2022

Agri-footprint 6 Methodology Report

Part 3: Data Comparison

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About us

Agri-footprint is a high-quality, comprehensive life cycle inventory (LCI) database focused on the agriculture and food sector. It covers data on agricultural products: food, feed, and agricultural intermediate products. Since its conception in 2014, Agri-footprint has been critically reviewed and is now widely accepted by the food industry, LCA community, scientific community, and governmental institutions.

Blonk is a leading international expert in food system sustainability, inspiring and enabling the agri-food sector to give shape to sustainability. Blonk's purpose is to create a sustainable and healthy planet for current and future generations. We support organizations in understanding their environmental impact in the agri-food value chain by offering advice and developing tailored software tools based on the latest scientific developments and data.

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Part III Data Comparison

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1. Introduction

Due to major updates in modelling and underlying data between Agri-footprint 5 and Agri-footprint 6, the environmental impacts may show significant differences between the two databases. In this document, we explain the updates and how they may affect environmental impact scores in various ways. Major updates from Agri-footprint 5 to Agri-footprint 6 include:

- Replacing the ELCD/USLCI library with the ecoinvent library for background processes. This affects impacts of energy and materials in all environmental impact categories.
- Peat oxidation emissions are now included for all products (previously only included for palm oil in Malaysia and Indonesia)
- Fertilizer production has been regionalized, causing higher impacts in all regions but the EU.
- Update of activity data (such as yield, manure use, land use change, energy use) to more recent statistical data, changing the reference year from 2016 to 2018.
- Nitrogen emission calculations have been updated to the latest IPCC standard (IPCC, 2019), causing changes in manure, fertilizer and crop residue emissions.
- Post-harvesting energy use is now regionalized in Europe and uses the EU default for all other countries, generally leading to lower energy use.
- New pricing data for processed products, causing allocations between products and co-products to change.
- Update of production and trade data, causing some market mixes to change significantly in composition

For a complete overview, please go to table 2-1 of Methodology Report Part 2: Description of Data. We explore overall trends in environmental impact changes for the entire databases in Section 2 and then take a more in-depth look at what changed in modelling inputs and how this affects global warming potential for important products in Section 3.

2. Impact Categories

Figures 1-1 and 1-2 show histograms of the relative changes between Agri-footprint 5 and 6 for all impact categories of the ReCiPe 2016 Midpoint (H) method (with an adaptation to include peat oxidation emissions in the global warming category). The following plots display all the Agri-footprint processes that exist in both libraries, excluding processes directly copied from the ELCD or ecoinvent library and transport processes. Transport processes were not included since the only change has been the underlying background process. The comparison of background and transport processes can be found in Appendix I. In the following section, we discuss the reasons for the various patterns seen.

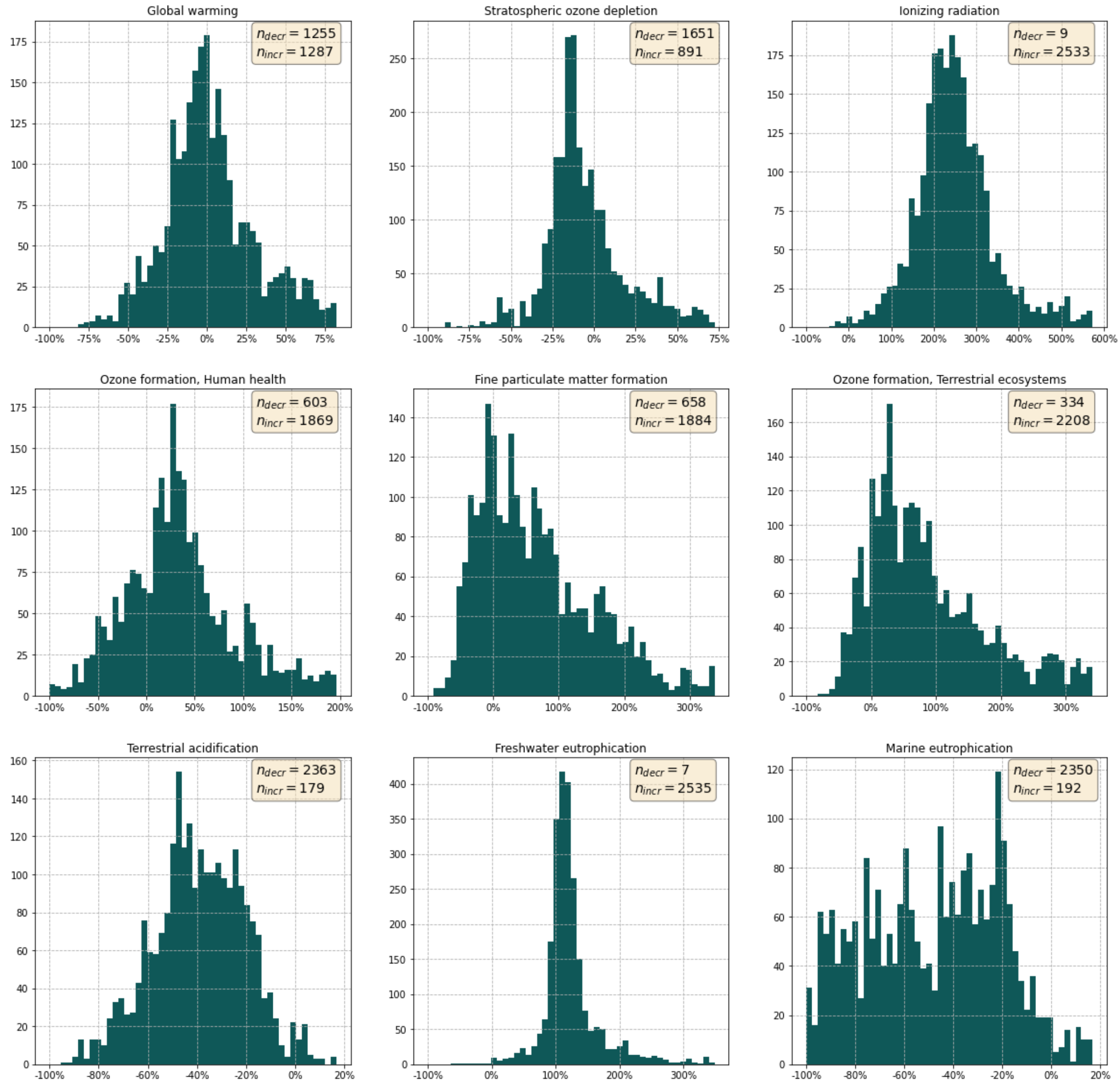

FIGURE 1-1 HISTOGRAMS OVER RELATIVE CHANGES FOR IMPACT CATEGORIES THAT WERE PRESENT IN BOTH AFP5 AND AFP6, EXCLUDING BACKGROUND PROCESSES AND TRANSPORT PROCESSES. PROCESSES AT THE 0% LINE HAVE NO DIFFERENCE IN IMPACT BETWEEN AFP5 AND AFP6. THE X-AXIS IS CAPPED ON THE RIGHT AT THE 95TH PERCENTILE. THE TEXT BOX INDICATES THE NUMBER OF PROCESSES THAT DECREASE (N_DECR) OR INCREASE (N_INCR) IN IMPACT SCORE.

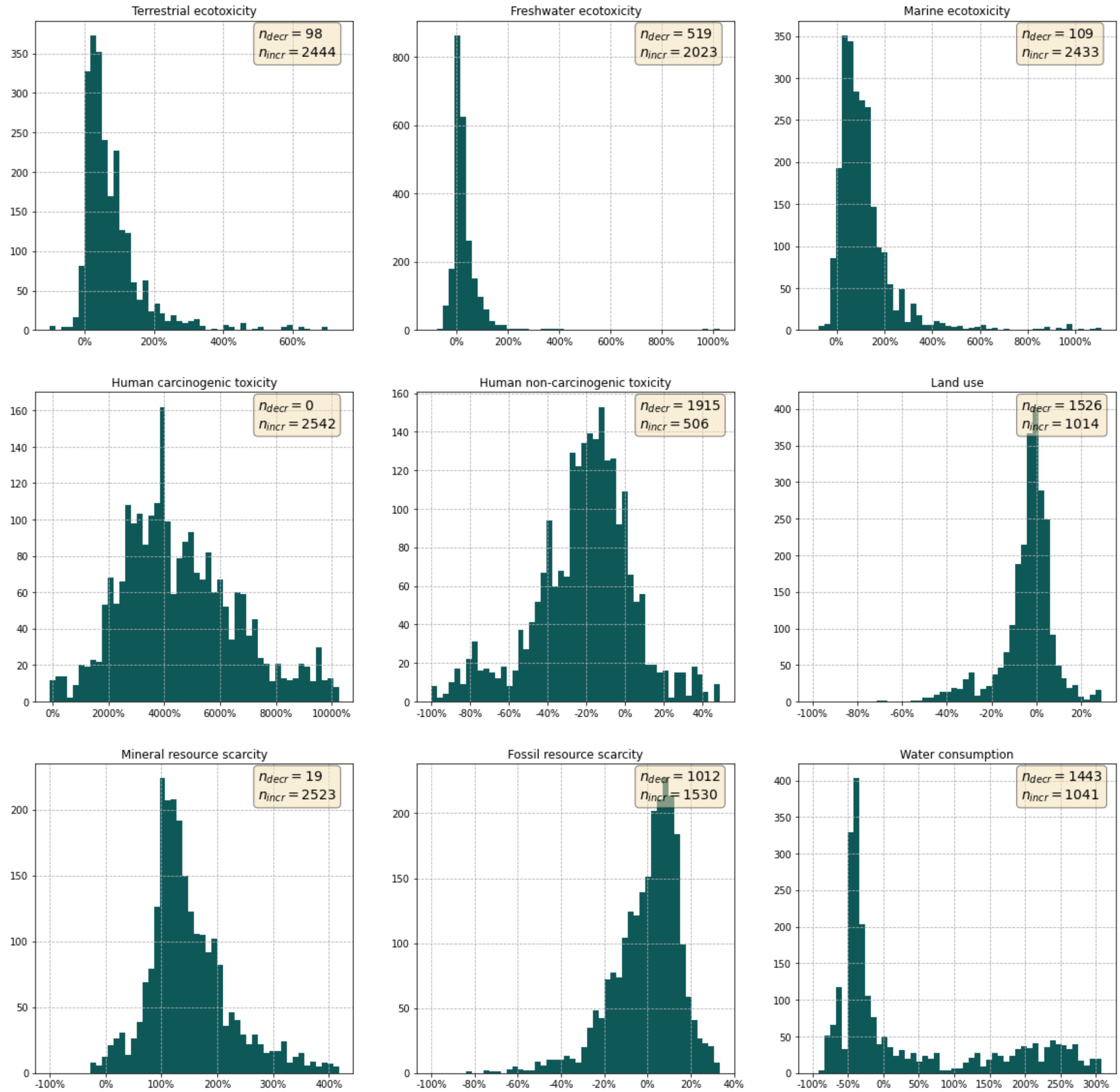

FIGURE 1-2 HISTOGRAMS OVER RELATIVE CHANGES FOR IMPACT CATEGORIES, CONTINUED

2.1 Global warming

Global warming impacts show some increases and decreases in scores, which are mostly balanced by each other (the median increase in impact is +2%). These changes are caused by modelling changes and data updates throughout the pipeline, which notably include:

- Peat oxidation was previously only modelled for palm oil in Malaysia and Indonesia and is now included for all products, causing many impacts to increase
- Emissions from land use change have generally decreased due to updates in the IPCC calculation rules for soil carbon stock change factors (IPCC, 2019), a shift in amortization period, retrospective updates of FAO statistical data and newer data on area used for agriculture.
- Updates in activity data (such as yield, manure use, energy use). Generally, yields have increased, while manure and fertilizer inputs have remained the same per hectare, causing impacts per kg of product to go down. The reverse also occurs in some cultivations, where yields have decreased in more recent years, causing impacts per kg to go up.
- Differences in crop residue emission factors (updated IPCC calculation rules), generally causing impacts to decrease.
- Prices of processed products and co-products have been updated, which affect results by economic allocation.

2.2 Stratospheric ozone depletion

Stratospheric ozone depletion impacts largely stayed in the same order of magnitude, with some processes showing increases and some showing decreases. Modelled stratospheric ozone depletion impacts are mostly driven by N_2O emissions and are therefore strongly driven by changes in manure, fertilizer, and crop residue emissions. Modelling changes in these emissions include updates to more recent statistics for manure use, a different parameter for manure use, changes in the crop residue modelling method and updates to IPCC calculation rules (see Section 3.3).

2.3 Ionizing radiation

With a mean increase of 251%, ionizing radiation impacts have starkly increased. Only 19 processes show a decrease in ionizing radiation impacts and all others increase in impact.

The changes are strongly driven by changes to background processes, which have been updated with the ecoinvent library to replace the ELCD library. Taking the average impact of all country-specific electricity background processes, the average impact increased from 0.0068 to 0.0213 kg CFC11 eq (+213%). Similarly, the impact for diesel increased from 0.00434 to 0.0324 (+646%) and the impact of concrete increased from 0.00148 to 0.0291 kg CFC11 eq (+1860%). Due to these background processes being used throughout the library, resulting impacts strongly increase.

2.4 Ozone formation, human health

Ozone formation, human health impacts show a slight increase (median increase at +24%), but there is a relatively large spread with the first and third quartile at +3% and +66% respectively.

Changes in ozone formation impacts are partly caused by changing the background processes. For instance, the process for diesel more than doubled in impact, while many other frequently used background processes (such as those for electricity and natural gas) mostly decreased.

Additionally, a large role in the spread is caused by the new regionalization of flows. Ozone formation impacts are largely driven by NO_x emissions, whose impacts have been made country-specific in the new update, as opposed to a global characterization in the previous version. In the following graphs, this global characterization factor has been plotted as a horizontal line, along with the regionalized characterization factors color-coded by the region these countries fall under. Notably the East Asia and South-East Asia region show strong increases over the previous global characterization and the Europe and North-America regions show steep decreases. These trends agree with the changes in impacts, where some of the largest increases in scores can be found in Asia and the largest decreases in western Europe.

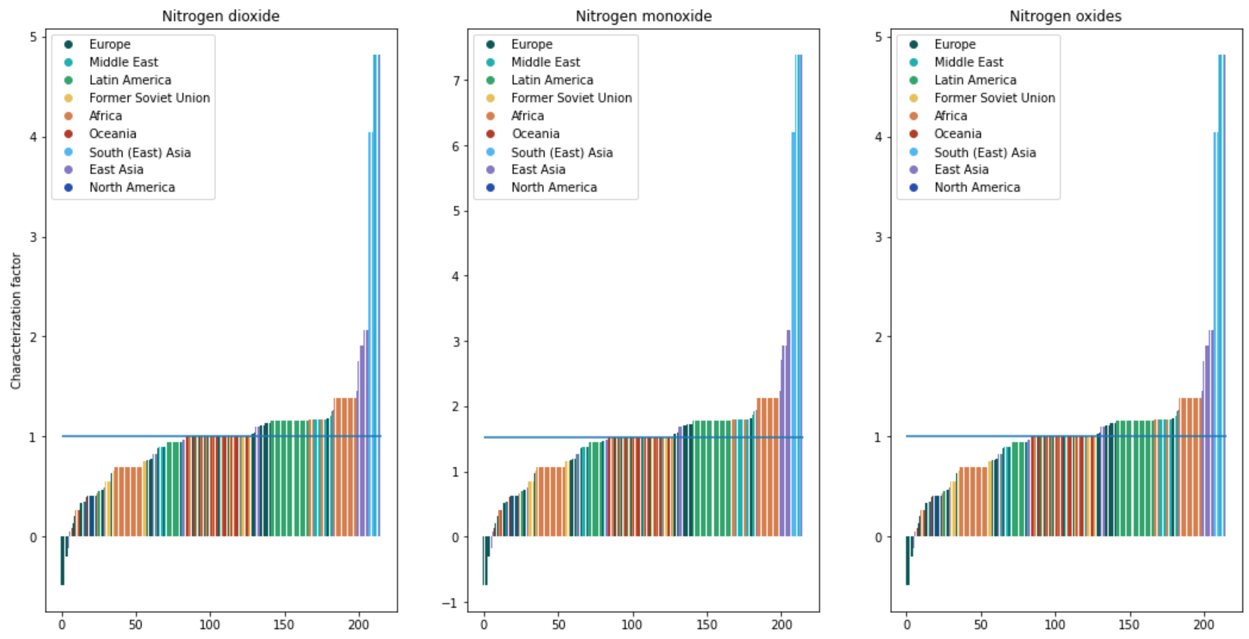

FIGURE 1-3 REGIONALIZED CHARACTERIZATION FACTORS OF NITROGEN DIOXIDE, NITROGEN MONOXIDE AND NITROGEN OXIDES FOR THE IMPACT CATEGORY OZONE FORMATION, HUMAN HEALTH. THE GLOBAL CHARACTERIZATIONS ARE PLOTTED AS A HORIZONTAL LINE, AT 1.0, 1.53, 1.0 RESPECTIVELY.

Notably, some characterization factors are negative for NO_x substances in Japan, Great Britain, Ireland, Belgium, the Netherlands and Luxembourg (Huijbregts et al., 2016). This causes 70 processes in these countries to have a negative impact on ozone formation. In figure 1-1, these processes are not shown, since a percentage increase or decrease is meaningless when comparing a process that changed from a positive to a negative impacts impact.

2.5 Fine particulate matter

Similarly to ozone formation impacts, the overall increase in impacts is small (median at +34%), but the spread is large (first and third quartile at +3% and +106%).

Changing background processes drive part of this change. There is generally an increase in impact for chemicals and a decrease in impact for electricity and natural gas background processes.

The new regionalization of flows of ammonia, nitrogen oxides and sulfur oxides causes changes in various countries. In the graphs below, we can for instance see that there are sharp decreases in impact characterization in Latin America and sharp increases in Europe. For nitrogen oxides, we see strong decreases in Africa and Latin America, and increases in Europe, South East Asia and East Asia. Sulfur oxides have stronger impacts in South-East Asia and East Asia and weaker impacts in Latin America and North America. These trends agree with the changes in impacts between Agri-footprint 5 and 6, where we see processes in European and Asian countries among the largest increases and processes in Latin America and North America among the steepest decreases.

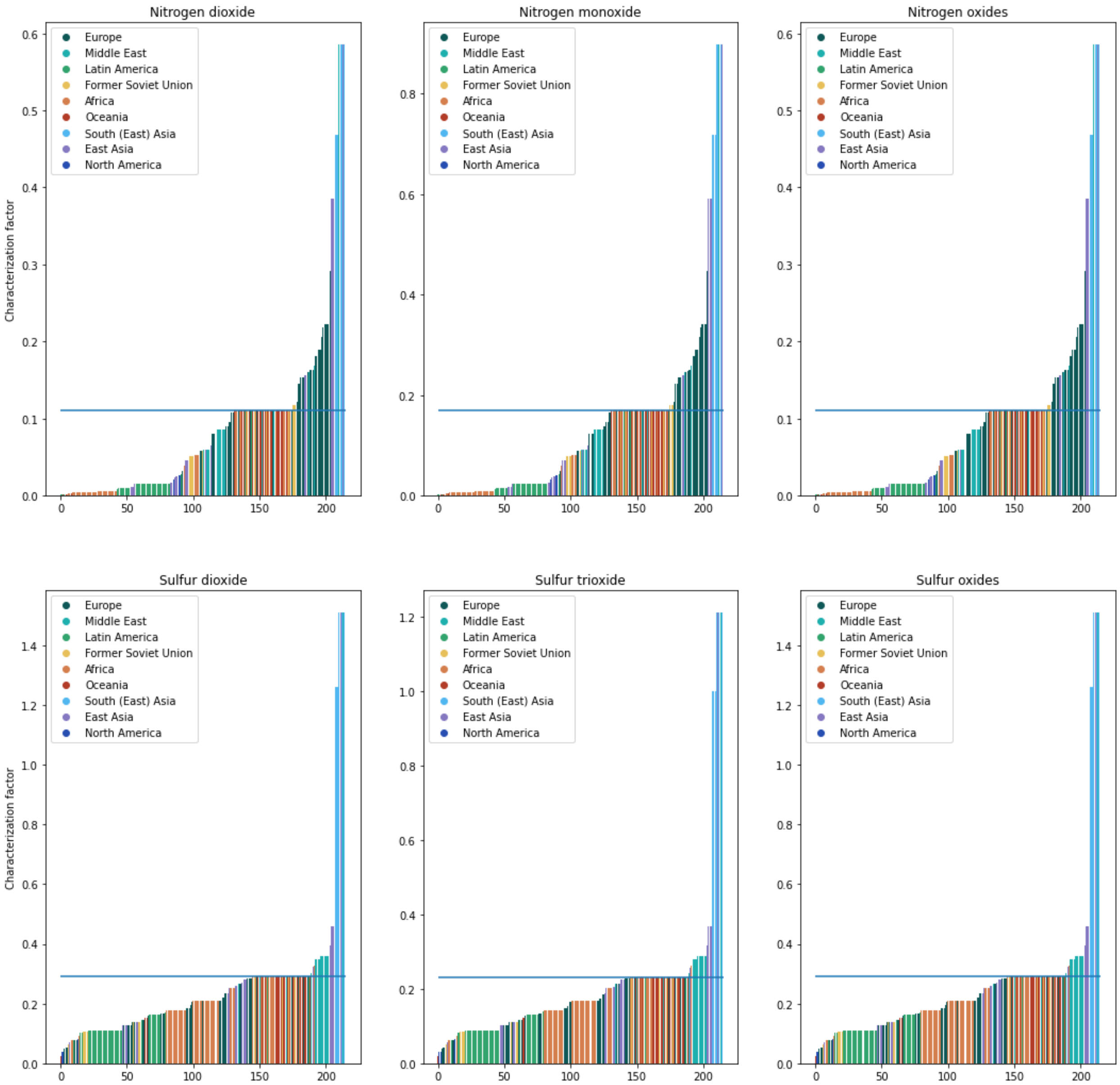

FIGURE 1-4 REGIONALIZED CHARACTERIZATION FACTORS OF NITROGEN DIOXIDE, NITROGEN MONOXIDE, NITROGEN OXIDES, SULFUR DIOXIDE, SULFUR TRIOXIDE AND SULFUR OXIDES FOR THE IMPACT CATEGORY FINE PARTICULATE MATTER FORMATION. THE GLOBAL CHARACTERIZATIONS ARE PLOTTED AS A HORIZONTAL LINE, AT 0.11, 0.17, 0.11, 0.29, 0.23 AND 0.29 RESPECTIVELY.

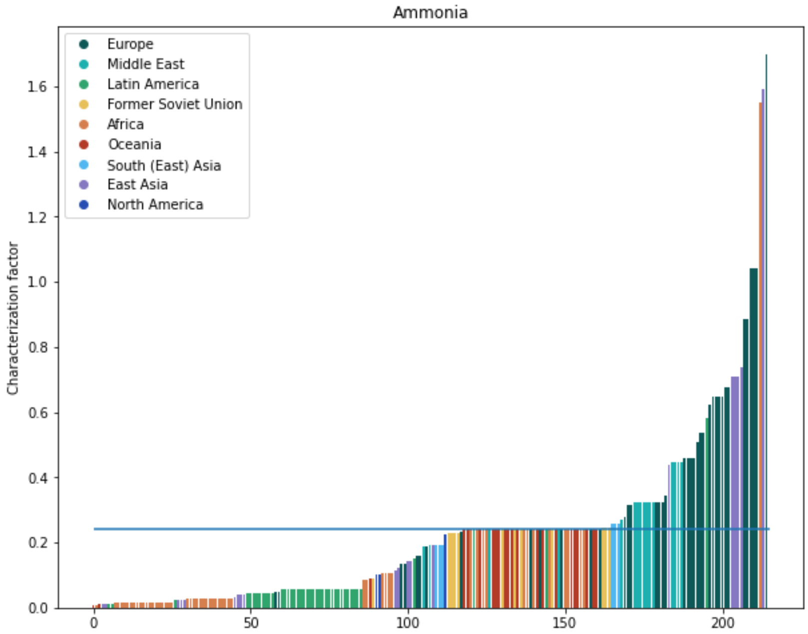

FIGURE 1-5 REGIONALIZED CHARACTERIZATION FACTORS OF AMMONIA FOR THE IMPACT CATEGORY FINE PARTICULATE MATTER FORMATION. THE GLOBAL CHARACTERIZATION IS PLOTTED AS A HORIZONTAL LINE AT 0.24.

2.6 Ozone formation, terrestrial ecosystems

As with the previous two impact categories, the large spread in impacts is mostly due to regionalization of nitrogen oxides. In the following graphs, the regional characterization can be seen:

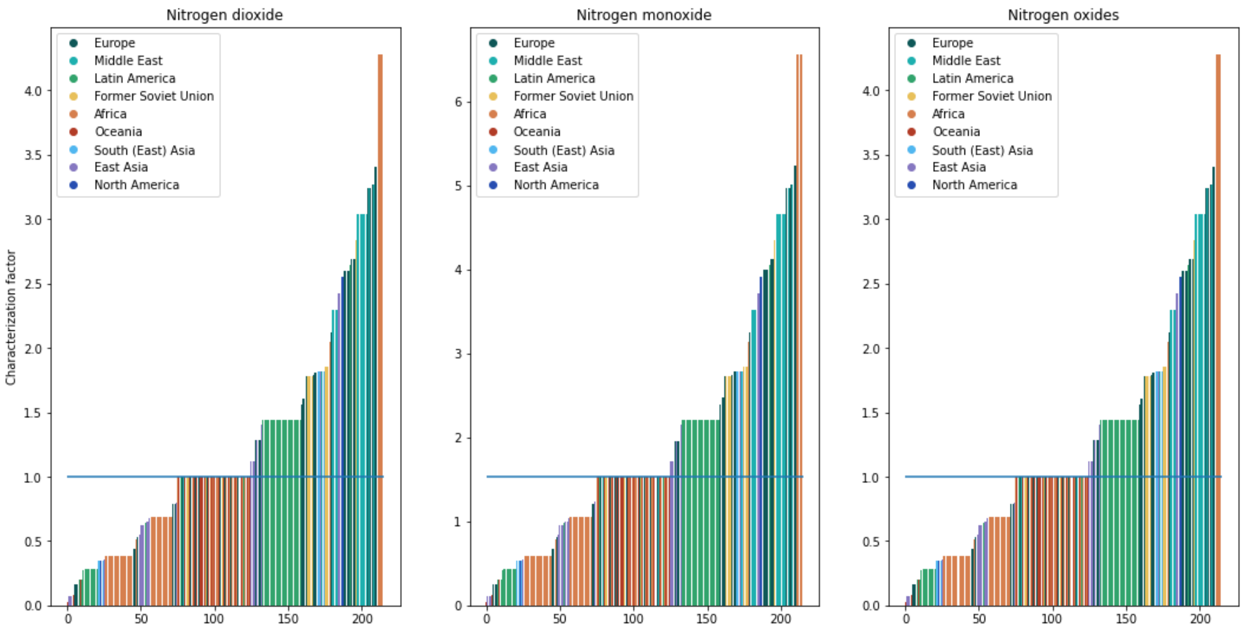

FIGURE 1-6 REGIONALIZED CHARACTERIZATION FACTORS OF NITROGEN DIOXIDE, NITROGEN MONOXIDE AND NITROGEN OXIDES FOR THE IMPACT CATEGORY OZONE FORMATION, TERRESTRIAL ECOSYSTEMS. THE GLOBAL CHARACTERIZATIONS ARE PLOTTED AS A HORIZONTAL LINE, AT 1.0, 1.53, 1.0 RESPECTIVELY.

Changes are furthermore driven by changes in background processes, e.g. increase in the impact of chemicals and a decrease in impact for most electricity and natural gas processes.

2.7 Terrestrial acidification

Impacts for terrestrial acidification show a strong decrease (median decrease of -61%). This is largely due to regionalization of flows, in particular that of ammonia, where all countries now either have the same characterization as the previous global value or far less (see figure below). Increasing yields but unchanged manure and fertilizer inputs also cause a decrease in ammonia emissions per kg of product. Additionally, there is a sharp decrease in impact of background processes for electricity and natural gas.

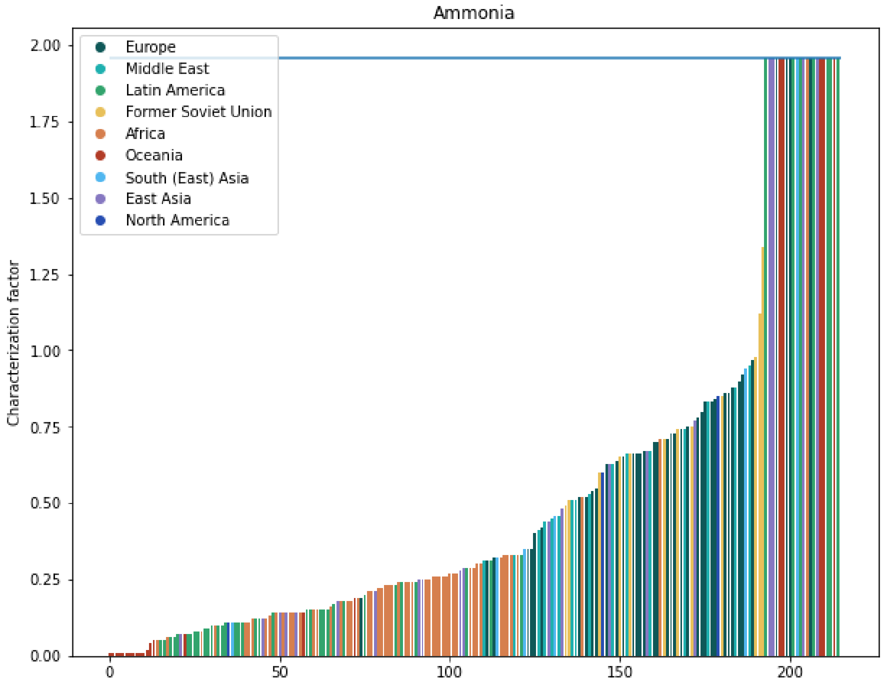

FIGURE 1-7 REGIONALIZED CHARACTERIZATION FACTORS OF AMMONIA FOR THE IMPACT CATEGORY TERRESTRIAL ACIDIFICATION. THE GLOBAL CHARACTERIZATION IS PLOTTED AS A HORIZONTAL LINE AT 1.96.

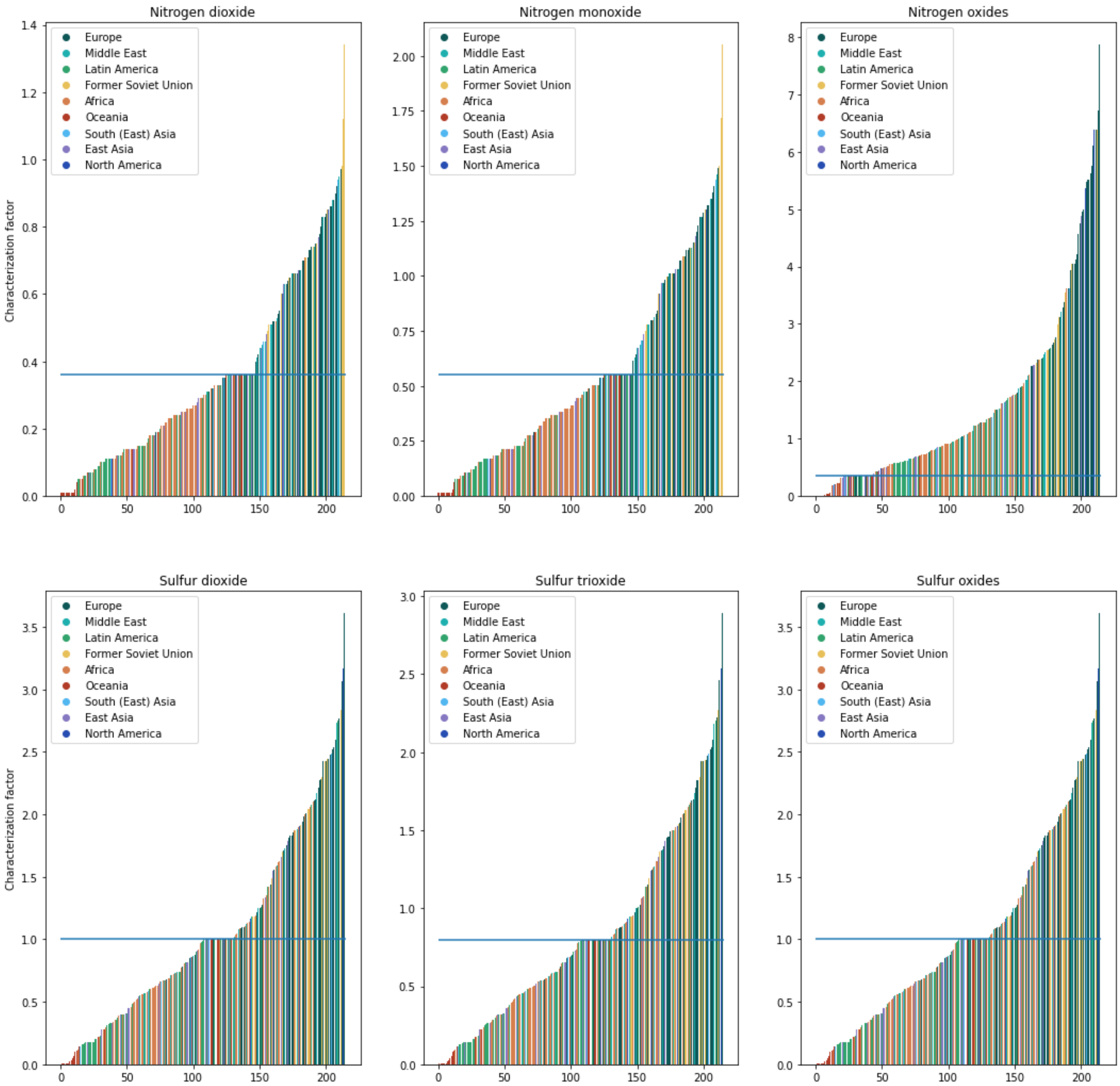

FIGURE 1-8 REGIONALIZED CHARACTERIZATION FACTORS OF NITROGEN DIOXIDE, NITROGEN MONOXIDE, NITROGEN OXIDES, SULFUR DIOXIDE, SULFUR TRIOXIDE AND SULFUR OXIDES FOR THE IMPACT CATEGORY TERRESTRIAL ACIDIFICATION. THE GLOBAL CHARACTERIZATIONS ARE PLOTTED AS A HORIZONTAL LINE, AT 0.36, 0.552, 0.36, 1.0, 0.8 AND 1.0 RESPECTIVELY.

2.8 Freshwater eutrophication

The freshwater eutrophication impacts mostly increase in the new Agri-footprint version, with a median increase of +123%. The increase can be explained by an update in emissions modelling for phosphorous emissions, for which the emission factor increased from 0.053 to 0.1 (Huijbregts et al., 2016). Since phosphorous emissions are the main driver for freshwater eutrophication impacts, this leads to an approximate doubling in impacts for processes with unchanged manure and fertilizer inputs.

2.9 Marine eutrophication

Nitrate emissions have been updated in Agri-footprint 6 to meet the new nitrate emission calculations rules from the IPCC (2019). Additionally, a correction factor for wet climates as a fraction of the total area in each country has been added to the modelling of nitrate emissions resulting from fertilizers and crop residues. This leads to a sharp decrease in nitrate emissions, causing marine eutrophication impacts to go down for nearly all processes (with a median decrease of -33%).

2.10 Terrestrial ecotoxicity

Terrestrial ecotoxicity impacts have mostly increased due to changes in fungicide emissions, which are based on statistics that have been updated to more recent data.

2.11 Freshwater ecotoxicity

Freshwater ecotoxicity impacts have mostly increased due to changes in herbicide emissions, which are based on statistics that have been updated to more recent data.

2.12 Marine ecotoxicity

Marine ecotoxicity impacts have mostly increased due to changes in insecticide (and to a lesser extent herbicide and fungicide) emissions, which are based on statistics that have been updated to more recent data.

2.13 Human carcinogenic toxicity

The strong increase in human carcinogenic toxicity impact is virtually solely caused by different background processes, all of which show a strong increase over ELCD. In particular, the background processes for concrete (4951x), sulfuric acid (615x), biowaste (292x) and diesel (106x) drive the large increases.

2.14 Human non-carcinogenic toxicity

Human non-carcinogenic toxicity impacts mostly show a slight decrease with a large spread in score differences. These are partly caused by a correction in heavy metal modelling that was present in Agri-footprint 5. The increase is furthermore caused by different background processes, all of which show a strong increase over ELCD. In particular the background processes for sulfuric acid (775x) and biowaste (503x) drive the large increases. Furthermore, there was a bug in Agri-footprint 5 causing zinc uptake to be modelled wrong (was based on Nickel) which has been corrected in Agri-footprint 6.

As in Agri-footprint 5, our modelling allows more uptake of heavy metals by the crop than are added as input, due to which some heavy metal emissions to soil for certain products are negative. Since the uptake of zinc is considerable per kg of product, the cultivation itself often results into a negative emission for this. This causes 121 processes in Agri-footprint 6 to have a negative impact on human non-carcinogenic toxicity, which have not been plotted in the comparison histograms (as this was also the case in Agri-footprint 5).

2.15 Land use

Land use impacts have remained mostly the same. The small differences in scores are generally the results of differences in activity data.

2.16 Mineral resource scarcity

For mineral resource scarcity, there is a sharp increase in the impacts scores and a large spread in the results. Most of these changes are due to updates in the background library, notably a sharp increase in the impact of the process used to model diesel. Changes in heavy metals calculations also drive impact differences.

2.17 Fossil resource scarcity

Most impact scores for fossil resource scarcity remain mostly the same, with some spread in results mostly due to differences in allocation and activity data such as yields. The impacts of the background processes mostly decrease with the replacing of ELCD with ecoinvent processes.

2.18 Water consumption

Water consumption shows a wide spread with no clearly discernible trend. Many processes decrease in impact due to a change in modelling irrigation water as described in Section 3.2.2 of Part 2 (Description of the data), which takes into account that not all applied water is necessarily taken up by the crop. Other changes are due to changes in the background processes for wastewater processing, currently no water "credits" are given when wastewater is processed, which is in line with the water footprint standard ISO 14046.

58 processes have an impact that changes sign between Agri-footprint 5 and 6, due to allowing negative water consumption modelling in Agri-footprint 5. This has been changed in Agri-footprint 6, causing some processes to go from a negative to a positive impact in the new version. These processes have not been plotted in the histogram (Figure 1-2).

3. Product comparison

In this chapter, we take an in-depth look at various highly produced feed products and explore how changes in activity data, modelling updates, background processes and other changes from Agri-footprint 5 to Agri-footprint 6 affect the global warming impacts of these products. The products considered are wheat cultivation in Germany, maize cultivation in the United States, soybean cultivation in Argentina, soybean meal production in Brazil and soybean market mix in the Netherlands.

3.1 Wheat cultivation in Germany

In Agri-footprint 6, the total climate change impact of wheat cultivation in Germany has increased from 0.345 kg CO2e to 0.438 kg CO2e per kg of wheat produced. This change is due to various updates in the modelling and the statistical data used in the calculations.

The activity data per hectare has not changed much for most data points, but there are a few small differences. The yield per hectare has decreased from 7937 to 7735 kg/ha and the co-product yield decreased from 4072 to 3254 kg /ha according to more recent FAO statisticsAgri-footprint 6 (FAO, 2021). As a result, small changes in activity data occur in energy use, manure application and pesticide use, which are all based in part on yield data.

The environmental impact per kg of product is shown in the contribution analysis below:

TABLE 3-1: CONTRIBUTION ANALYSIS OF WHEAT GRAIN CULTIVATION IN GERMANY, IMPACT AS CARBON FOOTPRINT EMISSIONS PER KG OF PRODUCT

Product AFP6	**Product AFP5**						Allocation co-product	
Wheat grain, at farm/DE Economic	heat grain, at farm/DE Economic					AFP5	16.13%	
						AFP6	13.62%	
Allocation main product AFP6	Allocation main product AFP5							
86.38%	83.87%						Yield co-product	
						AFP5	4072	
Overview	CC impact	Yield [kg]				AFP6	3254	
AFP5	0.344745958	7937						
AFP6	0.43849759	7735						
Difference	0.093751631	-202						
Relative difference	27%	-3%						
Activity data (per kg of output)		**Agricultural (kg)**	**Transport (tkm)**	**Energy (MJ)**	**Fertilizer (kg)**	**Pesticides (kg)**	**Manure (kg)**	
AFP5		1.016172394	0.050842205	0.710477118	0.157998828	0.000326429	0.412603096	
AFP6		1.017096823	0.182547021	0.839027511	0.224781054	0.000407418	0.434453196	
Relative difference		0%	259%	18%	42%	25%	5%	
Product impacts (kg CO2 eq.)	**Total**	**Agricultural**	**Transport**	**Energy**	**Fertilizer**	**Pesticides**	**Manure**	**Other**
AFP5	0.131967352	4.90424E-05	0.004458903	0.055436321	0.014901903	0	0	0.057121182
AFP6	0.12534031	6.20844E-05	0.00696105	0.060780326	0.015993988	0	0	0.041542861
Relative difference	-5%	27%	56%	10%	7%			-27%
Foreground impacts (kg CO2 eq.)	**Total**	**Peat oxidation**	**LUC**	**Fertilizer application**	**Manure application**	**Crop residues**		
AFP5	0.212778606	0	0.009932459	0.128765877	0.023317584	0.050762685		
AFP6	0.31315728	0.097195163	0.00273882	0.139812254	0.027383215	0.046027828		
Relative difference	47%		-72%	9%	17%	-9%		

The main difference in climate change impact is due to modelling peat oxidation emissions in Agri-footprint 6, which were not included in Agri-footprint 5 (except for palm fruit in Indonesia and Malaysia). Changes in other product and foreground impacts mostly cancel each other out in the final impact score, but a few are still notable:

- Land use change has decreased strongly due to a reduction in area harvested at present, a change in the stock change factors for perennial cropland and a shift of two years in amortization period – land use increased notably 20 years ago, of which the first two years no longer contribute towards expanding land.
- Increase in transport is due to using market mixes of fertilizers instead of exclusively locally produced fertilizers and an increase in the impact of the underlying diesel background process (which increased in impact by 18%)
- Manure and fertilizer application emissions per kg of product have gone up due to a decreased yield, but no change in total fertilizer application per hectare
- Crop residue emissions have decreased due to an update in modelling (see Section 3.3.1 of Part 2)

3.2 Maize cultivation in the United States

The climate change impact of maize cultivation in the United States has increased slightly from 0.286 kg CO2e in Agri-footprint 5 to 0.293 kg CO2e in Agri-footprint 6. The activity data per hectare can be seen in the following table:

TABLE 3-2: MAIN COLLECTED AND GENERATED ACTIVITY DATA PER HECTARE FOR MAIZE CULTIVATION IN THE UNITED STATES.

Item	AFP5	AFP6	Difference
Yield main product	9984	11040	Update in FAO yield statistics
Allocation factor grain	94.17%	94.67%	Updated yields, same prices
Yield co-product	1648	1656	Update in FAO yield statistics
Allocation factor stover	5.83%	5.33%	Updated yields, same prices
Fertilizer N	167.32	167.32	No update
Fertilizer P2O5	60.39	60.39	No update
Fertilizer K2O	60.88	60.88	No update
Energy use - diesel	3298 MJ	3368 MJ	Higher yield and manure input to the energy model
Energy use - electricity	473 MJ	523 MJ	Higher yield input to the energy model
Manure – poultry	370 kg	358 kg	New FAO data and "application" statistic chosen
Manure – swine	527 kg	426 kg	New FAO data and "application" statistic chosen
Seed input	37.74 kg	37.74 kg	No update

Lime	400 kg kg	400 kg	Default value
Pesticides	3.28 kg a.i	3.25 kg a.i.	Update in FAO pesticide application statistics

As with wheat cultivation in Germany, the differences in activity data are mostly small. The main difference on a per hectare basis is the increase of the yield from Agri-footprint 5 to Agri-footprint 6 due to an update in FAO data (reference year 2018 instead of 2016). This also causes a slight increase in energy use, since the energy model is dependent on the yield of the crop. Manure application is based on newer FAO data, but also changes due to modelling with the "manure applied to soil" statistic, whereas in Agri-footprint 5 the statistic "manure management" was chosen, which described total manure production in a country. This causes a decrease in swine manure application per hectare between Agri-footprint 5 and 6 and also causes diesel use to not increase as much as electricity use despite an increase in yield, since the energy model is also dependent on manure application rates (more manure applied means more diesel used). Pesticide application is based on FAO pesticide application statistics, which show a slight decrease in the new reference period.

TABLE 3-3: CONTRIBUTION ANALYSIS OF MAIZE CULTIVATION IN THE UNITED STATES, IMPACT AS CARBON FOOTPRINT EMISSIONS PER KG OF PRODUCT

Product AFP6	**Product AFP5**						Allocation co-product	
Maize, at farm/US Economic	Maize, at farm/US Economic					AFP5	5.83%	
						AFP6	5.33%	
Allocation main product AFP6	Allocation main product AFP5							
94.67%	94.17%						Yield co-product	
						AFP5	1648	
Overview	CC impact	Yield [kg]				AFP6	1656	
AFP5	0.285889103	9984						
AFP6	0.293212554	11040						
Difference	0.007323452	1056						
Relative difference	3%	11%						
Activity data (per kg of output)		**Agricultural (kg)**	**Transport (tkm)**	**Energy (MJ)**	**Fertilizer (kg)**	**Pesticides (kg)**	**Manure (kg)**	
AFP5		1.003609893	0.084485668	0.692177045	0.143577232	0.00062692	0.085555831	
AFP6		1.003281477	0.261517642	0.71629803	0.172083333	0.000563957	0.067917035	
Relative difference		0%	210%	3%	20%	-10%	-21%	
Product impacts (kg CO2 eq.)	**Total**	**Agricultural**	**Transport**	**Energy**	**Fertilizer**	**Pesticides**	**Manure**	**Other**
AFP5	0.106274607	9.44708E-05	0.002138672	0.058333925	0.014221788	0	0	0.031485752
AFP6	0.11382272	8.50328E-05	0.005373269	0.055030046	0.012422509	0	0	0.040911862
Relative difference	7%	-10%	151%	-6%	-13%			30%
Foreground impacts (kg CO2 eq.)	**Total**	**Peat oxidation**	**LUC**	**Fertilizer application**	**Manure application**	**Crop residues**		
AFP5	0.179614495	0	0.003266538	0.125403306	0.009221415	0.041723236		
AFP6	0.179389835	0.011190695	0.001872289	0.117697336	0.008654427	0.039975088		
Relative difference	0%		-43%	-6%	-6%	-4%		

Most foreground impacts decrease due to a higher yield, but due to the inclusion of peat oxidation emissions, the total climate change impact on land remains nearly the same. Aside from an increased yield, land use change emissions per kg are less due to updating the modelling data to a more recent period (2014 – 2018 instead of 2012 – 2016), in which a shift in the amortization period causes the historical land use to go up and therefore the difference between historical land use and current land use to go down, since land that changed over 20 years ago is no longer counted as expanded area. Fertilizer and manure application impact per kg of product is less due to higher yields but nearly unchanged application rates per hectare. Crop residue emissions are slightly less due to an update in modelling described in Section 3.3.

Fertilizer production emissions decrease due to a different fertilizer mix (due to updates in underlying data determining fertilizer ratios) and the replacement of fertilizers by regionalized market mixes. Replacing locally produced fertilizers with fertilizer market mixes also cause transport emissions to go up, since there are more transport movements involved. Transport emissions also increase because the background process for diesel from ecoinvent has a 18% higher impact than the equivalent process from ELCD.

3.3 Soybean cultivation in Argentina

The climate change impact of soybean cultivation in Argentina has decreased from 5.48 to 4.49 kg CO2e / kg product. Main collected activity data for soybean cultivation in Argentina for both datasets in shown in the table below.

TABLE 3-4: MAIN COLLECTED AND GENERATED ACTIVITY DATA FOR SOYBEAN CULTIVATION IN ARGENTINA.

Item	AFP5	AFP6	Difference
Yield main product	**2757 kg**	**2890 kg**	**Update in FAO yield statistics**
Allocation factor grain	93.01%	96.56%	Updated yield, same prices

Yield co product	**1243**	**617 kg**	**Update in FAO yield statistics, AGDM soybeans 0.3 -> 0.1 (see Section 3.2.1.1 of Part 2)**
Allocation factor straw	6.99%	3.44%	Updated yield, same prices
Fertilizer N	**3.37 kg**	**3.37 kg**	**No change**
Fertilizer P2O5	10.83 kg	10.83 kg	No change
Fertilizer K2O	**0.30 kg**	**0.30 kg**	**No change**
Energy use - diesel	1960 MJ	1968 MJ	Higher yield and manure input to the energy model
Energy use - electricity	**2.77 MJ**	**2.90 MJ**	**Higher yield input to the energy model**
Manure – poultry	28.5 kg	28.7 kg	New FAO data and "application" statistic chosen
Manure – swine	**197 kg**	**283 kg**	**New FAO data and "application" statistic chosen**
Seed input	65.41 kg	65.41 kg	No change
Lime	**400 kg**	**400 kg**	**Default value**
Pesticides	6.27 kg a.i.	5.86 kg a.i.	Update in FAO pesticide application statistics

Most activity data remained the same, and the main changes are in the co-product yield and swine manure. Co-product yield was reduced between Agri-footprint 5 and 6 due to an update in above ground dry matter of soybeans, which was adjusted from 30% to 10%. The higher application of manure is related to an update to more recent data and using the "manure applied to soils" statistic by FAO as opposed to the "manure management" statistic that was used in Agri-footprint 5 to estimate total manure use in countries.

TABLE 3-5: CONTRIBUTION ANALYSIS OF SOYBEAN CULTIVATION IN THE ARGENTINA, IMPACT AS CARBON FOOTPRINT EMISSIONS PER KG OF PRODUCT

Product AFP6	Product AFP5						Allocation co-product	
Soybeans, at farm/AR Economic	ybeans, at farm/AR Economic					AFP5	6.99%	
						AFP6	3.44%	
Allocation main product AFP6	Allocation main product AFP5							
96.56%	93.01%						Yield co-product	
						AFP5	1243	
Overview	CC impact	Yield [kg]				AFP6	617.2	
AFP5	5.481240057	2757						
AFP6	4.489603397	2890						
Difference	-0.99163666	133						
Relative difference	-18%	5%						
Activity data (per kg of output)		Agricultural (kg)	Transport (tkm)	Energy (MJ)	Fertilizer (kg)	Pesticides (kg)	Manure (kg)	
AFP5		1.022411315	0.06458144	1.111520933	0.170032951	0.004408912	0.079343896	
AFP6		1.022172923	0.105822399	1.020138736	0.171305949	0.004073662	0.108391694	
Relative difference		0%	64%	-8%	1%	-8%	37%	
Product impacts (kg CO2 eq.)	Total	Agricultural	Transport	Energy	Fertilizer	Pesticides	Manure	Other
AFP5	0.130959263	0.000648286	0.003066348	0.097507801	0.000415685	0	0	0.029321143
AFP6	0.137653204	0.000598729	0.003859189	0.078608921	0.000394237	0	0	0.054192127
Relative difference	5%	-8%	26%	-19%	-5%			85%
Foreground impacts (kg CO2 eq.)	Total	Peat oxidation	LUC	Fertilizer application	Manure application	Crop residues		
AFP5	5.350280794	0	5.214860784	0.070551887	0.005042215	0.059825909		
AFP6	4.351950193	0.000874882	4.16864408	0.070029844	0.007027028	0.10537436		
Relative difference	-19%		-20%	-1%	39%	76%		

The main change in total climate change impact is due to a decrease in land use change: the currently cultivated area has decreased since 2016, the reference point for historical land use has shifted (causing the difference between current land use and land use 20 years prior to decrease) and soil carbon stock change factors have been updated to the new IPCC calculation rules (specifically impacting perennial cropland carbon content in Argentina) (IPCC, 2019). Other notable changes include an increase in transportation emissions, in manure application and crop residues. Transport emissions increased due to the increase in amount of manure applied and because the background process for diesel from ecoinvent has a 18% higher impact than the equivalent process from ELCD. Manure emissions per kg of product increase due to an increase in manure used per hectare. Crop residues increase due to changes in the modelling method and new IPCC emission calculation rules.

3.4 Soybean meal production in Brazil

For the soybean crushing process, output amounts, electricity use, process steam and sourcing have not changed. The climate change impact of the input source (soybeans from Brazil) has decreased from 5.6 kg CO2e to 4.5 kg CO2e per kg of soybean (mostly due to a reduction in land use change). Prices for soybean oil, meal and hull have also changed, causing the allocation to change and relatively more impact to be attributed to soybean meals and less to soybean oils.

TABLE 3-6: MAIN COLLECTED AND GENERATED ACTIVITY DATA FOR SOYBEAN CRUSHING IN BRAZIL.

Item	AFP5	Allocation	AFP6	Allocation
Crude soybean oil	190 kg	41.46%	190 kg	33.59%
Soybean meal	706 kg	55.61%	706 kg	64.3%
Soybean hull	74 kg	2.93%	74 kg	2.11%
Soybean	1000 kg		1000 kg	
Electricity	200 MJ		200 MJ	
Process steam	1200 MJ		1200 MJ	
Source grain	100% Brazil		100% Brazil	

As a result, the climate change impact of soybean meals changes from 4.7 kg CO2e to 4.3 kg CO2e per kg meal, which is a smaller decrease than would be expected based on just the change in source product alone. For crude soybean oil, the impact decrease is much steeper: from 12.9 kg CO2e to 8.3 kg CO2e.

Although the background process for electricity changed a lot relatively, the total impact is for the most part attributable to the changes in the soybean cultivation.

TABLE 3-7: CONTRIBUTION ANALYSIS OF SOYBEAN MEAL PROCESSING IN BRAZIL

Item	AFP5	AFP6	Difference
Soybeans (dried)	4.57	4.2	-8%
Electricity	0.0061	0.0125	81%
Process steam	0.0778	0.0776	0%
Others	0.0209	0.0068	-67%

3.5 Soybean market mix in the Netherlands

The climate change impact of the soybean market mix in the Netherlands has decreased from 3.272 to 2.173 kg CO2e / kg product. Various modelling changes have an impact on market mixes of crops, namely:

- The impact of soybeans from various origins has changed
- Market mixes now include a post-harvesting drying step, which was not included in Agri-footprint 5
- Trade statistics used to model the mix composition of various origins have been updated to more recent data
- In case compositions change, travel distances and their associated emissions change too, as well as a different background process used to model fuel use during transportation

In this example, the effect of changing trade statistics can be seen in the following figure. Soybeans from the United States now make up a larger portion of the market mix composition (46% to 59%), whereas soybeans from Canada, Brazil and Paraguay have decreased in the mix. The contribution of soybeans from Germany was negligible in Agri-footprint 5 (0.4%) and not present in Agri-footprint 6.

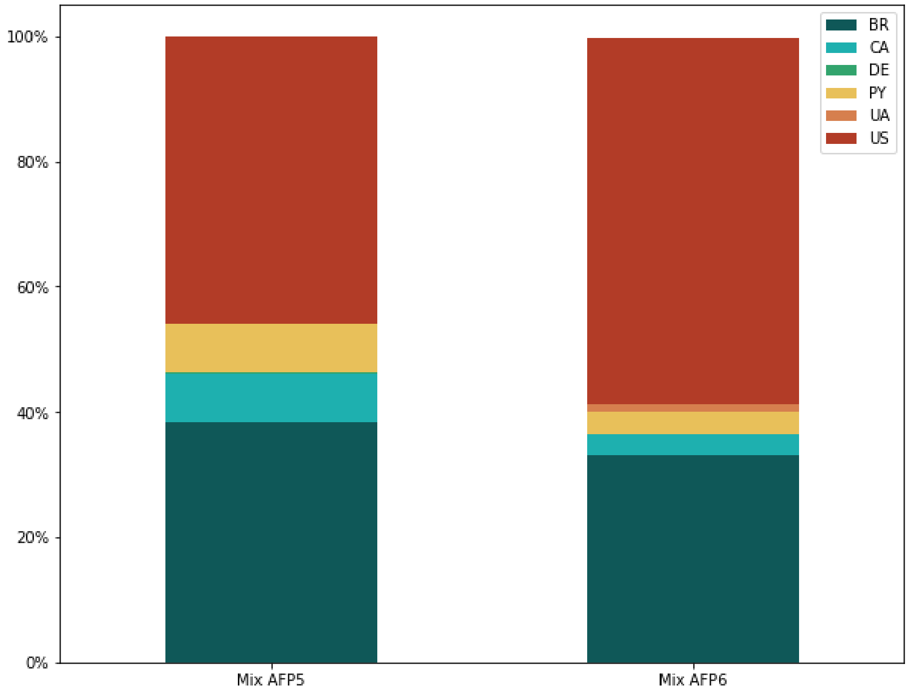

FIGURE 2-2 MARKET MIX COMPOSITION OF SOYBEANS IN THE NETHERLANDS IN AFP5 AND AFP6

In the following table, a comparison of the different climate change impact scores of the soybeans can be seen. Impact of soybeans from Brazil and Paraguay have decreased (mostly due to a reduction in land use change), whereas the impact of soybeans from Canada and the United States have increased in impact. The sharp decrease in soybeans from Paraguay is due to a significant reduction (162 to 51 ton C/ha) in the estimated carbon stock of forests between the data from the Forest Resource Assessment from FAO in 2015 and in 2020, which is used to model land use changes (FAO, 2020). The soil carbon stock change factors have also changed significantly from 2006 to 2019, impacting tropical land use change calculations especially (IPCC, 2019). The increases in emissions excluding land use change are due to a reduced yield in Agri-footprint 6 and an increase in crop residue emissions.

TABLE 3-9: CONTRIBUTION ANALYSIS OF SOYBEAN MEAL PROCESSING IN BRAZIL

Origin	AFP5 – excl LUC	AFP5 – LUC	AFP6 – excl LUC	AFP6 – LUC	Difference total impact
Brazil	0.352	5.251	0.456	4.058	-19%
Canada	0.273	0.696	0.389	1.143	+58%
Germany	0.703	0.184			
Paraguay	0.304	9.532	0.357	2.502	-71%
Ukraine			0.658	0.145	
United States	0.389	0.013	0.426	0.011	+9%

The following graph shows the contribution of all different soybeans towards the total climate change impact. As can be seen, the reduction is generally due to large decreases in land use change for soybeans from Brazil and Paraguay.

Although the total climate change impact from soybeans from the United States has increased, this is mainly due to a larger share in the market mix composition. Since soybeans from the United States have a smaller carbon footprint than the soybeans it replaces (namely from Brazil and Paraguay), this further helps to drive down the impact.

The drying step for all soybeans adds a small contribution to the impact for the mix (0.0245 kg CO_2e / kg product, or 1% of the total impact). Transport emissions change slightly due to changing distances as a result of a changing market mix composition and other background processes (0.114 to 0.113 kg CO_2e / kg product).

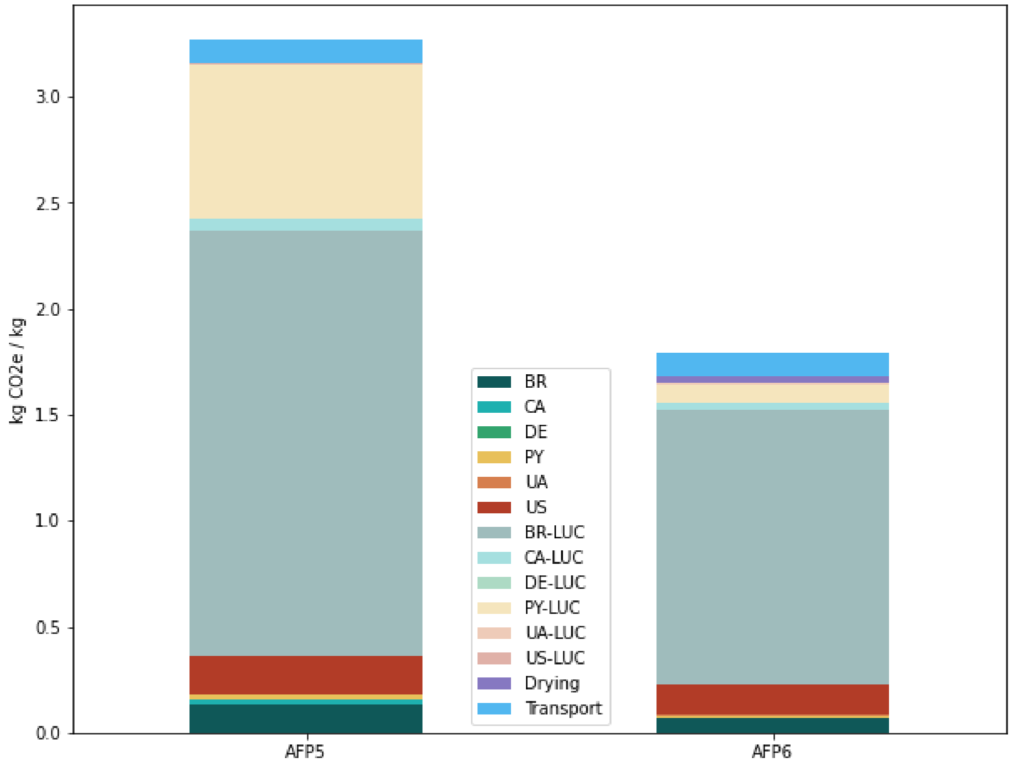

FIGURE 2-2 CONTRIBUTIONS FROM SOYBEANS FROM DIFFERENT ORIGINS, DRYING AND TRANSPORT STAGE TOWARDS TOTAL IMPACT OF SOYBEANS MARKET MIX IN THE NETHERLANDS

3.6 Milk production in the Netherlands

Agri-footprint 6 includes a revision and large update of the animal farm systems, which is described in detail in chapter 7 of part 2 of the documentation. In Agri-footprint 5, some animal systems in the Netherlands and Ireland were already modelled. To give insight into what changed and how this influences results, we look in more detail at the modelling of the production of milk in the Netherlands.

Newer and different sources have been used as input data, leading to the following significant changes:

TABLE 3-10: CHANGES IN THE DAIRY FARM SYSTEM BETWEEN AFP5 AND 6. NOTE THAT MILK YIELD PER COW IN AFP6 HAS BEEN CORRECTED FOR FAT AND PROTEIN, WHICH WAS NOT DONE IN AFP5

	Agri-footprint 5	Agri-footprint 6
Dairy cows	82	102
Milk yield per cow (kg/year)	8063	9277
Replacement animals	63.3	57
Liveweight of cows sold (kg/year)	14431	16250
Liveweight of calves sold (/year)	1979	3126
Milk production (kg/year)	661972	943465
Electricity (MJ/year)	137,880	162,601
Natural gas (MJ/year)	37,980	41,496

The combination of an increase in number of dairy cows, higher milk production per cow and correcting for fat and protein caused an increase in total milk production from 661,972 to 943,465 kg / year for one farm. Since the total output weight of calves and cows sold also increases due to new data sources relating to herd dynamics and the weights of the animals and since prices of calves, cows and milk remained the same between Agri-footprint 5 and 6, the total economic allocation towards milk has not changed significantly (from 92.92% to 92.15%). For more details, see chapter 7 of part 2 of the documentation.

The impact per kg of milk changes as follows:

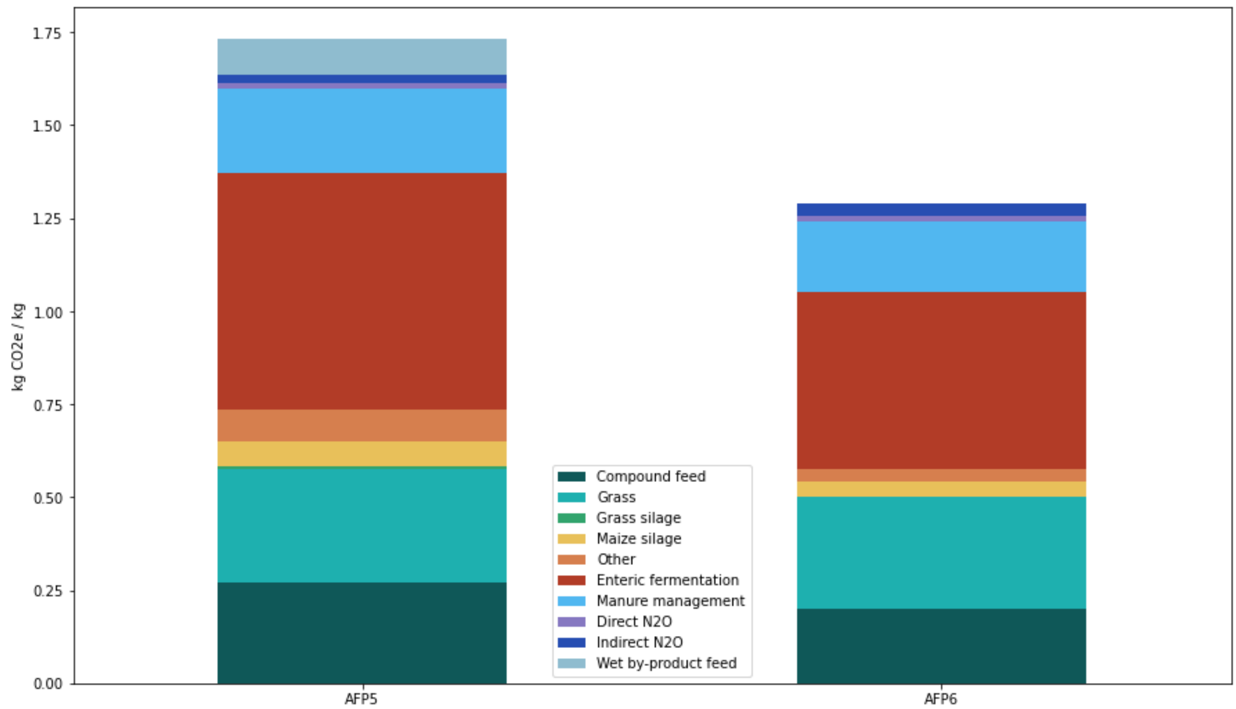

FIGURE 2-3 CONTRIBUTIONS FROM DIFFERENT FEEDS AND AT-FARM EMISSION SOURCES TOWARDS TOTAL IMPACT OF MILK PRODUCTION IN THE NETHERLANDS

The largest reductions can be found in enteric fermentation, maize silage, compound feeds and wet by-products. Enteric fermentation emissions per cow go down between Agri-footprint 5 and 6 (128.7 to 119.1 kg CH_4 per dairy cow) due to a combination of changing feed nutritional characteristics (because of different diet compositions) and increase in milk production, causing emissions per kg of output to go down. Maize silage intake has gone down according to the new data sources used (5787 to 3923 kg of feed per dairy cow per year) and has reduced slightly in global warming impact due to changes in cultivation modelling (0.101 to 0.094 kg CO2 / kg maize silage). Wet by-products are no longer used as feed in the Dutch farm system.

The compound feed used has not changed in composition between Agri-footprint 5 and 6, but since the impacts of the underlying products did change, the impact has gone down from 1.223 to 0.945 kg CO2e per kg of compound feed. This is mostly due to a reduction in impact for soybean meals, palm kernel expeller and rapeseed meal due to changing market mixes and updates in modelling.

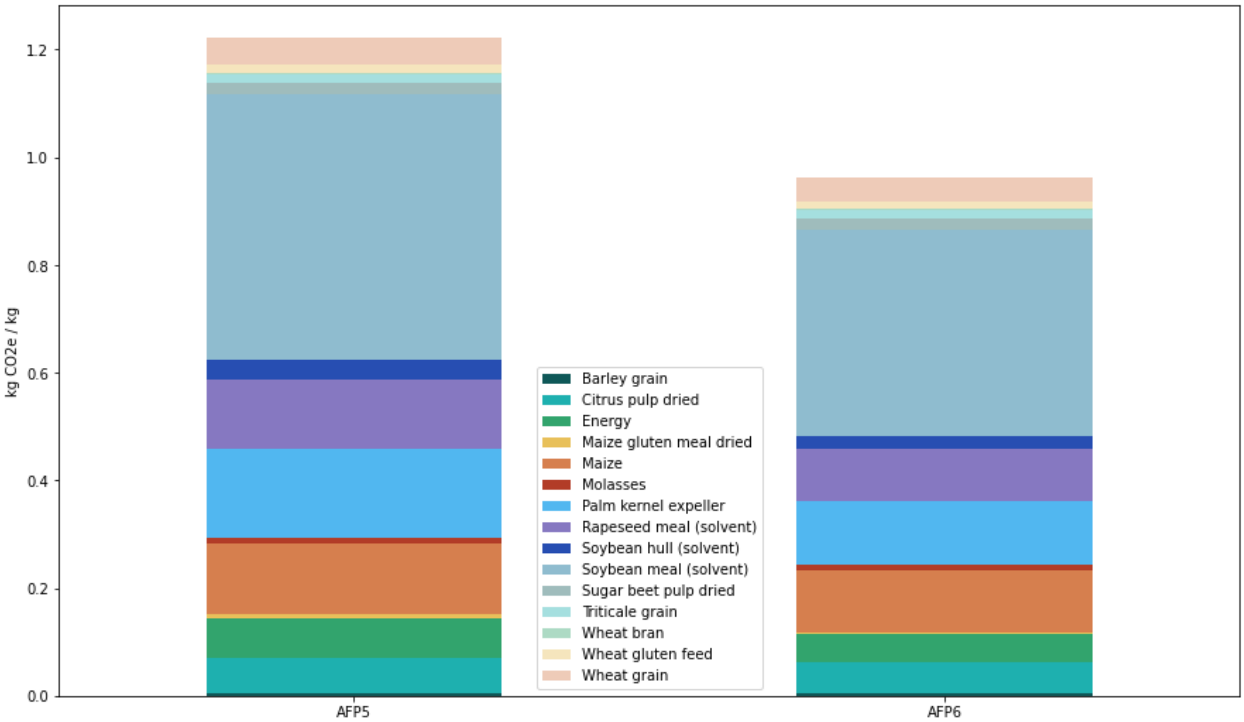

FIGURE 2-4 CONTRIBUTIONS FROM DIFFERENT FEED INGREDIENTS TOWARDS TOTAL IMPACT OF DAIRY COW COMPOUND FEED IN THE NETHERLANDS

4. References

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Appendix I

The following figures show the changes in all 18 impact categories for the background processes and transport processes. Since the only change in 383 transport processes has been the underlying background processes, the peaks in the graphs below correspond with these transport processes.

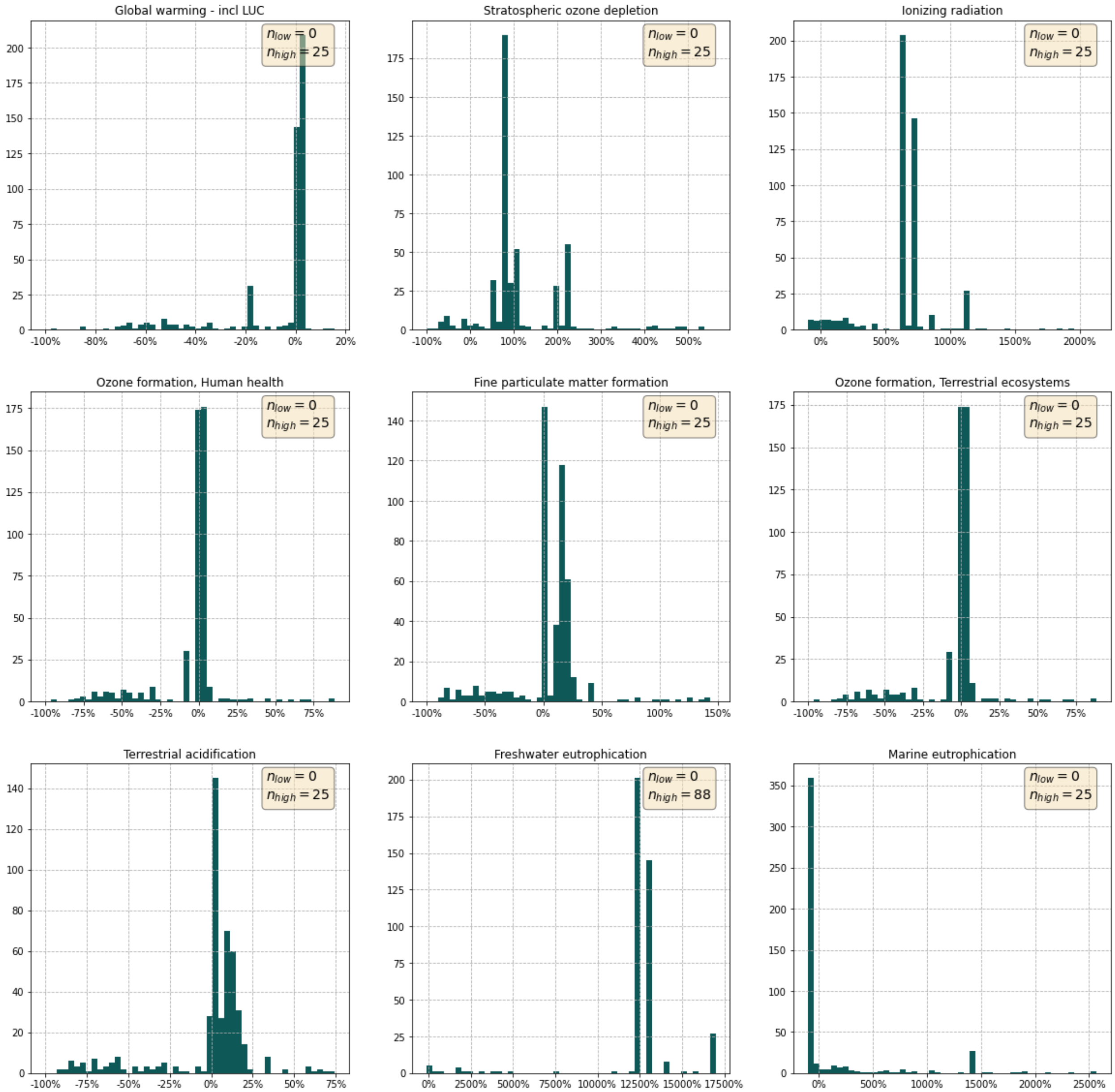

FIGURE A-3 HISTOGRAMS OVER RELATIVE CHANGES FOR IMPACT CATEGORIES IN BACKGROUND PROCESSES AND TRANSPORT PROCESSES. THE TEXT BOX INDICATES THE NUMBER OF PROCESSES THAT ARE FURTHER LEFT (N_LOW) OR RIGHT (N_HIGH) THAN THE FIGURE AXIS.

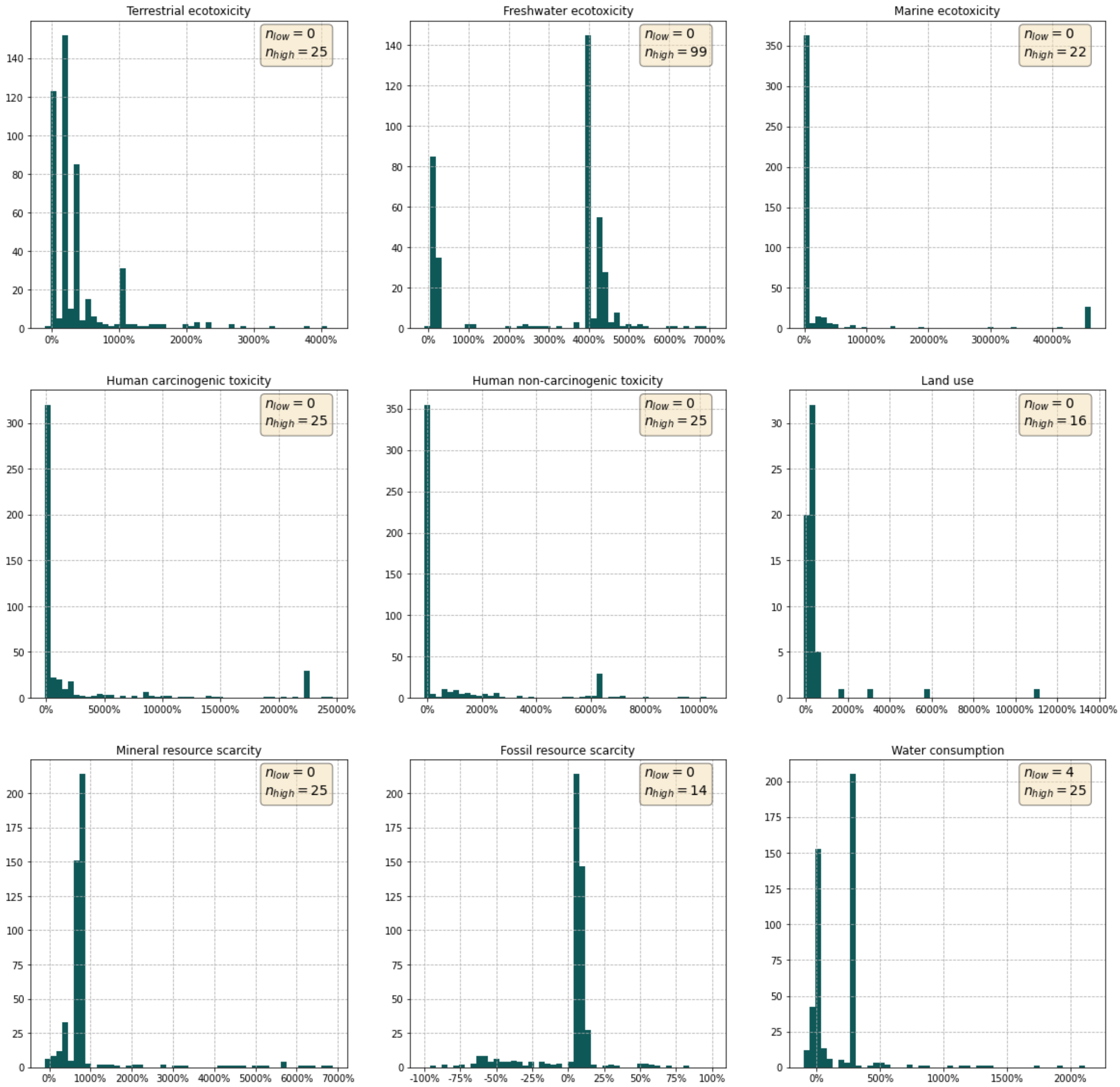

FIGURE A-2 HISTOGRAMS OVER RELATIVE CHANGES FOR IMPACT CATEGORIES, CONTINUED. THE PROCESS FOR BENZENE AND WASTEWATER TREATMENT IN AFP5 (ELCD) AND THE NEW TAP WATER PROCESS FROM AGRI-FOOTPRINT 6 (ECOINVENT) (USED TWICE) HAVE A NEGATIVE IMPACT VALUE IN WATER CONSUMPTION, CAUSING 4 PROCESSES TO BE PLOTTED LEFT OF THE -100% LINE.

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