount of flexibility to allow for a wide range of different types of studies and goals, which the part a deals with organizations, and part b deals mainly with projects. In order to provide more accurate and convenient method to calculate CF, several other standards has developed, the first one is Publicly Available Specifications - 2050 (PAS 2050) of British Standard Institution (BSI, 2008). PAS 2050 is developed by BSI specifically for assessing agriculture GHG emissions. An updated version followed in 2011 (BSI, 2011) and in 2012 a version specifically targeted at calculating CF for horticultural products was released (BSI, 2012). Several companies also developed 'specific standards' for International Dairy Federation (IDF, 2010).

4.5 Tracing the carbon footprint of food products

Donal Murphy Bokern (2010) claimed that there are other much more damaging GHGs other than CO_2 from fossil fuels, particularly from agriculture activities and bovine animal biological process (i.e. enteric fermentation in ruminants) , these gases are in the form of nitrous oxide (N_2O), and methane (CH_4). When these emissions from agricultural soils and animals are added to the CO_2 from processing, manufacture, and so on, food accounts for a large proportion of all emissions. Worldwide, the farms emitted 6 billion tonnes of GHGs in 2011 that means about 13 % of total global emissions, and these are dominated by nitrous oxide from fertilizing practices and manure management (4.3–5.8Tg/year, N_2O-N), and emissions from natural soils (6–7 Tg/year, N_2O-N) represent 56–70 % of all global N_2O sources (WRI, 2014; Syakila, 2011). Regarding CO_2, soil respiration is an important source, but the majority of the farm operations and inputs, such as energy use for tillage and irrigation(i.e. pumping water) also have embodied major CO_2 content (Lal, 2004). Neverthless, the exact global CO_2 emissions from agriculture section is hard to quantify due to the biomass and soil C pools not only emit large amounts of CO_2, but also take up CO_2 (GHG protocol, 2014). Regarding nowadays carbon credits accounting if associated with agriculture soils, Corsi (2012) suggested that direct and indirect costs should also be estimated for the production and distribution of pesticides and herbicide.

4.5.1 GHG missions and from agricultural soil

4.5.1.1 Nitrous oxide emissions

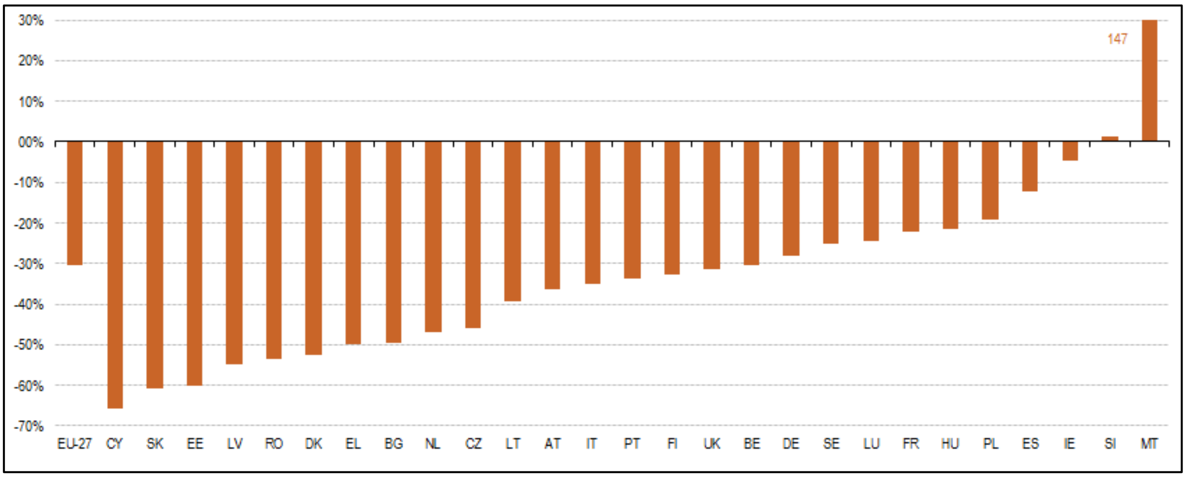
Global warming caused from nitrous oxide is mainly result in two facts,N_2O is stable and remains in the atmosphere approximately 120 years, and N_2O has a large GWP that is 296 times greater than CO_2 in a 100 years period, which is related to the catalytic destruction of stratospheric ozone (Ussiri, 2012).There is a great deal of measurements and research has been done to estimate emissions of nitrogen oxide(NO_x) from soils(EPA,1996). Del Grosso (2008) estimated that agricultural activities add into the atmosphere about 4.2 to 7 Tg annually in the form of N_2O.

Emissions of N_2O from arable soils is predominantly result in receiving high inputs of nitrogen-rich amendments fertilizers or land use change ,which release inorganic nitrogen is going to be converted to N_2O though microbial process by nitrification under microaerophilic soil conditions and denitrification under anaerobic soil conditions; the latter process became the most important dominant sources of anthropogenic N_2O emissions (EPA, 1996; Corsi,2012).Its effect on soil structural quality and influences the terrestrial nitrogen cycle worldwide .Agricultural lands and grasslands are the most significant emission sources within this category(Ball et al, 1999).

However, emissions from soils also show variability depends on the soil type, moisture, climate conditions, crop type, fertilization, and other agricultural practices play a part in emissions from soil.

Some research also mentioned the climate influenced the emissions. Barton’s research (2010) claimed that soil nitrous oxide and methane fluxes are rather low from bioenergy crop (canola) in semi-arid climate and thus less influence on the global warming potential of biofuel production than in temperate climate. N_2O emissions from soil are challenging to estimate the magnitude since it’s hard to develop valid emission measurements under large fields.

Figure 5 Change in nitrogenous fertiliser applications (%), 1990-2010, EU 27



(Source: Eurostat, 1990-2010)

Figure 5 shows the change in nitrogenous fertiliser applications (%) in ten years from 1990 to 2010 in EU-27 countries and the details of some of them. Overall, EU-27 countries present a negative growth, a decrease of 30 %. The largest decline was in Cyprus almost 68 %, followed by Slovakia and Estonia nearly 60 %, Latvia about 58%. Ireland was the smallest decline country which was accounted for 4 %.In contrast, Slovenia and Malta presented positive growth, like in Malta almost 30% .Malta country study guide (2013) explained since 2004 the intensive cultivation by human activities.

4.5.1.2 Methane emissions

CH_4 emissions from soil to atmosphere results mainly from bacterial microbial activities that are strongly influenced by land use, land management and the type of soil (Corsi, 2012). CH_4 is produced in strictly anaerobic environment of soil by methanogens, and is oxidized by methanotrophs in aerobic environment of wetland soils. i.e. in the flooded rice field. Rice fields alone emit 32 to 44 Tg CH_4 /year(Le et al, 2001).

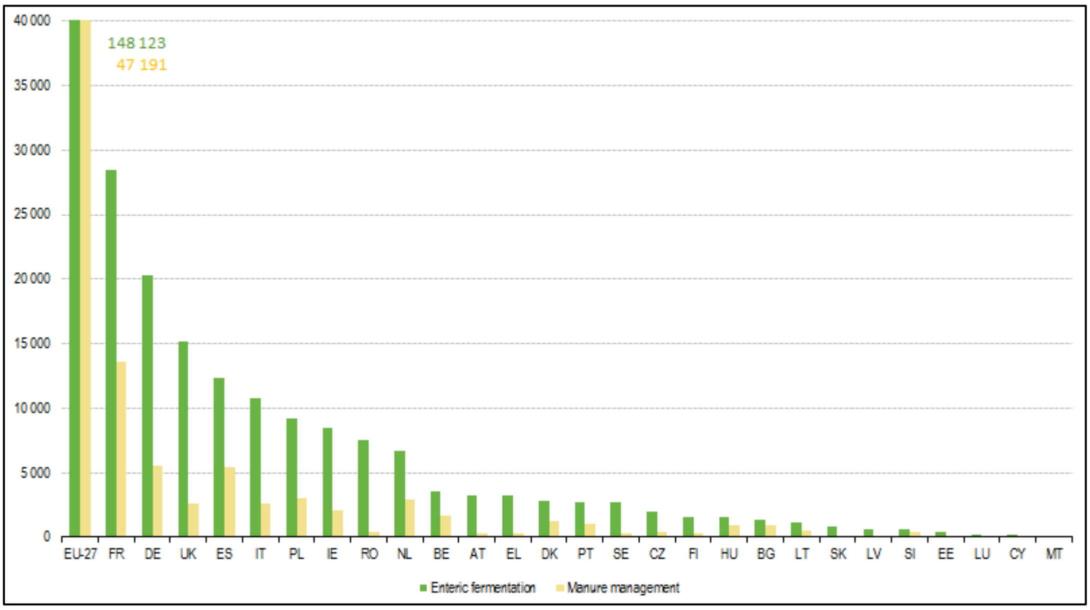
The IPCC report (2006) indicates that CH_4 emissions depend on several indicators as well, like water management, temperature as well as soil type.

4.5.2 Emissions from livestock

A global life cycle assessment showed that livestock production is a major contributor to the world's environmental problems, accounted for 2,448 million tonnes CO_2-eq, of which 76% is emitted by cattle, buffalo, and other small ruminants represent 14.5 % of total human induced GHG emissions (Gerber, 2013). In Europe, report from European commission joint research centre (Leip, 2010) first time measured the detailed product-based emissions of main livestock products (i.e. bovine meat) amount to 661 Mt CO_2-eq.

For livestock production systems, three main GHG emitted by this section, carbon dioxide is emitted through the consumption of fossil fuel as energy along the section supply chains by processing and transportation of animal products, while manure and enteric fermentation produce both nitrous oxide and methane in aerobic and anaerobic conditions.

Figure 6 Methane emissions from enteric fermentation and manure management Kilotons of CO_2 equivalents), 2010, EU-27



(Source: Eurostat, 2010)

Figure 6 present the amount of methane emissions were produced from enteric fermentation and manure management in EU-27 countries (measured by kilotons/CO_2-eq).Overall France, UK and Germany together are on the top, and total amount are above half of them all, approximately 63,000 kilotons /CO_2-eq; the least is from Estonia and Lithuania just about 1 kilotons/CO_2-eq; Cyprus and Malta were accounted none for methane emission.

Several studies have been done about the influence of emissions growth result in many reasons, Carlsson (2009) analysed modern people's meat intake with relation of emissions, which the animal protein based products particularly rely on dedicated crops feeding, less efficient than the production of equivalent amounts of plant protein. Gerber (2013) claimed that modern livestock breeding ways, and chosen places tends to centralized in locations close to cities or ports where insufficient land is available for the recycling of waste from livestock; also grazing requires land and feed production cause deforestation and soil degradation. Somehow reflect the policy and regulations are in need of implementation.

4.5.2.1 Enteric fermentation in ruminants

Methane is produced in herbivores (i.e. cow, sheep) from enteric fermentation, a microbial digestion by which carbohydrates are broken down by microorganisms into simple molecules for better absorption to the bloodstream. The amount of methane released depends on the type of digestive tract in what extent fosters extensive enteric fermentation, the quality and quantity of feed, and the physical characteristics of livestock (IPCC, 2006). FAO (2013) reported over 55 % of emissions is accounted from ruminant meat and milk production result in this gut structure.

Calculations for methane from enteric fermentation are based on the feed intake combined with LCA methods. The Revised 1996 IPCC Guidelines recommend that CH4 emissions from enteric fermentation be estimated by multiplying the number of animals for each animal type by an appropriate emissions factor. For instance, the more feed intake, the higher the methane emissions, due to higher fibre content of feed (i.e. grass and hay) generate higher emissions than grain-based diet. When the efficiency of converting feed into food is low, emissions per unit of food are high. Birds and pigs convert feed more efficiently than cattle and sheep. As a result, methane emissions from enteric fermentation counted per unit of beef can be the largest single contribution to total GHG emissions (FAO, 2013).

4.5.2.2 Manure management

Livestock generate both methane and nitrous oxide from manure deposits. The term 'manure' is used collectively to include both solids and the liquid manure produced by livestock.

Methane is produced from the decomposition of livestock manure under anaerobic conditions in confined area naturally on pasture or grassland or in lagoons. For estimation depends on the amount and portion produced, and other factors vary from actual manure system ,like poultry manure with or without litter, liquid or slurry .Indirect nitrous oxide emissions from solid manure system are calculated based on based on crude protein content. Dairy cattle and swine produce about 85% of the methane emissions (IPCC, 2006).

Nitrous oxide is produced during storage and treatment of animal wastes can occur via combined nitrification-denitrification of nitrogen contained in the wastes. The amount of N_2O released depends on the system and duration of waste management (IPCC, 2006).

LCA studies used IPCC $Tier_2$ calculation methods the most to model emissions from livestock manure. The $Tier_2$ estimates require additional data on manure characteristics and management practices, for which country-specific data should be used. Manure management practices that ensure the recovery and recycling of nutrients and energy contained in manure and improvements in energy use efficiency along supply chains benefits for the further contribution on mitigation.

Regarding the beef and cow milk production are major emissions result in both enteric fermentation and livestock manure system. Therefore, we can see that how consumers' food choice influenced food CF. In developed and developing countries, the growing consumption of beef and milk would need to be concerned. Figure 5 and figure 6 in section 4.3 shows Czech Republic milk consumption yearly is 100 times more than China whereas china has 100 times larger population.

4.6 Food carbon footprint reduction scheme

One regional analysis for Europe food accounts for 31% of the EU-25's total GHG impacts, with a further 9 % arising from the hotel and restaurants section (European commission 2006). In addition to country level estimates, there are numerous LCA of individual food products. These generally find that meat and dairy products, and air freighted foods, tend to carry the highest GHG burden (European Commission, 2006; Sim et al., 2007; Garnett, 2011).

In this section the following paragraphs summarise the measures that have been proposed for reducing GHG emissions at the agricultural management improvements and the potential mitigation through food consumer's behaviours, as well as the labelling scheme, and highlight some broader sustainability approaches.

4.6.1 The carbon footprint labelling scheme

The purpose of carbon labels scheme is to improve households' behaviour towards to lower carbon consumption. In recent years, increasing studies and researches have investigated the effectiveness of carbon label. CF labelling scheme presents various situations and effectiveness in different countries and different consumer groups.

A critical review of CF labelling values in policy development is under debate whether it would be effective or not in reduce emissions. Labelling standards that ensure consistency and comparability among products with a label, once calculated, it will show the amount of carbon in grams much like the nutrition content label in foods (Gadema, 2011). It was first created by Carbon Trust in 2006, a company was established by the UK government to help Britain move forward to low carbon economy and lifestyle. Carbon Reduction Label is a methodology based on the PAS2050.The initiative Europe countries Sweden, France and the UK (Angelo,2013).

A survey was carried out by researchers examining the shopping habits and preferences of 428 shoppers in the UK. Food sold with carbon footprint label at supermarkets account for around 75% of all, the same survey also found that 89 % of respondents thought existing carbon footprint scheme was hard to understand (European Commission, 2012).

Figure 7 shows three examples of numerical CF labels. The first and second one, starting from the left, is the Carbon Trust label (Carbon Trust, 2013), which was used by the British retailer Tesco to label of juice. The third one is the Swedish hamburger MAX (MAX, 2013)

Figure 7. Three examples of CF labels (Tesco juice, carbon trust, Max 2013.)

4.6.2 Eco-friendly meals and communication intervention

A sustainable catering project was carried out 2014 in campus ETH, Zurich, which aims to investigate the environmental factor intervention of food choice. One canteen provided customers with new choice 'climate-friendly meals' accompanied with information highlighted the relation between food, climate and the environment. The second canteen provided choices with climate impact labelling scheme on the menu. The research is carried out with analysis of meals greenhouse gas potentials, sales data and consumer behaviour data from surveys that during intervention throughout the summer 2014.

The project comprises three phase: Phase1, Climate-impact of food choices; Phase 2, food waste; Phase3, environment impact and perceived healthiness of meals. The results of Phase 1 of the sustainable catering project have been published by Visschers (2015) and pointed out the introduction of the climate friendly choice label increased the number of climate friendly meals choice and also did not change consumer satisfaction. Therefore, offering more meals with a label of climate-friendly choice can affect consumers' meal choices, beneficial for the climate, consumers and gastronomic establishments.

4.6.3 Agricultural management reduce GHG emissions

To improve farm performance and sustainability, scientists and experts have worked on it. GHG protocol (2014) recommended to switch from constantly flooded to intermittently flooded rice fields so that allow oxygen to reach soil and eventually reduction in CH_4 emissions; To reduce nitrogen fertilizer application or indirect N_2O emissions from soil but still keep soil nutrient, the use of non-commodity cover crops planted onto bare fields during fallow period or in between rows of commodity crops; to reduce CH_4 emissions from enteric fermentation regarding the feedstuff ,mob grazing on pasture is suggested; on the aspect of reduction of N_2O and CH_4 from manure management, anaerobic digester system is recommended which the organic material (i.e. manure) is broken down by microorganisms under anaerobic conditions. Also other studies have shown that organic manure application increases the carbon sequestration capacity of soil in the range of 70–551 kg C ha^{-1} as compared to synthetic fertilizer use (Mandal et al, 2007).

5. General discussions

CF values used for calculating the food processed from agriculture and how consumers' diets impacts on environment, both for research and practice, which enable to compare same functional food products but from different production systems, i.e. the CF of fish(protein source) can be compared with beef(another protein source).For more convenient to calculate, internet-based carbon calculator is available for calculating the climate impact related to the dietary habits of individuals (Amani,2011).What's more the dietary patterns can adjust with it. There are some difficulties are leading uncertainties happens during estimating the magnitude of emissions and calculating CF from agriculture since the major emissions of CO_2, N_2O and CH_4 are from the complex and highly variable biological processes. Some emissions from agriculture has been concerned to develop statistically valid estimates of emission factors due to lack of emissions measurement (Mandal, 2014). In this sections will carry out two topics regarding dietary recommendations and uncertainties.

5.1 Dietary recommendations

How foods and dietary patterns inteconnect with ecosystems and use of natural resources in the way more environmentally, economically, socially, and culturally sustainable is a growing concern. FAO (2012) defined that sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Food products rely on local within communities for farms are no longer common. Efforts toward sustainable food supplies should base delivery on environment and farm production capacities, transport distances, etc. Reconnecting production and consumption of local foods could be an important step toward food system sustainability.

To reduce the GHG emissions throughout the food supply chains, researchers suggested that technological improvements in agriculture alone will likely be insufficient to keep pace with population growth and rising demand for meat and dairy (Garnett, 2011).

Behavioural choices, including shifts in diet and minimizing food waste, particularly in developed countries, can have large influences (Heller, 2014). There are several research has been done regarding the dietary choice relation with climate, environment, and various recommendation was given varies from countries, culture, and nutrition facts (Heller, 2014; Carlsson, 2009; Meier, 2013). Another interesting research made by Masset and Vieux (2013) have estimated the difference in dietary GHG emissions of self-selected dietary groups, the results showed those who consumed a healthy diet with low energy density, high nutrient density and low consumption of saturated fat, sugar and sodium, had higher dietary GHG emissions than those who consumed an unhealthy diet, and the goal is to present 'sustainable diets' were considered, not only nutritional quality and GHGE but also affordability and cultural acceptability.

Carlsson (2009) measured the commonly consumed food in Sweden are ready to cook at home. Table 8 data is based on (IPCC, 2007) GWP measure total emissions CO_2-equivalents.Table 8 shows the emissions during cultivation of feed required for the animals and results for beef and pork.

Table 8 GHG emissions from commonly consumed foods

Commonly consumed foods Unit: kg CO_2-e/kg product	Carbon dioxide	Nitrous oxide	Methane	Total
Carrots: domestic, fresh	0.38	0.04	0.0	0.42
Potatoes: cooked, domestic	0.40	0.06	0.0	0.45
Whole wheat: domestic, cooked	0.54	0.08	0.0	0.63
Soybeans: cooked, from overseas	0.92	0.0	0.0	0.92
Milk: domestic, 4% fat	0.45	0.14	0.45	1.0
Sugar: domestic	1.04	0.03	0.0	1.1
Italian pasta: cooked	0.96	0.12	0.0	1.1
Oranges: fresh, overseas by boat	1.1	0.10	0.0	1.2
Rice: cooked	0.59	0.21	0.52	1.3
Green beans: South Europe, boiled	1.2	0.12	0.0	1.3
Eggs: Swedish, cooked	1.7	0.74	0.04	2.5
Rapeseed oil: from Europe	1.5	1.5	0.0	3.0

Chicken: fresh, domestic, cooked	3.1	1.2	0.01	4.3
Beef ,fresh cooked	6.9	6.6	17	30

(Source: Carlsson, 2009)

Table 8 showed the fresh vegetables, cereals, and legumes present the lowest emissions. Fresh beef and overseas oranges, soybeans together have the highest total GHG emissions. Local carrots less than 1kg CO2-e/kg, if transported will present higher since fuel consumed. Animal products range from 0.36 to 30 kg of GHG emissions/kg of food. We can also see that some products commonly have low GHG emissions, such as fruits, but when they are transported by air, the emissions are growing as large as some types of meat.

Table 9 below showed the different values of methane and nitrous oxide emissions for beef and pork accounted for almost 5 times higher.

Table 9 Non–carbon dioxide emissions for producing carcasses of beef and pork

(Source: Carlsson, 2009)

Source	Emissions from cattle		Emissions from pigs	
	kg CO_2- eq/ kg carcass	%	kg CO_2- eq/ kg carcass	%
Nitrous oxide				
Feed	1.25	12	0.38	13
Manure	1.07	10	0.07	3
Methane				
Manure	1.78	17	2.06	75
Enteric	6.33	61	0.24	9
Total non–carbon dioxide emissions	10.43	–	2.75	–

Based on the previous studies, recommendations of diets are recommended:

- Local food preference

The energy (i.e. fossil fuels) consumption in transportation travel far distance from subtropics to another hemisphere, GHG should be concerned, and thus local food should be encouraged.

- Intake more protein source from legumes than animal

Previous studies showed that plant based protein has a very low environmental effect from legume and soybeans compared with protein based animal products. (Reijnders, 2003). However, on the other hand, deforestation, soil erosion, run-off has to be concerned to cultivate protein rich massive soy production as well. The most climate efficient way to consume protein is to eat a mixture of cereals, legumes, and fish in near sea.

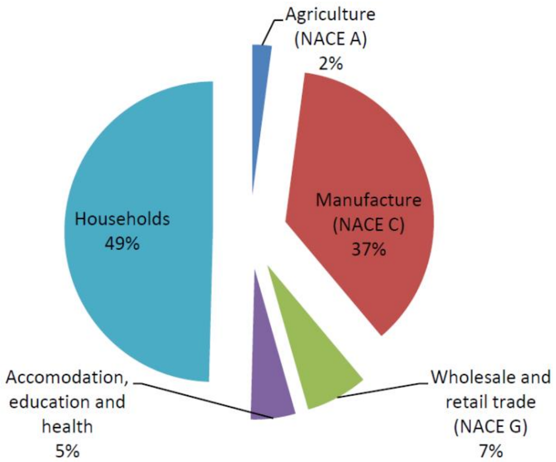
- Less waste

It is estimated 1.6 Gtonnes of global food wastage from primary product equivalent, while the wastage for edible food is 1.3 Gtonnes (FAO, 2013).

Wastage from cereals in Asia has major impacts on carbon since the high carbon-intensity rice production combined with high volume of rice wastage (i.e. paddies are major emitters of methane).Food waste happens at every stage of the production and supply chain as well as at the consumption stage.

From pie chart 8 below showed almost 50% waste generates from household ,manufacture section little less about 37 % , while the least from agriculture, we can see that EU regulation to farming operations (pesticide, synthetic fertilizers) is implemented well. We can assume that in other continent may present different figures. If we don’t have policy to restrict our consumption, then we must reduce food waste (FAO, 2013).

Figure 8, seventeen EU-countries reported food waste data in 2014 on 2012



(Source: Eurostat, 2015)

5.2 Uncertainties

While individual food CF is simpler to calculate than doing a full LCA, it is still quite challenging due to the difficulties in measuring GHG emissions from the biological systems involved and the great variability in agricultural systems, so uncertainties must be considered.

For agricultural practices, the unavailable specific emission factors of the activities are an important factor of uncertainty, because agriculture is largely influenced by the climate, long-term monitoring, and how it modulates with changes in different components. In addition, the associated land use changes and N_2O emissions from soil under different agricultural practices are not easy to predict precisely, because the selection of boundaries and tiers are very unclear (Muthu, 2014).

The large uncertainty in N_2O emissions from soil overshadowed most other uncertainties and a major difficulty in estimating the magnitude of emissions from agriculture has been concerned to develop statistically valid estimates of emission factors due to lack of emissions measurement, make it impossible to develop precision by collecting data on on-farm parameters other than yield and amount of nitrogen fertilizer used, and also the various soil management, climatic conditions how much extent affects are unclear (Mandal, 2014). Scientific knowledge showed the much uncertainty of the direction and magnitude of the effects when the happening interaction of nitrogen fertilizer process and emissions from fertilized soils. The relationship between rates of fertilizer application and N_2O emissions is not well proved yet ,for example, the high fertilizer application rates may cause higher N_2O emission rates, but eventually in what ways would the remaining of nitrogen fertilizer in the soil evolves into gaseous nitrogen or N_xO is not well understood (EPA, 1996).

As for the CF uncertainty would be small or large. The answer depends on the purpose of the CF estimation. If the purpose is to compare products from several different farms, the uncertainty range would be large and difficult to make comparison, and mainly due to the large uncertainty of N_2O emissions from soils. A CF value should not be represent as a single value and as for LCA results but to be presented together with results from relevant uncertainty analysis figures. (Marland, 2014).

The development of better methods for estimating N_2O emissions will increase the knowledge about the causes of N_2O emissions and how they can be reduced. However, it is unlikely to increase the precision in general food CF values, since yearly variations can be as large as the IPCC uncertainty intervals used, but researches are going on to estimate and identify different mechanisms operating in nature that control GHG emissions. National GHG inventories have been accepted worldwide as a reference methodology to account for the GHGs emissions from land use, land use change, and forestry.

Even though the uncertainties are happening for food CF, they do play an important role and important knowledge to quantify the emissions. Relevant uncertainty analysis will reveal whether solid conclusions can be drawn or not.

6. Conclusion

The main conclusions can be drawn from this thesis are:

- A sustainable food system can be achieved when the food supplying stages including mitigate the GHG emissions from agriculture practice and the use of natural resources being operate economically, environmentally.
- There is no concrete definition of CF since previous researches focused more on CO_2 emissions as the framework guidelines, but it has emerged perfectly GHG expression. Until more suggestions indicate that all the important GHG emissions should be included for calculations.
- The uncertainties make it difficult to precisely measure GHG emissions from food supply chains due to the great variability in agricultural systems and biological process, especially to make estimation of emissions NxO of the soil.
- CF functions mostly as an indicator for energy, pesticide use, and also importantly to land use change, which is directly affect the exchange of greenhouse gases between terrestrial ecosystems and the atmosphere. Especially for ruminants.
- CF calculations provide knowledge about sustainable diet with intake less GHG intensive food products, such as bovine meat and dairy products are highly recommend. Also waste less food important in current food system.
- The effectiveness of CF labelling varies from countries and retailers, consumers .However, it provides a direct information for consumers to when they make food choice in a retail, as a message to influence consumers' food consumption.
- The CF methodology indicated several advantages of a full LCA. One of the advantages is being quantitative expression of GHG emissions from the activities, which would help carbon management efficiency and cost reduction through identify the sources and to take mitigation measures of the areas (CarbonTrust, 2007b). The greatest advantage of CF perhaps is the increasing in response to real market requirements. It has been generated by organizations, authorities, companies to count their carbon and head towards to reduce the emissions. The calculations are following

the GHG protocol worldwide, and becomes essential to deal with the unavoidable emissions. In addition to its business importance, CF has been used as an indicator of a citizen's lifestyle of a country on carbon emissions. It gives evidence showing that in addition to technological mitigation it will also be necessary to shift patterns of consumption, and in particular away from diets rich in GHG intensive bovine meat and dairy products. For a long term view, this will be necessary no matter developed countries, but also in the developing world.

List of abbreviations and symbols

CF	Carbon footprint
CO2	Carbon dioxide
CO_2-eq	equivalent tons of carbon dioxide
CEDA	Central European Data Agency
CH_4	Methane
FAO	Food and agriculture organization of the united nations
GLEM	Global livestock emissions model
GWP	Global warming potential
HVPs	high-value products
HLEP	High level panel of experts on food security and nutrition
IPCC	Intergovernmental panel on climate change
ISO	International organization for standardization
LCSA	Life cycle sustainability assessment
LCA	Life cycle assessment
LUC	Land use change
NBSC	National Bureau of China Statistics
SOM	Soil Organic Matter
STATS	China's National Bureau of Statistics
Tg	Teragram
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute

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