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November 2011

Geographical extrapolation of environmental impact of crops by the MEXALCA method

Unilever-ART project no. CH-2009-0362 "Carbon and Water Data for Bio-based Ingredients": final report of phase 2: Application of the Method and Results

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Executive summary

The extrapolation method MEXALCA (Modular EXtrapolation of Agricultural LCA) enables LCIA results to be estimated for a crop in a specific (target) country using the LCIA data of the same crop in another (original) country. The existing or original crop inventory (LCI) is split into nine modules corresponding to the main on-field and post-harvest activities, each associated to its key farming input. This approach reduces the complexity of the inventories, and data collection is focused on nine inputs in the target country. Additionally, data can be approximated by means of statistical estimators if necessary. Impacts per unit of farming input are calculated for each module in the original country and combined with the quantity of farming inputs in the target countries in order to determine the impacts in the latter. Combining MEXALCA with available national statistics provides the means for a rapid evaluation of environmental impacts of a given crop for all producing countries globally and the determination of their statistical distribution.

This report describes the changes made since the first report (Roches & Nemecek, 2009), namely the improvement of the agricultural indices (treatment of missing and extreme values), adaptations to the irrigation and drying indices, consideration of carbon loss through deforestation, and adoption of no-till farming.

The method was applied to a total of 27 different crops in this report. The goal of this report is to present the results for these crops, to validate the method against data from ecoinvent and the literature, to determine the most relevant factors contributing to the global warming potential (GWP), and to identify the factors driving the variability of Global Warming Potential (GWP).

Validation was performed with data from the ecoinvent database and from the literature for the impact categories non-renewable energy demand and global warming potential. Overall the validation showed a fair agreement between extrapolated impacts and ecoinvent or the literature values. The extrapolation fit was better when expressed per ha than per kg of product. The fit between extrapolated results and ecoinvent data was lower, when only the target countries were considered, i.e. the original countries were omitted from the analysis. The variability of the impacts seems to be generally underestimated by MEXALCA, which can be explained by the fact that not all sources of variability are included in the model.

The weighted worldwide means of GWP values of the studied crops varied across a wide range (factor of 20 per hectare, factor of 100 per kg of product). The lowest GWP values per kg of fresh mass (without considering land use change) were found for the sugar crops with high yields (sugarcane and sugarbeet), followed by root crops (carrot, potato), fruits, vegetables and oil palm. Cereals (except rice), pulses, rapeseed and soybean had medium GWP values. High values were found for treenuts, the oil crops (linseed, cotton, peanuts), and rice. Fruits, vegetables and cereals (except rice) each formed relatively homogeneous groups with widely overlapping ranges. The same holds for the sugar crops and root crops. Treenuts seem to have relatively similar values, but only two species were included in the study. Oil crops are a very inhomogeneous group including oil palm with low GWP, rapeseed with medium values and linseed, cotton and peanuts with high values.

The GWP was dominated by N fertilisers and nitrogenous emissions, energy use for irrigation, use of the machinery and carbon losses following land use change. The relative contribution of the different modules varied widely between the crops.

The yield and the farming intensity in the different countries (as expressed by the agricultural indices) were found to be relevant factors for the variability of GWP. The GWP values varied more per area than per kg, except for the crops, where the area-related impacts dominated (rice, pea). The variability of GWP increased with its magnitude, which led to relatively constant coefficients of variation. When the impacts of different crops were compared, no

relationship per ha was found, but the GWP tended to decrease per kg with higher yields. The highest yields are achieved for crops with high water contents in the harvested products, like vegetables, fruits, roots and sugar crops. The comparison of the production of the same crop in different countries showed an increasing tendency of GWP per ha with higher yields, which is explained by a higher production intensity. There was in general no relationship for the GWP per kg. The selection of the producing countries was found to have a dominant effect on the variability of GWP. Crops that are produced in a few countries only and crops with homogeneous production conditions tend to have a low variability of GWP.

Further factors that were not considered in this study are also expected to contribute to the variability of GWP: different farming systems, differences in input use, pedo-climatic conditions, variability of the production within a country, and land use change impacts.

An analysis performed on regionally grouped countries (grouping by development level, and part of continents) showed that the yields generally increase in the order least developed countries (LDC), developing and developed countries. The GWP per ha (average of relative values of all studied crops) showed the same trend without consideration of the deforestation. Inclusion of deforestation almost compensated the differences between the development levels. GWP per kg was highest in developing countries, followed by developed and LDC with deforestation. With the inclusion of deforestation, it increased in the order developed < developing < LDC; i.e. the finding suggests that the currently observed deforestation is linked to low level of development.

A principal component analysis showed the similarities and different between the environmental profiles of the studied crops. It seems difficult to derive general rules to group similar crops together. Cereals (without rice), sugar crops (sugar cane and sugarbeet), and tuber and root crops were relatively similar, while oil crops formed a very inhomogeneous group. A lot of variation was found within fruits and vegetables, however clear subgroups could not be identified. Treenuts seem to be quite different from other crops.

Options for future development of the model include: using more robust irrigation data, combining several original inventories in order to reduce the dependency on a single original inventory, or the inclusion of crop specific data in the agricultural indices and the input estimators, in order to assess better the farming practices of the individual crops.

Acknowledgements

We would like to thank Unilever company for funding this research. The following collaborators of Unilever contributed to this research in numerous discussions and exchanges: Llorenç Milà i Canals, Sarah Sim, Tirma Garcia-Suarez, Donna Jefferies and Henry King.

The authors would like to thank the following contacts for their valuable advice and/or the provision of data:

Linseed: B. Hall, President, Flax Council of Canada; M. Praczyk and K. Heller, Institute of Natural Fibres and Medicinal Plants, Poland.

Almonds: J. Connell, Farm Advisor, University of California Cooperative Extension, Oroville, California, USA.

Peach: Colors Foundation, South Africa.

Oil palm: M. Razalia Mahidin, Malaysian Palm Oil Board, Malaysia.

Oranges: B. Boman, University of Florida, Indian River Research and Education Centre, Florida, USA.

Onions: R. Jampen, Onion Farmer, Switzerland, Schweizerische Zentralstelle für Gemüsebau, Koppingen, Switzerland.

Onions/Spinach: R. Neuweiler, Deputy Head Vegetable Gardening, Research Station Agroscope Changins-Wädenswil ACW, Switzerland.

Tomatoes: N. Schauer; USDA – National Agricultural Statistics Service; USA; David Meester, Operations/Engeneering Manager, California Tomato Machinery, USA.

Hazelnuts: K. Demiryurek, Ondokuz Mayis University, Turkey; J. Tous, Director Olivicultura, Spain.

Bananas: I. de Barros, INRA - ASTRO Agrosystemes Tropicaux, Guadeloupe, France; T. Lescot, CIRAD, France.

Pumpkins: R.E. Call, Area Horticulture Educator/Agent, University of Arizona, USA.

Apples: A. Butcher, AgriLINK NZ Ltd, New Zealand; M. Butcher, Technical Manager, Pipfruit NZ Inc, New Zealand.

Irrigation: A. Hoekstra, Professor in multidisciplinary water management, University of Twente, Netherlands.

No-till cultivation: Rolf Derpsch, Shopping del Sol, Asunción, Paraguay; Wolfgang Sturny, Andreas Chervet, Bodenschutzfachstelle des Kantons Bern, Rütti, Zollikofen, Switzerland; Bernhand Streit, Swiss College for Agriculture, SHL, Switzerland; Hanspeter Lauper, Swiss No-Till; Thomas Anken, Agroscope Reckenholz-Tänikon Research Station ART, Switzerland.

General: We thank Gérard Gaillard for his valuable comments. Magda Walker, Institute of Soil Science and Plant Cultivation, Pulawy, Poland who contributed data to several inventories during their stay at ART.

Abbreviations and acronyms

ART	Agroscope Reckenholz-Tänikon Research Station
BR	Brazil
CED	Cumulative Energy Demand
CH	Switzerland
D.M.	Dry matter
Eq (or eq)	Equivalent
F.M.	Fresh matter
FS	File System
GS	Growing season
GWP	Global warming potential
ha	Hectare
IP	Integrated Production
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
l	Litre
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LDC	Least developed countries
LU	Livestock Unit
MJ	Mega joules
MY	Malaysia
SALCA	Swiss Agricultural Life Cycle Assessment
USA or US	United States of America

1 Introduction

Life Cycle Assessments (LCAs) are increasingly used in the food sector to estimate the environmental impacts of agricultural and processed products. Because of today's globalised and rapidly changing supply chains, businesses wishing to assess and reduce the impacts of their product portfolios urgently need data on diverse production systems and many crops for use in LCA studies. However, these data are seldom available and it is too time and cost intensive to calculate detailed LCAs for a multitude of products and ingredients of processed foods originating from all over the world. Nevertheless, businesses are attempting to address environmental issues such as climate change, pollution and land use due to corporate needs and the ever increasing importance of environmental management. In order to overcome the problem of lacking data, several approaches are currently applied, e.g. the use of proxy data and generalisations or simplified LCAs that do not consider all processes involved (2011). For example, inventories and assessment results obtained in a particular study might be used in a new and different situation without adaptation to the specific situation analysed. Simplified and streamlined approaches require less input data than a full LCA, but might exclude potentially important inputs or processes.

Another possible approach to generate the large amounts of data needed to assess complete product portfolios in a faster and more practicable way is the geographical extrapolation of existing detailed life cycle inventories and impacts. The method presented here allows this extrapolation in an attempt to enable a simplified assessment for agricultural and horticultural crops for all producing countries worldwide while still considering all relevant processes. The data generated are intended to inform strategic decision making, identify hot spots of environmental impacts during the crop production stage, and help understand the variability of production systems across different geographical scales.

This is the final report of the second project phase of the development of the methodology MEXALCA (**M**odular **EX**trapolation of **A**gricultural **LCA**) for geographical extrapolation (see Roches & Nemecek (2009) for the first phase). The geographical extrapolation as conducted by MEXALCA is a series of mostly automated Excel spreadsheets independent of any particular LCA software, but in the present study the software TEAM and additional tools called SALCA (Swiss Agricultural LCA, Nemecek *et al.* (2010)) were used to calculate the environmental impacts of one original country system that are then used during the extrapolation.

The report is structured as follows: chapter 2 briefly presents the methodology and highlights in particular the changes since the report of Roches & Nemecek (2009). Chapter 3 briefly outlines the construction of the original inventories (a full description is included in Appendix A). Chapters 4 to 7 present the results of MEXALCA for 27 crops, complemented by regionally detailed results for GWP in Appendix B. The discussion (chapter 8) shows the potentials and limitations of MEXALCA, followed by the conclusions and outlook in chapter 9. For a full documentation of the method and complete analysis results, the reader is also referred to:

- Roches & Nemecek (2009): report of project phase 1
- Roches *et al*. (2010): description of the methodology and first validation
- Weiler *et al*. (2010): sensitivity of MEXALCA to varying yields
- Nemecek *et al.* (2011a): results of the contribution analysis and the analysis of relationships between yield and GWP
- Nemecek *et al.* (2011b): validation results and analysis of variability of GWP

2 Methodology

2.1 Overview

The MEXALCA method is based on a modular system and covers crop production from the extraction of raw materials to the farm gate. The starting point for any crop to be analysed is a detailed production dataset from one country, preferably one of the main producers of this crop worldwide and representing the average across different production systems in that country. Because this original inventory is the basis for the extrapolation, its data quality determines the results for all other countries, and it should be attempted to define as representative and complete a system as possible, using data from respected sources and/or expert knowledge. This 'original' dataset is split into nine modules corresponding to the main farming operations and inputs known to dominate the environmental impacts of crop cultivation: basic cropping operations (including the minimum operations and inputs to grow the crop); variable machinery use (any additional use of machinery to increase yields); use of machinery for tillage; nitrogen, potassium and phosphorus fertilisation; plant protection; irrigation; and product drying. Using LCA software, the environmental impacts per unit input are determined for each module. Because each of the nine modules is driven by a single parameter (Roches *et al.*, 2010), the extrapolation to other countries then only requires data on the main input per module. If these data are not available for the countries under study, they can be estimated using input quantities calculated on the basis of the amount of input used in the original country, scaled up or down by dividing the yield in the target country by the average yield in the original country and agricultural indices reflecting the intensity of agricultural production in each country (use of estimators). These latter were defined for each country worldwide based on FAOSTAT (2009) data by dividing the average amount of input use per country (e.g. kg N fertiliser ha^{-1}) obtained from FAOSTAT (2009) by the weighted world average. The extrapolation therefore is carried out by defining the intensity of input use relative to the original country system. The results are an estimation of the environmental impacts for each country in the world producing the crop analysed. A detailed description of the methodology is available in Roches & Nemecek (2009) and Roches *et al*. (2010). The flow chart in Fig. 1 illustrates the MEXALCA model. The environmental impacts from crop production for the original country system are assessed using the LCA software TEAM and SALCA tools (Nemecek *et al.*, 2010).

The method was validated in the first project phase using data from ecoinvent, in order to test whether MEXALCA produces results which are consistent with the ecoinvent data. It was conducted for barley, wheat, rye, potatoes and peas, plotting the ecoinvent results against those obtained using MEXALCA, both for the original country and any other country contained in ecoinvent. The results of this first validation are described in Roches *et al*. (2009, 2010) and indicate that MEXALCA works reasonably well for the impact categories energy demand, global warming potential, ozone formation and land occupation, but not for nutrient enrichment, acidification and toxicity.

In section 2 of this report, the changes that were made to the methodology since the report on the first project phase which concluded in June 2009 (Roches *et al*., 2009) are described, namely the treatment of data gaps and extreme values in the data from FAOSTAT (2009; section 2.2.2), the calculation of the agricultural indices for irrigation and drying (sections 2.2.3 and 2.2.4) as well as carbon losses resulting from deforestation (section 2.3) and the adoption of no-till cultivation methods (section 2.4) which are new additions to MEXALCA.

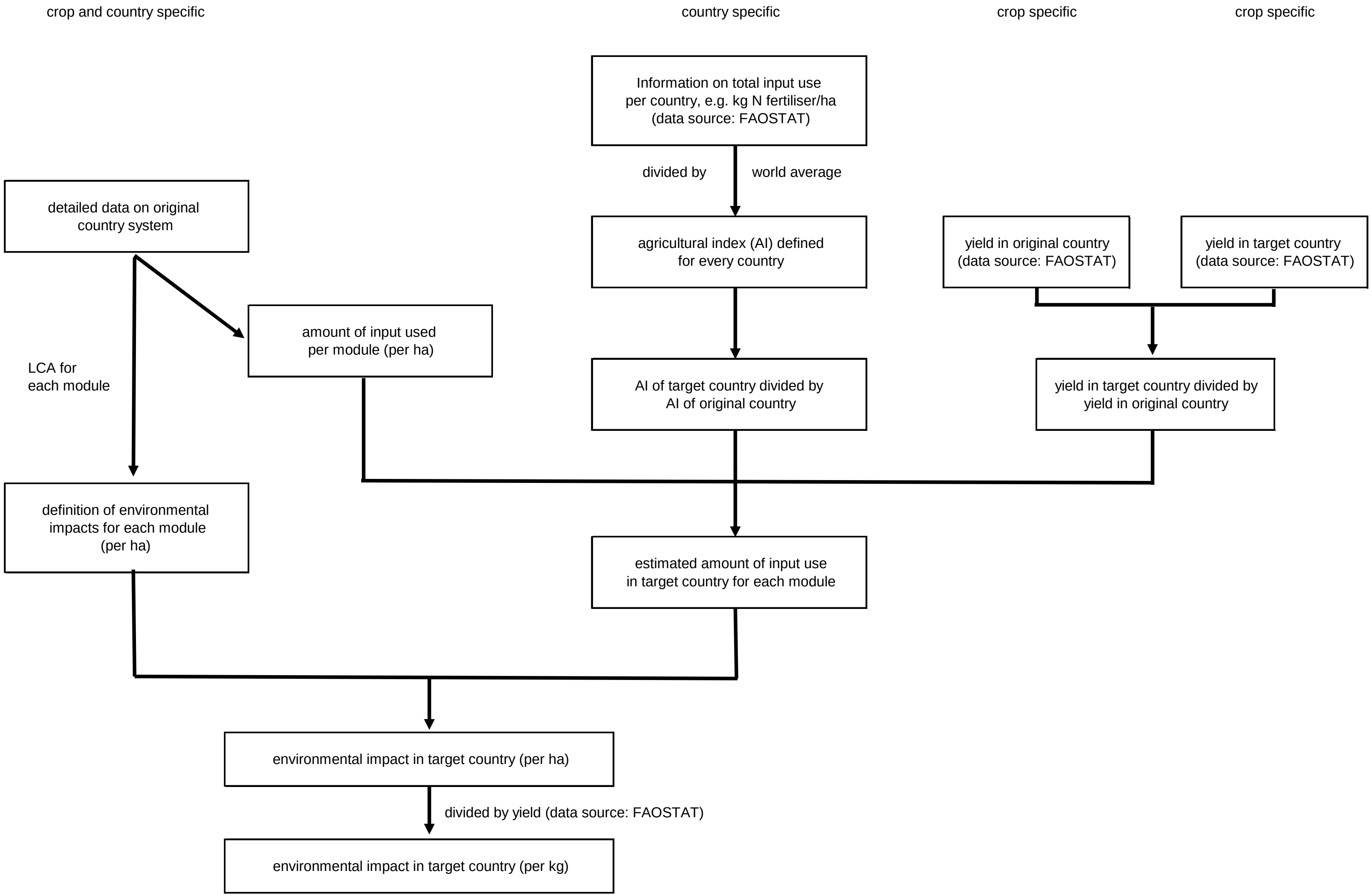


Fig. 1: An overview of the workflow of MEXALCA.

2.2 AGRICULTURAL INDICES

This section explains the changes and additions to the methodology as described in Roches & Nemecek (2009). Note that the publication of Roches *et al.* (2010) already included most of these changes with the following exceptions: the change in the formula of the irrigation estimator (inclusion of the yield effect) and the effects of deforestation were not considered in Roches *et al.* (2010).

2.2.1 Data gaps in FAOSTAT

Missing data in FAOSTAT (2009) on some inputs meant that agricultural indices could not be calculated for all countries and modules. In the previous version such data gaps were replaced by the world average, which is expected to lead to an underestimation of the effective variability. In order to be able to fill in data gaps for agricultural indices all countries were classified using two classifications as defined by the UN (http://unstats.un.org/unsd/methods/m49/m49regin.htm).

First, all countries were classified according to geographical regions and sub-regions. All regions are mutually exclusive and are arranged according to continents where possible. Second, the level of development was also considered based on the UN classification of countries as either developed or developing. This grouping of countries is an aggregation of geographical regions and sub-regions on the basis of whether they are mainly composed of developed or developing countries. In addition, the category ‘developing countries’ was further divided into developing countries and Least Developed Countries (LDCs) as defined by the UN, because LDCs are expected to differ in their agricultural indices from developing countries. A first exploration of the data confirmed that regional averages for many modules were lower for LDCs than developing countries, justifying the approach.

A combination of both classifications was then used to define average values for all agricultural indices across all regions, and missing values in the original dataset were filled with this regional average. This method gives results that take the geography and level of development of a country into account and thus should provide a better approximation of the agricultural intensity of a country than the previously used world average.

Some combinations of geography and development contained only one country. In these cases, in order to calculate averages and fill in potential gaps, the relevant country was re-classified and added to the category that was deemed closest in terms of both geography and development (Table 1). For example, Haiti was the only LDC in the category ‘Americas > Latin America and the Caribbean’ and was thus added to the ‘Americas > Latin America and the Caribbean > Developing countries’ category. Similarly, because very little data were available for the sub-regions of Oceania (Polynesia, Micronesia and Melanesia), these were aggregated to the new category ‘Oceania > all countries except Australia and New Zealand’.

South Africa and Israel are classified as developed countries according to trade statistics. They are classified as developing countries here though in accordance with the broad UN definition described above for consistency and because they would otherwise be the only developed countries in their respective geographical regions.

Table 1: Countries and regions that had to be re-classified for the purpose of the agricultural indices calculation, showing the original UN classification and the adjusted classification (LDC=Least Developed Country).

Country or region	Original classification	New classification
Haiti	LDC	Developing
Sudan	LDC	Developing
Lesotho	LDC	Developing
Japan	Asia, Eastern	America, Northern
St. Pierre and Miquelon	America, Northern	America, Central
Yemen	LDC	Developing
Polynesia	Oceania, Polynesia	Oceania all but Australia and New Zealand
Micronesia	Oceania, Micronesia	Oceania all but Australia and New Zealand
Melanesia	Oceania, Melanesia	Oceania all but Australia and New Zealand

2.2.2 Treatment of extreme values

Extreme values in agricultural indices for all countries and modules were identified and the underlying data checked against other data sources to ensure their accuracy. An extreme maximum was defined as any value greater than 10 times the world average and an extreme minimum any value 30 times less the world average. For LDCs, it was decided to accept extremely low values due to their low level of development and resources and no further checking was conducted.

Alternative data sources were identified for several but not all of the input variables. Differences between the originally used FAO data and other data ranged from slight to significant, and the approach taken here was to prefer the FAO data as a first choice where possible and sensible to ensure consistency. Because countries with a small area of arable and permanent crops were deemed relatively unimportant in the scope of this study, it was decided to exchange extreme values with the regional average as described in section 2.1.1 for all countries with an area of less than 1/5000 of the total world area of arable and permanent crops. This was a pragmatic approach to deal with extreme values for many very small countries with little data available to compare the FAOSTAT values against.

For all countries with areas greater than 1/5000 of the world area of arable and permanent crops, decisions on how to deal with extreme values were made on a case by case basis as to which data source appeared most reliable. If no other data sources were found, the regional average was usually used to replace the extreme value. Pesticide use in China had an extremely low index based on the FAOSTAT data which was deemed unlikely because China is one of if not the world's greatest user, producer and exporter of pesticides (Yang, 2007). Using a regional average to replace this minimum was not possible because only one other country in the region 'Asia East, Developing', namely the Republic of Korea, had a value based on FAOSTAT (2009), which was an extreme high. No other data were found for either country. Thus, it was decided to combine the regions 'Asia East, Developing', 'Asia South-East, Developing' and 'Asia Southern, Developing' to calculate an average pesticide index across these regions to enable the calculation of a more robust regional average to replace missing and extreme values.

Additionally, the ten countries with the largest area of arable and permanent crops in the world were checked for any results that might be incorrect because these countries will have the greatest impact on overall results.

Any values that were not considered extreme according to the definition above were not checked for possible errors in the FAOSTAT database because this simply was not possible for 9 modules and over 200 countries within the resources of this project. Information on yields and agricultural areas were considered less likely to contain errors in the first place, and no corrections were undertaken. Furthermore, as we used 5-year averages for production volumes and areas, the consequences of a potentially wrong value in one year will be reduced.

Anybody wishing to apply MEXALCA to a particular country should check the data that are based on figures taken from FAOSTAT (2009) because this database might contain errors and only extreme values were checked for plausibility.

2.2.3 Irrigation index

In the previous version of the model, the agricultural index for irrigation was calculated based on FAOSTAT data on the area equipped for irrigation per country. However, the area that is actually irrigated in a given year might be smaller than the area equipped for irrigation (e.g. due to water shortage or surplus, crop rotations, damage to the equipment). Moreover, the area equipped for irrigation does not necessarily give an accurate indication of the actual quantity of water used. For these reasons, the method was refined by using data on the actual quantity of water used in the agricultural sector (mainly for irrigation) per hectare of temporary and permanent cropland in 2000 provided by the World Resources Institute in a searchable database (http://earthtrends.wri.org). Data were available for most countries and are given in m^3 per hectare of temporary cropland (including arable land, temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow) and permanent cropland (including land under crops, flowering shrubs, fruit trees, nut trees and vines). The figures provided in m^3 per hectare per year were then divided by the world average to define the agricultural index for irrigation for each country. Gaps in the resulting dataset were filled according to the method described in section 2.1.

Roches *et al*. (2010) applied MEXALCA to barley, wheat, rye, potato, and pea. In this study, MEXALCA was applied to altogether 27 crops. For some of the newly studied crops, irrigation turned out to be a key factor. This implied a revision of the estimator for the module "irrigation". In contrast to the approach of Roches *et al*. (2010) the yield ratio was introduced in the "irrigation" estimator and for consistency reasons with respect to other yield dependent estimators, the square root is applied to the ratio of the agricultural indices. Thus, the modified estimator has the following form:

$$\hat{W}_t^c = W_0^c \cdot \frac{Y_t^c}{Y_0^c} \sqrt{\frac{irr_t}{irr_0}}$$

$\hat{W}_t^c$ represents the extrapolated amount of water used in each target country ($m^3\ ha^{-1}$), W_0^c the water input in the original country. The average crop yields (FAO, 2009) in $kg\ ha^{-1}$ as applicable for the original and the target countries are denoted by Y_0^c and Y_t^c. irr_t and irr_0 represent the irrigation intensity in a country. The latter are constructed from data on the actual quantity of water used in the agricultural sector (mainly for irrigation) for temporary and permanent cropland in 2000 (WRI, 2009) and listed in Roches *et al*. (2010).

Under water limiting conditions a linear relationship between crop yields and deficit irrigation exists (Stewart *et al*. (1977) as presented in Kirda (2002)). Deficit irrigation means a lack of evapotranspiration to the plant, which is essential for the growing process and the production of dry matter (Heyland, 1996). The response of a crop to deficit irrigation varies depending on the species. High-yielding varieties e.g. are more sensitive to deficit irrigation than low-yielding varieties and those with a short growing season and a high tolerance of drought respond least to deficit irrigation (Kirda, 2002). Neither crop type, nor country specific climatic or topographic conditions are explicitly accounted for by the irrigation estimator as mentioned above, because MEXALCA can only consider single country averages.

2.2.4 Drying index

Product drying was assumed to be necessary in wet areas which need little or no irrigation. Thus, the drying index was calculated as the inverse of the area equipped for irrigation in a country according to the formula:

$$\hat{X}_t^c = X_o^c \frac{Y_t^c}{Y_o^c} \frac{ind_t^X}{ind_o^X}$$

$\hat{X}_t^c$: Amount of input in the target country [kg water evaporated (ha)$^{-1}$ (GS)$^{-1}$]

X_o^c: Amount of input in the original country (i.e. in the original inventory) [kg water evaporated (ha)$^{-1}$ (GS)$^{-1}$] respectively

Y_t^c: Yield in the target country [kg raw product (ha)$^{-1}$(GS)$^{-1}$]

Y_o^c: Yield in the original country [kg raw product (ha)$^{-1}$(GS)$^{-1}$]

ind_t^X: Agricultural index in the target country for the intensity of use of input *X*, here 100 minus % area equipped for irrigation in the target country [-]

ind_o^X: Agricultural index in the original country for the intensity of use of input *X*, here 100 minus % area equipped for irrigation in the target country [-]

In contrast to the first version of the model, the yield in both the base system and target country are now considered in the formula too, since the amount of water to be evaporated is linearly related to the yield.

For the poorest countries in the world a different procedure was applied. The farmers in these countries usually do not have the resources to equip large areas for irrigation although there is an important water deficit, which would result in a high drying index. For example, some hot African countries had large drying indices although their climates would rather necessitate a lot of irrigation, which should result in a low drying index. Because of this, it was decided to set the drying index to zero for LDC countries, i.e. it is assumed that no drying apart from air drying without fossil fuels is used.

2.3 CARBON LOSS THROUGH DEFORESTATION

Carbon emissions from deforestation depend on the area lost and the original forests' biomass stocks. Deforestation might have different reasons: to increase the area of arable and permanent cropping; to increase the area of permanent meadows and pastures for livestock farming; or other reasons such as the expansion of built areas, mining or logging. In MEXALCA, it was assumed that agriculture is the only driver for deforestation.

Data on changes in forest area were obtained from FAOSTAT (2009) and the annual change rate between 2002 and 2007 was calculated. All increases in forest areas reported by countries mainly in Europe were set to zero in the present model because the aim of the analysis was not to include any carbon credits for afforestation. The figures given for forest losses, however, are net figures which may include some afforestation as well, masking some or even all of the actual loss. For example, FAO (2006) reports a net increase in forest area between 1990 and 2005 for India due to an increase in plantations, despite one of the highest rates of deforestation worldwide (Houghton, 2005).

The total reduction in forest area per country was then combined with information on the carbon stocks in above-ground biomass (Marklund & Schoene, 2006) to give a total carbon loss per country through deforestation. This approach only considers continental or sub-continental averages of carbon stocks in above-ground biomass due to a lack of more detailed information for many countries in the world. This large scale aggregation cannot reflect the considerable differences between and within countries, depending on type of forest, degree of naturalness, natural disturbances or human induced degradation, etc.

Two scenarios were calculated for each country to estimate carbon emissions resulting from deforestation: an average scenario applicable to the whole country, and a scenario per hectare of actually deforested land. In the former, emissions were allocated across the total agricultural area of a country in 2007, including arable and permanent crops as well as meadows and pastures (see below). This scenario can be used if the country or larger scale region of origin of a product is known but not whether the product was grown on recently deforested land. In the latter scenario, emissions are expressed per hectare of actually deforested land, and the loss of above-ground carbon stocks was divided by 20, allocating 5% of total GHG emissions to each of the 20 years following the land use change. This approach is in accordance with PAS 2050 (BSI 2008), the main carbon footprinting methodology in the public domain at the time of writing. This scenario should be used in cases where a product is known to originate from an area that was deforested on or after 1 January 1990, again following the approach taken in PAS 2050.

Average scenario

Because the expansion for livestock farming clearly is an important driver for deforestation, including the country with the greatest loss of forest during 2000-2005 by far (FAOSTAT, 2009), Brazil, it was decided to relate the carbon stock loss due to deforestation for the average scenario to the combined area of arable and permanent crops and permanent meadows and pastures of a country. We also have to consider that an important part of the arable area is used to produce feedstuffs for livestock.

The results of the average scenario calculation are average figures for the CO_2eq lost through deforestation per hectare of total agricultural land within a country, including both recently deforested land and land that was cleared decades ago. The resulting figures are much lower than figures resulting from calculations that relate to a hectare of land on a particular farm that is known to have been deforested for almost every country; the only exceptions are a few small islands with high rates of deforestation and little current agricultural area. IPCC (2006) calculations will also yield greater figures because they include the loss of soil carbon too. The results will greatly underestimate emissions relating to products derived from deforested land because emissions are allocated to the total area of crops, meadows and pastures in a country. As such, a country which deforests a great area but already has a large area of cleared agricultural land will have a lower result than a country which is expanding a currently small agricultural area. For example, the average scenario results for Indonesia and Brazil are comparatively low to medium figures per hectare of total cropland and pasture, although it is estimated that 30% and 20% of land use change emissions worldwide occur in Indonesia and Brazil respectively, almost entirely driven by deforestation (Stern *et al*., 2006). As these countries also have an important agricultural area, the total absolute emissions from deforestation estimated for these countries will be important. Furthermore, the figures presented are applied to all crops produced in a country and do not differentiate between crops and livestock products that might contribute to the destruction of tropical rainforest (e.g. soya in Brazil) and products that in all likelihood are only grown on established fields with no direct impact on further deforestation.

For these reasons, the results should be interpreted with great caution.

Further limitations

The data used here to estimate CO_2eq losses per hectare of agricultural land per country are derived from the FAO Forest Resources Assessment, following the FAO definition of what constitutes a forest. There may be problems with consistency between countries because data were compiled from reports of individual countries which might imply slightly different definitions and methods for estimation (Ramankutty *et al*., 2007).

In order to estimate carbon fluxes from land use change, it is important to know the fate of the land after conversion. For example, more carbon will be lost if land is converted from forest to agriculture than to shifting cultivation, eventually allowing a secondary forest to re-grow (Ramankutty *et al.,* 2007). The type of management (e.g. deep ploughing or no-till, annual or perennial cropping, addition of organic materials) will also have an impact on total carbon losses (IPCC, 2006). In the present model, only above-ground carbon losses were considered because it was impossible to develop a detailed model of management regimes and their different impacts on soil and below-ground carbon stocks for each country within the resources available for this project. Furthermore, only immediate changes were considered; however, it is known that carbon losses can continue for decades after conversion (Fargione *et al.,* 2008). The model presented here assumes all carbon stored in above-ground biomass to be lost as a result of forest clearance. Moreover, there is evidence that carbon stocks in the tropics are decreasing through degradation, i.e. without a change of area, or increase through recovering secondary forest growth (Houghton, 2005). Although these changes are difficult to record and quantify, they may lead to significant changes in carbons stocks (Houghton, 2005).

Another limitation relates to the inclusion of deforestation only. Although carbon emissions through (tropical) deforestation probably are greatest, large scale land use change from grassland to cropland can also cause carbon losses, e.g. the Cerrado savannah in Brazil which is rapidly decreasing due to conversion to agriculture (Brannstrom *et al.,* 2008, Fargione *et al.,* 2008). As the conversion of grasslands to croplands is occurring in many countries, e.g. in Brazil for the cultivation of sugar cane and soybeans, this limitation excludes a significant amount of land use change related GHG emissions. It also means that emissions from land use change that occur in countries where no deforestation takes place are assumed to be zero here, even if the conversion of grasslands and associated carbon losses do happen (e.g. the conversion of rangelands or former cropland that was taken out of production for conservation purposes for corn production for biofuel in the United States (Fargione *et al.,* 2008)). Land use, drainage and deforestation of tropical peatlands also contribute significantly to global CO_2 emissions, accounting for about 8% of global emissions from the burning of fossil fuels (Strack, 2008); however, emissions from the land use change of these organic soils could not be considered in the scope of this project.

No emissions of GHGs other than CO_2 were considered, nor were any impacts of indirect land use change or the issue of forest degradation and associated carbon loss. Finally, the estimation of carbon stocks in vegetation is a significant source of error surrounded with great uncertainties (IPCC, 2006; Ramankutty *et al.,* 2007).

2.4 ADOPTION OF NO-TILL FARMING

Hardly any statistics are available on the adoption and extent of area under no-till worldwide. Derpsch & Friedrich (2009) present figures for 32 countries which are best estimates based on information gathered from various organisations, government agencies and experts. These figures were used here to derive the percentage of land under no-till per continent on the basis of the countries and figures available and the total arable area for each of these countries (Table 2). It was then assumed that the percentage adoption is the same for all other countries within each continent. South America has the widest adoption of no-till practices, followed by Australia and New Zealand and North America. It has to be stressed that these percentages are based on few countries per continent and can thus only be a very rough estimate. The figures relate to the area of arable land in each country only, not the area of arable and permanent crops. This is because there is not enough information available to support the inclusion of permanent crops. It is however known that in some countries, the adoption of no-till systems in perennial trees exceeds the area under annual crops, e.g. Spain (Derpsch & Friedrich, 2009). An assessment of the percentage area of arable and permanent crops managed as no-till was thus not possible due to lack of data. No data were available for any country in the regions Oceania and Latin America and Caribbean. These gaps were filled using the world average, based on the total known hectares of land under no-till and the sum of all arable land in these countries. Finally, the percentages in Table 2 are averages across all crops produced; although the adoption of no-till cultivation may vary greatly between different crops, this average is used here due to a lack of reliable data specific to each of the crops analysed.

In contrast to the first version of MEXALCA, the impacts resulting from tillage are now estimated by multiplying the impacts calculated for the module MachTill in the original country by the percentage of area within each country that is managed under conventional tillage (i.e. 100% - % of area managed under no-till). Previously, the ratio of the tillage index in both the target and original countries was calculated and 1 was set as upper boundary for the resulting figure. The base inventory always assumes 100% conventional tillage.

Note that only the operation ploughing is allocated to the module MachTill; all other soil preparation operations, e.g. chiselling, disking or bed forming, are allocated to MachVar.

Table 2: Hectares under no-till management, total area of arable crops and percentage of area managed as no-till per continent in 2007, based on data available for 1-10 countries in each continent. Sources: Derpsch & Friedrich (2009), FAOSTAT (2009).

	ha under no-till	total arable ha	% no-till
South America	49,579,000	107,201,000	46.2
Australia and New Zealand	17,162,000	45,046,000	38.1
North America	40,074,000	215,528,000	18.6
Asia	2,533,000	166,130,000	1.5
Europe	1,167,500	78,105,000	1.5
Africa	495,500	75,883,000	0.7
Central America	50,000	24,500,000	0.2

When individual crops are analysed, a decision has to be made about the suitability of the crop for no-till cultivation (Table 3). In principle any crop is suited for no-till practices (R. Derpsch, personal communication). However, in practice some crops pose more difficulties than other crops, when implementing no-till management.

We decided for a simple system based on two options: a crop is well suited for no-till methods under most conditions; or it is not suited in most conditions. A value judgement has to be made in cases where a crop might be grown under no-till in some countries, but is thought to be not well suited in most conditions. Decisions on the case study crops were made after consultation with several experts[1], since statistics on the adoption of no-till practices per crop worldwide are not available. If MEXALCA is used to study a crop in a

[1] Rolf Derpsch, Shopping del Sol, Asunción, Paraguay
Wolfgang Sturny, Andreas Chervet, Bodenschutzfachstelle des Kantons Bern, Rütti, Zollikofen, Switzerland
Bernhand Streit, Swiss College for Agriculture, SHL, Switzerland
Hanspeter Lauper, Swiss No-Till
Thomas Anken, Agroscope Reckenholz-Tänikon Research Station ART, Switzerland

particular country, then the analyst is urged to assess the situation based on the most common practice in that country. All perennial crops were classified as not suited to no-till because this distinction is not relevant in this case.

Table 3: Classification of crops as either well suited to no-till cultivation under most conditions or as not well suited in most situations, based on expert opinion.

CROP	well suited	not well suited
Vegetables and root crops		
Tomatoes (without greenhouse production)		X
Spinach (without greenhouse production)		X
Onions (without greenhouse production)		X
Potatoes		X
Carrots		X
Bell peppers (without greenhouse production)		X
Pumpkin (without greenhouse production)	X	
Sugar beet	X	
Cereals and starch crops		
Wheat	X	
Barley	X	
Rye	X	
Rice	X	
Maize	X	
Protein crops		
Peanut (groundnut)		X
Protein pea	X	
Soya beans	X	
Oil crops		
Linseed	X	
Oil palm		X
Rape seed	X	
Nut and fruit tree crops		
Almonds		X
Hazelnuts		X
Apples		X
Oranges		X
Peaches		X
Bananas		X
Other crops		
Sugar cane		X
Cotton crop	X	

3 Original country inventories

This section introduces the farming inputs and field operations required for the calculation of the original country inventories (section 3.1) and describes the procedure of data collection. The original country inventories for rape seed, soya beans, oil palm, sugar cane, sugar beet, rice, maize and cotton are constructed from data sets available in the ecoinvent data base (ecoinvent Centre, 2007). The inventories for those crops not contained in ecoinvent (peanuts, linseed, peaches, apples, bananas, oranges, spinach, onions, pumpkins, bell peppers, tomatoes, almonds, hazelnuts) are based on literature and expert knowledge. The general procedure of the construction of the original country inventories is described in sections 3.2 and 3.3. Specific information on the data collection and a summary of the most important farming inputs is presented in Appendix A for each single crop.

3.1 FARMING INPUTS FOR ORIGINAL COUNTRY INVENTORIES

It is assumed that crop production can be described by a few key management axes (Nemecek *et al*., 2005) named modules. Those are basic cropping operations, tillage machinery use, variable machinery use, application of nitrogen (N), phosphorus (P) and potassium (K) fertilizer, pesticide use, irrigation and drying. In the following paragraphs the nine modules together with the attribution of the corresponding farming inputs and field operations are briefly described.

Basic cropping operations: This module contains farming inputs referring to seeding or planting including the production of plantlets and seeds. In addition, harvesting and base dressing are taken into account.

Tillage machinery use: This module includes the process of ploughing only.

Variable machinery use: Variable machinery refers to all machinery in addition to basic cropping operations and tillage, like mechanical weeding or seedbed preparation.

Nitrogen (N), Phosphorus (P) and Potassium (K) fertilizer use: These modules contain the amount of N, P, and K fertilizers applied. Organic fertilizer application is not explicitly taken into account with MEXALCA. Instead the nitrogen contained is added to the amount of N applied as mineral fertilizer. Nutrients are attributed to different fertilizer types representing a global average following data summarized by the International Fertilizer Association (IFA, www.fertilizers.org). In addition, the fertilizer modules contain the machinery use for top dressing that has not been attributed to basic cropping operations.

Pesticide use: This module contains pesticides, herbicides and fungicides expressed as total amount of unspecified active ingredient. Exception has been made, if a high amount of substance suspected to have a much lower environmental impact than assumed for the unspecified pesticides has been applied (e.g. sulphur as fungicide (ecoinvent Centre, 2007)). In such a case the amount of utilized product is explicitly taken into account in order not to overestimate the impact. Additionally, the machine passes for pesticide applications are included.

Irrigation: This module includes the amount of irrigation water. This amount is scaled by the irrigated fraction of acreage in the original country in case that not all of the production systems in the original country apply irrigation. If the irrigation practices of the original country do not seem to be representative for world production, original country data for this module are constructed based on a globally more representative country.

Drying: This module requires data on the amount of water extracted in the process of drying from the harvested fruit of one hectare and a classification of the drying method according to its energy requirement (high or low temperature drying).

Transportation of inputs to the farm is included in the respective modules. Nemecek *et al.* (2010) gives an overview of the methodology used. Nitrous oxide (N_2O) released to air is calculated following the 2006 IPCC Guidelines (IPCC, 2006). Nitrate leaching to water as an indirect N_2O source is calculated applying the SALCA (Swiss Agricultural Life Cycle Assessment) model described in Richner *et al*. (2010). The model requires information on the soil properties (organic matter and clay content of the top soil), the dates of intensive soil tillage operations (which are only ploughing and rotary harrowing for the analyzed crops), the dates of planting and harvesting, the amount of winter rainfall, the timing of N fertilizer application and information on the crop rotation (Richner *et al*., 2010). Default values of soil properties were only changed if explicit data are available for crops inventories based on case studies or if representative data with respect to the original country or the crop in general are available[2].

3.2 CROPS INCLUDED IN THE ECOINVENT DATABASE

Data on the inputs to and outputs from this group of crop production systems are obtained from the ecoinvent database (ecoinvent Centre, 2007), and the reader is referred to this database for detailed information. The descriptions in Appendix A.1 only explain additional assumptions, issues and limitations as well as data sources for inputs or variables that are not contained in ecoinvent but are considered for the calculation of the original country inventory using Team and SALCA. The SALCA models are deemed unsuitable for the estimation of nitrate leaching to ground water for the following crops: sugar cane, oil palm, rice and cotton. For these crops, ecoinvent data on nitrate emissions are used for further modelling. An attempt was made to enter the parameters and dates required by the nitrate leaching model for the most representative region within the original country, i.e. the main producing area of this crop within the original country. However, these parameters may vary greatly between different growing areas within large countries such as the USA and can thus not be regarded as an average across the country. The choice of the original country system for these crops was mainly determined by the availability of data in ecoinvent and therefore the country chosen is not always one of the main producers in the world as recommended for MEXALCA. Most ecoinvent inventories are intended to be representative for the production in a country.

3.3 CROPS NOT CONTAINED IN THE ECOINVENT DATABASE

No detailed data on the crops in this group were available in the ecoinvent database. They were modelled using data provided by experts and from the literature. Detailed information on the inputs to these systems is provided in the corresponding sections of Appendix A.2.

The inventories belonging to this group are not always representative of the whole country chosen for the original country, because they often stem from case studies. This is because of data availability issues. Within the constraints of the present project, data have to be used that apply at best to particular regions but do not represent an average production system

[2]This was the case for: almonds (pH), bananas (slope), oranges (pH), peanuts (slope, organic matter, soil type, pH), pumpkin (pH), rapeseed (region, clay, organic matter, slope, pH, profundity), rice (pH), sugar beet (slope), sugarcane (pH, profundity), tomatoes (slope, organic matter)

with average amounts of inputs and outputs. Further, as the SALCA model needs input parameters such as average rainfall and dates of planting, harvesting and fertilisation, these can never apply to an entire country. Within large countries, e.g. the USA or Australia, this can be an issue because the original country might vary significantly from one region to another, so that the region chosen will have an impact on the whole extrapolation. This is a constraint and a difference from the crops in section 3.2 that are based on the average production system in the original country as defined by ecoinvent.

4 Extrapolation results

This section presents MEXALCA results of the modular extrapolation for the 27 studied crops. The results are given for all studied impact categories in Table 4 to Table 8. Details of the emissions contributing to GWP are listed. Note that only the weighted means are additive. All other statistical measures like the median, the 10^{th} and 90^{th} percentiles and the weighted SD are not additive. For these measures the sum of the contributions of the different emissions deviates from the total GWP.

In general we recommend to use the median and the 10^{th} and 90^{th} percentile to describe the distribution of the impacts. The use of percentiles has the following advantages:

- They are not sensitive to extreme values.
- They can represent the asymmetric nature (skewness) of the distribution.

However, in the following situations the use of the weighted mean and weighted standard deviation is preferable:

- When the production is dominated by a few or even a single producer country. In this case, the use of the percentiles may be misleading (e.g. it can happen that the median and the 90^{th} percentiles are identical, since the largest producer includes both).
- If there is a need to add up impacts (e.g. to add the contribution of the different greenhouse gases to the total global warming impact).

We advise the user against the application of arithmetic means of producer countries. This is because the producing countries have a very unequal contribution to the world production. Furthermore among the extreme values small producer countries are found more frequently, which can yield biased results.

The following methods were used to characterise the environmental impacts:

- Demand for non-renewable energy resources [MJ-eq] (oil, coal and lignite, natural gas and uranium), using the upper heating or gross calorific value for fossil fuels according to Frischknecht *et al.* (2004).
- Global warming potential over 100 years [kg CO_2-eq] (IPCC, 2007), excluding biogenic carbon flows. The results are given with and without deforestation as described in section 2.3 (average scenario).
- Ozone formation potential [kg ethylene-eq] (so-called “summer smog” according to the EDIP97 method) (Hauschild & Wenzel, 1998).
- Eutrophication potential (nutrient enrichment) [kg N-eq] (impact of the losses of N and P to aquatic and terrestrial ecosystems), according to the EDIP97 method (Hauschild & Wenzel, 1998)
- Acidification potential [kg SO_2-eq] (impact of acidifying substances released into ecosystems), according to the EDIP97 method (Hauschild & Wenzel, 1998)

- Terrestrial ecotoxicity potential [kg 1,4-DCB-eq] (impact of toxic pollutants on terrestrial ecosystems), according to the CML01 method (Guinée *et al.*, 2001)
- Aquatic ecotoxicity potential [kg 1,4-DCB-eq] (impact of toxic pollutants on aquatic ecosystems), according to the CML01 method (Guinée *et al.*, 2001)
- Human toxicity potential [kg 1,4-DCB-eq] (impact of toxic pollutants on human health), according to the CML01 method (Guinée *et al.*, 2001)

For the ecotoxicity and human toxicity assessment methods, new and additional characterisation factors have been calculated by ART for about 400 pesticide active ingredients. They have been used in the LCA calculations by SALCA. As these factors are not included in ecoinvent, the results for these three categories cannot be compared.

Other indicators have been calculated on LCI level, namely total water use in m^3 (sum of all consumptive flows according to the ecoinvent database and total land occupation in m^2*year.

Table 4: Extrapolation results from MEXALCA for cereals per kg of fresh mass of product. SD = standard deviation.

					Contribution of emissions to the GWP													
Crop	Value	energy demand [MJ-eq]	GWP 100a without deforestation [kg CO2-eq]	GWP 100a with deforestation [kg CO2-eq]	*CO2, fossil [kg CO2-eq]*	*CH4 [kg CO2-eq]*	*N2O [kg CO2-eq]*	*Other GHG [kg CO2-eq]*	*CO2 deforestation [kg CO2-eq]*	ozone formation [kg ethylene-Eq]	Resource P [kg P]	Resource K [kg K2O]	Land occupation [m2a]	Water use [m3]	nutrient enrichment [kg N-eq]	acidification [kg SO2-Eq]	aquatic ecotoxicity, 100a [kg 1,4-DCB-Eq]	terrestrial ecotoxicity, 100a [kg 1,4-DCB-Eq]
Wheat	10th percentile	4.25E+00	3.76E-01	3.84E-01	*2.33E-01*	*9.31E-03*	*1.15E-01*	*1.58E-03*	*0.00E+00*	1.17E-04	1.56E-03	1.68E-03	1.56E+00	4.89E-02	1.25E-02	4.17E-03	5.08E-02	1.31E-03
Wheat	median	5.89E+00	5.89E-01	5.89E-01	*2.97E-01*	*1.30E-02*	*2.59E-01*	*2.34E-03*	*0.00E+00*	1.69E-04	3.92E-03	3.20E-03	3.80E+00	1.55E-01	3.54E-02	7.95E-03	9.97E-02	2.53E-03
Wheat	90th percentile	7.25E+00	7.68E-01	7.68E-01	*3.46E-01*	*1.62E-02*	*4.04E-01*	*2.79E-03*	*4.32E-02*	2.06E-04	6.15E-03	5.39E-03	5.50E+00	2.89E-01	5.78E-02	1.17E-02	1.89E-01	4.75E-03
Wheat	Weighted mean	6.06E+00	5.84E-01	6.20E-01	*2.98E-01*	*1.32E-02*	*2.70E-01*	*2.27E-03*	*3.56E-02*	1.69E-04	3.98E-03	3.59E-03	3.77E+00	1.82E-01	3.71E-02	8.15E-03	1.05E-01	2.67E-03
Wheat	Weighted SD	1.46E+00	1.46E-01	2.53E-01	*5.46E-02*	*3.12E-03*	*1.04E-01*	*5.14E-04*	*2.21E-01*	3.78E-05	1.42E-03	1.46E-03	1.80E+00	1.14E-01	1.61E-02	2.74E-03	4.51E-02	1.12E-03
Barley	10th percentile	3.16E+00	3.08E-01	3.34E-01	*1.87E-01*	*7.19E-03*	*7.55E-02*	*1.24E-03*	*0.00E+00*	1.00E-04	1.39E-03	1.98E-03	1.68E+00	2.10E-03	1.03E-02	3.44E-03	4.35E-02	1.13E-03
Barley	median	3.75E+00	4.37E-01	4.37E-01	*2.23E-01*	*8.51E-03*	*1.90E-01*	*1.62E-03*	*0.00E+00*	1.31E-04	3.68E-03	3.64E-03	3.44E+00	3.51E-03	2.80E-02	6.25E-03	7.45E-02	1.92E-03
Barley	90th percentile	4.52E+00	5.77E-01	5.77E-01	*2.76E-01*	*1.04E-02*	*2.82E-01*	*2.02E-03*	*3.13E-02*	1.66E-04	4.89E-03	6.58E-03	5.83E+00	6.09E-03	4.18E-02	8.15E-03	1.35E-01	3.45E-03
Barley	Weighted mean	3.95E+00	4.30E-01	4.50E-01	*2.37E-01*	*8.89E-03*	*1.82E-01*	*1.70E-03*	*2.08E-02*	1.41E-04	3.34E-03	4.17E-03	3.94E+00	4.02E-03	2.67E-02	6.04E-03	8.20E-02	2.11E-03
Barley	Weighted SD	9.60E-01	1.03E-01	2.36E-01	*5.88E-02*	*2.01E-03*	*7.91E-02*	*5.66E-04*	*2.12E-01*	5.30E-05	1.35E-03	2.10E-03	2.31E+00	1.87E-03	1.21E-02	1.91E-03	2.90E-02	7.35E-04
Rye	10th percentile	4.00E+00	3.44E-01	3.79E-01	*2.38E-01*	*8.72E-03*	*8.29E-02*	*1.43E-03*	*0.00E+00*	1.09E-04	1.62E-03	2.29E-03	2.06E+00	3.59E-03	1.11E-02	3.74E-03	5.02E-02	1.31E-03
Rye	median	4.23E+00	4.89E-01	4.89E-01	*2.51E-01*	*9.57E-03*	*2.07E-01*	*1.96E-03*	*0.00E+00*	1.58E-04	4.16E-03	6.66E-03	4.46E+00	4.23E-03	3.01E-02	6.67E-03	7.72E-02	2.00E-03
Rye	90th percentile	4.81E+00	5.58E-01	5.58E-01	*2.88E-01*	*1.07E-02*	*3.09E-01*	*2.06E-03*	*3.48E-02*	1.79E-04	4.69E-03	7.85E-03	6.37E+00	9.49E-03	4.52E-02	8.57E-03	1.02E-01	2.63E-03
Rye	Weighted mean	4.36E+00	4.71E-01	4.95E-01	*2.60E-01*	*9.70E-03*	*2.00E-01*	*1.88E-03*	*2.40E-02*	1.54E-04	3.56E-03	5.33E-03	4.55E+00	5.98E-03	2.89E-02	6.40E-03	7.73E-02	2.00E-03
Rye	Weighted SD	5.63E-01	1.02E-01	2.68E-01	*3.42E-02*	*1.33E-03*	*8.95E-02*	*3.50E-04*	*2.33E-01*	3.37E-05	1.48E-03	2.34E-03	1.77E+00	3.20E-03	1.35E-02	2.03E-03	2.36E-02	6.00E-04
Maize	10th percentile	4.06E+00	4.02E-01	4.25E-01	*2.38E-01*	*8.03E-03*	*1.64E-01*	*8.62E-04*	*0.00E+00*	8.02E-05	2.32E-03	4.23E-03	1.31E+00	4.35E-03	8.58E-03	3.94E-03	1.75E-02	4.85E-04
Maize	median	4.07E+00	4.29E-01	4.29E-01	*2.43E-01*	*8.41E-03*	*1.76E-01*	*1.04E-03*	*0.00E+00*	9.18E-05	2.98E-03	8.89E-03	1.83E+00	5.83E-03	1.11E-02	5.61E-03	2.18E-02	6.25E-04
Maize	90th percentile	4.83E+00	5.70E-01	1.50E+00	*2.81E-01*	*1.04E-02*	*2.79E-01*	*1.20E-03*	*1.06E+00*	1.09E-04	4.52E-03	1.05E-02	4.20E+00	8.99E-03	1.73E-02	8.41E-03	4.67E-02	1.36E-03
Maize	Weighted mean	4.39E+00	4.71E-01	7.10E-01	*2.59E-01*	*9.07E-03*	*2.02E-01*	*1.03E-03*	*2.39E-01*	9.24E-05	3.24E-03	8.06E-03	2.57E+00	6.57E-03	1.21E-02	5.89E-03	3.05E-02	8.69E-04
Maize	Weighted SD	6.12E-01	7.92E-02	7.89E-01	*3.29E-02*	*1.29E-03*	*5.27E-02*	*2.59E-04*	*7.72E-01*	2.09E-05	8.07E-04	2.34E-03	2.05E+00	2.28E-03	3.32E-03	1.67E-03	2.06E-02	6.14E-04
Rice	10th percentile	1.15E+01	1.82E+00	1.82E+00	*3.74E-01*	*1.14E+00*	*1.13E-01*	*3.79E-03*	*0.00E+00*	5.84E-04	1.31E-03	1.92E-03	1.60E+00	7.55E-01	8.08E-03	5.86E-03	3.63E-03	-4.84E-04
Rice	median	1.42E+01	2.24E+00	2.89E+00	*4.86E-01*	*1.54E+00*	*1.50E-01*	*4.21E-03*	*0.00E+00*	7.68E-04	1.85E-03	3.70E-03	2.19E+00	9.45E-01	1.08E-02	8.19E-03	4.26E-03	-2.91E-04
Rice	90th percentile	1.93E+01	2.89E+00	3.97E+00	*5.85E-01*	*2.24E+00*	*1.87E-01*	*6.12E-03*	*1.85E+00*	9.27E-04	2.78E-03	5.03E-03	3.19E+00	1.46E+00	1.62E-02	1.08E-02	5.85E-03	-1.72E-04
Rice	Weighted mean	1.48E+01	2.38E+00	2.80E+00	*4.88E-01*	*1.74E+00*	*1.55E-01*	*4.55E-03*	*4.13E-01*	7.77E-04	2.03E-03	3.52E-03	2.46E+00	9.97E-01	1.22E-02	8.72E-03	4.55E-03	-3.34E-04
Rice	Weighted SD	3.10E+00	6.40E-01	1.14E+00	*8.47E-02*	*6.61E-01*	*3.56E-02*	*9.90E-04*	*8.27E-01*	1.97E-04	7.76E-04	1.31E-03	9.55E-01	3.08E-01	3.96E-03	2.35E-03	1.39E-03	1.99E-04

Table 5: Extrapolation results from MEXALCA for oil crops per kg of fresh mass of product. SD = standard deviation.

					Contribution of emissions to the GWP															
Crop	Value	energy demand [MJ-eq]	GWP 100a without deforestation [kg CO2-eq]	GWP 100a with deforestation [kg CO2-eq]	*CO2, fossil [kg CO2-eq]*	*CH4 [kg CO2-eq]*	*N2O [kg CO2-eq]*	*Other GHG [kg CO2-eq]*	*CO2 deforestation [kg CO2-eq]*	ozone formation [kg ethylene-Eq]	Resource P [kg P]	Resource K [kg K2O]	Land occupation [m2a]	Water use [m3]	nutrient enrichment [kg N-eq]	acidification [kg SO2-Eq]	aquatic ecotoxicity, 100a [kg 1,4-DCB-Eq]	terrestrial ecotoxicity, 100a [kg 1,4-DCB-Eq]	human toxicity, 100a [kg 1,4-DCB-Eq]
Oil palm	10th percentile	1.24E+00	6.25E-02	3.30E-01	*4.10E-02*	*2.61E-03*	*2.73E-02*	*4.39E-04*	*1.87E-01*	2.33E-05	5.20E-04	2.72E-03	4.86E-01	8.17E-02	3.53E-03	9.77E-04	9.61E-04	2.83E-07	2.29E-02
Oil palm	median	1.77E+00	1.43E-01	4.69E-01	*6.93E-02*	*4.12E-03*	*6.67E-02*	*6.26E-04*	*3.41E-01*	3.24E-05	7.05E-04	5.02E-03	5.52E-01	1.01E-01	7.87E-03	2.29E-03	1.21E-03	4.38E-06	3.38E-02
Oil palm	90th percentile	2.41E+00	1.53E-01	6.14E-01	*8.03E-02*	*5.06E-03*	*6.89E-02*	*7.88E-04*	*4.61E-01*	4.32E-05	7.31E-04	1.35E-02	7.14E-01	1.76E-01	8.15E-03	2.32E-03	1.23E-03	1.06E-05	4.45E-02
Oil palm	Weighted mean	1.99E+00	1.38E-01	4.92E-01	*7.08E-02*	*4.34E-03*	*6.23E-02*	*6.74E-04*	*3.54E-01*	3.63E-05	6.82E-04	8.42E-03	7.36E-01	1.32E-01	7.38E-03	2.13E-03	1.12E-03	5.26E-06	3.73E-02
Oil palm	Weighted SD	5.68E-01	3.34E-02	2.41E-01	*1.67E-02*	*1.13E-03*	*1.66E-02*	*1.74E-04*	*2.56E-01*	9.29E-06	1.81E-04	4.58E-03	7.59E-01	5.10E-02	1.96E-03	5.42E-04	2.90E-04	5.59E-06	1.01E-02
Rapeseed	10th percentile	5.21E+00	4.40E-01	4.40E-01	*3.15E-01*	*1.17E-02*	*1.11E-01*	*2.30E-03*	*0.00E+00*	1.84E-04	4.74E-03	1.19E-02	2.71E+00	2.23E-03	6.12E-03	6.12E-03	8.69E-03	3.09E-04	1.16E-01
Rapeseed	median	5.91E+00	5.94E-01	5.94E-01	*3.58E-01*	*1.40E-02*	*2.07E-01*	*2.67E-03*	*0.00E+00*	2.16E-04	6.74E-03	2.60E-02	5.73E+00	3.10E-03	1.05E-02	9.24E-03	1.10E-02	6.16E-04	1.41E-01
Rapeseed	90th percentile	7.39E+00	7.08E-01	7.08E-01	*4.53E-01*	*1.67E-02*	*2.64E-01*	*3.48E-03*	*0.00E+00*	3.02E-04	1.10E-02	3.16E-02	9.21E+00	4.19E-03	1.36E-02	1.19E-02	1.52E-02	8.74E-04	1.56E-01
Rapeseed	Weighted mean	6.23E+00	5.88E-01	5.99E-01	*3.79E-01*	*1.46E-02*	*1.91E-01*	*2.73E-03*	*1.14E-02*	2.28E-04	7.53E-03	2.22E-02	5.65E+00	3.17E-03	9.95E-03	9.14E-03	1.14E-02	5.73E-04	1.40E-01
Rapeseed	Weighted SD	8.73E-01	1.05E-01	1.51E-01	*5.53E-02*	*2.12E-03*	*6.33E-02*	*4.31E-04*	*1.16E-01*	4.01E-05	2.45E-03	8.29E-03	2.19E+00	7.48E-04	2.96E-03	2.23E-03	3.06E-03	1.75E-04	1.62E-02
Linseed	10th percentile	7.64E+00	6.67E-01	6.67E-01	*4.53E-01*	*1.70E-02*	*1.82E-01*	*3.42E-03*	*0.00E+00*	3.05E-04	5.11E-03	1.09E-02	8.36E+00	3.03E-03	1.30E-02	8.78E-03	6.58E-03	-7.77E-04	1.57E-01
Linseed	median	8.96E+00	8.41E-01	8.41E-01	*5.34E-01*	*2.07E-02*	*2.83E-01*	*3.90E-03*	*0.00E+00*	3.35E-04	8.99E-03	2.28E-02	8.65E+00	4.28E-03	2.58E-02	1.20E-02	1.17E-02	-3.17E-04	1.88E-01
Linseed	90th percentile	1.53E+01	1.40E+00	1.56E+00	*9.03E-01*	*3.50E-02*	*4.20E-01*	*7.04E-03*	*8.46E-02*	6.22E-04	1.45E-02	3.63E-02	1.67E+01	5.84E-03	3.89E-02	1.79E-02	1.72E-02	-2.84E-04	3.08E-01
Linseed	Weighted mean	1.05E+01	9.33E-01	1.01E+00	*6.22E-01*	*2.33E-02*	*2.83E-01*	*4.64E-03*	*7.72E-02*	4.10E-04	8.88E-03	2.50E-02	1.12E+01	4.23E-03	2.50E-02	1.25E-02	1.11E-02	-4.26E-04	2.12E-01
Linseed	Weighted SD	3.86E+00	3.04E-01	5.50E-01	*2.28E-01*	*8.01E-03*	*1.08E-01*	*1.85E-03*	*4.59E-01*	1.75E-04	3.53E-03	1.23E-02	5.58E+00	1.28E-03	1.03E-02	4.12E-03	3.99E-03	2.90E-04	7.29E-02
Peanuts	10th percentile	1.04E+01	8.37E-01	1.01E+00	*4.05E-01*	*2.11E-02*	*2.22E-01*	*3.82E-03*	*0.00E+00*	3.18E-04	9.67E-04	6.17E-03	2.22E+00	4.98E-01	6.21E-03	3.16E-03	4.96E-02	1.44E-03	1.75E-01
Peanuts	median	2.52E+01	1.01E+00	1.52E+00	*7.36E-01*	*4.80E-02*	*3.47E-01*	*8.36E-03*	*0.00E+00*	5.45E-04	3.72E-03	1.76E-02	3.51E+00	2.00E+00	7.64E-03	4.60E-03	6.80E-02	2.19E-03	4.58E-01
Peanuts	90th percentile	2.86E+01	1.52E+00	4.91E+00	*8.99E-01*	*5.63E-02*	*7.27E-01*	*1.00E-02*	*3.64E+00*	6.86E-04	5.71E-03	2.64E-02	7.50E+00	2.14E+00	1.38E-02	6.24E-03	1.31E-01	4.24E-03	5.19E-01
Peanuts	Weighted mean	2.27E+01	1.18E+00	2.09E+00	*7.18E-01*	*4.46E-02*	*4.11E-01*	*7.90E-03*	*9.11E-01*	5.41E-04	3.77E-03	1.87E-02	4.18E+00	1.66E+00	9.03E-03	4.97E-03	7.95E-02	2.49E-03	4.11E-01
Peanuts	Weighted SD	7.07E+00	3.12E-01	2.17E+00	*1.71E-01*	*1.28E-02*	*2.40E-01*	*2.23E-03*	*2.11E+00*	1.35E-04	1.89E-03	8.68E-03	2.49E+00	7.11E-01	3.97E-03	1.13E-03	4.02E-02	1.34E-03	1.31E-01
Cotton	10th percentile	1.36E+01	9.62E-01	1.09E+00	*5.99E-01*	*3.13E-02*	*1.93E-01*	*4.67E-03*	*0.00E+00*	3.54E-04	3.08E-03	8.79E-03	3.27E+00	4.14E-01	2.64E-02	9.34E-03	6.27E-03	2.45E-04	2.64E-01
Cotton	median	2.10E+01	1.37E+00	1.37E+00	*8.43E-01*	*4.55E-02*	*5.08E-01*	*6.96E-03*	*0.00E+00*	4.93E-04	1.17E-02	4.13E-02	5.00E+00	9.29E-01	7.16E-02	1.75E-02	1.79E-02	4.01E-04	3.94E-01
Cotton	90th percentile	2.52E+01	1.73E+00	1.77E+00	*9.28E-01*	*5.39E-02*	*7.76E-01*	*8.40E-03*	*2.59E-01*	5.83E-04	1.74E-02	4.67E-02	1.02E+01	1.49E+00	1.10E-01	2.44E-02	2.48E-02	5.91E-04	4.75E-01
Cotton	Weighted mean	2.00E+01	1.38E+00	1.65E+00	*8.08E-01*	*4.42E-02*	*5.21E-01*	*6.80E-03*	*2.74E-01*	4.98E-04	1.18E-02	3.27E-02	5.68E+00	9.13E-01	7.33E-02	1.77E-02	1.74E-02	3.96E-04	3.80E-01
Cotton	Weighted SD	4.63E+00	3.55E-01	1.02E+00	*1.51E-01*	*9.78E-03*	*2.16E-01*	*1.43E-03*	*1.12E+00*	8.96E-05	4.62E-03	1.63E-02	3.19E+00	4.26E-01	3.06E-02	5.95E-03	6.22E-03	1.72E-04	8.72E-02

Table 6: Extrapolation results from MEXALCA for pulses, potato and sugar crops per kg of fresh mass of product. SD = standard deviation.

					Contribution of emissions to the GWP														
Crop	Value	energy demand [MJ-eq]	GWP 100a without deforestation [kg CO2-eq]	GWP 100a with deforestation [kg CO2-eq]	*CO2, fossil [kg CO2-eq]*	*CH4 [kg CO2-eq]*	*N2O [kg CO2-eq]*	*Other GHG [kg CO2-eq]*	*CO2 deforestation [kg CO2-eq]*	ozone formation [kg ethylene-Eq]	Resource P [kg P]	Resource K [kg K2O]	Land occupation [m2a]	Water use [m3]	nutrient enrichment [kg N-eq]	acidification [kg SO2-Eq]	aquatic ecotoxicity, 100a [kg 1,4-DCB-Eq]	terrestrial ecotoxicity, 100a [kg 1,4-DCB-Eq]	human toxicity, 100a [kg 1,4-DCB-Eq]
Soybeans	10th percentile	2.90E+00	1.73E-01	2.09E-01	*1.20E-01*	*6.00E-03*	*4.60E-02*	*9.45E-04*	*0.00E+00*	6.56E-05	2.12E-03	2.60E-03	3.79E+00	6.69E-02	7.41E-03	1.16E-03	3.35E-02	8.21E-04	4.34E-02
Soybeans	median	3.26E+00	2.09E-01	3.00E-01	*1.37E-01*	*7.04E-03*	*6.42E-02*	*1.16E-03*	*0.00E+00*	7.60E-05	2.94E-03	1.14E-02	3.84E+00	9.33E-02	1.16E-02	1.54E-03	3.43E-02	8.60E-04	5.36E-02
Soybeans	90th percentile	4.07E+00	2.82E-01	1.65E+00	*1.71E-01*	*9.47E-03*	*9.27E-02*	*1.48E-03*	*1.46E+00*	1.03E-04	3.50E-03	1.45E-02	6.11E+00	1.50E-01	1.22E-02	2.15E-03	5.42E-02	1.32E-03	7.15E-02
Soybeans	Weighted mean	3.24E+00	2.06E-01	6.83E-01	*1.37E-01*	*7.10E-03*	*6.08E-02*	*1.14E-03*	*4.77E-01*	7.71E-05	2.98E-03	1.01E-02	4.43E+00	8.85E-02	1.07E-02	1.49E-03	3.92E-02	9.75E-04	5.24E-02
Soybeans	Weighted SD	4.42E-01	3.54E-02	8.07E-01	*1.88E-02*	*1.27E-03*	*1.59E-02*	*2.14E-04*	*8.13E-01*	1.55E-05	7.03E-04	4.24E-03	1.40E+00	3.03E-02	3.17E-03	3.09E-04	1.09E-02	3.44E-04	9.86E-03
Pea	10th percentile	3.79E+00	4.17E-01	4.17E-01	*1.86E-01*	*7.52E-03*	*1.74E-01*	*1.51E-03*	*0.00E+00*	1.16E-04	2.08E-03	5.62E-03	2.51E+00	4.27E-02	8.26E-03	2.17E-03	9.33E-03	3.42E-04	8.04E-02
Pea	median	5.85E+00	5.00E-01	5.00E-01	*2.80E-01*	*1.12E-02*	*2.22E-01*	*2.46E-03*	*0.00E+00*	1.92E-04	4.52E-03	9.63E-03	5.11E+00	5.90E-02	1.63E-02	2.83E-03	1.67E-02	6.02E-04	1.07E-01
Pea	90th percentile	9.38E+00	8.22E-01	8.22E-01	*4.58E-01*	*1.84E-02*	*3.77E-01*	*4.18E-03*	*3.77E-02*	3.36E-04	7.84E-03	1.47E-02	9.51E+00	2.19E-01	2.94E-02	4.69E-03	2.34E-02	8.18E-04	1.79E-01
Pea	Weighted mean	6.30E+00	5.80E-01	6.75E-01	*3.20E-01*	*1.23E-02*	*2.45E-01*	*2.78E-03*	*9.48E-02*	2.26E-04	4.48E-03	9.91E-03	6.49E+00	1.03E-01	1.72E-02	3.36E-03	1.73E-02	5.97E-04	1.22E-01
Pea	Weighted SD	2.49E+00	2.03E-01	8.37E-01	*1.30E-01*	*4.99E-03*	*7.82E-02*	*1.24E-03*	*7.66E-01*	1.04E-04	1.76E-03	3.92E-03	3.47E+00	7.63E-02	6.67E-03	1.32E-03	4.55E-03	1.48E-04	4.77E-02
Potato	10th percentile	1.10E+00	8.97E-02	9.08E-02	*5.06E-02*	*2.55E-03*	*3.62E-02*	*4.94E-04*	*0.00E+00*	3.22E-05	1.69E-04	1.59E-03	3.00E-01	6.86E-03	1.93E-03	1.14E-03	1.27E-02	5.57E-03	6.84E-02
Potato	median	1.94E+00	1.29E-01	1.32E-01	*8.53E-02*	*4.14E-03*	*4.40E-02*	*1.09E-03*	*0.00E+00*	7.00E-05	5.27E-04	5.02E-03	8.21E-01	5.87E-02	3.44E-03	1.53E-03	2.32E-02	1.40E-02	1.03E-01
Potato	90th percentile	3.92E+00	2.16E-01	2.22E-01	*1.39E-01*	*8.03E-03*	*6.72E-02*	*1.63E-03*	*4.67E-03*	1.01E-04	8.66E-04	6.76E-03	1.04E+00	2.35E-01	5.59E-03	2.41E-03	4.06E-02	2.48E-02	1.80E-01
Potato	Weighted mean	2.69E+00	1.57E-01	1.76E-01	*1.01E-01*	*5.60E-03*	*4.88E-02*	*1.20E-03*	*1.87E-02*	7.60E-05	5.40E-04	3.98E-03	7.47E-01	1.40E-01	3.80E-03	1.72E-03	2.42E-02	1.43E-02	1.22E-01
Potato	Weighted SD	1.85E+00	6.27E-02	1.43E-01	*4.82E-02*	*3.44E-03*	*1.45E-02*	*6.48E-04*	*1.15E-01*	3.84E-05	2.67E-04	2.00E-03	3.51E-01	1.71E-01	1.52E-03	5.66E-04	1.08E-02	7.86E-03	4.41E-02
Sugarbeet	10th percentile	4.00E-01	3.28E-02	3.48E-02	*2.09E-02*	*9.20E-04*	*5.99E-03*	*1.43E-04*	*0.00E+00*	1.11E-05	1.00E-04	4.77E-04	1.51E-01	6.36E-03	5.14E-04	2.99E-04	-2.15E-05	-8.96E-05	6.72E-03
Sugarbeet	median	5.33E-01	4.60E-02	4.60E-02	*2.57E-02*	*1.14E-03*	*2.01E-02*	*1.89E-04*	*0.00E+00*	1.44E-05	3.19E-04	1.64E-03	2.20E-01	1.80E-02	1.59E-03	4.96E-04	1.09E-05	-6.55E-05	8.93E-03
Sugarbeet	90th percentile	8.04E-01	6.39E-02	6.39E-02	*3.46E-02*	*1.62E-03*	*3.13E-02*	*2.79E-04*	*2.03E-03*	2.06E-05	4.55E-04	2.20E-03	4.28E-01	3.45E-02	2.43E-03	7.08E-04	4.70E-05	-2.21E-05	1.32E-02
Sugarbeet	Weighted mean	5.53E-01	4.91E-02	4.93E-02	*2.68E-02*	*1.18E-03*	*2.09E-02*	*2.01E-04*	*2.60E-04*	1.59E-05	3.11E-04	1.44E-03	2.66E-01	1.88E-02	1.65E-03	5.28E-04	7.55E-06	-6.17E-05	9.26E-03
Sugarbeet	Weighted SD	1.70E-01	1.30E-02	1.41E-02	*5.61E-03*	*3.32E-04*	*9.78E-03*	*5.54E-05*	*5.74E-03*	3.91E-06	1.27E-04	6.59E-04	1.06E-01	1.43E-02	7.33E-04	1.63E-04	2.16E-05	2.40E-05	2.97E-03
Sugarcane	10th percentile	2.40E-01	1.60E-02	2.32E-02	*9.70E-03*	*5.38E-04*	*5.80E-03*	*1.01E-04*	*0.00E+00*	4.73E-06	1.75E-04	5.00E-04	1.18E-01	9.17E-03	2.26E-04	3.40E-04	3.18E-04	-2.90E-06	4.39E-03
Sugarcane	median	3.48E-01	2.23E-02	3.93E-02	*1.39E-02*	*7.79E-04*	*7.99E-03*	*1.31E-04*	*6.94E-03*	6.73E-06	2.60E-04	1.08E-03	1.35E-01	1.38E-02	2.94E-04	4.59E-04	4.22E-04	-1.07E-06	6.43E-03
Sugarcane	90th percentile	4.91E-01	3.49E-02	6.80E-02	*2.11E-02*	*1.16E-03*	*1.25E-02*	*1.94E-04*	*4.90E-02*	8.97E-06	3.10E-04	1.76E-03	1.79E-01	2.51E-02	4.42E-04	7.12E-04	5.69E-04	3.73E-06	9.13E-03
Sugarcane	Weighted mean	3.43E-01	2.40E-02	5.04E-02	*1.45E-02*	*7.88E-04*	*8.60E-03*	*1.41E-04*	*2.64E-02*	6.65E-06	2.57E-04	1.15E-03	1.51E-01	1.63E-02	3.31E-04	4.98E-04	3.94E-04	-5.42E-07	6.45E-03
Sugarcane	Weighted SD	1.20E-01	8.37E-03	4.76E-02	*4.68E-03*	*2.62E-04*	*3.47E-03*	*4.24E-05*	*4.97E-02*	2.17E-06	7.47E-05	5.55E-04	5.31E-02	8.20E-03	1.11E-04	1.90E-04	1.03E-04	2.50E-06	2.19E-03

Table 7: Extrapolation results from MEXALCA for vegetables per kg of fresh mass of product. SD = standard deviation.

					Contribution of emissions to the GWP														
Crop	Value	energy demand [MJ-eq]	GWP 100a without deforestation [kg CO2-eq]	GWP 100a with deforestation [kg CO2-eq]	*CO2, fossil [kg CO2-eq]*	*CH4 [kg CO2-eq]*	*N2O [kg CO2-eq]*	*Other GHG [kg CO2-eq]*	*CO2 deforestation [kg CO2-eq]*	ozone formation [kg ethylene-Eq]	Resource P [kg P]	Resource K [kg K2O]	Land occupation [m2a]	Water use [m3]	nutrient enrichment [kg N-eq]	acidification [kg SO2-Eq]	aquatic ecotoxicity, 100a [kg 1,4-DCB-Eq]	terrestrial ecotoxicity, 100a [kg 1,4-DCB-Eq]	human toxicity, 100a [kg 1,4-DCB-Eq]
Spinach	10th percentile	3.32E+00	3.07E-01	3.07E-01	*1.48E-01*	*7.48E-03*	*1.20E-01*	*1.03E-03*	*0.00E+00*	7.18E-05	7.26E-04	1.03E-02	5.44E-01	1.30E-01	1.47E-02	4.39E-03	1.91E-03	6.45E-06	6.05E-02
Spinach	median	3.32E+00	3.07E-01	3.07E-01	*1.48E-01*	*7.48E-03*	*1.51E-01*	*1.03E-03*	*0.00E+00*	7.18E-05	1.02E-03	1.03E-02	5.44E-01	1.47E-01	1.87E-02	4.82E-03	2.30E-03	1.15E-05	6.05E-02
Spinach	90th percentile	3.32E+00	3.07E-01	3.07E-01	*1.48E-01*	*7.48E-03*	*1.51E-01*	*1.03E-03*	*0.00E+00*	7.18E-05	1.02E-03	1.03E-02	5.44E-01	1.47E-01	1.87E-02	4.82E-03	2.30E-03	1.15E-05	6.05E-02
Spinach	Weighted mean	3.33E+00	3.02E-01	3.28E-01	*1.49E-01*	*7.46E-03*	*1.45E-01*	*1.05E-03*	*2.61E-02*	7.33E-05	9.89E-04	1.04E-02	5.80E-01	1.46E-01	1.80E-02	4.69E-03	2.25E-03	9.61E-06	6.08E-02
Spinach	Weighted SD	4.81E-01	3.19E-02	2.68E-01	*1.90E-02*	*9.66E-04*	*1.95E-02*	*1.68E-04*	*2.59E-01*	1.31E-05	1.46E-04	2.20E-03	2.34E-01	3.43E-02	2.45E-03	5.43E-04	2.63E-04	1.18E-05	8.99E-03
Tomatoes	10th percentile	1.90E+00	9.67E-02	1.09E-01	*7.82E-02*	*3.82E-03*	*1.11E-02*	*9.25E-04*	*0.00E+00*	5.34E-05	1.46E-04	1.70E-04	1.46E-01	1.02E-01	6.00E-04	8.92E-04	5.77E-04	3.37E-05	4.00E-02
Tomatoes	median	3.39E+00	1.51E-01	1.51E-01	*1.18E-01*	*6.66E-03*	*2.53E-02*	*1.53E-03*	*0.00E+00*	8.17E-05	2.54E-04	5.24E-04	3.07E-01	2.29E-01	1.10E-03	1.42E-03	9.02E-04	5.17E-05	7.00E-02
Tomatoes	90th percentile	4.33E+00	1.85E-01	2.32E-01	*1.57E-01*	*8.49E-03*	*3.97E-02*	*2.35E-03*	*9.01E-03*	1.19E-04	3.78E-04	5.76E-04	6.28E-01	3.22E-01	1.65E-03	1.94E-03	1.28E-03	7.03E-05	9.19E-02
Tomatoes	Weighted mean	3.22E+00	1.49E-01	1.67E-01	*1.12E-01*	*6.44E-03*	*2.86E-02*	*1.53E-03*	*1.88E-02*	7.94E-05	2.69E-04	4.36E-04	3.74E-01	2.16E-01	1.23E-03	1.55E-03	9.32E-04	5.30E-05	6.76E-02
Tomatoes	Weighted SD	1.27E+00	4.74E-02	1.20E-01	*3.53E-02*	*2.41E-03*	*1.31E-02*	*5.42E-04*	*1.11E-01*	2.57E-05	9.73E-05	1.99E-04	2.55E-01	1.18E-01	4.96E-04	5.29E-04	2.71E-04	1.49E-05	2.36E-02
Pumpkin	10th percentile	9.20E-01	6.36E-02	6.36E-02	*3.53E-02*	*1.97E-03*	*2.32E-02*	*2.84E-04*	*0.00E+00*	1.81E-05	9.69E-04	1.80E-03	5.22E-01	3.72E-02	1.36E-03	9.26E-04	1.63E-03	6.41E-05	1.85E-02
Pumpkin	median	1.90E+00	1.37E-01	1.46E-01	*7.26E-02*	*4.11E-03*	*6.01E-02*	*6.03E-04*	*0.00E+00*	3.52E-05	3.04E-03	3.92E-03	5.83E-01	1.04E-01	3.49E-03	2.13E-03	3.78E-03	1.67E-04	3.86E-02
Pumpkin	90th percentile	2.40E+00	2.05E-01	2.47E-01	*9.92E-02*	*5.30E-03*	*1.00E-01*	*7.29E-04*	*2.83E-02*	4.37E-05	4.99E-03	6.35E-03	1.13E+00	1.27E-01	5.79E-03	3.44E-03	5.53E-03	2.44E-04	4.82E-02
Pumpkin	Weighted mean	1.92E+00	1.52E-01	2.28E-01	*7.79E-02*	*4.26E-03*	*6.89E-02*	*5.99E-04*	*7.67E-02*	3.52E-05	3.44E-03	4.58E-03	8.28E-01	9.63E-02	4.00E-03	2.42E-03	3.96E-03	1.73E-04	3.91E-02
Pumpkin	Weighted SD	7.40E-01	6.26E-02	7.59E-01	*2.96E-02*	*1.64E-03*	*3.21E-02*	*2.33E-04*	*7.65E-01*	1.32E-05	1.51E-03	2.29E-03	7.88E-01	4.70E-02	1.79E-03	1.07E-03	1.53E-03	7.06E-05	1.49E-02
Carrot	10th percentile	1.12E+00	7.82E-02	8.10E-02	*5.68E-02*	*2.39E-03*	*1.04E-02*	*4.24E-04*	*0.00E+00*	3.41E-05	9.22E-05	1.17E-03	2.63E-01	1.55E-02	1.11E-03	7.20E-04	3.20E-03	1.54E-04	2.67E-02
Carrot	median	1.87E+00	1.15E-01	1.18E-01	*8.68E-02*	*4.09E-03*	*2.97E-02*	*6.77E-04*	*0.00E+00*	5.85E-05	3.27E-04	3.93E-03	5.91E-01	6.38E-02	3.14E-03	1.28E-03	1.01E-02	4.63E-04	4.70E-02
Carrot	90th percentile	2.24E+00	1.53E-01	1.53E-01	*1.06E-01*	*4.60E-03*	*4.16E-02*	*8.30E-04*	*2.80E-03*	7.30E-05	4.72E-04	5.42E-03	7.06E-01	8.64E-02	4.41E-03	1.73E-03	1.56E-02	7.68E-04	5.35E-02
Carrot	Weighted mean	1.81E+00	1.21E-01	1.37E-01	*8.64E-02*	*3.71E-03*	*3.00E-02*	*6.67E-04*	*1.61E-02*	5.68E-05	3.37E-04	3.43E-03	5.40E-01	6.15E-02	3.20E-03	1.32E-03	9.52E-03	4.55E-04	4.36E-02
Carrot	Weighted SD	5.73E-01	3.35E-02	9.41E-02	*2.59E-02*	*1.11E-03*	*1.35E-02*	*2.10E-04*	*8.32E-02*	1.86E-05	1.49E-04	1.60E-03	2.44E-01	3.64E-02	1.38E-03	3.97E-04	4.44E-03	2.27E-04	1.12E-02
Onions	10th percentile	6.60E-01	5.62E-02	6.64E-02	*3.66E-02*	*1.65E-03*	*1.38E-02*	*2.87E-04*	*0.00E+00*	2.32E-05	2.45E-04	1.03E-03	2.18E-01	2.38E-03	1.53E-03	6.64E-04	6.32E-04	1.60E-05	1.82E-02
Onions	median	1.05E+00	1.01E-01	1.15E-01	*5.95E-02*	*2.70E-03*	*3.72E-02*	*4.53E-04*	*0.00E+00*	3.65E-05	8.00E-04	4.30E-03	5.02E-01	5.82E-03	4.15E-03	1.30E-03	1.63E-03	2.81E-05	2.88E-02
Onions	90th percentile	1.13E+00	1.20E-01	1.70E-01	*6.32E-02*	*2.79E-03*	*5.76E-02*	*5.93E-04*	*2.53E-02*	5.06E-05	1.19E-03	5.32E-03	8.80E-01	7.33E-03	6.41E-03	1.82E-03	2.19E-03	3.81E-05	3.58E-02
Onions	Weighted mean	9.67E-01	9.84E-02	1.35E-01	*5.43E-02*	*2.44E-03*	*4.12E-02*	*4.58E-04*	*3.70E-02*	3.80E-05	8.58E-04	3.43E-03	5.70E-01	5.35E-03	4.60E-03	1.39E-03	1.65E-03	2.89E-05	2.85E-02
Onions	Weighted SD	2.88E-01	3.06E-02	1.57E-01	*1.65E-02*	*7.22E-04*	*1.89E-02*	*1.79E-04*	*1.56E-01*	1.62E-05	3.60E-04	1.77E-03	3.62E-01	2.36E-03	2.06E-03	5.10E-04	6.16E-04	9.50E-06	1.03E-02
Peppers	10th percentile	3.69E+00	1.78E-01	2.04E-01	*1.23E-01*	*7.22E-03*	*3.46E-02*	*1.18E-03*	*0.00E+00*	7.14E-05	1.56E-03	1.40E-03	3.77E-01	2.64E-01	1.76E-03	2.00E-03	2.23E-03	1.34E-04	7.22E-02
Peppers	median	6.28E+00	3.12E-01	3.12E-01	*2.02E-01*	*1.27E-02*	*9.53E-02*	*1.98E-03*	*0.00E+00*	1.19E-04	3.97E-03	4.64E-03	5.22E-01	4.74E-01	4.40E-03	4.56E-03	4.37E-03	2.51E-04	1.23E-01
Peppers	90th percentile	6.28E+00	3.12E-01	4.74E-01	*2.02E-01*	*1.27E-02*	*9.53E-02*	*1.98E-03*	*2.06E-01*	1.19E-04	3.97E-03	4.64E-03	1.35E+00	4.74E-01	4.40E-03	4.56E-03	4.37E-03	2.51E-04	1.23E-01
Peppers	Weighted mean	5.64E+00	2.70E-01	3.80E-01	*1.82E-01*	*1.13E-02*	*7.52E-02*	*1.81E-03*	*1.10E-01*	1.12E-04	3.11E-03	3.84E-03	7.18E-01	4.22E-01	3.50E-03	3.74E-03	3.58E-03	2.09E-04	1.12E-01
Peppers	Weighted SD	1.87E+00	8.57E-02	4.09E-01	*5.49E-02*	*3.67E-03*	*2.99E-02*	*5.75E-04*	*4.16E-01*	3.36E-05	1.14E-03	1.62E-03	7.12E-01	1.60E-01	1.30E-03	1.32E-03	1.14E-03	6.40E-05	3.54E-02

Table 8: Extrapolation results from MEXALCA for fruits and treenuts per kg of fresh mass of product. SD = standard deviation.

					Contribution of emissions to the GWP														
Crop	Value	energy demand [MJ-eq]	GWP 100a without deforestation [kg CO2-eq]	GWP 100a with deforestation [kg CO2-eq]	*CO2, fossil [kg CO2-eq]*	*CH4 [kg CO2-eq]*	*N2O [kg CO2-eq]*	*Other GHG [kg CO2-eq]*	*CO2 deforestation [kg CO2-eq]*	ozone formation [kg ethylene-Eq]	Resource P [kg P]	Resource K [kg K2O]	Land occupation [m2a]	Water use [m3]	nutrient enrichment [kg N-eq]	acidification [kg SO2-Eq]	aquatic ecotoxicity, 100a [kg 1,4-DCB-Eq]	terrestrial ecotoxicity, 100a [kg 1,4-DCB-Eq]	human toxicity, 100a [kg 1,4-DCB-Eq]
Apples	10th percentile	2.08E+00	1.15E-01	1.15E-01	*9.64E-02*	*4.60E-03*	*7.11E-03*	*2.55E-03*	*0.00E+00*	1.18E-04	3.03E-05	3.93E-04	2.93E-01	4.85E-02	3.84E-04	9.63E-04	8.86E-04	3.63E-05	7.57E-02
Apples	median	3.38E+00	1.55E-01	1.55E-01	*1.26E-01*	*6.99E-03*	*1.28E-02*	*5.05E-03*	*0.00E+00*	1.91E-04	4.90E-05	1.32E-03	8.10E-01	1.83E-01	5.75E-04	1.41E-03	1.51E-03	5.73E-05	1.35E-01
Apples	90th percentile	3.63E+00	1.76E-01	1.93E-01	*1.52E-01*	*7.59E-03*	*1.68E-02*	*8.08E-03*	*1.14E-02*	2.75E-04	6.53E-05	1.64E-03	1.40E+00	2.03E-01	6.20E-04	1.44E-03	2.04E-03	7.70E-05	1.92E-01
Apples	Weighted mean	3.13E+00	1.48E-01	1.57E-01	*1.23E-01*	*6.51E-03*	*1.32E-02*	*4.91E-03*	*9.54E-03*	1.88E-04	5.14E-05	1.17E-03	7.92E-01	1.51E-01	5.39E-04	1.27E-03	1.41E-03	5.51E-05	1.29E-01
Apples	Weighted SD	8.22E-01	3.16E-02	6.89E-02	*2.72E-02*	*1.61E-03*	*4.09E-03*	*2.46E-03*	*5.90E-02*	7.02E-05	1.67E-05	4.73E-04	5.00E-01	7.12E-02	1.18E-04	2.61E-04	4.31E-04	1.36E-05	4.86E-02
Bananas	10th percentile	1.24E+00	7.87E-02	2.11E-01	*5.59E-02*	*2.81E-03*	*2.40E-02*	*4.17E-04*	*0.00E+00*	2.67E-05	2.71E-03	8.16E-03	3.18E-01	3.65E-02	1.17E-03	1.19E-03	2.13E-03	1.43E-04	2.64E-02
Bananas	median	2.84E+00	2.36E-01	3.87E-01	*1.36E-01*	*7.06E-03*	*9.46E-02*	*9.71E-04*	*2.86E-02*	5.29E-05	9.94E-03	2.73E-02	4.26E-01	9.22E-02	4.89E-03	4.31E-03	7.41E-03	4.87E-04	6.22E-02
Bananas	90th percentile	4.03E+00	3.61E-01	5.47E-01	*2.09E-01*	*1.05E-02*	*1.40E-01*	*1.38E-03*	*3.93E-01*	7.50E-05	1.53E-02	5.82E-02	1.04E+00	1.18E-01	7.29E-03	6.48E-03	1.17E-02	7.61E-04	9.03E-02
Bananas	Weighted mean	2.68E+00	2.30E-01	4.07E-01	*1.32E-01*	*6.79E-03*	*9.07E-02*	*9.25E-04*	*1.77E-01*	5.18E-05	9.32E-03	3.17E-02	6.16E-01	8.07E-02	4.59E-03	4.15E-03	7.18E-03	4.64E-04	5.91E-02
Bananas	Weighted SD	9.16E-01	8.87E-02	2.67E-01	*4.59E-02*	*2.43E-03*	*4.10E-02*	*3.10E-04*	*2.91E-01*	1.54E-05	3.89E-03	1.85E-02	4.57E-01	3.54E-02	1.88E-03	1.73E-03	2.89E-03	1.87E-04	2.07E-02
Oranges	10th percentile	1.30E+00	7.72E-02	1.00E-01	*4.96E-02*	*2.98E-03*	*2.26E-02*	*6.26E-04*	*0.00E+00*	3.10E-05	2.69E-04	2.84E-03	3.17E-01	7.51E-02	8.71E-04	1.24E-03	5.40E-04	2.73E-05	2.90E-02
Oranges	median	1.75E+00	1.04E-01	1.38E-01	*6.59E-02*	*3.92E-03*	*3.18E-02*	*8.40E-04*	*0.00E+00*	4.07E-05	3.99E-04	7.81E-03	4.67E-01	1.05E-01	1.22E-03	1.80E-03	6.65E-04	3.28E-05	3.84E-02
Oranges	90th percentile	2.75E+00	1.62E-01	2.45E-01	*1.03E-01*	*6.03E-03*	*4.74E-02*	*1.26E-03*	*1.66E-01*	6.04E-05	4.78E-04	1.03E-02	1.25E+00	1.98E-01	1.77E-03	2.63E-03	9.42E-04	4.66E-05	5.68E-02
Oranges	Weighted mean	1.93E+00	1.07E-01	1.89E-01	*6.77E-02*	*4.15E-03*	*3.39E-02*	*8.74E-04*	*8.27E-02*	4.37E-05	4.02E-04	6.93E-03	6.16E-01	1.28E-01	1.31E-03	1.87E-03	6.98E-04	3.42E-05	4.10E-02
Oranges	Weighted SD	8.51E-01	4.12E-02	1.60E-01	*2.57E-02*	*1.68E-03*	*1.42E-02*	*2.82E-04*	*1.67E-01*	1.52E-05	1.06E-04	3.05E-03	3.66E-01	7.18E-02	4.97E-04	7.50E-04	1.60E-04	9.93E-06	1.53E-02
Peach	10th percentile	4.77E+00	1.96E-01	1.96E-01	*1.38E-01*	*9.34E-03*	*4.23E-02*	*1.72E-03*	*0.00E+00*	9.44E-05	1.45E-03	3.56E-03	5.61E-01	3.98E-01	1.62E-03	2.45E-03	2.58E-03	6.24E-05	9.25E-02
Peach	median	7.93E+00	3.23E-01	3.32E-01	*2.32E-01*	*1.56E-02*	*6.49E-02*	*2.79E-03*	*0.00E+00*	1.55E-04	2.33E-03	7.30E-03	9.46E-01	6.57E-01	2.53E-03	3.65E-03	4.30E-03	1.01E-04	1.53E-01
Peach	90th percentile	8.38E+00	3.32E-01	3.32E-01	*2.32E-01*	*1.59E-02*	*8.12E-02*	*2.79E-03*	*0.00E+00*	1.57E-04	2.53E-03	7.50E-03	1.12E+00	7.17E-01	2.82E-03	4.25E-03	4.30E-03	1.01E-04	1.57E-01
Peach	Weighted mean	7.08E+00	2.85E-01	3.01E-01	*2.04E-01*	*1.39E-02*	*6.45E-02*	*2.55E-03*	*1.56E-02*	1.41E-04	2.08E-03	6.65E-03	8.96E-01	5.92E-01	2.29E-03	3.46E-03	3.67E-03	9.23E-05	1.37E-01
Peach	Weighted SD	2.45E+00	8.47E-02	1.43E-01	*6.26E-02*	*4.61E-03*	*2.04E-02*	*7.33E-04*	*1.21E-01*	4.26E-05	5.66E-04	2.17E-03	4.64E-01	2.31E-01	6.39E-04	1.02E-03	8.53E-04	2.61E-05	4.42E-02
Almonds	10th percentile	1.88E+01	9.08E-01	9.08E-01	*6.52E-01*	*3.86E-02*	*2.11E-01*	*6.06E-03*	*0.00E+00*	3.87E-04	1.14E-05	1.18E-02	2.91E+00	1.28E+00	7.44E-03	1.29E-02	2.97E-03	2.12E-04	3.53E-01
Almonds	median	1.96E+01	1.12E+00	1.12E+00	*7.07E-01*	*4.24E-02*	*3.62E-01*	*6.06E-03*	*0.00E+00*	3.87E-04	1.97E-05	6.05E-02	2.91E+00	1.28E+00	1.24E-02	2.03E-02	5.51E-03	2.42E-04	3.69E-01
Almonds	90th percentile	2.96E+01	1.36E+00	1.36E+00	*9.84E-01*	*6.22E-02*	*3.69E-01*	*8.94E-03*	*0.00E+00*	5.90E-04	3.03E-05	6.66E-02	3.08E+01	2.28E+00	1.25E-02	2.11E-02	6.37E-03	3.53E-04	5.46E-01
Almonds	Weighted mean	2.24E+01	1.16E+00	1.16E+00	*7.77E-01*	*4.69E-02*	*3.30E-01*	*7.18E-03*	*3.06E-03*	4.64E-04	1.95E-05	5.06E-02	9.44E+00	1.54E+00	1.13E-02	1.89E-02	5.12E-03	2.73E-04	4.21E-01
Almonds	Weighted SD	5.40E+00	1.99E-01	2.03E-01	*1.47E-01*	*9.97E-03*	*7.89E-02*	*1.74E-03*	*2.10E-02*	1.10E-04	5.58E-06	2.17E-02	1.04E+01	5.44E-01	2.55E-03	3.90E-03	1.26E-03	6.24E-05	9.84E-02
Hazelnuts	10th percentile	2.71E+01	1.44E+00	1.44E+00	*1.00E+00*	*5.13E-02*	*3.61E-01*	*1.97E-02*	*0.00E+00*	8.05E-04	1.26E-02	1.53E-02	6.09E+00	1.32E+00	2.01E-02	2.07E-02	1.82E-02	5.62E-04	6.94E-01
Hazelnuts	median	2.71E+01	1.44E+00	1.44E+00	*1.00E+00*	*5.13E-02*	*3.61E-01*	*2.22E-02*	*0.00E+00*	8.38E-04	1.26E-02	1.53E-02	8.11E+00	1.32E+00	2.01E-02	2.07E-02	1.82E-02	5.62E-04	6.94E-01
Hazelnuts	90th percentile	3.02E+01	1.54E+00	1.54E+00	*1.07E+00*	*5.87E-02*	*3.96E-01*	*2.22E-02*	*0.00E+00*	8.41E-04	1.45E-02	3.94E-02	8.11E+00	1.71E+00	2.23E-02	2.28E-02	2.25E-02	6.83E-04	7.04E-01
Hazelnuts	Weighted mean	2.84E+01	1.46E+00	1.47E+00	*1.02E+00*	*5.40E-02*	*3.62E-01*	*2.19E-02*	*3.65E-03*	8.43E-04	1.30E-02	2.16E-02	7.69E+00	1.48E+00	2.03E-02	2.09E-02	1.90E-02	5.93E-04	7.09E-01
Hazelnuts	Weighted SD	3.11E+00	1.20E-01	3.31E-01	*7.07E-02*	*6.29E-03*	*6.40E-02*	*3.33E-03*	*3.14E-01*	1.09E-04	2.24E-03	1.16E-02	1.57E+00	4.10E-01	3.31E-03	3.13E-03	3.06E-03	7.28E-05	9.07E-02

5 Contribution analysis

The absolute contribution of the nine MEXALCA modules as well as of deforestation to the global warming potential is shown in Fig. 2 per ha and in Fig. 3 per kg. The highest values per ha are found in rice (mainly due to the methane emissions from rice fields that are included in the MachFix module), followed by bananas, oil palm, bellpeppers and tomatoes. Low values are found for pea, rapeseed, linseed and the cereals. Soybean had the lowest value of all crops without consideration of deforestation, the latter however leads to a substantial increase of the GWP.

Per kg the pattern is different due to the very different yields. Rice has still a very high value but peanuts are at a similar level. The lowest values are found for the sugar crops (sugar cane and sugar beet). We have to consider that the results are given per kg of fresh mass and that the dry matter content differs considerably between crops.

The contributions of deforestation vary considerably between the crops. Please note that only the area used (inverse of yield) and the producing countries are considered. Each ha of land occupied in a given country like Brazil carries the same burden of deforested land, not taking into account the fact that some crops may be grown more on deforested land than others. Furthermore we have to stress that the total above ground biomass is calculated as an emission of CO_2, while changes in below ground carbon (soil organic matter) are not included at all. The emissions of deforestation are allocated to 100% to the agricultural area, other reasons for deforestation (like timber production) are not considered. As a general tendency the effect of land use changes might be overestimated. This is a rough approach and the results must thus be interpreted with caution. Nevertheless, the results give indications of potential risks. The relative contributions from deforestation to the GWP (Fig. 4) are highest for oil palm (mainly Indonesia and Malaysia) and soybeans (mainly Brazil), two crops much discussed in respect to land use change issues. Sugar cane could also have a considerable contribution, which is due to the fact that 32% of the production is located in Brazil. For oranges, the main contributions come from Brazil and Indonesia. For peanuts, Indonesia, Nigeria and Myanmar contribute most to this impact. Onions: Indonesia, Myanmar and Brazil. Bell pepper: Indonesia. Pumpkin: Indonesia, Cameroon and Philippines. Maize: Brazil and Indonesia.

Without the inclusion of land use change the N fertilisers (and related emissions) irrigation and basic cropping operations have the highest impacts.

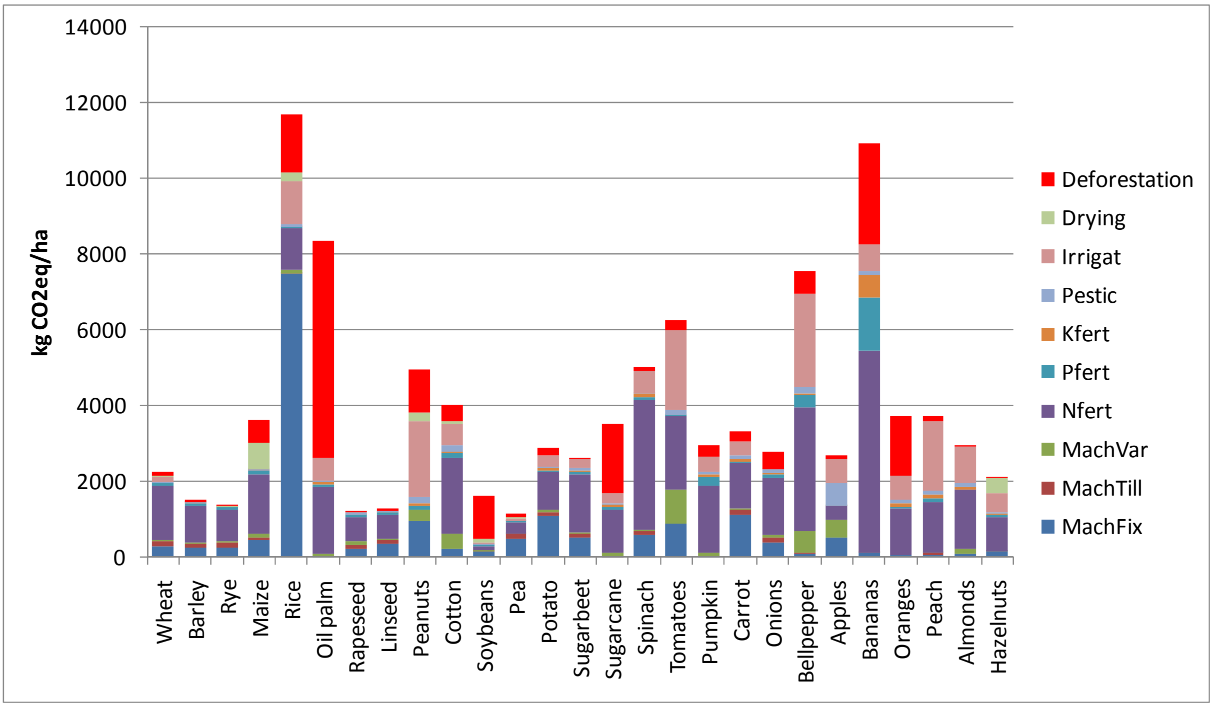


Fig. 2: Absolute contribution of the different modules to the GWP per ha.

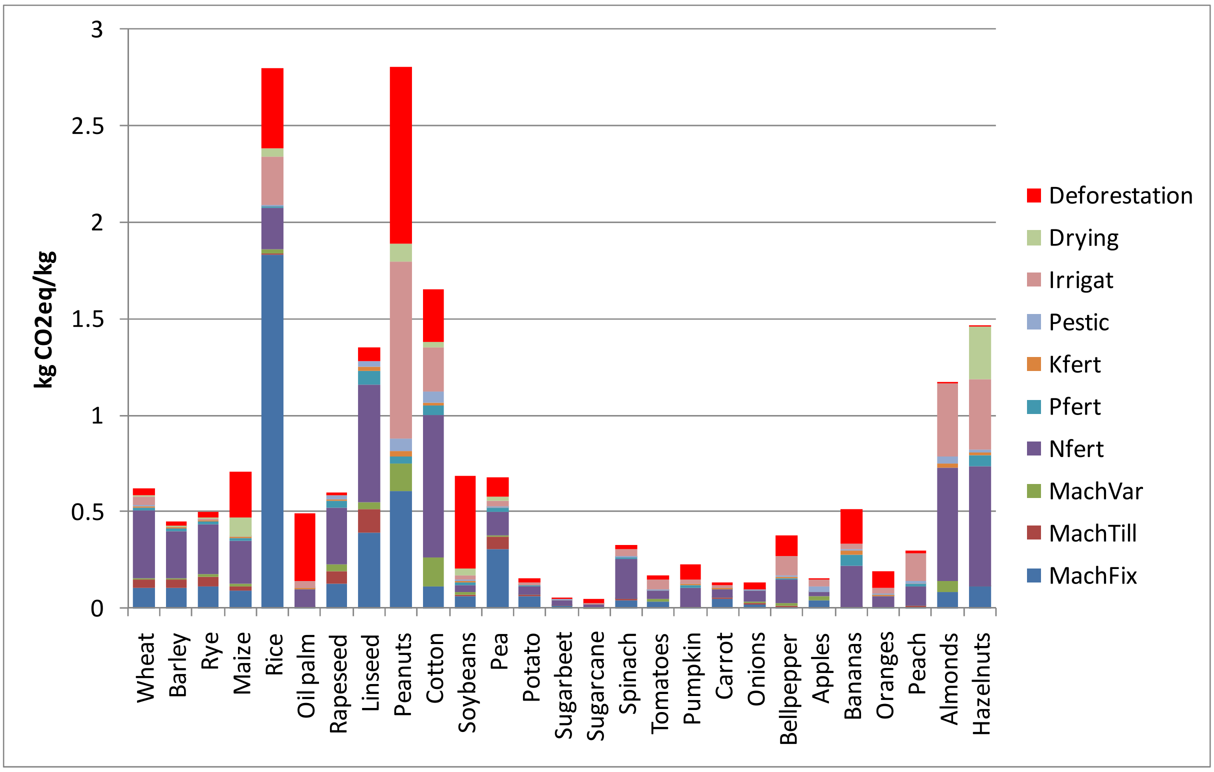


Fig. 3: Absolute contribution of the different modules to the GWP per kg.

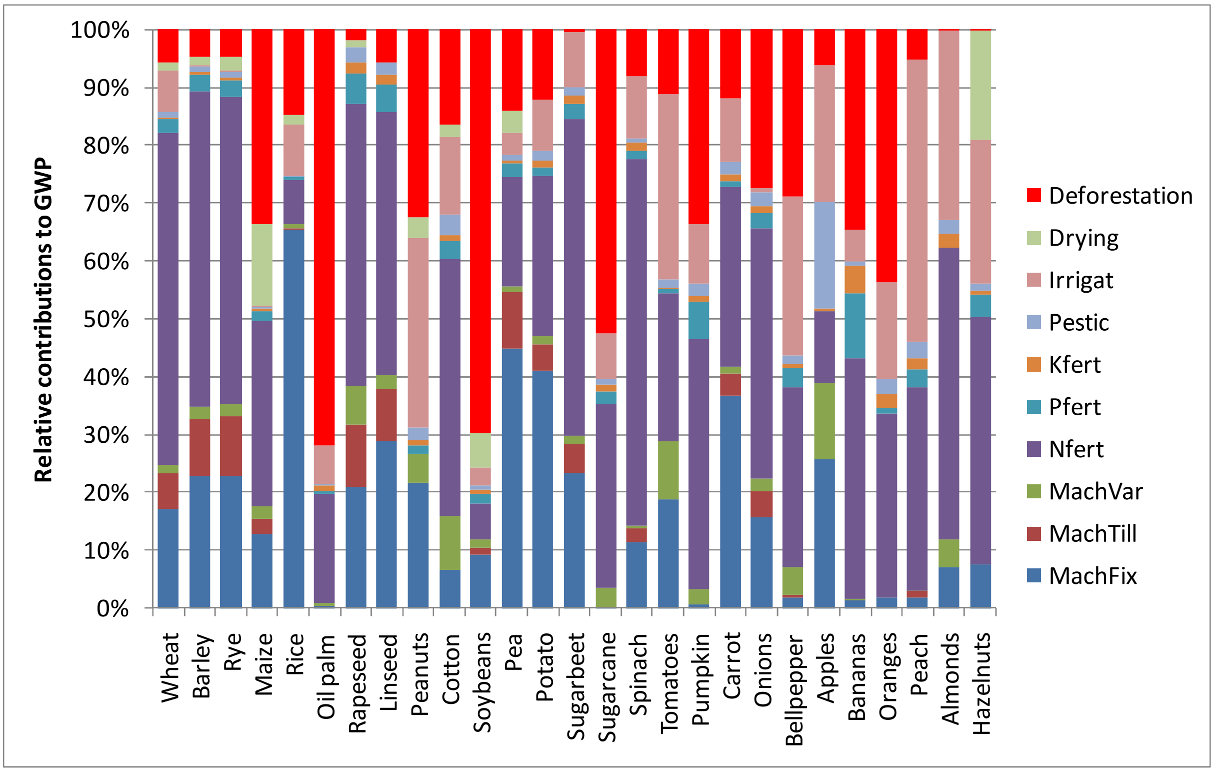


Fig. 4: Relative contribution of the different modules to the GWP with deforestation.

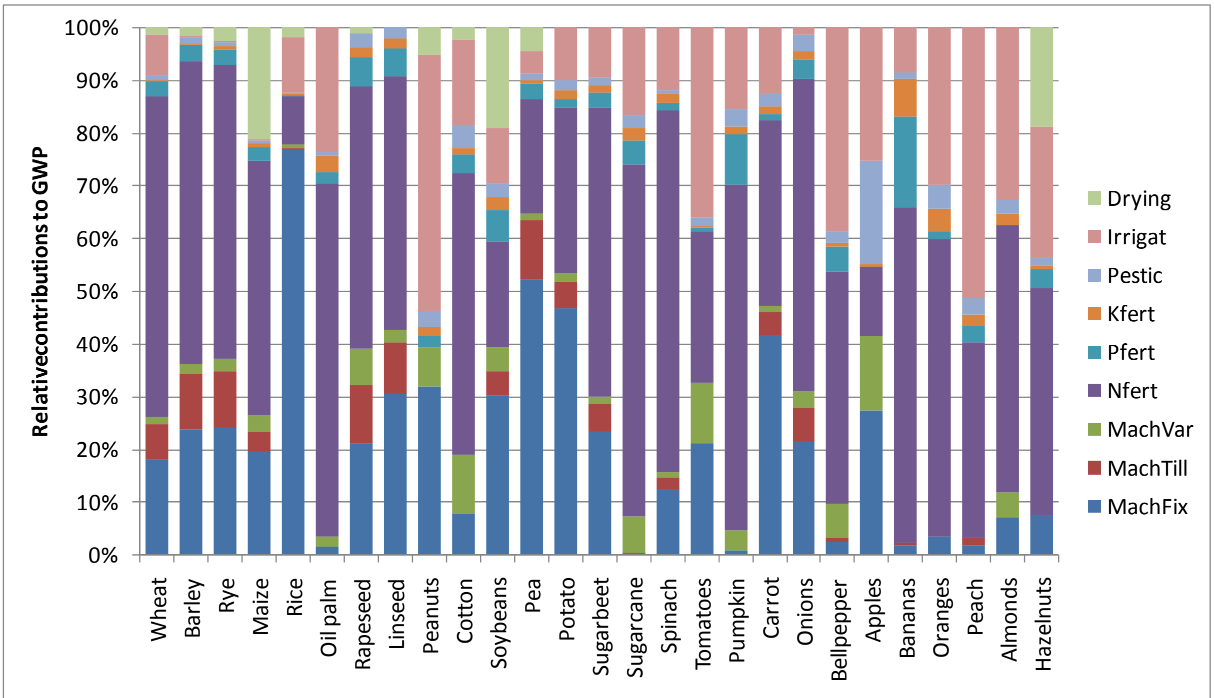


Fig. 5: Relative contribution of the different modules to the GWP without deforestation.

6 Sources of variability

The following analysis refers to the global warming potential of crop production. This topic is discussed in detail in Nemecek *et al.* (2011b).

Yield effects are analysed first, followed by the analysis of regional differences. The chapter concludes with a multivariate analysis, attempting to identify patterns that could be used for grouping crops.

6.1 YIELD EFFECTS

The effects of the yield are investigated first for the weighted global means of the 27 crops. All results presented in section 6.1 are excluding the deforestation effects, since the latter depends only on the producing countries and by definition has no relationship with the yield.

The global warming potential per ha (weighted global mean) is not dependent on the yield (Fig. 6). Crops with low yields can have low or high impacts and high yielding crops do not necessarily have high impacts. Per kg there is a clear dependence on the yield. The higher the yield of a crop on average, the lower the GWP per kg. The weighted means per ha are less variable (coefficient of variance, CV=71%) than per kg (CV=107%).

Assuming that the GWP per kg would be determined only by the yield would imply a hyperbolic relationship to the yield. This hypothesis is tested by relating the GWP per kg to the inverse of the yield (ha kg^{-1}), which corresponds to the land occupation by the crop. Fig. 7 shows that this relationship exists, but it is not very strong (r^2=0.39), which shows that the yield explains only part of the variability. The highest values around 2.4 kg CO_2eq/kg corresponds to rice.

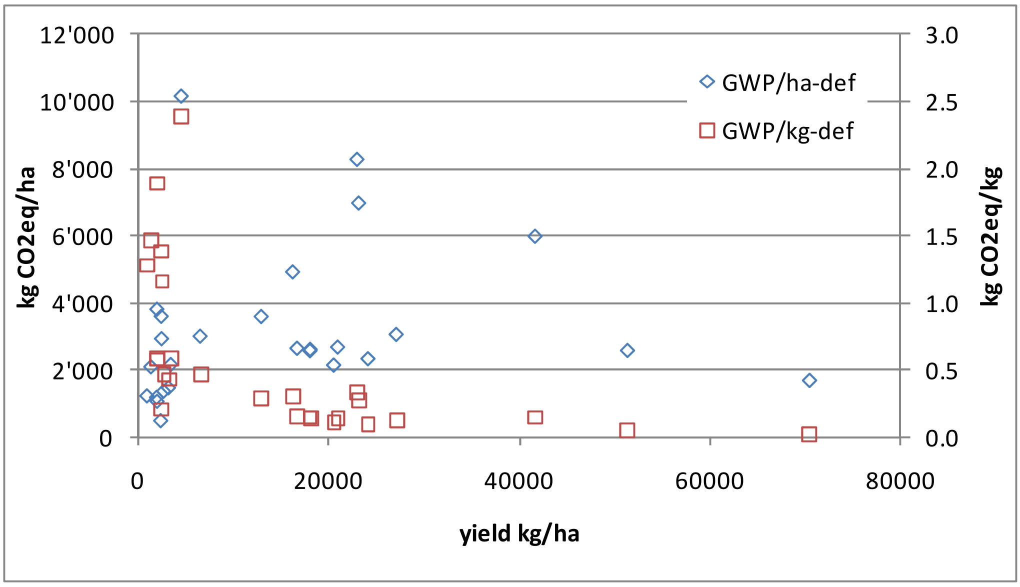


Fig. 6: Global warming potential (“GWP”, per ha and per kg) in function of the yield without considering the deforestation impacts (“-def”).

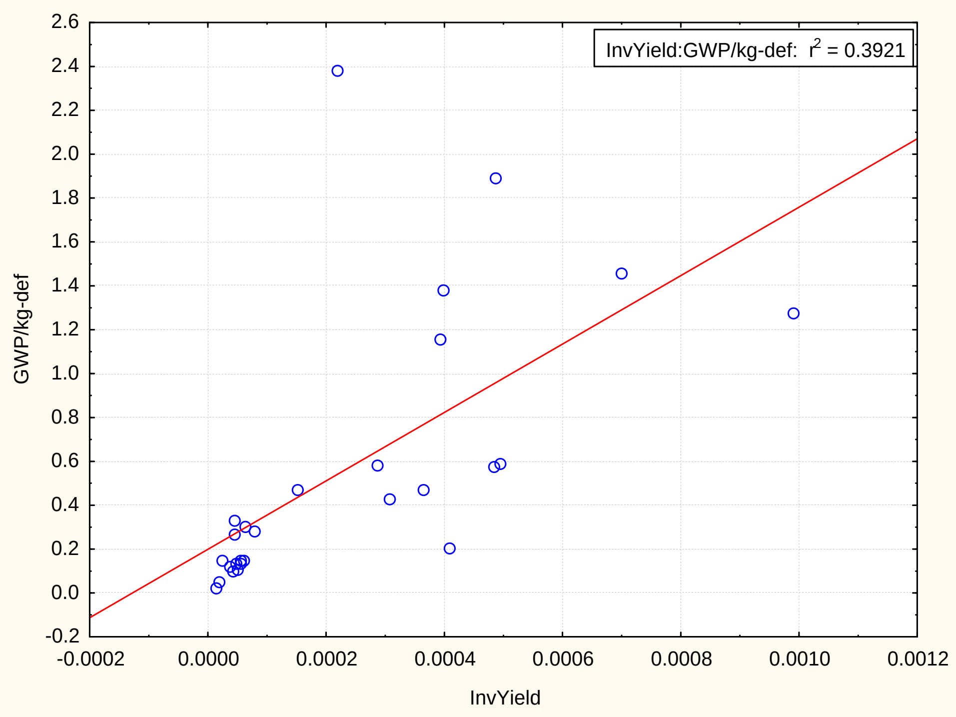


Fig. 7: Global warming potential per kg (weighted means of 27 crops without deforestation) in function of the inverse of yield.

In a second step the yield effects are investigated for all country values of selected crops. For all investigated crops, the GWP per ha increases with the yield, but the relationship has a different strength for these crops.

Per kg, those crops where the impact of the basic cropping operations (MachFix) is highest, have a close relationship. The extreme case is rice, where the methane emissions from the rice fields are so dominant, that the impact of the basic cropping operations is nearly 80% (Fig. 5). In this case, the yield is a determining factor, since the basic cropping operations are assumed constant worldwide. However, we have to keep in mind that the emission per ha was assumed constant in MEXALCA, which in reality is highly variable according to IPCC (2006). This leads to almost constant impacts per ha (Fig. 12) and a nearly hyperbolic function per kg (Fig. 13).

The other extreme example is peach, where the basic cropping operations have a very low contribution according to MEXALCA. The impact per ha increases with the yield (Fig. 14), but the impact per kg shows no trend in function of the yield (Fig. 15).

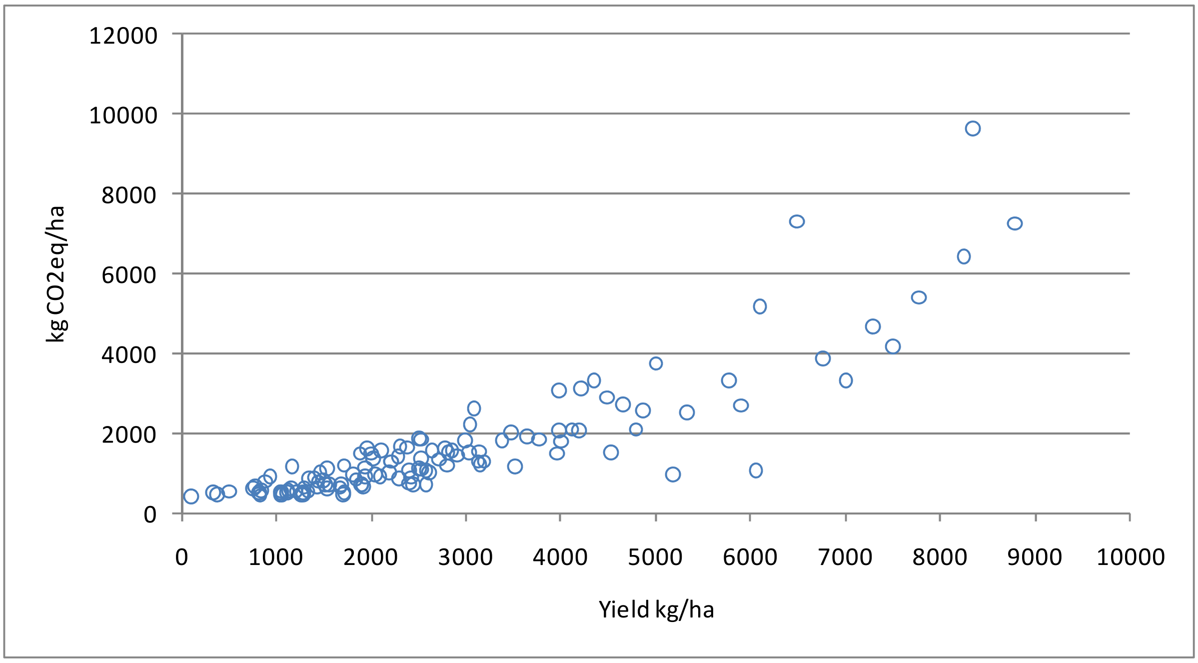


Fig. 8: Global warming potential (without deforestation) of wheat per ha in function of the yield.

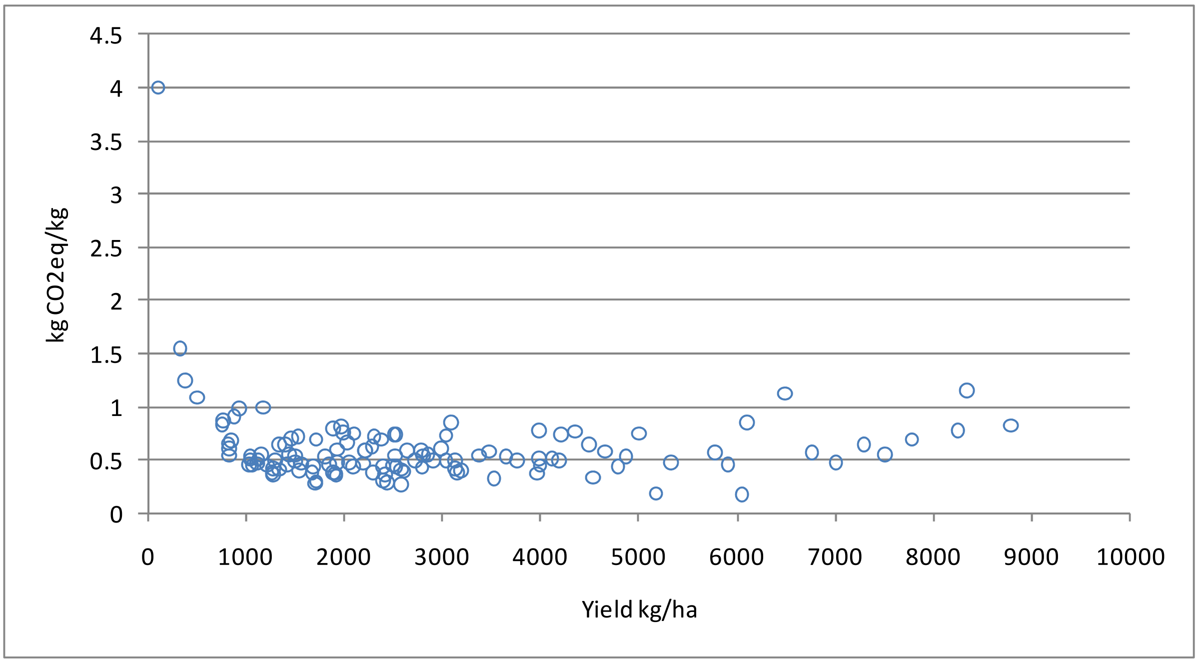


Fig. 9: Global warming potential (without deforestation) of wheat per kg in function of the yield.

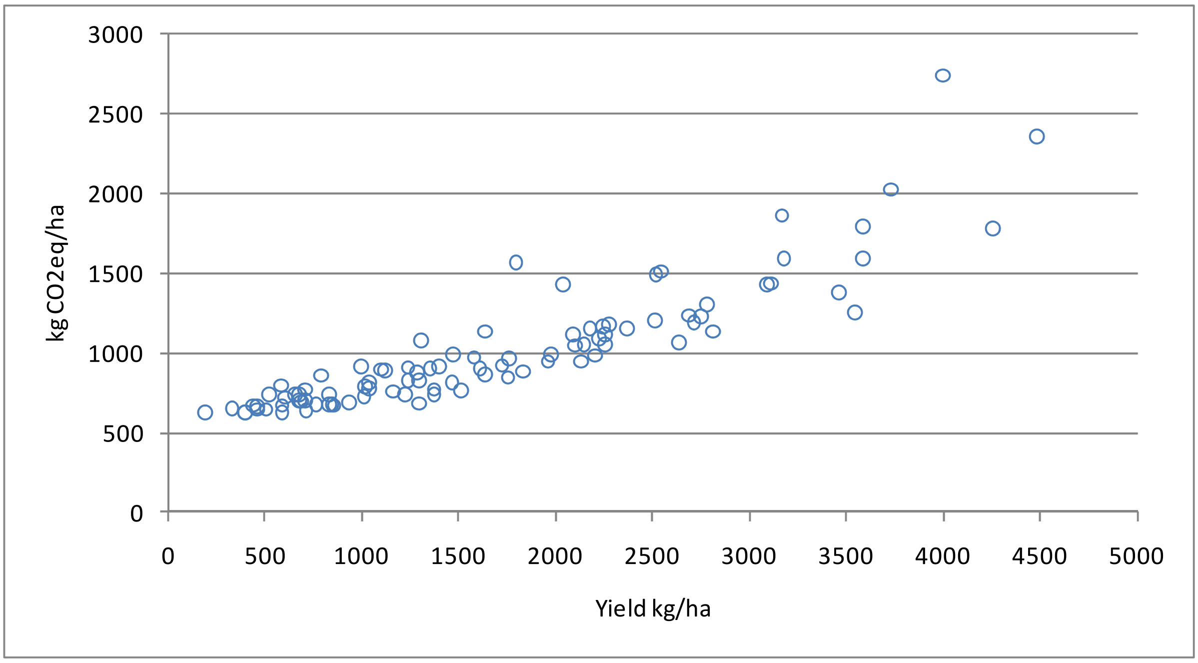


Fig. 10: Global warming potential (without deforestation) of pea per ha in function of the yield.

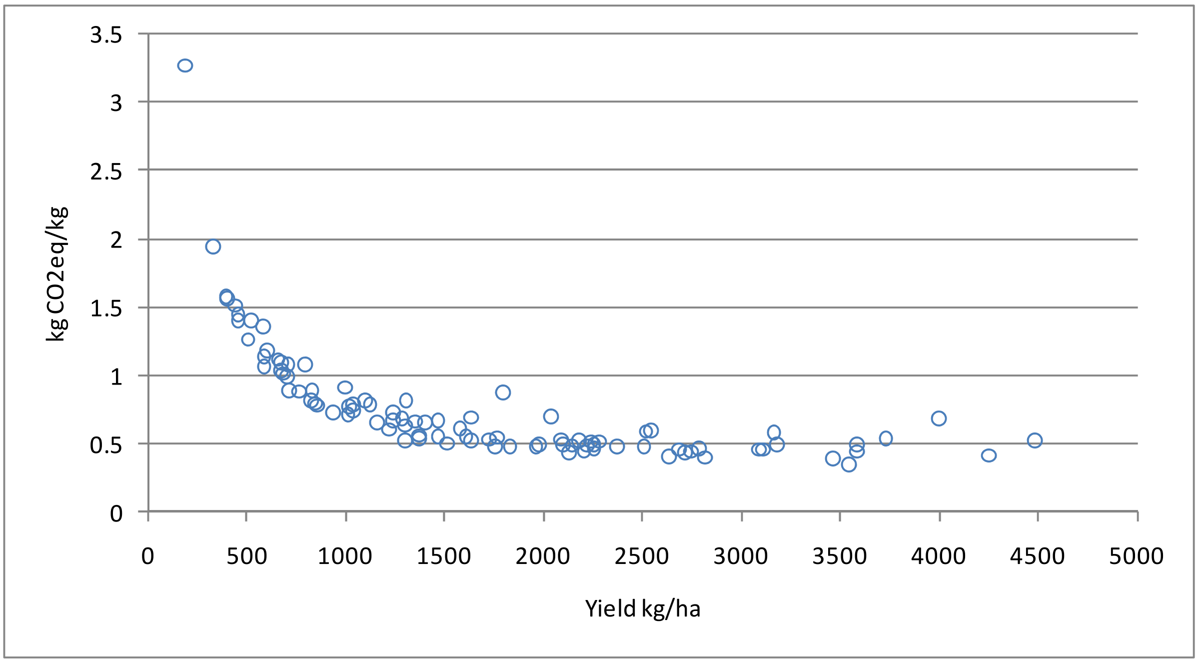


Fig. 11: Global warming potential (without deforestation) of pea per kg in function of the yield.

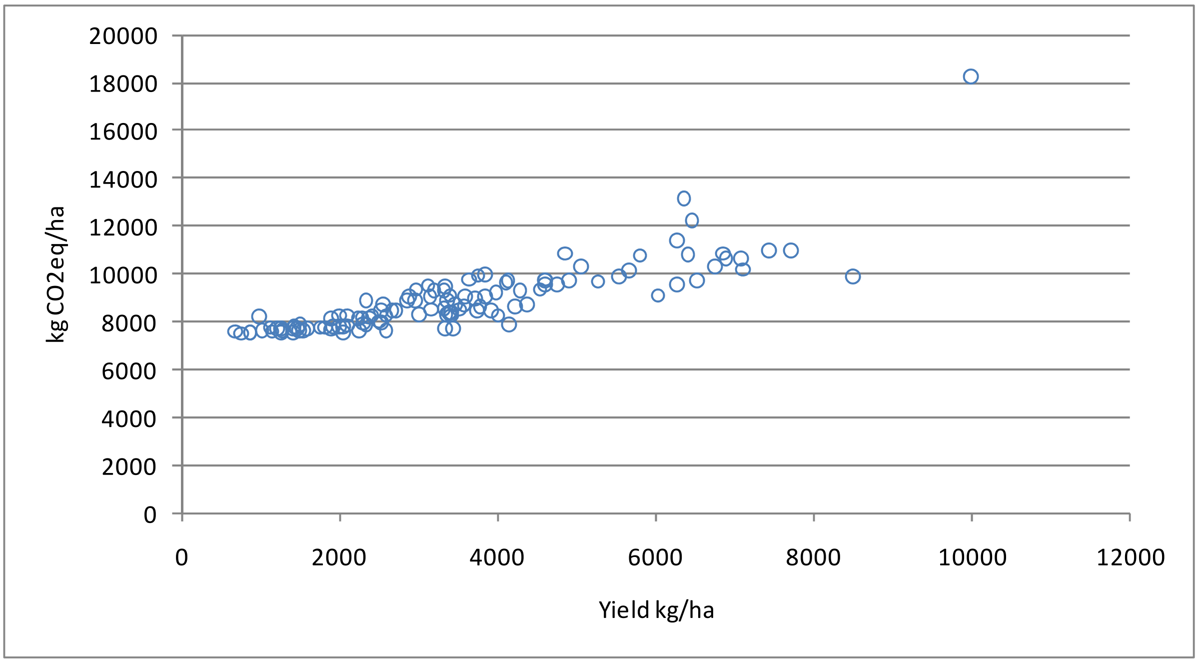


Fig. 12: Global warming potential (without deforestation) of rice per ha in function of the yield.

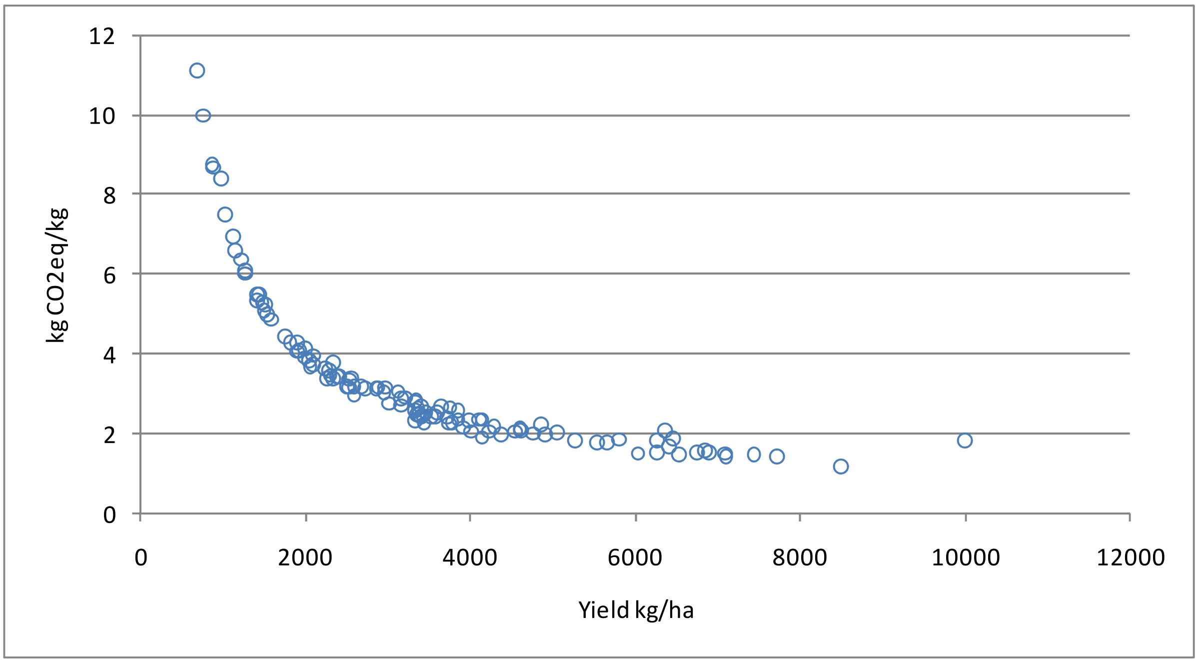


Fig. 13: Global warming potential (without deforestation) of rice per kg in function of the yield.

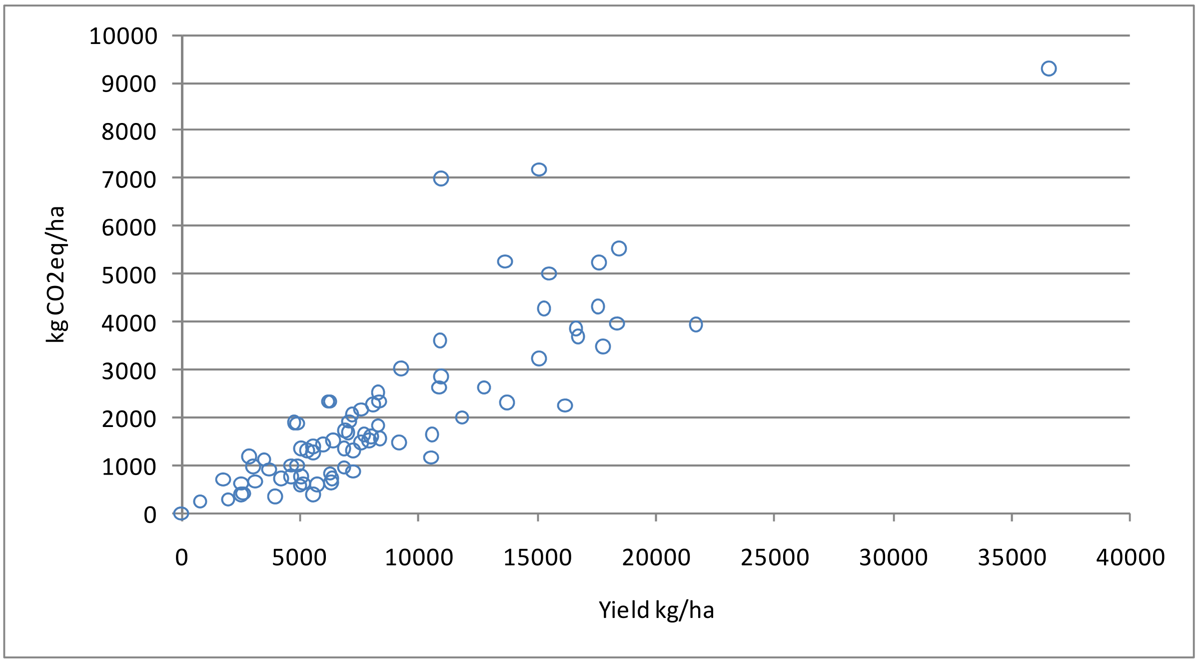


Fig. 14: Global warming potential (without deforestation) of peach per ha in function of the yield.

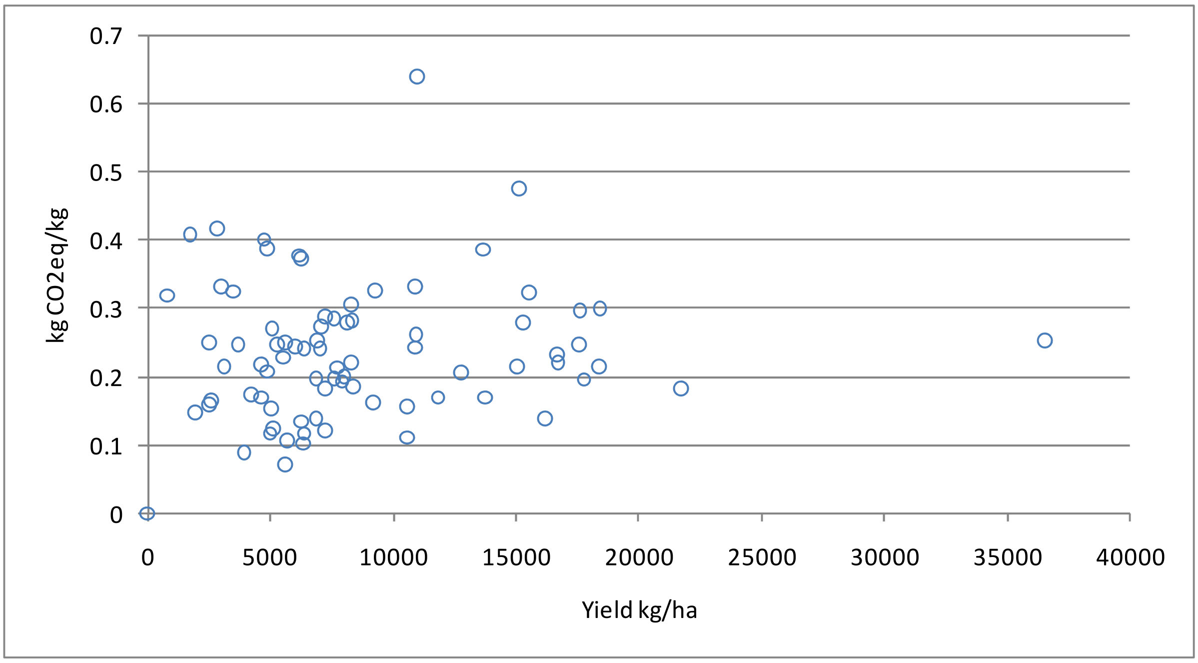


Fig. 15: Global warming potential (without deforestation) of peach per kg in function of the yield.

6.2 Regional differences

In the following analysis only those regions (or groups of countries) which contribute at least 0.2% to the global production were included. This was done for two reasons: First, very small producers are not important for the global production and second, there is a higher risk of wrong values, since data for country with a very small production might be less reliable.

In the following, a summary of the results of the regional analysis is shown. Detailed results for each studied crop are presented in Appendix B.

First we compare the yields weighted by the production volumes expressed as % of the weighted world average (Table 9, Fig. 16). As expected, yields are lowest for the least developed countries (LDC), medium for the developing countries and highest for the developed countries. However, within each of these three groups of countries, considerable differences exist. Highest relative yields are observed in Western Europe. Northern Europe, Northern America, Southern Europe, Southern Africa, Oceania and Western Asia show yields above the world average. The lowest yields are found in Africa, with the exception of Northern and Southern Africa, which are near the world average.

Table 9: Weighted mean yields and mean global warming potentials per region (averages of the respective %-values of all studied crops).

	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing
Yield	100%	46%	86%	128%	52%	40%	46%	36%	100%	114%	46%	56%	95%	57%	130%	94%
Weighted mean per ha (without def.)	100%	37%	94%	118%	41%	31%	18%	13%	142%	71%	33%	28%	81%	45%	117%	82%
Weighted mean per ha (with def.)	100%	91%	99%	103%	60%	51%	216%	86%	121%	59%	84%	67%	98%	36%	101%	130%
Weighted mean per kg (without def.)	100%	84%	110%	90%	92%	84%	50%	54%	137%	65%	98%	67%	89%	76%	90%	89%
Weighted mean per kg (with def.)	100%	213%	114%	74%	167%	139%	1086%	300%	111%	49%	258%	233%	106%	56%	73%	149%

	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Yield	66%	92%	68%	51%	64%	51%	106%	72%	149%	116%	248%	71%	109%
Weighted mean per ha (without def.)	62%	118%	75%	38%	71%	57%	98%	56%	149%	110%	294%	37%	70%
Weighted mean per ha (with def.)	59%	103%	191%	291%	63%	65%	87%	51%	141%	96%	275%	195%	64%
Weighted mean per kg (without def.)	101%	131%	113%	68%	114%	112%	93%	78%	99%	97%	108%	55%	67%
Weighted mean per kg (with def.)	93%	107%	327%	556%	97%	123%	78%	67%	91%	80%	94%	250%	59%

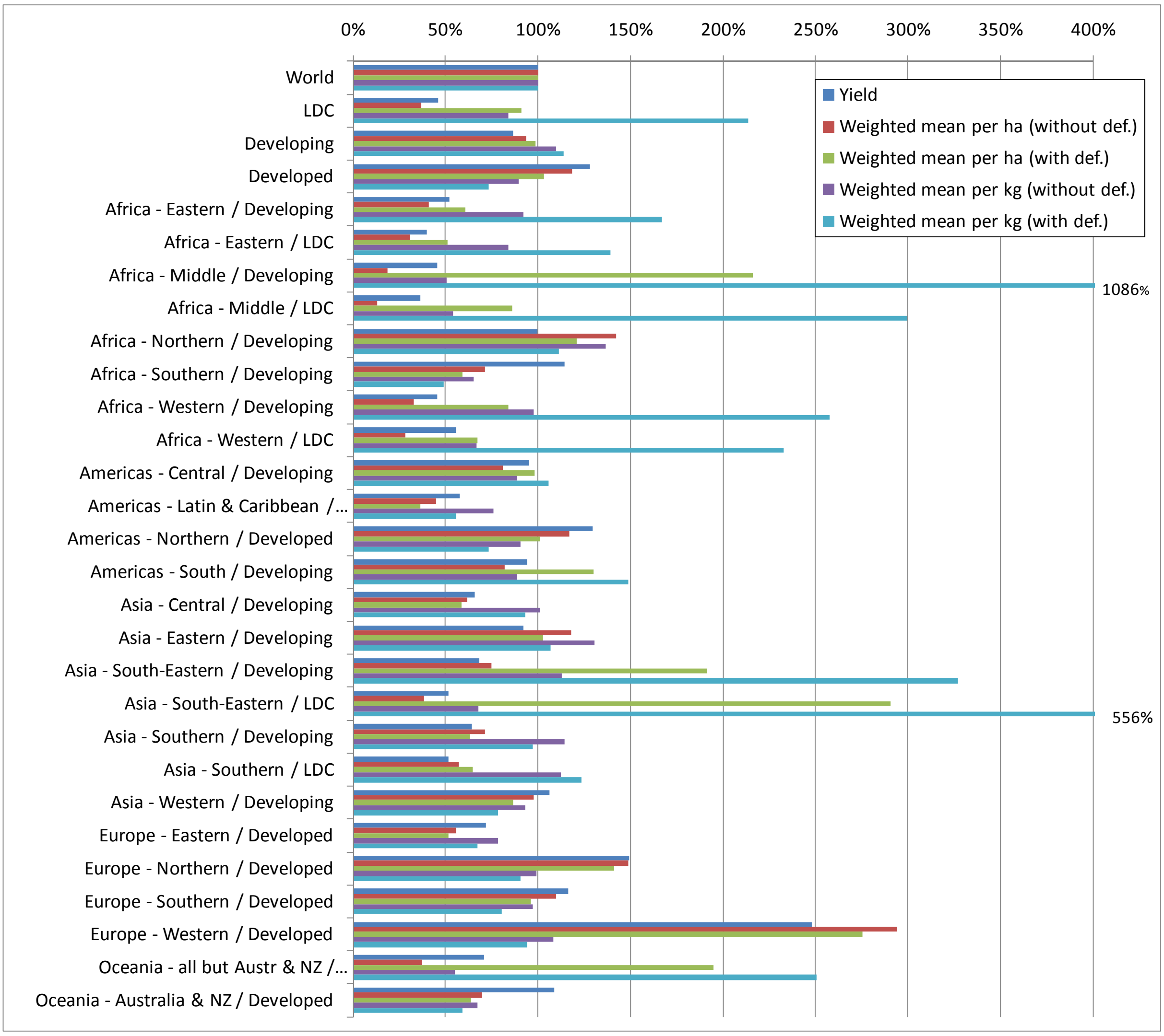


Fig. 16: Weighted mean yields and mean global warming potentials per region.

The weighted GWP per ha (without deforestation) are lowest in the LDC, medium in developing and highest in developed countries, i.e. the impacts follow the yields. The higher the yield the higher also the GWP per ha (see also section 6.1). If deforestation is included, the differences in GWP per ha between these three groups of countries almost disappear.

Per kg the differences are not systematic between LDC, developing and developed countries (without deforestation). They increase in the order LDC < developed < developing. If deforestation is included we found by far the highest values in LDC, medium in developing and lowest in developed countries.

Favourable results (low GWP both with and without deforestation) are found in “Africa - Southern / Developing”, “Oceania - Australia & NZ / Developed”, “Americas - Latin & Caribbean / Developing” and “Europe - Eastern / Developed”. In these countries the ratio between inputs and yields seem to be relatively favourable and there is not a high risk of deforestation. However, there are differences between crops as shown in Appendix B.

6.3 MULTIVARIATE ANALYSIS

The main objective of the multivariate analysis is to identify groups of crops with relatively similar environmental profiles. Such criteria could then be used to select suitable proxy data for crops, where no LCA data are available.

The multivariate analysis is performed with the impact values per kg (GWP without deforestation) using the countries contributing at least 0.2% to the global production, in order to avoid a strong influence of irrelevant and possibly biased values of very small producers. Principal component analysis is used here.

The ecotoxicity and human toxicity impacts were excluded, since they strongly dominated the results and therefore would hide other relationships. Furthermore, toxicity is not the focus of the current project. The impact values were transformed by *i' = ln (i+1)*, where *i* is the untransformed impact value, and *i'* is the impact value after transformation. The reason for using this transformation is that the ln-transformation yielded impact values close to normal distributions. The addition of *+1* was used in order to use the 0-values in the ln-transformation.

Two factors had Eigen values >1 and were therefore retained for further analysis (Fig. 17). Together they explain 75% of the variance.

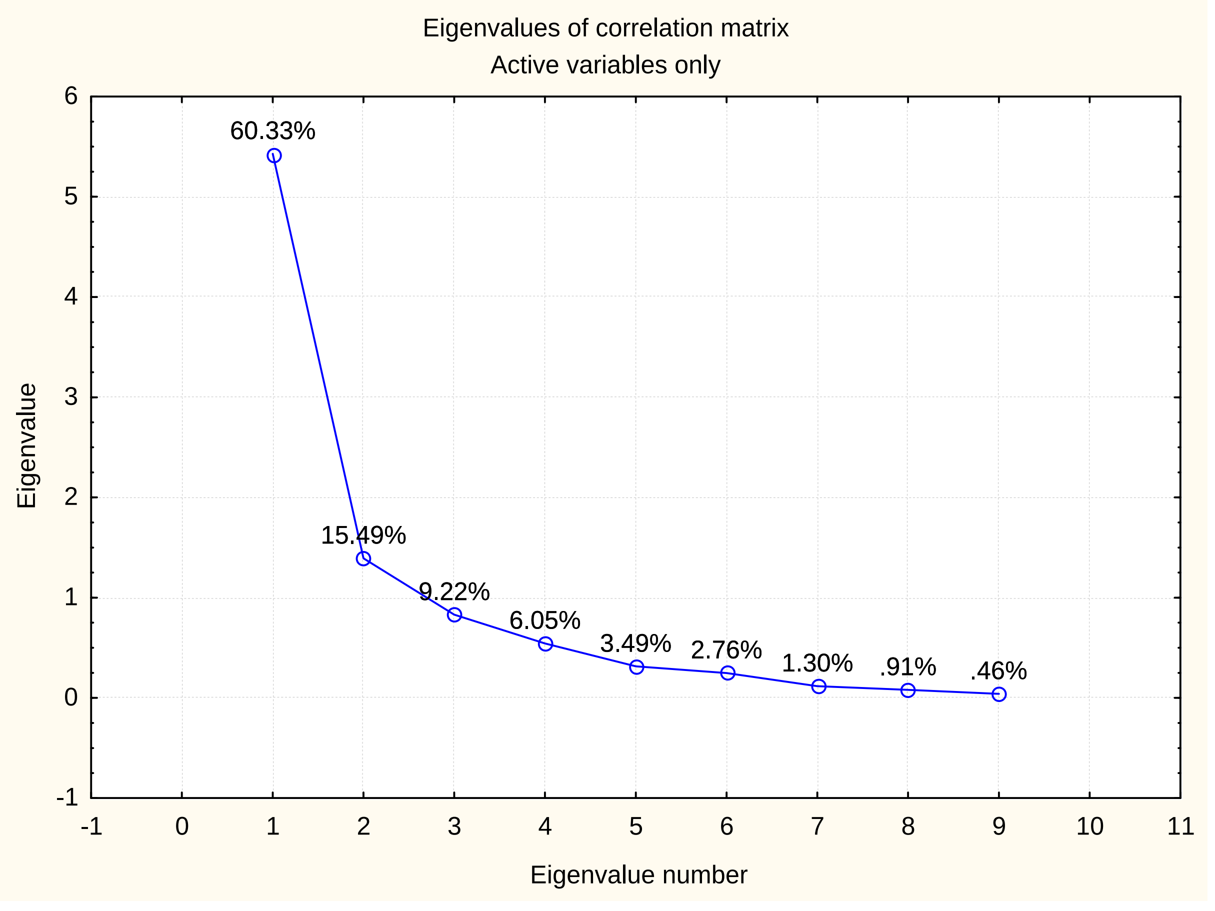


Fig. 17: Eigen values of the extracted factors.

Fig. 18 shows that Factor 1 is related to the yield (low yield means high land use, which implies that low yielding crops have low Factor 1 values (left), high yielding crops have high Factor 1 values (right). Furthermore it is related to high energy use, a high GWP and also high ozone formation and acidification potentials.

Factor 2 is positively correlated to high water use and negatively correlated to high P and K resource use and eutrophication potential. Crops with high water demand are thus found in the upper part of the graph, those with high nutrient demand and associated high nutrient losses (eutrophication and acidification) in the lower part.

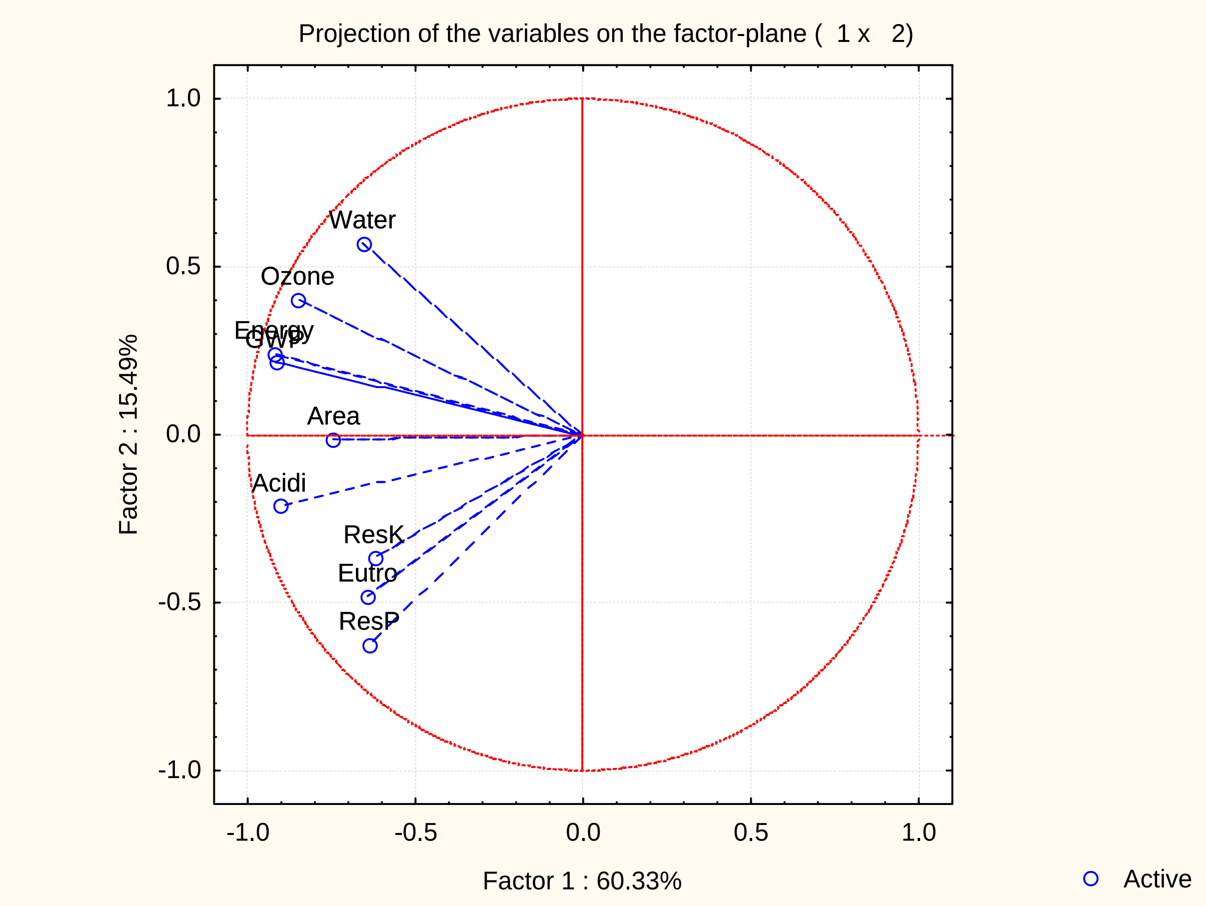


Fig. 18: Factor coordinates of the investigated environmental impacts (or life cycle inventory items): Water = use of blue water, Ozone = ozone formation potential, Energy = non-renewable energy demand, GWP = global warming potential, Area = land occupation, Acidi = acidification potential, ResK = potassium (K) resource use, Eutro = eutrophication potential, ResP = phosphorus (P) resource use.

The positioning of the crop-country combinations is shown in Fig. 18 in order to detect tendencies between the country groups. A clear distinction between industrialised, developing and least developed countries is not possible; the overlap is very large. The LDC have a slight tendency to the left (lower factor 1 scores), which can be explained by lower yields and consequently a higher land use and associated impacts. They have also a tendency to have higher factor 2 scores, which could be explained by lower use of P and K and possibly higher irrigation amounts relative to the yield.

The differences between industrialised and developing countries are relatively small, with a slight tendency for lower factor 2 scores in industrialised countries. This could be due to higher amounts of fertilisers and lower amounts of irrigation water in industrialised countries.

We have to keep in mind that the differences are not due to the countries alone, but also to the crops grown in these countries. Bananas are grown in developing countries mainly, whereas rapeseed is mainly cultivated in developed countries. As the following analysis shows, there exist considerable differences between the crops.

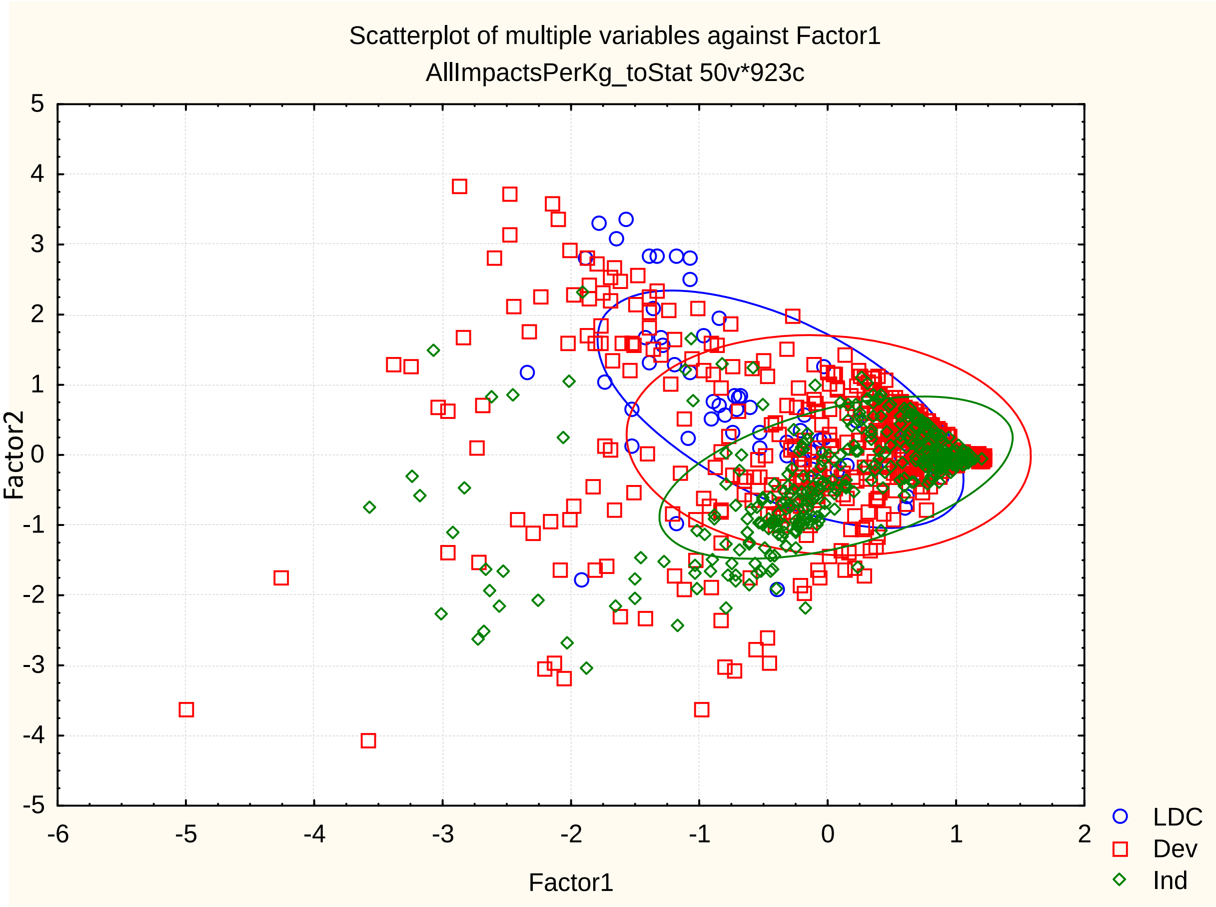
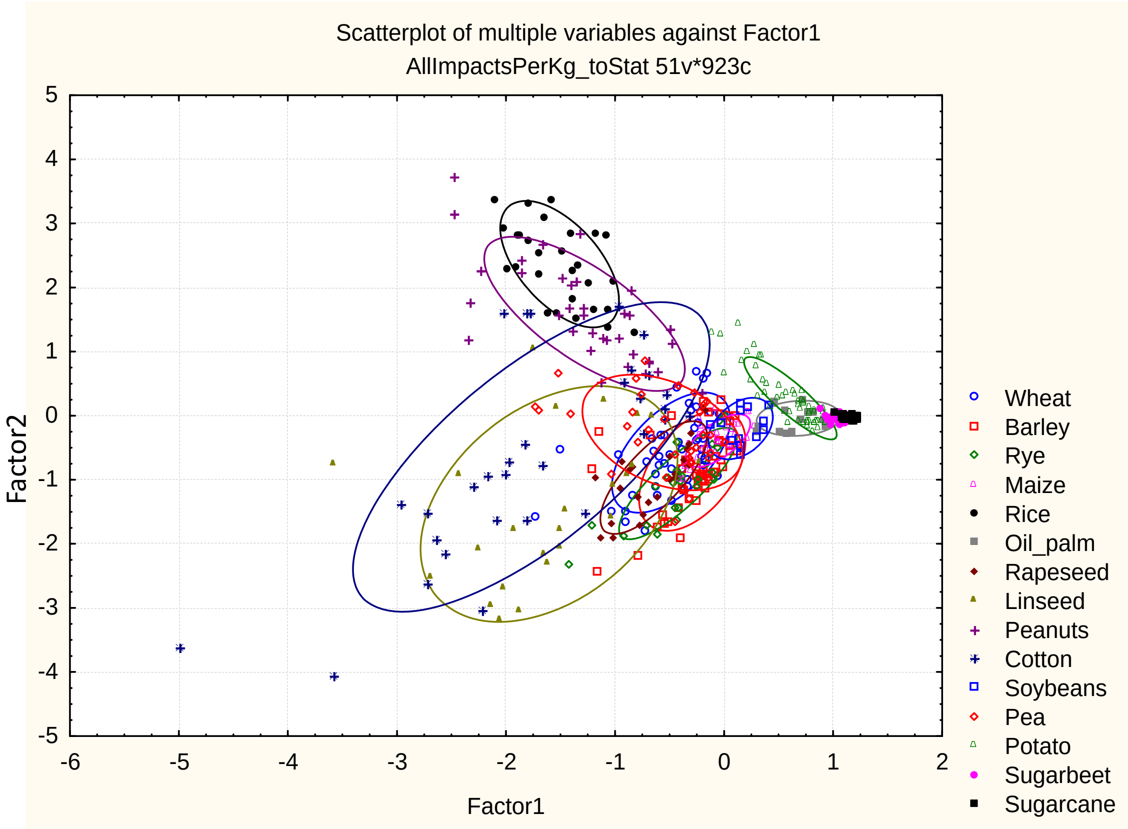


Fig. 19: Positioning of the environmental profiles of all crop-country combinations (for producers with a share >0.2% of the worldwide production) according to the group of countries: Ind = industrialised (developed), Dev = developing, LDC = least developed countries. The ellipses show 67% of the bivariate normal distribution, which corresponds roughly to +/- one standard deviation.

The grouping of the environmental profiles by crop results in large differences. The graph is split up in two graphs in order to be readable (Fig. 20 and Fig. 21).

The cereals wheat, barley and rye have relatively similar ranges of values, which could be expected by their similar growing and input patterns. Maize is also quite close to the other cereals, but has a narrower range and tends to have higher factor 1 and 2 values. Rapeseed is close to the cereals, but with slightly higher factor 1 scores (lower yields). The highest factor 1 values and narrow ranges are found for sugarcane and sugarbeet (the crops with the highest yields).

Potato and oil palm are also relatively high yielding crops and therefore are also found on the right side of the graph. The yields of soya beans are lower, but only little inputs are used to produce soya and therefore the factor 1 values are also relatively high. Rice and peanuts have low factor 1 and high factor 2 scores, which can be associated with high irrigation water use. Cotton and linseed are characterised by low yields and have ranges close to each other.



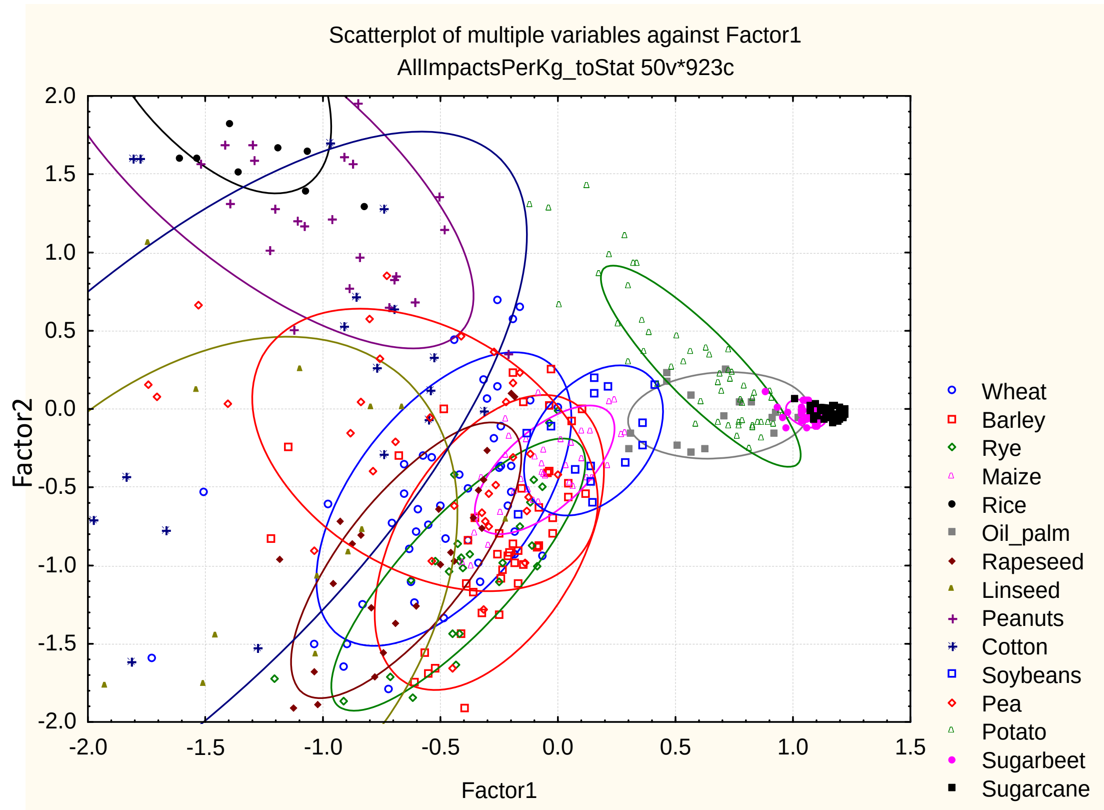
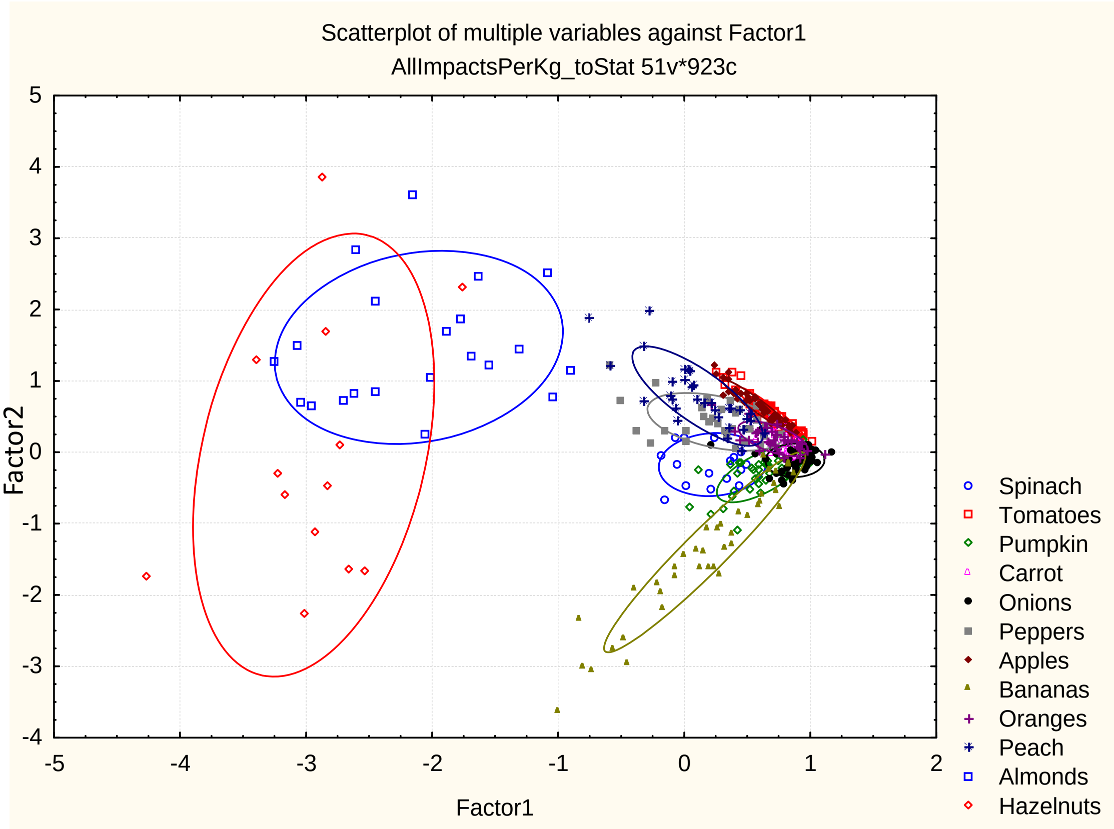


Fig. 20: Positioning of the environmental profiles of all crop-country combinations (for producers with a share >0.2% of the worldwide production) according to the crop (cereals, oil crops, pulses, sugar and root crops). The ellipses show 67% of the bivariate normal distribution, which corresponds roughly to +/- one standard deviation. Upper part: full representation, lower part central area magnified.

The treenuts (almonds and hazelnuts) are characterised by low yields and clearly distinguished from fruits and vegetables (Fig. 21). Fruits and vegetables are not clearly distinguishable regarding their environmental profiles. However, the vegetables (generally annual crops) have a closer range than the fruits (generally permament crops). Bananas need high amounts of nutrients, which is correlated to low factor 2 scores.

Surprisingly tomatoes and apples seems to have similar profiles, which could be explained by high yields and relatively similar input patterns. Also bell peppers and peach seem to be relatively close. The same holds for carrots and oranges. It seems difficult to derive general rules from these results.



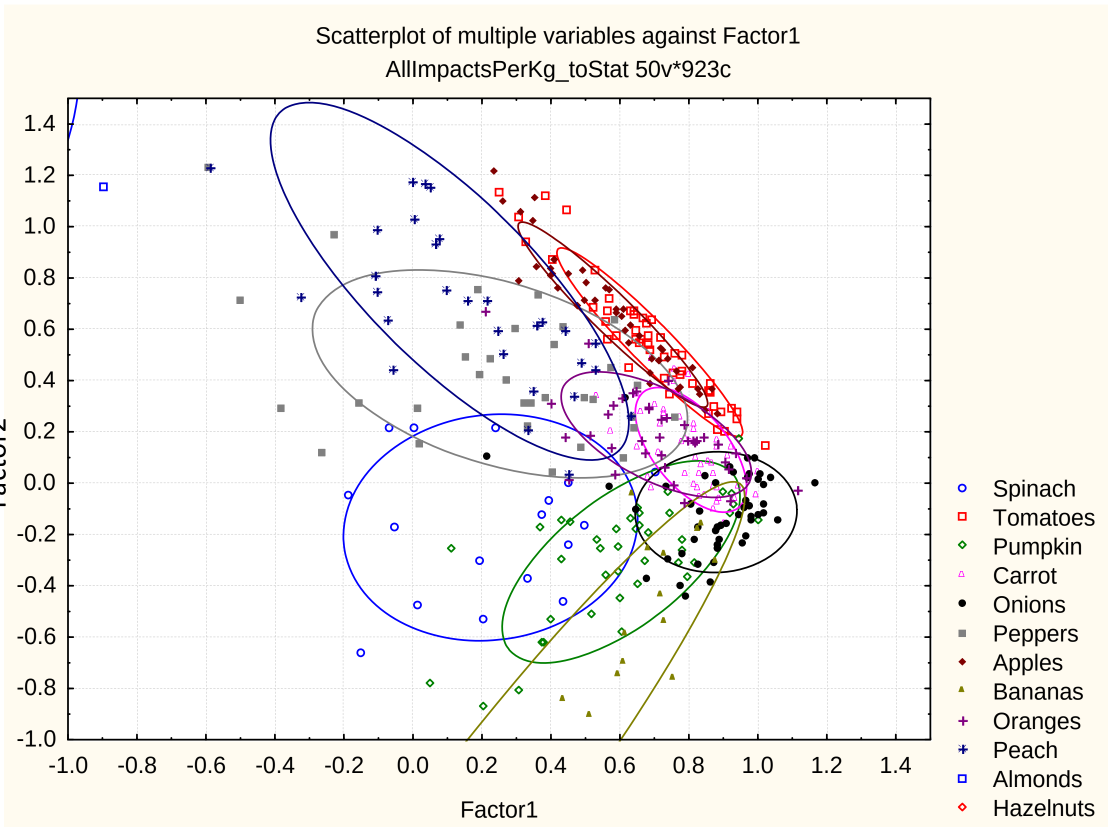


Fig. 21: Positioning of the environmental profiles of all crop-country combinations (for producers with a share >0.2% of the worldwide production) according to the crop (fruits, treenuts and vegetables). The ellipses show 67% of the bivariate normal distribution, which corresponds roughly to +/- one standard deviation. Upper part: full representation, lower part central area magnified.

7 Validation of the extrapolation results

Validation is performed first by comparing extrapolation results for individual crops and countries to the values from the ecoinvent database (section 7.1). Then the extrapolated ranges of values are compared to literature data (section 7.2). The validation is limited to the two impact categories that showed to have a relatively good agreement in the first validation (Roches *et al.*, 2010): non-renewable energy demand and global warming potential (GWP).

7.1 Validation against LCIA data from the ecoinvent database

Validation of the results is accomplished by comparing the extrapolated impacts per hectare and per kilogram (modular inventory) with corresponding LCIA data obtained from the ecoinvent data base (ecoinvent Centre, 2007). In addition to the crops validated in Roches *et al*. (2009), in phase 2 of the project validation is based on eight more crops, for which LCIA data are available in the ecoinvent data base. Since the GWP values in the ecoinvent database were calculated using the higher emission factors for N_2O according to IPCC (2001), they were recalculated with the emission factors for N_2O according to IPCC (2006), in order to be comparable with MEXALCA, which also uses the new emission factors. Furthermore the GWP from land use change have been subtracted.

Fig. 22a shows the validation for the impact non-renewable energy demand (unit MJ-eq) with respect to the functional unit 1 hectare. Linear regression through 13 of the altogether 27 MEXALCA crops leads to a coefficient of determination of $r^2 = 0.69$. In case of GWP shown in kilogram CO_2-equivalent and for a time period of 100 years (Fig. 22b), a coefficient of determination of $r^2 = 0.84$ is obtained.

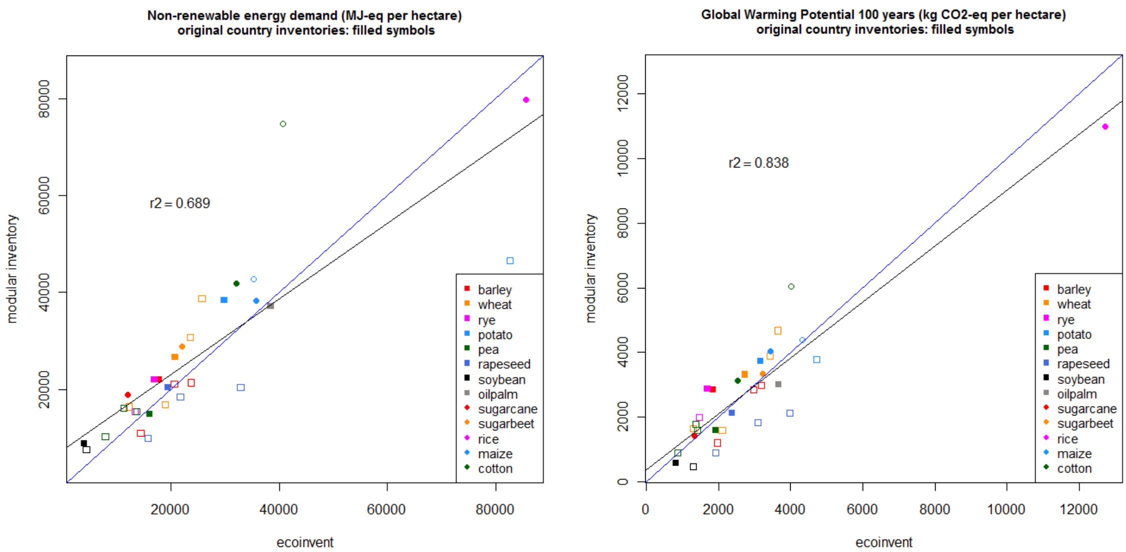


Fig. 22: Validation of the extrapolated ("modular inventory") Non-renewable energy demand (a) and the GWP (b) per hectare with ecoinvent data. Filled symbols = original countries, open symbols = target countries, blue line = bisecting line, black line = fitted linear regression function.

Validation with respect to the functional unit 1 kilogram is shown in Fig. 23. Linear regression of the extrapolated non-renewable energy demand (unit MJ-eq, y-axis) compared to LCIA data obtained from ecoinvent (ecoinvent Centre, 2007, x-axis) leads to a coefficient of determination of $r^2 = 0.73$. The same procedure carried out for the GWP (CO_2-eq, 100 years) results in a coefficient of determination of r^2 = 0.62. Thus, agreement slightly decreases by changing the functional unit from area to fresh mass of the products.

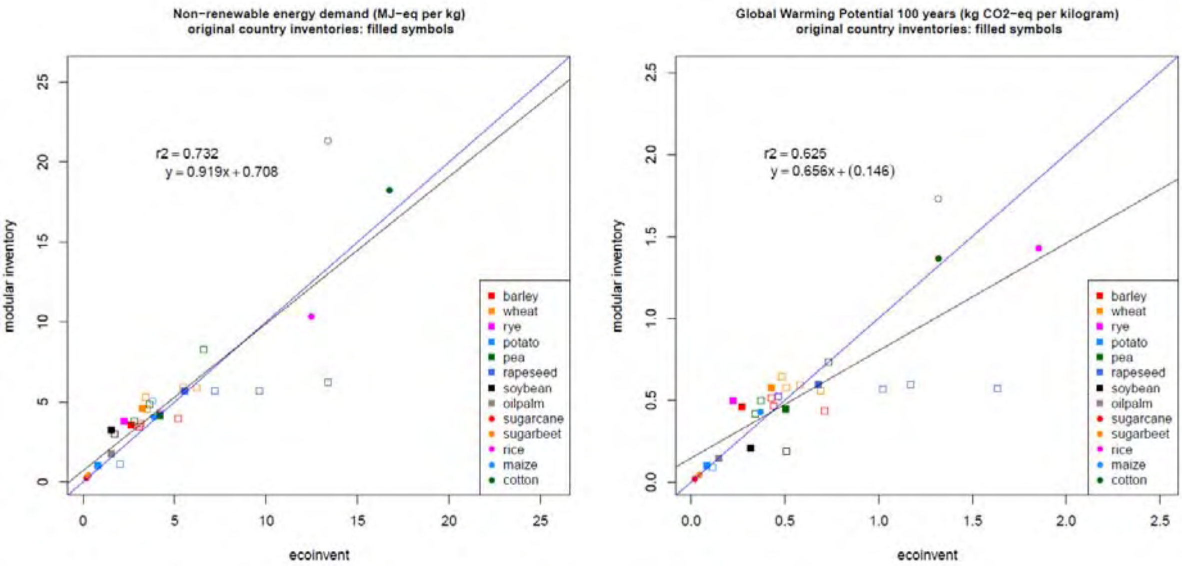


Fig. 23: Validation of the extrapolated ("modular inventory") Non-renewable energy demand (a) and the GWP (b) per kilogram with ecoinvent data. Filled symbols = original countries, open symbols = target countries, blue line = bisecting line, black line = fitted linear regression function.

Three statistical parameters are calculated in order to assess the performance of the MEXALCA results against the LCIA data from ecoinvent: the Pearson's correlation coefficient (PMCC), the mean difference between all pairs of results (MD) and the mean absolute difference between all pairs of results (MAD). In addition, MD% and MAD% give the mean difference and the mean absolute difference between all pairs of results as percentage of the mean ecoinvent values. For a detailed description of the approach see Roches *et al*. (2010).

MEXALCA results and ecoinvent LCIA data are well correlated as represented by a PMCC of 0.92 per ha and 0.79 per kg (Table 10). MEXALCA slightly underestimated the ecoinvent results, as expressed by MD% of -1% per ha and -10% per kg, respectively. The mean absolute deviations were between 20% and 30%. If the validation was performed with the target countries only, deviation between the ecoinvent data and MEXALCA was consistently higher (Table 10). A better agreement between MEXALCA and ecoinvent was found per ha than per kg.

Table 10: Validation of the GWP results per ha and per kg against values from ecoinvent V2.1. PMCC = Pearson's correlation coefficient, MD = mean deviation, MAD = mean absolute deviation, MD%/MAD% = MD/MAD as percentage of the mean (see Roches *et al*. (2010) for details).

			n	PMCC	MD	MD%	MAD	MAD%
All inventories	GWP	kg CO_2eq ha^{-1}	31	0.92	-34	-1.2%	661	23.1%
Only target countries	GWP	kg CO_2eq ha^{-1}	18	0.80	-140	-5.3%	699	26.7%
All inventories	GWP	kg CO_2eq kg^{-1}	31	0.79	-0.056	-9.6%	0.172	29.2%
Only target countries	GWP	kg CO_2eq kg^{-1}	18	0.56	-0.099	-14.9%	-0.099	32.7%

7.2 VALIDATION AGAINST LITERATURE VALUES

Plausibility of the extrapolated GWP and non-renewable energy demand with respect to the functional units 1 hectare and 1 kilogram fresh matter has been tested against various LCIA data obtained from literature. Table A.22 summarizes the corresponding data sources. To the best of our knowledge no LCIA data are available in literature for peanuts, linseed, pumpkin, peppers, bananas, almonds, hazelnuts, and peach.

The results of this validation in respect to the GWP are presented and discussed in Nemecek *et al.* (2011b).

The validation results for the non-renewable energy demand are presented below (Fig. 24 and Fig. 25).

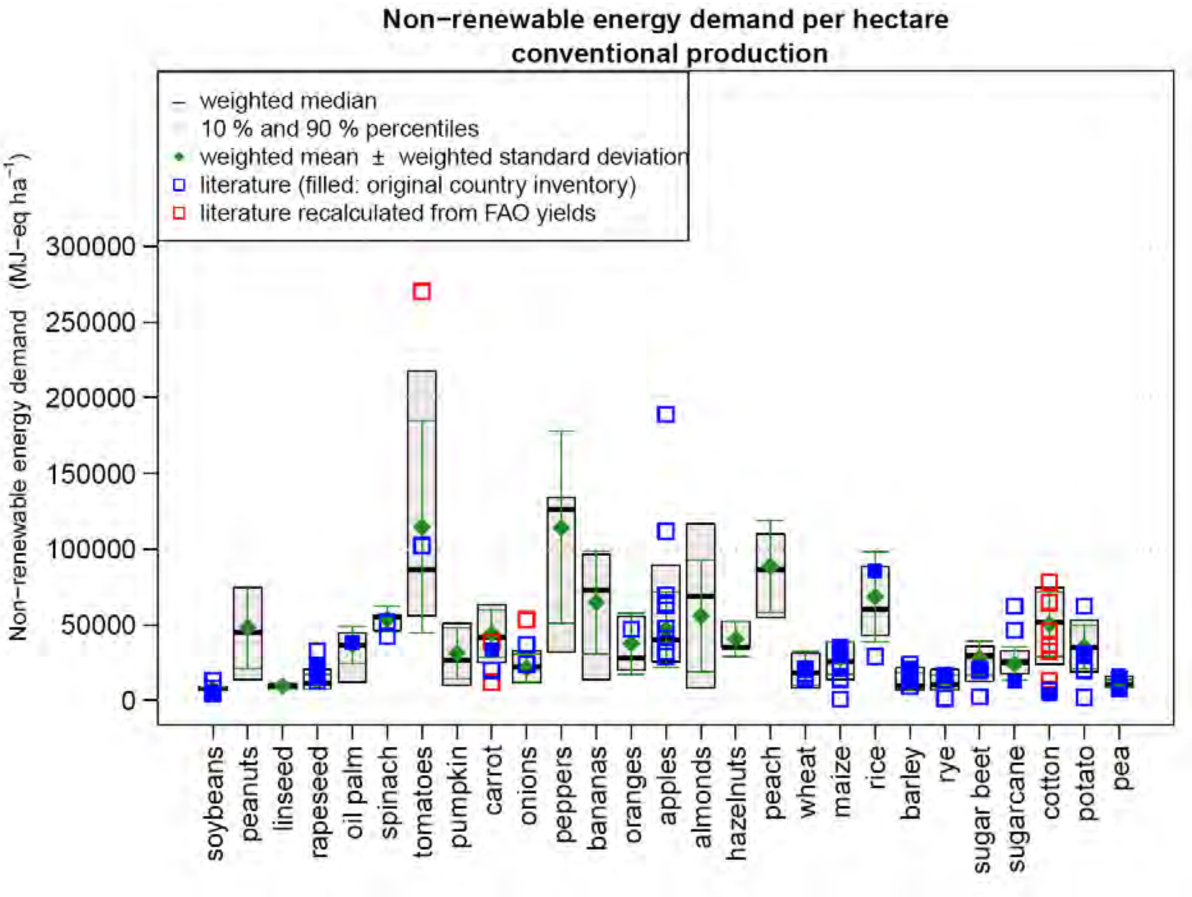


Fig. 24: Non-renewable energy demand for 27 crops (crop classification according to FAO, 2005) in MJ-eq ha^{-1}. For weighting, the contribution of a country to the world production (FAO, 2009) is used.

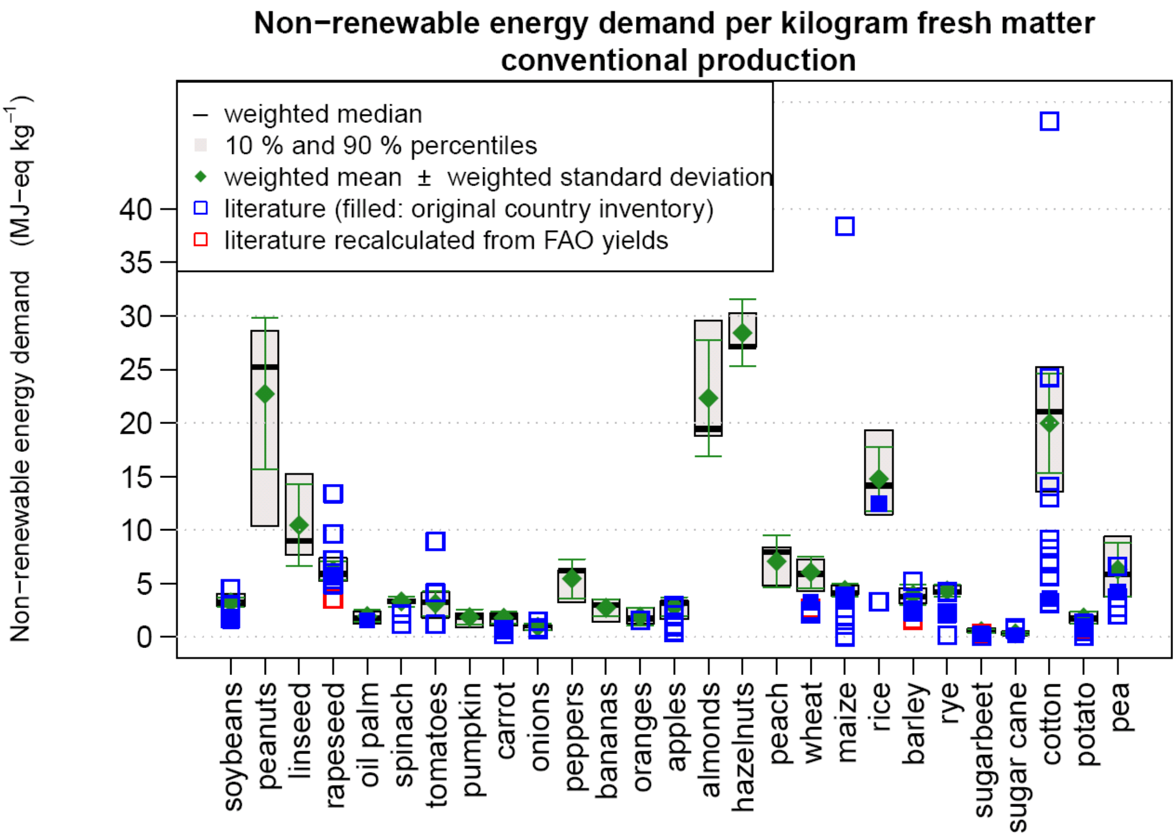


Fig. 25: Non-renewable energy demand for 27 crops (crop classification according to FAO, 2005) in MJ-eq kg^{-1}. For weighting, the contribution of a country to the world production (FAO, 2009) is used.

8 Discussion

For the discussion of the potentials and limitations of the modular extrapolations method see also Roches & Nemecek (2009) and Nemecek *et al*. (2011).

8.1 POTENTIALS OF MEXALCA

MEXALCA allows to extrapolate rapidly environmental impacts of crops from a known situation to any producer country in the world. This enabled us to gain insight into the mechanisms driving the worldwide variability of environmental impacts of products from crop production. It allows a structured analysis of data on yields and use of agricultural inputs from FAOSTAT.

The method can be used

- To assess the worldwide (or at least for a larger area) variability of the impacts of crops with the limitations listed in section 8.2.
- For an assessment of the worldwide mean or median. Use makes more sense at large scales such as continents or biomes.
- For a first screening of countries or regions, where a production could be eco-efficient. GWP results presented in Appendix B can serve this purpose. This should be followed by a detailed assessment of the most promising productions. Only general trends can be derived and for a particular situation a detailed analysis must follow.
- In situations, where the considered product has only a relatively small contribution to the total life cycle impact, in order to fill existing data gaps, or for initial impact screening, as long as the expected variability is taken into account.
- For estimates of the energy demand, ozone formation, GWP and land occupation.
- For the comparison between two crops, if the base inventories are created from sufficiently representative data (preferably several inventories).

MEXALCA is not limited to the use of the SALCA method. The modular extrapolation approach can be equally applied with other LCA methodologies in agriculture.

8.2 LIMITATIONS OF MEXALCA

When interpreting the results we should bear in mind also the limitations of the model, as already mentioned by Roches *et al*. (2010): factors not considered in the model, modelling simplifications and uncertainty of the underlying data.

Factors not considered:

- It is limited to commercial production only. Subsistence farming, with little or no use of external inputs and machinery is not considered.
- Organic production was not explicitly considered. The FAOSTAT database does not contain data that would make a reliable modelling of organic production possible. However, in the average yield and input use data drawn from FAOSTAT, organic farming is implicitly included, generally leading to lower yields and lower use of fertilisers and pesticides than conventional production alone would do.

- The impacts of pesticides could only be roughly estimated. Only the average quantities applied per country are known, which allows at best for a very rough estimate. The differences in active ingredients between countries could not be considered.
- Manure and other organic fertilisers were not considered. We assumed that cash crops are mainly fertilised by mineral fertiliser and farmyard manure is applied primarily to the grassland. However, this is not true for all countries and will lead to some over- and underestimation of impacts. Mineral fertilisers generally lead to a higher energy demand, but lower acidification and eutrophication (Gaillard & Nemecek, 2006).
- Different pedo-climatic conditions are not considered, or only implicitly by differences in input use.
- The variation within a country is not considered.
- Packaging was excluded, even if the products are packed on farm.
- Greenhouse production is not considered. For crops, where greenhouse production has a large share, the model is likely to fail. Note that FAOSTAT does not distinguish between field and greenhouse production, even if the yields might be quite different. In MEXALCA these differences could not be considered, since only field production is modelled.

Modelling simplifications:

- The impacts were modelled as linearly dependent on the input, which is a simplification.
- The same type of input is assumed worldwide.
- Drying was only roughly approximated.
- The models used in SALCAcrop were developed for Swiss conditions. While they are also applicable under similar climatic and soil conditions, e.g. in Central Europe, the transferability to substantially different conditions e.g. in the tropics is questionable.
- Land use change was included by a simplified modelling only.
- The indices for agricultural input use are country but not crop specific.

Quality of the underlying data:

- The FAOSTAT database was used for the calculation of the various indices as well as for the yield data. This database gives a rather complete dataset for all countries, but the quality of the data is not always very high. The method does not work for crops where the FAOSTAT database contains no yield data and these data cannot be found in other sources either.
- The base inventory and the selection of the original country play a critical role. All calculations are relying on the base inventory. A parameter that is not representative will give a biased estimate for the respective module over the whole world. Great care must therefore be taken for defining this inventory. Preferably it should be based on several inventories from several countries, which should give more robust estimates.

The validation is limited mainly to data from developed countries. LCA studies in developed countries are still scarce and studies from least developed countries almost inexistent. For many of the studied crops no validation was possible, since this is the first LCA study in the public domain.

For the following impacts, the validation did not yield a good agreement or could not be performed: eutrophication, water use, ecotoxicity and human toxicity.

9 Conclusions and outlook

The MEXALCA model enabled us to extrapolate environmental impacts of the production of 27 crops worldwide. It provided insight into the mechanisms driving the variability of the impacts. Worldwide means and standard deviations of impacts can be produced as well as the worldwide distribution of the impacts, weighted by the production volume.

Validation was performed with data from the ecoinvent database and from the literature for the impact categories non-renewable energy demand and global warming potential. Overall the validation showed a fair agreement between extrapolated impacts and ecoinvent or the literature values. The extrapolation was better per ha than per kg of product. The fit between extrapolated results and ecoinvent data was lower, when only the target countries were considered. The variability of the impacts seems to be generally underestimated by MEXALCA, which can be explained by the fact that not all sources of variability are included in the model.

The weighted worldwide means of GWP values of the studied crops varied in a wide range (factor of 20 per hectare, factor of 100 per kg). The lowest GWP values per kg of fresh mass (without considering land use change) were found for the sugar crops with high yields (sugarcane and sugarbeet), followed by root crops (carrot, potato), fruits, vegetables and oil palm. Cereals (except rice), pulses, rapeseed and soybean had medium GWP values. High values were found for treenuts, the oil crops (linseed, cotton, peanuts), and rice. Fruits, vegetables and cereals (except rice) each formed relatively homogeneous groups with widely overlapping ranges. The same holds for the sugar crops and root crops. Treenuts seem to have relatively similar values, but only two species were included in the study. Oil crops are a very inhomogeneous group including oil palm with low GWP, rapeseed with medium values and linseed, cotton and peanuts with high values.

The GWP was dominated by N fertilisers and nitrogenous emissions, energy use for irrigation, use of the machinery and carbon losses following land use change. The relative contribution of the different modules varied widely between the crops.

The yield and the farming intensity in the different countries (as expressed by the agricultural indices) were found to be relevant factors for the variability of GWP. The GWP values varied more per area than per kg, except for the crops, where the area-related impacts dominated (rice, pea). The variability of GWP increased with its magnitude, which led to relatively constant coefficients of variation. When the impacts of different crops were compared, no relationship per ha was found, but the GWP tended to decrease per kg with higher yields. The highest yields are achieved for crops with high water contents in the harvested products, like vegetables, fruits, roots and sugar crops. The comparison of the production of the same crop in different countries showed an increasing tendency of GWP per ha with higher yields, which is explained by a higher production intensity. There was in general no relationship for the GWP per kg. The selection of the producing countries was found to have a dominant effect on the variability of GWP. Crops that are produced in a few countries only and crops with homogeneous production conditions tend to have a low variability of GWP.

Further factors that were not considered in this study are also expected to contribute to the variability of GWP: different farming systems, differences in input use, pedo-climatic conditions, variability of the production within a country, and land use change impacts.

An analysis performed on regionally grouped countries (grouping by development level, and part of continents) showed that the yields generally increase in the order least developed countries (LDC), developing and developed countries. The GWP per ha (average of relative values of all studied crops) showed the same trend without consideration of the deforestation. Inclusion of deforestation almost compensated the differences between the development levels. GWP per kg was highest in developing countries, followed by developed and LDC with deforestation. With the inclusion of deforestation, it increased in the order developed < developing < LDC.

A principal component analysis showed the similarities and differences between the environmental profiles of the studied crops. It seems difficult to derive general rules to group similar crops together. Cereals (without rice), sugar crops (sugar cane and sugarbeet), and tuber and root crops were relatively similar, while oil crops formed a very inhomogeneous group. A lot of variation was found within fruits and vegetables, however clear subgroups could not be identified. Treenuts seem to be quite different from other crops.

Options for future development of the model are using more robust irrigation data, combining several original inventories in order to reduce the dependency on a single original inventory, or the inclusion of crop specific data in the agricultural indices and the input estimators, in order to assess better the farming practices of the individual crops.

10 References

Brannstrom, C., Jepson, W., Filippi, A.M., Redo, D., Zengwang, X. & Ganesh, S., 2008. Land change in the Brazilian savanna (Cerrado), 1986-2002: Comparative analysis and implications for land-use policy. Land Use Policy 25, 579-595.

BSI, 2008. PAS 2050:2008. Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services. London, UK: British Standards.

Derpsch, R. & Friedrich, T., 2009. Development and current status of no-till adoption in the world. Proceedings on CD, 18th Triennial Conference of the International Soil Tillage Research Organisation (ISTRO), June 15-19, 2009, Izmir, Turkey.

ecoinvent Centre, 2007. ecoinvent Data - The Life Cycle Inventory Data. Swiss Centre for Life Cycle Inventories, Dübendorf Switzerland. www.ecoinvent.org.

FAO, 2005. A system of integrated agricultural censuses and surveys. FAO, Rome, Italy, FAO Statistical Development Series.

FAO, 2006. Global forest resources assessment 2005. Progress towards sustainable forest management. Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAOSTAT, 2009. http://www.faostat.org (accessed April 2009 to March 2010).

Fargione, J., Hill, J., Tilman, D., Polasky, S. & Hawthorne, P., 2008. Land clearing and the biofuel carbon debt. Science 319, 1235-1238.

Frischknecht, R., Jungbluth, N., Althaus, H.-J., Doka, G., Hellweg, S., Hischier, R., Nemecek, T., Margni, M. & Spielmann, M., 2004. Implementation of life cycle assessment methods - ecoinvent data v1.1. Swiss Centre for Life Cycle Inventories (ecoinvent), Dübendorf, ecoinvent report, 116 p.

Gaillard, G. & Nemecek, T., 2006. Ökobilanz des Einsatzes von Wirtschafts- und Mineraldünger im Acker- und Futterbau. In: KTBL-Schrift 444: Verwertung von Wirtschafts- und Sekundärrohstoffdüngern in der Landwirtschaft - Nutzen und Risiken, 19.-20.2006, Osnabrück. KTBL, 63-74.

Guinée, J.B., Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., van Oers, L., Wegener Sleeswijk, A., Suh, S., Udo de Haes, H.A., de Bruijn, H., van Duin, R., Huijbregts, M.A.J., Lindeijer, E., Roorda, A.A.H. & Weidema, B.P., 2001. Life cycle assessment - An operational guide to the ISO standards. Ministry of Housing, Spatial Planning and Environment (VROM) and Centre of Environmental Science (CML), Den Haag and Leiden, Netherlands.

Hauschild, M. & Wenzel, H., 1998. Environmental assessment of products. Vol. 2: Scientific background. 2. Chapman & Hall, London, 565 p.

Heyland, K.-U., Allgemeiner Pflanzenbau. 7th ed. Ulmer, (Stuttgart) Germany.

Houghton, R.A., 2005. Tropical deforestation as a source of greenhouse gas emissions. In: Moutinho, P. & Schwartzman, S. (eds.) Tropical deforestation and climate change. IPAM, Instituto de Pesquisa Ambiental da Amazonia. Washington, DC, USA: Environmental Defence.

IPCC, 2001. Climate Change 2001: The Scientific Basis. In: Houghton, J.T. et al. (eds). Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), IPCC, Intergovernmental Panel on Climate Change, Cambridge University Press, The Edinburgh Building Shaftesbury Road, Cambridge, UK.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T. and Tanabe, K. (eds). IGES, Japan.

IPCC, 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, Cambridge, United Kingdom and New York, NY, USA, 996 p.

Kirda, C., 2002. Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Food and Agricultural Organization of the United Nations, Deficit Irrigation Practices, Water Reports, 22, 102 p.

Marklund, L.G. & Schoene, D., 2006. Global assessment of growing stock, biomass and carbon stock. Forest Resources Assessment Programme, Working paper 106/E. Forestry Department, Food and Agriculture Organisation of the United Nations, Rome.

Milà i Canals, L., Sim, S., Azapagic, A., Doka, G., Frischknecht, R., Jefferies, D., King, H., Mutel, C., Nemecek, T., Roches, A., Stichnothe, H., Thoma, G. & Williams, A., 2011. Approaches for addressing Life Cycle Assessment data gaps for bio-based products. Journal of Industrial Ecology, 15: 707-725.

Nemecek, T., Freiermuth Knuchel, R., Alig, M. & Gaillard, G., 2010. The advantages of generic LCA tools for agriculture: examples SALCAcrop and SALCAfarm. In: Proceeding of the 7th Int. conference on life cycle assessment in the agri-food sector, 22-24 September 2010, Bari, Italy. 433-438.

Nemecek, T., Huguenin-Eile, O., Dubois, D., and Gaillard, G., 2005. Ökobilanzierung von Anbausystemen im schweizerischen Acker- und Futterbau. Schriftenreihe der FAL 58. Agroscope FAL Reckenholz, Zurich, Switzerland.

Nemecek, T., Weiler, K., Plassmann, K., Schnetzer, J., Gaillard, G., Jefferies, D., García–Suárez, T., King, H. & Milà i Canals, L., 2011a. Modular extrapolation approach for crop LCA MEXALCA: global warming potential of different crops and its relationship to the yield. In: 5th International Conference on Life Cycle Management, 29-31 August 2011, Berlin.

Nemecek, T., Weiler, K., Plassmann, K., Schnetzer, J., Gaillard, G., Jefferies, D., García–Suárez, T., King, H. & Milà i Canals, L., 2011b. Estimation of the variability in global warming potential of worldwide crop production using a modular extrapolation approach. Journal of Cleaner Production, submitted.

Ramankutty, N., Gibbs, H.K., Achard, F., Defries, R., Foley, J.A. & Houghton, R.A., 2007. Challenges to estimating carbon emissions from tropical deforestation. Global Change Biology 13, 51-66.

Richner, W., Oberholzer, H.R., Freiermuth, R., Huguenin, O. & Walther, U., 2006. Modell zur Beurteilung des Nitratauswaschungspotenzials in Ökobilanzen – SALCA-Nitrat. Agroscope FAL Reckenholz, Zürich, Switzerland.

Roches, A., Nemecek, T., 2009. Unilever-ART project no. CH-2008-0779 on variability of bio-based materials: final report. Agroscope Reckenholz-Tänikon Research Station ART, Zurich, Switzerland.

Roches, A., Nemecek, T., Gaillard, G., Plassmann, K., Sim, S., King, H. & Milà i Canals, L., 2010. MEXALCA: a modular method for the extrapolation of crop LCA. Int. J. LCA, 15: 842-854.

Stern, N., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., Crane, D., Cruickshank, S., Dietz, S., Edmonson, N., Garbett, S.-L., Hamid, L., Hoffman, G., Ingram, D., Jones, B., Patmore, N., Radcliffe, H., Sathiyarajah, R., Stock, M., Taylor, C., Vernon, T., Wanjie, H. & Zenghelis, D., 2006. Stern review: The economics of climate change. HM Treasury, London.

Stewart, J.I., Cuenca, R.H., Pruitt, W.O., Hagan, R.M. & Tosso, J., 1977. Stewart, J.I., Cuenca, R.H., Pruitt, W.O., Hagan, R.M. & Tosso, J. Davis, United States of America, University of California, W-67 California Contributing Project Report.

Strack, M. (ed.), 2008. Peatlands and climate change. International Peat Society, Finland.

Walter, C. and Stützel, H., 2009. A new method for assessing the sustainability of land-use systems (II): Evaluating impact indicators. Ecological Economics, 68 (5), 1288-1300.

Weiler, K., Plassmann, K., Nemecek, T., Gaillard, G., Garcia-Suarez, T., King, H. & Milà i Canals, L., 2010. Modular extrapolation of crop LCA (MEXALCA): Sensitivity to varying crop yields. In: 7th Int. Conf. on LCA in the Agri-Food Sector, Notarnicola, B. (eds.). Bari, Italy. 97-102.

Yang, Y., 2007. Pesticides and environmental health trends in China. Fact sheet produced for the China Environment Forum's partnership with the Western Kentucky University on the USAID-supported China Environmental Health Project. Available at: http://www.wilsoncenter.org/topics/docs/pesticides_feb28.pdf (accessed September 2009).

Appendix A: Construction of original country inventories

A.1 Crops included in the ecoinvent database

A.1.1 Rape seed

The original country inventory is taken from the SALCA database and refers to the Saxony-Anhalt region in Germany (ecoinvent process no. 6957, rape seed conventional, Saxony-Anhalt, at farm, DE, [kg]). This base inventory did not include any irrigation, and the extrapolation is carried out on the assumption that irrigation is not used for rapeseed cultivation worldwide. Although there are some countries where rapeseed is irrigated, this appears to be more the exception than the norm, even in those countries where it is practised (Portmann *et al*., 2008). As such, the omission of irrigation in the extrapolation appears to be more accurate than adding irrigation to the base system which would result in including irrigation and associated environmental impacts in every producing country.

A.1.2 Soya beans

The original country inventory is constructed using data from ecoinvent on soya bean production in the USA (ecoinvent process no. 6659, soybeans, at farm, US, [kg]) as the biggest producer in 2003-2007 (FAOSTAT, 2009). This inventory does not include any irrigation. About 8 % of soya beans in the USA are irrigated (www.soyconnection.com/pdf/usbs_position/English/USB_CAST_English_HI.pdf, accessed 03.11.2009). Several references are used to estimate the annual amount of irrigation water used (Heatherly *et al*., 2004, 2002; Bastidas *et al*., 2008; Cooperative Extension Services of the University of Arkansas, 2000). This amount (3105 m^3 ha^{-1}) is then allocated across the total area under soybeans in the USA to represent the average situation (248 m^3 ha^{-1}). Due to a lack of detailed information, it is assumed that 50 % of soya beans are dried using high temperatures and 50 % using low temperatures. Emissions from an amount of 22 kg ha^{-1} $year^{-1}$ lime application as listed in ecoinvent cannot be considered with MEXALCA. The machinery use for the application of lime is, however, included.

A.1.3 Oil palm: Fresh fruit bunches

Data on the production of fresh oil palm fruit bunches in Malaysia, the main producer worldwide in 2003-2007 (FAOSTAT, 2009), is taken from the ecoinvent database (ecoinvent process no. 199, palm fruit bunches, at farm, MY, [kg]). The functional unit is ‘1 kg of palm fruit bunches (fresh matter)’. Oil palm plantations in Malaysia have an economic life span of about 25 years. Although oil palm trees can live much longer than this, the difficulties attached to harvesting once they become too high mean that replanting takes place after 25-30 years. The cost of plant material for replanting the plantations is included in the other inputs and therefore not inventoried separately. Oil palms require high nutrient inputs, especially of nitrogen and potassium, to ensure optimal yields (Khalid *et al*., 1999).

Ecoinvent assumes lime applications of 43 kg ha^{-1} $year^{-1}$ for the neutralisation of the pH value. Field emissions and emissions from the production of this lime are not included in our calculations because MEXALCA cannot consider lime applications. Ecoinvent state that oil palm plantations in Malaysia are irrigated at 2100 m^3 ha^{-1} (Sutter, 2007a). We assumed this figure to represent an average across the country.

Nitrogen fertiliser is applied three times a year (pers. comm. M. Razalia Mahidin, Malaysian Palm Oil Board, December 2009). We assumed three equal applications in May, July and

September. Data on the return of nitrogen to the soil through the biomass of old palm trees left in the field after felling was taken from Khalid *et al*. (1999) and then allocated over 25 years across the whole growing cycle.

The ecoinvent data are incomplete, especially with regards to machinery usage and the replanting at the end of the productive life of old plantations (Sutter, 2007a). For example, the machinery used to dig holes for manual planting of new trees or the cutting and shredding of trunks and fronds which are then used for mulching are not included. Due to a lack of information, we do not include these operations either. No cover crops or wire netting that might be used to protect the seedlings are considered in the ecoinvent dataset.

A.1.4 Sugar cane

The original country inventory is constructed using data from ecoinvent on sugar cane production in Brazil (ecoinvent process no. 6258, sugarcane, at farm, BR, [kg]). This inventory does not include any irrigation because the majority of sugar cane in Brazil is grown under rainfed conditions. However, according to FAO (2008), 24 % of sugar cane in Brazil is irrigated, and irrigation is also used in many other producing countries (Portmann *et al*., 2008). Therefore irrigation is added to the original inventory, assuming 2800 m^3 ha^{-1} of irrigation (Silva *et al*., 2008) in those areas in Brazil where irrigation is necessary. This is then allocated across Brazil's entire area under sugar cane. This approach is likely to underestimate irrigation in many sugar cane producing countries (FAO, 2008), but it was decided to use the figures for Brazil as the original country and the world's largest sugar cane producer. Irrigation is essential where mean annual rainfall is less than 600-800 mm, but irrigation is not uncommon in countries that receive more than this amount (Watson *et al*., 2008), and irrigation water can also be applied in order to increase yields (Ramjeawon, 2000). For example, sugar cane in Australia, the 7th largest cane producer in the world, is on average irrigated with 5200 m^3 ha^{-1} and up to 12,300 m^3 ha^{-1} in drier areas (Renouf *et al*., 2008). The potential use of vinasse, the waste water from sugar cane processing, as fertiliser and for irrigation is not taken into account.

The ecoinvent data set assumes that 20 % of sugar cane is harvested mechanically and 80 % manually. This split will of course not be the same in every country, introducing another source of potential error. The use of ripeners and the field operation earthing up are not considered in the ecoinvent inventory for Brazil, which means that they are not considered either for any other producing countries.

The growing cycle modelled for Brazil is 5 years long. This might be different in other countries which will impact on average yields and the allocation of operations like planting across the whole growing cycle. Inputs such as fertiliser applications are also usually different between the planting year and the following ratoon years, so the total amount of fertiliser per year across the whole growing cycle also is influenced by the length of the cycle.

Because no organic fertilisers are considered in MEXALCA, the nitrogen contained in vinasse applications (0.36 kg N t^{-1}; Macedo, 2005) is added to the amount of nitrogen applied as mineral fertilisers, where the nitrogen in the vinasse account for over one third of the total nitrogen applied. Two even nitrogen fertiliser applications are assumed to be made in October and December.

Burning of cane prior to harvest is common practice and the ecoinvent dataset assumes burning of the cane on the majority of the area. On the one hand, this causes emissions to air, and on the other hand it means that no residuals are left in the field. This means that the extrapolation will be inaccurate for countries where no or much reduced pre-harvest burning is practised and the tops and leaves are left in the field as a protective thrash blanket, although some harvesters also collect tops and leaves for further use. No nitrogen return in ashes left after burning is considered.

The use of fertilisers is low in Brazilian sugar cane cultivation, both in comparison with other crops grown in Brazil (e.g. cotton, coffee, oranges) and with sugar cane in other countries. For example, Macedo (2005) claims that Australia uses 48 % more fertilisers than Brazilian sugar cane farmers. This could mean that using Brazil as the original country in this analysis may not be very representative of fertilisation practices in the world, which will have an impact on the extrapolation.

In the ecoinvent calculations, actual yields are reduced to account for the production of the cuttings used for re-planting (12000 kg ha^{-1}), i.e. cuttings are assumed to be produced on the same farms. It is unknown whether the FAOSTAT (2009) yields consistently include or exclude these cuttings for all the different sugar cane producing countries. The reduced yield used in ecoinvent (66300 kg ha^{-1}) is lower than the figure for Brazil given in FAOSTAT (2009) of 74612 kg ha^{-1}, but no corrections as described for peanuts (section A.2.1) are applied because this difference is relatively small.

A.1.5 Sugar beet

Data on sugar beet production in Switzerland from the ecoinvent database (process no. 234, sugar beets IP, at farm, CH, [kg]) are used to define the original country system. No irrigation is applied in the Swiss inventory, but as much sugar beet around the world is irrigated and a lot of the crop water use is provided by irrigation (Portmann *et al*., 2008; Siebert and Döll, 2008), irrigation is included in the original country model and based on literature data for summer production of sugar beet in Spain (Sorensen, 2008), using an amount of 7770 m^3 ha^{-1} where irrigation is used. Because no information on the amount of sugar beet in Spain that is irrigated was available, the FAOSTAT figure of 20.5 % area equipped for irrigation in Spain is used to calculate an average amount of water applied of 1598 m^3 ha^{-1}. 36 kg N ha^{-1} contained in vinasse, i.e. the waste water from sugar beet processing is included as mineral nitrogen fertilizer. The environmental impact of 345 kg ha^{-1} lime application cannot be taken into account with MEXALCA.

A.1.6 Rice

Ecoinvent contains data on rice production in the USA (ecoinvent process no. 6970, rice, at farm, US, [kg]). Rice is grown under a variety of conditions, e.g. cultivation systems in South and Southeast Asia range from irrigated or rainfed to rainfed shallow lowland and rainfed deep lowland systems. China's major rice production systems are: rainfed; irrigated with intermittent irrigation and/or distinct drainage periods; and rice areas that are never or very rarely drained (Verburg and van der Gon, 2001). All rice in the USA is grown on flooded fields (EPA, 2009). Differences in environmental conditions lead to major differences in the length of the growing period (70-160 days; Wichmann, 1992). Rice cultivars can differ by 9-55.7 % in their methane emission rates (Wang *et al*., 1999). Other factors that can greatly influence methane emissions include water regime, organic amendments used, soil characteristics, cropping practices and season (Wang *et al*., 1999; IPCC, 2006; EPA, 2009). These factors will vary to a large extent between and within rice producing countries, with potentially large impacts on the reliability of the global extrapolation from one original country system.

The burning of crop stubble after harvest is not included in the ecoinvent database, and is thus not included in MEXALCA. However, it appears to be a widespread practice, even though it is now banned in some parts of the world (Eagle *et al*., 2000; McCarty *et al*., 2006). Data on the amount of residuals left in the field after harvest is taken from ecoinvent (Nemecek *et al*., 2007) and the amount of N contained in these residuals (0.7 %) from IPCC (2006) and Mandal *et al*. (2004). Nitrogen fertiliser applications are assumed to be split evenly between three applications in April, June and July. Cultivation is assumed to be in a soybean-rice rotation.

Because rice is cultivated under flooded conditions, nitrate leaching and methane emissions cannot be calculated using the SALCA models as for the other crops, and the figures contained in ecoinvent are used.

According to ecoinvent, rice cultivation in the USA requires 7297 m^3 ha^{-1} of irrigation water. About 59.4 % of the area under lowland rice in the world are equipped for irrigation (www.knowledgebank.irri.org/watermanagement/index.php#m3x_top), so for the extrapolation it is assumed that 4334 m^3 ha^{-1} are used to represent a global average across irrigated and non-irrigated areas.

Information on dates of harvest and seeding is obtained from http://pestdata.ncsu.edu/croptimelines/pdf/Rice.pdf. Rice residuals are typically burned in the USA (EPA, 2009) but this was not considered in ecoinvent and MEXALCA.

China, the world's major rice producer in 2003-2007 (FAOSTAT, 2009), uses a lot of organic fertilisers in general, including rice (e.g. farmyard manure, straw, compost, fermented residuals, agricultural, agri-industrial and municipal wastes, green manures). Organic fertilisers have a large impact on methane emissions from paddy fields but cannot be represented by MEXALCA. Verburg and van der Gon (2001) estimate that rice paddies accounted for 70 % of total agricultural methane emissions in China.

Water management has an important impact on methane emissions from rice paddies, leading to significant differences in methane emissions (Verburg and van der Gon, 2001) and making it very difficult or impossible to define a representative system. Most measured methane emissions from fields at different locations in China are between 10 and 70 g CH_4 m^{-2} per season, with an absolute minimum of 0.4 and a maximum of 103 g CH_4 m^{-2} per season (Verburg and van der Gon, 2001). These emissions are strongly influenced by the application of organic fertilisers and local water management.

A.1.7 Maize

Ecoinvent data for the USA as the main producer in the world (FAOSTAT, 2009) are used for the original country inventory (ecoinvent process no. 6528, corn, at farm, US, [kg]). For irrigation, ecoinvent quotes a figure of 40.86 m^3 ha^{-1}, and it is assumed that this already is an average across the whole country, including irrigated and non-irrigated areas. The amount of nitrogen returned to the soil in crop residuals is estimated using data from GRUDAF (2009). It is assumed that 70 % of the total nitrogen fertiliser used is applied in June and the remaining 30 % pre planting (Beegle and Durst, 2003). The environmental impact from application of 283 kg ha^{-1} lime cannot be considered with MEXALCA.

A.1.8 Cotton fibers and seed

The original country inventory for cotton production is based on an ecoinvent dataset on production in the USA (ecoinvent process no. 201, cotton, US, [ha]). The USA are the second largest producer of cotton with a contribution of 17 % to world production. The biggest producer is China with a contribution of 28 %.

Seeding and harvesting occur in mid of May and mid of October, respectively. The date for ploughing is October of the preceding year. Nitrogen fertilizer is applied to equal shares in May and June and in November of the preceding year.

Application of a chisel plough is modeled with the ecoinvent process "tillage, cultivating, chiselling, CH, [ha] (#180)". Although this process is actually not meant to be an intensive cropping operation with respect to the nitrate model applied (Richner, 2006), it is considered as such as it is assumed that nitrate leaching to soil is affected by this process.

Any pesticide application is expressed as ground application even if more than half of the pesticides applications are listed in the ecoinvent dataset to be carried out by air spraying.

The process of ginning is approximated with the ecoinvent process “grain drying, high temperature, CH, [kg] (#158)”.

The parameters for the nitrate leaching model are approximated with those valid for tobacco. The reason for this choice is tobacco to be the most similar among the available crops with respect to the relevant factors (like seeding and harvesting dates, biomass production and nitrogen uptake from soil).

In order to define a crop rotation cycle a general recommendation in UNCTAD (2010) proposing a three-year rotation cycle is taken into account. Based on this assumption, cotton is accompanied by a legume and a cereal, while the cereal preceding cotton is specified as maize, because maize occupies the largest acreage in American cereal production. The average harvesting date for maize in US American cotton producing states is the 5th of September (NASS, 2003).

FAOSTAT (2009) presents numbers of cotton yields for the whole harvested cotton bolls consisting of seeds and fibers. For this reason the farming inputs in the original country inventory also refer to the production of the whole cotton bolls. However, in order to allow an allocation with respect to the two products, cotton seeds and fibers, the process of ginning is included in the inventory. Allocation factors for an economic allocation are based on at-farm prices of cotton fibers and cottonseeds in the period 2003 to 2007 (FAOSTAT, 2009) and averaged among all cotton producing countries. This leads to 86 % of the environmental impact to be assigned to cotton fibers, while the remaining 14 % are at the expenses of the cotton seeds. In case of mass allocation 40 % of the impact refers to cotton fibers and 60 % to the cotton seeds. The latter numbers are calculated from the mean seed mass content of cotton bolls according to FAOSTAT (2009).

The average cotton yield for the USA as given in the ecoinvent database is 1919 kg ha^{-1} from which 775 kg are fibers and 1144 kg are seeds. This number is in an acceptable agreement with the value of 2289 kg ha^{-1} as obtained from FAOSTAT (2009).

A.2 Crops not contained in the ecoinvent database

A.2.1 Peanuts

Detailed data on the cultivation of irrigated peanuts in Australia (Queensland) have been obtained in confidence and therefore no details on inputs and outputs for the original country system or the business providing the data are disclosed here. This is a very high input production system with high yields. Queensland produces about 95 % of all peanuts in Australia. Peanuts are susceptible to pests and diseases and therefore require considerable agro-chemical inputs (Maraseni *et al.*, 2007). The main nutrients that need to be applied are phosphorus, calcium and sulphur. As legumes, peanuts can fix nitrogen from the atmosphere and do thus not need additional nitrogen fertiliser inputs. Planting occurs between October and December and harvesting between March and May.

Peanut production systems differ markedly between some of the main producing countries in the world. Amongst the top five producers in 2003-2007 (FAOSTAT, 2009), there are countries such as the USA and China where production is characterised by high inputs and high yields. However, in India or Nigeria which are also amongst the top five producers in the world, peanut cultivation is dominated by smallholder farming with little use of inputs and irrigation, achieving much lower yields. It is thus difficult or impossible to use a system for the original country which is representative of the main production practices of the major producers. We have decided to use a more intensive production system for the original country because of good data availability; it was not possible to obtain detailed data on smallholder farming in India or African countries within the resources of this project.

The original dataset includes the application of a biological pest control agent, which is not included in our calculations. However, the environmental impact of such agents is assumed to be small. The same is true for lime applications (once every four years) which cannot be considered in MEXALCA, as well as the application of micronutrients and seed inoculants. For the calculations of environmental impacts at the farm gate, we also did not distinguish between high quality kernels for direct consumption and low grade kernels that are crushed for peanut oil.

About 50 % of the hay in the original country system is sold as animal feed. No economic allocation to this co-product is applied, but the nitrogen inputs to the system from hay residuals that are actually left in the field included. On average, between 4 to 5 tonnes of dry matter with a nitrogen content of about 2 to 3 % are left in the fields. However, in some systems all hay may remain in the field because it can provide valuable nutrients to the following crop, reducing the need for fertilisation (www.pca.com.au/bmp/pdfs/3e_rotation.pdf). Most research conducted in the USA, a major producer of peanuts, suggests that no nitrogen fertiliser is needed if the soil is limed to a suitable pH and inoculated with the correct strain of *Rhizobium* sp. (Wichmann, 1992). However, there probably are production systems in the world or unusual years when some nitrogen fertiliser is applied.

Irrigation often is applied in peanut cultivation because it provides control over growing conditions and reduces the risk of aflatoxin (mycotoxins produced by fungi). In Australia, a large percentage of peanuts are grown using irrigation. This percentage has increased in recent years due to drought conditions prevailing in dryland production regions. India and China, in contrast, are unlikely to use much irrigation (pers. comm. Andrew Emmott, Twin and Twin Trading Ltd., London, December 2009). Artificial drying is employed in the original country system to reduce moisture levels.

The Australian peanut industry has undergone major changes in the last few years, with a significant increase of irrigated, high input production and a decline of traditional dryland production which was badly affected by changes in climate represented as reduced rainfall and higher temperatures. This recent change is not reflected in the mean yields obtained from FAOSTAT (2009) dating from 2003-2007 that are used for every producing country in the world in this project.

Yields obtained from FAOSTAT (2009) represent averages across irrigated and rainfed production, while the data used to construct the original country inventory refer to irrigated production only. Cook (2008) presents average yields in Australia of 2000 kg ha^{-1} for dryland cultivation in South Queensland, 4000 kg ha^{-1} for dryland cultivation in North Queensland where rainfall is higher, and 5000 kg ha^{-1} for irrigated cultivation. The latter corresponds to the magnitude of the yield in the original country inventory, which refers to irrigated cultivation as well, whereas the national longterm yield of 1500 to 2000 kg ha^{-1} after Cook (2008) is in accordance with FAOSTAT (2239 kg ha^{-1}). According to Cook (2008) the proportion of peanuts under irrigation is still low in Australia explaining the low national average, though there is a trend towards irrigation because of the increasing frequency of droughts. On the other hand, already as much as 80 % of Australian peanut production is under irrigation (confidential source).

Because FAOSTAT yields are used during the extrapolation and the estimation of impacts per kilogram of crop, inclusive of the original country, this discrepancy between the actual and FAOSTAT yield means that impacts per kilogram are over-estimated by MEXALCA. This is because farming inputs used to define the original country system represents an intensive, high input-high yield system, but environmental impacts are related to less than half the actual yield. In order to address this problem, a correction factor is introduced into the extrapolation: the amount of input used in each country is reduced by multiplying with the ratio of the FAOSTAT yield and the real yield for each module that is influenced by the yield in the target and original country (this applies to the modules explicitly depending on the yield, i.e. variable machinery use, nitrogen, phosphorus and potassium fertiliser use, pesticide use and drying).

A.2.2 Linseed

Data on linseed production are obtained from the Institute of Natural Fibres and Medicinal Plants, Poznań, Poland (pers. comm. Krzysztof Heller and Marcin Praczyk, November 2009). For details on the production system, see Table A.1.

Nitrogen returns via crop residuals are calculated assuming 2.7 tonnes of straw per hectare and a nitrogen content of 0.006 kilograms of nitrogen per kilogram of straw (GRUDAF, 2009).

Chemical pre-harvest desiccation is not practised in Poland but appears to be common in linseed cultivation in other countries. No statistics were found on how widespread this practice is in the world and therefore it was added to the base inventory assuming that 50 % of farmers apply herbicides for desiccation (600 grams of active ingredient per hectare). Irrigation is not practised in Poland and only little or no linseed is grown under irrigation in Canada, the largest producer worldwide (pers. comm. Barry Hall, President of the Flax Council, November 2009). Therefore, no irrigation is included in the original country inventory.

Actual yields for the original country system were 1.8 times higher (2150 kg ha^{-1}) than the mean yield obtained from FAOSTAT (2009) for the years 2003-2007 (1180 kg ha^{-1}). The cause for the discrepancy in yields between the data in the inventory (2150 kg ha^{-1}) and in the FAOSTAT database (1180 kg ha^{-1}) is not obvious. Too little information is contained in the data source of the inventory. Yields can vary strongly with annual weather conditions, cultivars and row spacing at seeding (Zając *et al*. 2005; Kocjan Ačko and Trdan 2008). Comparing the yields in the inventory to yields cited in Zając *et al*. (2005) and Kocjan Ačko and Trdan (2008) they seem realistic but point to rather optimal conditions. The data in the inventory might originate from a single farm or experiment using a high yielding linseed cultivar and optimal row spacing with measurements in a single year with beneficial weather conditions.

Because MEXALCA uses FAOSTAT yields for all countries, including the original country, this problem had to be corrected and the same methodology is applied as described in section A.2.1 for peanuts.

Table A.1: Production data of linseed (original country: Poland)

Inputs		
Fertilisers – N	50	kg N ha^{-1}
Fertilisers – P	40	kg P_2O_5 ha^{-1}
Fertilisers – K	70	kg K_2O ha^{-1}
Pesticides	0.42	kg active ingredient ha^{-1}
Seeds	40	kg ha^{-1}
Nitrogen in residuals returned to field	16.1	kg N ha^{-1}
Machinery operations		
Ploughing	1	pass ha^{-1}
Harrowing	3	pass ha^{-1}
Pesticide application	1.5	passes ha^{-1}
Fertiliser application	3	passes ha^{-1}
Sowing	1	pass ha^{-1}
Harvesting	1	pass ha^{-1}
Irrigation		
Irrigation water applied	0	m^3 ha^{-1}
Fraction of acreage irrigated	0	%
Output		
Yield	2150	kg ha^{-1}
No-till cultivation		
Generally well suited		

A.2.3 Peaches

Data on peach production are obtained from the Western Cape region of South Africa (pers. comm. Colors Group, January 2010). These data apply to stone fruit from the Colors Foundation's farms in general, but the system modelled can be regarded as a very close indication of peach cultivation because the inputs to the other stone fruit varieties with significant production volumes (plums, nectarines, etc.) are very similar to peaches. The data correspond to one particular farming year which could be regarded as an average year. No detailed data on the inputs and outputs are presented here due to confidentiality reasons.

The peach plantations analysed have a commercial life span of 20 years with full production starting in the fifth year. The LCA is calculated to represent an average farming year, with the inputs needed during the establishment phase of the orchard added to account for the full life cycle of the plantation, assuming that average inputs and outputs remain unchanged from the fifth year to the end of the productive life of the orchard. For the first four years after establishment, assumptions are made about the intensity of input use and irrigation. Because our calculations stop at the farm gate, no distinction was made between fruits of export quality and peaches sold on the local market or for processing. Nitrogen fertilisers are applied three times per year in September, October or November and March. The amount of nitrogen that is returned to the soil via chopped waste prunings is calculated using figures given in Rufat and DeJong (2001). All orchards are irrigated. Pruning and the removal of excess fruit are by hand. No data on the amount of active ingredient applied for plant protection are available for the original country system and therefore an average of the figures given in Hogmire and Biggs (2005) for West Virginia and Hamilton and Polk (1992) for Florida is used (6.3 kg active ingredient ha^{-1}). FAOSTAT (2009) data on yields per hectare used to express the extrapolation results per kg of product include peach *and* nectarines which may lead to increased uncertainties. Harrowing and subsoiling operations before and after planting of young trees are modelled using information from Fonsah *et al*. (2007).

The amount of planting material for annual replacement of trees has to be represented by the ecoinvent process ‘apple plantlets’ as this is the only process available to account for plantlets. For this purpose the number of trees per hectare is divided by the average orchard lifetime and then scaled by the production time of plantlets relative to apple plantlets in order to account for a different quantity of inputs and related impacts due to a different time required for production in nursery. For peaches one year was assumed as the age of plantlets according to the purchase recommendation for planting material in Clemson Extension (1999), whereas two years apply for apples (Alig and Kägi, 2008). Owing to lack of data, transport of the young trees from the nursery to the orchard and emissions of pre-plant soil fumigation and clear felling at the end of the economic life of the orchard could not be included.

A.2.4 Apples

The five main producers of apples are China, USA, Iran, Turkey and France contributing with 39, 7, 4, 4 and 3 % to world production. For reasons of data availability New Zealand is chosen to construct the original country data set, where less than 1 % of world’s apple production takes place. Data on farming inputs and field operations are mainly taken from Saunders *et al*. (2006), while data gaps are filled with data from Milà i Canals (2003). The average annual apple yield reported in Saunders *et al*. (2006) is 50000 kg ha^{-1}, which is in the same order of magnitude as the 43986 kg ha^{-1} reported by FAOSTAT (2009). On the other hand, the average of the apple yields of four different farms reported in Milà i Canals (2003) is with 101500 kg ha^{-1} much higher than the latter. Thus, apple yields as recorded for New Zealand obviously show a very high variability.

Lipe and Kamas (2001) report that apples are produced from the second year, marketable yields are obtained from the third year and full production is obtained from the fifth year. Thus, assuming the yield reported in Saunders *et al*. (2006) to be referring to apple orchards in full production (i.e. not considering the lower productivity of apple plants in the first years) the yields in the different years since orchard establishment have to be adjusted as fractions relative to the yield at full production. Based on this adjustment the yield in the original country inventory is calculated by averaging these yields across the whole orchard lifetime. The estimated fractions are 0, 25, 50, 75 and 100 % for the first, second, third, fourth and fifth to 20th year resulting in a yield of 43750 kg ha^{-1}.

The description of the production system in Saunders *et al*. (2006) is based on data from the area around Nelson in the north of the South Island. Apple orchards have an average lifetime of 20 years. Gras growing between the planting rows is managed by mowing and mulching but also by herbicide sprayings. The cut-off branches from pruning are also mulched. Both, mulch and pruning residuals are left of the orchard floor. Most pruning is done by hand with the help of hydra-ladders but mechanized shelter trimming also occurs. In addition to nitrogen, phosphorus and potassium fertilization, lime is applied. The environmental impact of the latter can only be taken into account in terms of machinery operations with MEXALCA. Pesticide applications on apple trees include insecticides, fungicides and calcium which are applied by machine along with each other. Mineral oils used as pesticides were inventoried separately because of their low production cost being a by-product of gasoline refinement. Harvest is accomplished by hand with the support of hydra-ladders. No data were found on ploughing at replanting of the orchards in New Zealand. However, taking into account an orchard lifetime of 20 years this process can be neglected.

Environmental impacts from tractor movements are described by taking into account diesel consumption per cultivated hectare, the mass of the tractor consumed with respect to total lifetime per cultivated hectare, and the corresponding space requirement (shelter). Usage of the hydra-ladder is approximated with the ecoinvent process “mowing, by rotary mower, CH, [ha] (#170)” and usage of the forklift and mower by “mowing, by motor mower, CH, [ha] (#169)”. The process shelter trimming and mulching of pruning residuals is estimated from the ecoinvent process “mulching, CH, [ha] (#171)”. The cultivated area of all farming operations mentioned above has been scaled with the diesel consumptions as recorded for the actual process in Saunders *et al*. (2006) and in the ecoinvent data base for the process applied.

Assuming pruning residuals from apples and peaches to have similar nitrogen contents, the nitrogen content in prunings of apple trees is approximated by scaling the nitrogen content of prunings of peach trees with the tree densities in orchards of the two crops. Nitrogen contained in cut grass is calculated based on Engel *et al*. (2009, numbers correspond to orchards in Germany) to be 60 kg ha^{-1} and thus considerably higher than the nitrogen contained in the pruning residuals. However, this value cannot be considered with MEXALCA.

In order to estimate a globally common irrigation practice for apples irrigation data were searched in literature focussing on the top five producers. For Iran no data was found. Apples produced in China and Turkey turned out to obviously be irrigated, however no quantitative information on the irrigation water amount could be obtained. Literature on apple production in the USA revealed most of the acreage to be irrigated (Jackson, 2003), while no information on the irrigation water amount is available. Only for France quantitative data were found (fraction of irrigated area: 91 %, water volume: 2000 m^3 ha^{-1}; ENDURE, in preparation). Thus, for the original country inventory, irrigation is modelled following these data, as irrigation seems to be a common practice on a global scale.

Table A.2: Production data of apples (data per year, original country: New Zealand)

Inputs		
Fertilisers – N	80	kg N ha^{-1}
Fertilisers – P	8	kg P_2O_5 ha^{-1}
Fertilisers – K	60	kg K_2O ha^{-1}
Pesticides – unspecified	21	kg active ingredient ha^{-1}
Pesticides – mineral oil	29	kg active ingredient ha^{-1}
Tree density	800	trees ha^{-1}
Nitrogen in prunings and mulch returned to field	74	kg N ha^{-1}

Machinery operations		
Mulching – prunings	1.4	passes ha^{-1}
Shelter trimming	0.5	passes ha^{-1}
Fungicide spraying	17.5	passes ha^{-1}
Insecticide spraying (along with fungicides)	4.5	passes ha^{-1}
Calcium application (along with fungicides)	12.0	passes ha^{-1}
Herbicide spraying – understory weed management	2.5	passes ha^{-1}
Mowing	5.0	passes ha^{-1}
Fertilizer application	1.5	passes ha^{-1}
Lime application	0.4	passes ha^{-1}
Hydra ladder – pruning & harvest	15.4	kg diesel ha^{-1}
Tractor – harvest and other uses	106.4	kg diesel ha^{-1}
Forklift	10	kg diesel ha^{-1}
Transport of harvested fruit	50	t·km ha^{-1}

Irrigation		
Irrigation water applied (including frost fighting)	2000	$m^3\ ha^{-1}$
Fraction of acreage irrigated	91	%

Output		
Yield	43750	$kg\ ha^{-1}$

A.2.5 Bananas

The five main banana producing countries are India, China, Brazil, Philippines, and Ecuador with a contribution to world production of 23, 9, 9, 8 and 8 % (FAOSTAT, 2009). The original country data set is constructed on data from Guadeloupe (French West Indies, de Barros *et al*., 2009) as this study provided the most complete input data even if Guadeloupe contributes with less than 1 % to the global banana production only. The study of de Barros *et al*. (2009) provides six different inventory data sets covering all farm types present in Guadeloupe. The data applied for the original country inventory are weighted averages over those six farms, where the contribution of each single farming type to the national production of Guadeloupe is used as weight. Most of banana production is located in the so called "Croissant Bananier", which denotes an area stretching between the cities of Vieux Habitantes and Petit-Bourg along the southern coast of the island Basse Terre ranging from the coastline up to the limits of the mountain forest in the centre of the island (Tixier, 2004).

An average banana yield of 25998 kg ha^{-1} is recorded in the FAOSTAT database (FAOSTAT, 2009). The weighted mean of the yield as obtained from de Barros *et al*. (2009) on the other hand is by 46 % higher. Stoorvogel *et al*. (2004) found banana yields in Costa Rica to increase during the first three years from replanting a plantation. Even if adjusting the yield for Guadeloupe for the first three years of the entire plantation lifetime, it is still 37 % above the FAOSTAT value. In addition it is assumed that yields in de Barros *et al*. (2009) represent an average already, because plantations are usually replanted on various lots at different times so that plants of all ages coexist in the same plantation. Thus, the yield as obtained from de Barros *et al*. (2009) should be representative. The discrepancy rather originates from the value achieved from FAOSTAT (2009) as it might be comprised by fresh and dried bananas as mentioned in the metadata on classifications. With a water content of about 74 % dried bananas have a much lower mass than the fresh ones. As the share of dried banana included in the FAOSTAT data for Guadeloupe is unknown a yield correction as already described for peanuts in section A.2.1 is applied.

Bananas are planted in spring (Morton, 1987) and require ten to twelve months until harvesting. Plantlets are either suckers cut directly from plants on the plantation or in vitro plants, while the latter account for 100 % of plantlets in the high yielding production systems. The average planting density is 2450 plants per hectare (Wichmann, 1992). Only the fraction of in vitro plants is considered for impacts of seedling production. For the calculation of the plantlets needed per year the planting density is divided by the plantation lifetime and scaled down by space requirement (estimated from photos of nurseries) and production time (Rashid *et al*., 2000) of transplants relative to apple plantlets (see section A.2.3, peaches, for detail).

Bananas require nitrogen, phosphorus and potassium fertilizers as base dressing. In addition, two more nitrogen topdressings carried out in August and October (Morton, 1987) are taken into account. The nitrogen content of discarded bananas applied as organic fertiliser as recorded for one farm type is considered as mineral fertiliser, as MEXALCA does not cover organic fertilisation. The treatment of chopped down pseudostems is not mentioned in de Barros *et al*. (2009). Wichmann (1992) recommends the mulching of chopped plant material, in particular for minerally fertilized systems as is the case for Guadeloupe, amounting to 200 tonnes of plant material per hectare. The nitrogen content of this mulch is ascribed to the nitrogen content of the crop residuals using the nitrogen content of banana leaves at full expansion of fruit bunches and optimum nutrition (Wichmann, 1992) and a water content of pseudostem tissue of 96.8 % (Pothavorn, 2008). There was no information on the treatment of the understory herb layer and thus, the nitrogen content cannot be considered.

Plantations in Guadeloupe are generally not irrigated. However, as irrigation seems to be a common practice in most of the main banana producing countries it is modelled following data from Puerto Rico (Goenaga and Irizarry, 2000), where 4830 m^3 water per hectare are applied. Irrigation is carried out using a drip system, while the water supply is controlled by evaporation measurements (class A pan evaporation factor of 1.0, i.e. the irrigation water amount corresponds one on one to the water evaporated). Even if drip irrigation is applied, the process is modelled using the ecoinvent process "irrigating, CH, [m3] (#6978)" representing a mobile sprinkler system with a fix installed pump (30 m^3 h^{-1}, 7-8 bar, 22 kW). Thus, impacts arising from irrigation will most probably be overestimated this way.

Herbicides account for the greatest share of applied pesticides. The total active ingredient in herbicides, insecticides and fungicides amounts to over 16 kg ha^{-1} a^{-1}.

In contrast to many banana producing countries, where field operations are carried out by hand the use of machines is high in Guadeloupe due to high costs of human labour. Machinery operations corresponding to the six farm types described in Barros (2009) are derived from Blazy (2008). The degree of mechanization varies strongly in-between the different farm types, while the greatest producers with strongest mechanization dominate the weighted mean values. The machine passes are scaled down by the fraction of mechanizable farmland for each farm type which is zero for the small producers in the mountainous regions. Machinery operations include application of fertilizer, application of pesticides (the chemical destruction of plantations at the end of a plantation life cycle is also ascribed to this process), the mechanical destruction of plantations (ascribed to mulching), and ploughing before replanting. Processes occurring only once in a plantation lifetime are divided by the average plantation lifetime. Transportation is calculated as the product of the assumed average farm-field distance of 1 km and the yield.

Table A.3: Production data of bananas (data per year, original country: Guadeloupe)

Inputs		
Fertilisers – N	389	kg N ha^{-1}
Fertilisers – P	447	kg P_2O_5 ha^{-1}
Fertilisers – K	633	kg K_2O ha^{-1}
Pesticides	16.2	kg active ingredient ha^{-1}
Plant density	2450	plants ha^{-1}
Nitrogen return in prunings	201	kg N ha^{-1}
Machinery operations		
Ploughing before replanting	0.14	passes ha^{-1}
Mechanical destruction of plantation	0.09	passes ha^{-1}
Chemical destruction of plantation	0.06	passes ha^{-1}
Fertilizer application	11.86	passes ha^{-1}
Pesticide application	6.17	passes ha^{-1}
Transportation	38.1	t·km ha^{-1}
Irrigation		
Irrigation water applied	4830	m^3 ha^{-1}
Fraction of acreage irrigated	36	%

Output		
Yield	38085	kg ha^{-1}

A.2.6 Oranges

The original country inventory is constructed using data on orange production in Florida. In 2003-2007, the USA was the second largest producer of oranges in the world after Brazil (FAOSTAT, 2009). Within the USA, Florida is the main growing region producing about 70 % of oranges harvested in the USA (Mossler and Aerts, 2009). Information on production practices was mainly obtained from the University of Florida's extension services website (www.crec.ifas.ufl.edu/extension).

Usually, young trees are planted where previous trees have died, become diseased or unproductive. The average rate of grove replacement is 3 % and trees start bearing fruit in their third year. This means that an average commercial orchard contains about 90 % of fruit bearing trees. The information on inputs and inputs gathered for the base system relate to this system and thus no calculations had to be carried out in order to represent an average year across the full commercial life time of the orchard as described for peaches (section A.2.3). The average yield is 36000 kg ha^{-1} (Romero *et al*., 2009).

With a stand density of 480 trees per hectare the annual replacement rate accounts for 14.4 trees. This number was scaled by production time in order to be represented by the process "production of apple plantlets" (Alig and Kägi, 2008). Production time for orange plantlets is estimated to be 1.2 years (Mossler and Aerts, 2009) and the needed planting material as equivalent to 8.6 apple plantlets (see section A.2.3, peaches, for detail).

The amounts of fertilisers applied are calculated as an average across three major production regions within Florida: Central Florida (Muraro, 2009a), Southwest Florida (Muraro 2009b) and Indian River (Muraro, 2009c). The operations carried out to remove old trees are also modelled as an average across these three regions, as are the application of fertilisers and pesticides and mowing for weed control. The amount of pesticides applied is calculated using data in Mossler and Aerts (2009) as 6.1 kg active ingredient per hectare. Nitrogen fertilisers are assumed to be applied in four even applications in February, March, April and May (O'Connell *et al*., 2009). Harvesting of mature oranges, removal of excess fruit and planting are assumed to be manual operations.

Irrigation is essential to increase yields due to the low water holding capacity of sandy soils in Florida and the poor distribution of rainfall over the year (Romero *et al*., 2009). Micro-sprinkler irrigation is the main irrigation method and irrigation is also used to protect trees from cold weather. Information on the amount of irrigation water applied (3389 m^3 ha^{-1}) is obtained from Romero *et al*. (2009) as an average of actual amounts applied in three counties between 1995 and 2005. Virtually all commercial citrus in Florida is irrigated, with only very small groves that were established many years ago not using any irrigation (pers. comm. B. Boman, March 2010). Although micro-sprinkler irrigation systems are widespread in Florida, irrigation is modelled here using the ecoinvent process "irrigating, CH, [m3] (#6978)" representing a mobile sprinkler system with a fix installed pump (30 m^3 h^{-1}, 7-8 bar, 22 kW). Thus, as already mentioned in case of bananas, impacts arising from irrigation will probably be overestimated.

Due to a lack of information on machinery used during the replanting of individual trees, these operations were not included. No biological pest control, copper and sulphur, mineral, gypsum, lime, plant growth regulator, fumigant, sterilant and organic fertiliser applications are included either due to a lack of data or because of the inability of MEXALCA to consider these inputs. No data was available on the amount of waste prunings and their nitrogen content; as a substitute, data on peach production in South Africa were used (22.1 kg N ha^{-1}) and adapted to reflect the lower tree density of the orange orchards.

Table A.4: Production data of oranges (data per year, original country: USA)

Inputs		
Fertilisers – N	217	kg N ha^{-1}
Fertilisers – P	27	kg P_2O_5 ha^{-1}
Fertilisers – K	217	kg K_2O ha^{-1}
Pesticides	6.1	kg active ingredient ha^{-1}
Tree density	480	trees ha^{-1}
Nitrogen in residuals returned to field	8.5	kg N ha^{-1}
Machinery operations		
Pesticide application	6	passes ha^{-1}
Mowing for weed control	3	passes ha^{-1}
Fertiliser application	4	passes ha^{-1}
Mulching	1	pass ha^{-1}
Removal of tree trunks	13	trees ha^{-1}
Transport of harvested fruit	9.4	t·km ha^{-1}
Irrigation		
Irrigation water applied	3389	m^3 ha^{-1}
Fraction of acreage irrigated	100	%
Output		
Yield	36000	kg ha^{-1}

N.B. Inputs and outputs are averaged across the full lifetime of the orchard.

A.2.7 Spinach

With about 85 % production volume (FAOSTAT, 2009) China is dominating the global spinach market. However, data on Chinese crop production are sparse and difficult to access. Thus, the original country inventory has been constructed by using two different data sources (LBL, SRVA, FiBL, 2004; SZG, 2009) on spinach production from Switzerland, even if Switzerland, number 21 in the global ranking, is contributing with less than 0.1 % (FAOSTAT, 2009) to the world market only.

The majority of spinach produced in Switzerland is leaf spinach grown in the western and easternmost (Rhine valley) cantons of the country (SZG, 2008). The vegetable prefers a loamy soil and especially during its growing period a high water consumption has to be taken into account (Lattauschke and Laber, 2002). Irrigation is frequently reported to be carried out for spinach (e.g. Switzerland: LBL, SRVA, FiBL (2004), SZG (2009); USA: LeStrange *et al*. (1996); India: Jacobi *et al*. (2009)) and is thus assumed to be a common practice. For Switzerland as the original country an irrigation water requirement of 200 (LBL, SRVA, FiBL, 2004) or 550 m^3 ha^{-1} (SZG, 2009) is recommended and thus, the average value of 375 m^3 ha^{-1} is used for the original country inventory.

A number of farming operations are carried out on the fields including seeding, different types of soil tillage, the application of fertilizer and pesticides and harvesting. Spinach is an appropriate second order crop in the crop rotation cycle following cereals, peas, beans or potatoes and can be precedent to any crop but beets (Lattauschke and Laber, 2002). Based on this information the following crop rotation cycle has been assumed for the original country inventory (Wonneberger and Keller, 2004): triticale (1st year), winter barley (2nd year) and spinach (spring/summer, 3rd year). The effect of catch crops in the crop rotation cycle is not covered by MEXALCA and thus, cannot be taken into account. Emissions are balanced from July of the second year (assumed harvest of winter barley) till spinach harvest in May of the third year (seeded in March/April; SZG, 2009, LBL, SRVA, FiBL, 2004). Owing to a lack of a process describing full spinach harvesting in the ecoinvent data base the environmental impact of the latter is approximated with the ecoinvent process “harvesting, by complete harvester, beets, CH, [ha] (#161)” (Nemecek *et al*., 2007). The reason for the choice is the spinach harvesting machine possibly being constructed to be pulled by a tractor as it is the case for the full beet harvester.

The average annual spinach yield is 12550 kg ha^{-1} (SZG, 2009, LBL, SRVA, FiBL, 2004), which is in good agreement with a value of 12930 kg ha^{-1} averaged over the time period 2003–2007 as listed in the FAO–database for Switzerland (FAOSTAT, 2009). The amount of nitrogen conserved in the crop residuals remaining on the field is considered with 0.0025 kg nitrogen per kg fresh matter (Lattauschke and Laber, 2006). In order to calculate the dry matter yield a water content of 93 % is assumed for spinach (Tränkner, 1968).

The average (SZG, 2009, LBL, SRVA, FiBL, 2004) amount of mineral nitrogen fertilizer recommended is 145 kg ha^{-1}. Based on the recommendation of Lattauschke and Laber (2002) 100 kg ha^{-1} nitrogen are assumed to be applied as base dressing in March and the remaining 45 kg ha^{-1} as top dressing in April. The required amount of phosphorus fertilizer (base dressing) is given to 20 kg ha^{-1} and that of potassium fertilizer to 150 kg ha^{-1} (SZG, 2009; LBL, SRVA, FiBL, 2004). A recommended amount of 15 kg ha^{-1} magnesium fertilizer (SZG, 2009; LBL, SRVA, FiBL, 2004) cannot be considered with MEXALCA. Neither of the references (SZG, 2009; LBL, SRVA, FiBL, 2004) give a hint for organic fertilizer application.

Pesticide and herbicide application is considered with an amount of 25 kg ha^{-1} active ingredients taking into account weed and pest control and diseases like e.g. downy mildew (SZG, 2009).

Table A.5: Production data of spinach (original country: Switzerland)

Inputs		
Fertilisers – N	145	kg N ha^{-1}
Fertilisers – P	20	kg P_2O_5 ha^{-1}
Fertilisers – K	150	kg K_2O ha^{-1}
Pesticides (unspecified)	25	kg active ingredient ha^{-1}
Seeds	35	kg ha^{-1}
Nitrogen in residuals returned to field	26	kg N ha^{-1}
Machinery operations		
Soil tillage, spring-tine weeder	1	passes ha^{-1}
Ploughing	1	passes ha^{-1}
Rolling	1	passes ha^{-1}
Rotary cultivation	1	passes ha^{-1}
Pesticide application	0.96	passes ha^{-1}
Fertiliser application	2	passes ha^{-1}
Harvesting (beets) with complete harvester	1	passes ha^{-1}
Transport of harvested fruit	13	t·km ha^{-1}
Irrigation		
Irrigation water applied	375	m^3 ha^{-1}
Fraction of acreage irrigated	100	%
Output		
Yield	12550	kg ha^{-1}

A.2.8 Onions

The original country inventory for the production of onions is constructed on data summarized for Switzerland (SZG, 2009). Globally, the main onion producing countries are China (31 %), India (11 %) and the USA (6 %).

The majority of onions in Switzerland is grown in the western part of the country (SZG, 2008). The vegetable prefers nutrient–rich soils with a high humus content like sandy loam (Lattauschke and Schön, 2006). Irrigation is reported frequently for the production of onions (e.g. USA: Pelter and Sorensen, 2003; Pakistan: Khan *et al*., 2005; Switzerland: SZG, 2009, LBL, SRVA, FiBL, 2004) and thus, for the base inventory an irrigation water requirement of 600 m^3 ha^{-1} as recommended for Switzerland (SZG, 2009; LBL, SRVA, FiBL, 2004) is assumed.

Among other soil tillage operations like ploughing, harrowing or rolling, hoeing and earthing up is with 6 passes during one growing season the most frequent process. Other cropping operations are fertilizer and pesticide application as well as seeding and harvesting (LBL, SRVA, FiBL, 2004). Onion harvest is carried out in three passes, which are the removal of the haulms, the elevation of the vegetables using an onion digger and finally the picking up of the swath (SZG, 2009; Wonneberger and Keller, 2004).

The removal of haulms is approximated with the ecoinvent process “potato haulm cutting, CH, [ha] (#174)” (Nemecek *et al*., 2007). The environmental impact of the onion digging has to be approximated with the ecoinvent process “harvesting, by complete harvester, potatoes, CH, [ha] (#162)” (Nemecek *et al*., 2007), as no appropriate process is available in the ecoinvent data base. For the latter process a diesel consumption of 33.9 l ha^{-1} potatoes harvested is registered (Tab. A10, p. 192 of Nemecek *et al*., 2007). From KTBL (2006) a diesel consumption of 11.9 l ha^{-1} can be obtained for swathing potatoes of 2 m row width (as it is recommended for onions, Wonneberger and Keller, 2004) and by taking into account an area of 0.5 hectare swathed per hour. Thus, from scaling with diesel consumption, the environmental impact of 1 hectare onion digging can be approximated by about one third (i.e. 11.9 l ha^{-1} / 33.9 l ha^{-1}) of the impact originating from harvesting 1 hectare potatoes by complete harvester. The machinery used to carry out the third step of the harvesting process, i.e. the picking up of the swath, usually is a construction based on a potato complete harvester (Wonneberger and Keller, 2004) and is thus, approximated with the latter process (“harvesting, by complete harvester, potatoes, CH, [ha] (#162)”, Nemecek *et al*., 2007).

In order to minimize the risk of diseases, a 4-5 year crop rotation cycle is recommended for onions (Lattauschke and Schön, 2006). Based on this requirement, onions are assumed to be preceded by round cabbage (1st year), potatoes (2nd year), and winter wheat (3rd year; Wonneberger and Keller, 2004). Emissions are balanced for the time frame August of the previous year (harvest of winter wheat) till August of the main year (onion harvest; SZG, 2009). An amount of 60 kilograms nitrogen per hectare is assumed to be stored in the crop residuals (IGZ, 2007). Mineral nitrogen fertilization is recommended to 130 kg ha^{-1}. In addition, 60 kilograms phosphorus and 160 kilograms potassium fertilizer per hectare are required (SZG, 2009, LBL, SRVA, FiBL, 2004). There is no hint for organic fertilizer application. Magnesium fertilization (20 kg ha^{-1}, LBL, SRVA, FiBL, 2004) is not covered by MEXALCA. Fertilization is carried out in two passes, where base dressing takes place in March and top dressing in May of the main year (Lattauschke *et al*., 2002). The pesticides applied contain an amount of 14 kg active ingredient.

The average annual onion yield is 41050 kilograms of fresh matter per hectare. In order to increase the durability of the vegetable, fresh onions are dried leading to an about 10 % mass reduction (personal communication R. Jampen, onion farmer in Switzerland). The latter value is obtained from comparison of the fresh weight of a box full of onions with the weight of the same box, when onions are ready for storage. Thus, the weight of the annual harvest is reduced to 37553 kg onions ready for storage per hectare. This value is in a good agreement with the average annual onion yield of 33023 kg ha^{-1} dry matter, as obtained from FAOSTAT (2009).

Table A.6: Production data of onions (original country: Switzerland)

Inputs		
Fertilisers – N	130	kg N ha^{-1}
Fertilisers – P	60	kg P_2O_5 ha^{-1}
Fertilisers – K	160	kg K_2O ha^{-1}
Pesticides (unspecified)	14	kg active ingredient ha^{-1}
Seeds	3.3	kg ha^{-1}
Nitrogen in residuals returned to field	60	kg N ha^{-1}
Machinery operations		
Rotary harrowing	2	passes ha^{-1}
Ploughing	1	passes ha^{-1}
Rolling	1	passes ha^{-1}
Hoeing and earthing up	6	passes ha^{-1}
Pesticide application	5.6	passes ha^{-1}
Fertiliser application	3	passes ha^{-1}
Harvesting (potatoes) with complete harvester	1.4	passes ha^{-1}
Removal of potato haulms	1	passes ha^{-1}
Transport of harvested fruit	41	t·km ha^{-1}
Irrigation		
Irrigation water applied	600	m^3 ha^{-1}
Fraction of acreage irrigated	6	%
Output		
Yield	37553	kg ha^{-1}

A.2.9 Pumpkins

The original country inventory for pumpkins is constructed on data from the USA representing the fourth biggest producer on the global scale with a contribution to world production of 4 %. With 28 % contribution China is the leading pumpkin producer followed by India (15 %) and Russia (6 %).The inventory is based on a study from Arizona for the crop season 2001 in Cochise county (Teegerstrom *et al*., 2001). Additional information is retrieved from studies from Ohio, Pennsylvania, and Kansas (Ohio State University Extension, 1999; Orzolek *et al*., 2000; Marr *et al*., 2004; Egel 2010). A summary of the farming inputs and cropping operations is given in Table A.7.

The average yield of pumpkins in the USA is 21119 kg ha^{-1} (FAOSTAT, 2009). The yield given in the Arizona case study is 22416 kg ha^{-1}, which is in a good agreement with the FAOSTAT value.

Pumpkins are seeded in mid of June. Harvest takes place from beginning of October. Seedbed preparation comprises the processes disking, base dressing, laser levelling, land plane, list up and scratching. No ploughing is performed, which entails that for all extrapolations no ploughing is assumed. However, soil tillage is still intensive and thus, the latter should not be considered as the assumption of no-till practice. During plant growth fields are cultivated and bucked, and pesticides are applied several times each. In addition, the soil on planting rows is capped in order to remove salt, and field ends are disked to keep them free of vegetation. Harvest is accomplished by hand, and transportation of harvested fruit is calculated in the same way as for bell peppers (see section A.2.10). After harvest residuals are disked.

Some of the above mentioned farming operations do not exist in the ecoinvent database. Thus, disking, laser levelling, land plane, scratching and removing soil cap are approximated by the ecoinvent process “tillage, harrowing, by spring tine harrow, CH, [ha] (#183)”. The processes list up, cultivating, and bucking rows are approximated by “tillage, hoeing and earthing-up, potatoes, CH, [ha] (#184)”. The numbers of passes of all operations are scaled by the operation time per ha relative to the ecoinvent processes (see bell peppers, section A.2.10, for a detailed description). In addition, the process “prepare ends” mentioned in the data sources is included in the irrigation defined by the water volume. The processes “pick and load” and “haul” are represented by transportation. Since there is no ploughing and no other machinery operation classified as intensive soil tillage in terms of nitrate leaching (Richner *et al*., 2006), none of the machinery processes is considered in this respect.

Water supply is provided through gravitational irrigation several times per season. As the applied ecoinvent process represents pump irrigation (see section A.2.5, bananas for further explanation), the impact from irrigation is most probably overestimated. Arizona is a rather dry state, whereas Illinois, the main production area for pumpkins in the USA, receives four times higher rainfalls making irrigation unnecessary. Therefore, the proportion of only 13 % of agricultural area equipped for irrigation as given by FAOSTAT (2009) is adopted for the construction of the original country inventory

Fertilizer rates for nitrogen and phosphorus are taken from Teegerstrom *et al*. (2001). The amount of potassium fertilizer applied is adopted from another source (Ohio State University Extension, 1999). Application dates and times of nitrogen fertilization are estimated following Marr *et al*. (2004). While nitrogen base dressing is applied by broadcasting before seeding, the remaining nitrogen is applied through fertigation when the vines of pumpkin plants start to run. The nitrogen amount contained in crop residuals is obtained from Wonneberger and Keller (2004).

The number of machine passes for pesticide application is approximated following Teegerstrom *et al*. (2001). For the amount of active ingredients in the applied pesticides the study of Orzolek *et al*. (2000) is taken into account.

Crop rotation is constructed on recommendations for pest management through crop rotation (Engel, 2010), as no data is available with respect to pumpkins. A four year cycle is assumed with pumpkin as the primary crop followed by vegetables, a winter cereal and a leguminous crop.

Table A.7: Production data of pumpkins (original country: USA)

Inputs		
Fertilisers – N	139	kg N ha^{-1}
Fertilisers – P	149	kg P_2O_5 ha^{-1}
Fertilisers – K	112	kg K_2O ha^{-1}
Pesticides (unspecified)	15.7	kg active ingredient ha^{-1}
Seeds	4.2	kg ha^{-1}
Nitrogen in residuals returned to field	100	kg N ha^{-1}
Machinery operations (unscaled)		
Disk	2	passes ha^{-1}
Apply fertilizer	1	passes ha^{-1}
Laser level	0.3	passes ha^{-1}
Landplane	0.5	passes ha^{-1}
List	1	passes ha^{-1}

Buck rows	3	passes ha^{-1}
Scratch	1	passes ha^{-1}
Seeding	1	passes ha^{-1}
Insecticide application	1	passes ha^{-1}
Remove cap	1	passes ha^{-1}
Cultivate/Herbicide application	1	passes ha^{-1}
Disk field ends	3	passes ha^{-1}
Cultivate	1	passes ha^{-1}
Fungicide application	2	passes ha^{-1}
Disk residuals	1	passes ha^{-1}
Transport of harvested fruit	28	t·km ha^{-1}

Irrigation		
Irrigation water applied	10668	m^3 ha^{-1}
Fraction of acreage irrigated	13	%

Output		
Yield	22416	kg ha^{-1}

No-till cultivation
Generally well suited

A.2.10 Bell peppers

The original country inventory is built on data from the USA as these studies provide the most complete data availability (Hartz *et al*., 2008; Takele, 2001; Barbosa, 2000; Boyhan and Kelley, 2009). The USA is the sixth biggest producer of bell peppers in the world with a contribution of 3 % following China (50 %), Turkey (7 %), Mexico (7 %), Indonesia (4 %), and Spain (4 %) (FAOSTAT, 2009). In particular, data mainly refer to California as it accounts for 48 % of the national bell pepper production and for 31 % of chile pepper production (USDA, 2008a). The main production areas in California are located in the southern desert valleys, southern coast of Ventura county, the central coast and the Central Valley.

Bell peppers are nowadays rather transplanted than seeded because the germination process is very sensitive and seed material of the common hybrid cultivars is expensive. Dates for transplanting and harvesting reach from January to August and from May to December. Transplanting is assumed in March and harvest in August. Transplanting is done by machine, harvesting rather by hand.

A great part of fertilizers is applied prior to planting. Nitrogen topdressing is further carried out once or twice depending on plant and fruit development. Lacking a more appropriate source nitrogen supplied by crop residuals has to be estimated from protected bell pepper production according to Wonneberger and Keller (2004).

Fields are always irrigated, virtually all fields through drip or furrow irrigation. Thus, irrigation modelled with MEXALCA as pump irrigation following the ecoinvent process (see section A.2.5, bananas for further explanation) is probably overestimated. Soil tillage comprises deep ripping, ploughing, disking prior planting and after harvest (the latter for incorporating crop residuals), landplane and chiselling. Pest management is accomplished by cultivating and field spraying of pesticides. A detailed summary of the amount of farming inputs and machinery operations can be found in Chillies and peppers, green" in FAOSTAT is "Capsicum annuum; C. fructescens; Pimenta officinalis. Production data exclude crops cultivated explicitly as spices. In contrast, trade data include these crops, provided they are fresh, uncrushed and unground."

Table A10.8.

Lacking a proper source crop rotation is constructed from crop rotation recommendations for pest management (Barbosa, 2000). Assuming a four year cycle and taking into account vegetables, alfalfa and corn to be suitable secondary crops (Barbosa, 2000), bell peppers as the primary crop are expected to be followed by corn, a different vegetable and alfalfa at the end.

Several of the machinery operations do not exist as ecoinvent processes and have to be approximated by similar operations with comparable fuel consumption, working time and machinery requirements. Chiselling and ripping are approximated with 1.88 times the ecoinvent process “tillage, cultivating, chiselling, CH, [ha] (#180)”. The ecoinvent process “tillage, harrowing, by spring tine harrow, CH, [ha] (#183)” is applied to approximate the disking and landplaning processes. The processes listing and preplant fertilization, cultivating, and bed shaping and rolling are approximated through the ecoinvent process “tillage, hoeing and earthing-up, potatoes, CH, [ha] (#184)”. In order to express the machinery operations as passes per hectare the working time given in the original study is scaled with the same number as given in the ecoinvent data base. Transportation of the harvested peppers by tractor with trailer is estimated in the same way than it is described in section A.2.11 (tomatoes) while assuming a working width of 10 m (hand harvest).

Irrigation is modelled following a case study of bell pepper irrigation in California (POLY CAL, 1996), where the average annual water use for the period 1993-95 for furrow irrigation (“before CEC Project”) is used.

The number of transplants per hectare is calculated based on spacing recommendations of Hartz *et al*. (2008). The number given in Harz *et al*. (2008) is scaled with the production time of pepper transplants (1.5 months) relative to apple transplants (24 months), which are the reference unit for transplants production in ecoinvent (see section A.2.3, peaches). The number was further scaled by the ratio of space requirements (0.002 m^2 vs. 0.5 m^2) of pepper and apple plants (Kelley and Boyhan, 2009, Nemecek *et al*., 2007). Space per pepper transplant in the trays is multiplied by two in order to account for the additional space required by corridors.

Data on pesticide use explicitly applying to bell peppers are averages across the whole state of California (USDA, 2008a). Sulphur applied as a fungicide is excluded from pesticides summarized as amount of unspecified active ingredient applied per hectare. This is because sulphur is a low-molecular substance with much less energy consumed for production than assumed for the production of unspecified pesticide (ecoinvent Centre 2007). Chloropicrin applied as fumigant is included in unspecified pesticide.

The bell pepper yield for California is given to 41097 kg ha^{-1} (average of 2004-06, USDA in Hartz *et al*., 2008). In contrast, the average yield covering the time span 2003-07 provided by FAOSTAT (2009) for the USA is 28106 kg ha^{-1}. The reason for this discrepancy is that the yield given in the FAOSTAT database comprises peppers and chillies. As chillies are contributing with much lower yields per hectare the average yield is reduced. Furthermore, Californian production systems are more productive than the national average (USDA, 2008a): While an average chile pepper yield of 18382 kg ha^{-1} covering the time period 2003-07 is recorded for the USA, a yield of 30375 kg ha^{-1} only is observed in California for the same time frame. Similarly, with 32415 kg ha^{-1} the average bell pepper yield in the USA is lower than for California (40911 kg ha^{-1}). As the share of chillies contained in the yield given in the FAOSTAT data base is unknown a yield correction as already described for peanuts in section A.2.1 is applied. It has to be noted that the pooling of products in the FAOSTAT database implies clear limitations for the interpretation of the results. Thus, in case of bell peppers the extrapolation is executed on data including bell peppers but also several other types of peppers with varying ratios in different countries. The definition of the commodity “Chillies and peppers, green” in FAOSTAT is “Capsicum annuum; C. fructescens; Pimenta officinalis. Production data exclude crops cultivated explicitly as spices. In contrast, trade data include these crops, provided they are fresh, uncrushed and unground.”

Table A10.8: Production data of bell peppers (original country: USA)

Inputs		
Fertilisers – N	268	kg N ha^{-1}
Fertilisers – P	224	kg P_2O_5 ha^{-1}
Fertilisers – K	168	kg K_2O ha^{-1}
Pesticides (unspecified)	10.3	kg active ingredient ha^{-1}
Pesticides (sulphur)	10.5	kg active ingredient ha^{-1}
Plants	27211	plants ha^{-1}
Nitrogen in residuals returned to field	75	kg N ha^{-1}
Machinery operations (unscaled)		
Deep ripping	2	passes ha^{-1}
Landplane	3	passes ha^{-1}
Disking (preplant)	5	passes ha^{-1}
Ploughing	1	passes ha^{-1}
Chiselling	1	passes ha^{-1}
Shape beds & roll	1	passes ha^{-1}
Listing & preplant fertilizing	1	passes ha^{-1}
Planting	1	passes ha^{-1}
Pesticide application	8	passes ha^{-1}
Fertiliser application	1	passes ha^{-1}
Disking (postharvest, residual incorporation)	2	passes ha^{-1}
Transport of harvested fruit	46	t·km ha^{-1}
Irrigation		
Irrigation water applied	8229	m^3 ha^{-1}
Fraction of acreage irrigated	100	%
Output		
Yield	41097	t ha^{-1}

A.2.11 Tomatoes

With a share of 9 % the USA are the second biggest tomato producer in the world following China with 25 % contribution to world production (FAOSTAT, 2009). 85 % of the tomatoes in the USA are produced as processing tomatoes (USDA, 2010) and the USA holds with a 35 % contribution to world production the lead for production of the latter product (Hartz, 2008). Thus, as the USA play an important role on the global tomato market and owing to a good data availability the original country inventory is constructed on data from the USA. The main data sources describing production of processing tomatoes in California are McMaster *et al*. (2003) and Hartz (2008). California accounts for 90 % of the national tomato production.

In the study of McMaster *et al*. (2003) agricultural production data of four Californian tomato growers for the year 2002 is presented. The farms represented are located in the Central Valley counties of San Joaquin, Fresno, Yolo and Stanislaus which are among the main producing regions in California (Hartz, 2008). Farming and machinery inputs applied for the construction of the original country inventory are averaged values across all four farms. For the consideration of processes like e.g. the crop rotation cycle, for which averaging would not have led to a suitable result, the most representative data are selected.

McMaster *et al*. (2003) give a yield of 93875 kg ha^{-1} for processing tomatoes produced in the USA. In contrast, the average tomato yield of 72 tonnes ha^{-1} as provided by FAOSTAT (2009) is considerably lower. The reason for this discrepancy is the FAOSTAT database pooling processing and fresh tomato yields, and yields achieved from the production of processing tomatoes are substantially higher than for the fresh market production (USDA, 2010).

Processing tomatoes are usually planted mechanically in California (Hartz, 2008). However in this case study for Californian farms all fields are seeded. Seeding occurs from late January through early June, so that tomatoes can be harvested continuously from late June through October. Based on this information, the seeding date is determined to 1^{st} of April and the harvesting date to 1^{st} of September. According to Hartz (2008) seeding rates are between 100,000 and 150,000 seeds ha^{-1}. Assuming a thousand-seed weight of 25 g (Ohio State University, online) this leads to an average of 3.125 kg of seeds per hectare.

Soil preparation at the four Californian farms includes deep ripping, laser grading (generation of a constant slope for surface), (furrow) irrigation, ploughing, and setting of irrigation furrows. According to Hartz (2008) bed forming generally occurs in fall in order to avoid the accommodate wet soil conditions in spring and to allow early planting. Thus, ploughing, an intensive preplant tillage operation relevant for the nitrate module, is assumed to occur in October after the relevant intensive postharvest tillage operation in September (rotary hoeing). During the season fields are cultivated, beds listed up, vines trained and mechanical application of fertilizer and pesticides occurs. Pesticide application from air reported to occur frequently cannot be taken into account and ordinary application by field sprayer is assumed instead. Harvesting is carried out by application of self propelled complete harvesters. Crop residuals are incorporated using a rotary hoe or by disking or mulching (McMaster, 2003). The number of passes applying to each of the machinery operations are averages across the values given for the four different farms.

Farming operations not provided by the ecoinvent database are translated to the most similar ecoinvent processes. Laser grading/land plane and application of an offset disk plough are expressed with the ecoinvent process “tillage, harrowing, by spring tine harrow, CH, [ha] (#183)”. The latter is an extensive process with respect to the model applied for the simulation of nitrate leaching (Richner *et al*., 2006). However, as application of a disk plough is rather an intensive farming operation in this respect, this operation is taken into account as ploughing in the context of nitrate leaching. The process deep ripping/use of chisel and roll is expressed with the ecoinvent process “tillage, cultivating, chiselling, CH, [ha] (#180)”. The process “tillage, rolling, CH, [ha] (#186)” is applied to account for the use of a stubble disk and roll. The processes hilling up and bed forming, list up and bed forming, application of various cultivating implements (Lilliston bar, Alloway cultivator, B knives and/or crescent knives), and vine training are expressed with the ecoinvent process “tillage, hoeing and earthing-up, potatoes, CH, [ha] (#184)”. The ecoinvent process “tillage, rotary cultivator, CH, [ha] (#187)” is applied to express the use of a rotary hoe/mulcher. In order to translate crust picking, the ecoinvent process “tillage, currying, by weeder, CH, [ha] (#181)” is applied. Harvesting with a self propelled complete harvester is expressed with the process “chopping, maize, CH, [ha] (#154)” (Nemecek *et al*., 2007; Meester, pers. comm.). Except for transportation and irrigation all machinery operations expressed as number of passes per hectare are scaled with respect to diesel consumption given in McMaster *et al*. (2003) compared to the value included in the corresponding ecoinvent process.

The field operations furrow out and setting and breaking ditches for furrow irrigation are included in the irrigation process determined by the volume of irrigation water and thus, not explicitly taken into account. The process grading paddock/field edges is neglected as it occurs only linearly at the field edges.

The low number of fertiliser applications in the original data (even zero for two of the farms leading to 0.5 passes per hectare) can be explained by fertilizers being applied along with other field operations, e.g. ripping, and thus not being listed explicitly. The harvesting operation is accounted for with six passes per hectare in McMaster *et al*. (2003). However, this number includes two tractors and trailers receiving the harvested tomato directly from the complete harvester. As this transportation process is calculated separately passes for harvest are set to one.

The transportation process is comprised by transporting tomatoes from the field to the farm (assumption of 1 km distance) and the distance covered by the tractor with trailer beside the complete harvester to take up the harvested tomatoes. In order to estimate the latter a working width of 1.54 m (CTM, 2002), and a turning circle diameter of 10 m is assumed. The resulting distance is about 4 kilometres per hectare harvested. The way from the farm to the field has to be covered about 12 times (each time when the trailer is full). As the ecoinvent process “transport, tractor and trailer, CH, [tkm] (#188)” includes the empty return both distances, on the field and to the farm, are divided by two. Thus, another 12 km have to be taken into account for the distance between field and farm. Assuming a maximum trailer load of 8 t transport is taken into account with 128 t km.

Crop rotation cycles as represented by the four farms under consideration show a strong variability with respect to duration and choice of crops and with tomatoes appearing several times in one rotation (McMaster *et al*., 2003). From such a rotation one segment, which appeared in another rotation in a similar form, is chosen as a representative crop rotation: tomato as the primary crop followed by winter wheat.

Only mineral fertilizers are applied. Nitrogen rates as derived from McMaster *et al*. (2003) are in accordance with data presented in Hartz (2008). Phosphorus and potassium fertilizer rates on the other hand are much lower, which might be due to the specific soil conditions on the farms represented by McMaster *et al*. (2003). Phosphorus is mostly applied prior to planting (Hartz, 2008), while nitrogen and potassium base dressing occurs at the time of planting. The remaining fertilizer is applied with irrigation or in one or more topdressings. Top dressings are recommended to be applied prior or at early blooming (UC IPM, 2009), which occurs about four to five weeks after planting (Weerakkody, 1998). For the original country inventory the base dressing and one top dressing are taken into account, while 25 % of the nitrogen fertilizer is assumed to be applied at planting in April and another 75 % at early flowering in May. The nitrogen content in crop residuals remaining on the field is estimated following McMaster *et al*. (2003).

The average pesticide use of the four Californian farms turned out to be very high with 38.7 kilograms of active ingredient per hectare. A closer look at the list of applied pesticides revealed that sulphur (fungicide) and metam-sodium (fumigant) account for most of the active ingredient. The data provided by McMaster *et al*. (2003) can be confirmed from comparison with a study of Davis *et al*. (1998), who present similar application rates. Taking into account the different energy requirement for the production of sulphur compared to the assumptions made for the production of unspecified active ingredient, sulphur is excluded from the latter in the same way as described in section A.2.10 (bell peppers). Due to its complex molecular structure it is assumed that production costs for metam-sodium are well represented by those of unspecified pesticides, and metam-sodium is included in unspecified pesticides.

All processing tomato fields in California are irrigated (Hartz, 2008) as especially in the Central Valley summer precipitation is very low. On all four farms investigated by McMaster *et al*. (2003) furrow irrigation is applied with an annual consumption of irrigation water of 10,173 m^3 ha^{-1}.

Table A10.9: Production data of tomatoes (original country: USA)

Inputs		
Fertilisers – N	223	kg N ha^{-1}
Fertilisers – P	38	kg P_2O_5 ha^{-1}
Fertilisers – K	34	kg K_2O ha^{-1}
Pesticides (unspecified)	20.8	kg active ingredient ha^{-1}

Pesticides (sulphur)	17.9	kg active ingredient ha^{-1}
Seeds	3.125	kg ha^{-1}
Nitrogen in residuals returned to field	100.9	kg N ha^{-1}

Machinery operations (unscaled)		
Deep ripping	1.25	passes ha^{-1}
Laser grading	1.75	passes ha^{-1}
Ploughing (offset disc)	2	passes ha^{-1}
Sowing	1	passes ha^{-1}
Hilling up & bed forming	0.25	passes ha^{-1}
Listing up & bed forming	1.25	passes ha^{-1}
Vine training	0.5	passes ha^{-1}
Pesticide application	2.25	passes ha^{-1}
Fertiliser application	0.5	passes ha^{-1}
Crust picker	0.75	passes ha^{-1}
Cultivating (Lilliston bar, Alloway cultivator, B knives, crescent knives)	2.75	passes ha^{-1}
Harvesting	1	passes ha^{-1}
Transport of harvested fruit	128	t·km ha^{-1}
Mulching	0.75	pass ha^{-1}
Hoeing (rotary hoe)	2	passes ha^{-1}
Stubble disc & roll	1.25	passes ha^{-1}

Irrigation		
Irrigation water applied	10173	m^3 ha^{-1}
Fraction of acreage irrigated	100	%

Output		
Yield	93875	kg ha^{-1}

A.2.12 Almonds

The USA are the world’s biggest producer of almonds (FAOSTAT, 2009). Within the USA, California is the only state that produces almonds commercially, with over 99 % of almonds produced in the San Joaquin and Sacramento Valleys, covering about 368,000 ha in 2008 (FAOSTAT, 2009) and representing one of the most important cash crops and the largest horticultural export from the USA. The main variety grown is Nonpareil.

California is chosen to model the original country inventory because it is the world’s largest almond producer (45 % of the world production) and because of relatively good data availability. However, almond culture is very different in most parts of the world, making California a poor model for the rest of the world’s almond production (pers. comm. J. Connell, April 2010). Almond cultivation in California is intensive, with high inputs and high yields. Spain, the world’s second largest producer, has much lower yields and more extensive, low input production systems, often relying on natural rainfall (García-Suárez, 2006). This needs to be taken into consideration when interpreting the data.

Most of the information used to prepare the original country inventory is taken from USDA (1999), Duncan *et al*. (2006) for flood irrigated almond orchards in the Northern San Joaquin Valley, Freeman *et al*. (2008) for micro-sprinkler irrigated orchards in the southern San Joaquin Valley and Connell *et al*. (2006) for low-volume sprinkler irrigated orchards in the

Sacramento Valley. The last three publications describe typical production practices in the area. Details of the production system are shown in Table A.10.

The first commercial harvest occurs in years 3 or 4, where harvesting might be carried out manually to avoid damage to the young trees. After the first 3-7 years, harvesting is usually mechanical using tree shakers, with full crops occurring from year 6 or 7. Most orchards are removed after about 25 years although the trees may be productive for 50 years or more (Mosz, 2002). Tree densities average 284 trees per hectare, which corresponds to an annual number of eleven planted trees. This number is scaled in order to be represented by apple plantlets (see section A.2.3, peaches, for detail) assuming a mean plantlet age of 1.5 years (Micke, 1996). The data used to model this original country inventory represent averages across the economic life time of the orchard.

In California, no response of almond trees to phosphorus fertilisation has been observed (Woodroof, 1967), and nitrogen (N) and potassium (K) are the only major elements that need to be added through fertilisation. The amounts of N and K_2O applied are averaged between the two major growing areas in California and across the full commercial life span of the orchards, giving a yearly application of 229 kg N ha^{-1} and 198 kg K_2O ha^{-1}. The method and timing of N applications differ between the San Joaquin and Sacramento Valleys. In the former, N is sprayed in three applications (50 % in April, 25 % in June, 25 % in August), while in the latter, N fertiliser is applied through the irrigation system in three equal applications (April, May, June). It was decided to use the common practice in San Joaquin Valley for this project because a much larger proportion of Californian almonds originates there. Boron and zinc deficiencies can be common (Wichmann, 1992; Duncan *et al*., 2006), but fertilisation with minor elements is not considered in MEXALCA. Pruning is done manually; the prunings are commonly shredded and left in the orchard. Nitrogen returns in pruning residuals are calculated assuming the same amount of prunings per year as for peach, scaled down because the much lower almond tree density, and the same percentage nitrogen content as for peach prunings (see section A.2.3, peaches, for detail).

Pesticide usage is determined using USDA (1999). This indicated that an average of 4763 grams of active ingredient per hectare are applied per year, which may however not be a complete figure due to a lack of usage information on some pesticides. The number of pesticide applications and mowing for weeds control during the fully productive years are averaged between Duncan *et al*. (2006), Connell *et al*. (2006) and Micke (1996) as 8.7 and 6 respectively.

After being shaken from the trees, the almonds are left to dry on the orchard floor for up to two weeks. Artificial drying is virtually never used (pers. comm. J. Connell, March 2010). Discing and levelling of the orchard floor is only necessary if other operations during the year caused unevenness in the non-cultivated surface (Connell, 1994) and are not considered here. Little information is available to us on the type, size and diesel usage of some of the machines used for harvesting operations and these processes can therefore only be approximated very roughly.

Irrigation is essential to achieve economic yields and virtually all almond orchards in California are irrigated, with irrigation methods varying from sprinklers to drip and flood irrigation (Connell, 1994; USDA, 1999). The average amount of irrigation water used is estimated across the 25 years of commercial life of the orchards and across three different irrigation systems: flood and micro-sprinkler irrigation in the San Joaquin Valley and low-volume sprinkler irrigation in the Sacramento Valley (4499 m^3 ha^{-1}).

Any impacts associated with the provision of honey bees used for pollination of the almond trees are not included. *Bacillus thuringiensis* is commonly used to control the peach twig borer, a major pest in almond orchards, but cannot be considered here, along with sulphur, growth regulators, any potential rodent control and post harvest fumigation.

The outer leathery cover of the almonds, the hull, is removed and used as livestock feed. Because this process takes place beyond the farm gate at the hullers, no economic allocation of impacts between co-products was conducted. In some areas, the clear-felled trees at the end of the productive life of the orchard are chipped and sold as fuel. This is not considered in our study.

Due to a lack of data, no operations associated with the clear felling of old orchards, uprooting, chipping, soil preparation, soil fumigation, planting and re-planting of individual trees in the first few years are included in our calculations.

FAOSTAT (2009) reports yields as inshell weights. These differ considerably between varieties and countries, e.g. kernel weights in California vary between 45 % and 65 %, whereas Spanish almond varieties typically have kernel weights of 25-34 % (pers. comm. J. Connell, March 2010). Because MEXALCA uses FAOSTAT (2009) data, results are presented for inshell almonds, and the differences between countries should be considered when interpreting these results. Data on typical yields in California in Duncan *et al*. (2006), Connell *et al*. (2006) and Freeman *et al*. (2008) are presented as kernel weight, i.e. the shelled product. These had to be converted to inshell weights in order to align yields for the original country system with FAOSTAT (2009) yields for all other almond producing countries; this conversion was done assuming a kernel weight of 55 % of the inshell product.

Table A.10: Production data of almonds (data per year, original country: USA)

Inputs		
Fertilisers – N	229	kg N ha^{-1}
Fertilisers – P	0	kg P_2O_5 ha^{-1}
Fertilisers – K	198	kg K_2O ha^{-1}
Pesticides	4.8	kg active ingredient ha^{-1}
Tree density	284	trees ha^{-1}
Nitrogen return in prunings	5.9	kg N ha^{-1}
Machinery operations		
Pesticide application	7.6	passes ha^{-1}
Fertiliser application	3	passes ha^{-1}
Mowing for weed control	6	passes ha^{-1}
Pruning		manual operation
Shredding of prunings	1	pass ha^{-1}
Removal of unharvested almonds	0.92	passes ha^{-1}
Harvest: tree shaking	0.84	passes ha^{-1}
Harvest: sweeping	1.84	passes ha^{-1}
Transport of harvested almonds	20	t·km ha^{-1}
Irrigation		
Irrigation water applied	4499	m^3 ha^{-1}
Fraction of acreage irrigated	100	%
Output		
Yield	4013	kg ha^{-1} (inshell weight, assuming 55 % kernel weight)

N.B. Inputs and outputs are averaged across the full lifetime of the orchard.

A.2.13 Hazelnuts

The biggest hazelnut producer in the world is Turkey (66 %), while the USA contributes with 4 % and Azerbaijan and Spain with 3 % for each to global production. The original country inventory for hazelnuts is constructed on data from Italy. Italy is the second biggest producer contributing with 15 % to global production and studies referring to Italian hazelnut production (Monarca *et al*., 2005; Colorio *et al*., 2009; Fanigliulo and Tomasone, 2009) provide the most complete data availability. Hazelnuts are mainly produced in the province Viterbo in Central Italy. In order to fill data gaps, studies from Tous (2005) and MARM (2010) on Spanish hazelnut production and from Bozoğlu (2001) on Turkish production are taken into account. In particular, data on irrigation and drying refer to Spanish production conditions.

The yields presented in the case studies for Italy, Spain and Turkey deviate considerably from yields given by FAOSTAT (2009), especially when irrigated cultivation occurring in Spain and Italy is taken into account. Differences in yields arise further from the variety of cultural practices reflecting the contrast between traditional production on hillslopes with a low degree of mechanization and long orchard lifetimes and highly mechanized modern production systems with orchard lifetimes of around 30 years. In order to create a representative yield applicable for the original country inventory, both forms of cultivation are considered. The yield is calculated as a weighted average of the yields resulting from both production forms, where the ratio of irrigated and non-irrigated acreages of hazelnut production is applied as weight. The latter is available for Spanish hazelnuts orchards (MARM, 2010) only and thus, has to be applied to Italian conditions. The resulting yield is 26 % higher than provided by the FAOSTAT (2009). However, from comparison with yields as presented in Monarca *et al*. (2005) it can be the case that unproductive years before the first harvest have not been considered with the calculations above. Adjusting the yield following this assumption (five unproductive years after orchard establishment; HGANZ, 2008) hazelnut yields for Italy turn out to be comparable to the FAOSTAT (2009) value (2162 kg ha^{-1}).

Hazelnut is a permanent crop grown in orchards with about 385 plants ha^{-1}. The herb layer is mown twice a year. It is also beneficial to disk the orchard floor every two or three years, but this has not yet established as common practice and is therefore not considered for the original country inventory. Pruning is mostly done by hand and pruning residuals (2396 kg ha^{-1} a^{-1}) are burned. Neither the potential additional nitrogen input from the latter nor emissions from combustion in open fires (in accordance with the inventory of sugarcane, section A.1.4) are taken into account. In order to obtain an optimal picking surface for mechanized harvest the cuttings of the herb layer is removed (Colorio *et al*., 2009). Assuming this procedure to be a common practice no nitrogen input from this weed layer is considered for the original country inventory.

Fertilizers are spread with a broadcaster once a year in March (Wichmann, 1992). Only mineral (nitrogen, phosphorus, and potassium) fertilizers are applied. Fertilizer rates, which are given separately for irrigated and non-irrigated production, are averaged in the same way than described for the yields above, i.e. also taking into account a reduced demand of fertilization in the first five years.

Pesticides are applied three to four times a year with a pulled atomizer (Tous 2001). Pesticide rates are approximated by average recommended application rates on fruit and nut tree crops for the products Sevin 85 (Carbaryl) and Marshall (Carbosulfan) which are the most common ones in hazelnut production in Turkey (Bozoğlu 2001).

After windfall hazelnuts are windrowed with a tractor-mounted turbine blower in preparation of mechanical harvest. Harvest is assumed to be performed with a pick-up harvester (Jolly 2800 harvester), where nuts are picked up by a rotating cylindrical brush (Fanigliulo and Tomasone, 2009). These two working steps are executed twice per season.

Ploughing of the orchard floors for soil preparation before replanting is not reported and taking into account the assumed orchard lifetime of 30 years this process can be neglected.

Mowing is approximated with the ecoinvent process "mowing, by motor mower, CH, [ha] (#169)". The same is true for windrowing and harvesting, because the size and fuel consumption of the motor mower matches best with the requirements of the machines typically used in the orchards. In case of the harvester the number of passes is scaled by the ratio of fuel consumption per hectare (literature source vs. ecoinvent data base). For mowing and windrowing, where the fuel consumption is not available in literature, the working time per hectare is taken into account. Owing to the lack of specific machinery data, fertilizer broadcasting and pesticide spraying cannot be adjusted with respect to the ecoinvent processes applied ("fertilising, by broadcaster, CH, [ha] (#156)" and "application of plant protection products, by field sprayer, CH, [ha] (#152)"). Transportation is calculated from the amount of harvested nuts per hectare and the average assumed distance of 1 km in-between field and farm. No on-field transportation is considered as the collected fruits are transported in a container on the harvesting vehicle.

Neither for the amount irrigation water nor for the process of nut drying data on Italian production is provided. Thus, data on Spanish production is adopted by assuming a similar level of technology and comparable in cultural practices. In Camp de Tarragona, the main producing area in Spain, over 60 % of the acreage is irrigated, in the whole of Spain it is 54 % (average for the years 2003-2007, excluding 2005 where data are not available; MARM, 2010). About 2750 cubic meter of water per hectare and year are applied by drip irrigation systems (Tous, 2001). Hazelnuts are dried in order to increase their storage time. Based on a moisture content at harvest of around 25 % (Demirats *et al*., 1998) moisture is reduced to 7 % during the drying process (Tous, 2001). In contrast to Turkey, where nuts are dried in the sun, drying in Spain is carried out by forced air circulation at temperatures between room temperature and 40°C. Thus, low temperature drying is assumed for the original country inventory.

In order to provide the number of plantlets with respect to apple plantlets (see section A.2.3, peaches, for detail), the number of hazelnut trees per hectare has to be known. To estimate this value, an orchard lifetime of 30 years is assumed, which is an average value for modern plantations in Camp de Tarragon (Tous pers. comm.). Based on this assumption, 13 trees ha^{-1} need to be replanted on average every year. Information on hazelnut seedling production are obtained from USDA (2008b).

Table A.11: Production data of hazelnuts (original country: Italy)

Inputs		
Fertilisers – N	116	kg N ha^{-1}
Fertilisers – P	52	kg P_2O_5 ha^{-1}
Fertilisers – K	57	kg K_2O ha^{-1}
Pesticides	3.2	kg active ingredient ha^{-1}
Tree density	385	plants ha^{-1}
Nitrogen return in prunings	0	kg N ha^{-1}
Machinery operations		
Pesticide application	3.5	passes ha^{-1}
Fertiliser application	1	passes ha^{-1}
Mowing for weed control	2	passes ha^{-1}
Pruning		manual operation
Harvest	2	passes ha^{-1}
Transport of harvested hazelnuts	2.7	t·km ha^{-1}
Irrigation		
Irrigation water applied	2750	m^3 ha^{-1}
Fraction of acreage irrigated	55	%
Output		
Yield	2162	kg ha^{-1} (dried nuts with shell)

N.B. Inputs and outputs are averaged across the full lifetime of the orchard.

A.3 Overview of crop inventories and sources used for validation

Table A.12: Water content, original country and original country data source as well as production volumes corresponding to the original country and the three global main producers (FAO, 2009) for the 27 MEXALCA crops. References to the literature LCIA data applied for the plausibility check (section 3.2) are provided. Crop classification is according to FAO (2010).

Crop name	Water content (%)	Original country	Data source original country input	Production volume original country (%)	Data source GWP 100 years (kg CO2-eq)	Production volume of the three biggest producers (%)
Oil Crops						
Soybeans	11 1)	USA	ecoinvent Centre (2007)	37	ecoinvent Centre (2007); Williams *et al.* (2006); Nemecek *et al*. (2005)	USA (37), Brazil (25), Argentina (18)
Peanuts	12	Australia	confidential	< 0.1	no data available	China (38), India (20), Nigeria (10)
Linseed	6 2)	Poland	Heller and Praczyk (2009)	< 0.1	no data available	Canada (34), China (21), USA (13)
Rapeseed	9 1)	Germany	ecoinvent Centre (2007)	11	ecoinvent Centre (2007); Williams *et al*. (2006); Haas *et al*. (2005); Nemecek *et al*. (2005); Tzilivakis *et al*. (2005)	China (26), Canada (18), India (14)
Oil palm	47 1)	Malaysia	ecoinvent Centre (2007)	42	ecoinvent Centre (2007)	Malaysia (42), Indonesia (39), Nigeria (5)
Cotton seed	6 1)	USA	ecoinvent Centre (2007)	17	ecoinvent Centre (2007)	China (28), USA (17), India (15)
Vegetables						
Spinach	93 3)	Switzerland	SZG (2009), LBL, SRVA, FiBL (2004)	0.1	Walter and Stützel (2009)	China (85), USA (3), Japan (2)
Tomato	94 3)	USA	McMaster *et al*. (2003)	10	Muñoz *et al*. (2008)	China (25), USA (10), Turkey (8)
Pumpkin	91 2)	USA	Teegerstrom *et al*. (2001)	4	no data available	China (28), India (17), Russia (6)
Carrot	88 4)	Switzerland	Nemecek *et al*. (2005)	0.2	Lightart *et al*. (2005); Nemecek *et al*. (2005); Mattsson (1999); Fuentes and Carlsson-Kanyama (2006)	China (33), Russia (7), USA (6)
Onions	85 3)	Switzerland	SZG (2009),	< 0.1	Fuentes and	China (31),

			LBL, SRVA, FiBL (2004)		Carlsson-Kanyama (2006)	India (11), USA (6)
Bell peppers	92 [2,3)]	USA	Hartz *et al*. (2008), Takele (2001)	4	no data available	China (50), Turkey (7), Mexico (7)
Fruits						
Bananas	74 [2)]	Guadeloupe (Irrigation: Puerto Rico)	de Barros *et al*. (2009), Goenaga and Irizarry (2000)	< 0.1	no data available	India (23), China (9), Brazil (9)
Oranges	84 [3)]	USA	University of Florida's extension services website (www.crec.ifas.ufl.edu/extension), Mossler and Aerb (2009), Muraro (2009a, b, c), O'Connell *et al*. (2009), Romero *et al*. (2009)	15	Mordini *et al*. (2009); Munasinghe *et al*. (2009); Ribal *et al*. (2009); Tropicana (2009); Tesco (2009); PepsiCO UK and Ireland (2008); Sanjuán *et al*. (2005)	Brazil (28), USA (15), Mexico (6)
Apples	85 [2)]	New Zealand (Irrigation: France)	Saunders *et al*. (2006)	0.7	Williams *et al*. (2008); Sim *et al*. (2007); Milà i Canals *et al*. (2006)	China (39), USA (7), Iran (4)
Almonds	6 [3)]	USA	USDA (1999)	45	no data available	USA (45), Spain (11), Syria (7)
Hazelnuts	5 [3)]	Italy (Irrigation: Spain)	Monarca *et al*. (2005)	15	no data available	Turkey (66), Italy (15), USA (4)
Peach	87 [2)]	South Africa (Irrigation: USA)	confidential	1.1	no data available	China (43), Italy (9), USA (7)
Cereals						
Wheat	15 [1)]	Switzerland (Irrigation: China)	ecoinvent Centre (2007)	< 0.1	Schenck *et al*. (2008); ecoinvent Centre (2007); Charles *et al*. (2006); Haas *et al*. (2005); Nemecek *et al*. (2005); Tzilivakis *et al*. (2005); Ahlgren (2003); Wechselberger (2000)	China (16), India (12), USA (9)
Maize	14 [1)]	USA	ecoinvent Centre (2007)	40	ecoinvent Centre (2007); Williams *et al*. (2006); Nemecek	USA (40), China (19), Brazil (6)

					et al. (2005);	
Rice	13 [1]	USA	ecoinvent Centre (2007)	1.5	Wang *et al*. (2010); ecoinvent Centre (2007)	China (29), India (22), Indonesia (9)
Barley	15 [1,4]	Switzerland (Irrigation: Poland)	ecoinvent Centre (2007)	0.2	ecoinvent Centre (2007); Williams *et al*. (2006); Haas *et al*. (2005); Nemecek *et al*. (2005); Tzilivakis *et al*. (2005); Ahlgren (2003)	Russia (12), Germany (8), Canada (8)
Rye	15 [1,4]	Switzerland (Irrigation: Germany)	ecoinvent Centre (2007)	< 0.1	ecoinvent Centre (2007); Nemecek *et al*. (2005)	Russia (23), Poland (22), Germany (20)
Sugar Crops						
Sugar beet	77 [4]	Switzerland (Irrigation: Spain)	ecoinvent Centre (2007)	0.6	ecoinvent Centre (2007); Tzilivakis *et al*. (2005)	France (13), USA (12), Russia (10)
Sugarcane	71 [1]	Brazil	ecoinvent Centre (2007)	32	ecoinvent Centre (2007)	Brazil (32), India (20), China (7)
Tuber Crops						
potato	78 [4]	Switzerland (Irrigation: Turkey)	ecoinvent Centre (2007)	0.2	Williams *et al*. (2008); ecoinvent Centre (2007); Williams *et al*. (2006); Nemecek *et al*. (2005); Tzilivakis *et al*. (2005); Wechselberger (2000); Reitmayr (1995)	China (22), Russia (12), India (8)
Leguminous Crops						
Pea	13 [4]	Switzerland (Irrigation: New Zealand)	ecoinvent Centre (2007)	0.2	ecoinvent Centre (2007); Nemecek *et al*. (2005)	Canada (26), France (12), China (12)

[1] ecoinvent Centre (2007)
[2] Souci *et al*. (2000)
[3] Tränkner (1968)
[4] Nemecek *et al*. (2005)

REFERENCES FOR APPENDIX A

Ahlgren, S., 2003. Environmental Impact of Chemical and Mechanical Weed Control in Agriculture. A comparison Study using Life Cycle Assessment Methodology. Master thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Alig, M. & Kägi, T., 2008. Ökoinventar(e) für Baumschule Obst Bio & IP. Internal report. Agroscope Reckenholz-Tänikon, 27 August 2008, Zürich.

Barbosa, M., 2000. Crop profile for bell peppers in California. Western Integrated Pest Management Center. February 2000. Available at: http://www.ipmcenters.org/cropprofiles/docs/CAbellpepper.pdf (accessed August 2010).

Beegle, D.B. & Durst, P.T., 2003. Agronomy facts 12: Nitrogen fertilisation of corn. Pennsylvania State University. Available at: http://pubs.cas.psu.edu/FreePubs/pdfs/uc049.pdf (accessed March 2010).

Blazy, J.M., 2008. Evaluation ex ante de systèmes de culture innovants par modelisation agronomique et economique: de la conception a l'adoption – Cas des systèmes de culture bananiers de Guadeloupe. PhD thesis. Montpellier SupAgro. Available at: http://www.prodinra.inra.fr/prodinra/pinra/data/2009/12/PROD2009224822e_20091204092740965.pdf (accessed September 2010).

Boyhan, G.E. & Kelley, W.T., 2009. Transplant production. In: Commercial pepper production handbook. University of Georgia Cooperative Extension. Bulletin 1309, March 2009. Available at: http://pubs.caes.uga.edu/caespubs/pubs/PDF/B1309.pdf (accessed August 2010).

Bozoğlu, M., 2001. Econometric analysis of hazelnut productivity in Ordu and Giresun provinces, Turkey. Acta Horticulturae 556, 125-129.

CAL POLY (California Polytechnic State University, Irrigation Training and Research Center), 1996. Row crop drip irrigation on peppers study – High Rise Farms. California Energy Commission. November 1996.

Charles R., O. Jolliet, G. Gaillard, and D. Pellet, 2006. Environmental analysis of intensity level in wheat production using life cycle assessment. Agriculture, Ecosystems and Environment, 113, pp. 216—225.

Clemson Extension, 1999. Peaches and nectarines. HGIC 1354, June 1999. Available at: http://www.clemson.edu/extension/hgic (accessed August 2010).

Colorio, G., Tomasone, R., Cedrola, C. & Pagano, M., 2009. Overall mechanization of hazelnut orchards in southern Italy. Acta Horticulturae 845, 425-428.

Connell, J.H., 1994. Almond harvest operations in California – maintaining nut quality. Acta Horticulturae 373, 241-247.

Connell, J.H., Edstrom, J.P., Krueger, W.H., Buchner, R.P., Niederholzer, F., Klonsky, K.M. & De Moura, R.L., 2006. Sample costs to establish an orchard and produce almonds. Sacramento Valley, low-volume sprinkler irrigation. University of California Cooperative Extension.

Cook, D. (ed.), 2008. Peanut production guide. Peanut Company of Australia, June 2008. Available at: www.pca.com.au (accessed August 2010).

Cooperative Extension Services of the University of Arkansas, 2000. Arkansas soybean handbook (MP 197). Available at: http://www.uaex.edu/Other_Areas/publications/PDF/MP197/MP-197.asp (accessed 3.11.2009).

CTM (California Tomato Machinery), 2002. Johnson Harvester - Specifications. Available at: http://www.tomatoharvester.com/johnson_specifications.htm (accessed August 2010).

Davis, R.M., G. Hamilton, Lanini, W.T., Spreen, T.H. and Osteen, C., 1998. The Importance of Pesticides and other Pest Management Practices in U.S. Tomato Production. U.S.D.A. National Agricultural Pesticide Impact Assessment Program, Document 1-CA-98.

De Barros, I., Blazy, J.M., Stachetti Rodrigues, G., Tournebize, R. & Cinna, J.P., 2009. Emergy evaluation and economic performance of banana cropping systems in Guadeloupe (French West Indies). Agriculture, Ecosystems and Environment 129, 437-449.

Demirats, C., Ayhan, T. & Kaygusuz, K., 1998. Drying behaviour of hazelnuts. Journal of the Science of Food and Agriculture 76, 559-564.

Duncan, R.A., Verdegaal, P.S., Holtz, B.A., Klonsky, K.A. & De Moura, R.L., 2006. Sample costs to establish an orchard and produce almonds. San Joaquin Valley North, Flood irrigation. University of California Cooperative Extension.

Eagle, A.J., Bird, J.A., Horwath, W.R., Linquist, B.A., Brouder, S.M., Hill, J.E. & van Kessel, C., 2000. Rice yield and nitrogen utilisation efficiency under alternative straw management practices. Agronomy Journal 92, 1096-1103.

ecoinvent Centre, 2007. ecoinvent Data - The Life Cycle Inventory Data. Swiss Centre for Life Cycle Inventories, Dübendorf, ISBN 3-905594-38-2.

Egel, D. (Lead Author), 2010. Midwest vegetable production guide for commercial growers 2010. Purdue University. Available at: http://www.btny.purdue.edu/Pubs/ID/id-56/ (accessed September 2010).

ENDURE (in preparation. DR2.23 Report on description of CS, AS, and IS for Orchards. ENDURE (European Network for the Durable Exploitation of Crop Protection Strategies). http://www.endure-network.eu/.

Engel, A., Blanke, M. & Lenz F., 2009. Wie viele Nährstoffe werden mit dem Mulchen der Fahrgassen in den Baumstreifen einer Obstanlage verfrachtet? Erwerbs-Obstbau 51, 151-161.

EPA, 2009. Inventory of U.S. greenhouse gas emissions and sinks: 1990-2007. U.S. Environmental Protection Agency, Washington DC, USA. Available at: http://www.epa.gov/climatechange/emissions/downloads09/GHG2007-Upfront-508.pdf (accessed February 2010).

Fanigliulo, R. & Tomasone, R., 2009. Operative performance and work quality of a hazelnut pick-up machine. Acta Horticulturae 845, 425-428.

FAO, 2008. The state of food and agriculture. Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAO, 2009. FAOSTAT. http://faostat.fao.org/ (accessed April 2009 to March 2010).

FAO, 2010. Food and Agricultural Organization of the United Nations, Crops Statistics – Concepts, Definitions and Classifications. http://www.fao.org/economic/ess/methodology/methodology-systems/crops-statistics-concepts-definitions-and-classifications/en/. Accessed November 2010.

Fonsah, E.G., Taylor, K.C. & Funderburk, F., 2007. Enterprise cost analysis for Middle Georgia peach production. AGECON-06-118. The University of Georgia Cooperative Extension. Colleges of Agricultural and Environmental Sciences & Family and Consumer Sciences. Available at: http://www.ces.uga.edu/Agriculture/agecon/Printed%20budgets%20files/Middle_GA_Peach_Production01-29-08.pdf (accessed April 2010).

Fuentes, C. and A. Carlsson-Kanyama, 2006. Environmental information in the food supply system, FOI-Swedish Defence Research Agency, Stockholm, 117 p.

Garcia-Suarez, T., 2006. Almonds sustainability scan for California and Spain. Unpublished report.

Goenaga, R. & Irizarry, H., 2000. Yield and quality of banana irrigated with fractions of class A pan evaporation on an Oxisol. Agronomy Journal 92 (5), 1008-1012.

Goenaga, R. and Irizarry, H., 2000. Yield and quality of banana irrigated with fractions of class A pan evaporation on an Oxisol. Agronomy Journal 92 (5), pp. 1008—1012.

GRUDAF, 2009. Grundlagen für die Düngung im Acker- und Futterbau. Agrarforschung 16 (2). Research Stations Agroscope Changins–Wädenswil ACW and Agroscope Reckenholz–Tänikon ART (eds.), Switzerland.

Haas, G., U. Geier, B. Frieben, and U. Köpke, 2005. Estimation of environmental impact of conversion to organic agriculture in Hamburg using the Life-Cycle-Assessment method. Institute of Organic Agriculture, University of Bonn, Katzenburgweg 3, D-53115 Bonn, Germany.

Hamilton, G.C. & Polk, D., 1992. Pesticide use in New Jersey. An analysis of pesticide use by peach growers participating in the Rutgers Cooperative Extension Tree Fruit IPM Program during 1992. Available at: http://www.pestmanagement.rutgers.edu/NJinPAS/pesticidesurveys/peach.pdf (accessed April 2010).

Haron, K., Zakaria, Z.Z. & Anderson, J.M., 2000. Nutrient cycling in an oil palm plantation: The effects of residue management practices during replanting on dry matter and nutrient uptake of young palms. Journal of Oil Palm Research 12, 29-37.

Hartz, T., 2008. Processing tomato production in California. University of California, publication 7228, http://anrcatalog.ucdavis.edu/pdf/7228.pdf (accessed July 2010).

Hartz, T., Cantwell, M., Lestrange, M., Smith, R., Aguiar, J. & Daugovish, O., 2008. Bell pepper production in California. University of California, publication 7217. http://anrcatalog.ucdavis.edu/pdf/7217.pdf (accessed August 2010).

Hartz, T., M. Cantwell, M. Lestrange, R. Smith, J. Aguiar, and O. Daugovish, 2008. Bell pepper production in California. University of California, publication 7217. http://anrcatalog.ucdavis.edu/pdf/7217.pdf (accessed August 2010).

Heller, K. and M. Praczyk, 2009. Institute of Natural Fibres and Medicinal Plants, Poznań, pers. comm.

HGANZ (Hazelnut Growers Association of New Zealand), 2008. Growing hazelnuts in New Zealand. Hazelnut Growers Association of New Zealand. September 2008. Available at: http://www.hazelnut-growers.org.nz/_resource/new_growers_intro.pdf (accessed September 2010).

Hogmire, H.W. & Biggs, A.R., 2005. Crop profile for peaches in West Virginia. Kearneysville Tree fruit research and Education centre. http://www.ipmcenters.org/CropProfiles/docs/WVpeaches.pdf (accessed April 2010).

IGZ, 2007. Düngung im Freilandgemüsebau. Schriftenreihe des Institutes für Gemüse- und Zierpflanzenbau. Grossbeeren and Erfurt, Germany, p. 225.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T. and Tanabe, K. (eds). IGES, Japan.

Jackson, J.E., 2003. Biology of apples and pears. Cambridge University Press. Cambridge, United Kingdom.

Jacobi, J., Drescher, A.W., Weckenbrock, P., Simmons, R. and Amerasinghe P., 2009. Risks and benefits from wastewater irrigated vegetable cultivation in Periurban Hyderabad, India. Tropentag 2009: Biophysical and Socio-economic Frame Conditions for Sustainable Management of Land Resources and Water Bodies, 06.–08. October 2009, Hamburg, Germany.

Khalid, H., Zin, Z.Z. & Anderson, J.M., 1999. Quantification of oil palm biomass and nutrient value in a mature plantation. 1. Above-ground biomass. Journal of Oil Palm Research 11, 23-32.

Khan, M.H., Imran, M. & Chattha, T. H., 2005. Effect of Irrigation Intervals on Growth and Yield of Onion Varieties Swat–1 and Phulkara. Journal of Applied Sciences Research 1 (2), 112-116.

Kirda, C., 2002. Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. In: Food and Agricultural Organization of the United Nations (ed.), Deficit Irrigation Practices, Water Reports, 22.

Kocjan Ačko, D., Trdan, S., 2008. Influence of row spacing on the yield of two flax cultivars (Linum usitatissimum L.). Acta agriculturae Slovenica 91 (1), 23-35.

KTBL, 2006. Betriebsplanung Landwirtschaft 2006/07. Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) (ed.), 20th ed., (Lokay) Reinheim, Germany.

Lattauschke, G. & H. Laber (ed.), 2002. Hinweise zum umweltgerechten Anbau von Freilandgemüse im Freistaat Sachsen, Spinat. Sächsische Landesanstalt für Landwirtschaft, Dresden, Germany. Available at: http://www.smul.sachsen.de/lfl/publikationen/download/67_1.pdf (accessed February 2010).

Lattauschke, G. & Schön, B. (ed.), 2006. Faltblatt Zwiebeln. Sächsische Landesanstalt für Landwirtschaft, Dresden, Germany. Available at: http://www.smul.sachsen.de/lfl/publikationen/download/2204_1.pdf (accessed March 2010).

Lattauschke, G. and H. Laber (ed.), 2006. Versuche im deutschen Gartenbau. Sächsische Landesanstalt für Landwirtschaft, Dresden, Germany. Available at: http://www.landwirtschaft.sachsen.de/landwirtschaft/download/Spinat_N-Aufnahme_06.pdf (accessed February 2010).

Lattauschke, G., H. Laber & D. Gentzsch (ed.), 2002. Hinweise zum umweltgerechten Anbau von Frilandgemüse im Freistaat Sachsen: Zwiebeln. Landesanstalt für Landwirtschaft, Dresden, Germany. Available at: http://www.smul.sachsen.de/lfl/publikationen/download/68_1.pdf (accessed August 2010).

LBL, SRVA, FiBL, 2004. Deckungsbeiträge Getreide, Hackfrüchte, Übrige Ackerkulturen, Futterbau, Spezialkulturen, Tierhaltung. Landwirtschaftliche Beratungszentrale Lindau (LBL), Service romand de vulgarisation agricole (SRVA), and Forschungsinstitut für biologischen Landbau (FiBL. (edts.), Lindau, Switzerland.

LeStrange, M., Koike, S., Valencia, J.& Chaney, W., 1996. Spinach Production in California. Vegetable Research and Information Center, University of California, USA. Available at: http://anrcatalog.ucdavis.edu/pdf/7212.pdf (accessed August 2010).

Macedo, I.d.C. (ed.), 2005. Twelve studies on Brazilian sugar cane agribusiness and its sustainability. UNICA – União da Agroindústria Canavieira do Estado de São Paulo. Berlendis & Vertecchia, São Paulo.

Mandal, K.G., Misra, A.K., Hati, K.M., Bandyopadhyay, K.K., Ghosh, P.K. & Mohanty, M., 2004. Rice residue-management options and effects on soil properties and crop productivity. Food, Agriculture & Environment 2, 224-231.

Maraseni, T.N., Cockfield, G. & Apan, A., 2007. A comparison of greenhouse gas emissions from inputs into farm enterprises in Southeast Queensland, Australia. Journal of Environmental Science and Health Part A 42, 11-18.

MARM (Ministerio de medio ambiente y medio rural y marino), 2010. Anuario de estadística agroalimentaria. Available at: http://www.mapa.es/es/estadistica/pags/anuario/introduccion.htm (accessed September 2010).

Marr, C., Schaplowsky, T. & Carey, T., 2004. Commercial vegetable production: pumpkins. Kansas State University, November 2004, publication MF-2030. Available at: http://www.agmrc.org/media/cms/MF2030_0C42997F934A4.pdf (accessed September 2010).

Mattsson, B., 1999. Life cycle assessment (LCA) of carrot purée: Case studies of organic and integrated production. SIK-Rapport No. 653, The Swedish Institute for Food and Biotechnology, Gothenburg, Sweden.

McCarty, J.L., Justice, C.O. & Korontzi, S., 2006. Agricultural burning in the Southeastern United States detected by MODIS. Remote Sensing of Environment 108, 151-162.

McMaster, J., A. Morrison, and A. Johnson, 2003. Grow Sustainably: Sustainability Review Key Findings and Recommendations: Brazil and Californian Processing Tomato Pilots. Outsourced Environmental for Unilever, March 2003, Unilever confidential study.

Meester, D. (pers. comm.) Operations/Engines Manager at California Tomato Machinery. Email from 9 July 2010.

Micke, W., ed.), 1996. Almond production manual. University of California. Division of Agriculture and Natural Resources. Publication 3364. ISBN 1-879906-22-8.

Milà i Canals, L., 2003. Contributions to LCA methodology for agricultural system - Site dependency and soil degradation impact assessment. PhD thesis. Universitat Autònoma de Barcelona.

Milà i Canals, L., G.M. Burnip, and S.J. Cowell, 2006. Evaluation of the environmental impacts of apple production using Life Cycle Assessment (LCA): Case study in New Zealand. Agriculture, Ecosystems and Environment, 114, 226-238.

Monarca, D., Cecchini, M. & Mordacchini Alfani, M.L., 2009. The mechanization of crop management and the analysis of its influence on production quality. Acta Horticulturae 845, 431-435.

Monarca, D., Cecchini, M., Mordacchini Alfani, M.L. & Antonelli, D., 2005. The Mechanized Management of Orchards in Central Italy. Acta Horticulturae 686, 351-358.

Mordini, M., T. Nemecek, and G. Gaillard, 2009: Cabon and Water Footprint of Oranges and Strawberries - a Literature Review. Research Station Agroscope Reckenholz Tänikon – ART, Zurich, Switzerland.

Morton, J., 1987. Banana. In: Morton, J.F (1987) Fruits of warm climates., Miami, Florida, pp. 29-46. http://www.hort.purdue.edu/newcrop/morton/banana.html. Accessed July 2010.

Mossler, M.A. & Aerts, M.J., 2009. Florida crop/pest management profiles: Citrus (oranges/grapefruit). Cir 124, Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Mosz, N., 2002. Almond timeline. Available at: http://pestdata.ncsu.edu/croptimelines/pdf/CAalmond.pdf (accessed March 2010).

Munasinghe, M., P. Dasgupta, D.A.B. Southerton, and A.M. Southerton, 2009. 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, Manchaster, UK, 59 p.

Muñoz, P., A. Antón, M. Nuñez, A. Paranjpe, J. Ariño, X. Castells, J.I. Montero, and J. Rieradeval, 2008. Comparing the environmental impacts of greenhouse versus open-field tomato production in the Mediterranean region. Acta Horticulturae, 801, pp. 1591—1596.

Muraro, R.P., 2009a. Summary of 2008-2009 citrus budget for the Central Florida (Ridge) production region. University of Florida, IFAS Extension, Citrus Research and Education Centre, Lake Alfred, Florida. Available at: http://www.crec.ifas.ufl.edu/extension/economics/pdf/CF_Budget_Summ_2008-2009.pdf (accessed March 2010).

Muraro, R.P., 2009a. Summary of 2008-2009 citrus budget for the Central Florida (Ridge) production region. University of Florida, IFAS Extension, Citrus Research and Education Centre, Lake Alfred, Florida. Available at: http://www.crec.ifas.ufl.edu/extension/economics/pdf/CF_Budget_Summ_2008-2009.pdf (accessed March 2010).

Muraro, R.P., 2009b. Summary of 2008-2009 citrus budget for the Southwest Florida production region. University of Florida, IFAS Extension, Citrus Research and Education Centre, Lake Alfred, Florida. Available at: http://www.crec.ifas.ufl.edu/extension/economics/pdf/SW_Budget_Summ_2008-2009.pdf (accessed March 2010).

Muraro, R.P., 2009c. Summary of 2008-2009 citrus budget for the Indian River production region. University of Florida, IFAS Extension, Citrus Research and Education Centre, Lake Alfred, Florida. Available at: http://www.crec.ifas.ufl.edu/extension/economics/pdf/IR_Budget_Summ_2008-2009.pdf (accessed March 2010).

NASS (National Agricultural Statistics Service), 1997. Usual planting and harvesting dates for U.S. field crops – Agricultural Handbook Number 628. USDA NASS, December 1997. Available at: http://usda.mannlib.cornell.edu/usda/nass/planting/uph97.pdf (accessed July 2010).

NASS (National Agricultural Statistics Service), 2003. Acreage. USDA NASS, Washington D.C., June 2003. Available at: http://usda.mannlib.cornell.edu/usda/nass/Acre//2000s/2003/Acre-06-30-2003.pdf (accessed October 2010).

Nemecek T., Kägi T. & Blaser S., 2007. Life Cycle Inventories of Agricultural Production Systems. Final report ecoinvent v2.0 No.15. Swiss Centre for Life Cycle Inventories, Dübendorf, CH.

Nemecek, T., O. Huguenin–Elie, D. Dubois, and G. Gaillard, 2005. Ökobilanzierung von Anbausystemen im schweizerischen Acker- und Futterbau. Schriftenreihe der FAL, 58, Agroscope FAL Reckenholz, Zürich, Switzerland, 156 pp.

O'Connell, N.V. C.E. Kallsen, K.M. Klonsky, and R.L. De Moura, 2009. Sample costs to establish an orange orchard and produce oranges. San Joaquin Valley – South, low volume irrigation. University of California Cooperative Extension. http://coststudies.ucdavis.edu/files/orangevs2009.pdf (accessed March 2010).

Ohio State University (online) Vegetable seed production – "Wet" seeds. Available at: http://www.ag.ohio-state.edu/~seedsci/vsp03.html (accessed Semptember 2010).

Ohio State University Extension, 1999. 1999 commercial pumpkins production budget. Available at: http://ohioline.osu.edu/e-budget/99pump.html (accessed September 2010).

Orzolek, M.D., Greaser, G.L. & Harper, J.K., 2000. Agricultural Alternatives – Pumpkin production. Pennsylvania State University. Available at: http://agalternatives.aers.psu.edu/Publications/pumpkin.pdf (accessed September 2010).

Paramasivam, S., Alva, A.K., Fares, A. & Sajwan, K.S., 2001. Estimation of nitrate leaching in an entisol under optimum citrus production. Soil Science Society of America Journal 65, 914-921.

Pelter, G.Q. & E.J. Sorensen, 2003. Crop Profile for Onions in Washington, Washington State University, USA. Available at: http://www.ipmcenters.org/cropprofiles/docs/waonions.html (accessed August 2010).

PepsiCO UK and Irland, 2008. Environmental Sustainability Report.

Portmann, F., Siebert, S., Bauer, C. & Döll, P., 2008. Global dataset of monthly growing areas of 26 irrigated crops. Version 1.0. Frankfurt Hydrology Paper 6, Institute of Physical Geography, Johann Wolfgang von Goethe University of Frankfurt (Main), Germany.

Pothavorn, P., 2008. Sap phenolic compositions in some bananas in Thailand. Master's thesis. Mahidol University. Thailand. Available at: http://mulinet10.li.mahidol.ac.th/e-thesis/2551/cd416/4836405.pdf (accessed September 2010).

Ramjeawon, T., 2000. Cleaner production in Mauritian cane-sugar factories. Journal of Cleaner Production 8, 503-510.

Rashid, A.A., Mohamed M.T.M., Alang Zahari, M.Z. & Aziz, M.A., 2000. In vitro and post transplant performance of banana cv. Berangan as affected by Triadimefon. P. 179-185 in: Wahad, Z. *et al*. Proceedings of the first national banana seminar at Awana Genting and country resort. UPM: Serdang (MYS), 2000.

Reitmayr, T., 1995. Entwicklung eines rechnergestützten Kennzahlensystems zur ökonomischen und ökologischen Beurteilung von agrarischen Bewirtschaftungsformen – dargestellt an einem Beispiel. Agrarwirtschaft, Sonderheft 147.

Renouf, M.A., Wegener, M.K. & Nielsen, L.K., 2008. An environmental life cycle assessment comparing Australian sugarcane with US corn and UK sugar beet as producers of sugars for fermentation. Biomass and Bioenergy 32, 1144-1155.

Ribal, J., N. Sanjuán, G. Clemente, and L. Fenollosa, 2009. Medición de la eco-eficiencia en procesos productivos en el sector agrario. Caso de estudio sobe producción de cítricos, Economía Agraria y Recursos Naturales, 9 (1), pp. 125—148.

Richner, W., Oberholzer, H.R., Freiermuth, R., Huguenin, O. & Walther, U., 2010. Modell zur Beurteilung des Nitratauswaschungspotenzials in Ökobilanzen – SALCA-Nitrat. Agroscope FAL Reckenholz, Zürich, Switzerland.

Romero, C.C., Dukes, M.D., Baigorria, G.A. & Cohen, R., 2009. Comparing theoretical irrigation requirement and actual irrigation for citrus in Florida. Agricultural Water Management 96, 473-483.

Rufat, J. & DeJong, T.M., 2001. Estimating seasonal nitrogen dynamics in peach trees in response to nitrogen availability. Tree Physiology 21, 1133-1140.

Sanjuán, N., L. Úbeda, G. Clemente, A. Mulet, and F. Girona, 2005. LCA of integrated orange production in the Comunidad Valenciana (Spain). International Journal of Agricultural Resources, Governance and Ecology, 4, pp. 163—177.

Saunders, C., A. Barber, and G. Taylor, 2006. Food miles - comparative energy/emissions performance of New Zealand's agriculture industry. Lincoln University, Research Report No. 285, July 2006.

Schenck, R.C., M. Ostrom, D. Granatstein, K. Painter, and C. Kruger, 2008. Life cycle assessment of wheat grown in Washington State. Proceedings of the 6th International Conference on LCA in the Agri-Food Sector, Zurich, November 12–14, 2008, pp. 248—253.

Sheard, A.G. (ed.), 2006. Fruit and nut production in KwaZulu-Natal. KZN Agri-Report N/A/2006/24. Department of Agriculture and Environmental Affairs. South Africa. Available at: http://agriculture.kzntl.gov.za/portal/Portals/0/Horticulture/Veg%20prod/Fruit%20&%20%20Nut%20Production%20in%20KZN.pdf (accessed April 2010).

Siebert, S. & Döll, P., 2008. The Global Crop Water Model (GCWM): Documentation and first results for irrigated crops. Frankfurt Hydrology Paper 07, Institute of Physical Geography, University of Frankfurt, Frankfurt am Main, Germany.

Silva, M.A., Soares, R.A.B., Landell, M.G.A. & Campana, M.P., 2008. Agronomic performance of sugarcane families in response to water stress. Bragantia 67, 655-661.

Sim, S., M. Barry, R. Clift and S.J. Cowell, 2007. The relative importance of transport in determining an appropriate sustainability strategy for food sourcing. International Journal of Life Cycle Assessment, 12 (6), pp. 422—432.

Sorensen, M.L. (ed.), 2008. Agricultural water management. Research trends. Nova Science Publishers, Inc.

Souci, Fachmann, and Kraut, 2000. Food Composition and Nutrition Tables, on behalf of the Bundesministerium für Ernährung, Landwirtschaft und Forsten, Bonn, ed. by Deutsche Forschungsanstalt für Lebensmittelchemie, Garching near Munic, 6th ed., medpharm (Stuttgart), CRC Press (Boca Raton, London, New York, Washington D.C.), pp. 1182.

Storvogel, J.J., Bouma, J. & Orlich, R.A., 2004. Participatory research for systems analysis: Prototyping for a Costa Rican banana plantation. Agronomy Journal 96 (2), 323-336.

Sutter, J., 2007a. Oil palm production in Malaysia. In: Jungbluth, N., Chudacoff, M., Dauriat, A., Dinkel, F., Doka, G., Faist Emmenegger, M., Gnansounou, E., Kljun, N., Schleiss, K., Spielmann, M., Stettler, C. & Sutter, J. (2007. Life cycle inventories of bioenergy. ecoinvent report No. 17, Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland.

Sutter, J., 2007b. Sugar cane production in Brazil. In: Jungbluth, N., Chudacoff, M., Dauriat, A., Dinkel, F., Doka, G., Faist Emmenegger, M., Gnansounou, E., Kljun, N., Schleiss, K., Spielmann, M., Stettler, C. & Sutter, J., 2007. Life cycle inventories of bioenergy. ecoinvent report No. 17, Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland.

SZG, 2008. Anbauflächen Schweiz. Schweizerische Zentralstelle für Gemüsebau und Spezialkulturen (SZG) (ed.), Koppigen, Switzerland.

SZG, 2009. Produktionskosten Gemüse, Daten zur Kalkulation der Produktionskosten und Deckungsbeiträge. Schweizerische Zentralstelle für Gemüsebau und Spezialkulturen (SZG) (ed.), Arbeitsgruppe Betriebswirtschaft VSGP, Koppigen, Switzerland.

Takele, E., 2001. Bell pepper production: sample costs and profitability analysis. University of California, publication 8026. http://anrcatalog.ucdavis.edu/pdf/8026.pdf (accessed August 2010).

Teegerstrom, T., Call, R. & Gibson R., 2001. 2001-2002 Arizona vegetable crop budgets. University of Arizona Cooperative Extension, publication AZ1262. Available at: http://ag.arizona.edu/arec/pubs/vegcropbudgets/southvegcropbudgets2001.pdf (accessed September 2010).

Tesco, 2009. Tesco Greenerlivingeveryday: Our carbon label findings. Available at: http://www.tesco.com/assets/greenerliving/content/documents/pdfs/carbon_label_findings.pdf (accessed January 2011).

Tixier, P., 2004. Conception assistée par modèle de systèmes de culture durable: Application aux systèmes bananiers de Guadeloupe. PhD thesis. Ecole Nationale Superieure Agronomique de Montpellier, December 2004. Available at : http://tel.archives-ouvertes.fr/docs/00/04/87/43/PDF/tel-00010937.pdf (accessed September 2010).

Tous, J., 2005. Hazelnut production in Spain. Acta Horticulturae 686, 659-663.

Tränkner, G. (ed.), 1968. Taschenbuch Maschinenbau, vol. 3/II: Stoffumformung, Verarbeitungsmaschinen. VEB Verlag Technink, Berlin, Germany.

Tropicana, 2009. Understanding Our Carbon Footprint. Available at http://www.tropicana.com/pdf/carbonFootprint.pdf (accessed January 2011).

Tzilivakis, J., K. Jaggard, K.A. Lewis, M. May, and D.J. Warner, 2005. Environmental impact and economic assessment for UK sugar beet production systems. Agriculture, Ecosystems and Environment, 107, pp. 341—358, doi: 10.1016/j.agee.2004.12.016.

UC IPM (UC Statewide Integrated Pest Management Program), 2009. UC IPM – Pest Management Guidelines: Tomato. University of California, April 2009, publication 3470, http://www.ipm.ucdavis.edu/PDF/PMG/pmgtomato.pdf (accessed July 2010).

UNCTAD (United Nations Conference on Trade and Development), 2010. Market information in the commodities area – Information on cotton. UNCTAD. Available at: http://r0.unctad.org/infocomm/anglais/cotton/sitemap.htm (accessed August 2010).

USDA, 1999. Crop profile for almonds in California, United States Department of Agriculture, Prepared: January 26, 1999. Available at: http://www.ipmcenters.org/cropprofiles/CP_form.cfm (accessed March 2010).

USDA (United States Department of Agriculture - Forest Service), 2008b. The woody plant seed manual - Agriculture handbook 727. April 2008. Available at: http://www.nsl.fs.fed.us/nsl_wpsm.html (accessed September 2010).

USDA (United States Department of Agriculture), 2008a. U.S. Bell & Chile Pepper Statistics. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1659 (accessed August 2010).

USDA (United States Department of Agriculture), 2010. U.S. Tomato Statistics. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1210 (accessed July 2010).

Verburg, P.H. & van der Gon, H.A.C., 2001. Spatial and temporal dynamics of methane emissions from agricultural sources in China. Global Change Biology 7, 31-47.

Wang, B., Xu, Y., Wang, Z., Li, Z., Guo, Y., Shao, K. & Chen, Z., 1999. Methane emissions from rice fields as affected by organic amendment, water regime, crop establishment and rice cultivar. Environmental Monitoring and Assessment 57, 213-228.

Wang, M., X. Xia, Q. Zhang, and J. Liu, 2010. Life cycle assessment of a rice production system in Taihu region, China. International Journal of Sustainable Development and World Ecology, 17 (2), pp. 157—161.

Watson, H.K., Garland, G.G., Purchase, B., Dercas, N., Griffee, P. & Johnson, F.X., 2008. Bioenergy for sustainable development and global competitiveness: The case of sugar cane in Southern Africa. A compilation of results from the thematic research network Cane Resources Network for Southern Africa (CARENSA). CARENSA/SEI special report series, CARENSA/SEI 2008-01. Stockholm Environmental Institute, Sweden.

Wechselberger, P., 2000. Ökonomische und ökologische Beurteilung unterschiedlicher landwirtschaftlicher Bewirtschaftungsmaßnahmen und -systeme anhand ausgewählter Kriterien. Lehrstuhl für Wirtschaftslehre des Landbaues der Technischen Universität München, Germany.

Weerakkody, W.A.P., Peiris, B.C.N., 1998. Plant growth, flowering and fruit formation of tomato grown under protected culture. Trop. Agri. Res. 6, 236-245.

Wichmann, W. (ed.), 1992. World fertilizer use manual. International Fertilizer Industry Association (IFA). http://www.fertilizer.org/ifa/Home-Page/LIBRARY/World-Fertilizer-Use-Manual (accessed 14 January 2010).

Williams, A.G., E. Audsley, and D.L. Sandars, 2006. Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra.

Williams, A.G., E. Pell, J. Webb, E. Tribe, D. Evans, E. Moorhouse, and P. Watkiss, 2008. Comparative Life Cycle Assessment of Food Commodities Procured for UK Consumption through a Diversity of Supply Chains, Final Report for DEFRA Project FO0103, DEFRA, Semptenber 2008.

Wonneberger C. And Keller, F., 2004. Gemüsebau. 1st ed. Eugen Ulmer GmbH & Co, Stuttgart, Germany.

Woodroof, J.G., 1967. Tree nuts: Production, processing, products. Volume One. The Avi Publishing Company, Inc., Westport, Connecticut.

Zając, T., Grzesiak, S., Kulig, B., Poláček, M., 2005. The estimation of productivity and yield of linseed (Linum usitatissimum L.) using the growth analysis. Acta Physiologiae Plantarum 27 (4), 549-558.

Appendix B: Regional results for GWP

Only groups of countries contributing at least 0.2% to the global production were included. LDC = least developed countries.

Yield	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC
Wheat	3507	1756	3183	3893		1837			3761	2403		
Barley	3267	1210	2217	3566		1204			1148			
Rye	2759		2071	2810					1939			
Maize	6586	1634	4314	8805	1473	1468		760	7802	3061	1677	1468
Rice	4606	3416	4705	6893		2286			9945		1526	1873
Oil palm	18120	7255	18327				21436	7840			3676	6428
Rapeseed	2025	831	1459	2445								
Linseed	1010	598	893	1130		585			1808			
Peanuts	2057	947	2149	3374	603	705	679	847	1410	1454	1536	868
Cotton	2510	951	2589	2537	712	731	1293	631	2089		901	1067
Soybeans	2457	1125	2311	2681							927	
Pea	2074	779	1187	2408		765			768			
Potato	20999	11818	17090	25277	8467	9474			22426	31892	3081	
Sugarbeet	51382		42949	52954					50269			
Sugarcane	70467	62088	70246	79590	79698	79917			112813	57425		
Spinach	16286	4967	16277	16657	11734				17857			
Tomatoes	41694	12966	30295	70380	22113	7875	9026		37836	68635	6743	18674
Pumpkin	16743	7635	15388	22392		5091	1126		17522	12412		
Carrot	27139		20148	35580					21437	28243	8586	
Onions	24179	13863	21133	36018		8683			24716	22112	14501	31933
Peppers	23205	3645	18213	49508		2989			17490		6679	4916
Apples	18102		14745	24347					15816	31261		
Bananas	23027	8851	24635	31282	13669	6911	9652	6277	40080	44764	40620	27265
Oranges	20583	9164	18483	27230		6334		14147	18815	29399	8133	
Peach	12990	5960	11214	16438					9549	16177		
Almonds	2545	1771	2240	2704					551			
Hazelnuts	1429		1297	1841								

Yield	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	4778		2718	2578	2124	4337			2561	1732	2448	2540	6972	3141	6971		1599
Barley	2757		3138	2797	1180	3998			1829	1229	2185	2252	4901	2849	5929		1864
Rye			2099	1188	847	2252					1954	2047	3726	1896	4992		
Maize	2809		9383	4342		5119	3261	3140	2634	2508	5630	4396		7932	8767		
Rice		3881	6992	4522		6243	4162	3484	3185	3645				6649			
Oil palm	17287			16256		14255	19609									14901	
Rapeseed			1615	1930		1694			1049	804		2195	2878		3417		1110
Linseed			1160	993		976			398	621		823	1651	928	823		1042
Peanuts	2892		3402	2011		2963	1840	1401	1168		3833						
Cotton	3445		2289	2809	2193	3500		868	1502		3873			3095			4429
Soybeans			2706	2546		1673	1353		1124			1340		2874			
Pea			2125	1200	1321	1306		848	1016			1694	3228	1659	3941		1203
Potato	24817		39035	18269	15728	14791	14774		18456	13603	23307	14163	34228	21452	41168		37789
Sugarbeet			55655	78894	19043	38071			32406		42666	32865	51592	55365	69841		
Sugarcane	77765	41323	71670	75412		66555	64822	48439	63430	39203						49520	85700
Spinach			15955			16601	3580		11698	4967	10759			15038	19493		
Tomatoes	25545	21083	72388	52329	22148	24858	15161		22430		39623	20741		55958	303879		66045
Pumpkin	14485	7080	19180	15558		19631	15908		10062	7744	17140	18862		32407	36546		16653
Carrot	24519		35977	23547	27484	18866	16469		16151		25292	21110	52580	37779	50637		44492
Onions	26792	13623	50381	26123	18963	23001	8915	12676	15958	5941	23362	14971	37716	35952	41360		41997
Peppers	17400	9166	29667	16464	28490	19825	5829		15784		22281	15432		35574	240367		21944
Apples	9502		26875	30124	5539	12779			10697		17267	9028	14845	27017	41615		32393
Bananas	38602	17172		20044		24028	14981	5440	31950	15683	32151			37351		13614	21292
Oranges	13454	11020	32231	20953		7455	26238		11348		28231			20143			20667
Peach	5201		17870	11758	4755	10926			12292		15430	5102		16239	21982		6364
Almonds			3547	1494	2645	2280			941	1854	4316			917			1158
Hazelnuts			2860		946	1661			872		1302	1357		1624	1956		

Fig. 26: Absolute weighted yields (fresh matter, kg/ha) by region.

Yield	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	100%	50%	91%	111%		52%			107%	69%			136%		78%	74%	61%	124%			73%	49%	70%	72%	199%	90%	199%		46%
Barley	100%	37%	68%	109%		37%			35%				84%		96%	86%	36%	122%			56%	38%	67%	69%	150%	87%	181%		57%
Rye	100%		75%	102%					70%						76%	43%	31%	82%					71%	74%	135%	69%	181%		
Maize	100%	25%	66%	134%	22%	22%		12%	118%	46%	25%	22%	43%		142%	66%		78%	50%	48%	40%	38%	85%	67%		120%	133%		
Rice	100%	74%	102%	150%		50%			216%		33%	41%		84%	152%	98%		136%	90%	76%	69%	79%				144%			
Oil palm	100%	40%	101%				118%	43%			20%	35%	95%			90%		79%	108%									82%	
Rapeseed	100%	41%	72%	121%											80%	95%		84%			52%	40%		108%	142%		169%		55%
Linseed	100%	59%	88%	112%		58%			179%						115%	98%		97%			39%	61%		81%	163%	92%	82%		103%
Peanuts	100%	46%	104%	164%	29%	34%	33%	41%	69%	71%	75%	42%	141%		165%	98%		144%	89%	68%	57%		186%						
Cotton	100%	38%	103%	101%	28%	29%	51%	25%	83%		36%	43%	137%		91%	112%	87%	139%		35%	60%		154%			123%			176%
Soybeans	100%	46%	94%	109%							38%				110%	104%		68%	55%		46%			55%		117%			
Pea	100%	38%	57%	116%		37%			37%						102%	58%	64%	63%		41%	49%			82%	156%	80%	190%		58%
Potato	100%	56%	81%	120%	40%	45%			107%	152%	15%		118%		186%	87%	75%	70%	70%		88%	65%	111%	67%	163%	102%	196%		180%
Sugarbeet	100%		84%	103%					98%						108%	154%	37%	74%			63%		83%	64%	100%	108%	136%		
Sugarcane	100%	88%	100%	113%	113%	113%			160%	81%			110%	59%	102%	107%		94%	92%	69%	90%	56%						70%	122%
Spinach	100%	31%	100%	102%	72%				110%						98%			102%	22%		72%	31%	66%			92%	120%		
Tomatoes	100%	31%	73%	169%	53%	19%	22%		91%	165%	16%	45%	61%	51%	174%	126%	53%	60%	36%		54%		95%	50%		134%	729%		158%
Pumpkin	100%	46%	92%	134%		30%	7%		105%	74%			87%	42%	115%	93%		117%	95%		60%	46%	102%	113%		194%	218%		99%
Carrot	100%		74%	131%					79%	104%	32%		90%		133%	87%	101%	70%	61%		60%		93%	78%	194%	139%	187%		164%
Onions	100%	57%	87%	149%		36%			102%	91%	60%	132%	111%	56%	208%	108%	78%	95%	37%	52%	66%	25%	97%	62%	156%	149%	171%		174%
Peppers	100%	16%	78%	213%		13%			75%		29%	21%	75%	39%	128%	71%	123%	85%	25%		68%		96%	67%		153%	1036%		95%
Apples	100%		81%	134%					87%	173%			52%		148%	166%	31%	71%			59%		95%	50%	82%	149%	230%		179%
Bananas	100%	38%	107%	136%	59%	30%	42%	27%	174%	194%	176%	118%	168%	75%		87%		104%	65%	24%	139%	68%	140%			162%		59%	92%
Oranges	100%	45%	90%	132%		31%		69%	91%	143%	40%		65%	54%	157%	102%		36%	127%		55%		137%			98%			100%
Peach	100%	46%	86%	127%					74%	125%			40%		138%	91%	37%	84%			95%		119%	39%		125%	169%		49%
Almonds	100%	70%	88%	106%					22%						139%	59%	104%	90%			37%	73%	170%			36%			45%
Hazelnuts	100%		91%	129%											200%		66%	116%			61%		91%	95%		114%	137%		
Mean	100%	46%	86%	128%	52%	40%	46%	36%	100%	114%	46%	56%	95%	57%	130%	94%	66%	92%	68%	51%	64%	51%	106%	72%	149%	116%	248%	71%	109%

Fig. 27: Relative weighted yields (fresh matter, in % of the weighted global mean) by region.

Weighted mean per ha (without def.)	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	2165	785	2170	2201		654			3704	1056			2103		1495	1180	914	3331			1585	850	1370	1083	4365	1783	4342		789
Barley	1472	478	1064	1592		483			610				1048		1162	967	485	2361			884	459	1002	815	2480	1247	2965		720
Rye	1370		1356	1371					1868						932	599	461	1574					1000	885	1617	996	2805		
Maize	3006	657	2236	3800	884	631		559	5061	1347	840	610	1345		4004	1760		2918	1678	632	1359	963	2377	1848		3367	4595		
Rice	10143	9034	10256	11828		8082			18156		7774	7807		9028	12141	9344		11391	9802	8368	9145	9793				10773			
Oil palm	2617	233	2662				753	176			162	256	2282			2548		3267	2903									917	
Rapeseed	1188	608	1000	1329											726	881		1199			671	631		1073	1778		2001		518
Linseed	1233	721	1438	1192		588			3130						1148	934		1629			747	944		746	2422	1185	1413		1040
Peanuts	3808	1612	4064	5253	1514	1301	1264	1070	3962	2207	1758	1445	3968		5306	2967		5538	3953	2674	2791		6711						
Cotton	3597	528	3858	3260	728	439	632	313	4695		520	523	3936		3117	2743	2310	6047		541	2235		4665			4394			3356
Soybeans	495	210	452	560							241				564	462		474	385		332			303		637			
Pea	1071	679	969	1121		668			736						973	794	796	1073		677	865			833	1528	1020	1727		791
Potato	2683	1841	2519	2897	1466	1402			3049	2444	1244		2639		3771	2225	1874	2620	2235		2444	2240	2646	1689	3790	2622	5288		2959
Sugarbeet	2582		2428	2611					3497						2711	4206	1030	2637			1728		1947	1295	2662	2543	3785		
Sugarcane	1691	655	1726	1588	1487	593			5366	956			1700	749	2024	1500		2611	1755	383	1750	1147						774	1253
Spinach	4918	1908	4989	4329	1588				7464						4068			5108	1362		3334	1908	2474			3294	5665		
Tomatoes	5977	1433	4674	9289	1920	1178	1096		8209	4809	1068	1531	3237	2645	8134	5303	3760	4209	2522		3430		5063	2185		7643	52925		5133
Pumpkin	2647	794	2736	2563		183	55		3911	1058			1703	569	2945	1870		4077	2039		1398	1392	2426	1041		4675	6546		2148
Carrot	3059		2725	3466					2595	2239	1363		2524		3511	2583	2629	2877	2205		2361		2783	1900	4809	3541	5771		2825
Onions	2337	724	2133	3284		663			2467	1375	710	745	1911	1001	4203	1982	993	2752	1050	604	1449	950	1842	1069	4098	2783	5937		2769
Peppers	6963	420	5186	16309		368			5050		519	402	3720	1584	7908	3403	6395	6204	1439		4066		5043	2722		8020	######		2923
Apples	2575		2122	3417					2613	2505			1687		3500	3624	1194	1998			1570		2175	1167	2143	4501	6011		2804
Bananas	8262	1464	9055	9975	2608	715	908	426	27120	10132	3929	2541	13428	4471		6578		13560	5203	526	11299	7092	12205			13098		2559	4690
Oranges	2147	386	1892	2971		390		246	3904	2001	262		1433	874	3539	1670		1269	3100		1460		2899			2245			1259
Peach	3592	1358	3505	3772					4471	2256			1287		4261	2810	1786	3637			3513		3352	842		3808	4057		884
Almonds	2932	1221	2685	3079					429						3987	2278	3554	3808			1461	1286	5016			1176			767
Hazelnuts	2096		1869	2806											4331		1433	3442			1428		1844	1606		2503	2968		

Fig. 28: Absolute weighted global warming potentials without deforestation (kg CO_2eq/ha) by region.

Weighted mean per ha (without def.)	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	100%	36%	100%	102%		30%			171%	49%			97%		69%	54%	42%	154%			73%	39%	63%	50%	202%	82%	201%		36%
Barley	100%	32%	72%	108%		33%			41%				71%		79%	66%	33%	160%			60%	31%	68%	55%	168%	85%	201%		49%
Rye	100%		99%	100%					136%						68%	44%	34%	115%					73%	65%	118%	73%	205%		
Maize	100%	22%	74%	126%	29%	21%		19%	168%	45%	28%	20%	45%		133%	59%		97%	56%	21%	45%	32%	79%	61%		112%	153%		
Rice	100%	89%	101%	117%		80%			179%		77%	77%		89%	120%	92%		112%	97%	82%	90%	97%				106%			
Oil palm	100%	9%	102%				29%	7%			6%	10%	87%			97%		125%	111%									35%	
Rapeseed	100%	51%	84%	112%											61%	74%		101%			56%	53%		90%	150%		168%		44%
Linseed	100%	58%	117%	97%		48%			254%						93%	76%		132%			61%	77%		61%	197%	96%	115%		84%
Peanuts	100%	42%	107%	138%	40%	34%	33%	28%	104%	58%	46%	38%	104%		139%	78%		145%	104%	70%	73%		176%						
Cotton	100%	15%	107%	91%	20%	12%	18%	9%	131%		14%	15%	109%		87%	76%	64%	168%		15%	62%		130%			122%			93%
Soybeans	100%	42%	91%	113%							49%				114%	93%		96%	78%		67%			61%		129%			
Pea	100%	63%	90%	105%		62%			69%						91%	74%	74%	100%		63%	81%			78%	143%	95%	161%		74%
Potato	100%	69%	94%	108%	55%	52%			114%	91%	46%		98%		141%	83%	70%	98%	83%		91%	83%	99%	63%	141%	98%	197%		110%
Sugarbeet	100%		94%	101%					135%						105%	163%	40%	102%			67%		75%	50%	103%	98%	147%		
Sugarcane	100%	39%	102%	94%	88%	35%			317%	57%			101%	44%	120%	89%		154%	104%	23%	103%	68%						46%	74%
Spinach	100%	39%	101%	88%	32%				152%						83%			104%	28%		68%	39%	50%			67%	115%		
Tomatoes	100%	24%	78%	155%	32%	20%	18%		137%	80%	18%	26%	54%	44%	136%	89%	63%	70%	42%		57%		85%	37%		128%	886%		86%
Pumpkin	100%	30%	103%	97%		7%	2%		148%	40%			64%	21%	111%	71%		154%	77%		53%	53%	92%	39%		177%	247%		81%
Carrot	100%		89%	113%					85%	73%	45%		83%		115%	84%	86%	94%	72%		77%		91%	62%	157%	116%	189%		92%
Onions	100%	31%	91%	141%		28%			106%	59%	30%	32%	82%	43%	180%	85%	43%	118%	45%	26%	62%	41%	79%	46%	175%	119%	254%		119%
Peppers	100%	6%	74%	234%		5%			73%		7%	6%	53%	23%	114%	49%	92%	89%	21%		58%		72%	39%		115%	1565%		42%
Apples	100%		82%	133%					101%	97%			66%		136%	141%	46%	78%			61%		84%	45%	83%	175%	233%		109%
Bananas	100%	18%	110%	121%	32%	9%	11%	5%	328%	123%	48%	31%	163%	54%		80%		164%	63%	6%	137%	86%	148%			159%		31%	57%
Oranges	100%	18%	88%	138%		18%		11%	182%	93%	12%		67%	41%	165%	78%		59%	144%		68%		135%			105%			59%
Peach	100%	38%	98%	105%					124%	63%			36%		119%	78%	50%	101%			98%		93%	23%		106%	113%		25%
Almonds	100%	42%	92%	105%					15%						136%	78%	121%	130%			50%	44%	171%			40%			26%
Hazelnuts	100%		89%	134%											207%		68%	164%			68%		88%	77%		119%	142%		
Mean	100%	37%	94%	118%	41%	31%	18%	13%	142%	71%	33%	28%	81%	45%	117%	82%	62%	118%	75%	38%	71%	57%	98%	56%	149%	110%	294%	37%	70%

Fig. 29: Relative weighted global warming potentials per ha without deforestation (in % of global mean) by region.

Weighted mean per ha (with def.)	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	2240	1566	2284	2214		1149			3713	1058			2533		1496	2275	916	3341			1654	1573	1373	1112	4365	1783	4342		853
Barley	1509	783	1175	1605		785			610				1465		1162	1973	487	2478			892	768	1005	842	2480	1247	2965		783
Rye	1402		1629	1385					1868						932	1254	464	1953					1001	907	1617	996	2805		
Maize	3612	2953	3436	3801	2033	1900		4486	5064	1349	3219	3386	2400		4004	4445		2971	6481	9046	1413	2837	2378	1854		3367	4595		
Rice	11694	12749	11503	11847		8782			18157		9863	9615		9044	12160	12241		11460	13721	16945	9220	10107				10773			
Oil palm	8358	4584	8430				10867	5691			2487	3794	9395			5885		3267	8826									25256	
Rapeseed	1203	695	1030	1333											726	3199		1199			689	692		1079	1778		2001		583
Linseed	1285	1024	1519	1195		880			3130						1148	2074		1629			753	1265		777	2422	1185	1413		1093
Peanuts	4948	4897	4937	5254	4557	2731	10501	3955	4183	2214	4235	3136	7206		5306	4828		5538	9845	11236	2798		6711						
Cotton	4006	2838	4273	3265	4089	2070	11631	1421	4788		2077	2697	4508		3117	5842	2310	6055		9101	2366		4665			4394			3422
Soybeans	1612	5522	2302	561							2627				564	2730		570	5584		333			325		637			
Pea	1145	2098	1036	1132		1354			736						973	2265	798	1073		9253	885			866	1528	1020	1727		850
Potato	2888	3005	2854	2911	1697	2192			3064	2444	3623		3909		3775	4048	1876	2742	7954		2474	3067	2664	1715	3790	2622	5288		3005
Sugarbeet	2589		2432	2619					3497						2716	4257	1031	2637			1737		1947	1316	2662	2543	3785		
Sugarcane	3522	3539	3617	1626	2783	1835			5458	956			4171	860	2025	4795		2611	4458	8947	1810	1959						3280	1318
Spinach	5013	1968	5094	4338	1669				7464						4084			5111	9887		3643	1968	2474			3294	5665		
Tomatoes	6271	3840	5064	9294	2157	2740	12011		8223	4810	3587	4779	4559	2660	8136	7664	3760	4223	8165		3452		5069	2206		7643	52925		5186
Pumpkin	2951	1325	3117	2580		184	11054		3930	1058			2226	598	2952	2673		4156	5745		1470	1451	2426	1072		4675	6546		2175
Carrot	3307		3168	3479					2595	2239	3747		3524		3520	4131	2629	2883	10271		2630		2791	1925	4809	3541	5771		2878
Onions	2780	4058	2560	3295		1697			2474	1376	3164	1400	2763	1005	4212	3886	994	2790	6191	9181	1537	1010	1848	1094	4098	2783	5937		2804
Peppers	7549	3047	5866	16311		783			5052		3159	5242	4239	1612	7913	4972	6397	6235	9748		4855		5043	2722		8020	#####		2983
Apples	2701		2311	3424					2613	2505			2243		3506	4727	1194	2115			1596		2184	1183	2143	4501	6011		2830
Bananas	10916	3470	11811	9999	3057	2437	10800	4133	27140	10132	4261	6249	16463	4617		11837		13560	9459	9134	11302	7311	12205			13098		20605	4755
Oranges	3736	4372	3986	2973		671		6316	3905	2001	3565		2859	977	3539	5082		1269	9153		1539		2899			2245			1323
Peach	3707	2539	3676	3775					4471	2256			1777		4265	4078	1786	3716			3553		3364	853		3808	4057		945
Almonds	2938	1317	2699	3079					429						3987	2295	3554	3808			1534	1378	5016			1176			833
Hazelnuts	2098		1871	2806											4331		1433	3443			1428		1844	1613		2503	2968		

Fig. 30: Absolute weighted global warming potentials with deforestation (kg CO_2eq/ha) by region.

Weighted mean per ha (with def.)	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	100%	70%	102%	99%		51%			166%	47%			113%		67%	102%	41%	149%			74%	70%	61%	50%	195%	80%	194%		38%
Barley	100%	52%	78%	106%		52%			40%				97%		77%	131%	32%	164%			59%	51%	67%	56%	164%	83%	197%		52%
Rye	100%		116%	99%					133%						66%	89%	33%	139%					71%	65%	115%	71%	200%		
Maize	100%	82%	95%	105%	56%	53%		124%	140%	37%	89%	94%	66%		111%	123%		82%	179%	250%	39%	79%	66%	51%		93%	127%		
Rice	100%	109%	98%	101%		75%			155%		84%	82%		77%	104%	105%		98%	117%	145%	79%	86%				92%			
Oil palm	100%	55%	101%				130%	68%			30%	45%	112%			70%		39%	106%									302%	
Rapeseed	100%	58%	86%	111%											60%	266%		100%			57%	57%		90%	148%		166%		48%
Linseed	100%	80%	118%	93%		68%			244%						89%	161%		127%			59%	98%		60%	188%	92%	110%		85%
Peanuts	100%	99%	100%	106%	92%	55%	212%	80%	85%	45%	86%	63%	146%		107%	98%		112%	199%	227%	57%		136%						
Cotton	100%	71%	107%	81%	102%	52%	290%	35%	120%		52%	67%	113%		78%	146%	58%	151%		227%	59%		116%			110%			85%
Soybeans	100%	343%	143%	35%							163%				35%	169%		35%	346%		21%			20%		39%			
Pea	100%	183%	90%	99%		118%			64%						85%	198%	70%	94%		808%	77%			76%	133%	89%	151%		74%
Potato	100%	104%	99%	101%	59%	76%			106%	85%	125%		135%		131%	140%	65%	95%	275%		86%	106%	92%	59%	131%	91%	183%		104%
Sugarbeet	100%		94%	101%					135%						105%	164%	40%	102%			67%		75%	51%	103%	98%	146%		
Sugarcane	100%	100%	103%	46%	79%	52%			155%	27%			118%	24%	58%	136%		74%	127%	254%	51%	56%						93%	37%
Spinach	100%	39%	102%	87%	33%				149%						81%			102%	197%		73%	39%	49%			66%	113%		
Tomatoes	100%	61%	81%	148%	34%	44%	192%		131%	77%	57%	76%	73%	42%	130%	122%	60%	67%	130%		55%		81%	35%		122%	844%		83%
Pumpkin	100%	45%	106%	87%		6%	375%		133%	36%			75%	20%	100%	91%		141%	195%		50%	49%	82%	36%		158%	222%		74%
Carrot	100%		96%	105%					78%	68%	113%		107%		106%	125%	80%	87%	311%		80%		84%	58%	145%	107%	174%		87%
Onions	100%	146%	92%	119%		61%			89%	49%	114%	50%	99%	36%	151%	140%	36%	100%	223%	330%	55%	36%	66%	39%	147%	100%	214%		101%
Peppers	100%	40%	78%	216%		10%			67%		42%	69%	56%	21%	105%	66%	85%	83%	129%		64%		67%	36%		106%	1443%		40%
Apples	100%		86%	127%					97%	93%			83%		130%	175%	44%	78%			59%		81%	44%	79%	167%	223%		105%
Bananas	100%	32%	108%	92%	28%	22%	99%	38%	249%	93%	39%	57%	151%	42%		108%		124%	87%	84%	104%	67%	112%			120%		189%	44%
Oranges	100%	117%	107%	80%		18%		169%	105%	54%	95%		77%	26%	95%	136%		34%	245%		41%		78%			60%			35%
Peach	100%	68%	99%	102%					121%	61%			48%		115%	110%	48%	100%			96%		91%	23%		103%	109%		26%
Almonds	100%	45%	92%	105%					15%						136%	78%	121%	130%			52%	47%	171%			40%			28%
Hazelnuts	100%		89%	134%											206%		68%	164%			68%		88%	77%		119%	141%		
Mean	100%	91%	99%	103%	60%	51%	216%	86%	121%	59%	84%	67%	98%	36%	101%	130%	59%	103%	191%	291%	63%	65%	87%	51%	141%	96%	275%	195%	64%

Fig. 31: Relative weighted global warming potentials per ha with deforestation (in % of global mean) by region.

Weighted mean per kg (without def.)	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	0.58	0.45	0.65	0.52		0.38			0.78	0.44			0.44		0.55	0.45	0.47	0.77			0.62	0.48	0.59	0.41	0.61	0.57	0.62		0.49
Barley	0.43	0.40	0.49	0.41		0.41			0.55				0.38		0.37	0.36	0.42	0.59			0.49	0.37	0.50	0.35	0.49	0.44	0.50		0.38
Rye	0.47		0.65	0.46					0.95						0.46	0.50	0.60	0.70					0.51	0.42	0.42	0.54	0.56		
Maize	0.47	0.45	0.52	0.43	0.66	0.45		0.76	0.66	0.45	0.50	0.43	0.49		0.43	0.42		0.57	0.52	0.21	0.55	0.38	0.43	0.41		0.43	0.52		
Rice	2.38	2.78	2.34	1.75		3.83			1.83		5.19	4.65		2.46	1.77	2.17		1.83	2.43	2.46	2.88	2.70				1.63			
Oil palm	0.14	0.04	0.14				0.04	0.02			0.05	0.04	0.13			0.15		0.23	0.15									0.06	
Rapeseed	0.59	0.74	0.68	0.52											0.45	0.44		0.71			0.64	0.78		0.48	0.61		0.59		0.47
Linseed	1.28	1.19	1.67	1.07		1.01			1.77						0.99	0.95		1.67			1.88	1.51		1.08	1.47	1.30	1.75		0.96
Peanuts	1.89	1.73	1.94	1.57	2.83	1.94	1.88	1.35	2.55	1.56	1.16	1.72	1.56		1.57	1.50		1.87	2.16	1.91	2.39		1.71						
Cotton	1.38	0.55	1.44	1.32	1.03	0.62	0.49	0.51	2.06		0.58	0.50	1.14		1.36	0.98	1.06	1.73		0.64	1.46		1.20			1.42			0.76
Soybeans	0.21	0.20	0.20	0.21							0.26				0.21	0.18		0.28	0.28		0.30			0.23		0.22			
Pea	0.58	0.94	0.85	0.48		0.93			1.04						0.46	0.71	0.64	0.82		0.80	0.90			0.49	0.47	0.66	0.44		0.69
Potato	0.14	0.16	0.16	0.12	0.18	0.16			0.13	0.08	0.41		0.11		0.10	0.14	0.12	0.18	0.16		0.13	0.16	0.12	0.12	0.11	0.13	0.13		0.08
Sugarbeet	0.05		0.06	0.05					0.07						0.05	0.05	0.06	0.07			0.05		0.05	0.04	0.05	0.05	0.05		
Sugarcane	0.02	0.01	0.02	0.02	0.02	0.01			0.05	0.02			0.02	0.02	0.03	0.02		0.04	0.03	0.01	0.03	0.03						0.02	0.01
Spinach	0.30	0.38	0.31	0.26	0.14				0.39						0.27			0.31	0.38		0.29	0.38	0.23			0.22	0.29		
Tomatoes	0.15	0.15	0.16	0.12	0.09	0.18	0.12		0.22	0.07	0.16	0.11	0.13	0.13	0.12	0.10	0.17	0.17	0.17		0.16		0.13	0.11		0.14	0.15		0.07
Pumpkin	0.15	0.10	0.17	0.11		0.04	0.05		0.22	0.09			0.12	0.08	0.16	0.11		0.21	0.13		0.14	0.18	0.14	0.06		0.15	0.17		0.13
Carrot	0.12		0.14	0.10					0.13	0.08	0.16		0.10		0.10	0.12	0.10	0.15	0.14		0.15		0.12	0.09	0.09	0.10	0.11		0.06
Onions	0.10	0.08	0.10	0.09		0.10			0.09	0.06	0.05	0.02	0.07	0.07	0.08	0.08	0.05	0.12	0.14	0.05	0.10	0.16	0.08	0.07	0.11	0.08	0.14		0.07
Peppers	0.27	0.15	0.28	0.24		0.17			0.30		0.08	0.09	0.21	0.18	0.25	0.21	0.18	0.32	0.25		0.28		0.22	0.17		0.23	0.43		0.13
Apples	0.15		0.15	0.14					0.15	0.08			0.18		0.14	0.12	0.22	0.16			0.15		0.13	0.14	0.16	0.17	0.14		0.09
Bananas	0.33	0.13	0.36	0.30	0.19	0.09	0.09	0.07	0.66	0.23	0.10	0.09	0.34	0.25		0.33		0.56	0.35	0.10	0.35	0.45	0.35			0.35		0.19	0.22
Oranges	0.11	0.05	0.11	0.11		0.06		0.02	0.19	0.07	0.03		0.11	0.08	0.11	0.08		0.17	0.13		0.13		0.11			0.11			0.06
Peach	0.28	0.23	0.31	0.23					0.42	0.14			0.25		0.24	0.22	0.38	0.33			0.29		0.23	0.16		0.23	0.18		0.14
Almonds	1.16	0.68	1.14	1.18					0.82						1.12	1.54	1.35	1.67			1.44	0.69	1.16			1.32			0.66
Hazelnuts	1.46		1.44	1.52											1.51		1.51	2.06			1.64		1.42	1.18		1.54	1.52		

Fig. 32: Absolute weighted global warming potentials without deforestation (kg CO_2eq/kg) by region.

Weighted mean per kg (without def.)	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Oceania - Australia & NZ / Developed
Wheat	100%	77%	111%	90%		65%			134%	76%			75%		94%	77%	81%	131%			106%	83%	101%	69%	104%	97%	106%		84%
Barley	100%	94%	115%	96%		96%			127%				89%		86%	84%	97%	137%			113%	87%	117%	81%	113%	102%	117%		88%
Rye	100%		138%	97%					201%						97%	107%	128%	149%					109%	89%	90%	114%	119%		
Maize	100%	96%	110%	91%	140%	97%		161%	140%	95%	107%	91%	103%		91%	90%		121%	110%	45%	118%	81%	91%	88%		91%	111%		
Rice	100%	117%	98%	73%		160%			77%		218%	195%		103%	74%	91%		77%	102%	103%	121%	113%				68%			
Oil palm	100%	25%	101%				25%	16%			33%	32%	95%			111%		166%	107%									44%	
Rapeseed	100%	126%	116%	89%											76%	75%		120%			109%	134%		82%	104%		100%		79%
Linseed	100%	94%	131%	84%		79%			139%						78%	74%		131%			147%	118%		85%	115%	102%	137%		76%
Peanuts	100%	92%	102%	83%	150%	103%	99%	71%	135%	83%	61%	91%	83%		83%	80%		99%	114%	101%	127%		90%						
Cotton	100%	40%	105%	96%	74%	45%	35%	37%	149%		42%	36%	83%		99%	71%	76%	125%		46%	106%		87%			103%			55%
Soybeans	100%	96%	99%	101%							126%				101%	88%		137%	138%		144%			112%		108%			
Pea	100%	163%	146%	83%		159%			179%						79%	123%	111%	142%		137%	156%			85%	82%	114%	77%		120%
Potato	100%	117%	114%	86%	130%	115%			97%	58%	302%		78%		71%	99%	89%	130%	115%		98%	121%	86%	88%	82%	95%	94%		57%
Sugarbeet	100%		115%	97%					143%						99%	109%	119%	141%			109%		93%	79%	105%	95%	112%		
Sugarcane	100%	52%	102%	86%	80%	31%			190%	68%			91%	71%	118%	82%		163%	115%	33%	116%	122%						65%	61%
Spinach	100%	127%	101%	87%	45%				130%						88%			102%	126%		95%	127%	76%			74%	96%		
Tomatoes	100%	104%	107%	83%	61%	119%	82%		145%	48%	108%	72%	86%	90%	77%	68%	113%	114%	114%		107%		87%	72%		93%	101%		50%
Pumpkin	100%	67%	109%	72%		24%	32%		145%	56%			77%	52%	105%	73%		136%	85%		92%	118%	91%	37%		97%	114%		84%
Carrot	100%		116%	81%					108%	66%	132%		86%		84%	96%	80%	127%	112%		122%		99%	76%	76%	81%	92%		53%
Onions	100%	83%	104%	90%		101%			93%	63%	51%	25%	74%	76%	85%	77%	54%	122%	138%	48%	99%	163%	81%	72%	108%	85%	145%		68%
Peppers	100%	55%	102%	90%		64%			111%		29%	32%	79%	66%	93%	76%	65%	116%	91%		103%		80%	63%		85%	160%		48%
Apples	100%		102%	96%					105%	54%			120%		92%	79%	151%	106%			103%		91%	93%	109%	112%	97%		60%
Bananas	100%	39%	107%	91%	58%	28%	28%	22%	197%	68%	29%	28%	101%	76%		98%		169%	104%	30%	106%	135%	105%			105%		56%	66%
Oranges	100%	47%	100%	102%		57%		17%	176%	65%	30%		99%	73%	103%	75%		160%	117%		121%		99%			105%			57%
Peach	100%	81%	110%	80%					148%	49%			87%		85%	78%	134%	117%			103%		79%	56%		82%	64%		48%
Almonds	100%	59%	98%	102%					70%						97%	132%	116%	144%			124%	60%	100%			114%			57%
Hazelnuts	100%		99%	104%											104%		103%	141%			112%		97%	81%		105%	104%		
Mean	100%	84%	110%	90%	92%	84%	50%	54%	137%	65%	98%	67%	89%	76%	90%	89%	101%	131%	113%	68%	114%	112%	93%	78%	99%	97%	108%	55%	67%

Fig. 33: Relative weighted global warming potentials per kg without deforestation (in % of global mean) by region.

Weighted mean per kg (with def.)	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	0.62	0.88	0.70	0.53		0.64			0.78	0.44			0.54		0.55	0.97	0.47	0.77			0.65	0.84	0.59	0.42	0.61	0.57	0.62		0.53
Barley	0.45	0.66	0.55	0.42		0.66			0.55				0.54		0.37	0.97	0.42	0.63			0.49	0.65	0.50	0.36	0.49	0.44	0.50		0.42
Rye	0.50		0.88	0.47					0.95						0.46	1.07	0.61	1.02					0.51	0.43	0.42	0.54	0.56		
Maize	0.71	2.08	0.94	0.43	2.10	1.40		5.79	0.66	0.45	1.96	2.64	1.05		0.43	1.21		0.59	2.02	2.99	0.57	1.32	0.43	0.41		0.43	0.52		
Rice	2.80	3.96	2.64	1.75		4.24			1.83		6.62	5.96		2.47	1.77	2.93		1.84	3.32	5.00	2.90	2.81				1.63			
Oil palm	0.49	0.66	0.49				0.49	0.82			0.80	0.55	0.61			0.40		0.23	0.46									1.65	
Rapeseed	0.60	0.84	0.70	0.52											0.45	1.89		0.71			0.66	0.86		0.49	0.61		0.59		0.52
Linseed	1.35	1.75	1.76	1.08		1.51			1.77						0.99	2.24		1.67			1.89	2.17		1.12	1.47	1.30	1.75		1.02
Peanuts	2.80	4.89	2.55	1.57	9.53	4.03	15.82	4.92	2.83	1.57	2.86	3.70	2.49		1.57	2.53		1.87	5.32	8.02	2.40		1.71						
Cotton	1.65	3.15	1.66	1.32	5.57	2.78	9.00	3.01	2.12		2.45	2.54	1.35		1.36	2.12	1.06	1.73		10.99	1.52		1.20			1.42			0.77
Soybeans	0.68	5.05	0.98	0.21							2.83				0.21	1.10		0.37	4.31		0.30			0.25		0.22			
Pea	0.68	2.91	0.92	0.49		2.05			1.04						0.46	2.28	0.64	0.82		10.91	0.94			0.52	0.47	0.66	0.44		0.75
Potato	0.15	0.27	0.19	0.12	0.20	0.25			0.13	0.08	1.20		0.16		0.10	0.27	0.12	0.19	0.51		0.14	0.23	0.12	0.12	0.11	0.13	0.13		0.08
Sugarbeet	0.05		0.06	0.05					0.07						0.05	0.06	0.06	0.07			0.05		0.05	0.04	0.05	0.05	0.05		
Sugarcane	0.05	0.08	0.05	0.02	0.04	0.02			0.05	0.02			0.05	0.02	0.03	0.06		0.04	0.07	0.19	0.03	0.05						0.06	0.02
Spinach	0.33	0.40	0.34	0.26	0.14				0.39						0.27			0.31	2.90		0.31	0.40	0.23			0.22	0.29		
Tomatoes	0.17	0.50	0.18	0.12	0.11	0.38	1.33		0.22	0.07	0.55	0.59	0.17	0.13	0.12	0.15	0.17	0.17	0.62		0.16		0.13	0.11		0.14	0.15		0.08
Pumpkin	0.23	0.15	0.27	0.11		0.04	9.82		0.22	0.09			0.15	0.08	0.16	0.19		0.21	0.35		0.15	0.19	0.14	0.06		0.15	0.17		0.13
Carrot	0.14		0.17	0.10					0.13	0.08	0.44		0.15		0.10	0.21	0.10	0.15	0.62		0.17		0.12	0.09	0.09	0.10	0.11		0.07
Onions	0.14	0.38	0.14	0.09		0.30			0.09	0.06	0.23	0.06	0.13	0.08	0.08	0.17	0.05	0.12	0.72	0.72	0.10	0.17	0.08	0.07	0.11	0.08	0.14		0.07
Peppers	0.38	1.41	0.40	0.24		0.37			0.30		0.56	2.34	0.26	0.18	0.25	0.35	0.18	0.33	1.70		0.51		0.22	0.17		0.23	0.43		0.13
Apples	0.16		0.16	0.14					0.15	0.08			0.24		0.14	0.17	0.22	0.17			0.15		0.13	0.14	0.16	0.17	0.14		0.09
Bananas	0.51	0.49	0.51	0.31	0.28	0.37	1.10	1.09	0.66	0.23	0.16	0.52	0.41	0.27		0.58		0.56	0.63	1.88	0.35	0.47	0.35			0.35		1.48	0.22
Oranges	0.19	0.52	0.21	0.11		0.11		0.46	0.19	0.07	0.45		0.22	0.09	0.11	0.25		0.17	0.32		0.14		0.11			0.11			0.06
Peach	0.30	0.41	0.34	0.23					0.42	0.14			0.43		0.24	0.37	0.38	0.34			0.30		0.23	0.16		0.23	0.18		0.15
Almonds	1.16	0.75	1.14	1.18					0.82						1.12	1.54	1.35	1.67			1.47	0.74	1.16			1.32			0.72
Hazelnuts	1.47		1.45	1.52											1.51		1.51	2.06			1.64		1.42	1.19		1.54	1.52		

Fig. 34: Absolute weighted global warming potentials with deforestation (kg CO_2eq/kg) by region.

Weighted mean per kg (with def.)	World	LDC	Developing	Developed	Africa - Eastern / Developing	Africa - Eastern / LDC	Africa - Middle / Developing	Africa - Middle / LDC	Africa - Northern / Developing	Africa - Southern / Developing	Africa - Western / Developing	Africa - Western / LDC	Americas - Central / Developing	Americas - Latin & Caribbean / Developing	Americas - Northern / Developed	Americas - South / Developing	Asia - Central / Developing	Asia - Eastern / Developing	Asia - South-Eastern / Developing	Asia - South-Eastern / LDC	Asia - Southern / Developing	Asia - Southern / LDC	Asia - Western / Developing	Europe - Eastern / Developed	Europe - Northern / Developed	Europe - Southern / Developed	Europe - Western / Developed	Oceania - all but Austr & NZ / Developing	Ocenania - Australia & NZ / Developed
Wheat	100%	142%	113%	86%		103%			127%	71%			88%		88%	157%	76%	125%			104%	135%	95%	68%	98%	92%	100%		86%
Barley	100%	146%	123%	94%		146%			121%				119%		82%	215%	93%	141%			110%	144%	112%	80%	108%	97%	111%		92%
Rye	100%		178%	94%					192%						92%	216%	122%	206%					103%	88%	85%	108%	114%		
Maize	100%	293%	133%	61%	296%	198%		816%	93%	64%	276%	372%	148%		60%	171%		82%	285%	421%	81%	186%	61%	58%		61%	73%		
Rice	100%	142%	95%	63%		152%			65%		237%	213%		88%	63%	105%		66%	119%	179%	104%	100%				58%			
Oil palm	100%	133%	99%				100%	167%			162%	111%	123%			81%		47%	93%									336%	
Rapeseed	100%	140%	117%	87%											75%	316%		118%			110%	144%		81%	102%		98%		88%
Linseed	100%	130%	130%	80%		111%			131%						73%	165%		123%			140%	160%		82%	109%	96%	130%		75%
Peanuts	100%	175%	91%	56%	340%	144%	564%	176%	101%	56%	102%	132%	89%		56%	90%		67%	190%	286%	86%		61%						
Cotton	100%	190%	100%	80%	336%	168%	544%	182%	128%		148%	154%	82%		82%	128%	64%	105%		664%	92%		73%			86%			47%
Soybeans	100%	738%	144%	31%							415%				31%	160%		54%	631%		44%			37%		33%			
Pea	100%	431%	137%	73%		304%			154%						68%	338%	95%	122%		1616%	139%			76%	70%	98%	66%		111%
Potato	100%	174%	120%	76%	127%	158%			86%	51%	774%		105%		63%	174%	79%	122%	328%		88%	150%	77%	79%	72%	83%	83%		51%
Sugarbeet	100%		115%	97%					142%						98%	117%	118%	140%			108%		93%	80%	105%	95%	111%		
Sugarcane	100%	150%	102%	42%	70%	43%			92%	33%			105%	37%	56%	127%		78%	129%	374%	58%	99%						126%	30%
Spinach	100%	121%	102%	81%	43%				120%						81%			94%	883%		96%	121%	70%			68%	88%		
Tomatoes	100%	299%	108%	74%	68%	226%	793%		129%	42%	329%	353%	102%	80%	69%	91%	101%	102%	370%		96%		77%	64%		83%	90%		45%
Pumpkin	100%	64%	117%	48%		16%	4301%		97%	37%			68%	35%	70%	84%		93%	151%		64%	82%	60%	25%		64%	76%		57%
Carrot	100%		124%	71%					95%	58%	320%		113%		75%	156%	71%	112%	452%		122%		88%	68%	67%	71%	81%		48%
Onions	100%	284%	101%	66%		224%			69%	46%	169%	43%	93%	56%	62%	125%	39%	90%	532%	535%	77%	126%	59%	53%	78%	62%	105%		50%
Peppers	100%	370%	104%	64%		97%			79%		147%	615%	67%	48%	66%	91%	46%	86%	447%		135%		57%	45%		60%	114%		35%
Apples	100%		105%	91%					99%	51%			154%		86%	106%	142%	108%			98%		86%	89%	102%	106%	91%		57%
Bananas	100%	96%	101%	60%	54%	73%	215%	214%	129%	44%	31%	101%	81%	52%		114%		111%	123%	369%	70%	91%	68%			69%		290%	44%
Oranges	100%	276%	112%	58%		60%		245%	99%	36%	240%		115%	49%	58%	131%		90%	169%		73%		56%			59%			34%
Peach	100%	137%	112%	76%					141%	46%			145%		81%	123%	127%	114%			101%		76%	54%		78%	61%		49%
Almonds	100%	64%	98%	101%					70%						97%	133%	116%	143%			126%	64%	99%			114%			62%
Hazelnuts	100%		99%	104%											103%		103%	141%			112%		97%	81%		105%	104%		
Mean	100%	213%	114%	74%	167%	139%	1086%	300%	111%	49%	258%	233%	106%	56%	73%	149%	93%	107%	327%	556%	97%	123%	78%	67%	91%	80%	94%	250%	59%

Fig. 35: Relative weighted global warming potentials per kg with deforestation (in % of global mean) by region.

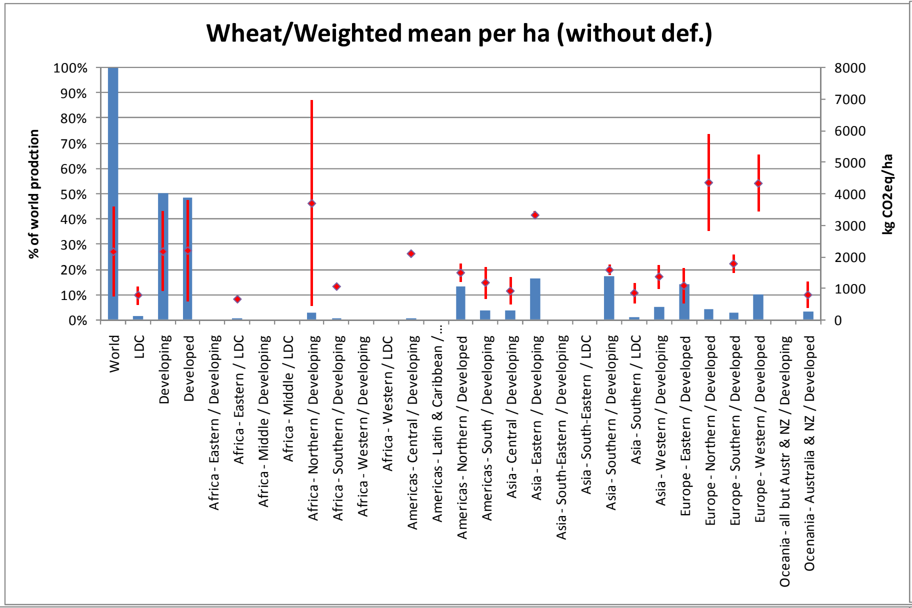
The following graphs show the production volumes shares (in %, blue bars) as well as the weighted means of the global warming potentials per region for all 27 crops (red symbols) together with the weighted standard deviation (red lines).

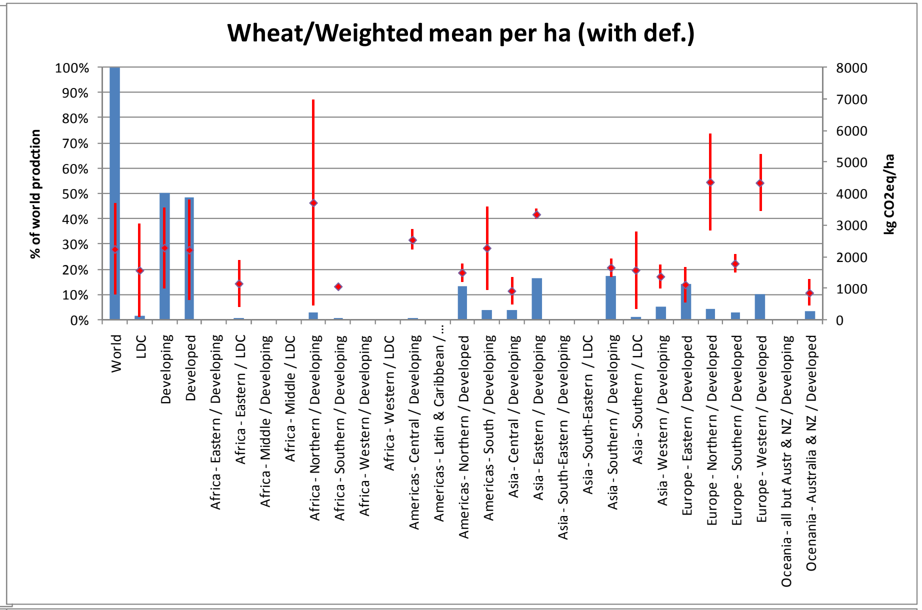
Upper left figure: kg CO_2eq/ha without deforestation

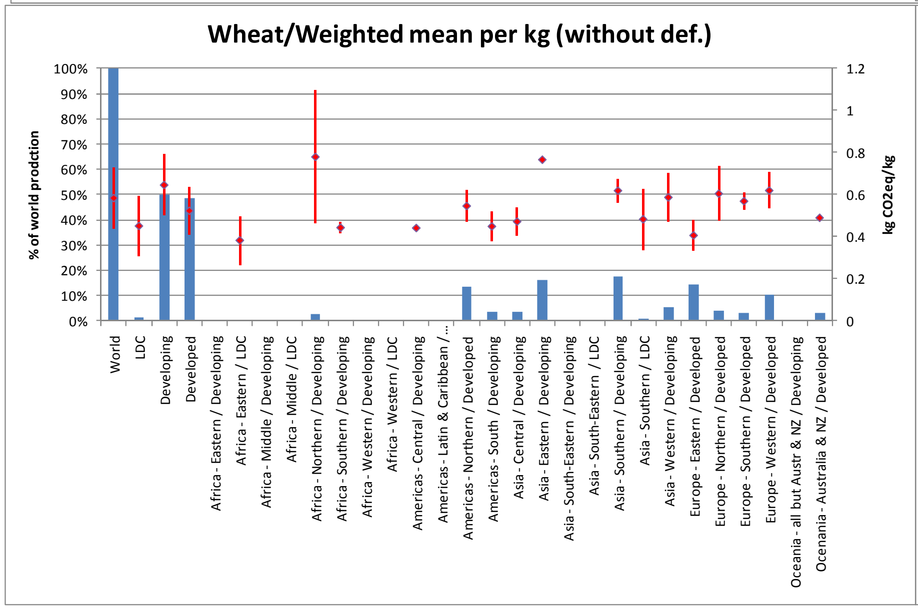
Upper right figure: kg CO_2eq/ha with deforestation

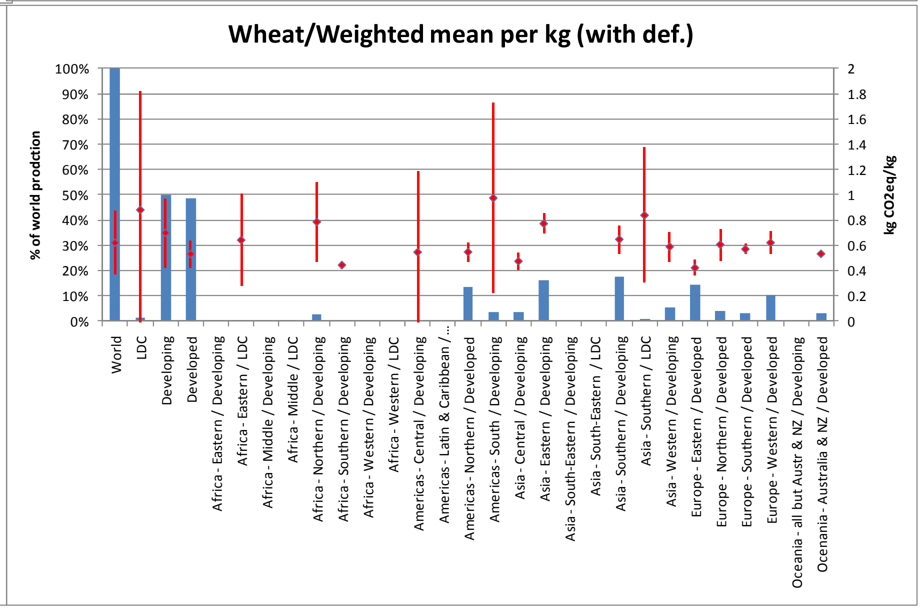
Lower left figure: kg CO_2eq/kg without deforestation

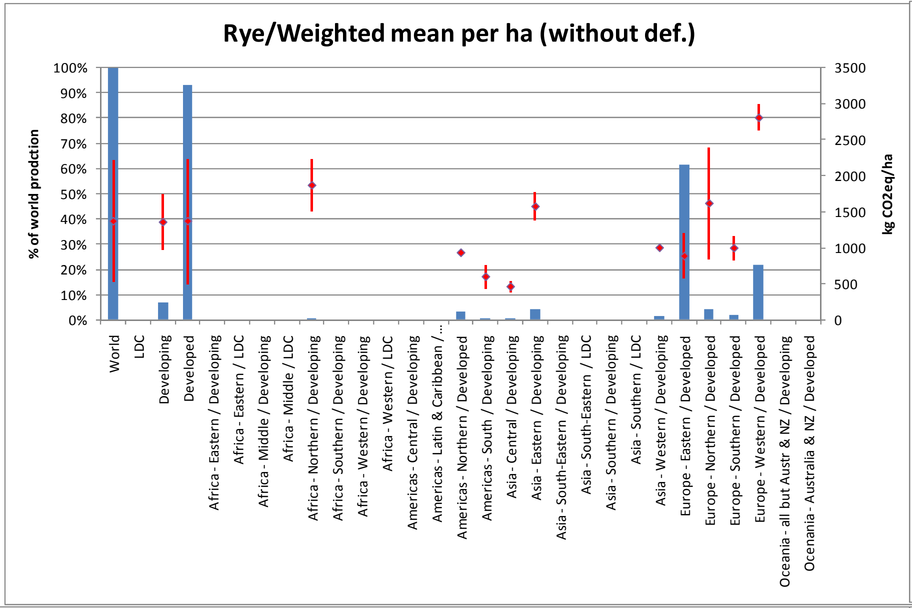
Lower right figure: kg CO_2eq/kg with deforestation

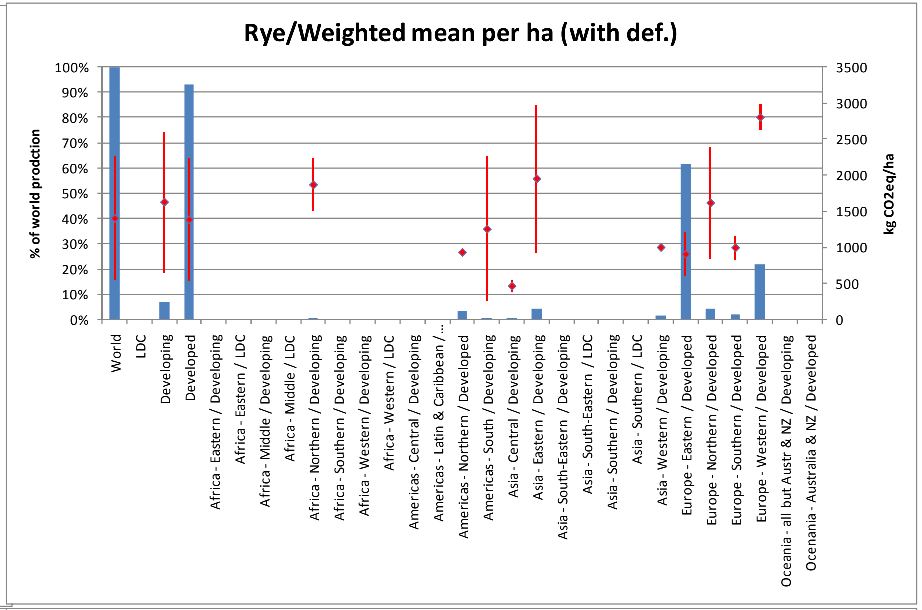

Wheat/Weighted mean per ha (without def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/ha
8000
7000
6000
5000
4000
3000
2000
1000
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed

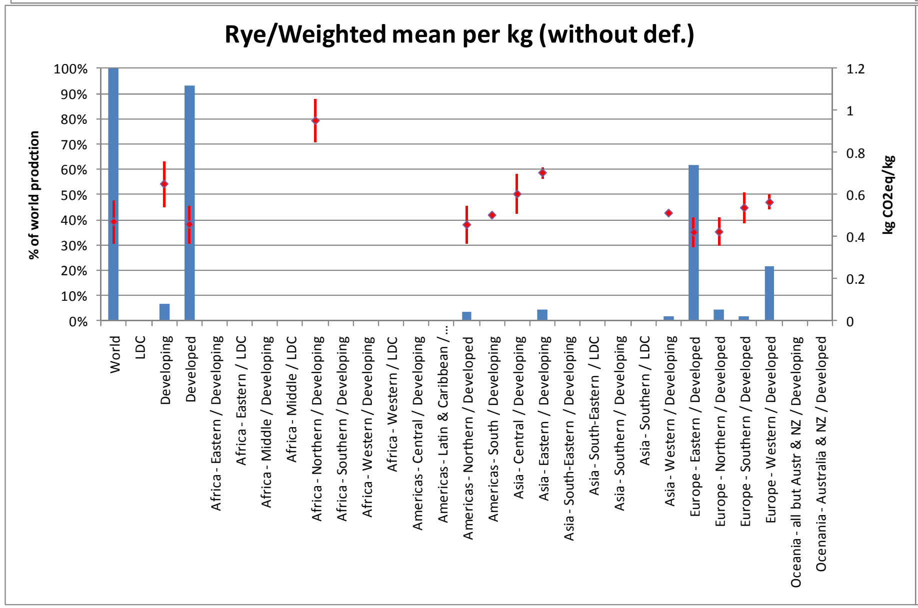

Wheat/Weighted mean per ha (with def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/ha
8000
7000
6000
5000
4000
3000
2000
1000
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed

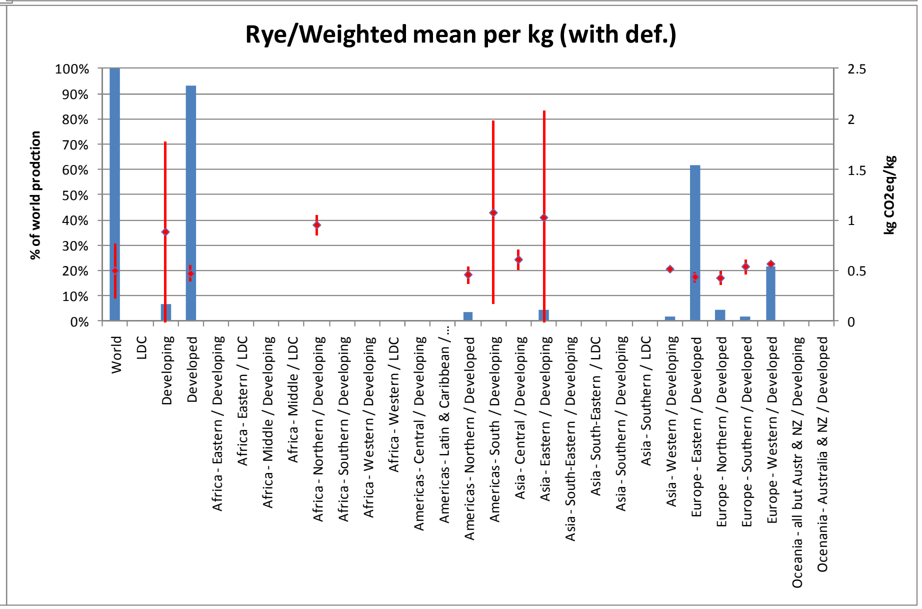

Wheat/Weighted mean per kg (without def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/kg
1.2
1
0.8
0.6
0.4
0.2
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Wheat/Weighted mean per kg (with def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/kg
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Rye/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3500
3000
2500
2000
1500
1000
500
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Rye/Weighted mean per ha (with def.)
% of world prodction
kg CO2eq/ha
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3500
3000
2500
2000
1500
1000
500
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Rye/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.2
1
0.8
0.6
0.4
0.2
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Rye/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2.5
2
1.5
1
0.5
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
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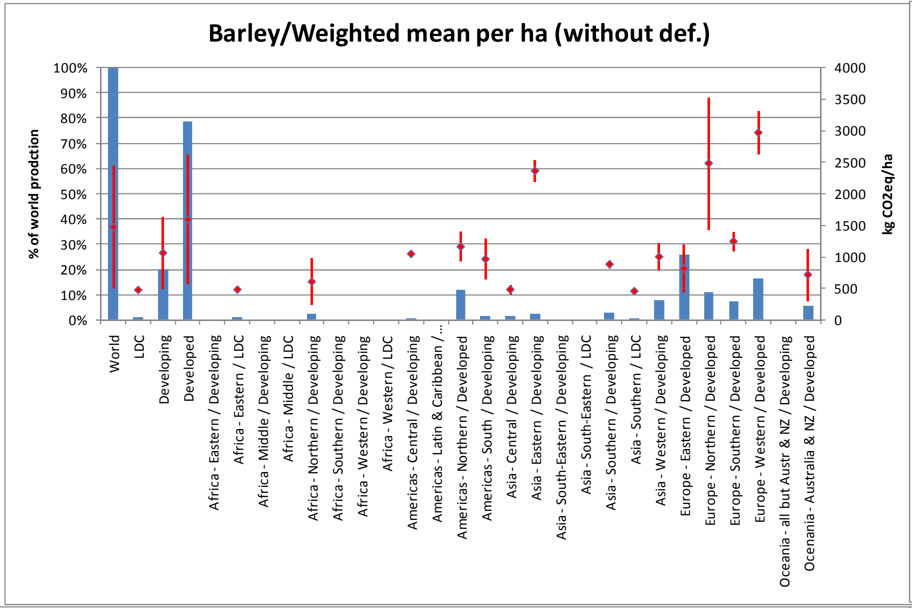
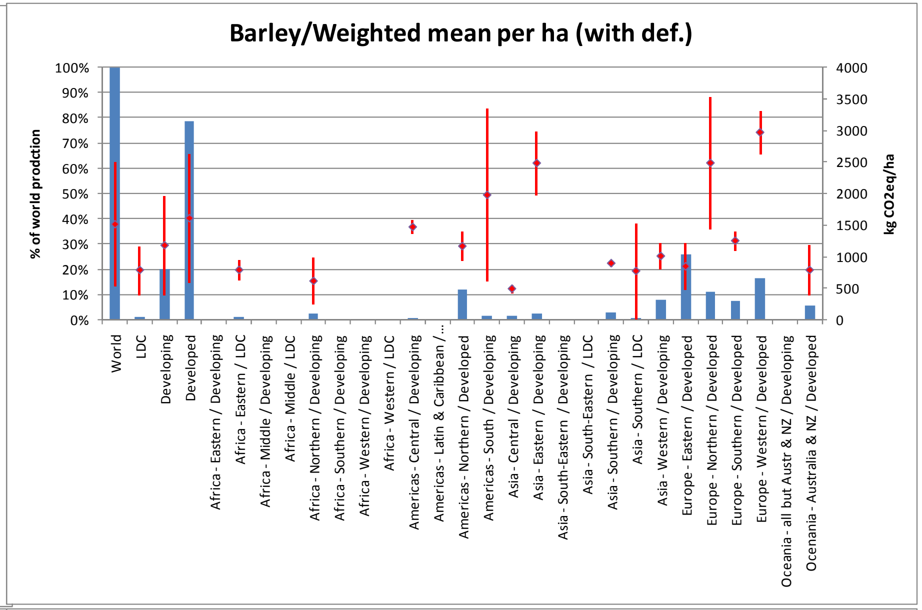
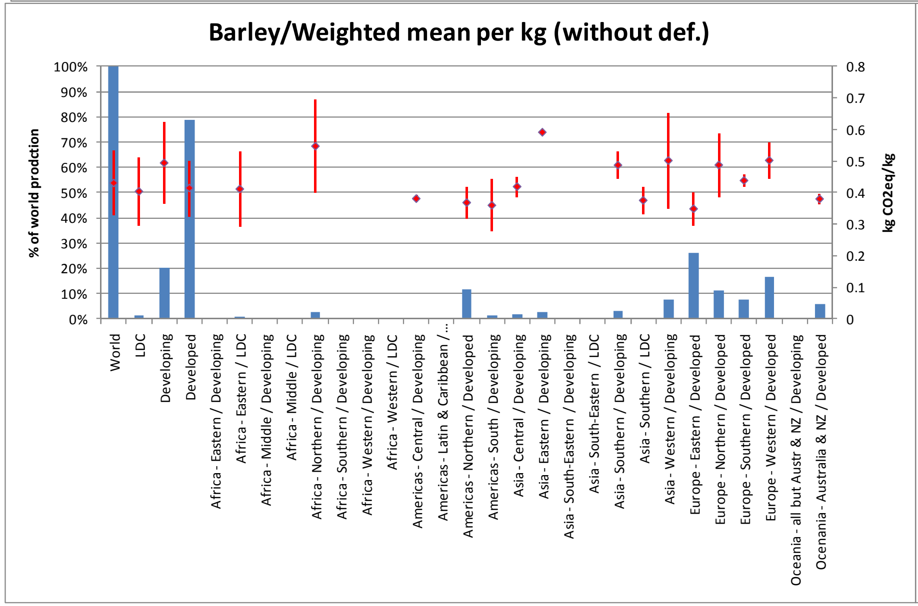
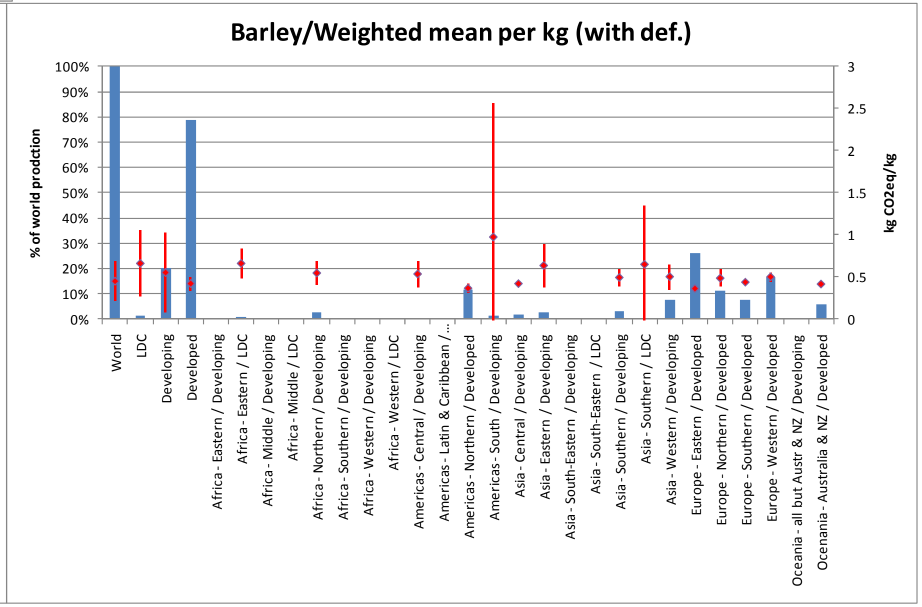
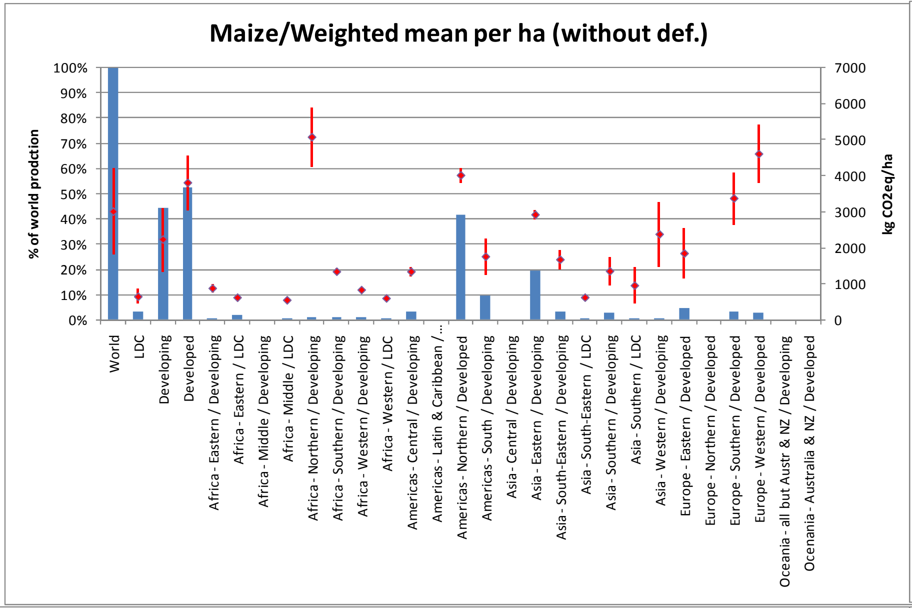
Ocenania - Australia & NZ / Developed

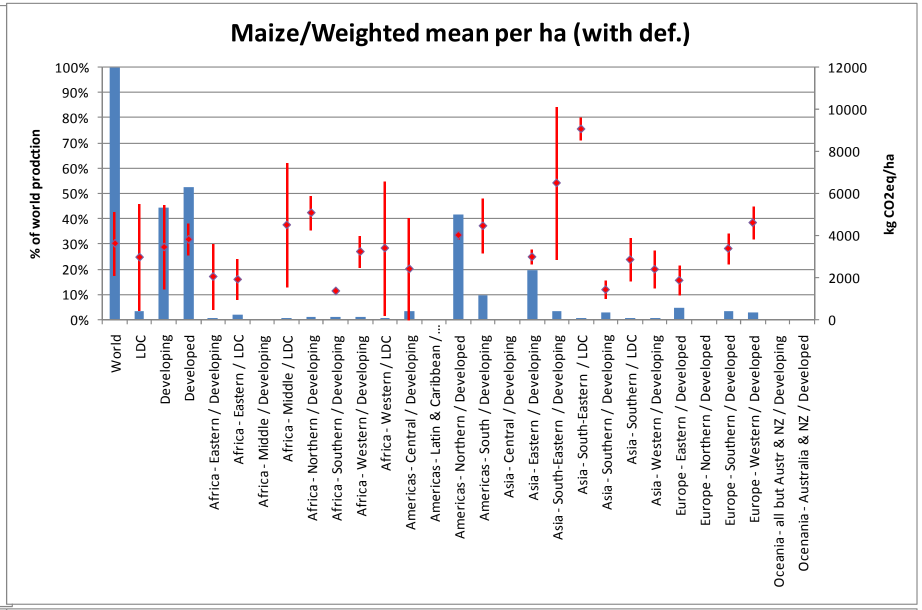

Barley/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha

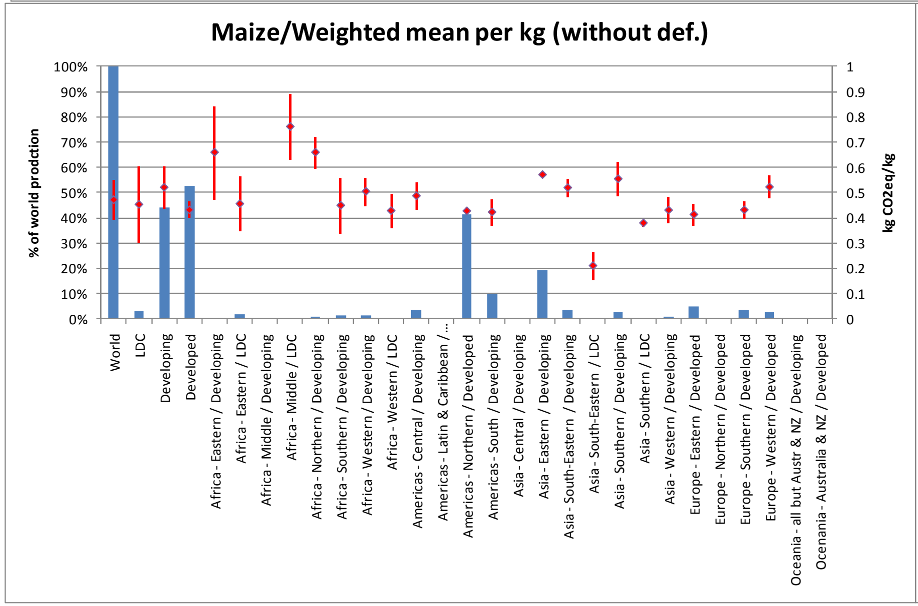

Barley/Weighted mean per ha (with def.)
% of world prodction
kg CO2eq/ha

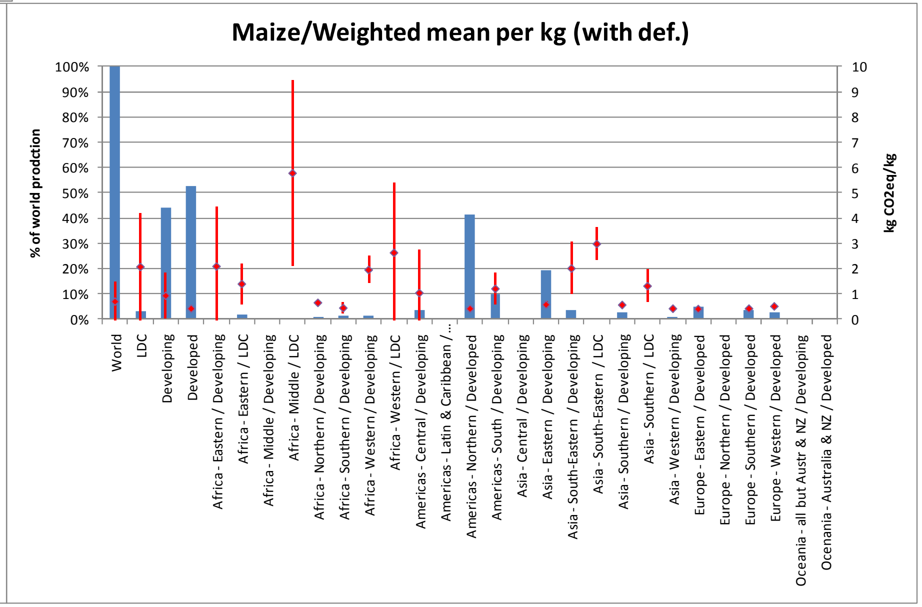

Barley/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg

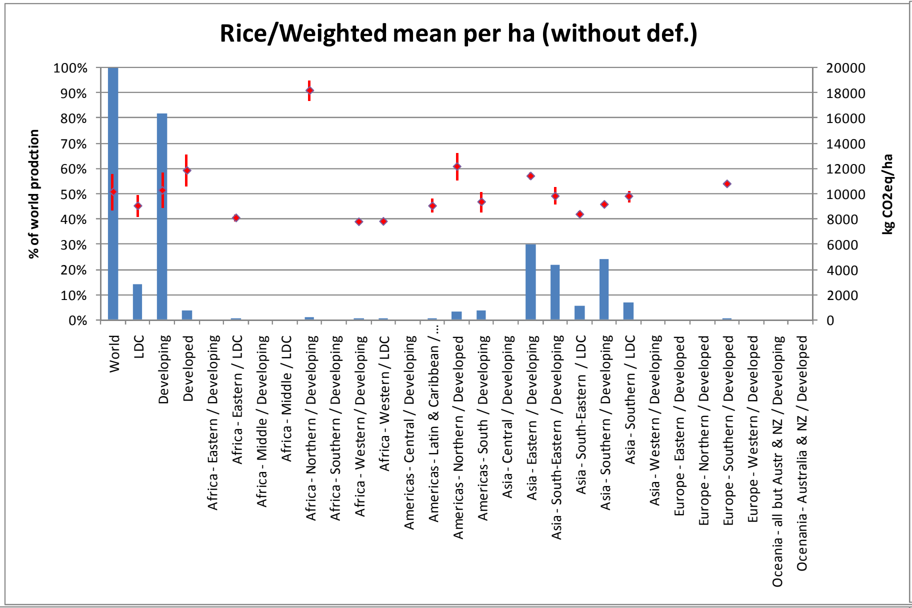

Barley/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg

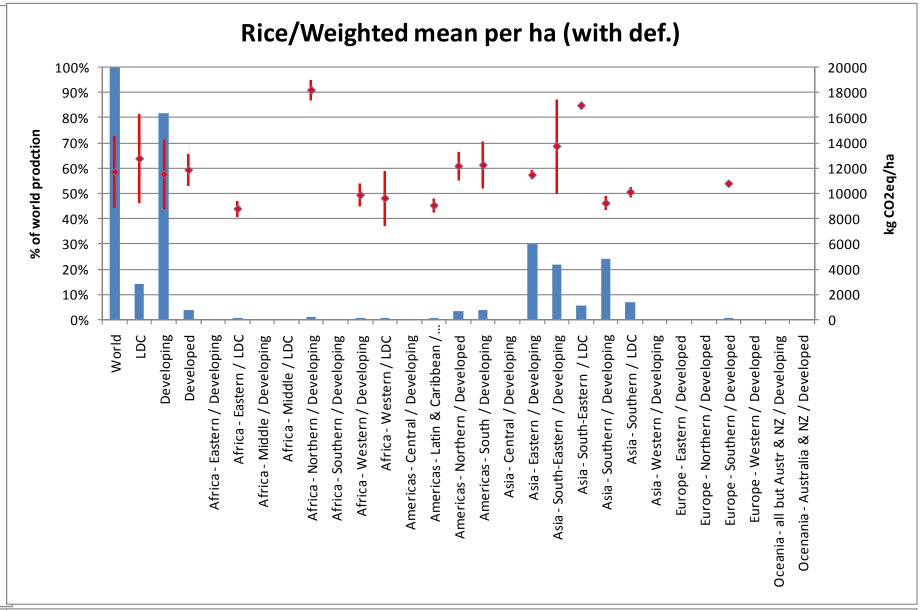

Maize/Weighted mean per ha (without def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/ha
7000
6000
5000
4000
3000
2000
1000
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed

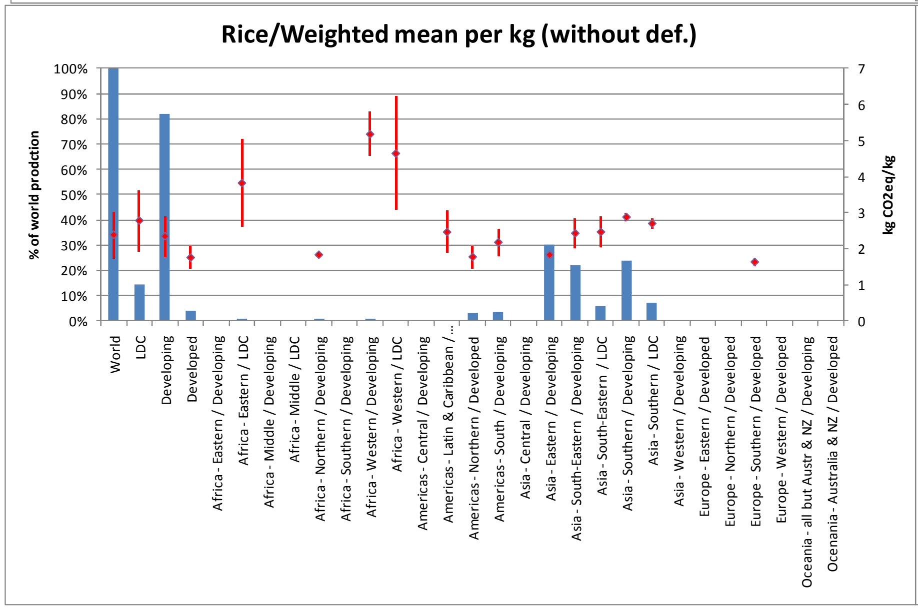

Maize/Weighted mean per ha (with def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/ha
12000
10000
8000
6000
4000
2000
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed

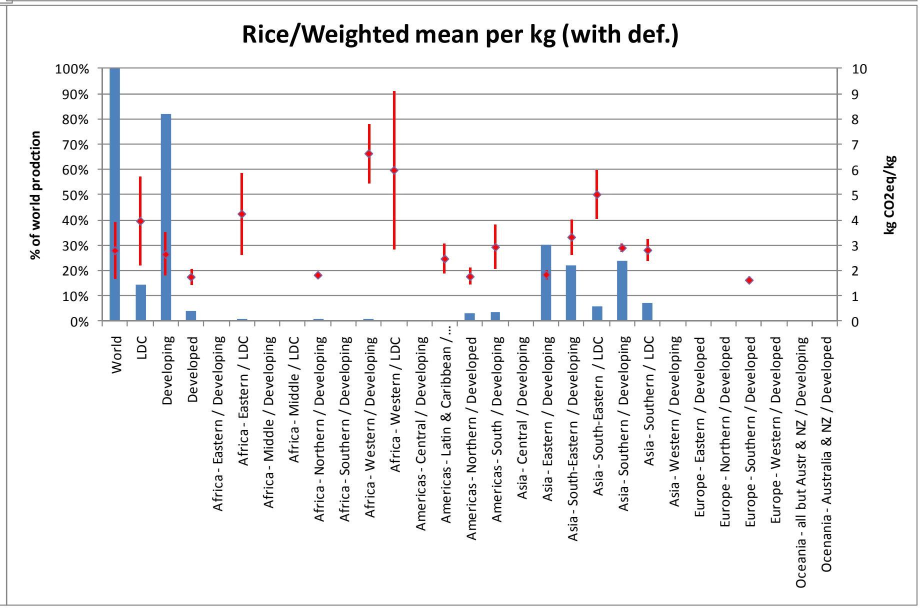

Maize/Weighted mean per kg (without def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/kg
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Maize/Weighted mean per kg (with def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/kg
10
9
8
7
6
5
4
3
2
1
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Rice/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Rice/Weighted mean per ha (with def.)
% of world prodction
kg CO2eq/ha
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Rice/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
7
6
5
4
3
2
1
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Rice/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg
100%
90%
80%
70%
60%
50%
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Americas - Latin & Caribbean / ...
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Americas - South / Developing
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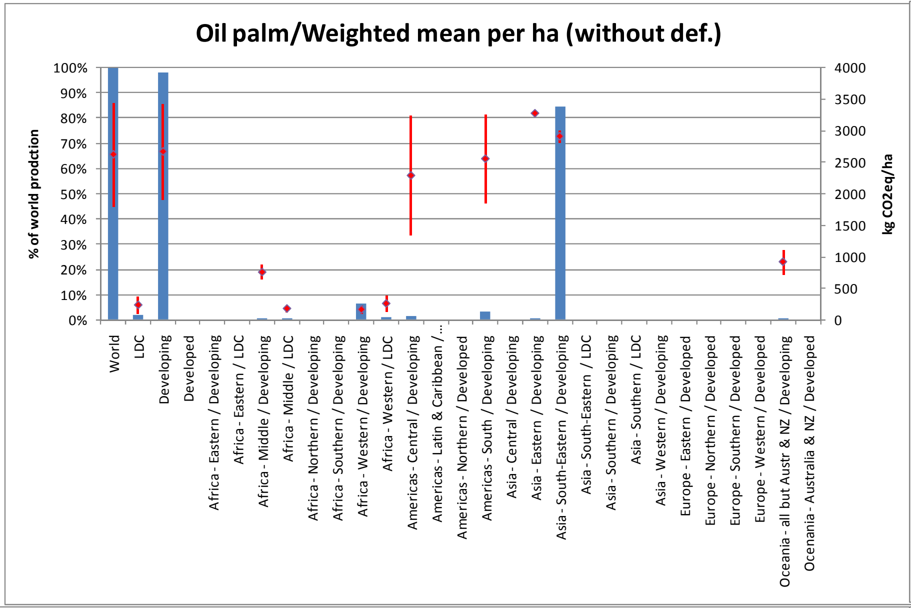
Oil palm/Weighted mean per ha (without def.)
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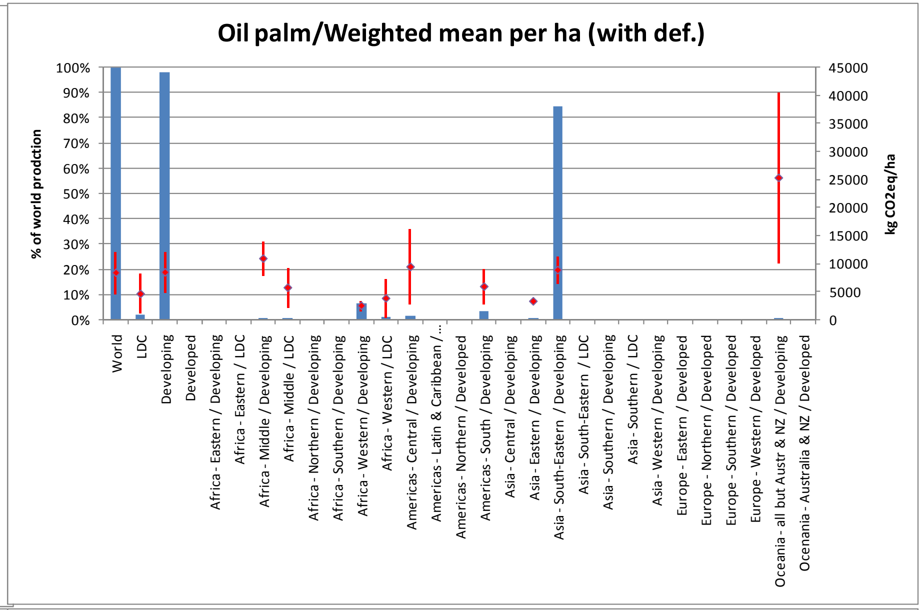
Oil palm/Weighted mean per ha (with def.)
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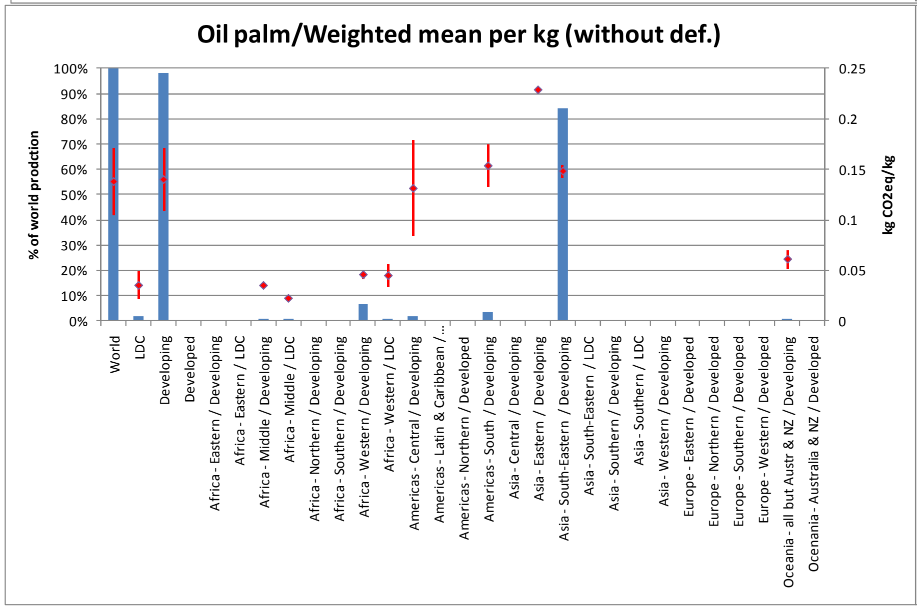
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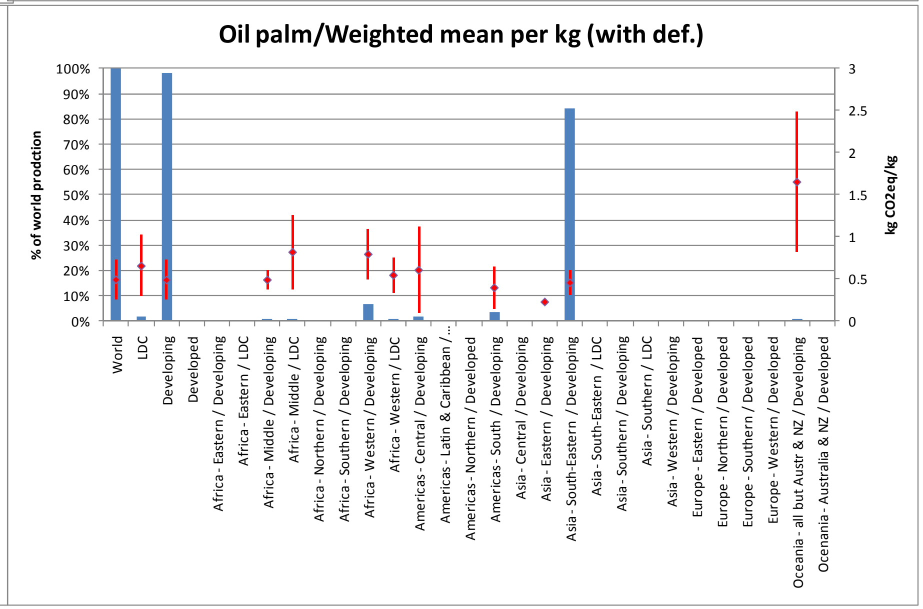
Oil palm/Weighted mean per kg (with def.)
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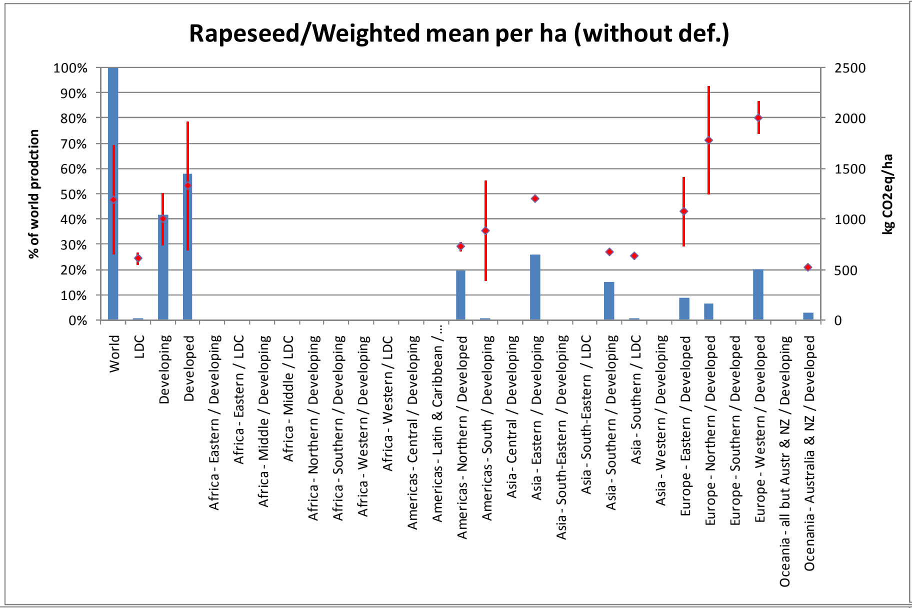
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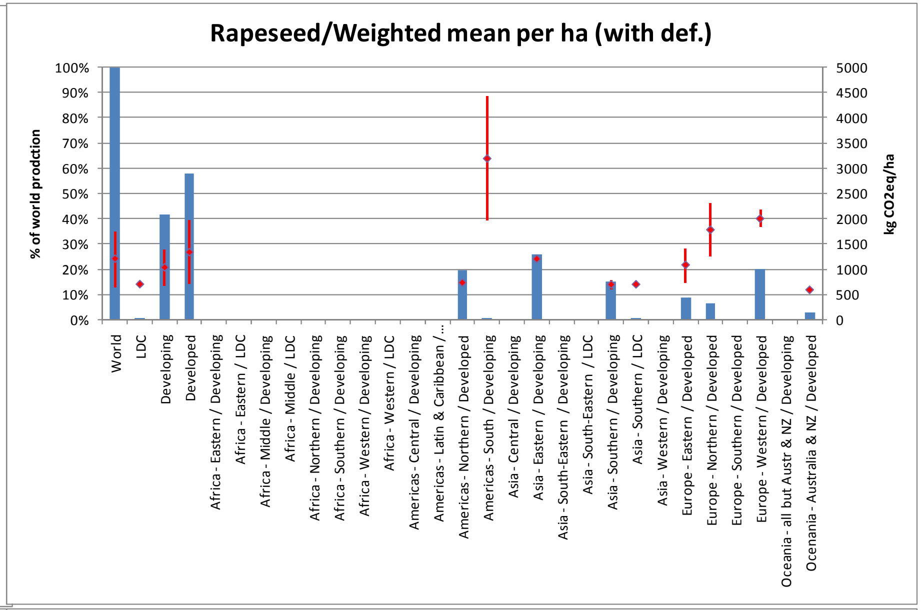
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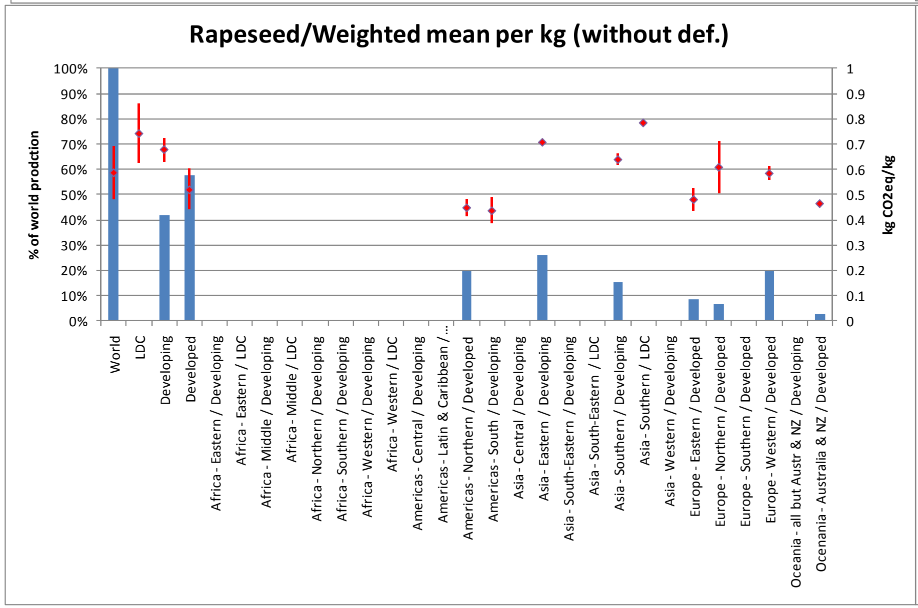
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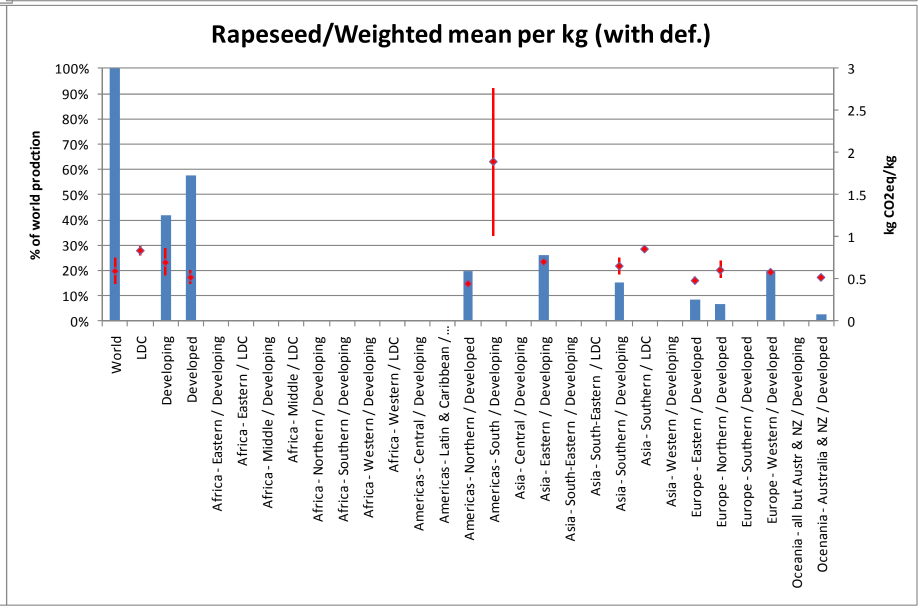
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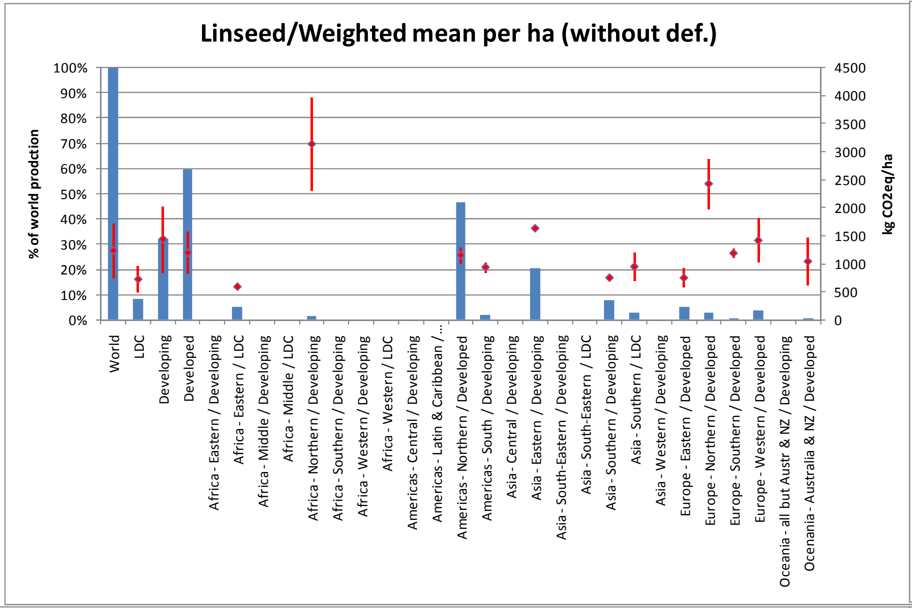
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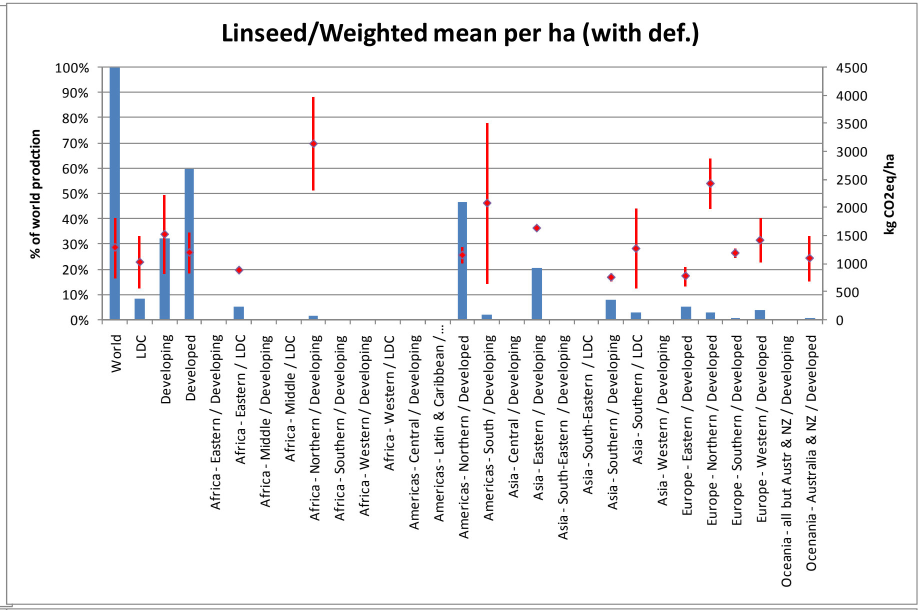
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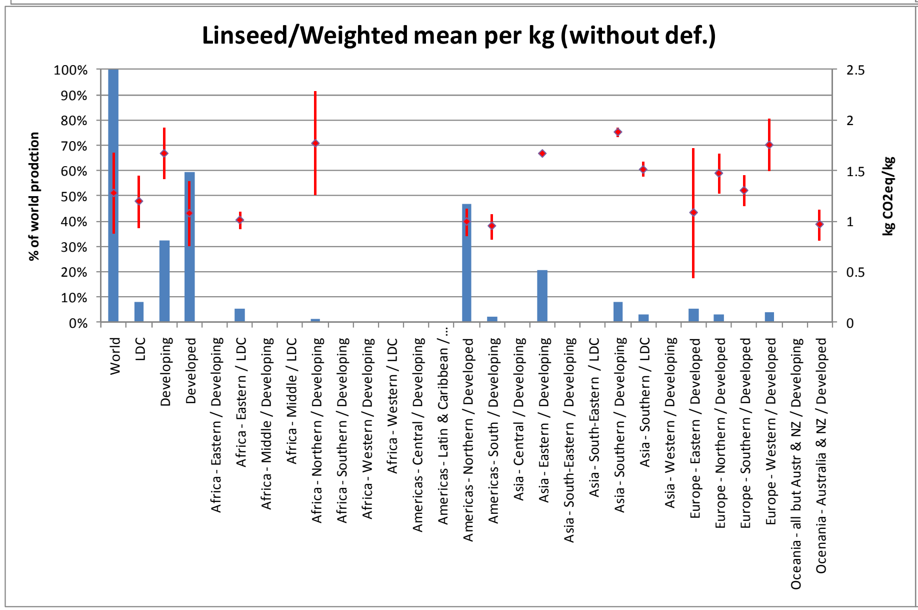
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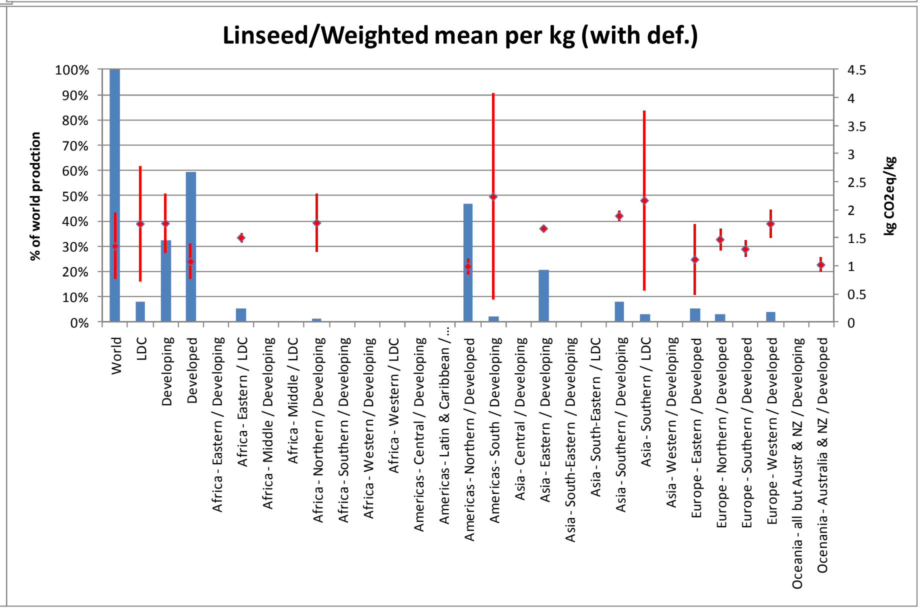
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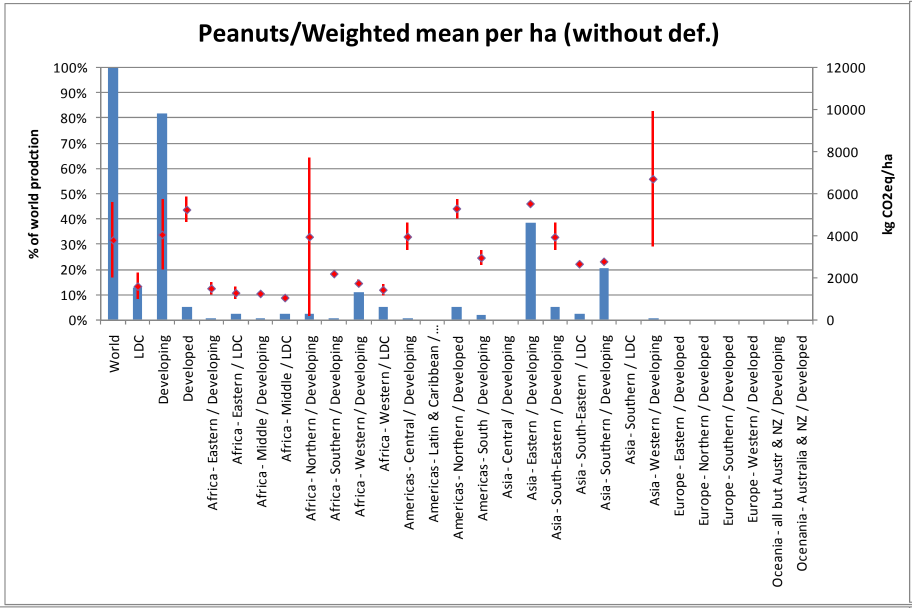
Peanuts/Weighted mean per ha (without def.)
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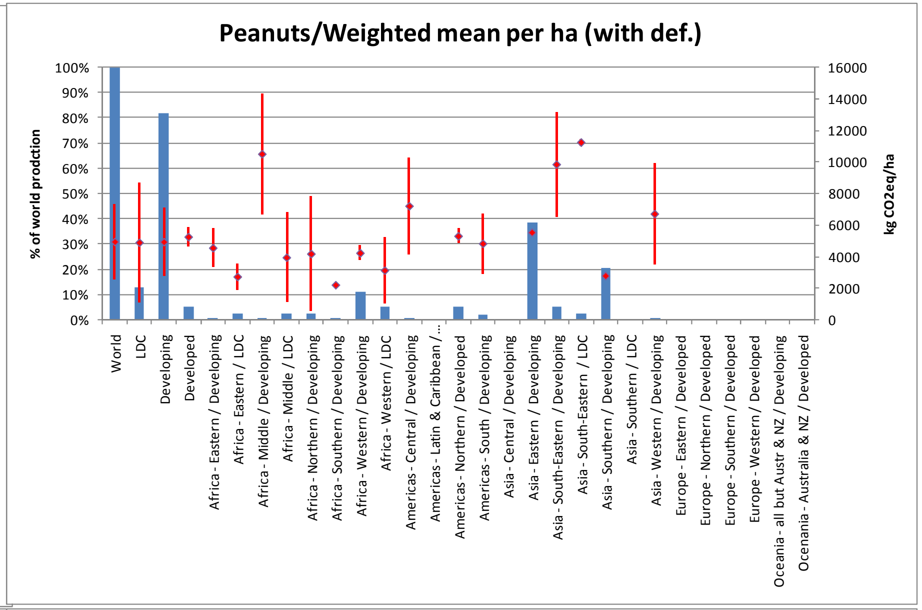
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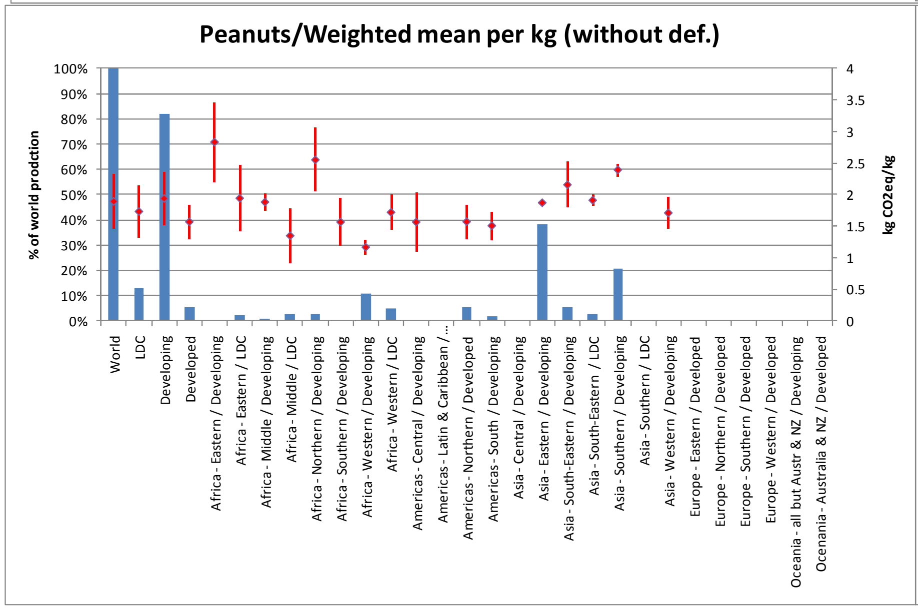
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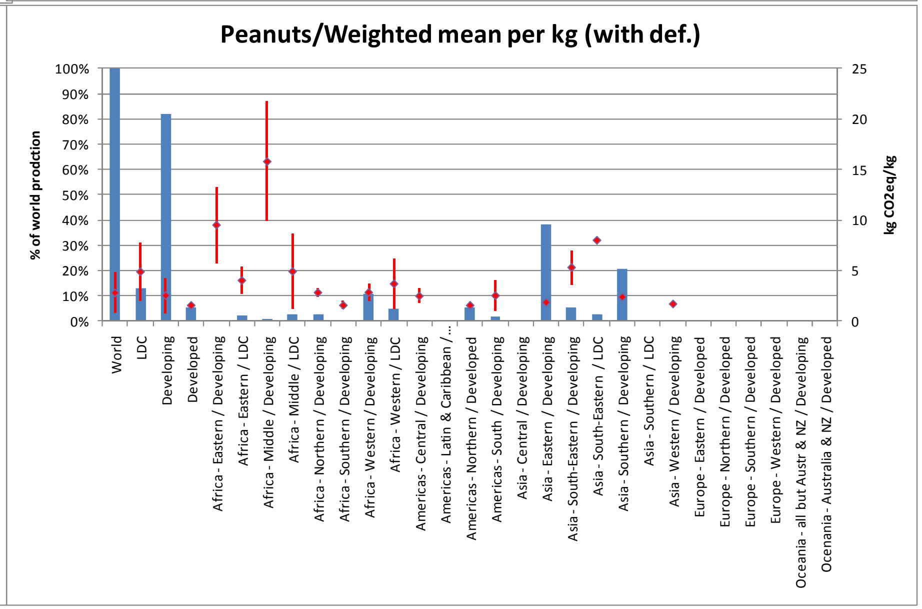
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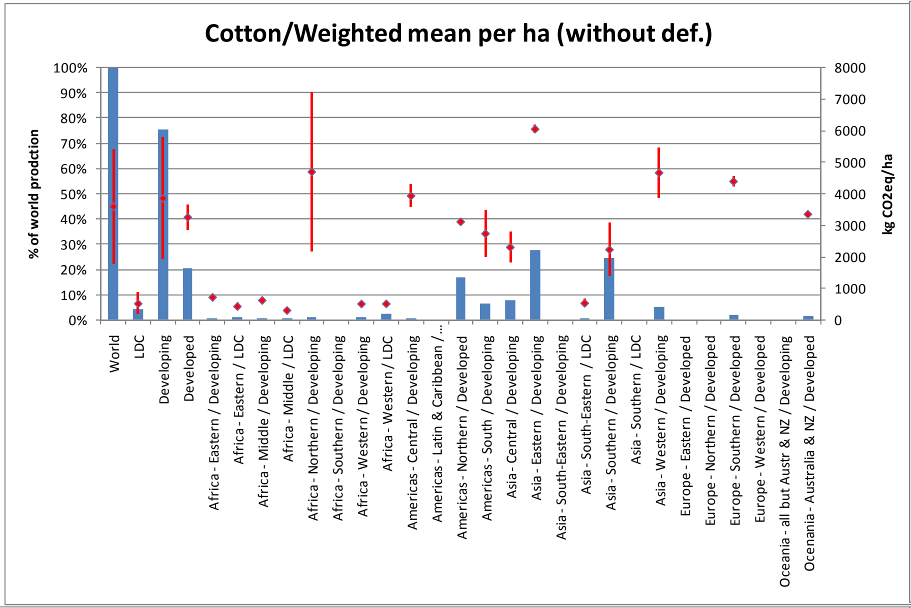
Cotton/Weighted mean per ha (without def.)
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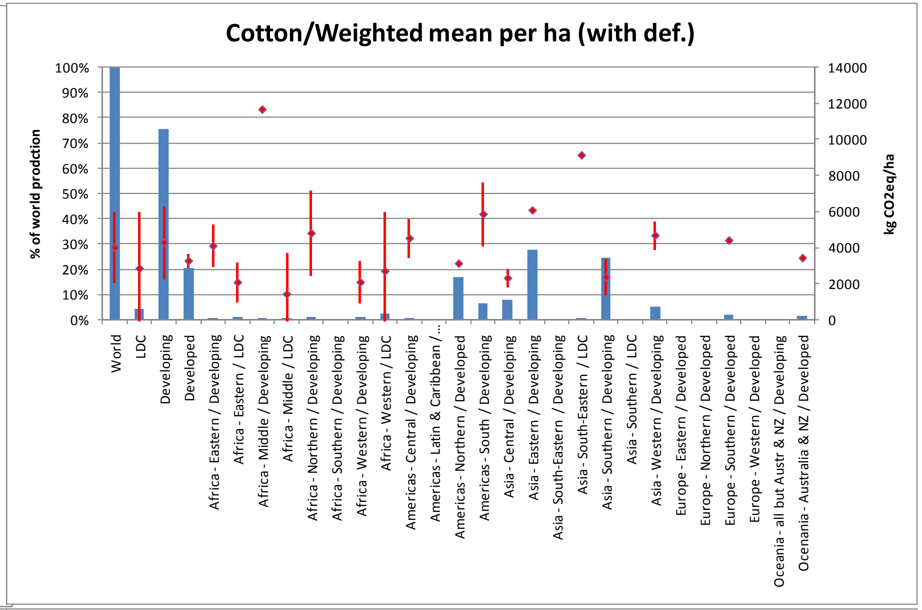
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World
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Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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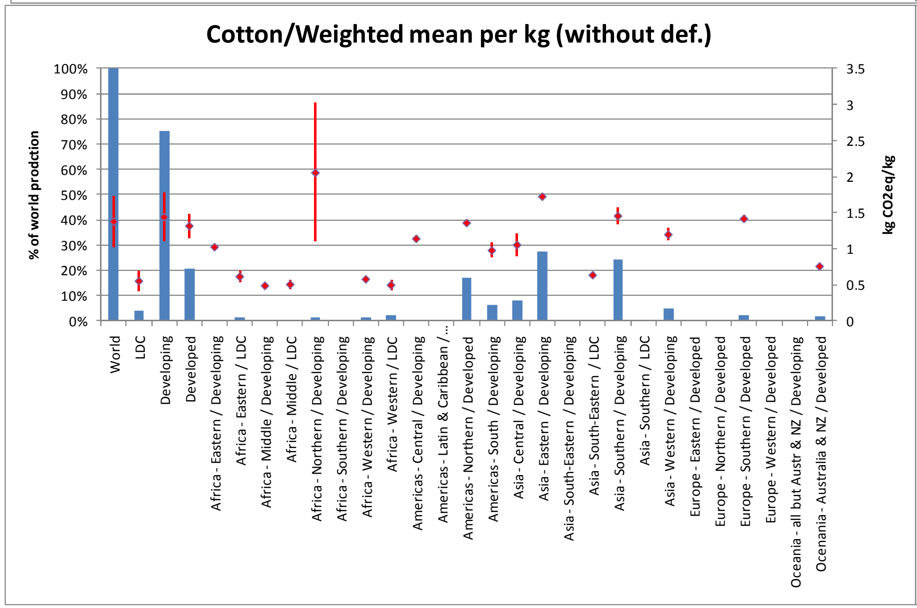
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Cotton/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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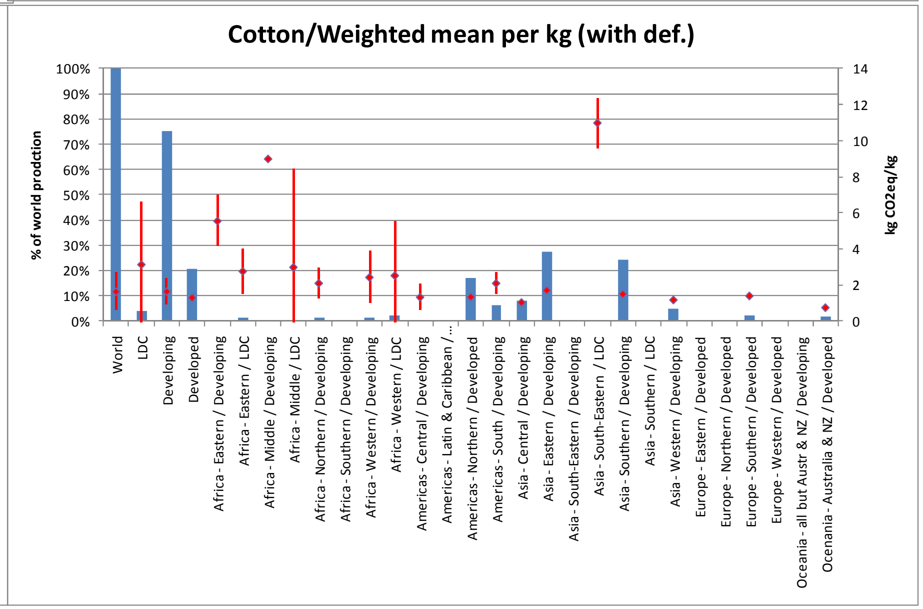
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Cotton/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg
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World
LDC
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Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
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Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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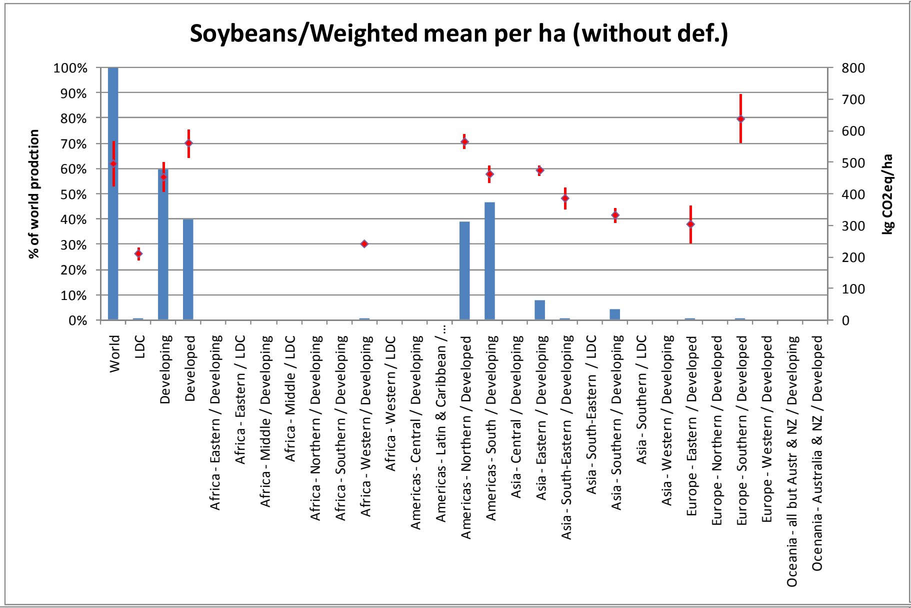
Ocenania - Australia & NZ / Developed


Soybeans/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
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World
LDC
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Africa - Eastern / Developing
Africa - Eastern / LDC
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Africa - Middle / LDC
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Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
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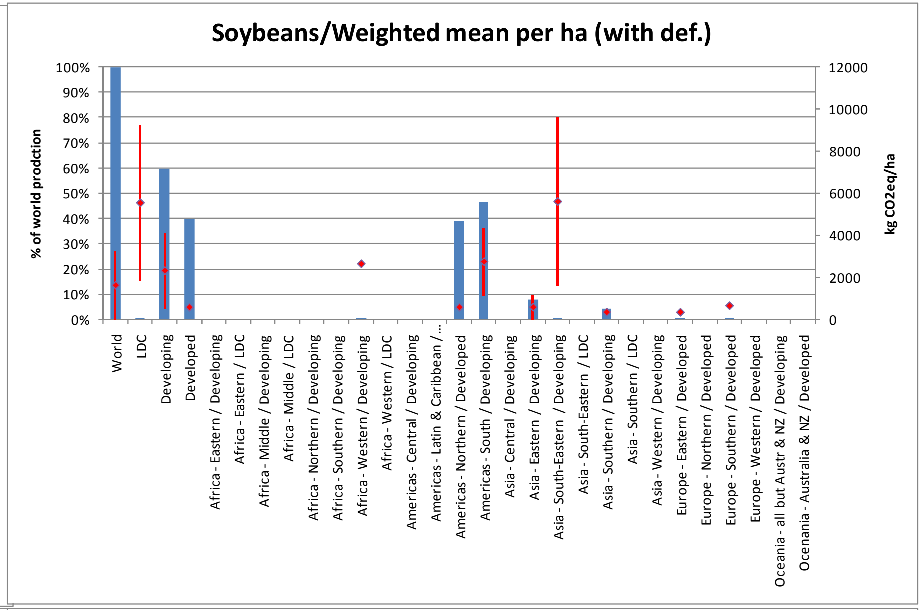
Soybeans/Weighted mean per ha (with def.)
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World
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Africa - Eastern / Developing
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Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
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Americas - South / Developing
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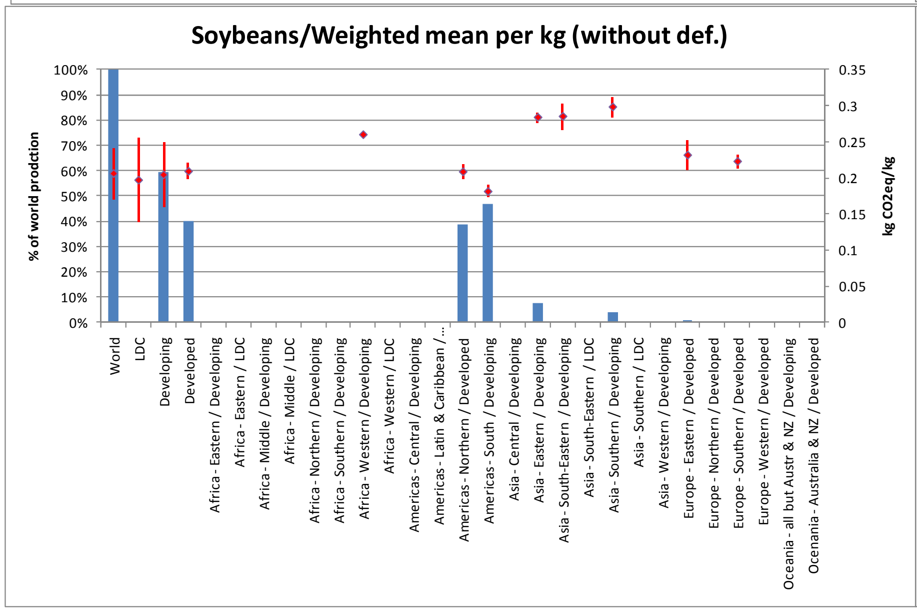
Soybeans/Weighted mean per kg (without def.)
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World
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Africa - Eastern / Developing
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Africa - Western / LDC
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Americas - Latin & Caribbean / ...
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Americas - South / Developing
Asia - Central / Developing
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Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
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Asia - Southern / LDC
Asia - Western / Developing
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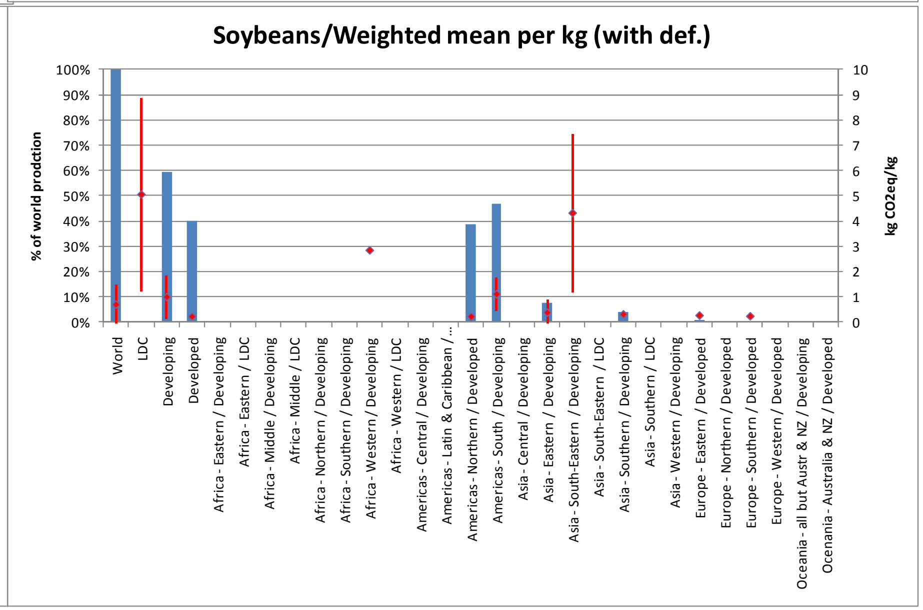
Soybeans/Weighted mean per kg (with def.)
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Americas - South / Developing
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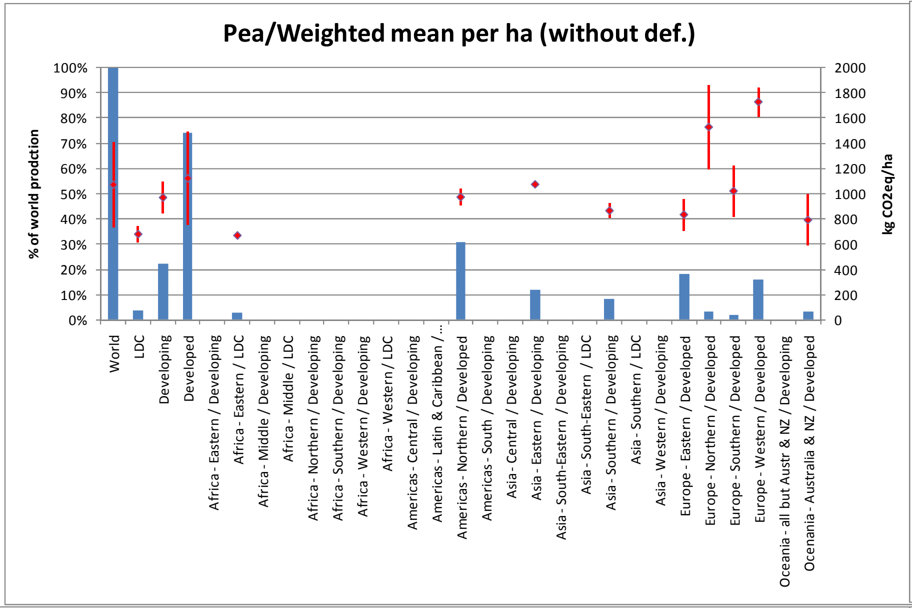
Pea/Weighted mean per ha (without def.)
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World
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Americas - Latin & Caribbean / ...
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Americas - South / Developing
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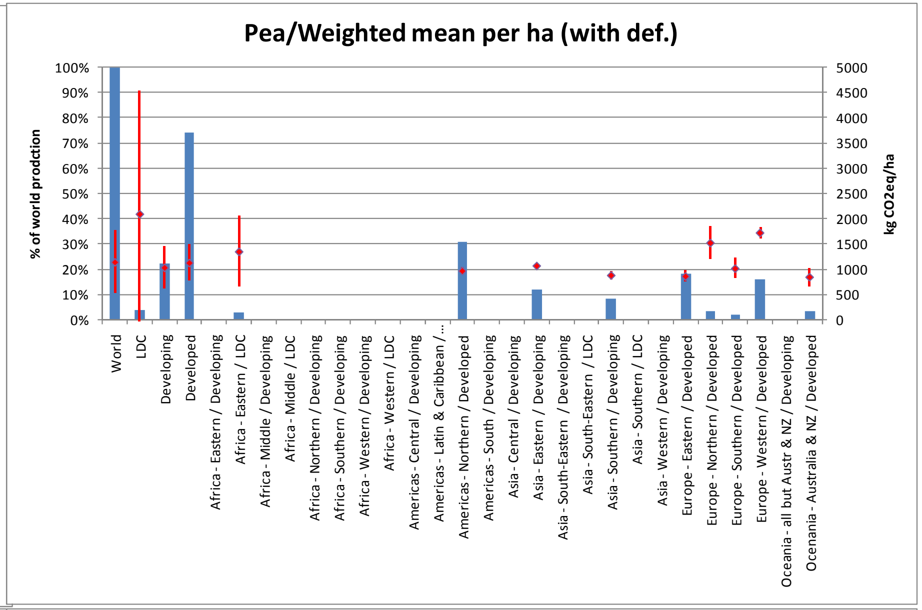
Pea/Weighted mean per ha (with def.)
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World
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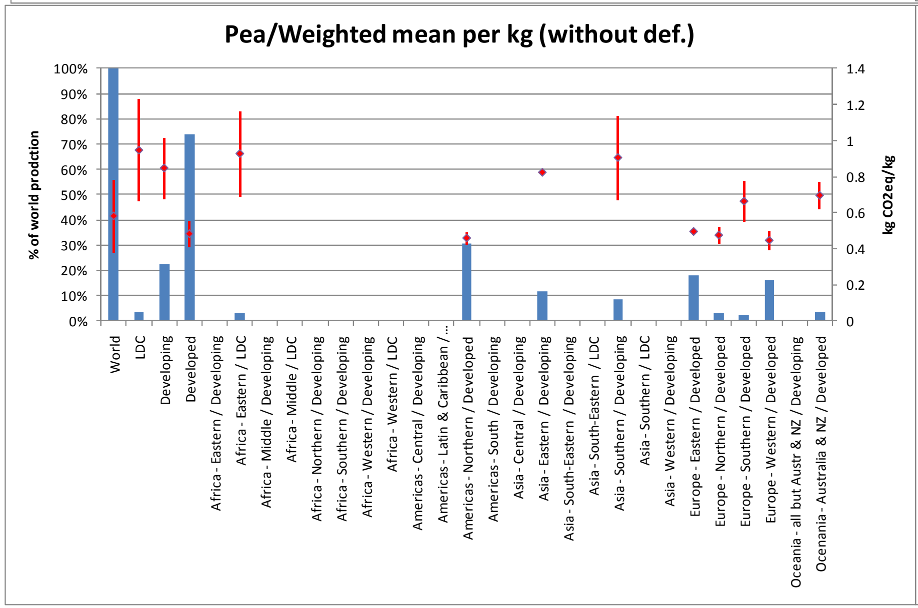
Pea/Weighted mean per kg (without def.)
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Africa - Eastern / LDC
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Americas - Latin & Caribbean / ...
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Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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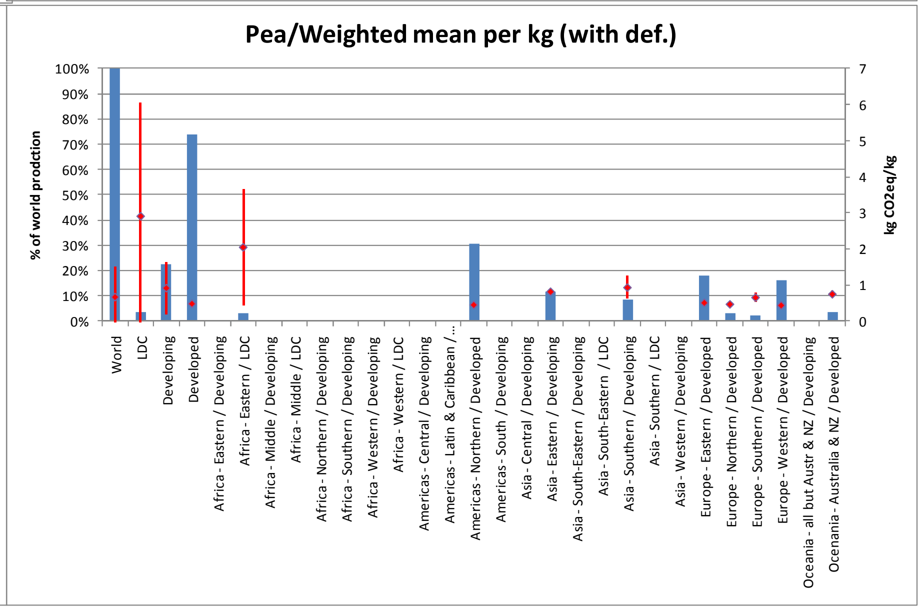
Pea/Weighted mean per kg (with def.)
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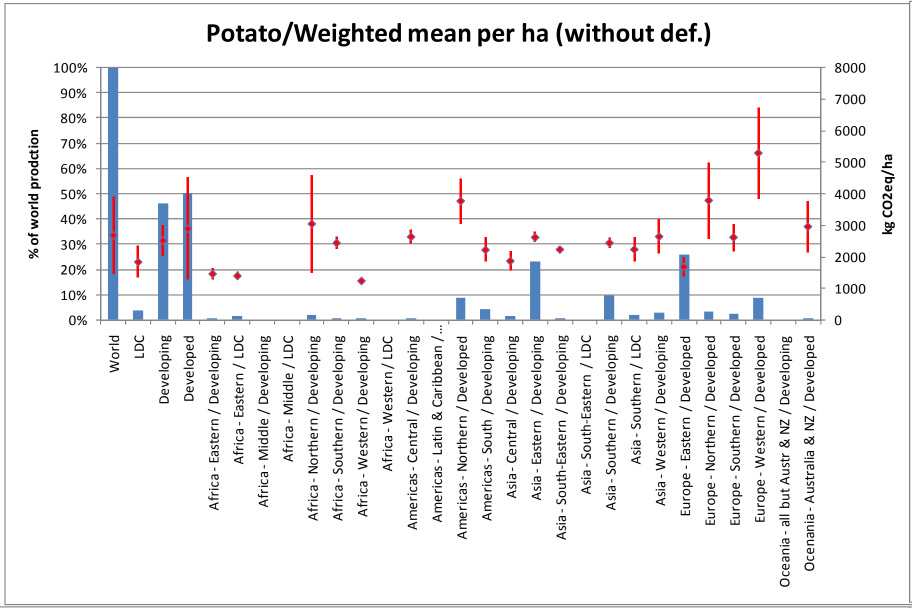
Potato/Weighted mean per ha (without def.)
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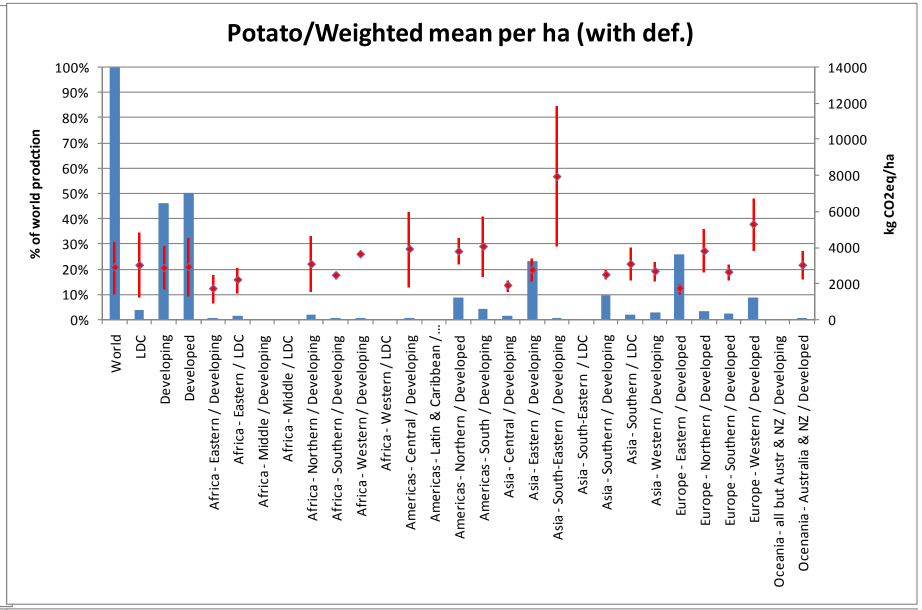
Potato/Weighted mean per ha (with def.)
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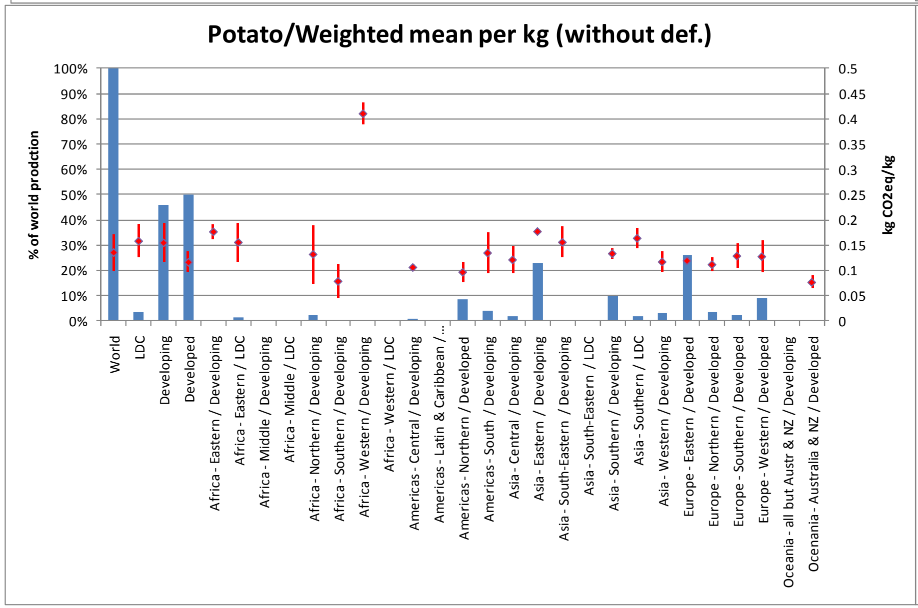
Potato/Weighted mean per kg (without def.)
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World
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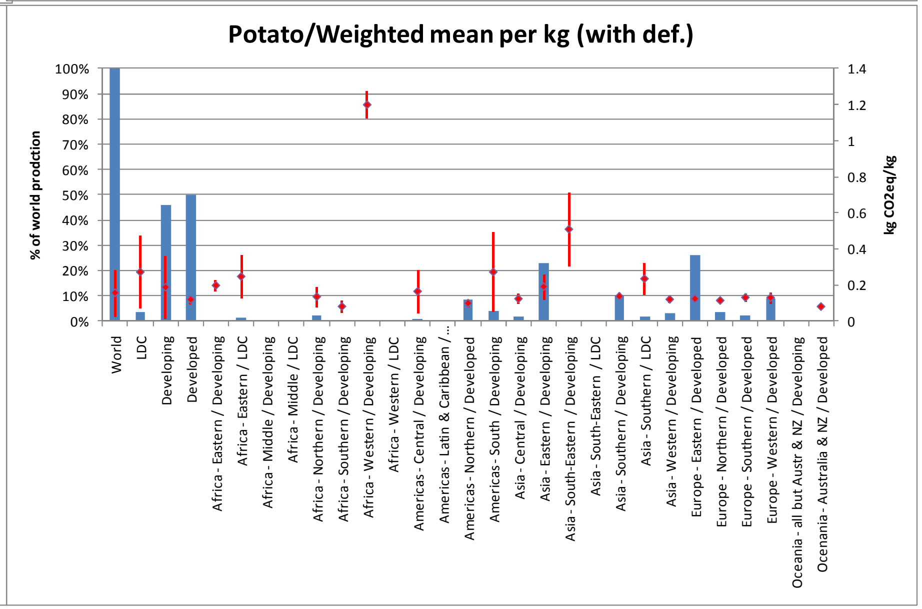
Potato/Weighted mean per kg (with def.)
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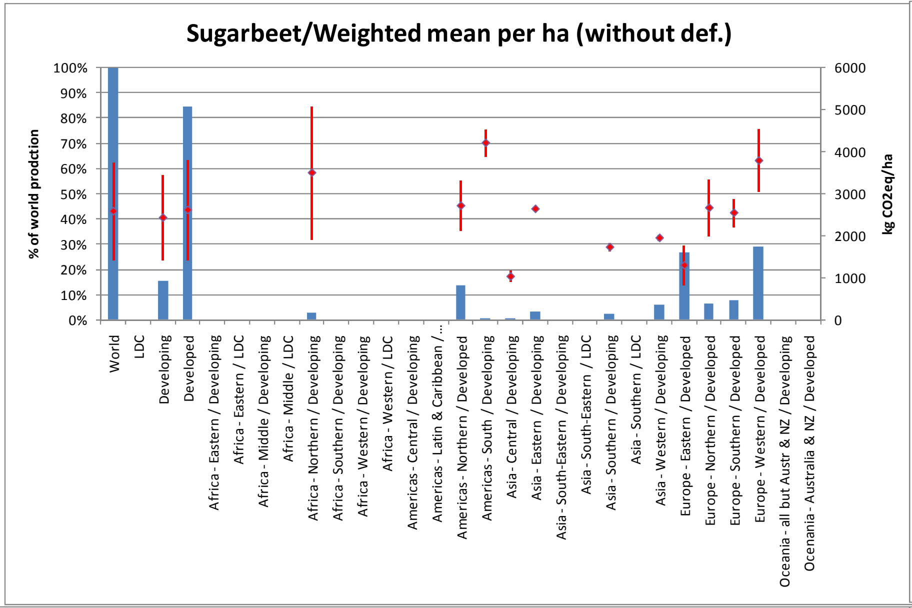
Sugarbeet/Weighted mean per ha (without def.)
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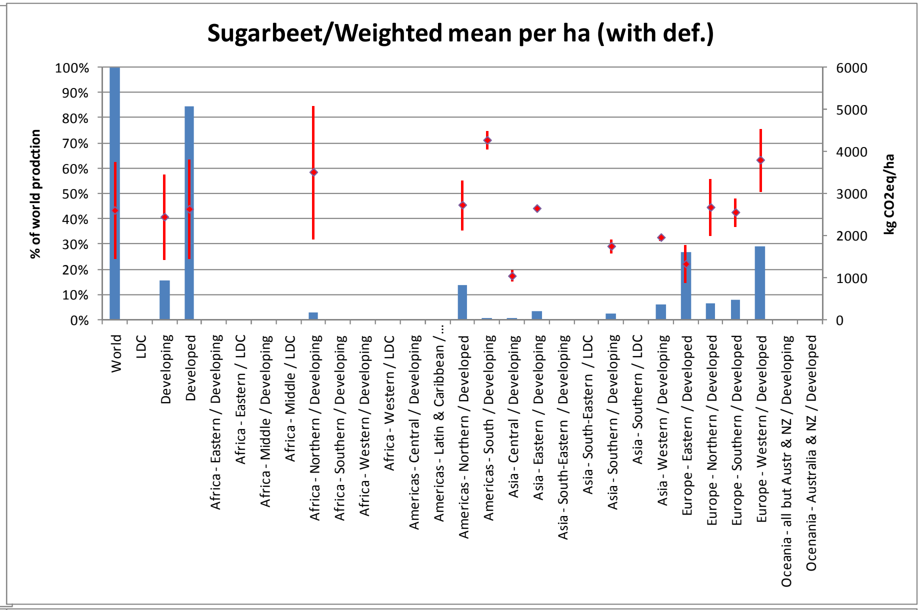
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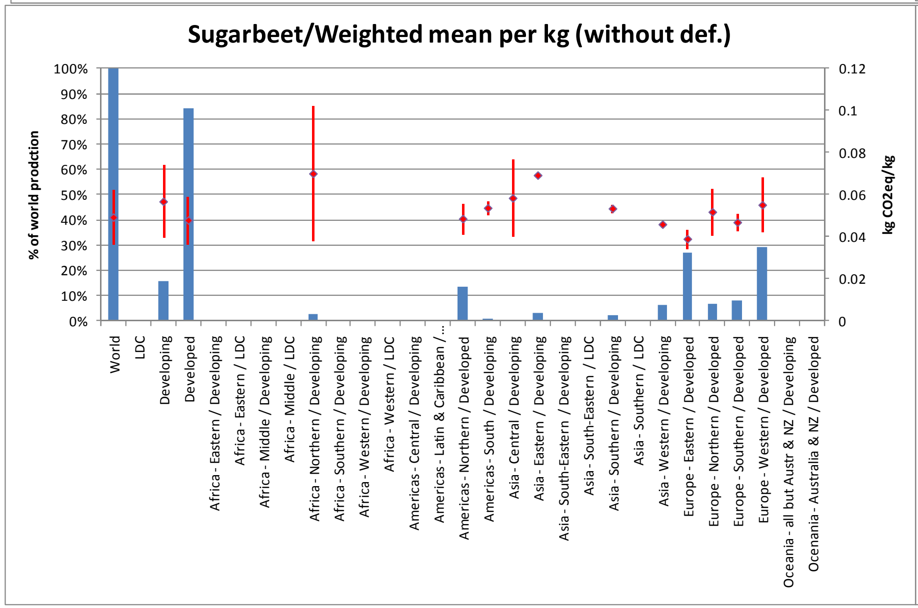
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World
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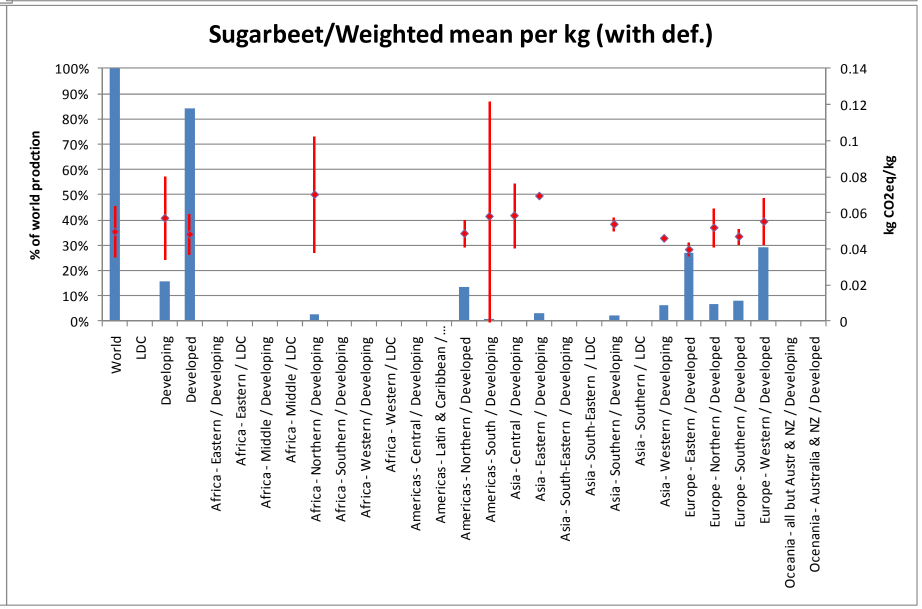
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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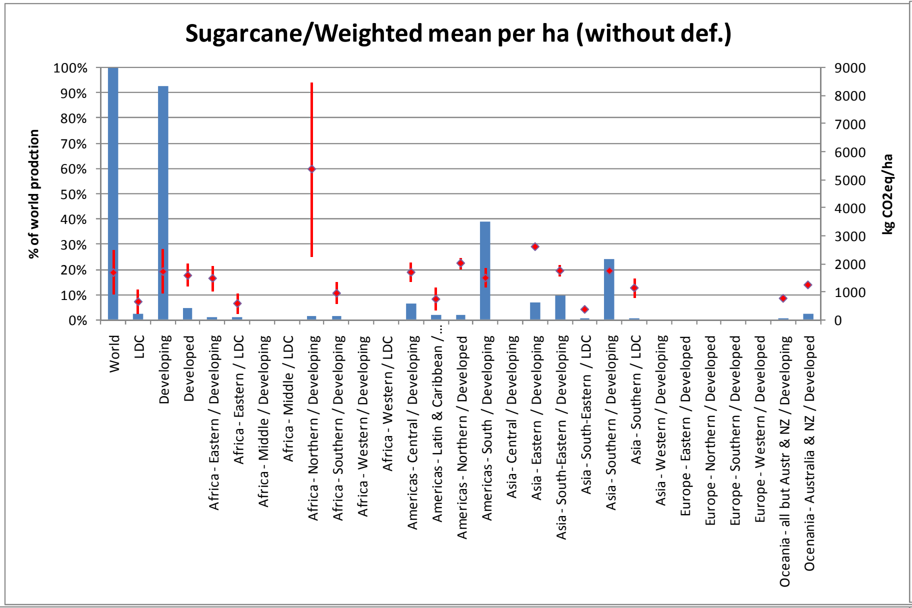
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Sugarcane/Weighted mean per ha (without def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/ha
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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Oceania - all but Austr & NZ / Developing
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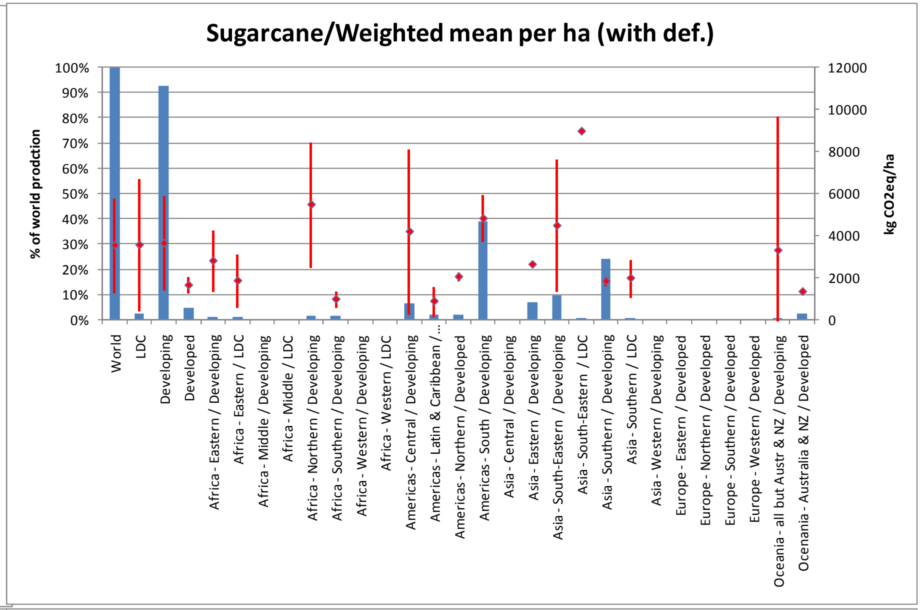
Sugarcane/Weighted mean per ha (with def.)
% of world prodction
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kg CO2eq/ha
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6000
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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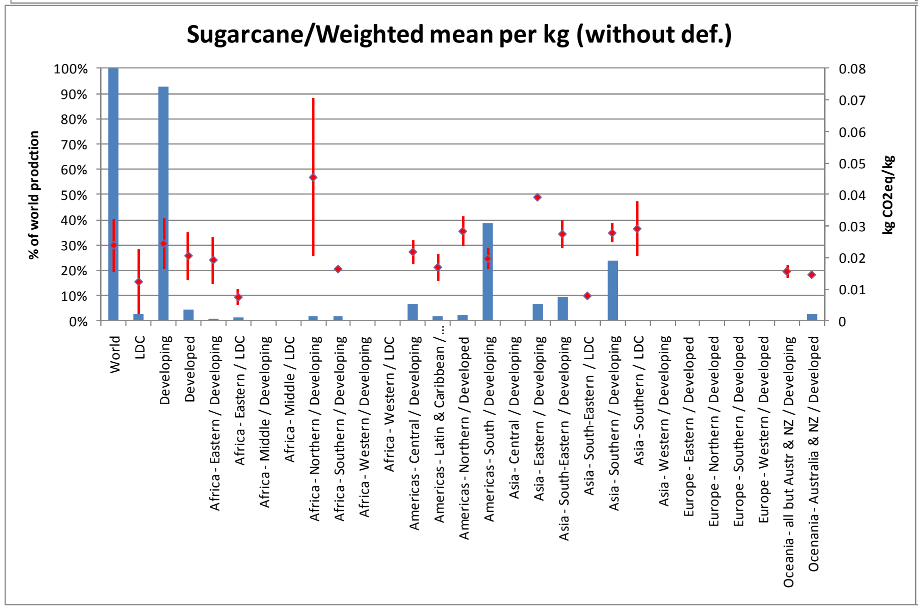
Ocenania - Australia & NZ / Developed


Sugarcane/Weighted mean per kg (without def.)
% of world prodction
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20%
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kg CO2eq/kg
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0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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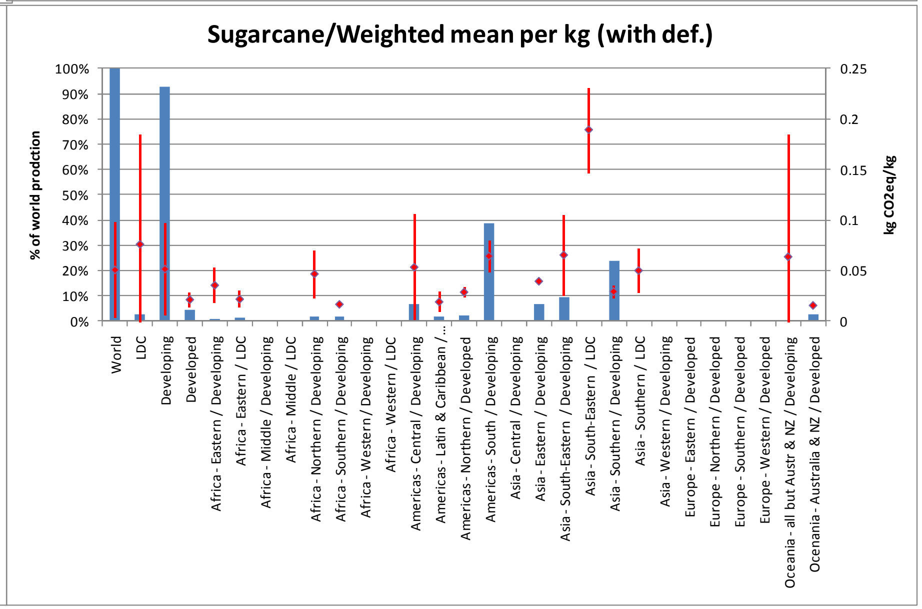
Ocenania - Australia & NZ / Developed


Sugarcane/Weighted mean per kg (with def.)
% of world prodction
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40%
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20%
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0%
kg CO2eq/kg
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0.1
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0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
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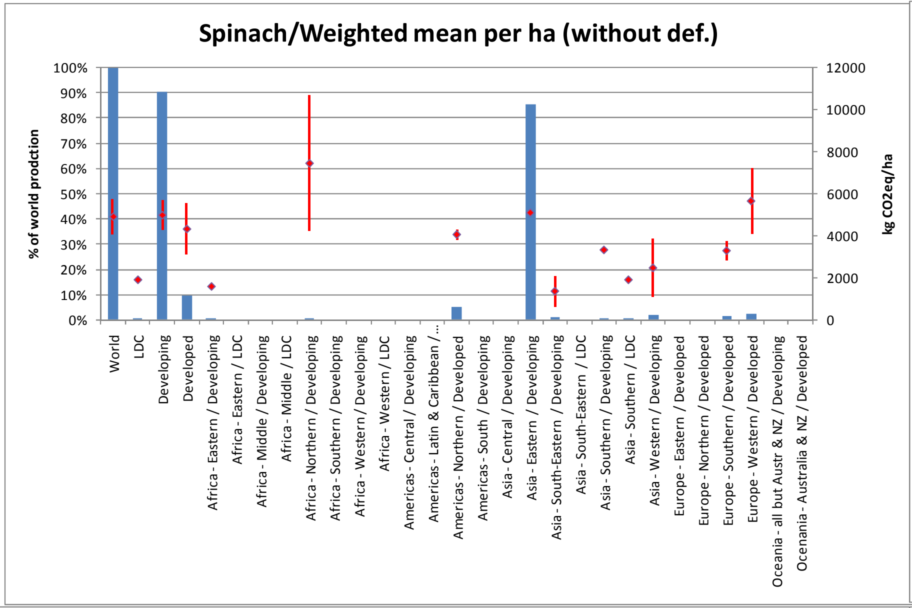
Spinach/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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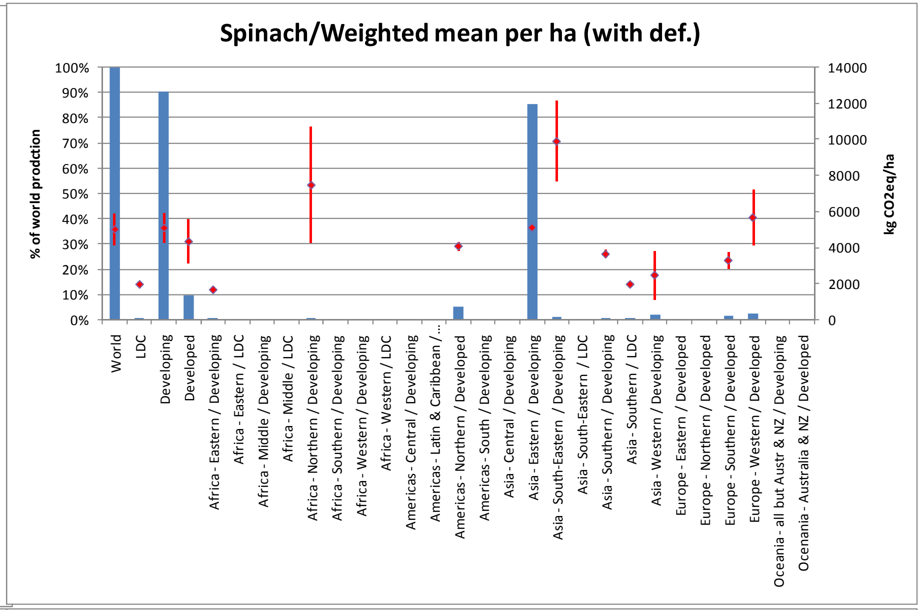
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Spinach/Weighted mean per ha (with def.)
% of world prodction
kg CO2eq/ha
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World
LDC
Developing
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Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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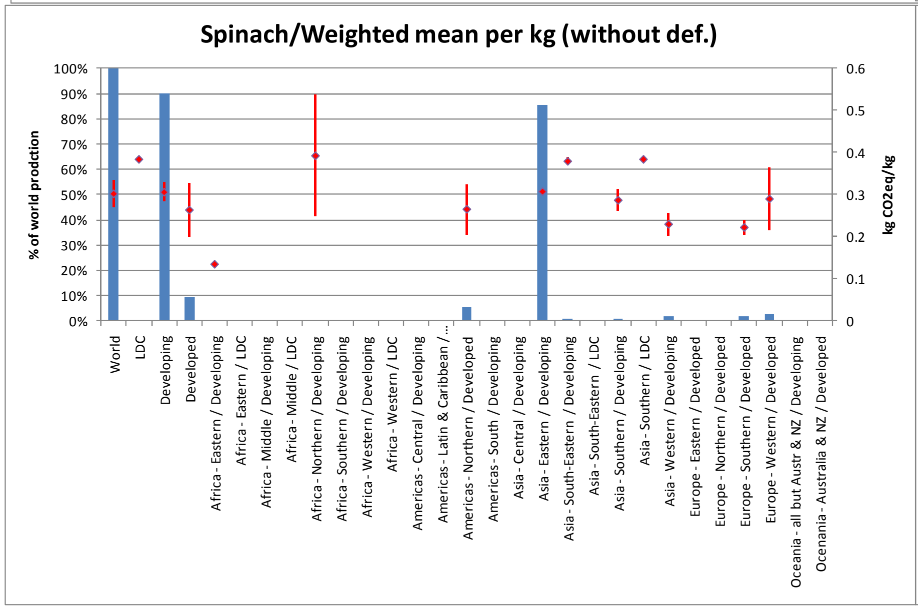
Spinach/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg
100%
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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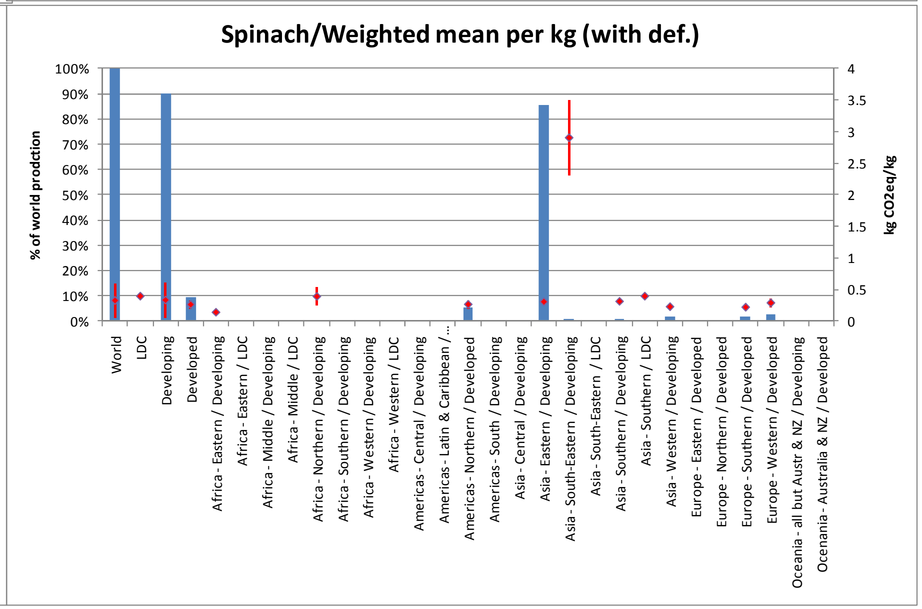
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Spinach/Weighted mean per kg (with def.)
% of world prodction
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
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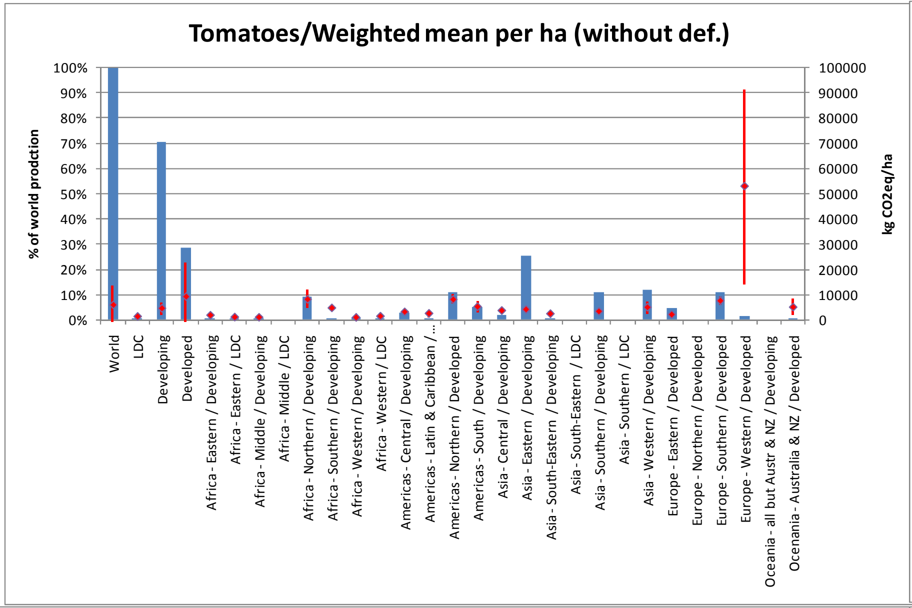
Tomatoes/Weighted mean per ha (without def.)
% of world prodction
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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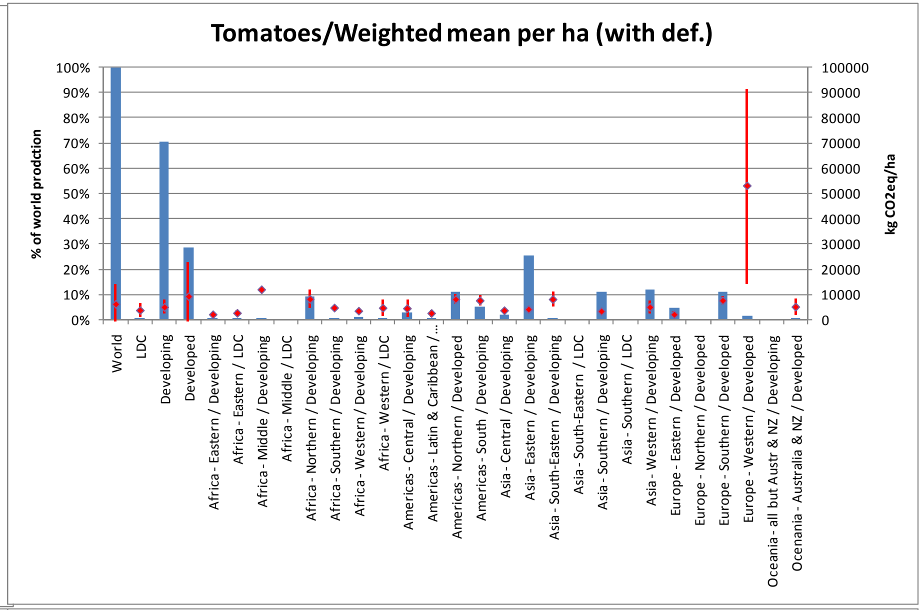
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Tomatoes/Weighted mean per ha (with def.)
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World
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Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
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Africa - Western / Developing
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Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
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Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
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Asia - Southern / LDC
Asia - Western / Developing
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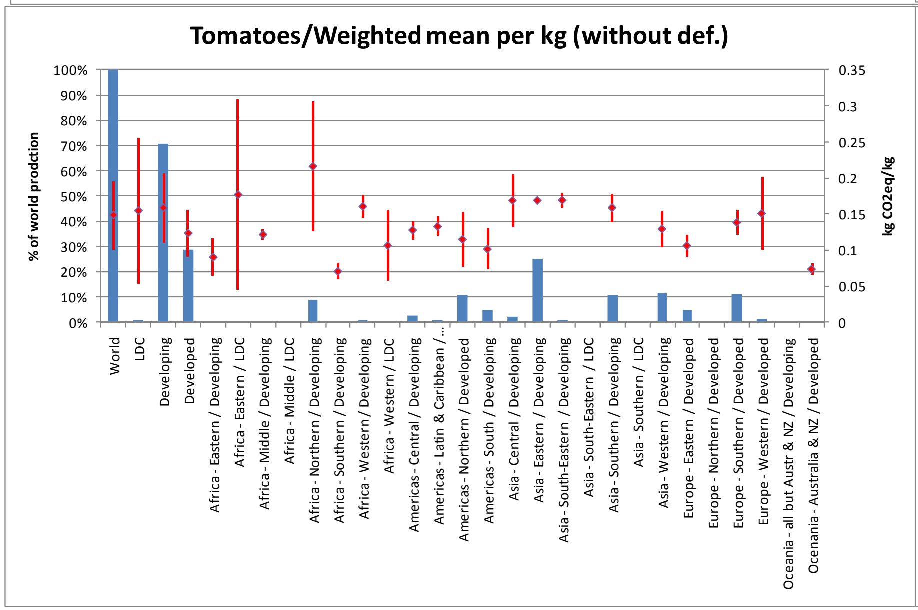
Oceania - Australia & NZ / Developed


Tomatoes/Weighted mean per kg (without def.)
% of world prodction
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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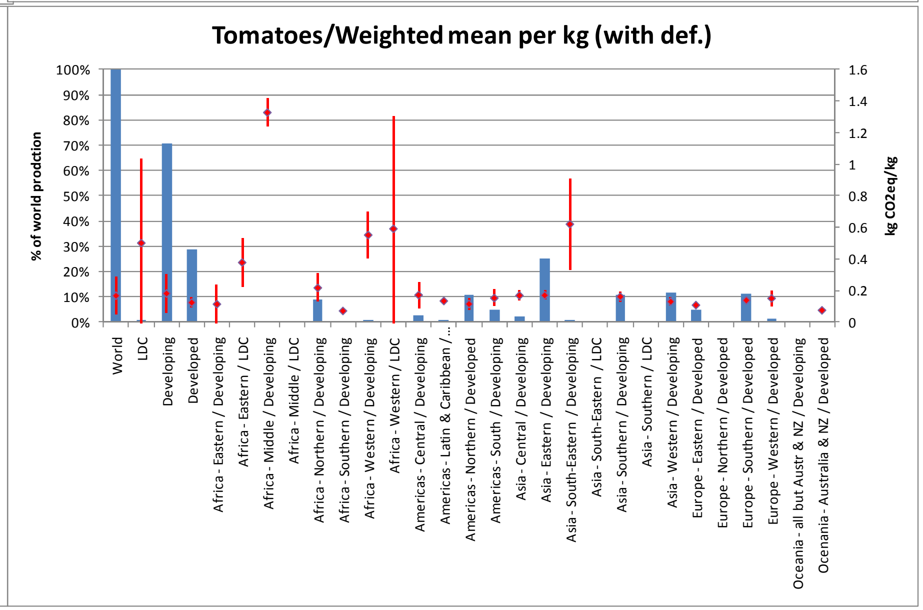
Tomatoes/Weighted mean per kg (with def.)
% of world prodction
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
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Africa - Southern / Developing
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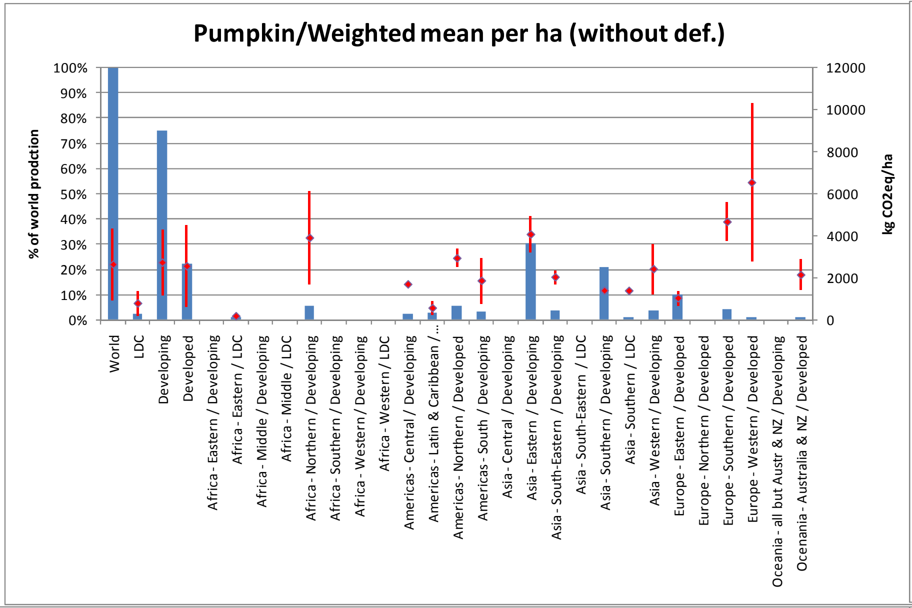
Pumpkin/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
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World
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Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
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Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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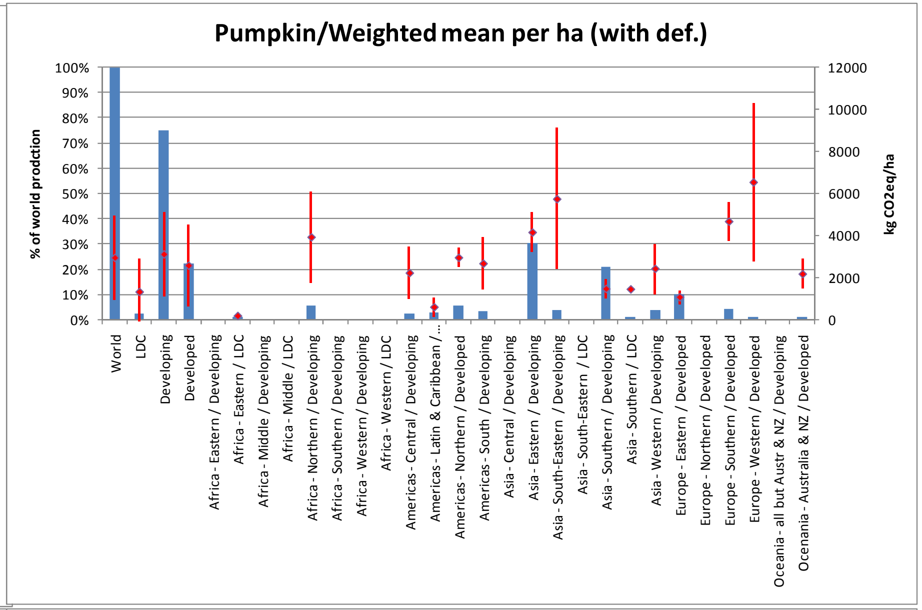
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Pumpkin/Weighted mean per ha (with def.)
% of world prodction
kg CO2eq/ha
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World
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Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
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Asia - South-Eastern / LDC
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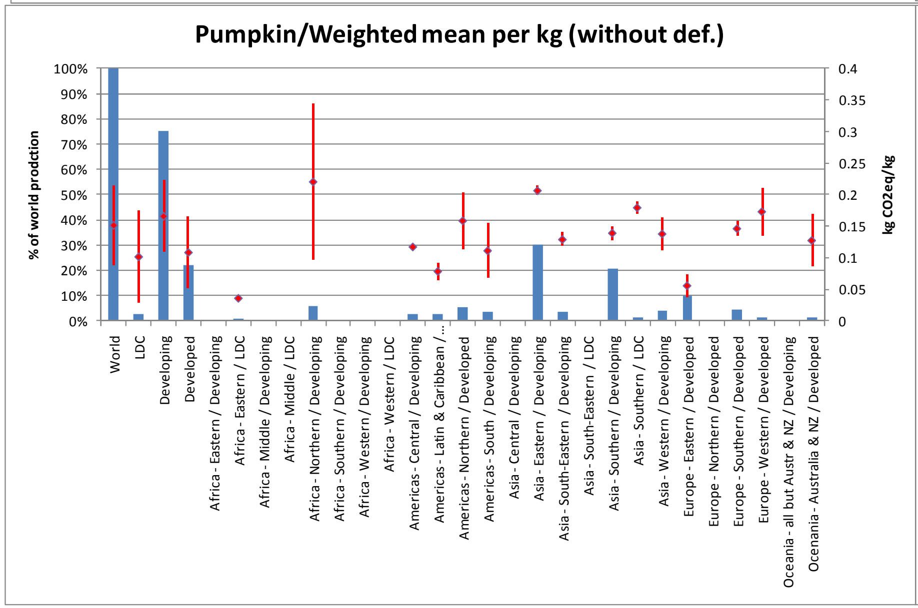
Oceania - Australia & NZ / Developed


Pumpkin/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg
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World
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Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
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Africa - Middle / LDC
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Asia - South-Eastern / Developing
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Asia - Southern / Developing
Asia - Southern / LDC
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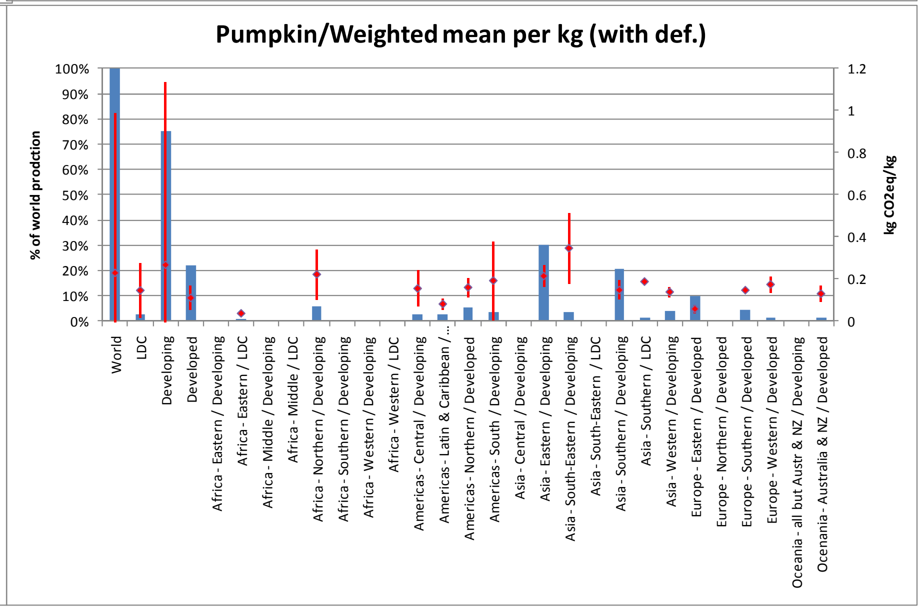
Pumpkin/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg
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World
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Developing
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Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
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Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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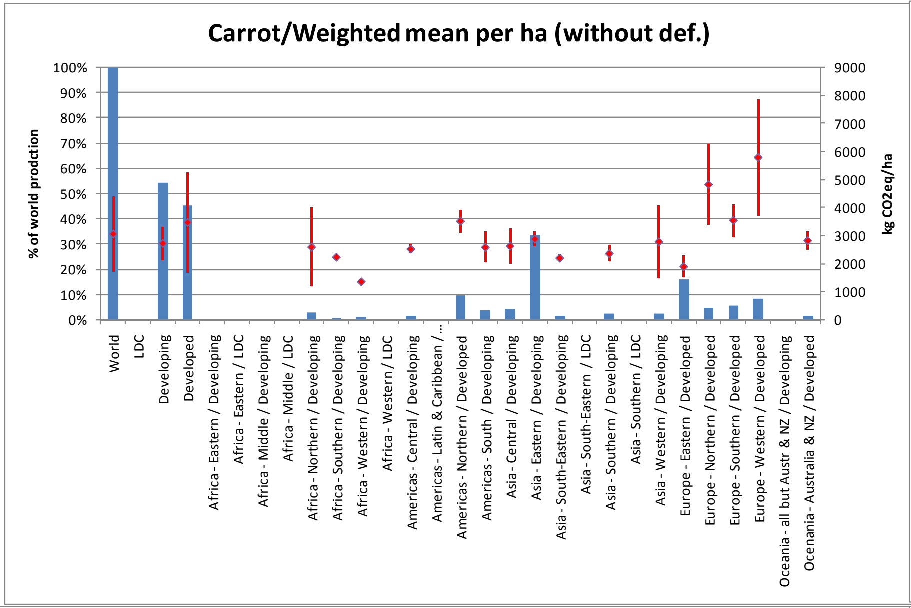
Oceania - Australia & NZ / Developed


Carrot/Weighted mean per ha (without def.)
% of world prodction
100%
90%
80%
70%
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10%
0%
kg CO2eq/ha
9000
8000
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6000
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4000
3000
2000
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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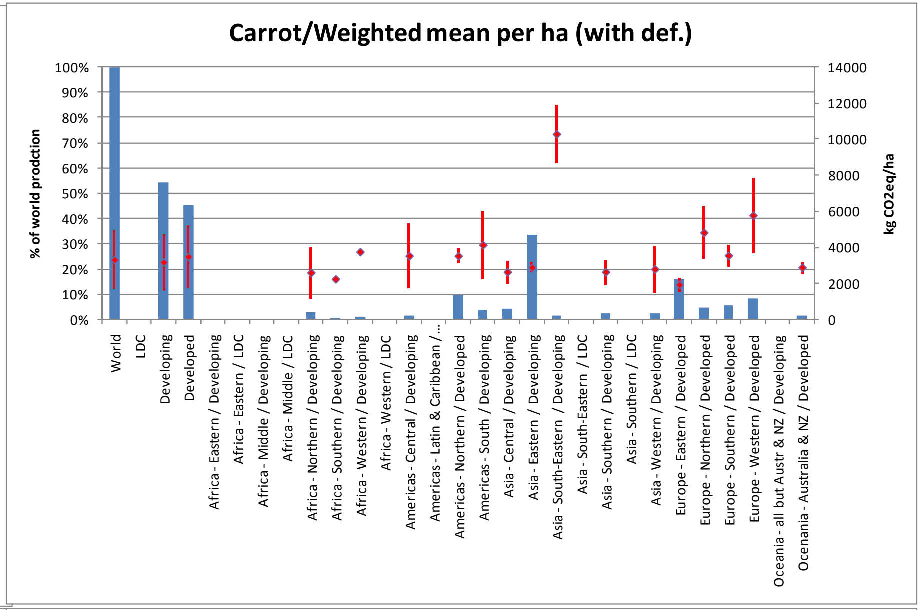
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Carrot/Weighted mean per ha (with def.)
% of world prodction
100%
90%
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30%
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0%
kg CO2eq/ha
14000
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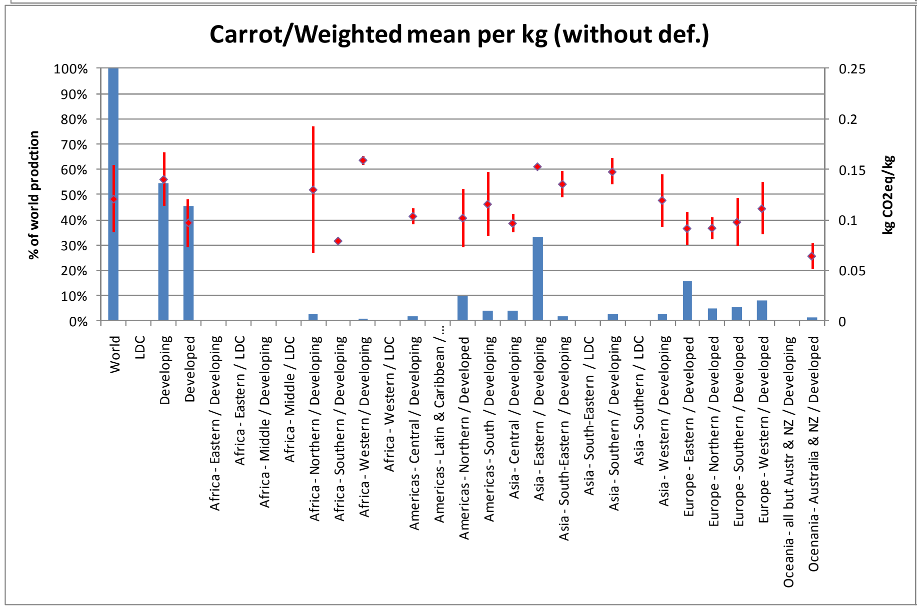
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Carrot/Weighted mean per kg (without def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/kg
0.25
0.2
0.15
0.1
0.05
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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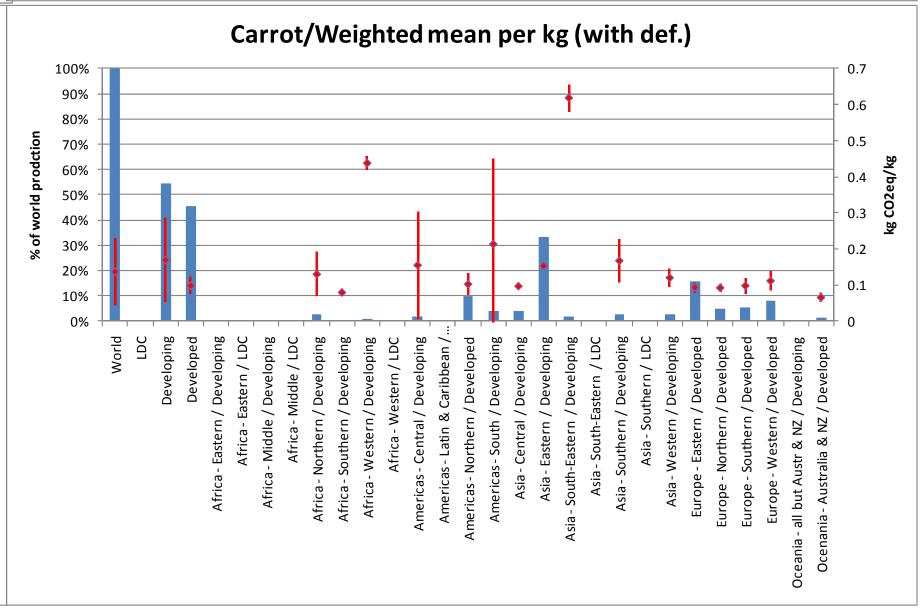
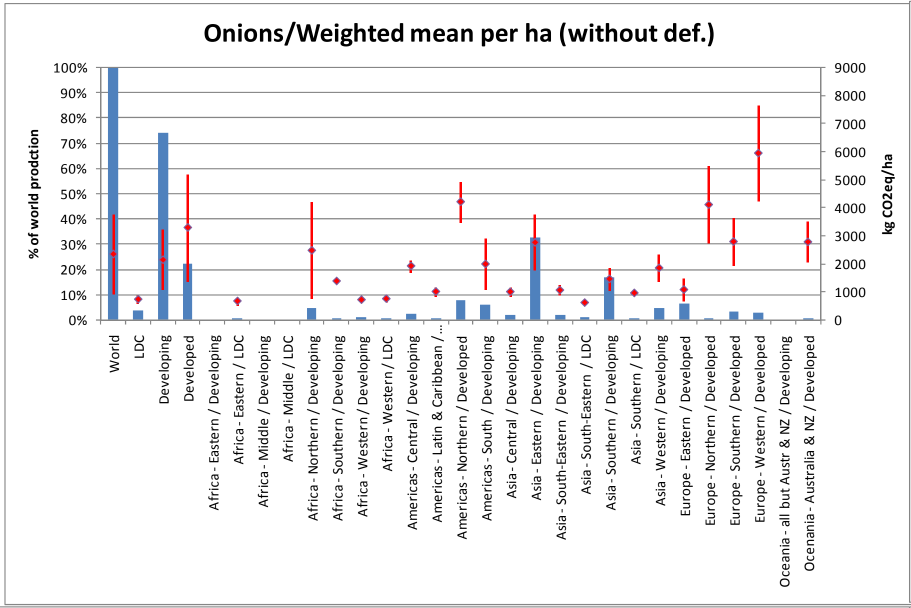
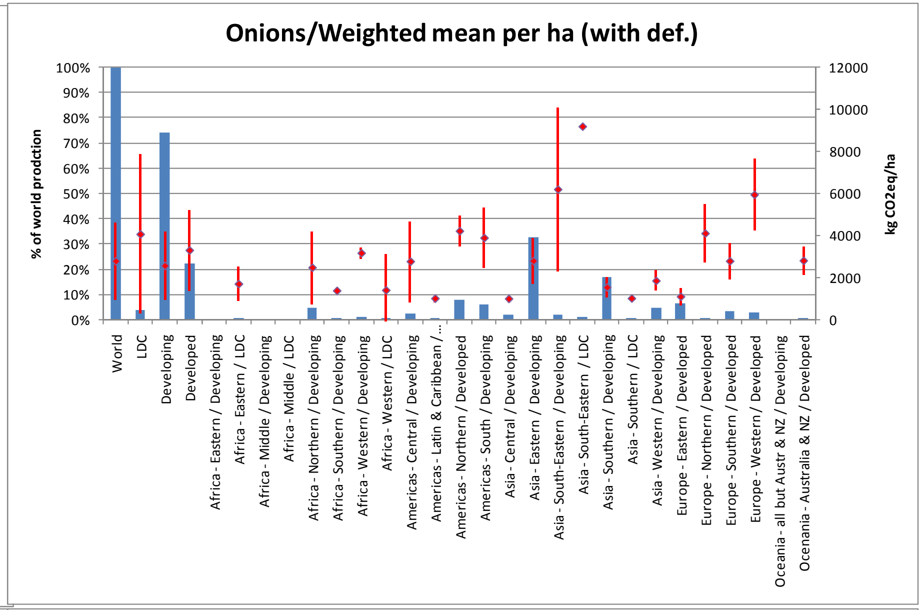
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Carrot/Weighted mean per kg (with def.)
% of world prodction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2eq/kg
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Onions/Weighted mean per ha (without def.)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of world prodction
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
kg CO2eq/ha
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Onions/Weighted mean per ha (with def.)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of world prodction
12000
10000
8000
6000
4000
2000
0
kg CO2eq/ha
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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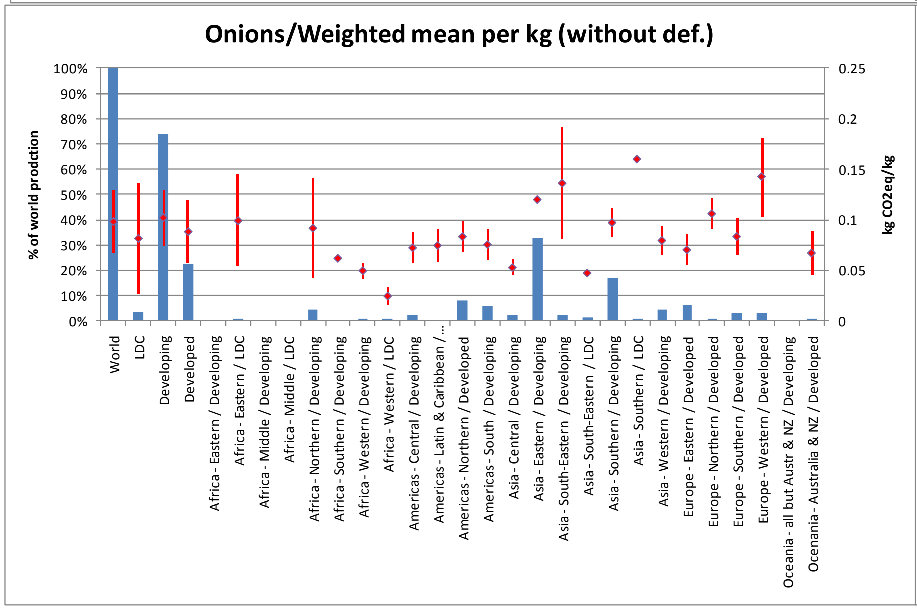
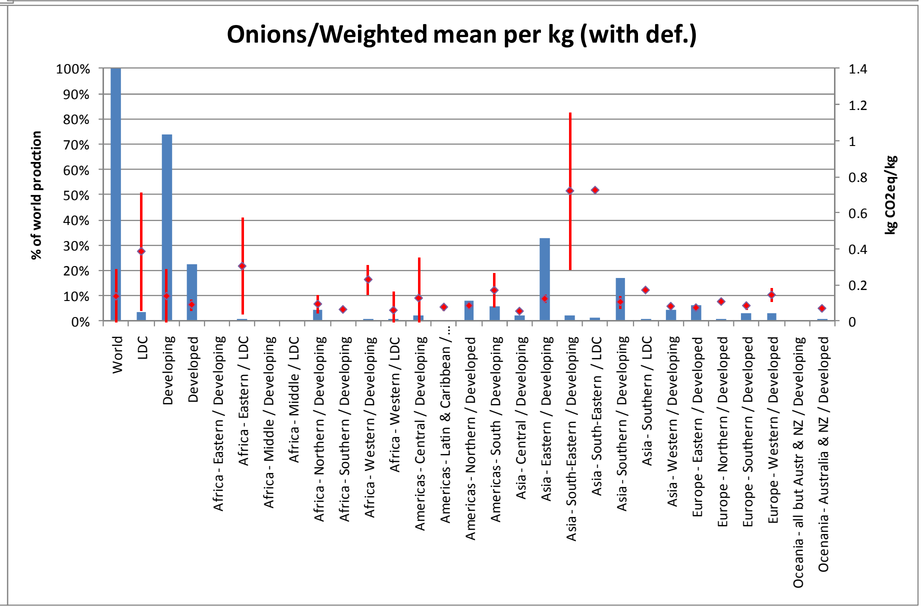
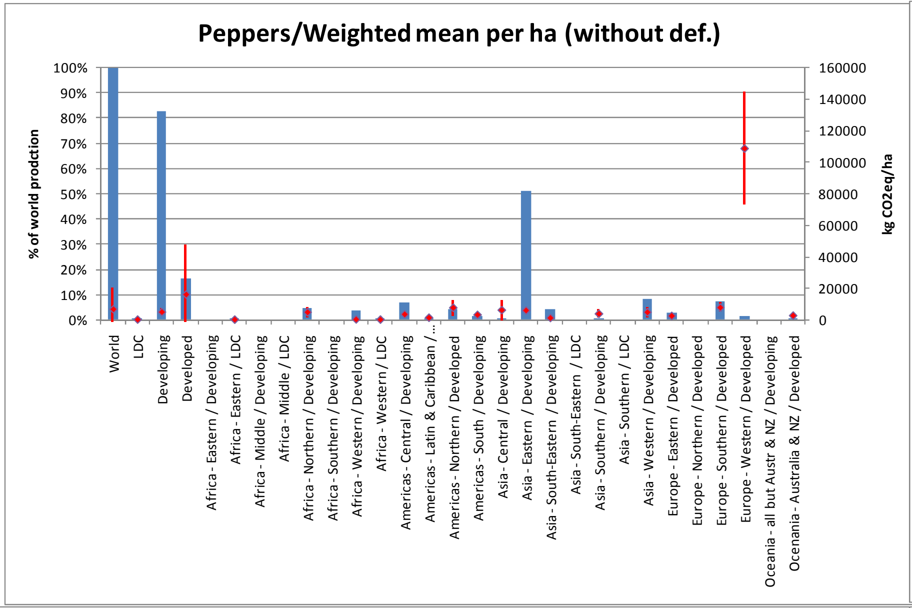
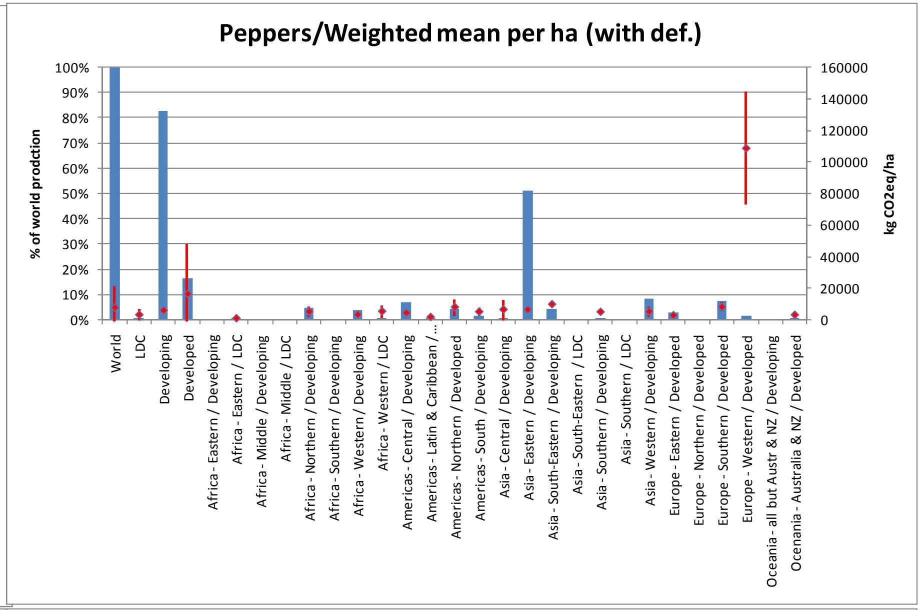
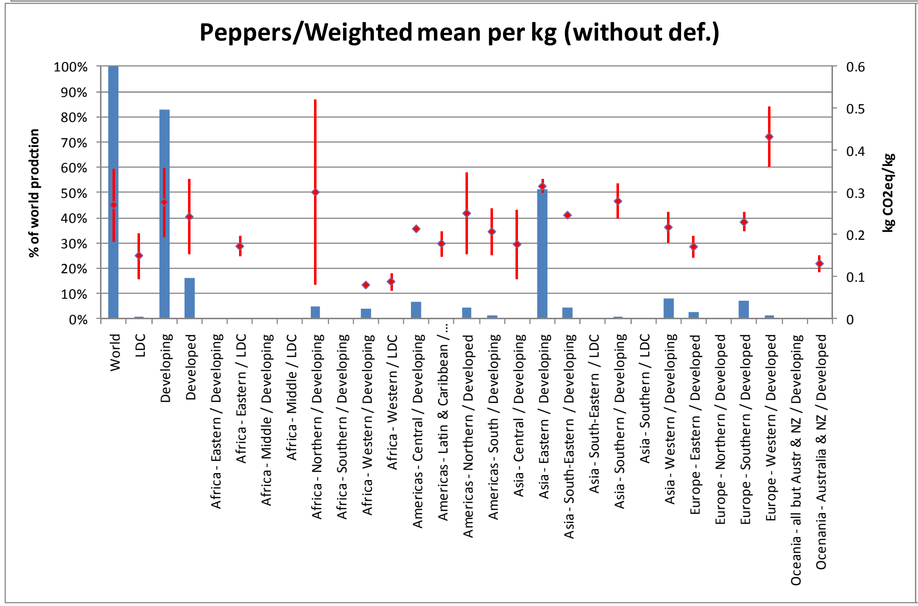
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed

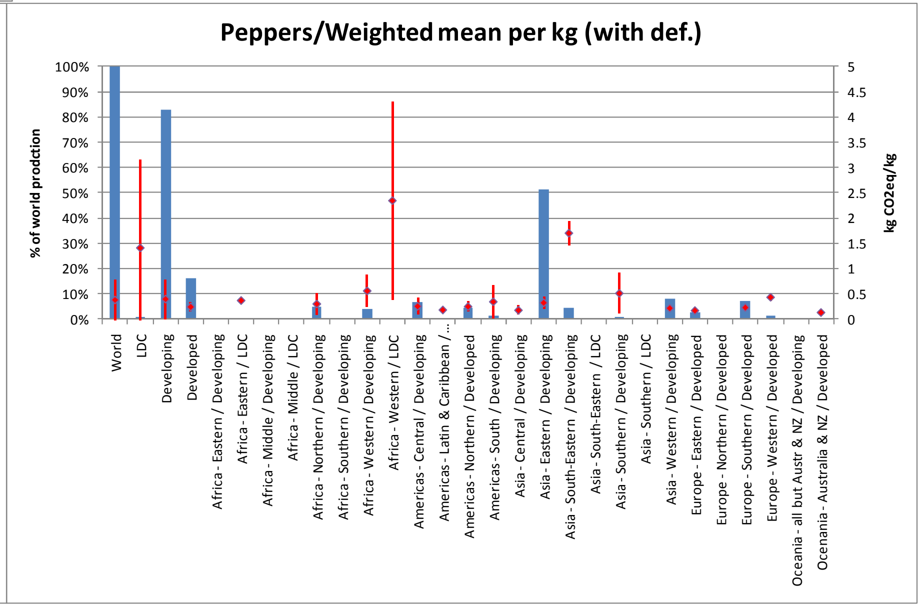

Onions/Weighted mean per kg (without def.)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of world prodction
0.25
0.2
0.15
0.1
0.05
0
kg CO2eq/kg
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed

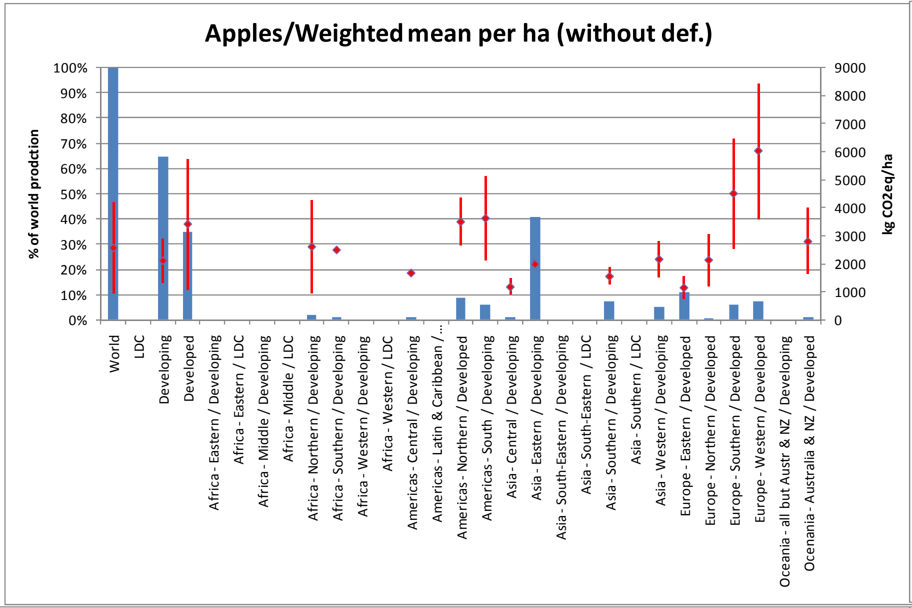

Onions/Weighted mean per kg (with def.)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of world prodction
1.4
1.2
1
0.8
0.6
0.4
0.2
0
kg CO2eq/kg
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Peppers/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Peppers/Weighted mean per ha (with def.)
% of world prodction
kg CO2eq/ha


Peppers/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg


Peppers/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg


Apples/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
100%
90%
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20%
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1000
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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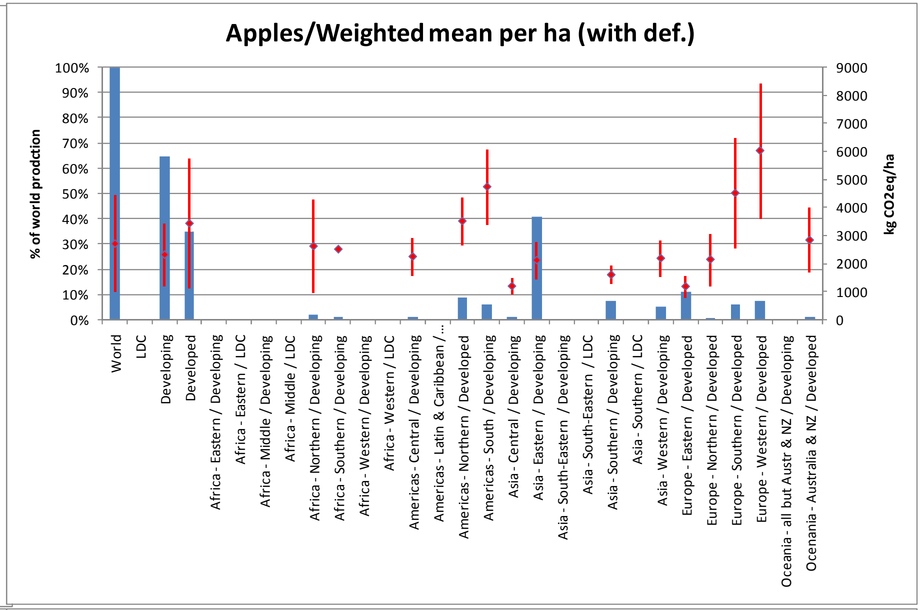
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Apples/Weighted mean per ha (with def.)
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kg CO2eq/ha
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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Europe - Northern / Developed
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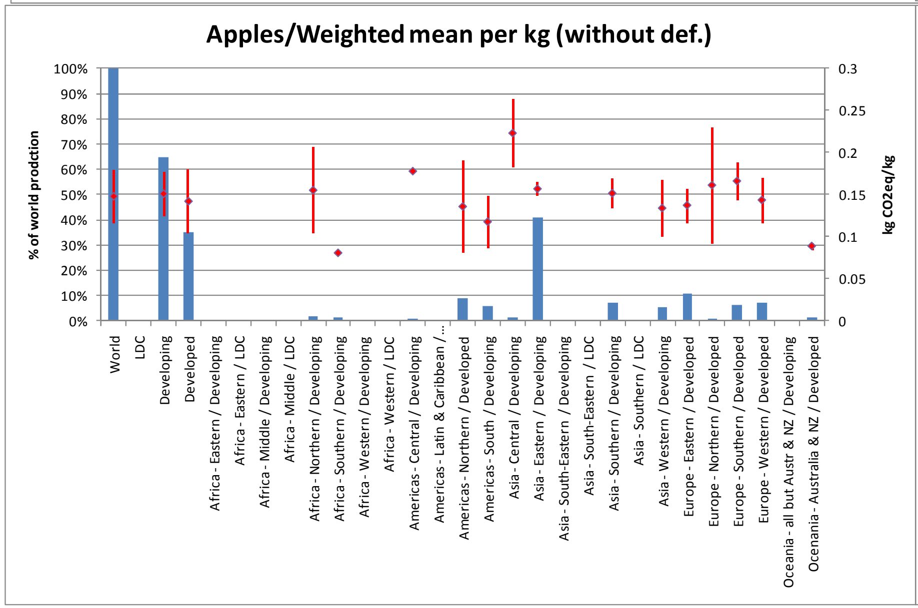
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Apples/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg
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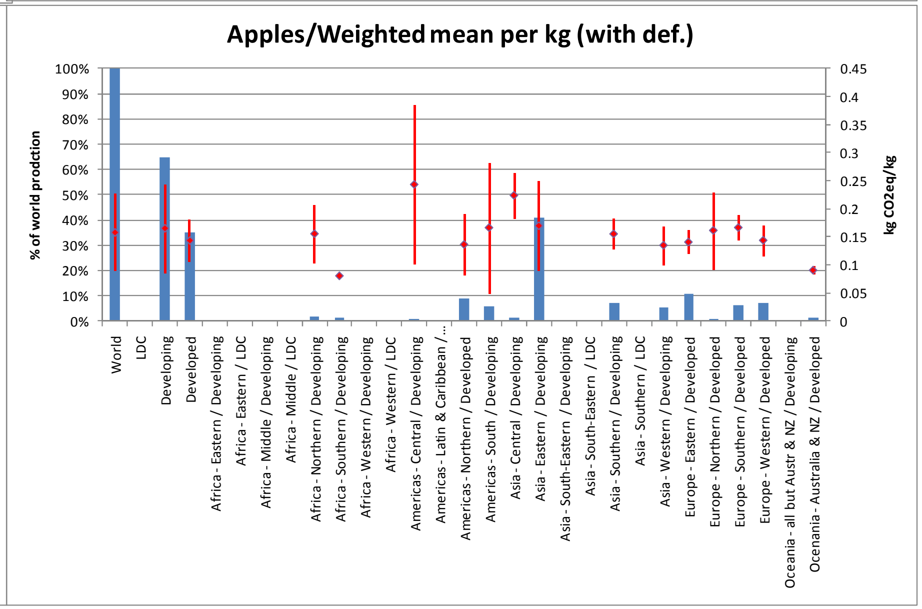
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Apples/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
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Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
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Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
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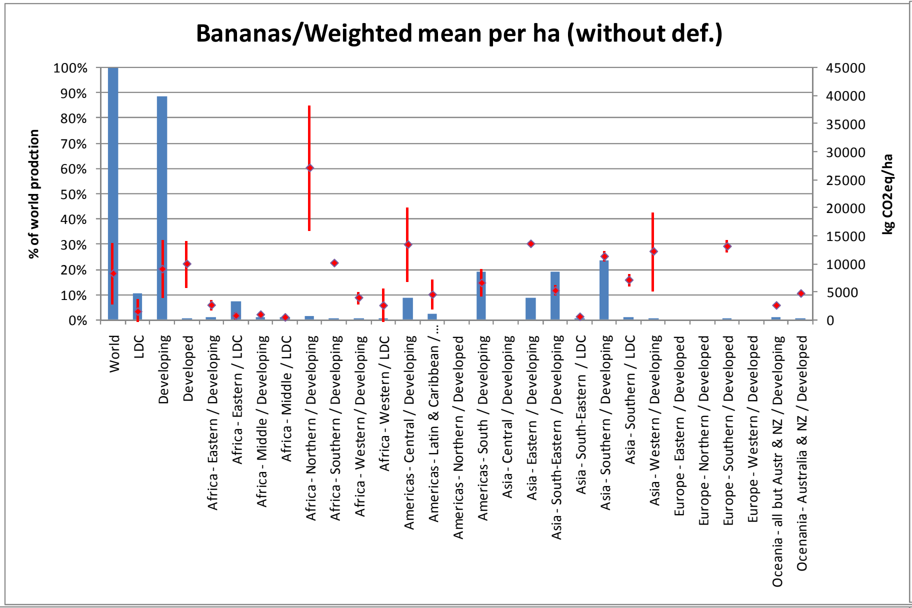
Oceania - all but Austr & NZ / Developing
Oceania - Australia & NZ / Developed


Bananas/Weighted mean per ha (without def.)
% of world prodction
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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Europe - Northern / Developed
Europe - Southern / Developed
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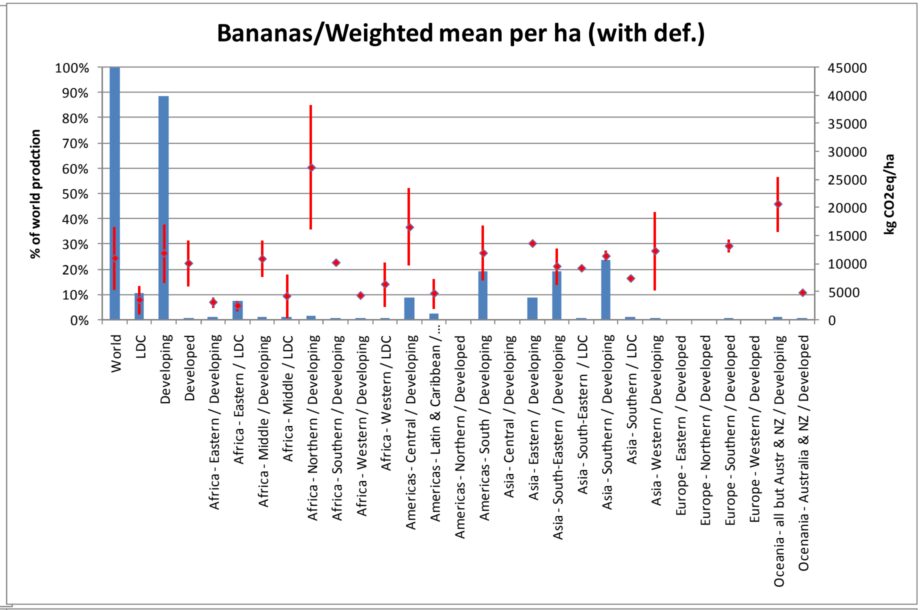
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Bananas/Weighted mean per ha (with def.)
% of world prodction
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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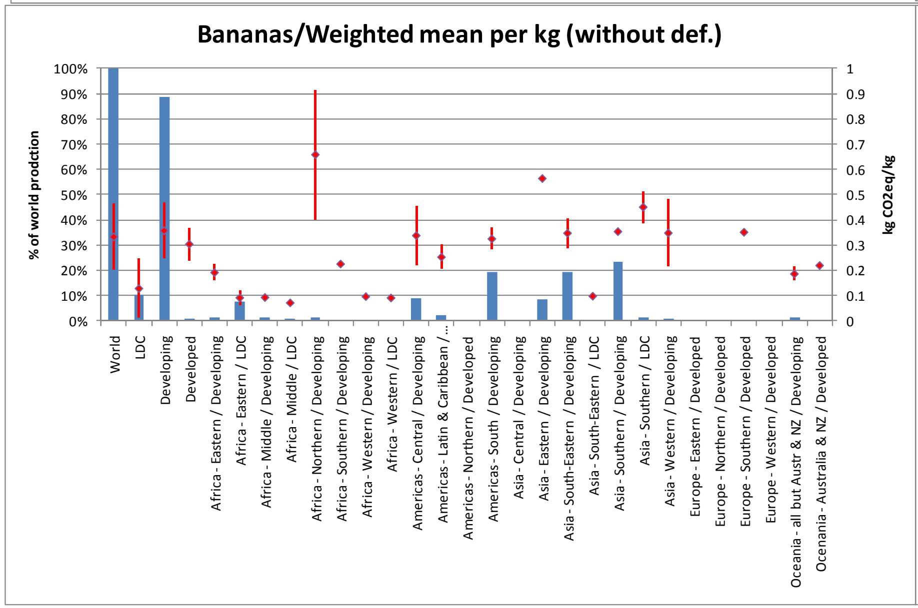
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Bananas/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
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Africa - Western / Developing
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Americas - Central / Developing
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Americas - Northern / Developed
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Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
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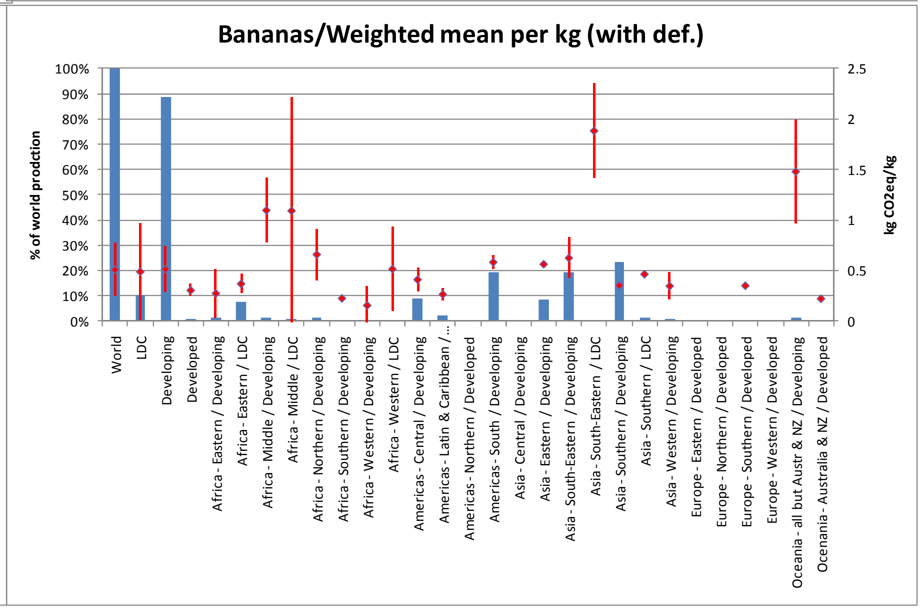
Bananas/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg
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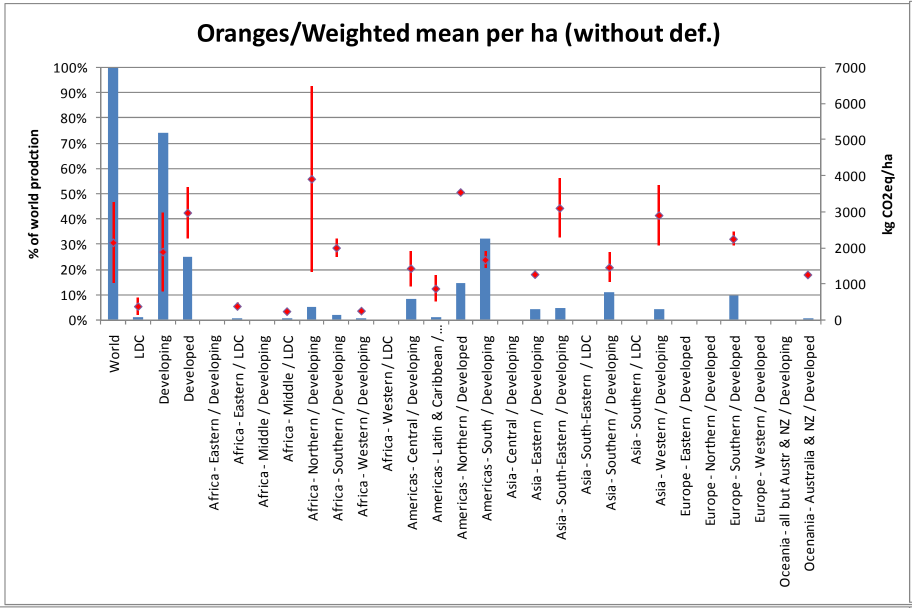
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Oranges/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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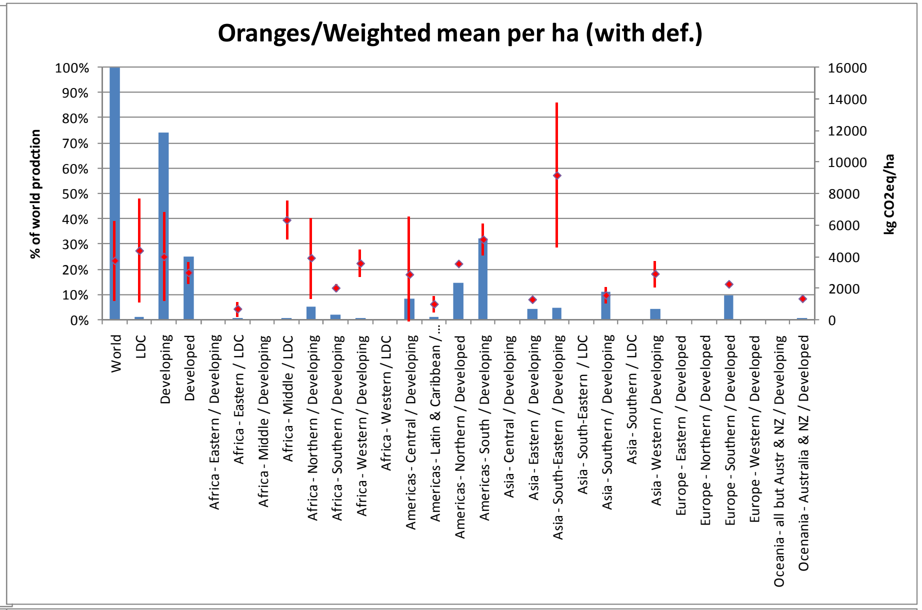
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Oranges/Weighted mean per ha (with def.)
% of world prodction
kg CO2eq/ha
100%
90%
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16000
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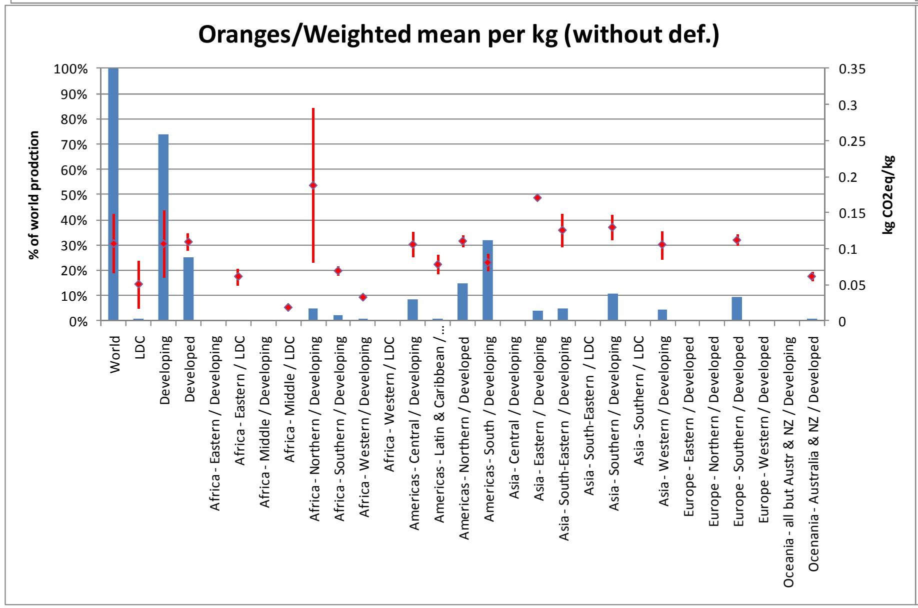
World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Oranges/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg
100%
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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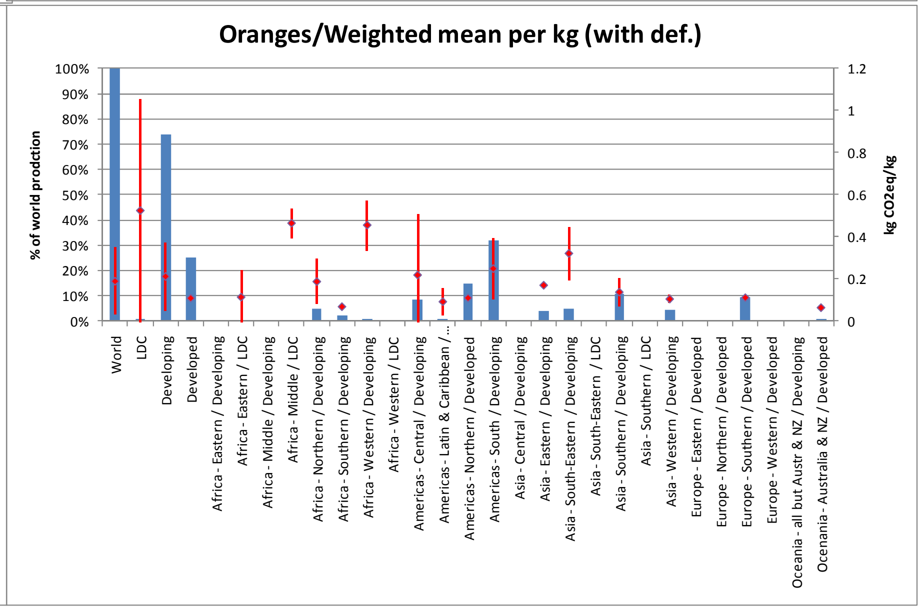
Oranges/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg
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World
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Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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Europe - Western / Developed
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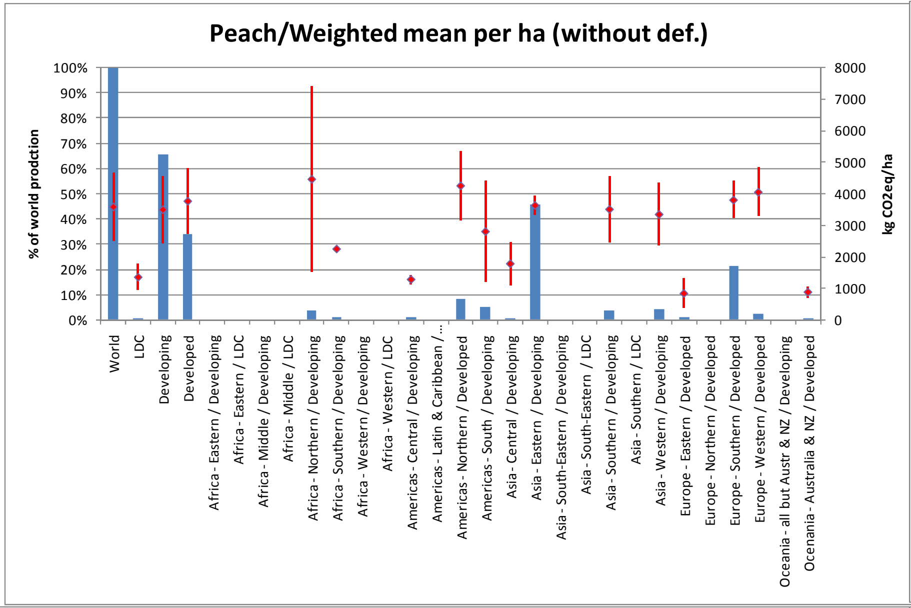
Ocenania - Australia & NZ / Developed


Peach/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
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Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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Europe - Western / Developed
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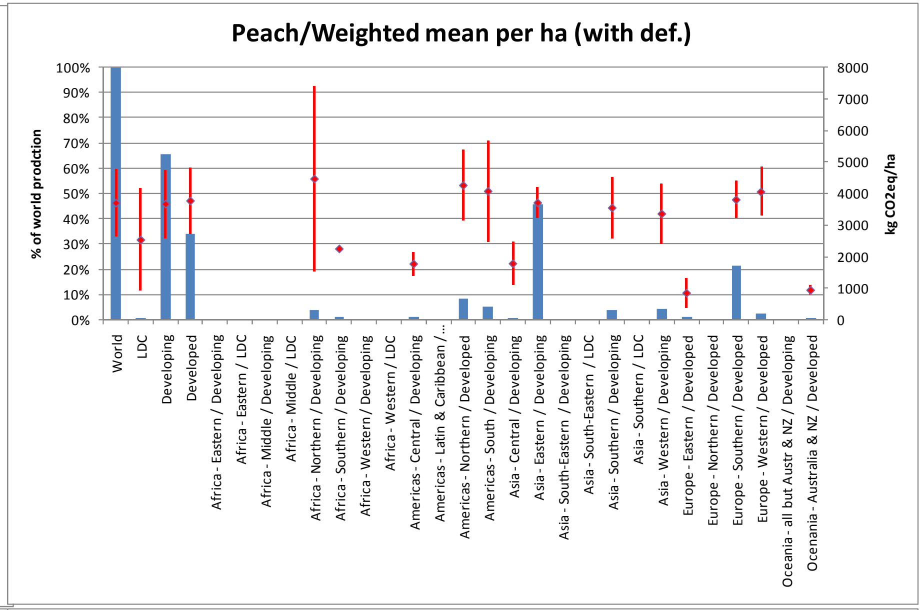
Peach/Weighted mean per ha (with def.)
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World
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Africa - Eastern / Developing
Africa - Eastern / LDC
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Africa - Middle / LDC
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Africa - Western / Developing
Africa - Western / LDC
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Asia - South-Eastern / LDC
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Asia - Southern / LDC
Asia - Western / Developing
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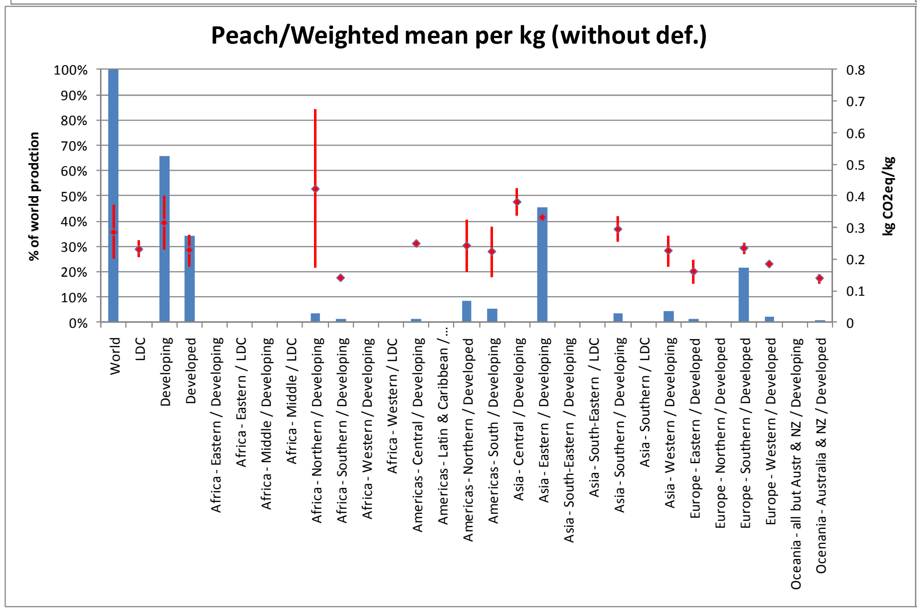
Peach/Weighted mean per kg (without def.)
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World
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Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
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Africa - Northern / Developing
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Africa - Western / LDC
Americas - Central / Developing
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Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
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Oceania - all but Austr & NZ / Developing
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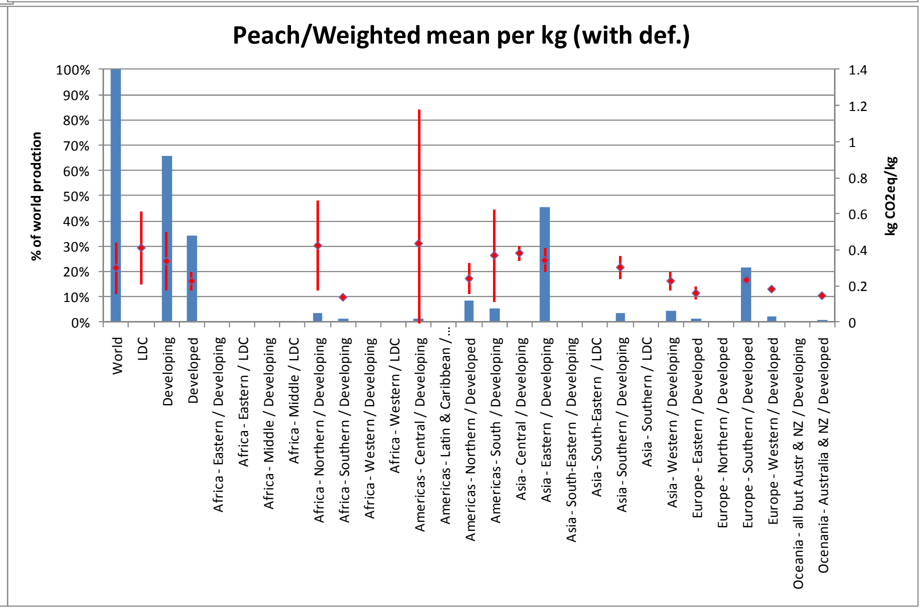
Peach/Weighted mean per kg (with def.)
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World
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Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
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Asia - Central / Developing
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Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
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Asia - Southern / LDC
Asia - Western / Developing
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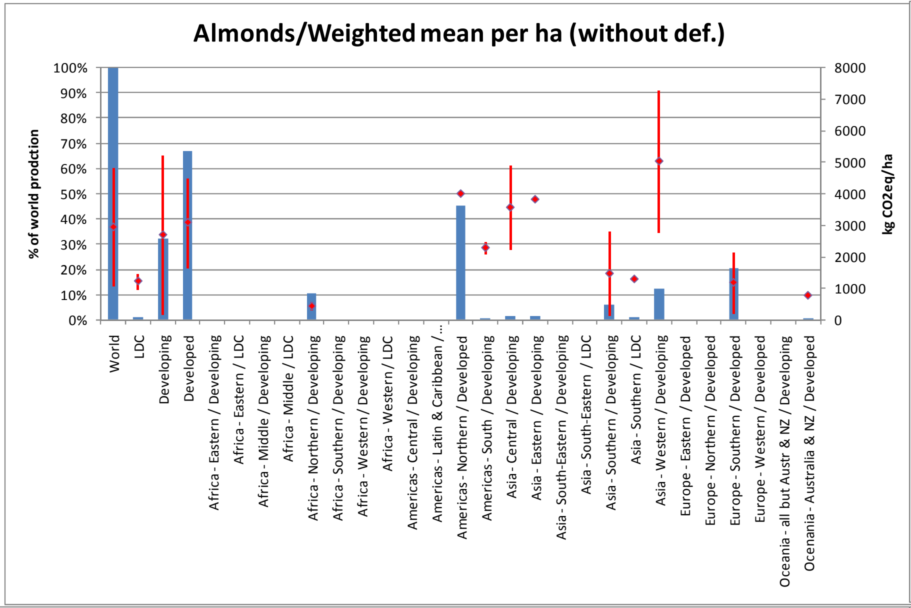
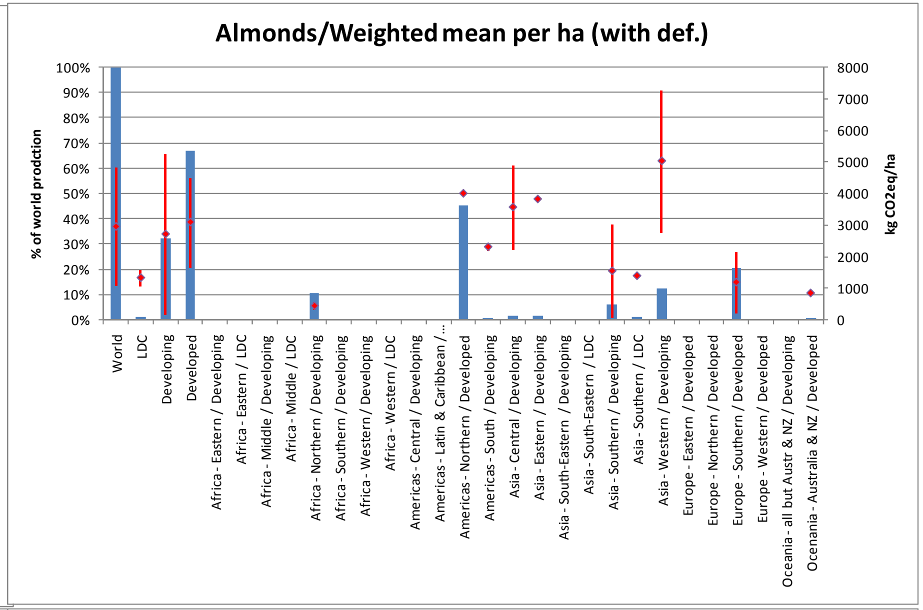
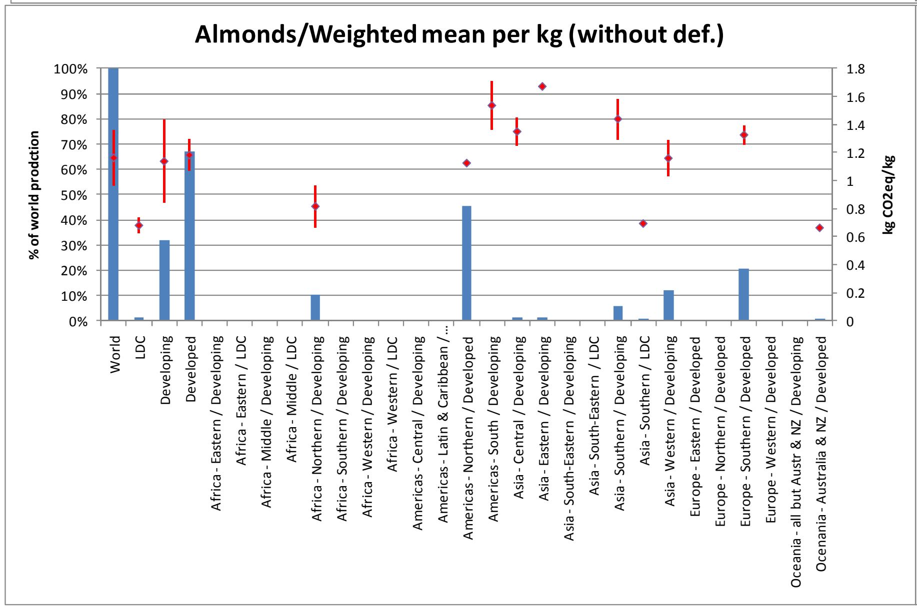
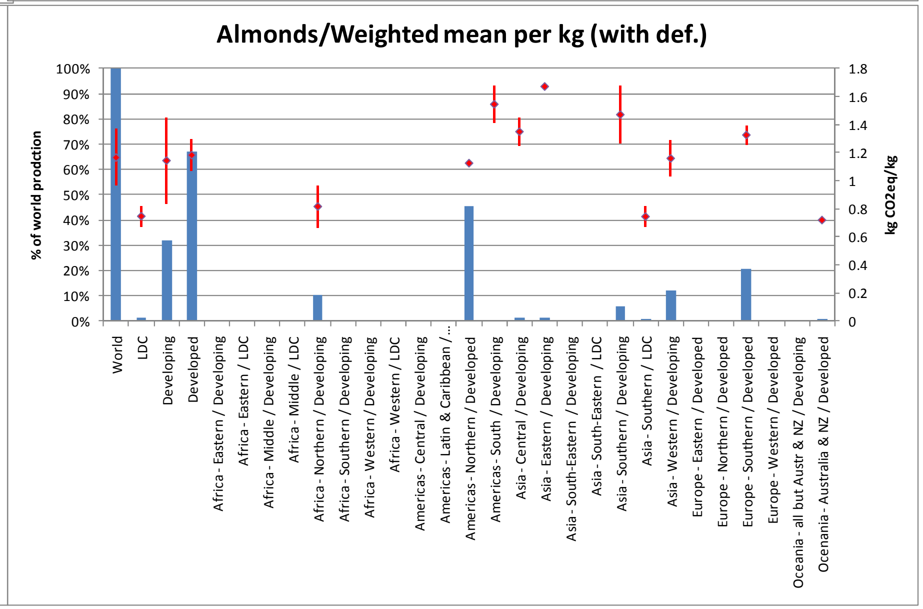
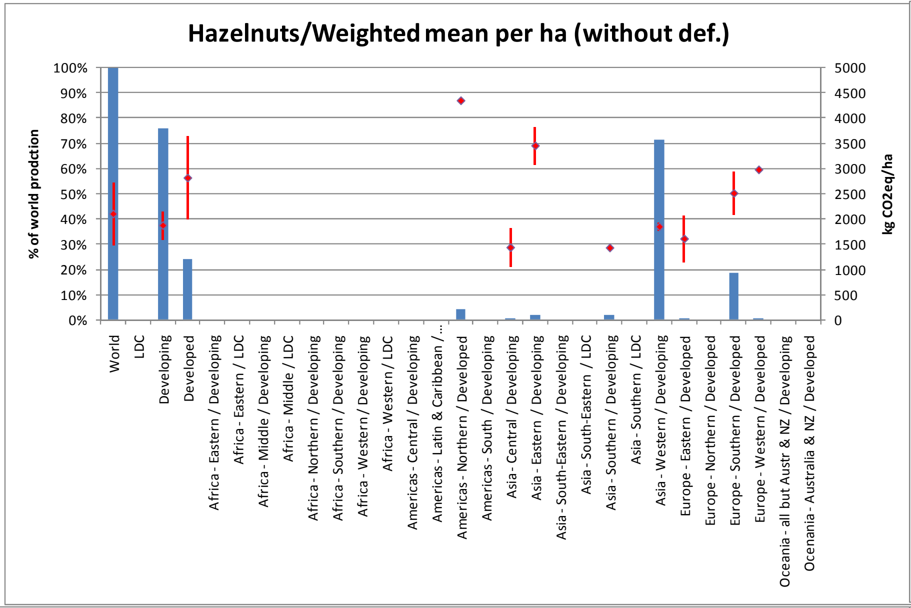
Oceania - all but Austr & NZ / Developing
Ocenania - Australia & NZ / Developed


Almonds/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha


Almonds/Weighted mean per ha (with def.)
% of world prodction
kg CO2eq/ha


Almonds/Weighted mean per kg (without def.)
% of world prodction
kg CO2eq/kg


Almonds/Weighted mean per kg (with def.)
% of world prodction
kg CO2eq/kg


Hazelnuts/Weighted mean per ha (without def.)
% of world prodction
kg CO2eq/ha
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2500
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1500
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World
LDC
Developing
Developed
Africa - Eastern / Developing
Africa - Eastern / LDC
Africa - Middle / Developing
Africa - Middle / LDC
Africa - Northern / Developing
Africa - Southern / Developing
Africa - Western / Developing
Africa - Western / LDC
Americas - Central / Developing
Americas - Latin & Caribbean / ...
Americas - Northern / Developed
Americas - South / Developing
Asia - Central / Developing
Asia - Eastern / Developing
Asia - South-Eastern / Developing
Asia - South-Eastern / LDC
Asia - Southern / Developing
Asia - Southern / LDC
Asia - Western / Developing
Europe - Eastern / Developed
Europe - Northern / Developed
Europe - Southern / Developed
Europe - Western / Developed
Oceania - all but Austr & NZ / Developing
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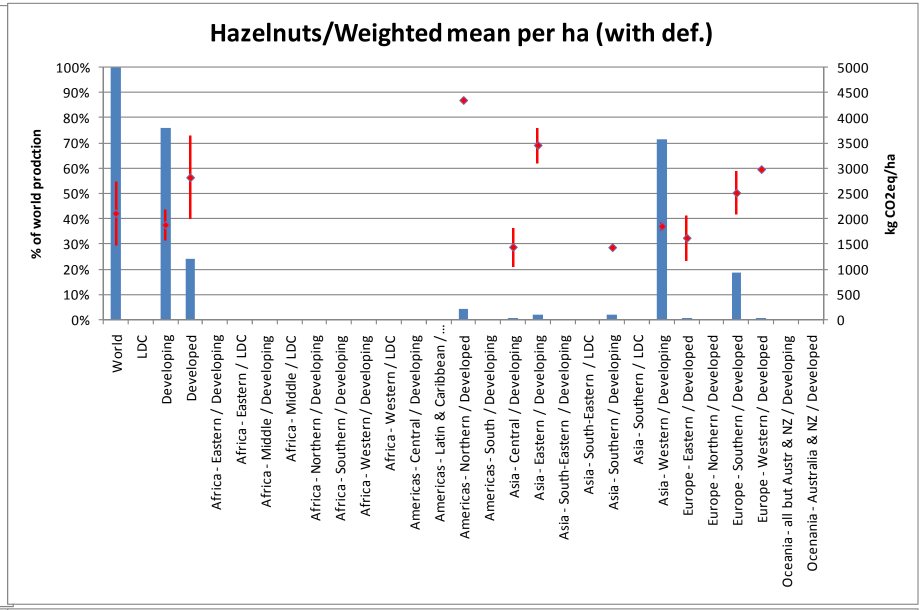
Hazelnuts/Weighted mean per ha (with def.)
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World
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Asia - South-Eastern / LDC
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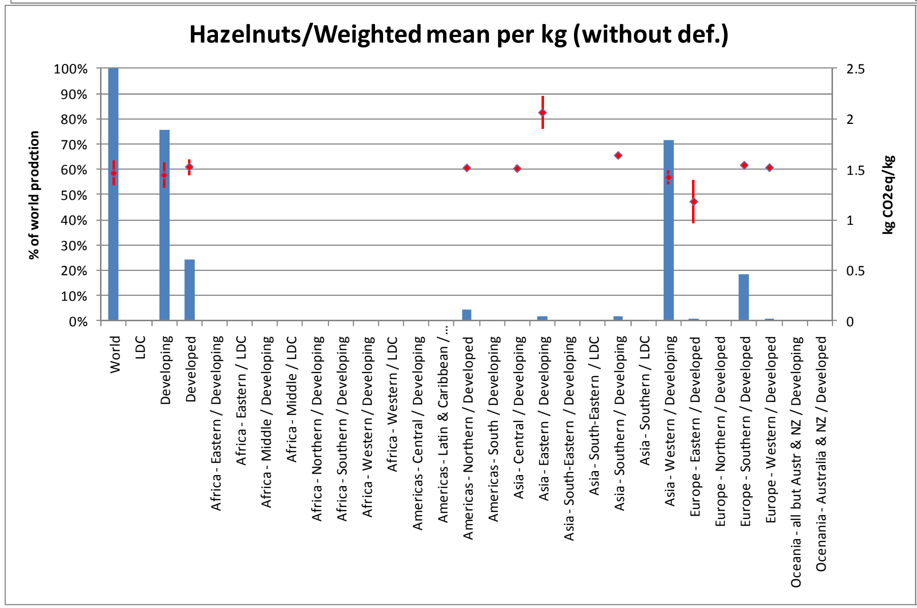
Hazelnuts/Weighted mean per kg (without def.)
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Africa - Middle / Developing
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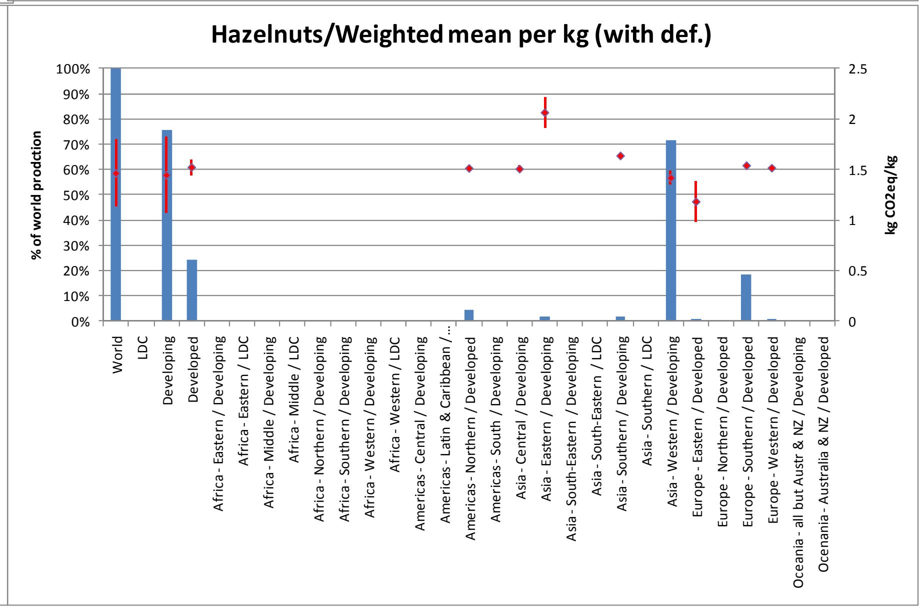
Hazelnuts/Weighted mean per kg (with def.)
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World
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