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Environmental footprint of apples: Summary of the representative product study

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Introduction

This document is a summary of a representative product (RP) study carried out in the context of the development of a methodology for calculating the environmental footprints of horticultural products, the HortiFootprint category rules (HFCR, see Helmes et al., 2020). The development of the HFCR was initiated by Royal FloraHolland, Dutch Fresh Produce Centre and Wageningen Economic Research, with co-financing from the Dutch Fund for Horticulture & Propagation Materials, ABN AMRO Bank N.V., the Dutch sector organisation for greenhouse horticulture (Glastuinbouw Nederland), MPS, Rabobank, Foundation Benefits of Nature and in co-production with experts from Blonk Consultants and PRé Sustainability.

This is one of the six studies on horticultural representative products that have been selected based on a wide variety of applied technologies and origins of productions. These are:

- apples (temperate perennial fruit with variability in energy consuming storage and global transport);
- bananas (tropical perennial fruit with variability in energy consuming global transport);
- phalaenopsis (ornamental plant cultivated in two stages, in substrate and in greenhouse);
- roses (perennial plant yielding flower stems, grown in soil in a greenhouse, with and without air transport);
- tomatoes (annual vegetable cultivated in greenhouse, on substrate);
- tulip bulbs (annual crop in soil, grown without greenhouse protection, with ornamental function).

This summary is prepared on the basis of an RP study for assessing the environmental footprint of the complete life cycle of apples, which was completed in 2018.

Goal & scope

The representative product under study is apples. The objectives of this study are:
- To identify the most relevant impact categories, life cycle stages and processes;
- To determine the data (quality) requirements;
- To support the development of the HFCR; an earlier draft of the HFCR was tested to check the draft HFCR for completeness and clarity, and to check the feasibility of completing a study in accordance with the draft HFCR.

The system boundaries of the study include the cultivation of apples (in the Netherlands or in New Zealand), packaging, land and maritime transport, distribution, retail via a Dutch supermarket and consumption in the Netherlands. The reference flow is 1 kg of apples as weighed just after packaging (excluding the packaging weight). The apples are grown by planting propagation material on a prepared orchard and the crop is then managed with fertilisers, water and pesticides. After harvest the apples are stored at 1^{o}C, packed and transported to retail, then consumed and the packaging and excess organic material is treated at disposal.

Data collection and modelling

Foreground data was collected from literature. Data was used from several peer-reviewed LCA studies. For the field phase, data from the FAO was also used. For storage, retail and the use stage, datasets were created using default data for these processes using the PEFCR guidance documentation.

The following key methodological choices and assumptions were made:
- The inventory of the pre-productive phase was taken from the background database where the reference flow of 1 tree, a planting density of 2,800 trees per hectare and a productive phase of 15 years was assumed (CBS, 2018).
- The apple yields are based on 5-year average national statistics and the important cultivation inputs are based on a mix of sources: fertilisers from Goossens et al. (2017), field operations from Notarnicola et al. (2017), crop protection from Keyes et al. (2015).
- Nutrient balances were calculated according to the PEF Guidance v6.3 (EC, 2018).
- No land use change was assumed for apples in the Netherlands and New Zealand, because the harvested area of apples in these countries did not increase in the past 20 years.
- An average storage time of 150 days was assumed based on Blanke and Burdick (2005).
- The cooling energy requirement was assumed to be 0.7 kWh per tonne per day as an average reported by the Dutch fruit growers organisation (Nederlandse Fruittelers organisatie, 2010).
- Packaging was modelled using GroentenFruit Huis (2018) and Davis et al. (2011).
- Distribution was modelled by conservatively assuming transport distances for the Dutch and New Zealand situation. The transport modes for New Zealand apples were truck to the port, boat to the Netherlands, truck in the Netherlands.
- It was assumed that 10% of the harvested apples are not consumed due to losses during cooling, packaging, distribution and retail, and 19% during consumption (according to OEFSR Retail).
- It was assumed that 62% of the apples are transported by the consumer by passenger car and 5% are delivered by the retailer to the consumer (according to OEFSR Retail).
- It was also assumed that 5% of the harvest weight is moisture loss during cooling and packaging.
- It was assumed that the apples are mainly consumed raw.

For the background data, ecoinvent v3.4 cut-off (Wernet et al., 2016) was used, among others for end of life. The circular footprint formula (EC, 2018) was implemented using processes from this background database. The EF Life Cycle Inventory (LCI) database could not be used, because the original study was not part of an official PEF pilot by the European Commission, as it was conducted before the current transition phase. The conclusions in this study and the aims this study can be used for have been drafted in such a way to ensure validity (see disclaimer). The modelling was done in SimaPro version 8.5.2, following the PEF rules at that time (EC, 2018). The impact assessment was done using the EF Impact Assessment Model version 2.0.

Most relevant impact categories, life cycle stages and processes

The **most relevant impact categories** for apples cultivated in the Netherlands or New Zealand, which contribute cumulatively to at least 80% of the normalised and weighted life cycle results of this study, are:

- Climate change;
- Resource use, energy carriers;
- Terrestrial and freshwater acidification;
- Respiratory inorganics;
- Land use;
- Eutrophication terrestrial;
- Resource use, mineral and metals;
- Photochemical ozone formation, human health impacts;
- Freshwater ecotoxicity (not included in the weighted results, but considered as relevant due to the perceived importance of the environmental impact of pesticides).

The **most relevant life cycle stages** are cultivation, post-harvest handling, packaging, distribution (only in the case of apples from New Zealand) and consumption (only in the case of apples from the Netherlands).

Figure 1 and Figure 2 show the contribution of the apple life cycle stages to the relevant impact categories. From this we observe that the most relevant life cycle stages of the studied apples are:

- Cultivation
- Post-harvest handling
- Packaging
- Distribution (only in case of apples from New Zealand)
- Consumption (only in case of apples from the Netherlands).

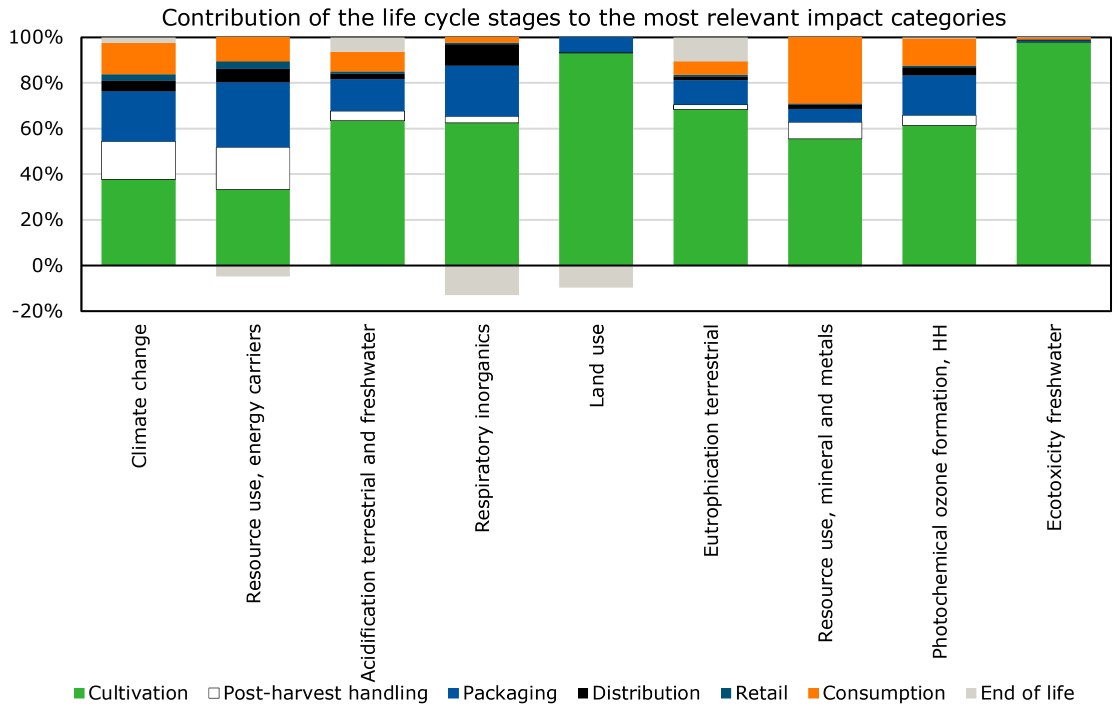

Figure 1 *Contribution of the apple life cycle stages to the relevant impact categories for apples cultivated in the Netherlands*

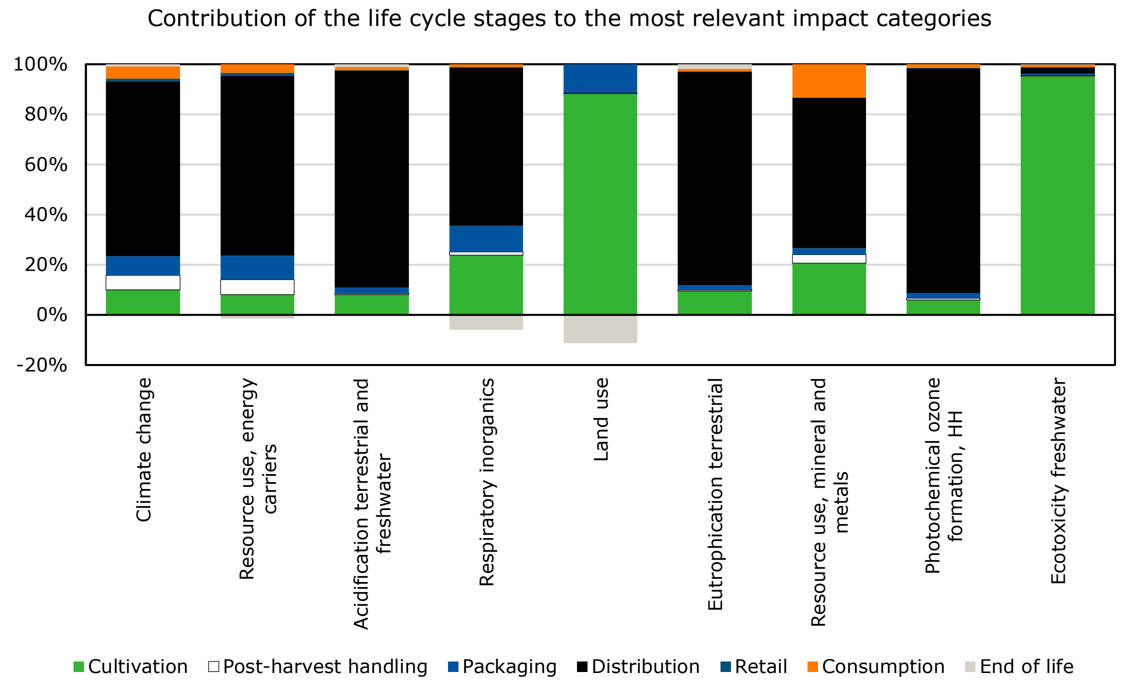

Figure 2 *Contribution of the apple life cycle stages to the relevant impact categories for apples cultivated in New Zealand*

The most relevant processes and most relevant elementary flows are shown in Table 1 and Table 2, respectively.

Table 1 *The most relevant processes contributing in total to at least 80% of the impact of one or more relevant impact categories*

Process	Life cycle stage	Cultivated in the Netherlands	Cultivated in New Zealand
Ammonium nitrate, as N {RER}|	Cultivation	x	x
Apple, at grower	Cultivation	x	x
Fertilising, by broadcaster {GLO}|	Cultivation	x	x
Pesticide, unspecified {RER}|	Cultivation	x	x
Trellis system {GLO}|	Cultivation	x	x
Electricity, low voltage {NL}|	Cultivation, post-harvest handling, retail, end of life	x	
Establishing orchard {GLO}|	Cultivation	x	
Phosphate fertiliser, as P2O5 {GLO}|	Cultivation	x	
Planting tree {GLO}|	Cultivation	x	
Transport, passenger car {RER}|	Cultivation	x	x
Heat, centr./small, nat. gas {RER}|	Post-harvest handling	x	x
Sulfate pulp {RoW}|	Cultivation	x	x
Absorption chiller, 100 kW {GLO}|	Post-harvest handling	x	
Corrugated board box {GLO}|	Packaging	x	x
HDPE, granulate {GLO}|	Packaging	x	
Transport, lorry >32 mt, E6 {GLO}|	Distribution		x
Transport, ship, cooling {GLO}|	Distribution		x
Transport, lorry >32mt, E6 {GLO}|	Distribution	x	
Transport, passenger car {RER}|	Consumption	x	x
Biowaste {NL}| treatment	End of life	x	
Municipal waste collection {CH}|	End of life	x	
Waste PE {Europe}| incineration	End of life	x	

Table 2 *Most relevant elementary flows contributing in total to at least 80% of the impact of one or more relevant impact categories*

Elementary flow	Emission compartment	Cultivated in the Netherlands	Cultivated in New Zealand
Carbon dioxide, fossil	Air	x	x
Dinitrogen monoxide	Air	x	x
Oil, crude	Raw	x	x
Gas, natural/m^3	Raw	x	x
Coal, hard	Raw	x	x
Cadmium	Raw	x	x
Gold	Raw	x	x
Lead	Raw	x	x
Iodine	Raw	x	x
Copper	Raw	x	x
Ammonia	Air	x	x
Nitrogen oxides	Air	x	x
Sulfur dioxide	Air	x	x
Particulates, < 2.5 um	Air	x	x
Occupation, permanent crop, irrigated	Raw	x	x
Occupation, forest, intensive	Raw	x	x
Captan	Soil	x	x
Pyrene	Water	x	x
Chlorpyrifos	Soil	x	x
Ziram	Soil	x	x
Chlorpyrifos	Water	x	x

Data quality requirements

This study also aimed at identifying the data collection and data quality requirements to ensure robust and high-quality results for similar horticultural products. The requirements determined on the basis of this study are displayed in Table 3.

Table 3 *Data quality requirements resulting from the insights provided by the apples RP study*

Life cycle stage	Data collection needs	Data quality requirement (DQR)
Cultivation	Amounts of inputs and elementary flows	$\leq$1.6: Very good to excellent quality
Post-harvest handling	Amounts of inputs and elementary flows	$\leq$1.6: Very good to excellent quality
Packaging	Amounts of components of primary packaging	$\leq$1.6: Very good to excellent quality
	Amounts of all other inputs and elementary flows	$\leq$3.0: Good quality
Distribution	Distance and transport mode	$\leq$1.6; Very good to excellent quality
Retail	Generic data allowed	$\leq$3.0: Good quality
Consumption	Generic data allowed	$\leq$3.0: Good quality
End of life	Percentages and types of waste treatment, generic data allowed	$\leq$3.0: Good quality

Disclaimer

The screening is NOT intended to make statements about the product group impacts as such, nor is it intended to be used in the context of comparison or for comparative assertions to be disclosed to the public. The results can be used to see where potential hotspots are by looking at the most relevant impact categories, life cycle stages, processes and elementary flows.

In practice there is a significant variety in apple production especially with respect to field operations and storage, dependent on the timing of cultivation as well as consumption. In many cases energy use for cultivation and storage will vary year by year due to weather conditions and economic developments. So, the absolute results of the current cases cannot be regarded as representative of the large variety in practice, but it is expected that the general conclusions on the hotspots and the resulting data quality requirements will apply to Dutch and New Zealand apples in general.

Acknowledgement

This study was carried in the framework of the public-private partnership project HortiFootprint 'Methodology for environmental footprint TU17005' for the Topsector Agri & Food, as part of the Programme 'Consumer, Market and Society'. The authors would like to thank Marisa Vieira from PRé Sustainability for a review of the draft representative product full study and a study group from the Dutch Fruit Producer Association (NFO) for insightful discussion of the results in March 2019.

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2020-041d