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**Agroscope Reckenholz-Tänikon Research Station ART**

# Carbon & Water Footprint of Oranges and Strawberries

## A Literature Review

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# Abbreviations

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| ART | Agroscope Reckenholz-Tänikon Research Station ART |
| CF | Carbon Footprint |
| $CH_4$ | Methane |
| $CO_2$ | Carbon dioxide |
| $CO_2$-eq. | $CO_2$-equivalents |
| FAO | Food and Agriculture Organisation of the United Nations |
| FASS | Florida Agricultural Statistics Service |
| GHG | Greenhouse Gas |
| IP | Integrated production |
| LCA | Life Cycle Assessment |
| $N_2O$ | Nitrous oxide |
| OF | Organic farming |
| SAI Platform | Sustainable Agriculture Initiative Platform |
| USA | United States of America |
| VWC | Virtual Water Content |
| WF | Water Footprint |
| WGWA | Working Group on Water and Agriculture |

# Executive Summary

A literature review of existing publications and data on the carbon footprint (CF) and water footprint (WF) for oranges and strawberries with a focus on countries selected by the SAI Platform Working Group on Fruits has been performed. The selected countries were Brazil, China, Florida and Spain for oranges and China, Morocco and Poland for the strawberries. Only data for the agricultural production were of interest. As no or only little information is published for the CF in the selected countries for both products the SAI Platform Working Group on Fruits decided to consider also data from other countries and studies where not only the agricultural part of the production but also the whole life cycle was analysed.

A total of 35 sources have been evaluated for oranges and 31 sources for strawberries with respect to the CF. After an evaluation 26 sources for oranges and 23 sources for strawberries have been excluded from a further analysis. 9 sources for oranges and 7 sources for strawberries were analysed in depth with respect to the CF resp. the GHG emissions. In 4 sources the CF was calculated for the whole life cycle of orange juice production. To be able to compare these values with the ones that reported data on the agricultural phase of the production the values of the orange juices have been converted. Data on GHG emissions for oranges were found for Brazil, Italy and Spain and for strawberries for Spain, Japan and the United Kingdom.

The literature review showed that only a few publications report data on the CF of oranges for the agricultural production. Some data are documented for the whole production chain of orange juice. The agricultural production stage in these publications is either not specified at all or just reported as a general value. The analysis of the sources showed that the CF for oranges is between 0.08 to 0.33 kg $CO_2$-eq./kg oranges harvested. The reported values for Spain were higher than for Brazil and Italy (only one source). As the system boundaries are not always clear or they are not defined in a similar same way a comparison of the values is difficult. According to the evaluated sources, the key input factors leading to GHG emissions in the agricultural production seem to be associated with the fertiliser production and application but the GHG emissions also differ depending on the fertilisers and pesticides applied, the agricultural practices performed, the machinery and irrigation system used as well as on the production system. Diesel use in the context of irrigation and the country of origin respectively the production region seem to be important as well.

For the CF of strawberries the review showed that only little data on the CF is available from published literature. The CF of strawberries from the analysed sources varies from 0.27 to 3.99 kg $CO_2$-eq./kg strawberries. The lowest figures have been reported for Spain, higher ones for the UK and the highest for Japan, but the values are difficult to compare. Several production techniques are applied in the strawberry production (e.g. plastic tunnels, greenhouses, different growth media) and the key drivers for the GHG emissions seem to vary with the production system (e.g. growth media, protection, glasshouse, open field). The key input factors of the GHG emissions in the agricultural production seem to be the production and the waste transport and disposal of the polyethylene from the polytunnels (when used for the production, the growth medium and pesticides. The country of origin respectively the production region seems to matter as well.

Only one source provides data on the WF (i.e. virtual water content, VWC) of oranges and strawberries. The green and blue components are not documented separately. In the case of oranges the VWC is reported as a single value for the countries Brazil, China, Italy, Spain and the USA. It varies between 0.149 and 0.490 $m^3$/kg oranges. In the case of strawberries the VWC is reported for the countries China, Morocco, Poland, Japan, Spain and the United Kingdom. It is between 0.190 and 0.876 $m^3$/kg strawberries. Additional literature on irrigation that has been analysed shows that the water use may differ depending on soil and irrigation type, used growth media, protection system usedas well as the yield. Furthermore, the average VWC may vary significantly over time and space, especially for countries with a great spatial variation of climate (e.g. China, USA). The reported figures are 0.148-0.229 $m^3$/kg oranges, 3’520-6’000 $m^3$/ha orange plantation. For strawberries, 0.096-

0.299 $m^3$/kg and 1'000-5'200 $m^3$/ha were reported. It seems that the VWC does not or only insufficiently cover these aspects as the value is based on average climate data and only calculated for open systems. This fact might be especially important in the case of strawberries as in some countries a high percentage of strawberries is grown under covered systems.

# 1 Introduction

The presented project "Fruit Carbon & Water Footprint of Oranges and Strawberries" has been mandated and funded by the SAI Platform Working Group on Fruits. Its scope was to perform a literature review of existing publications and data on the carbon footprint (CF) and water footprint (WF) for oranges and strawberries with a focus on countries selected by the SAI Platform Working Group on Fruits, namely Brazil, China, Florida and Spain for oranges and China, Morocco and Poland for the strawberries. Only data for the agricultural production were of interest. Special focus was put on studies observing LCA principles. Data on the greenhouse gas (GHG) emissions were intended to be collected for the emissions $CO_2$, $N_2O$ and $CH_4$. A global picture of the carbon and water footprints of oranges and strawberries, the identification of influencing factors for these footprints as well as their relative importance were of interest.

A first evaluation of the available literature showed that no or only little information is published for the CF in the selected countries for both products. Therefore, the SAI Platform Working Group on Fruits decided to consider also data from other countries and studies where not only the agricultural part of the production but also the whole life cycle was analysed.

In chapter 2, the methodologies applied for the review on water use in agricultural production, the analysis of the producing countries and the literature review on the CF and WF of oranges and strawberries are described. A review of the methodology of water use in the agricultural production including the definition and calculation of the WF of a product respectively the virtual water content (VWC) of a product and a short description of other concepts to assess water use is reported in chapter 3. Chapter 4 contains a brief analysis of the producing countries of oranges and strawberries on the basis of statistics from the Food and Agricultural Organisation of the United Nations (FAO) and the Florida Agricultural Statistics Service (FASS) as well as some additional country specific information. The results of the literature review on the CF and WF of oranges respectively strawberries are presented and discussed in the chapters 5 respectively 6. The conclusions drawn from the results of the literature review are reported in chapter 7.

# 2 Methodology

## 2.1 Literature Review on Water Use

The assessment of water resources is a relatively new topic. Therefore a brief literature review on the state of the art to quantify the water use (e.g. water footprint) in agriculture has been performed. Scientific papers, reports, books, posters, and websites were reviewed. Information on relevant definitions, LCI inputs and outputs, impact pathways, impact characterisation, weighing and normalisation, and impact categories for the different methods were gathered. A special focus has been put on some of the established LCA methods and how they assess the use of water resources.

## 2.2 Analysis of the Producing Countries

Data on the area harvested, the production and yield from 2003 to 2007 have been analysed for strawberries and oranges by using FAO statistical data (2009). The aim was to quantify the worldwide production and to get an overview on the main producing countries and the ones selected by the SAI platform Working Group on Fruits (i.e. Brazil, China, Spain, and USA representing Florida for oranges and China, Morocco and Poland for strawberries). Data consistency has been checked by building mean values and some data sets have been excluded, because either data on the production or the area harvested were not reported for them. For the selected countries by the SAI platform a 20 years analysis (1988-2007) of the data has been performed in order to visualise general production trends.

In addition, data of the orange production, the bearing area[1] and yields have been analysed for Florida and the United States of America (USA) for the period 1987/88-2006/07. The aim was to see how much Florida contributed to the whole orange production of the USA as data for Florida are not documented in the FAO statistics. Data consistency has been checked by calculating mean values. In the statistics the data are reported per production period and not for one year (Florida Agricultural Statistics Service, 2009).

When considered as important for the present report, some country specific additional information on production systems from other publications has been integrated.

## 2.3 Carbon Footprint of Oranges and Strawberries

The literature review has been performed mainly on a web basis with keywords (e.g. carbon footprint, greenhouse gas emissions for oranges resp. strawberries). Official national websites, websites of universities, research institutes, NGO's and industries were browsed as well. In addition to that, a number of research institutes and researchers have been contacted (Appendices 9.2.5 and 9.2.6).

A total of 35 sources have been evaluated for oranges from which 26 have been excluded after a first and second, more detailed evaluation, for strawberries a total of 31 sources have been evaluated and 23 have been excluded. For the excluded sources refer to Appendices 9.2.3. and 9.2.4. The main reasons for this exclusion were that some sources provided information on GHG emissions but not explicitly for oranges or strawberries, some sources gave information that was based on a primary source already included in the present analysis (i.e. redundant information) and some sources only listed the data inventory without having calculated the emissions from the production.

[1] Bearing area: The area of fruit crops that have reached a commercially productive bearing age. This age varies by crop, by area, and by producer (Source: http://www.nass.usda.gov/Statistics_by_State/New_York /Publications/Agricultural_Chemical_Use/FruitChemuse/Terms.pdf).

9 sources for oranges (Appendix 9.2.1) and 7 sources for strawberries (Appendix 9.2.2) were analysed in depth with respect to the CF resp. the GHG emissions. Data on GHG emissions for oranges were found for Brazil, Italy and Spain. For strawberries the countries were Spain, Japan and the UK.

In 4 sources the CF was calculated for the whole life cycle of orange juice production. To be able to compare these values with the ones that reported data on the agricultural part of the production the values of the orange juices have been converted. The assumptions and calculation steps for these conversions are described in Chapters 5.1 and 5.2.

## 2.4 Water Footprint of Oranges and Strawberries

There are several methods and concepts to assess and quantify water use in the agricultural production (see section 3.2). To assure a consistent application in assessing water use within the SAI Platform, the Working Group on Fruits has decided to focus on the methodology proposed by the SAI Platform Working Group on Water and Agriculture (WGWA). According to a discussion paper from SAI Platform (2009) the WGWA is actually working on the water footprint methodology and its application. The literature review was performed with by web search and by contacting experts in different countries (see Appendices 9.2.5 and 9.2.6).

Only one source provides data on the virtual water content[2] (VWC) of oranges and strawberries (Chapagain & Hoekstra, 2004a, b). One other source with information on the VWC for fruits in China (Liu & Savenije, 2008) was excluded from further analysis as data had been estimated based on apples (Appendices 9.2.1and 9.2.2).

The VWC is reported as a single value for a certain country and product and is based on data from 1999 to 2001. Although the green and blue components were taken into account in the calculations by Chapagain & Hoekstra (2004a; 2004b) they are not documented separately. Data on the VWC with a distinction between the green and blue component will be published in approximately one year[3].

The VWC is given in $m^3$/kg of a certain product (Chapagain & Hoekstra, 2004a; 2004b). To put the single VWC values in a broader context and to be able to discuss them, these have been converted in $m^3$/ha by using data on the yields from Chapagain & Hoekstra (2004a; 2004b). In addition, some information on irrigation was gathered based on the same literature that was analysed for the carbon footprint and on information from contacted researchers.

[2] The water footprint of a product is the same as its virtual water content (see section 3.1.1).
[3] Personal communication A.Y. Hoekstra, Scientific Director, Water Footprint Network, 19.10.2009.

# 3 Review of Methodology of Water Use

The assessment of water use in agricultural production is becoming increasingly important. Different concepts to quantify water use in agricultural systems do exist. The SAI Platform Working Group on Fruits decided to focus on the concept of the water footprint (WF) of a product resp. the virtual water content (VWC) of a product (see section 2.4). In the following section, information on the definition of the WF resp. VWC and on the main points of its calculation is provided. Furthermore, some other concepts to quantify water use will be briefly outlined.

## 3.1 Water Footprint of a Product / Virtual Water Content of a Product

### 3.1.1 Definition

The water footprint (WF) of a product is the same as its virtual[4] water content (VWC). The VWC of a product is defined as the volume of freshwater that is required to produce a product, i.e. a commodity, good or service. It is measured at the place where the product is produced and given for a certain time period Chapagain & Hoekstra (2004a; 2004b). The VWC of a product is composed of the green, blue and grey component. For the agricultural products these components are defined as follows (WFN, 2009):

1. The green VWC of an agricultural product corresponds to the total volume of rainwater evaporated from the field and transpirated by the plants during the growing period of the crop.
2. The blue VWC of an agricultural product refers to volume of water abstracted from water bodies (surface water or groundwater) and evaporated during the production. It is the sum of the evaporation of irrigation water from the field and the evaporation of water from irrigation canals and artificial storage reservoirs.
3. The grey VWC of an agricultural product is the volume of water that is required to dilute pollutants emitted to the natural water system during the production process to such an extent that the quality of the ambient water remains beyond agreed water quality standards.

The definitions correspond to those used in the SAI Platform discussion paper on Water Footprint from the WGWA (SAI Platform, 2009).

### 3.1.2 Calculation of the Virtual Water Content of a Product

The reported VWC of a particular primary crop (e.g. oranges, strawberries) is calculated with data on the volume of water that is used for the production of the crop at farm level and the total volume of a crop that is produced per year in a country. The calculation of the total volume of water used to produce a particular crop is based on production, yield and "crop water requirement" data. The latter is used as an indicator of actual crop water use and refers to the evapotranspiration under optimal growth conditions i.e. adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield (Chapagain & Hoekstra, 2004a; 2004b). Therefore, actual crop water use is overestimated when a crop is grown under water shortage or if a grown crop tolerates water stress and is managed under water shortage (SAI Platform, 2009). On the contrary, irrigation losses and drainage water are excluded from the calculations of the VWC what leads to an underestimation of the water needed to grow certain crops (Chapagain & Hoekstra, 2004a; 2004b).

[4] Water is termed as „virtual" as most of the water used to produce the product is not contained in the final product (WFN, 2009).

Own calculations of the green and blue components would be possible by applying the method used in the book by Hoekstra & Chapagain (2008), but this was out of scope in the present project. The necessary data can be taken from the FAO tools CROPWAT, CLIMWAT and FAOSTAT[5].

## 3.2 Other Concepts to Assess Water Use in the Agricultural Production

In addition to the WF resp. VWC concept in the literature review 8 other methods to quantify water use were analysed. The Ecological Scarcity Method 2006 (Frischknecht *et al.*, 2009), ReCiPe 2008 (Goedkoop *et al.*, 2009) and EDIP 1997 (Wenzel *et al.*, 2000), Milà i Canals *et al.* (2009), Pfister *et al.* (2009) and Bayart *et al.* (submitted) are LCA methods in which water use is taken into account. Other approaches that are not based on LCA principles are the Global Water Tool (WBCSD, 2007) and the OECD Key Environmental Factors (OECD, 2004).

The concepts differ mainly in the required input data and their explanatory power. The assessment of water use with EDIP 1997 for example requires less data than with the method of (Bayart *et al.*, submitted) but provides also less information on the impacts.

The full report is given in Appendix 9.1.

[5] Personal communication A.Y. Hoekstra, Scientific Director, Water Footprint Network, 19.10.2009.

# 4 Analysis of the Producing Countries

The orange and strawberry production has been analysed. The main points of this analysis are outlined in the following section. For more detailed data on oranges refer to Appendix 9.3 and to Appendix 9.4 for strawberries.

## 4.1 Production of Oranges

The main producing country for the time period 2003 to 2007 was Brazil with 28.3 % of the world production followed by the USA (14.5 %) and Mexico (6.4 %), India (5.0 %), Spain (4.5 %) and China (4.1 %). The largest areas harvested were in Brazil, India and China and the highest yields were obtained in Turkey, the USA and Indonesia (FAO, 2009).

In **Brazil** about 70 % of the total orange production is delivered to frozen concentrated orange juice processors. Usually, the yields in Brazil are relatively low (20'000-25'000 kg per hectare). The main factors leading to low yields are wide spacing, inadequate tillage practices, applications of fertilisers and soil acidity correctors as well as the absence of a good pest management. In well managed and tightly spaced orchards yields of over 40'000 kg per ha can be produced (Coltro *et al.*, 2009).

For the time period 2003 to 2007 the mean yield in **China** amounted to about 7'500 kg/ha only (FAO, 2009). When comparing this with the information from Coltro *et al.* (2009) such a yield has to be considered as very low. According to Houjiu (2001), most citrus plantations in China are very small and this is one factor that explains these figures.

Data for the time period 2002/03 to 2006/07 show that the main producing state in the **USA** with about 80% of the total production and about 73 % of the total bearing area was Florida. The mean yield in Florida (38’700 kg/ha) was a little bit higher than in the USA (35’000 kg/ha) (Florida Agricultural Statistics Service, 2009).

**Spain** is also one of the main producing countries for oranges. A large proportion is produced in the region Comunidad Valenciana (Sanjuán *et al.*, 2005). The oranges produced in **Italy** are primarily for national consumption including industry uses (Beccali *et al.*, 2009).

## 4.2 Production of Strawberries

The main producer of strawberries is the **USA** with approximately 28 % of the total strawberry production in the world. They also have the 3rd largest area harvested and are ranked at number one in terms of yield in the world (50’200 kg/ha) (FAO, 2009).

The analysed FAO data for strawberries show a mean production of 11’650 resp. 7’764 metric tonnes per year in **China** for the periods 2003 to 2007 and 1988 to 2007 (FAO, 2009). The estimated production of fresh strawberries for the season 2009/2010 is 1.8 Million metric tonnes on an estimated cultivation acreage of 120’000 hectares (USDA Foreign Agricultural Service, 2009). The yield calculated with these estimates is 15’000 kg/ha. When comparing the data from these two sources a large difference is obvious. It is possible that China has rapidly expanded its production lately so that FAO data are not up to date anymore. Roudeillac (2007) assumes that the FAO only reports values from Taiwan and therefore a discrepancy in production data from different sources occurs. When analysing data from China (e.g. the VWC that is based on yield data from FAO statistics) this fact has to be considered. In China, about 70 to 80 % of the strawberries are grown in greenhouses and 20 to 30 % in open fields[6].

The production in **Morocco** is mainly located in the Northern part of the country, south of the city Larache. The strawberry seedlings that are planted are often imports from Spain or France (Bosc &

[6] Personal communication Dr. Yun-Tao Zhang, 10.10.2009.

Mention, 2008). The Moroccan production data seem to be rough estimations, especially when looking at the period from 1995 to 2000. There is was major increase in the production due to increasing yields; the harvested area remained constant. When using data from FAO for Morocco the uncertainty in data has to be taken into consideration.

**Poland** has remarkably low yields (3'300 kg/ha) compared to the other producing countries. It is ranked at the 70th position from the total of 76 countries (FAO, 2009). The rather low yields are a consequence of the cultivation on small farms where possibilities for irrigation during drought periods are lacking (Makowska *et al.*, 2005). Only a few percents of the strawberry plantations are irrigated[7]. A case study on integrated fruit production of strawberries report that the average yields are at least doubled when compared to conventional production systems (UNEP, 2002).

In **Spain** suppliers have concentrated their fresh strawberry production during the winter months. Most crops are grown in annual monoculture and in soil. Polyethylene clad tunnels are used for the protection of most crops where about 90 % are micro-tunnels and 10 % are macro-tunnels. There is an extensive use of soil fumigation. Spanish strawberry producers had an exemption from the ban on the usage of methyl bromide for soil fumigation until the end of 2007 but it is not clear if all stocks in Spain have been used yet. In the interpretation of results from studies, even from recent ones, this aspect should be considered (Williams *et al.*, 2008).

In the **United Kingdom** (UK) there are about 14 main production systems. Including subsystems there are in total 21 systems. The variations include the growth medium (soil, substrate, coir peat, raised bag, table bag), crop variety (June bearer, ever-bearer), planting time (spring planted, summer planted), years of cropping (one to three), polytunnel and the use of soil fumigation (fumigated or not fumigated). There is only little organic production (Williams *et al.*, 2008).

[7] Personal communication Waldemar Treder, Research Institute of Pomology and Floriculture, Poland, 30.09.2009.

# 5 Oranges

## 5.1 Carbon Footprint of Oranges

Data on the GHG emissions for orange production was found for Brazil, Italy and Spain. Two detailed studies from Spain report the GHG emissions for different production steps of the agricultural phase of orange production in Spain (Ribal *et al.*, in press; Sanjuán *et al.*, 2005), one publication calculated the emissions for Italian oranges and orange juices (Beccali *et al.*, 2009) and in four sources the emissions are quantified for Brazilian orange juice (Munasinghe *et al.*, 2009; PepsiCo UK & Ireland, 2008; Tesco, 2009; Tropicana, 2009). A mean value for the GHG emissions related to oranges imported to Sweden from different countries is published in Wallén *et al.* (2004). Kramer *et al.* (1999) gives a value for oranges consumed in the Netherlands. The evaluated sources are described in more detail in the following parts. Table 1 provides an overview on the CF from the different sources.

A detailed LCA of integrated orange production in Spain (Comunidad Valenciana) was performed by Sanjuán *et al.* (2005). Only the agricultural phase of the orange production was investigated. Eight different scenarios were taken into account. The analysis of the GHG emissions showed that the main emissions for all scenarios arise from the fertiliser production and from direct field emissions although the production of the manure applied is outside the system boundaries. The fertilisers applied differ with the irrigation system (i.e. other fertilisers are applied under drip than under gravity irrigation). The results showed that the fertilisers used under drip irrigation contributed more to the emissions than those applied under gravity irrigation. Fertiliser production has a higher impact in the drip irrigation system than in the gravity irrigation system, but the authors did not state the exact reason. However, drip irrigation implies higher water efficiency and lower nitrate leaching. The pesticide production contributes less to the GHG emissions in tillage scenarios than in non tillage scenarios but tillage systems entail more toxic herbicides and tillage practices also affect soil characteristics and fertility. The highest emissions from machinery and irrigation arouse if irrigation was a combination of groundwater and drip irrigation whereas gravity irrigation in combination with surface water use resulted in the lowest emissions, probably due to less fossil fuels used for irrigation. The diesel energy used in these systems seems to be the main driver for these scenarios. However, although surface water use implies lower GHG emissions, access to surface water is limited or even impossible for some farmers. The agricultural phase including the practices performed on the farm contributed to the same degree to the emissions in all scenarios. Some more detailed data published for one scenario show that 55 % of the total GHG emissions come from $CO_2$ emissions whereof 66 % are due to ammonium nitrate production. The $N_20$ emissions amount to 35 % of the total GHG emissions whereof more than 90 % result from the denitrification in the agricultural phase (Sanjuán *et al.*, 2005).

Ribal *et al.* (in press) investigated the orange production in Spain (Comunidad Valenciana) for integrated production (IP) and organic farming (OF). 24 different scenarios have been taken into account. The manure production was not included in the calculations. The results showed that in the IP mineral fertilisers had the highest impact. The $CO_2$ and $CH_4$ emissions contributed to a large extent to the total GHG emissions due to the production of chemical fertilisers. It is not stated in the paper from where the $CH_4$ emissions arise during the chemical fertiliser production. The agricultural practices contributed also much to the GHG emissions in consequence of the $N_20$ emissions from soil denitrification. The agricultural practices had the highest impacts in OF scenarios due to the emissions from manure spreading. However, the impact that arouse from the fertiliser production in IP scenarios was still higher than the one caused by manure application. The shredding of the pruning leftovers instead of the burning was also associated with lower emission in the OF. The application of herbicides did not have much influence on the GHG emission in both production systems (Ribal *et al.*, in press).

Beccali *et al.* (2009) performed a LCA study on the whole life cycle of natural and concentrated orange juices in Italy. The fertiliser, herbicide and pesticide production contributed about 38 % for natural juices and 30 % for concentrated juices to the total GHG emissions from the whole life cycle. The emissions associated with diesel use in the cultivation stage were about 10 % of the total emissions for natural juice and 8 % for concentrated juice (Beccali *et al.*, 2009). The emissions from the cultivation and crop stage are in total 0.10 kg $CO_2$-eq./kg oranges harvested whereof 40% arise from $CO_2$ emissions and 60% from $N_2O$ emissions[8].

Tesco (2009) analysed three natural juices and one concentrated orange juice from Brazil with respect to the CF. The CF is broken down into five lifecycle stages (production, distribution, store, use and end of life waste management) but no specific data are given for the agricultural phase (TESCO, 2009). The raw material production driven by inorganic fertilisers used by the supplier should be the main factor of the emissions (Carbon Trust, 2008)[9]. But is not stated in the publication what is included in the raw material production and no specific values are documented in this publication.

Munasinghe *et al.* (2009) published data for the production steps of Tesco orange juice from Brazil[10]. The raw material production there is reported as 28 % of the total life cycle CF but it is not specified if the raw material production only includes the agricultural part of the production or other production steps too. There is a contradiction when comparing the statement from the Carbon Trust (2008) that the main factor for the GHG emissions should be the raw material production when it only amounts to 28 % of the total CF. As no further information is documented in both publications, it is not possible to reconstruct this discrepancy, but it probably due to another definition of the raw material production.

PepsiCo UK & Ireland (2008) calculated the whole life cycle of the Tropicana Pure Premium orange juice. The CF for the whole life cycle is reported as 1.1 kg $CO_2$-eq./litre orange juice. From that value, 37 % stem from orange growing and juicing. Tropicana (2009) published more details on the CF of the Tropicana Pure Premium juices but reported another figure for the total CF (0.94 kg $CO_2$-eq./litre orange juice). 60 % of the total GHG emissions come from the juice production step, whereof 58 % are due to the fertiliser production and application (Tropicana, 2009). The values calculated for the Tropicana orange juices are based on data from Florida and were extrapolated to the Brazilian orange juice production[11].

Wallén *et al.* (2004) investigated the annual greenhouse gas emissions associated with food production and consumption in Sweden. It is not clear which countries had been included in the calculations and how the calculations have been performed in detail. The GHG emissions are given in $CO_2$-eq per kg of oranges consumed. The total value is 0.25 kg $CO_2$-eq./kg of oranges consumed. This figure includes the cultivation of oranges, their processing, transport and distribution to consumers in Sweden. Considering that post farm life cycle phases are included, the calculated value seems rather low compared to the other sources (refer to Table 1).

Kramer *et al.* (1999) have calculated the total emissions of $CO_2$, $N_2O$ and $CH_4$ from the purchase of oranges and the GHG emissions per household food consumption in the Netherlands (21.11 kg $CO_2$-eq. per household orange consumption). In addition to the agricultural emissions, emissions from other life cycle steps such as distribution are included in the total value, which makes it not comparable to the other figures analysed. Similarly to Wallén *et al.* (2004), it was not possible to disaggregate the results in order to estimate the CF per kg of oranges harvested.

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[8] Figures calculated on the basis of data on $CO_2$ and $N_2O$ emissions of the cultivation stage from Beccali *et al.* (2009) with the IPCC 2001 factors.
[9] The Carbon Trust labelled the Tesco orange juices with respect to their CF (Carbon Trust, 2008).
[10] Munasinghe *et al.* (2008) refer to 1 litre of Tesco fresh squeezed chilled orange juice. As the value of the CF is not specified in the publication, it is assumed that they refer to the Tesco pure orange juice (1 litre) with a total CF of 0.96 kg $CO_2$-eq./litres.
[11] Personal communication Mitch Willis, PepsiCo, member of the SAI Platform Working Group on Fruits, 08.10.2009.

A summary of the values on the CF is given in Table 1 and the value are visualised in Figure 1[12]. The comparison of the CF of oranges from the different sources shows that the values vary considerably from 0.08 to 0.33 kg $CO_2$-eq./kg oranges harvested. The comparison of the different countries analysed shows that in Spain the GHG emissions from the agricultural production are higher than in Brazil and Italy (only one figure). It seems that the CF is influenced by the producing country (i.e. the location where the oranges are produced). The figure shows also that the CF can vary within a producing country, too. The mean CF for organic farming in Spain for example is lower than the one from integrated production (Ribal *et al.*, in press).

However, only little convincing data to determine the CF of oranges are published. When analysing the values it has to be considered that the CF values were not calculated based on the same methodology and the system boundaries are different (refer to Table 2). Furthermore it is not clear enough where the production data comes from (e.g. statistical data, data from suppliers). A direct comparison of the values is therefore complicated. Furthermore, it has to be considered that the values have been recalculated based on different assumptions in order to make them comparable (see Table 1). Due to these differences and uncertainties, the explanatory power of the values and a deeper interpretation is limited.

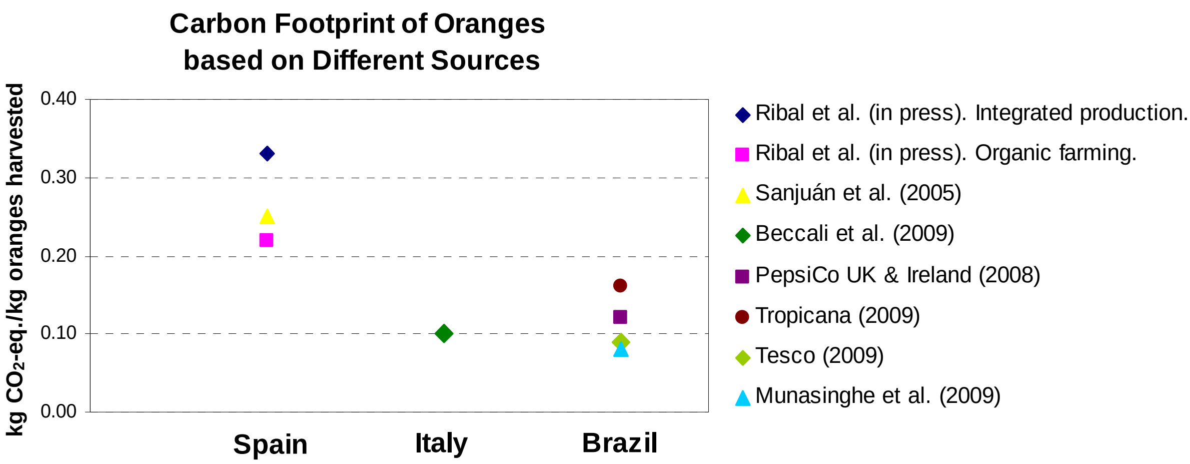


**Figure 1: Carbon footprint of oranges from different sources based on the values listed in Table 1.**

[12] The data from Wallen *et al.* (2004) and Kramer *et al.* (1999) have not been included as they are not comparable to the other values.

**Table 1: Total carbon footprint respectively production carbon footprint for oranges from different sources. Values in italics have been calculated on the basis of the published figures. For detailed information on the system boundaries and the methodology used to calculate the CF refer to Table 2.**

| **Source** | **Producing Country** | **Product** | **Carbon Footprint (CF)** | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Total** | | | | **Agricultural Production** | |
| | | | kg $CO_2$-eq. per | | | | kg $CO_2$-eq. per | in % of the total natural juice in litres |
| | | | litre natural orange juice | litre concentrated orange juice | kg natural orange juice | kg concentrated orange juice | kg oranges harvested | |
| Ribal *et al.* (in press) | Spain | Oranges from integrated production | | | | | *0.33*[a] | |
| Ribal *et al.* (in press) | Spain | Oranges from organic farming | | | | | *0.22*[a] | |
| Sanjuán *et al.* (2005) | Spain | Oranges from integrated production | | | | | *0.25*[a] | |
| Beccali *et al.* (2009) | Italy | Oranges | | | 1.00 | 6.00 | *0.10*[b] | |
| PepsiCo UK & Ireland (2008) | Brazil | Tropicana orange juice | 1.10 | | *1.05*[c] | | *0.12* | 37[d] |
| Tropicana (2009) | Brazil[e] | Tropicana Pure Premium orange juice | 0.94 | | *0.90*[c] | | *0.16* | 60[f] |
| Tesco (2009) | Brazil | 3 natural and 1 concentrated orange juice | *1.09*[g] | *1.04* | *1.04*[c] | *0.83*[h] | *0.09* | *28*[i] |
| Munasinghe *et al.* (2009) | Brazil | Tesco freshly squeezed chilled orange juice | *0.96*[j] | | *0.92*[c] | | *0.08* | *28*[k] |

[a] Mean value of the total CF from all scenarios calculated with help of detailed data received from Neus Sanjuán (personal communication, 26.10.2009).
[b] The CF has been calculated by the authors of the present report with the published data by Beccali *et al.* (2009) on the $CO_2$ and $N_2O$ emissions from the cultivation stage with the IPCC 2001 factors ($CO_2$ -factor = 1, $N_2O$-factor = 296).
[c] The value has been calculated with the following assumptions: 1. Specific gravity of natural orange juice (20°) = 1.047 kg/l (Source: Sandhu, K.S. & Minhas, K.S., 2007. Oranges and Citrus Juices. In: Hui, Y.H., Handbook of Fruits and Fruit Processing, 1 ed, 309-358. Blackwell Publishing.) 2. 0.3 kg natural orange juice corresponds to 1 kg oranges harvested (calculated with inventory data published by Beccali *et al.* (2009)).
[d] The value includes growing and juicing i.e. not only the agricultural part of the production. The CF seems to have been estimated for orange juice consumed in the UK.
[e] Personal communication Mitch Willis, PepsiCo, member of the SAI Platform Working Group on Fruits, 08.10.2009: The values calculated for the Tropicana orange juices are based on data from Florida and were extrapolated to the Brazilian orange juice production.
[f] The value includes fertiliser production and application, natural gas, electricity and transportation as the agricultural production is not reported separately. 58 % of the production value are from fertiliser production and application. It is not stated in which country the juice is consumed.
[g] Mean value of the CF from all natural juices reported in the source.
[h] The value has been calculated with the following assumptions: 1. Specific gravity of concentrated blood orange juice = 1.25 kg/l (Source: http://obiolla.com/boj50.aspx) 2. 0.03 kg concentrated orange juice corresponds to 1 kg oranges harvested (calculated with inventory data published by Beccali *et al.* (2009)).
[i] The total CF for natural juice in litres is the mean value of the CF of 3 products (pure squeezed orange juice; pure orange juice, 1 litre; pure orange juice,3*200 millilitres). The percentage for the production is published for the whole production stage (range 88 to 93 %) but not for the agricultural part of the production. As Munasinghe *et al*. (2009) refer in their publication to orange juice from Tesco (2009), it is assumed by the authors of the present report that the value stated in Munasinghe *et al.* (2009) for the raw material production approximates the agricultural part of the production for the Tesco orange juices. The value refers to natural juices.
[j] To calculate the CF for the raw material production the value for the total CF used in the present report was taken for the pure orange juice (1 litre) from Tesco (2009).
[k] The report only documents the percentages of the different life cycle stages of the total CF. Raw material production is reported as 28 % of the total CF across the life cycle. It is not stated what exactly is included in the raw material production, so that it is assumed that this value approximates the agricultural part of the production.

**Table 2: Information on the system boundaries and the methodology used to calculate the CF for oranges.**

| **Source** | **Producing Country** | **Product** | **Methodology** | **System boundary** |
|---|---|---|---|---|
| Ribal *et al.* (in press) | Spain | Oranges from integrated production | LCA (CML 2001) | Integrated agriculture. Agricultural part of the production on a plantation of less than 4 ha (representative case for actual plantations in the Comunidad Valenciana, Spain) where 24 scenarios (including organic farming, see below) have been analysed. Fertiliser and pesticide production, machinery and irrigation and agricultural practices are included. Manure production, the transport of fertilisers and pesticides and the fabrication and maintenance were not included in the study. |
| Ribal *et al.* (in press) | Spain | Oranges from organic farming | LCA (CML 2001) | Organic farming. Agricultural part of the production on a plantation of less than 4 ha (representative case for actual plantations in the Comunidad Valenciana, Spain) where 24 scenarios (including integrated farming, see above) have been analysed. Fertiliser and pesticide production, machinery and irrigation and agricultural practices are included. Manure production, the transport of fertilisers and pesticides and the fabrication and maintenance were not included in the study. |
| Sanjuán *et al.* (2005) | Spain | Oranges from integrated production | LCA (WMO method) | Integrated agricultural part of the production in the Comunidad Valenciana, Spain, including fertiliser and pesticide production, machinery and irrigation and agricultural practices. Manure production, the transport of fertilisers and pesticides and the construction and maintenance were not included. |
| Beccali *et al.* (2009) | Italy | Oranges | IPCC 2001 ($GWP_{100}$) | 1. Agricultural part (cultivation and crop) in Sicily, Italy for the year 2005. The use of fertilisers, herbicides and pesticides, fuel (diesel) and irrigation water as well as production and transportation of raw materials and fuels are included.<br>2. The whole life cycle of natural/concentrated juice production in Sicily, Italy for the year 2005 including agricultural production (cultivation and crop), production and transport of raw materials and fuels, manufacturing process, packing process as well as transport of the final product to distribution firms. The construction of facilities and equipment, the market phase, use and disposal of organic residues and packaging are not included. |
| PepsiCo UK & Ireland (2008) | Brazil | Tropicana orange juice | LCA (ISO 14040) | The whole life cycle including orange growing and juicing in Brazil, cross-atlantic shipping, bottling, distribution, supermarket refrigeration and packing supply chain. More details on the system boundaries and possible excluded in- or outputs are not published. |
| Tropicana (2009) | Brazil | Tropicana Pure Premium orange juice | LCA (calculation method not specified) | Full life cycle analysis including growing and squeezing, manufacturing energy use, the distances or raw materials and packing transport, transport of the final product from the factories to the supermarkets. More details on the system boundaries and possible excluded inputs or outputs are not published. |
| Tesco (2009) | Brazil | 3 natural and 1 concen-trated orange juice | PAS2050 (draft version) | Full life cycle analysis including orange juice production, distribution, store, use and end of life waste management. More details on the system boundaries and possible excluded inputs or outputs are not published. |
| Munasinghe *et al.* (2009) | Brazil | Tesco freshly squeezed chilled orange juice | PAS 2050 (version not specified). | As they refer to Tesco orange juice it is assumed that the system boundaries are the same as in Tesco (2009). |

## 5.2 Water Footprint of Oranges

As described in section 2.4, the WF respectively the VWC of oranges is specified only in one source (Chapagain & Hoekstra, 2004a, b). It is reported as one single value without a subdivision into a green and blue component what makes a discussion and interpretation of the values difficult. To put these values in a broader context, the VWC given in $m^3$/kg oranges has been converted in $m^3$/ha with help of data on the yields from Chapagain & Hoekstra (2004a; 2004b). Five additional sources were analysed in terms of water use for the agricultural production of oranges. The VWC of oranges and the yields for the countries Brazil, China, Spain, USA, and Italy are listed in Table 3 and the values for the irrigation as well as the corresponding yields are stated in Table 4.

As showed in Table 3 and Figure 2, China has the VWC per kg oranges followed by Spain, Italy and Brazil. Oranges produced in the USA have the lowest VWC per kg oranges. When comparing the VWC in $m^3$/ha for the same countries, oranges produced in Brazil and Spain have the highest VWC followed by Italy, China and the USA (refer to Table 4 and Figure 3). A low VWC per kg oranges is generally associated with higher yields. Another observation is that nearly the same amount of water is used per hectare to produce oranges in the USA and in China (approximately 5'000 $m^3$/ha) but the VWC $m^3$/kg oranges is lower in the USA due to a higher yield. It suggests that the production in the USA is more efficient.

Data on irrigation from Spain from Ribal *et al.* (in press)[13] show that the water use might also differ depending on the irrigation system applied (i.e. drip or gravity irrigation) and the producing system (IP and OF). For both production systems the total water used per hectare is lower under drip than under gravity irrigation. The irrigation water use per hectare under gravity irrigation in the OF is lower than in the IP. According to Ribal *et al.* (in press) the content of organic matter is higher in the soils used for the OF. Therefore, the water retention capacity is higher and water use is lower per ha than in the IP. Due to lower yields in the OF, the water use per kg orange is higher than in the IP. This shows that depending on the irrigation system and the soil type the water needed for irrigation can differ to some extent. Data on irrigation for Brazil based on Coltro *et al.* (2009) and on a personal communication[14] show that the water use for irrigation per hectare differs between the sources. It is not possible to determine the reasons for this difference directly from the sources. The difference might arise from climatic factors as well as other factors (e.g. soils, different producing regions).

All values from irrigation are lower than the VWC for the corresponding countries. This seems to be a logical consequence as in the VWC not only irrigation water but also rainwater is included. The data on irrigation show that several factors might influence the actual water use at a specific site or region to produce oranges. It is obvious that the VWC calculated as single value for a whole cannot represent these differences sufficiently. The average VWC for example may vary significantly over time and space, especially for countries with a great spatial variation of climate (e.g. China, USA). This fact is not accounted in the VWC as the calculations of it are based on average climate (Chapagain & Orr, 2009).

[13] The values for the IP are the same as listed in Sanjuán *et al*. (2005).
[14] Personal communication Dr. Dirceu Mattos Jr., Sylvio Moreira Citrus Research Center, Brazil, 30.09.2009.

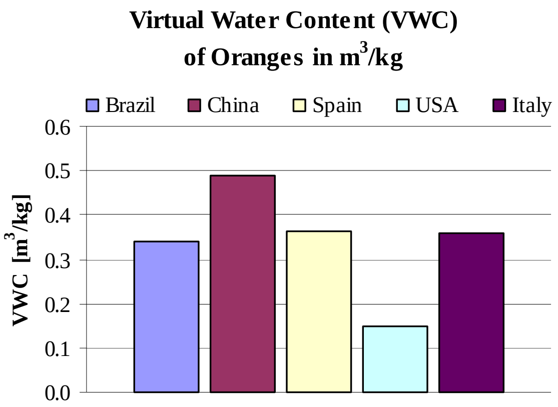


**Figure 2: Virtual water content of oranges in m$^3$/kg for selected countries. Source: Chapagain & Hoekstra (2004a; 2004b).**

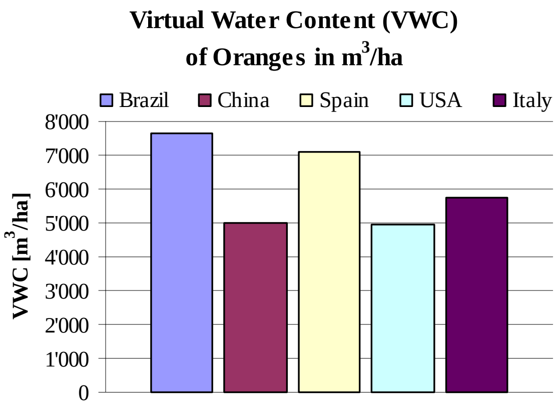


**Figure 3: Virtual water content of oranges in m$^3$/ha for selected countries. Source: Chapagain & Hoekstra (2004a; 2004b). (Converted data, see section 2.4).**

**Table 3: Yield and virtual water content (VWC) of oranges for selected countries. Source: Chapagain & Hoekstra (2004a; 2004b). The data in italics have been converted (see section 2.4).**

| Country | Yield [kg/ha] | VWC [m$^3$/kg] | VWC [m$^3$/ha] |
|---|---|---|---|
| Brazil | 22'329 | 0.342 | *7'637* |
| China | 10'251 | 0.490 | *5'023* |
| Spain | 19'653 | 0.362 | *7'114* |
| USA | 33'326 | 0.149 | *4'966* |
| Italy | 16'006 | 0.359 | *5'746* |

**Table 4: Data on yield and irrigation water use in orange production from selected sources. Values in italics have been calculated.**

| Source | Country | Yield [kg/ha] | Irrigation [m$^3$/kg] | Irrigation [m$^3$/ha] | Remarks |
|---|---|---|---|---|---|
| Coltro *et al.* (2005) | Brazil | 30'500 | *0.176* | 5'368 | Data based on the weighted average drip and gravity irrigation. |
| Direceu Mattos, personal communi-cation, 30.09.2009 | Brazil | *21'954*[a] | *0.148* | *3'250* | The irrigation value is based on a mean irrigation 325 mm/year stated by D. Mattos. |
| Beccali *et al.* (2009) | Italy | 25'000 | *0.168* | 4'200 | Direct consumption of irrigation water. |
| Ribal *et a*l. (in press) | Spain | 30'000 | *0.200* | 6'000 | Integrated production, gravity irrigation |
| | | 30'000 | *0.167* | 5'000 | Integrated production, drip irrigation |
| | | 24'000 | *0.229* | 5'500 | Organic farming, gravity irrigation |
| | | 24'000 | *0.208* | 5'000 | Organic farming, drip irrigation |

[a] The mean yield was calculated with FAO data from 2003-2007 (see Appendix 9.3).

# 6 Strawberries

## 6.1 Carbon Footprint of Strawberries

Publications on the GHG emissions for strawberry production were found for Japan, Spain and the UK. Detailed data on the emissions associated with the agricultural part of strawberry production for Spain are reported in two publications (REWE Group, 2009; Williams *et al.*, 2008), in one further source the emissions are documented for the whole life cycle but not analysed in detail with respect to the agricultural part (The Co-operative Group, 2008). Four publications report the CF for the UK (Lillywhite, 2008; The Co-operative Group, 2008; University of Hertfordshire, 2005; Williams *et al.*, 2008) and one for Japan (Yoshikawa *et al.*, 2008).

The REWE Group (2009) investigated the whole life cycle of the strawberry production in Spain. The total emissions amount to 0.88 kg $CO_2$-eq./kg strawberry punnet including all production steps, distribution, shopping, product usage and waste disposal. The whole production stage amounts to approximately 41 % of the total emission; this figure includes farm activity emissions as well as emissions from the polyethylene package production and transport, the energy use in the packhouse and the transport from the farm to the packhouse. For the relevant emissions from the agricultural production, data are documented for the raw material production (cultivation and transport of seedlings), energy use on the farm, fertilisers (subdivided into N-, P- and K-fertilisers), pesticides (subdivided into insecticides, fungicides and herbicides), the polytunnel and plastic mulch production and the polyethylene waste transport and disposal. The main drivers for the GHG emission in the agricultural production are the polytunnel and plastic mulch production (46 %) as well as pesticides and polyethylene waste transport and disposal (both 23 %) and fertilisers (6 %). The N-fertilisers contribute 66 % to the total fertiliser emissions, the P- and K-fertilisers 17 resp. 18 %. As for the pesticides, the 86 % of the emissions are fungicides, 12 % from herbicides and 2 % from insecticides. In the production stage one uncertainty results from the variability of the diesel use on the farm that is depending on the agricultural production method and the extraction of well water for irrigation.

Williams *et al*. (2008) performed a comparative LCA study of strawberry production in the UK and in Spain. The GHG emissions for the agricultural phase of the production were higher in the UK than in Spain (0.85 kg resp. 0.35 $CO_2$-eq./kg). According to Williams *et al*. (2008) it was difficult to obtain actual data on pesticide use for Spain. Therefore, the pesticides were assumed to be as the UK average. Furthermore, it was assumed that methyl bromide is no longer applied as a soil fumigant in the Spanish production (refer to section 4.22.2). If it is still applied the values for the GHG emission would be about 10% higher than the reported values. Both facts (i.e. uncertainties from the use of pesticides and methyl bromide) have to be taken into account when using the data for further analysis.

Lillywhite (2008) has calculated the environmental footprint of several crops produced in the UK. Data was based on official survey data and standard texts on farm management. The boundary is the farm gate but includes energy required to store, dry and cool the crops. The production of strawberries amounts to 1.2 kg $CO_2$-eq./kg strawberries. The general analysis of the results for several crops shows that $CO_2$ is emitted at almost every farming stage but that $CO_2$ emissions from nitrogen fertilisers and from glasshouse and polytunnel production are the two dominating factors. The $N_2O$ emissions are dominantly associated with the application of nitrogen fertilisers, tillage of agricultural land and emissions from manure. Again, this statement refers to all crops that were analysed in the study and not only for strawberry production.

Another detailed analysis of the strawberry production in the UK was performed by the University of Hertfordshire (2005). 14 different production systems and 6 additional sub-systems where identified. The differences in the systems are among others the use of soil fumigation, protection with polytunnels, organic production and whether soil or other media are used to grow the strawberries. A very detailed analysis of the different systems including the GHG emissions was performed, but the results that are reported are difficult to reconstruct (e.g. the values are not documented for all scenarios and it is not clear enough for which systems respectively subsystems the emissions have been calculated). That is why only selected results on the GHG emissions are stated in the present report. The emissions vary between the analysed production systems. The GHG emissions per kg strawberries were lower within coir (coconut husk) grown crops than in some of the soil grown systems as a result of higher yields in coir systems, but the coir systems had the highest GHG emissions per hectare. Coir tends to buffer nitrogen preventing its availability to the plant. Therefore, more nitrate fertilisers have to be applied in coir systems.

The Co-operative group (2008) calculated the GHG emissions for the whole life cycle of strawberry production in the UK (2 varieties) and in Spain (1 variety) with a draft version of PAS2050. In the case of strawberries from the UK the emissions associated with the cultivation of "Ava" strawberries where the growth media were peat bags are reported as 64 % of the total emissions. The main driver for the emissions was the use of the peat bags as a growth medium. Data from the UK on "Elsanta" strawberries that were grown in the soil showed that the GHG emissions from cultivation were only 46 % of the total emissions. The emissions of the latter were primarily driven by the use of agrochemicals and not by the growth medium. The emissions from the cultivation of the Spanish strawberries only amounted to 31 % of the total emissions i.e. the CF for the agricultural part of strawberry production is lower in Spain than in the UK.

Yoshikawa *et al.* (2008) documented the GHG emissions from the strawberry production in greenhouses in Japan. The largest contribution to the emissions are from fuel, electricity and clean water (75.9 %) followed by fertilisers (6.3 %) and machines and equipment (5.3 %)[15]. They conclude that the $CO_2$ emissions from crude oil combustion in greenhouses are the main driver of the GHG emissions for the investigated system.

Kramer *et al.* (1999) calculated the total emissions of $CO_2$, $N_2O$ and $CH_4$ from the purchase of strawberries and the GHG emissions per household food consumption in the Netherlands (2.1 kg $CO_2$-eq. per household orange consumption). Emissions from other life cycle steps than only the agricultural part of the production (e.g. distribution) are included in the total value. That is why these values are not comparable to the other GHG emissions documented in the present report.

The summary of the values from the analysed sources shows that the CF for the different countries analysed vary from 0.27 to 3.99 kg $CO_2$-eq./kg strawberries (refer to Table 5 and Figure 4)[16]. There is a higher variation in the values for the strawberry production in the UK than in Spain. As described in section 2.2 the producing system in Spain is more uniform (mainly in soil and protected) whereas in the UK there is a greater variety of systems to produce strawberries. This might be one reason for the differences mentioned above. By trend the CF of strawberries produced in the UK seems to be higher than for Spanish strawberries. But as only few data are available from literature it is difficult to further analyse the geographical relevance of the CF. The CF of Japanese strawberries is much higher than for both other countries. This might arise from the fact that this CF was calculated for greenhouse production.

It has to be considered that the calculations of the CF in the reported sources were performed with different methodologies, the system boundaries were not defined in a similar way and different producing systems were analysed (refer to Table 6). Additionally, some values have been recalculated (refer to Table 5). Therefore, a direct comparison and a deeper analysis of these values are very difficult.

[15] Personal communication Naoki Yoshikawa, 28.10.2009 and 29.10.2009.
[16] The data from Kramer *et al.* (1999) have not been included as they are not comparable to the other values.

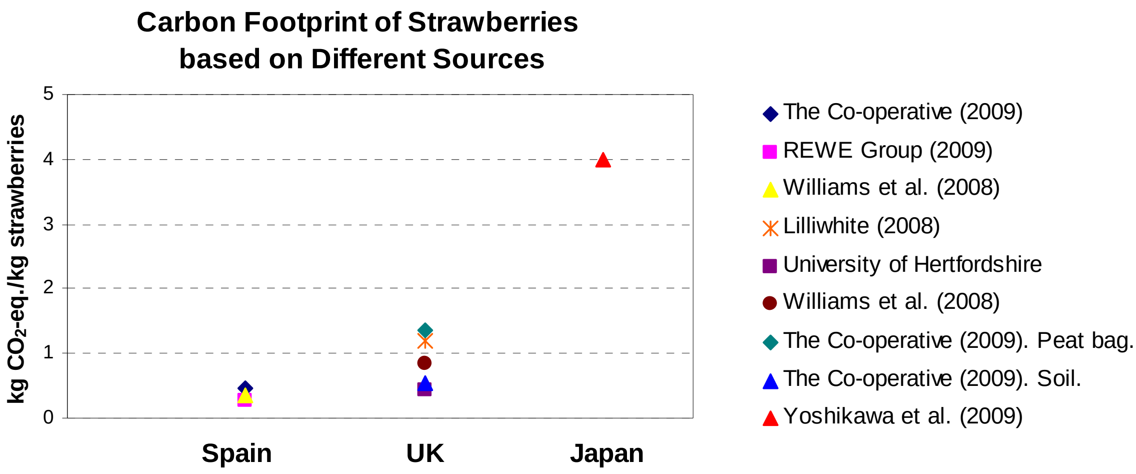


**Figure 4: Carbon footprint of strawberries from Spain, the UK and Japan based on different sources.**

**Table 5: Total carbon footprint respectively production carbon footprint for strawberries from different sources. Values in italics have been calculated. For detailed information on the system boundaries and the methodology used to calculate the CF refer to Table 6.**

| **Source** | **Producing Country** | **Product** | **Carbon Footprint** | | | |
|---|---|---|---|---|---|---|
| | | | **Total** | | **Production** | |
| | | | kg CO2-eq. per strawberry punnet | kg CO2-eq./kg strawberries | kg CO2-eq./kg strawberries | in % of the total |
| The Co-operative (2009) | Spain | Strawberries | 1.50 | | *0.47* | 31[a] |
| REWE Group (2009) | Spain | Strawberries | 0.88 | | *0.27*[b] | *30* |
| Williams et al. (2008) | Spain | Strawberries | | 0.91 | 0.35[c] | *38* |
| Lillywhite (2008) | UK | Strawberries | | | 1.20[d] | |
| University of Hertfordshire (2005) | UK | Strawberries | | | 0.44[e] | |
| Williams et al. (2008) | UK | Strawberries | | 0.99 | 0.85[c] | *86* |
| The Co-operative (2009) | UK | Strawberries (Growth medium: peat bag) | 2.13 | | *1.36*[a] | 64 |
| The Co-operative (2009) | UK | Strawberries (Growth medium: soil) | 1.18 | | *0.54*[a] | 46 |
| Yoshikawa et al. (2009) | Japan | Strawberries | | | 3.99[f] | |

[a] The value includes only the cultivation stage.
[b] The production CF includes the relevant emissions from the agricultural production the raw material production (cultivation and transport of seedlings), energy use on the farm, fertilisers (subdivided into N-, P- and K-fertilisers), pesticides (subdivided into insecticides, fungicides and herbicides), the polytunnel and plastic mulch production and the polyethylene waste transport and disposal.
[c] The value includes fertilisers, cultivations, containers, polytunnels etc. (personal communication Adrian Williams, 29.10.2009)
[d] The value includes the energy required to store, dry and cool the strawberries.
[e] Mean value calculated by the authors of the present report with data on the GHG emissions from 8 different production systems with reference to first year outputs of strawberries all scenarios.
[f] The production CF includes seeds, fertilisers, chemicals, other materials, fuel, electricity and clean water machines as well as equipments buildings and horticultural facilities, irrigation, $NO_2$ -fertiliser, $NO_2$- and $CH_4$-fuel combustion (personal communication Naoki Yoshikawa, 28.10.2009).

**Table 6: Information on the system boundaries and the methodology used to calculate the CF for strawberries.**

| Source | Producing Country | Product | Methodology | System boundary |
|---|---|---|---|---|
| The Co-operative (2009) | Spain | Strawberries | PAS2050 (draft version) | Full life cycle analysis including cultivation and other life cycle stages for Sabrosa strawberries produced in Spain and sold in Co-operative stores. More details on the system boundaries and possible excluded in- or outputs are not published. Data refer to 1 kg strawberry punnet. |
| REWE Group (2009) | Spain | Strawberries | LCA | Full life cycle analysis including raw material, production, distribution, consumer shopping, product usage and waste disposal strawberries produced in Spain and sold in Germany. More details on the system boundaries and possible excluded inputs or outputs are not published. Data refer to 1 kg strawberry punnet. |
| Williams et al. (2008) | Spain | Strawberries | LCA | Full life cycle analysis from the production in Spain to the delivery to the regional distribution centre in the UK. Methyl bromide use is not included. It is not clear what production systems have been analysed and included to the system. Further details on the system boundaries and possible excluded inputs or outputs are not published. |
| Lillywhite (2008) | UK | Strawberries | Environmental footprint | Farm gate including energy required to store, dry and cool the strawberries. All transport and point of sale packing is excluded. The analysis concentrated on CO2, N2O and CH4. Further details on the system boundaries and possible excluded in- or outputs are not published. |
| University of Hertfordshire (2005) | UK | Strawberries | LCA (calculation method not specified) | Life cycle analysis of the production in the UK. 14 production systems with six additional subsystems were analysed. The system differed in the use of soil fumigation, protection with polytunnels, and organic production and whether soil or media is used to grow the strawberries. |
| Williams et al. (2008) | UK | Strawberries | LCA | Full life cycle analysis from the production in the UK to the delivery to the regional distribution centre in the UK. Methyl bromide use is not included. It is not clear what production systems have been analysed and included to the system. |
| The Co-operative (2009) | UK | Strawberries (Growth medium: peat bag) | PAS2050 (draft version) | Full life cycle analysis including cultivation and other life cycle stages for Ava strawberries produced in Scotland and sold in Co-operative stores. The growth media are peat bags. More details on the system boundaries and possible excluded in- or outputs are not published. Data refer to 1 kg punnet of strawberries. |
| The Co-operative (2009) | UK | Strawberries (Growth medium: soil) | PAS2050 (draft version) | Full life cycle analysis including cultivation and other life cycle stages for Elsanta strawberries produced in Scotland and sold in Co-operative stores. The growth medium is soil. More details on the system boundaries and possible excluded in- or outputs are not published. Data refer to 1 kg punnet of strawberries. |
| Yoshikawa et al. (2009) | Japan | Strawberries | Process-based hybrid LCA | Full life cycle analysis including agricultural production in the greenhouse, shipment, transportation, retailing, cooking in the household, management of solid waste from agriculture, distribution and household. Food processing, cooking and waste water treatment is not included. The GHG emissions are based $CO_2$, $N_2O$ and $CH_4$ emissions. |

## 6.2 Water Footprint of Strawberries

The WF respectively the VWC of strawberries is only specified in Chapagain & Hoekstra (2004a; Chapagain & Hoekstra, 2004b) and reported as a single value. The green and blue components are not documented in that source. A discussion and interpretation of this single value is difficult. That is why the given VWC in $m^3$/kg strawberries has been converted in $m^3$/ha on the basis of yield data from Chapagain & Hoekstra (2004a; Chapagain & Hoekstra, 2004b). Furthermore, five sources were analysed with respect to the amount of water used for the irrigation in the strawberry production to be able to discuss some particularities in a more detailed manner. The VWC of strawberries and the yields for the countries China, Morocco, Poland, Japan, Spain and the UK are listed in Table 7 and the data on irrigation in Table 8.

Poland has the highest VWC in $m^3$/kg strawberries followed by China, the UK, Morocco and Spain. The lowest VWC is reported for Japan (see also Figure 5). Similarly to oranges (chapter 5.2), higher yields are associated with a lower VWC per kg strawberries. The comparison of the VWC per hectare for the same countries shows that strawberries produced in Morocco and Spain have the highest VWC followed by Japan, China, Poland and the UK (see also Figure 6). The VWC per kg strawberries in Poland is more than three times higher than for example in the UK although the VWC per hectare is approximately in the same range for both countries (2’730 $m^3$/ha for Poland, 2’308 $m^3$/ha for the UK). This is probably mostly connected with the low yields in the Polish strawberry production compared to the UK. The low yields in Poland have already been mentioned in chapter 2.2.

The VWC that is reported in Chapagain & Hoekstra (2004a; 2004b) is higher than the data reported for irrigation. This is a comprehensible fact because as already stated in Chapter 3.1.2, the VWC includes both blue and green water (i.e. rainwater and irrigation water).

Based on an estimation of the water use from sprinkler and drip irrigation[17] the total water use for irrigation in $m^3$/kg strawberries in Poland is much lower than the reported VWC. Both sources that specify irrigation water use in Spain report approximately the same values (REWE Group, 2009; Williams *et al.*, 2008). This can be attributed to the fact that both studies were performed in approximately the same production region with similar climatic conditions.

According to Williams *et al.* (2008) larger amounts of irrigation water are used in Spain compared to the UK and therefore the eutrophication is higher in Spain as well if there is an excess in water use. In the long term, this fact is associated with a higher energy use for water delivery as aquifers have become more and more polluted and the water has to be desalinated. In the VWC calculated by Chapagain & Hoekstra (2004a; 2004b) the grey component (i.e. polluted water) is not quantified and the described effect is therefore not accounted.

Data published by the University of Hertfordshire (2005) on the strawberry production in the UK show that water use for irrigation varies with the production system. Furthermore, it is shown that irrigation quantities may differ depending on the growth media used (e.g. coir has higher water use per ha than peat). Another factor that influences water use is if the strawberries are grown under protected or unprotected conditions. According to Chapagain & Orr (2009), the production under protected systems is not covered by the VWC as it is calculated for open systems only.

[17] Personal communication Waldemar Treder, 30.09.2009.

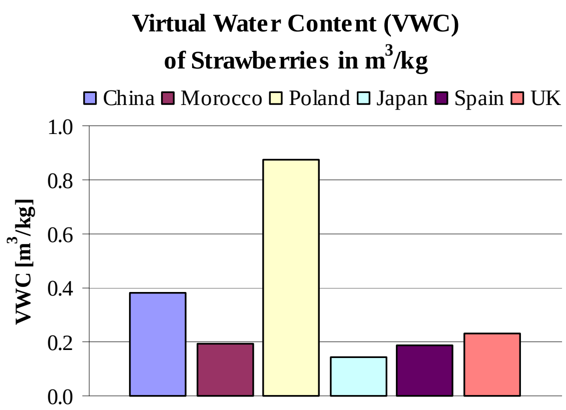


**Figure 5: Virtual water content of strawberries in $m^3$/kg for selected countries. Source: Chapagain & Hoekstra (2004a; 2004b).**

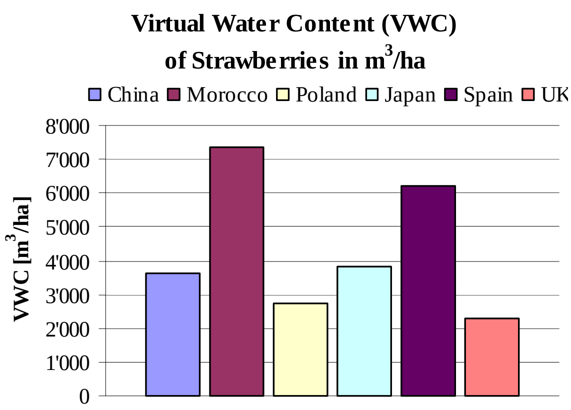


**Figure 6: Virtual water content of strawberries in $m^3$/ha for selected countries. Source: Chapagain & Hoekstra (2004a; 2004b). Data converted (see section 2.4).**

**Table 7: Yield and Virtual Water Content (VWC) of strawberries for selected countries. Source: Chapagain & Hoekstra (2004a; 2004b).**

| Country | Yield [kg/ha] | VWC [$m^3$/kg] | VWC [$m^3$/ha] |
|---|---|---|---|
| China | 9'619 | 0.379 | 3'646 |
| Morocco | 37'618 | 0.196 | 7'373 |
| Poland | 3'117 | 0.876 | 2'730 |
| Japan | 26'369 | 0.146 | 3'850 |
| Spain | 32'802 | 0.190 | 6'232 |
| UK | 10'079 | 0.229 | 2'308 |

**Table 8: Data on yield and irrigation water use in strawberry production from selected sources. Values in italics have been calculated by the authors of the present report.**

| Source | Country | Yield [kg/ha] | Irrigation [$m^3$/kg] | Irrigation [$m^3$/ha] | Remarks |
|---|---|---|---|---|---|
| Lillywhite (2008) | UK | 18'000 | *0.128* | 2'303 | The data on the yield is based on a personal communication by Robert Lillywhite, 26.10.2009. |
| Williams et al. (2008) | UK | 20'000 | *0.110* | 2'200 | The data on the yield is based on a personal communication by Adrian Williams, 29.10.2009. |
| University of Hertfordshire (2005) | UK | 19'318 | *0.119* | 2'299 | Production system: protected soil grown crops. The yield was calculated as a mean value for the production system. |
| | | 15'117 | *0.102* | 1'546 | Production system: unprotected soil grown crops. The yield was calculated as a mean value for the production system. |
| | | 20'450 | *0.080* | 1'637 | Production system: protected container grown crops with peat. The yield was calculated as a mean value for the production system. |
| | | 7'100 | *0.208* | 1'475 | Production system: unprotected container grown crops with peat. The yield was calculated as a mean value for the production system. |
| | | 22'900 | *0.096* | 2'200 | Production system: protected container crops with coir. The yield was calculated as a mean value for the production system. |
| Williams et al. (2008) | Spain | 40'000 | *0.130* | 5'200 | The data on the yield is based on a personal communication by Adrian Williams, 29.10.2009. |
| REWE (2009) | Spain | 45'500 | *0.110* | 5'000 | |
| Treder Waldemar, personal communication, 30.09.2009 | Poland | *3'340* | *0.299* | *1'000* | The irrigation value is based on a mean irrigation 100 mm/year stated by Waldemar Treder. The yield was calculated with FAO data from 2003-2007. |

# 7 Conclusions

## 7.1 Approach and methodology

A total of 35 sources have been evaluated for oranges and 31 sources for strawberries with respect to the carbon footprint. After a first evaluation 9 sources and 7 sources were retained for oranges and strawberries, respectively. Since the system boundaries and the methodology differs between the studies, a comparison of the references as well as deriving robust and detailed figures is difficult and shows the limits of the approach. It is often not possible to determine, whether the differences are dues to different countries of origin, different production systems or different methodology.

The WF resp. the VWC of the selected fruits and for the selected countries is only reported in one source and given as a single value with no subdivision into the green and blue component (Chapagain & Hoekstra, 2004a, b). Data on both components will be published in about one year from now on (see section 3.1.2), but it would also be possible to calculate them according to the method applied in (Hoekstra & Chapagain, 2008). However, this was out of scope of the current project. Values for the grey VWC are not published, but polluted water is a more and more important factor in agriculture. The average VWC may vary significantly over time and space, especially for countries with a great spatial variation of climate (e.g. China, USA). This fact is not accounted in the VWC as the calculations of it are based on average climate data. Furthermore, the VWC is calculated for open systems.

## 7.2 Carbon Footprint of Oranges and Strawberries

*Oranges*

The literature review showed that only a few publications report data on the CF of oranges for the agricultural production. Some data are documented for the whole production chain of orange juice. The agricultural production stage in these publications is either not specified at all or just reported as a general value. According to the evaluated sources, the key factors determining the GHG emissions in the agricultural production are:

- Country of origin: the reported values for Spain were higher than for Brazil and Italy (only one source).
- Yield
- Fertiliser production and application (Beccali *et al.*, 2009; Carbon Trust, 2008; Ribal *et al.*, in press; Sanjuán *et al.*, 2005; Tropicana, 2009).
- Machinery and irrigation system the diesel use seems to be the main driver for the GHG emissions in the production (Sanjuán *et al.*, 2005).

Moreover, the GHG emissions differ depending on the fertilisers and pesticides applied, the agricultural practices performed, the machinery and irrigation system used as well as on the production system (i.e. IP and OF) (Ribal *et al.*, in press; Sanjuán *et al.*, 2005).

*Strawberries*

The review showed that only little data on the CF are available from published literature. Several production techniques to grow strawberries are applied in the strawberry production (e.g. plastic tunnels, greenhouses, different growth media). The key drivers for the GHG emissions seem to vary with the production system (e.g. growth media, protection, glasshouse, open field). The key input factors of the GHG emissions in the agricultural production seem to be:

- Production and the waste transport and disposal of the polyethylene from the polytunnels (REWE Group, 2009).
- Growth medium (The Co-operative Group, 2008; University of Hertfordshire, 2005).
- Pesticides (REWE Group, 2009).
- Production system in general e.g. glasshouse in Japan has a very high CF compared to the other CF.

The country of origin respectively the production region seems to be important as well.

Furthermore is seems difficult to generate reliable LCI data of the strawberry production for long time periods as there is a lot of innovation (Williams *et al.*, 2008).

## 7.3 Water Footprint of Oranges and Strawberries

The water footprint for oranges and strawberries varies widely between the investigated countries. The variation seems to be higher per kg or product than per hectare cultivated. The main factors determining the water footprint are:

- Country of origin: logically the climate conditions (precipitation, saturation deficit) are key factors determining the water footprint.
- Yield: high yield usually goes along with a lower water footprint per kg of product.
- Irrigation system: drip irrigation uses less water than gravity irrigation (Sanjuán *et al.*, 2005)
- Production system: protected or open production
- Farming system: Ribal *et al.* (in press) reports lower water use per hectare in organic farming, but higher per kg of product, as compared to conventional farming.

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# 9 Appendix

## 9.1 Report: Review on the State of the Art to Quantify Water Use

### 1. Introduction

A literature review on the state of the art to quantify the water use (i.e. water footprint) has been performed. For that, some of the established LCA methods (Ecological Scarcity Method 2006, ReCiPe 2008, Impact 2002 +, Eco-indicator 99, EDIP 1996, EDIP 2003, and CML 2001) as well as recent LCA methods and other approaches were considered. The focus was put on the methodology. In the present report the main findings of this literature review are summarised.

### 2. Methodology

The literature review has been performed using scientific papers, reports, books, posters, and websites. Information on relevant definitions, LCI inputs and outputs, impact pathways, impact characterisation, weighing and normalisation, and impact categories for the different methods was gathered.

### 3. Definitions in the context of water use

| | |
|---|---|
| In-stream water use | In situ utilisation of water such as a dam for hydroelectric power or navigational transport on a river (Owens, 2002). Other terms: In-stream use (Pfister *et al.*, 2009). |
| Off-stream water withdrawal | Water removal from a natural water body or groundwater aquifer such as pumping (Owens, 2002). Other terms: Off-stream use (Pfister *et al.*, 2009). |
| Water release or return | Water release after off-stream use to surface waters (Owens, 2002). |
| Water use | Off-stream use where water is released or returned to the original river basin. Downstream users (humans, ecosystem) are not deprived from water volume (Owens, 2002). Other terms: nonevaporative water use (Milà i Canals *et al.*, 2009). Other definitions: Any withdrawal of freshwater for production or consumption processes (Frischknecht *et al.*, 2009). |
| Water consumption | Off-stream use where water release or return does not occur (e.g. evaporation from a reservoir, evaporation from irrigation, evaporation from thermal cooling, transfer out of the natural river basin). Downstream users are deprived of some water (Owens, 2002). Other terms: evaporative water use (Milà i Canals *et al.*, 2009), consumptive use (Pfister *et al.*, 2009). |
| Water depletion | Water withdrawal from a water source that is not replenished or recharged at approximately the same or greater rate than human withdrawal (Owens, 2002). |
| Degradative use | Quality change in water used and released back to the same watershed (Pfister *et al.*, 2009). |
| Green water | Rainwater that is stored in the soil as soil moisture (Hoekstra, 2008). Other definition: Water stored as soil moisture and available for evaporation (Milà i Canals *et al.*, 2009). |
| Blue water | Surface and ground water (Hoekstra, 2008). |
| Grey water | Polluted water that associates with the production of all goods and services for the individual or community (Hoekstra, 2008). |
| Water resource types | Flows (rainwater, river, lake), funds (aquifers), stocks (fossil water) (Milà i Canals *et al.*, 2009). |
| Natural sources | Surface (lake, river), ground, brackish, sea, and rain water (Koehler, 2009). |
| Technical sources | Tap water, reclaimed water (Koehler, 2009). |

# 4. Results

## 4.1. Approaches to assess water use outside LCA

The review resulted in the inclusion of four approaches to assess water use: water footprint, virtual water content of a product (i.e. water footprint of a product), global water tool, and OECD key environmental indicators.

### Water footprint

To describe the water footprint approach the two sources Hoekstra (2008) and Hoekstra & Chapagain (2007) were summarised. The water footprint (WF) of an individual, community or business is defined as the total volume of freshwater that is used resp. polluted directly or indirectly to produce a product. The total WF is composed of the following three components: the green WF (volume of water that evaporated from the global green water resources), the blue WF (volume of freshwater that evaporated from the global blue water resources), and the grey WF (volume of polluted water that associates with the production of all goods and services for the individual or community). The water footprint for each nation of the world has been calculated for the period 1997-2001 (Hoekstra & Chapagain, 2007).

### Virtual water content of a product

Virtual water (VW) is defined as the volume of water that is required to produce a product, i.e. commodity, good or service measured at the place where the product was produced (Hoekstra & Chapagain, 2007). The VW content of a product corresponds to the water footprint of a product and is defined as the volume of freshwater used to produce the product measured at the place where the product was produced (Hoekstra, 2008). It is composed of the following three components: the green VW content (for agricultural products as the total rainwater evaporation from the field during the growing period of the crop including transpiration by the plants and other forms of evaporation), the blue VW content (for crop it corresponds to the sum of the evaporation of irrigation water from the field and the evaporation of water from irrigation canals and artificial storage reservoirs), and the grey VW content (volume of water that is required to dilute pollutants emitted to the natural water system during its production process to such an extent that the quality of the ambient water remains beyond agreed water quality standards). This concept is more or less applied in the paper of Chapagain & Orr (2009), where two different production systems (open system and covered system) for tomato production in Spain are analysed applying water footprint methodology.

### Global Water Tool

The Global Water Tool (WBCSD, 2007) is an Excel-based tool to calculate and map water use and assess risks relative to global operations and supply chains of a company or organisation. For the calculation the water input resp. water withdrawal and the water output resp. water discharge of freshwater and non-freshwater sources are necessary.

### OECD Key Environmental Indicators

In the OECD Key Environmental Indicators an indicator for the use of freshwater is defined to assess the intensity of freshwater use that is calculated as abstractions divided by available resources (OECD, 2004).

## 4.2. Established LCA methods

Water use is not taken into account in the methods IMPACT2000 + (Jolliet *et al.*, 2003), Eco-Indicator 99 (Goedkoop & Spriensma, 2001) and EDIP 2003 (Hauschild & Potting, 2004). According to Koehler (2008) freshwater resources are considered as nondepletable in the methods CML 2001, IMPACT2000 +, and Eco-Indicator 99. That is why characterisation models for freshwater exhaustion are lacking. Water use is included in the following three established LCA methods: Ecological Scarcity Method 2006, ReCiPe 2008, EDIP 1997 (Wenzel *et al.*, 2000). Table 1 (see section 4.4.) provides an overview on the main findings on these three methods. Some additional information on two of the methods is given below.

**Ecological Scarcity Method 2006**

Three types of eco-factors for freshwater use are defined in the Ecological Scarcity Method 2006 (country specific factor, average of OECD countries, six different scarcity situations). Weighing can be done according to the scarcity situation. It is possible to deduce specific regional or local eco-factors (Frischknecht *et al.*, 2009).

**ReCiPe 2008**

The method ReCiPe 2008 has limited validity for well-developed temperate regions (Goedkoop *et al.*, 2009).

## 4.3. Further LCA methods

Three recent LCA methods to assess water use can be identified ("Milà i Canals method", "Pfister method", "Bayart method"). According to Milà i Canals *et al.* (2009) the paper of Owens (2002) provides useful definitions of different water inputs and outputs of freshwater use. The definitions are applied to some extent in three recent methods. The main findings on these methods are listed in Table 1 (see section 4.4.). Some additional information on the methods is presented below.

**"Milà i Canals method"**

It is possible that local effects are underestimated with this method as non-evaporative use of water is not considered (Milà i Canals *et al.*, 2009). The method is applied in the study "Assessing Freshwater Use Impacts in LCA Part II: Case study for broccoli production in the UK and Spain" (Milà i Canals *et al.*, in preparation).

**"Pfister method"**

The damage assessment in the paper was performed according to Eco-Indicator 99 method, but it is also possible to integrate the "Pfister method" in similar methods such as LIME, IMPACT2000 + (Pfister *et al.*, 2009). The method is applied in the study "Regionalised LCIA of vegetable and fruit production: Quantifying the environmental impacts of freshwater use" (Pfister *et al.*, 2008).

**"Bayard method"**

The "Bayard method" was analysed by using two different sources (a poster with information on (Bayart *et al.*, submitted) where the methodology is briefly described and a presentation held by Koehler (2009). For the moment it is not clear what water inputs and outputs are used in the inventory and how the impact characterisation is modelled.

## 4.4. Overview on LCA methods where water use is taken into account

**Table 9: Overview on LCA methods that take into account water use.**

| Method | Inventory: Input/Output considered | Inventory: Water use considered | Impact pathways | Impact characterisation | Normalisation/ Weighing | Impact categories | Impact: Areas of protection |
|---|---|---|---|---|---|---|---|
| Ecological Scarcity Method 2006 | Input/Output | All types of freshwater | - | - | Yes | - | - |
| ReCiPe 2008 | Input/Output desirable | 5 default water types. Others can be integrated. | - | Yes | - | Midpoint category:<br>Water depletion | - |
| EDIP 1997 | Input | All types of renewable water | - | - | Yes | Resource consumption | - |
| „Milà i Canals“ | Input/Output | 3 different inputs and outputs | Yes | Yes | - | 1. Freshwater Ecosystem Impact<br>2. Freshwater Depletion | 1. Ecosystem quality<br>2. Natural Resources |
| „Pfister“ | Input/Output | Blue virtual water consumption | Yes | Yes | Yes | Suggested midpoint categories:<br>1. Water deprivation (not clear)<br>2. Freshwater depletion | 1. Human health<br>2. Ecosystem Quality<br>3. Resources |
| „Bayart“ | Input/Output | 2 different inputs and outputs proposed | Yes | No information | No information | Midpoint assessment categories:<br>1. Water depletion<br>2. Water deprivation for ecosystems<br>3. Water deprivation for human use (insufficiency scenario) or traditional / commonly accepted LCIA environmental impacts (compensation scenario) | 1. Abiotic environment (subcategories: biotic natural environment, abiotic natural resources, abiotic man-made environment)<br>2. Biotic environment (subcategories: biodiversity, biotic production)<br>3. Human life (subcategories: human health, labour) |

## 5. Remarks

1. The following information is not or only partially presented in this report, but listed in the file Literature_Review_Water_Footprint.xls as it might be useful for future work:
   - In-depth information on the water footprint of a nation (Hoekstra & Chapagain, 2007).
   - The paper of Chapagain & Orr (2009), where two different production systems (open system and covered system) for tomatoes in Spain are analysed applying water footprint methodology.
   - Information on life cycle inventories for various vegetables and fruits such as citrus fruits and strawberries (Stoessel & Hellweg, 2008).
   - A short description of databases respectively tools used in some of the mentioned methods (Aquastat, CROPWAT, CLIMWAT for CROPWAT, AQUACROP, WaterGAP 2).

2. An interesting source would have been the paper "Assessing water in LCA: state-of-the art" by Sebastien Humbert, Ecointesys, where the methods to describe water use in LCA are reviewed and briefly described.

## 6. Literature used for the review on water use

Bayart, J.B., Bulle, C., Deschênes, L., Margni, M., Pfister, S., Vince, F. & Koehler, A., submitted. A Framework for Assessing Off-Stream Freshwater Use in LCA. Submitted to International Journal of Life Cycle Assessment.

Chapagain, A.K. & Orr, S., 2009. An improved water footprint methodology linking global consumption to local water resources: A case of Spanish tomatoes. Journal of Environmental Management, 90: 1219-1228.

Frischknecht, R., Steiner, R. & Jungbluth, N., 2009. Methode der ökologischen Knappheit – Ökofaktoren 2006. Methode für die Wirkungsabschätzung in Ökobilanzen. Bundesamt für Umwelt (BAFU). Öbu – Netzwerk für nachhaltiges Wirtschaften, Bern, Umwelt-Wissen Nr. 0906, 188 p.

Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J. & van Zelm, R., 2009. ReCiPe 2008: A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. First edition Report I: Characterisation.

Goedkoop, M. & Spriensma, R., 2001. The Eco-indicator 99: A damage oriented method for life cycle impact assessment. Methodology Report. PRé Consultants, Amersfort, The Netherlands, 144 p.

Hauschild, M. & Potting, J., 2004. Spatial differentiation in life cycle impact assessment - the EDIP 2003 methodology. Institute for Product Development, Technical University of Denmark, 150 p.

Hoekstra, A.Y., 2008. The water footprint of food. In: Förare, J., Water for food, 49-60. The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas), Stockholm, Sweden.

Hoekstra, A.Y. & Chapagain, A.K., 2007. Water footprints of nations: Water use by people as a function of their consumption pattern. Water Resources Management, 21: 35-48.

Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G. & Rosenbaum, R., 2003. IMPACT 2002+: A new life cycle impact assessment methodology. International Journal of Life Cycle Assessment, 8: 324-330.

Koehler, A., 2008. Water use in LCA: managing the planet's freshwater resources. International Journal of Life Cycle Assessment, 13: 451-455.

Koehler, A., 2009. Framework and methods for assessing water use in the product value chain. Presentation UNEP/CSCP Workshop Wuppertal.

Milà i Canals, L., Chapagain, A., Chenoweth, J. & Orr, S., in preparation. Assessing Freshwater Use Impacts in LCAPart II: Case study for broccoli production in the UK and Spain. International Journal of Life Cycle Assessment.

Milà i Canals, L., Chenoweth, J., Chapagain, A., Orr, S., Antón, A. & Clift, R., 2009. Assessing freshwater use impacts in LCA: Part I-inventory modelling and characterisation factors for the main impact pathways. International Journal of Life Cycle Assessment, 14: 28-42.

OECD, 2004. Key environmental indicators. Paris.

Owens, J.W., 2002. Water Resources in Life Cycle Impact Assessment. Considerations in Choosing Category Indicators. Journal of Industrial Ecology, 5: 37-54.

Pfister, S., Koehler, A. & Hellweg, S., 2009. Assessing the Environmental Impacts of Freshwater Consumption in LCA. Environmental Science & Technology, 43: 4098-4104.

Pfister, S., Stoessel, F., Juraske, R., Koehler, A. & Hellweg, S., 2008. Regionalised LCIA of vegetable and fruit production: Quantifying the environmental impacts of freshwater use. In: Proceedings of the 6th International Conference on LCA in the Agri-Food Sector – Towards a sustainable management of the Food chain, Nemecek, T. & Gaillard, G. (eds.). November 12–14, 2008, Zurich. Agroscope ART, 16-21.

Stoessel, F. & Hellweg, S., 2008. LCI of vegetable and fruit production in different countries. In: Book of Abstracts of the 6th International Conference on LCA in the Agri-Food Sector – Towards a sustainable management of the Food chain, Nemecek, T. & Gaillard, G. (eds.). November 12–14, 2008, Zurich. Agroscope ART.

WBCSD, 2007. The global water tool. World business council on sustainable development. Accessed 25.08.2009.

Wenzel, H., Hauschild, M. & Altig, L., 2000. Environmental Assessment of Products. Volume 1: Methodology, tools and case studies in product development. . 2nd ed. Kluwer Academic Publishers, London, 543 p.

## 9.2 Literature Review CF and WF: Details on Sources

### 9.2.1 Literature for Oranges Included in the Analysis

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product | Objectives |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tropicana orange juice carbon footprint, includes all juice production stages (growing/juicing in % of total given). Supplier Citrosuco. Methodology ISO 14040. | LCA (ISO 14040) | Report | PepsiCo UK & Ireland | Environmental Sustainability Report | Retrieved September 2009 from http://www.pepsico.co.uk/download/113 | 2008 | Brazil | Orange juice | Carbon footprint in for orange juice production. Carbon reduction. |
| 2 | Tropicana orange juice carbon footprint, includes all juice production stages. | LCA (not specified) | Fact Sheet | Tropicana | Understanding Our Carbon Footprint | Retrieved October 2009 from http://www.tropicana.com/#/trop_environment/environment.swf. | 2009 | Brazil | | Carbon footprint in for orange juices. |
| 3 | No calculation data, carbon footprint broken down into life-cycle stages e.g. for the whole production in % of total given. Information on methodology and country from: Carbon Trust. 2008. Working with Tesco. Product carbon footprinting in practice. Case Study CTS055. | PAS2050 (draft version) | Fact Sheet | Tesco | Our carbon label findings | Retrieved September 2009. http://www.tesco.com/assets/greenerliving/content/documents/pdfs/carbon_label_findings.pdf | | Brazil | Orange juice | Carbon footprint in for orange juices. |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product | Objectives |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | As they refer to Tesco orange juice it is assumed that methodology is PAS2050 (draft version). | Assumed: PAS2050 (draft version) | Report | Munasinghe, M., Dasgupta, P., Southerton, D., A., B. & A., M., | Consumers, Business and Climate Change. A report prepared by the Sustainable Consumption Institute at the University of Manchester, UK, in collaboration with members of the CEO forum of companies., Manchester, UK, 59 p. | | 2009 | Assumption: Brazil | | Carbon footprint in for orange juices. |
| 5 | Detailed information on carbon footprint and irrigation water use. | LCA | Article | Sanjuán, N., Úbeda, L., Clemente, G., Mulet, A., Girona, F. | LCA of integrated orange production in the Comunidad Valenciana (Spain) | International Journal of Agricultural Resources, Governance and Ecology, 4(2): 163-177 | 2005 | Spain | Orange (Navelina orange) | 1. Evaluation of environmental impact of the IP of citrus fruits.<br>2. Contribution to the development of LCA methodology application in Spanish agriculture. |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product | Objectives |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | Detailed information on carbon footprint and irrigation water use for integrated production and organic farming | LCA | Article (in press) | Ribal, J., Sanjuán, N., Clemente, G. & Fenollosa, L., . | Medición de la eco-eficiencia en procesos productivos en el sector agrario. Caso de estudio sobe producción de cítricos. | | in press | Spain | Orange (Navelina orange) | Assessment of eco-efficiency of orange production |
| 7 | Host country Sweden. Information on GHG emissions for oranges and juice available but processing and distribution to Sweden is included in the amount. Oranges from Spain, Morocco, Israel, calculated as they were from France. Other countries not specified, calculated as if products were from New Zealand. | LCA | Article | Wallén, A. Brandt, N., Wennersten, R. | Does the Swedish consumer's choice of food influence greenhouse gas emissions? | Environmental Science & Policy 7: 525-535 | 2004 | Spain, Morocco, Israel. Other countries? | Orange | Investigation of annual green house emissions associated with food production and consumption in Sweden. |
| 8 | Inputs and outputs of the agricultural production stage are given. Post-agricultural production steps are included in total GHG calculations . Reference year 2005. | LCA | Article | Beccali, M., Cellura, M., Iuidicello, M., Mistretta, M. | Resource Consumption and Environmental Impacts of the Agrofood Sector: Life Cycle Assessment of Italian Citrus-Based Products | Environmental Management 43(4): 707-724 | 2009 | Italy | Orange, lemon, citrus | Estimation of environmental impacts associated with life cycles of agrofood chain (e.g. primary energy consumption, water exploitation, global warming) |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product | Objectives |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Host country Netherlands. GHG emissions given per household. It is unclear how it is calculated and where data comes from. Country not specified. | Not clear | Article | Kramer, K.J., Moll, H.C., Nonhebel, S., Wilting, H.C. | Greenhouse gas emissions related to Dutch food consumption | Energy Policy 27, 203-216 | 1999 | Not clear | Orange | Discussion of greenhouse gases that are related to Dutch house food consumption. |
| 10 | Virtual water content. Data given in m3/t for the period 1997-2001. | Water footprint | Report | Hoekstra, A.Y. & Chapagain, A.K. | Water footprints of nations. Volume 2: Appendices | Value of Water Research Report Series No. 16. UNESCO-IHE, Delft | 2004 | Brazil, China, Spain, USA | Orange | Determination of the water footprint of nations |

### 9.2.2 Literature for Strawberries Included in the Analysis

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product | Objectives |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | GHG emission for strawberries in Japan. Data given in kg for consumption. Data for emissions for the production received per e-mail 28.10.09 | LCA | Not clear | Yoshikawa, N., Amano, K., Shimada, K. | Evaluation of Environmental Load on Fruits and Vegetables Consumption and its Reduction Potential | http://www.ritsumei.ac.jp/se/rv/amano/pdf/2008EBJ-yoshikawanaoki.pdf | 2009 | Japan | Strawberry | 1. Building inventory data covering general food consumed in Japan<br>2. Evaluating reduction potential of some measures contains cost analysis |
| 2 | Detailed information on GHG emissions, GWP and water use. In table 5 the unit for GHG are printed wrong. Raw data is in kg CO2-eq./t strawberries. In the text 0.7 instead of 0.85 is reported. Personal communicaton A. Williams, 29.10.09) | LCA | Proceedings | Williams, A., Pell, E., Webb, J., Moorhouse, E., Audsley, E. | Strawberry and tomato production for the UK compared between the UK and Spanin | Proceedings of the 6th International Conference on LCA in the Agri-Food Sector, Zürich (254-262) | 2008 | Spain, United Kingdom | Strawberry | Comparison of tomato and strawberry production in the UK and Spain. |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product | Objectives |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Detailed information on GHG emissions, GWP and water use | LCA | Report | University of Hertfordshire | Sustainability of UK Strawberry Crop. Final report to Defra on project HH3606 | Work concluded by the University of Hertfordshire, UK | 2007 | Spain, United Kingdom | Strawberry | To apply current state-of-the-art environmental impact and economic and socio-economic assessment techniques to a range of strawberry production scenarios to develop a better understanding of the sustainability of the UK crop. |
| 4 | Carbon footprint for whole life cycle including transport and other steps. | PAS2050 | Report | The Co-operative Group | Sustainability Report 2008/09 | http://www.co-operative.coop/upload/Sustainability/Report0809/downloads/The%20Co-operative%20Sustainability%20Report%202008-09.pdf | 2008 | Spain, Scotland | Strawberry | Carbon reduction. |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product | Objectives |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Showing the environmental footprint and CO2eq and water use in kg/ha. Yield is not given. See also pdf Lillywhite_2007 | Environ-mental footprint | Article (reviewed?) | Lillywhite, R. | The environmental footprint: A method to determine the environmental impact of agricultural production | University of Warwick, UK | 2008 | United Kingdom | Strawberry (protected) | 1. Identify and quantify the key inputs/outputs associated with horticultural and agricultural production and determine their environmental impact. 2. Construct environmental footprints for selected horticultural and agricultural crops. |
| 6 | Very detailed study on production. | PAS2050 | Case study | REWE Group, Rheinische Friedrich-Wilhelms-Universität | Fallstudie "Best Alliance". Früherdbeeren der REWE Group. Dokumentation. Fallstudie im Rahmen des PCF (Product Carbon Footprint) Pilotprojekts Deutschland. | http://www.pcf-projekt.de/files/1232962839/pcf_rewe_erdbeeren.pdf | 2009 | Spain | Strawberry | Calculation of carbon emissions of strawberry production. |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product | Objectives |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Host country Netherlands. GHG emissionsgiven per household. It is unclear how it is calculated and where data comes from. Country not specified. | Not clear | Article | Kramer, K.J., Moll, H.C., Nonhebel, S., Wilting, H.C. | Greenhouse gas emissions related to Dutch food consumption | Energy Policy 27, 203-216 | 1999 | Not clear | Strawberry | Discussion of greenhouse gases that are related to Dutch house food consumption. |
| 8 | Virtual water content. Data given in m3/t and given for the period 1997-2001. | Water footprint | Report | Hoekstra, A.Y. & Chapagain, A.K. | Water footprints of nations. Volume 2: Appendices | Value of Water Research Report Series No. 16. UNESCO-IHE, Delft | 2004 | China, Morocco, Poland | Strawberry | Determination of the water footprint of nations |

### 9.2.3 Literature for Oranges Excluded from the detailed Analysis

These literature sources have been reviewed but not selected for a detailed analysis in the report.

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No agricultural process is analysed. | LCA | Procee-dings | Aranda A., Scarpellini, S., Zabalza, I., Valero A. | An analysis of the present food's transport model based on a case study carried out in Spain | Proceedings of the 6th International Conference on LCA in the Agri-Food Sector, Zürich (332-414) | 2008 | Spain | Orange |
| 2 | Energy inputs in MJ for the whole life cyle. Data based on Carlsson-Kanyama & Faist (2000). | LCA | Article | Carlsson-Kanyama, A., Ekstrom, M.P., Shanahan, H. | Food and life cycle energy inputs: consequences of diet and ways to increase efficiency | Ecological Economics 44(2-3): 293-307. | 2003 | Southern Europe, Overseas | Orange, fresh, orange juice |
| 3 | No new data. Reference to Schlich & Fleissner (2005). They write that no detailed overall impact of orange juice in any form has been found. | LCA | Report | Foster C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn, A., Mylan, J. | Environmental Impacts of Food Production and Consumption: A report to the Departement of Environment, Food and Rural Affairs | Manchester Business School. Defra, London | 2006 | Brazil | Orange (juice) |
| 4 | Host country UK. Summary on other studies. No new data given. | Not clear | Working paper | Garnett, T. | Fruit and Vegetables & UK Greenhouse Gas Emissions: Exploring the relationship | Centre for Environmental Strategy, University of Surrey | 2006 | Not clear | Orange |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 5 | No explicit data on production. Mentions Tesco carbon labelling. | Not clear | Unpub-lished paper | Hasit S. | The Carbon Footprint in Agricultural Trade. A Background Paper prepared for the International Centre for Trade and Sustainable Development (ICTSD) and the session titled Agriculture, Climate Change and Sustainable Development at The Future of Agriculture. | Barcelona, 30th and 31st May 2008 | 2008 | Not clear | Orange |
| 6 | Gives an overview on different studies associated food production and Energy use resp. GHG. | Not clear | Technical Paper | International Trade Center | Airfreigth Transport of Fresh Fruit and Vegetables: A Review on Environmental Impacts and Policy Options | UNCTAD/WTO, Geneva: ITC | 2007 | Not clear | Orange |
| 7 | No information on GHG emissions and water use. | Not clear | Article | Khan, S., Hanjra, M.A. | Footprints of water and energy inputs in food production - Global perspectives | Food Policy 34 (2): 130-140 | 2009 | Not clear | |
| 8 | No information on GHG emissions and water use. | Not clear | Paper | Khan, S., Hanjra, M.A., Mu, J., | Water management and crop production for food security in China: A review | Agricultural Water Management 96 (3): 349-36 | 2009 | China | |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 9 | Total GHG emissions for all production stages (including cultivation and processing) of orange juice production. | Not clear | Poster | Koronoes, C., Rovas, D., Tzanis, N. | Environmental Impact Assessment of Orange Juice Production | Life Cycle Approaches for Conservation Agriculture. CML Report 171. Department of Industrial Ecology & Department of Environmental Biology. | 2006 | Greece | Orange |
| 10 | GHG emissions of agricultural crop production in the Netherlands. Oranges not analysed. | Not clear | Article | Kramer, K.J., Moll, H.C., Nonhebel, S. | Total greenhouse gas emissions related to the Dutch crop production system | Agriculture, Ecosystems & Environment 72: 9-16 | 1999 | Not clear | |
| 11 | Seems to analyse only the transport by air and surface and not the agricultural processes. See presentation of Marriott in the literature folder. | Not clear | Dissertatio n | Marriott, C. | From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004 | MSc Dissertation, University of Surrey, Surrey. | 2004 | ? | Orange |
| 12 | Methodology description. No data analysed. Basis for Coltro et al. (2009). | LCA | Article | Mourad, A. L., Coltro, L., Oliveira, P., Kletecke, R. M., Baddini, J. | A simple methodology for elaborating the life cycle inventory of agricultural products | International Journal of Life Cycle Assessment 12(6): 408-413 | 2007 | Brazil | Orange |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 13 | No specific fruits analysed. | Not clear | Article | Pretty, J.N., Ball, A.S., Lang, T., Morison, J.I.L. | Farm costs and food miles: An assessment of the full cost of the UK weekly food basket | Food Policy 30:1-19 | 2005 | Not clear | Fruit |
| 14 | No data on oranges. | LCA | Article | Sim, S., Barry, M., Clift, R., Cowell, S.J. | The Relative Importance of Transport in Determining an Appropriate Sustainability Strategy for Food Sourcing. A Case Study of Fresh Produce Supply Chains | International Journal of Life Cycle Assessment 12(6): 422-431 | 2007 | | |
| 15 | Results not published yet. | LCA | Presentation | Stoessel, F., Pfister, S. Mutel, C., Hellweg, S. | Assessing the impact of vegetable and fruit production for decision-making in the retail sector | 15th LCA Case Studies Symposium. LCA for decision support in business and government for Sustainable Consumption and Production. 22-23 January 2009, Paris France. (12-14) | 2009 | Brazil, Florida, others? | Citrus |
| 16 | Refers to Carlsson-Kanyama et al. (2003) and Schlich & Fleissner (2005) | Not LCA | Report | Wangler, Z.L. | Fresh Insights 2 - Sub-Saharan African horticultural exports to the UK and climate change: a literature review | International Institute for Environment and Development, London | 2006 | Sub-Saharia | Orange |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 17 | Only transportation assessed. | Not clear | Article | Weber, C. & Matthews, H.S. | Food-Miles and the Relative Climate Impacts of Food Choices in the United States | Environmental Science & Technology 42: 3508-3513 | 2008 | USA | |
| 18 | Before farm, farm and after farm sales are given in USD. More information on calculation would be needed. | Not clear | Article | Neves, M.F., Do Val, A.M., Marino, M.K. | The orange network in Brazil | Journal for the Fruit Processing and Juice Producing European and Overseas Industry 11(12): 486-490 | 2001 | Brazil | Oranges, processed oranges |
| 19 | Each production step is analysed but data is not listed in the paper. No detailed analysis of impacts. More detailed data could maybe be found in a disseration of Fleissner from the year 2001 (Costs approx. 50 Euro). | LCA | Article | Schlich, E.H. & Fleissner, U. | The Ecology of Scale: Assessment of Regional Energy Turnover and Comparison with Global Food | International Journal of Life Cycle Assessment 10(3): 219-223 | 2005 | Brazil | Orange (juice) |
| 20 | Annual emmissions of CO2 and N2O per m2 are given for Satsuma mandarin. | Field Study | Article | Okuda, H, Noda, K., Sawamoto, T., Tsuruta, H., Hirabayashi, T., Yonemoto, J.Y, Yagi, K. | Emission of N2O and CO2 and Uptake of CH4 in Soil from a Satsuma Mandarin Orchard under Mulching Cultivation in Central Japan | Journal of the Japanese Society for Horticultural Science 76 (4): 279-287 | 2007 | Japan | Satsuma mandarin |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 21 | Data (fertilisers, diesel, water etc.) is given in energy equivalents. No GHG emission calculation performed in the study. Management practises are specified. Reference year: 2000. | Not clear | Article (reviewed) | Ozkan, B., Akcaoz, H., Karadeniz, F. | Energy requirement and economic analysis of citrus production in Turkey | Energy Conversion and Management 45(11-12): 1821-1830. | 2004 | Turkey | Orange, lemon, mandarin |
| 22 | GHG emission for mandarin orange in Japan. | LCA | Not clear | Yoshikawa, N., Amano, K., Shimada, K. | Evaluation of Environmental Load on Fruits and Vegetables Consumption and its Reduction Potential | | 2008 | Japan | Mandarin orange |
| 23 | Own study (not peer-reviewed). Estimate of used fertilisers, pesticides, machines, water. Data can be bought. They would revise data in that case. | LCA | Database | ESU-Services, Jungbluth, Niels | LCI database | | 2002 | USA, Brazil | Orange |
| 24 | Information on virtual water content of fruits in China. Fruits are estimated with data based on apples. Data given in m3/kg. | Water footprint | Article | Liu, J. & Savenije, H.H.G. | Foot consumption patterns and their effect on water requirement in China | Hydrology and Earth System Sciences 12:881-898 | 2008 | China | Fruit (based on apples) |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 25 | Carbon footprint is not calculated explicitly. LCI for the orange production is given but in the data transport from farm to processing industry is included. Reference year: 2002/2003. Used in the report for the water use/irrigation. | LCA | Article | Coltro, L., Mourad, A.L., Kletecke, R.M., Mendonça, T.A., Germer, S.P.M. | Assessing the environmental profile of orange production in Brazil | International Journal of Life Cycle Assessment (online publication) | 2009 | Brazil | Orange |
| 26 | Provides data on orange production in USA from 4 different sources (yield, diesel, gasoline, N, P, K, pesticides, machinery, limestone). Sources from 1980, 1996, 1997. | Not clear | Report | Carlsson-Kanyama, A. & Faist, M. | Energy Use in the Food sector: A Data Survey | Swedish Environmental Protection Agency, AFR Report 291, Sweden | 2000 | USA, Florida | Orange |

### 9.2.4 Literature for Strawberries Excluded from the detailed Analysis

These literature sources have been reviewed but not selected for a detailed analysis in the report.

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No agricultural process is analysed. | LCA | Proceeding s | Aranda A., Scarpellini, S., Zabalza, I., Valero A. | An analysis of the present food's transport model based on a case study carried out in Spain | Proceedings of the 6th International Conference on LCA in the Agri-Food Sector, Zürich (332-414) | 2008 | Spain | Strawberry |
| 2 | Energy inputs in MJ for the whole life cycle. Data based on Carlsson-Kanyama & Faist (2000). | LCA | Article | Carlsson-Kanyama, A., Ekstrom, M.P., Shanahan, H. | Food and life cycle energy inputs: consequences of diet and ways to increase efficiency | Ecological Economics 44(2-3): 293-307. | 2003 | Sweden, Southern Europe, Middle East, Central Europe | Strawberry |
| 3 | Host country UK. Summary on other studies. No new data given. | Not clear | Working paper | Garnett, T. | Fruit and Vegetables & UK Greenhouse Gas Emissions: Exploring the relationship | Centre for Environmental Strategy, University of Surrey | 2006 | Not clear | Strawberry |
| 4 | Refers to University of Hertfordshire, 2007. | Not clear | Report | Garnett, T. | Cooking up a storm - Food, greenhouse gas emissions and our changing climate. Food Climate Research Network | Centre for environmental Strategy. University of Surrey. | 2008 | Not clear | Strawberry |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 5 | No information on GHG emissions and water use. | Not clear | Article | Khan, S., Hanjra, M.A. | Footprints of water and energy inputs in food production - Global perspectives | Food Policy 34 (2): 130-140 | 2009 | Not clear | |
| 6 | No information on GHG emissions and water use. | Not clear | Article | Khan, S., Hanjra, M.A., Mu, J., | Water management and crop production for food security in China: A review | Agricultural Water Management 96 (3): 349-36 | 2009 | China | |
| 7 | GHG emissions of agricultural crop production in the Netherlands. Strawberries not analysed. | Not clear | Article | Kramer, K.J., Moll, H.C., Nonhebel, S. | Total greenhouse gas emissions related to the Dutch crop production system | Agriculture, Ecosystems & Environment 72: 9-16 | 1999 | Not clear | |
| 8 | Carbon footprint given for a bottle of 250 ml of a strawberry/banana smoothie and for the whole life cycle. Not specified for strawberries. Several changes carbon footprint value. | Not clear | Web site | Innocence, United Kingdom. | Carbon Footprint for strawberry and banana smoothies | Information retrieved from http://www.innocentdrinks.co.uk/us/ethics/resource_efficient/our_carbon_footprint/ | 2008 | Not clear | Strawberry and banana |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 9 | Seems to analyse only the transport by air and surface and not the agricultural processes. See presentation of Marriott in the literature folder. | Not clear | Dissertation | Marriott, C. | From Plough to Plate by Plane: An investigation into trends and drivers in the airfreight importation of fresh fruit and vegetables into the United Kingdom from 1996 to 2004 | MSc Dissertation, University of Surrey, Surrey. | 2004 | Not clear | Strawberry |
| 10 | No specific fruits analysed. | Not clear | Article | Pretty, J.N., Ball, A.S., Lang, T., Morison, J.I.L. | Farm costs and food miles: An assessment of the full cost of the UK weekly food basket | Food Policy 30:1-19 | 2005 | Not clear | Fruit |
| 11 | Gives an overview on production regions, not for further analyse, German. | Not LCA | Article | Roudeillac, P. | Vom Luxusgut der Kapitalisten zum Exportschlager – Erdbeeranbau, Vermarktung und Züchtung in China als drittgrösster Erdbeerproduzent weltweit | Erwerbs-Obstbau 49: 57-63 | 2007 | China | Strawberry |
| 12 | No data on strawberries. | LCA | Article | Sim, S., Barry, M., Clift, R., Cowell, S.J. | The Relative Importance of Transport in Determining an Appropriate Sustainability Strategy for Food Sourcing. A Case Study of Fresh Produce Supply Chains | International Journal of Life Cycle Assessment 12(6): 422-431 | 2007 | Not clear | |

| **Key** | **Evaluation of the source** | **Method** | **Medium** | **Author / Source** | **Title / Method / Concept Name** | **Journal / Book / Publication / Publisher** | **Year** | **Producing Country** | **Product** |
|---|---|---|---|---|---|---|---|---|---|
| 13 | No data on GHG and water use. | Not clear | Article | Stevens, M.D., Black, B.L., Lea-Cox, J.D., Hapeman, C.J. | Sustainability of Cold-Climate Strawberry Production Systems | Acta Hort. (ISHS) 708:69-72 | 2006 | USA | Strawberry |
| 14 | Results not published yet. | LCA | Presentation | Stoessel, F., Pfister, S. Mutel, C., Hellweg, S. | Assessing the impact of vegetable and fruit production for decision-making in the retail sector | 15th LCA Case Studies Symposium. LCA for decision support in business and government for Sustainable Consumption and Production. 22-23 January 2009, Paris France. (12-14) | 2009 | Spain, others? | Strawberries |
| 15 | Gives information on yield and production techniques and not on GHG emissions. | Not clear | Report | UNEP | Case Studies on Alternatives to Methyl Bromide – Volume 2. Technologies with low environmental impact in countries with economies in transition | | 2002 | Poland | Strawberry |
| 16 | Seem to be the same data as in University of Hertfordshire, 2007. | Not clear | Proceedings | Warner, D.J., Tzilivakis, J., Hipps, N., Davies, M., Osborne, N., and Lewis, K.A. | Environmental impact assessment of the UK strawberry crop | Proceedings of the International Fertiliser Society and Dahlia Greidinger Symposium. Izmir, Turkey, 7 – 10 December 2003, pages 396 - 398. | 2003 | United Kingdom | Strawberry |

| **Key** | **Evaluation of the source** | **Method** | **Medium** | **Author / Source** | **Title / Method / Concept Name** | **Journal / Book / Publication / Publisher** | **Year** | **Producing Country** | **Product** |
|---|---|---|---|---|---|---|---|---|---|
| 17 | Only transportation assessed. | Not clear | Article | Weber, C. & Matthews, H.S. | Food-Miles and the Relative Climate Impacts of Food Choices in the United States | Environmental Science & Technology 42: 3508-3513 | 2008 | USA | |
| 18 | No information on GHG and water footprint. | Not clear | Article | Zhao, M., Su, J., Qiang, Y. and Wang, Z. | Advances in Strawberry Breeding in China | Acta Hort. (ISHS) 708: 557-558 | 2006 | China | Strawberry |
| 19 | Provides raw data on strawberry production in Sweden, Switzerland and USA (open ground production) and Sweden (greenhouse production from 4 different sources). | Not clear | Report | Carlsson-Kanyama, A., Faist, M. | Energy Use in the Food sector: a Data Survey | Swedish Environmental Protection Agency, AFR Report 291, Sweden | 2000 | USA, Switzerland, Sweden | Strawberry (open ground, greenhouse) |
| 20 | Estimate of used fertilisers, pesticides, machines, water. Data is rather old. Data can be bought. | LCA | Database | ESU-Services, Jungbluth, Niels | LCI database | | Not clear | Switzerland | Strawberry |

| Key | Evaluation of the source | Method | Medium | Author / Source | Title / Method / Concept Name | Journal / Book / Publication / Publisher | Year | Producing Country | Product |
|---|---|---|---|---|---|---|---|---|---|
| 21 | Data on irrigation water use for Spain and Italy, but no analysis of GHG | LCA | Bachelor thesis | Beyer, J. | Regionale Bewertung der Wassernutzung in einer Oekobilanz am Beispiel der Erdbeerproduktion | Bachelor thesis, Chair of Ecological Systems Design, Swiss Federal Institute of Technology Zurich. | 2008 | Not clear | Strawberry |
| 22 | Information on virtual water content for fruits in China. Fruits are estimated with data based on apples. Data given in m3/kg. | Water footprint | Article | Liu, J. & Savenije, H.H.G. | Foot consumption patterns and their effect on water requirement in China | Hydrology and Earth System Sciences 12:881-898 | 2008 | China | Fruit (based on apples) |
| 23 | Host country Sweden. Information on GHG emissions for berries in general available but processing and distribution to Sweden is included in the amount. | LCA | Article | Wallén, A. Brandt, N., Wennersten, R. | Does the Swedish consumer's choice of food influence greenhouse gas emissions? | Environmental Science & Policy 7: 525-535 | 2004 | Not clear | Berries (fresh & frozen), not strawberries |

### 9.2.5 Contacted Research Institutes and Researchers for Oranges

| Country / Countries | Institution | Name | E-Mail / Telephone | Output |
|---|---|---|---|---|
| All countries | Swiss Federal Institute of Technology Zurich, Switzerland | Franziska Stoessel, Scientific Assistant, Institute of Environmental Engineering (IfU) | franziska.stoessel@ifu.baug.ethz.ch | She has sent some literature abstracts. |
| All countries | ADEME, France | General address for the section of carbon balance | bilan-carbone@ademe.fr | There is no information in the carbon balance of ADEME. |
| All Countries | ESU-Services | Nils Jungbluth | 0041 44 940 61 32 ; jungbluth@esu-services.ch | Information on LCI database for strawberries. Data can be bought. |
| All countries | Water Footprint Network | Arjen Y. Hoekstra, Professor in Multidisciplinary Water Management, University of Twente Scientific Director - Water Footprint Network | A.Y.Hoekstra@ctw.utwente.nl | No distincion between green and blue water footprint in the publication "Water footprints of nations" by Hoekstra & Chapagain (2004). The distinction between green and blue water will be available for strawberries approximately in October 2010. For own calculations of green and blue water he recommends to use the method from the book: Hoekstra, A.Y. & Chapagain, A.K. 2008. Globalization of Water: Sharing the Planet's Freshwater Resources. Wiley-Blackwell. 232 pp. (Appendix I). For the data he recommends to use CROPWAT, CLIMWAT, and yield data from FAO. He adds the information that irr requirement = crop water requirement (output from cropwat) minus effective precipitation AND actual irr depends on irr req and whether irr takes place yes/no. |

| Country / Countries | Institution | Name | E-Mail / Telephone | Output |
|---|---|---|---|---|
| Brazil | Sylvio Moreira Citrus Research Center, Brazil | Dirceu Mattos Junior, Dr. | ddm@centrodecitricultura.br | Reference to LCA study Okuda et al. (2007) from Japan for satsuma mandarin but he does not know of any studies of GHG emission from citrus cultivation in Brazil. The main growing area in Brazil is in São Paolo. Citrus water demand is considered 900-1'200 mm/year. Irrigation usually supplies 300-350 mm/year. The amount is greater during spring and summer. Average application rate is 4 mm/day in North of São Paulo and South of Minas Gerais, based on daily water consumption of 70-150 L/plant/day. Application rates: 0.4-1 mm/hour (literature in Portuguese available e.g. Mattos Jr., D., De Negri, J.D., Pio, R.M., Pompeu Jr. J. 2005. Citros. Campinas: Instituto Agronômico e Fapesp. 929. Estimations on caron stocks in citus groves: Contatct person Mr. Mattos. |
| Brazil | The Carbon Trust, London, UK | Andie Stephens, Senior Customer and Project Manager, Carbon Label Company | Andie.Stephens@CarbonTrust.co.uk | He sent the report from the University of Manchester, Sustainable Consumption Institute. "Consumer, business and climate change". On page 28 there is a breakdown of the Tesco Orange Juice. For more detailed information he recommends to contact Tesco as the own the data. |
| Florida | University of Florida, Institute of Food and Agriculture | James Syvertsen, Professor, Citrus Research and Education Center, Horticultural Sciences | jmsn@ufl.edu | Reference to PepsiCo Carbon Footprint and information on how much Carbon is sequestered and how much Oxygen is release to the air form an average citrus grove per year. |
| Spain | Universitat Politècnica de València, Dpt. Tecnologia d'Aliments, Spain | Sanjuan Pellicer, Neus, Researcher | nsanjuan@tal.upv.es | She has sent an unpublished paper on orange production as well as Further request: The values for the greenhouse gas emissions for both publications. |

### Contacts with experts without response

| Country / Countries | Institution | Name | E-Mail / Telephone |
|---|---|---|---|
| All countries | Ecointesys, Switzerland | Yves Loerincik | yves.loerincik@ecointesys.ch |
| Brazil | Sylvio Moreira Citrus Research Center, Brazil | General address | faleconosco@centrodecitricultura.br |
| Brazil | Sylvio Moreira Citrus Research Center, Brazil | Communication center | cct@iac.sp.gov.br |
| Brazil | Sylvio Moreira Citrus Research Center, Instituto Agronômico, Centro de Frutas, Brazil | General institute address | frutas@iac.sp.gov.br |
| Brazil | | Leda Coltro | Undeliverable. Address invalid. No other contacts found. |
| Brazil | Tesco | Corporate Responsibility Team, Tesco PLC, England. | 'crreport09@uk.tesco.com' |
| China | China Agricultural University, Beijing, China | General university address | caui@cau.edu.cn |
| China | China Agricultural University, Beijing, China | College of Water Conservancy and Civil Engineering | dongquing@cau.edu.cn |
| China | China Agricultural University, Beijing, China | College of Resources and Environmental Sciences | deplnu@cau.edu.cn Undeliverable. Address invalid. No other contact given. |
| China | China Academy of Agriculture Science (CAAS), China | Hyu Zhai | wangxyj@caas.net.cn |
| China | China Academy of Agriculture Science (CAAS), China | Shiwei Xu, Agricultural Information Institute | xushiwei@mail.cass.net.cn |
| China | Chinese Academy of Agricultural Sciences | General academy address | fao@xjau.edu.cn |
| China | South China Agricultural University | General academy address | caie@scau.edu.cn |
| China | South China Agricultural University | Contacts, Office of Communications | xcb@scau.edu.cn |
| Florida | University of Florida, Institute of Food and Agriculture | Arnold Schumann, Associate Professor, Citrus Research and Education Center, Soil and Water Science | schumaw@ufl.edu |
| Florida | University of Florida, Institute of Food and Agriculture | Larry Parsons, Dr., Citrus Research and Education Center, Horticulture, Irrigation | lparsons@ufl.edu |
| Spain | Instituto Valenciano de Investigaciónes Agrarias | Citrus Network, general address | redcitricos@ivia.es |

| Country / Countries | Institution | Name | E-Mail / Telephone |
|---|---|---|---|
| Spain | Instituto Valenciano de Investigaciónes Agrarias | Office for Transfer of Results of Investigation, general adress | otri@ivia.es |
| Spain | Instituto de Agroqímica y Technología de Alimentos (IATA | General adress | info@iata.csic.es |
| Spain | Instituto Valenciano de Investigaciónes Agrarias | Florentin Juste Perez, Director | juste_flo@ivia.gva.es |
| Spain | Mediterranean Agronomic Institute of Zaragoza, Spain | General institute address | iamz@iamz.ciheam.org |

### 9.2.6 Contacted Research Institutes and Researchers for Strawberries

| Country / Countries | Institution | Name | E-Mail / Telephone | Output |
|---|---|---|---|---|
| All Countries | Agroscope Changins-Wädenswil Research Station ACW, Switzerland | André Ançay, Scientific Assistant, Section: Berries | +41 27 345 35 50 | He would not recommend to substitute strawberries with an other fruit as there is no fruit that is similar enough.<br>Contact addresses:<br>Poland: agnieszka.masny@insad.pl<br>China: ytaozhang@gmail.com<br>Morocco: no contacts available |
| All countries | ADEME, France | General address for the section of carbon balance | bilan-carbone@ademe.fr | There is no information in the carbon balance of ADEME. |
| All countries | Swiss Federal Institute of Technology Zurich, Switzerland | Franziska Stoessel, Scientific Assistant, Institute of Environmental Engineering (IfU) | franziska.stoessel@ifu.baug.ethz.ch | She has sent some literature abstracts and the bachelor thesis from Beyer, J. 2008. Regionale Bewertung der Wassernutzung in einer Ökobilanz. Am Beispiel der Erdbeerproduktion in Südeuropa. Institute of Environmental Engineering Ecological System Design. ETH Zürich. Bachelorarbeit. |
| All countries | ESU-Services | Nils Jungbluth | 0041 44 940 61 32 ; jungbluth@esu-services.ch | Information on LCI database for strawberries. Data can be bought. |

| Country / Countries | Institution | Name | E-Mail / Telephone | Output |
|---|---|---|---|---|
| All countries | Water Footprint Network | Arjen Y. Hoekstra, Professor in Multidisciplinary Water Management, University of Twente Scientific Director - Water Footprint Network | | No distinction between green and blue water footprint in the publication "Water footprints of nations" by Hoekstra & Chapagain (2004). The distinction between green and blue water will be available for strawberries approximately in October 2010. For own calculations of green and blue water he recommends to use the method from the book: Hoekstra, A.Y. & Chapagain, A.K. 2008. Globalization of Water: Sharing the Planet's Freshwater Resources. Wiley-Blackwell. 232 pp. (Appendix I). For the data he recommends to use CROPWAT, CLIMWAT, and yield data from FAO. He adds the information that irr requirement = crop water requirement (output from cropwat) minus effective precipitation AND actual irr depends on irr req and whether irr takes place yes/no. |
| China | Unknown | Dr. Yun-Tao Zhang, Contact from Agroscope Changins-Wädenswil Research Station | ytaozhang@gmail.com | Area: 130'000 ha, About 70-80% are greenhouse culture, 20-30% open field culture. He does not have information on GHG emissions or quantities of water used. Recommendation: qiujj@caas.net.cn or qiujj@public3.bta.net.cn |
| Morocco | Institut Agronomique et Vétérinaire Hassan II, Agadir, Morocco | Lachen Kenny, Professor, Department: Horticulture, Section: Horticulture | kenny@iavcha.ac.ma | He does not know of any LCA literature on GHG and water. Data on water consumption and GHG emissions of strawberry may exist but in Master or PhD Thesis and technical reports of the private companies. |
| Poland | Warsaw University of Life Science | General university address for enquiries | info@sggw.pl | They suggest to contact Edward Zurawicz<br>Contact: Edward.Zurawicz@insad.pl |

| Country / Countries | Institution | Name | E-Mail / Telephone | Output |
|---|---|---|---|---|
| Poland | Research Institute of Pomology and Floriculture, Poland | Waldemar Treder | wtreder@insad.pl | Water usage in strawberry production. Glasshouse production rather marginal. Climatic conditions and technologies of production similar to East areas of Germany. No Co2 application in glasshouse production. Only a few percents of strawberry plantations are irrigated by sprinklers or drippers. Approx. 50-150 mm of water season depending on weather conditions and irrigation type. He does not know of any LCA research centres or studies on Strawberries in Poland. |
| United Kingdom | University of Warwick, United Kingdom | Robert Lillywhite | Robert.Lillywhite@warwick.ac.uk | Yield = 18 t/h, values in CO2e/ha |
| United Kingdom | | Adrian Williams | adrian.williams@cranfield.ac.uk | Spain: 40 t/ha, UK: weighted mean of several systems: 20 t/ha. The 0.7 vs. 0.85 t CO2e/t difference probably comes from editing the paper while still working on the results. 0.85 is the correct value. Pre-farm gate includes fertilisers, cultivations, containers, poly tunnels etc and the output is strawberries. |
| Japan | Ritsumeikan University, Japan | Yoshikawa, Naoki | ec081018@se.ritsumei.ac.jp | The difference of two values comes from their functional unit: kg-production and kg-consumption.Because of assumption of distribution loss (18%), farmers produce 1/(1-0.18)kg strawberry for 1kg consumption.So LC-GHG emission per kg-consumption in agricultural production stage is 3.99 / (1-0.18)=4.9 kg. |

### Contacts with experts without response

| Country / Countries | Institution | Name | E-Mail / Telephone |
|---|---|---|---|
| All countries | Ecointesys, Switzerland | Yves Loerincik | yves.loerincik@ecointesys.ch |
| China | China Agricultural University, Beijing, China | General university address | caui@cau.edu.cn |
| China | China Agricultural University, Beijing, China | College of Water Conservancy and Civil Engineering | dongquing@cau.edu.cn |
| China | China Agricultural University, Beijing, China | College of Resources and Environmental Sciences | deplnu@cau.edu.cn |
| China | China Academy of Agriculture Science (CAAS), China | Hyu Zhai | wangxyj@caas.net.cn |
| China | China Academy of Agriculture Science (CAAS), China | Shiwei Xu, Agricultural Information Institute | xushiwei@mail.cass.net.cn |
| China | Chinese Academy of Agricultural Sciences | General academy address | fao@xjau.edu.cn |
| China | South China Agricultural University | General academy address | caie@scau.edu.cn |
| China | South China Agricultural University | Contacts, Office of Communications | xcb@scau.edu.cn |
| Morocco | Ministry of Agriculture and Fishery, Morocco | General address | info@madrpm.gov.ma |
| Morocco | Moroccan Association of Producers/Exporters of Strawberries "AMCEF", Morocco | Mr. Mohamed Alamouri, President of the association | alamouri@menara.ma |
| Morocco | Fresouer Sarl, Morocco | General address of the company, Mr. Larbi Chaib, Manager | fresouersarl@menara.ma |
| Morocco | Institut Agronomique et Vétérinaire Hassan II, Agadir, Morocco | Hassan Mounhim, Department: Horticulture, Section: Irrigation | mounhim@iavcha.ac.ma |
| Morocco | Institut Agronomique et Vétérinaire Hassan II, Agadir, Morocco | Hassan Elattir, Professor, Department: Horticulture, Section: Horticulture & Irrigation | elattir@gmail.com |
| Morocco | Institut Agronomique et Vétérinaire Hassan II, Agadir, Morocco | Aomar Amellouk, Department: Horticulture, Section: Fertilisers | amellouk@iavcha.ac.ma |

| Country / Countries | Institution | Name | E-Mail / Telephone |
|---|---|---|---|
| Morocco | Légumes et Fruits au Maroc, Morocco | Author of the site is M. Ahmed Skiredj, who has worked in the Horticulture Department at the Institut Agronomique et Vétérinaire Hassan II, Agadir, Morocco | http://www.legume-fruit-maroc.com/contact.php |
| Morocco | Mediterranean Agronomic Institute of Zaragoza, Spain | General institute address | iamz@iamz.ciheam.org |
| Morocco | fruit & legume. L'art de produire le legumes et les fruit au Maroc | General address | http://www.legume-fruit-maroc.com/contact.php |
| Poland | Research Institute of Pomology and Floriculture, Poland | General research Institute address | isad@insad.pl |
| Poland | Research Institute of Pomology and Floriculture, Poland | Barbara Michalczuk, Contact for general enquiries of the research institute | Barbara.Michalczuk@insad.pl |
| Poland | Research Institute of Pomology and Floriculture, Poland | E. Zurawicz, Research on Strawberries | e.zurawicz@insad.pl |
| Poland | Research Institute of Pomology and Floriculture, Poland | Agnieszka Masny, Contact from Agroscope Changins-Wädenswil Research Station | agnieszka.masny@insad.pl |
| Spain, Scotland | The Co-operative Group, United Kingdom | Customer Relations | customer.relations@co-operative.coop |
| Spain, Scotland | The Co-operative Group, United Kingdom | Customer Relations | customer.relations@co-operative.coop |

## 9.3 Producing Countries: Detailed Data Oranges

**Top 20 Countries 2003-2007. Source: FAO (2009).**

**Production (t)**

| Country | Mean (2003-2007) | % of all countries | Rank |
|---|---|---|---|
| Brazil | 17'960'415 | 28.3 | 1 |
| United States of America | 9'213'497 | 14.5 | 2 |
| Mexico | 4'068'267 | 6.4 | 3 |
| India | 3'166'820 | 5.0 | 4 |
| Spain | 2'838'393 | 4.5 | 5 |
| China | 2'613'207 | 4.1 | 6 |
| Iran, Islamic Republic of | 2'214'536 | 3.5 | 7 |
| Indonesia | 2'183'642 | 3.4 | 8 |
| Italy | 2'147'934 | 3.4 | 9 |
| Egypt | 1'865'357 | 2.9 | 10 |
| Pakistan | 1'551'093 | 2.4 | 11 |
| Turkey | 1'391'554 | 2.2 | 12 |
| South Africa | 1'320'299 | 2.1 | 13 |
| Greece | 856'442 | 1.4 | 14 |
| Morocco | 782'820 | 1.2 | 15 |
| Argentina | 774'843 | 1.2 | 16 |
| Viet Nam | 568'220 | 0.9 | 17 |
| Syrian Arab Republic | 500'874 | 0.8 | 18 |
| Australia | 494'133 | 0.8 | 19 |
| Algeria | 441'425 | 0.7 | 20 |
| **All countries (114)** | **63'422'549** | **100** | |

**Area (ha)**

| Country | Mean (2003-2007) | % of all countries | Rank |
|---|---|---|---|
| Brazil | 818'415 | 21.5 | 1 |
| India | 381'260 | 10.0 | 2 |
| China | 348'516 | 9.1 | 3 |
| Mexico | 327'213 | 8.6 | 4 |
| United States of America | 284'991 | 7.5 | 5 |
| Spain | 143'267 | 3.8 | 6 |
| Iran, Islamic Republic of | 142'167 | 3.7 | 7 |
| Pakistan | 131'568 | 3.5 | 8 |
| Italy | 104'654 | 2.7 | 9 |
| Egypt | 85'419 | 2.2 | 10 |
| Indonesia | 67'674 | 1.8 | 11 |
| Argentina | 60'000 | 1.6 | 12 |
| Viet Nam | 56'700 | 1.5 | 13 |
| Ghana | 54'700 | 1.4 | 14 |
| Morocco | 49'160 | 1.3 | 15 |
| South Africa | 44'527 | 1.2 | 16 |
| Turkey | 40'898 | 1.1 | 17 |
| Greece | 40'095 | 1.1 | 18 |
| Cuba | 35'463 | 0.9 | 19 |
| Algeria | 30'334 | 0.8 | 20 |
| **All countries (114)** | **3'812'391** | **100** | |

**Yield (kg/ha)**

| Country | Mean (2003-2007) | Rank |
|---|---|---|
| Turkey | 34'030 | 1 |
| United States of America | 32'361 | 2 |
| Indonesia | 32'019 | 3 |
| South Africa | 30'104 | 4 |
| Guatemala | 29'791 | 5 |
| Syrian Arab Republic | 29'354 | 6 |
| Israel | 28'830 | 7 |
| Occupied Palestinian Terr. | 24'190 | 8 |
| Lebanon | 22'238 | 9 |
| Brazil | 21'954 | 10 |
| Egypt | 21'832 | 11 |
| Greece | 21'355 | 12 |
| Australia | 20'789 | 13 |
| Italy | 20'531 | 14 |
| Spain | 19'968 | 15 |
| Uruguay | 19'899 | 16 |
| Azerbaijan | 18'878 | 17 |
| Thailand | 17'579 | 18 |
| Chile | 17'440 | 19 |
| Jordan | 17'302 | 20 |
| **All countries (114)** | **16'635** | |

**Brazil, China, Spain, United States of America 2003-2007. Source: FAO (2009).**

**Production (t)**

| Country | Mean (2003-2007) | % of all countries | Rank |
|---|---|---|---|
| Brazil | 17'960'415 | 28.3 | 1 |
| China | 2'613'207 | 4.1 | 6 |
| Spain | 2'838'393 | 4.5 | 5 |
| United States of America | 9'213'497 | 14.5 | 2 |
| **All countries (114)** | **63'422'549** | **100** | |

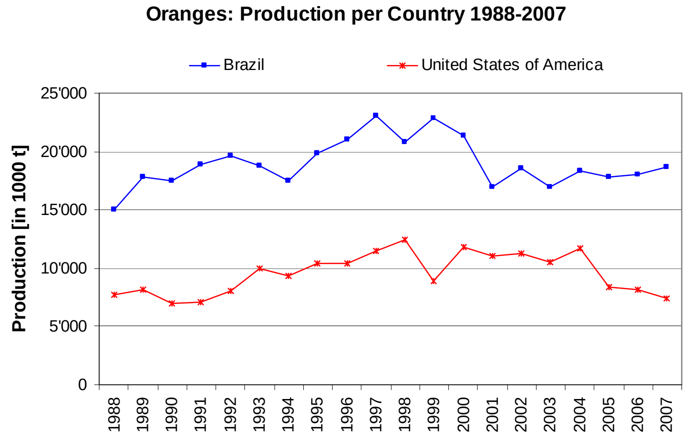
**Area (ha)**

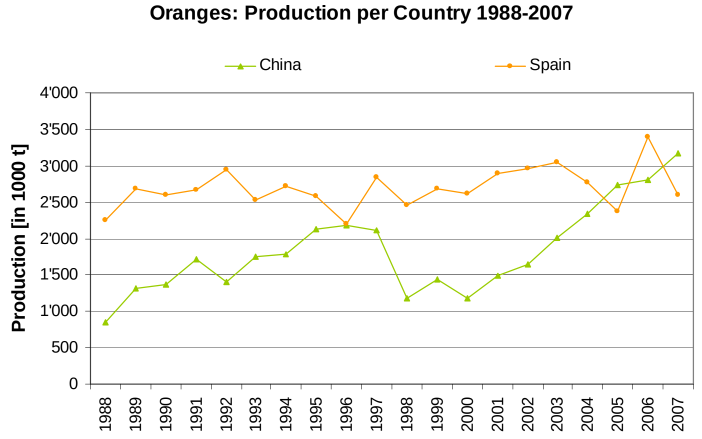
| Country | Mean (2003-2007) | % of all countries | Rank |
|---|---|---|---|
| Brazil | 818'415 | 21.5 | 1 |
| China | 348'516 | 9.1 | 3 |
| Spain | 143'267 | 3.8 | 6 |
| United States of America | 284'991 | 7.5 | 5 |
| **All countries (114)** | **3'812'391** | **100** | |

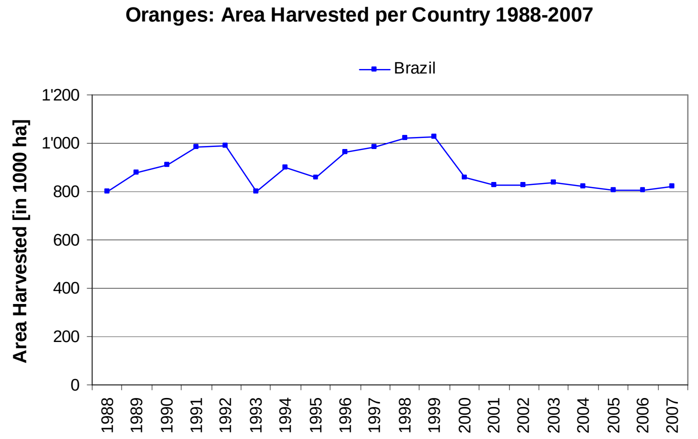
**Yield (kg/ha)**

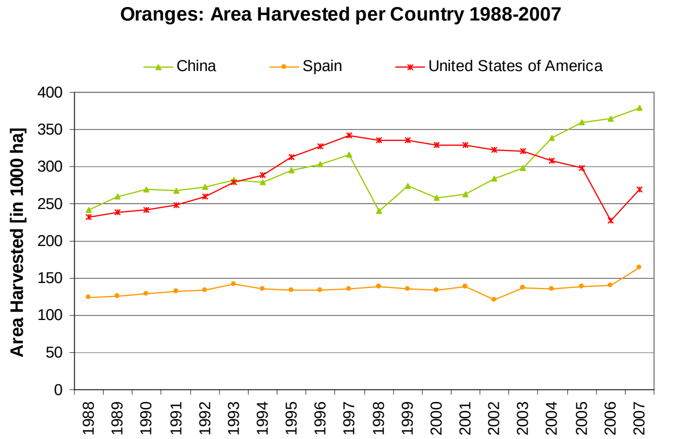
| Country | Mean (2003-2007) | Rank |
|---|---|---|
| Brazil | 21'954 | 10 |
| China | 7'455 | 67 |
| Spain | 19'968 | 15 |
| United States of America | 32'361 | 2 |
| **All countries (114)** | **16'635** | |

**Production and Area harvested Brazil, China, Spain, United States of America 1998-2007. Source: FAO (2009).**

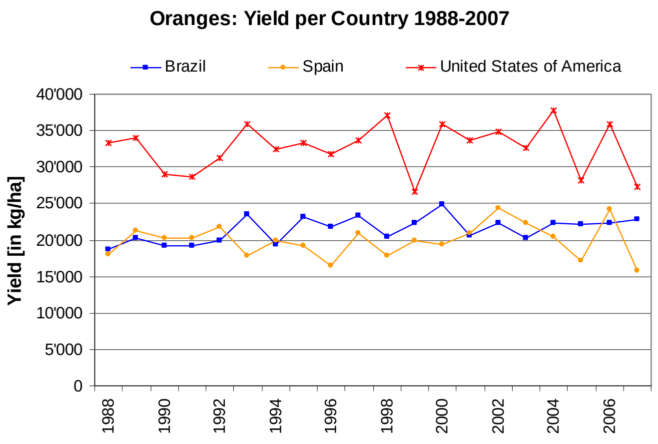


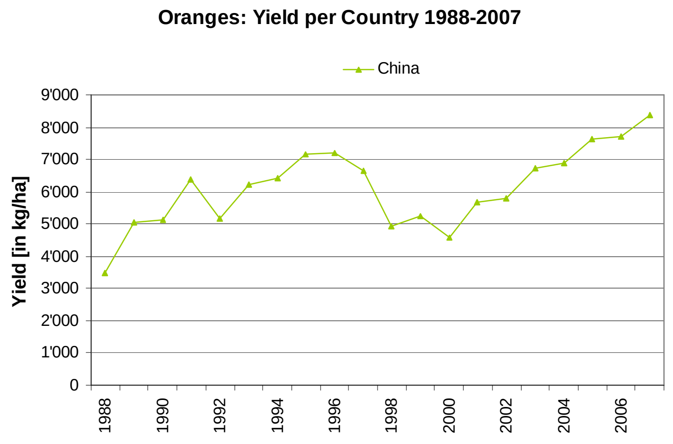



## Yield for Brazil, China, Spain, United States of America 1998-2007. Source: FAO (2009).



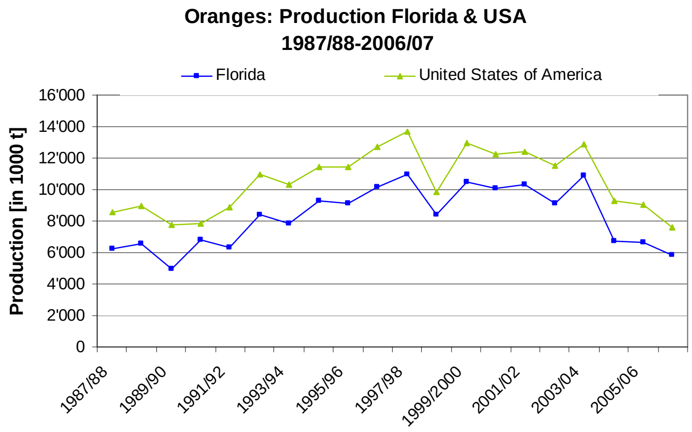



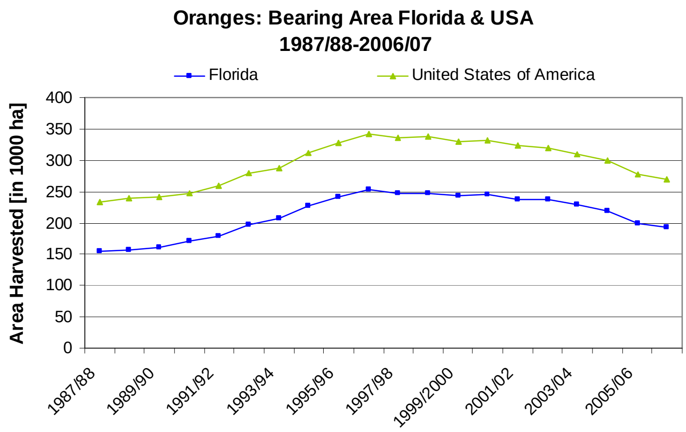

.

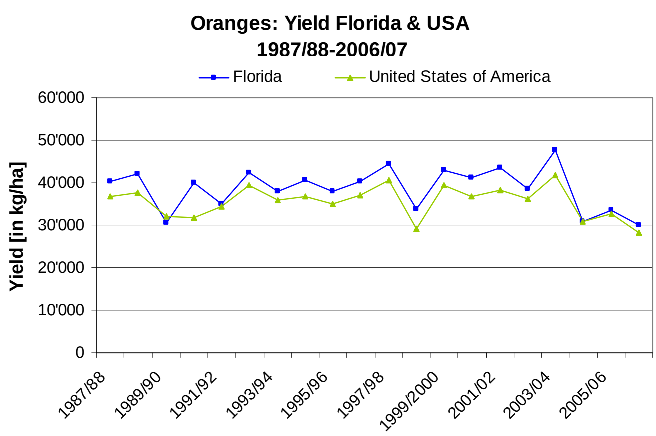
**Florida and United States of America 2002/03-2006/07. Source: FASS (2009)**

| | Production (t) | | Area (ha) | | Yield (kg/ha) |
|---|---|---|---|---|---|
| | Mean (02/03-06/07) | % of total | Mean (02/03-06/07) | % of total | Mean (02/03-06/07) |
| Florida | 7'843'600 | 77.9 | 215'384 | 73.0 | 38'680 |
| USA | 10'063'000 | 100.0 | 295'059 | 100.0 | 35'515 |

**Production, Bearing Area and Yield for Florida and United States of America 2002/03-2006/07. Source: FASS (2009).**



## 9.4 Producing Countries: Detailed Data Strawberries

**Top 20 Countries 2003-2007. Source: FAO (2009).**

**Production (t)**

| Country | Mean (2003-2007) | % of all countries | Rank |
|---|---|---|---|
| United States of America | 1'051'898 | 28.4 | 1 |
| Spain | 302'873 | 8.2 | 2 |
| Russian Federation | 216'780 | 5.9 | 3 |
| Korea, Republic of | 203'691 | 5.5 | 4 |
| Japan | 196'200 | 5.3 | 5 |
| Turkey | 193'289 | 5.2 | 6 |
| Poland | 173'957 | 4.7 | 7 |
| Mexico | 171'671 | 4.6 | 8 |
| Germany | 138'610 | 3.7 | 9 |
| Italy | 131'666 | 3.6 | 10 |
| Morocco | 105'440 | 2.8 | 11 |
| Egypt | 97'748 | 2.6 | 12 |
| United Kingdom | 65'860 | 1.8 | 13 |
| France | 49'705 | 1.3 | 14 |
| Belgium | 41'500 | 1.1 | 15 |
| Ukraine | 40'800 | 1.1 | 16 |
| Netherlands | 38'840 | 1.0 | 17 |
| Iran, Islamic Republic of | 35'243 | 1.0 | 18 |
| Belarus | 34'420 | 0.9 | 19 |
| Serbia | 34'293 | 0.9 | 20 |
| **All countries (76)** | **3'705'603** | **100** | |

**Area (ha)**

| Country | Mean (2003-2007) | % of all countries | Rank |
|---|---|---|---|
| Poland | 51'873 | 20.5 | 1 |
| Russian Federation | 33'920 | 13.4 | 2 |
| United States of America | 20'964 | 8.3 | 3 |
| Germany | 12'585 | 5.0 | 4 |
| Turkey | 10'610 | 4.2 | 5 |
| Serbia and Montenegro | 8'695 | 3.4 | 6 |
| Spain | 8'490 | 3.4 | 7 |
| Ukraine | 8'120 | 3.2 | 8 |
| Serbia | 8'001 | 3.2 | 9 |
| Korea, Republic of | 7'056 | 2.8 | 10 |
| Belarus | 6'940 | 2.7 | 11 |
| Japan | 6'940 | 2.7 | 12 |
| Mexico | 6'008 | 2.4 | 13 |
| Italy | 5'292 | 2.1 | 14 |
| Canada | 4'064 | 1.6 | 15 |
| United Kingdom | 3'994 | 1.6 | 16 |
| Egypt | 3'662 | 1.5 | 17 |
| Iran, Islamic Republic of | 3'652 | 1.4 | 18 |
| Finland | 3'527 | 1.4 | 19 |
| France | 3'484 | 1.4 | 20 |
| **All countries (76)** | **252'471** | **100** | |

**Yield (kg/ha)**

| Country | Mean (2003-2007) | Rank |
|---|---|---|
| United States of America | 50'154 | 1 |
| Morocco | 38'824 | 2 |
| Spain | 35'939 | 3 |
| Belgium | 33'580 | 4 |
| Israel | 32'000 | 5 |
| Occupied Palestinian Territ. | 31'114 | 6 |
| Costa Rica | 30'309 | 7 |
| Colombia | 29'641 | 8 |
| Korea, Republic of | 28'924 | 9 |
| Mexico | 28'551 | 10 |
| Japan | 28'273 | 11 |
| Egypt | 26'663 | 12 |
| Kuwait | 26'044 | 13 |
| Chile | 25'341 | 14 |
| Réunion | 25'000 | 15 |
| New Zealand | 24'647 | 16 |
| Italy | 24'323 | 17 |
| Netherlands | 23'971 | 18 |
| Tunisia | 23'756 | 19 |
| Greece | 22'095 | 20 |
| **All countries (76)** | **14'668** | |

**China, Morocco and Poland 2003-2007. Source: FAO (2009).**

**Production (t)**

| Country | Mean (2003-2007) | % of all countries | Rank |
|---|---|---|---|
| China | 11'656 | 0.3 | 31 |
| Morocco | 105'440 | 2.8 | 11 |
| Poland | 173'957 | 4.7 | 7 |
| **All countries (76)** | **3'705'603** | **100** | |

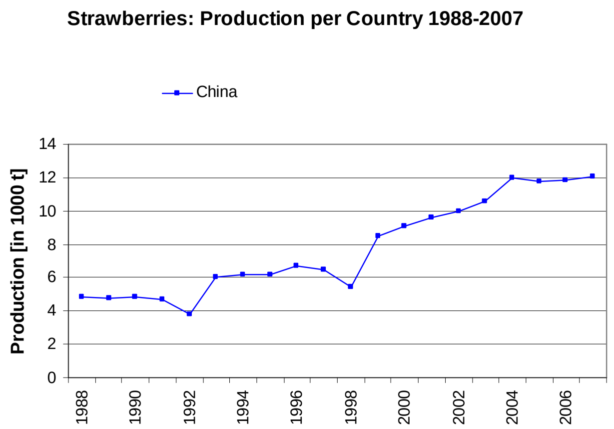
**Area (ha)**

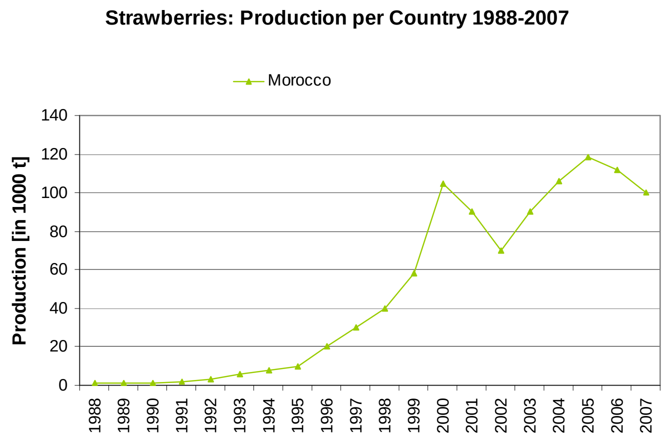
| Country | Mean (2003-2007) | % of all countries | Rank |
|---|---|---|---|
| China | 971 | 0.4 | 38 |
| Morocco | 2718 | 1.1 | 21 |
| Poland | 51'873 | 20.5 | 1 |
| **All countries (76)** | **252'471** | **100** | |

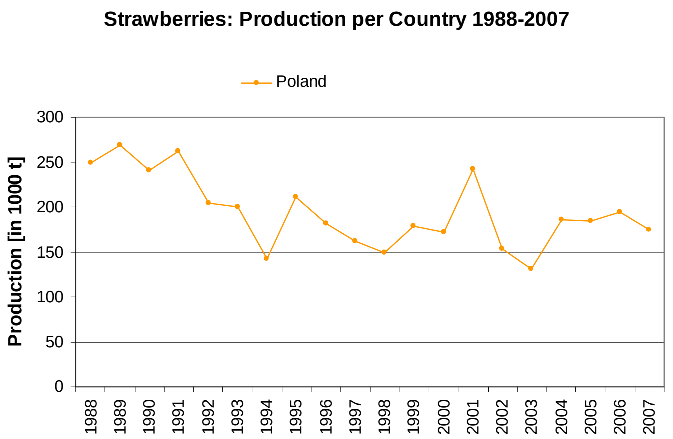
**Yield (kg/ha)**

| Country | Mean (2003-2007) | Rank |
|---|---|---|
| China | 12'284 | 33 |
| Morocco | 38'824 | 2 |
| Poland | 3'340 | 70 |
| **All countries (76)** | **14'668** | |

**Production China, Morcco and Poland 1998-2007. Source: FAO (2009).**



## Area Harvested and Yield for China, Morcco and Poland 1998-2007. Source: FAO (2009).