Department of Physical Geography

Stockholm University

Environmental impacts of sustainable diets in Sweden

A systematic review

Héloïse Venaut

Master's thesis
Environmental Management and Physical Planning, 30 Credits

MA 52
2018

Department of Physical Geography

Stockholm University

Preface

This Master's thesis is Héloïse Venaut's degree project in Environmental Management and Physical Planning at the Department of Physical Geography, Stockholm University. The Master's thesis comprises 30 credits (one term of full-time studies).

Supervisor has been Salim Belyazid at the Department of Physical Geography, Stockholm University. Examiner has been Peter Schlyter at the Department of Physical Geography, Stockholm University.

The author is responsible for the contents of this thesis.

Stockholm, 21 June 2018

Lars-Ove Westerberg
Vice Director of studies

Table of content

Abstract

The production and consumption of food, throughout the whole supply chain, have negative and large impacts on the environment (Tukker *et al*., 2006). Environmental impacts could be reduced using sustainable diets, such as the vegetarian or the vegan diets (Baroni *et al.*, 2006). In Sweden, in addition to these two diets, the New Nordic Diet and the Nordic Nutritional Recommendation are diets for Nordic countries that can be considered as sustainable (Saxe *et al.*, 2012). Sustainable diets are seldom adopted by the Swedish population, even if they could considerably reduce negative impacts on the environment (Stehfest *et al.*, 2009; Marlow *et al.*, 2009). Depending on diets composition and type of products eaten, each diet might not reduce to the same degree environmental impacts compared to the others. The research will try to answer the question: How much environmental impacts can be reduced by different sustainable diets in Sweden?

Key words: environmental impacts, New Nordic Diet, Nordic Nutritional Recommendations, vegetarian diet, vegan diet, food production, sustainable diet, Sweden

Introduction

Food production is the cause of major land degradation, water depletion, deforestation and greenhouse gas emissions all over the world (Wood *et al.*, 2006; Pimentel *et al.*, 1994). Through the increase of population, that stimulates more food production, negative consequences on the environment become even more serious (Pimentel *et al.*, 1994). The increase of the world population over the last 50 years, together with higher living standards, has swelled food demand by threefold (Bordisky *et al.*, 2015). The demand for food products is forecast to continue to grow as the world population increases towards 9 billion by 2050, with even further environmental impacts (Paillard *et al.*, 2014). In the European Union, one of the region with relatively high population density, food production is responsible for some of the major environmental impacts (Tukker *et al*., 2006).

Dietary change could be one way to reduce environmental impacts of food production (Stehfest *et al.*, 2009; Baroni *et al.*, 2006). Several studies have shown that diets composed of more vegetables and less or no meat have a lower impact on the environment (Pimentel *et al.*, 2003; Baroni *et al.*, 2006; Marlow *et al.*, 2009; Saxe, 2011; Hallström *et al.*, 2015). The vegetarian and vegan diets are in the spotlight among meat-free diets that are considered as the most sustainable. The vegetarian diet is mainly plant-based, excluding meat and fish but tolerating other animal-based products such as dairy and eggs. The vegan diet is fully plant-based and strictly excludes all types of animal products (Baroni *et al.*, 2006).
The Nordic countries have developed their own model of diets with consideration for the environment. The New Nordic Diet is one example aiming to establish the Nordic cuisine as a gastronomic and environmentally sustainable alternative. The diet claims to use local, organic, seasonal, healthy and palatable products (Mithril *et al.*, 2012). The Nordic Nutritional Recommendation is another example of diet that recommends a healthier diet for citizens of Nordic countries and to reduce the risks of diet-related diseases (Nordic co-operation, 2018).

The Nordic Nutritional Recommendation was updated in 2012 to include environmental sustainability in the choice of food consumption (Nordic Council of Ministers, 2014).

In a review of environmental impacts of different diets, Hallström *et al.* (2015) suggest that further studies are needed to investigate the environmental impacts of meat-free diets, and to analyse them in a specific geographical context. Sweden presents a well-suited case for such study, considering that agriculture is restricted by climate mainly to the South of the country, where only limited varieties of crops can grow. Sweden produces mostly cereals such as wheat, oilseed, grains and oats, as well as potatoes and sugar beets (Jordbruksverket, 2011). It means that 70% of fresh vegetables and fruits consumed in Sweden are imported (FAO, 2018). The long transportation distances necessary for the importation of food implies higher environmental impacts through transportation, storage (refrigeration, freezing) and packing (Sim *et al.*, 2007). In this case, what might be labelled as a sustainable meat-free diets may carry substantial environmental cost all along the production process.

Aim

This study aims to investigate the reduction of impact resulting from a shift toward sustainable diets of the Swedish population. It will determine which type of diets are the most sustainable between the Nordic diets and the meat-free ones. A comparative assessment will be made to evaluate what are the capacity of reduction of environment impacts between the studied diets. Six different types of environmental impacts will be analysed as suggested Bauhmann (2013), because there are numerous studies documenting the emission of greenhouse gas from diets, but less studies refer to other types of impacts. The study will try to answer the question: How much environmental impacts can be reduced by different sustainable diets in Sweden? The hypothesis of research states that depending on the structure of the diet, the consumption of local products from Nordic diets is as competitive as the reduction or cessation of animal-based products from meat-free diets.

The study is a systematic review of different life cycle assessment analysis of environmental impacts of sustainable diets. It has the objectives 1) To analyse how much environmental impacts studied can be reduced by sustainable diets, 2) to get to know if the Nordic diets can be sustainably competitive compared to the meat-free diets, 3) to identify which diets could be the most ecological in Sweden and 4) to analyse the reduction of environmental impacts if the entire population of Sweden is feed with one of the sustainable diet. This paper can be used as a help to know which type of consumption to adopt in Sweden, in the most sustainable way.

Background

1. Environmental impacts of food production

Food production, from all the stages of production to distribution, causes fresh water depletion (Rosegrant, 1997; Pimentel *et al.*, 1997), greenhouse gas emissions, use of energy (Carlsson-Kanyama, 1998; Steinfeld *et al.*, 2006; Pimentel *et al.*, 1994), land degradation (Pimentel *et al.*, 1994; Oldeman, 1992), biodiversity loss (Lenzen *et al.*, 2012; Donald, 2004) and waste accumulation (Steinfeld *et al.*, 2006; Marlow *et al.*, 2009). In Sweden, food production has primarily an impact on climate change, eutrophication and use of primary energy (Nilsson *et al.*, 2011).
Environmental impacts from food production are nevertheless numerous and broad, and can have a global impact such as climate change or ocean acidification (Harrould-Kolieb *et al.*, 2012). To summarize the interconnections between all these impacts, figure 1 illustrates the complexity of one main component of food production which is agriculture production. Below is a closer description of the environmental impacts of food production and consumption.

1.1. Water use

Agriculture production is the biggest consumer of fresh water in the world, using 86% of the overall accessible surface and ground water reserves (Shiklomanov *et al.*, 2004; Pimentel *et al.*, 1997). Most of the water is used for irrigation of crops (Shiklomanov *et al.*, 2004). Nearly two third of wheat and rice produced in the world are grown on irrigated lands. This agricultural practice has therefore serious environmental impacts. The excessive groundwater mining leads to water exhaustion of fossil and renewable water resource. In addition, the mining degrades aquifers by introducing saline and pollutant components. Agriculture production affects water quality through the contamination of surface and ground water by fertilizers, pesticides or wastes (Rosegrant, 1997). For example, the use of fertilizers or the leakage of high amount of manure into the water can lead to eutrophication of fresh water and damage local ecosystem and living species (Saxe, 2011).

1.2. Greenhouse gas emissions

Agriculture production is responsible for one-fifth of the total emissions of greenhouse gases (GHG) in the world, which include Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O). Within this part, livestock production accounts for 80% of the emissions (McMichael *et al.*, 2007). It includes emissions from deforestation and land use to create grazing lands, methane emission from enteric fermentation, manure, and emissions from feed crops using fertilizers (Steinfeld *et al.*, 2006; Kahrl *et al.*, 2010). An important part of GHG emissions is due to the use of energy along the process of food production (Pimentel *et al.*, 1994). Energy, under the form of fuel or electricity, is used for transportation, refrigeration and storage of products (Steinfeld *et al.*, 2006; Sim *et al.*, 2007). Fossil combustion is one of the anthropogenic activity that rejects the most CO_2 particles into the atmosphere (Menon *et al.*, 2007). Fossil energy is used as fuel for agriculture machines, to pump water for irrigation and to produce chemical inputs (Marlow *et al.*, 2009). Fossil combustion also emits other type of particles than GHG that can lead to acidification of air and water and damage local fauna and flora (Saxe, 2011).

1.3. Land use issues

The use of lands for agriculture production leads to degradation or land transformation that have an important impact on the environment. Irrigation of lands is in cause of major loss of arable lands and decrease of land productivity through salinization, erosion, terrestrial acidification, or loss of nutrients of the soil (Oldeman, 1992). 70% of the use of agricultural land in the world is dedicated to livestock production, which represents 30% of the overall lands on the planet. The expansion of livestock leads to a massive deforestation and ecosystem change, from forest to grasslands, in regions such as South America (Steinfeld *et al.*, 2006). Land transformation through deforestation is also driven by the expansion of extensive monocultures such as palm oil crops in Indonesia (Wicke *et al*., 2011). Overgrazing, heavy machines and tilling methods degrade the soil through compaction, erosion or pollution (Oldeman, 1992; Lal, 1993). The loss of soil from croplands is 20 to 40 times higher than the time it needs to regenerate, which means it is a long-term loss of arable lands (Pimentel, 1999).

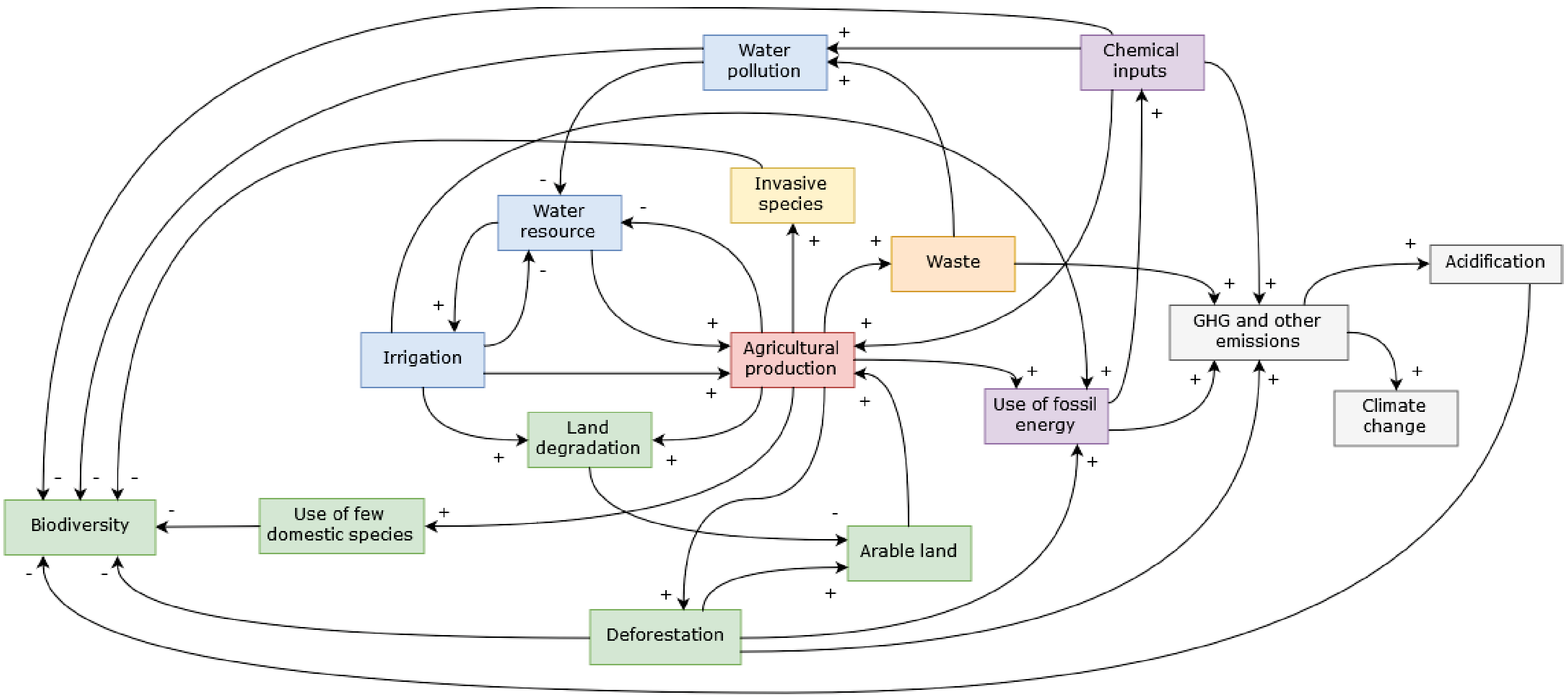
1.4. Biodiversity

During the process of agriculture production, the biodiversity is highly impacted through the pollution of water, soil and air, the change of lands and loss of habitats or the introduction of invasive species by international trade (Lenzen *et al.*, 2012; Donald, 2004). Intensive agriculture production reduces field margins and hedgerows that play an essential role for ecosystem services, such as habitats for pollinators or pest regulators. One other main driver of biodiversity loss is the spread of invasive species. Intensive animal production and international trade of goods contribute to the expansion of invasive species all over the world, and can disturb native species (Marlow *et al.*, 2009). Agriculture biodiversity itself is threatened by the loss of variety of species. The use of genetically uniform individuals reduces the spread of different varieties of plant and domestic animals and their potential for genetical crossing (Frison *et al.*, 2011).

1.5. Wastes

Wastes are generated at all stages of the food supply chain. During the process of production, livestock farming generates high amount of manure. If it is not controlled and properly recycled, it can lead to water, soil and air pollution (Marlow *et al.*, 2009). For example, the leakage of manure that have a high content of nutrients can cause eutrophication of surface water, threaten soil fertility and lead to a loss of biodiversity from water pollution (Menzi, 2001). During the transport and storage of products, the packaging of food becomes a waste after use. Some packages are derived from fossil fuel, that once are thrown away can pollute air and water with toxic components and relieve GHG emissions (Marsh *et al.*, 2007). Finally, once the food arrived to the consumer, the non-consumption of food is a form of waste. It is an environmental issue, because it means that the impacts enumerated above could be avoided by a better individual food management. In Sweden, the average food waste of household is estimated at 72 Kg per person per year (Jensen *et al.*, 2011).

Figure 1: Explanatory causal loop diagram of the environmental impacts of agriculture production in the world system



2. Definition of a sustainable diet

Diets chosen for this study can be classified under the term of environmental sustainable diets. However, the definition of a sustainable diet is abstract and can be interpreted in various ways. An agreement on the definition was made in 2010 during an International Scientific Symposium organized by FAO and Biodiversity International. It is defined as follow: "*Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generation. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources*." (Burlingame *et al.,* 2012).

Adding to this definition Aiking *et al.* (2006) interpret sustainability as the fact that it is not about keeping a static situation but to get closer to a state of resilience and adaptability from the natural systems. They say, "*the pursuit of sustainability may involve a combination of avoidance and approach*" (Aiking *et al.*, 2006). It is in fact not possible to not jeopardize the environment but it is reachable to avoid and to tend toward less impacts possible. It means that sustainability behaviour is to try to avoid any impacts on the environment but, since it is hardly reachable, the purpose is to approach the closest possible to a minimum of impact on the environment.

Basing on these two ideas, the definition of sustainable diets for this research is understood by a diet that enables to lower the environmental impacts compared to a business-as-usual diet. The best diet being the one that reduce to its maximum impacts on the environment. The economic, social and ethical part of sustainability will not be considered to narrow down the research.

3. Studied diets

3.1. Vegetarian and vegan diets

The consumption of meat in european countries starts to decrease. It is related, among other reasons, to the raise of consciousness for a more sustainable lifestyle (Jordbruksverket, 2018). In Sweden, 10% of the population already adopted meat-free diets (Nilsson, 2015). The choice for this study of both the vegetarian and the vegan diet is to show different degree of use of diets mainly based on plants, vegan being the most extreme choice. The vegetarian diet will be an ovo-lacto vegetarian type of diet. It will be compared to diets from Nordic countries, that include meat consumption, to examine if meat is the only driver of a sustainable diet.

3.2. New Nordic diet (NND)

The New Nordic diet is a 5 years research project established by the University of Copenhagen for the OPUS project, 'Optimal well-being, development and health for Danish children through a healthy New Nordic Diet' (OPUS, 2018a). The project aimed to develop a new meal system with Nordic ingredients that is healthy, palatable and environmentally sustainable (OPUS, 2018b). The diet accentuates the importance of seasonal, organic and local ingredients as a sign of sustainability.

3.3. Nordic Nutritional Recommendation (NNR)

The Nordic Nutritional Recommendation are guidelines for a balanced and healthy diet in Nordic countries. It is a project funded by the Nordic Council of Ministers and is used as reference for professional's nutrition recommendation (Nordic co-operation, 2018). Its food composition is based on the Average Swedish diet and improved by healthy and sustainable recommendations. For example, the diet takes into consideration the sustainability of food consumption by trying to reduce meat consumption and food wastes (Nordic Council of Ministers, 2014).

3.4. Average Swedish diet (ASD)

The Average Swedish diet is not considered as a potential sustainable diet for this study. The diet is an average calculation of food habits of the Swedish population, and can be assimilate as a business-as-usual diet. The four diets will be compared with the Average Swedish diet to have an element of comparison with the current type of diet choose by Swedes.
The Average Swedish diet is characterised by a high consumption of animal products such as dairy and meat. Sweden has a low vegetable/animal ratio among the other European countries (EC/JRC, 2009). Cereals and bread are the first most consumed plant-based products. One other noticeable element of the diet is the high consumption of soft drinks (Eidstedt, 2013).

Method

1. Literature and data search strategy

The study is a literature and data review mostly based on researches made in Sweden. The research was conducted with search engines of Google Scholar and Libris (the research engine from Stockholm University). The key words mostly used were "New Nordic Diet", "Nordic Nutritional Recommendations", "vegetarian diet", "vegan diet" or "sustainable diet", combined with "environmental impacts", "food production", "Sweden", or "Life cycle assessment". For each research, only the first three pages of the search engine were examined. What helped the most to find the papers needed was to use the technic of the snowball literature search to navigate from one study to another. It helped for example to find Swedish written papers containing important information.

The environmental impacts of food items were combined with the amount of food items consumed by each diet. It enables to know the overall environmental impacts of the studied diets. The criteria to select research papers about environmental impacts of food products were to have studies made in Sweden, with a Life Cycle Assessment (LCA) and referring to any sorts of environmental impacts from food products. The choice of impact was made depending on the availability of data and the time constraint of the study.

The researches about environmental impacts of products selected are all using the method of Life Cycle Assessment (LCA). The technique of the LCA is a way to assess environmental impacts of a product through the different stages of production and consumption. The use of LCA not only gives an analysis about Sweden, but also about the rest of the world, because some foodstuffs are produced abroad.

2. Synthesis of researches used

2.1. Presentation of environmental impacts

The six environmental impacts selected to realise this study are energy use, greenhouse gas emissions, land use, biodiversity, acidification and eutrophication. Below is summarized how theses impacts are defined and calculated.

2.1.1. Energy use

Data for the energy use comes from the study of Wallén *et al.* (2004), made in Sweden. It is calculated in Mega joule (MJ) and refers to all types of consumption of energy such as fossil fuels and electricity, used during all the steps of production. Energy use is a major cause of GHG emissions and abiotic resource depletion. The LCA of energy use is calculated from cradle until the consumer. It includes agricultural use, storage, handling and packaging use, food processing and transportation.

2.1.2. Greenhouse gas emissions (GHG)

The data for GHG emissions are also from Wallén *et al.* (2004). GHG emissions are calculated in CO_2 equivalents, which include all the gas participating to global warming (carbon dioxide, methane, nitrous oxide, etc...). It is calculated basing on the emissions of GHG from the energy use. GHG are in cause of climate change and atmospheric acidification. The LCA of GHG emissions is calculated from cradle until the consumer, including the distribution of food.

2.1.3. Land use

The data of land use comes from the study of Röös *et al.* (2015), realised in Sweden. Data unit is in m^2 and refers to the area needed to produce the food. The changing of land use for agriculture production can lead to deforestation and highly decreases biodiversity and space for wild ecosystems. The LCA of land use is calculated from cradle-to-grave. It means that the LCA is calculated from the resource extraction to the end of the product as a waste.

2.1.4. Biodiversity Damage Potential (BDP)

The data for BDP come from the study of Röös *et al.* (2015). BDP is an index gathering different type of variables. It considers hectares of land occupied, land type (annual crops, permanent crops, pastures and meadows), and type of biogeographical region (Röös *et al.*, 2015). The method of calculation by de Baan *et al.* (2013) in Röös *et al.* (2015) uses a comparison of the species richness between a natural land and the land occupied by an agriculture field. BDP includes consequently data from the land use impact. The LCA use for the calculation is from cradle-to-grave.

2.1.5. Acidification

Acidification data comes from the study of Saxe (2011), realised in Denmark. Data of environmental impacts of food products for acidification and eutrophication were not findable for Sweden, consequently Denmark was chosen because it is part of the Nordic countries. Acidification is calculated in sulphur dioxide equivalent (SO_2-e), which includes nitrogen oxide and ammonia. For this study, according to Saxe (2011), acidification is calculated from the combustion of fossil fuel, that releases sulphur and nitrogen particles into the atmosphere. These particles are in cause of acid rain that destabilized natural ecosystems and damage or kill living species. Saxe (2011) used a LCA from cradle-to-gate, which considers the extraction of the resource to the end of the process of production, the gate of the firm. It does not consider the transport towards the consumer and the stages of consumption.

2.1.6. Eutrophication

The data for eutrophication also comes from Saxe (2011). Eutrophication is calculated per gram of nitrate equivalents (NO_3-e), which include phosphorus particles. Nitrates and its equivalents come from the overuse of nutrients from chemical inputs, high amount of animal faeces or air pollution. Once in the water, it creates an overgrowth of algae, bacteria and aquatic plants that overuse the oxygen and asphyxiate other living aquatic species. This process is named eutrophication (Saxe, 2011). The LCA use for the calculation of eutrophication is from cradle-to-gate.

2.2. Calculation of diets composition

The composition of diets was calibrated for the calculation under the unit of kilogram per person per year. All the diets were adjusted into the same amount of food as the ASD which is 760,6 Kg of food per person per year. It was made by using the proportionality. Diet composition does not consider dietary supplement, alcohol, mineral and fresh water. When a paper separates the diet composition of men, women or children, the average of all categories is used. When data was condensed into one big category, they were proportionally split basing on the

ASD. For example, if there was only one data for a category named "dairy products", this data was split into "milk", "cream" or "butter" basing on the percentage of each category eaten in the ASD. The name of the categories is taken from Wallén *et al.* (2004). Categories named "jam and marmalade", "spices" and "processed sour milk" were removed from the calculation because of a lack of data, which created too much uncertainties in the composition of the diet.

- The data for the composition of the Average Swedish diet are based on the paper of Eidstedt (2013).

- The vegetarian diet is based on several papers. The main composition is extracted from Haddad *et al.* (2003). A supplement of data for eggs and butter comes from Meier *et al.* (2012). For coffee, tea and soft drink, data comes from Chiu *et al.* (2014).

- The main source of composition of the vegan diet comes from Larsson (2001) and a supplement of data for the sugar is from Meier *et al.* (2012).

- The New Nordic diet composition is based on the study of Mithril *et al.* (2013). Another part of the food composition is from data of Saxe *et al.* (2012) for dairy products, cheese, egg, butter, cooking oils, sugar, sweets, soft drinks, juice and coffee and tea. Frozen products were excluded from the calculation because the diet claims to eat fresh seasonal products, which consequently does not need a high process of storage. Rice, banana, orange, or other fresh fruits are also excluded from the diet composition because it is not products that can be produced in Sweden. An exception is made for coffee and tea that are products not easily replaceable.

- The composition of Nordic Nutritional Recommendation is based on scenario 5 of Tetens (2013). Coffee and tea have the same value as the Average Swedish diet.

The ASD, NND and NNR are based on data from Sweden. The vegan diet is almost entirely made of data from Sweden, except for the consumption of sugar. None of the data of the vegetarian diet are from Sweden.

2.3. Categorisation of food items

The composition of studied diets was classified in 9 food categories, gathering 50 food items. Table 1 sums up food items that are gathered on the categories. The special categorisation for potatoes is based on the classification of Jordbruksverket that separated it from the category of vegetables.

Table 1: Food items gathered under chosen categories

Categories	Items
Vegetables	Leaf and root vegetables, pulses, seeds, mushrooms, herbs, seaweed, processed vegetables, other fresh vegetables
Potatoes	Unprocessed potatoes, mashed powder, frozen and processed potatoes
Fruits	Fruits, berries, nuts, juices
Cereals and bread	All types of cereals, bread, pasta, rice, cakes, pies, biscuits
Meat	Beef, pork, poultry, other meats (lamb, venison), frozen meat products, cured meat and sausage
Eggs	Eggs
Dairy products	Milk, cream, cheese, butter
Fish and seafood	Unprocessed fish, frozen fish, fish products, shellfish, shellfish products
Miscellaneous	Margarine, cooking oils, sugar, honey, treacle, chocolate, sweets, soft drinks, coffee, tea and cocoa

Results

1. Current knowledge of environmental impacts of diets in Sweden

The first objectives of the research were to make a literature review of studies about environmental impact of diets in Sweden. The criteria of research were to find studies about diets in Sweden using the method of LCA, having available numerical data, and with several environmental impacts analysed. Very few studies corresponded to these criteria. The data were either in a wrong place of location, or either did not analysed enough environmental impacts. Below, table 2 summarises the type of study found that was the closest from the criteria of research. It is extended to the European scale to have a broader view of the different studies of environmental impacts of diets. This table is non-exhaustive. A cross represents the study of an environmental impact for the diet related.

Table 2: Literature review of environmental impacts of diet in Sweden, extended to Europe

Studies	Country	Type of diet	GHG	Land use	Acidification	Eutrophication	Energy use	Ecotoxicity	Human toxicity	Ozone layer degradation	Photochemical ozone	BDP	Water Use
Baumann, 2013	Sweden	Vegetarian Vegan	X										
Wallen *et al.*, 2004	Sweden	Proposed sustainable diet	X				X						
Röös *et al.*, 2015	Sweden	NNR	X	X								X	
Martin *et al.*, 2017	Sweden	Vegetarian Vegan Reduced meat Organic Sweden	X	X	X	X		X	X			X	
Saxe *et al.*, 2012	Denmark	NNR NND	X										
Saxe, 2011	Denmark	Vegetarian Healthy diet	X	X	X	X		X	X	X	X		
Hallström *et al.*, 2015	Europe	Vegetarian Vegan	X	X									
Meier *et al.*, 2012	Germany	Vegetarian Vegan Recommendation	X	X	X	X	X						X
Baroni *et al.*, 2007	Italy	Vegetarian Vegan	X	X	X	X	X	X		X			

Looking at the table, the vegetarian and vegan diets are largely studied in different European countries. There are few studies for healthy diets and recommendations, which could be equivalent of the NND and NNR. The NND and NNR are thus little studied, and on few environmental impacts.

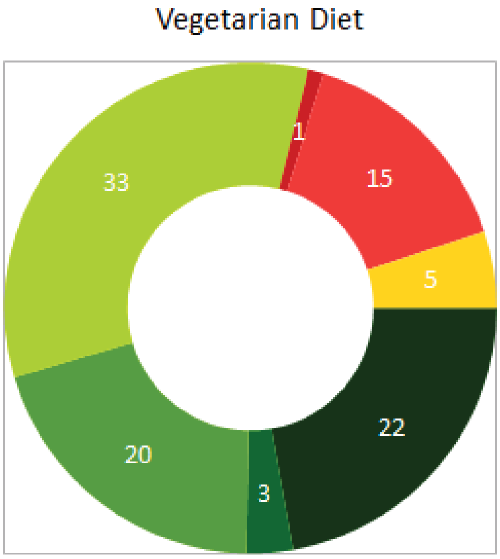
There is a lack of research about environmental impacts of diets in Sweden studying other impacts than GHG emissions. Food production in Sweden has primarily an impact on climate change, eutrophication and primary energy use (Nilsson *et al.*, 2011). Consequently, energy use and eutrophication must be emphasized for studies in Sweden. Martin *et al.* (2017) is the only study meeting almost all the criteria of research, but the data were not available.

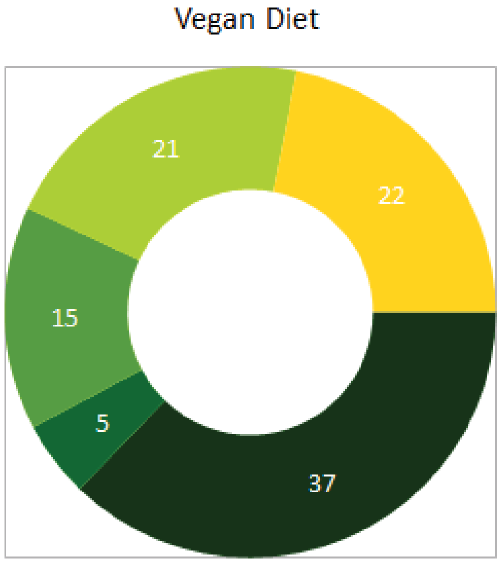
GHG emissions and land use are the impacts with the most accessible data for diets in Europe. Other types of impact are less easily findable in studies of diets in Europe. Water use, human toxicity, photochemical ozone and BDP are the impacts with less accessible data. In the case of Sweden, it is in addition water use, ozone layer degradation and photochemical ozone impacts that does not have available data. Some impacts do not have accessible data at all such as waste, water pollution or soil degradation.

2. Composition of the studied diets

Figure 2 shows the proportion of food eaten for each diet. Three groups of food can be distinguished from each other's. Plant-based products are represented by the green colours, animal-based products are represented by the red ones. The miscellaneous category in yellow is a special category gathering mostly fat and sugar processed products from plants. There is one exception for honey that is an animal-based product.

Figure 2: Food composition of studied diet in percentage of kilogram of food per year





Each studied diet has a food content composed of plant-based products of respectively 49% for the NNR, 75% for the NND, and 78% for the vegetarian diet and vegan diet, without considering miscellaneous. In comparison, the composition of the ASD has 46% of plant-based products. The NNR has a food composition quite similar from the ASD, with a high consumption of animal-based products. In comparison, more than 3/4 of the composition of other studied diets is composed of plant-based products.

Compared to the Average Swedish diet, the NNR reduces by half the consumption of meat. It is compensated by the consumption of potatoes, vegetables, eggs and dairy products. The NND has an equal consumption of fruits and vegetables and consumes little of bread and cereals. Meat-free diets compensate the loss of animal protein by a higher consumption of cereals and vegetables. The vegetarian diet privileges a higher intake of cereals than vegetables, whereas it is the contrary for the vegan diet.

3. Environmental impacts of studied diets

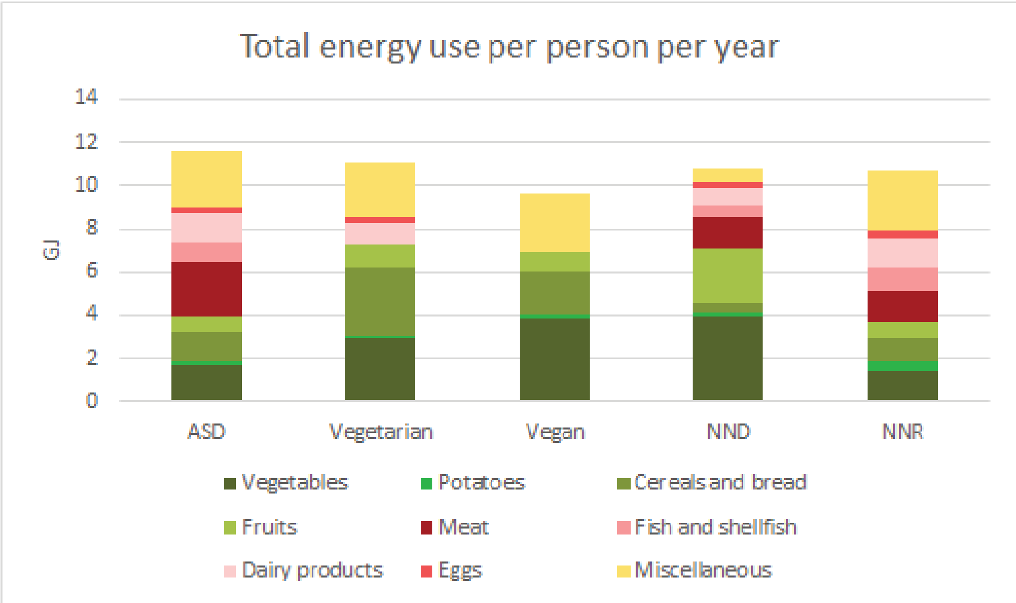
The results from the study are presented in bar charts disaggregated into food categories. It is followed by a second bar chart presenting a what if scenario. It analyses what if all the Swedes chose to adopt one of the studied diets. It is calculated with the today 2018 population of 9,8 million Swedes. The result, under the form of a reduction of impact, is calculated based on the ASD.

Since the results are based on a LCA, it is important to keep in mind that the reduction of environmental impacts of the Swedish population through a change of diet has global consequences. It is explained by a high importation of foodstuffs that cannot be produced in Sweden. 97% of imported foodstuffs come from the European Union and the other 3% come from outside the EU (Jordbruksverket, 2017).

3.1. Energy use

Figure 3 shows the energy use per person per year depending on the type of diet. Food items that have the highest energy use are, in order of magnitude, frozen fish fillet, coffee and tea, beef and all imported vegetables such as tomatoes, cucumber, and lettuce. The products with the lowest energy use are unprocessed potatoes, root crops, cabbages and onions, which are all produced in Sweden (Wallén *et al.*, 2004).

Figure 3: Total energy use per person per year

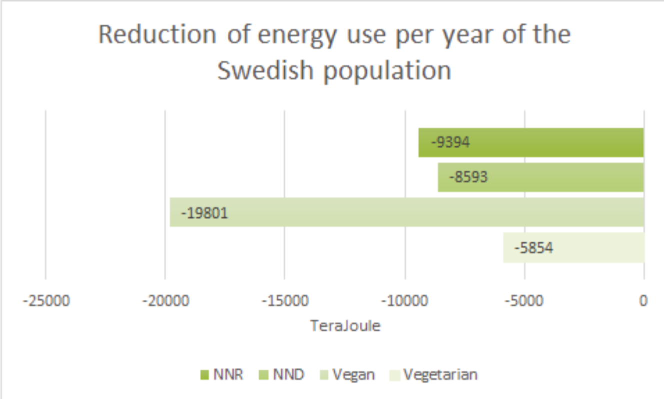


The choice to adopt one of the sustainable diets could save between 1 to 3 Gj of energy per person per year. The vegan diet has the lowest use of energy and can reduce up to 17% of the overall use of energy per person per year compared to the ASD. Even if the vegan diet has the same environmental impact for plant based products than the vegetarian diet and the NND, it has the lowest use of energy because of a non-consumption of animal-based products.
The NND and NNR approximately equally reduce the energy use to 8%. They have a lowest impact than the vegetarian diet. It is explained by a high consumption of local products, which uses less energy to be transported and stored from the place of production to the place of consumption. In comparison the vegetarian diet consumes a lot of vegetables and fruits that are not all produced in Sweden. As mentioned before, 70% of vegetables and fruits are imported. Transport and storage use more energy than local products. It is the reason why the vegetarian diet has the highest environmental impact among the studied diets.

If every Swedes chose to adopt one of the studied diets, figure 4 shows how much energy Sweden could reduce per year in the world compared to the Average Swedish Diet.

In 2016, Sweden consumed 1,35 million terajoules (Energimyndigheten, 2018). The reduction of energy use would represent a reduction to its maximum of 1,5% compared to the energy used by Sweden per year. It means that the shift to sustainable diets represents only a low reduction of energy use compared to the energy used in Sweden. In fact, Sweden mostly consumes energy for industrial, residential and transport sectors (Energimyndigheten, 2018). Consequently, energy use from food production represents a small part of the overall energy use. It means that the shift of diet cannot highly decrease this impact.

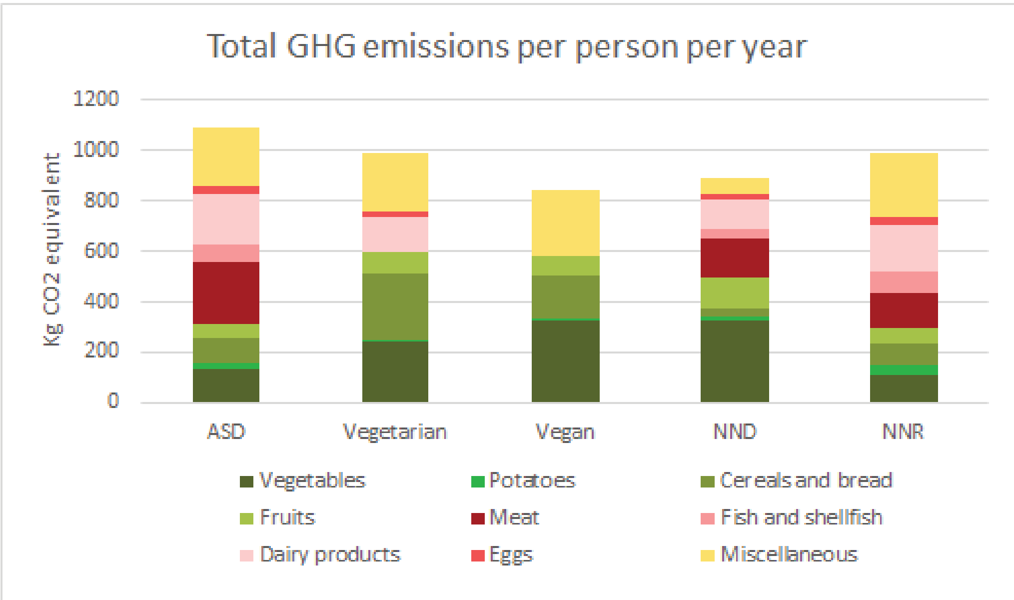
Figure 4: Reduction of energy use per year of the Swedish population



3.2. Greenhouse gas emissions

Figure 5 shows the total amount of GHG emissions produced per person per year depending on the type of diet chosen. Products that emits the most GHG are, in order of magnitude, cheese, coffee, tea, frozen fish, beef and pork. On the contrary unprocessed potatoes, frozen meat, apples and oranges are the ones that emits the less GHG (Wallén *et al.*, 2004).

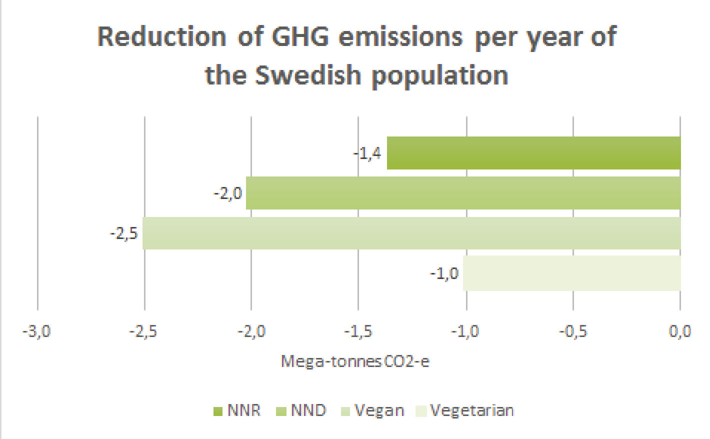
Figure 5: Total GHG emissions per person per year



Looking at the figure, the shift of diet could reduce between 100 to 250 Kg of CO_2-e per person per year. The vegan diet is the lowest producer of GHG emissions. It can reduce 23% of the total emissions per year compared to the ASD. As for energy use, the difference with other diets is made by the non-consumption of animal-based products. The NND can reduce up to 19% of GHG emissions per year compared to the ASD. It has a lower impact than the vegetarian diet due to a high consumption of local products that does not go through long distance of transport. The vegetarian diet has one of the highest emissions of GHG among the studied diets. As for energy use, this rate is explained by the high consumption of imported vegetables and fruits. The vegetarian diet has the highest consumption of coffee and tea among studied diets, and a non-negligible consumption of cheese. It is the reason why emissions associated with vegetarian diet are so high compared to the other diets. NNR follows the vegetarian diet closely with a consumption of all the food items that emit the most GHG emissions such as meat, cheese and coffee.

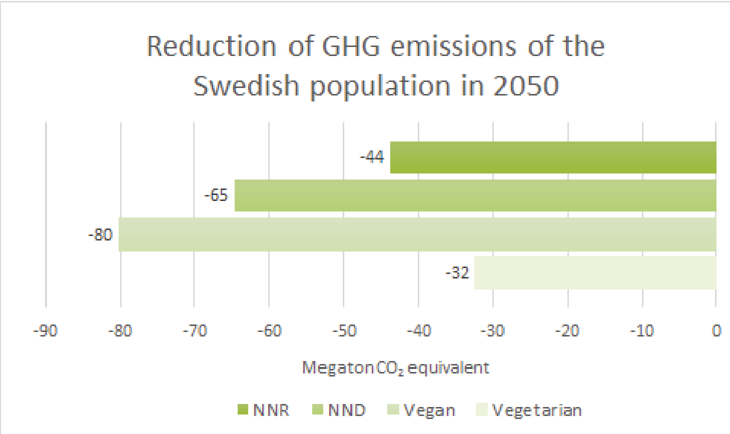
If every Swedes chose to adopt one of the studied diets, figure 6 shows how much GHG emissions Sweden could reduce per year in the world compared to the ASD. The shift to a sustainable diet for the Swedish population would represent a reduction of GHG emissions from 1 to 2,5 Mt of CO_2-e.
In 2050, Sweden was emitting 53,7 Mt of GHG without considering land use, land-use change and forestry (LULUCF) (Naturvårdsverket, 2017a). It means that the change of diet can reduce from 2% to 4,5% of GHG emissions compared to overall emissions from Sweden.

Figure 6: Reduction of GHG emissions per year of the Swedish population



For 2050, Sweden has the objective to reduce GHG emissions by 80% from 1990 levels (Swedish institute, 2018). In 1990, Sweden was emitting 72,2 Mt of CO_2-e without LULUCF (UNFCCC, unknown). It means that the country wants to have a decrease of 57,76 Mt of CO_2-e for 2050.
If from now all the Swedish population chose to adopt a sustainable diet, figure 7 represents how much cumulated emissions Sweden could reduce in the world in 2050. It is calculated based on 2018 year. Looking at the figure, the change to the vegetarian diet or the NNR would not reach the goals by themselves, it would only reduce from 32 to 44 Mt of CO_2-e for 2050. These diets would need to be combined with other actions to reach the goals in 2050. However, by a shift of diets to the NND or the vegan diet, Sweden could decrease GHG emissions even more than the objectives for 2050. It could decrease the GHG emissions from 65 to 80 Mt of CO_2-e in 2050. It means that by only the change of food habits a non-negligible reduction of GHG emissions is possible. A decrease of meat consumption from all the Swedish population could have a great influence on the global reduction of GHG emissions. The shift of diet can be an efficient tool for policy making to reach environmental goals and fight against climate change.

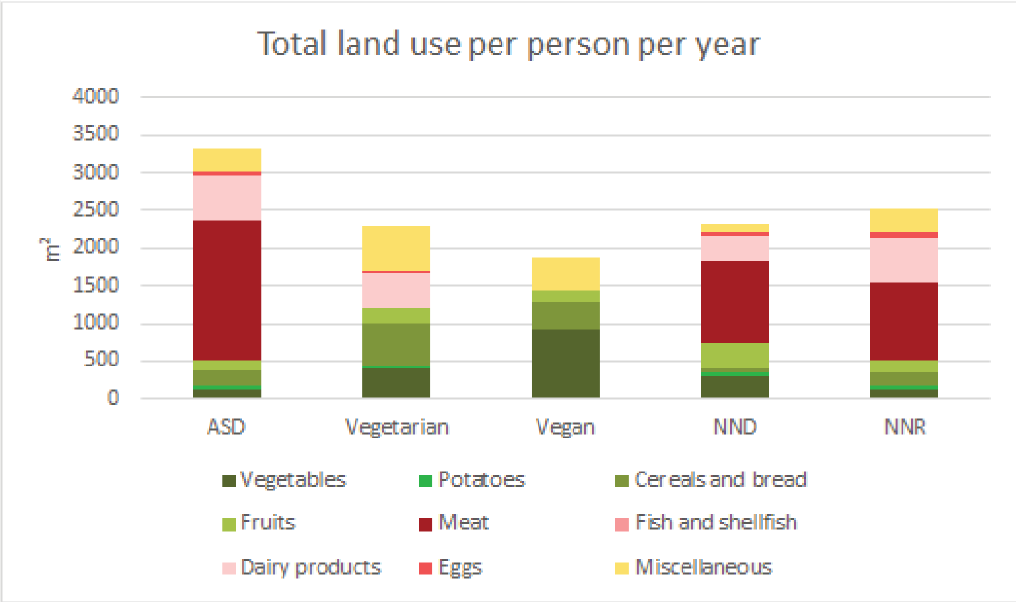
Figure 7: Reduction of GHG emissions of the Swedish population in 2050



3.3. Land use and biodiversity damage potential

Figure 8 shows the total land use for each diet per person per year. The products that require the most lands are other meats (lamb), beef, pork and poultry. Root crops and potatoes are the food items that require the less lands to be produced (Röös *et al.*, 2015).

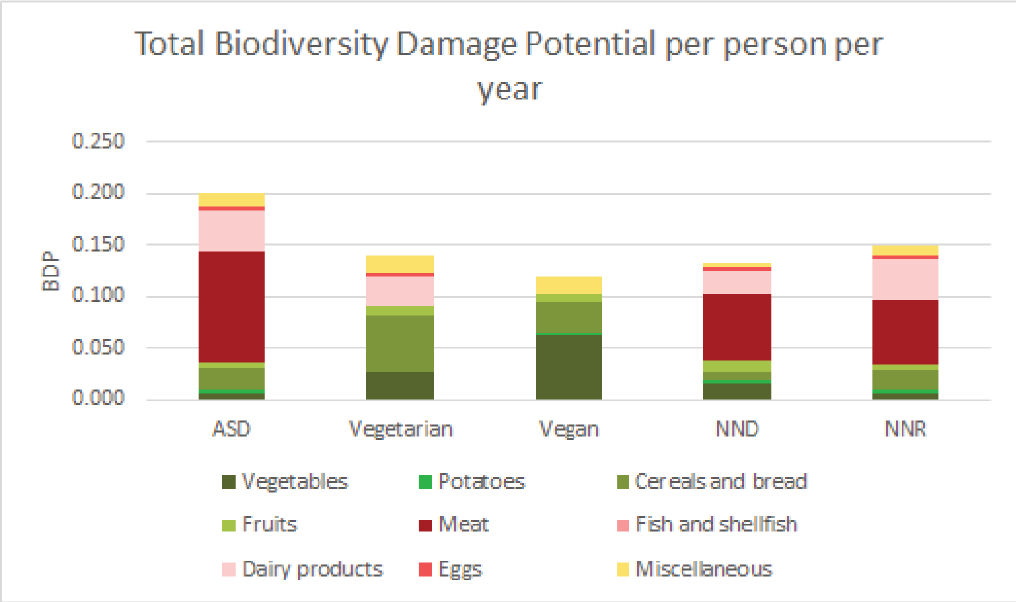
Figure 8: Total land use per person per year



The shift of diet could reduce between 800 to 1400 m^2 of land per person each year in the world. It means it is a reduction from 25% with the NNR to 44% with the vegan diet of the lands used in the world compared to the ASD. Meat and dairy products are highly noticeable on the graph since cattle needs more space than any other food items to be produced. More than half of the overall impact on land use of the NND and NNR comes from the consumption of meat. Meat-free diets have consequently a low land use impact due to a non-consumption of meat. In the case of the NND, even with a high impact through meat consumption, the diet has the same overall impact than the vegetarian diet. It is explained by a high consumption of products with a low use of lands such as root crops and potatoes. These items compensate the high impacts from meat consumption and are the reason why the NND reaches the same overall impact than the vegetarian diet. Miscellaneous category is also a noticeable category in this graph, due to coffee and tea that is one of the plant products that require as much lands as pork for example.

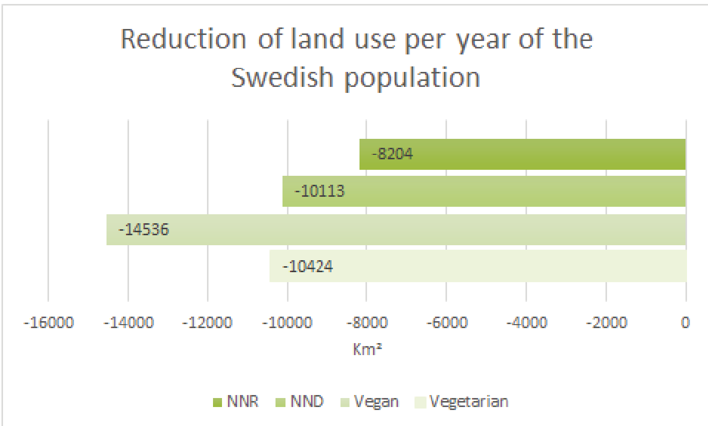
Figure 9 shows the Biodiversity Damage Potential of each diet per person per year. Since BDP is calculated depending on land use, there is similarities of impacts from products. The food items that have the highest environmental impact are other fresh meats (lamb), beef, pork and poultry. It is followed by dairy products, with mainly cheese and butter. The products with the lowest environmental impact are all the unprocessed fruits and the potatoes (Röös *et al.*, 2015).

Figure 9: Total BDP per person per year



Looking at the figure, it is noticeable that sustainable diets highly decrease damages on biodiversity by at least a quarter of its impact compared to the ASD. The shift of diet can reduce between 0.05 and 0.08 points of BDP per person per year. It represents for the vegan diet a drop of the damage on the biodiversity of 44% compared to the ASD. The vegetarian diet and NND would both reduce from 34% to 30% of this impact each year. Meat and dairy products are highly noticeable due to a high need of lands for animal farming. More than half of the overall impact on land use of the NND and NNR comes from the consumption of meat. The NND is equal to the vegetarian diet regarding the overall impact. It is due to a high consumption of fruits and potatoes that are products with the lowest impact on biodiversity. The change from the ASD to the NNR could reduce by half the impact coming from meat consumption, which represents a considerable decrease of impact.
Since BDP is an index linked to land use, the change of diet from the overall Swedish population is analysed through land use in figure 10.

Figure 10: Scenario of a land use reduction per year of the Swedish population



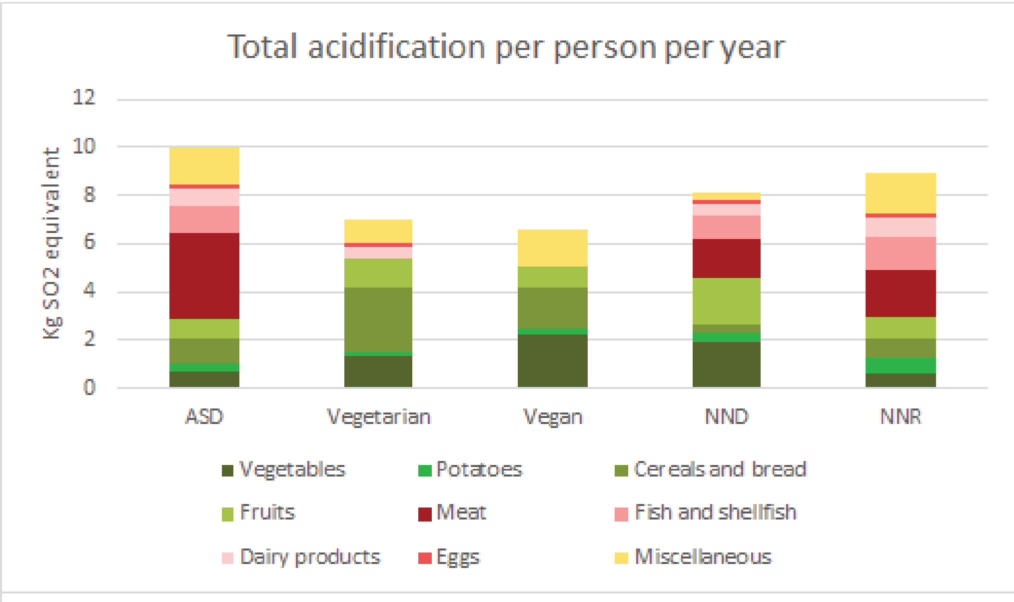
If every Swedes chose to adopt one of the studied diets, figure 10 shows how much land use Sweden could reduce per year in the world compared to the ASD.
In 2010, Sweden had approximately 3000km^2 of utilized agricultural area (Eurostat, 2012). It means that if Swedes shift their diet to one of the sustainable diets, it would represent 2,5 to 5 times the amount of land use for agriculture in Sweden per year. These new unused lands could represent space for wildlife to settle again all over the world. It would consequently have a positive impact on the biodiversity. Only for the choice of the NNR, it would

relieve the equivalent of the size of Yellowstone national park each year in the world. It means that the shift toward sustainable diets can have an important global reduction of physical pressure on the environment.

3.4. Acidification

Figure 11 shows the amount of Sulphur dioxide equivalent, in cause of acidification of the atmosphere, for each diet per person per year. Meat and fish are the biggest emitters of SO_2-e in the atmosphere. The products that emit the less SO_2-e are dairy products, potatoes and unprocessed cereals (Saxe, 2011).

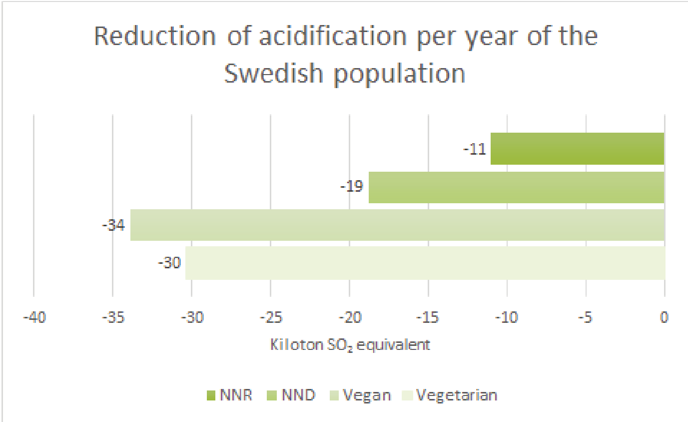
Figure 11: Total acidification per person per year



To the maximum, acidification level can decrease from 11% (with the NNR) to 30-34% (with the vegetarian and the vegan diet). It means that between 1 to 3 kg of SO_2-e emissions can be reduced per person per year in the world. Nordic diets have a significantly higher impact on the environment than meat-free diets. Half of the impacts of NNR comes from the consumption of animal products. It is due to the consumption of fish and meat that are the biggest emitters of SO_2-e. Meat-free diets are consequently the best diets to choose to reduce acidification impact.

If every Swedes chose to adopt one of the studied diets, figure 12 shows how many kilotons of SO_2-e can be reduced per year in the world compared to the ASD. Looking at the figure, meat-free diets have the highest reduction per year, with a decrease from 34 to 30 kilotons of SO_2-e. The Nordic diets would have a weaker action on the reduction of this impact, with a reduction of 11 and 19 kt of SO_2-e per year.

Figure 12: Scenario of an acidification reduction per year of the Swedish population

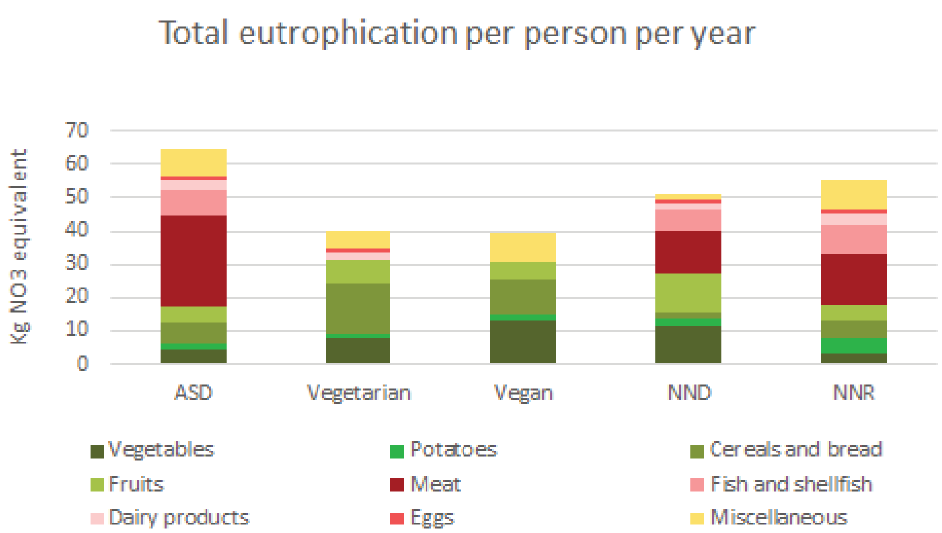


In 2015, Sweden was emitting 19,3 kt of SO_2 (Naturvårdsverket, 2017b). There is not any data found about the cumulation of SO_2 equivalent in Sweden. The shift to a meat-free diet could result to a global decrease of almost twice the emissions of SO_2 from Sweden. The Nordic diets could decrease SO_2 emissions equally or less than the one produced by Sweden. However, if ammonia and nitrogen oxide are added to the emissions from Sweden, it would represent higher overall emissions. It means that the reduction of acidification presented in figure 12 would have a lower power of reduction of this impact. In 2015, the European Union was emitting 18500 kt of SO_2-e (Eurostat, 2018). In comparison to the reduction of SO_2-e per diet, it represents less than 1% of reduction of this impact. It means that at a higher geographical scale, shift of diets has a lower capacity of reduction of atmospheric acidification.

3.5. Eutrophication

Figure 13 shows the amount of nitrate equivalent, responsible for eutrophication, per person per year. The products that emit the most of NO_3-e are meat and fish. On the contrary, the ones that emit the less of NO_3-e are dairy products, potatoes and unprocessed cereals (Saxe, 2011).

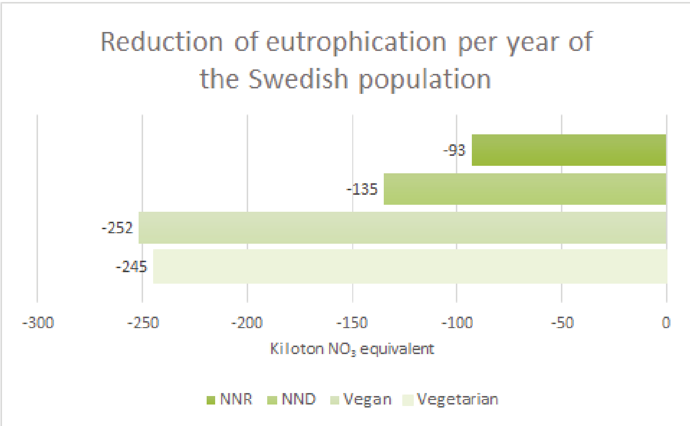
Figure 13: Total eutrophication per person per year



The change to sustainable diets could reduce between 10 to 25 kg of NO_3-e per person per year in the world. It could represent a reduction of 40% from meat-free diets, and a reduction of approximately 10% from Nordic diets. There is a considerable difference of reduction of impacts between meat-free diets and Nordic diets. It means that meat and fish are one of the main drivers of eutrophication related to the consumption of food. Half of the impacts on the NNR is due to the consumption of animal-based products for example. The consumption of meat-free diets is then the best choice of diets to reduce eutrophication impact. Except from meat and fish, all other types of products have low impact on eutrophication. For this reason, the vegetarian diet has almost the same overall impact than the vegan diet.
Except for fish and meat products, the difference between other products is driven by quantity. It explains why cereals and bread in the vegetarian category are highly noticeable, whereas it is one of the items with the lowest impact. It is due to the high consumption of this food item by the diet.

If every Swedes chose to adopt one of the studied diets, figure 14 shows how much kilotons of nitrate equivalent could be reduced per year in the world compared to the ASD. The consumption of meat-free diets could reduce each year between 252 and 245 kilotons of NO_3-e all over the world. In 2012, Sweden emitted 484 kt of nitrates (ECA, 2016). It means that meat-free diets can almost reduce half of the amount of nitrate emitted by Sweden. It would represent for the NNR a reduction of 19% compared to the amount of nitrates emitted by Sweden. The shift to sustainable diets, and mainly meat-free ones, can have an important effect on the reduction of the phenomenon of eutrophication in the world.

Figure 14: Scenario of eutrophication reduction per year of the Swedish population



4. Result summary

Some environmental impacts have a similar structure because they are link to each other's. GHG emissions are the consequences of energy use, as well as biodiversity is for land use. Acidification and eutrophication are also closely linked because they come from the same source. Consequently, these impacts have sometimes the same outcome.
The shift toward sustainable diets is the most efficient to reduce GHG emissions, land use, biodiversity and eutrophication impacts. It has a low capacity of change concerning energy use and acidification. Nevertheless, the four diets have an environmental impact lower than the Average Swedish diet. It confirms that they can be considered as sustainable diets.

The vegan diet is without exception the one that has the lowest impact on the environment. The reason is that the most environmental costly products such as meat, fish and cheese are not consumed.

The vegetarian diet has also a low impact due to the non-consumption of meat and fish, and is the second-best diet with the lowest environmental impact. However, the diet emits the highest GHG emissions through a high consumption of energy. It would not be the best diet to choose to tackle climate change, even if there is a decrease of GHG emissions compared to the ASD. The vegetarian diet would need to be combined with the consumption of local products to efficiently reduce GHG emissions.

The New Nordic Diet is an interesting case because it has almost the same outcomes than the vegetarian diet. What distinguish them is the higher environmental impact on acidification and eutrophication for the NND. Otherwise, the NND has a lower impact for GHG emissions and energy use than the vegetarian diet, and is at equality for land use and BDP impacts. These low outcomes can be first explained by the consumption of local products. Local products require less transport and less storage, so less energy use. Also, the New Nordic diet choses seasonal-local products. It is represented in this study by the removal of frozen products from the calculation, which lower the overall environmental costs. Secondly, the diet claims to eat healthy products. It has the lowest consumption of sugar, chocolate and sweets among the other diets, and soft drinks are not consumed at all. It makes the difference compared to other diets that consumed these products in high quantity.

Finally, the Nordic Nutritional Recommendation is the least environmental friendly diet among the ones studied. The high consumption of products with high environmental impacts such as meat, fish, dairy products and cheese must be diminished to have a more efficient reduction of impacts. The diet would need to consume more local products. For example, imported products such as bananas, oranges can be substituted with local apples and berries. It is also necessary to reduce the consumption of unhealthy products such as sweets, chocolate and soft drinks that are items consumed more than 20 kilograms per year by the diet. However, this diet is a good way to show how important is the reduction of meat consumption, since it has a positive reduction of environmental impacts compared to the Average Swedish diet. The NNR could be an interesting diet to use as a transition toward other sustainable diets. Since it is not easy to change dietary habits of a population, starting to reduce consumption of meat and to eat in a healthier way would educate people and lead them toward the most sustainable diets.

Discussion

The reduction or the cessation of meat and animal-based products has a positive impact on the environment. Meat consumes a lot of energy to be produced and uses high amount of lands for the raising of cattle and the growth of feed plant. It leads to high emissions of GHG, important decrease of biodiversity and high emissions of particles in cause of acidification of air and eutrophication of water. Consequently, diets that consumes animal products are reducing less efficiently impacts on the environment than meat-free diets.

Wallen *et al.* (2004) noticed that the debate should not only focus on eating animal products or not, but also on where and how the food is produced. It means that the consumption of local products is one component to consider for a sustainable diet. The adoption of a meat-free diets involves the decrease or the cessation of animal products. These products will need to be replaced by substitutes. Meat substitutes can have high environmental impact if they are imported. Sweden imports 70% of fruits and vegetables, which means that these products are using high amount of energy for transport, storage and packing. It leads to more GHG emissions. This effect is noticeable with the consumption of coffee and tea from the vegetarian diet that highly increase GHG emissions. The reason is that these items use more energy than other products to arrive in Sweden. Even if plant-based products have a reduced impact on the environment compared to animal-based products, their impacts are not negligible, mostly if consumed products come from far. Eating local products is then an additional way to reduce GHG emissions and energy use. The New Nordic diet is a good example of how eating local products can have positive impact for the environment. The diet almost reaches the same overall impacts on the environment than the vegetarian diet, even with a consumption of meat. It is due to the reduction of energy use and GHG emissions through a selection of local products. It means that adapting its diet to the place of living is a way to have a sustainable food habit.
Eating seasonal products is also a way to reduce the consumption of energy through less storage. The combination of local and seasonal products can lead to a reduction of impact on the environment. The study intents to show it through the non-consumption of frozen products that highly reduce the energy used for storage. However, this particularity in production pattern must be analyses deeper in another study.

The shift toward sustainable diets from the whole population of Sweden could highly decrease the environmental impacts all over the world. It could enable the country to reach some of its environmental targets and to save resources such as energy and land for other uses. For example, the recolonization of forest on former agricultural lands could represent a bigger carbon sink to fight climate change and ocean acidification. It would also represent an increase of habitat for wildlife that suffers from a depletion of physical space to thrive. The reduction of eutrophication could have the same benefits for wildlife. The reduction of air acidification could prevent the destruction of northern forest from acid rain and in consequence preserve an important resource of wood for forestry. The reduction of energy use and GHG emissions could slow down the process of global warming and all the consequences it causes on the Earth. It means that private consumption has a role to play in the reduction of impacts that humans have on the environment. The outcomes of such a change will have great positive impacts on the environment.

However, it is not easy to shift the whole diet of a population within a short time. Diet transition must be supported by policy making to be implemented efficiently and quickly. Governments should support such transition through awareness campaigns, new legislations, fiscal policy, food labelling, cooperation with specialized NGOs or through an easier access to local, seasonal or organic food, at a low price. It can be supported by multiple ways, but it is in any case necessary to have the help of an institution to support a project of transition. The country has also to consider the consumer acceptance of new dietary habits. The change of food consumption can affect strong cultural, ethnical, economic or social values, and make the transition harder to realise.

The comparison of this study with other researches shows similar results. During the research, the study of Martin *et al.* (2017) was found with a similar subject as this study. The two studies distinguished each other's by a use of different type of diets and different sources of calculation. The comparison of the two studies shows nevertheless some similarities in the results. The vegan diet is incontestably the best choice of diet for the environmental impacts of land use, BDP, GHG emissions, acidification and eutrophication. The vegetarian diet is the second-best option as well for Martin *et al.* However, in their study the vegetarian diet has one of the lowest GHG emissions and they mentioned that the consumption of local products has only a little improvement on GHG emissions. It does not totally correspond to the results of this study. It can be explained by the difference between the choice to use representative food items for Martin *et al.*, and the choice to have more details food items for this study. One other reason can be due to the high consumption of coffee and tea of the vegetarian diet that have as result to increase the GHG emissions. The calculation of impacts is highly sensitive to any change of quantity of food consumed. A choice of a lower number based on another study can change the results. Moreover, the composition of the vegetarian diet is not based on sources for Sweden, which might influence the results.
For other diets, the results found by Martin *et al.* and this research are quite similar. The diet named "reduced meat" (similar as the NND) and nutritional guidelines (similar as NNR), are both highly decreasing the impacts on the environment compared the business-as-usual (equivalent to the ASD).

Other studies, such as Saxe (2011) confirms for the Danish case, that the vegetarian diet is more sustainable than the healthy diet for the environmental impacts of land occupation, eutrophication and acidification.
The study of Hallström *et al.* (2015), made in different European countries, have also similar results than this study. They found that vegan and vegetarian diets have the best potential to reduce impacts of GHG emissions and land use, followed by the healthy diet (similar as the NND).

This study had some limitations for the calculation of environmental impacts. For example, it could be interesting to study other types of environmental impacts than the ones of this study. However, there was not any available data concerning food products in Sweden or in Nordic countries that mentioned environmental impacts such as water pollution, water use, land degradation or waste. Some other environmental impacts had data available in Denmark such as acidification, eutrophication, ecotoxicity, human toxicity, photochemical ozone and ozone layer degradation, but there was a lack of data for Sweden.
To go further, the study could explore different type of diets depending on the food production pattern. Type of products could be more specific, depending if it is organic or conventional farming, local or imported products and seasonal or stored. Taking these parameters into account might change the results of the study. However, the study of all the possibilities of different type of products for the four diets would represented 24 different diets to analyse. It cannot fit to the time frame of this study.
Moreover, the composition of a same diet can change depending on the use. Food composition

of a vegetarian eater for example can change from one person to another, depending on choices, taste, budget. It means that the composition of diets can be interpreted differently and that one type of diet does not necessary reflects the reality.

There are some issues in the calculation of impacts of the study. First, the analysis of impact can be made in different way depending on the studies use, which can bend the results from one research to another. For example, the use of different LCAs can make the comparison between them inaccurate. Different steps of production are considered, which means that some LCA will under estimate some impacts, whereas others will take every step into account.
The use of LCA is driving the study to two different scales of interpretation of the results. Either the production of food is made abroad and concerns a global scale, either it is produced locally and relies into Swedish regulations. The evaluation of impacts might be different between countries of production depending on the different national environmental policy and the production patterns. For example, the use of data from Denmark to study the case of Sweden can bend the results because of different types of food production and regulations between the two countries. Results of acidification and eutrophication impacts might not be representative of some food produced in Sweden. Nevertheless, since Sweden imports many foodstuffs from Denmark, it is a representative country to calculate impacts for imported products (Jordbruksverket, 2017).

Some calculations of impact have drawbacks. It is the case of the Biodiversity Damage Potential. The calculation of BDP must be improved and must consider more factors representative of biodiversity, even if it is a broad and complex term. The current calculation of BDP is only a record of the presence or the absence of a specie on a land. It means it gives an equal weight to all species, without considering if they are endemic or invasive species, or if they are present in high or low numbers. As well as the BDP indicator does not give any information about diversity of habitat or species turnover. Then there is a risk that the quality of the sampling forgets to count some species. It can be due to an underestimation from a lack of knowledge of some species or from undiscovered species (De Baan *et al.*, 2013). Finally, the notion of biodiversity can differ from one study to another. For example, in the case of meat and dairy produced in Sweden, livestock farming on semi-natural grassland can contribute to maintain a high level of biodiversity compared to other types of land uses (Ihse, 1995). However, according to De Baan *et al.* (2013) pasture and meadow have a higher biodiversity damage potential than unmanaged natural land uses. Differences between studies complicates the evaluation of the real impact on biodiversity of animal husbandry.

The calculation of GHG emissions has likewise some drawbacks. Its calculation takes only into account the emissions from energy use whereas other sources of emissions are possible. For example, cows are a source of emission of methane through the process of enteric fermentation. If this source of emission was considered in the study, frozen meat would not have appeared in the products that emits less GHG emissions. It is consequently important to consider the maximum of sources in cause of an impact to avoid any underestimations.
However, the possibility of an underestimation of impacts is not easy to avoid. Cumulative effects for example can be forgotten during the calculation of impacts. They are hard to measure or their impacts can be indirect. It is the case of damage on biodiversity that have several direct and indirect causes, but are hard to properly measure.

The study has some uncertainties in the calculation of impacts and in the diet composition. The adjustment of all the diets under the same amount as the ASD highly decreases the gaps potentially created by a difference of food intake. It reduces the uncertainty rate and enables to compare the diets together. However, there was still missing data for some food items during the calculation. It could lead to uncertainties about the real environmental impact of diets. The lack of data for the composition of diet represents respectively 2% of uncertainty for the vegetarian and vegan diet and 4% for the NND and NNR. The Average Swedish diet does not have any uncertainties.

The calculation of environmental impact has missing data. These data uncertainties are only present for data that does not come from Wallen *et al.* (2004). Land use and biodiversity have 22% of uncertainty in their calculation and acidification and eutrophication have 8% of uncertainty.

Conclusion

Environmental impacts from food consumption are numerous and have different level of seriousness. Among the six environmental impacts studied, the change of the dietary habits to a sustainable diet would efficiently reduce GHG emissions, land use, biodiversity damage potential and eutrophication impacts. The change of diet would have a lower power of action in the reduction of energy use and acidification.

The most sustainable diet is by far the vegan diet, that highly reduces all the studied impacts through a non-consumption of animal-based products. Then the New Nordic diet has almost the same overall impacts than the vegetarian diet. While one reduces environmental impacts through the consumption of local products, the other reduces these impacts through the non-consumption of meat. One of the Nordic diets is consequently as sustainable as meat-free diets due to a high consumption of local products. The Nordic Nutritional Recommendation is the least sustainable diet among the ones studied. However, it represents an interesting reduction of environmental impacts compared to the Average Swedish diet. It could be used to make a transition toward other more sustainable diets.

The shift toward sustainable diets of the overall population can be a difficult and long process. However, if all Swedes adopted one of the sustainable diets, studied impacts could be massively reduced. It could allow the country to fulfil some European and world environmental objectives through the change of diet. It means that the action of multiple individuals can help governments to reach global goals.

In future studies, more environmental impacts such as water pollution, water use, land degradation or wastes should be considered. The study of a sustainable diet could be broadened and consider the social and economic aspects of sustainability. The study would be interesting to reproduce in different geographical locations with different type of diets and production patterns such as organic, local or seasonal types of production.

Reference list

(1) Aiking, H., de Boer, J., & Vereijken, J. (Eds.). (2006). *Sustainable protein production and consumption: Pigs or peas?* (Vol. 45). Springer Science & Business Media. View Link (Accessed 2018-05-16)

(2) Baroni, L., Cenci, L., Tettamanti, M., & Berati, M. (2006). Evaluating the environmental impact of various dietary patterns combined with different food production systems. *European Journal of Clinical Nutrition*, *61*(2), 279-286. View Link (Accessed 2018-05-16)

(3) Baumann, A. (2013). Greenhouse gas emissions associated with different meat-free diets in Sweden. View Link (Accessed 2018-05-16)

(4) Burlingame, B., & Dernini, S. (2012). Sustainable Diets and Biodiversity: Directions and Solutions for Policy, Research and Action. International Scientific Symposium, Biodiversity and Sustainable Diets United Against Hunger, FAO Headquarters, Rome, Italy, 3-5 November 2010. Food and Agriculture Organization of the United Nations (FAO).View Link (Accessed 2018-05-16)

(5) Carlsson-Kanyama, A. (1998). Climate change and dietary choices—how can emissions of greenhouse gases from food consumption be reduced? *Food policy*, *23*(3-4), 277-293. View Link (Accessed 2018-05-16)

(6) Chiu, T. H., Huang, H. Y., Chiu, Y. F., Pan, W. H., Kao, H. Y., Chiu, J. P., ... & Lin, C. L. (2014). Taiwanese vegetarians and omnivores: dietary composition, prevalence of diabetes and IFG. *PLoS One*, *9*(2), e88547. View Link (Accessed 2018-05-16)

(7) De Baan, L., Alkemade, R., & Koellner, T. (2013). Land use impacts on biodiversity in LCA: a global approach. *The International Journal of Life Cycle Assessment*, *18*(6), 1216-1230. View Link (Accessed 2018-05-16)

(8) Donald, P. F. (2004). Biodiversity impacts of some agricultural commodity production systems. *Conservation biology*, *18*(1), 17-38.

(9) Eidstedt, M. (2013). Livsmedelskonsumtion och näringsinnehåll. Statistikrapport 2013:04. Statistik från jordbruksverket.

(10) Energimyndigheten (2018) Energy in Sweden Facts and Figures 2018. View Link (Accessed 2018-05-16)

(11) ECA, European Court of Auditors (2016) Combating eutrophication in the Baltic Sea: further and more effective action needed, special report, pursuant to Article 287(4), second subparagraph, TFEU. View Link (Accessed 2018-05-19)

(12) Eurostat (2012) Agricultural census in Sweden, Statistic Explained. View link (Accessed 2018-05-16)

(13) Eurostat (2018) Air pollution statistics - air emissions accounts. View Link (Accessed 2018-05-16)

(14) EC/JRC, European Commission Joint Research Centre (2009) Environmental impacts of

diet changes in the EU. Technical Report, View Link (Accessed 2018-05-16)

(15) FAO (2018). World Markets for Organic Fruit and Vegetable; SWEDEN. View Link (Accessed 2018-05-16)

(16) Frison, E. A., Cherfas, J., & Hodgkin, T. (2011). Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. *Sustainability*, *3*(1), 238-253. View Link (Accessed 2018-05-16)

(17) Haddad, E. H., & Tanzman, J. S. (2003). What do vegetarians in the United States eat? *The American journal of clinical nutrition*, *78*(3), 626S-632S. View Link (Accessed 2018-05-16)

(18) Hallström, E., Carlsson-Kanyama, A., & Börjesson, P. (2015). Environmental impact of dietary change: a systematic review. *Journal of Cleaner Production*, *91*, 1-11. View Link (Accessed 2018-05-16)

(19) Harrould-Kolieb, E. R., & Herr, D. (2012). Ocean acidification and climate change: synergies and challenges of addressing both under the UNFCCC. *Climate Policy*, *12*(3), 378-389. View Link (Accessed 2018-05-16)

(20) Ihse, M. (1995). Swedish agricultural landscapes—patterns and changes during the last 50 years, studied by aerial photos. *Landscape and urban planning*, *31*(1-3), 21-37. View Link (Accessed 2018-06-13)

(21) ISO, International Standards Organization (2006) Environmental management – life cycle assessment – principles and framework, standard ISO 14040:2006, Geneva, Switzerland

(22) Jensen, C., Stenmarck, Å., Sörme, L., & Dunsö, O. (2011). Matavfall 2010 från jord till bord.

(23) Jordbruksverket (2011) Sweden's agriculture in numbers, you as a consumer, About the board of Agriculture, View Link (Accessed 2018-05-16)

(24) Jordbruksverket (2017) Svensk handel medjordbruksvaror och livsmedel 2016, Swedish trade in agricultural products and foodstuffs 2016, View link (Accessed 2018-05-16)

(25) Jordbruksverket (2018) *Clear development - we eat less meat and more Swedish*. View Link (Accessed 2018-05-16)

(26) Kahrl, F., Li, Y., Su, Y., Tennigkeit, T., Wilkes, A., & Xu, J. (2010). Greenhouse gas emissions from nitrogen fertilizer use in China. *Environmental Science & Policy*, *13*(8), 688-694. View Link (Accessed 2018-05-16)

(27) Lal, R. (1993). Tillage effects on soil degradation, soil resilience, soil quality, and sustainability. *Soil and Tillage Research*, *27*(1-4), 1-8.

(28) Larsson, C. (2001). *Young vegetarians and omnivores: Dietary habits and other health-related aspects* (Doctoral dissertation, Institutionen för kostvetenskap, Umeå universitet). View Link (Accessed 2018-05-16)

(29) Lenzen, M., Moran, D., Kanemoto, K., Foran, B., Lobefaro, L., & Geschke, A. (2012). International trade drives biodiversity threats in developing nations. *Nature*, *486*(7401), 109.

View Link (Accessed 2018-05-16)

(30) Marlow, H. J., Hayes, W. K., Soret, S., Carter, R. L., Schwab, E. R., & Sabate, J. (2009). Diet and the environment: does what you eat matter? *The American journal of clinical nutrition*, *89*(5), 1699S-1703S. View Link (Accessed 2018-05-16)

(31) Marsh, K., & Bugusu, B. (2007). Food packaging—roles, materials, and environmental issues. *Journal of food science*, *72*(3).

(32) Martin, M., & Brandão, M. (2017). Evaluating the Environmental Consequences of Swedish Food Consumption and Dietary Choices. *Sustainability*, *9*(12), 2227. View Link (Accessed 2018-05-16)

(33) McMichael, A. J., Powles, J. W., Butler, C. D., & Uauy, R. (2007). Food, livestock production, energy, climate change, and health. *The lancet*, *370*(9594), 1253-1263. View Link (Accessed 2018-05-16)

(34) Meier, T., & Christen, O. (2012). Environmental impacts of dietary recommendations and dietary styles: Germany as an example. *Environmental science & technology*, *47*(2), 877-888. View Link (Accessed 2018-05-16)

(35) Menon, S., Denman, K. L., Brasseur, G., Chidthaisong, A., Ciais, P., Cox, P. M., ... & Jacob, D. (2007). *Couplings between changes in the climate system and biogeochemistry* (No. LBNL-464E). Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA (US). View Link (Accessed 2018-05-16)

(36) Menzi, H. (2001). Needs and implications for good manure and nutrient management in intensive livestock production in developing countries. In *Area Wide Integration Workshop, unpublished*.

(37) Mithril, C., Dragsted, L. O., Meyer, C., Blauert, E., Holt, M. K., & Astrup, A. (2012). Guidelines for the new Nordic diet. *Public health nutrition*, *15*(10), 1941-1947. View Link (Accessed 2018-05-16)

(38) Mithril, C., Dragsted, L. O., Meyer, C., Tetens, I., Biltoft-Jensen, A., & Astrup, A. (2013). Dietary composition and nutrient content of the New Nordic Diet. *Public health nutrition*, *16*(5), 777-785. View Link (Accessed 2018-05-16)

(39) Naturvårdsverket (2008) Konsumtionens klimatpåverkan. Stockholm. Report No.: 5903 View Link (Accessed 2018-05-16)

(40) Naturvårdsverket (2017a) National Inventory Report Sweden 2017, Greenhouse Gas Emission Inventories 1990-2015, View Link (Accessed 2018-05-16)

(41) Naturvårdsverket (2017b) Informative inventory report Sweden 2017 View Link (Accessed 2018-05-16)

(42) Nilsson, K., Sund, V., & Florén, B. (2011). *The environmental impact of the consumption of sweets, crisps and soft drinks*. Nordic Council of Ministers.

(43) Nilsson, P. (2015) *Var tionde svensk är vegetarian.* Djurens Rätt. View Link (Accessed

2018-05-19)

(44) Nordic Council of Ministers. (2014). *Nordic Nutrition Recommendations 2012: integrating nutrition and physical activity*. View Link (Accessed 2018-05-16)

(45) Nordic co-operation (2018) *What is the NNR*. View Link (Accessed 2018-05-16)

(46) Oldeman, L. R. (1992). Global extent of soil degradation. In *Bi-Annual Report 1991-1992/ISRIC* (pp. 19-36). ISRIC. View Link (Accessed 2018-05-16)

(47) OPUS (2018a) About OPUS, research center OPUS, food of life, University of Copenhagen. View Link (Accessed 2018-05-16)

(48) OPUS (2018b) Developing the New Nordic Diet, research center OPUS, food of life, University of Copenhagen. View Link (Accessed 2018-05-16)

(49) Paillard, S., Treyer, S., & Dorin, B. (Eds.). (2014). *Agrimonde–Scenarios and Challenges for Feeding the World in 2050*. Springer Science & Business Media.

(50) Pimentel, D., & Giampietro, M. (1994). Global population, food and the environment. *Trends in ecology & evolution*, *9*(6), 239. View Link (Accessed 2018-05-16)

(51) Pimentel, D., Houser, J., Preiss, E., White, O., Fang, H., Mesnick, L., ... & Alpert, S. (1997). Water resources: agriculture, the environment, and society. *BioScience*, *47*(2), 97-106. View Link (Accessed 2018-05-16)

(52) Pimentel, D. (1999). 10. Environmental and Economic Benefits of Sustainable Agriculture. *Sustainability in Question: The Search for a Conceptual Framework*, 153. View Link (Accessed 2018-05-16)

(53) Pimentel, D., & Pimentel, M. (2003). Sustainability of meat-based and plant-based diets and the environment. *The American journal of clinical nutrition*, *78*(3), 660S-663S. View Link (Accessed 2018-05-16)

(54) Röös, E., Karlsson, H., Witthöft, C., & Sundberg, C. (2015). Evaluating the sustainability of diets–combining environmental and nutritional aspects. *Environmental Science & Policy*, *47*, 157-166. View Link (Accessed 2018-05-16)

(55) Rosegrant, M. W. (1997). *Water resources in the twenty-first century: Challenges and implications for action* (Vol. 20). Intl Food Policy Res Inst. View Link (Accessed 2018-05-16)

(56) Saxe, H. (2011). Diet as a healthy and cost-effective instrument in environmental protection. In *Encyclopedia of environmental health* (pp. 70-82). Elsevier Science. View Link (Accessed 2018-05-16)

(57) Saxe, H., Larsen, T. M., & Mogensen, L. (2012). The global warming potential of two healthy Nordic diets compared with the average Danish diet. *Climatic Change*, *116*(2), 249-262. View Link (Accessed 2018-05-16)

(58) Shiklomanov, I. A., & Rodda, J. C. (Eds.). (2004). *World water resources at the beginning of the twenty-first century*. Cambridge University Press.

(59) Sim, S., Barry, M., Clift, R., & Cowell, S. J. (2007). The relative importance of transport in determining an appropriate sustainability strategy for food sourcing. *The International Journal of Life Cycle Assessment*, *12*(6), 422. View Link (Accessed 2018-05-16)

(60) Stehfest, E., Bouwman, L., Van Vuuren, D. P., Den Elzen, M. G., Eickhout, B., & Kabat, P. (2009). Climate benefits of changing diet. *Climatic change*, *95*(1-2), 83-102. View Link (Accessed 2018-05-16)

(61) Steinfeld, H., Gerber, P., Wassenaar, T. D., Castel, V., & De Haan, C. (2006). *Livestock's long shadow: environmental issues and options*. Food & Agriculture Org. View Link (Accessed 2018-05-16)

(62) Swedish institute (2018) *Sweden tackles climate change*. View Link (Accessed 2018-05-16)

(63) Tetens, I. (2013) *Nutritional Evaluation of Lowering Consumption of Meat and Meat Products in the Nordic Context: A Nordic Ozone Group Project 2011*. Nordic Council of Ministers. View Link (Accessed 2018-05-16)

(64) Tukker, A., Huppes, G., Guinée, J., Heijungs, R., de Koning, A., van Oers, L., ... & Nielsen, P. (2006). Environmental impact of products (EIPRO). *Analysis of the Life Cycle Environmental Impacts Related to the Total Final Consumption of the EU25*, *22284*(May), 1-13. View Link (Accessed 2018-05-19)

(65) UNFCCC, United Nations Framework Convention on Climate Change (*unknown*) Summary of GHG emissions for Sweden, View Link (Accessed 2018-05-16)

(66) Wallén, A., Brandt, N., & Wennersten, R. (2004). Does the Swedish consumer's choice of food influence greenhouse gas emissions? *Environmental Science & Policy*, *7*(6), 525-535. View Link (Accessed 2018-05-16)

(67) Wicke, B., Sikkema, R., Dornburg, V., & Faaij, A. (2011). Exploring land use changes and the role of palm oil production in Indonesia and Malaysia. *Land use policy*, *28*(1), 193-206. View Link (Accessed 2018-05-16)

(68) Wood, R., Lenzen, M., Dey, C., & Lundie, S. (2006). A comparative study of some environmental impacts of conventional and organic farming in Australia. *Agricultural systems*, *89*(2-3), 324-348. View Link (Accessed 2018-05-16)

Annexes

Table 1: Food composition of studied diets in Kg per person per year

	Average Swedish Diet	Vegetarian	Vegan	NND	NNR
	Kg/p/yr	Kg/p/yr	Kg/p/yr	Kg/p/yr	Kg/p/yr
Potatoes, unprocessed	45	20,1	32,1	58,77	88,1
Mashed potato powder	0,3	0,1	0,2	0,39	0,6
Frozen potato products	8,8	3,9	6,3	0	17,2
Other potato products	2,2	1,0	1,6	2,87	4,3
Rice	5,4	27,9	26,6	0	4,3
Flour, including baking	10	10,9	11,1	3,72	8,0
Oatmeal and other grains	3,5	3,8	3,9	1,30	2,8
Breakfast cereals	3,4	3,7	7,2	1,26	2,7
Plain bread	51,2	137,0	56,9	19,03	40,9
Crispbread	3,5	9,4	3,9	1,30	2,8
Biscuits and crackers	4,2	11,2	4,7	1,56	3,4
Buns and cakes	13,6	36,4	9,2	5,06	10,9
Pasta	9,2	10,0	36,3	0	7,3
Pulses	6,9	51,5	136,8	13,29	5,8
Root crops	11,7	15,1	21,1	66,47	9,9
Onions	8	10,3	14,4	18,13	6,8
Cabbages	4,9	6,3	8,8	12,85	4,1
Tomatoes	10,1	20,8	18,2	22,89	8,5
Green salads	6,1	11,5	11,0	13,82	5,2
Cucumber	5,6	7,2	10,1	12,69	4,7
Other fresh vegetables	12,1	15,6	21,8	27,42	10,2
Processed vegetables	22,2	28,7	40,0	50,31	18,8
Apples	14,1	20,3	11,2	146,23	13,5
Bananas	22,6	12,1	18,0	0	21,7
Oranges	18,8	55,9	15,0	0	18,0
Other fresh fruits	12,9	5,6	10,3	0	12,4
Fresh and frozen berries	3,8	9,3	3,0	33,24	3,6
Fruit juices and syrups	25,4	51,5	54,3	63,37	34,9
Unprocessed beef	12,8	0	0	7,55	7,0
Unprocessed pork	17,3	0	0	10,20	9,5
Unprocessed poultry	17,3	0	0	10,20	12,6
Other meats	3,4	0	0	2,01	1,9
Frozen meat product	10,8	0	0	0	5,9
Cured meat, sausage	21,7	0	0	12,80	0
Unprocessed fish	6,5	0	0	6,42	7,8
Frozen, filleted fish	3,8	0	0	0	4,6
Fish products	9,3	0	0	9,18	11,2
Unprocessed shellfish	1,5	0	0	1,48	1,8
Processed shellfish	2	0	0	1,97	2,4
Milk	121,9	89,2	0	80,72	143,8
Cream	10,6	7,8	0	7,02	12,5
Cheese	18,2	11,5	0	9,70	15,1
Eggs	10,7	9,0	0	10,55	12,0
Butter	2,5	4,5	0	0,58	2,9
Margarine	9,8	5,6	9,7	/	6,7
Cooking oils	2,6	1,5	/	5,18	/
Sugar, honey and treacle	8	3,5	14,8	1,11	11,8
Chocolate and sweets	15,4	6,7	7,0	4,48	22,7
Ice-cream	10,4	/	0,0	/	15,4
Soft drinks	87,7	0	120,3	0	68,9
Coffee, tea and cocoa	10,9	24,0	14,9	3,46	12,6
Total	760,6	760,6	760,6	760,6	760,6
/ = missing data	0	1	1	2	1
% of uncertainty	0	2	2	4	2

Figure 2: Most consumed food items per diets

	ASD	Vegetarian	Vegan	NND	NNR
Highest consumption	Milk	Plain bread	Pulses	Apple	Milk
	Soft drinks	Milk	Soft drinks	Milk	Potatoes
	Plain bread	Oranges	Plain bread	Root crops	Soft drinks
	Potatoes	Fruit juices	Fruit juices	Fruit juices	Plain bread
	Fruit juices	Pulses	Processed vegetables	Potatoes	Fruit juices
	Bananas	Buns and cakes	Pasta	Processed vegetables	Chocolate and sweet
	Processed vegetables	Rice	Potatoes	Berries	Bananas
	Cured meat, sausage	Processed Vegetables	Rice	Other fresh vegetables	Processed vegetables
Lower consumption	Oranges	Coffee, tea	Other fresh vegetables	Tomatoes	Oranges

Figure 3: Food items with the highest environmental impact

	GHG emissions	Energy use	Land use	BDP	Acidification	Eutrophication
Highest impact	Cheese	Frozen, filleted fish	Other meat (lamb)	Other meat (lamb)	Beef	Beef
	Coffee, tea and cocoa	Coffee, tea and cocoa	Beef	Beef	Pork	Pork
	Frozen, filleted fish	Beef	Pork	Pork	Other meat (lamb)	Other meat (lamb)
	Beef	Green salads	Coffee, tea and cocoa	Poultry	Frozen meat products	Frozen meat products
	Pork	Cucumber	Cheese	Cheese	Fish	Fish
	Sugar, honey and treacle	Other fresh vegetables	Butter	Butter	Frozen, filleted fish	Frozen, filleted fish
	Cooking oils	Tomatoes	Poultry	Coffee, tea and cocoa	Fish products	Fish products
	Green salads	Poultry	Cream	Cream	Shellfish	Shellfish
Lower impact	Cucumber	Fish	Pulses	Pulses	Processed shellfish	Processed shellfish

Table 4: Summary of environmental impacts of studied diets per person per year

	GHG emissions	Energy use	Land use	Biodiversity	Acidification	Eutrophication
	Kg CO_2-e	GJ	m^2	BDP	Kg SO_2-e	Kg NO_3-e
Vegetarian	990	11,0	2291	0,14	7,0	40
Vegan	840	9,6	1879	0,12	6,6	39
NND	889	10,7	2322	0,13	8,1	51
NNR	954	10,7	2514	0,15	8,9	55
Average Swedish diet	1092	11,6	3336	0,20	10,0	65

Table 5: Summary of environmental impacts of studied diets of the Swedish population per year

	GHG emissions	Energy use	Land use	Biodiversity	Acidification	Eutrophication
	Mega-tonnes CO_2-e	TeraJoule	Km^2	BDP	Kilo-tonnes SO_2-e	Kilo-tonnes NO_3-e
Vegetarian	10	109998	22867	1394507	69	399
Vegan	8	96051	18755	1182880	66	392
NND	9	107260	23178	1319852	81	509
NNR	10	106458	25087	1499488	89	551
Average Swedish diet	11	115852	33291	1990218	100	644

Table 6: Energy use of studied diets in megajoule per person per year

MJ	ASD	Vegetarian	Vegan	NND	NNR
Potatoes	220	98	157	174	430
Cereals and bread	1324	3182	2001	425	1057
Vegetables	1691	2935	3846	3939	1431
Fruits	674	1086	884	2522	754
Meat	2524	0	0	1446	1419
Fish and shellfish	906	0	0	539	1091
Dairy products	1357	962	0	801	1373
Eggs	291	245	0	287	327
Miscellaneous	2621	2514	2736	614	2785
Total	11608	11022	9624	10747	10667

Table 7: GHG emissions of studied diets in kilogram of CO_2 equivalent per person per year

Kg CO_2-e	ASD	Vegetarian	Vegan	NND	NNR
Potatoes	18	8	13	17	36
Cereals and bread	105	265	170	33	84
Vegetables	135	239	323	325	114
Fruits	50	84	74	124	59
Meat	252	0	0	148	142
Fish and shellfish	68	0	0	43	82
Dairy products	202	136	0	114	188
Eggs	27	22	0	26	30
Miscellaneous	234	235	260	59	254
Total	1092	990	840	889	988

Table 8: Land use of studied diets in square meter per person per year

m^2	ASD	Vegetarian	Vegan	NND	NNR
Potatoes	34	15	24	37	66
Cereals and bread	224	569	337	75	179
Vegetables	133	417	911	307	113
Fruits	129	216	174	322	146
Meat	1843	0	0	1087	1035
Fish and shellfish	0	0	0	0	0
Dairy products	599	452	0	345	611
Eggs	48	41	0	47	54
Miscellaneous	326	582	433	102	310
Total	3336	2291	1879	2322	2514

Table 9: Biodiversity Damage Potential of studied diets per person per year

BDP	ASD	Vegetarian	Vegan	NND	NNR
Potatoes	0,003	0,001	0,002	0,003	0,005
Cereals and bread	0,022	0,054	0,030	0,008	0,018
Vegetables	0,007	0,027	0,063	0,016	0,006
Fruits	0,005	0,008	0,007	0,012	0,006
Meat	0,108	0	0	0,064	0,063
Fish and shellfish	0	0	0	0	0
Dairy products	0,038	0,029	0	0,022	0,039
Eggs	0,004	0,003	0	0,004	0,004
Miscellaneous	0,013	0,018	0,016	0,004	0,010
Total	0,199	0,140	0,119	0,132	0,150

Table 10: Acidification of studied diets in gram of SO_2 equivalent per person per year

Gram SO_2-e	ASD	Vegetarian	Vegan	NND	NNR
Potatoes	338	151	241	372	661
Cereals and bread	1063	2644	1656	334	849
Vegetables	701	1337	2259	1903	593
Fruits	781	1237	894	1943	833
Meat	3521	0	0	1676	1926
Fish and shellfish	1155	0	0	953	1390
Dairy products	697	512	0	446	790
Eggs	203	171	0	200	229
Miscellaneous	1543	908	1561	296	1630
Total	10003	6960	6610	8123	8900

Table 11: Eutrophication of studied diets in gram of NO_3 equivalent per person per year

Gram NO_3-e	ASD	Vegetarian	Vegan	NND	NNR
Potatoes	2252	1008	1604	2482	4407
Cereals and bread	6386	15361	10855	1895	5101
Vegetables	4117	7853	13269	11180	3484
Fruits	4587	7266	5252	11413	4893
Meat	27503	0	0	13375	15041
Fish and shellfish	7346	0	0	6059	8841
Dairy products	3170	2352	0	2031	3624
Eggs	974	820	0	960	1094
Miscellaneous	8186	5331	8330	1633	8690
Total	64522	39991	39311	51029	55175