Guidelines for calculating food supply GHG emissions with the ACE calculator

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Author: Jan Broeze, Wageningen Food & Biobased Research.

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DISCLAIMER:
The developer of this tool checked correctness through comparison with other calculations. However, since the secondary offered in this tool are based on averages the results cannot be expected to exactly predict the GHG emissions and food losses in a specific practical situation.

For further information and recommendations please contact jan.broeze@wur.nl

1 Introduction

The Agro-Chain greenhouse gas Emissions (ACE) calculator is a tool for estimating total greenhouse gas (GHG) emissions associated to a food product. It addresses the most common stages of 'linear' agro-food chains (chains for fresh and simple processed products, including canned, frozen, packaged and other minimal processed forms; the current version cannot cope with fractionation processes). The tool combines a calculation framework with datasets containing crops GHG intensities and Food Loss factors along the chain. Combined with user-definition parameters for the product-chain considered it generates an estimate for GHG emissions associated to a product when bought by a consumer. The default data that the calculator derives from the dataset may be overruled by the user if more specific data are available; this will make the calculations more case specific.

2 Calculator details

The method can be used at relatively little effort. Based on a chain flow diagram (that includes region of production, transport modalities and distances, duration of refrigered and frozen storage, packaging material use and energy use) a spread-sheet can be filled, resulting in estimate of total impact per unit product bought by the consumer.

Table 1. Scope and factors addressed by the calculator

Chain stage	Factors addressed
On-farm	• crop ghg intensity • losses in harvesting, on-field and on-farm post-harvest operations. • fuels use in these operations • on-farm refrigerated storage (inducing electricity use) • on-farm other electricity use
Transport	• transportation distance • transportation modality
Processing and packaging	• losses at this stage (including losses in transport, which are mostly detected at this chain stage) • losses waste management method • refrigerated storage • other electicity use • fuel use • other energy use • packaging material use (plastics, steel, paper, etc.)
Transport *(up to three transportation steps can be chosen here, for instance for intercontinental transport: large truck – cargo sea ship – large truck)*	• transportation distances • transportation modalities • optional refrigeration
Processing/repackaging/distribution activities	(same as in *processing and packaging*)
Distribution transport	• transportation distance • transportation modality • optional refrigeration
Market/Retail outlet	• food waste • waste management • refrigerated storage • other electicity use • fuel use • other energy use

Some parameter values (like transportation distances and packaging material use) will be situation-specific, and should be filled in by the user (if different from 0). For all other parameter values can be derived from data sets in the calculator.

Table 2. Data sets in the ACE calculator

Data set	Description
Crop GHG intensities	Default values for crop GHG intensities, differentiated at global region and country level, derived from review literature and FAO Crop Emission Intensities. These default values are differentiated to global region and crop category.
Production chain dataset	Default values for loss and emission factors in *Agricultural production* and *Processing and packaging* chain stages; differentiated to global region and crop category. Per crop and global regin one option (with typical loss and emission factors per chain stage) or multiple options (for different technology options) are available.
Distribution chain dataset	Default values for loss and emission factors in *Processing/repackaging/distribution* and *Market/retail outlet* chain stages; differentiated to global region and crop category. For many crop category and global region one data record is predefined (with typical loss and emission factors per chain stage), for some multiple entries are listed (for different technology options).
Unit-operations-specific dataset	For a number of crops (current version limited to rice; will be extended) specific default loss factors and fuel/electricity use for unit-operations (like manual harvesting, mechanized harvesting, tradirional threshing, etc.) are given. The values were derived from literature. When selecting a specific unit-operation, default values for that chain stage are overwritten in the scenario study.
Transport modalities	Contains ypical GHG emission factors for various transportation modalities, including non-motorized transport, delivery van, various sizes trucks, electric and diesel cargo trains, inland cargo ships, sea cargo ships, sea container ships and continental and intercontinental air cargo. Values in line with EcoInvent 3 and ecotransit.org (visited December 2018).
Material and fuel emission factors	Emissions associated to various packaging materials and fuel ("well-to-wheel").
Electricity emission factors	Country-specific GHG emission factors for electricity (related to the national electricity mix).
Residue management options	Default emission factors for management of losses (including neglecting emissions due to losses).

The calculator distinguishes 4 levels of data entry:

1. The highest aggregation level contains high-over/average values for crop GHG intensity and loss factors and fuel use along the chain. With only these data fields selected, a full calculation can be done (default no electricity and packaging material use and no transport). Entries are specific for
    - global regions and countries of production and distribution
    - crop type

    When only using this data level, typical average losses and associated GHG emissions in country or region situation are obtained.
2. Per chain stage the user may select a different record (loss factors, fuel use, electricity use, packaging material use, etc.) that is considered more represenative or valid for a specific technology option.

    This data level enables the comparison of typical situations (like comparing manual product handling and mechanized operations).
3. Within a chain stage the user can select individual technology options for unit operations (with loss factors, fuel use, etc., mostly derived from dedicated technology studies).

    This data level supports the analysis of specific interventions.
4. Any lookup value can be overwritten by a user-defined value.

    Through this option chain configurations and technology options with lacking or inadequate data can be defined.

In a scenario study, choosing a dataset at the highest level (level 1) is obligatory; through this choice values are predefined for each parameter in the calculator. Upon selecting a data entry from any of

the other data levels, the concering subset of parameter values are replaced by those (more specific) values.

More background information can be found in Broeze et al. (2019).

3 Calculator worksheets format

The calculator is implemented in Excel, with a set of work sheets:

- Instructions (instructions per field);
- ACE Calculator (this is the actual calculator user-interface);
- GHGI_XXX (contains crop GHG intensity factors for region XXX[1]);
- LossFXXX (contains loss factors and some other emission factors for region XXX);
- TransportModalities (contains emission factors for transportation modalities);
- ResiduesManagmOptions (contains emissions factors for residues management options).

The data sheets for crops are open for editing; when available the user may add a crop with more specific data to enrich his working set.
Also the last two datasheets are user-amendable, for instance for correcting the data to country-specific best-known values or by adding alternative technology options.

[1] We distinguish region groups based on FAO definitions:

- Europe
- Industrialised Asia
- Latin America
- North Africa, West & Central Asia
- North America & Oceania
- South & South-East Asia
- Sub-Saharan Africa

4 Instructions for use of the calculator

ACE calculator
Agro-Chain greenhouse gases Emissions Calculator

Jan Broeze
Wageningen Food & Biobased Research
Version 12 May 2021

Case/scenario title:	Scenario 1: traditional handling		Scenario 2: mechanized	
Marketed food product CLIMATE IMPACT	*8.49 kg CO2-EQ. per kg sold on market*		*6.07 kg CO2-EQ. per kg sold on market*	
FOOD LOSS (lost edible part)	*34.84%*		*8.81%*	
FOOD LOSS ASSOCIATED GHG EMISSIONS	*2.96 kg CO2-EQ. per kg sold on market*		*0.53 kg CO2-EQ. per kg sold on market*	
Moisture and residues loss	*30.75%*		*30.75%*	
Case formulation: product and geographic scope; selection of underlying datasets				
Geographical region (production)	SubSaharanAfrica		SubSaharanAfrica	
Specific country / Electr. GHG emission factor	Nigeria	0.55	Nigeria	0.55
Geographical region (distribution)	SubSaharanAfrica		SubSaharanAfrica	
Specific country / Electr. GHG emission factor	Nigeria	0.55	Nigeria	0.55
Crop category	Rice		Rice	
Production chain data set (loss factors, etc.)	rice: traditional system		rice: combine harvest, industrial storage and milling	
Distribution chain data set (loss factors, etc.)	rice: traditional system		rice: traditional system	
Harvesting and on-field post-harvest operations (optionally: select when different from default)				
(On-farm) Transport				
Postharvest handling and storage (on-farm)				
Transport				
Processing and Packaging				
(Possibly international) Transport				
Processing/repackaging/distribution				
Distribution transport				
Market/Retail shop				
Summary of climate impacts results				

Overview of climate impacts per chain stage	*Direct emissions*	*FLW-associated*	*Total*	*Direct emissions*	*FLW-associated*	*Total*
Harvesting and on-field post-harvest operations	3.830	0.426		3.830	0.118	
(On-farm) Transport	0.000			0.000		
Postharvest handling and storage (on-farm)	0.000	0.411		0.000	0.016	
Transport	0.000			0.000		
Processing and Packaging	0.000	1.095		0.000	0.152	
(Possibly international) Transport	0.000			0.000		
Processing/repackaging/distribution	0.000	0.058		0.000	0.042	
Distribution transport	0.000			0.000		
Market/Retail shop	0.000	0.059		0.000	0.042	
TOTAL (incl. correction for moisture and residues los	*5.531*	*2.957*	*8.488*	*5.531*	*0.535*	*6.066*

Figure 1. ACE Calculator user-interface (all rows with fill-in fields collapsed).

4.1 Scenario comparison

Two scenarios can be compared in the user-interface (arranged in 2 columns). Differences between the scenario configurations are highlighted through colouring of the cells concerned for the second scenario (that is: the right column)

Crop category	Rice		Rice	
Production chain data set (loss factors, etc.)	rice: traditional system		rice: combine harvest, industrial storage and milling	
Distribution chain data set (loss factors, etc.)	rice: traditional system		rice: traditional system	
Harvesting and on-field post-harvest operations (optionally: select when different from default)				
Optionally: select specific crop GHG intensity	Rice Eastern Africa, least developed countries, without defore		Rice Eastern Africa, least developed countries, without defore	
(Comment)				
Crop GHG intensity (kg CO2-eq per kg crop)		3.83		3.83
Optionally derive crop GHG intensity from production global warming potential (per hectare) and crop yield:				
Production global warming potential (kg CO2-eq./ha)		0		0
Crop yield (kg/ha)		0		0
Apply either typical loss factor and total on-farm post-harvest GHG inducing emissions:				
Select data set for on-field operations				
Moisture and residues loss		4.88%		4.88%
Food loss		10.00%		3.00%
Harvesting and postharvest on-field Fuel use (liter per kg product)		0		0
... or select specific operations (expand rows)	Include process for: 1. Harvest, 2. Field drying (optional, default 22 ->18% moisture), 3. Hauling 4. Threshing/winnowing			

Figure 2. Differences between both scenarios are automatically highlighted through colours of cells.

All below instructions apply to both scenario columns.

4.2 Selecting geographic location and crop

Since GHG emission factors and loss factors largely differ amongst global regions, the first step must be choice a region of production, a region of consumption and a crop.
Because GHG emission factors vary amongst countries (related to the energy mix), also the country must be selected here.

ACE calculator
Agro-Chain greenhouse gases Emissions Calculator

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Case/scenario title:	**Scenario 1: traditional handling**
Marketed food product CLIMATE IMPACT	***8.49 kg CO2-EQ. per kg sold on market***
FOOD LOSS (lost edible part)	***34.84%***
FOOD LOSS ASSOCIATED GHG EMISSIONS	***2.96 kg CO2-EQ. per kg sold on market***
Moisture and residues loss	***30.75%***
Case formulation: product and geographic scope; selection of underlying datasets	
Geographical region (production)	SubSaharanAfrica
Specific country / Electr. GHG emission factor	
Geographical region (distribution)	
Specific country / Electr. GHG emission factor	
Crop category	
Production chain data set (loss factors, etc.)	
Distribution chain data set (loss factors, etc.)	rice: traditional system

Europe
IndustrializedAsia
LatinAmerica
NorthAfricaWestCentralAsia
NorthAmericaOceania
SouthSouthEastAsia
SubSaharanAfrica

4.3 Selecting complete sets of loss and emission factors along the chain

At the highest aggregation level high-over/average/typical data sets for all parameters in the scenario are chosen (optionally different sets for the production and distribution phase, because these may be in different regions). .

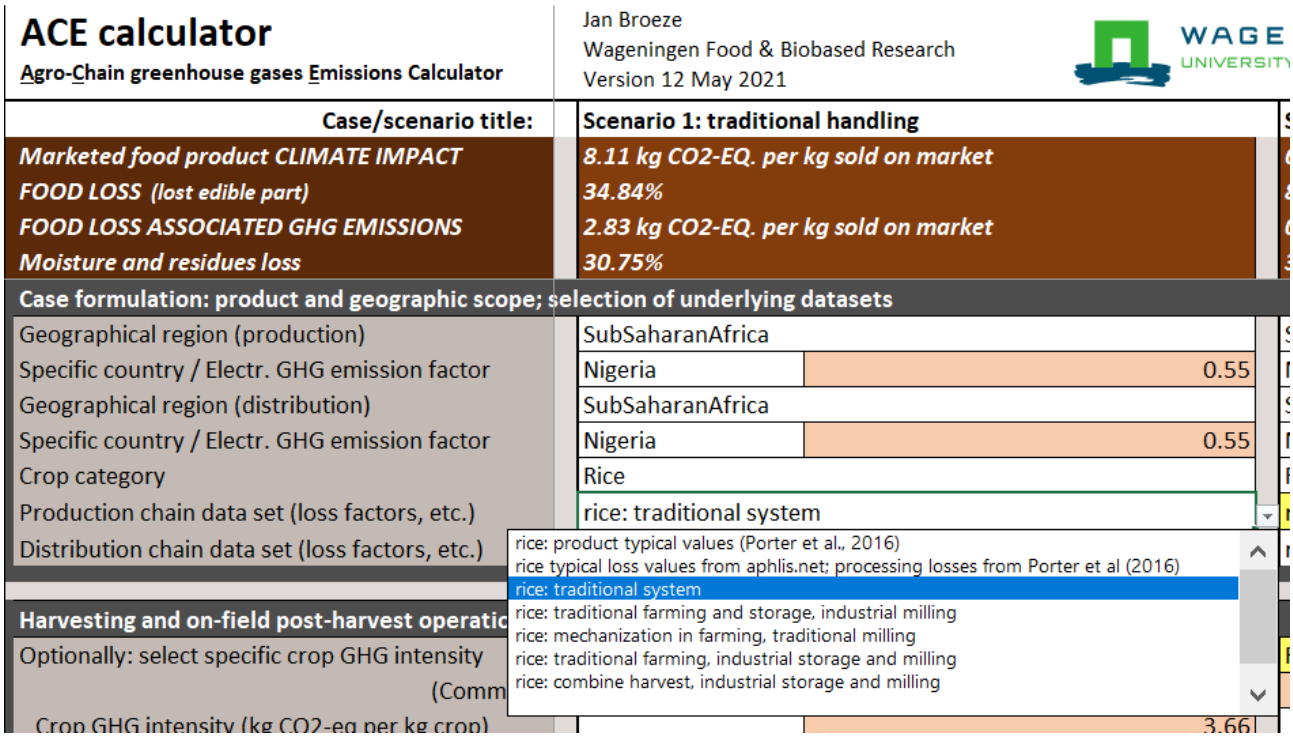

Figure 3. Selecting a level-1 data set for the production chain.

4.4 Selecting an entry for crop GHG intensity

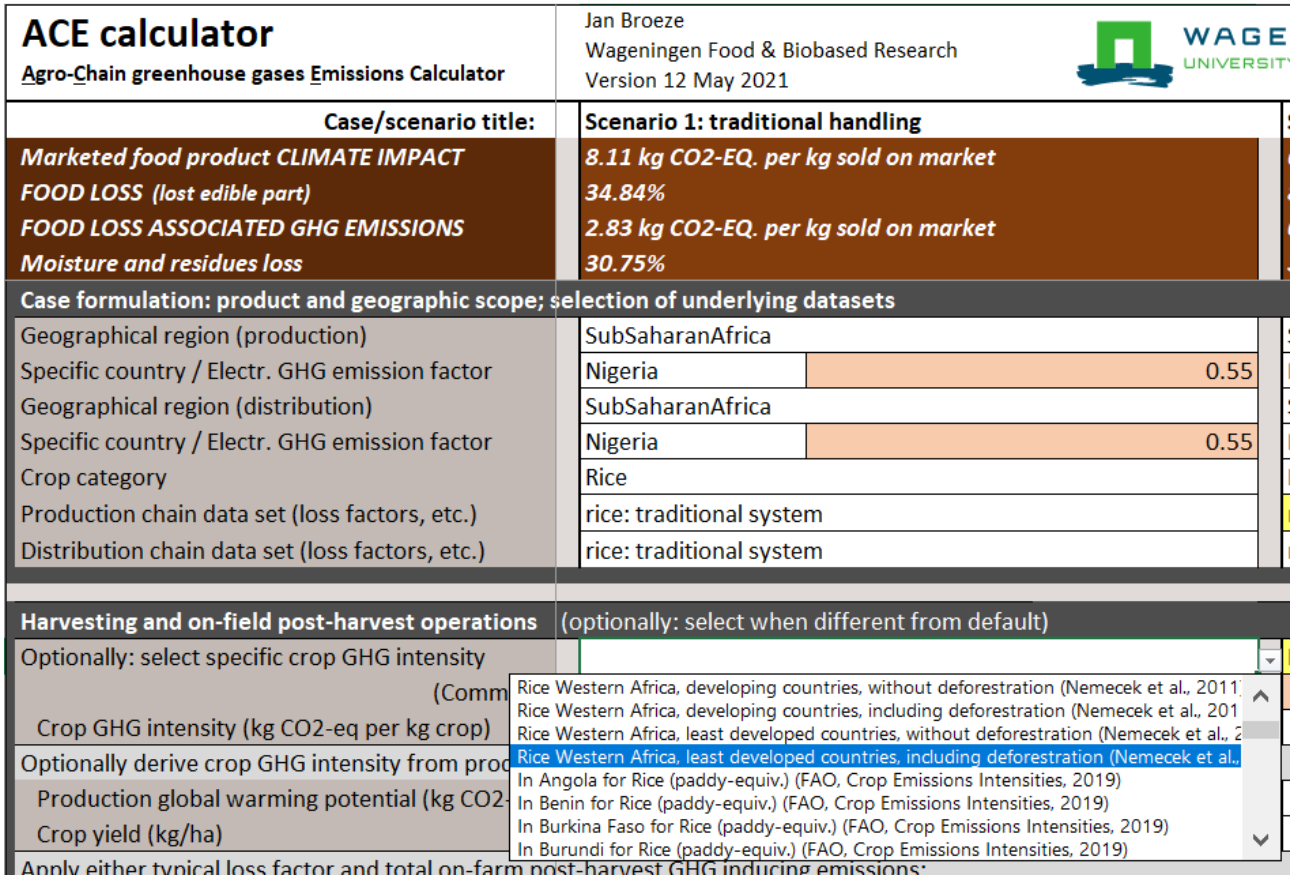

Figure 4. The user may select another GHG intensity factor than the 'default' (default values are derived from Porter et al, 2016).

4.5 Inserting chain configuration data and optionally overrule default parameter values

Subsequently the user can select specific datasets per chain stage (Figure 5) and even overrule individual values (Figure 6).

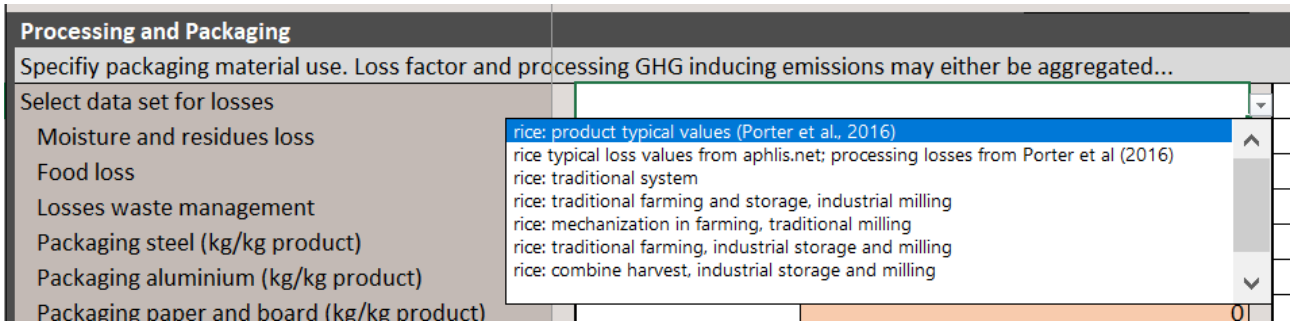

Figure 5. Selecting a specific level-2 data set for the chain stage (when different values apply at this chain stage than in the level-1 data set chosen).

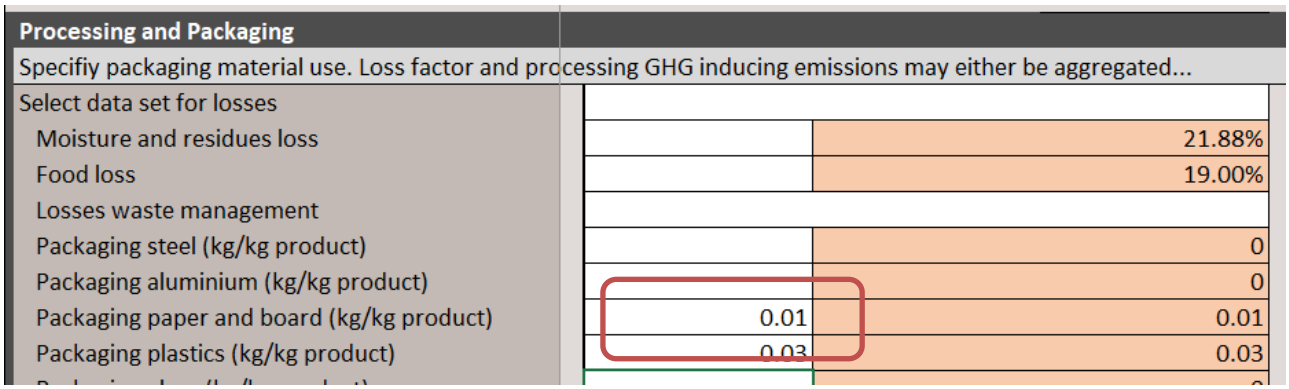

Figure 6. Values adopted from a dataset can be overruled by filing in a value in the white field.

4.6 Results

The results (cumulative climate impact per kg product sold on the market, total losses and total loss-associated GHG emissions) are summarized in the top rows of the calculator (Figure 7). Details per chain stage are presented at the bottom of the calculator (Figure 8).

Figure 7. Summary of scenario results

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Case/scenario title:	Scenario 1: traditional handling	Scenario 2: mechanized
Marketed food product CLIMATE IMPACT	*8.27 kg CO2-EQ. per kg sold on market*	*6.07 kg CO2-EQ. per kg sold on market*
FOOD LOSS (lost edible part)	*34.84%*	*8.81%*
FOOD LOSS ASSOCIATED GHG EMISSIONS	*2.86 kg CO2-EQ. per kg sold on market*	*0.53 kg CO2-EQ. per kg sold on market*
Moisture and residues loss	*30.75%*	*30.75%*

Summary of climate impacts results

Overview of climate impacts per chain stage	*Direct emissions*	*FLW-associated*	*Total*	*Direct emissions*	*FLW-associated*	*Total*
Harvesting and on-field post-harvest operations	3.661	0.407		3.830	0.118	
(On-farm) Transport	0.000			0.000		
Postharvest handling and storage (on-farm)	0.000	0.393		0.000	0.016	
Transport	0.000			0.000		
Processing and Packaging	0.084	1.066		0.000	0.152	
(Possibly international) Transport	0.000			0.000		
Processing/repackaging/distribution	0.000	0.057		0.000	0.042	
Distribution transport	0.000			0.000		
Market/Retail shop	0.000	0.057		0.000	0.042	
TOTAL (incl. correction for moisture and residues loss)	*5.409*	*2.858*	*8.267*	*5.531*	*0.535*	*6.066*

Figure 8. Details of climate impacts per chain stage are given at the bottom of the calculator.

5 References

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