sustainability

MDPI

Article

Evaluating the Environmental Consequences of Swedish Food Consumption and Dietary Choices

Michael Martin [1,*] and **Miguel Brandão** [2]

1 IVL Swedish Environmental Research Institute, Valhallavägen 81, 114 27 Stockholm, Sweden
2 KTH—Royal Institute of Technology, Department of Sustainable Development, Environmental Science and Engineering, Teknikringen 34, 114 28 Stockholm, Sweden; miguel.brandao@abe.kth.se
* Correspondence: michael.martin@ivl.se

Received: 29 September 2017; Accepted: 28 November 2017; Published: 1 December 2017

Abstract: In recent years, a growing interest from consumers to know the origins and contents of foods has put alternative choices, such as organic foods and dietary changes, on the agenda. Dietary choices are important to address, as many studies find that activities related to food production account for nearly 20–30% of anthropogenic greenhouse gas (GHG) emissions. Nonetheless, while GHG emissions are important, often other environmental impact categories are not considered in the assessment of the sustainability of different foods, diets and choices. This study aims to quantify the implications of dietary choices for Swedish food consumption on a broad range of environmental impact categories using life cycle assessment to provide insight into the impacts, and potential tradeoffs, associated with certain food products and dietary choices. Scenarios are used to assess the implications of diets with reduced meat, increased Swedish food consumption, increased organic foods, vegan and semi-vegetarian diets. The results indicate that tradeoffs could be possible with certain dietary choices. Increasing Swedish food production and consumption may lead to lower impacts for all impact categories by reducing imports, although limitations in growing season and availability of foods in Sweden allows only for minor increases. The results also indicate that large reductions of greenhouse gas emissions are possible by reducing meat consumption, i.e., by halving meat consumption and through vegan and vegetarian diets. Nonetheless, an increase in vegetable, legume and fruit products may lead to a potential increase in human and ecosystem toxicity. Diets based on nutritional guidelines, show reductions in all impact categories, as these guidelines call for an increase in vegetables and fruits and a reduction in meat consumption. An increase in organic foods showed no significant change in climate impact, although toxicity potential was reduced significantly. Increasing consumption of organic foods may also lead to a reduction in biodiversity damage potential, and if all food is produced organically, it risks increasing eutrophication and land use.

Keywords: Life cycle assessment (LCA); food consumption; diets; Sweden; sustainable consumption

1. Introduction

In the developed world, behavioral choices, such as dietary choices, have a large influence on the environmental impacts of consumption [1]. Jones and Kammen [2] in addition to Reisch et al. [3] also identified dietary changes as one of the most economically-effective abatement options for climate change in affluent countries. There is therefore potential to address environmental impacts throughout the food chain. Activities related to food production have been found to account for roughly 20–30% of anthropogenic greenhouse gas (GHG) emissions; see, e.g., [4–7].

There has been a growing interest in knowing the origins and contents of the foods throughout the world. This has stemmed from the intensification of agricultural production, leading to questions about technologies, ingredients and safety of food, which has put pressure on conventional producers and manufacturers [8,9]. In recent years, consumers have also become more aware of the impact that their behavioral choices may have on the environment. Swedish supermarkets offer consumers a broad array of alternatives, and consumers may be overwhelmed with making the 'right' choice from the number of products labeled to show the environmental, ethical and health qualities [10]. The concerns of consumers have created interest in alternative food products that promote sustainability, ethical questions and quality [8].

The emergence (or re-emergence) of organic food and a larger selection of local foods has begun to play an important role in offering alternatives to conventionally-produced foods and setting the agenda for sustainable food production and consumption [11,12]. In Sweden, consumers have increased their purchases of organic foods in the last few decades. In 2014, the organic food sector consisted of nearly 6% of the market; recent figures for 2016 have indicated an increase to near 9% of market sales [13]. The retail sector has also increased its provisions of these foods, and a wider selection of organic and regional foods has provided consumers with many alternatives. Many of the retailers have also set goals for shares of organics in the next ten years. This trend is not unique to Sweden, as it is seen throughout Europe and the U.S., as consumers are becoming increasingly aware of the environmental and socio-economic effects of their food choices [14,15].

Consumers have also begun to purchase local foods and are positive toward increased consumption of Swedish and regional foods [16]. In a report based on consumer analysis, The Swedish Board of Agriculture, Jordbruksverket [17], found that nearly 67 percent of consumers were willing to pay more for Swedish products. They also found that 69 percent of consumers sought Swedish products when purchasing foods and 61 percent were interested in buying more regionally-produced foods. The study found that consumers believe that regionally-produced foods have the potential to reduce environmental impacts and strengthen local economies and are even of higher quality and taste compared to imported varieties [8,10,15,18]. Despite this substantial increase in the last few years, organic foods and regional (or seasonal) foods remain a niche market in today's supermarkets [11].

Previous assessments of the sustainability of food consumption and production have placed a large focus on climate impacts. Often, emphasis is placed on the impacts associated with European food consumption and the potential climate impacts related to meat consumption, as this has been shown to be a large source of emissions from food consumption [3,19–21]. Recently, a number of studies have focused on the role of dietary choices, the role of farming practices and seasonal availability for reducing environmental impacts [11,15,22–26]. Portraying a larger selection of environmental impact categories is important to allow for more understanding and a comparison of the environmental implications of changes and transitions in the consumption patterns. Nonetheless, there are very few studies that have reviewed the implications of Swedish diets, comparing only a few selected environmental impact categories; see, e.g., [20,22].

This study aims to understand the implications of dietary choices for Swedish food consumption on a broad range of environmental impact categories. The study will limit the assessment to reviewing certain dietary changes, such as increasing organic and regional food consumption in addition to reducing meat, vegetarian and vegan diets and eating based on nutritional guidelines by addressing the following research questions:

- Can a greater influx of organic food reduce environmental impacts?
- Would an increase of Swedish produced foods, and reduced imports, lead to reduced environmental impacts?
- What are the implications of reducing meat consumption through various diets?
- What are the environmental tradeoffs of the different dietary choices?

2. Methods

Life cycle assessment (LCA) was used in this study to identify and assess the environmental impacts of Swedish food consumption from a cradle-to-gate perspective. The functional unit of the study is the annual consumption of food in Sweden in order to compare impacts between different dietary choice scenarios. This study is limited to food consumption and the implications of changes in dietary choices, reviewing only the impacts from upstream processes up to the consumer, and does not include subsequent stages, as the study only addresses the consumption of primary food categories and not meals; see Figure 1 below. As such, energy and emissions from food storage and preparation are not included in the study. Nonetheless, food waste is taken into consideration at all life cycle stages in order to allow for a review of the total amount of food available for consumption. This was because waste at the household level is significant, even before consumption [5,27]. However, the waste handling impacts and methods are not taken into consideration in this study. Furthermore, as it links changes in consumption to life cycle inventory (LCI) data for food products, the scenarios reviewed in this study are limited by excluding consequential effects arising due to changes in consumption patterns, such as land use change effects from changes in demand for legumes, animal products, etc.

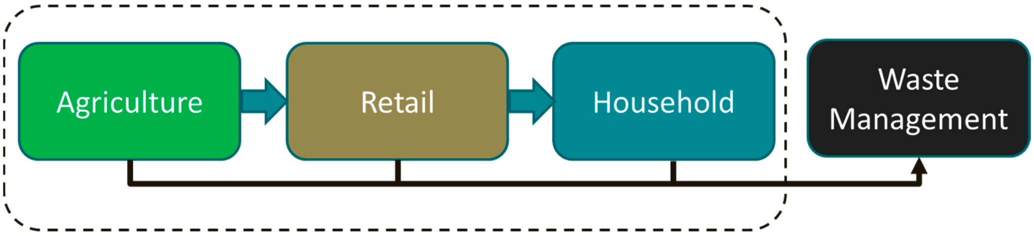

Figure 1. System boundaries of the LCA in the study.

Data from the Food Balance Sheets by the Food and Agriculture Organization (FAO) [28] were employed to quantify the amounts of import, export, consumption and waste of food for Sweden with a base year of 2011. Using these data, a matrix including the different food categories was compiled to compare with the different scenarios for changes in dietary choices. Data for food consumption in this study included only food for consumption and manufacturing, excluding that used for fodder and seed. The food balance sheets provide only raw materials and food groups used for food production and not final products. For example, the types of fruits are not outlined, only the aggregated sector "fruits". Similarly, the food category "cereals" is outlined and not processed products such as bread and pasta. To allow for the calculations, representative food products (RFPs) were chosen for food categories. This was done by selecting the products accounting for more than 80% of the category. Upon identifying the RFPs, data for the origins and production methods were compiled. This included dividing the products into origins from domestic (Swedish) production or representing imports from abroad, i.e., the rest of world. After that, production methods for organic and conventional fractions were compiled; all production other than organic was assumed to be produced using conventional agricultural methods. Thereafter, to identify the quantities of organic food from imports and domestic supplies, a triangulation of data was used from, e.g., [13,16,29–33]. See a listing of the RFPs in Table S5 and their categorization into Swedish, imported, conventional and organic fractions in Table S10 in the Supplementary Materials.

Scenarios were created to assess the environmental implications of Swedish food consumption in the future, i.e., 2020. These included increased organic food consumption, increased Swedish food production and consumption, reduced meat consumption, vegetarian and vegan diets and diets based on nutritional recommendations from the Swedish National Food Agency (Livsmedelsverket); see more in the Supplementary Materials. Table 1 provides a brief review of these scenarios. The year 2011 was chosen as the reference based on the latest data available from the FAO food balance data sheets for Sweden. Scenarios for different dietary choices were assessed for the year 2020; population estimated at roughly 10.5 million [34]. See also Tables S6 and S7 in the Supplementary Materials for a review of the amount of consumed foods represented in each of the scenarios and for further information about how the increase or decrease was selected. As previously mentioned, only changes in amounts of RFPs were reviewed. No consequential effects of changes in dietary changes on other systems were modeled.

Table 1. A review of dietary scenarios reviewed.

Scenario	Description/Assumptions
BAU (Business as Usual)	Consumption figures based on 2011 levels, but adjusted to population levels in 2020
Reduced Meat	Assumes a reduction of meat consumption (bovine, pork and chicken) by 50% in 2020
Organic	Assumes an increase of 200% in organic food consumption in 2020 compared to 2011 levels
Organic Sweden	Assumes an increase of 200% in organic food consumption in 2020 compared to 2011 levels (from Swedish sources only)
Sweden Increase (Sweden Incr.)	Assumes an increase in Swedish food consumption of 30% in 2020 (with reduction in imports)
Vegetarian	Assumes a "semi-vegetarian diet" with calorie intake similar to BAU; increases in beans, soy and vegetables
Vegan	Assumes no meat, dairy or fish consumption, with increases in vegetables, fruits legumes, nuts compared to vegetarian diet
Nutrition	Uses guidelines from the Swedish Dietary Guidelines to assess the impacts from recommended diets
All Organic	The scenario reviews replacing all conventional food with organic food
All Conventional	The scenario reviews replacing all organic food with conventional food

LCI data used in the study originate from available research on food and food consumption. In the literature, there is a large base of studies portraying primarily GHG emissions (measured in CO_2-eq) from different foods. To be able to compare the results with global and local impacts, different criteria were applied for the LCI data collection. These included (1) only including data for studies portraying at least three impact categories (i.e., greenhouse gas emissions, eutrophication and acidification), (2) data should include cradle-to-farm emissions or cradle-to-gate (consumer) emissions and (3) data should represent conditions for typical imports and Swedish production for each respective food product, origin and type. Datasets for imports were assumed to be primarily of European origin, with the exception of, e.g., bananas, coffee, soy and other typically imported products from outside of Europe. The primary sources for data included LCI databases such as Ecoinvent [35] and Agribalyse [36]. Thereafter, a collection of studies in the article and Supplementary Materials provided by Meier et al. [24], Environmental Product Declarations (EPD) reports [37] and peer-reviewed scientific articles were also employed. See Tables S9 and S10 in the Supplementary Materials for a more detailed list of all data sources employed.

From the LCI databases, data for impact categories were computed using the life cycle impact assessment (LCIA) methodology produced by Institute of Environmental Sciences of Leiden University (CML), i.e., CML baseline 2011 in order to portray the results for global warming in kg CO_2-eq (GWP, 100 years), acidification in kg SO_2-eq, eutrophication in kg PO_4-eq and toxicity for both human and terrestrial ecosystem toxicity in kg 1,4-Dichlorobenzene (DCB)-equivalent. Land use was used to review the land occupation and requirements for the different dietary scenarios, which accounts for only direct land occupation and no other impacts related to direct and indirect land use.

Biodiversity damage potential (BDP) was also included to provide a screening of potential biodiversity damage from production practices based on an extensive review by Röös et al. [23], which was based on methods provided by De Baan et al. [38] for global biodiversity damage potential. Biodiversity for organic production practices was assumed to be 30% higher in organic products in comparison to conventional farming practices based on assumptions from Tuck et al. [39]; see also similar results in studies such as those by, e.g., [24,25,40]. No reduction in BDP for Swedish foods was considered, as no data could be found for Swedish production compared to conventional practices.

For datasets covering only cradle-to-farm emissions, transportation emissions were added to allow for functional equivalency. The distance from farm to retail included an assumed shipping distance of 1000 km by boat (assumed distance from Europe to Sweden) and 400 km by truck for imports. For domestic products, a distance of 100 km by truck was assumed to ship products from farm to retail. An average distance of 24 km for retail to availability at the household was assumed [41]. LCI data for the different transportation methods are taken from Ecoinvent v. 3.1 [35] for transportation by boat, truck and personal vehicle, respectively. See Table S10 in the Supplementary Materials for further information on the LCI data and assumptions used.

3. Environmental Impacts of Swedish Food Consumption

3.1. Greenhouse Gas Emissions

The results illustrated in Figure 2 compare the GHG emissions for the scenarios in 2020. Results suggest that reducing meat consumption will lead to reductions in GHG emissions in 2020. Increasing the production and consumption of organic foods did not show significant changes compared to the business as usual (*BAU*) scenario. A slight reduction in impacts is apparent when more Swedish food was included in the diet (*Sweden Incr.*). *Vegetarian* and *Vegan* diet scenarios could significantly reduce GHG emissions, with reductions of roughly 40% and 70%, respectively. If consumption followed nutritional guidelines (*Nutrition*) and *Reduced Meat* scenarios, GHG emissions would also be reduced by roughly 20%.

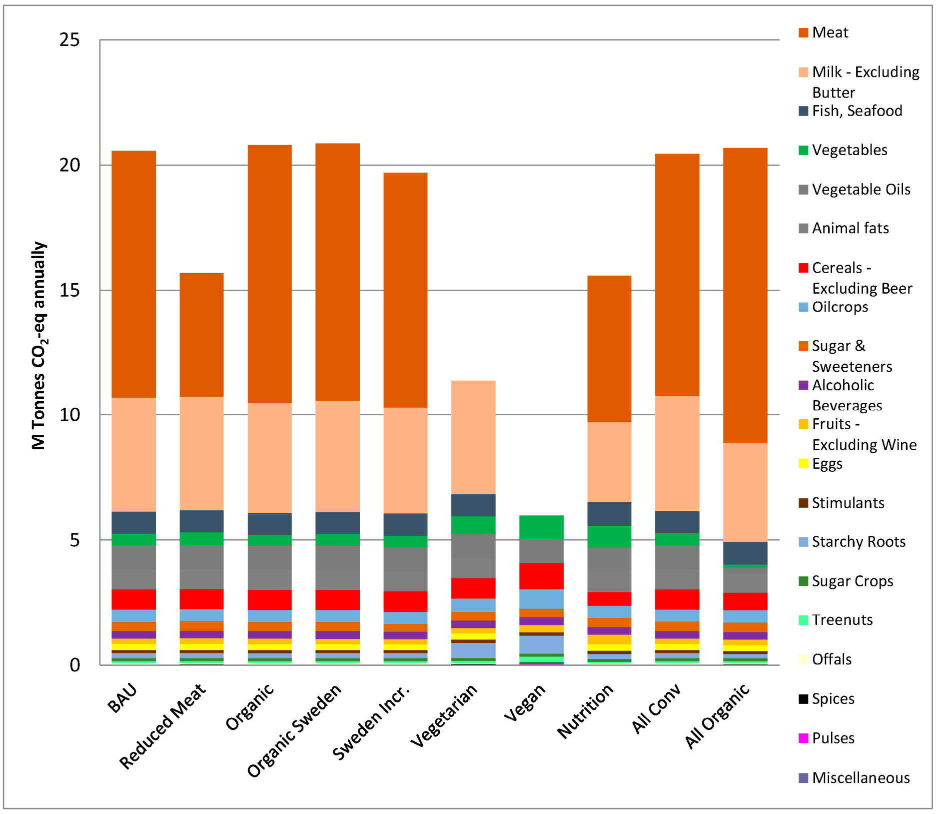

Figure 2. Climate change for all scenarios. Measured in million tonnes CO_2-eq annually. Conv., conventional.

For all scenarios, except for *Vegetarian* and *Vegan* scenarios, the consumption of different meats, which is primarily caused by impacts from beef, and less from the other reviewed meat categories (i.e., chicken and pork), has the largest share of GHG emissions. This is followed by milk, fish and seafood, vegetables and vegetable oils. Together, the aforementioned RFPs account for more than 80% of the GHG emissions. The Supplementary Materials (Figures S1–S7) provides further details of the contribution of different foods to the reviewed impact categories for the different scenarios.

3.2. Acidification

Figure 3 provides a review of the acidification impacts for all scenarios. The results indicate that acidification impacts are decreased when meat consumption is reduced in 2020 through different scenarios. The largest reductions are apparent for *Vegetarian* and *Vegan* scenarios, with reductions of 70% and 90% respectively compared to BAU in 2020. The *Reduced Meat* scenario resulted in a reduction of nearly 35%.

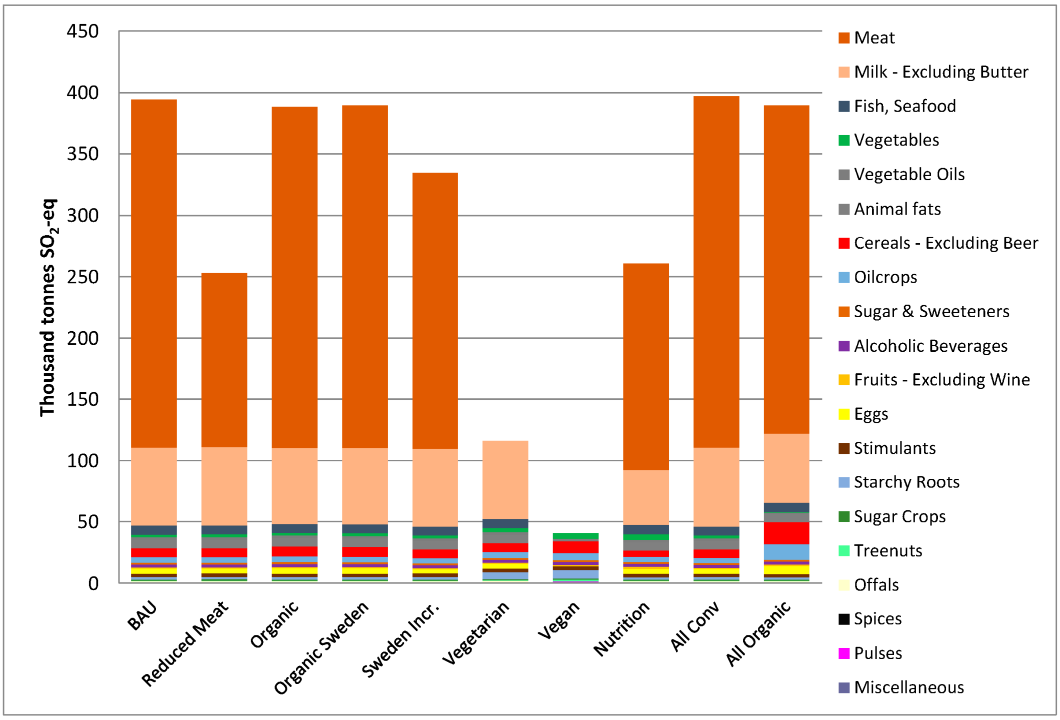

Figure 3. Acidification for all scenarios (measured in million tonnes SO_2-eq annually).

Increasing organic foods (*Organic*, *Organic Sweden* and *All Organic*) has no significant impact on acidification. If more Swedish food were produced and consumed (*Sweden Incr.*), this could lead to reduced acidification impacts. If all food consumed were produced using conventional methods (*All Conv.*), this may result in a slight increase in acidification. The animal-based categories, meat and dairy, contribute to over 80% of the acidification impacts from nearly all scenarios, with the exception of the vegan and vegetarian scenarios.

3.3. Eutrophication

As illustrated in Figure 4, *Vegan* and *Vegetarian* and *Reduced Meat* scenarios resulted in the largest reductions in eutrophication impacts. Following nutritional guidelines (*Nutrition*) may also lead to a decrease in eutrophication, and a slight reduction can be observed if more Swedish food were produced and consumed (*Sweden Incr.*). Increasing organic food consumption has no significant change in eutrophication impacts, but if all food were produced from organic production methods (*All Organic*), this would lead to significant increases of eutrophication impacts; see Figure 4.

Meat, milk, eggs, fruit and vegetables contribute to over 70% of the eutrophication impacts in all scenarios, except for *Vegetarian*, *Vegan* and *Nutrition* scenarios. Once again, animal-based products (meat, milk and eggs) make up the largest contribution. For further details, see Figure S3 in the Supplementary Materials.

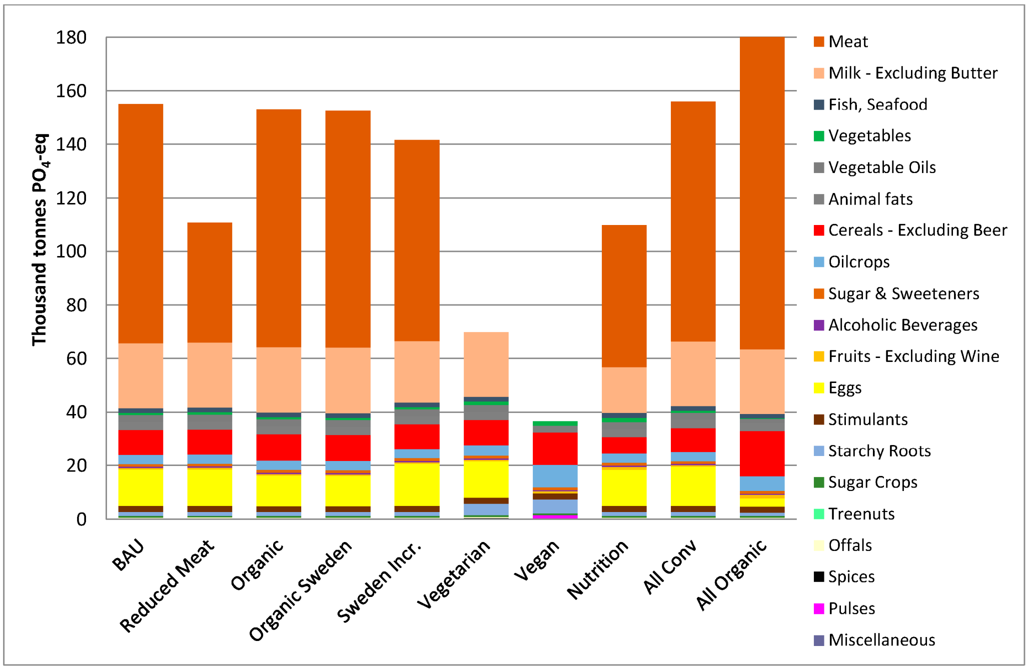

Figure 4. Eutrophication for all scenarios (measured in thousand tonnes PO_4-eq annually).

3.4. Land Use

Figure 5 illustrates the land use for different consumption scenarios. Results suggest that land use is decreased if meat consumption is reduced (*Reduced Meat*); a reduction of nearly 25% in 2020. For all scenarios involving organic food production, there is an increase of land use. For the *All Organic* scenario, an increase of roughly 20% was illustrated. Increasing the amount of food from Swedish sources (*Sweden Incr.*) had no significant increase in land use. Large land use reductions of roughly 20% and 40%, respectively, were illustrated in the *Vegetarian* and *Nutrition* scenarios. The largest reductions are possible from the *Vegan* scenario, with roughly 50% land use reductions.

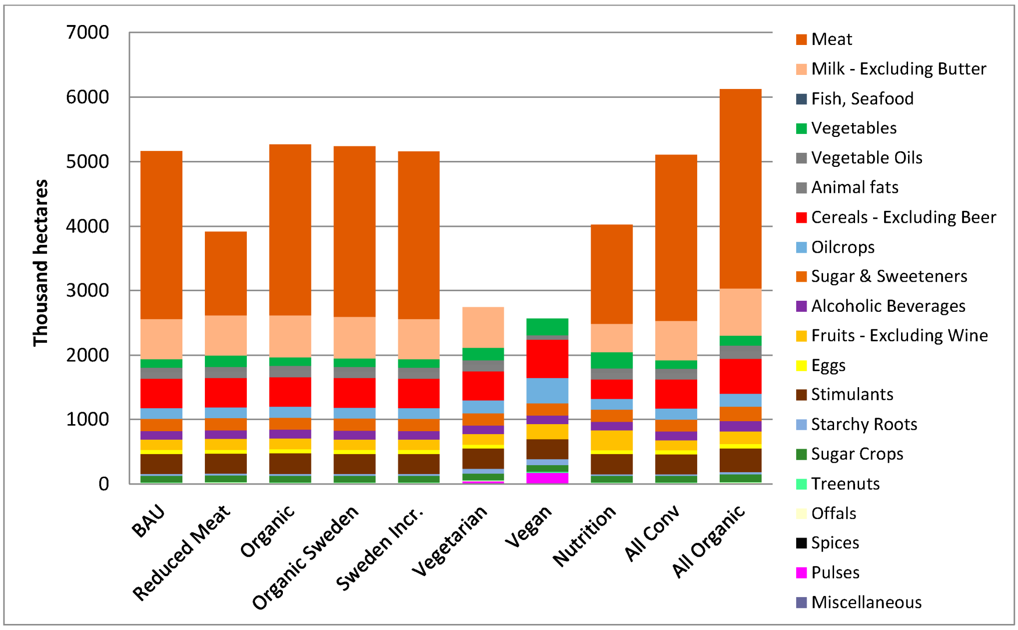

Figure 5. Land use for all scenarios (measured in million hectares).

For land use (LU), the groups, meat, milk, cereals, coffee and cocoa contribute to over 70% of the land use. Once again, meat and milk make up the largest contribution to land use. For further details, see Figure S4 in the Supplementary Materials.

3.5. Toxicity

Terrestrial ecotoxicity is significantly reduced only in the *All Organic* scenario; a reduction of roughly 60%. The *Vegan* scenario showed a slight increase in terrestrial ecosystem toxicity (TET) impacts. Other scenarios show no significant changes; see Figure 6.

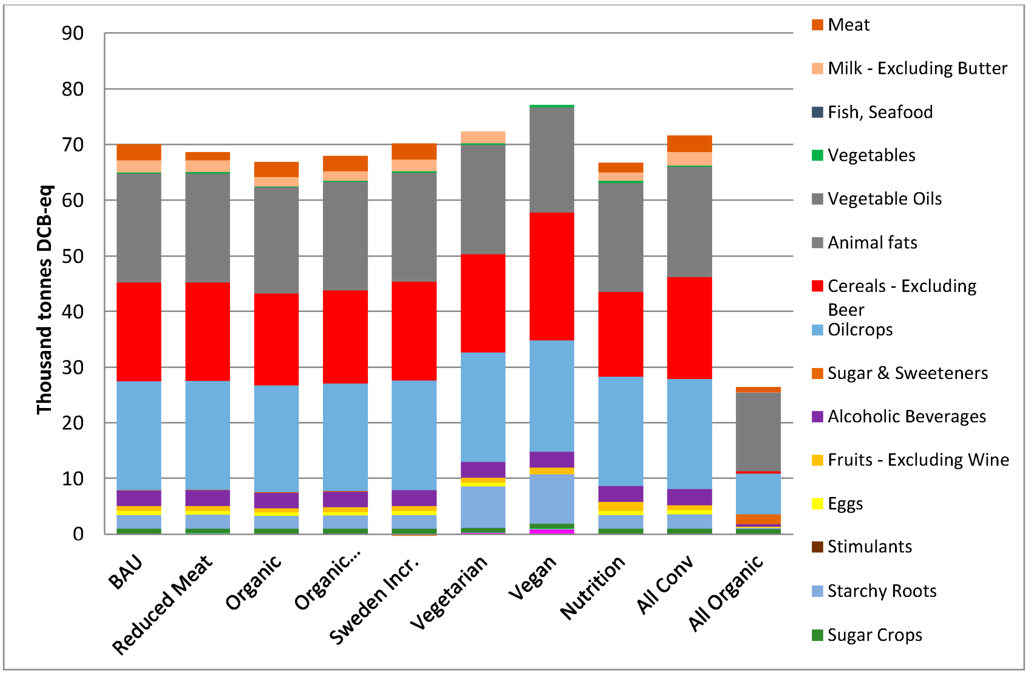

Figure 6. Terrestrial ecosystem toxicity (TET) for all scenarios (measured in million tonnes DCB-eq annually).

Similar to the results of TET, human toxicity (HT) shows significant reductions only in the *All Organic scenario* (reductions of roughly 35%). Human toxicity impacts were also increased significantly in the *Vegan* scenario (roughly a 25% increase) and a slight increase for the *Vegetarian* scenario; see Figure 7. For further details, see Figures S5 and S6 in the Supplementary Materials.

Toxicity, unlike the other impact categories, is not dominated by animal-based products. For the TET, the largest potential impacts are from oil crops, vegetable oils and cereals, which have roughly 25–28% of the TET impacts each. For HT, the greatest potential comes from cereals, animal fats, oil crops, alcoholic beverages, vegetable oils, starchy roots and sugars. The largest HT comes from cereals. Additionally, in the *Vegan*, *Vegetarian* and *Nutrition* scenarios, the contributions from vegetables are larger than other scenarios. The increase in toxicity potential illustrated in scenarios with reduced meat consumption was found to be a result of the prevalence of certain metals. Food products in the categories with substantial toxicity potential, i.e., cereals and vegetable oils, wheat and rapeseed oil, were analyzed further to understand the origin of the toxicity potential. It was found that the largest impacts for toxicity, both human and terrestrial ecotoxicity, when reviewing LCI data from Ecoinvent, originate from metals such as chromium and cypermethrin (as found in insecticides). The exposure and emission of chromium adding to human toxicity potential originated primarily from machinery used for agricultural purposes and fertilizer production. For terrestrial ecotoxicity potential, as seen in both rapeseed oil and wheat, cypermethrin originated once again from agricultural production practices and fertilizer production.

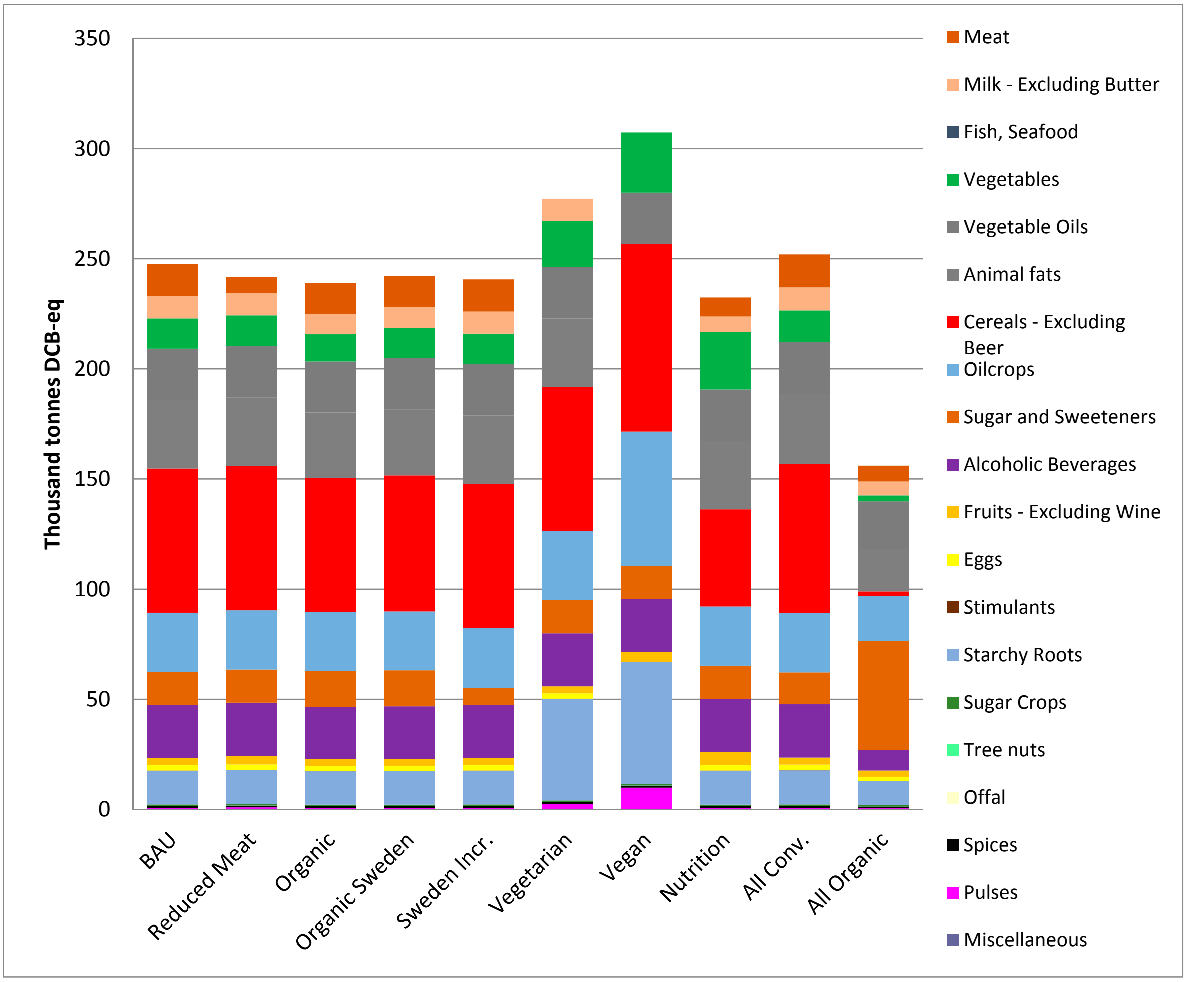

Figure 7. Human toxicity (HT) for All Scenarios (measured in million tonnes DCB-eq annually).

3.6. Screening of Biodiversity Damage

The results suggest that significant reductions in potential biodiversity damage are possible if meat consumption is reduced through the scenarios with *Vegan*, *Vegetarian* and *Reduced Meat* diets. Similar results can be found in the *Nutrition* scenario and if all food consumed in Sweden is produced organically in the *All Organic* scenario. The remaining scenarios have no significant changes in BD; see Figure 8.

The biodiversity damage has over a 60% contribution from meat and milk in all scenarios with no reduction in meat consumption. In the scenarios removing meat consumption, the largest biodiversity damage potential comes from cereals, fruit, vegetables and oil crops (and milk for the *Vegetarian* scenario); see Figure S7 in the Supplementary Materials for further information.

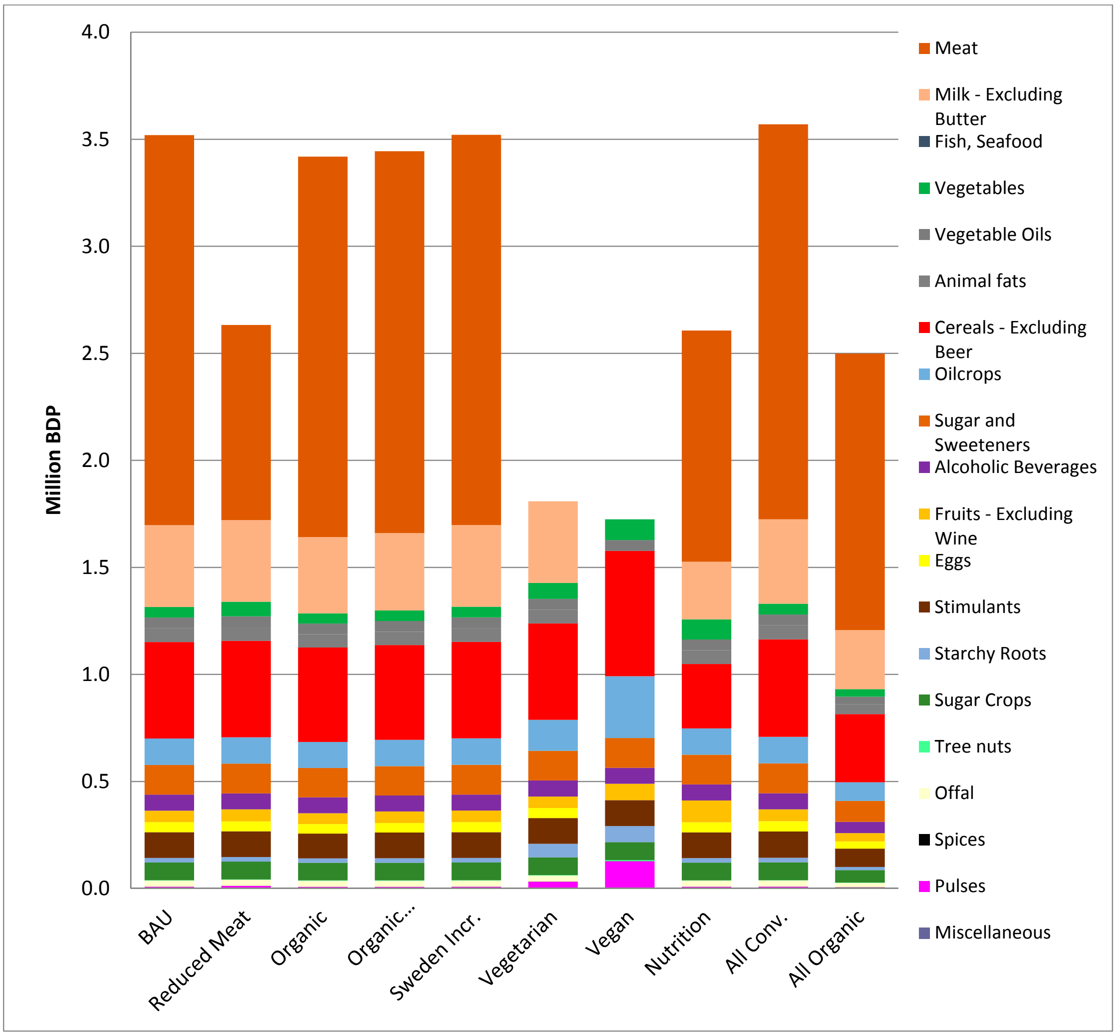

Figure 8. Biodiversity damage for All Scenarios (measured in million biodiversity damage potential (BDP)).

4. Analysis

The following sections provide an analysis of the results for the different dietary considerations addressed in this study to provide a more detailed description of the implications and tradeoffs possible for the various scenarios for dietary choices. Further details are provided in the Supplementary Materials.

4.1. Comparing Scenarios and Impact Categories

Figure 9 provides a review of the environmental implications of the different scenarios for all environmental impact categories in 2020. As the figure illustrates, there are significant tradeoffs between the scenarios when comparing the different environmental impact categories. For instance, *Vegetarian* and *Vegan* diet scenarios, despite large reductions in other impact categories, may result in an increase in potential human toxicity and terrestrial ecotoxicity impacts. Furthermore, while diets with increased amounts of organic foods have reduced biodiversity damage and toxicity potential, there is no significant change in GHG emissions, and large increases in land use and eutrophication are possible. Nutritional guidelines, if followed, in the *Nutrition* scenario could lead to large reductions in nearly all environmental impact categories compared to the *BAU* scenario.

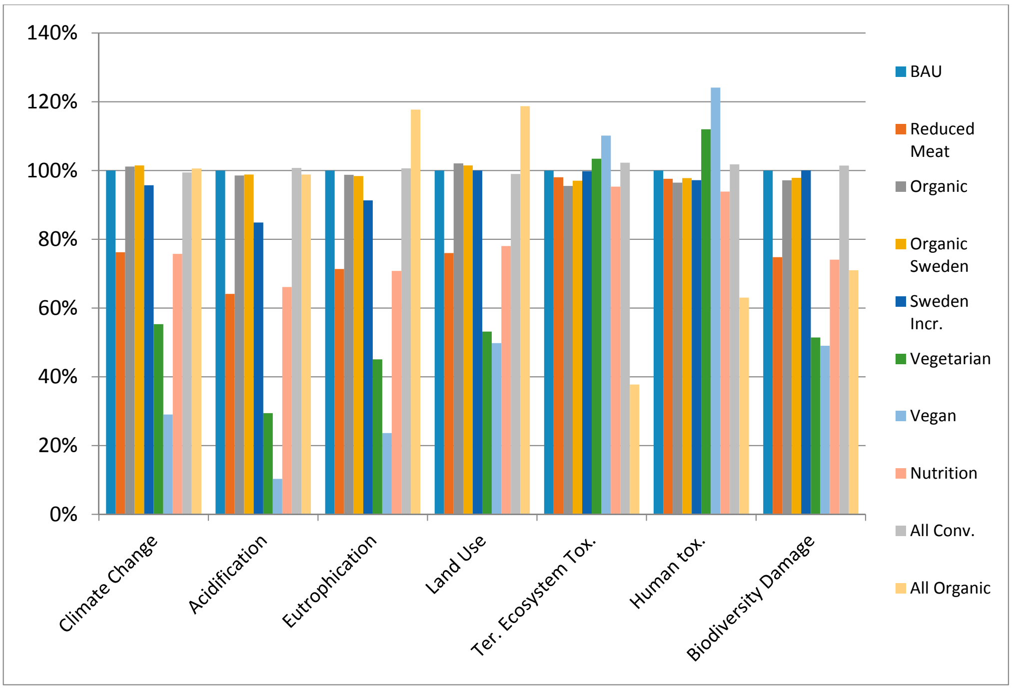

Figure 9. Review and comparison of the environmental impacts of all scenarios in 2020 in order to show the potential tradeoffs.

4.2. Per Capita Details

Previous studies have discussed the impact of diets on overall national per capita emissions. Due to the variance in food consumption between the scenarios, Figure 10 provides an analysis of the GHG emissions per capita for the different scenarios. As Figure 10 reviews, the *BAU* emissions amount to roughly 1.9 tonnes CO_2-eq per year in 2020. By reducing our meat consumption, as illustrated in the *Reduced Meat*, *Vegan*, *Vegetarian* and *Nutrition* scenarios, there is a significant reduction in per capita emissions. In particular, *Vegetarian* and *Vegan* diets have significant potential to reduce per capita emissions, the latter being reduced to roughly 0.6 tonnes CO_2-eq per year/capita. Other scenarios show no significant reduction in per capita emissions.

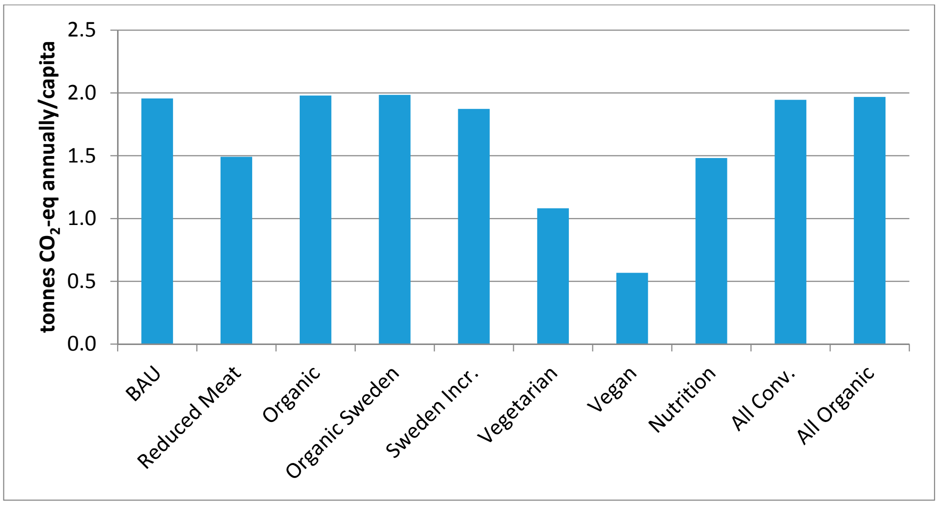

Figure 10. Per capita GHG emissions for the different scenarios in 2020 (measured in tonnes CO_2-eq annually).

4.3. Origin of Impacts

In Table 2, we provide a summary of the origin of food consumed in Sweden for the different scenarios. As illustrated in the *BAU* scenario for 2020, around 60% of the food consumed originates from Sweden. In scenarios increasing Swedish food consumption, this would be increased just over 10%. When *Vegan* and diets following nutritional guidelines are followed, potential decreases in foods of Swedish origin are possible to meet the demand for increased legumes and other fruit and vegetables, which are not able to be produced in Sweden. No significant changes are seen in other scenarios.

Table 2. Amount of food consumed (including wastes) from Sweden and abroad for different Scenarios. Shown in percentage of total mass consumed.

Scenario	Sweden	Import
BAU	62%	38%
Reduced Meat	61%	39%
Organic	62%	38%
Organic Sweden	62%	38%
Sweden Increase	75%	25%
Vegetarian	62%	38%
Vegan	53%	47%
Nutrition	55%	45%
All Conventional	62%	38%
All Organic	62%	38%

While Swedish foods made up roughly 60% of foods consumed in many of the scenarios, they accounted for only around 40–50% of the GHG emissions in nearly all scenarios. However, an increase in GHG emissions due to Swedish food products is seen in the *Sweden Increase* scenario and a decrease of emissions of Swedish origin in the *Vegan* scenario. This is due primarily to the data pointing to less impact for Swedish products compared with imported counterparts and, once again, vegan diets with increased imports.

The scenario *Swedish Increase* resulted in larger impacts of Swedish origin. The *Vegetarian* and *Vegan* scenarios illustrated increased emissions created abroad, due to a larger share of food products (vegetables and other legumes); see Table 3. Further details are provided in Figures S8 and S9 in the Supplementary Materials.

Table 3. Share of potential environmental impacts for all scenarios in 2020 for Swedish (SWE) and imported foods, denotedRest of World-(ROW). Shown in % share of impacts from each category.

Impact	*Origin*	*BAU*	*Red. Meat*	*Org.*	*Org. SWE*	*SWE Incr.*	*Veget.*	*Vegan*	*Nutr.*	*All Conv.*	*All Organ.*
GW	SWE	49%	50%	50%	50%	65%	50%	39%	47%	49%	54%
	ROW	51%	50%	50%	50%	35%	50%	61%	53%	51%	46%
Acid.	SWE	36%	42%	36%	36%	54%	60%	49%	38%	37%	44%
	ROW	64%	58%	64%	64%	46%	40%	51%	62%	63%	56%
Eutr.	SWE	47%	52%	46%	46%	64%	65%	52%	49%	47%	42%
	ROW	53%	48%	54%	54%	36%	35%	48%	51%	53%	58%
LU	SWE	56%	55%	56%	56%	70%	55%	47%	52%	56%	56%
	ROW	44%	45%	44%	44%	30%	45%	53%	48%	44%	44%
TET	SWE	57%	57%	57%	56%	71%	58%	59%	56%	57%	35%
	ROW	43%	43%	43%	44%	29%	42%	41%	44%	43%	65%
HT	SWE	61%	61%	60%	60%	79%	60%	53%	56%	61%	63%
	ROW	39%	39%	40%	40%	21%	40%	47%	44%	39%	37%
BD	SWE	60%	61%	59%	59%	75%	62%	56%	58%	60%	60%
	ROW	40%	39%	41%	41%	25%	38%	44%	42%	40%	40%

Scenarios: *Red. Meat*, *Reduced Meat*; *Org.*, *Organic*; *Org. SWE*, *Organic Sweden*; *SWE Incr.*, *Sweden Increase*; *Veget.*, *Vegetarian*; *All Conv.*, *All Conventional*; *All Org.*, *All Organic*. Impact categories: GW, global warming; Acid, acidification; Eutr., eutrophication; LU, land use; TET, terrestrial ecosystem toxicity; HT, human toxicity; BD, biodiversity damage.

5. Discussion

The scenarios outline dietary choices based on available options to current consumers and provide the environmental implications of these choices. By no means can the results be used to choose the "best" diet, but only illustrate potential impacts and tradeoffs associated with different types of foods and diets, given the limitations outlined in the study. The following sections provide a discussion of the implications that dietary choices may have and review different insights from the literature on the subject.

5.1. Meeting Targets and Shifting Burdens

In this study for Sweden in 2020, food consumption accounted for roughly 21 million tonnes of CO_2-eq emissions, equating to roughly 1.9 tonnes of CO_2-eq emissions per capita. This is comparable to results found in Röös et al. [23] and Bryngelsson et al. [20] for Sweden and in Martin and Danielsson [21] for Europe, where roughly 20–30% of per capita emissions originate from food production [6]. Reducing GHG emissions was found to be most feasible through scenarios reducing meat consumption. However, similar to results in Martin and Danielsson [5], these reductions may not be enough to meet European targets for emissions reductions, and technological advances, both in the food chain and in other sectors (e.g., transportation, housing, etc.) will be needed [20].

While animal-based production and consumption lead to large potential impacts in all other categories, the impacts on human toxicity and terrestrial ecotoxicity are low in comparison to agriculturally-based foods (e.g., cereals and oils). Nonetheless, vegetarian and vegan diets with an increased amount of organic foods may further improve upon the toxicity potential by removing conventionally-produced products and removing pesticides.

There is an extensive body of literature available reviewing the GHG emissions of food production and consumption. Articles concerned with assessing consumption generally address a limited set of impact categories, typically climate impacts. While GHG emissions and energy use continue to be apparent in policy, as Laurent et al. [42] and Lazarevic and Martin [43] discuss, a focus on GHG emissions in policy may lead to a sub-optimization of production systems. Röös et al. [44] suggest that this violates the principles of LCA, although its use has become a proxy for environmental impacts, even arguing that it serves as an important indicator of environmental pressure.

While results suggest that food products with a large share of GHG emissions generally have significant impacts in many of the other environmental impact categories, this may not be applicable when reviewing toxicity potential. As illustrated in other bio-based systems, despite decreases in GHG emissions, increases in other impact categories are possible [43,45].

The results presented in this study may be an under- or over-estimation of the actual impacts from imported foods. Once again, due to the data availability, European data for food products were employed for most imported food and even for many Swedish food products. Despite a large share of imports from Europe, a significant portion of products may originate from, e.g., Asia, North and South America and Africa [16]. Differences in production methods, energy used in the different locations for supporting activities and processing may be considerable between these regions; see, e.g., a discussion in Peters and Hertwich [46] and Pelletier et al. [47].

5.2. Organic vs. Conventional Foods

Results show that the GHG emissions for a food system with an increased share of, or entirely based on, organic methods can increase GHG emissions. Previous studies of organic foods have typically reviewed the impact of conventional and organic food production methods on a comparative basis per food product [24,25,40]. While these provide interesting results to compare different food products, there is no consensus that organic production methods result in reductions of environmental impacts across all impact categories; or for total consumption and diets.

In all scenarios with increased organic food production, land use is increased. This observation is plausible, as data available for organic food production outline less productivity for organic methods; see, e.g., statistics on harvests for Swedish organic versus conventional crops [31] and the review by Meier et al. [24]. Given the assumption used in this study for reduced BDP for organic systems, the BDP was decreased in organic systems. However, the assumptions are not robust for all food products, despite many studies showing an increase in biodiversity, i.e., less biodiversity damage, with organic systems.

Toxicity impacts, both terrestrial ecosystem and human toxicity, could potentially be reduced if a larger share of organic food were consumed in Sweden; and both produced in Sweden and abroad. In a review of available literature on LCAs of organic and conventional products, Meier et al. [24] find similar reductions in toxicity for organic products. Nonetheless, many studies question the "safe" levels of toxicity for humans and the environment in conventional systems; see, e.g., [48,49]. In Sweden, there has also been considerable attention focused on conventional and organic foods due to a recent lawsuit filed against retailer COOP for providing "faulty" information to the public on the potential of organic foods to reduce toxicity [50]. This lawsuit has also sparked debate in Sweden about the power of lobbying and disregard for scientific information [51]. Despite the lack of consensus, the emergence of organic and regional foods has been essential in bringing about a debate on sustainable food production and consumption [11,12], and consequently, the consumption of organic foods in Sweden has also continued to increase dramatically [13].

5.3. Reducing Meat Consumption

As discussed previously, many studies have outlined how environmental impacts can be reduced through reductions in meat consumption. Meat consumption is often targeted as a prominent cause of many environmental impacts. This study has provided further justification of results in previous assessments of potential impact reductions through reductions in meat consumption; see, e.g., studies focusing on GHG emissions [4,19,20,44,52] and other impacts such as biodiversity, land and water use [21,23,53]. Nonetheless, this study provides new insights into toxicity potential from meat consumption.

Many previous studies have shown the effects of vegetarian diets for reducing climate impacts [20,54–56]. Nonetheless, the studies do not review indicators other than climate impacts, risking providing guidance that sub-optimizes choices [46]. Results also indicate higher toxicity in diets with more vegetable-based products and less meat. Accordingly, Finley and Davis [57] discuss the potential toxicity of vegetarian diets due to increased manganese intake. Gibson [58] associate increased levels of Mg, in addition to selenium and copper, from increased intake of cereals.

In the LCA community, the development of toxicity assessment models has led to some consensus on the limitations of their use of characterization factors in addition to fate and effect modeling [59]. Despite this, the issue of toxicity, and the overall dominance of certain metals, has perplexed LCA researchers in the past decade. Several studies have identified the contribution of metals such as chromium dominating the toxicity assessments of different products [60,61]. Nonetheless, there is a poor agreement between the various methods on the toxic impacts of metals [62]. The validity of various methods, such as the Uniform System for the Evaluation of Substances (USES-LCA) method, as applied in this study, has therefore been questioned, although no consensus for the different fate and effect and characterization factors among the various methods has been reached [61]. For more information on the differences between ecological toxicity and human toxicity assessment methods in LCA, see an extensive review provided by Pizzol et al. [62] and Plouffe et al. [61].

The toxicity level increases are only relative to a BAU in 2020 based on consumption figures in 2011, and there is no consensus on the risk that current toxicity levels, or an increase, may have. Therefore, uncertainty in the toxicity assessments provided in this report must be stressed. Vegetarian and vegan diets, despite the potential for increased toxicity, have the potential to reduce many environmental impacts. Furthermore, the data for vegetarian and vegan diets are based on current consumption figures, with only a relatively small share of organic foods. Vegetarians and vegans may consume more organic foods, which may also reduce toxicity levels, although this was not taken into account in this study; potentially leading to an overestimate of the toxicity from vegetarian and vegan diets.

Customers may also choose not to eat different meats, regardless of the environmental impact. Many perspectives can be reviewed, such as the ecological, ethical and emotional effect of meat consumption [63]. Nevertheless, meat consumption and potential reductions is a complex issue to tackle. Besides the environmental impacts, the consumption of meat has both positive and negative nutritional attributes; being a rich source of high-quality protein and nutrients, while also associated with increased risks for some diseases [64]. Previous research neglects to review the social and cultural aspects of meat consumption, which may inhibit potential reductions in certain cultures and countries [64]. The Swedish Board of Agriculture [65] reviewed many of the potential positive environmental implications of cattle grazing and meat production, which may not be reviewed in studies based on climate change. These include, e.g., biodiversity, preserving landscapes and even socio-economic impacts of meat production. However, as mentioned previously, no data were found for biodiversity improvements, or impacts, for Swedish meat products and production methods.

Consumers will ultimately have to tackle the challenge, which may be difficult as many retailers have used meat, and in particular minced meat, to entice customers to shop at their supermarkets. Tjärnemo and Södahl [66] suggest that the meat department of a supermarket is what sets different stores apart and may provide competitive advantages. Swedish supermarkets also obtain a large share of their economic returns from meat sales; thus, Swedish retailers may be confronted with a complex economic conflict.

5.4. Data and Modeling Limitations

Variability of data available to assess the environmental impacts of dietary choices is a significant limitation to studies such as this. These limitations include LCI data for foods, LCI data specific for Swedish conditions, statistical data on country of origin for the different foods and statistics on organic food production and consumption; see, e.g., similar limitations outlined in a study for U.S. dietary choices in Heller and Keoleian [1]. Meier et al. [24] also recognize the limitations in data availability and variability and provide a review of data variability for many conventional and organic food products and impact categories.

The results show a reduction of many impacts when consumption of foods originating in Sweden is increased. This is consistent with many available LCI data available for Swedish foods. Nonetheless, European averages [35] and French data were used [36] to represent some Swedish foods and other imported foods, which may not be entirely representative of the environmental impacts for Swedish conditions. This can be improved by developing more representative data for Swedish food production.

The assessment of biodiversity damage potential may also have large uncertainties. Figures were based on a study by Röös et al. [23], and assumptions of reduced BDP were made for organic production methods. While these assumptions may be robust in the aforementioned study, their use in this study may not be representative of Swedish and organic conditions, and improvements in both data availability and methods may be needed in the future to provide more transparent and robust data for biodiversity damage potential. This is similar for toxicity potential assessment methods.

A major limitation in this study, as well as in previous studies [1,20,21,23], is the exclusion of the indirect consequences of changes in diets on demand and availability for other foods; these are indirect impacts arising via market-mediated mechanisms, such as those via price changes that result in rebound and substitution. For example, in the scenarios outlined in this study, a reduction of consumption of meats, and in particular bovine meat, did not affect the consumption of dairy products (and the origin of these products). Thus, results provided for the scenarios with vegetarian diets and reduced meat could lead to an underestimation of the impacts. Previous studies have systematically shown that there are benefits from switching from a meat-based diet to a vegetarian diet on, for example, climate change [4,19–21,23]. Furthermore, the consequences associated with increasing demand for land in future scenarios, and in scenarios with an increase in vegetable-based products, were not reviewed as they were beyond the scope of this study, but can contribute to significant increases in environmental impacts.

Additionally, this study has not reviewed the impact of cooking and preparation of food. As such, there could be an underestimation of the impacts from the household consumption phase of the life cycle of food. Previous work reviewing the energy use and environmental impacts of cooking for different dietary choices, food products, etc., confirms these results are not insignificant [67,68]. However, the impacts from cooking were beyond the scope of this paper. Furthermore, the consumption figures in this study include wastes throughout the life cycle. Nonetheless, wastes created in, e.g., the diets including meat production may be underestimations of the total waste. This is confirmed by Laurenti et al. [69] in a review for the waste footprint of different food products, where meat products have large differences and uncertainties.

In the analysis, the impacts for different regions were reviewed, i.e., based on Swedish and imports. However, the results are not computed for each region separately, as the LCIA methods applied are typically based on global averages. In order to provide more detail, LCIA methods with more region-specific transparency may be needed to assess impacts and provide characterization factors that are spatially explicit [70]. This is important as environmental impacts have local implications on, e.g., acidification, eutrophication, biodiversity damage, etc.; see, e.g., the discussions on regional impacts and impact categories [71–76]. Despite the lack of consensus for many LCIA methods, e.g., toxicity assessment, Hauschild et al. [59] deliberate on the development of methods and how different approaches have led to harmonization in the scientific community. It is, therefore, possible that future assessment methods may become more robust to take into account a large number of factors affecting the outcomes.

5.5. Assuring Sustainability and Implementing Changes

While this study provides results assuming different degrees of increase and decreases in certain foods, realizing these changes may require support from all actors along the supply chain, from consumers to policy makers. Increasing the consumption of sustainable food choices will need an array of instruments in addition to consumers' willingness to accept changes. The FAO also recommends that sustainability be included in designing food-based dietary guidelines and policies [26]. Reisch et al. [3], Ekvall et al. [77] and Åström et al. [52] provide a collection of potential instruments, which can are aimed at producers, distributors and consumers. These include instruments related to information and voluntary agreements, in addition to economic and legal instruments. A recent study outlines the divergence in approaches and reasons for reducing meat consumption [78]. While this study does not aim to deliberate on the effectiveness of policies, or outline potential policies, it is important to recognize their potential for shifting toward more sustainable diets [79]. Further research will be needed on how policies can be applied across Europe, and globally, as consumer demands on food and other products are becoming more arduous. Current work with Product Environmental Footprint (PEF) and Environmental Product Declarations (EPD) comprise one such method to ensure transparent information on food products. As such, this could also provide demands on food producers in public procurement and the retail sector to improve food systems and to improve upon current systems to offer more environmentally-benign products.

6. Conclusions

Swedish food consumption has implications on many environmental aspects other than climate change. This research report reviews these implications by assessing scenarios on dietary choices including reducing meat consumption, increasing organic food production and consumption based on nutritional recommendations. The results are not meant to provide a comparison of the "best" methods, but to provide an indication of the impacts associated with increasing and decreasing the consumption of different foods.

The results indicate that an increased influx of organic foods showed no significant reductions in GHG emissions. However, when reviewing if all food were produced using organic practices, large reductions in ecotoxicity and human toxicity were apparent in addition to reduced biodiversity damage. Despite this, organic production methods may lead to increased eutrophication and increased land use due to reduced yields.

It was found that a reduction in meat consumption led to potential impact reductions in nearly all impact categories. Vegan and vegetarian diets led to large potential GHG emissions reductions of nearly 40% and 70%, respectively, in agreement with previous assessments. Other impact categories could also be reduced dramatically, although the terrestrial ecosystem toxicity and human toxicity were shown to increase due to an increase in vegetable products. Eating based on nutritional guidelines had similar reductions in environmental impacts as vegetarian diets, as guidelines suggest largely reduced meat consumption and an increase in vegetables and fruit.

An increase in consumption of Swedish foods showed reduced environmental impacts compared to imported foods in nearly all impact categories. However, it should be noted that with a growing population and limited growing season, the availability of foods for consumers may be restricted. It is important, therefore, that further transparency in the methodology for consumption models be improved in the future through a larger base of LCI data and region-specific characterization factors to have a more robust review of the impacts created both domestically and abroad.

The results indicate that tradeoffs could be possible with certain dietary choices; e.g., while climate-related impacts may be reduced, others impacts may increase. This is illustrated in the diets with no meat consumption and additionally in organic diet scenarios. It is therefore important to understand the implications of these changes both regionally and globally to make sound decisions about the environmental impact of food choices. As there is currently no standard to assess the sustainability of food products from a broader range of sustainability indicators, consumers will need to make choices based on their own values. Basing these only on climate impacts may not be important to all, and impacts such as toxicity, biodiversity and cultural or ethical reasons may be most important to some.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/9/12/2227/s1, Table S1: Population for years 2012, 2015 and 2020 in thousand persons, Table S2: Increase and Decrease of RFPs in the *Reduced Meat* scenario, Table S3: Changes in Food Consumption for Vegan Diets, Table S4: Recommendations from Livsmedelsverket on Food Consumption given in Amounts per day, week respectively, Table S5: Food Categories and Products Included in Study based on FAO Stat Food Balance Sheets, Table S6: Per Capita Consumption for different Representative Food Products in 2011, measured in kg per year (FAOStat, 2015), see Appendix for final amounts used in the reviewed scenarios, Table S7: Scaling factors for the different diets to denote increases or reductions, Table S8: Waste from Different Stages of the Life Cycle Accounted for in this study based on information from (Martin et al, 2015), Table S9: Percentage of Conventional vs. Organic in Each Food Category (see references), Table S10: LCI data references and assumptions, Table S11: Nutritional values per kg food, Figure S1: GHG emissions for different foods in 2015 and 2020, Figure S2: AP Contribution for different foods in 2015 and 2020, Figure S3: EP contribution for different foods in 2015 and 2020, Figure S4: Land Use contribution for different foods in 2015 and 2020, Figure S5: TETP Contribution for different foods in 2015 and 2020, Figure S6: HTP contribution for different foods in 2015 and 2020, Figure S7: BDD contribution for different foods in 2015 and 2020, Figure S8: AP Contribution from Foods Produced in Sweden and Imports, Figure S9: EP Contribution from Foods Produced in Sweden and Imports, Figure S10: Comparing tradeoffs with impact categories for scenarios tested in 2015 and 2020, Figure S11: Food consumed and waste in 2015 for different scenarios.

Acknowledgments: We would like to acknowledge ÅForsk and Stiftelsen IVL for their financial support to complete this project and article. Furthermore, gratitude is also owed to Felipe Oliveira, Joakim Thornéus and Lena Dahlgren for their help developing scenarios and data collection.

Author Contributions: Michael Martin (M.M.) conceived of and designed the project. M.M. also contributed to the primary data collection for food and LCI data in addition to the environmental analysis and the majority of the writing. Miguel Brandão contributed with a critical review, analysis of the data, the development of new scenarios, figures, writing of the text and revisions.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Heller, M.C.; Keoleian, G.A. Greenhouse Gas Emission Estimates of U.S. Dietary Choices and Food Loss. *J. Ind. Ecol.* **2014**, *19*, 391–401. [CrossRef]
2. Jones, C.M.; Kammen, D.M. Quantifying Carbon Footprint Reduction Opportunities for U.S. Households and Communities. *Environ. Sci. Technol.* **2011**, *45*, 4088–4095. [CrossRef] [PubMed]
3. Reisch, L.; Eberle, U.; Lorek, S. Sustainable food consumption: An overview of contemporary issues and policies. *Sustain. Sci. Pract. Policy* **2013**, *9*, 7–25. [CrossRef]
4. Hallström, E.; Carlsson-Kanyama, A.; Börjesson, P. Environmental impact of dietary change: A systematic review. *J. Clean. Prod.* **2015**, *91*, 1–11. [CrossRef]
5. Martin, M.; Danielsson, L.; Ekvall, T. *Environmental Implications of Dynamic Policies on Food Consumption and Waste Handling in the European Union*; EXPO LCA Conference Food and Bioenergy Stressa: Stressa, Italy, 2015. Available online: http://www.aforsk.se/sites/default/files/15-397.pdf (accessed on 27 November 2017).
6. Naturvårdsverket. *Konsumtions Klimatpåverkan*; Naturvårdsverket, The Swedish Environmental Protection Agency: Stockholm, Sweden, 2008.
7. Guinée, J.; Heijungs, R.; De Koning, A.; Van, L.; Geerken, T.; Van Holderbeke, M.; Jansen Vito, B.; Eder, P.; Delgado, L. *Environmental Impact of Products (EIPRO): Analysis of the Life Cycle Environmental Impacts Related to the Total Final Consumption of the EU25*; Technical Report Series, EUR 22284 EN, 1-136; European Commission, Joint Research Centre, Institute for Prospective Technological Studies: Hague, The Netherlands, 2006.
8. Toler, S.; Briggeman, B.C.; Lusk, J.L.; Adams, D.C. Fairness, Farmers Markets, and Local Production. *Am. J. Agric. Econ.* **2009**, *91*, 1272–1278. [CrossRef]
9. Fortune. The War on Big Food. Available online: http://fortune.com/2015/05/21/the-war-on-big-food/ (accessed on 30 November 2015).
10. Joosse, S.; Hracs, B.J. Curating the quest for 'good food': The practices, spatial dynamics and influence of food-related curation in Sweden. *Geoforum* **2015**, *64*, 205–216. [CrossRef]
11. Vittersø, G.; Tangeland, T. The role of consumers in transitions towards sustainable food consumption. The case of organic food in Norway. *J. Clean. Prod.* **2015**, *92*, 91–99. [CrossRef]
12. Klintman, M.; Boström, M. Political consumerism and the transition. Towards a more sustainable food regime. Looking behind and beyond the organic food shelf. In *Food Practices in Transition: Changing Food Consumption, Retail and Production in the Age of Reflexive Modernity*; Routledge: London, UK, 2012.
13. Ekoweb. *Ekologisk Livsmedelsmarknad: Rapport om den Ekologiska Branschen Sammanställd av Ekoweb.nu*; Ekoweb: Lidköping, Sweden, 2015.
14. Lang, T.; Barling, D. Nutrition and sustainability: An emerging food policy discourse. *Proc. Nutr. Soc.* **2013**, *72*, 1–12. [CrossRef] [PubMed]
15. Hempel, C.; Hamm, U. How important is local food to organic-minded consumers? *Appetite* **2016**, *96*, 309–318. [CrossRef] [PubMed]
16. Jordbruksverket. Livsmedelskonsumtionen i siffror—Hur har konsumtionen utvecklats de senaste femtio åren och varför? In *Food Consumption Statistics—How Has Food Consumption Developed the Last 50 Years and Why?* Rapport 2015:15; Jordbruksverket-Swedish Board of Agriculture: Stockholm, Sweden, 2015. (In Swedish)
17. Jordbruksverket. *Sverige—Det nya matlandet. En Undersökning om Svenskarnas Matvanor Och Attityder Till Mat*; Jordbruksverket—Swedish Board of Agriculture: Stockholm, Sweden, 2014.
18. Edwards-Jones, G.; Milà i Canals, L.; Hounsome, N.; Truninger, M.; Koerber, G.; Hounsome, B.; Cross, P.; York, E.H.; Hospido, A.; Plassmann, K.; et al. Testing the assertion that 'local food is best': The challenges of an evidence-based approach. *Trends Food Sci. Technol.* **2008**, *19*, 265–274. [CrossRef]
19. Westhoek, H.; Lesschen, J.P.; Rood, T.; Wagner, S.; De Marco, A.; Murphy-Bokern, D.; Leip, A.; van Grinsven, H.; Sutton, M.A.; Oenema, O. Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. *Glob. Environ. Chang.* **2014**, *26*, 196–205. [CrossRef]
20. Bryngelsson, D.; Wirsenius, S.; Hedenus, F.; Sonesson, U. How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. *Food Policy* **2016**, *59*, 152–164. [CrossRef]
21. Martin, M.; Danielsson, L. Environmental Implications of Dynamic Policies on Food Consumption and Waste Handling in the European Union. *Sustainability* **2016**, *8*, 282. [CrossRef]

22. Röös, E.; Karlsson, H. Effect of eating seasonal on the carbon footprint of Swedish vegetable consumption. *J. Clean. Prod.* **2013**, *59*, 63–72. [CrossRef]
23. Röös, E.; Karlsson, H.; Witthöft, C.; Sundberg, C. Evaluating the sustainability of diets–combining environmental and nutritional aspects. *Environ. Sci. Policy* **2015**, *47*, 157–166. [CrossRef]
24. Meier, M.S.; Stoessel, F.; Jungbluth, N.; Juraske, R.; Schader, C.; Stolze, M. Environmental impacts of organic and conventional agricultural products—Are the differences captured by life cycle assessment? *J. Environ. Manag.* **2015**, *149*, 193–208. [CrossRef] [PubMed]
25. Tuomisto, H.L.; Hodge, I.D.; Riordan, P.; Macdonald, D.W. Does organic farming reduce environmental impacts?—A meta-analysis of European research. *J. Environ. Manag.* **2012**, *112*, 309–320. [CrossRef] [PubMed]
26. FAO. *Sustainable Diets and Biodiversity: Directions and Solutions for Policy*; Research and Action; FAO-Food and Agricultural Organization: Rome, Italy, 2012.
27. Gustavsson, J.; Cederberg, C.; Sonesson, U.; van Otterdijk, R.; Meybeck, A. *Global Food Losses and Food Waste*; FAO: Düsseldorf, Germany, 2011.
28. FAO. *Food Balance Sheets*; FAO-Food and Agricultural Organization: Rome, Italy, 2014.
29. Willer, H.; Lernoud, J. *The World of Organic Agriculture: Statistics and Emerging Trends*; IFOAM: Bonn, Germany, 2015.
30. SCB. *Livsmedelsförsäljningsstatistik 2012-Livsmedelsförsäljningen Inom Detaljhandeln*; SCB: Stockholm, Sweden, 2013.
31. Jordbruksverket. *Skörd för Ekologisk och Konventionell Odling*; Jordbruksverket-Swedish Board of Agriculture: Stockholm, Sweden, 2014.
32. SCB. *Livsmedelsförsäljningsstatistik 2013—Livsmedelsförsäljningen Inom Detaljhandeln*; SCB-Statistics Sweden: London, UK, 2014.
33. Systembolaget. *Systembolagets Försäljning, Ekologiskt Odlade Produkter*; Systembolaget: Stockholm, Sweden, 2014.
34. SCB. *The Future Population of Sweden 2015–2060*; SCB-Statistics Sweden: Stockholm, Sweden, 2015.
35. Ecoinvent. The Ecoinvent Database v 3.1. Zurich, Switzerland, 2014. Available online: http://www.ecoinvent.org/database/older-versions/ecoinvent-31/new-data-in-ecoinvent-31/new-data-in-ecoinvent-31.html (accessed on 27 November 2017).
36. Colomb, V.; Ait, S.A.; Mens, C.B.; Gac, A.; Gaillard, G.; Koch, P.; Mousset, J.; Salou, T.; Tailleur, A.; Van Der Werf, H.M.G. AGRIBALYSE®, the French LCI Database for agricultural products: High quality data for producers and environmental labelling. *OCL* **2015**, *22*, 6. Available online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.906.1405&rep=rep1&type=pdf (accessed on 27 November 2017). [CrossRef]
37. Environdec. *The International EPD System—A Communication Tool for International Markets*; International EPD Sytem: Stockholm, Sweden, 2015.
38. De Baan, L.; Alkemade, R.; Koellner, T. Land use impacts on biodiversity in LCA: A global approach. *Int. J. Life Cycle Assess.* **2013**, *18*, 1216–1230. [CrossRef]
39. Tuck, S.L.; Winqvist, C.; Mota, F.; Ahnström, J.; Turnbull, L.A.; Bengtsson, J. Land-use intensity and the effects of organic farming on biodiversity: A hierarchical meta-analysis. *J. Appl. Ecol.* **2014**, *51*, 746–755. [CrossRef] [PubMed]
40. Bengtsson, J.; AhnstrÖM, J.; Weibull, A.-C. The effects of organic agriculture on biodiversity and abundance: A meta-analysis. *J. Appl. Ecol.* **2005**, *42*, 261–269. [CrossRef]
41. Sonesson, U.; Anteson, F.; Davis, J.; Sjoden, P.O. Home transport and wastage: Environmentally relevant household activities in the life cycle of food. *Ambio* **2005**, *34*, 371–375. [CrossRef] [PubMed]
42. Laurent, A.; Olsen, S.; Hauschild, M. Limitations of carbon footprint as indicator of environmental sustainability. *Environ. Sci. Technol.* **2012**, *46*, 4100–4108. [CrossRef] [PubMed]
43. Lazarevic, D.; Martin, M. Life cycle assessments, carbon footprints and carbon visions: Analysing environmental systems analyses of transportation biofuels in Sweden. *J. Clean. Prod.* **2016**, *137*, 249–257. [CrossRef]
44. Röös, E.; Sundberg, C.; Tidåker, P.; Strid, I.; Hansson, P.A. Can carbon footprint serve as an indicator of the environmental impact of meat production? *Ecol. Indic.* **2013**, *24*, 573–581. [CrossRef]
45. Martin, M.; Larsson, M.; Olivera, F.; Rydberg, T. Reviewing the environmental implications of increased consumption and trade of biofuels for transportation in Sweden. *Biofuels* **2017**. [CrossRef]

46. Peters, G.P.; Hertwich, E.G. Pollution embodied in trade: The Norwegian case. *Glob. Environ. Chang.* **2006**, *16*, 379–387. [CrossRef]
47. Pelletier, N.; Tyedmers, P.; Sonesson, U.; Scholz, A.; Ziegler, F.; Flysjö, A.; Kruse, S.; Cancino, B.; Silverman, H. Not All Salmon Are Created Equal: Life Cycle Assessment (LCA) of Global Salmon Farming Systems. *Environ. Sci. Technol.* **2009**, *43*, 8730–8736. [CrossRef] [PubMed]
48. Winter, C.K.; Katz, J.M. Dietary Exposure to Pesticide Residues from Commodities Alleged to Contain the Highest Contamination Levels. *J. Toxicol.* **2011**, *2011*, 589674. [CrossRef] [PubMed]
49. Castorina, R.; Woodruff, T.J. Assessment of potential risk levels associated with U.S. Environmental Protection Agency reference values. *Environ. Health Perspect.* **2003**, *111*, 1318–1325. [CrossRef] [PubMed]
50. Senapathy, K. Organic Marketers Take Note: Makers Of 'Misleading' Viral 'Organic Effect' Video Lose Lawsuit. *Forbes*, 6 July 2017.
51. Karlsscon, M.; Björnberg, K.; Gilek, M.; Hansson, S.O. Forskare: Farligt när vetenskapen förnekas. *Svenska Dagbladet-Debatt*, 8 September 2017.
52. Åström, S.; Roth, S.; Wranne, J.; Jelse, K.; Lindblad, M. *Food Consumption Choices and Climate Change*; Report B2091; IVL–Swedish Environmental Research Institute: Stockholm, Sweden, 2013.
53. Machovina, B.; Feeley, K.J.; Ripple, W.J. Biodiversity conservation: The key is reducing meat consumption. *Sci. Total Environ.* **2015**, *536*, 419–431. [CrossRef] [PubMed]
54. Berners-Lee, M.; Hoolohan, C.; Cammack, H.; Hewitt, C.N. The relative greenhouse gas impacts of realistic dietary choices. *Energy Policy* **2012**, *43*, 184–190. [CrossRef]
55. Vieux, F.; Soler, L.-G.; Touazi, D.; Darmon, N. High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults. *Am. J. Clin. Nutr.* **2013**, *97*, 569–583. [CrossRef] [PubMed]
56. Vieux, F.; Darmon, N.; Touazi, D.; Soler, L.G. Greenhouse gas emissions of self-selected individual diets in France: Changing the diet structure or consuming less? *Ecol. Econ.* **2012**, *75*, 91–101. [CrossRef]
57. Finley, J.W.; Davis, C.D. Manganese deficiency and toxicity: Are high or low dietary amounts of manganese cause for concern? *Biofactors* **1999**, *10*, 15–24. [CrossRef] [PubMed]
58. Gibson, R.S. Content and bioavailability of trace elements in vegetarian diets. *Am. J. Clin. Nutr.* **1994**, *59*, 1223S–1232S. [PubMed]
59. Hauschild, M.Z.; Huijbregts, M.; Jolliet, O.; Macleod, M.; Margni, M.; van de Meent, D.; Rosenbaum, R.K.; McKone, T.E. Building a Model Based on Scientific Consensus for Life Cycle Impact Assessment of Chemicals: The Search for Harmony and Parsimony. *Environ. Sci. Technol.* **2008**, *42*, 7032–7037. [CrossRef] [PubMed]
60. Haye, S.; Slaveykova, V.I.; Payet, J. Terrestrial ecotoxicity and effect factors of metals in life cycle assessment (LCA). *Chemosphere* **2007**, *68*, 1489–1496. [CrossRef] [PubMed]
61. Plouffe, G.; Bulle, C.; Deschênes, L. Case study: Taking zinc speciation into account in terrestrial ecotoxicity considerably impacts life cycle assessment results. *J. Clean. Prod.* **2015**, *108*, 1002–1008. [CrossRef]
62. Pizzol, M.; Christensen, P.; Schmidt, J.; Thomsen, M. Eco-toxicological impact of "metals" on the aquatic and terrestrial ecosystem: A comparison between eight different methodologies for Life Cycle Impact Assessment (LCIA). *J. Clean. Prod.* **2011**, *19*, 687–698. [CrossRef]
63. Vinnari, M.; Tapio, P. Sustainability of diets: From concepts to governance. *Ecol. Econ.* **2012**, *74*, 46–54. [CrossRef]
64. Macdiarmid, J.I.; Douglas, F.; Campbell, J. Eating like there's no tomorrow: Public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. *Appetite* **2016**, *96*, 487–493. [CrossRef] [PubMed]
65. Jordbruksverket. *Hållbar Köttkonsumtion-Vad är Det? Hur når vi Dit?* Rapport 2013:01; Jordbruksverket-Swedish Board of Agriculture: Stockholm, Sweden, 2013.
66. Tjärnemo, H.; Södahl, L. Swedish food retailers promoting climate smarter food choices—Trapped between visions and reality? *J. Retail. Consum. Serv.* **2015**, *24*, 130–139. [CrossRef]
67. Oberascher, C.; Stamminger, R.; Pakula, C. Energy efficiency in daily food preparation. *Int. J. Consum. Stud.* **2011**, *35*, 201–211. [CrossRef]
68. Hager, T.J.; Morawicki, R. Energy consumption during cooking in the residential sector of developed nations: A review. *Food Policy* **2013**, *40*, 54–63. [CrossRef]
69. Lavers, A.; Kalmykova, Y.; Rosado, L.; Oliveira, F.; Laurenti, R. Selecting representative products for quantifying environmental impacts of consumption in urban areas. *J. Clean. Prod.* **2017**, *162*, 34–44. [CrossRef]

70. Martin, M.; Lazarevic, D.; Larsson, M.; Aid, G. *Carbon Vision? A Review of Biofuel Environmental Systems Analyses Research in Sweden*; Report No. 2015:02, f3; The Swedish Knowledge Centre for Renewable Transportation Fuels: Gothenburg, Sweden, 2015.
71. Finnveden, G.; Nilsson, M. Site-dependent life-cycle impact assessment in Sweden. *Int. J. Life Cycle Assess.* **2005**, *10*, 235–239. [CrossRef]
72. Potting, J.; Schöpp, W.; Blok, K.; Hauschild, M. Site-Dependent Life-Cycle Impact Assessment of Acidification. *J. Ind. Ecol.* **1998**, *2*, 63–87. [CrossRef]
73. Huijbregts, M.A.J.; Schöpp, W.; Verkuijlen, E.; Heijungs, R.; Reijnders, L. Spatially explicit characterisation of acidifying and eutrophying air pollution in life-cycle assessment. *J. Ind. Ecol.* **2000**, *4*, 125–142. [CrossRef]
74. Curran, M.; De Baan, L.; De Schryver, A.M.; Van Zelm, R.; Hellweg, S.; Koellner, T.; Sonnemann, G.; Huijbregts, M.A.J. Toward meaningful end points of biodiversity in life cycle assessment. *Environ. Sci. Technol.* **2011**, *45*, 70–79. [CrossRef] [PubMed]
75. Henryson, K.; Hansson, P.-A.; Sundberg, C. Spatially differentiated midpoint indicator for marine eutrophication of waterborne emissions in Sweden. *Int. J. Life Cycle Assess.* **2017**. [CrossRef]
76. Koellner, T.; de Baan, L.; Beck, T.; Brandão, M.; Civit, B.; Margni, M.; i Canals, L.; Saad, R.; de Souza, D.; Müller-Wenk, R. UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA. *Int. J. Life Cycle Assess.* **2013**, *18*, 1188–1202. [CrossRef]
77. Ekvall, T.; Elander, M.; Umpfenbach, K.; Hirschnitz-Garbers, M.; Hudson, C.; Wunder, S.; Nesbit, M. *Development of DYNAMIX Policy Mixes, Deliverable D4.2*; IVL—Swedish Environmental Research Institute: Gothenburg, Sweden, 2015.
78. Molin, E. Whats the Beef? Reviewing the Divergence and Convergence in Approaches to Reduce Beef Consumption. Master's Thesis, KTH—Royal Institute of Technology, Stockholm, Sweden, 2017.
79. Garnett, T. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy* **2011**, *36* (Suppl. 1), S23–S32. [CrossRef]