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– data collection for the development of a consumer guide for plant-based foods

Hanna Karlsson Potter, Lina Lundmark, Elin Röös

Swedish University of Agricultural Sciences, SLU
NL Faculty/Department of Energy and Technology
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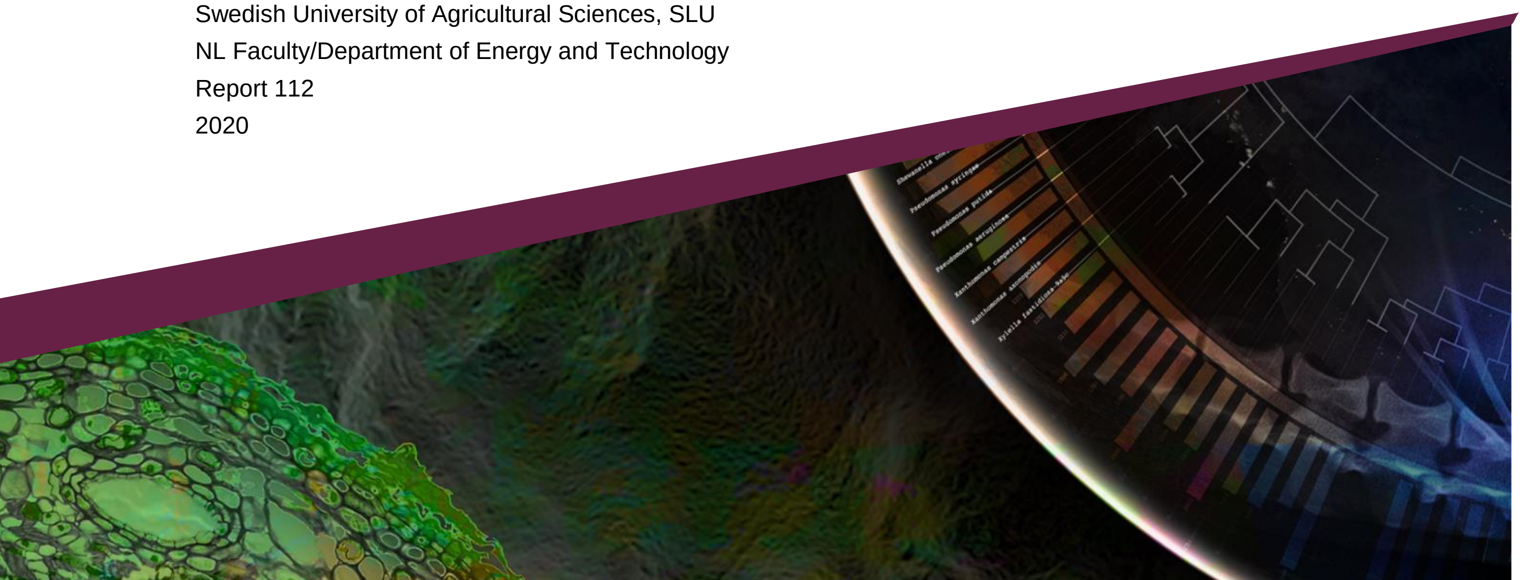

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Hanna Karlsson Potter, Lina Lundmark, Elin Röös at the Department of Energy and Technology, SLU

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Table of contents

1. INTRODUCTION

The current food system puts enormous pressures on natural ecosystems. To mitigate these pressures, three overarching strategies are necessary – improvements in production, reductions in food waste and food losses, and dietary change (Willett *et al.*, 2019; Röös *et al.*, 2017). The focus has long been on reductions in meat and dairy in Westernized diets, as animal products have substantially higher climate impacts than most plant-based foods (Moberg *et al.,* 2020). However, there is increasing interest in the sustainability of plant-based foods, reaching beyond the climate impact. For example, concerns have been raised about water and pesticide use in fruit, nut, and vegetable production, high energy use in ready-made food production, and high emissions from products transported over long distances. To provide guidance on such issues, WWF Sweden initiated development of a new consumer guide for plant-based products in a project called 'World-class Veggie' ('*Vego i världsklass*'). The Vego-guide will complement their current consumer guides on meat (Spendrup *et al.*, 2019; Röös *et al.*, 2014) and fish.

This report was prepared for WWF Sweden, to provide scientific background information for its consumer guide on plant-based products targeting Swedish consumers. The remainder of the report is structured as follows: Chapter 2 describes the methodology used for collecting data for the Vego-guide. Chapter 3 presents the results obtained for individual plant-based products and Chapter 4 presents more general results. A short concluding discussion is provided in Chapter 5. A comprehensive set of appendices (Appendix A1-A8), providing examples of data from all underlying studies for all individual products and specific details on the methodology used in the studies, is provided at the end of the report.

Motives and reasoning behind selection of environmental impact categories, the establishment of limits and criteria for the different environmental impact categories, and a description of the underlying work in development of the consumer guide are presented in a separate scientific paper (Karlsson Potter & Röös, manuscript).

2. METHOD

This chapter provides a description of methods applied in data collection, i.e., data sources (section 2.2), environmental impact assessment methods used (section 2.3), functional unit and system boundaries for the data collection (section 2.4), and selected food products and food groups (section 2.5). The strategy used for arriving at a final estimate of the climate impact, water use, land use, and biodiversity impact of the products on the Swedish market is described in section 2.6.

Selection of environmental impact categories, the development of evaluation criteria, underlying indicators used for environmental assessment, and thresholds for environment evaluation for the different levels in the Vego-guide are not described in this report, as it was not part of data collection. It is explained in the scientific paper on the process of developing the consumer guide (Karlsson Potter & Röös, manuscript).

2.1. Overview

Literature data were compiled from life cycle assessment (LCA) studies on 91 products, from 123 scientific papers, 31 conference papers, 42 reports, and other grey literature, and data were also obtained from two LCA databases. For all products, land use, biodiversity impact from land use, total water use, and regional impact of blue water use were also estimated. The results were stored in an Excel-sheet, hereafter called ‘the database’ (see section 2.2).

The aim was to collect and estimate environmental information relevant for products on the Swedish market, since the Vego-guide targets Swedish consumers and therefore it is important that it is based on information relevant for Swedish products. For all products on the Swedish market, country of origin was traced using import statistics (see subsection *Country of origin* in section 2.2).

The following environmental impact categories were selected to be included in the Vego-guide: climate impact, land use, biodiversity impact from land use, water use, regional impact from blue water use, and pesticide use (see section 2.3). The selection of impact categories was carried out collaboratively by researchers involved in the project and WWF Sweden. The criteria for selection were: environmental relevance in relation to production of plant-based foods, relevance for the user of the Vego-guide, availability of scientifically acceptable methods to assess impacts, and availability of data. Selection of criteria and other aspects related to development of the consumer guide are presented in the scientific paper (Karlsson Potter & Röös, manuscript).

In the presentation of results in this report, the products are divided into six product groups: ‘Protein sources’, ‘Nuts and seeds’, ‘Carbohydrate sources’, ‘Plant-based drinks and cream’, ‘Fruits and berries’, and ‘Vegetables and mushrooms’. For the purpose of the environmental assessment in the Vego-guide, the products were evaluated using different boundaries for different food groups. More details can be found in in Karlsson Potter & Röös (manuscript).

2.2. Data collection

2.2.1. Literature review

A recent review on the climate impact of food products by Clune *et al.* (2017) was used as a basis for finding previous LCA studies on food products. This review includes results from 369 studies on 168 food products from several world regions, but only includes the climate impacts of food. Therefore data on land use and water use (where available) from the individual studies reviewed by Clune *et al.* (2017) were also added to the database. The climate impacts assessed by previous studies were used as a basis for the final assessment on climate impact. The data on land use and water use collected from the literature were used for comparing the results from the consistent calculations of water and land use presented in this report. Therefore, literature data on land and total water use are not included in the graphs in this report, except for the food categories ‘Protein sources’ and ‘Plant-based drinks and cream’, as these categories contain composite products for which the exact amounts of different ingredients, information needed for estimating land and water use, are not known.

Data from additional studies on all types of products were added to the database, particularly focusing on Swedish produce, vegetarian alternatives to meat, and plant-based drinks and cream. Vegetarian alternatives are not included in the review by Clune *et al.* (2017) and some studies on Swedish produce are not included in that review, since they were published in Swedish. In addition, some studies have since been published. Searches were made in Google scholar, using the key words “LCA *food item*”, “life cycle assessment *food item*” and “environmental impact *food item*”. In addition, for all food products, a search was made in the databases ecoinvent (version 3.4) and Agri-footprint (4.0), and data on climate impact, land use, and water use were extracted and added to the database.

For a study to be included, results had to be presented so that they could be further analyzed and processed. Thus the study had to report characterized results, not normalized or weighted values where the climate impact of the individual food product could not be extracted. Results also had to be presented for individual food items, not for whole meals or diets. Publications in which emissions could not be divided between the different life cycle steps (no detailed information about contributions of different steps could be found) were excluded.

Many studies included more than one scenario on the same type of production. If scenarios represented different years, the average was added to the database as one data point, while if the scenarios represented different production systems (i.e., open field and greenhouse), then the values were kept as individual data points.

For studies with system boundaries beyond cradle to retail, the impact from cradle to farm gate/regional distribution center (for unprocessed products) and factory gate (ready-made products) was extracted from the reports/articles, and emissions from transport to Sweden were then added to the result.

Climate impact assessments where land use change (LUC) was included were included in the analysis, but these data points are marked separately in the graphs. If the studies that included LUC were relevant for the Swedish market, this was noted, but not included, in the final assessment. LUC was not included in the final assessment for two reasons: (i) it is not normally included in a common LCA of food products and therefore it is most often not included in the earlier studies identified; and (ii) methods for including LUC, such as time period over which the carbon loss or gain is allocated, can differ between studies and can therefore be difficult to compare between studies.

Country of origin

To determine the country of origin of imported foods, the following procedure was performed. Trade statistics were taken from the Statistics Sweden category '*Handel med varor och tjänster*' ('Trade in goods and services')[1]. For each food commodity, the average volume of imports over the previous five years (2013-2017) from each country was calculated. The countries that contributed more than 10% to total imports were included. The remaining imports for a specific commodity were assumed to come from the country with the largest trade surplus (export minus import) for that commodity according to FAOSTAT data for the previous five-year period (2012-2016).

Trade statistics do not always show the country of production. For example, according to trade statistics, imports to Sweden include products that are produced in tropical areas and come via the Netherlands and Denmark. Therefore, for each country contributing more than 10% of total imports for a certain product, it was verified using FAOSTAT data that the country had primary production of the product. If not, the import was assumed to come from the largest exporter globally.

Apart from country-specific land and water use per product (see section 2.3.2 and 2.3.4 on how this was assessed), global average land use and water use for all products were also calculated. The global average value could be seen as an indicator of possible impacts of import to Sweden that were not captured by the way in which export countries were identified here.

Following initial selection of export countries, when diverging results on land use, biodiversity, or water use were found for the same product coming from different countries, at least two additional export countries were identified. This selection was based on the identified large global exporters (as described above). When the imports were coming from both Europe and outside Europe, the extra countries were selected so that there were two *European* countries and two countries located outside Europe, called *Rest of the world* in the analysis. When the export countries identified were only countries outside Europe, two extra countries were added. Extra countries were added for: dry beans, faba beans, almonds, cashews, coconuts, pistachios, walnuts, corn, apricots, cherries, dates, grapefruit, guavas and mangoes, lemons and lime, melons, oranges, pineapples, plums and sloes, mandarins, asparagus, avocados, and garlic. The purpose of this addition was to provide more background data for products where the results differed greatly between the identified export countries.

For dry and canned beans, it is known that a large proportion of the beans sold in Sweden are imported from China and Canada (Ekqvist *et al.*, 2019), but these countries did not show up in the trade statistics. Therefore, data on land use, biodiversity impact, and water use were collected for these countries and included in the results for dry beans.

2.2.2. Food losses and waste

Food losses and waste were accounted for, to estimate the primary food production required for generating 1 kg product at a Swedish retailer, using factors taken from Gustavsson *et al.* (2011). Post-harvest losses, processing and packaging losses, and distribution and handling losses were included (see Appendix A5).

For some of the products, such as some nuts, data on yield are given for products with shells. However, since the products are often sold without shells, this was accounted for using conversion factors to eatable product (these can be found in Appendix A5).

In estimating global average production, average losses (average for all regions) were calculated and used to estimate food losses (Appendix A5).

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[1] www.statistikdatabasen.scb.se

2.3. Environmental assessment

2.3.1. Climate impact

Data on climate impact in kg CO_2e per kg product in a Swedish store were collected from LCA studies, reports, and databases, identified as explained in section 2.2. For commodities produced outside Sweden, emissions from transportation to Sweden and packaging (Moberg *et al.*, 2019) were added if not already included in the study. The system boundary for all data added to the climate impact database was cradle to a retail store in Sweden.

All studies included used the climate impact assessment metric GWP_{100}. However, characterization factors differ across studies for the main climate gases (methane and nitrous oxide). No adjustment made for this was done. This means that differences in results between studies could be partly explained by the use of different characterization factors. Differences in results may also be due to other choices made in the modeling.

When climate impact effects from land use change were included in the studies (as e.g., in all data from ecoinvent (Wernet *et al.*, 2016) and Agri-footprint (2018)), these studies were included in the database and the results are included in the graphs in Chapters 3 and 4 of this report. However, if these studies were identified as important for the Swedish market, and therefore included as a basis for the final climate impact assessment, the impact from land use change was not included, as land use change was only included in parts of the studies and, when making comparisons, the same system boundaries should be used. However, where land use change proved to have possible large effects on the climate impact of the product, it was noted in the final assessment.

Some plant-based products are transported by air to Sweden. To determine products for which there is a probability of air transport, we (WWF Sweden and the authors of this report) compiled a list of products for which we perceived a risk of air transport. This list was sent to fruit and vegetable importers and food retailers (two importers and two retailers) for verification. The resulting list of seven products was used as a basis for estimating climate impact from transportation by air of these products. Climate impact from air transport was estimated by calculating the climate impact from traveling by air from the capital in the identified export country to Stockholm, Sweden, using NTM calc (NTM, 2019).

Ecoinvent (Wernet *et al.*, 2016) has processes called “Global market” for several products and processes called “Rest of the world” for a number of products. Global market processes represent consumption mixes of certain products, and include transportation and losses along the chain. The system boundary for a global market process is cradle to retailer. The so-called rest of the world processes are estimates by ecoinvent for rest of the world data not represented in the ecoinvent dataset. The processes have a system boundary, which is the same as for the processes representing production in individual countries, i.e., cradle to farm gate. Both these processes were added to the database. However, these processes were rarely relevant in the final assessment of the climate impact, when we were often trying to find data for specific regions, e.g., in many cases data on European production were considered most relevant if most of the imports originate from within Europe.

2.3.2. Land use

To calculate the land requirements for producing a certain food product, yield statistics from FAOSTAT for the last five years available (2012-2016) were used, with data from Statistics Sweden (2012-2016) used for Swedish products not available in FAOSTAT. For the product groups ‘Protein sources’ and ‘Plant-based drinks and cream’, land use assessments from earlier studies are presented together with our own assessments. This because these product groups contain several different types of ready-made products involving many ingredients. It was therefore useful to include earlier assessments, as the amounts of the different ingredients are not always known.

Land use for global average production of the different products was estimated using global average yields (FAOSTAT, 2012-2016).

In some regions, the climate allows for multiple harvests through the year, a system called multicropping. Multicropping in the regions where this is possible was corrected for following Röös *et al.* (2017), with the exception that no intercropping was assumed for Northern Europe (United Nations (UN) definition) including Denmark, Finland, Iceland, Norway, Sweden, Estonia, Latvia, Lithuania, and the United Kingdom (UK) (Table 1). Multicropping was assumed to be possible for the following crops: vegetables, cereals, roots, pulses (Röös *et al.*, 2017) and seeds (including sunflower seeds, linseeds, and sesame seeds).

For world average land use estimates, multicropping was included by using the multicropping factor for the country with the largest production globally (based on FAOSTAT).

Table 1*. Factors applied for multicropping systems, taken from Röös* et al. *(2017)*

	Limited double cropping	Double cropping	Limited triple cropping	Triple cropping
Yield increase	50%	100%	150%	200%
Proportion of cropland assumed to be suitable for multicropping:				
Region				
E Europe	2%	0%	0%	0%
W Europe	5%	1%	0%	0%
C Asia	0%	0%	0%	0%
E Asia	5%	15%	14%	1%
S Asia	6%	6%	1%	0%
SE Asia	1%	33%	5%	29%
W Asia	0%	0%	0%	0%
L America	7%	38%	11%	7%
N America	17%	15%	7%	1%
SS Africa	11%	23%	5%	1%
N Africa	2%	0%	0%	0%
Oceania	2%	3%	0%	0%

Organic produce

Land use and biodiversity impacts were also calculated for organic produce, by accounting for the lower yields in organic production using yield statistics from FAOSTAT and lowering these in accordance with De Ponti *et al.* (2012). Since there are no trade statistics on organic products to determine the country of origin, the same import countries as for conventional products were assumed.

2.3.3. Biodiversity impact

Land use for agriculture is one of the most important drivers of biodiversity loss (IPBES, 2019). Impacts on biodiversity from land occupation was estimated using the method presented in Chaudhary *et al.* (2018) (an updated version of the method in Chaudhary *et al*., 2015), combined with estimated land use data (see Karlsson Potter & Röös, manuscript for details). The Chaudhary *et al.* (2018) method was chosen since it was the most recent method and represents an improvement on earlier methods to account for biodiversity impacts in LCA (de Baan *et al.*, 2012). It is also the method recommended by the United Nations Environment Programme-Society of Environmental Toxicology and Chemistry (UNEP-SETAC) for assessing biodiversity impacts from agriculture (UNEP, 2019). The method provides a global characterization factor, which was required in the present context, and allows for distinction between different land use types, although these are still rather broad. The method uses country area species richness (SAR), which is a model for estimating, based on available data, species richness (number of species) for different taxa (such as mammals and plants) in different land use types, compared with the natural habitat (Chaudhary *et al.*, 2018). The method also incorporates a vulnerability score that takes the presence and range of endangered species into account (Chaudhary *et al.*, 2018). Impact on species richness in five different taxa is included: mammals, birds, amphibians, reptiles, and plants (notably leaving out e.g., insects) and five different land use types: natural habitat, regeneration secondary vegetation, managed forests, plantation forests, crop land, and urban land, the latter four with three different intensity levels (minimal, light, and intensive) (Chaudhary *et al.*, 2018). In the present analysis, land use intensity was assumed to be *cropland-intensive use* for conventional farming and *cropland-light use* for organic production. The taxa-aggregated characterization factors for land occupation were used.

2.3.4. Water use

Food production is one of the most water-demanding sectors globally, with around 70% of all freshwater use estimated to be in agriculture (FAO, 2017).

The environmental assessment of water use was based on total water use (as an indicator of water use as an resource demand), blue water use (as an indicator of freshwater use), and potential impacts on local water stress, assessed by the AWARE method (explained below).

Data on total water use (green, blue, and grey water) and blue (fresh) water use were collected from Mekonnen *et al.* (2011). Figure 1 illustrates water types included in green and blue water (Hoekstra *et al.*, 2011). Green water is the precipitation on land that does not run off or recharge the groundwater, i.e., water that is (temporarily) stored in the soil and will eventually be taken up by plants or evaporate (Hoekstra *et al.*, 2011). The green water use reported in Mekonnen *et al.* (2011) corresponds to the rainwater consumed during crop production. Blue water is surface or fresh water consumed during crop production, i.e., irrigation water that is evaporated from the field or taken up by plants (Hoekstra *et al.*, 2011). Grey water is the theoretical amount of water needed to dilute pollutants and nutrients leaching from the field (Hoekstra *et al.*, 2011). Due to lack of data, only nitrogen leaching was considered by Mekonnen *et al.* (2011) when estimating the amount of grey water, and hence also in this study.

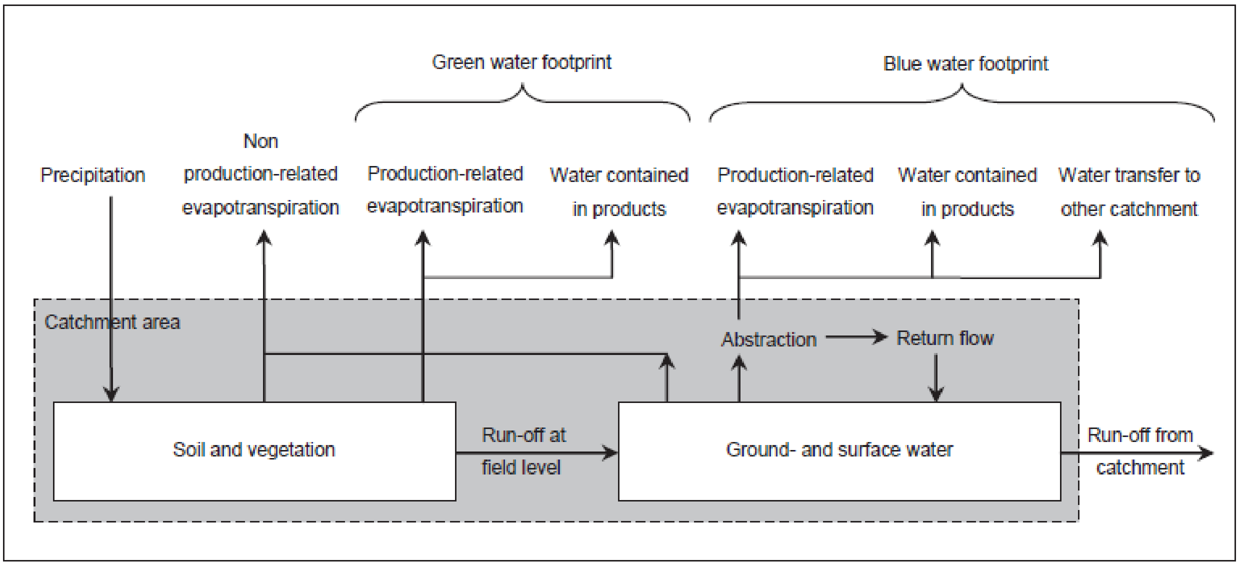

***Figure 1**. Description of green and blue water, taken from Hoekstra* et al. *(2011). Evapotranspiration = evaporation and transpiration by plants.*

Water use for processing was included for ready-made protein sources (Appendix A2) and plant-based dairy replacements (Appendix A3). Water use for washing e.g., vegetables was not included.

AWARE

The water footprint scarcity method AWARE (Available Water Remaining) was used to assess local (country-level) impacts from water consumption (blue water use) (Boulay *et al.*, 2018). Methods for assessing freshwater use and the impact on water availability are currently under development for application in LCA. A well-known earlier method, developed by Pfister *et al.* (2009), is primarily based on withdrawal in relation to availability, i.e., human use of freshwater. The AWARE method is based on demand in relation to availability, meaning that both ecosystem and human demands are accounted for (Boulay *et al.*, 2018). On analyzing the methods of Pfister *et al.* (2009) and Boulay *et al.* (2018), Lundmark (2019) found that the results differed somewhat, but that the ranking of the products, i.e., the best to worst performing products, was largely similar. The AWARE method (Boulay *et al.*, 2018) was selected here because it builds on consensus by the working group on Water Use in Life Cycle Assessment (WULCA) under the UNEP-SETAC Life Cycle Initiative (Boulay *et al.*, 2018). It is currently the recommended method for water scarcity assessment in LCA, but it is also recommended that a complementary method be used for sensitivity analysis (Jolliet *et al.*, 2018). Sensitivity analysis of the results in this report is described by Lundmark (2019).

The AWARE method offers yearly average characterization factors and country average factors for agricultural land and unspecified land for different countries. Characterization factors are also given on watershed level, which would be preferable (over country average) for assessing the impact on water stress. Similarly, there are temporal differences in the effect of freshwater use on water scarcity (Boulay *et al.*, 2018). However, since geographical location and time of crop production were not known for all crops assessed, we used country average characterization factors for agricultural land.

2.3.5. Pesticide use

Estimating the impact of pesticide use in food production is challenging. This is mainly due to lack of data on pesticide use (especially divided into different food products) and limitations in methods to assess eco-toxicity and human toxicity, i.e., the actual negative impacts on ecosystems and humans, for the vast number of pesticides on the market. To compare all products on the Swedish market, statistics on pesticide use for all countries exporting to Sweden would be needed. No such data are currently available, especially for countries outside the EU, for which data on pesticide use are very scarce.

In this report, statistics on pesticide use based on the amount of active substance (kg AS) per hectare, in Sweden and Europe (only for EU member states), are presented. These data can give an indication of the ecotoxicity impacts from the production of different crops. The most recent statistics on EU pesticide use do not include data for individual crops, but give aggregated figures for the whole country. For European products, an publication from 2007 was therefore used (EUROSTAT, 2007). It presents average (1999-2003) pesticide use for different European countries for “cereals, maize, oil seeds, potatoes, sugar beet, other arable crops (arable crops total), fruit trees, vegetables (fruit and vegetables total)”. The most recent available statistics were used for Swedish products (SBA, 2018b).

For imports from outside Europe, no uniform dataset could be found for pesticide use in different crops in different countries. Therefore, no data on pesticide use were collected for production outside Europe. In the Vego-guide, this was treated as “lack of data”, similarly to European and Swedish production for which no data could be found. See Karlsson Potter and Röös (manuscript) for more details on how this was handled in the Vego-guide.

Results from data collection on pesticide use, aggregated for all food categories, are presented in Chapter 3 of this report. Detailed data for all food products are presented in Appendix A7.

2.4. Functional unit and system boundaries

The functional unit (FU) selected was 1 kg product at a store in Sweden, i.e., the following steps in the production chain were included: primary production including the production of inputs, processing (in the case of processed products), storage, packaging, and transport to a store in Sweden.

There are several alternatives to using a mass-based functional unit. For food products, the functional unit could be e.g., protein content for protein foods, energy content for carbohydrate sources, or based on different nutrient indices. This issue is further discussed in Appendix A4.

The functional unit when collecting data from earlier studies was 1 kg product, and studies with varying system boundaries were included. To enable us to compare the results from earlier studies, the results were modified to represent the same system boundary. This meant that if e.g., cooking and waste management were included in the study, these steps were removed. For studies that ended at factory gate/farm gate, emissions from transport to a retailer (in Sweden) were added. More detailed information about this can be found in Appendix A1.

Emissions from transport and packaging were added using emission factors from Moberg *et al.* (2019) (Tables 2 and 3). In general, all transport was considered to be road and/or sea transport. Transport within Sweden was also included for both imported and domestic products. Transport within Sweden was calculated using weighted average for food transport within Sweden, meaning that population distribution was accounted for (Moberg *et al.*, 2019).

For packaging, representative packaging type was considered for the different products in Table 3, after analysis by Moberg *et al.* (2019). The climate impact for packaging used is well in line with the climate impact of different packaging types presented by Nilsson *et al.* (2009), with the exception of metal cans and glass jars. This because no such packaging was assumed for the products included. Beans sold as ready-to eat in Sweden today are mainly packaged in cardboard cartons (see Appendix A6). However, it is important to note that the climate impact from transport and packaging was considered using rather general figures, i.e., no specific analysis of transportation mode and typical packaging type was made for each product.

Table 2. *Emission factors for transport to Sweden and within Sweden (Moberg* et al.*, 2019)*

	Emissions, kg CO_2e/kg transported to Sweden (sea and/or road)	**Emissions factor, kg CO_2e/kg transported by road in Sweden**
Nordic and Baltic countries[a]	0.05	0.03
West Europe[b]	0.1	0.03
South Europe[c]	0.2	0.03
East Europe[d]	0.3	0.03
Rest of Europe	0.2	0.03
West Africa[e]	0.3	0.03
North, Central and South America[f]	0.3	0.03
Southeast Asia[g]	0.4	0.03
China	0.5	0.03
Oceania[h]	0.5	0.03
Rest of the world	0.4	0.03

[a] Includes Denmark and Norway.
[b] Includes Germany, Belgium, the Netherlands, France, and Ireland.
[c] Includes Italy and Spain.
[d] Includes Greece and Turkey.
[e] Includes Ivory Coast.
[f] Includes United States, Panamá, Costa Rica, Brazil, and Ecuador.
[g] Includes Thailand and Vietnam.
[h] Includes New Zealand.

Table 3. *Emission factors for packaging based on data collection from Moberg* et al. *(2019)*

Product category	**kg CO_2e/kg product**
Berries	0.15
All other plant-based foods	0.05
Soda, cider, beer, mineral water, juice, and squash drink	0.15
All other processed foods	0.05
Milk and dairy products	0.05

Beans, peas, and lentils are bought either as dried or canned. For these products to be comparable, the weight of dried legumes was adjusted to that of the canned equivalent. For beans, 1 kg dry beans equals 2.5 kg boiled beans (for the subcategories dry beans and faba beans) (Bognár, 2002). For chickpeas, lentils, and soybeans, specific conversion factors were calculated based on the protein content of dry versus boiled beans based on information in *Livsmedelsdatabasen* (SFA, 2019), to 2.5 kg for chickpeas, 2.3 kg for lentils, and 3.1 kg for soybeans. Since cooking is included in canned legumes, this step was also added to the dried legumes. Environmental impact for boiling at home was added assuming that cooking requires 4.6 MJ electricity per kg boiled beans (Carlsson-Kanyama & Faist, 2000) and using the environmental impact from the Swedish electricity mix taken from Ecoinvent (Wernet *et al.*, 2016).

In the group ‘Carbohydrate sources’, the weight of the dried grains was adjusted to represent edible product. This was done to enable comparison with other carbohydrate sources such as potato and root vegetables. All grains were adjusted so that 1 kg of grain (barley, corn, pasta, sorghum, oats, rye, wheat) represented 1.9 kg edible product (average for three types of bread, whole wheat boiled, and pasta) (taken from RAC tables and Bognár (2002)). One kilogram of dry rice was assumed to equal 3 kg edible product, 1 kg millet 2.4 kg edible product, and 1 kg quinoa 3.4 kg edible product (Bognár, 2002).

2.5. Food products and food groups

The food products were divided into the following food categories: Protein sources, Plant-based drinks and cream, Carbohydrate sources, Nuts and seeds, Fruits and berries, and Vegetables and mushrooms.

The Vego-guide aims to include the main plant-based commodities on the Swedish market, including plant-based protein sources and other products such as nuts that are interesting for many consumers choosing to eat less animal-based products, and which are relevant for a more plant-based diet. The list of products assessed was continuously discussed with WWF Sweden.

Some products were excluded due to lack of data. For example, the aim was to include more variants of plant-based protein sources, but this was not possible due to lack of data. Similarly, there are few studies on different types of mushrooms and it was therefore decided to provide data only for *Agaricus bisporus* (common mushroom, *champinjon* in Swedish).

Table 4. *Food categories and food products included in the analysis, but not necessarily in the final guide*

Protein sources	Carbohydrate sources	Plant-based drinks and cream	Fruit and berries	Vegetables and mushrooms
Green peas Yellow peas Dry beans Faba beans Canned beans (including lentils) Chickpeas Dry lentils Soybeans **Ready-made products** Mixed without animal products[1] Pea-protein products Quorn Soy-based Tofu and tempeh **Nuts and seeds** Almonds Cashew nuts Chestnuts Coconut (grated) Hazelnuts Walnuts Pistachios Peanuts Sesame seeds Sunflower seeds	**Cereals** Barley Maize Millet Oats Pasta Quinoa Rice Rye Sorghum Wheat **Root vegetables** Beetroot Carrots Potatoes Swedes Sweet potato Jerusalem artichoke Parsnips	Almond drink Coconut drink Soy drink Oat drink Oat cream Coconut milk	Apples Apricots Bananas Cherries Dates Grapefruit and pomelo Grapes Guavas and mangoes Kiwi fruit Lemons and limes Melons Oranges Papayas Peaches Pears Pineapples Plums and sloes Tangerines, mandarins etc. Watermelon **Berries** Cranberries Blueberries Raspberries and other berries Strawberries	Artichokes Asparagus Avocados Broccoli Cabbage Capsicums/ Peppers Cauliflower Celery Cucumber Eggplant Garlic Ginger Lettuce Green beans Olives Onions Pumpkins and squash Spinach Tomatoes Mushrooms

[1] For example falafel.

2.6. Strategy used for producing final estimates for the Vego-guide

Here we describe the method used for analyzing the data and arriving at likely impact, or range of impact, of the specific product on the Swedish market.

Climate impact

The final assessments on the climate impact of different products were based on the results from the literature review of earlier studies and an analysis of the applicability of the results for products found on the Swedish market. This analysis was based on information regarding countries that export to Sweden and how representative the study was of current production systems including technological developments. For many products, there were a limited number of studies available. In these cases, available earlier studies were used to give an indication of possible climate impact. After each final assessment in tables in this report, the number of references used for making the final assessment for each individual product is shown. The sources included scientific papers, reports, databases, and in some cases company documents. We compiled the results from previous studies and expressed the likely climate impact in terms of “likely below X kg CO_2e per kg product”, where the relevant study with the highest climate impact was used to describe the climate impact that the particular product will most likely not exceed (since all other identified studies showed a lower climate impact). For most products, relatively few studies were identified and it was therefore not considered feasible to use an average value of the studies found.

Land use, biodiversity, and water use (including water scarcity indicator)

Final assessments for land use, biodiversity and water use (see Chapter 3) were primarily based on assessments performed within this study (see section 2.3.2, 2.3.3, 2.3.4). For the product groups ‘Protein sources’ and ‘Plant-based drinks and cream’, results from earlier studies were used in the final assessment, because these groups contain ready-made products with several processed ingredients and therefore information from previous studies is particularly relevant. Swedish production, production in the countries identified as main exporters to Sweden, and global average production were included. In the final assessments, we describe the range of land use and water use for the production regions. We also state whether the results are homogenous or heterogeneous, and discuss the reasons. For impact on biodiversity and water scarcity, we discuss the products that risk having the largest impact on these parameters.

3. RESULTS: FOOD CATEGORIES

This chapter presents a summary of the results of data collection for the different food groups and products. More details on individual earlier studies that formed the basis for the climate impact assessment can be found in Appendix A1.

Below, the results from earlier studies and from the assessments performed in the present analysis are presented for the impact categories climate impact, land use, biodiversity impact, and water use for all six product groups. Lastly, pesticide use is presented separately for all product groups under one heading, because only aggregated results are presented in this report. Detailed results for all products are presented in Appendix A7.

3.1. Protein sources

Note that the environmental impact of dry legumes was modified to be comparable with canned legumes and ready-to-eat meat alternatives (see section 2.4). Results that were modified in this way are marked with * in diagrams. This means that the protein content in the legume-based product is approximately 7-8%. For many of the meat replacement products, such as soy-based "meat", the protein content is more similar to that of meat (approximately 20%).

For ready-made products, the symbol in graphs representing the region of origin shows country of processing. This means that soy-based products produced in e.g., Sweden will be listed as Swedish even though ingredients are imported.

3.1.1. Climate impact

Results for climate impact from earlier studies on plant-based protein sources are presented in Figure 2.

Most studies on unprocessed beans and peas show a climate impact below 1 kg CO_2e per kg product. However, there are some exceptions: a study on green peas produced in Australia and transported to Sweden (which is unlikely for fresh green peas in practice), and the following data-points, all from the databases of ecoinvent (Wernet *et al.*, 2016) and Agri-footprint (Agri-footprint, 2018), where LUC is included: yellow peas from Spain, chickpeas from Australia, and several studies on soybeans produced in South America (Argentina and Brazil). Australia is the country with the largest export of chickpeas and therefore chickpeas from Australia could potentially be relevant for the Swedish market (FAOSTAT, 2019). Note that no dry or canned chickpeas from Australia were found in the main supermarkets in Sweden during an inventory performed in 2019 (Ekqvist *et al.*, 2019). However, soybeans from Brazil and Argentina are interesting to take into consideration, as these countries are major producers of soybeans, although they were not identified as countries exporting to Sweden in this study. It has been estimated that soybeans produced in South America are rarely used for human consumption in the EU, since they are often GM soybeans and therefore unlikely to be used for human consumption in the EU (Fraanje & Garnet, 2020). Soybeans have multiple uses, including direct human consumption, vegetable oil production for human consumption and biofuel production, and animal feed production. It has been estimated that around 6% of total soybean production is used directly for human consumption, most of the oil and a small fraction (less than 1%) of the protein press cake (a co-product from oil pressing) is used for human consumption, and most of the global soybean production is used for animal feed, primarily for poultry and pork production (Fraanje & Garnet, 2020).

Dry lentils have a climate impact of between 0.9 and 2.6 kg CO_2e per kg product (including transport to Sweden) for lentils produced in Australia, Iran, and Canada. Lentils from Australia have the highest climate impact, as mainly due to LUC (Agri-footprint, 2018). Data for Iranian and Australian lentils were not considered relevant for the Swedish market. The main countries from which Sweden imports lentils were found to be Turkey, UK, and Canada (Canada being the largest producer globally, and identified as the largest exporter) (FAOSTAT, 2019). Ekqvist *et al.* (2019) found that most lentils on the Swedish market come from Canada. Therefore, data for Canadian lentils were used as the basis for the final assessment.

For canned beans, chickpeas, and lentils, some studies show impacts exceeding 1 kg CO_2e per kg product. It is unclear from these studies whether metal or cardboard packaging was used, as this has an impact on the results. However, the electricity mix in the country where the beans are boiled, and the fact that more weight has to be transported to Sweden if the beans are boiled before transport, are clearly important for the final climate impact. An assessment of the climate impact of canned beans produced in Italy and of dry beans transported and boiled at home in Sweden is presented in Appendix A6. Currently, there is no facility in Sweden producing canned beans, and beans grown in Sweden and sold as canned beans in Sweden are likely to have been canned in Italy (Tidåker *et al*., manuscript).

For ready-made plant-based protein sources, such as soy-based mince, sausages, etc., most studies show a climate impact of 1-4 kg CO_2e per kg product. However, some studies show an even higher impact. One study on dairy-based protein (Broekema & Blonk, 2009) shows a climate impact of just below 6 kg CO_2e per kg product. This is an animal-based product of a type that is currently not very common on the Swedish market. Mixed (especially mixed with eggs) products have very diverse impacts, due to the diversity of ingredients in these products. All products that show an impact higher than 4 kg CO_2e per kg product are products with eggs produced in the USA (Quantis, 2016) and assumed to be transported to Sweden. These products are, to our knowledge, not available on the Swedish market.

Studies on Quorn often report a climate impact of between 2-3 kg CO_2e per kg product (Louise Needham, Quorn, personal communication 2019). Blonk *et al.* (2008), Head *et al.* (2011), Broekema and Blonk (2009), and Finnigan *et al.* (2010) found a higher impact, of around 7 kg CO_2e per kg product, for Quorn. Finnigan *et al.* (2010) report a higher impact from processing than e.g., Blonk *et al.* (2008), but the impact from raw materials is similar in the two studies. Later studies on Quorn by the same author show a lower impact (Finnigan *et al.*, 2017). The later studies were considered in the recommendation in this report, since the company producing Quorn has modified its process to lower the climate impact (Louise Needham, personal communication 2017).

Soy-based products show an impact of 1-3 kg CO_2e per kg product. In particular, products partly produced in Sweden have a low impact, likely due to the low climate impact of Swedish electricity production. Two studies show an impact above 4 kg CO_2e per kg product, both for products produced in the USA (Quantis, 2016) and transported to Sweden. Tofu and tempeh likely have an impact lower than 3 kg CO_2e per kg product (range 1-4 kg CO_2e per kg product, the higher range of impact was not considered in the recommendation due to the large discrepancies with the other studies) (Table 5). Very few studies were found on wheat protein-based products. The results in Figure 2 show results from one study (Broekema & Blonk, 2009) for wheat protein, and not the finished (ready-to-eat) product.

No studies were found on processed products produced from Swedish ingredients, such as tempeh made from peas or faba beans. Our judgment is that the climate impact is lower than for imported products, as transportation is shorter and the Swedish electricity mix has a low climate impact, giving a low impact from the processing step.

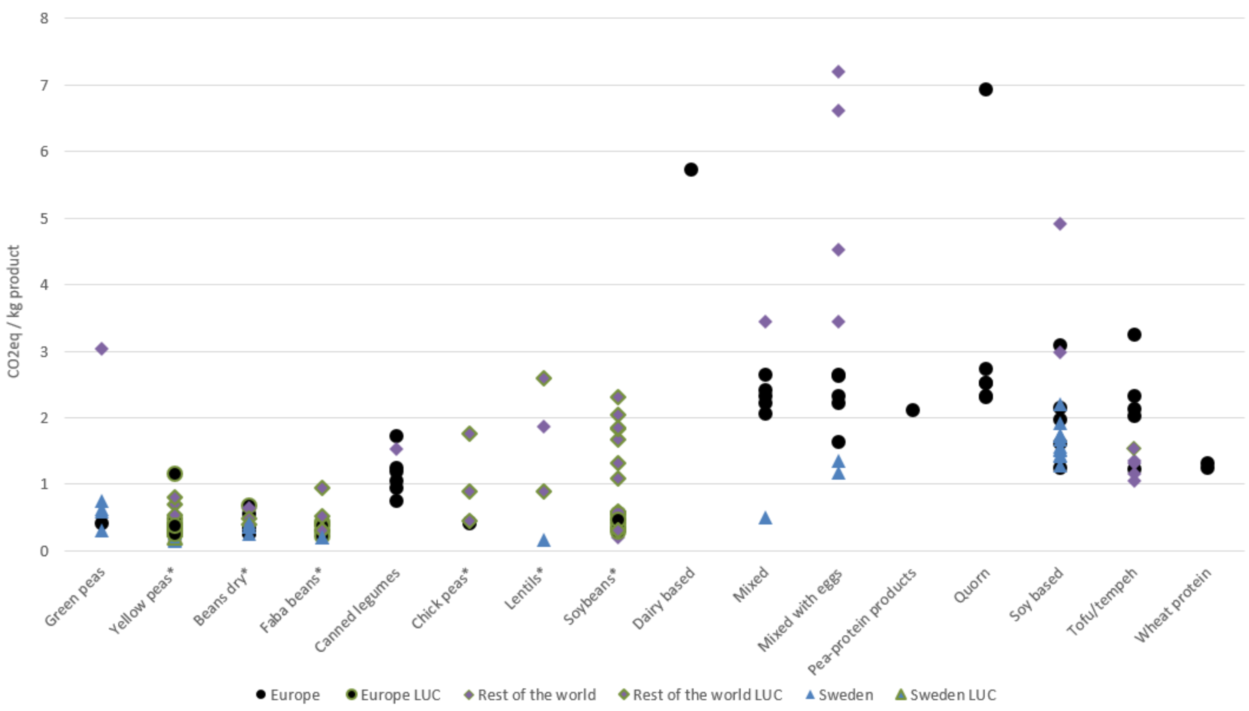

Figure 2. *Climate impact of plant-based protein sources. Functional unit 1 kg packaged product at a Swedish retailer. *Weight of the product modified to equal 1 kg boiled beans and climate impact from cooking added. Note that the graph shows the climate impact from all identified earlier studies for this product group, and not only those identified as relevant for the Swedish market. The final assessment (see Table 5) was based on relevance for the Swedish market.*

Table 5*. Summary of assessments of the climate impact of plant-based protein sources on the Swedish market*

Product	**Final assessment (kg CO_2e per kg product in a Swedish store)**		**No. of relevant references**	**Total no. of references**	**Comment**
	General	Sweden			
Green peas	0.8	No data	3	4	Only European produce considered relevant
Yellow peas	0.5	0.3	7 (5 SW)	8	Only European produce considered relevant, Agri-footprint data from Spain excluded due to relatively high LUC impact. Spain was not identified as one of the countries exporting yellow peas to Sweden.
Dry beans	0.7	0.4	7 (4 SW)	7	All studies considered relevant for the general recommendation. Three studies on Swedish beans were found, showing an impact below 0.4 kg CO_2e per kg.
Faba beans	0.5	0.2	3 (1 SW)	3	All studies considered relevant. The higher impact is for faba beans from Australia, dominated by emissions from transportation and land use change. Only one study was found on Swedish faba beans, so this assessment is uncertain.
Canned legumes	1.7	No data	4	4	All studies considered relevant. No data on Swedish canned beans found. Climate impact today is likely to be lower, since many beans are sold in cardboard containers (Tetra Pak^{TM}) and many of the identified studies considered tin cans.
Chickpeas	0.6	No data	3	3	All studies considered relevant. Data for Australian chickpeas excluded due to high LUC and questionable relevance for the Swedish market.
Dry lentils	0.6	0.2	2 (1 SW)	3	Data for lentils from Canada, Australia, and Sweden considered relevant for the Swedish market. Assessments for imported and Swedish lentils are both

					based on only one reference, so this assessment is considered relatively uncertain.
Soybeans	0.6	No data	4	4	Data for soybeans from Brazil and Argentina excluded due to high LUC impact and these countries not being identified as important exporters of soybeans for human consumption to Sweden. They are important producers globally, and it should be noted that soybeans can be associated with high LUC impacts.
Processed					
Mixed without animal products	2.6	1	4 (1 SW)	5	Data on products produced in Europe and Sweden considered relevant. Swedish-produced falafel has an impact well below 1 kg CO_2e per kg product. Only data on products produced in the USA were available for production outside Europe, and were considered less relevant for the Swedish market.
Mixed with animal products	2.6	1.4	3 (1 SW)	4	Data on products produced in Europe and Sweden considered in the assessment. Only data on product produced in the USA were available for production outside Europe, and were considered less relevant for the Swedish market.
Pea-protein products	2.2	No data	1	1	Only one study of European-produced (German) pea-protein product was found, so the data should be considered uncertain.
Quorn	2.7	No data	4	5	Data on European Quorn production considered relevant. One older study was identified showing a significantly higher climate impact per kg product. This study was not considered in the assessment, since it has been updated with newer studies.
Soy-based	2.2	2.2	3 (2 SW)	5	Data for soy protein isolates (that cannot be eaten as is but is processed into other products) and data on US production were considered less relevant for the Swedish market. One study showed an impact of 3.1 kg CO_2e per kg. However, this was excluded due to deviation from the other identified studies.
Tofu and tempeh	2.3	No data	4	5	All data considered relevant for the assessment. Most studies show a climate impact below 2.3 kg CO_2e per kg product. One study showed an impact of above 3 kg CO_2e per kg product. This was not considered in the assessment due to its deviation from the other identified studies. For Swedish-produced products such as tempeh made from peas or faba beans, the climate impact is likely to be somewhat lower than for similar imported products.
Wheat protein	1.3	No data	1	1	Only one study was identified, the assessment is therefore uncertain.

3.1.2. Land use

Combined assessment of land use (earlier studies plus own assessment)

Land use calculated based on import statistics and yield data is shown in Figure 3. Assessments on ready-made soy-based meat alternatives were made based on Orklafoods's products, containing mainly soy protein concentrate and rapeseed oil, and the soybeans were assumed to be produced in the USA (main exporter to Sweden). Organic produce with yields adjusted according to De Ponti *et al.* (2012) (Appendix A8) was also included. Organic produce was assumed to originate from the same countries as the conventional products.

Yellow peas, faba beans, soybeans, Quorn (made from wheat-based sugar), and ready-made vegetarian meat alternatives based on mainly soy protein concentrate were found to have relatively low land use (mainly below 2 m^2 per kg product). All literature data-points on soy-based European products are from the same study (blonkconsultans, 2017), in which land use values for the products covered are higher than the land use calculated here for Swedish products. This can be partly be due to South American soybeans being assumed in blonkconsultans (2017), whereas for Swedish ready-made soy-based meat alternatives the beans were assumed to come from the USA, which has higher yields (FAOSTAT, 2019). However, this cannot explain the whole difference. One identified study (Thrane *et al.*, 2017) looking at soy protein isolate production in the US was not included in the assessment, as soy protein isolate has a very high protein content and is further processed into products containing much lower protein content. Comparison to ready-to-eat products is therefore not relevant.

Results from existing studies (Figure 3) show that ready-made meat alternatives have higher land use than unprocessed legumes per kg. The reason for this is that ready-made products often contain other ingredients than legumes, such as oil, seeds, or nuts. Tofu is often produced from soybean, but fractions of the bean are removed from the products (in this case fibers and some of the carbohydrates). For products such as tofu, the results for land use will depend partly on how the land use is allocated between the different fractions in the processing. Quorn, with the primary input of glucose (produced from wheat), is an exception, with low land use due to high sugar yield per hectare. Soy-based meat alternatives made primarily from soy-protein concentrate also show low land requirements.

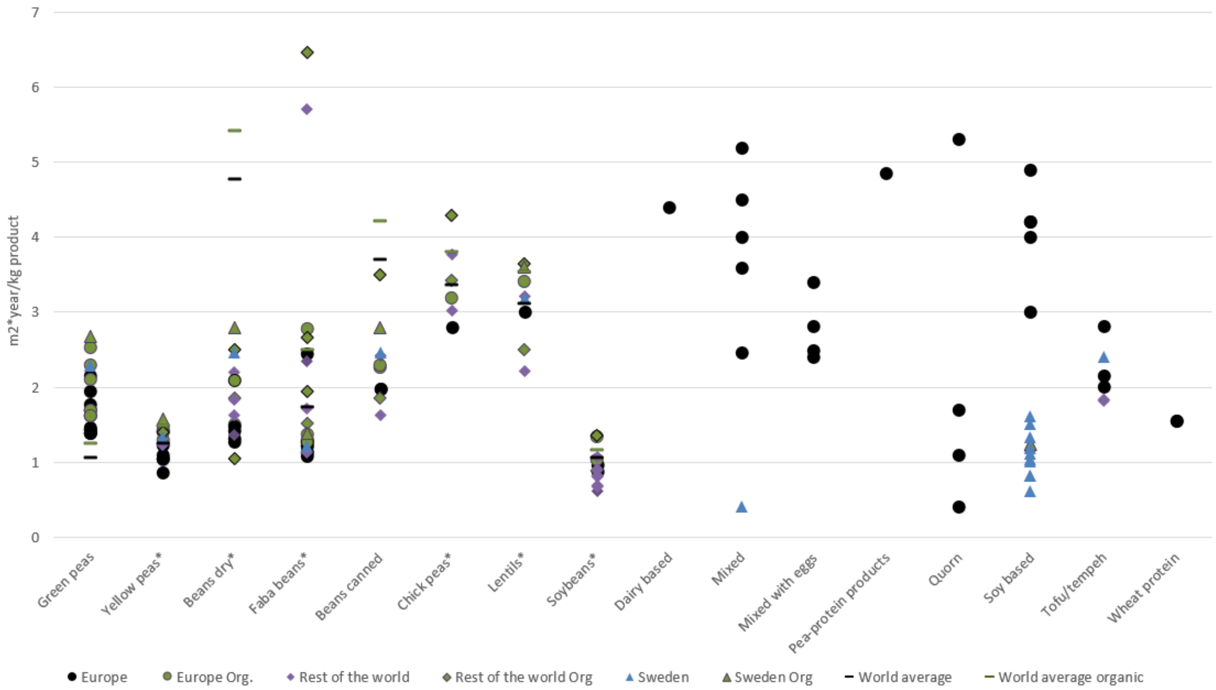

Figure 3. *Land use for plant-based protein sources in m^2/year per kg ready-to-eat product. Earlier studies and own assessments on land use are shown. *Weight of the product modified to equal 1 kg boiled beans. World average land use is based on average yield for all countries that produce the crop.*

For reference, land use for all plant-based products (same as in Figure 3) and meat (bone-free meat) is presented in Figure 4. Land use data for meat were taken from Röös *et al.* (2013, 2015). Two data points show land use of above 150 m^2 per kg beef (Röös *et al.*, 2013), but these were removed from the graph to enable more details to be shown. Both beef and pork clearly have a much higher land use than vegetable protein source. Chicken is in the same range as the vegetable protein sources with relatively high land use, but more than double the land use of most European soy-based products.

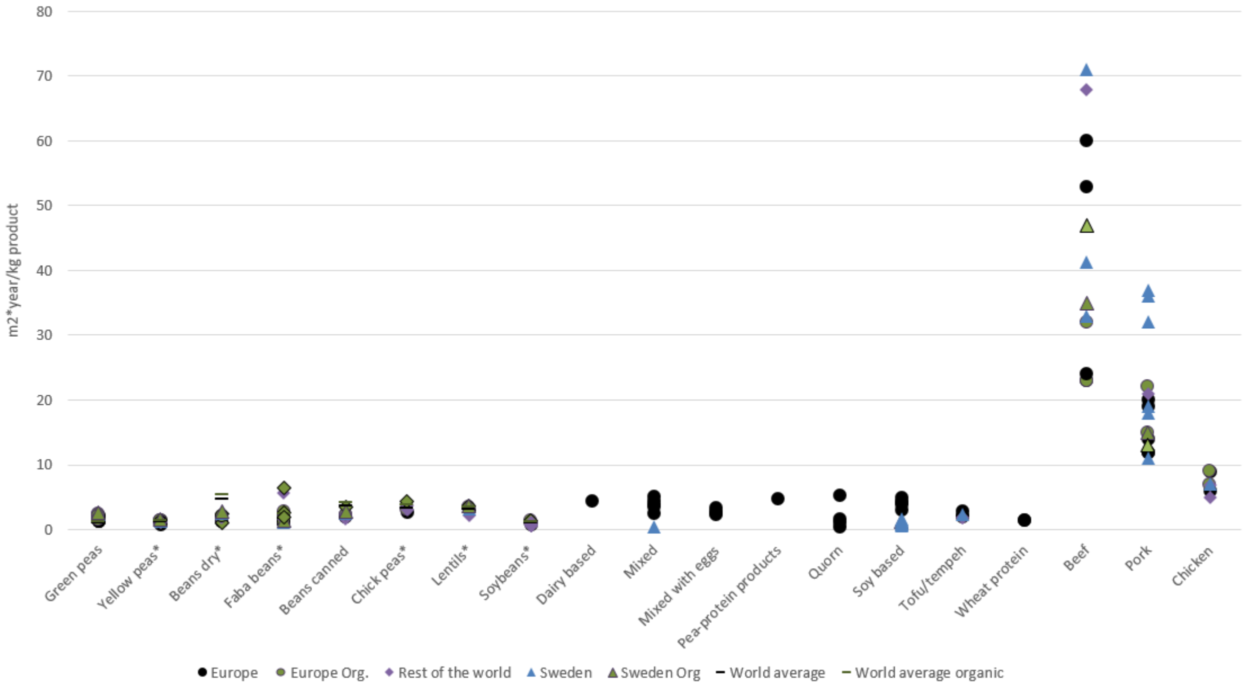

Figure 4. *Land use for vegetable protein sources and meat in m²/year per kg product. *Weight of the product modified to equal 1 kg boiled beans. Note that land use for beef is to varying extents grazing land, and therefore direct comparison to cropland-based products, including plant-based protein sources, pork, and chicken, is difficult.*

3.1.3. Biodiversity impact

Products with relatively high land use and that are imported from countries with high biodiversity such as Lebanon (faba beans) have a high impact on biodiversity. Legumes from the south of Europe, e.g., lentils from Italy, tend to have a higher impact on biodiversity than Swedish produce.

Organic produce has a higher biodiversity impact for all crops assessed, due to higher land use. The lower factor for lower-intensity agriculture in Chaudhary *et al.* (2018) does not compensate for the lower yield of organic produce. However, Chaudhary *et al.* (2018) present gross factors, so this should be interpreted with great care.

Biodiversity impact for Quorn, tofu, and tempeh was calculated using land use data from earlier studies (Figure 3) and by attributing all that land use to the main ingredient in the respective product (glucose from wheat for Quorn, soybeans for tofu and tempeh).

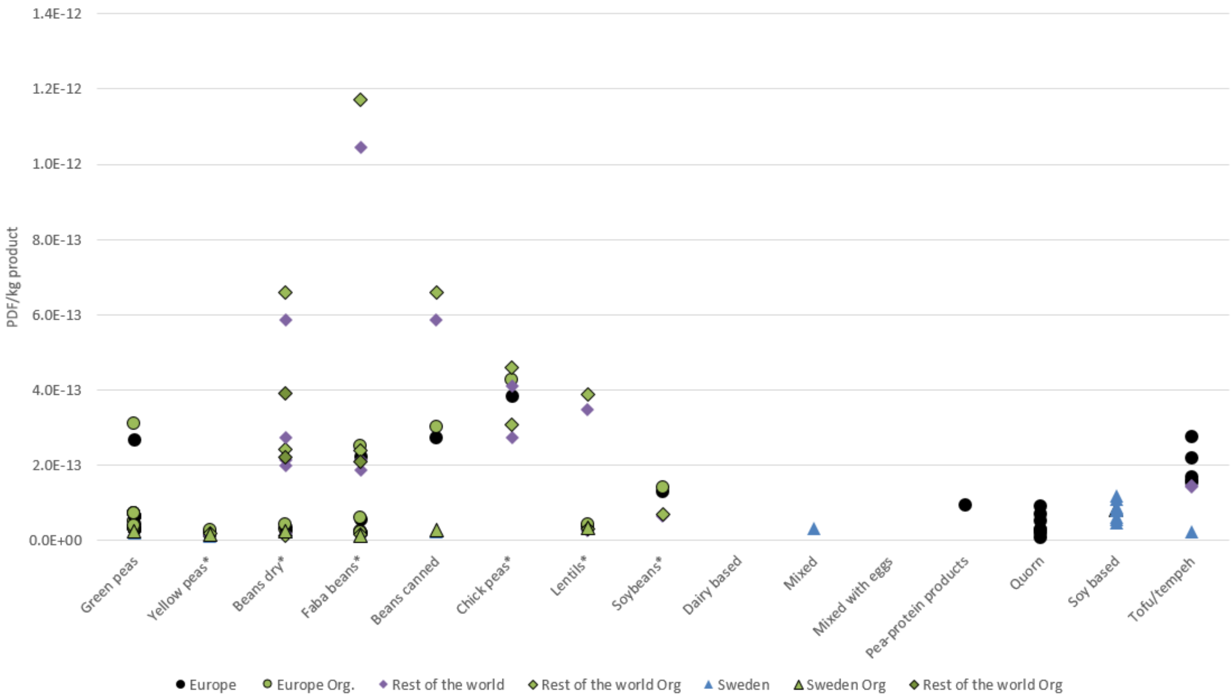

Figure 5. *Biodiversity impact from land use occupation for plant-based protein production. Results presented in PDF (Potentially Disappeared Fraction) per kg product in a store in Sweden. *Weight of the product modified to equal 1 kg boiled beans.*

For comparison, meat was added, with land use values from Röös *et al.* (2015) for beef from Sweden, Ireland, and Germany, and chicken and pork from Sweden (Figure 6). Since livestock in northern European countries are fed domestically grown crops to a large extent, the difference in biodiversity impact between meat- and plant-based food is not as large as for land use (Figure 4). This is because northern European countries have relatively low biodiversity potential. The arrow in Figure 6 represents Swedish beef in comparison with Swedish beans.

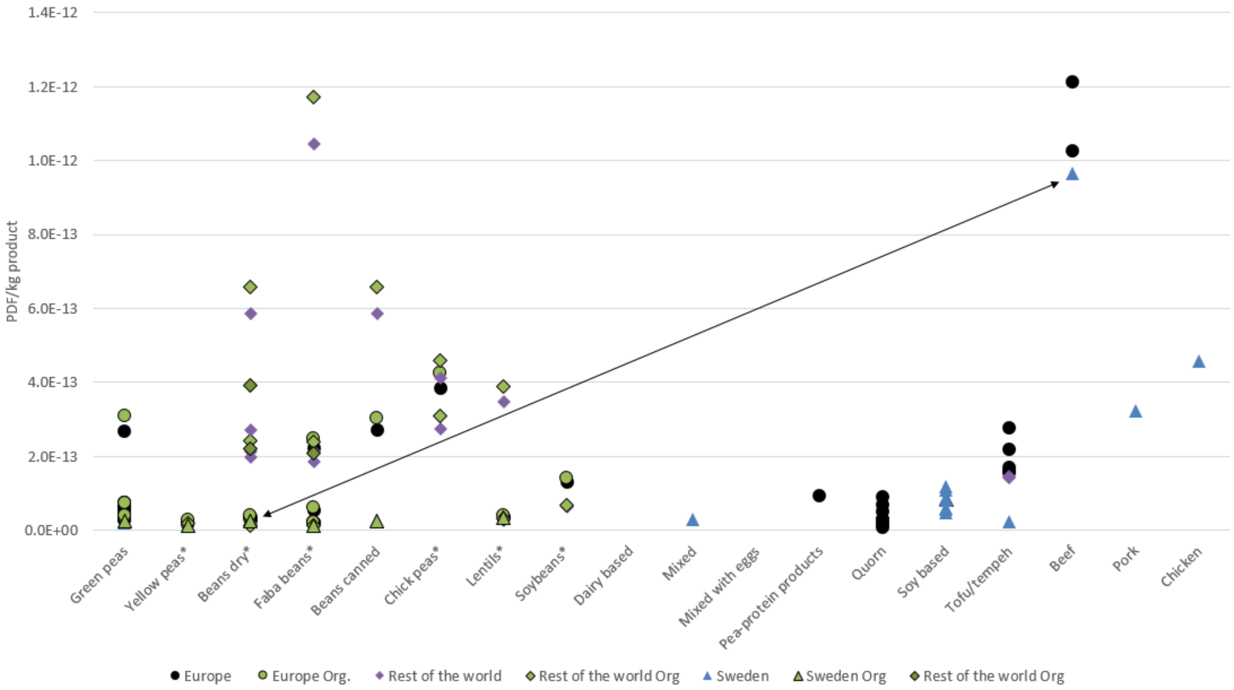

Figure 6. *Biodiversity impact from land use occupation by vegetable protein production and meat production. Results in PDF (Potentially Disappeared Fraction) per kg product. *Weight of the product modified to equal 1 kg boiled beans.*

Table 6. *Range of results for all identified export countries and Swedish produce for land use (m^2/year per functional unit (FU)) and biodiversity impact (Potentially Disappeared Fraction (PDF) per FU) for plant-based protein sources*

Product	**Land use (*m^2/year per FU*)**	**Biodiversity impact (*PDF per FU*)**	**Comment**
Green peas	1.1-2.7	2.1E-14-3.1E-13	Green peas from Sweden, the Netherlands, and Italy have land use of around 2-2.7 m^2 per kg. For all other countries assessed and global average, land use is below 2 m^2 per kg for both conventional and organic.
Yellow peas	0.9-1.6	1.2E-14-2.7E-14	For all export countries assessed, global average and Swedish production land use is below 1.6 m^2 per kg.
Dry beans	1.3-5.4	1.3E-14-6.6E-13	For all export countries assessed except Argentina, land use is below 3 m^2 per kg. World average land use is significantly higher, which indicates a risk of higher land use in other export countries.
Faba beans	1.1-6.5	1.1E-14-1.2E-12	Land use for imports was assessed to be 1.1-6.5 m^2 per kg. Production from Lebanon (16% of Swedish import) has the highest land use. Swedish production has land use of around 1.2-1.4 m^2 per kg (lower values for conventional and higher for organic). The biodiversity assessment showed a risk that faba beans from Lebanon have a high impact on biodiversity from land occupation (close to or above 1.22E-12 PDF).
Beans canned	1.6-4.2	2.3E-14-6.6E-13	According to Swedish import statistics, Sweden imports canned beans mainly from Italy, but the beans could have been processed there (most likely Italy) and then exported to Sweden, i.e., produced in a different country. Beans produced in Italy were assessed to have land use of 2.0-2.3 m^2 per kg products. World average production has a land use of 3.7-4.2 m^2 per kg (lower values for conventional and higher for organic). Due to uncertainties in import statistics, other countries could be relevant, some of which are included in the assessments of dried beans. Swedish beans are likely to have land use of 2.5-2.8 m^2 per kg (lower values for conventional and higher for organic).
Chickpeas	2.8-4.3	2.7E-13-4.6-13	Land use in the export countries assessed and world average varies between 2.8-3.4 (conventional) and 3.2-4.3 (organic) m^2 per kg.

Lentils	2.2-3.6	3.0E-14-3.9E-13	Land use in the export countries assessed and world average varies between 2.2-3.2 (conventional) and 2.5-3.6 (organic) m^2 per kg. Swedish lentils were assessed to have land use of 3.2-3.6 m^2 per kg (lower values for conventional and higher for organic).
Soybeans	0.8-1.2	6.4E-14-1.4E-13	Soybeans are likely to have land use of around 1 m^2 per kg.
Ready-made products			
Mixed	0.4-5.2	2.1E-14	Earlier studies on European products show land use of 2.5-5.2 m^2 per kg (3 references). The Swedish product in the graph is falafel (imported ingredients) with land use of 0.4 m^2 per kg. Biodiversity impact was assessed only for falafel where the origin of all ingredients was known.
Mixed with eggs	2.4-3.4		Earlier studies on European products show land use of 2.4-3.4 m^2 per kg (2 references).
Pea-protein products	4.9	9.4E-14	Only one study was found, showing land use of 4.9m^2 per kg (1 reference).
Quorn	0.2-1.7	7.1E-15-6.9E-14	Quorn is likely to have land use of 0.4-1.7 m^2 per kg. The higher value in the graph is from an older study.
Soy-based	0.6-4.9	4.7E-14-1.2E-13	Land use for soy-based products varies greatly, depending on yield of the soybean (country origin) and other ingredients. Swedish-produced products are mainly produced from soy protein concentrate from imported ingredients. Land use for these products is likely to be around 1-1.5 m^2 per kg. Similar European products are likely to have similar land use, the higher land use in the graph can partly be explained by a different country of origin for the soybeans.
Tofu/tempeh	1.8-3.5	2.3E-14-2.8E-13	Most studies show land use of around 2 m^2 per kg. Swedish tempeh was estimated to have land use of around 2.5 m^2 per kg (4 references).
Wheat protein	1.6	9.4E-14	Only one study was found showing land use of 1.6 m^2 per kg.

3.1.4. Water use

Earlier studies

Blue water use for the different products is shown in Figure 7, with one study on Quorn (Finnigan *et al.*, 2010) removed since a more recent study by the same main author shows much lower results (Finnigan *et al.*, 2017). In all cases shown, blue water use is below 0.5 m^3 per kg product (Figure 7).

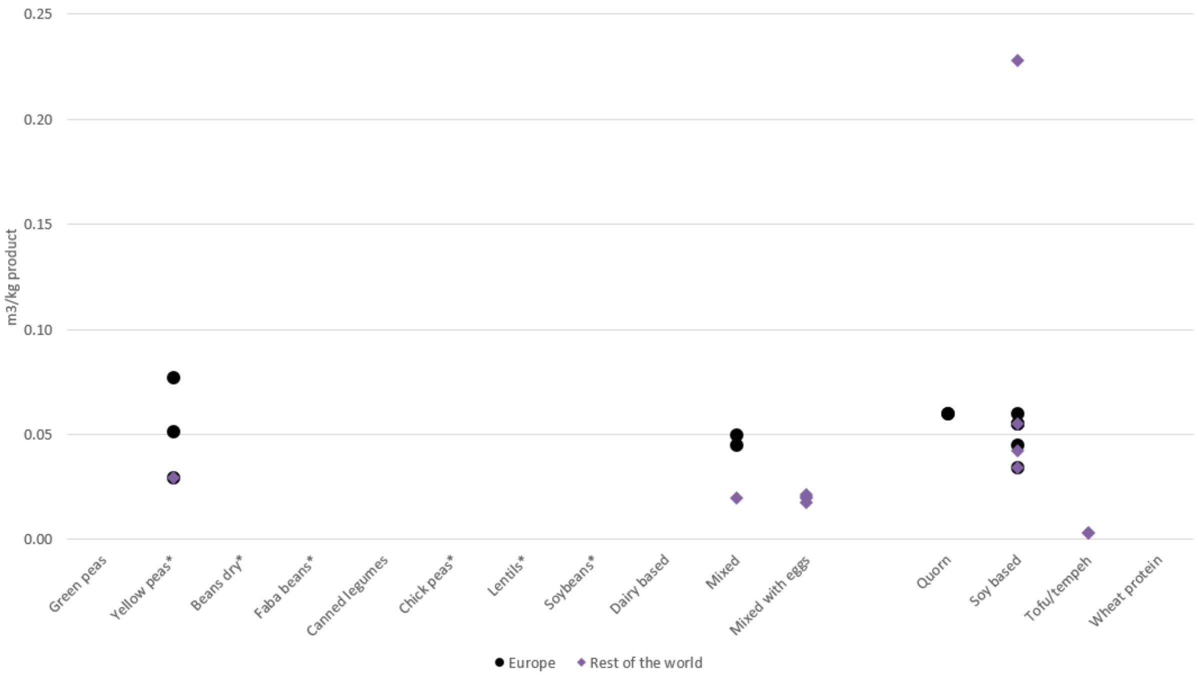

Figure 7. *Blue water use in m^3 per kg product from earlier studies. *Weight of the product modified to equal 1 kg boiled legumes.*

Water footprint, total water use, and AWARE

Total water use (green, blue, grey) for pulses, ready-made meat alternatives, and animal products is shown in Figure 8. Water use for animal products is taken from Mekonnen and Hoekstra (2012) and for crops from Mekonnen *et al.* (2011). Note that soy-based and mixed products shown as Swedish products in the graph (Figure 8) are processed in Sweden, but using raw material from outside Sweden.

Animal products (beef, pork, chicken) have substantially higher total water use. For nearly all products, green water use dominates and products with high land use (animal products) use much more green water. For world average production, animal products also use significant amounts of blue water. The product using the most blue water is irrigated faba beans from Egypt.

Grey water use, calculated as the amount of water needed to dilute the nitrogen fertilizer load to legally acceptable concentrations, is relatively high for legumes, especially dry beans, lentils, chickpeas and faba beans (Mekonnen *et al.*, 2011). This is because of the relatively high nitrogen leaching in relation to the relatively low yield (M. Mekonnen, personal communication 2018). Naturally fixed nitrogen by legumes was not included in the assessment.

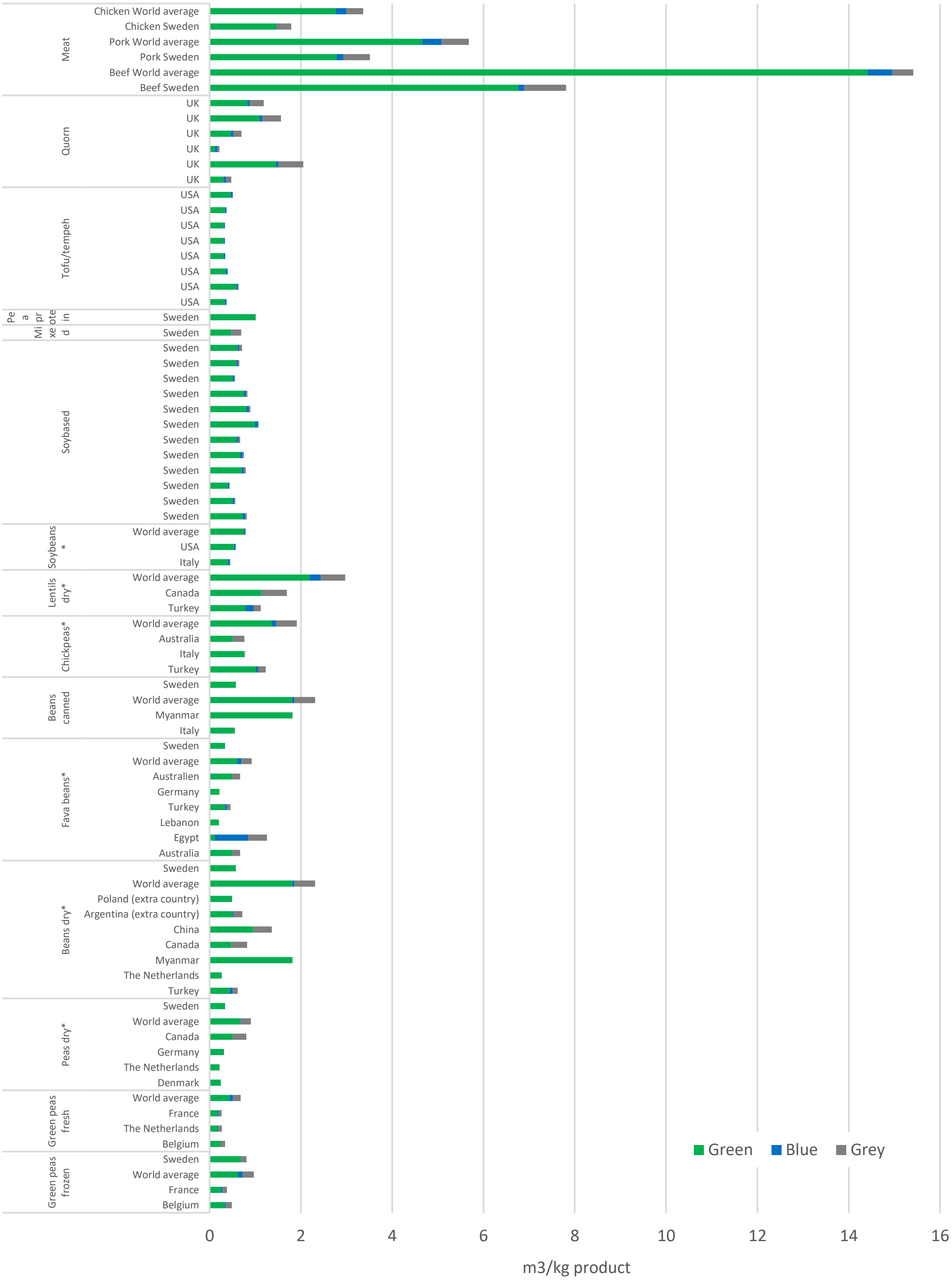

***Figure 8**. Green, blue, and grey water use for the protein sources in m^3 per kg product in a store in Sweden for the identified export countries, and world average water use for comparison.*

Total water use (as in Figure 8) with geographical origin of the vegetarian protein sources is shown in Figure 9.

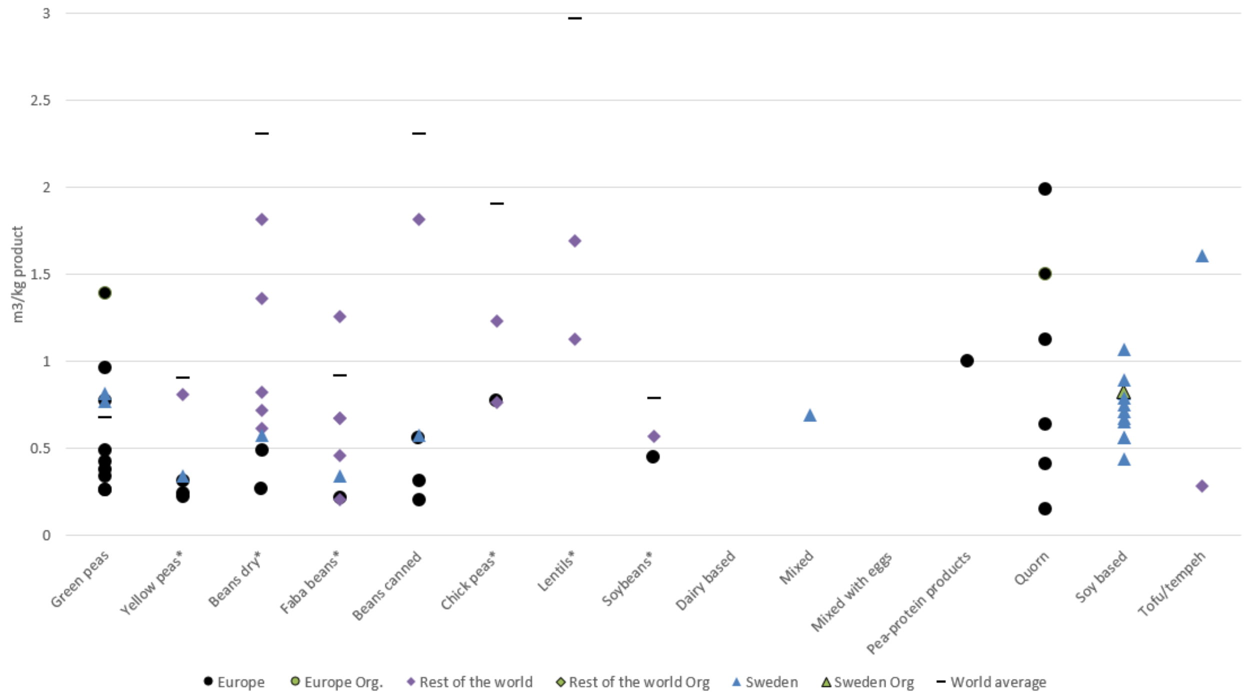

Figure 9. *Total water use (green + blue + grey) in m*^{3} *per kg product in a store in Sweden and world averages. *Weight of the product modified to equal 1 kg boiled beans.*

Applying the AWARE method to assess the impact of the use of blue water on local water availability showed that many of the products have a water footprint close to zero (Figure 10). This is explained by either the products not being irrigated or use of blue water having very little local impact. The product with the highest AWARE score was faba beans from Egypt, due to the high blue water use and the relatively high AWARE score for Egypt, indicating that use of blue water can have a high local impact.

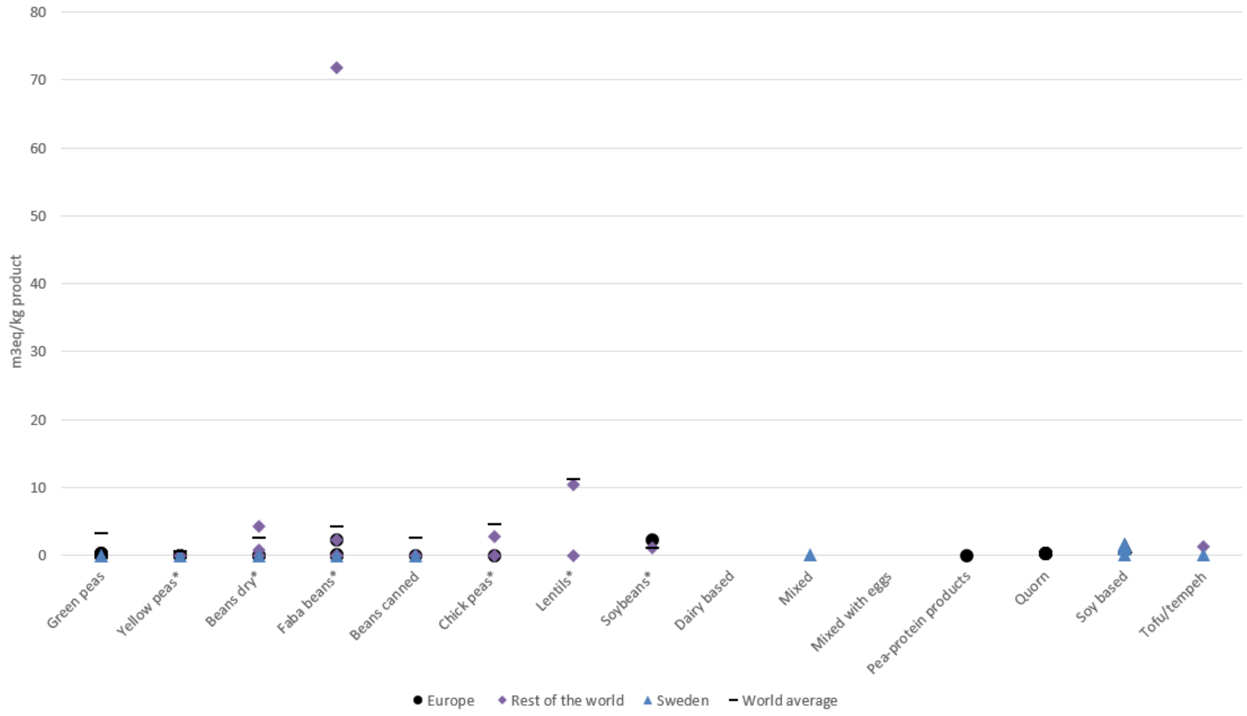

Figure 10. *Water footprint in m*^{3}*eq per kg product in a store in Sweden, estimated using the water scarcity method AWARE (Available Water Remaining).*

In order to assess animal products using AWARE for comparison, it was assumed that all water use takes place in the country of origin, i.e., that all fodder is produced in the same country as the meat, which is a simplification. When including the animal products in the assessment using AWARE, world average animal products have higher impact than all beans and ready-made vegetarian meat alternatives, except for faba beans from Egypt (excluded from the diagram to reveal the differences between the other products) (Figure 11). Swedish meat products have lower impact than some pulses and most of the soy-based meat alternatives (produced in Sweden, but with raw materials from outside Sweden). However, the water footprint of Swedish animal products would likely increase if fodder production from outside Sweden were included, e.g., soybeans from Brazil.

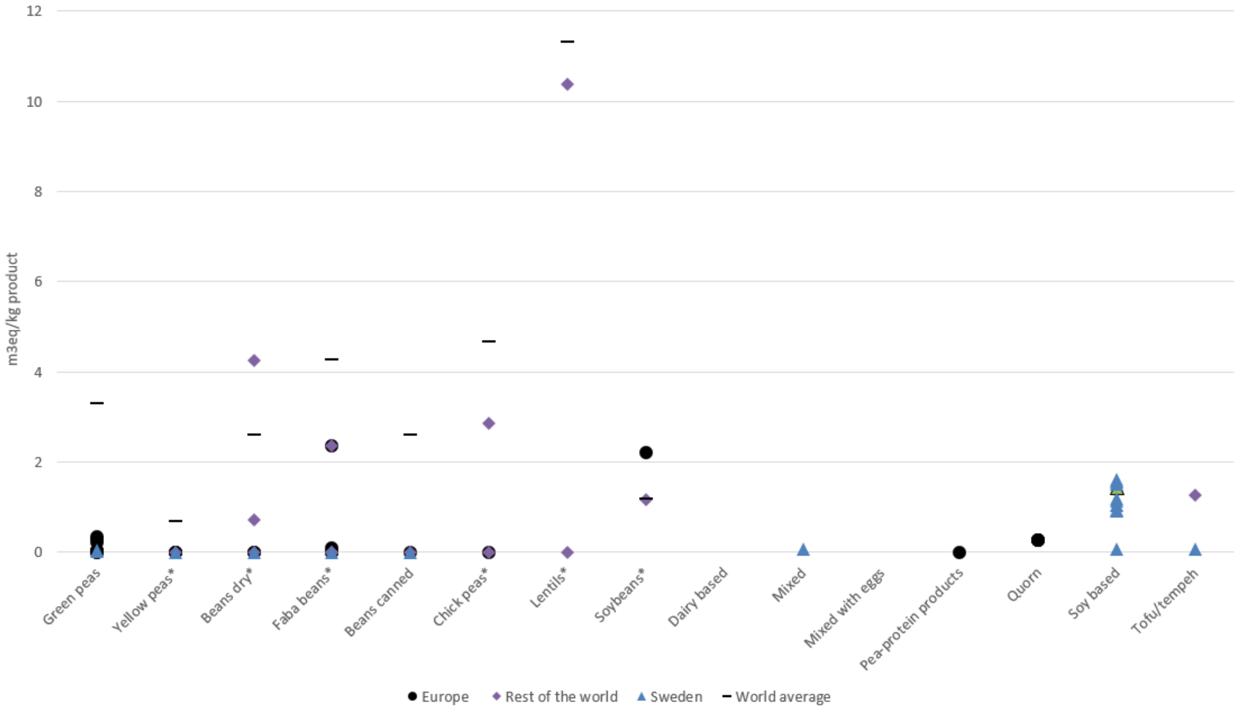

Figure 11. *Water footprint in m^3eq per kg product in a store in Sweden and world averages using the water scarcity method AWARE (Available Water Remaining), including animal products. Faba beans from Egypt are excluded.*

Table 7. *Range of results for all identified export countries and Swedish produce for total water use (m^3 per functional unit (FU)) and AWARE (Available Water Remaining, m^3eq per FU) for plant-based protein sources*

Product	**Total water use (*m^3 per FU*)**	**AWARE (*m^3eq per FU*)**	**Comment**[a]
Green peas	0.3-1.4	0-0.3	Total water use for Swedish production, main export countries, and global average. AWARE figures do not include world average, since it differs considerably from the values for Swedish production and the identified import countries.
Yellow peas	0.2-0.9	0	Yellow peas from Sweden, Denmark, and Germany are likely to have total water use of below 0.3 m^3 per kg product, Canadian and world average production were assessed to have total water use below 0.9 m^3 per kg product. The AWARE value is zero for all identified export countries, since yellow peas are generally not irrigated in these countries. The AWARE figure for global average production is excluded.
Dry beans	0.3-2.3	0-2.3	Swedish, Dutch, Canadian, Argentinean, Polish, and Turkish production has total water use below 1 m^3 per kg product. Beans from China, Myanmar and world average production have water use above 1 m^3 per kg product.
Faba beans	0.2-1.3	0-72	Total water use for faba bean production is mainly below 1 m^3 per kg product, including Swedish production. Except for Egyptian production with 1.3 m^3 per kg product. AWARE figures are generally below 4 m^3eq, the high value (72 m^3eq) is for Egypt.

Beans canned	0.6-2.3	0-2.6	According to Swedish import statistics, Sweden imports canned beans mainly from Italy and Myanmar, but the beans could have been processed elsewhere (most likely Italy) and exported to Sweden, i.e., produced in a different country. Due to uncertainties in import statistics other countries could be relevant, some of which are included in the assessments of dried beans. The highest value is for global average production. European production from Italy and Sweden has the lowest water use.
Chickpeas	0.8-1.9	0-4.7	For total water use, the highest value is for global average production. The lowest water use is for Italy and Australia.
Lentils	1.1-3.0	0-11	Canada, the world's largest producer of lentils, has water use of around 1.7 m^3 per kg product. No data for Swedish lentil production could be found.
Soybeans	0.5-0.8	1.2-2.2	Water use in the main export countries to Sweden (Italy and USA) is relatively similar to world average.
Ready-made products			Water use for many ready-made products is based on assessments made in this study, see Appendix A3.
Mixed	0.7	0.07	For falafel, water use is approx. 0.7 m^3 per kg product.
Mixed with eggs			No data.
Pea-protein products	1.0	0.0002	Water use estimated to be 1 m^3 per kg product.
Quorn	0.4-2.0	0.28	
Soy-based	0.4-1.1	0.1-1.6	Total water use for soy-based products produced in Sweden from mainly imported ingredients is 0.4-1.1 m^3 per kg product.
Tofu/tempeh	0.3-1.6	0.1-1.3	Total water use was estimated to be 0.3-1.6 0.4-1.2 m^3 per kg product.
Wheat protein			No data

[a] Comments included when applicable.

3.2. Nuts and seeds

3.2.1. Climate impact

Climate impact for nuts and seeds is presented in Figure 12. Most studies show a climate impact of below 4 kg CO_2e per kg product. The two studies on peanuts that show significantly higher impact (15.6 and 27.3 kg CO_2e per kg products) are on peanuts from Uganda and Sudan, respectively. Most of this impact is from LUC (Agri-footprint, 2018). According to Swedish import statistics, Sweden does not import peanuts from those two countries (SS, 2018). These two studies were therefore considered to be of low relevance for the Swedish market and not included in the final assessment (Table 8).

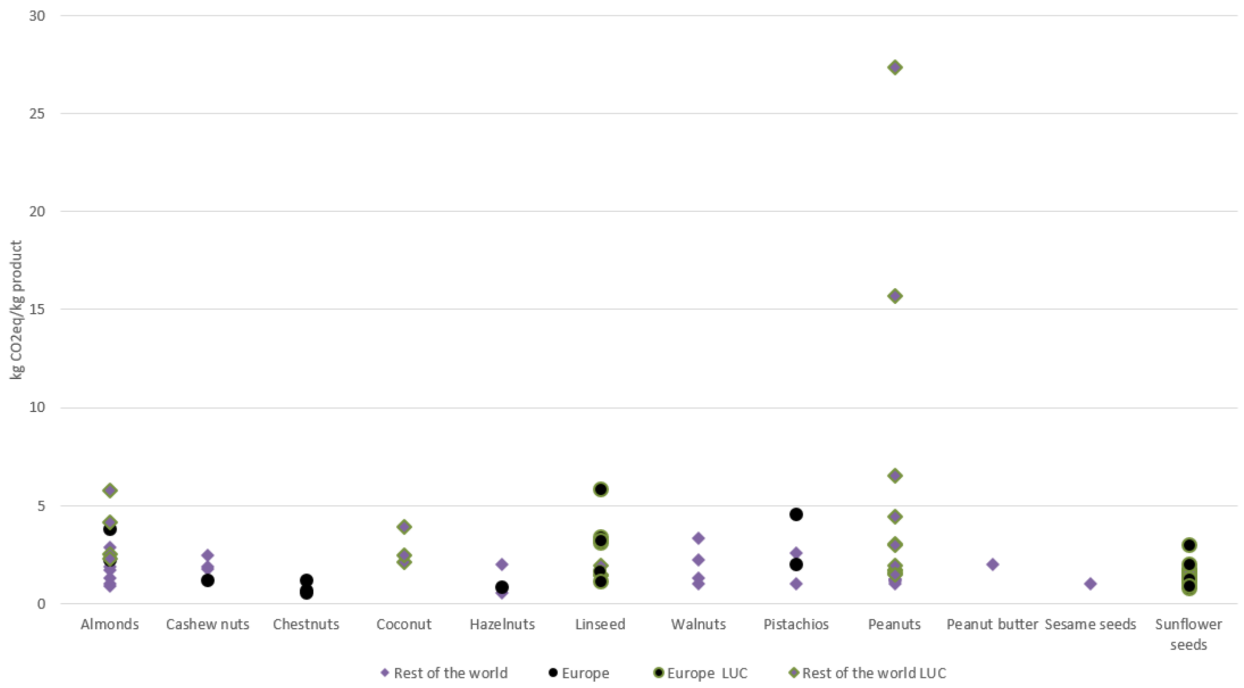

Figure 12. *Climate impact of nuts and seeds. Functional unit 1 kg nuts and seeds without shells at a Swedish retailer. A green symbol border indicates that land use change (LUC) is included in the climate impact assessments. Note that the graph shows the climate impact from all identified earlier studies for this product group, and not only those identified as relevant for the Swedish market. The final assessment in Table 8 is based on relevance for the Swedish market.*

For almonds, two studies show higher impact than 4 CO_2e per kg product, namely the data for the global market average and “rest of the world” from the ecoinvent database. This is mainly due to energy use for irrigation (Wernet *et al.*, 2016). Sweden mainly imports almonds from the USA (55%), but also from Argentina and Spain (SS, 2018). There are several studies on almonds produced in the USA (Kendall & Brodt, 2014; Marvinney *et al.*, 2014; Venkat, 2012), all showing a climate impact below 4 kg CO_2e per kg product (0.9-2.9 kg CO_2e per kg product).

For studies on linseeds, a climate impact lower than 4 kg CO_2e per kg product is reported in all but one case, Agri-footprint data on linseeds from Italy, where the majority of the impact is from LUC (Agri-footprint, 2018). Around 9% of the linseeds imported to Sweden are from Italy, while the majority come from Denmark (42%). For pistachios, one study on pistachios from Greece reports a higher impact than 4 kg CO_2e per kg product (Bartzas *et al.*, 2017). This could be explained by the functional unit used; in that study the functional unit was nuts in shell, which was converted here to shelled nuts without allocating any impact to the shells. Further, the yield in the study by Bartzas *et al.* (2017) was rather low. According to trade statistics, Sweden did not import pistachios from Greece during the past five years (SS, 2018). The data on pistachios from Volpe *et al.* (2015) are based on Marvinney *et al.* (2014), and therefore Volpe *et al*. (2015) was excluded from the recommendation. For peanuts, two studies show a higher impact than 4 kg CO_2e per kg product, both on peanuts produced in Argentina where direct LUC is the most important contributor to the climate change impact (Agri-footprint, 2018; Wernet *et al.*, 2016). According to import statistics, Sweden imports 37% of its peanuts from Argentina (SS, 2018).

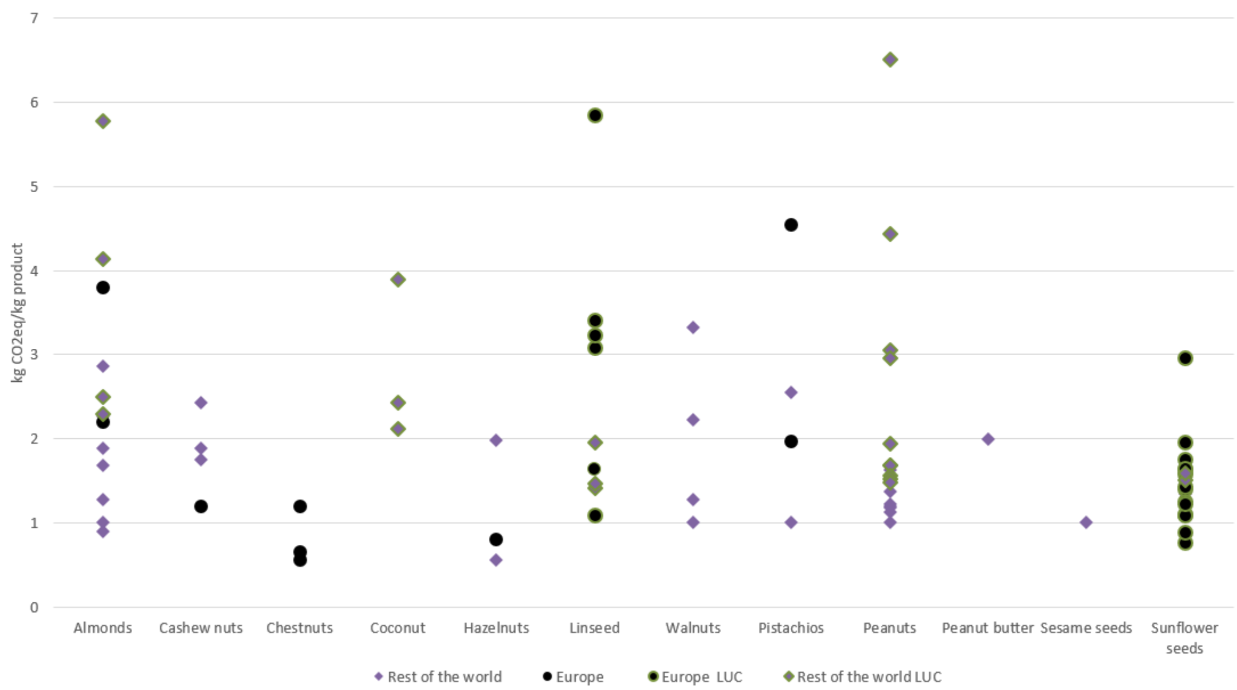

Figure 13. *Climate impact of nuts and seeds (excluding peanuts from Sudan and Uganda). Functional unit 1 kg packaged nuts and seeds without shell in a store in Sweden. A green symbol border indicates that land use change (LUC) is included in the climate impact assessment. Note that the graph shows the climate impact from all identified earlier studies for this product group, and not only those identified as relevant for the Swedish market. The final assessment in Table 8 is based on relevance for the Swedish market.*

Table 8. *Final assessment of climate impact of nuts and seeds on the Swedish market*

Product	**Final assessment (kg CO$_2$e per kg product in a Swedish store)**		**No. of relevant references**	**Total no. of references**	**Comment**
	General	**Sweden**			
Almonds	3.8		10	9	Data on almonds from the USA and Europe considered most relevant for the Swedish market. Rest of the world data and global market data from Ecoinvent not considered in the final assessment.
Cashew nuts	2.4		3	3	All identified studies considered relevant for the Swedish market.
Chestnuts	1.2		2	2	The recommendation is for European chestnuts. No data were found for “rest of the world”.
Coconut (grated)	2.4		1	1	This study considered relevant for the Swedish market.
Hazelnuts	2.0		3	3	All identified studies considered relevant for the Swedish market. The assessment is based on two studies on “rest of the world” production and one study on European hazelnuts showing a climate impact of 0.8 kg CO$_2$e per kg.
Linseeds	3.4		1	1	European production considered relevant for the Swedish market. The differences in the results can partly be explained by inclusion of LUC (1 reference)
Walnuts	3.3		4	4	Two studies are on production in USA, which is highly relevant for the Swedish market. The other two studies are on “rest of the world” production, i.e., country not specified. However, all four studies were considered relevant for the Swedish market.
Pistachios	2.6		2	4	Based on import statistics, pistachio nut production in the USA considered most relevant for the Swedish market.

Peanuts	1.8			Differences in the results can partly be explained by inclusion of LUC in some studies. Without LUC, most studies show a climate impact below 1.8 kg CO_2 per kg product. Climate impact, including LUC of peanuts from Argentina, Sudan, and Uganda, is likely to be above 4 kg CO_2eq per kg product. Imports from Argentina are relevant for the Swedish market (6 references).
Sesame seeds	1.0	1	1	The recommendation is based on only one study and is therefore uncertain.
Sunflower seeds	1.8			Differences in the results can partly be explained by inclusion of LUC in some studies. The studies that did not include LUC show results below 1.8 kg CO_2e per kg product. In total, all but one study show a climate impact below 2 kg CO_2e per kg product, even when LUC is included (5 references).

3.2.2. Land use

Overall, nuts and seeds were found to have higher land use than the other product groups. This is due to relatively low yield of shelled nuts and seeds (edible). However, it is important to note that nuts and seeds are generally high in energy and valuable macro- and micronutrients. This is not reflected in the results when the functional unit 1 kg product is used. See Appendix A4 for a discussion on functional unit and the use of nutrient indices.

Earlier studies

Earlier studies provide limited data on land use for nuts and seeds, with the exception of sunflower seeds and peanuts. The highest land use was found for cashew nuts from production outside Europe (Blonk *et al.*, 2008). Peanuts from India also show fairly high land use (Wernet *et al.*, 2016).

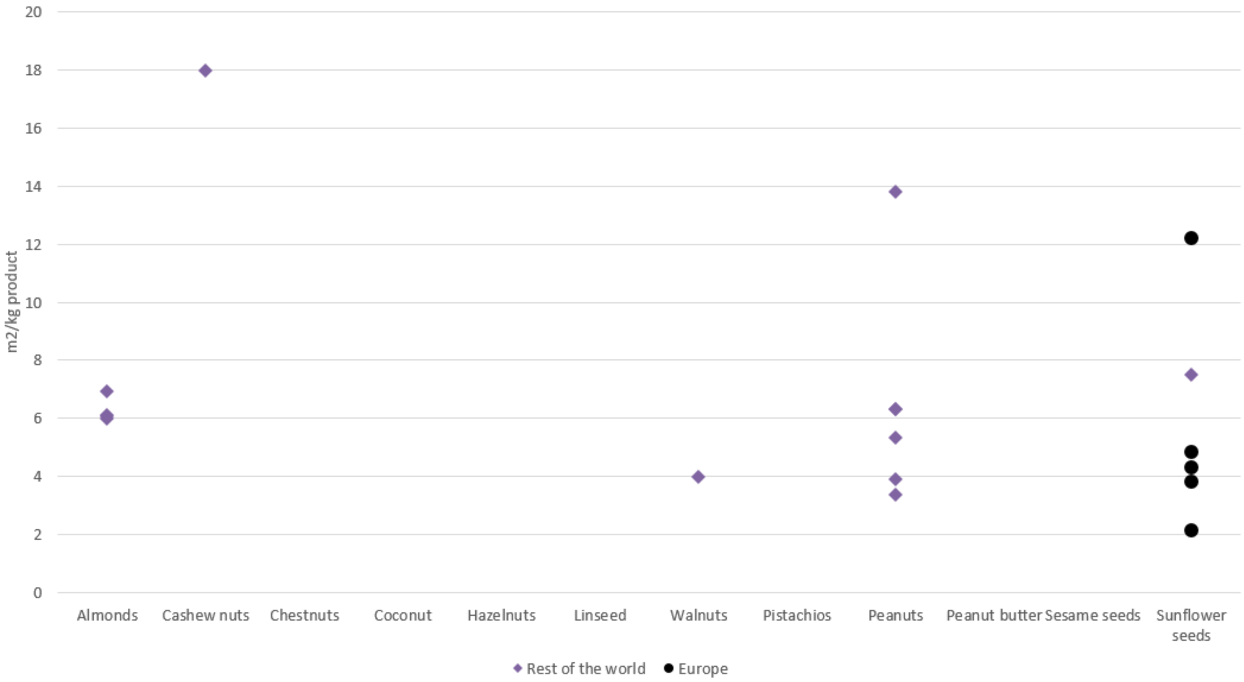

Figure 14. *Land use for nuts (shelled) and seeds from earlier studies, in m^2 per kg product.*

Calculations of land use

Land use for almonds imported to Sweden varies greatly, with notably high land use of above 50 m^2 per kg product for Spanish almonds. Although Spain is a large producer globally, Spanish almond production has variable yield, and in dry areas and on smaller farms the yield can be low (FAO, year unknown). Around 10% of the almonds imported to Sweden during the past five years came from Spain (SS, 2018). Spain is the second largest producer of almonds globally, while the USA is the largest producer and dominates the global market for almonds (FAOSTAT, 2019). Almond production in the USA (which accounts for around 55% of Swedish imports) has significantly higher yields (almost six-fold higher than in Spain) (FAOSTAT, 2019). Italy is another European producer of almonds with fairly large production globally and Italian yields are 3.6-fold higher than Spanish yields (FAOSTAT, 2019), indicating that European almond production does not have to be associated with such high land use as Spanish almond production. Almond production in Turkey and Greece produces similar yields to that in the USA (FAOSTAT, 2019).

Cashew nuts from Brazil were estimated to have very high land use (above 300 m^2 per kg product). Brazil was not identified as one of the main export countries to Sweden, but was added as an extra country due to relatively high total exports. The main exporter to Sweden and the main exporter globally was found to be Vietnam. Global average land use for cashew nuts is much higher than the land use for nuts from Vietnam in the one previous study on cashew nuts that included land use (Blonk *et al.*, 2008). The global average yield is around six-fold lower than the yield in Vietnam. This indicates that land use for cashews can differ widely depending on country of origin.

Linseeds from Denmark have land use of around 35 m^2 per kg product. Swedish linseed production is associated with much lower land use, around 6-7 m^2 per kg product (the higher value is for organic production). Considering the similarities between the two countries in climate conditions and the agricultural sector, this difference in yield is somewhat suspicious. Denmark has rather limited production of linseeds, 107 hectares in 2017, no linseed cultivation in 2018, and 831 hectares in 2019 (StatisticsDenmark, 2020). The linseeds imported from Denmark may therefore originate from other countries. Denmark was not considered to be an important producer for the Swedish market in the final assessment.

Notably, only one product has land use below 2 m^2 per kg product, namely chestnuts from China. Sesame seeds from India, which represent 32% of Swedish imports during the past five years, have land use of around 20-25 m^2 per kg product.

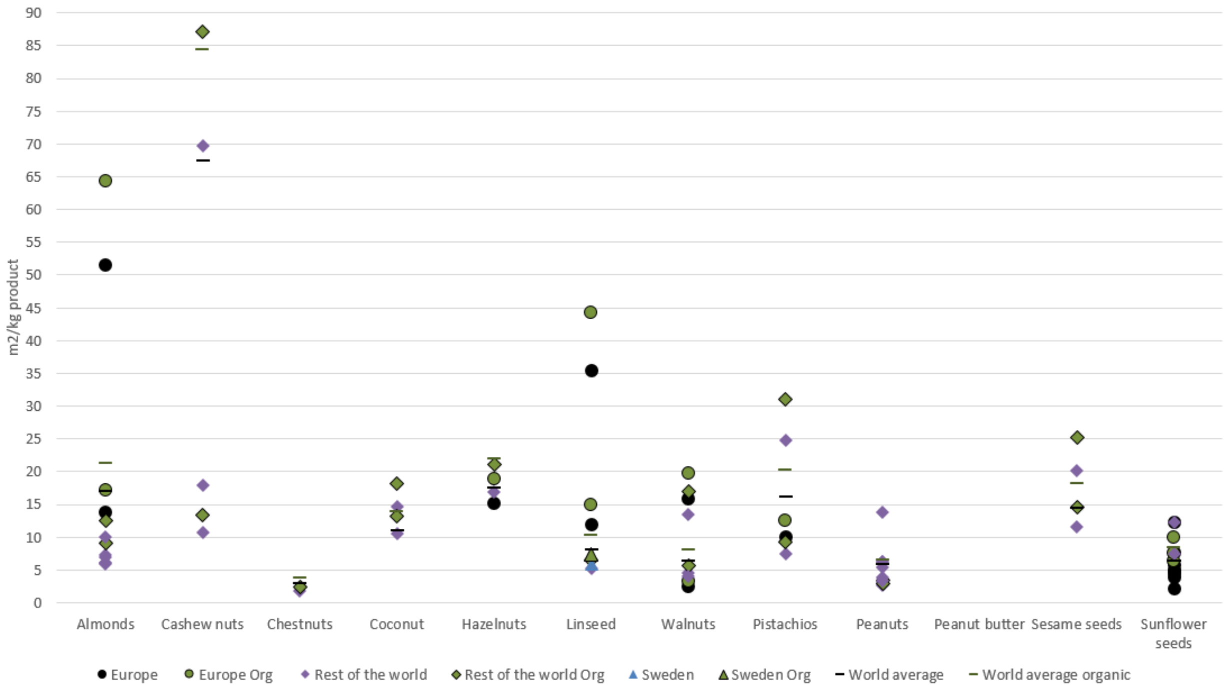

Figure 15. *Earlier studies and own assessments on land use for shelled nuts and seeds in m*^{2} *per kg product. Cashew nuts from Brazil are excluded from the graph, but land use for these was estimated to be 305 and 380 m*^{2} *per kg nuts without shells for conventional and organic production, respectively.*

3.2.3. Biodiversity

In general, impacts on biodiversity are higher for nuts and seeds than for the other food categories studied. This is partly due to the relatively high land use (due to low yields per hectare) and partly to many of these products being imported from countries with high biodiversity values, i.e., high species richness and high degree of indigenous species, such as Indonesia and the Philippines (Pimm *et al.*, 1995), which were identified as export countries for coconuts.

The highest biodiversity impacts were found for almonds from Spain, cashews from Brazil, India, and Vietnam, coconuts from Philippines and Sri Lanka, walnuts from Mexico, and sesame seeds from India (Figure 16). Results for coconut are for grated coconut.

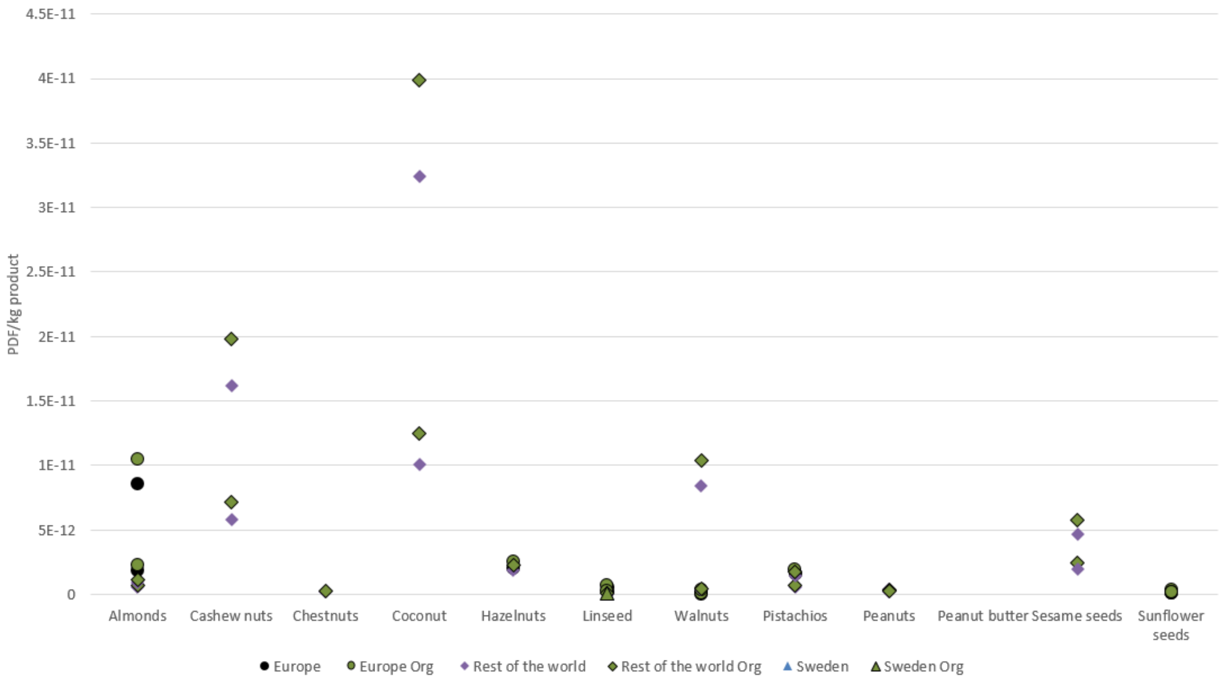

Figure 16. *Biodiversity impact from land use occupation from nuts and seeds in PDF (Potentially Disappeared Fraction) per kg product in a store in Sweden. Cashew nuts from Brazil are excluded from the graph.*

Table 9. *Range of results for all identified export countries and Swedish produce for land use (m^2/year per functional unit (FU) and biodiversity impact (Potentially Disappeared Fraction (PDF) per FU) for nuts and seeds*

Product	**Land use *(m^2/year per FU)***	**Biodiversity impact *(PDF per FU)***	**Comments**
Almonds	5.0-64	5.7E-13-2.3E-12	Almonds from the USA dominate Swedish imports (55%), and their land use was assessed to be around 8 m^2 per kg. There is a risk of higher land use for almonds imported from some countries. Figures for global average production show land use of approx. 17-21 m^2 per kg (lower values for conventional and higher for organic). Spanish production was assessed as having particularly high land use of 52-64 m^2 per kg (lower values for conventional and higher for organic).
Cashew nuts	11-380	5.8E-12-9.3E-11	There is a risk of high land use for cashew nuts imported from some countries. Vietnam is the main exporter to Sweden, with land use of 11-13 m^2 per kg (lower values for conventional and higher for organic). Global average land use is high, approx. 68-84 m^2 per kg (lower values for conventional and higher for organic). Brazilian production shows particularly high land use (above 300 m^2 per kg). Brazil was added as an extra country (see section 2.2). It is unknown why Brazil has such high land use and uncertain whether this production is relevant for the Swedish market. The highest biodiversity scores were found for Brazil and India.
Coconut (grated)	9.7-18	1.0E-11-4E-11	Around 2.0-3.7 m^2 per kg. Biodiversity scores are relatively high (compared with most other products assessed in this product group) for all export countries assessed (Philippines, Indonesia, Sri Lanka).
Chestnuts	1.9-3.8	9.6E-14-9.7E-14	China was identified as the main exporter. Land use was assessed to be 1.9 m^2 per kg for conventional production and 2.3 m^2 per kg for organic. Global average was estimated to be higher.
Hazelnuts	15-21	1.8E-12-2.2E-12	Italy and Turkey were identified as main export countries to Sweden. Land use in these countries is similar, but somewhat lower than the global average.
Linseeds	5.2-14.9	5.6E-14-6.6E-13	Land use for imported linseeds varies between 5.2-35.4 (conventional) and 6.4-44 (organic) m^2 per kg. Data on Danish linseeds are questionable due to the sharp difference between similar countries such as Sweden and the Netherlands, and Denmark was excluded due to low production. Swedish linseeds were assessed to have land use of 5.9-7.4 m^2 per kg (lower values for conventional and higher for organic).

Walnuts	2.6-20	5.4E-14-1.0E-11	Land use varies between 2.6 and 20 m^2 per kg. The USA was identified as the main exporter to Sweden, with land use of 4.5-5.6 m^2 per kg (lower values for conventional and higher for organic). The highest scores for biodiversity impact were found for Mexico, which was added as an extra country (see section 2.2).
Pistachios	7.4-31	5.8E-13-1.9E-12	Pistachios are mainly imported from the USA, with land use estimated to be 7.4-9.2 m^2 per kg (lower values for conventional and higher for organic). The highest land use was found for Iran (extra country, see section 2.2).
Peanuts	3.1-8.4	2.5E-13-1.9E-12	Sweden mainly imports from Argentina and China, with higher yields than the global average.
Sesame seeds	4.7-25	2.0E-12-7.2E-12	Sesame seeds from the largest exporter to Sweden, India, have land use of approx. 20-25 m^2 per kg (lower values for conventional and higher for organic). The highest biodiversity impact was found for Guatemala, which was identified as one of the main export countries to Sweden.
Sunflower seeds	4.9-10	1.0E-13-3.9E-13	Mainly imported to Sweden from European countries. Land use varies between 5-8 (conventional) and 6-10 (organic) m^2 per kg.

3.2.4. Water use

Earlier studies

Figure 17 shows the results for blue water use for nuts and seeds. Almond production is known to be water-intensive, which is confirmed by the results from earlier studies. The highest blue water use for almonds was found for almonds produced in the USA, 13 m^3 per kg almonds (Marvinney *et al.*, 2014), but lower water use of around 5.3 m^3 per kg almonds is reported in one study on USA production (Fulton *et al.*, 2018). The lower values for almonds represent production in China (Wernet *et al.*, 2016).

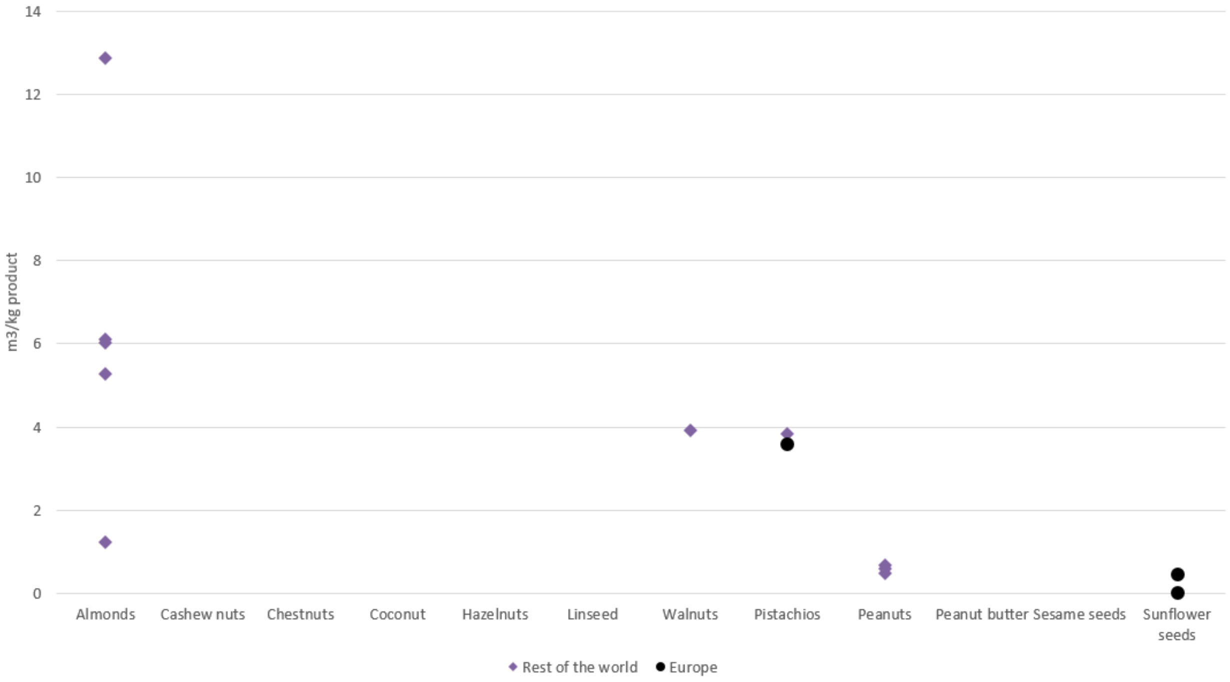

Figure 17. *Blue water use for nuts (shelled) and seeds from earlier studies, in m^3 per kg product.*

Water footprint, total water use, and AWARE

Almonds from Spain and cashew nuts from Brazil have the highest total water use, above 30 m^3 per kg product. The majority of this water is green water use and can partly be explained by the low yield in both cases. The USA was identified as an exporter of nuts to Sweden, particularly almonds, pistachio nuts, and walnuts. Walnuts and almonds from the USA seem to have similar water use, while pistachios from the USA have lower total water use. Grey water use for almonds and walnuts produced in the USA is notably high, which indicates high nitrogen fertilizer application rates. Sesame seeds from India show high green water use. Pistachios from Iran have high total water use (22 m^3 per kg product), mostly blue water (Mekonnen *et al.*, 2011). Iran is the largest producer globally of pistachios, but is not among the main exporters (FAOSTAT, 2019), indicating high domestic consumption.

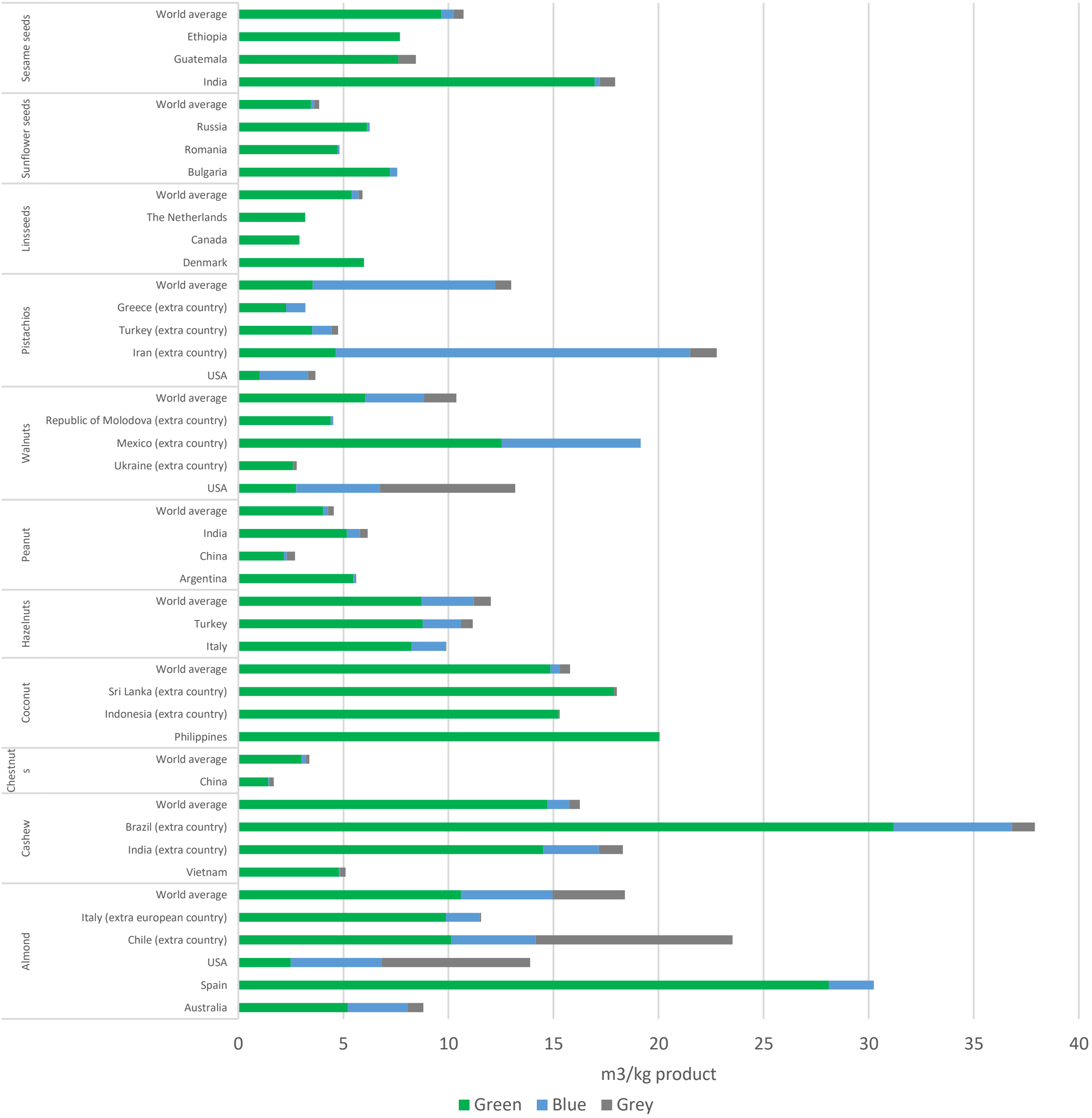

Figure 18. *Total water use, divided into green, blue, and grey water use, for nuts (shelled) and seeds, in* m^3 *per kg product in a store in Sweden, for the identified export countries, and world average water use for comparison.*

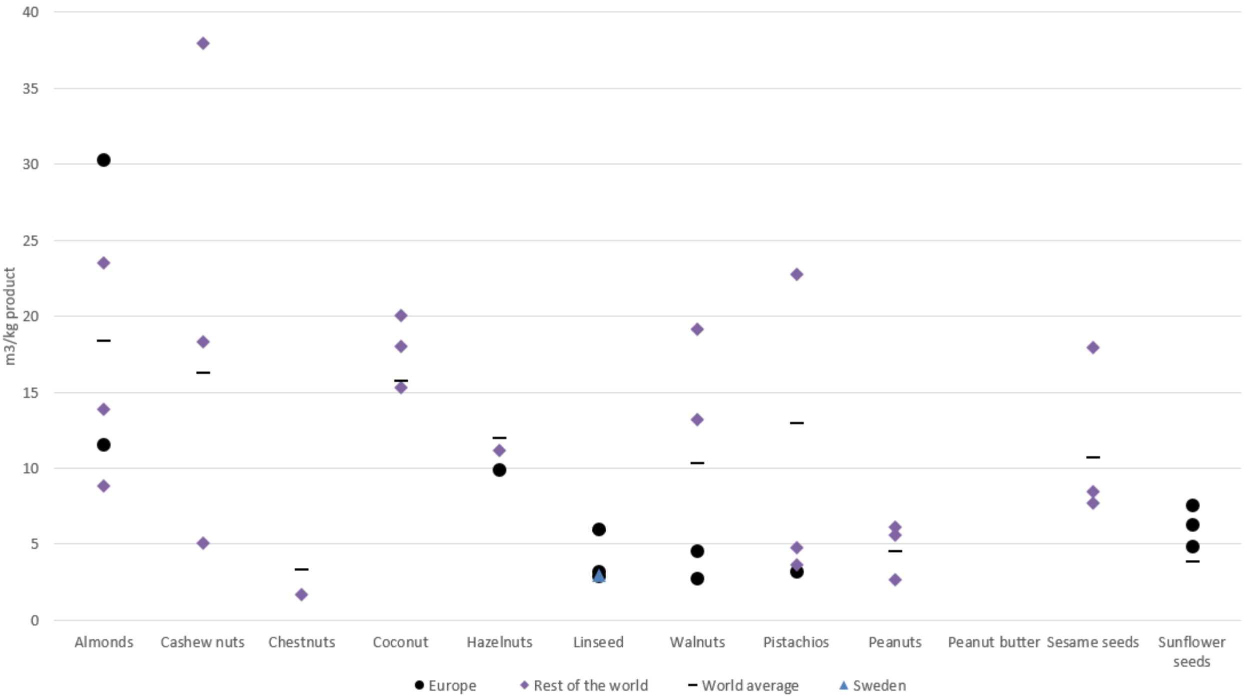

Figure 19. *Total water use (sum of green, blue, and grey water use) for nuts (shelled) and seeds in m^3 per kg product in a store in Sweden and world averages.*

Results from the assessment using AWARE are shown in Figure 20. The results for pistachio nuts from Iran are removed from the graph, to reveal the details of the other data points. AWARE results for pistachios from Iran are much higher than for other countries, due to high use of blue water and high AWARE characterization factor for Iran. Almonds from all assessed import countries score relatively high when assessed with AWARE, as do walnuts and pistachios from the USA due to high irrigation of these crops. Cashews from Brazil have the highest AWARE score, due to use of blue water. Cashews from Vietnam are sparsely irrigated compared with other nuts (52 m^3 per ton cashews), but world average water use for cashews is around 920 m^3 per ton (Mekonnen *et al.*, 2011), so the global average AWARE score for cashews is higher than that for Vietnam. The hazelnuts with the highest AWARE score are hazelnuts from Turkey.

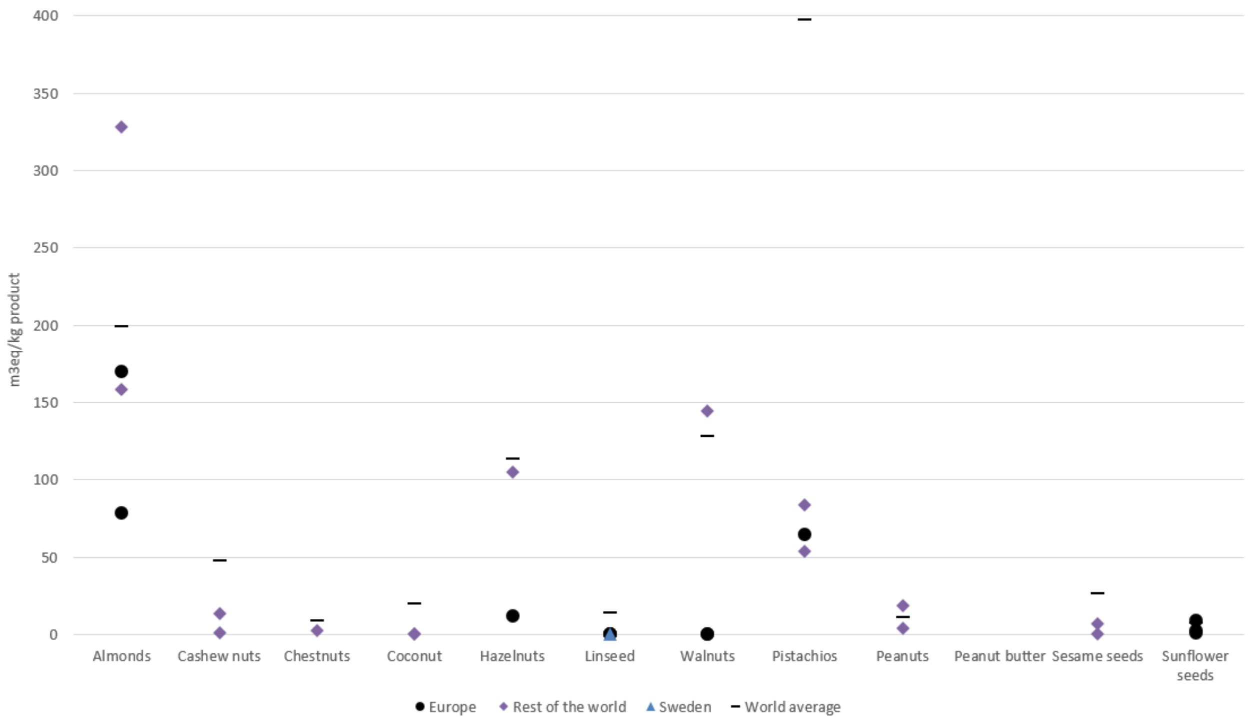

Figure 20. *Water use for nuts and seeds, assessed with the water scarcity method AWARE (Available Water Remaining, m^{3}eq per kg product) in a store in Sweden, and world averages. Pistachio nuts from Iran are excluded from the graph, as their AWARE impact is above 1000 m^{3}eq per kg product.*

Table 10*. Range of results for all identified export countries and Swedish produce for total water use (m^3 per functional unit (FU)) and AWARE (Available Water Remaining, m^{3}eq per FU) for nuts (shelled) and seeds*

Product	**Total water use *(m^3 per FU)***	**AWARE *(m^{3}eq per FU)***	**Comments[a]**
Almonds	9-30	78-330	Total water use differs greatly between export countries, global average is intermediate. AWARE scores highest for Australia and Chile.
Cashew nuts	5-38	1-79	Total water use differs greatly between export countries, global average is intermediate. AWARE score highest for India.
Chestnuts	2-3	3-9	
Coconuts	15-20	0-21	Highest AWARE score found for global average production.
Hazelnuts	10-12	78-110	Total water use in main export countries to Sweden (Italy and Turkey) and global average is similar.
Linseeds	3-6	0.3-14	Not irrigated in the three identified export countries (Denmark, Netherlands, Canada), so AWARE scores are generally low. Highest AWARE score found for global average production.
Walnuts	3-19	0-230	The largest exporter to Sweden, USA, was found to have an AWARE score of 140 m^{3}eq per kg product.
Pistachios	3-23	54-1130	The USA, the main export country to Sweden, has water use of 3.7 m^3 per kg product. Highest AWARE score found for Iran.
Peanuts	3-6	4-18	Total water use in the main export countries (Argentina, China, India) is similar to the global average.
Sesame seeds	8-18	0-27	Water use in the main export country to Sweden (India) was estimated to be higher than the global average water use for sesame seeds.
Sunflower seeds	4-8	1-9	

[a]Comments included when applicable.

3.3. Carbohydrate sources

3.3.1. Climate impact

For barley, corn, millet, oats, rye, and wheat, the majority of the literature data show a climate impact below 0.7 kg CO_2e per kg edible product. A study on Australian corn (Maraseni *et al.*, 2010) was considered less relevant for the Swedish market. The identified export countries to the Swedish market were France and Poland (SS, 2018), and South Africa was identified as the country with the largest trade surplus of corn (FAOSTAT, 2019). Corn from South Africa has the second highest impact, around 0.7 kg CO_2e per kg edible product, primarily due to the longer transport (0.4 kg CO_2e per kg from transport). Data for primary production of South African corn were taken from Agri-footprint (2018).

Two studies were found on quinoa, one scientific article (Cancino-Espinoza *et al.*, 2018) and one company report (Alter eco, 2012). The highest climate impact for quinoa was found for dark quinoa, with around 0.9 kg CO_2e per kg edible product (Alter eco, 2012). Rice has a higher climate impact than the other cereals, but with large variation in the results. The higher climate impact is mainly due to the methane emissions during wet rice cultivation. The large variation in results may be due to actual variation in production methods and sites, combined with different methods to estimate methane emissions (see e.g., Thanawong *et al.* (2014)). Data on European rice production were taken from two studies (Kägi *et al.*, 2010; Blengini & Busto, 2009).

All root vegetables have a climate impact below 0.5 kg CO_2e per kg product, with the exception of beetroot transported from Australia (Maraseni *et al.*, 2010), sweet potato transported from Korea (So *et al.*, 2010), and frozen Jerusalem artichoke (lower value for fresh) (Landqvist & Woodhouse, 2015). The study by Landqvist and Woodhouse (2015) on fresh and frozen Swedish products (carrots, swedes, Jerusalem artichoke, parsnip) showed that processing and freezing doubles the climate impact of these root vegetables. When comparing fresh and frozen products, it is important to note that the frozen products have been cleaned, blanched, and frozen, which could potentially reduce energy use and waste in the household. Further, root vegetables have a low climate impact in both cases (fresh and frozen) compared with other products.

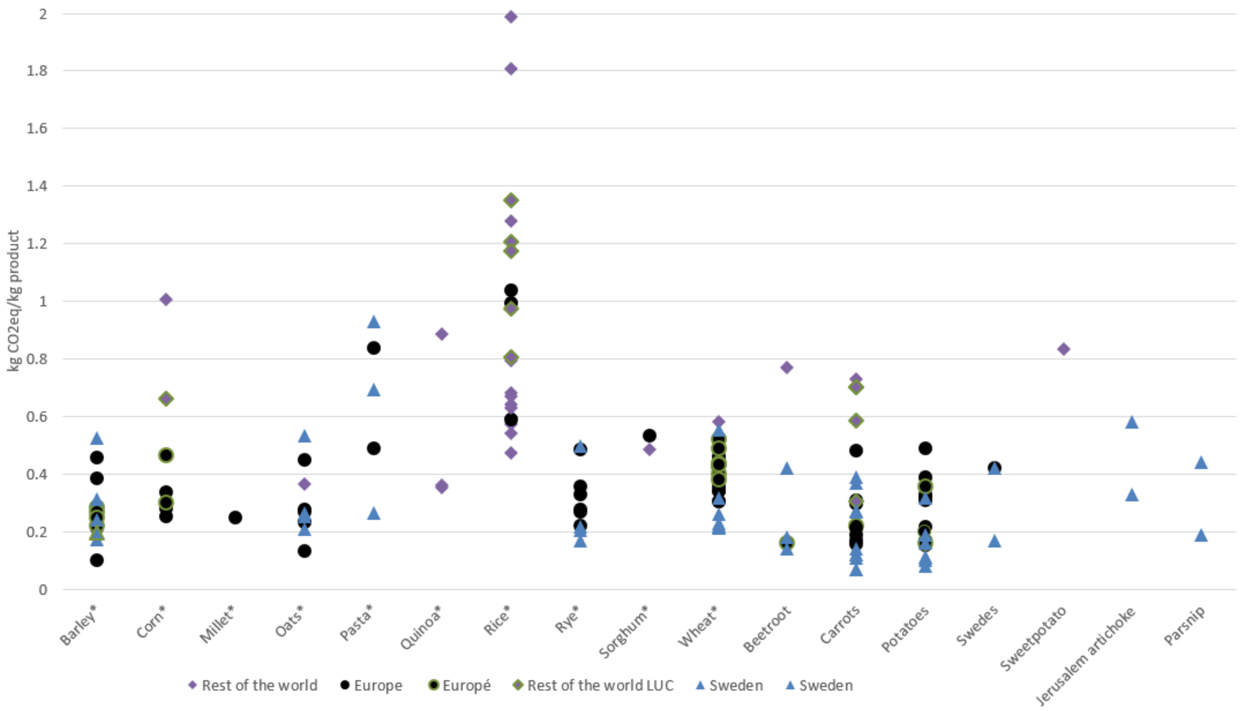

Figure 21. *Climate impact of carbohydrate sources in kg CO_2e per kg edible product in a store in Sweden. *Weight of the product modified to equal 1 kg edible product, i.e., bread or ready-to-eat pasta or grains excluding the emissions caused by energy use from baking and cooking. Note that the graph shows the climate impact from all identified earlier studies for this product group, and not only those identified as relevant for the Swedish market. Final assessments in Table 11 are based on relevance for the Swedish market.*

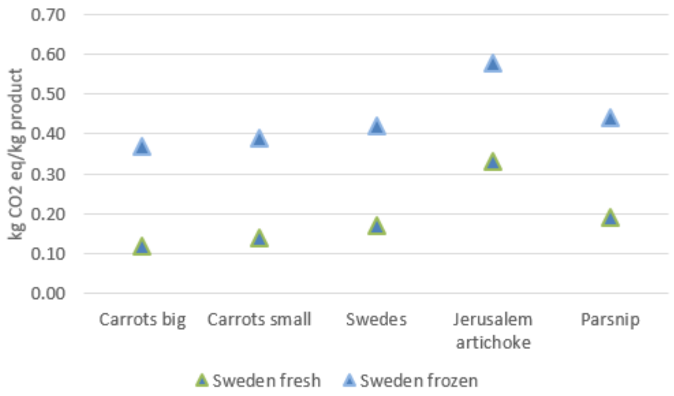

Figure 22. *Climate impact of fresh and frozen root vegetables, from Landqvist and Woodhouse (2015).*

Table 11*. Final assessment of climate impact of carbohydrate sources on the Swedish market*

Product	**Final assessment (kg CO_2e per kg product in a Swedish store)**		**No. of relevant references**	**Total no. of references**	**Comment**
	General	**Sweden**			

Cereals					
Barley	0.5	0.5	9 (5 SW)	9	Most studies show an impact below 0.5 kg CO_2e per kg edible product. No clear difference between Swedish and European barley.
Maize	0.5		4	6	European products considered most relevant for the Swedish market.
Millet	0.3		1	1	Only one study was found, the recommendation is therefore uncertain.
Oats	0.5	0.5	8 (4 SW)	8	All identified studies considered relevant for the Swedish market.
Pasta	0.9	0.7	4 (2 SW)	4	All identified studies considered relevant for the Swedish market.
Quinoa	0.9	No data	2	2	Two studies were identified, a scientific article showing climate impact of Peruvian quinoa of 0.4 kg CO_2e per kg edible product (including transport to Sweden) (2 references)
Rice	2.0		14	14	Climate impact in the studies varies between 0.5-2.0 kg CO_2e per kg edible product. All data-points were considered relevant for the Swedish market, indicating that the climate impact of rice can vary greatly, but some studies show that climate impact is likely to be approximately 2 kg CO_2e per kg edible product. European rice may have a lower impact (below 1 kg CO_2e per kg edible product), but only two studies investigated emissions from European rice production.
Rye	0.5	0.5	5 (4 SW)	5	Earlier studies show that climate impact is likely to be below 0.5 kg CO_2e per kg edible product. No clear difference was found between Swedish rye and imported rye (from Europe).
Sorghum	0.5		1	1	Only one study was found, so this is an uncertain assessment.
Wheat	0.6	0.6	12 (11 SW)	11	Studies on Swedish and European wheat production considered relevant for the Swedish market. No clear difference was found for Swedish and European wheat.
Root vegetables					
Beetroot	0.4	0.4	3 (2 SW)	4	European and Swedish production considered relevant for the Swedish market.
Carrots	0.5	0.3	8 (6 SW)	10	European and Swedish production considered most relevant for the Swedish market. Climate impact is likely to be below 0.5 kg CO_2e per kg product. Swedish fresh products have lower impact with transport added, fresh Swedish carrots have an impact below 0.3 kg CO_2e per kg product, European products have a higher impact with transport added, between 0.2-0.5 kg CO_2e per kg product.
Potatoes	0.4	0.3	9 (4 SW)	9	European and Swedish production considered relevant for the Swedish market.
Swedes	0.5	0.5	2 (2 SW)	2	Swedish and European production considered relevant for the Swedish market.
Sweet potato	0.8	No data	1	1	Only one study was found, the recommendation is uncertain.
Jerusalem artichoke and parsnips	0.6	0.6			The results are based on one study (a report). However, due to similarities with other production (other root vegetables), climate impact is likely to be below 0.6 kg CO_2e per kg product.

3.3.2. Land use

Land use for Swedish production and Swedish imports of carbohydrate sources and root vegetables is presented in Figure 23. The results show that millet requires more land than other cereals, due to lower yields. Global average land use for millet, quinoa, and sorghum is clearly higher than for Swedish imports, due to higher yields in countries found to export to Sweden. The higher values for the global average production can be seen as an indicator that these products may be associated with higher land use than the current Swedish imports show.

Root vegetables all have low land use, below 1 m^2 per kg product. For root vegetables, organic production was assumed to have slightly higher yields (5%) than conventional. This was based on three earlier studies on sweet potato and sugar beet (De Ponti *et al.*, 2012). In this study, 5% higher yield for organic was assumed for beetroot, carrots, sweet potato, parsnip, and Jerusalem artichoke. We found no statistics on yields of organic and conventional carrot production, or any other root vegetables. Official yield statistics for root vegetables in Sweden include both organic and conventional production, but do not show them separately.

For potatoes, organic potato yield in De Ponti *et al.* (2012) was 70% of the conventional yield. For Swedish organic potato production, yield was 50%-68% of the conventional yield in 2013-2018, with higher yield toward the end of this period (SBA, 2019).

When comparing root vegetables with cereals in Figure 23, it is important to note that although the cereals were recalculated to edible products, they generally have a lower water content and a higher energy content than the raw root vegetables (which were assumed to be edible as-is, or to undergo very little change during cooking to edible form).

Land use for Swedish quinoa production was estimated to be 2.3-2.9 m^2 per kg (lower values for conventional and higher for organic), based on yield data from Hushållningssällskapet (2013).

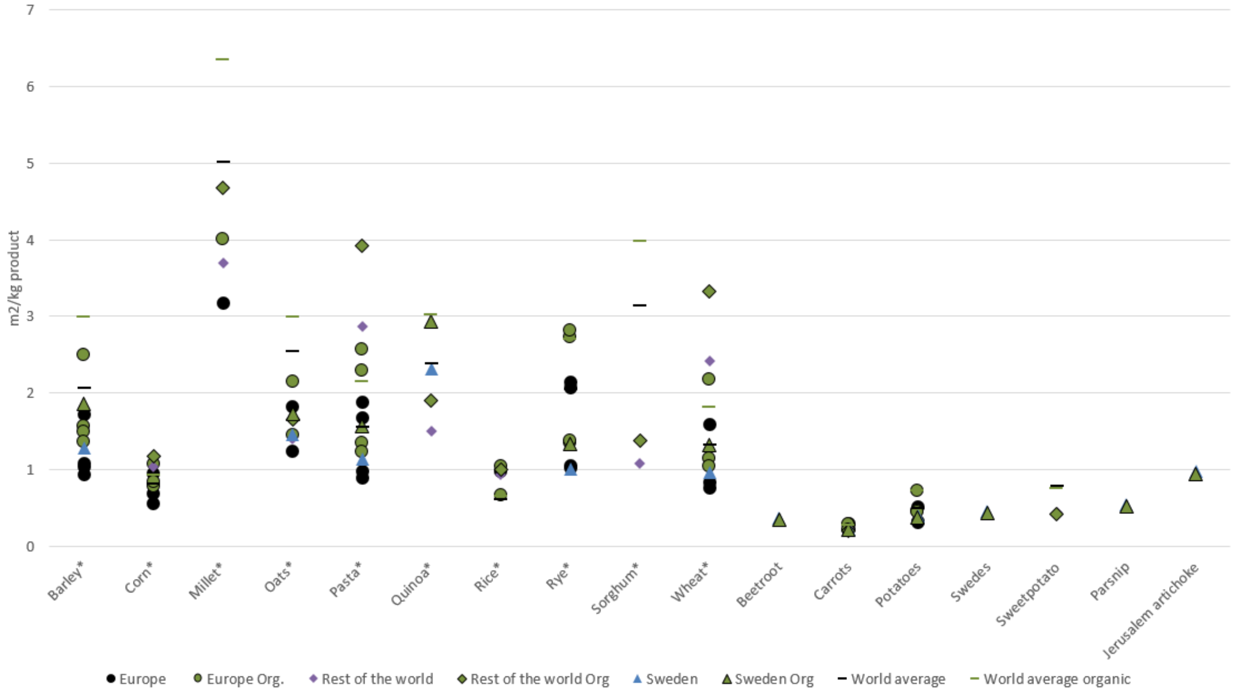

Figure 23. *Land use for carbohydrate sources in* m^2 *per kg product in a store in Sweden and world averages. *Weight of the product modified to equal 1 kg edible product, i.e., bread or ready-to-eat pasta or grains. Energy use for cooking was not included.*

3.3.3. Biodiversity

Impact on biodiversity from land use was generally below $2E^{-13}$ PDF per kg product for carbohydrate sources (Figure 24). This is primarily due to the relatively low land use, but also to the fact that most of these products are either produced in Sweden or imported from northern European countries with quite low biodiversity in natural vegetation. Millet from India and quinoa from Peru and Bolivia are clear exceptions, with (for this group) much higher impact than the other products due to low yields and high biodiversity in these regions.

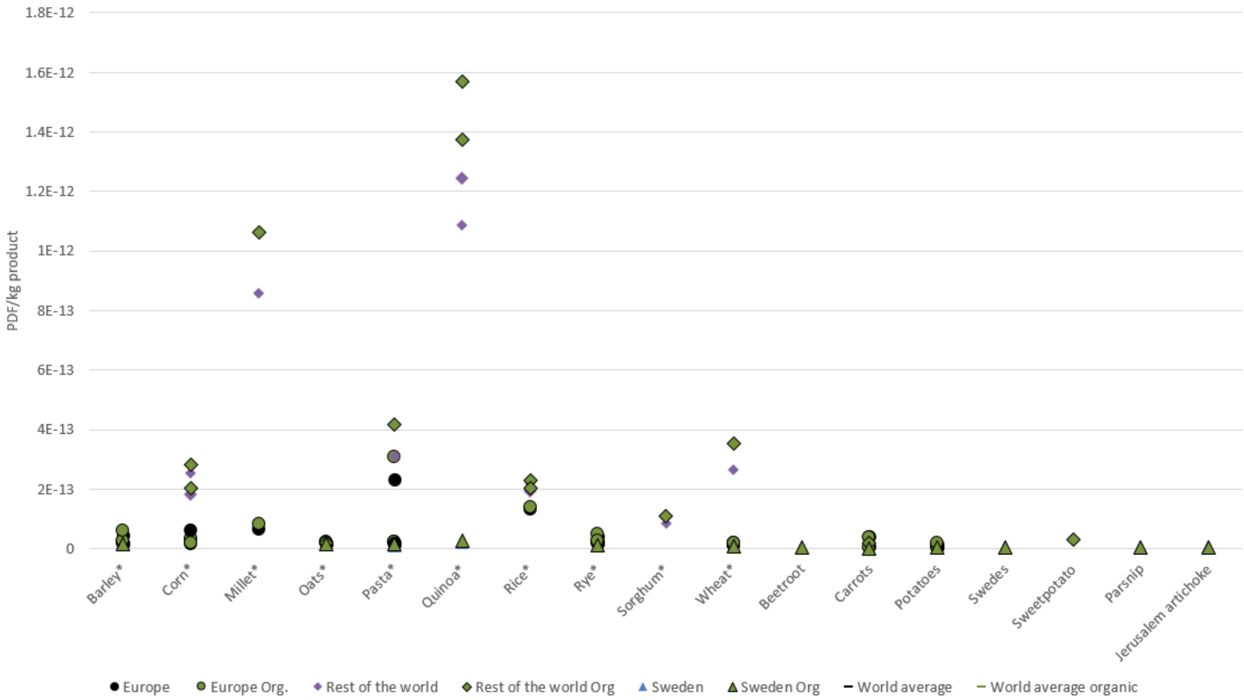

*Figure 24. Biodiversity impact from land use occupation from carbohydrate sources in PDF (Potentially Disappeared Fraction) per kg edible product in a store in Sweden. *Weight of the product modified to equal 1 kg edible product, i.e., bread or ready-to-eat pasta or grains.*

Table 12. *Range of results for all identified export countries and Swedish produce for land use (m^2/year per functional unit (FU)) and biodiversity impact (Potentially Disappeared Fraction (PDF) per FU) for carbohydrate sources*

Product	**Land use (m^2/year per FU)**	**Biodiversity impact (PDF per FU)**	**Comment^a**
Cereals			
Barley	0.9-3.0	1.2E-14-6.1E-14	The higher values are for conventional and organic production based on the global average, indicating a risk of somewhat higher land use if imports come from other countries than those included in this report. Swedish produce has land use of 1.3 m^2 per kg for conventional and 1.9 m^2 per kg product for organic.
Corn	0.6-1.2	1.8E-14-2.8E-13	
Millet	3.2-6.4	6.7E-14-1.1E-12	Biodiversity impact highest for India.
Oats	1.2-2.1	1.4E-14-2.2E-14	
Pasta	0.9-3.9	1.1E-14-4.2E-13	Swedish pasta has land use of 1.1-1.6 m^2 per kg (lower values for conventional and higher for organic). The highest land use is in Turkey, which was not identified as a main exporter to Sweden, but is the main exporter globally of wheat. The highest biodiversity impact was found for Italy and Turkey.
Quinoa	1.5-5.0	1.1E-12-1.6E-12	Bolivia has the highest land use and the highest biodiversity impact. Sweden has very limited quinoa production, and land use was estimated to be 2.3-2.9 m^2 per kg (lower values for conventional and higher for organic).
Rice	0.6-1.0	1.3E-13-2.3E-13	Land use in the main export countries identified (India, Italy, Thailand) is similar to the global average.

Rye	1.0-2.8	1.6E-14-5.1E-14	Global average similar to that in the main export countries. Land use for Swedish production is approximately 1.0-1.3 m^2 per kg (lower values for conventional and higher for organic).
Sorghum	1.1-4.0	8.6E-14-1.1E-13	Main export country (USA) has lower land use than the global average.
Wheat	0.8-3.3	9.1E-15-3.5E-13	Land use for Swedish import varies between 0.8-2.4 (conventional) and 1.0-3.3 (organic) m^2 per kg. Highest land use and biodiversity impact were found for Turkey. Land use for Swedish production is approx. 1.0-1.3 m^2 per kg (lower values for conventional and higher for organic).
Root vegetables			
Beetroot	0.4	3.2E-15-7.6E-15	Only data on Swedish production. Land use in other countries was assumed to be the same as for Swedish production, likely 0.4 m^2 per kg.
Carrots	0.2-0.3	2.0E-15-4.2E-14	Similar land use for Swedish and imported products.
Potatoes	0.3-0.7	3.5E-15-1.4E-14	Land use is likely to be 0.3-0.7 m^2 per kg. Swedish potatoes were assessed to have land use of 0.4 m^2 per kg.
Sweet potato	0.4-0.8	3.3E-14-3.4E-14	
Parsnip, swedes and Jerusalem artichoke	0.5-1.0	3.7E-15-6.7E-15	Only data on Swedish production found. Land use is likely to be around 0.5 m^2 per kg for Swedes and parsnips, and around 1 m^2 per kg for Jerusalem artichoke.

[a] Comments included when applicable.

3.3.4. Water use

Earlier studies

Water use is rarely included in earlier studies on the climate impact of carbohydrate sources (Figure 25). One study on rice shows high blue water use, of around 1.6 m^3 per kg rice (Blengini & Busto, 2009). Blue water use in carrot production is included in the ecoinvent database (Wernet *et al.*, 2016) and the study by Fuentes *et al.* (2006). Blue water use in carrot production from these data sources varies between 0.03-0.12 m^3 per kg carrots.

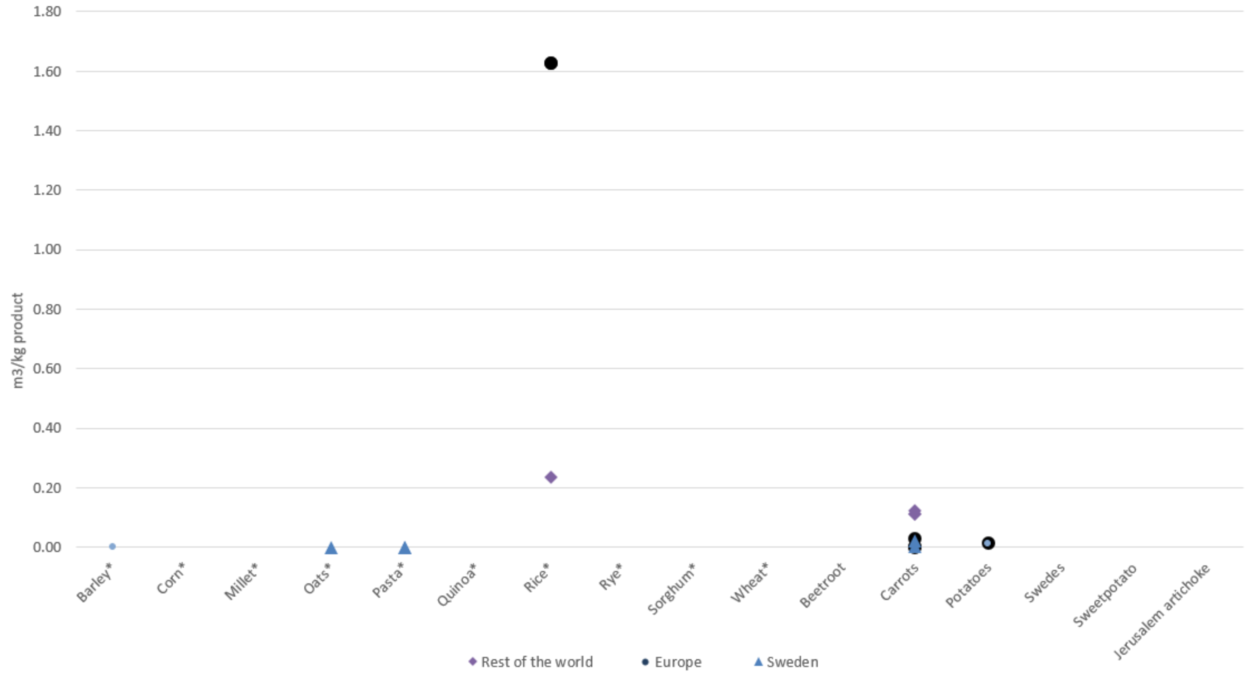

Figure 25*. Blue water use from earlier studies on carbohydrate sources. *Weight of the product modified to equal 1 kg edible product, i.e., bread or ready-to-eat pasta or grains.*

Water footprint, total water use, and AWARE

Looking at water use in Mekonnen *et al.* (2011), divided into green, blue, and grey water (Figure 26) and as total water (Figure 27), total water use is highest for quinoa and millet, most likely due to lower yields. Blue water use is highest for rice, indicating high irrigation rates in all three identified export countries (India, Thailand, Italy) but also for the world average production.

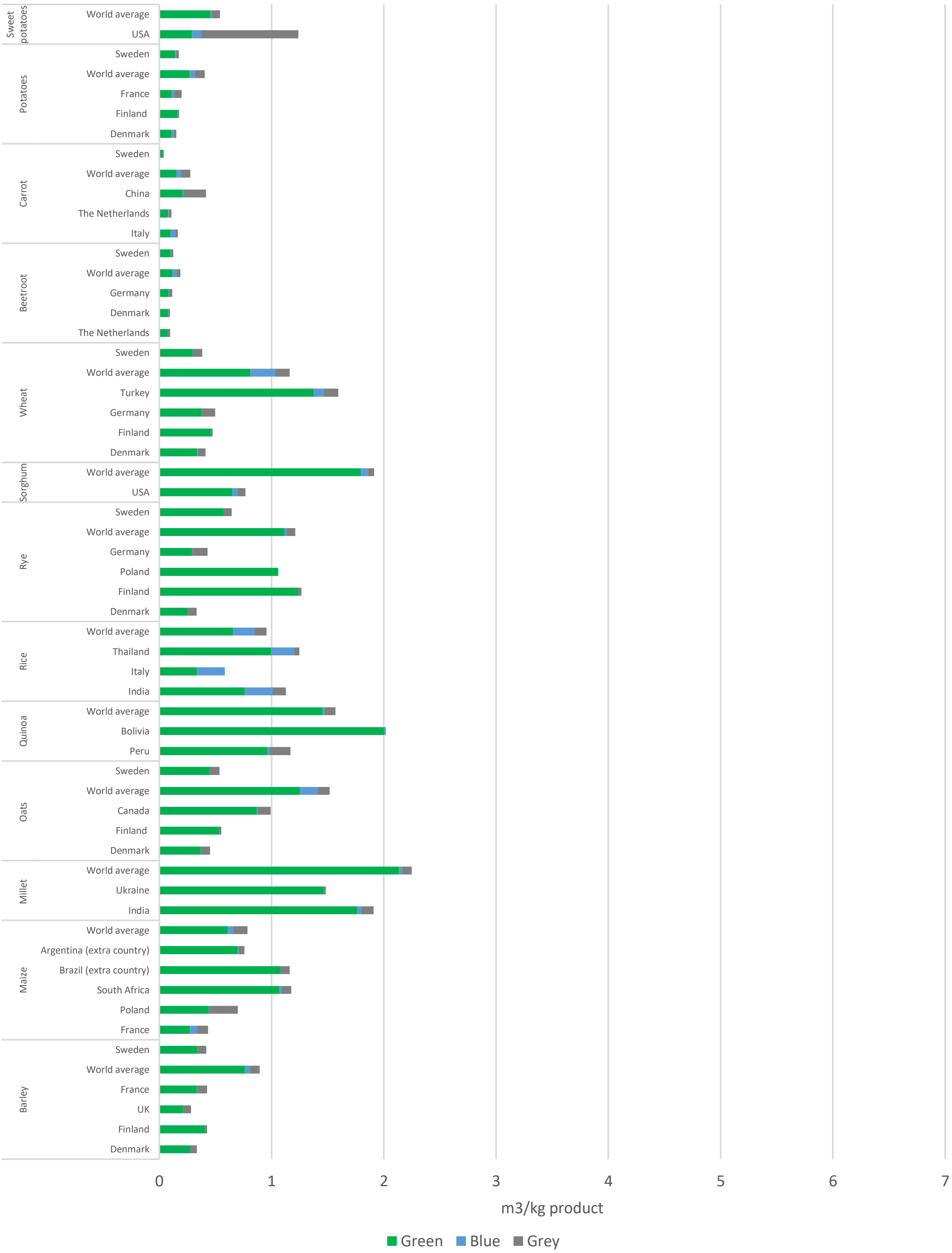

Figure 26. *Total water use, divided into green, blue, and grey water use, for carbohydrate sources in m*^{3} *per kg edible product in a store in Sweden for the identified export countries, and world average water use for comparison.*

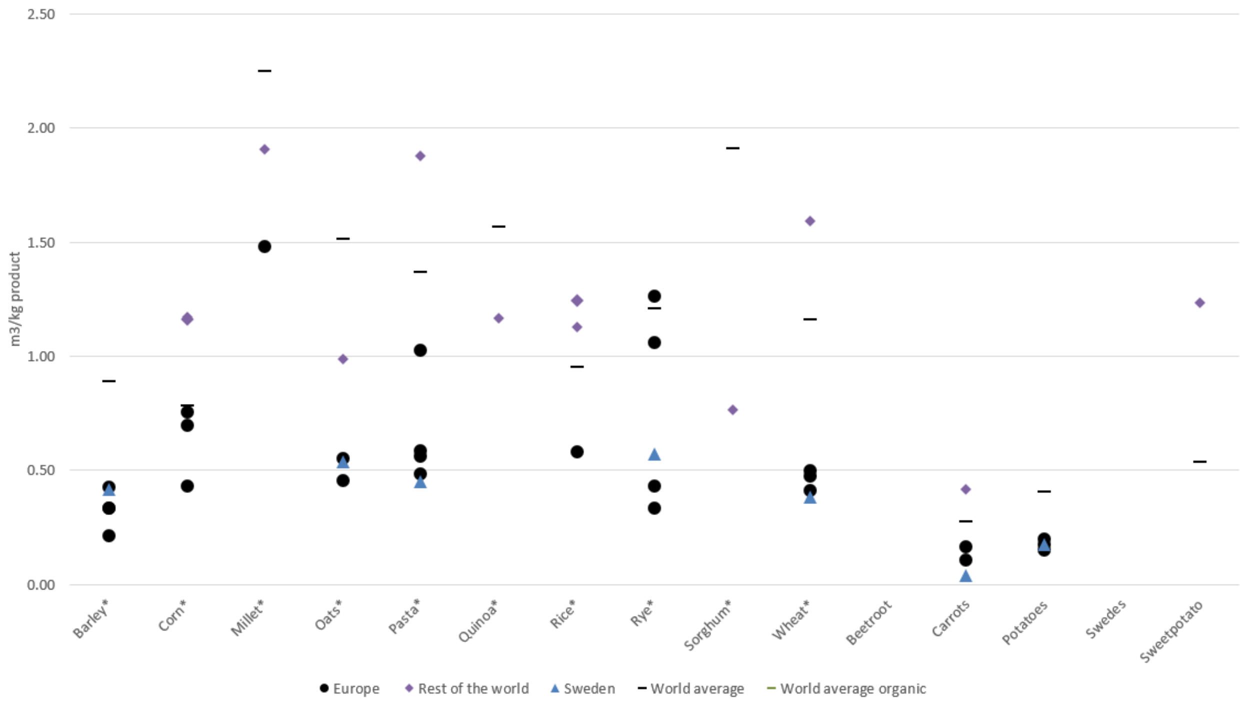

Figure 27. *Total water use (sum of green, blue, and grey water use) for carbohydrate sources in m^3 per kg edible product in a store in Sweden, and for the world average. *Weight of the product modified to equal 1 kg edible product, i.e., bread or ready-to-eat pasta or grains.*

When applying the water scarcity indicator AWARE, rice from Italy has a higher impact due to large amounts of blue water and high AWARE characterization factors for Italy (Figure 28). Further, global average production of rice and wheat uses relatively large amounts of blue water (Mekonnen *et al.*, 2011) which is the reason behind the higher impacts. In general, both total water use and AWARE indicators are low compared with e.g., those for some nuts.

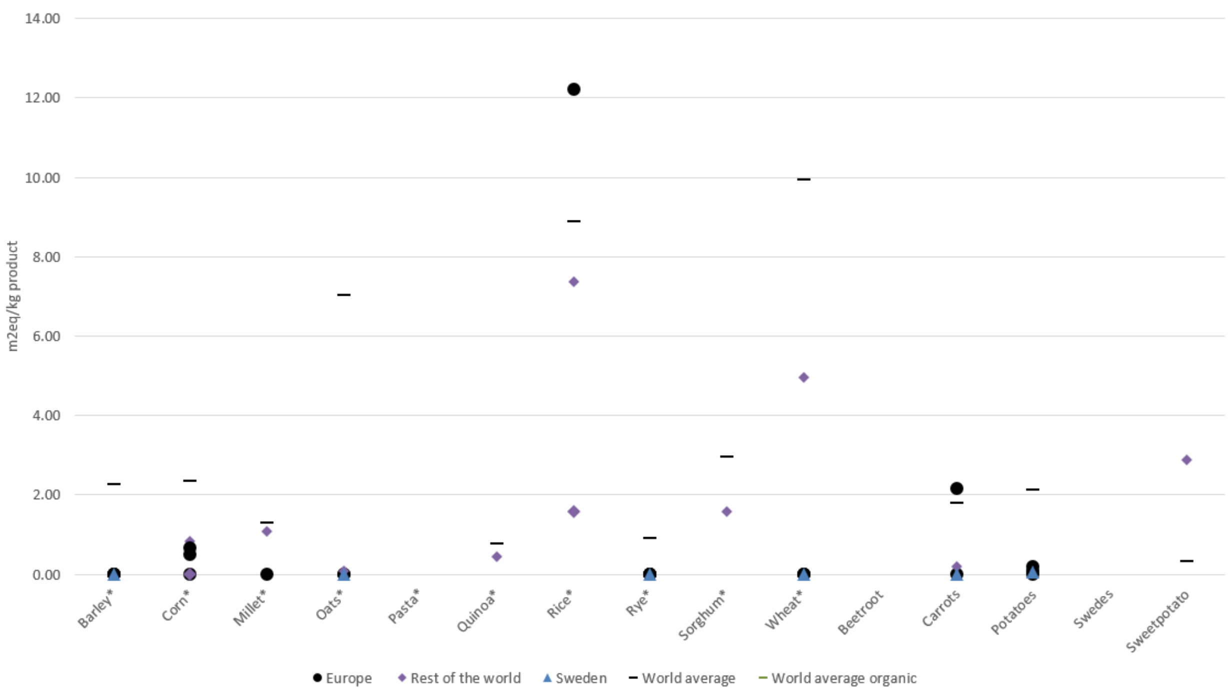

Figure 28. *Water use for carbohydrate sources assessed with the water scarcity method AWARE (Available Water Remaining) in m*^{3}*eq per kg product in a store in Sweden and the world average. *Weight of the product modified to equal 1 kg edible product, i.e., bread or ready-to-eat pasta or grains.*

Table 13*. Range of results for all identified export countries and Swedish produce for total water use (m*^{3} *per functional unit (FU)) and AWARE (Available Water Remaining, m*^{3}*eq per FU) for carbohydrate sources*

Product	**Total water use *(m*^{3} *per FU)***	**AWARE *(m*^{3}*eq per FU)***	**Comment**
Barley	0.3-0.9	0-2.3	Total water use for Swedish production and Swedish imports is likely to be below 0.4 m^3 per kg. Global average is 0.9 m^3 per kg. For Sweden and the main import countries, the AWARE score is 0 m^{3}eq (or close to), due to no or very low irrigation rates. The AWARE value is higher for world average production.
Corn	0.4-1.2	0-2.4	Assessed to be below 0.8 m^3 per kg for the identified European export countries (France and Poland), global average water use is also below 0.8 m^3 per kg. South Africa and Brazil have total water use of 1.2 m^3 per kg. South Africa was identified as the main exporter globally and Brazil was added as an extra country in the analysis.
Millet	1.5-2.3	0-1.3	
Oats	0.5-1.5	0-7.0	Water use in the main export countries (Finland and Denmark) and in Sweden is likely to be below 0.6 m^3 per kg. Global average and the largest global exporter (Canada) have higher water use, around 1.0-1.5 m^3 per kg. A higher AWARE score was found for global average production.
Pasta	0.5-1.9	0-12	Italian pasta was assessed to have total water use of around 1 m^3 per kg. Pasta made of wheat from Turkey (identified as main exporter of wheat) or global average wheat was estimated to have the highest total water use. Highest AWARE score found for global average production.
Quinoa	1.2-2.0	0.13-0.76	

Rice	0.6-1.3	1.6-12	Water use varied between 0.6 (Italy) and 1.3 m^3 per kg. Proportion of blue water in total water is relatively high in all identified export countries and in the global average.
Rye	0.3-1.3	0-0.9	Water use in Sweden, Denmark, and Germany is below or close to 0.6 m^3 per kg. Global average, Finland, and Poland have slightly higher water use, of around 1.1-1.3 m^3 per kg. For Sweden and the main import countries, the AWARE score is 0 m^3eq (or close to) due to no or very low irrigation rates. A higher AWARE value was found for world average production.
Wheat	0.4-1.6	0-10	Most Swedish imports and Swedish production have water use below 0.5 m^3 per kg. Turkey was identified as the largest exporter globally and is the country with the highest water use (of the countries assessed) with approx. 1.5 m^3 per kg. A higher AWARE value was found for world average production.
Root vegetables			
Beetroot			No data.
Carrots	0.04-0.4	0-2.2	All export countries assessed, Swedish production, and global average show water use below 0.4 m^3 per kg. Highest AWARE score found for Italian production. Italy was identified as the main exporter of carrots to Sweden.
Potatoes	0.15-0.4	0.1-2.3	All export countries assessed, Swedish production, and global average have water use below 0.4 m^3 per kg. A higher AWARE value was found for world average production.
Swedes			No data.
Sweet potatoes	0.5-1.2	0.3-2.9	The largest exporter to Sweden (USA) has water use of 1.2 m^3 per kg. Global average water use is around 0.5 m^3 per kg. A higher AWARE score was found for the USA.

3.4. Plant-based drinks and cream

3.4.1. Climate impact

Results from earlier studies on plant-based drinks and cream are shown in Figure 29. As earlier studies used functional units based on volume (e.g., 1 liter) and based on mass (e.g., 1 kg), it was assumed that 1 liter plant-based drink equals 1 kg (the functional unit used in the Vego-guide). In general, all drinks and plant-based cream alternatives have a climate impact below 1 kg CO$_2$e per kg product. Swedish oat drink has the lowest impact, around 0.24-0.34 kg CO$_2$e per kg (Florén *et al.*, 2013), mainly explained by the shorter transport.

For plant-based cream alternatives, climate impact for oat cream is just above 0.5 kg CO$_2$e per kg (Nilsson & Florén, 2015). No data on coconut cream and soy-based cream could be found, so the value in Table 14 is based on calculations made in this report (see Appendix A3) and climate impact values from the ecoinvent database (Wernet *et al.*, 2016). Following the methodology applied in this report, transport from North America was added for almond, coconut, and soy drink, since the studies originated from the USA or Canada. This means that the data in Figure 29 for many products show the impact of transporting mainly water long distances (the drinks typically contain 90-92% water). The climate impact will hence be considerably lower if the drinks are produced in Sweden or closer to Sweden, i.e., only the raw materials are transported long distances. This is probably the case for products on the Swedish market, particularly when the market for plant-based drinks and cream increases. For comparison, Figure 29 also shows the climate impact from Swedish dairy milk and cream (Moberg *et al.*, 2019; Röös, 2012).

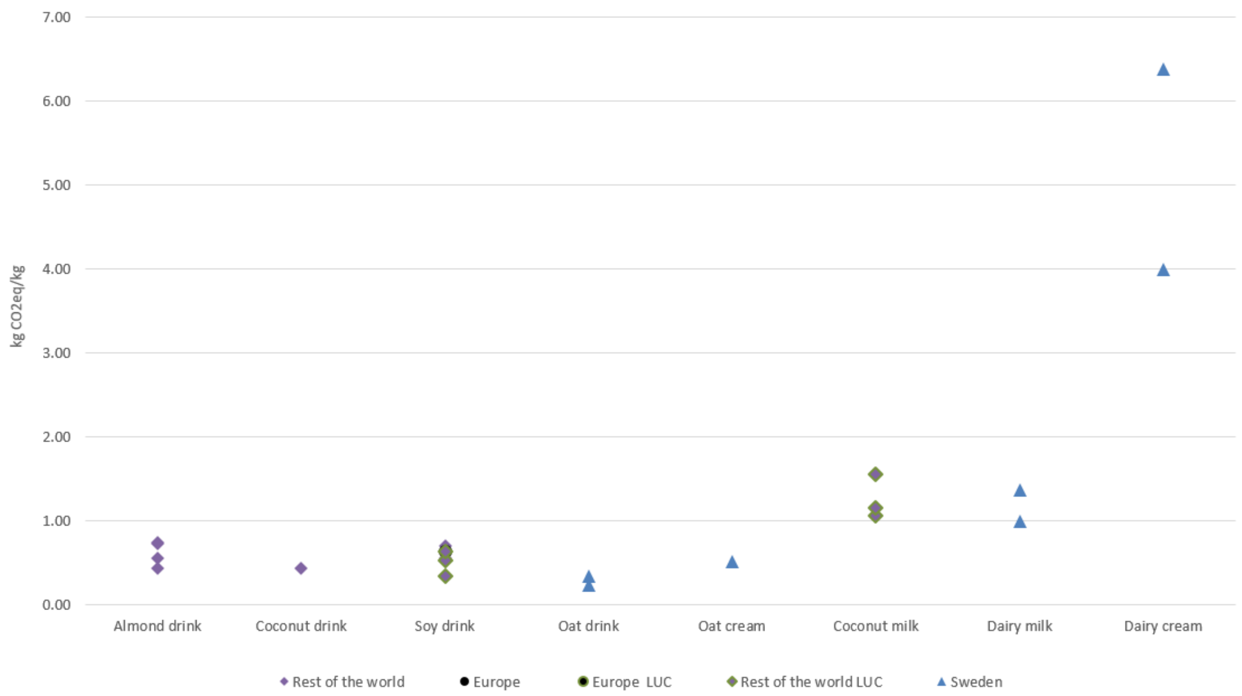

Figure 29. *Climate impact of plant-based drinks and cream in kg CO_2e per kg product in a store in Sweden. Note that the graph shows the climate impact from all identified earlier studies for this product group, and not only those identified as relevant for the Swedish market. Recommendations in Table 14 are based on relevance for the Swedish market.*

Table 14. *Final assessment of the climate impact of plant-based drinks and cream on the Swedish market*

Product	**Final assessment (kg CO_2e per kg product in a Swedish store)**		**No. of relevant references**	**Total no. of references**	**Comment**
	General	Sweden			
Almond drink	0.8		4	4	Likely to have climate impact below 0.8 kg CO_2e per liter.
Coconut drink	0.4		1	1	Only one reference was found, assessment uncertain.
Soy drink	0.7		5	5	Climate impact is likely well below 0.7 kg CO_2e per kg, due to lower impact from shorter transport than assessed in the studies identified. The shorter transport is because the product is likely to be produced in Europe, for the European market.
Oat drink	0.3	0.3	1	1	Only one study was found, showing that oat drink produced in Sweden has a climate impact below 0.34 kg CO_2e per kg. However, that study was assessed to be of high quality and very relevant for the Swedish market.
Oat cream	0.5	0.5	1	1	Only one study was found, showing that oat cream produced in Sweden has a climate impact below 0.52 kg CO_2e per kg. However, that study was assessed to be of high quality and very relevant for the Swedish market.
Coconut milk	1.2		Own assessment		Climate impact was estimated based on climate impact of coconuts and yield of coconut milk (see Appendix A3). Impacts from land use change were excluded in the final assessment.

3.4.2. Land use

Combined assessment of land use (earlier studies plus own assessment)

Land use and biodiversity impacts for plant-based drinks and cream (Figure 30) were estimated based on the raw material ingredients (Appendix A3) and data from earlier studies. Coconut milk (fat content 17%) was found to have the highest land use. However, the amount of coconut needed to produce 1 kg of coconut milk was not known and was estimated based on mass balance (see Appendix A3 and Kool *et al.* (2012)). The results are therefore uncertain. Results from earlier studies (Nilsson & Florén, 2015) on oat cream show relatively high land use compared with that based on the ingredients (Appendix A3). Rapeseed was found to be most land-demanding for oat cream. Nilsson and Florén (2015) used economic allocation to allocate between rapeseed oil and rapeseed cake, while in this report mass allocation was used, which could explain the difference in the results.

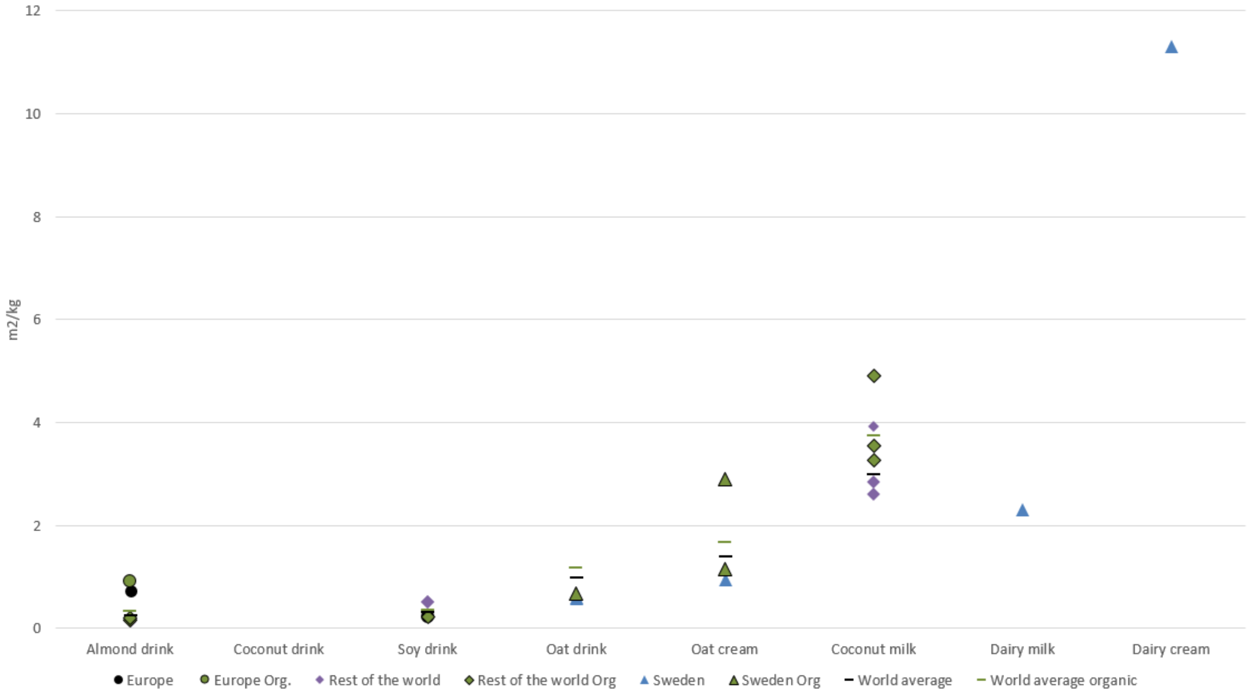

Figure 30. *Land use for plant-based drinks and cream, and dairy milk and cream, in m^2 per kg in a store in Sweden, and the global average.*

3.4.3. Biodiversity

Coconut milk has the highest impact as regards biodiversity loss, due to high biodiversity in the areas in which coconuts are produced. All other products have a relatively low impact, again because they do not contain as much raw material (mainly water).

Several products that are substitutes for hard cheese contain coconut oil. The largest exporter of coconuts to Sweden is the Philippines and the largest producer globally is Indonesia. Both are tropical countries with relatively high biodiversity impact factors from land use (Chaudhary *et al.*, 2018), and therefore there is a risk that these products are associated with high impact on biodiversity. However, the impact from these products was not included in the assessment.

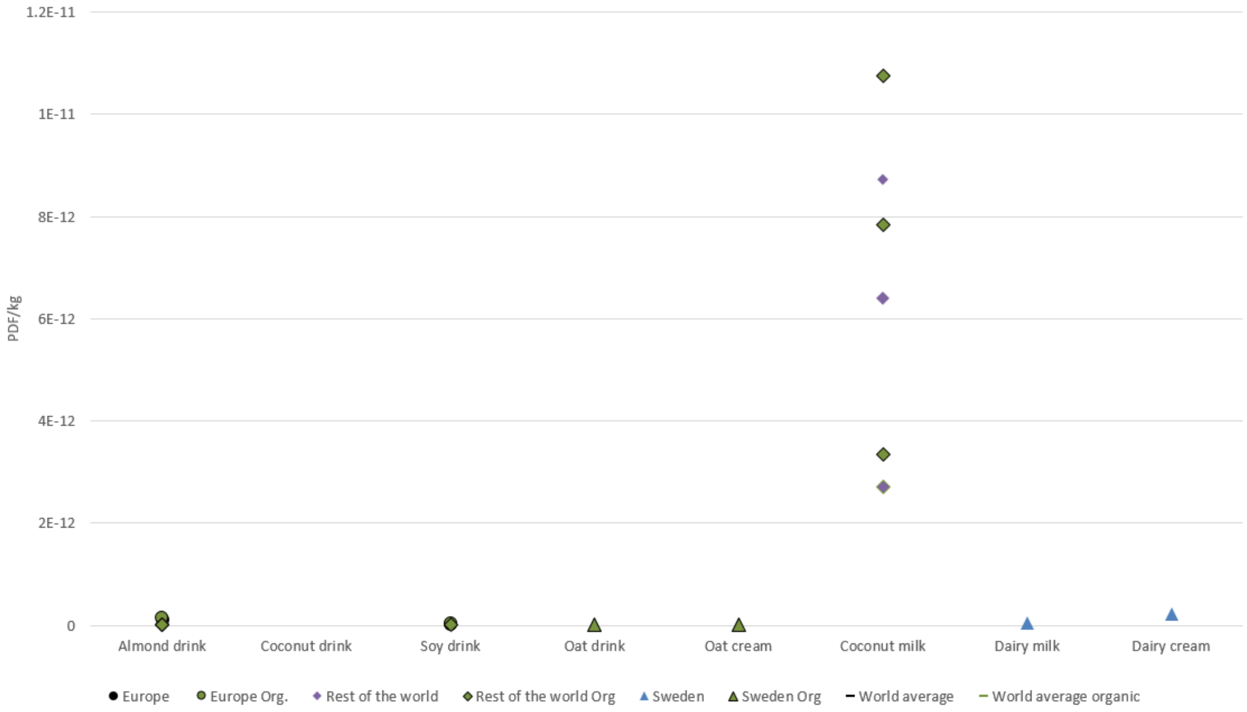

Figure 31*. Biodiversity impact from land use occupation from plant-based drinks and cream in PDF (Potentially Disappeared Fraction) per kg in a store in Sweden.*

Table 15 *Range of results for all identified export countries and Swedish produce for land use (m^2/year per functional unit (FU)) and biodiversity impact (Potentially Disappeared Fraction (PDF) per FU) for plant-based drinks and cream*

Product	**Land use *(m^2/year per FU)***	**Biodiversity impact *(PDF per FU)***	**Comment**[a]
Almond drink	0.1-0.9	1.6E-14-1.5E-13	
Soy drink			Land use for all products assessed was found to be below 0.5 m^2 per kg product.
Oat drink	0.6-1.0	5.4E-15-6.3E-15	Land use was assessed to be below 1 m^2 per kg product, Swedish products likely to have land use below 0.7 m^2 per kg product.
Oat cream	1.0-2.9	9.0E-15-1.1E-14	Assessments in this report found land use of 1.7 m^2 per kg product, while an earlier study found 2.9 m^2 per kg product.
Coconut milk	2.6-4.9	2.7E-12-1.1E-11	Method for assessing land use was particularly uncertain due to lack of information about the production chain. Land use varied between 3 and 5 m^2 per kg product.

[a]Comments included when applicable.

3.4.4. Water use

Earlier studies

Two earlier studies on plant-based drinks and creams include blue water use (Henderson & Unnasch, 2017; Wernet *et al.*, 2016). Both indicate relatively low blue water use compared with other products assessed in this report. Almond production is water-demanding, with around 4.3 m^3 of irrigation water used to produce 1 kg of almonds in USA. However, since almond drink does not contain much almonds (2.3% assumed in this study), blue water use for producing almond drink is substantially lower.

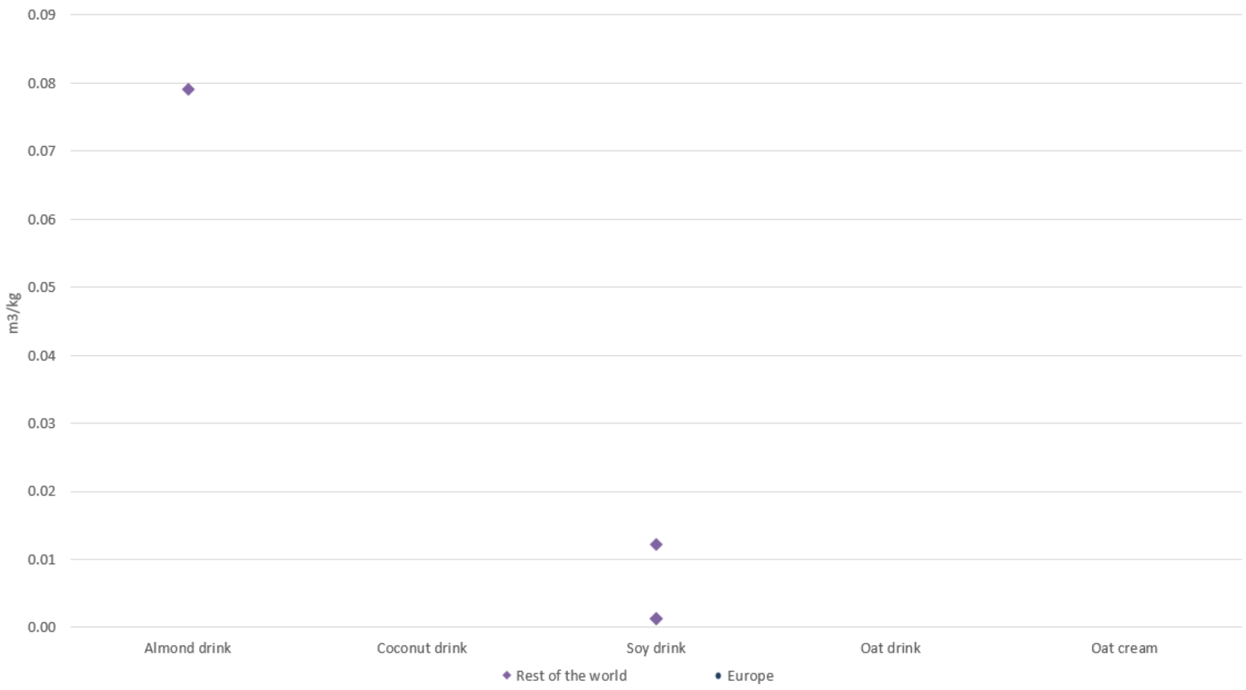

Figure 32. *Blue water use for plant-based dairy, in m^3 per kg in a store in Sweden.*

Water footprint, total water use, and AWARE

Based on the ingredients and the process requirements (Appendix A3), total water use and water use using AWARE were calculated. Note that process water requirements were only found (and included) for soy and oat drinks and oat cream, and not for the other products. However, process water use is small in relation to the amount of water used by the crops. Results for total water use are shown in Figures 33 and 34 and AWARE scores in Figure 35.

Global average production of oat drink, oat cream, and coconut drink is based on crops which are irrigated to a larger extent than Swedish oat drink and oat cream or coconut drink from the Philippines, Sri Lanka, and Indonesia (Mekonnen *et al.*, 2011). This, combined with a higher AWARE score for the global average than for Sweden and the Philippines (Boulay *et al.*, 2018), contributed to global average production having much higher AWARE scores than Swedish and Philippian production (Figure 33). This is especially important in the case of coconut drink, since import statistics on coconut products do not specify coconut drink, and therefore coconut imports were used to find likely export country for coconut drink. This assumption is uncertain, and global average production therefore provides valuable additional information. For oat products, however, the raw material is likely produced in Sweden.

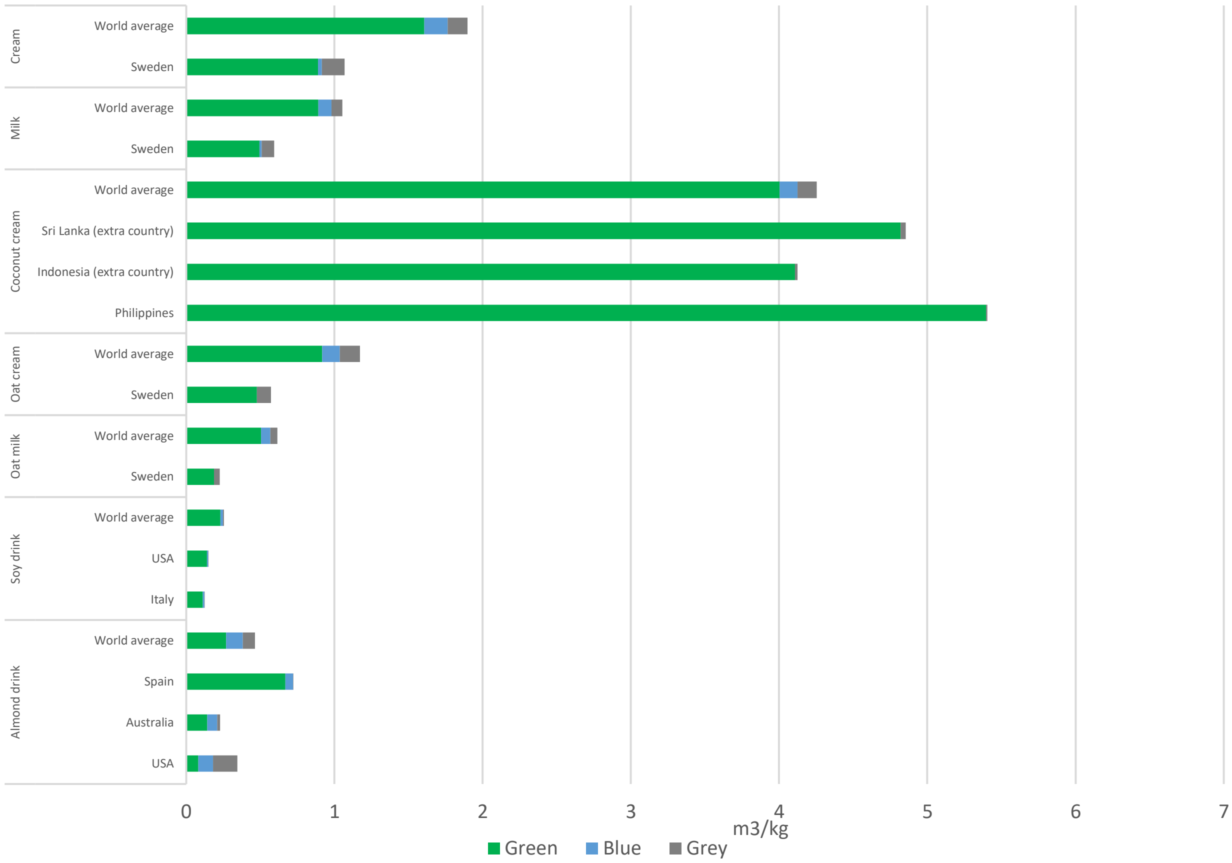

Figure 33. *Total water use, divided into green, blue, and grey water use, for plant-based drinks and cream, and dairy milk and cream, in m^3 per kg product in a store in Sweden, and world averages.*

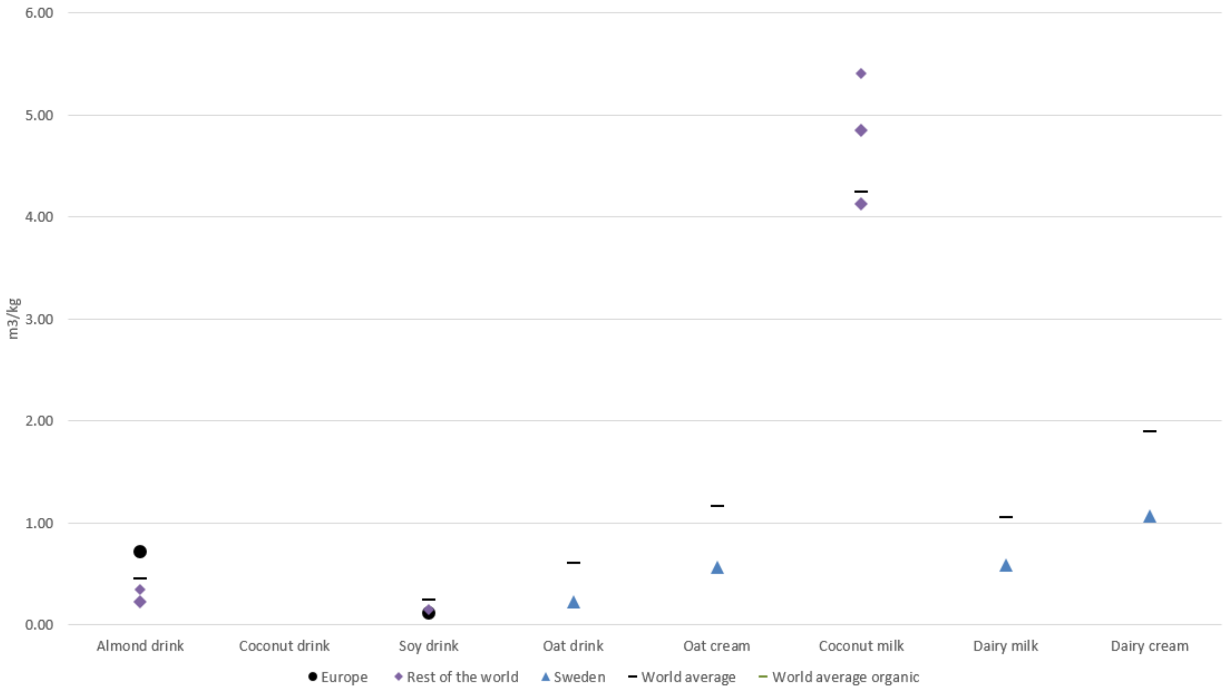

Figure 34. *Total water use (sum of green, blue, and grey water use) for plant-based dairy and cream, and dairy milk and cream, assessed in m^3 per kg product in a store in Sweden, and world averages.*

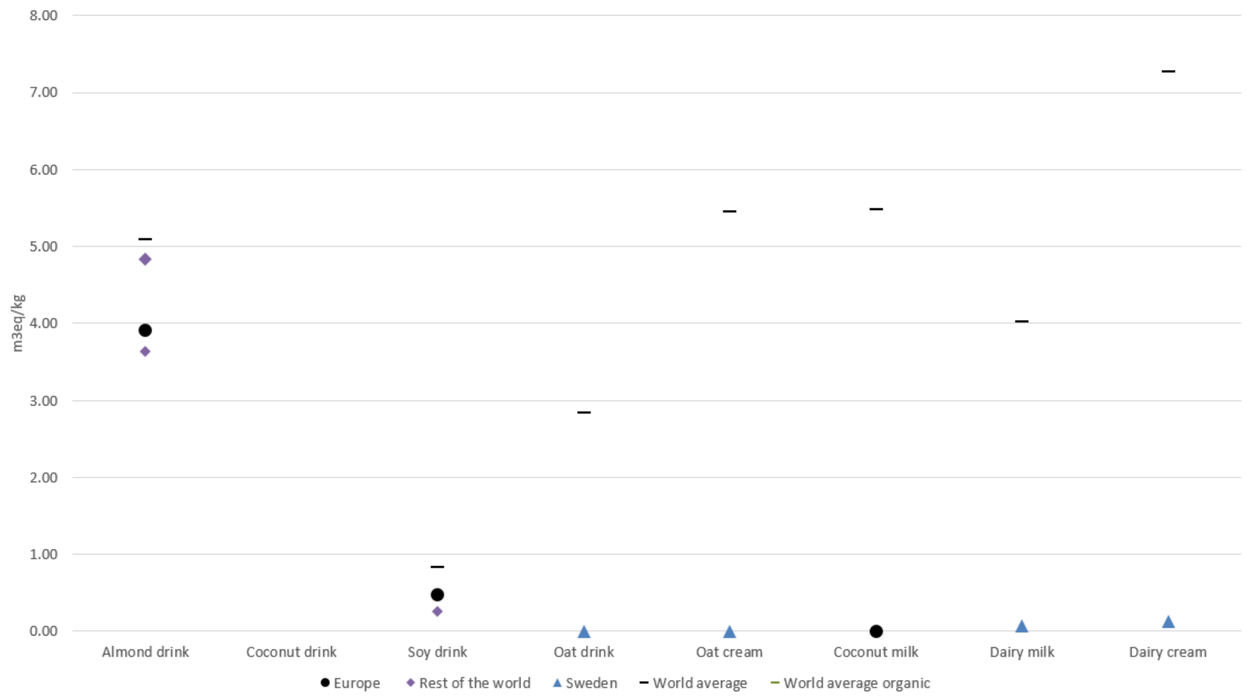

Figure 35. Water use for plant-based drinks and cream, and dairy milk and cream, assessed with the water scarcity method AWARE (Available Water Remaining, m^3eq per kg product) in a store in Sweden, and the world average.

Table 16. Range of results for all identified export countries and Swedish produce for total water use (m^3 per functional unit (FU)) and AWARE (Available Water Remaining, m^3eq per FU) for plant-based dairy

Product	**Total water use (*m^3 per FU*)**	**AWARE (*m^3eq per FU*)**	**Comment[a]**
Almond drink	0.2-0.7	4-5	
Coconut drink			No data
Soy drink	0.1-0.3	0.3-0.8	Total water use below 0.25 m^3 per kg. Higher total water use and AWARE score were found for world average production.
Oat drink	0.2-0.6	0-2.9	Total water use for Swedish oat drink below 0.2 m^3 per kg, global average production below 0.6 m^3 per kg. A higher AWARE score was found for global average production.
Oat cream	0.6-1.2	0-5.5	Total water use for Swedish oat cream below 0.6 m^3 per kg, global average production below 1.2 m^3 per kg. A higher AWARE score was found for global average production.
Coconut milk	4.1-5.4	0-5.5	Total water use around 5 m^3 per kg. A higher AWARE score was found for global average production.

[a] Comments included when applicable.

3.5. Fruit and berries

3.5.1. Climate impact

Results from earlier studies on the climate impact of fruits and berries are presented in Figure 35. In general, there is good access to data for this food category compared with other categories. Fruits and berries that are transported long distances generally have a higher impact than European and Swedish products, due to emissions caused by the transport. All European and Swedish products assessed have a climate impact below 1 kg CO_2e per kg product in a Swedish store, with the exception of melons from unheated greenhouses (Cellura *et al.*, 2012) and watermelon and raspberries/blueberries from Europe (country unspecified) (Audsley *et al.*, 2010).

In general, emissions from transport are more important for fruits and berries, which generally have a low climate impact per kg product from primary production. This is one of the reasons why some studies on products from “rest of the world” report climate impact higher than 1 kg CO_2e per kg in a Swedish store. World average production of dates and organic and non-organic (fresh) dates (Wernet *et al.*, 2016) show the highest climate impact, above 4 kg CO_2e per kg product (including transport). This is primarily due to high emissions of nitrous oxide (N_2O) from fertilizer use.

Some products in this product group are transported to Sweden by air, which causes exceptionally high emissions from transport. Airfreighted products include some berries produced outside Europe and some exotic fruits with short durability, such as starfruit. Common exotic fruits such as bananas, pineapple, and the most common mango type sold in Swedish stores have longer duration times and are generally transported by boat, with a lower climate impact (per kg product transported) (SverigesKonsumenter, 2018). The data in Figure 35 only include one study that considered air transport, for pineapple (Brenton *et al.*, 2010), and it was considered less relevant for the Swedish market. For more information on how climate impact from air transport was estimated, see section 2.3.

Strawberries for the Swedish market are primarily sourced from within Europe. According to import statistics, around 40% of strawberry imports to Sweden come from Belgium (SS, 2018). Belgium strawberry production can be in heated or unheated greenhouses (Proefcentrum, 2019). No earlier study was found on Belgian strawberries, and the climate impact and energy use is therefore unknown. Further, no data were found on wild blueberries or lingonberries. For raspberries, one study (Foster *et al.*, 2014) showed much higher impact than the other studies, but was only presented in a conference abstract and provided little information about reasons for the relatively high impact compared with other studies on raspberries and other berries.

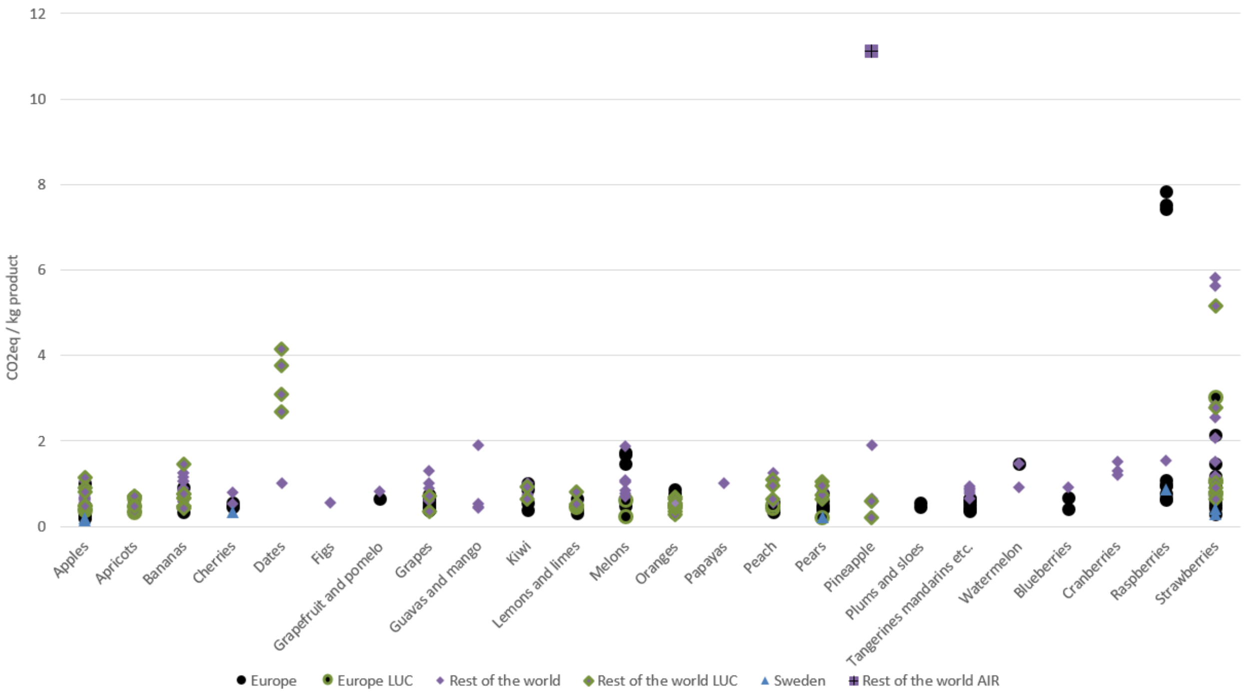

***Figure 36**. Climate impact of fruits and berries in kg CO_2e per kg product in a store in Sweden. Note that the graph shows the climate impact from all identified earlier studies for this product group, and not only those identified as relevant for the Swedish market. Final assessments in Table 17 are based on relevance for the Swedish market.*

Table 17. *Final assessment of the climate impact of fruits and berries on the Swedish market*

Product	**Final assessment (kg CO_2e per kg product in a Swedish store)**		**No. of relevant references**	**Total no. of references**	**Comment**
	General	Sweden			
Apples	0.5	0.2	14 (2 SW)	24	European apple production considered relevant for the final assessment. Only one study on European apple production shows an impact slightly above 1 kg CO_2e per kg product, for an old low-yielding orchard not representative of all orchards. Apples from outside Europe are likely to have a climate impact below 1 kg CO_2e per kg product.
Apricots	0.7		3	3	European apricot production was considered for the general final assessment. There was no difference between European production and production outside Europe.
Bananas	1.5		13	13	All studies were considered relevant for the general recommendation. Many studies show an impact below 1 kg CO_2e per kg.
Cherries	0.8		4	4	All studies considered relevant in the general recommendation. European cherries likely to have an impact below 0.5 kg CO_2e per kg. Possibly sometimes transported by air, no earlier study was found on air transport of cherries.
Dates	4		2	2	All studies considered relevant for the recommendation.
Figs	0.6		1	1	Only one study was found, the assessment is uncertain.
Grapefruits and pomelo	0.8		1	1	Only one study was found, the assessment is uncertain.
Grapes	1.3		11	11	All studies considered relevant for the final assessment. European grapes are likely to have a climate impact below 0.7 kg CO_2e per kg grapes (8 references).
Guavas and mango	1.9		4	4	All studies considered relevant for the final assessment. Possibly sometimes transported by air, no earlier study was found on air transport of guavas and mango.
Kiwifruit	1		9	9	All studies considered relevant for the final assessment. European production tends to have slightly lower impact, but no clear trend.
Lemons and limes	0.8		5	5	All studies considered relevant for the final assessment. No clear difference between European products and “rest of the world”.
Melons	1.9		9	9	All studies considered relevant for the final assessment. No clear trend between European products and “rest of the world”. Melons are sometimes produced in greenhouses, which can explain the large variation in results.
Oranges	0.7		9	9	All studies considered relevant for the final assessment. No clear difference between European products and “rest of the world” was found.
Papayas	1		1	1	Only one study was found, the assessment is uncertain. High risk of air transport, no study that considered air transport for papaya was found.
Peaches	0.5		4	8	European production was considered for the final assessment. Production outside Europe is likely to have an impact below 1.2 kg CO_2e per kg peaches.
Pears	0.8	0.2	7 (1 SW)	9	Only European production was considered for the final assessment. “Rest of the world” production is likely to have a climate impact below 1 kg CO_2e per kg pears. Data on Swedish production are only based on one study, the assessment is uncertain.

Pineapples	0.7		7	9	All studies considered relevant. Most studies (7/9) show a climate impact below 0.7 kg CO_2e per kg, while one study shows an impact close to 2 kg CO_2e per kg. One study considers pineapples transported by air, which was considered less relevant for the Swedish market.
Plums and sloes	0.6		1	1	Only one study was found, the assessment is uncertain.
Tangerines, mandarins etc.	0.9		9	9	All considered relevant for the general recommendation. European products likely below 0.6 kg CO_2e per kg.
Watermelon	1.5		1	2	European studies considered most relevant for the Swedish market. Only one study on European produce was found. Both identified studies showed a climate impact below 1.5 kg CO_2e per kg.
Cranberries	1.5		2	2	All studies considered relevant for the final assessment.
Blueberries	0.9		3	3	All studies considered relevant for the general recommendation. Two studies were identified on European production showing an impact of below 0.7 kg CO_2e per kg. No study was found on Swedish cultivated or wild blueberries.
Raspberries	1.1	0.9	4 (1 SW)	5	European studies was considered most relevant for the Swedish market. Data on Swedish production based on one study, so the final assessment is uncertain.
Strawberries	1.5	0.4	13 (2 SW)	19	European studies were considered most relevant for the Swedish market. Two studies showed higher impact than 1.5 kg CO_2e per kg strawberries, but considering the amount of studies indicating an impact well below 1 kg CO_2e per kg, the final assessment was set to 1.5 kg CO_2e per kg. Strawberries from heated greenhouses in Europe are likely to have a higher impact, around 3 kg CO_2e per kg. Two studies were found on Swedish strawberries.

3.5.2. Land use

Land use for fruits is commonly below 2 m^2 per kg product, except for cherries and dates, where all the data points show higher land use than 2 m^2. Berries (cranberries, cultivated blueberries, raspberries, and strawberries) tend to have more varied land use, depending on country of origin. This could be due to e.g., strawberries being produced in greenhouses or open fields, with large variations in yield. In general, land use for world average production seems to be well in line with the identified export countries and Swedish production, with the exception of plums and sloes, for which global average land use is higher.

The Netherlands was identified as one of the countries of origin for cherries. Land use for cherry production in the Netherlands was assessed to be 25-35 m^2 (higher values for organic production), which is very much higher than for the other identified export countries (Chile, Turkey, Germany). However, the Netherlands is most likely not the origin of most cherries sold in Sweden, since it is not a significant producer of cherries (it produces 1.3% of the level in e.g., Germany, from which Sweden also imports cherries). The cherries imported from the Netherlands most likely originate from one of the major production countries.

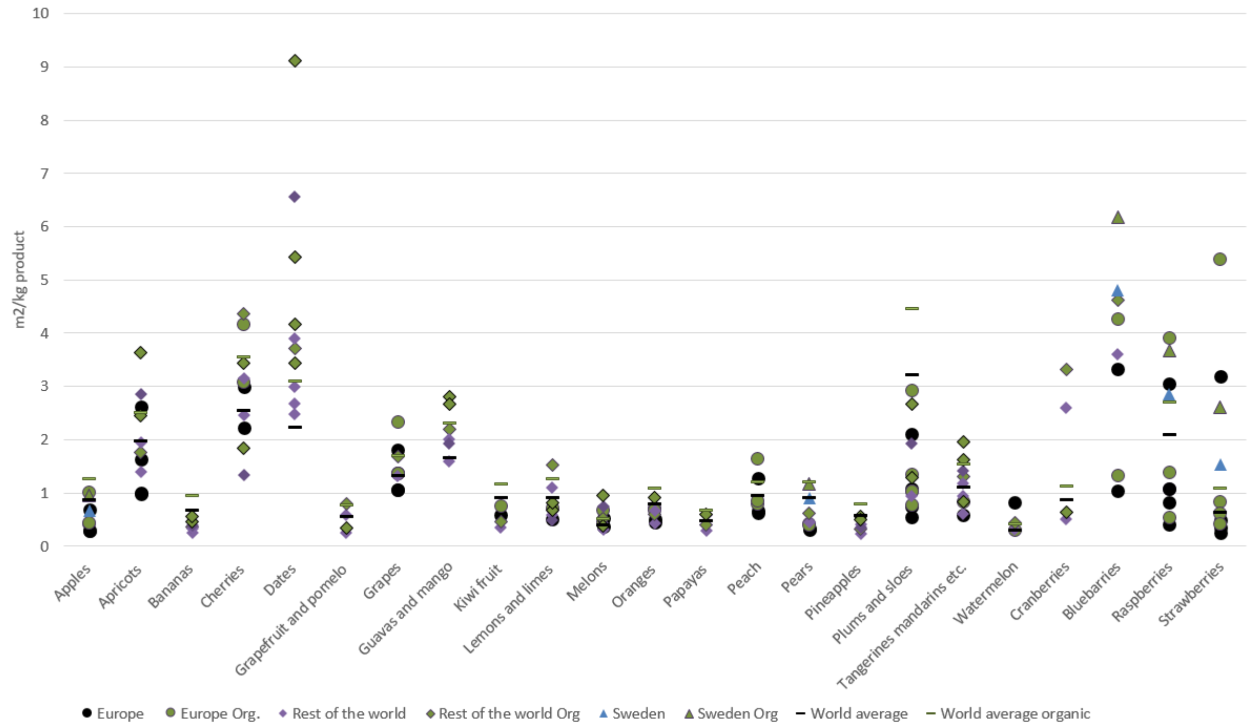

Figure 33. *Land use for fruit and berries in m^2 per kg in a store in Sweden (cherries from the Netherlands excluded), and the global average.*

3.5.3. Biodiversity

Biodiversity impact from land use is generally higher for fruits imported from tropical regions, including bananas from Costa Rica, Dominican Republic, and Ecuador, cherries from Chile, guavas and mangoes from Mexico, and limes from Mexico.

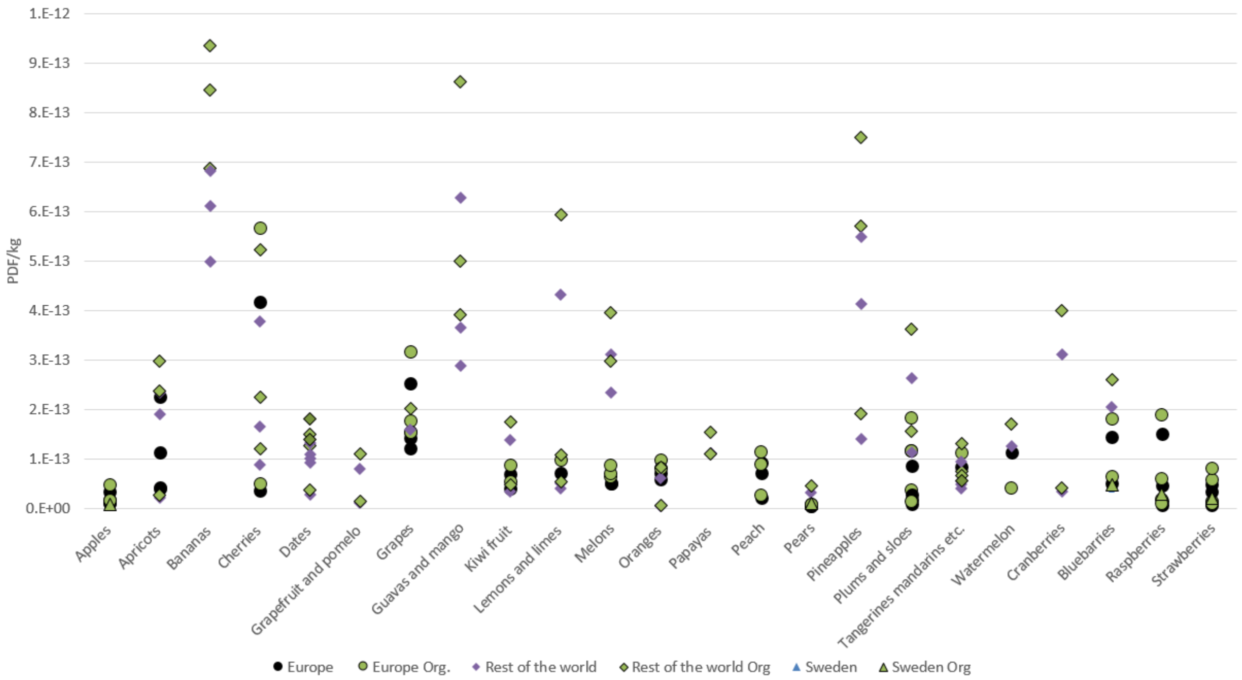

Figure 348*. Biodiversity impact from land use occupation for fruit and berries in PDF (Potentially Disappeared Fraction) per kg product in a store in Sweden.*

Table 18. *Range of results for all identified export countries and Swedish produce for land use (m^2/year per functional unit (FU)) and biodiversity impact (Potentially Disappeared Fraction) (PDF) per FU) for fruits and berries*

Product	**Land use *(m^2/year per FU)***	**Biodiversity impact *(PDF per FU)***	**Comment**[a]
Fruit			
Apples	0.3-1.0	5.2E-15-4.7E-14	
Apricots	1.0-3.6	2.1E-14-3.0E-13	Turkey, which was added as an extra country (see section 2.2), has the highest land use of the countries assessed. The highest biodiversity impact was found for Armenia and Turkey. Spain was identified as the largest exporter globally.
Bananas	0.3-1.0	5.0E-13-8.4E-13	Land use varies between 0.3-0.7 (conventional) and 0.4-1.0 (organic) m^2 per kg.
Cherries	1.3-4.4	3.6E-14-5.7E-13	Products from the Netherlands excluded from the analysis. The highest biodiversity impact was found for Chile (largest exporter globally) and Spain (extra country, see section 2.2)
Dates	2.2-9.1	2.7E-14-1.8E-13	
Grapefruits and pomelo	0.2-0.8	1.0E-14-1.1E-13	
Grapes	1.1-2.3	1.2E-13-3.2E-13	The highest biodiversity impact was found for Spain.
Guavas and mango	1.6-2.7	2.9E-13-8.6E-13	The highest biodiversity impact was found for Mexican production, Mexico was identified as the main exporter globally.
Kiwifruit	0.4-1.2	6.8E-14-1.7E-13	
Lemons and lime	0.5-1.5	3.5E-14-5.9E-13	The highest biodiversity impact was found for Mexican production, Mexico was identified as the main exporter globally.
Melons	0.3-1.0	5.1E-14-3.9E-13	The highest biodiversity impact was found for Guatemala production, Guatemala was identified as the main exporter globally.
Oranges	0.4-1.1	3.9E-15-9.7E-14	
Papayas	0.3-0.7	8.1E-14-1.5E-13	
Peach	0.6-1.6	2.1E-14-1.1E-13	
Pears	0.3-1.2	5.4E-15-4.4E-14	
Pineapples	0.2-0.8	1.4E-13-5.7E-13	
Plums and sloes	0.6-4.5	9.6E-15-3.6E-13	Global average had the highest land use. South Africa, added as an extra country (see section 2.2), was found to have the highest land use.
Tangerines and mandarins	0.6-2.0	4.0E-14-1.3E-13	
Watermelon	0.2-0.4	4.0E-14-1.3E-13	
Berries			
Cranberries	0.5-3.3	3.3E-14-4.0E-13	The highest biodiversity impact was found for cranberries from Chile, Chile was identified as the main exporter globally.
Blueberries (cultivated)	1.0-6.2	3.8E-14-2.6E-13	Land use for Swedish production was the highest.
Raspberries (cultivated)	0.4-3.9	9.1E-15-1.9E-13	The highest biodiversity impact was found for Spanish production of raspberries.
Strawberries	0.2-5.4	6.2E-15-5.7E-14	Strawberries from Poland have the highest land use.

[a] Comments included when applicable.

3.5.4. Water use

Earlier studies

Fruit and berry plantations are often irrigated, which can be seen by comparing Figure 27 (water use for carbohydrate sources) and Figure 39. The fact that these crops are often irrigated is most likely the reason why blue water use is often included in earlier studies. However, information about use of water in berry plantations is largely lacking.

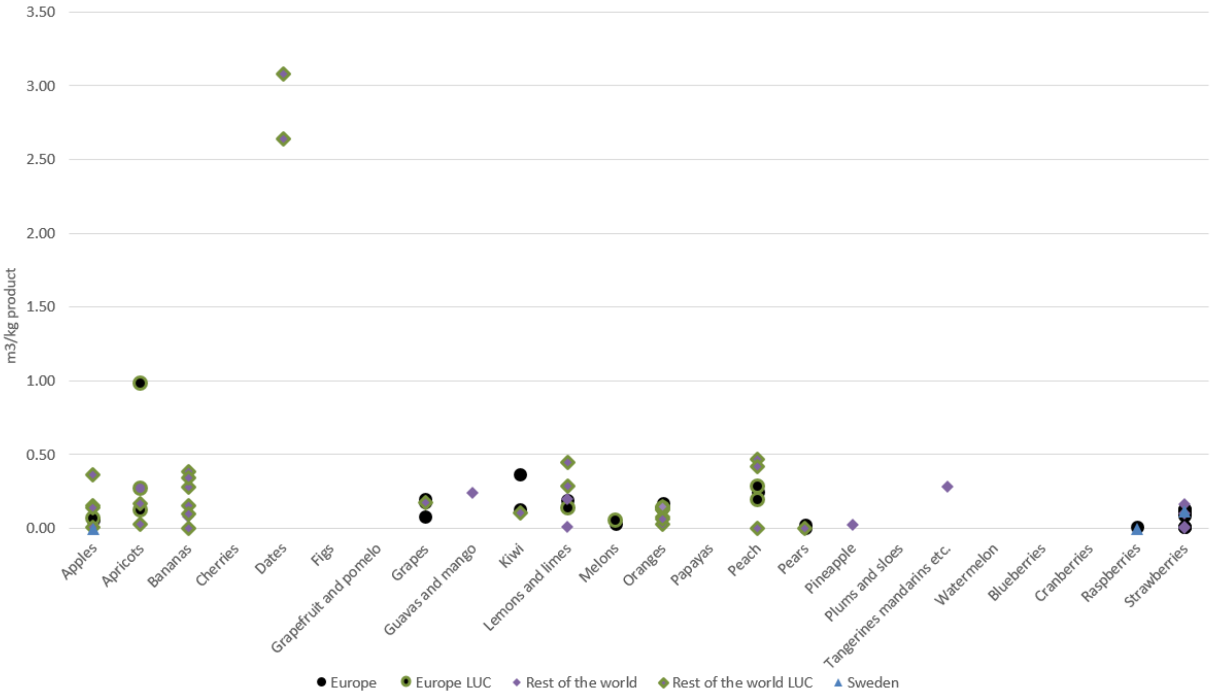

Figure 39. *Blue water use for fruits and berries from earlier studies, in m^3 per kg product.*

Water footprint, total water use, and AWARE

Most fruit and berries from Sweden and the identified export countries have total water use below 2 m^3 per kg. Dates stand out as being particularly water-demanding and irrigated to a large extent (with the exception of production from Iraq) (Mekonnen *et al.*, 2011). Cherries from the Netherlands have particularly high total water use (see Figure 40), most likely due to the low yield. However, as described above, the cherries imported from the Netherlands in the import statistics are likely not grown in the Netherlands.

Looking at the AWARE scores (Figure 42), dates stand out again, due to high irrigation as described above, but also relatively high AWARE characterization factors for water scarcity for Iran and Saudi Arabia, which were identified as export countries together with Iraq. Cherries from Chile also have a relatively high score.

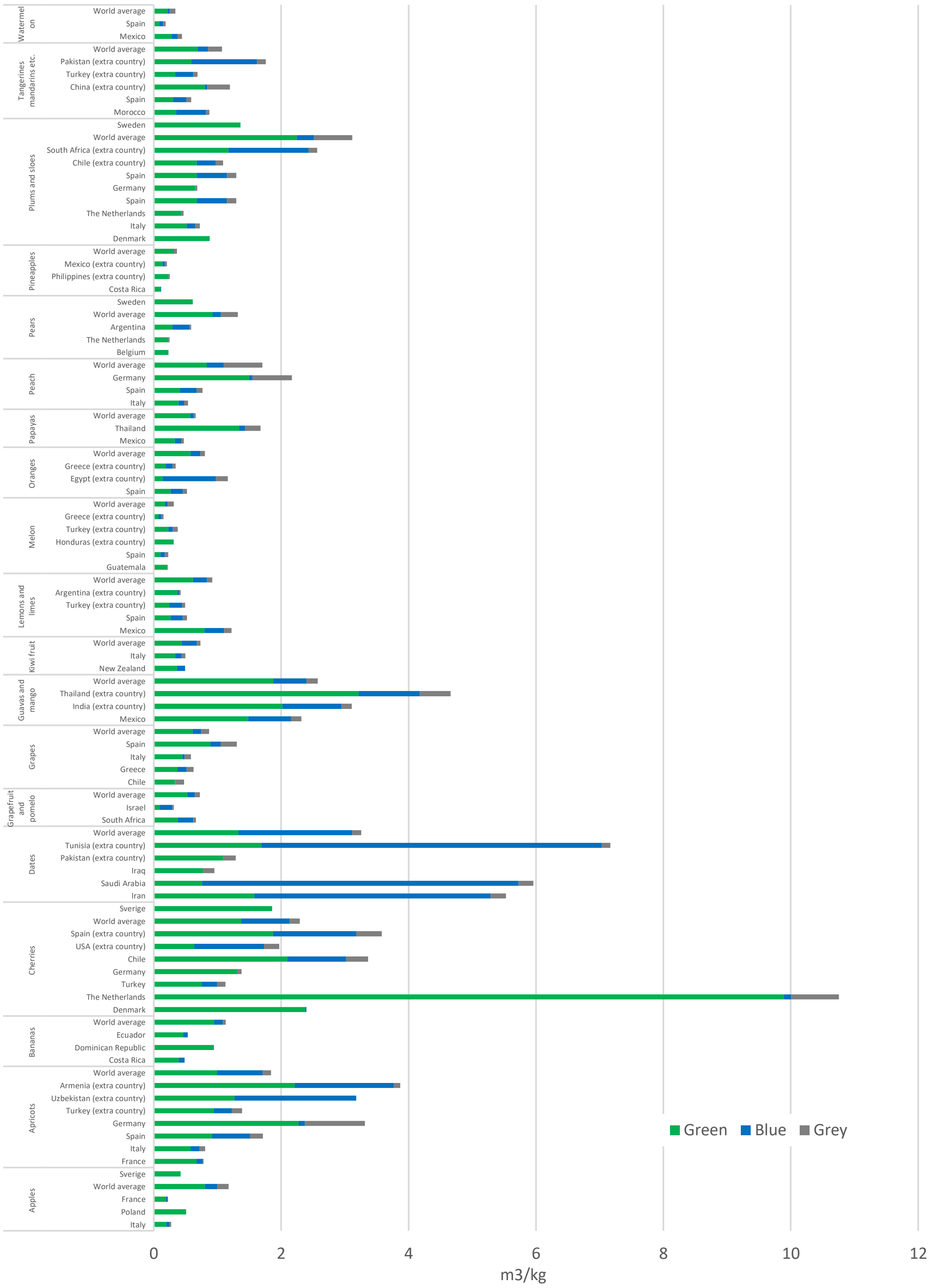

Figure 40. *Total water use, divided into green, blue and grey water use, for fruit and berries in m*^{3} *per kg product in a store in Sweden for the identified export countries, and world average water use for comparison.*

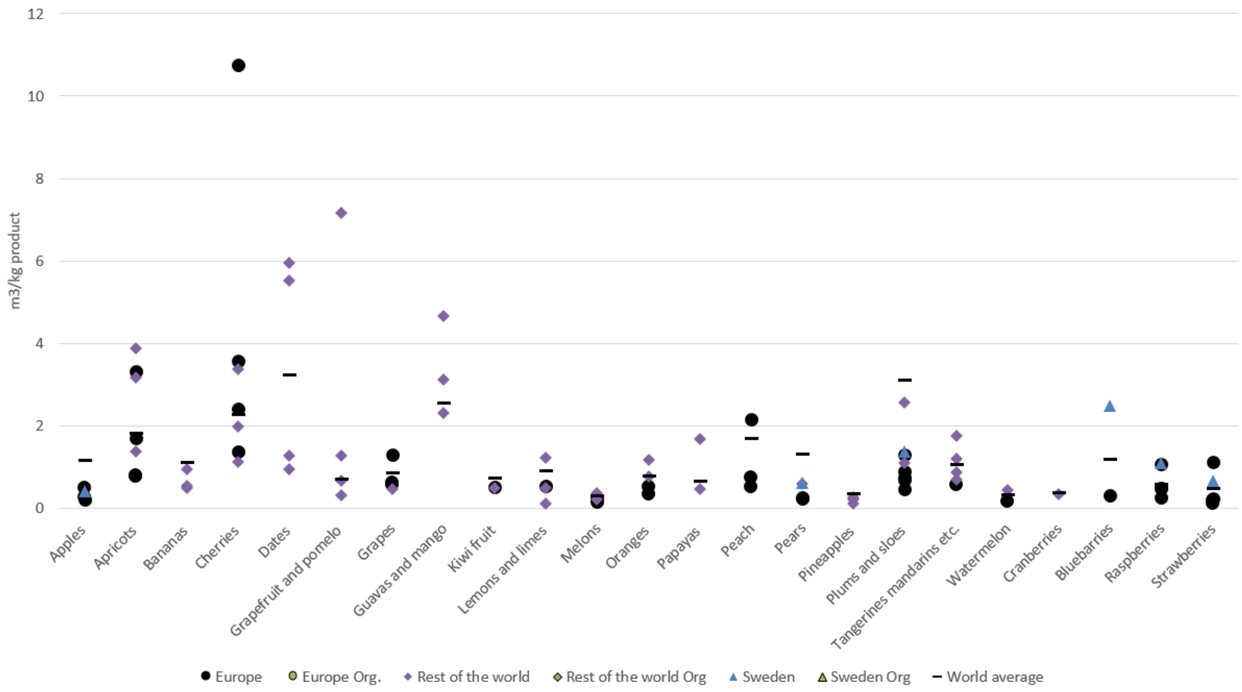

Figure 41. *Total water use for fruit and berries in m*^{3} *per kg product.*

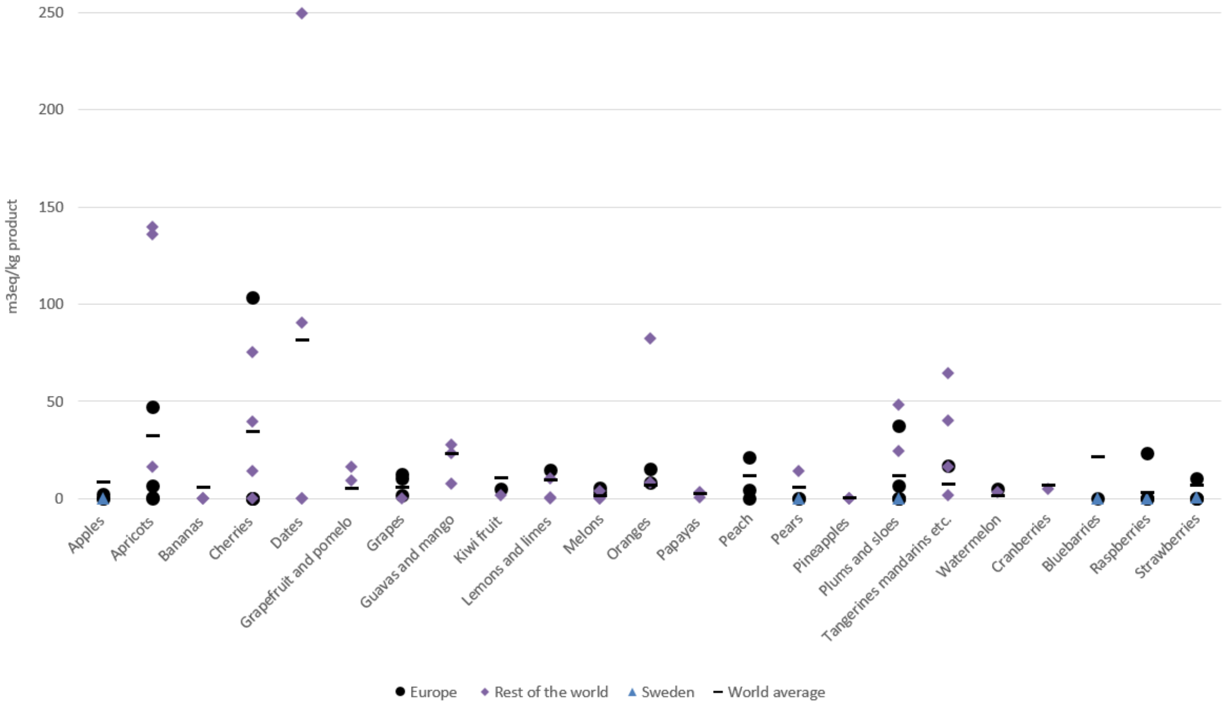

Figure 42. *Water use for fruits and berries assessed with the water scarcity method AWARE (Available Water Remaining, m*^{3}*eq per kg product), and the world average.*

Table 19. *Range of results for all identified export countries and Swedish produce for total water use (m^3 per functional unit (FU)) and AWARE (Available Water Remaining, m^3eq per FU) for fruit and berries*

Product	**Total water use** *(m^3 per FU)*	**AWARE** *(m^3eq per FU)*	**Comment**[a]
Apples	0.2-1.2	0-8.7	Total water use for European production (including Swedish) is likely to be 0.5 m^3 per kg. World average water use is higher, around 1.2 m^3 per kg. AWARE scores were highest for global average production.
Apricots	0.8-3.9	0.8-140	Total water use varies. It is highest for two of the extra countries (Armenia and Uzbekistan) (see section 2.2), which also showed the highest AWARE scores.
Bananas	0.5-1.1	0.3-24	Highest AWARE score found for the global average, the identified export countries had lower scores.
Cherries	1.1-3.6	0.1-103	The Netherlands was excluded from the analysis. Total water use for Swedish production is 1.9 m^3 per kg and for the identified export counties varies between 1.12-3.6 m^3 per kg. Higher AWARE scores were found for Spain and Chile.
Dates	1.0-7.2	0-910	Total water use varies greatly. Iraq, with the largest trade surplus globally, has water use of 1 m^3 per kg. In other identified export countries it varies between 5.5-7.2 m^3 per kg. The world average is lower, 3.3 m^3 per kg, indicating that total water use can be lower than for the identified export countries. AWARE scores were found to be high for many of the countries. AWARE scores close to zero are due to low irrigation rates.
Grapefruits and pomelo	0.3-0.7	5.6-16	Total water use for global average and identified export countries was found to be similar, 0.3-0.7 m^3 per kg.
Grapes	0.5-1-3	0-10	Total water use for Chile, Greece, and Italy is relatively similar, below 0.6 m^3 per kg. Spanish production has total water use of 1.3 m^3 per kg. AWARE scores are highest for Greece.
Guavas and mango	2.3-4.7	7.5-24	
Kiwi fruit	0.5-0.7	1.6-11	Similar water use for the main export countries, Italy and New Zealand (0.5 m^3 per kg). Global average is similar (0.7 m^3 per kg). Highest AWARE score found for world average production.
Lemons and limes	0.5-1.2	0.1-15	Total water use varies between 0.4-1.2 m^3 per kg. Highest AWARE scores found for Mexico and Spain.
Melons	0.2-0.4	0-6.0	For all identified export countries, total water use was assessed to be below 0.4 m^3 per kg.
Oranges	0.2-1.2	7.2-82	Spain was identified as the main export country, with total water use of 0.5 m^3 per kg. Highest AWARE score found for Egypt.
Papayas	0.5-1.7	0.7-3.4	Highest total water use is for produce from Thailand (1.7 m^3 per kg), Mexican export and global average is lower (0.5-0.7 m^3 per kg).
Peaches	0.5-2.2	0.1-21	European production was assessed to have total water use of 0.5-2.2 m^3 per kg. The higher water use is for Germany. Highest AWARE score found for Spain.
Pears	0.2-1.3	0-14	Total water use for the two identified European export countries was below 0.3 m^3 per kg, for Swedish production 0.6 m^3 per kg. Global average water use is higher, indicating a risk of higher water use than the identified export countries. Highest AWARE score found for Argentina.
Pineapples	0.1-0.4	0-1.2	Total water use for all export countries assessed is below 0.4 m^3 per kg.
Plums and sloes	0.5-3.1	0-48	Total water use varies between 0.5-3.1 m^3 per kg. Swedish production has water use around 1.4 m^3 per kg. AWARE scores were highest for South Africa, Spain, and Chile.
Tangerines and mandarins	0.6-1.8	1.8-64	The two highest AWARE scores were found for Pakistan (extra country; see section 2.2) and Morocco (main identified export country)
Watermelon	0.2-0.4	1.6-5.0	
Berries			
Cranberries	0-0.4	0-7.1	The USA was identified as the main export country, with total water use estimated at 0.3 m^3 per kg, similar to global average.
Blueberries (cultivated)	0-2.5	0-22	Total water use is highest for Swedish blueberries (2.5 m^3 per kg). Global average has about half as high water use (1.2 m^3 per kg) and Polish around 0.3 m^3 per kg. In general, water use for imported blueberries is likely to be below 1.2 m^3 per kg. Highest AWARE score found for global average, all

			other identified export countries and Sweden have AWARE scores below 0.01 m^3eq per kg.
Raspberries (cultivated)	0.3-1.1	0-23	Swedish and Spanish production have the highest water use, around 1.1 m^3 per kg. Global average is lower, 0.6 m^3 per kg. Highest AWARE score found for Spain.
Strawberries	0.1-1.1	0.3-11	Total water use is 0.1-1.1 m^3 per kg (only European export countries were identified), global average water use is 0.5 m^3 per kg. Swedish strawberries were assessed to have total water use of 0.7 m^3 per kg. Highest AWARE score found for Spain.

[a]Comments included when applicable.

3.6. Vegetables and mushrooms

3.6.1. Climate impact

A number of vegetables for the Swedish market are produced in heated greenhouses (LCA results from studies on heated greenhouses are marked with a red border in Figure 43). Fossil fuels are often used for heating, which explains some of the higher values. Alternatively, greenhouses are heated with waste heat or bioenergy, which leads to considerably lower climate impact. Today, Swedish greenhouse production uses a large share of renewable energy sources. The latest statistics (for 2017) for greenhouses producing tomatoes, cucumbers, and ornamental plants show that 59% of energy use is bioenergy and 23% is from other energy sources, such as district heating and electricity. In tomato production, the share of bioenergy was around 70% in 2017 (SBA, 2018a). In Sweden, transition to renewable energy has happened during recent decades, so older studies on tomatoes (González *et al.*, 2011; Fuentes *et al.*, 2006; Carlsson-Kanyama, 1998) show considerably higher impacts than newer studies (Moberg *et al.*, 2019; Röös & Karlsson, 2013). Newer data are therefore more relevant for Swedish greenhouse production. Based on more recent studies on the climate impact of Swedish tomato production (Moberg *et al.*, 2019; Röös & Karlsson, 2013) and the statistics on renewable energy use, the climate impact of Swedish tomatoes sold in a Swedish store is likely to be below 1 kg CO_2e per kg.

For tomatoes from the Netherlands (61% of imports), all existing studies (Röös & Karlsson, 2013; Torrellas *et al.*, 2012b; González *et al.*, 2011; Blonk *et al.*, 2010; Wernet *et al.*, 2016; Hofer, 2009) except one study that looked at unheated greenhouses (Hofer, 2009) show a climate impact of 1 kg CO_2e per kg or above. Unheated greenhouse production was considered less relevant for Dutch exports, as further explained below. Similarly to Swedish greenhouse production, the Netherlands is starting to use more renewable energy in greenhouse production, e.g., in 2015 the share of renewable energy in the sector was above 5%, increasing from around 3% in 2013 (Ruijs, 2017), but it is still low. Therefore, we recommend that Dutch tomatoes in a Swedish store are assumed to have a climate impact above 1 kg CO_2e per kg. For Spanish tomatoes (22% of imports), all existing studies (Sanyé-Mengual *et al.*, 2014; Röös & Karlsson, 2013; Torrellas *et al.*, 2012a; Torrellas *et al.*, 2012b; Wernet *et al.*, 2016; Lindenthal *et al.*, 2010; Hofer, 2009) except one (Blonk *et al.*, 2010) show a climate impact below 1 kg CO_2e per kg in a Swedish store. Based on this, our assessment is that Spanish tomatoes in a Swedish store can be considered to have a climate impact of below 1 kg CO_2e per kg.

Similarly to tomatoes, cucumbers for the Swedish market are often produced in greenhouses. The main export countries to Sweden were identified as the Netherlands (32%) and Spain (56%) (SS, 2018). Only a few studies on cucumber production in Sweden, the Netherlands, and Spain were found (Moberg *et al.*, 2019; González *et al.*, 2011; Hofer, 2009). Although bioenergy use in cucumber production in Sweden is similar to that in tomato production (approximately 70%), in cucumber production the remaining energy used for heating, close to 30%, comes from fossil fuels (SBA, 2018a). The study considered most relevant for Swedish production was Moberg *et al.* (2019), due to its use of the most recent data for heating.

Some high data-points for lettuce, pumpkin, and spinach are from a study lacking details of the inventory and the results (Audsley *et al.*, 2010), and therefore it is difficult to determine why the figures are much higher than in other studies on the same crops. It is likely due to high fossil fuel use in greenhouses, but this could not be confirmed.

Several studies on mushrooms were found (Robinson *et al.*, 2019; Leiva *et al.*, 2015; Ueawiwatsakul *et al.*, 2014; Tongpool & Pongpat, 2013; Gunady *et al.*, 2012; Audsley *et al.*, 2010; Blonk *et al.*, 2010; Maraseni *et al.*, 2010). These studies focus on different types of mushrooms with large variation in the climate impact. One of the most common mushroom types on the Swedish market is *Agaricus bisporus* (Sw: *trädgårdsschampinjon*), which is the same type sold as portobello mushrooms (used as a substitute for burgers, among other things). No study was found on production of mushrooms in the main exporting countries to Sweden, which are Poland and Lithuania (SS, 2018). Three studies from other countries on *Agaricus bisporus* were found (Robinson *et al.*, 2019; Leiva *et al.*, 2015; Gunady *et al.*, 2012), with a climate impact at farm gate varying from 2.1-4.4 kg CO_2e per kg product. Climate control and the energy use for this are important contributors to climate change for this type of production (Robinson *et al.*, 2019; Leiva *et al.*, 2015), but also transport of substrate (manure and peat) (Gunady *et al.*, 2012). There is some commercial production of mushrooms in Sweden. However, no earlier study was found on this production and no statistics on yearly production or yield were found.

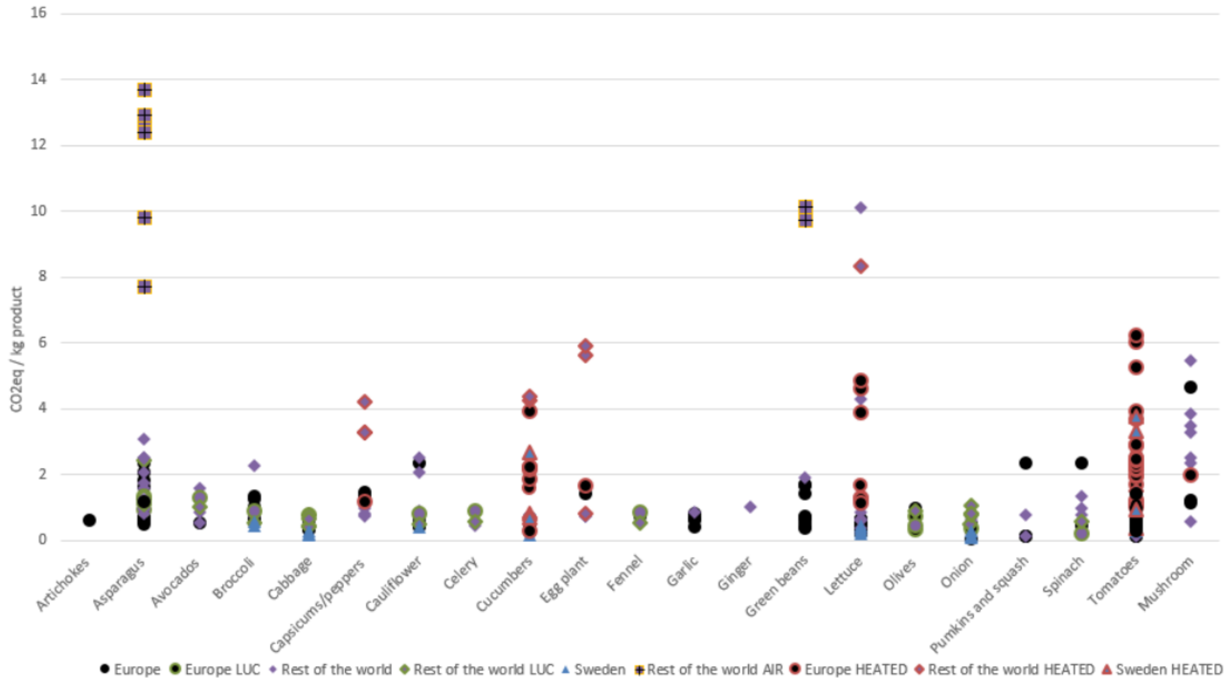

Figure 43. *Climate impact of vegetables and mushrooms in kg CO_2e per kg product in a store in Sweden. The squares represent earlier studies on products transported by air. Note that the graph shows the climate impact from all identified earlier studies for this product group, and not only those identified as relevant for the Swedish market. The final assessment in Table 20 is based on relevance for the Swedish market.*

Table 20. *Summary of recommendations for climate impact of vegetables and mushrooms on the Swedish market*

Product	**Final assessment (kg CO_2e per kg product in a Swedish store)**		**No. of relevant references**	**Total no. of references**	**Comment**
	General	**Sweden**			

Artichoke	0.6		1	1	European production considered most relevant for the Swedish market. Only one study was found, so the assessment is uncertain.
Asparagus	2.1		5	8	Final assessment is for European production. Three studies show an impact below 1 kg CO_2e per kg. Import from the rest of the world carries a high risk of air transport. Earlier studies show that the impact can be as high as approx. 14 kg CO_2e per kg product (3 references).
Avocado	1.6		6	6	All identified studies considered relevant.
Broccoli	1.3	0.6	5 (2 SW)	8	Broccoli on the Swedish market is likely to originate from southern Europe. Most studies show an impact below or close to 1 kg CO_2e per kg. However, two studies show an impact above 1 kg CO_2e per kg for Spanish production, which is highly relevant for the Swedish market. Climate impact for broccoli is therefore likely to be below 1.3 kg CO_2e per kg for European production. Two studies were found on Swedish production.
Cabbage	0.6	0.3	4 (3 SW)	7	European produce considered most relevant for the Swedish market.
Capsicums/ peppers	1.5		2	7	Sweden imports come mainly from the Netherlands and Spain, but no data were found for these countries. Studies on European produce (Italian and Swiss) were used for the final assessment.
Cauliflower	0.7	0.4	3 (1 SW)	6	European production considered relevant for the final assessment. One study on European production shows an impact above 2 kg CO_2e per kg. However, not enough detail is presented in that study to explain the higher climate impact compared with other studies, so it was not considered. Only one study was found on Swedish production, this assessment is uncertain.
Celery	0.6		0	3	European production considered most relevant for the Swedish market. No study on European production of celery was found. Considering the LCA data found and the shorter transportation distance, we estimated climate impact of celery for the Swedish market based on production impact from “rest of the world” (Australia, the USA and a global average production) and general impact for transport within Europe.
Cucumber	2.3	0.7	6 (2SW)	10	Often produced in heated greenhouses for the Swedish market. Data on European production vary greatly, mainly due to differences between heating source for the greenhouses. Overall recommendation based on earlier studies: European produce likely to have a climate impact below 2 kg CO_2e per kg, but the impact can be lower, around 0.5 kg CO_2e per kg, depending mainly on greenhouse production or not, and heating source. Products from outside Europe are considered less relevant for the Swedish market. Two relevant studies were found for the Swedish market. This assessment is not valid for open field-produced cucumbers grown in Sweden, such as “*västeråsgurka*”.
Eggplant	1.7		2	6	European production considered relevant. The higher impact is due to heated greenhouse.
Fennel	0.8		1	2	European production considered most relevant.
Garlic	0.8		2	3	European production considered most relevant. Only one study was found on “rest of the world” production, showing an impact of around 0.9 kg CO_2e per kg product.
Ginger	1.0		1	1	Only one study identified, the assessment is uncertain.

Lettuce	0.7	0.4	7 (3 SW)	14	European production considered most relevant for the final assessment. Assessment based on open field production for iceberg lettuce, for both European and Swedish production. Fresh lettuce sold in pots can be cultivated in heated greenhouses and therefore associated with substantially higher climate impact.
Green beans	0.8		2	5	European production considered most relevant. This assessment included one study on frozen green beans. One study on European green beans was not considered, since it showed much higher climate impact than the other studies and did not explain the processes in detail. Further, canned green beans were considered less relevant for the Swedish market. For green beans imported from outside Europe, there is a risk of air transport. One earlier study was found on green beans transported from Kenya and Uganda with a total climate impact of 9.7-10.1 kg CO_2e per kg product.
Olives	1.0		4	5	European production considered most relevant. One study on European olives was excluded, due to much higher climate impact and insufficient data in the report to evaluate the figure.
Onions	1.0	0.3	8 (4 SW)	8	All studies considered relevant. European production likely below 0.8 kg CO_2e per kg onions (6 references).
Pumpkins and squash	0.13		1	3	European studies considered most relevant for the Swedish market. One study on European production was excluded due to much higher climate impact and insufficient amount of data in the report to evaluate the figure. The assessment is based on one study, and is therefore uncertain.
Spinach	0.5		1	5	European studies considered most relevant for the Swedish market. One study on European production was excluded. One study on European spinach was excluded due to much higher climate impact and insufficient data to evaluate the figure. The assessment is based on one study and is therefore uncertain. However, this study has a result similar to the studies on "rest of the world" production.
Tomatoes	2.3	0.9	17 (2 SW)	28	Fresh tomatoes on the Swedish market are likely to originate from within Europe. Climate impact varies greatly, the main reason being the heating source for the greenhouses. The most recent study on Swedish tomatoes shows a climate impact of around 0.9 kg CO_2e per kg. Data for European production varies greatly. Clearly many of the data-points are below 1 kg CO_2e per kg. Some show impacts of around 6 kg CO_2e per kg, but often older studies, and the energy mix for heating has changed greatly in Sweden over time. In summary, earlier studies show that tomatoes produced in Europe are likely to have a climate impact below 2.3 kg CO_2e per kg or in many cases much lower. However, the climate impact can be higher, depending on heating source for heating the greenhouses. Sweden mostly imports tomatoes from Spain and the Netherlands. Spanish tomatoes are likely to have climate impact below 1 kg CO_2e per kg, Dutch tomatoes are likely to have climate impact below 2.3 kg CO_2e per kg in a store in Sweden.
Mushrooms	4.7		3	8	Sweden imports mushrooms mainly from Europe. No study on production of *Agaricus bisporus* (Sw: *trädgårdsschampinjon*) from the identified export countries was found. Studies on *Agaricus bisporus* show a climate impact of 2.5-4.7 kg CO_2e per kg product. Climate impact is therefore considered to be below 4.7 kg CO_2e per kg product. Earlier studies indicate that climate control and the energy source

	for this can be important (similar to greenhouse production) (3 references)

3.6.2. Land use

For most vegetables, land use was assessed to be below 2 m^2 per kg product. Artichokes, asparagus, and avocados can be associated with higher land use than 2 m^2 (Figure 44). Olives from all countries of origin assessed had higher land use, 4-9 m^2 (global average), due to low yields.

The biodiversity assessment (Figure 45) showed that asparagus from Mexico, avocados from Mexico and Peru, and peppers from Mexico and olives from Greece and Spain risk having a higher impact on biodiversity than the other products in the vegetables and mushrooms category.

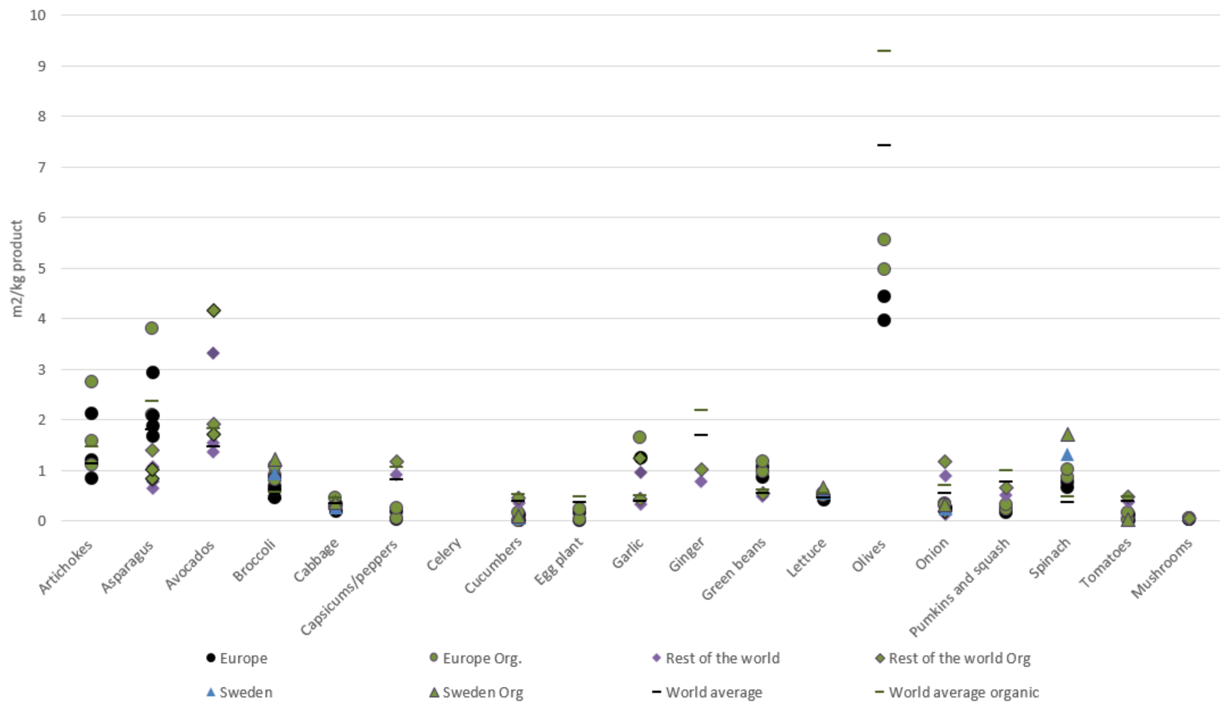

Figure 44. *Land use for vegetables and mushrooms in m^2 per kg in a store in Sweden, and the global average.*

3.6.3. Biodiversity

In this product group, biodiversity impact was highest for avocados, olives, and asparagus from Mexico and Peru, and peppers from Mexico, due to high land use for these products in combination with high biodiversity in the areas where they are produced.

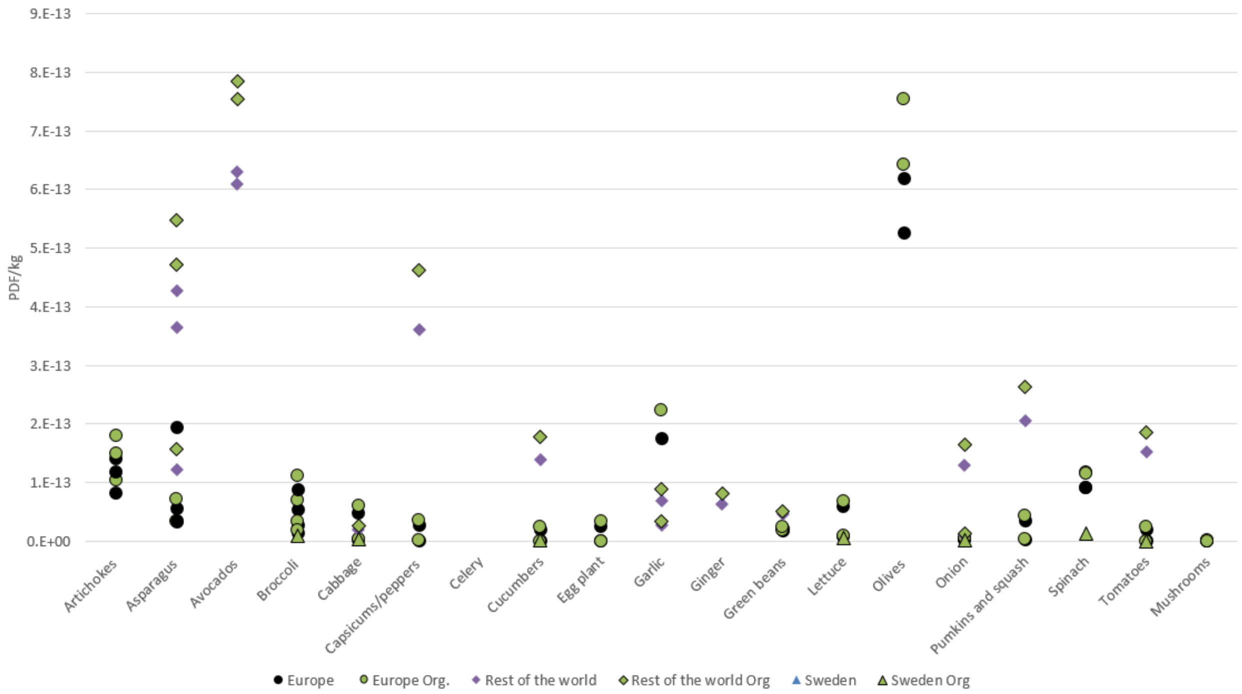

Figure 35. *Biodiversity impact from land use occupation from vegetables in PDF (Potentially Disappeared Fraction) per kg product in a store in Sweden.*

Table 21. *Range of results for all identified export countries and Swedish produce for land use (m^2/year per functional unit (FU)) and biodiversity impact (Potentially Disappeared Fraction (PDF) per FU) for vegetables and mushrooms*

Product	**Land use *(m^2/year per FU)***	**Biodiversity impact *(PDF per FU)***	**Comment[a]**
Artichoke	0.9-2.8	8.2E-14-1.8E-13	Highest land use for French production.
Asparagus	0.6-3.8	3.3E-14-5.5E-13	Highest land use for production in Hungary (extra country, see section 2.2). highest biodiversity impact for Mexico (identified as the largest exporter globally) and Peru (extra country).
Avocados	1.4-4.2	4.0E-13-7.9E-13	All identified export countries have relatively high biodiversity impact, compared with other vegetables.
Broccoli and cauliflower	0.4-1.2	7.4E-15-1.1E-13	Swedish production has the highest land use.
Cabbage	0.2-0.5	2.2E-15-6.1E-14	
Capsicums/peppers	0.04-1.2	7.4E-16-4.6E-13	Highest land use and biodiversity impact found for Mexican production, Mexico was identified as the main exporter globally.
Celery			No data available in FAOSTAT
Cucumber	0.02-0.5	2.9E-16-1.8E-13	Highest land use and biodiversity impact found for Mexican production. Mexico was identified as the main exporter globally, but not considered to be an exporter to Sweden of fresh cucumber due to the distance.
Eggplant	0.02-0.5	4.0E-16-3.3E-14	
Garlic	0.4-1.6	2.7E-14-2.2E-13	
Ginger	0.8-2.2	6.3E-14-8.2E-14	
Green beans	0.5-1.2	1.8E-14-5.1E-14	Land use varies between 0.5- 1.1 (conventional) and 0.6-1.2 (organic) m^2 per kg.
Lettuce	0.4-0.7	4.5E-15-6.7E-14	Swedish production has land use of 0.6 (conventional) and 0.7 (organic) m^2 per kg.

Olives	4.0-9.3	5.3E-13-7.5E-13	Higher land use value for both conventional and organic production is global average.
Onions	0.1-1.2	2.0E-15-1.6E-13	Swedish production has land use of 0.2 (conventional) and 0.3 (organic) m^2 per kg.
Pumpkins and squash	0.2-1.0	3.2E-15-2.6E-13	Highest biodiversity impact for Mexican production, Mexico was identified as the main exporter globally.
Spinach	0.4-1.7	1.0E-14-1.2E-13	Swedish production has land use of 1.3 (conventional) and 1.7 (organic) m^2 per kg.
Tomatoes	0.02-0.5	3.2E-16-1.9E-13	Swedish production has land use of 0.03 (conventional) and 0.04 (organic) m^2 per kg. Highest biodiversity impact found for Mexican production, Mexico was identified as the main exporter globally. Highest biodiversity impact for European production found for Spanish production.
Mushrooms	0.04-0.06	5.3E-16-8.7E-16	

[a] Comments included when applicable.

3.6.4. Water use

Earlier studies

Blue water use is included in several earlier studies on vegetables (Appendix A1). The highest water use is reported for asparagus and avocados.

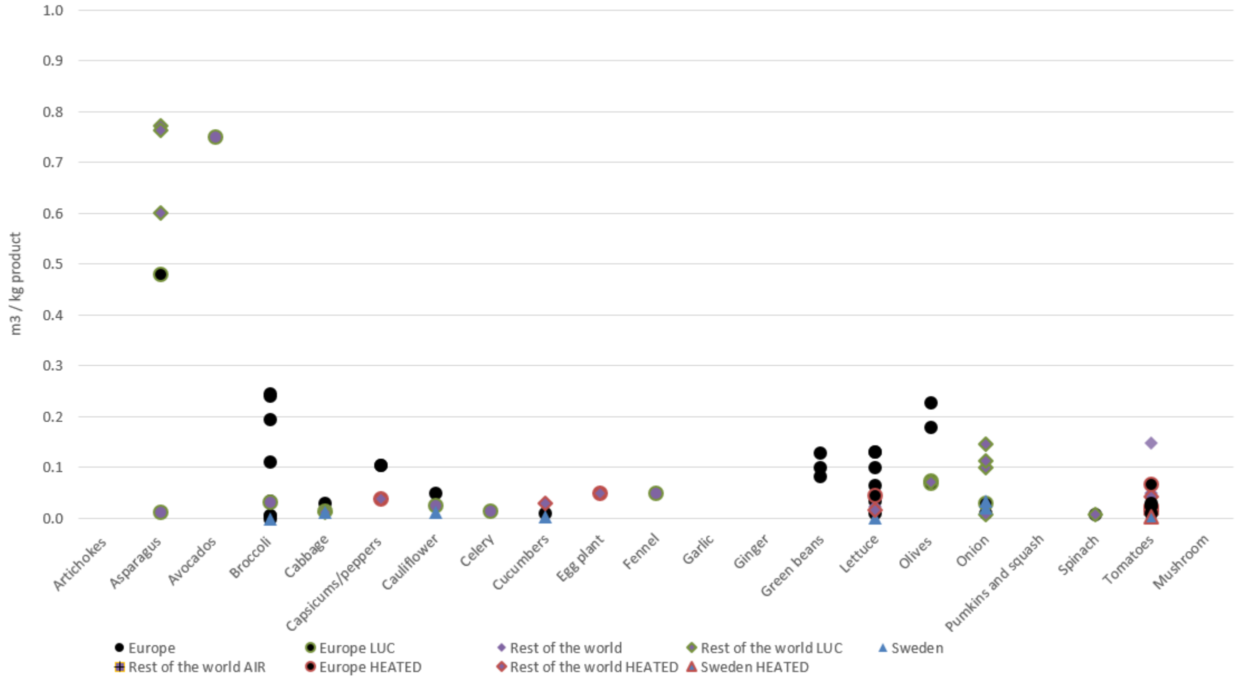

Figure 46. *Blue water use in earlier studies for vegetables and mushrooms.*

Own assessment

Olives, ginger (world average production), asparagus, avocados, and artichokes are the crops within the category ‘Vegetables and mushrooms’ that have the highest total water use (Figures 47 and 48). Generally, the use of irrigation (blue water) is also high for these crops (Mekonnen *et al.*, 2011). World average production and the selected export countries have similar water use for all crops except ginger, where world average production has much higher water use than Chinese production. Assessed with the water scarcity method AWARE, avocados from Chile and olives from Spain were found to have a higher score for this product group, with scores above 50 m^{3}eq per kg product.

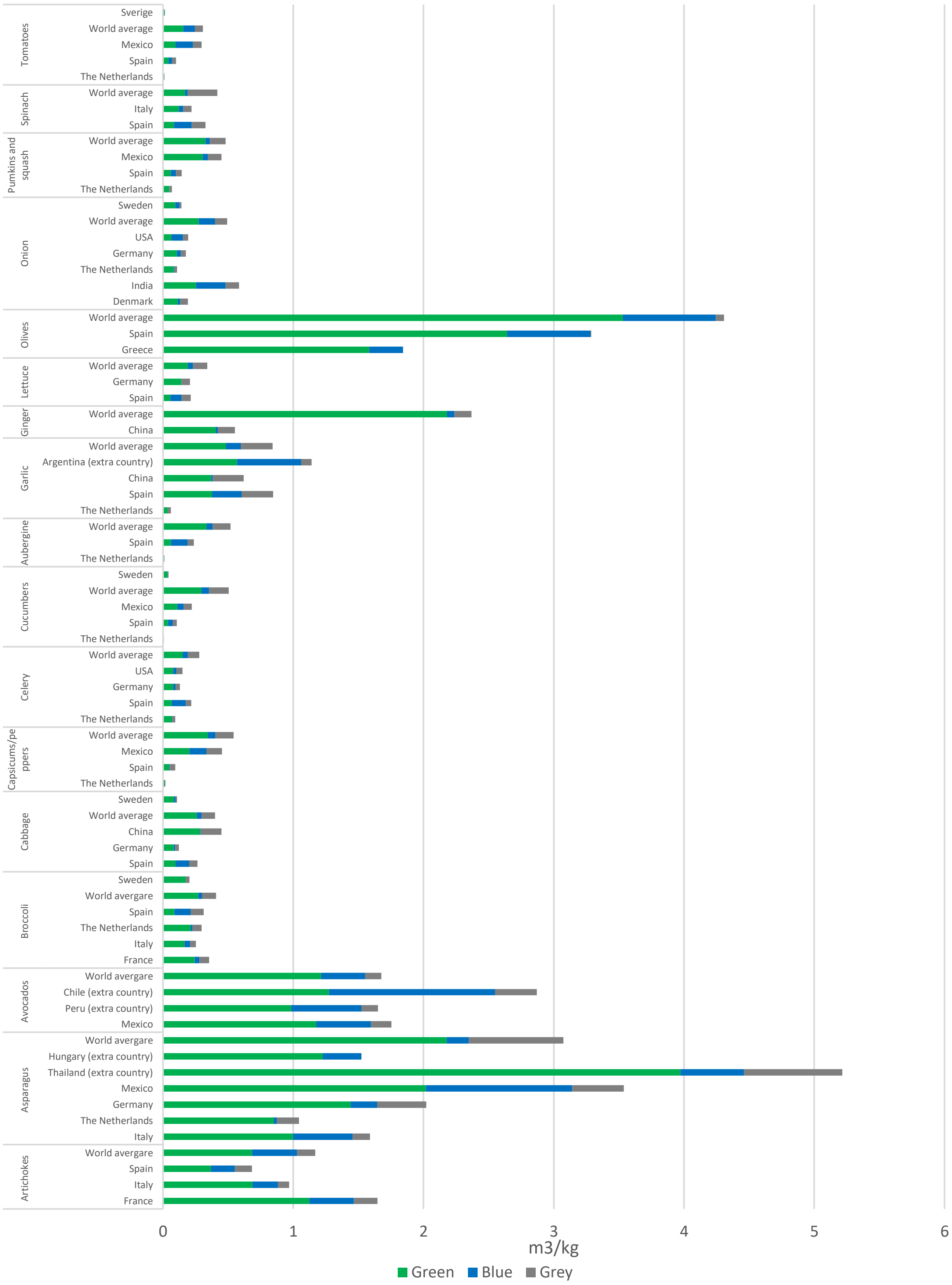

__Figure 47.__ Total water use, divided into green, blue and grey water use, for vegetables in m^3 per kg product in a store in Sweden for the identified export countries, and world average water use for comparison.

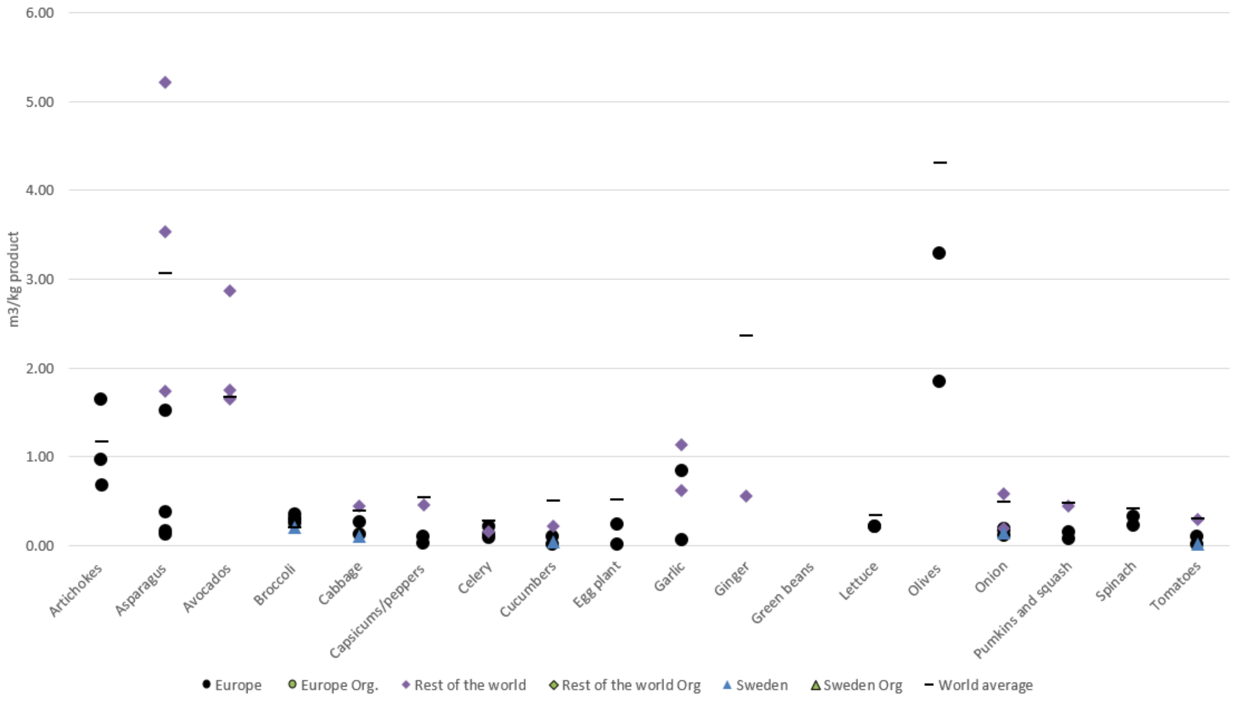

Figure 48. *Total water use for vegetables in m*^{3} *per kg product.*

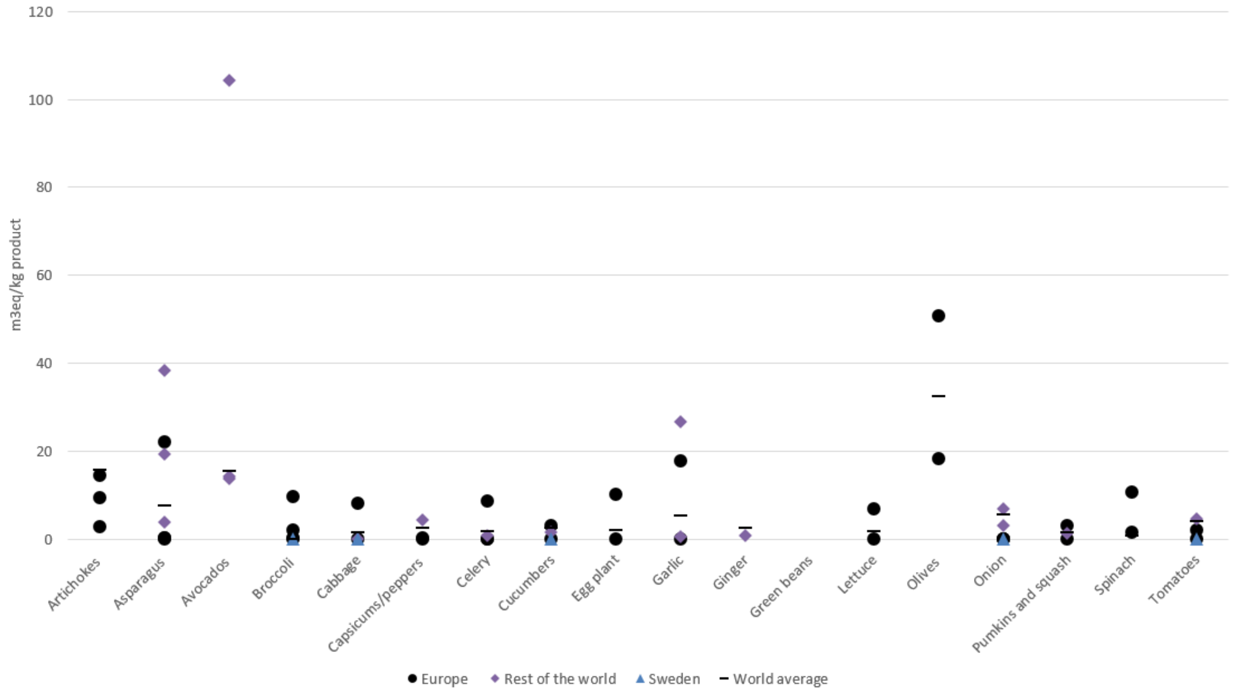

Figure 49. *Water use for vegetables and mushrooms assessed with the water scarcity method AWARE (Available Water Remaining, m*^{3}*eq per kg product) in a store in Sweden, and world average.*

Table 22. *Range of results for all identified export countries and Swedish produce for total water use (m*^{3} *per functional unit (FU)) and AWARE (Available Water Remaining, m*^{3}*eq per FU) for vegetables and mushrooms*

Product	**Total water use *(m^3 per FU)***	**AWARE *(m^{3}eq per FU)***	**Comments**[a]
Artichokes	0.7-1.7	2.9-16	Highest AWARE score found for Spanish production.
Asparagus	1.0-5.2	0.5-39	Highest AWARE score found for Mexico, the country identified as the main exporter globally, but not to Sweden (not appearing in import statistics).
Avocados	1.7-2.9	14-100	Mexico, Peru, and world average production have similar water use, below 1.8 m^3. Avocados from Chile were assessed to have water use of around 2.9 m^3 per kg product. Chile also has the highest AWARE score for avocado production.
Broccoli and cauliflower	0.2-0.4	0-10	Water use for identified export countries, Swedish production and world average production is similar, total water use for these crops is likely to be below 0.4 m^3. Highest AWARE score found for Spanish production.
Cabbage	0.1-0.4	0.02-8.3	Highest AWARE score found for Spain.
Capsicums/peppers	0.02-0.5	0-4.4	
Celery	0.1-0.3	0.1-8.6	Highest AWARE score found for Spain.
Cucumber	0.1-0.5	0-3.0	Highest AWARE score found for Spain.
Eggplant	0.01-0.5	0-10	Highest AWARE score found for Spain.
Garlic	0.1-1.1	0-27	Spanish and world average production had total water use of 1 m^3. Highest AWARE scores found for Argentina (extra country) and Spain (one of the identified export countries).
Ginger	0.6-2.4	0.8-2.6	China was identified as the main exporter, with water use of 0.6 m^3. World average production has much higher water use, 2.4 m^3, indicating a risk of higher water use than the main export country.
Lettuce	0.2-0.3	0-6.9	Highest AWARE score found for Spain.
Olives	1.8-4.3	18-51	Total water use in the main exporting country (Spain with 54% of Swedish imports) was estimated to be 3.3 m^3. World average production 4.3 m^3. AWARE scores were found to be relatively high.
Onions	0.1-0.6	0.01-6.8	Total water use for Swedish production was assessed to be 0.1 m^3. Imported onions from European countries generally have water use below 0.2 m^3. India (identified as one of the export countries and the largest exporter globally) has the highest total water use and highest AWARE score for onions.
Pumpkins and squash	0.1-0.5	0-3.1	The Netherlands and Spain were identified as main export countries in Europe, total water use was assessed to be below 0.14 m^3. Mexico is the largest exporter globally, with water use similar to the global average, below 0.5 m^3. Highest AWARE score found for Spain.
Spinach	0.2-0.4	1.0-11	Spain, Italy, and world average have similar total water use of below 0.4 m^3. Highest AWARE score found for Spain.
Tomatoes	0.01-0.3	0-4.6	Sweden and the Netherlands have similar water use for tomato production, approx. 0.01 m^3. Spanish production uses around 0.1 m^3 and Mexican production and world average production 0.3 m^3.
Mushrooms			No data

[a] Comments included when applicable.

4. RESULTS GENERAL

This chapter presents general results on pesticide use, the final assessment of climate impact for different food groups, results for products assumed to be transported by air and the climate impact of this, and finally recommendations on climate impact estimates for conventional and organic products.

4.1. Pesticide use

Results for individual products are presented in Appendix A7.

For European produce, the EU report from 2007 was used (EUROSTAT, 2007). Data were collected for each country identified as an exporter to Sweden, and the general figures for "cereals", "fruits", etc. were used for the different products. Table A94 in Appendix A7 presents data for each product. Based on general data for European production (Figure 50), production of fruits and vegetables generally uses more pesticides than production cereals, maize, and oilseeds (including soybean). The group "other vegetables" used most pesticides per hectare. Unfortunately, it is not clear from the report (EUROSTAT, 2007) what this group includes, but it is likely to include bell peppers, root and tuber vegetables (including carrots, turnips, and sweet potato), pulses (legumes), but also cropping in kitchen gardens. The use in the category "other plant protection products" (yellow bars in Figure 50) is particularly high for this group. The most commonly used pesticide in this category is the nematocide 1,3-dichloropropane (see Table 2.4.8 in EUROSTAT (2007)).

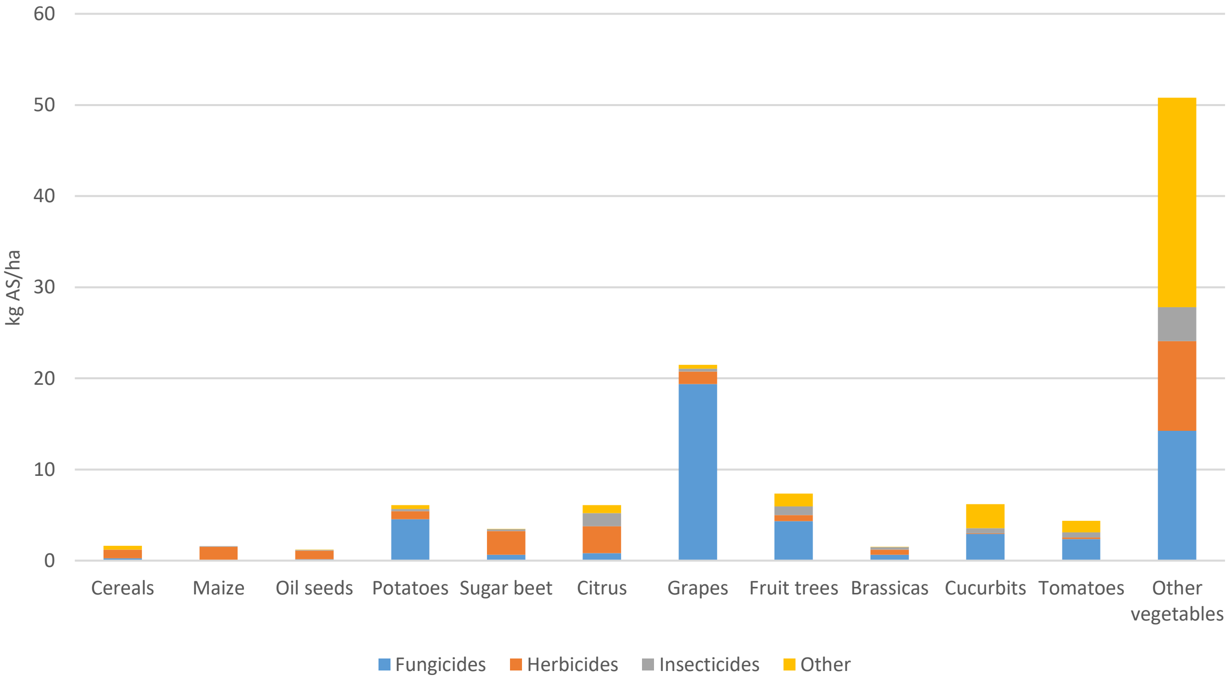

Figure 50. *Use of plant protection products in different crops in all European countries, 1999-2003, presented as kg active substance (AS) per hectare (ha) (data from EUROSTAT, 2007).*

Use of plant protection products in Sweden in active substance per hectare is shown in Figure 51. Carrots and onions stand out as having particularly high per-hectare doses.

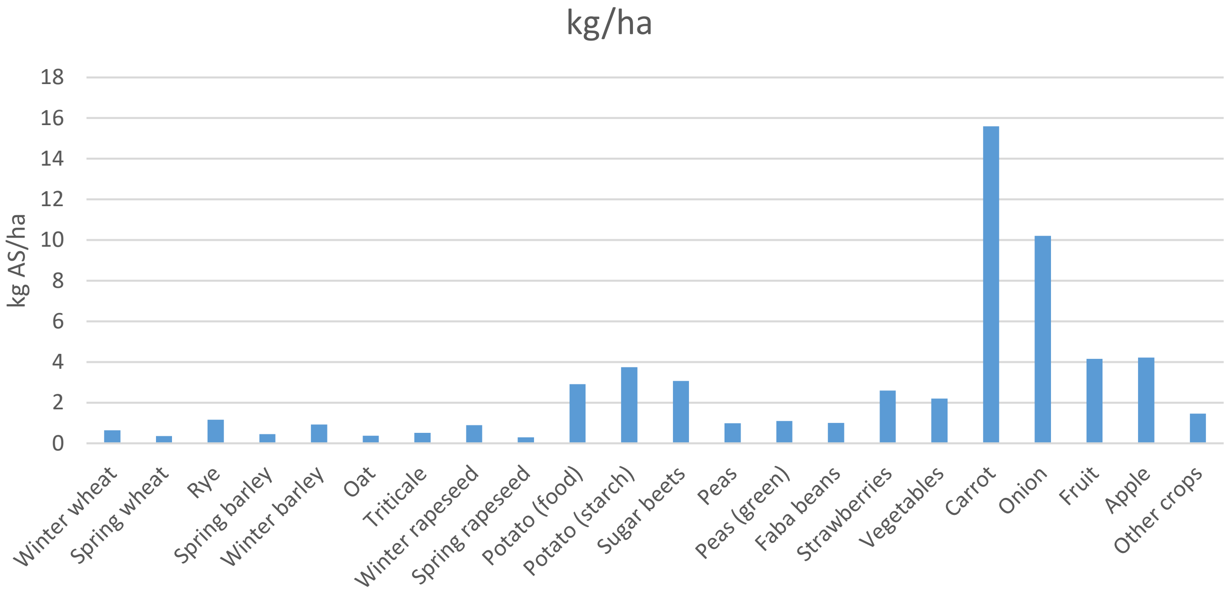

Figure 51. *Use of plant protection products in different crops in Sweden, 2017 (data from SBA, 2018).*

4.1.1. Organic and conventional production

It was assumed that no or very low rates of chemical pesticides are used in organic production.

In general, organic produce has much lower rates of plant protection residues in the products, expressed as quantified residues below and above the maximum residue level (MRL), for all plant-based foods and especially for fruits and nuts, vegetables, and cereals (EFSA, 2018).

4.2. Estimated climate impact of the Swedish market for the different product groups

Figure 52 shows the climate impact of the different product groups. Only studies considered relevant for the Swedish market are included in the diagram.

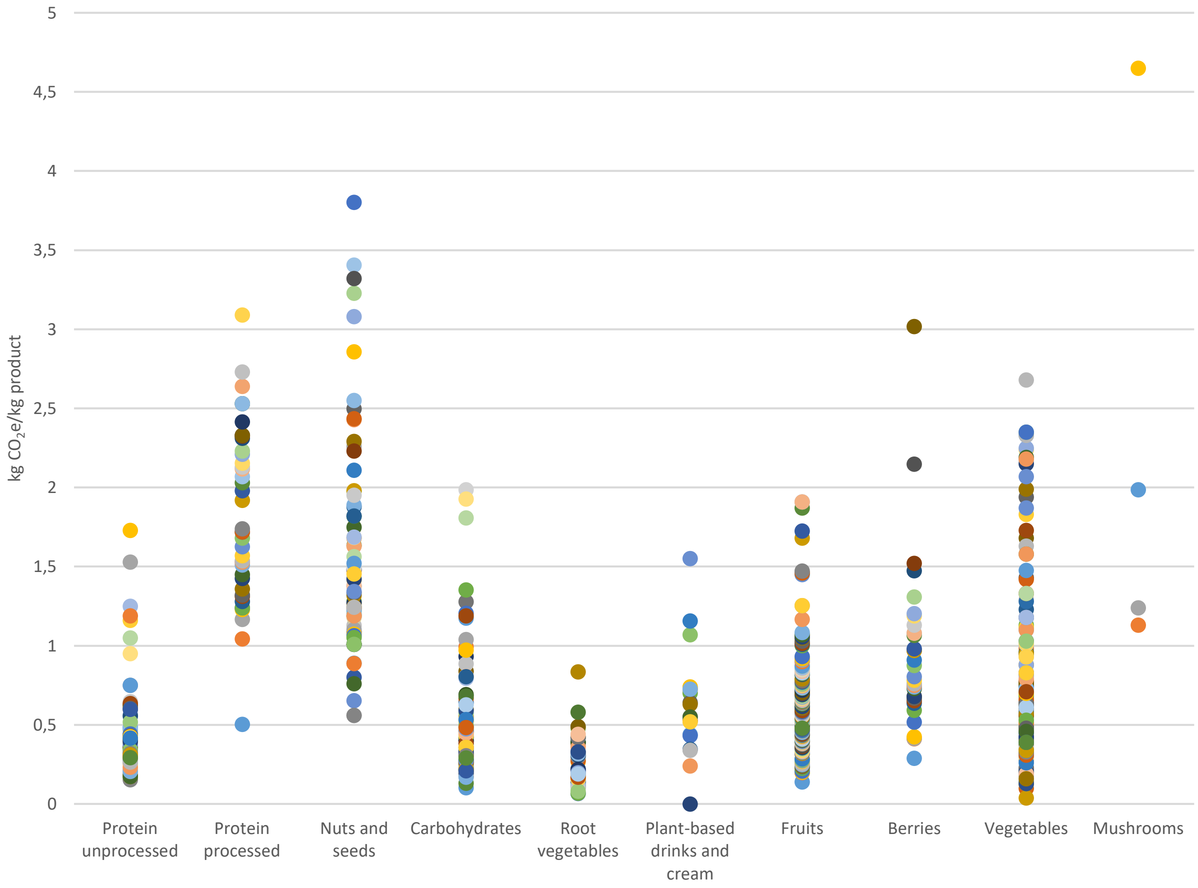

Figure 52. *Climate impact in kg CO_2e per kg product from studies relevant for the Swedish market for different product categories. Each dot represents a data-point taken from a previous study.*

4.3. Air transport

The consumer organization Sveriges konsumenter recently listed food products that are likely to be transported by air to Sweden. These products include some seafood, some fruits, vegetables such as asparagus (especially from Peru), fresh peas and beans (from Kenya and other African countries), fresh berries (from e.g., Egypt, Ethiopia, Mexico, USA, and Canada), and exotic unusual fruit such as starfruit (SverigesKonsumenter, 2018). Similarly, Axfood (a food retailer) presents a list of food products that are transported by air, at least part of the year, including (the relevant products for the Vego-guide) asparagus, haricoverts, sugar-snap peas and papaya (all fresh products) (Axfood, 2019). For these products and for products identified in communication with food importers (see section 2), emissions from air transport were added to the climate impact. Table 23 shows the estimates made from the information gathered.

Table 23. *Products assumed to be transported by air to Sweden (when production is located outside Europe)*

Product
Fresh peas and green beans
Cherries
Papayas

Table 24 presents climate impact of air transport of 1 kg from five different countries (from each country's capital to Stockholm). The climate impact was calculated using NTMCalc and additional climate impact from emitting greenhouse gases at high altitudes is not taken into account (NTM, 2019), but could double the climate impact caused by the emissions.

***Table 24**. Climate impact of air transport from relevant countries*

Country of origin	**kg CO_2e per kg transported to Sweden**
Canada	4.0
Chile	8.0
Egypt	2.5
Ethiopia	3.8
Guatemala	6.0
Honduras	5.9
India	3.6
Kenya	4.2
Mexico	5.9
Morocco	2.3
New Zealand	10.6
Peru	7.1
South Africa	5.9
Thailand	5.2
Turkey	2.1
USA	4.2

Earlier studies sometimes include air transport of fresh vegetables. For example, i Canals *et al.* (2008) assessed the climate impact of fresh green beans transported by air from Kenya and Uganda to the UK, and found it to be 10.7-10.9 kg CO_2e per kg product.

4.4. Climate impact of conventional and organic products

There are numerous LCA studies of both conventional and organic production systems. When reviewing earlier studies on climate impact and energy use, we did not differentiate between these two systems, but analyzed these studies jointly. Previous studies show that organic systems have similar climate impact to organic systems (Clark & Tilman, 2017).

5. DISCUSSION

5.1. Data availability

Rapid product development for plant-based ready-made protein sources is underway, but studies on the environmental impact are not available for all such products. As more products are introduced, it is likely that more studies on their environmental impact will emerge in the near future. There might therefore be a need to update the underlying data for the Vego-guide in coming years, to include new studies on the products included, but also to include a wider variety of products. For example, in this report an attempt is made to include plant-based cheese and deli meat. However, previous studies on the environmental impact of these products are very scarce.

Assessments on the likely climate impact of different products on the Swedish market were based on earlier studies and an assessment made by the authors on which of these are most representative for the Swedish market. For several products there are few studies, and in several cases no studies, on production in the identified export countries. In these situations, the final assessment was based on the available data and it was noted that the assessment was made with little access to representative data.

To determine common country of origin of the products, trade statistics were used. A well-known issue with trade statistics is that the country of origin is not always the country of primary production, as the countries listed as export countries in the statistics sometimes does not have any primary production of the product. For example, the Netherlands appears often as an export country, since it is a trade hub. In addition to the use of trade statistics, we tried to retrieve data on country of origin from wholesalers that primarily import fruits and vegetables. However, we were unable to verify our import data through information from wholesalers (Lundmark, 2019).

Data on pesticide use are particularly scarce, as is access to relevant and reliable indicators on ecotoxicity of pesticide use. The data used for European production are relatively old (from 2007), but no more recent data could be found. EUROSTAT includes data on pesticide use in the different countries, but we could not find a way to link this use to specific crops. In order to evaluate pesticide use, there is a need for better data which can be linked to different crops.

5.2. Methodological discussion

While emissions of greenhouse gases have the same impact on the climate no matter where they are emitted, the use of land in different regions of the world will have different impacts on biodiversity and the use of water will have different impacts on regional water availability. For the biodiversity impact assessment method (Chaudhary *et al.*, 2018) and water scarcity method (Boulay *et al.*, 2018), country average characterization methods were used, although both of these methods provide characterization factors for smaller regions than countries. The primary reason for using country average characterization factors was that import statistics do not report the region/s of a country in which products are produced. The assessment of products from large countries was likely to have been particularly affected by this, e.g., almonds from Spain and the USA. Almonds produced in the USA are likely to originate from California, which has a higher characterization factor for biodiversity loss due to land use than the average for agricultural land in USA. This means that growing almonds in California is likely to be associated with higher biodiversity loss than growing them on an average field in the USA. However, we used the characterization factor for the whole USA, to be consistent with using country average characterization factors for all imported products. Our results show that almonds from Spain are associated with higher biodiversity loss due to land occupation than almonds from USA. This is due to Spanish production being associated with higher land use, but also to the characterization factor for Spain being higher than that for the USA. In this comparison, a smaller country like Spain has a higher factor since most of the country has a more tropical climate than the overall USA.

Total water use was assumed to be the same for organic and conventional produce. Total water use information was retrieved from the water footprint network (Mekonnen *et al.*, 2011), where green, blue, and grey water use in an area is distributed over the yield of that area, based on FAO statistics. Considering that conventional agriculture is likely to be the dominant form of agriculture in most countries, the average FAOSTAT yield is likely to be more representative of conventional production. Assuming that water use is the same for conventional and organic production therefore risks underestimation of the water use for organic production, as it is often associated with lower yields. The lower yields in organic agriculture were accounted for in our land use and biodiversity assessments.

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Appendix A1. Literature review

Results from earlier studies

Appendix A1 presents the results from previous studies, together with the system boundaries used. When possible, the results were later modified to fit the system boundary of the Vego-guide, i.e., from cradle to a retailer in Sweden. These results are presented in the main report.

Data from the two databases ecoinvent (Wernet *et al.*, 2016; Agri-footprint, 2018) are included in the figures in the main report, but not presented in the tables in the appendices. For all products where such data were included in the background data, this is noted in the text below.

Protein sources

Green peas fresh

Earlier studies on green peas (Table A1) mainly focused on climate impact, with the exception of Sonesson *et al.* (2007), which included pesticide use, eutrophication, acidification, and energy use. The two studies on Swedish peas (Landquist, 2012; Sonesson *et al.*, 2007) included cultivation of the peas and transport to the factory gate, which involves cooling using ice during transport. The process in the factory and packaging material were not included. Landqvist and Woodhouse (2015) studied the climate impact of 10 different products (root vegetables, vegetables, herbs) processed in a factory in Sweden, and estimated the climate impact from washing, cutting, blanching, cooling, and freezing to be 0.25 kg CO_2e per kg product leaving the factory. If this were added to the climate impact for Swedish peas (Table A1), the total impact would be 0.57 and 0.70 (organic) kg CO_2e per kg peas leaving the factory.

Table A1. Results for 1 kg green peas at farm gate (SB1), retailer (SB2) and consumer (SB3) from earlier studies (F: fresh)

Country	**Climate impact (kg CO_2e)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
UK (F)	0.3		SB1	Audsley *et al.* (2009)
Australia (F)	2.5		SB1	Maraseni *et al.* (2010)
Sweden (F)	0.3/0.45[a]		SB1	Landquist (2012)
Sweden (F)	0.3	2.2	SB1	Sonesson *et al.* (2007)

[a] Conventional/organic.

Peas dried

The background data also included data from the databases ecoinvent (Wernet et al. 2016) and Agri-footprint (2018).

Table A2. Results for 1 kg dry peas at farm gate/regional distribution center (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
France	0.5		3.54			SB1	Meul *et al.* (2012)
World average	0.2					SB1	Audsley *et al.* (2009)
UK	0.5					SB1	Audsley *et al.* (2009)
Sweden	0.5				3.5	SB2	González *et al.* (2011)
Sweden	0.2				5.9	SB3	Fuentes *et al.* (2006)
Sweden	0.2				5.8	SB3	Fuentes *et al.* (2006)

Sweden	0.2				SB1	Tidåker *et al.* (2020) Manuscript
Sweden	0.2				SB1	Tidåker *et al.* (2020) (organic) Manuscript
Sweden	0.6	2.5			SB2	Moberg *et al.* (2020)

Beans dried

The background data also included data from the database Agri-footprint (2018).

All studies on dry beans showed a lower climate impact than 1 kg CO_2e per kg (Table A3), with the exception of Agri-footprint (2018) data for Dutch beans, which was primarily due to higher nitrogen fertilizer application, with related dinitrogen monoxide emissions.

Table A3. Results for 1 kg dry beans at farm gate/regional distribution center (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country/region	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Greece	0.3				SB1	Abeliotis *et al.* (2013)
Greece	0.4				SB1	Abeliotis *et al.* (2013)
Greece	0.4				SB1	Abeliotis *et al.* (2013) (organic)
USA	0.7			10	SB3	Fuentes *et al.* (2006)
Greece	0.2	3.7			SB1	Abeliotis *et al.* (2013)
Greece	0.3	3.57			SB1	Abeliotis *et al.* (2013)
Greece	0.4	3.19			SB1	Abeliotis *et al.* (2013) (organic)
The Netherlands	0.6			7.9	SB3	Fuentes *et al.* (2006)
EU	0.6				SB1	Audsley *et al.* (2009)
Sweden	0.7		7.4		SB2	González *et al.* (2011)
Sweden	0.3			7.25	SB3	Fuentes *et al.* (2006)
Sweden	0.4			7.50	SB3	Fuentes *et al.* (2006)
Sweden	0.4				SB1	Tidåker *et al.* (2020) manuscript
Sweden	0.8	7.6			SB2	Moberg *et al.* (2020)

Faba beans dried

The background data also included data from the databases ecoinvent (Wernet *et al*., 2016) and Agri-footprint (2018).

Table A4. Results for 1 kg dry faba beans at farm gate/regional distribution center (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**

Sweden	0.2				SB1	Tidåker *et al.* (2020) Manuscript
Sweden	0.2				SB1	Tidåker *et al.* (2020) (organic) Manuscript

Beans canned

Canned beans have higher climate impact and higher energy use than dried beans. This difference is even greater when comparing beans purchased dried and boiled at home, and comparing beans on the basis of wet or ready-to-eat weight (main report). However, two of the earlier studies assessed metal cans (Tesco, 2012; Fuentes *et al.*, 2006) and one considered glass jars (Blonk *et al.*, 2008). Canned beans in Sweden today are often sold in cardboard containers with plastic film (i.e., Tetra Pak™).

Table A5. Results for 1 kg canned or boiled beans at farm gate/regional distribution center (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
UK	1.4				SB3	Tesco (2012)
The Netherlands	1.1			14.2	SB3	Fuentes *et al.* (2006)
Italy	1.4			18.5	SB3	Fuentes *et al.* (2006)
The Netherlands	0.9			12.2	SB3	Fuentes *et al.* (2006)
Italy	1.2			16.5	SB3	Fuentes *et al.* (2006)
The Netherlands	1.7	3.5			SB2	Blonk *et al.* (2008)

Chickpeas dried

The background data also included data from the database Agri-footprint (2018).

Table A6. Results for 1 kg dry chickpeas at farm gate/regional distribution center (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
USA	1.1			6.45	SB3	Fuentes *et al.* (2006)
UK (rest of Europe)	0.77				SB1	Audsley *et al.* (2009)
UK (rest of the world)	0.8				SB1	Audsley *et al.* (2009)

Lentils canned

Table A7. Results for 1 kg canned lentils at farm gate/regional distribution center (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**

Australia	1.0				SB2	Eady *et al.* (2011)
UK	1.1				SB1	Audsley *et al.* (2009)
Sweden	0.2				SB1	Tidåker *et al.* (2020) (organic) Manuscript

Lentils dried

Only one scientific study was found on dry lentils. Several environmental impact categories were included in the study (Elhami *et al.*, 2017), but none (except climate change) was relevant. The high climate impact is due to a relatively high nitrogen fertilizer application (135 kg N/ha). According to trade statistics (SS, 2018), Sweden import lentils from Turkey, the UK, and Canada, with Canada being the largest exporter of lentils globally. According to Canadian and American fertilizer recommendations, little (<55 kg/ha) or no nitrogen fertilizer is needed in lentil cultivation (GovermentofSaskatchewan, 2017; Mahler, 2015). Therefore the applicability of the study by Elhami *et al.* (2017) can be considered limited for the Swedish market.

The background data also included data from the database Agri-footprint (2018) for Australian and Canadian lentils.

Table A8. Results for 1 kg dry lentils at farm gate/regional distribution center (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Iran	3.6				SB1	Elhami *et al.* (2017)

Soybeans dried

The background data also included data from the databases ecoinvent (Wernet *et al*., 2016) and Agri-footprint (2018).

The high impact from Brazilian and Argentinian soybeans is due to deforestation (Wernet *et al.*, 2016).

Table A9. Results for 1 kg dry soybeans at farm gate/regional distribution center (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Brazil	0.4			4.0	SB2	González *et al.* (2011)
USA	0.5			6.8	SB2	González *et al.* (2011)
Brazil	0.5	2.07		7.0	SB2	Da Silva *et al.* (2010)
Brazil	1.0	1.89		12.6	SB2	Da Silva *et al.* (2010)

Ready-made meat alternatives

Dairy-based

Table A10. Results for 1 kg product at factory gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies on dairy-based meat alternatives

Product	**Country**	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**System boundary**	**Reference**
Dairy-based meat alternative	Germany	4.7	3.4	53.9	SB3	Smetana *et al.* (2015)

Milk protein	The Netherlands	5.6	4.4	36.0	SB2	Broekema and Blonk (2009)

Mixed (bean burgers and falafel)

This category contains a wide variety of products, including falafel, schnitzel, and bean burgers. All results from the study by Quantis (2016) include cooking in the USA, and this had a rather high impact on the results. With cooking and transport home, the climate impact was found to be 5.8 kg CO_2e per kg, while the same product had an impact of 3.1 kg CO_2e per kg up to the retailer (Quantis, 2016).

Table A11. Results for 1 kg product at factory gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies on mixed products (bean burgers and falafel) (F: fresh, FZ: frozen)

Product	**Country**	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**System boundary**	**Reference**
Schnitzel (F)	The Netherlands	2.2		4.5	25	SB2	Broekema and Blonk (2009)
“Meatballs” (F)	The Netherlands	2.1		3.6	25	SB2	Broekema and Blonk (2009)
Chick-pea patties (FZ)	USA	5.8	0.04			SB3	Quantis (2016)
Falafel (FZ)	The Netherlands	2.5		2.5		SB2	Head *et al.* (2011)
Burger	The Netherlands	3.5	0.05	5.2		SB3	Consultants (2017)
Burger	The Netherlands	3.0	0.05	4		SB3	Consultants (2017)
Falafel (FZ)	Sweden	0.7				SB1	Orklafoods (L. Lundahl, 2018)

Mixed with eggs (or cheese)

Some vegetarian products include eggs or other products of animal origin. It is interesting to note that Dutch and Swedish products seem to have a climate impact in the same range (1.5-2.5 kg CO_2e per kg product). Again, the products from the study by Quantis (2016) show a high impact, and cooking is a substantial part of this, with impact including cooking (excluding cooking) of: 9.2 (6.9), 6.9 (5.8), and 11.3 (6.9) kg CO_2e per kg product. Impact up to retailer (i.e., excluding cooking) is still substantially higher for these products. They generally have long ingredients lists containing wheat protein, soy protein, etc. (Quantis, 2016).

Table A12. Results for 1 kg product at factory gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies on mixed with eggs (F: fresh, FZ: frozen)

Product	**Country**	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**

Sausage (F)	The Netherlands	1.5		2.8	24		SB2	Broekema and Blonk (2009)
Burger (F)	The Netherlands	2.1		2.5	22.5		SB2	Broekema and Blonk (2009)
Grilled pieces (F)	The Netherlands	2.2		3.4	27		SB2	Broekema and Blonk (2009)
“Meatballs” (F)	The Netherlands	2.5		2.4	22.5		SB2	Broekema and Blonk (2009)
Bean burger (FZ)	USA	9.2	0.04				SB3	Quantis (2016)
Bean burger (FZ)	USA	6.9	0.03				SB3	Quantis (2016)
Sausage patties (FZ)	USA	11.3	0.04				SB3	Quantis (2016)
“Carrotballs” (FZ)	Sweden	2.0					SB1	Orklafoods (L. Lundahl, 2018)
Burger (FZ)	Sweden	1.7					SB1	Orklafoods (L. Lundahl, 2018)

Pea-protein

Table A13. Results for 1 kg product at factory gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies on pea protein based products (F: fresh, FZ: frozen)

Product	**Country**	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Pea protein (FZ)	Sweden	3.1	4.9	57	SB2	Nilsson and Florén (2017)

Quorn - Mycoprotein

Results for mycoprotein (generally known as Quorn) seem to vary greatly. One reason could be that the process for growing mycoprotein is quite energy-demanding, so the energy source will be important. Two studies show higher impact than the others (Smetana *et al.*, 2015; Finnigan *et al.*, 2010). The latter study was later updated to report significantly lower impact (Finnigan *et al.*, 2017). Smetana *et al.* (2015) included cooking, which accounted for approximately 25% of the impact. Energy use in the process of producing mycoprotein was another important contributor. Smetana *et al.* (2015) only report weighted results for process contribution, and information on the importance of cooking for climate impact and energy used could therefore not be retrieved.

Table A14. Results for 1 kg product at factory gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies on Quorn (assumption that all is frozen)

Product	**Country**	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**

Quorn	The Netherlands	2.5		1.1			SB2	Blonk *et al.* (2008)
Quorn	Germany	5.9		0.8	68.4		SB3	Smetana *et al.* (2015)
Quorn mince	UK	6.8	2.9	5.3	50.6		SB1	Finnigan *et al.* (2010)
Quorn	The Netherlands	2.4		0.4			SB2	Head *et al.* (2011)
Quorn	The Netherlands	2.6		1.7	36.0		SB2	Broekema and Blonk (2009)
Quorn mince	UK	2.3	0.06	4			SB2	Quorn foods (2018)
Quorn pieces	UK	2.3	0.06	3			SB2	Quorn foods (2018)

Soy-based

We found six earlier LCA studies on soy-based meat replacement products. Two of these studies focused on soy protein isolate (SPI) (90% protein) (Thrane *et al.*, 2017; Berardy *et al.*, 2015), which is one ingredient in soy-based meat alternatives (another being soy protein concentrate with approx. 70% protein). The others focused on ready-made products such as soy burgers or minced meat.

The products in Table A15 marked with SB3 (system boundary three) involve cooking. Smetana *et al*. (2015) identified cooking by the consumer as the main activity that contributed to the overall environmental impact of soybean meal-based meat alternatives (more than 50%), but did not specify the energy use for frying. Consultants (2017) specify the energy use for cooking at the consumer to be 0.22 (or 0.79 MJ) kWh/kg prepared product (calculated from Table 4 in that study). Using the Dutch electricity mix, the climate impact from cooking would then be 0.14 kg CO_2e per kg ready-to-eat product (the study by Consultants (2017) is based on Dutch conditions). Using Swedish electricity mix, the climate impact would be 0.01 kg CO_2e per ready-to-eat product (environmental impact of electricity production taken from Wernet *et al.* (2016)).

The study by Berardy *et al.* (2015) was a conference paper with some inconsistencies in the results, e.g., energy use was found to be low, while climate impact was found to be high. Most of the climate impact was reported to come from heating in the process, but this is not consistent with the low energy use. Therefore, this study was not included in the summary. Further, the functional unit in the study was 1 kg soy protein isolate (90% protein). This is not used directly for human consumption, but is added to ready-made products (comprising around 25%).

Table A15. Results for 1 kg product at factory gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies on soy-based ready-made alternatives to meat (F: fresh, FZ: frozen)

Product	**Country**	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**System boundary**	**Reference**
Soy protein isolate (F)	USA	6.8/2.7[a]	0.04/0.23 [a]	6.7/8.9 [a]	SB1	Thrane *et al.* (2017)
Soy burger (F)	The Netherlands	-	0.16	-	SB1	Ercin *et al.* (2012)
Soy burger (F)	The Netherlands	3.0	0.05	4.0	SB3	Consultants (2017)

Soy meal based (F)	Germany	2.7	-	1.3	SB3	Smetana *et al.* (2015)
Soy minced meat 1 (frozen) (F)	The Netherlands	2.2	0.05	3.0	SB3	Consultants (2017)
Soy minced meat 2 (frozen) (F)	The Netherlands	2.7	0.06	4.9	SB3	Consultants (2017)
Soy minced meat (FZ)	USA	6.0 (2.7)	0.03 (0.02)	-	SB3 (SB1)	Quantis (2016)
Soy burger (FZ)	USA	7.4 (4.6)	0.02 (0.01)	-	SB3 (SB1)	Quantis (2016)
Soy burger (FZ)	The Netherlands	3.5	0.06	4	SB3	Consultants (2017)
Soy “chicken pieces” 1 (FZ)	The Netherlands	1.5	0.03	8	SB3	Consultants (2017)
Soy “chicken pieces” 2 (FZ)	The Netherlands	2.5	0.06	4.2	SB3	Consultants (2017)
Soy-based products (FZ)	Sweden	1.4-2.2 (average: 1.6)[b]				Orklafoods (L. Lundahl, 2018)

[a] Attributional/consequential modelling.
[b] Eleven different soy-based products.

Tofu and tempeh

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A16. Results for 1 kg product at factory gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies on tofu and tempeh

Product	**Country**	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Tofu	USA	1.0					SB1	Mejia *et al.* (2018)
Tofu	The Netherlands	2.0		2.0	27.5		SB2	Broekema and Blonk (2009)
Tofu	The Netherlands	2.2		2.8	28.0		SB2	Broekema and Blonk (2009)
Tofu	The Netherlands	3.1		2.16			SB2	Head *et al.* (2011)
Tofu	The Netherlands	2.3		3.5			SB2	Blonk *et al.* (2008)
Tempeh	The Netherlands	1.3		2			SB2	Blonk *et al.* (2008)

Nuts and seeds

Almonds

The majority of global almond production is in California, USA. Most of the earlier studies identified in this assessment estimated the climate impact for American almonds, and all found values below 4 kg CO_2e per kg (Kendall *et al.*, 2015; Kendall & Brodt, 2014; Marvinney *et al.*, 2014; Venkat, 2012). Bartzas *et al.* (2017) estimated the climate impact to be approximately 2 kg CO_2e per kg for Greek almonds in shell, with irrigation (pumping groundwater) and fertilizer production having the greatest impact on the result. In that assessment (Bartzas *et al.*, 2017), it was assumed that about 1.7 kg almonds in shell are required for 1 kg shelled almonds, which results in an impact of 3.4 kgCO_2e per kg almonds. The data in Volpe *et al.* (2015) for primary production were based on Marvinney *et al.* (2014), and therefore Volpe *et al.* (2015) was excluded from the recommendation.

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A17. Results for 1 kg almonds at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
USA	0.5						SB1	Kendall and Brodt (2014)
World	1.2						SB1	Nemecek *et al.* (2012)
USA	1.9	12.9					SB1	Marvinney *et al.* (2014)
USA	2.5/3.8[a]						SB1	Venkat (2012)
Greece	3.4[b]	2.4				47.7	SB1	Bartzas *et al.* (2017)
USA	0.9/1.5[c]					29/33[c]	SB1	Kendall *et al.* (2015)
USA (California)		539	10.2				SB1	Fulton *et al.* (2018)
Italy	1.9						SB1	Volpe *et al.* (2015)
Rest of world	0.9						SB1	Audsley *et al.* (2009)

[a] Conventional/organic.

[b] Assuming that about 1.7 kg almonds in shells are required for 1 kg almonds.

[c] System expansion/economic allocation.

Cashew nuts

Table A18. Results for 1 kg cashew nuts at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of Europe	1.2					SB1	Audsley *et al.* (2009)
Brazil	1.4/1.5[a]					SB1	de Figueirêdo *et al.* (2014)
Netherlands	2.3		18.0			SB2	Blonk *et al.* (2008)

[a] Traditional practice/observed field notes.

Chestnuts

Table A19. Results for 1 kg chestnuts at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of Europe	0.4					SB1	Audsley *et al.* (2009)
Portugal	0.9/0.4[a]			11.0/4.0		SB1	Rosa *et al.* (2017)

[a] Two different producers: producer 1/producer 2.

Coconuts

Only one earlier study was found on coconuts (Audsley *et al*., 2009), which focused solely on climate impact. The results included transportation to a regional distribution center in the UK from rest of the world. The background data also included data from the database Agri-footprint (2018).

Table A20. Results for 1 kg coconuts at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of the world[a]	1.8					SB1	Audsley *et al*. (2009)

[a] Including copra (coconut flesh).

Groundnuts/peanuts

The background data also included data from the databases ecoinvent (Wernet *et al.*, 2016) and Agri-footprint (2018).

Table A21. Results for 1 kg groundnuts/peanuts at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Netherlands	1.5		3.90			SB2	Blonk *et al.* (2008)
USA	0.8[a]					SB1	Mccarty *et al.* (2012)
USA	1.7[b]					SB2	Mccarty *et al.* (2012)
UK	0.9					SB1	Audsley *et al.* (2009)
USA	1.1					SB1	Nemecek *et al.* (2012)

[a] Including four different irrigation scenarios.

[b] Peanut butter.

Hazelnuts

Table A22. Results for 1 kg hazelnuts at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**

Rest of Europe	0.4						SB1	Audsley *et al*. (2009)
World	1.5						SB1	Nemecek *et al.* (2012)
Italy	0.5						SB1	Volpe *et al.* (2015)

Walnuts

In some of the identified studies, the walnuts were assumed to be shelled (Venkat, 2012; Audsley *et al.*, 2010; Blonk *et al.*, 2008). In the main report, data for all nuts were recalculated to show the results for shelled product.

Table A23. Results for 1 kg walnuts at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Netherlands	2.1			4.0			SB2	Blonk *et al.* (2008)
USA (organic)	2.9						SB1	Venkat (2012)
Rest of world	0.9						SB1	Audsley *et al*. (2009)
USA	0.9	3.9					SB1	Marvinney *et al.* (2014)

Pistachios

Looking at the results for shelled nuts, Bartzas *et al.* (2017) had the highest impact (main report). Assuming that 2.01 kg pistachios in shell are required for 1 kg shelled pistachios (Marvinney *et al.*, 2014), climate impact for the Bartzas *et al*. (2017) assessment would be 4.3 kg CO_2e per kg pistachios. This is much higher than in the other studies (Table A24). Using the functional unit “1 kg nuts in shell” as in Bartzas *et al.* (2017), none of the impact is allocated to the shells (which can potentially be used as e.g., an energy source). Another factor that could explain the higher impact in Bartzas *et al*. (2017) is that the yield was much lower than for Marvinney *et al*. (2014). The data in Volpe et al. (2015) for primary production were based on Marvinney *et al*. (2014), and therefore Volpe *et al*. (2015) was excluded from the recommendation.

Table A24. Results for 1 kg pistachios at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
UK	0.9						SB1	Audsley *et al*. (2009)
USA	2.2	3.8					SB1	Marvinney *et al.* (2014)
Greece[a]	2.1	1.8				27	SB1	Bartzas *et al.* (2017)
Italy	1.74						SB1	Volpe *et al.* (2015)

[a] Nuts in shell.

Linseeds

The background data were based on data from Agri-footprint (2018).

Sesame seeds

Table A25. Results for 1 kg sesame seed at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO_2e)	Total water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
UK	0.9					SB1	Audsley *et al*. (2009)

Sunflower seeds

The background data also included data from the databases ecoinvent (Wernet *et al*., 2016) and Agri-footprint (2018). For the data from ecoinvent, the sunflower seeds were assumed to be peeled.

Table A26. Results for 1 kg sunflower seed at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO_2e)	Blue water use (m^3)	Total water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
Rest of world	1.4						SB1	Audsley *et al.* (2009)
Portugal	0.6/0.8[a]						SB1	Figueiredo *et al.* (2012)
Chile	0.9		0.16			7.00	SB1	Iriarte *et al.* (2010)

[a]Non-irrigated/irrigated

Carbohydrate sources

Barley

The background data also included data from the database Agri-footprint (2018).

Table A27. Results for 1 kg barley at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO2e)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
EU	0.5				SB1	Tuomisto *et al.* (2014)
Sweden	0.3		1.1		SB1	Tidåker *et al*. (2005)
Sweden	0.3		1.5		SB1	Tidåker *et al*. (2005)
UK and EU	0.3				SB1	Audsley *et al*. (2009)
France	0.4				SB1	Meul *et al.* (2012)
Sweden	0.4			2.6	SB2	González *et al.* (2011)
Norway	0.8				SB1	Roer *et al.* (2012)
Sweden	0.6				SB2	Tynelius (2008)
Sweden	1.0	2.9			SB2	Moberg *et al.* (2020)

Maize

One of the identified studies was on sweetcorn (Maraseni *et al.*, 2010), this study was excluded from the analysis.

The background data also included data from the database Agri-footprint (2018).

Table A28. Results for 1 kg maize at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO2e)	Blue water use (m^3)	Total water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
France	0.4						SB1	Meul *et al.* (2012)
Spain	0.4	0.33	0.37				SB1	Torres *et al.* (2014)
EU	0.5						SB1	Audsley *et al.* (2009)
USA	0.7					6.1	SB1	González *et al.* (2011)
Australia[a]	1.4						SB1	Maraseni *et al.* (2010)

[a]Maize sweetcorn.

Oats

The background data also included data from the database Agri-footprint (2018).

Table A29. Results for 1 kg oats at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO2e)	Blue water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
EU	0.1					SB1	Audsley *et al.* (2009)
UK	0.4					SB1	Audsley *et al.* (2009)
Sweden	0.5				2.9	SB1	González *et al.* (2011)
Norway	0.8					SB1	Roer *et al.* (2012)
Sweden	0.5		0.03		3.3	SB1	Lantmännen personal communication (2019)
Sweden	1.0	0.0	3.6			SB2	Moberg *et al.* (2020)

Pasta

The study by Recchia *et al.* (2019) showed that a large part of the climate impact and energy use (fossil) can come from cooking at the consumer. Climate impact was 1.5 kg CO_2e per kg pasta at the factory gate and energy use (fossil) 10.3 MJ primary energy per kg pasta.

Table A30. Results for 1 kg pasta at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO2e)	Blue water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
Sweden	0.5					SB2	Röös *et al.* (2011)
Swedish market	1.8	0.0	2.7			SB2	Moberg *et al.* (2020)
Sweden	1.3	0.0	2.7			SB2	Moberg *et al.* (2020)
Italy	0.8					SB2	Ruini *et al.* (2013)
Italy	2.7			33		SB3	Recchia *et al.* (2019)

Quinoa

There are few earlier studies LCA studies on quinoa, only two were identified here. Compared with other carbohydrates (except rice), quinoa showed higher climate impact according to these two studies. This is likely due to the low yield obtained in quinoa cultivation, which leads to higher estimated results for quinoa (Cancino-Espinoza *et al.*, 2018). Additionally, the postharvest process where quinoa is dried and treated contributes to greenhouse gas emissions, as does transport through mountainous areas to the port in Lima (Cancino-Espinoza *et al.*, 2018).

Table A31. Results for 1 kg quinoa at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
South America	0.9					SB1	Alter eco (2012)
South America[a]	2.7					SB1	Alter eco (2012)
Peru[b]	0.9					SB1	Cancino-Espinoza *et al.* (2018)

[a]Dark quinoa.
[b]Organic.

Rice

Earlier studies show that rice is associated with higher climate impact than other carbohydrate sources. Field emissions (CH_4 and N_2O) were the largest contributor to global warming potential in several studies where the fields were irrigated or flooded (Brodt *et al.*, 2014; Thanawong *et al.*, 2014; Kägi *et al.*, 2010; Blengini & Busto, 2009; Hokazono *et al.*, 2009). For example, emissions of CH_4 from paddy fields made up more than half of the total emissions estimated in Hokazono *et al.* (2009). The study on upland Swiss rice cultivation (Kägi *et al.*, 2010), where flooding was not used, showed lower emissions of CH_4. Switzerland is not a significant producer of rice globally and the study is therefore considered less relevant for the Swedish market. The system boundary in Kägi *et al.* (2010) is up to a Swiss retailer, which means that the emissions from transport to Switzerland are included in the result for American rice.

Thanawong *et al.* (2014) estimated the climate impact to be 3.1-5.6 kg CO_2e per kg rice, depending on whether the field was rain-fed or irrigated and if it was wet season or dry season. These values are in the upper range of results reported for rice. This could be because the study used higher values for CH_4 emissions compared with those suggested in IPCC (2006). In addition, rice yield is relatively low in north-east Thailand, which could have contributed to the higher climate impact (Thanawong *et al.*, 2014). Berners-Lee *et al.* (2012) estimated the climate impact for several foods, but do not provide details of the inventory, so the higher climate impact is difficult to explain.

The background data also included data from the database Agri-footprint (2018).

Table A32. Results for 1 kg rice at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Japan	1.2					7.4	SB2	González *et al.* (2011)
USA	1.1					6.6	SB2	González *et al.* (2011)
Japan	1.3-1.6[a]						SB1	Hokazono *et al.* (2009)
USA	1.5-3.7[b]						SB1	Brodt *et al.* (2014)
Switzerland	1.7						SB2	Kägi *et al.* (2010)
USA	2.8						SB2	Kägi *et al.* (2010)
USA	2.1						SB1	Loijos (2008)

Italy[d]	2.8/2.9	4.9	8.0/8.2		14.6/16.6	15.7/17.8	SB2	Blengini and Busto (2009)
Thailand[e]	3.1-5.6		2.7-3.3	4.2-4.6		7.3-9.5	SB1	Thanawong *et al.* (2014)
Rest of the world	3.5						SB1	Audsley et al. (2009)
UK	5.7						SB2	Berners-Lee *et al.* (2012)
Rest of the world	3.6	0.7	4.5					Moberg *et al.* (2020)

[a] Sustainable system (low value), conventional system (in between value), environmentally friendly (high value).
[b] Using GWP100 (low value), GWP20 (in between value), and IPCC tier 1 (high value).
[c] Conventional/organic.
[d] Local distribution/exported rice.
[e] Rain-fed (low value), wet-season irrigated (in between value), dry-season irrigated (high value).

Rye

The background data also included data from the database Agri-footprint (2018).

Table A33. Results for 1 kg rye at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden	0.4				2.10	SB2	González *et al.* (2011)
EU	0.5					SB1	Audsley *et al.* (2009)
UK	0.9					SB1	Audsley *et al.* (2009)
Sweden	0.4					SB1	Woodhouse (2017)
Sweden	0.9		2.33				Moberg *et al.* (2020)

Sorghum

The background data also included data from the database Agri-footprint (2018).

Table A34. Results for 1 kg sorghum at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
UK	0.9					SB1	Audsley et al. (2009)

Wheat

Most of the earlier assessments on climate impact of wheat production showed an impact below 1 kg CO_2e per kg wheat.

The background data also included data from the database Agri-footprint (2018).

Table A35. Results for 1 kg wheat at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Switzerland	0.6/0.7/0.6[a]				2.31/3.45/3.30	SB1	Nemecek *et al.* (2010)
Germany	0.6				3.49	SB1	Nemecek *et al.* (2010)
USA	0.6				4.63	SB1	Nemecek *et al.* (2010)
France	0.6				3.58	SB1	Nemecek *et al.* (2010)
Spain	0.8				6.42	SB1	Nemecek *et al.* (2010)
Italy	0.3					SB1	Knudsen *et al.* (2014)
Germany	0.4					SB1	Knudsen *et al.* (2014)
Canada	0.4					SB1	Knudsen *et al.* (2014)
Sweden	0.5					SB1	Knudsen *et al.* (2014)
USA	0.5					SB1	Knudsen *et al.* (2014)
Romania	0.5					SB1	Knudsen *et al.* (2014)
Russia	0.5					SB1	Knudsen *et al.* (2014)
Sweden	0.4				2.00	SB2	González *et al.* (2011)
USA	0.8				8.90	SB2	González *et al.* (2011)
Sweden	0.4-0.6					SB2	Röös *et al.* (2011)
France	0.5		1.07			SB1	Meul *et al.* (2012)
UK (wheat flour)	0.5					SB2	Espinoza-Orias *et al.* (2011)
UK	0.5					SB1	Audsley *et al.* (2009)
EU	0.6					SB1	Audsley *et al.* (2009)
World	0.7					SB1	Audsley *et al.* (2009)
UK	0.7/0.8[b]		0.14/0.41		2.40/2.00	SB1	Williams *et al.* (2010)
World	1.1					SB2	Michaelowa and Dransfeld (2008)
Norway	0.7					SB1	Roer *et al.* (2012)
Sweden	0.4					SB1	Woodhouse (2017)
Sweden	1.1	0.0	2.26			SB2	Moberg *et al.* (2020)

[a] Organic/extensive/integrated production.

[b] Conventional/organic.

Carrots

The background data also included data from the database Agri-footprint (2018).

Table A36. Results for 1 kg carrots at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden (organic)	0.04		0.23	0.38		SB1	Cederberg *et al.* (2005)
Sweden	0.1/0.3[a]		0.22/0.26	2.38/7.60		SB2	Fuentes *et al.* (2006)
Netherlands	0.2		0.18	4.00		SB2	Fuentes *et al.* (2006)
Switzerland	0.1				1.70	SB2	González *et al.* (2011)

Sweden	0.1				0.97	SB2	González *et al.* (2011)
Sweden	0.1			1.50		SB2	Röös and Karlsson (2013)
Netherlands	0.2			2.80		SB2	Röös and Karlsson (2013)
Italy	0.3			4.10		SB2	Röös and Karlsson (2013)
Australia	0.2		0.21			SB1	Maraseni *et al.* (2010)
Switzerland	0.5	0.42	0.09			SB2	Stoessel *et al.* (2012)
UK	0.4					SB1	Audsley *et al.* (2009)
Sweden (small carrot)	0.1/0.4[a]					SB1	Landqvist and Woodhouse (2015)
Sweden (big carrot)	0.1/0.3[a]					SB1	Landqvist and Woodhouse (2015)
Sweden	0.2/0.4[b]					SB1	Landqvist and Woodhouse (2015)
Sweden	0.27	0.20	0.0			SB2	Moberg *et al.* (2020)
Swedish market	0.3	0.21	0.0			SB2	Moberg *et al.* (2020)

[a]Fresh/frozen.

[b]Parsnips fresh/frozen.

Potatoes

The background data also included data from the database Agri-footprint (2018).

Table A37. Results for 1 kg potatoes at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden	0.1[a]			0.53/0.57[a]		SB1	Cederberg *et al.* (2005)
Denmark	0.1				0.80	SB2	González *et al.* (2011)
Switzerland	0.1				1.50	SB2	González *et al.* (2011)
Sweden	0.2				1.50	SB2	González *et al.* (2011)
USA	0.4				4.30	SB2	González *et al.* (2011)
Sweden	0.1-0.2					SB2	Röös *et al.* (2010)
World	0.1				1.72	SB1	Nemecek (2010)
Austria	0.2[a]					SB2	Lindenthal *et al.* (2010)
Switzerland	0.2					SB2	Stoessel *et al.* (2012)
UK	0.2[a]		0.02/0.06[a]		1.40/1.60[a]	SB1	Williams *et al.* (2010)
UK	0.3					SB1	Audsley *et al.* (2009)
Germany	0.1					SB2	Gruber *et al.* (2016)
UK	0.4					SB2	Berners-Lee *et al.* (2012)
Sweden	0.3	0.01	0.46			SB2	Moberg *et al.* (2020)
Swedish market	0.4	0.01	0.46			SB2	Moberg *et al.* (2020)
Korea[b]	0.4					SB1	So *et al.* (2010)

[a]Either conventional and organic or conventional/organic.
[b]Sweet potato.

Swedes (rutabaga)

Table A38. Results for 1 kg swedes at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO_2e)	Blue water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
Switzerland	0.3					-	Svanes (2008)
Sweden	0.1/0.4[a]					SB1	Landqvist and Woodhouse (2015)

[a]Fresh/frozen

Beetroots

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A39. Results for 1 kg beetroots at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO_2e)	Blue water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
Sweden	0.1			1.10		SB2	González *et al.* (2011)
Australia	0.2		1.75			SB1	Maraseni *et al.* (2010)
Sweden	0.2/0.4[a]					SB1	Landqvist and Woodhouse (2015)

Jerusalem artichokes

Table A40. Results for 1 kg Jerusalem artichokes at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO_2e)	Blue water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
Sweden	0.3/0.6[a]					SB1	Landqvist and Woodhouse (2015)

[a]Fresh/frozen.

Fruits and vegetables

Apples

The earlier LCA studies on apples mainly focused on climate impact, but some also included other categories such as water use, energy use, and land use. The results in Table A41 generally show results for climate impact equal to or below 0.9 kg CO_2e per kg apples, regardless of where they are produced. According to González *et al.* (2011), Swedish and French apples have a low impact, 0.1 kg CO_2e per kg apple. Apples produced in New Zealand and then imported to a distribution center in Gothenburg, Sweden, have a higher impact, 0.5 kg CO_2e per kg apple, most likely due to the transportation between the countries. The highest climate impact was found by Audsley *et al*. (2009), approx. 0.9 kg CO_2e per kg apple, for apples imported to a regional distribution center in the UK from “rest of the world”. The emissions that arise from transport could be a reason for the relatively high climate impact. The system boundary in Yoshikawa *et al.* (2008) included stages such as production, shipping, cooking etc., but only the stages up to retailing were accounted for here, which can be seen in Table A41. The system boundary in Blonk *et al.* (2010) is up to a farm gate in the Netherlands.

According to trade statistics (SS, 2018), Sweden does not import apples from Switzerland and Peru, and according to FAOSTAT these countries import more apples than they export. The applicability of the studies by Stoessel *et al.* (2012) and Bartl *et al.* (2012) was therefore considered to be limited for the Swedish market.

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A41. Results for 1 kg apples at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
New Zealand	0.04-0.1[a]			0.41-0.71[a]		SB1	i Canals *et al.* (2006)
New Zealand	0.1				0.95	SB1	Saunders *et al.* (2006)
UK	0.3				5.0	SB1	Saunders *et al.* (2006)
Italy	0.2[b]					SB1	Cerutti *et al.* (2013)
Italy	0.2	0.06	0.0005	1.75 (calculated)		SB2	Assomela (2012)
Sweden	0.1				0.63	SB2	González *et al.* (2011)
France	0.1				1.60	SB2	González *et al.* (2011)
New Zealand	0.5				6.10	SB2	González *et al.* (2011)
Italy	0.2					SB2	Sessa *et al.* (2014)
France	0.1	0.05	0.24 (calc.)	1.12		SB1	Basset-Mens *et al.* (2014)
Netherlands	0.2					SB1	Blonk *et al.* (2010)
New Zealand	0.4					SB1	Blonk *et al.* (2010)
USA	0.1/0.2[c]					SB1	Venkat (2012)
Switzerland	0.3	0.02	0.3			SB2	Stoessel *et al.* (2012)
UK	0.3					SB1	Audsley *et al.* (2009)
Rest of Europe	0.4					SB1	Audsley *et al.* (2009)
Rest of the world	0.9					SB1	Audsley *et al.* (2009)
USA	0.5			8.0		SB2	Renz *et al.* (2014)
France	0.1[d]			0.9-1.2[d]		SB1	Alaphilippe *et al.* (2014)
Greece	0.1	0.1			1.2	SB1	Bartzas *et al.* (2017)
New Zealand	0.1					SB1	McLaren *et al.* (2010)
UK	0.6					SB2	Berners-Lee *et al.* (2012)
USA	0.8					SB1	Loijos (2008)

Japan	0.6					SB2	Yoshikawa *et al.* (2008)
China	0.2					SB1	Yan *et al.* (2016)
Italy	0.1				1.2	SB1	Tamburini *et al.* (2015)
Peru	0.4					SB1	Bartl *et al.* (2012)
Belgium (conventional)	0.1[e]					SB1	Goossens *et al.* (2017)
Belgium (integrated)	0.1[e]					SB1	Goossens *et al.* (2017)
Belgium (organic)	0.1-0.8[e]					SB1	Goossens *et al.* (2017)
Swedish market	0.4	0.03	0.6			SB2	Moberg *et al.* (2020)
Sweden	0.2	0.0	0.7			SB2	Moberg *et al.* (2020)

[a] Including four scenarios.
[b] Including four scenarios.
[c] Conventional/organic.
[d] Including two scenarios: north and south of France and extensive/semi-extensive.
[e] Including young and old low productive trees and full production. Highest impact in organic orchards corresponds to young productive trees, where the high impact is because of low yield.

Apricots

Only two earlier LCA studies were found on apricots, namely Audsley *et al*. (2009) and Pergola *et al.* (2017). Audsley *et al*. (2009) showed that apricots imported from rest of Europe have a climate impact of 0.4 kg CO_2e per kg apricots. Pergola *et al.* (2017) showed that climate impact for three orchard systems in Italy (including integrated and biodynamic system) ranged between 0.3-0.4 kg CO_2e per kg apricot, where the highest value corresponded to the biodynamic system. Other values for apricots and their climate impact were taken from ecoinvent (Wernet *et al.*, 2016), which all showed results below 0.4 kg CO_2e per kg apricot.

Table A42. Results for 1 kg apricots at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Europe	0.4					SB1	Audsley *et al.* (2009)
Italy	0.3-0.4[a]					SB1	Pergola *et al.* (2017)

[a] Three orchard systems, including two cultivation systems: integrated (lower value) and biodynamic which is similar to organic farming (higher value).

Bananas

Several earlier LCA studies were found on bananas, mainly focusing on the climate impact of bananas from Ecuador, Costa Rica, Colombia, China, and Spain. All earlier studies included overseas transport from Ecuador, Costa Rica, or Colombia to a European country or to USA, except those by Yan *et al.* (2016) and Aguilera *et al.* (2015). The particularly high value given in Svanes and Aronsson (2013), 1.4 kg CO_2e per kg banana, may be due to several reasons, e.g., the assumptions of using small ships (i.e., higher fuel usage per unit of banana transported) and empty return. In addition, the transport distance from Costa Rica to Norway, which is accounted for in Svanes and Aronsson (2013), is greater than the distance to e.g., a German retailer.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A43. Results for 1 kg bananas at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Ecuador	0.5/1.0[a]					SB2	Iriarte *et al.* (2014)
Ecuador	0.5					SB1	Blonk *et al.* (2010)
Switzerland (origin Colombia)	0.5	0.08	0.2			SB2	Stoessel *et al.* (2012)
USA (origin Costa Rica)	0.5			5.5		SB2	Renz *et al.* (2014)
EU (imported)	0.6					SB2	Lescot (2012)
EU (imported)	0.7					SB2	Lescot (2012)
EU (imported)	0.9					SB2	Lescot (2012)
EU (imported)	1.1					SB2	Lescot (2012)
UK (origin probably Costa Rica or Ecuador)	0.7					SB2	Berners-Lee *et al.* (2012)
Ecuador	0.8					SB2	Roibás *et al.* (2016)
Ecuador	1.1		0.2 (calculated)			SB2	Luske (2010)
Costa Rica	1.4		0.2 (calculated)			SB2	Svanes and Aronsson (2013)
Rest of the world	1.3					SB1	Audsley *et al.* (2009)
Rest of the world[b]	1.3					SB1	Audsley *et al.* (2009)
China	0.3					SB1	Yan *et al.* (2016)
Spain	0.05/0.6[c]					SB1	Aguilera *et al.* (2015)
Swedish market	0.7	0.004	0.5			SB2	Moberg *et al*. (2020)

[a]Mean value of best case - ships do not return empty/ mean value of worst case - ships return empty.
[b]Plantain.
[c]Organic/conventional.

Cherries

Four LCA studies were identified on cherries. González *et al*. (2011) calculated a climate impact for Swedish cherries of around 0.3 kg CO_2e per kg and for cherries from USA a higher impact, around 0.5 kg CO_2e per kg (transport to Sweden from the USA included). Audsley *et al*. (2009) reported similar results, 0.3 kg CO_2e per kg for cherries grown in the UK and 0.4 kg CO_2e per kg cherries grown outside the UK, but in Europe and transported to the UK. In the same study (Audsley *et al*., 2010), climate impact for cherries produced outside Europe was around 0.9 kg CO_2e per kg transported to the UK. The study by Tassielli *et al*. (2018) showed a climate impact of 0.2 kg CO_2e per kg for Italian cherries. Bravo *et al*. (2017) calculated a climate impact of 0.4 kg CO_2e per kg for cherries from Chile. In the last two studies mentioned, fuel and fertilizers had the greatest impact.

Table A44. Results for 1 kg cherries at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden	0.3				3.0	SB2	González *et al.* (2011)
USA	0.5				5.0	SB2	González *et al.* (2011)
UK	0.3					SB2	Audsley *et al.* (2009)
Rest of Europe	0.4					SB1	Audsley *et al.* (2009)
Imported (rest of the world)	0.9					SB1	Audsley *et al.* (2009)
Italy	0.2					SB1	Tassielli *et al.* (2018)
Chile	0.4					SB1	Bravo *et al.* (2017)

Citrus fruit

Nine earlier LCA studies were found on citrus fruit, which all showed a climate impact of equal to or below 0.7 kg CO_2e per kg product. According to trade statistics (SS, 2018) Sweden does not import from Japan, and according to FAOSTAT Japan imports more than it exports. Therefore, the applicability of the study by Yoshikawa *et al*. (2008) could be considered to be limited for the Swedish market.

Table A45. Results for 1 kg citrus at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Italy	0.3	0.06	0.3			SB2	Stoessel *et al.* (2012)
Rest of Europe	0.5[a]					SB1	Audsley *et al.* (2009)
Morocco	0.3	0.3	0.5 (calculated)	3.3		SB1	Basset-Mens *et al.* (2014)
Japan	0.4[b]					SB2	Yoshikawa *et al.* (2008)
Spain	0.08/0.14[c]					SB1	Aguilera *et al.* (2015)
Spain	0.1/0.3[c]					SB1	Ribal *et al.* (2017)
Peru	0.6					SB1	Bartl *et al.* (2012)
China (tangerine)	0.2					SB1	Yue *et al.* (2017)
China (citrus)	0.3					SB1	Yue *et al.* (2017)
Morocco	0.2-0.7[d]					SB1	Bessou *et al.* (2016)

[a] Both citrus fruit, misc. and tangerines, mandarins etc.

[b] Mandarin orange (small citrus).

[c] Citrus (incl. mandarins and oranges) organic/conventional.

[d] Including five scenarios that correspond to different years. The highest value corresponded to a year with low yield (leading to a higher result) and the lowest value to a year with high yield (leading to a lower result).

Dates

One earlier study was found on dates (Audsley *et al.*, 2009). This study included transportation to the UK. Data from ecoinvent were also found (Wernet *et al.*, 2016).

Table A46. Results for 1 kg dates at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of the world	0.9					SB1	Audsley *et al*. (2009)

Figs

The study by Audsley *et al*. (2009) includes little detail about the individual processes behind the results. The results are therefore difficult to verify, so recommendations on climate impact based solely on Audsley *et al*. (2010) should be interpreted with caution.

Table A47. Results for 1 kg figs at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of Europe	0.4					SB1	Audsley *et al*. (2009)

Grapefruit and pomelo

The study by Audsley *et al*. (2009) provides little detail about the individual processes behind the results. The results are therefore difficult to verify, so recommendations on climate impact based solely on Audsley *et al.* (2010) should be interpreted with caution.

Table A48. Results for 1 kg grapefruit and pomelo at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of Europe	0.5					SB1	Audsley *et al*. (2009)
Rest of the world	0.7					SB1	Audsley *et al*. (2009)

Grapes

According to trade statistics (SS, 2018), Sweden does not import grapes from Switzerland, Japan, the USA, or Canada.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A49. Results for 1 kg grapes at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Spain	0.2	0.2	0.2				SB1	Torres *et al.* (2014)

Switzerland (origin Spain)	0.3	0.2	0.3			SB2	Stoessel *et al.* (2012)
Japan	0.9					SB2	Yoshikawa *et al.* (2008)
USA	0.21/0.24[a]					SB1	Venkat (2012)
Rest of Europe	0.4					SB1	Audsley *et al.* (2009)
Rest of the world	0.8					SB1	Audsley *et al.* (2009)
Canada	0.6[b]				5.6	SB1	Point *et al.* (2012)
Spain	0.1/0.2[a]					SB1	Aguilera *et al.* (2015)
Italy	0.1[b]					SB1	Cichelli *et al.* (2016)
Italy	0.3-0.5[b]					SB1	Bartocci *et al.* (2017)
Italy	0.3[b]					SB1	Falcone *et al.* (2016)
Swedish market	0.7	0.08	1.4			SB2	Moberg *et al*. (2020)

[a] Wine grapes: organic/conventional.

[b] Wine grapes, may include several types.

Mangoes

Four studies were found on mangoes. Carneiro *et al.* (2018), Basset-Mens *et al.* (2014) and Graefe *et al*. (2013) estimated the climate impact to be equal to or below 0.1 kg CO_2e per kg for mangoes at farm gate grown in either Brazil or Colombia. If emissions from transport to Sweden and packaging were taken into account, the climate impact would be approximately 0.5 kg CO_2e per kg mangoes. However, Audsley *et al.* (2009) estimated the climate impact to be much higher, 1.8 kg CO_2e per kg for mangoes grown in other parts of the world than Europe and then imported to UK. It is not clear why this result is particularly higher compared with other results, but one reason could be the emissions that occur from transporting mangoes to the UK.

Table A50. Results for 1 kg mangoes at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of the world[a]	1.8					SB1	Audsley *et al.* (2009)
Brazil	0.1	0.4				SB1	Carneiro *et al.* (2019)
Brazil	0.1	0.2		1.5		SB1	Basset-Mens *et al.* (2014)
Colombia	0.05					SB1	Graefe *et al.* (2013)

[a] Guavas and mangoes.

Kiwi fruit

New Zealand did not show up in trade statistics (SS, 2018). However, New Zealand exports large amounts of kiwi fruit (FAOSTAT, 2019) and exports most kiwi fruit to Sweden via other European countries. The applicability of the study by Nikkhah *et al.* (2016) was considered to be limited for the Swedish market, since Iran did not show up in trade statistics (SS, 2018) and Iran imports more kiwi fruit than it exports according to FAOSTAT (2019).

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A51. Results for 1 kg kiwi fruit at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
New Zealand	0.1-0.2[a]					SB1	Müller *et al.* (2015)
Rest of Europe	0.4					SB1	Audsley *et al.* (2009)
Rest of world	0.9					SB1	Audsley *et al.* (2009)
New Zealand	0.3[b]					SB1	McLaren *et al.* (2010)
Switzerland (origin Italy)	0.7	0.1	0.3			SB2	Stoessel *et al.* (2012)
Greece	0.7	0.4	0.7	11.1	12.4	SB1	ZEUS (2011)
New Zealand	0.3						Mithraratne (2010)
Italy	0.1			2.7		SB1	Baudino *et al.* (2017)
Iran	0.2					SB1	Nikkhah *et al.* (2016)

[a] Four scenarios, including two kiwifruit cultivars (green and gold kiwi) and two management systems (integrated and organic system).

[b] Integrated production.

Lemons

Three earlier studies were found on lemons. The study by Pergola *et al.* (2013) showed low results for lemons grown in Sicily, varying between 0.04 and 0.1 kg CO_2e per kg for organic and conventional farming up to farm gate, respectively. Likewise, the study by Bell *et al*. (2018) showed low climate impact for lemons grown in USA, 0.2 kg CO_2e per kg. The study by Audsley *et al.* (2009) showed higher climate impact, for lemons and limes grown in Europe and then imported to a regional distribution center in the UK. This is most likely due to the inclusion of transport to Europe. According to Bell *et al.* (2018), variations in the results between these studies can also be due to differences in climate, production practices, and yields.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A52. Results for 1 kg lemons at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sicily	0.04/0.1[a]				2.10/2.9[a]	SB1	Pergola *et al.* (2013a)
Rest of Europe	0.5[b]					SB1	Audsley *et al.* (2009)
USA	0.2	0.2		2.9		SB1	Bell *et al.* (2018)
Swedish market	0.5	0.2	0.7			SB2	Moberg *et al.* (2020)

[a] Organic/conventional.

[b] Lemons and limes.

Melons (including melons, watermelons, rockmelons etc.)

Eight earlier studies were found on melons, which showed various results depending on whether they were grown in a greenhouse or not. A few studies showed climate impacts equal to or less than 0.5 kg CO_2e per kg (Stoessel *et al.*, 2012; Renz *et al.*, 2014; Maraseni *et al.*, 2010).

Cellura *et al.* (2012) estimated the climate impact for Italian melons grown in a greenhouse to be either 1.2 or 1.5 kg CO_2e per kg depending on whether tunnels or a pavilion tent was used. A relatively high result for climate impact was also shown in Audsley *et al.* (2009), 1.7 kg CO_2e per kg for unspecified melons imported to UK from rest of the world. However, the results in Audsley *et al.* are difficult to verify, since little information about the studied system is presented in that paper. According to Brito de Figueirêdo *et al.* (2013), variations in these results may be due to differences in the production systems (grown in open field or in a greenhouse, for example).

Table A53. Results for 1 kg melons at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
France (**Switzerland)**	0.3	0.33	0.07			SB2	Stoessel *et al.* (2012)
USA	0.3			4.75		SB2	Renz *et al.* (2014)
Brazil	0.7					SB2	de Figueirêdo *et al.* (2013)
Italy (G)	1.2/1.5[a]	0.14[a]				SB2	Cellura *et al.* (2012)
Australia[b]	0.3		0.39			SB1	Maraseni *et al.* (2010)
Australia[b]	0.4		0.32			SB1	Maraseni *et al.* (2010)
Rest of Europe[c]	1.3					SB1	Audsley *et al.* (2009)
Rest of world[c]	1.3					SB1	Audsley *et al.* (2009)
Rest of Europe[d]	1.6					SB1	Audsley *et al.* (2009)
Rest of the world[d]	1.7					SB1	Audsley *et al.* (2009)
Costa Rica	0.7[e]		0.71-0.73[e]			SB1	Flysjö and Ohlsson (2006)
Brazil	0.8					SB1	de Lima Santos *et al.* (2018)

[a] Greenhouse, tunnel/pavilion tent.
[b] Rockmelon/cantaloupe.
[c] Watermelons.
[d] Other melons.
[e] Including two scenarios.

Oranges

Eight earlier studies were found on oranges. The highest climate impact, 0.5 kg CO_2e per kg oranges, was found in Audsley *et al.* (2009), while the climate impact were lower in the other studies (Pergola *et al.*, 2013; Knudesen *et al.*, 2011; Jungbluth *et al.*, 2013; Dwivedi *et al.*, 2012; Beccali *et al.*, 2009; González *et al.*, 2011; Yan *et al.*, 2016).

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A54. Results for 1 kg oranges at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO$_2$e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sicily	0.04/0.1[a]				2.38/2.87[a]	SB1	Pergola *et al.* (2013a)
Brazil	0.1[b]		0.55 & 0.44/ 0.50[b]	0.764 & 0.954/1.265[b]		SB1	Knudsen *et al.* (2011)
Brazil	0.1[c]					SB1	Doublet *et al.* (2013)
Spain	0.2[d]					SB1	Doublet *et al.* (2013)
USA	0.3					SB1	Doublet *et al.* (2013)
USA	0.3					SB1	Dwivedi *et al.* (2012)
Rest of Europe	0.5					SB1	Audsley et al. (2009)
Italy	0.1					SB1	Beccali *et al.* (2009)
USA	0.3				3.7	SB2	González *et al.* (2011)
China	0.1					SB1	Yan *et al.* (2016)
Swedish market	0.7	0.17	0.68			SB2	Moberg *et al.* (2020)

[a] Organic/conventional.

[b] Three scenarios; organic small vs. large scale/conventional small scale.

[c] Two scenarios that include organic small and large scale.

[d] Integrated production.

[e] Four scenarios: organic and integrated.

Papaya

The study by Audsley *et al.* (2009) provides little detail about the individual processes behind the results. The results are therefore difficult to verify, so recommendations on climate impact based solely on Audsley *et al*. (2010) should be interpreted with caution.

Table A55. Results for 1 kg papaya at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO$_2$e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of the world	0.9					SB1	Audsley *et al*. (2009)

Peaches and nectarines

Eight earlier studies were found on peaches and nectarines, which showed climate impact equal to or below 0.9 kg CO$_2$e per kg product. The highest climate impact, again, was estimated by Audsley *et al.* (2009), where transport from the rest of the world to UK was included in the result. The lowest climate impact was estimated by Vinyes *et al.* (2015), who studied a 15-year period (the results are the average for these years). The study by Vinyes *et al.* (2015) excluded the nursery stage due to lack of data. Storage, processing, and packaging were also excluded from the study.

Japan does not show up in trade statistics (SS, 2018), and according to FAOSTAT the country has very little export of peaches. The applicability of the study by Yoshikawa *et al.* (2008) could therefore be considered to be limited for the Swedish market.

The background data also included data from the databases ecoinvent (Wernet *et al.*, 2016).

Table A56. Results for 1 kg of peaches and nectarines at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Japan[a]	0.8						SB2	Yoshikawa *et al.* (2008)
Spain[b]	0.4	0.1	0.1				SB1	Torres *et al.* (2014)
Rest of Europe	0.4						SB1	Audsley *et al.* (2009)
Rest of the world	0.9						SB1	Audsley *et al.* (2009)
France[a]	0.2	0.3			2.5		SB1	Basset-Mens *et al.* (2014)
Spain[c]	0.1-0.3				1.1-2.5		SB1	Vinyes *et al.* (2015)
China[a]	0.4						SB1	Yan *et al.* (2016)
Peru[a]	0.6						SB1	Bartl *et al.* (2012)
Iran[a]	0.2						SB1	Nikkhah *et al.* (2016)

[a] Only peach.
[b] Only nectarine.
[c] Only peach, but four scenarios, where the lowest value corresponds to the high yield scenario and the highest value to the growth period.

Pears and quinces

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A57. Results for 1 kg pears and quinces at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
China (Beijing suburb)	0.2/0.4[a]			2.4-2.6/2.1[a]		SB1	Liu *et al.* (2010)
China (Liaoning province)	0.1/0.3[b]			1.1/1.3[b]		SB1	Liu *et al.* (2010)
UK	0.6[c]					SB2	Berners-Lee *et al.* (2012)
Switzerland	0.3	0.03	0.4			SB2	Stoessel *et al.* (2012)
UK	0.3					SB1	Audsley *et al.* (2009)
Rest of Europe	0.4					SB1	Audsley *et al.* (2009)
Rest of world	0.9					SB1	Audsley *et al.* (2009)
China	0.2					SB1	Yan *et al.* (2016)

Portugal	0.1						SB1	de Figueirêdo *et al.* (2013)
Italy	0.4					6.7	SB1	Tamburini *et al.* (2015)
Swedish market	0.4	0.002	0.5				SB2	Moberg *et al.* (2020)
Sweden	0.2	0	0.8				SB2	Moberg *et al.* (2020)

[a] Organic (incl. 2 scenarios)/conventional (only pears).

[b] Organic/conventional (only pears).

[c] Only pears.

Pineapples

Seven earlier LCA studies were found on pineapple production, three of which (Ingwersen, 2012; Stoessel *et al.*, 2012; Blonk *et al.*, 2010) estimated the climate impact for pineapples grown in Costa Rica to be equal to or below 0.5 kg CO_2e per kg. The system boundary in Blonk *et al.* (2010) and Stoessel *et al*. (2012) included transport from Costa Rica to Europe. The system boundary in Ingwersen (2012) was from cradle to shelf in the USA, but only the results for the farming stage in Costa Rica are shown here (Table A58).

The higher climate impact from Audsley *et al.* (2009) is difficult to explain, since the study gives little detail on the underlying processes. Usubharatana and Phungrassami (2017), de Ramos and Taboada (2018), and Graefe *et al.* (2013) estimated the climate impact to be equal to or below 0.2 kg CO_2e per kg pineapple, where mainly fertilization contributed to the emissions.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A58. Results for 1 kg pineapples at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Total water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Costa Rica	0.4	0.02		0.2			SB2	Stoessel *et al.* (2012)
Costa Rica	0.5[a]						SB1	Blonk *et al.* (2010)
Costa Rica	0.2		0.1		1.9		SB2	Ingwersen (2012)
Rest of the world	1.8						SB1	Audsley *et al.* (2009)
Thailand	0.2-0.3[b]						SB1	Usubharatana and Phungrassami (2017)
Philip-pines	0.2				0.9		SB1	De Ramos *et al.* (2018)
Colom-bia	0.1						SB1	Graefe *et al.* (2013)

[a] Including organic and conventional farming.

[b] Including three farms, where the smallest farm had the highest value and the largest farm the lowest value.

Plums and sloes

The study by Audsley *et al*. (2009) provides little detail about the individual processes behind the results. The results are therefore difficult to verify, so recommendations on climate impact based solely on Audsley *et al.* (2010) should be interpreted with caution.

Table A59. Results for 1 kg plums and sloes at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
UK	0.3					SB1	Audsley *et al.* (2009)
Rest of Europe	0.4					SB1	Audsley *et al.* (2009)
Rest of the world	0.9					SB1	Audsley *et al.* (2009)

Artichokes

The study by Audsley *et al.* (2009) provides little detail about the individual processes behind the results. The results are therefore difficult to verify, so recommendations on climate impact based solely on Audsley *et al.* (2010) should be interpreted with caution.

Table A60. Results for 1 kg artichokes at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of Europe	0.5					SB1	Audsley *et al.* (2009)

Asparagus (including green and white)

Hofer (2009), Schäfer *et al.* (2014), and Stoessel *et al.* (2012) studied asparagus production in European countries and reported climate impact equal to or below 1 kg CO_2e per kg. However, Jungbluth *et al.* (2016) estimated the climate impact for green asparagus cultivated in Switzerland to be 1.9 kg CO_2e per kg, where the relatively high result could be because of low yield per hectare compared with other vegetables.

Air transportation can explain the relatively high climate impact figures in Table A61. For example, asparagus transported by air from Peru to Europe has a climate impact of about 12 kg CO_2e per kg (Hofer, 2009; Jungbluth *et al.*, 2014; Stoessel *et al.*, 2012). According to Jungbluth *et al.* (2016) Peruvian asparagus transported via airfreight has a climate impact of 24.9 kg CO_2e per kg, which is much higher than the result presented in Jungbluth *et al.* (2014). This is possibly due to use of radiative forcing index (RFI) (N. Jungbluth, personal communication 2019). The RFI factor is multiplied by emissions from aircraft to calculate the total global warming potential of high-altitude emissions.

The system boundary in Hofer (2009) was not completely clear, so it was assumed to be from cradle to a Swiss retailer.

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A61. Results for 1 kg asparagus at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO_2e)	Blue water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
Switzerland	0.6[a]					SB2	Hofer (2009)
Spain	0.8/1[a]					SB2	Hofer (2009)
USA	0.8/1[a]					SB2	Hofer (2009)
Peru	0.9/1.1[a]					SB2	Hofer (2009)
Mexico	0.9/1.2[a]					SB2	Hofer (2009)
Switzerland	0.4/0.5[b]					SB2	Hofer (2009)
Germany	0.5/0.6[b]					SB2	Hofer (2009)
Slovenia	0.7/0.8[b]					SB2	Hofer (2009)
Spain	0.8/1[b]					SB2	Hofer (2009)
Peru	0.8/1[b]					SB2	Hofer (2009)
Maldives	1.5/1.6[b]					SB2	Hofer (2009)
Peru	12,3[h]					SB2	Hofer (2009)
USA	11[f]					SB2	Hofer (2009)
Peru	12.4 [f]					SB2	Hofer (2009)
Mexico	12.6 [f]					SB2	Hofer (2009)
Germany	0.5		1.42			SB2	Schäfer *et al.* (2014)
Peru	2.4/7.6[c]					SB2	Schäfer *et al.* (2014)
Switzerland	1.5					SB2	Jungbluth *et al.* (2014)
Spain	1.7					SB2	Jungbluth *et al.* (2014)
Peru	12.8[g]					SB2	Jungbluth *et al.* (2014)
USA	9.7[g]					SB2	Jungbluth *et al.* (2014)
Australia	2.5		2.32			SB1	Maraseni *et al.* (2010)
UK	1.9					SB1	Audsley *et al.* (2009)
Rest of Europe	2.2					SB1	Audsley *et al.* (2009)
Rest of the world	2.4					SB1	Audsley *et al.* (2009)
Peru	1.1/12.2[c]					SB2	Stoessel *et al.* (2012)
Switzerland	0.4/0.5[d]		2/3.33[d]			SB2	Stoessel *et al.* (2012)
Slovenia	1.0[e]					SB2	Stoessel *et al.* (2012)
Mexico	13.5[f]					SB2	Stoessel *et al.* (2012)
Morocco	1.9[e]					SB2	Stoessel *et al.* (2012)
Peru	0.9					SB1	Bartl *et al.* (2012)
Switzerland	1.9					SB2	Jungbluth *et al.* (2016)
Spain	2.1					SB2	Jungbluth *et al.* (2016)
Mexico[g]	22.7					SB2	Jungbluth *et al.* (2016)
Peru[g]	24.9					SB2	Jungbluth *et al.* (2016)
USA[g]	18.7					SB2	Jungbluth *et al.* (2016)

[a] Green organic/green integrated production.
[b] White organic/white integrated production.
[c] Ship/air freight to a European retailer.
[d] White/green asparagus.
[e] White, by truck to a Swiss retailer.
[f] Green integrated, transported by air freight to a European retailer.
[g] Transported by air freight to a European retailer.
[h] White integrated, transported by air freight.

Avocado

The climate impact estimated in Bell *et al.* (2018) is lower than the result for avocados from the rest of the world given in Audsley *et al.* (2009) and Stoessel *et al.* (2012). According to Bell *et al.* (2018), the variations in the results may be due to differences in yield, climate, and agricultural production practices. In addition, the study by Bell *et al.* (2018) excluded some material inputs, which can have led to the lower climate impact. Most importantly, Audsley *et al.* (2009) also included emissions from transport when importing avocados to a regional distribution center in the UK, and Stoessel *et al.* (2012) included transport distance between Israel and Switzerland, likely explaining the higher impacts estimated in these studies.

Use of blue water (irrigation water), estimated by Bell *et al.* (2018) and Stoessel *et al.* (2012) to be 0.60 and 0.93 m^3/kg, respectively, is in line with the California average use (0.62 m^3/kg) and the country average use in Israel (0.70 m^3/kg) for avocado (Mekonnen *et al.*, 2011). However, according to trade statistics (SS, 2018), Sweden does not import avocados from USA, and the USA imports more avocados than it exports. Therefore, the applicability of the study by Bell *et al.* (2018) can be considered limited for the Swedish market.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A62. Results for 1 kg avocado at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of Europe	0.4					SB2	Audsley *et al.* (2009)
Rest of the world	0.9					SB2	Audsley *et al.* (2009)
Israel	1.3	0.93	1.0			SB2	Stoessel *et al.* (2012)
USA	0.5	0.60		6.70		SB1	Bell *et al.* (2018)
Peru	0.5					SB1	Bartl *et al.* (2012)
Colombia	0.2					SB1	Graefe *et al.* (2013)

[a]Organic/conventional.

Broccoli

Seven earlier LCA studies were found on broccoli. González *et al.* (2011) studied broccoli from Sweden, showing a climate impact of 0.4 kg CO_2e per kg, while Moberg *et al.* (2020) estimated a slightly higher climate impact. Similar results were shown for broccoli from UK, Switzerland, and USA (Stoessel *et al.*, 2012; Venkat, 2012; i Canals *et al.*, 2008). Jungbluth *et al.* (2016) estimated higher climate impacts of 0.6, 0.7 and 0.9 kg CO_2e per kg for broccoli grown in Switzerland, Italy, and Spain, respectively, where transport to a Swiss retailer was included.

Maraseni *et al.* (2010) estimated the highest climate impact for broccoli, 1.7 kg CO_2e per kg. However, according to trade statistics (SS, 2018), Sweden does not import broccoli from Australia. Furthermore, Australia imports more broccoli than it exports (FAOSTAT, 2019). Therefore, the applicability of the study by Maraseni *et al.* (2010) can be considered limited for the Swedish market.

The system boundary in i Canals *et al.* (2008) is from cradle to grave, but the retail to grave phase is excluded in the results shown in Table A63.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A63. Results for 1 kg broccoli at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden	0.4				3.60	SB2	González *et al.* (2011)

UK[a]	0.4-0.5		0.50-0.63		5.50-6.00	SB3	i Canals *et al.* (2008)
Spain[a]	0.7-1.1	0.11-0.25	0.01-0.04		13.00-17.00	SB3	i Canals *et al.* (2008)
Switzerland	0.5	0.03	0.10			SB2	Stoessel *et al.* (2012)
USA	0.4[b]					SB1	Venkat (2012)
Switzerland	0.6					SB2	Jungbluth *et al.* (2016)
Italy	0.7					SB2	Jungbluth *et al.* (2016)
Spain	0.9					SB2	Jungbluth *et al.* (2016)
Switzerland (F)[c]	0.66					SB2	Jungbluth *et al.* (2016)
Australia	1.7		1.55			SB1	Maraseni *et al.* (2010)
Swedish market	0.6					SB2	Moberg *et al.* (2020)
Sweden	0.6	0.01	1.4			SB2	Moberg *et al.* (2020)

[a]Including four scenarios.

[b]Including organic and conventional broccoli.

[c]Deep frozen.

Cabbage

Three earlier studies estimated climate impact for cabbage or kale grown in Sweden, which was estimated to be equal to or below 0.3 kg CO_2e per kg (Moberg *et al.*, 2020; Landqvist & Woodhouse, 2015; González *et al.*, 2011). Audsley *et al.* (2009) estimated the highest climate impact for imported cabbage to the UK from rest of the world, where emissions from transport probably play a significant role.

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A64. Results for 1 kg cabbage at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden	0.1				1.10	SB2	González *et al.* (2011)
Australia	0.2		0.25			SB1	Maraseni *et al.* (2010)
Japan	0.4					SB2	Yoshikawa *et al.* (2008)
UK	0.2					SB1	Audsley et al (2009)
Rest of Europe	0.5					SB1	Audsley *et al.* (2009)
Rest of the world	0.6					SB1	Audsley *et al.* (2009)
Swedish market	0.4	0.03	0.71			SB2	Moberg *et al.* (2020)
Sweden	0.3	0.01	0.3			SB2	Moberg *et al.* (2020)
Sweden[a]	0.2					SB1	Landqvist *et al.* (2014)
China	0.1					SB1	Yue *et al.* (2017)

[a]Kale.

Capsicums/peppers

Seven earlier LCA studies were found on capsicums/peppers. Yoshikawa *et al.* (2008) estimated the highest climate impact, for green peppers grown in a greenhouse. The heat source was not specified in the study. According to the same study, green peppers grown in the open field have a climate impact of 0.7 kg CO_2e per kg.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A65. Results for 1 kg capsicums/peppers at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies (G: greenhouse)

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Australia	0.2		0.38			SB1	Maraseni *et al.* (2010)
Japan	0.7					SB2	Yoshikawa *et al.* (2008)
Japan (G)	3.8					SB2	Yoshikawa *et al.* (2008)
Rest of the world	0.9					SB1	Audsley *et al.* (2009)
Greece		0.16/0.09[a]	0.40/ 0.25[a]				Chatzisymeon *et al.* (2017)
Switzerland[b] (G)	0.9	0.04	0.06			SB2	Stoessel *et al.* (2012)
Italy (G)	1.1/1.2[c]	0.11/0.10[d]				SB2	Cellura *et al.* (2012)
China	0.2					SB1	Yue *et al.* (2017)

[a] Organic/conventional.

[b] Greenhouse, fuel heating oil.

[c] Greenhouse tunnel/pavilion tent.

Cauliflower

Results from the study by Audsley *et al*. (2009) showed much higher climate impact than other studies. However, that study presents little information about the underlying processes, and the difference is therefore difficult to explain.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A66. Results for 1 kg cauliflowers at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Netherlands	0.34/0.28[a]					SB1	Blonk *et al.* (2010)
Australia	0.4		0.51			SB1	Maraseni *et al.* (2010)
Switzerland	0.4	0.03	0.11			SB2	Stoessel *et al*. (2012)
UK[b]	1.9					SB1	Audsley *et al*. (2009)
Rest of Europe[b]	2.2					SB1	Audsley *et al.* (2009)
Rest of the world[b]	2.4					SB1	Audsley *et al*. (2009)
China	0.1					SB1	Yue *et al.* (2017)
Swedish market	0.5	0.05	0.68			SB2	Moberg *et al.* (2020)
Sweden	0.4	0.7	0.01			SB2	Moberg *et al.* (2020)

[a] Organic/conventional.

[b] Cauliflowers and broccoli.

Celery

Only two earlier LCA studies were found on celery (Bell *et al.*, 2018; Maraseni *et al.*, 2010), which estimated the climate impact to be below 0.2 kg CO_2e per kg. The background data also included data from the database ecoinvent (Wernet *et al*.. 2016), which showed somewhat higher results.

Table A67. Results for 1 kg celery at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
USA	0.1	0.10		1.70		SB1	Bell *et al.* (2018)
Australia	0.2		0.20			SB1	Maraseni *et al.* (2009)

Chillies

Table A68. Results for 1 kg chillies at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Australia	0.7	0.98			SB1	Maraseni *et al.* (2010)
Rest of Europe	1.3[a]				SB1	Audsley *et al.* (2009)

[a]Chillies and peppers, dry.

Cucumbers and gherkins

Results from Marton *et al.* (2010) show that cucumbers grown in greenhouses heated with fuel oil can have a much higher climate impact (in this study around 1.7 kg CO_2e per kg cucumber) than when grown in greenhouses heated with waste heat where no fossil fuel is used (0.2 kg CO_2e per kg cucumber). Cucumbers grown in open fields in Sweden have a climate impact of 0.1 kg CO_2e per kg, according to González *et al.* (2011). According to the same study, cucumbers grown in greenhouses have a much higher impact if the greenhouse is heated with fuel oil instead of electricity.

The system boundary in Hofer (2009) was assumed to be up to a Swiss retailer.

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A69. Results for 1 kg cucumber and gherkins (only cucumbers if not specified) at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies (G: greenhouse)

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden	0.1					SB2	González *et al.* (2011)
Australia	0.1		0.14			SB1	Maraseni *et al.* (2010)
Austria	0.2[a]					SB2	Lindenthal *et al.* (2010)
Switzerland (G)	0.2[b]					SB2	Marton *et al.* (2010)
Switzerland (G)	1.3[c]					SB2	Stoessel *et al.* (2012)
Sweden (G)	2.6[d]				35	SB2	González *et al.* (2011)

Sweden (G)	0.75[g]				41	SB2	González *et al.* (2011)
Switzerland (G)	1.7[d]					SB2	Marton *et al.* (2010)
UK (G)	3.8[c]					SB1	Audsley *et al.* (2009)
Switzerland	0.1/0.2[e]					SB2	Hofer (2009)
Belgium	0.2/0.3[e]					SB2	Hofer (2009)
Netherlands	0.2/0.3[e]					SB2	Hofer (2009)
Spain	0.3					SB2	Hofer (2009)
Switzerland (G)	2[f]					SB2	Hofer (2009)
Belgium (G)	2.1[f]					SB2	Hofer (2009)
Netherlands (G)	2.1[f]					SB2	Hofer (2009)
China	0.1/0.2[h]					SB1	Yue *et al.* (2017)
Sweden	0.7	0.02	0.1			SB2	Moberg *et al.* (2020)
Swedish market	0.7	0.01	0.1			SB2	Moberg *et al.* (2020)

[a] Organic and conventional.

[b] Greenhouse heated from waste heat.

[c] Greenhouse, heat not specified.

[d] Plastic greenhouse heated with fuel oil.

[e] Gherkins, organic/conventional.

[f] Gherkins, greenhouse, integrated production, unspecified heated greenhouse.

[g] Greenhouse, electricity heating.

[h] Greenhouse/open field.

Eggplants (aubergines)

The studies showing a higher impact (Wernet *et al.*, 2016; Stoessel *et al.*, 2012) studied production in heated greenhouses. There was not sufficient background information in Audsley *et al.* (2009) to explain the results.

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A70. Results for 1 kg eggplants (aubergines) at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies (G: greenhouse)

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of Europe	1.3					SB1	Audsley *et al.* (2009)
Switzerland (G)[a]	1.4	0.05	0.06			SB2	Stoessel *et al.* (2012)
China	0.2/0.3[c]					SB1	Yue *et al.* (2017)

[a] Greenhouse heated.

[b] Open field/greenhouse.

Fennel

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A71. Results for 1 kg fennel at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Switzerland	0.5	0.05	0.14			SB2	Stoessel *et al.* (2012)

Garlic

Earlier studies show that garlic likely has a climate impact below 1 kg CO_2e per kg. For example, garlic from Iran has an impact of 0.4 kg CO_2e per kg (Khoshnevisan & Rafiee, 2014). However, if packaging and transport to Sweden were added, the climate impact would be 0.9 kg CO_2e per kg. European production was considered most relevant for the Swedish market.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A72. Results for 1 kg garlic at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
UK	0.6				SB1	Audsley *et al.* (2009)
Rest of Europe	0.7				SB1	Audsley *et al.* (2009)
Czech Republic	0.2/0.4[a]				SB1	Moudrý jr *et al.* (2016)
Iran	0.4				SB1	Khoshnevisan and Rafiee (2014)

[a] Organic/conventional.

Ginger

The study by Audsley *et al*. (2009) provides little detail about the individual processes behind the results. The results are therefore difficult to verify, so recommendations on climate impact based solely on Audsley *et al*. (2010) should be interpreted with caution.

Table A73. Results for 1 kg ginger at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Rest of the world	0.9				SB1	Audsley *et al.* (2009)

Green beans

Sweden has no significant production of green beans for the retailer market, and no earlier study could be found on green beans produced in Sweden.

Table A74. Results for 1 kg green beans at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies (F: fresh, FZ: frozen, C: canned)

Country	**Climate impact (kg CO2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Spain (F)	0.1-0.3[a]				SB1	Romero-Gámez *et al.* (2012)
The Netherlands (C)	1.3-1.6[b]				SB2	Blonk *et al.* (2010)
UK (F)	1.6				SB1	Audsley *et al.* (2009)
UK (F)[c]	0.08-0.13	0.08-0.13	1.21	20.1-22.4	SB3	i Canals *et al.* (2008)
UK (FZ)	0.1	0.10	1.14	27.7	SB3	i Canals *et al.* (2008)
Kenya (F)[d]	10.7	0.16	0.48	158.2	SB3	i Canals *et al.* (2008)
Uganda (F)[d]	10.9	0.09	0.82	158.2	SB3	i Canals *et al.* (2008)
Australia (F)	1.4		1.73		SB1	Maraseni *et al.* (2010)

[a] Six scenarios for three treatment over two years. Data presented as average for the two years. One year for one treatment (greenhouse with misting) resulted in much higher climate impact than the other scenarios due to very low yield that year.
[b] Two scenarios, one canned in glass jar (higher value) and one in tin can (lower value),
[c] Two scenarios for UK.
[d] Transported by air to UK.

Lettuce

The particularly high climate impact estimated by i Canals *et al.* (2008) corresponded to lettuce grown in a greenhouse year-round heated with natural gas. Lettuce in open fields showed lower climate impact, equal to or below 0.6 kg CO_2e per kg. It is unclear why the climate impact from the study by Audsley *et al*. (2009) (rest of the world) is so much higher, but a likely explanation is use of heated greenhouse and possibly high waste rates when traded from outside Europe. For the Swedish market, European production was considered most relevant.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A75. Results for 1 kg lettuce at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies (G: greenhouse)

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden	0.1				1.40	SB2	González *et al.* (2011)
Holland	0.1				1.30	SB2	González *et al.* (2011)
USA	0.3				3.90	SB2	González *et al.* (2011)
UK[a]	0.2-0.5	0.04-0.10	0.25-0.44		5-11	SB2	i Canals *et al.* (2008)
Spain[b]	0.4-0.6	0.04-0.13	0.20-0.24		10-11	SB2	i Canals *et al.* (2008)
UK (G)[c]	1.3	0.01	0.08		31	SB2	i Canals *et al.* (2008)
UK (G)[d]	4.7	0.05	0.08		105	SB2	i Canals *et al.* (2008)
Australia	0.3		0.37			SB1	Maraseni *et al.* (2010)
UK	0.3					SB1	Hospido *et al.* (2009)
Spain	0.3					SB1	Hospido *et al.* (2009)
UK (G)[d]	1.5-3.7					SB1	Hospido *et al.* (2009)
USA	0.3/0.2[e]					SB1	Venkat (2012)
Sweden	0.4					SB2	Strid and Eriksson (2014)
Switzerland (G)	0.5/4.5[f]					SB2	Marton *et al.* (2010)
Japan	0.6					SB2	Yoshikawa *et al.* (2008)
UK[g]	1.2					SB1	Audsley *et al.* (2009)
Rest of Europe[g]	1					SB1	Audsley *et al.* (2009)
Rest of the world[g]	10					SB1	Audsley *et al.* (2009)
Australia	3.6					SB2	Gunady *et al.* (2012)
Italy[h]	0.3				4.12	SB1	Tamburini *et al.* (2015)
Swedish market	0.3	0.01	0.48			SB2	Moberg *et al.* (2020)
Sweden	0.3	0.5	0.02			SB2	Moberg *et al.* (2020)

[a] Including five scenarios (different farms).
[b] Including four scenarios (different farms).
[c] Both indoor and outdoor growing (glass greenhouse with natural gas heating).
[d] Glass greenhouse year round with natural gas heating.
[e] Organic/conventional.
[f] Greenhouse from waste heat/plastic greenhouse with fuel heating oil.
[g] Lettuce and chicory.
[h] Lettuce and chicory.

Olives

The background data also included data from the database ecoinvent (Wernet *et al.* 2016).

Table A76. Results for 1 kg olives at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Italy	0.1[a]				4.43/2.80[a]	SB1	Pergola *et al.* (2013b)
Italy	0.5/0.7[b]	0.18/0.23[b]				SB1	De Gennaro *et al.* (2012)
Rest of Europe	3.7					SB1	Audsley *et al.* (2009)
Spain	0.3					SB1	Aguilera *et al.* (2015)

[a] Sustainable/conventional system.

[b] High density (common in Italy)/super high density (less common, require special technical conditions) (De Gennaro *et al.*, 2012).

Onions

Eight earlier LCA studies were found on onions. Four of them included studies on Swedish onions, which all showed a climate impact of 0.3 kg CO_2e per (Moberg *et al.*, 2020; González *et al.*, 2011; Fuentes *et al.*, 2006; Cederberg *et al.*, 2005).

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A77. Results for 1 kg onion at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Sweden	0.1				0.47	SB1	Cederberg *et al.* (2005)
Sweden	0.1	0.02	0.19		1.91	SB2	Fuentes *et al.* (2006)
Denmark	0.1	0.01	0.29		3.01	SB2	Fuentes *et al.* (2006)
UK	0.2				3.76	SB1	Saunders *et al.* (2006)
New Zealand	0.1				0.82	SB1	Saunders *et al.* (2006)
Sweden	0.1				1.00	SB2	González *et al.* (2011)
Australia	0.2		0.22			SB1	Maraseni *et al.* (2010)
Japan	0.3					SB2	Yoshikawa *et al.* (2008)
UK	0.4					SB1	Audsley *et al.* (2009)
Rest of Europe	0.5					SB1	Audsley *et al.* (2009)
Swedish market	0.4	0.03	0.31			SB2	Moberg *et al.* (2020)

Sweden	0.3	0.03	0.25			SB2	Moberg *et al*. (2020)

Pumpkins

The system boundary in Schäfer and Blanke (2012) is up to a German retailer, so emissions from transport between Argentina and Germany are accounted for in the result. Data from Audsley *et al*. (2009) were difficult to verify due to limited background information in the report.

Table A78. Results for 1 kg pumpkin at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Germany	0.04[a]					SB2	Schäfer and Blanke (2012)
Argentina	0.1					SB2	Schäfer and Blanke (2012)
Australia	0.3		0.58			SB1	Maraseni *et al.* (2010)
Rest of Europe	2.2[b]					SB1	Audsley *et al.* (2009)

[a] Including organic and integrated production, where organic production had a slightly higher impact than integrated.

[b] Pumpkins, squash and gourds.

Spinach

Data from Audsley *et al*. (2009) were difficult to verify due to limited background information in the report.

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A79. Results for 1 kg spinach at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Switzerland	0.2	0.01	0.04			SB2	Stoessel *et al.* (2012)
Japan	0.9					SB2	Yoshikawa *et al.* (2008)
Rest of Europe	2.2					SB1	Audsley *et al.* (2009)

Tomatoes

Many LCA studies were found on tomatoes, as listed in Table A80. Regarding tomato production in Sweden, the data from Moberg *et al.* (2020) were considered most relevant, because the energy sources for heating greenhouses have changed in recent years. In general, heating source for heating greenhouses is important for the climate impact results. For tomatoes produced in unheated greenhouses, the transport distance or materials such as plastic for covering the greenhouse can be more important for the climate impact (Röös & Karlsson, 2013).

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A80. Results for 1 kg tomatoes at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies (G: greenhouse)

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
World	0.2					SB3	Andersson (2000)
Switzerland	0.3/0.2[a]					SB2	Hofer (2009)
Belgium	0.4/0.3[a]					SB2	Hofer (2009)
Netherlands	0.4/0.3[a]					SB2	Hofer (2009)
Spain	0.4/0.4[a]					SB2	Hofer (2009)
Maldives	0.5/0.5[a]					SB2	Hofer (2009)
Belgium (G)	1[b]					SB2	Hofer (2009)
Switzerland (G)	1.1[b]					SB2	Hofer (2009)
Australia	0.2		0.25			SB1	Maraseni *et al.* (2010)
Sweden	0.2		0.09	3.30		SB2	Röös and Karlsson (2013)
Sweden (G)	0.3[c]		0.02	6.80		SB2	Röös and Karlsson (2013)
Sweden (origin Netherlands (G))	1.0[d]		0.02	16		SB2	Röös and Karlsson (2013)
Sweden (origin Spain)	0.5		0.08	8.60		SB2	Röös and Karlsson (2013)
USA	0.3				3.70	SB2	González *et al.* (2011)
Spain	0.4				3	SB2	González *et al.* (2011)
Netherlands (G)	2.8				49	SB2	González *et al.* (2011)
Sweden (G)	3.7				51	SB2	González *et al.* (2011)
Austria	0.2/0.2[a]					SB2	Lindenthal *et al.* (2010)
Spain	0.2-0.3[e]				2.9-4.8[e] (CED)	SB1	Sanyé-Mengual *et al.* (2014)
Morocco	0.2			3.61		SB1	Payen *et al.* (2015)
France (origin Morocco)	0.6			9.13		SB1	Payen *et al.* (2015)
Spain	0.3[f]				4 (CED)	SB1	Torrellas *et al.* (2012a)
Spain[f] (G)	0.3				4 (CED)	SB1	Torrellas *et al.* (2012b)
Hungary[g] (G)	0.4				6.9 (CED)	SB1	Torrellas *et al.* (2012b)
Netherlands[h] (G)	0.8				12 (CED)	SB1	Torrellas *et al.* (2012b)
Netherlands[i] (G)	2.0				31	SB1	Torrellas *et al.* (2012b)
Hungary[j] (G)	5.0				87	SB1	Torrellas *et al.* (2012b)
Australia (G)	0.4/1.9[k]	0.04/0 0.02[k]				SB1	Page *et al.* (2012)
Australia	0.3	0.05				SB1	Page *et al.* (2012)

Australia (G)	1.7[l]	0.04[l]				SB1	Page *et al*. (2012)
USA	0.5			7.05		SB2	Renz *et al*. (2014)
France	0.5[m]					SB1	Boulard *et al.* (2011)
France (G)	1.6-2.4[n]					SB1	Boulard *et al.* (2011)
Switzerland	0.7	0.03	0.02			SB2	Stoessel *et al.* (2012)
Japan	0.8					SB2	Yoshikawa *et al*. (2008)
Spain (G)	1[o]					SB1	Blonk *et al.* (2010)
Netherlands (G)	1.1[o]					SB1	Blonk *et al.* (2010)
Netherlands (G)	2.2[o] (organic)					SB1	Blonk *et al*. (2010)
Sweden (G)	2.7[p]	0.02	0.02		51	SB2	Fuentes *et al*. (2006)
Netherlands (G)	2.9[p]				53.40	SB2	Fuentes *et al*. (2006)
Denmark (G)	3.7[p]	0.02	0.02		61.91	SB2	Fuentes *et al*. (2006)
Sweden (G)	3.3[p]				42	SB2	Carlsson-Kanyama (1998)
UK (G)	3.8					SB1	Audsley *et al.* (2009)
UK (G)	6.1 (unspecified heated)					SB2	Berners-Lee *et al.* (2012)
UK (G)	2.2[q]	0.02	0.02		36	SB1	Williams *et al.* (2008)
UK (G)	5.1[r]	0.06	0.04		83	SB1	Williams *et al.* (2008)
UK (G)	5.9[s]	0.07	0.05		95	SB1	Williams *et al.* (2008)
Italy (organic)	0.1				0.87	SB1	Tamburini *et al.* (2015)
China	0.1/0.2[t]					SB1	Yue *et al.* (2017)
Swedish market	1.4	0.01	0.08			SB2	Moberg *et al.* (2020)
Sweden	0.9	0.03	0.002			SB2	Moberg *et al.* (2020)

[a] Organic/integrated production.

[b] Heated greenhouse (GH) (heat not specified), integrated production.

[c] Heated GH using mostly renewable energy.

[d] Heated GH using mostly natural gas.

[e] Rooftop GH, no auxiliary heat. Including three scenarios.

[f] Multi-tunnel GH.

[g] Venlo GH with no auxiliary heating (thermal energy).

[h] Venlo GH with avoided electricity at combined heat and power plant (CHP).

[i] Venlo GH with energy allocation at CHP.

[j] Venlo GH with natural gas.

[k] GH "low tech summer" with no auxiliary heating systems/GH "high tech year" with natural gas and coal.

[l] GH "mid tech year" with coal.

[m] Tunnel GH with no auxiliary heating systems.

[n] Eight scenarios, including plastic and glass greenhouse and tunnel, highest value corresponds to "Plastic North vine" with mainly natural gas.

[o] GH, natural gas heating.

[p] Sweden and Netherlands: fuel heating oil. Denmark: LPG and electricity heating.

[q]Heated GH for classic loose tomato, using a natural gas boiler-heater.
[r]Heated GH for classic vine tomato, using a natural gas boiler-heater.
[s]Heated GH for baby plum tomato, using a natural gas boiler-heater.
[t]Open field/greenhouse.

Zucchini/button squash

The system boundary in the study by Jungbluth *et al.* (2016) is not clear, but was assumed to be from cradle to a Swiss retailer (including packing).

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A81. Results for 1 kg zucchini at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies (G: greenhouse)

Country	Climate impact (kg CO_2e)	Blue water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
Sweden	0.1				0.96	SB2	González *et al.* (2011)
Austria	0.18/0.22[a]					SB2	Lindenthal *et al.* (2010)
Australia	1.2		1.03			SB1	Maraseni *et al.* (2010)
Italy (G)	1.6/1.9[b]	0.16/0.15[b]				SB2	Cellura *et al.* (2012)
Switzerland	0.6					SB2	Jungbluth *et al.* (2016)
Switzerland (G)	3.9[c]					SB2	Jungbluth *et al*. (2016)
Spain	0.9					SB2	Jungbluth *et al*. (2016)
Italy	0.7					SB2	Jungbluth *et al*. (2016)
Morocco	1.0					SB2	Jungbluth *et al*. (2016)

[a]Organic/conventional.
[b]Greenhouse, tunnel/pavilion with no auxiliary heating systems.
[c]Greenhouse heated with fuel oil.

Blueberries

No earlier studies were found on wild berries. All data included are for cultivated blueberries.

Table A82. Results for 1 kg blueberries at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO_2e)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
USA	0.7/0.8[a]				SB1	Venkat (2012)
Rest of the world	1.4				SB1	Audsley *et al.* (2009)
Italy	0.2		3.55		SB2	Girgenti *et al.* (2013)
Italy	0.4		8.98		SB2	Peano *et al.* (2015)
Chile	0.3-0.7[b]				SB1	Cordes *et al.* (2016)

[a]Organic/conventional.
[b]Organic, including results for five different orchards with varying fertilizer application.

Currants and gooseberries

The study by Audsley *et al*. (2009) provides little detail about the individual processes behind the results. The results are therefore difficult to verify, so recommendations on climate impact based solely on Audsley *et al*. (2010) should be interpreted with caution.

Table A83. Results for 1 kg currants and gooseberries at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	Climate impact (kg CO_2e)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
UK	0.8				SB1	Audsley *et al.* (2009)

Raspberries

Foster *et al.* (2014) report particularly high climate impact, but in a short conference contribution providing little background information on underlying processes and the reasons why the climate impact was estimated to be so much higher. Therefore, the results were not considered in the final assessment.

Table A84. Results for 1 kg raspberries at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies (FZ: frozen)

Country	Climate impact (kg CO_2e)	Blue water use (m^3)	Land use (m^2)	Energy use (fossil) (MJ)	Energy use (total) (MJ)	System boundary	Reference
UK	0.8					SB1	Audsley *et al.* (2009)
Rest of Europe	1.0					SB1	Audsley *et al.* (2009)
Rest of the world	1.4					SB1	Audsley *et al.* (2009)
Italy	0.4			8.6		SB2	Girgenti *et al.* (2013)
Spain[a]	7.3	2.7	1.1			SB2	Foster *et al*. (2014)
UK[b]	7.4	1.3	1.2			SB2	Foster *et al.* (2014)
UK (FZ)[b]	7.7	1.3	1.2			SB2	Foster *et al*. (2014)
Swedish market	0.8	0.01	2.4			SB2	Moberg *et al*. (2020)
Sweden	0.9	0.0	3.6			SB2	Moberg *et al*. (2020)

[a] Greenhouse, polytunnels in Spain, fresh in July.

[b] Greenhouse, polytunnels, fresh in May.

Strawberries

Several earlier LCA studies were found on strawberry production. The variation in the results can be explained mainly by the use of heated greenhouses or open field production.

Lillywhite (2008) presents the result per hectare, which was recalculated to the functional unit of 1 kg strawberries based on yield information from Mordini *et al.* (2009). Tabatabaie and Murthy (2016) estimated the climate impact for strawberries grown in plasticulture (in raised rows covered with black plastic) to be 1.8-5.5 kg CO_2e per kg, depending on location in the USA. California had the lowest value thanks to the high yield, while North Carolina had the highest impact. The main contributor to climate impact was the input of materials (mainly the plastic) (Tabatabaie & Murthy, 2016). European production was considered most relevant for the Swedish market.

The background data also included data from the database ecoinvent (Wernet *et al.*, 2016).

Table A85. Results for 1 kg strawberries at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Blue water use (m^3)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Austria	0.2/0.3[a]					SB2	Lindenthal *et al.* (2010)
Sweden	0.2				2.80	SB2	González *et al.* (2011)
USA	0.6				5.40	SB2	González *et al* (2011)
Switzerland	0.3	0.01	0.40			SB2	Stoessel *et al.* (2012)
USA	0.2/0.5[a]					SB1	Venkat (2012)
Spain	0.3					SB1	REWE Grupo (2009)
Iran	0.6/0.7[b]					SB1	Khoshnevisan and Rafiee (2014)
UK	0.8					SB1	Audsley *et al.* (2009)
Rest of Europe	1.1					SB1	Audsley *et al.* (2009)
Rest of the world	1.4					SB1	Audsley *et al.* (2009)
UK	0.9	0.11	0.05		13	SB1	Williams *et al.* (2008)
Spain	0.4	0.13	0.03		8.3	SB1	Williams *et al.* (2008)
UK	1.2	0.13				SB1	Lillywhite (2008)
Netherlands (open field)	0.9					SB1	Blonk *et al.* (2010)
Japan (G)	5.2					SB2	Yoshikawa *et al.* (2008)
Australia	3.8						Gunady *et al.* (2012)
USA	0.6	0.10		12		SB1	Bell *et al.* (2018)
Italy	0.6			14.8		SB2	Peano *et al.* (2015)
USA	1.8-5.5[c]					SB1	Tabatabaie and Murthy (2016)
Italy	0.2					SB1	Valiante *et al.* (2019)
Switzerland	1.9					SB1	Valiante *et al.* (2019)
Peru	0.3					SB1	Bartl *et al.* (2012)
UK	0.8	0.11			12.9	SB1	Webb *et al.* (2013)
Spain	0.3	0.13			8.3	SB1	Webb *et al.* (2013)
Swedish market	0.7	0.09	1.43			SB2	Moberg *et al.* (2020)
Sweden	0.4	0.12	1.8			SB2	Moberg *et al.* (2020)

[a] Organic/conventional.

[b] Open field/greenhouse, curved roof plastic greenhouses with electric heating.

[c] Including California, Florida, North Carolina, and Oregon. California has the lowest impact due to high yield, and North Carolina had the highest due to low yield.

Mushrooms

Three studies examined the same type of mushroom (*Agaricus bisporus*), grown in Australia, Spain, and USA (Robinson *et al.*, 2019; Leiva *et al.*, 2015; Gunady *et al.*, 2012). These studies showed a climate impact of 2.1-4.4 kg CO_2e per kg mushrooms. Transport of raw materials (such as peat, compost, and spawn) made the highest contribution to greenhouse gas emissions in mushroom production according to Gunady *et al.* (2012). The highest emissions in Leiva *et al.* (2015) were found in the growing phase.

In the study by Robinson *et al*. (2019), the use of electricity, compost, and fuels made the highest contribution. Ueawiwatsakul *et al.* (2014) and Tongpool and Pongpat (2013) performed LCA for oyster mushrooms and Shiitake mushrooms, respectively. The climate impact was found to be higher for oyster mushrooms than for shiitake. Transport of planting materials had a great impact on the results in both studies.

Audsley *et al.* (2009) and Maraseni *et al.* (2010) present climate impact results for unspecified mushrooms, showing lower impact compared with other studies. However, not enough detail is provided in these studies to explain the lower climate impact compared with other studies, so these studies were not considered in the recommendation.

Mushroom imports to Sweden are mainly from Poland and Lithuania, but no studies were found for mushrooms from these countries. The relevance of earlier studies from Australia, Thailand, USA, and Spain could therefore be considered to be limited for the Swedish market. A small amount of Swedish mushroom imports comes from the Netherlands (7%). Only one study was found on mushrooms from the Netherlands, which showed 1.9 kg CO_2e per kg for mushrooms grown in a greenhouse (Blonk *et al*. 2010), but type of mushrooms considered was not specified.

Table A86. Results for 1 kg mushrooms at farm gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
Australia	0.1	0.4			SB1	Maraseni *et al.* (2010)
Netherlands (G)	1.9				SB1	Blonk *et al*. (2010)
UK	1[d]				SB1	Audsley *et al*. (2009)
Rest of Europe	1.1[d]				SB1	Audsley *et al*. (2009)
Australia	2.8[b]				SB2	Gunady *et al*. (2012)
Thailand	3-5[a]				SB1	Ueawiwatsakul *et al.* (2014)
USA	2.1[b]		28.8	29.1	SB1	Robinson *et al*. (2019)
Spain	4.4[b]				SB1	Leiva *et al*. (2015)
Thailand	1.9[c]				SB1	Tongpool and Pongpat (2013)

[a] Sajor-caju/oyster mushroom: three farms of different sizes, highest impact for the medium farm where more fuel is used in sterilization and more material is needed for the substrate preparation, plastic bag cultivation.

[b] *Agaricus bisporus* (known as portobello mushroom when mature, and as common or champignon mushroom when white and immature), growing in climate controlled chambers (Leiva *et al*., 2015; Robinson *et al*., 2019).

[c] Shiitake mushroom, plastic bag cultivation.

[d] Mushrooms and truffles.

Plant-based drinks and cream

The background data also included data from the database ecoinvent (Wernet *et al*., 2016).

Table A87. Results for 1 kg or 1 liter plant-based drinks and cream at factory gate (SB1), retailer (SB2), and consumer (SB3) from earlier studies

Country (product)	**Climate impact (kg CO_2e)**	**Land use (m^2)**	**Energy use (fossil) (MJ)**	**Energy use (total) (MJ)**	**System boundary**	**Reference**
USA (almond drink)	0.06			0.7	SB1	Feraldi *et al.* (2012)

USA (almond drink)	0.4			SB1[a]	Henderson and Unnasch (2017)
USA (almond drink)	0.2		5.0	SB2	Grant and Hicks (2018)
USA (almond drink)	0.4			SB1	Ho *et al.* (2016)
USA market (coconut drink)	0.05		1.0	SB1	Feraldi *et al.* (2012)
USA (soy drink)	0.3		1.9	SB1	Feraldi *et al.* (2012)
UK market (soy drink)	0.7-1.4				Tesco (2012)
Dutch market (soy drink)	0.6	0.5			Blonk *et al.* (2008)
USA (soy drink)	0.2		6.7	SB2	Grant and Hicks (2018)
USA market (soy drink)	0.4			SB1[a]	Henderson and Unnasch (2017)
Sweden (oat drink)[b]	0.4	0.6	7.7	SB3	Florén *et al.* (2013)
Sweden (oat drink)[c]	0.5	0.6	9.2	SB3	Florén *et al.* (2013)
Sweden(oat cream)	0.5	2.9	7.0	SB1	Nilsson and Florén (2015)
(pea drink)	0.4			SB1[a]	Henderson and Unnasch (2017)

[a] Including packing and packing disposal.

[b] Aseptic oat drink.

[c] Fresh oat drink.

Appendix A2. Method for ready-made meat alternatives

Data collection for ready-made meat alternatives

In addition to the literature review on raw food commodities, data on the climate impact of ready-made meat alternatives for 11 soy-based meat alternatives and three mixed products (one mixed without animal products and two mixed with eggs) were obtained from two different companies. One of these companies buys soybeans from mainly North America (and to some extent Europe) and the other from central Europe.

To estimate land use, biodiversity impact, and water use, the amount of raw commodity ingredients in these products needed to be determined. Amount of soy protein concentrate or soy flour is often stated on the packaging (anamma.eu and foodforprogress.com). For all soy-based products from Orklafoods, soy flour or soy protein concentrate was the second ingredient after water. Based on the ingredients list showing their quantities in the product (in descending order) and the nutrition information on the package, the amounts of different ingredients were estimated. All fat was assumed to be rapeseed oil (since this is the only ingredient in most Orklafoods products that contains any substantial amounts of fat). Rapeseed oil was assumed to come from Germany (Lars Lundahl, Orklafoods, personal communication). For the ingredients that followed oil (e.g., onion) the amount was estimated based on the position in the ingredient list. For example, for a product with the ingredient list: *Water, soy protein concentrate (23%), rapeseed oil, onion, salt,* etc., and for which the nutritional information stated fat content (rapeseed) of 9.6% and salt content of 0.8%, the onion content was estimated to be around 5% (i.e., between the values stated for rapeseed oil and salt). These calculations were performed for 13 well-established products on the Swedish market (Table A88), mainly soy-based products and one falafel. The column "quantity needed at factory gate" in Table A88 gives the calculated amounts in the respective products. Losses for all products up to entering the processing factory were accounted for according to Gustavsson *et al.* (2011). Water use for processing was included for all soy-based and mixed products and assumed to be 0.015 m^3/kg ready-made product (Quantis, 2016). All water use for processing was assumed to be in Sweden.

There is much product development underway, with new products made from Swedish ingredients appearing on the market, e.g., tempeh made from yellow peas or faba beans can be found in regular Swedish stores. However, no studies were found on these products. It was assumed that land use for tempeh made with yellow peas or faba beans grown in Sweden is similar to that assessed for tempeh made from soybeans (Blonk *et al.*, 2008), since yield for soybeans (global average) and yield for yellow peas and faba beans are within the same range (FAOSTAT, 2018). However, due to the uncertainty in this assumption, land use for Swedish produce was increased by 20% from the value reported in Blonk *et al.* (2008).

Estimating the amount of soybeans needed for producing soy protein products

The soy-based ready-made meat alternatives included in this study contained 15-32% soybean protein concentrate or soy flour. Protein content in the different soy products was used to estimate the amount of soybeans needed to produce soy flour and soy protein concentrate, assuming that soybeans, soy flour, soy protein concentrate, and soy protein isolate contain 36%, 52%, 70%, and 90% protein, respectively (Thrane *et al.*, 2017). Losses during processing were assumed to be 5%. Allocation of environmental impact between soy flour and soy oil was based on mass; 16% on the oil and 84% on the flour (Dalgaard *et al.*, 2008).

It was calculated that, at the factory gate, 1.25 kg soybeans are needed to produce 1 kg soy flour and 2.04 kg soybeans to produce 1 kg soy protein concentrate. Using this method, land use for producing soy protein concentrate (70%) using beans from USA was estimated to be 5.9 m^2 per kg. This can be compared to land use for soy protein as estimated by Broekema and Blonk (2009) of 7.5 m^2 per kg. The higher land use in that study can be explained by the higher land use for soybeans (4.5 m^2 per kg beans) compared with this report (3.4 m^2 per kg beans, based on FAOSTAT, yield data for USA).

Table A88. Ingredients in ready-made soy-based and mixed products

Food type	**Ingredient**	**Country of origin**	**Yield 2007-2016 (kg/ha)**	**Reference yield**	**m^2/kg product harvested product**	**Harvested kg**	**Losses post harvest Factor**	**Quantity needed at factory gate**	**m^2/ ingredient**	**RESULT m^2/kg product**
Anamma formbar färs	Soy beans	USA	2565	FAOSTAT	3.9	0.4	1.0	0.4	1.5	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.1	1.0	0.1	0.3	
	Onion	Largest export	16055	FAOSTAT	0.6	0.1	0.9	0.1	0.0	1.8
Anamma pulled vego BBQ	Soy beans	USA	2565	FAOSTAT	3.9	0.3	1.0	0.3	1.1	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.0	1.0	0.0	0.1	
	Onion	Largest export	16055	FAOSTAT	0.6	0.0	0.9	0.0	0.0	1.3
Anamma vegobitar	Soy beans	USA	2565	FAOSTAT	3.9	0.3	1.0	0.3	1.0	1.0
Anamma vegobullar	Soy beans	USA	2565	FAOSTAT	3.9	0.4	1.0	0.4	1.5	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.1	1.0	0.1	0.3	
	Onion	Largest export	16055	FAOSTAT	0.6	0.1	0.9	0.1	0.0	1.8
Anamma vegoburgare	Soy beans	USA	2565	FAOSTAT	3.9	0.4	1.0	0.4	1.4	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.1	1.0	0.1	0.2	
	Onion	Largest export	16055	FAOSTAT	0.6	0.1	0.9	0.1	0.0	1.7
Anamma vegochorizo	Soy beans	USA	2565	FAOSTAT	3.9	0.3	1.0	0.3	1.1	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.1	1.0	0.1	0.3	
	Paprika	Mexico	16703	FAOSTAT	0.6	0.1	0.9	0.1	0.0	1.5
Anamma vegofärs	Soy beans	USA	2565	FAOSTAT	3.9	0.5	1.0	0.4	1.8	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.1	0.9	0.1	0.3	2.0
Anamma vegofärs eko	Soy beans	USA	2565	FAOSTAT	3.9	0.4	1.0	0.4	1.6	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.1	0.9	0.1	0.3	1.9
Anamma vego kebab	Soy beans	USA	2565	FAOSTAT	3.9	0.3	1.0	0.3	1.2	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.0	0.9	0.0	0.1	1.3
Anamma vegokorv	Soy beans	USA	2565	FAOSTAT	3.9	0.3	1.0	0.3	1.1	
	Rape seed	Germany	3895	FAOSTAT	2.6	0.1	0.9	0.1	0.3	1.5
Anamma vegoschnitzel	Soy beans	USA	3895	FAOSTAT	2.6	0.3	1.0	0.3	0.7	
	Rape seed	Germany	2565	FAOSTAT	3.9	0.1	0.9	0.1	0.5	
	Wheat	Largest export USA	3137	Jordbruksverket	3.2	0.2	1.0	0.2	0.6	
	Onion	Largest export	16055	FAOSTAT	0.6	0.0	0.9	0.0	0.0	1.7
Hälsanskök pulled beans	Soybeans	USA (assumed largest export)	2565	FAOSTAT	3.9	0.6	1.0	0.6	2.5	2.5
Anamma falafel	Chickpeas	Largest exporter	1346	FAOSTAT	7.4	0.3	1.0	0.3	0.3	
	Rapeseed	Germany	2565	FAOSTAT	3.9	0.1	0.9	0.1	0.1	
	Parsley	Largest export	2000	guess	5.0	0.0	0.9	0.0	0.0	
	Onion	Largest export	16055	FAOSTAT	0.6	0.0	0.9	0.0	0.0	0.4

Method for calculating water use and land use (biodiversity impact)

Land use was estimated from the ingredients (described above). Country of origin was based on producer information or assumed to be the largest exporter globally (FAOSTAT, 2019), information used to calculate biodiversity impact. Biodiversity impact was also calculated for the products from earlier studies where land use was given. Country of origin was either provided by the producer or assumed to be the largest exporter globally (FAOSTAT, 2019).

Water use was estimated from the ingredients. Water use for processing was estimated based on Quantis (2016) for soy-based products including tofu and tempeh. For Quorn, it was based on producer information (Louise Needham, Quorn, personal communication 2019). Blue water use for production was assumed to be in the country of processing.

Appendix A3. Methods for plant-based drinks and cream

Almond drink

Almond drink was assumed to contain 2.3% almonds and 2.4% sugar, in accordance with one of the main producers in Sweden (Alpro) (see Figure A1).

NÄRINGSVÄRDE (100ml)

energi	**93 kJ / 22 kcal**
fett	**1.1 g**
mättat	**0.1 g**
enkelomättat	**0.7 g**
fleromättat	**0.3 g**
kolhydrat	**2.4 g**
sockerarter	**2.4 g**
fiber	**0.4 g**
protein	**0.4 g**
salt	**0.14 g**
vitaminer	
vitamin D	**0.75µg* 15%***
vitamin B2	**0.21mg* 15%***
vitamin B12	**0.38µg* 15%***
vitamin E	**1.8mg* 15%***
mineraler	
kalcium	**120mg* 15%***

Referensintag för en genomsnittlig vuxen (8 400 kJ / 2 000 kcal)

RI TABLE (100ml)

energi	fett	mättat	sockerarter	salt
22 kcal	1.1 g	0.1 g	2.4 g	0.14 g
1%*	2%*	1%*	3%*	2%*

* Referensintag för en genomsnittlig vuxen (8 400 kJ/2 000 kcal)

INGREDIENSER

vatten, **MANDEL** (2,3%), socker, trikalciumfosfat, havssalt, stabiliseringsmedel (fruktkärnmjöl, gellangummi), emulgeringsmedel (lecitiner (solros)), vitaminer (riboflavin (B2), B12, E, D2), naturlig arom

Figure A1. Illustration of ingredients information provided by Alpro (Sweden) for its almond milk product.

Oat drink

Oat drink was assumed to contain 200 g oats and 0.8 g rapeseed oil (Florén *et al.*, 2013).

Soy drink

Soy drink was assumed to contain 70 g soybeans. 25 g sugar and 0.3 g corn (Ercin *et al.*, 2012).

Coconut milk (used for cooking, with fat content 17%)

Coconut milk is produced from the copra (coconut flesh). One ton of coconut contains approx. 239 kg copra, with around 144 kg fat (Van Zeist *et al.*, 2012). The amount of coconut milk that can be produced from 1 ton (dehusked coconut) was calculated assuming that coconut milk contains 17% fat (Kungmarkatta 17% fat, Santa maria 17% fat, Santa maria organic 18% fat), so 847 kg coconut milk can potentially be produced from 1 ton coconut. This was assumed to be reasonable, since coconut milk contains much water. Losses were assumed to be 10%, resulting in a yield of 762 kg coconut milk/kg dehusked coconut.

Water footprint calculations

Water use was calculated based on raw material ingredients. Process water use for oat and soy drinks and oat cream was estimated from the literature.

AWARE scores were calculated for each ingredient, for the respective production countries, and the process was assumed to take place in the country from which the main ingredient originated.

Appendix A4. Nutrient index

Background

To estimate the environmental impact in LCA, a functional unit has to be defined. This functional unit should reflect the actual function of the product and serve as a basis for the calculations. For the Vego-guide, the functional unit was defined as 1 kg of a food product delivered to a retailer in Sweden. Choosing a mass-based functional unit (kg) is common when estimating the environmental impact of different foods (Sonesson *et al.*, 2019). This unit is easy for the public to understand, as e.g., the price is given per kilogram in the grocery store. Other units based on specific content in the food, such as its protein (kg protein) or energy (kilocalorie) content, can also be used.

The problem with choosing a functional unit when performing LCA on food is that foods from different food groups have different functions. Use of a mass-based unit or other unit such as kilocalories in LCA of food would be beneficial for some products (those with high energy content), while it would be a disadvantage for other products (those with low energy content). For example, fruit and vegetables have a low calorie content but contain many nutrients, while some nuts have a high calorie content and at the same time contain important nutrients. When comparing these products from different food categories, it would be somewhat unfair to use kilocalories as the functional unit, since the health benefits of fruit and vegetables would not be fully captured. The same applies to the use of kilograms, which because of its simplicity has nevertheless become a widely used unit when assessing the environmental impact of food.

One way to address the issue with using only one functional unit for different food types is to employ a nutrition index (Hallström *et al.*, 2018). A nutrition index takes into account the overall nutritional quality of the food and covers both the climate impact and the health aspects. Analyzing the environmental impact of a food in combination with its nutritional value is a fast-growing research area, and there are now several methods available to calculate nutrition index (Hallström *et al.* 2018). Some of the methods involve awarding points to foods depending on whether their content meets specific criteria. However, the majority of the methods are based on a ratio between the product's nutrient content and a reference intake level (Hallström *et al*., 2018).

Here, we select a number of products for closer examination of the climate impact in combination with their nutrition index. Products that differed in their function were selected, e.g., where the nutrient content varied greatly. The selected products were peas, chickpeas, almonds, walnuts, Quorn, bananas, apples, tomatoes, cucumber, avocado, asparagus, celery, broccoli, blueberries, strawberries, quinoa, wheat, rice, and potatoes.

Method

A nutrition index adapted to Swedish conditions is the Swedish Nutrient Index (SNI) (Andersson, 2017), version SNI1 of which was used in this report. This method is based on existing nutrient profiling methods, but is adjusted with respect to food consumption, requirements, and recommendations for the Swedish population. SNI1 includes 18 nutrients to encourage in the diet (nutrient_i), such as protein, fiber, and different vitamins, and three nutrients to limit (nutrient_j), which are sodium, saturated fat, and sugar. The nutrients to limit should only be consumed in smaller amounts. The SNI1 for a particular food product is calculated by subtracting the sum of the nutrients to limit *(j)* from the sum of nutrients to encourage *(i)* as follows:

$$SNI1 = \sum_{i}^{i=18} Weighting\ factor_i \cdot Nutrient_i\ per\ 100\ kcal \Big/_{RDI_i} - \sum_{j}^{j=3} Weighting\ factor_j \cdot Nutrient_j\ per\ 100\ g/MRV_j$$

where the weighting factor (further explained below) for nutrients to encourage and nutrients to limit is multiplied by the nutrient content in 100 kcal and in 100 g of the product, respectively, and then divided by the reference value, which is the Recommended Daily Intake (RDI) for nutrients to encourage and the Maximum Recommended Value (MRV) for nutrients to limit. Values for RDI and MRV were taken from Andersson (2017) and information regarding the nutrient content of foods was retrieved from the food database provided by the Swedish Food Agency (SFA, 2019).

Some methods, including SNI1, perform weighting, which means that different weights are given to nutrients depending on how important they are in a person's diet. The calculation of the weighting factors varies for nutrients to encourage and nutrients to limit, and must be interpreted differently. For the nutrients to encourage, the weighting factor is the ratio of RDV and the mean intake of the nutrient i, while for the nutrients to limit it is the ratio of the mean intake of nutrient j and MRV. A weighting factor above one for the nutrients to encourage thus means that the Swedish population does not eat enough of this nutrient, while a value below one means that people are consuming enough of it according to Swedish recommendations. For the nutrients to limit, however, a value above one means that people are eating too much of it, and consumption should decrease. A value below one means that people are keeping consumption below the threshold of concern. Additionally, the nutrients are capped if 100 g of food contain more than the RDI, in order to avoid crediting over-consumption of nutrients. The inclusion of capping, and weighting, can vary between methods, see Andersson (2017) for more details.

The choice of reference amount varies between methods and can be e.g., per mass unit (100 g), per energy content (100 kcal) or per serving size (Hallström *et al.* 2018). For the method SNI1, nutrients to encourage ($nutrient_i$) are calculated per 100 kcal whereas nutrients to limit ($nutrient_j$) are calculated per 100 g. The choice of not using per 100 g as a reference unit for both was to prevent energy-dense products (that are often eaten in smaller amounts) from receiving unmerited low scores indicating that the products are healthy. See Andersson (2017) for more details behind this method choice.

The climate impact values of the food products assessed were thereafter normalized to fit the scale 0.0-1, where a value of 1 corresponds to the highest climate impact value among the foods assessed. Similarly, the SNI1 values were normalized. The climate impact can be related to SNI in several ways, depending on the method, by division, multiplication or addition, for example. Here, the total score was obtained by multiplication of the climate impact and the nutrition index, resulting in "SNI-adjusted GWP/kg".

Results and discussion

The climate impact of different foods, their nutrient indices, and the climate impact in combination with the nutrient indices, all normalized to fit the scale 0.0-1, are shown in Table A89.

Table A89. Normalized values of climate impact (CI), Swedish Nutrient Index (SNI1), and the combined score (CI x SNI1) to fit the scale 0.0-1. The higher the value of CI, the higher the climate impact, while *a low value of SNI1 means that the food is healthy according to the SNI1 index. A high value of the combined value (CI x SNI1) thus means that the product has a high carbon footprint among the foods assessed or is less healthy according to Swedish nutritional recommendations*

Product	**Climate impact (kg CO_2e/kg)**	**Climate norm.**	**SNI norm.**	**CI x SNI**
Peas	0.8	0.2	0.50	0.12
Chickpeas canned	1.7	0.4	0.67	0.35
Almonds	3.8	1.0	0.84	0.96
Walnuts	3.3	0.9	1.00	1.00
Quorn	2.2	0.6	0.45	0.30
Banana	1.5	0.4	0.80	0.36
Apple	0.5	0.1	0.88	0.13
Tomato	2.3	0.6	0.31	0.22
Cucumber	2.3	0.6	0.40	0.28
Avocado	1.6	0.4	0.82	0.40
Asparagus	2.1	0.6	0.10	0.06
Celery	0.6	0.2	0.18	0.03
Broccoli	1.3	0.3	0.10	0.04
Blueberries	0.9	0.2	0.75	0.20
Strawberries	1.5	0.4	0.36	0.16
Quinoa	0.9	0.2	0.75	0.20
Wheat	0.6	0.2	0.95	0.17
Rice	2.0	0.5	0.95	0.57
Potato	0.4	0.1	0.71	0.09

As the results in Table A89 show, certain foodstuffs are significantly affected when including the nutritional index of the products. Products that had the highest impact on the climate of the food examined did not necessarily have the greatest impact when their nutrition index was included. For example, the normalized value of the mean climate impact for asparagus received one of the highest scores of the products assessed. This is because the impact from airfreight was taken into account. However, the combined score (CI *x* SNI1, Table A89) was quite low when the nutrient index was taken into account. This is because asparagus is high in nutrients such as vitamin A, vitamin C, and folate which, despite the higher environmental impact, resulted in a low value when the environmental impact was combined with the nutrition index.

Almonds and walnuts have a higher climate impact than fruits, for example. Nuts contain many nutrients that are considered healthy for the human body. However, nuts are also quite high in saturated fat, which gives an adverse effect on the total score. Furthermore, the weighting factor for saturated fat is >1, indicating that the mean intake of saturated fat in Sweden is greater than recommended, which also affects the result. In addition, nuts are energy-dense, which means that nuts will be heavily affected by using 100 kcal instead of 100 g as a reference unit for the nutrients to encourage ($nutrient_i$). This, together with the earlier reasoning, explains why the total score (CI *x* SNI1) for nuts is relatively high compared with that for other products such as vegetables.

The mean climate impact for tomato and cucumber is higher than for other vegetables such as avocado and celery. This is because the impact from greenhouse cultivation is accounted for, which has a relatively large impact on the average climate impact for these products. When the climate impact of these foods was combined with their nutrition index, the combined score was relatively low, which indicates that cucumber and tomato are nutritious and at the same time have a relatively low climate impact. The same applies for broccoli, which thanks to its content of vitamin A, vitamin C, folate, iron, calcium, potassium, etc. received a low score when the climate impact was combined with the nutrient index. Additionally, the nutrients to limit are low for broccoli compared with the nutrients to encourage (sodium, saturated fat and sugar), which contributed to the low combined score. Avocado did not get a remarkably low score when the nutrition index was applied, which could be due to the amount of saturated fat. The weighting factor for saturated fat shows that Swedes generally eat too much.

The only nutrient to limit that is significant for fruits is sugar. This is probably the main reason why banana, which despite its health benefits (high in vitamin C, potassium, etc.) did not receive a lower score when its nutrition index was included. Unlike salt and saturated fat, Swedes eat within recommended limit when it comes to sugar. If this were not the case, however, the total score would have been even higher for sugar-rich fruits. Berries such as strawberries contain low amounts of sugar. They are also high in nutrients to encourage, such as folate, which is beneficial for the total score since the weighting factor shows that Swedes eat too little folate. This contributed to the lower score obtained for strawberries when the nutrient index was applied.

Potatoes had the lowest climate impact and one of the lowest combined impact values when the nutrition index was taken into account. This is because potatoes have a low climate impact to begin with, 0.4 kg CO_2e per kg, and contain many of the nutrients considered healthy. In addition, the less healthy nutrients that should be eaten in small amounts are not as significant in comparison with the beneficial nutrients.

Other nutrient indices

The method used in this report is only one among many existing methods to calculate nutrient index for food. Other methods include different method choices, which affect the final score in different ways. To address this, five additional methods were chosen for evaluation. First, three variations of SNI were chosen, here called SNI2, SNI3, and SNI4. Second, NRF9 and NRF9.3 (Nutrient-Rich Food index) were chosen for further evaluation. These methods, as well as SNI1, are based on existing nutrient profiling methods, but are adapted with respect to food consumption, requirements, and recommendations for the Swedish population. All 18 nutrients in SNI1 are included in SNI2, SNI3, and SNI4, but they vary in their choice of reference amount (per 100 g or 100 kcal), and also if they are divided by the number of nutrients included or not, see the following equations:

$$SNI2 = \sum_{i}^{i=18} Weighting\ factor_i \cdot Nutrient_i\ per\ 100\ kcal/RDI_i/18 - \sum_{j}^{j=3} Weighting\ factor_j \cdot Nutrient_j\ per\ 100\ g/MRV_j/3$$

$$SNI3 = \sum_{i}^{i=18} Weighting\ factor_i \cdot Nutrient_i\ per\ 100\ g/RDI_i - \sum_{j}^{j=3} Weighting\ factor_j \cdot Nutrient_j\ per\ 100\ g/MRV_j$$

$$SNI4 = \sum_{i}^{i=18} Weighting\ factor_i \cdot Nutrient_i\ per\ 100\ g/RDI_i/18 - \sum_{j}^{j=3} Weighting\ factor_j \cdot Nutrient_j\ per\ 100\ g/MRV_j/3$$

NRF9 and NRF9.3 were used, where the latter is an updated version of the former (Fulgoni III *et al.*, 2009). NRF9.3 is one of few published, fully validated methods available (Andersson, 2017). For the NRF indices, the following nine nutrients are included: protein, fiber, vitamin A, vitamin E, vitamin C, iron, calcium, potassium, and magnesium. NRF9.3 also includes three disqualifying nutrients: sodium, saturated fat, and sugar. NRF9 and NRF9.3 are calculated according to the following equations (note that a weighting factor is not included):

$$NRF9 = \sum_{i}^{i=9} Nutrient_i \; per \; 100 \; g / RDI_i$$

$$NRF9.3 = \sum_{i}^{i=9} Nutrient_i \; per \; 100 \; g / RDI_i - \sum_{j}^{j=3} Nutrient_j \; per \; 100 \; g / MRV_j$$

The normalized values (scale from 0.0-1) of the SNI and the NRF values were plotted in a chart in order to show how they vary among the foods assessed (Figure A2). A value close to zero indicates that the food product is healthy for the average Swedish person.

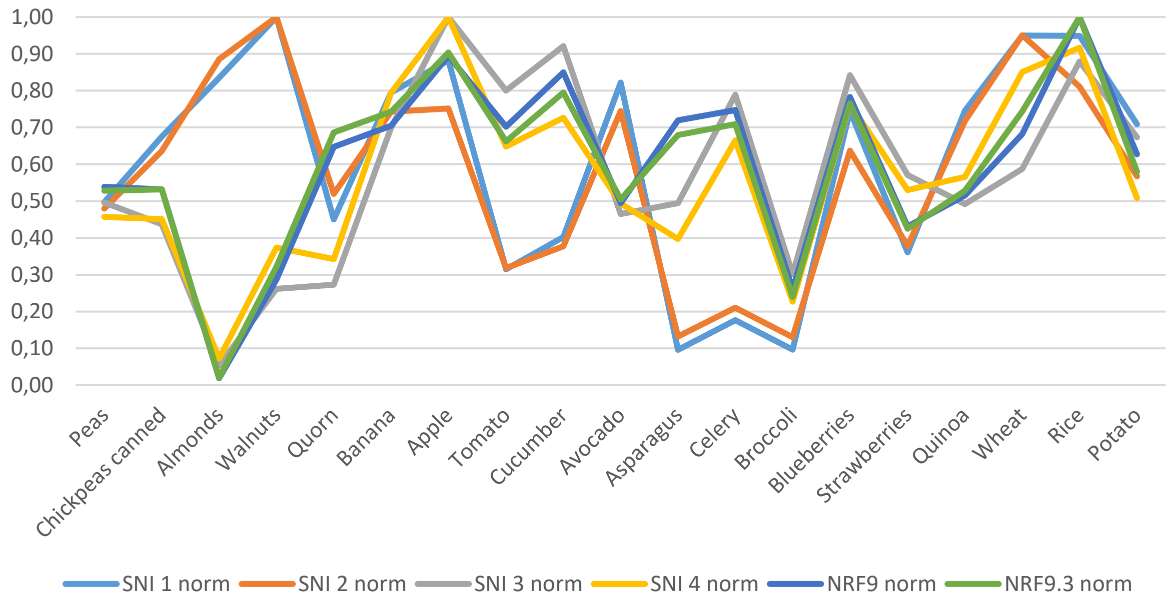

Figure A2. Normalized values (scale 0.0-1) of nutrient indices derived from different methods, where a low value indicates that the product is healthy according to Swedish conditions.

As can be seen, the outcomes of the methods vary greatly for different foods. The methods point at similar results for products such as Quorn, apple, celery, broccoli, blueberries, strawberries, and wheat, while the results differ for products such as almonds, walnuts, avocado, asparagus, and rice. This means that choice of method has a great impact on the nutrient index, which in turn affects the final score (CI *x* NI).

The SNI1 and SNI2 methods gave similar results for the foodstuffs examined, because these methods differ only in the division by number of nutrients in method SNI2. The results from SNI3, SNI4, NRF9, and NRF9.3 vary among the food products assessed, but follow the same pattern in general (Figure A2). This is because the calculations in these methods are based on the same reference value (per 100 g). However, the methods account for different numbers of nutrients and some do not include weighting, which may be a reason for the minor variations in the results.

Using SNI1 and SNI2 appears to be less favorable for energy-dense products such as nuts, avocado, and rice, while using SNI3, SNI4, NRF9, or NRF9.3 seems to be more favorable for these products. Similarly, low-energy fruit and vegetables seem to be favored by the SNI1 and SNI2 methods, while the other methods seem less favorable. One likely reason behind the various results among the methods assessed is the choice of reference unit (100 g or 100 kcal, or a mix of them), which seems to influence the result greatly.

Limitations

Designing a nutrition index means several subjective choices that affect the end result. For example, a decision is needed on how many and which nutrients to include. This is challenging, as a healthy food products can vary depending on the individual; a product that is healthy for one person is not necessarily healthy for another. A decision is also needed concerning the unit on which the calculations on nutrients to encourage/limit should be based, e.g., grams, kcal, or portion size. Furthermore, a decision is needed on whether weighting should be included or not. It is important to emphasize that weighting factors need to be updated from time to time because people's eating habits change, which will affect the factors. If weighting is not applied, equal weight will be given to the final score from all the nutrients included. The combination of the climate impact and nutrition index can also be obtained in different ways, which will affect the total score.

Conclusions

Designing a nutrient index involves many choices, which may limit the credibility of the results. Despite the limitations in the design of nutrition index, it can nevertheless be used to broaden the knowledge and understanding of the sustainability of foods. The combined measure can thus be useful and contribute an understanding of how climate footprint relates to nutrition, but should be interpreted and applied with caution as the method involves several subjective choices.

Appendix A5. Food losses, waste, and conversion factors

Table A90. Factors for calculating losses in post-harvest handling and storage, processing and packing, and distribution: supermarket retail (Gustavsson et al., 2011)

	Postharvest handling and storage	**Processing and packing**	**Distribution: supermarket retail**
Europe incl. Russia			
Cereals	4%	10.50%	
Roots and tubers	9%	15%	7%
Oilseeds and pulses	1%	5%	1%
Fruit and vegetables	5%	2%	10%
North America and Oceania			
Cereals	2%	10.50%	2%
Roots and tubers	10%	15%	7%
Oilseeds and pulses	0%	5%	1%
Fruit and vegetables	4%	2%	12%
Industrialized Asia			
Cereals	10%	10.50%	2%
Roots and tubers	7%	15%	9%
Oilseeds and pulses	3%	5%	1%
Fruit and vegetables	8%	2%	8%
Sub-Saharan Africa			
Cereals	8%	3.50%	2%
Roots and tubers	18%	15%	5%
Oilseeds and pulses	8%	8%	2%
Fruit and vegetables	9%	25%	17%
North Africa, West and Central Asia			
Cereals	8%	9%	4%
Roots and tubers	10%	12%	4%
Oilseeds and pulses	6%	8%	2%
Fruit and vegetables	10%	20%	15%
South and Southeast Asia			
Cereals	7%	3.50%	2%
Roots and tubers	19%	10%	11%
Oilseeds and pulses	12%	8%	2%
Fruit and vegetables	9%	25%	10%
Latin America			
Cereals	4%	9%	4%
Roots and tubers	14%	12%	3%
Oilseeds and pulses	3%	8%	2%
Fruit and vegetables	10%	20%	12%
AVERAGE	*Postharvest handling and storage*	*Processing and packing*	*Distribution: supermarket retail*
Cereals	6%	8%	3%

Roots and tubers	12%	13%	7%
Oilseeds and pulses	5%	7%	2%
Fruit and vegetables	8%	14%	12%

Conversion factors for nuts from in-shell to shelled

Table A91. Conversion factors for converting in-shell products to shelled products, showing the fraction of edible nut in 1 kg nuts in shell

Product	**Factor**	**Reference**
Almonds	0.59	Bartzas *et al.* (2017)
Cashew nuts	0.25	FAO (1994)
Hazelnuts	0.50	FAO (1994)
Peanuts	0.83	Mccarty *et al.* (2012)
Pistachios	0.50	Marvinney *et al.* (2014)
Walnuts	0.53	FAO (1994)

Conversion factors for carbohydrate sources

Table A92. Conversion factors for converting dried carbohydrate sources to edible products

Product	**Factor**	**Reference**
Soft whole grain bread	2.0	RAC
Bread rye	1.8	RAC
White bread	1.8	RAC
Pasta	2.1	Bognár (2002)
Wheat whole boiled	1.8	Bognár (2002)
Average for common grains[a]	1.9	
Rice	3.0	Bognár (2002)
Millet	2.4	Bognár (2002)
Quinoa	3.4	Bognár (2002)

[a]Used for barley, corn, oat, pasta, rye, sorghum and wheat.

Conversion factors for protein sources

Table A93. Conversion factors for converting dried grain legumes to edible products

Product	**Factor**	**Reference**
Beans and peas[a]	2.5	Bognár (2002)
Lentils	2.3	SFA (2019)[b]
Soybeans	3.1	SFA (2019)[b]
Chickpeas	2.5	

[a]Used for dried beans, kidney beans, faba beans, and dried peas.

[b]Calculated based on protein content in dried and edible product.

Appendix A6. Canned beans or boiling at home?

Grain legumes can either be bought dry and boiled at home or bought already cooked in a can or in a cardboard carton (Tetra Pak^{TM}). Earlier studies have examined both canned and dry legumes. Fuentes *et al.* (2006) found that cooking beans at home is more energy-efficient than buying canned beans, and thus has a lower climate impact. However, due to cooked beans being commonly sold in cardboard cartons, we calculated the climate impact from transport, packing, and boiling for two different scenarios: 1) Import of beans from Italy and boiling at home in Sweden; and 2) boiling of beans in Italy (industrially) and import of cooked beans in Tetra Pak^{TM} cartons. Assumptions and data used for the calculation are presented in Figure A3.

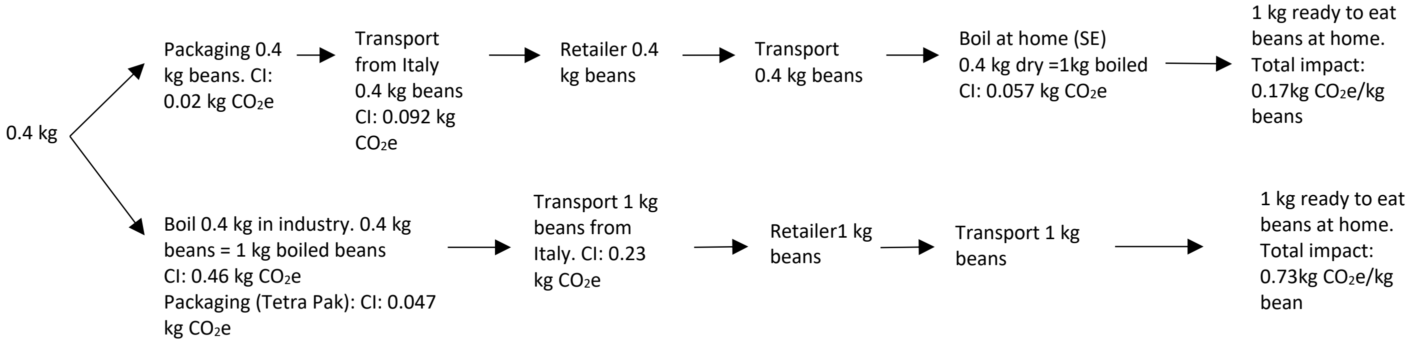

Figure A3. Calculation example of dried beans transported from Italy and boiled in Sweden and canned beans, boiled and canned in Italy and transported to Sweden. CI: climate impact. Note: climate impact for transport, cooking and packaging only.

Energy use for boiling legumes at home (after soaking) was assumed to be 4.6 MJ per kg output and for boiling beans in industry 4 MJ per kg output (Carlsson-Kanyama & Faist, 2000). Climate impact from electricity production was assumed to be the electricity mix in Sweden (0.012 kg CO_2e per kWh) and in Italy (0.11 kg CO_2e per kWh) (Wernet *et al.*, 2016). Climate impact from packaging was taken from Tetra Pak (2018) and for packing materials for dry beans from Moberg *et al.* (2019).

The results showed that boiling at home has a considerably lower climate impact (Figure A3). This is not primarily due to the packaging, but due to the electricity mix in Italy where the beans were assumed to be boiled, and the transport of packaged cooked beans to Sweden, which has a higher impact because of the higher weight during this transport (boiled beans are heavier than dry beans). If the beans were to be boiled and packaged in Sweden instead, the total climate impact from packaging, transport, and boiling would be 0.19 kg CO_2e per kg legumes, which is similar to boiling at home.

Appendix A7. Pesticide use results for individual products

Table A94. Pesticide for individual products in kg active substance (AS) per hectare and g AS per kg product (OE: outside Europe, ND: no data)

Product	Country	Comments pesticides	Pesticide use (kg AS/ha)	Pesticide use (g AS/kg)	Total pesticide for combined products	References
Peas fresh	Belgium	Other arable crops	0.25	0.04		EUROSTAT (2007)
	The Netherlands	No data for other arable crops	ND	ND		EUROSTAT (2007)
	France (largest trade surplus)	Other arable crops	0.10	0.01		EUROSTAT (2007)
	World average	OE	ND	ND		
Peas canned	Belgium	Other arable crops	0.25	0.04		EUROSTAT (2007)
	Italy	No data for other arable crops	ND	ND		EUROSTAT (2007)
	Germany	Other arable crops	0.13	0.02		EUROSTAT (2007)
	France (largest trade surplus)	Other arable crops	0.10	0.01		EUROSTAT (2007)
	World average	OE	ND	ND		
Peas fresh (frozen) Sweden	Sweden	Green peas	1.10	0.25		SBA (2018)
Peas dried	Denmark	Other arable crops	0.08	0.01		EUROSTAT (2007)
	The Netherlands	No data for other arable crops	ND	ND		
	Germany	Other arable crops	0.13	0.02		EUROSTAT (2007)
	Canada (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
	Sweden	Peas dried	0.99	0.13		SBA (2018)
Beans dried	Turkey	OE	ND	ND		
	The Netherlands	No data for other arable crops	ND	ND		
	Myanmar (largest trade surplus)	OE	ND	ND		
	Argentina (extra country)	OE	ND	ND		
	Poland (extra country)	No data for other arable crops	ND	ND		
	Canada	OE	ND	ND		
	China	OE	ND	ND		
	World average	OE	ND	ND		
	Sweden	Data for faba beans	1.01	0.25		SBA (2018)
Faba beans dried	Egypt	OE	ND	ND		
	Lebanon	OE	ND	ND		
	Turkey	OE	ND	ND		
	Germany	Other arable crops	0.13	0.01		EUROSTAT (2007)
	Australia (largest trade surplus)	OE	ND	ND		
	UK (extra country)	Other arable crops	2.60	0.29		EUROSTAT (2007)
	France (extra country)	Other arable crops	0.10	0.01		EUROSTAT (2007)

	World average	OE	ND	ND		
	Sweden	Faba beans	1.01	0.12		SBA (2018)
Beans canned	Italy	No data for other arable crops	ND	ND		
	Myanmar (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
	Sweden	Data for faba beans	1.01	0.25		SBA (2018)
Chickpeas dried	Turkey	OE	ND	ND		
	Italy	No data for other arable crops	ND	ND		
	Australia (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
Lentils dried	Turkey	OE	ND	ND		
	UK	No data for other arable crops	ND	ND		
	Canada (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
	Sweden	Data for faba beans	1.01	0.32		SBA (2018)
Soybeans dried	Italy	Data for oil crops	0.34	0.03		EUROSTAT (2007)
	USA (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
Soy-based products	USA (soybeans)		ND	ND		
Tofu/tempeh	USA		ND	ND		
Faba beans or peas (tofu/tempeh)	Sweden		1.01	0.24		SBA (2018)
Quorn	UK	Cereals (wheat)	3.18	0.35		EUROSTAT (2007)
Pea-protein based	Germany	Data for other arable crops	0.13	0.06		EUROSTAT (2007)
Almonds	USA	OE	ND	ND		
	Australia	OE	ND	ND		
	Spain	No data	ND	ND		
	USA (largest trade surplus)	OE	ND	ND		
	Chile (extra country)	OE	ND	ND		
	Italy (extra European country)	No data	ND	ND		
	World average	OE	ND	ND		
Cashew nuts	Vietnam (largest trade surplus)	OE	ND	ND		
	Extra India	OE	ND	ND		
	Brazil (extra country)	OE	ND	ND		
	World average	OE	ND	ND		
Chestnuts	China (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
Coconut	Philippines (largest trade surplus)	OE	ND	ND		
	Indonesia (extra country)	OE	ND	ND		
	Sri Lanka (extra country)	OE	ND	ND		
	World average	OE	ND	ND		
Hazelnuts	Italy	No data	ND	ND		

	Turkey (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
Peanuts	Argentina	OE	ND	ND	
	China	OE	ND	ND	
	India (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
Pistachios	USA (largest trade surplus)	OE	ND	ND	
	Iran (extra country)	OE	ND	ND	
	Turkey (extra country)	No data	ND	ND	
	Greece (extra country)	No data	ND	ND	
	World average	OE	ND	ND	
Walnuts	USA (largest trade surplus)	OE	ND	ND	
	Ukraine (extra country)	No data	ND	ND	
	Mexico (extra country)	OE	ND	ND	
	Republic of Moldova (extra country)	No data	ND	ND	
	World average	OE	ND	ND	
Sesame seeds	India	OE	ND	ND	
	Guatemala	OE	ND	ND	
	Ethiopia (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
Linseeds	Denmark	Oilseeds	0.26	0.92	EUROSTAT (2007)
	Canada	OE	ND	ND	
	The Netherlands	Oil crops	2.84	3.39	EUROSTAT (2007)
	World average	OE	ND	ND	
	Sweden	Oil crops	0.48	0.28	EUROSTAT (2007)
Sunflower seeds	Bulgaria	No data	ND	ND	
	Russia	OE	ND	ND	
	Romania (largest trade surplus)	no data	ND	ND	
	World average	OE	ND	ND	
Barley	Denmark	Cereals	0.92	0.10	EUROSTAT (2007)
	Finland	Cereals	0.56	0.10	EUROSTAT (2007)
	UK & Northern Ireland	Cereals	3.18	0.33	EUROSTAT (2007)
	France (largest trade surplus)	Cereals	2.58	0.24	EUROSTAT (2007)
	World average	OE	ND	ND	
	Sweden	Barley (average winter and spring)	0.50	0.06	SBA (2018)
Maize	France	Maize	2.16	0.15	EUROSTAT (2007)
	Poland	Maize	1.10	0.10	EUROSTAT (2007)
	South Africa (largest trade surplus)	OE	ND	ND	
	Brazil (extra country)	OE	ND	ND	
	Argentina (extra country)	OE	ND	ND	
	World average	OE	ND	ND	

Millet	India (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
Oats	Denmark	Cereals	0.92	0.11	EUROSTAT (2007)
	Finland	Cereals	0.56	0.10	EUROSTAT (2007)
	Canada	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden	Oats	0.37	0.05	SBA (2018)
Pasta	Denmark	Cereals	0.92	0.09	EUROSTAT (2007)
	Finland	Cereals	0.56	0.10	EUROSTAT (2007)
	Germany	Cereals	2.16	0.19	EUROSTAT (2007)
	Turkey (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
	Italy	cereals	0.48	0.08	EUROSTAT (2007)
	Sweden	Wheat (average spring and winter)	0.50	0.06	SBA (2018)
Quinoa	Peru	OE	ND	ND	
	Bolivia	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden	Assumption, no accepted value for quinoa in Sweden	0.00	0.00	
Rice	India	OE	ND	ND	
	Italy	Cereals	0.48	0.05	EUROSTAT (2007)
	Thailand	OE	ND	ND	
	India (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
Rye	Denmark	Cereals	0.92	0.09	EUROSTAT (2007)
	Finland	Cereals	0.56	0.12	EUROSTAT (2007)
	Poland	Cereals	0.70	0.15	EUROSTAT (2007)
	Germany	Cereals	2.16	0.23	EUROSTAT (2007)
	World average	OE	ND	ND	
	Sweden	Rye	1.16	0.12	SBA (2018)
Sorghum	USA (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
Wheat	Denmark	Cereals	0.92	0.08	EUROSTAT (2007)
	Finland	Cereals	0.56	0.09	EUROSTAT (2007)
	Germany	Cereals	2.16	0.16	EUROSTAT (2007)
	Turkey (largest trade surplus)	OE	ND	ND	
	UK (extra for Quorn)	Cereals	3.18	0.48	EUROSTAT (2007)
	World average	OE	ND	ND	
	Sweden	Wheat (average spring and winter)	0.50	0.05	SBA (2018)
Beetroot	The Netherlands	Vegetables	2.74	0.10	EUROSTAT (2007)
	Denmark	Vegetables	14.36	0.53	EUROSTAT (2007)
	Germany	Vegetables	2.16	0.08	EUROSTAT (2007)
	Not available in FAOSTAT		ND	ND	

	World average	OE	ND	ND		
	Sweden	Vegetables	2.20	0.08		SBA (2018)
Carrots	Italy	Vegetables	7.04	0.21		EUROSTAT (2007)
	The Netherlands	Vegetables	2.74	0.06		EUROSTAT (2007)
	China (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
	Sweden	carrots	15.60	0.36		SBA (2018)
Potatoes	Denmark	Potatoes	6.94	0.23		EUROSTAT (2007)
	Finland	Potatoes	3.48	0.18		EUROSTAT (2007)
	France (largest trade surplus)	Potatoes	17.26	0.54		EUROSTAT (2007)
	World average	OE	ND	ND		
	Sweden	Potatoes	2.91	0.12		SBA (2018)
Swede (rutabaga)	Sweden	Vegetables	2.20	0.10		SBA (2018)
Sweet potato	USA (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
Parsnip	Not available in import statistics		ND	ND		
	Sweden	Vegetables	2.20	0.12		SBA (2018)
Jerusalem artichoke	Sweden	Vegetables	2.20	0.22		SBA (2018)
Almond milk 1	USA (almonds)	OE	ND	ND	ND	
	Brazil (sugar)	OE	ND	ND	ND	
Almond milk 2	Australia (almonds)	OE	ND	ND	ND	
	Brazil (sugar)	OE	ND	ND	ND	
Almond milk 3	Spain (almonds)	No data	ND	ND	ND	
	Brazil (sugar)	OE	ND	ND	ND	
Almond milk 4	World average (almonds)	OE	ND	ND	ND	
	Brazil (largest producer) (sugar)	OE	ND	ND	ND	
Soy milk 1 (sweetened)	Italy (soybeans)	Oil seeds	0.34	0.01	0.007131	EUROSTAT (2007)
	Brazil (sugar)	OE	ND	ND		
	France (corn)	Maize	2.16	0.00		EUROSTAT (2007)
Soy milk 2 (sweetened)	USA (soybeans)	OE	ND	ND	8.5E-05	
	Brazil (sugar)	OE	ND	ND		
	France (corn)	Maize	2.16	0.00		EUROSTAT (2007)
Soy milk 3 (sweetened)	World average (soymilk)	OE	ND	ND	ND	
	Brazil (sugar)	OE	ND	ND	ND	
	World average (corn)	OE	ND	ND	ND	
Oat milk 1	Sweden (oats)	Oat	0.37	0.02	0.022187	SBA (2018)
	Sweden (rapeseed oil)	Average winter and spring rape	0.60	0.00		
Oat milk 2	World average (oats)	OE	ND	ND	ND	
	World average (rapeseed oil)	OE	ND	ND		
Oat cream 1	Sweden (oats)	Oat	0.37	0.02	0.046366	SBA (2018)
	Sweden (rapeseed oil)	Average winter and spring rape	0.60	0.03		
Oat cream 2	World average (oats)	OE	ND	ND	ND	
	World average (rapeseed oil)	OE	ND	ND		

Coconut milk 1	Philippines	OE	ND	ND	ND	
Coconut milk 2	Indonesia (extra country)	OE	ND	ND	ND	
Coconut milk 3	Sri Lanka (extra country)	OE	ND	ND	ND	
Coconut milk 4	World average	OE	ND	ND	ND	
Apples	Italy	Fruit trees	14.64	0.42		EUROSTAT (2007)
	Poland (largest trade surplus)	Fruit trees	2.38	0.17		EUROSTAT (2007)
	France (extra country)	Fruit trees	16.38	0.49		EUROSTAT (2007)
	World average	OE	ND	ND		
	Sweden	Apples	4.22	0.28		SBA (2018)
Apricots	France	Fruit trees	16.38	1.65		EUROSTAT (2007)
	Italy	Fruit trees	14.64	1.45		EUROSTAT (2007)
	Spain	Fruit trees	2.76	0.45		EUROSTAT (2007)
	Germany	Fruit trees	16.20	4.25		EUROSTAT (2007)
	Spain (largest exporter)	Fruit trees	2.76	0.45		EUROSTAT (2007)
	Turkey (extra country)	No data	ND	ND		
	Uzbekistan (extra country)	OE	ND	ND		
	Armenia (extra country)	OE	ND	ND		
	World average	OE	ND	ND		
Bananas	Costa Rica	OE	ND	ND		
	Dominican Republic	OE	ND	ND		
	Ecuador (largest exporter)	OE	ND	ND		
	World average	OE	ND	ND		
Cherries	Denmark (Chile)	OE	ND	ND		
	The Netherlands	Fruit trees	16.78	42.06		EUROSTAT (2007)
	Turkey	OE	ND	ND		
	Germany	Fruit trees	15.80	3.51		EUROSTAT (2007)
	Chile (largest exporter)	OE	ND	ND		
	USA (extra country)	OE	ND	ND		
	Spain (extra country)	Fruit trees	2.76	0.83		EUROSTAT (2007)
	World average	OE	ND	ND		
Dates	Iran	OE	ND	ND		
	Saudi Arabia	OE	ND	ND		
	Iraq (largest trade surplus)	OE	ND	ND		
	Pakistan (extra country)	OE	ND	ND		
	Tunisia (extra country)	OE	ND	ND		
	World average	OE	ND	ND		
Grapefruit and pomelo	South Africa (largest trade surplus)	OE	ND	ND		
	World average	OE	ND	ND		
Grapes	Chile (largest exporter)	OE	ND	ND		
	Greece	Grapes/vines	44.58	4.77		EUROSTAT (2007)
	Italy	Grapes/vines	32.24	3.42		EUROSTAT (2007)

	The Netherlands (Chile)	OE	ND	ND	
	Spain	Grapes/vines	10.48	1.90	EUROSTAT (2007)
	World average	OE	ND	ND	
Guavas and mango	Mexico (largest exporter)	OE	ND	ND	
	India (extra country)	OE	ND	ND	
	Thailand (extra country)	OE	ND	ND	
	World average	OE	ND	ND	
Kiwi fruit	New Zealand (largest trade surplus)	OE	ND	ND	
	Italy	Fruit trees	14.64	0.87	EUROSTAT (2007)
	World average	OE	ND	ND	
Lemons and limes	Mexico (largest trade surplus)	OE	ND	ND	
	Spain	Citrus	8.40	0.43	EUROSTAT (2007)
	Turkey (extra country)	No data	ND	ND	
	Argentina (extra country)	OE	ND	ND	
	World average	OE	ND	ND	
Melons	Guatemala (largest trade surplus)	OE	ND	ND	
	Spain	Fruit and vegetables total	8.38	0.31	EUROSTAT (2007)
		OE	ND	ND	
	Honduras (extra country)	OE	ND	ND	
	Turkey (extra country)	No data	ND	ND	
	Greece (extra country)	Fruits and vegetables total	16.54	0.87	EUROSTAT (2007)
	World average	OE	ND	ND	
	Sweden		ND	ND	
Oranges	Spain (largest trade surplus)	Citrus	8.40	0.43	EUROSTAT (2007)
	South Africa (extra country)	OE	ND	ND	
	Egypt (extra country)	OE	ND	ND	
	Greece (extra country)	Citrus	1.88	0.08	EUROSTAT (2007)
	World average	OE	ND	ND	
Papayas	Mexico (largest trade surplus)	OE	ND	ND	
	Thailand	OE	ND	ND	
	World average	OE	ND	ND	
Peach	Italy	Fruit trees	14.64	0.91	EUROSTAT (2007)
	Germany	Fruit trees	16.20	2.07	EUROSTAT (2007)
	Spain (largest trade surplus)	Fruit trees	2.76	0.18	EUROSTAT (2007)
	World average	OE	ND	ND	EUROSTAT (2007)
Pears	Belgium	Fruit trees	19.80	0.66	EUROSTAT (2007)
	The Netherlands	Fruit trees	16.78	0.53	EUROSTAT (2007)
	Argentina (largest exporter)	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden	Fruit	4.15	0.38	SBA (2018)

Pineapples	Costa Rica (largest trade surplus)	OE	ND	ND	
	Philippines (extra country)	OE	ND	ND	
	Mexico (extra country)	OE	ND	ND	
	World average	OE	ND	ND	
Plums and sloes	Denmark	Fruit trees	11.82	2.49	EUROSTAT (2007)
	Italy	Fruit trees	14.64	1.09	EUROSTAT (2007)
	The Netherlands	Fruit trees	16.78	0.93	EUROSTAT (2007)
	Germany	Fruit trees	16.20	1.76	EUROSTAT (2007)
	Spain (largest trade surplus)	Fruit trees	2.76	0.27	EUROSTAT (2007)
	Chile (extra country)	OE	ND	ND	
	South Africa (extra country)	OE	ND	ND	
	World average	OE	ND	ND	
Tangerines mandarins etc.	Morocco	OE	ND	ND	
	Spain (largest trade surplus)	Citrus	8.40	0.50	EUROSTAT (2007)
	China (extra country)	OE	ND	ND	
	Turkey (extra country)	OE	ND	ND	
	Pakistan (extra country)	OE	ND	ND	
	World average	OE	ND	ND	
Watermelon	Mexico (largest trade surplus)	OE	ND	ND	
	Spain	Fruit and vegetables total	8.38	0.18	EUROSTAT (2007)
	World average	OE	ND	ND	
Artichokes	France	Vegetables	7.82	1.66	EUROSTAT (2007)
	Italy	Vegetables	7.04	0.86	EUROSTAT (2007)
	Spain (largest trade surplus)	Vegetables	15.92	1.36	EUROSTAT (2007)
	World average	OE	ND	ND	
Asparagus	Italy	Vegetables	7.04	1.19	EUROSTAT (2007)
	The Netherlands	Vegetables	2.74	0.52	EUROSTAT (2007)
	Germany	Vegetables	2.16	0.45	EUROSTAT (2007)
	Mexico (largest trade surplus)	OE	ND	ND	
	Thailand (extra country)	OE	ND	ND	
	Hungary (extra country)	Vegetables	1.75	0.51	EUROSTAT (2007)
	World average	OE	ND	ND	
Avocados	Mexico (largest trade surplus)	OE	ND	ND	
	Peru (extra country)	OE	ND	ND	
	Chile (extra country)	OE	ND	ND	
	World average	OE	ND	ND	
Broccoli	France	Vegetables	7.82	0.54	EUROSTAT (2007)
	Italy	Vegetables	7.04	0.34	EUROSTAT (2007)
	The Netherlands	Vegetables	2.74	0.23	EUROSTAT (2007)

	Spain (largest trade surplus)	Vegetables	15.92	1.01	EUROSTAT (2007)
	World average	OE	ND	ND	
	Sweden	Vegetables	2.20	0.21	SBA (2018)
Cabbage	Spain	Vegetables	15.92	0.55	EUROSTAT (2007)
	Germany	Vegetables	2.16	0.04	EUROSTAT (2007)
	China (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden	Vegetables	2.20	0.06	SBA (2018)
Capsicums/peppers	The Netherlands	Vegetables	2.74	0.01	EUROSTAT (2007)
	Spain	Vegetables	15.92	0.32	EUROSTAT (2007)
	Mexico (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
Celery	The Netherlands		ND	ND	
	Spain		ND	ND	
	Germany		ND	ND	
	USA (assumption)		ND	ND	
	World average		ND	ND	
Cucumbers	The Netherlands	Vegetables	2.74	0.00	EUROSTAT (2007)
	Spain	Vegetables	15.92	0.22	EUROSTAT (2007)
	Mexico (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden	Vegetables	2.20	0.02	SBA (2018)
Eggplant	The Netherlands	Vegetables	2.74	0.01	EUROSTAT (2007)
	Spain (largest trade surplus)	Vegetables	15.92	0.30	EUROSTAT (2007)
	World average	OE	ND	ND	
Garlic	The Netherlands	Vegetables	2.74	0.00	EUROSTAT (2007)
	Spain	Vegetables	15.92	2.01	EUROSTAT (2007)
	China (largest trade surplus)	OE	ND	ND	
	Argentina (extra country)	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden		ND	ND	
Beans fresh (haricoverts)	Belgium	Vegetables	6.84	0.60	EUROSTAT (2007)
	The Netherlands	Vegetables	2.74	0.29	EUROSTAT (2007)
	Morocco (largest trade surplus)	OE	ND	ND	
	Kenya (extra country)	OE	ND	ND	
	Peru (extra country)	OE	ND	ND	
	World average	OE	ND	ND	
Ginger	China (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
Lettuce	Spain (largest trade surplus)	Vegetables	15.92	0.68	EUROSTAT (2007)
	Germany	Vegetables	2.16	0.10	EUROSTAT (2007)
	World average	OE	ND	ND	
	Sweden	Vegetables	2.20	0.13	SBA (2018)

Olives	Greece	Fruit and vegetables total	16.54	6.57	EUROSTAT (2007)
	Spain(largest trade surplus)	Fruit and vegetables total	8.38	3.73	EUROSTAT (2007)
	World average	OE	ND	ND	
Onions	Denmark	Vegetables	14.36	0.39	EUROSTAT (2007)
	India (largest trade surplus)	OE	ND	ND	
	The Netherlands	Vegetables	2.74	0.07	EUROSTAT (2007)
	Germany	Vegetables	2.16	0.05	EUROSTAT (2007)
	USA	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden	Onion	10.20	0.25	SBA (2018)
Pumpkins and squash	The Netherlands	Vegetables	2.74	0.05	EUROSTAT (2007)
	Spain	Vegetables	15.92	0.39	EUROSTAT (2007)
	Mexico (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden	Vegetables	2.20	0.00	SBA (2018)
Spinach	Spain (largest trade surplus)	Vegetables	15.92	1.06	EUROSTAT (2007)
	Italy	Vegetables	7.04	0.56	EUROSTAT (2007)
	World average	OE	ND	ND	
	Sweden	Vegetables	2.20	0.29	SBA (2018)
Tomatoes	The Netherlands	Vegetables	2.74	0.01	EUROSTAT (2007)
	Spain	Vegetables	15.92	0.23	EUROSTAT (2007)
	Mexico (largest trade surplus)	OE	ND	ND	
	World average	OE	ND	ND	
	Sweden	Vegetables	2.20	0.01	SBA (2018)
Cranberries	Finland		ND	ND	
	The Netherlands		ND	ND	
	Chile (largest trade surplus)		ND	ND	
	USA (extra country)		ND	ND	
	World average		ND	ND	
Blueberries	Poland		ND	ND	
	Spain		ND	ND	
	Morocco		ND	ND	
	World average		ND	ND	
	Sweden	Home-grown	2.44	1.17	SBA (2018)
Raspberries and other berries	Belgium		ND	ND	
	The Netherlands		ND	ND	
	Spain		ND	ND	
	Poland (largest trade surplus)		ND	ND	
	World average		ND	ND	
	Sweden	Home-grown	2.44	0.70	SBA (2018)
Strawberries	Belgium		ND	ND	
	The Netherlands		ND	ND	
	Spain (largest trade surplus)		ND	ND	
	World average		ND	ND	
	Poland		ND	ND	

	Sweden	2.59	0.40	SBA (2018)
Mushrooms	Poland	ND	ND	
	Lithuania	ND	ND	
	World average	ND	ND	

Appendix A8. Factors for calculating organic yield

Table A95. Factors for estimating organic yield from conventional yields, taken from De Ponti et al. (2012)

Product	**Factor**
Peas	85%
Pulses	88%
Soybeans	92%
Other pulses (used for peanuts, green beans)	91%
Barley	69%
Corn	89%
Oats	85%
Wheat	73%
Rice	94%
Rye	76%
Average cereals (used for millet, quinoa, sorghum)	79%
Carrot	89%
Potatoes	70%
Apples	69%
Other fruits (used for apricots, grapes, kiwi, melons, peach and watermelon, cranberries, blueberries, raspberries)	78%
Average fruits (used for bananas, cherries, dates, grape fruit, guava and mango, lemons and lime, oranges, papaya, pineapples, plums and mandarins)	72%
Other vegetables (used for artichokes, asparagus, broccoli, cabbage, peppers, cucumbers, eggplants, garlic, ginger, onions, pumpkins, spinach)	77%
Lettuce	86%
Tomatoes	81%
Strawberries	59%
Average for all crops (used for nuts, avocados, olives, mushrooms)	80%

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