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Life Cycle Assessment Cut Roses

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List of abbreviations

A	year
Av.	Average production
CBS	Central bureau for statistics
CH	Switzerland
CHP	Combined Heat and Power system
Femto	one quadrillionth (10^{-15})
FT	Fairtrade
IPCC	Intergovernmental Panel on Climate Change
K_2O	Potassium oxide (unit of measure for potassium content in fertilizers)
KE	Kenya
MGB	Migros-Genossenschafts-Bund
N	Nitrogen
NL	The Netherlands
P_2O_5	Phosphorpentoxid (unit of measurement for phosphate content in fertilizers)
PDF	Potentially disappeared fraction
RE	Renewable energy
tkm	Ton kilometres

1 Executive Summary

The present study aims to determine the environmental impacts of different production systems for cut roses. It compares the production of Fairtrade roses from Kenya transported by ship and by air and roses produced in Holland. Additionally, for the roses in Holland, an assessment of the use of geothermal heat was carried out. The agricultural production in the country of origin, the packaging of the roses and their transport to Switzerland are taken into account.

For the Dutch roses, the key figures for agricultural production were compiled from literature data. The key data on the agricultural production of Fairtrade roses were collected directly from producers using the HortiFootprint Calculator developed by MPS.

Overall, Fairtrade roses from Kenya show the lowest impact across all environmental impacts analyzed, while the differences are largest regarding cumulative energy demand, greenhouse gas emissions and freshwater eutrophication.

The energy use for greenhouse heating and artificial lighting for the roses produced in the Netherlands dominate the cumulative energy demand as well as the greenhouse gas emissions while for the Kenyan roses it is the transport of the roses produced. The cumulative energy demand ranges from 19 MJ per bunch for Kenyan roses transported by ship to 414 MJ for average Dutch roses. The greenhouse gas emissions of Dutch roses are 27 kg CO_2-eq per bunch, the impact of Fairtrade roses transported by air is 2.9 times and roses transported by ship is 21.4 times lower, respectively.

The water footprint is dominated by the agricultural stage in both systems. For Dutch roses the water footprint (7.9 m^3 water equivalent) is dominated by the electricity generation while in Kenya (2.8 and 2.9 m^3 water equivalent) the water use for irrigation is crucial due to the high water scarcity in this country. In terms of biodiversity loss all production stages show a relevant impact. The biodiversity loss caused by the production of Dutch roses is approximately twice as high (16.9 femto-PDF per year and bunch) as from the Fairtrade roses. For all production system the cardboard packaging, the provision of biodiesel in transport and in the Netherlands additionally the electricity production is dominating the impact.

For both systems acidification is mainly caused by fossil fuel combustion, in the Netherlands for greenhouse heating during the agricultural stage (0.026 kg SO_2-eq per bunch of roses) and for Fairtrade roses from Kenya during transport (0.006 kg SO_2-eq per bunch of roses transported by ship). Regarding aquatic eutrophication in the Dutch production system energy provision is the dominant driver. For the Fairtrade roses freshwater eutrophication is mainly caused by phosphate emissions during the production and disposal of inputs and marine eutrophication by nitrate emissions due to fertilizer use. The resulting impact of Dutch roses on freshwater eutrophication is 14 times higher than for the Fairtrade roses transported by air. Regarding marine eutrophication Fairtrade roses transported by air show a 19% lower impact than Dutch roses.

In terms of amount used, pesticide use is lowest for Dutch roses. However, the amount used does not reflect the effect of the pesticides in the environment and therefore does not indicate the environmental impact.

In general, it can be stated, that for most impact categories, including primary energy demand and greenhouse gas emission, for Fairtrade roses from Kenya the transport stage and for Dutch roses the agricultural stage is dominant, where in both cases fossil fuel combustion is a major driver.

For the Dutch rose production, a significant increase in the energy efficiency must be reached in order to reduce fossil energy demand to a similar or lower level as the roses from Kenya flown in. Also, switching to renewable energy sources should be explored further. Due to the large share of energy from fossil sources in the Dutch electricity mix, it is a prerequisite to not only switch to renewable heat sources but also to renewable electricity to significantly reduce the environmental impact.

Transporting the Fairtrade roses by ship would certainly improve the overall environmental footprint except for the impact on biodiversity and could be established as a transport mode. Another possible measure to further minimize the environmental impacts of cut roses is the optimization of the packaging in terms of material weight or the use of recycled carton/paper. Regarding the water footprint improving water efficiency in the Kenyan production system is central. Possibilities are e.g. the collection of rainwater or the recycling of used water.

2 Introduction

2.1 Background

The Migros-Genossenschafts-Bund (MGB) in cooperation with Fairtrade Max Havelaar would like to determine the environmental effects of cut roses of different origins and production systems. For this purpose, an ecological study of Fairtrade cut roses from Kenya (using five different Fairtrade certified farms as an example) and average cut roses from Holland has been carried out. The analysis takes into account both rose production in the country of origin and the packaging and transport of roses to Switzerland. Additionally to air freight, the environmental effects from Fairtrade Max Havelaar roses from Kenya transported to Switzerland by ship and lorry was determined.

2.2 Objectives

This study is based on the previous study by Alig & Frischknecht (2018) and is aimed at providing updated information on the environmental impacts of cut roses from Holland and Kenya. The agricultural production in the country of origin, the packaging of the roses and their transport to Switzerland are taken into account.

A total of three production systems are compared: Fairtrade roses from Kenya transported by plane or by ship and average roses from Holland.

3 Data basis and key figures

3.1 Investigated production systems and data basis

Table 1 shows an overview of the investigated production systems and the data used for the life cycle inventories of rose production. For the average Dutch roses, the key figures for agricultural production were compiled from literature data[1]. The key data on the agricultural production of Fairtrade roses were collected directly from the producers using the HortiFootprint Calculator developed by MPS. Five companies were surveyed for the Fairtrade roses.

The data was supplemented using further literature data as indicated in Table 1. The review study by Lan et al. (2022) shows that this currently was the most recent data available from scientific research.

Table 1: Overview of the production systems examined, and the data basis used for them, including an assessment of data quality.

Production system	Abbreviation	Data basis	Assessment Data quality [2]
Fairtrade roses Kenya	KE FT air / ship	HortiFootprint Calculator Consuming Water use: Mekonnen & Hoekstra, 2010	Good
Average roses Holland	NL av.	Raaphorst, et al., 2019, supplemented with information from Torrellas et al., 2012	Good

3.2 Key figures production systems

This chapter outlines the different production systems in more detail. The main characteristics and the used production resources are summarized in Tables 2 and 3. The impact of differences in the data basis on the results of the production systems are discussed in section 5.1.

Average roses from Holland
Data basis:
The production data for the average roses grown in Holland stem from Raaphorst et al. (2019) with some additional information from personal communication with the author. The data from Raaphorst et al. include the key figures of the production of two rose species (Rose Avalanche, Rose Red Naomi) in the Netherlands. The data provides a global view of greenhouse horticulture including different production systems, therefore represents average production of the two rose species in the Netherlands. An unweighted average of the data from the cultivation of the two rose species was used for the inventory. Missing information in the inventory was completed with data from Torrellas et al. (2012). This includes the construction and deconstruction of the greenhouses. The information on

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[1] The study relies on literature data for the Dutch production system, as no Dutch rose producers could be identified who wanted to participate in this study.

[2] The assessment of data quality refers to the representativeness of the data for the respective production system

packaging of the rose bunches for transport and distribution stem from Franze & Ciroth (2011), since no recent data was available. Pesticide use was taken from the Central bureau for statistics (CBS) in the Netherlands[3].

System description:
All roses are grown in greenhouses. In the Netherlands, Venlo greenhouses made of a metal structure and glass walls with a life span of 14 years are used. The roses are grown in trays filled with rockwool or coco and have a life span of about 8 years. The considered roses produced in the Netherlands have an average weight of 55 g (50 – 60 g) per stem. In a year, about 328 flowers per m^2 can be harvested. All roses are irrigated with a closed-loop drip water irrigation system.

The comparably high yields in the Dutch rose production are a result of the use of artificial light (HPS lighting) and heating of the greenhouses, which also leads to a high energy consumption. For most greenhouses a combined heat and power (CHP) system for the production of thermal energy and electricity is used. As some growers using a CHP produce more electricity than they need, they feed the excess electricity into the grid. But for other growers the own production cannot fully cover the electricity demand and the remaining power is drawn from the grid. In order to avoid an allocation to account for the excess electricity, the amount of electricity fed into the grid is subtracted from the purchased electricity, indicating the net electricity demand covered with electricity drawn from the grid.

The fertilizer input stated for the Dutch production reflects the average fertilizer use in cut flower production but can be expected to be also representative for average cut roses. However, because of the high artificial lighting in the rose production described, the use of nutrients might be higher as well. The input of potassium fertilizer makes up the largest share on the total fertilizer input. Also, nitrogen fertilizer makes up a significant share whereas phosphorus fertilizer input is small.

The data on pesticide use taken from CBS indicate the average amount of effective substances used in the production of roses in greenhouse horticulture in the year 2020, showing that Dutch producers mainly apply fungicides and some insecticides. No acaricides are applied.

Water demand in the Netherlands is rather small. Only the ground and surface water used was included in the consumptive water use. Dutch law requires a rainwater reservoir covering over half of the water demand, resulting in a consumptive water use of approximately 1.5 kg per rose harvested.

To investigate the potential of using renewable heating energy, the use of geothermal heat instead of natural gas for production was analysed. The main assumptions and results of this variation of the Dutch rose production can be found in Appendix A1.

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[3] http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=82886NED&D1=0-2,4-15&D2=a&D3=68&D4=a&HDR=T&STB=G1,G2,G3&VW=T; last visited on 15.01.2023

Fairtrade roses from Kenya
Data basis:
The production figures for Fairtrade roses in Kenya were collected directly from Fairtrade certified producers using the HortiFootprint Calculator[4] in early 2023. The Fairtrade certified farms are located within a maximum radius of 200 km around Lake Naivasha. For the calculation of the key figures, the mean value from the production data of each of the five producers were used.

The Fairtrade roses are grown in plastic tunnels with metal tubes. The metal structure has an average life span of 24 years, the plastic cover is replaced every 3 years. The yield[5] is 153 roses/m^2. Some of the farms use a coco substrate for plantation. Drip irrigation systems with mostly surface water is the most common irrigation system, but also some groundwater and rainwater is used.

As the greenhouses are not heated, the energy demand per flower harvested is low. Electricity is the most important energy source.

The use of fertilizer is generally higher than in the Dutch production. However, a large proportion of the fertilizer is indicated as unspecified fertilizer, including fertilizers with a variable composition like organic fertilizers, manure, etc. This amount is not provided in active ingredients but in total amount of fertilizer applied. The amounts are therefore not directly comparable. Pesticide use was not reported in detail for Fairtrade roses. Across all pesticides, Fairtrade roses apply more pesticides per harvested rose than the average production in the Netherlands.

Table 2: Key data of the investigated production systems

		NL av.	KE FT air/ship
Type of production		Heated greenhouse, glass	Plastic tunnel with metal tubes, non-heated
Number of plants per square metre	Plants/m^2	8.45	7.60
Life span of rose plants	Year	8.0	6.3
Yield	Flowers/m^2*year	328	153
Weight per flower	g/Flower	55	25
Proportion of substrate-based systems	%	100%	40%
Type of substrate		Rockwool[6]	Cocos
Irrigation system		Drip irrigation, closed circuit	Drip irrigation
Origin of water for irrigation		Rainwater tank & groundwater/surface water	Mostly surface water, some ground- and rainwater

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[4] https://www.hortifootprintcalculator.com/

[5] The yield per square metre is primarily dependent on the type of roses produced and does not reflect the efficiency of a farm. The higher the quality of the roses, the less flowers per square metre are harvested.

[6] Roses in the Netherlands are grown on rockwool as well as on coir (coco), for this study only rockwool is considered as a substrate.

Table 3: Use of production resources per harvested rose in the investigated production systems

		NL av.	**KE FT air/ship**
Seedlings	#	0.003	0.011
Substrate amount	g	0.743	2.705
Energy needs			
Electricity purchased	kWh	1.143	0.021
Electricity purchased from renewables	kWh	0	0.001
Heat purchased	kWh	0	0
Natural gas	m^3	0.210	0
Diesel	l	0	0
Petrol	l	0	0
Fertiliser Use			
N	g	0.294	1.044
P_2O_5	g	0.050	0.357
K_2O	g	0.433	1.262
Unspecified Fertilizer	g	0	3.039
Pesticides Use			
Insecticides	g	0.002	0
Fungicides	g	0.013	0
Herbicides	g	0.000	0
Acaricide	g	n.a.	0
Nematicides	g	n.a.	0
Hydrogen peroxide	g	0	0.001
Unspecified	g	0	0.152
Material Greenhouses			
Aluminium	g	0.8	0
Steel structure	g	3.2	0.972
Plastic sheeting (LDPE)	g	0	1.098
Glass sheet	g	2.9	0
Polyesters	g	0.3	0
Concrete	m^3	1.0E-06	0
Watering			
Water demand	l	3.10	12.3
Consuming use	l	1.50	5.1
Waste material			
Biowaste	g	12.83	22
Plastic	g	0.24	0.010
Substrate	g	0.74	0.002
Empty chem. container		0	0.308
Effluent water	l	0	7.2
Land occupation	m2*a	0.003	0.007

3.3 Packaging

The amount of packaging material per bunch of roses and the energy use for the cooling rooms for the Dutch roses were taken from Alig & Frischknecht (2018) and stem from Franze & Ciroth (2011), since no more recent and specific information was available. For the Fairtrade roses, detailed recent information from the producers on packaging material was available, the electricity consumption for cooling rooms was used from Fairtrade producers surveyed for the study from Alig & Frischknecht (2018).

In Kenya, the roses are wrapped in a corrugated cardboard and secured using a rubber band. The bound and secured bouquet is wrapped in a thin plastic wrapper. About 25 of the bouquets are then arranged in the transportation/export box made of cardboard. In the Netherlands, 20 roses are packaged to a bouquet with plastic. Then the bouquets are boxed into a cardboard container. Table 4 shows the amount of packaging material used for each system. The impact of differences in the data basis on the results are discussed in section 5.1.

Table 4: Amount of packaging material used for one packaging unit containing 25 bouquets à 20 roses

		KE FT air/ship	NL av.
Plastic	g	313	1250
Paper	g	202	0
Cardboard	g	2368	3125
Electricity for cold rooms	kWh	4.7	12.5

The packaging paper was modelled with a life cycle inventory for unbleached kraft paper made of fresh fibres, the cardboard was modelled with a life cycle inventory for a corrugated cardboard box made of fresh and recycled fibres.

3.4 Transport

Generally, overseas transports are made by air. For the Kenyan Fairtrade roses two different systems that differ in the mode of transport were investigated. In the first system the Fairtrade roses are transported by air and in the second system they are transported by sea freight in refrigerated containers. Delivery from the farm to the airport or to the port and from the airport or port in Holland to Switzerland is by refrigerated truck. The distances and ports were determined using the EcoTransIT calculator[7]. Table 5 shows an overview of the means of transport used and the transport distances taken into account.

Roses from Kenya transported by air are shipped from Jomo Kenyatta International Airport in Nairobi. The Fairtrade roses that are transported by ship are transported via port Mombasa and Amsterdam to the distribution center in the Netherlands. No specific information on post-harvest treatment or additional pesticide application of roses transported by sea was available.

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[7] http://www.ecotransit.org/index.en.html

Table 5: Overview of the transport routes taken into account in the life cycle assessment, the means of transport used and the transport distances.

Transport route	Means of transport	Transport distance (km)		
		NL	KE Air	KE Ship
Farm – Airport/ Harbour of origin	Refrigerated truck	-	90	565
Airport/ Harbour of origin – Airport/Harbour (NL)	Aircraft / ship	-	6772	11721
Airport/ Harbour (NL) resp. Farm (NL) - Distribution Center Aalsmeer (NL)	Refrigerated truck	169	8	24
Distribution Center Aalsmeer (NL) - Zürich (CH)	Refrigerated truck	778	778	778

3.5 Background data

The background data for the processes downstream of agriculture (packaging, transport) are based on the KBOB Life Cycle Assessment database DQRv2:2022 (KBOB et al. 2022).

3.6 Impact assessment

The impact assessment methods were selected in accordance with the ILCD Handbook (Hauschild et al. 2011) and the recommendations of the Life Cycle Initiative (Frischknecht & Jolliet 2017). The following impact assessment methods were evaluated:

- Cumulative energy demand, non-renewable according to Frischknecht et al. (2015)
- Greenhouse gas emissions according to IPCC (2021)
- Water scarcity due to the consumptive use of freshwater resources according to AWARE (Boulay et al. 2017; regionalized evaluation)
- Biodiversity loss through land use according to Chaudhary et al. (2015; regionalized evaluation)
- Terrestrial acidification according to ReCiPe (Huijbregts et al. 2016)
- Marine and freshwater eutrophication according to ReCiPe (Huijbregts et al. 2016)

The cumulative energy demand (CED) reflects the input of primary energy resources (natural gas, crude oil, hard coal, lignite, uranium, biomass, hydropower etc.), which are necessary for the supply of the final energy (fuels, electricity, district heating), including the energy content of the fuels.

For the global warming potential, the additional warming effects of the stratospheric emissions from aircrafts are taken into account according to the method of Fuglestvedt et al. (2010) and Lee et al. (2010). Allocated to the emission of one kilogram of CO_2 emitted by an aircraft, the global warming potential of the vapor trails generated by aircraft, the induced clouds and the water vapor emitted is 0.95 kg CO_2-eq. The global warming potential of CO_2 emissions from burning kerosene by aircrafts is thus 3.14 kg CO_2-eq/kg, resulting in an RFI of 2.5 (equal to the RFI used by the KBOB (2022)).

In the case of water scarcity, only the consumptive use of water from surface waters or groundwater (blue water consumption) is considered.

The indicator biodiversity loss quantifies the long-term potential loss of species (probability of irrevocable extinction) in amphibians, reptiles, birds, mammals and plants by using an area as farmland, permanent crop, pasture, intensively used forest, extensively used forest or settlement area. The potential loss caused by a specific use of an area is determined in comparison to the biodiversity of the natural state of the area in the region concerned. The indicator takes into account the vulnerability of species and weights endemic species higher than species that are common. The biodiversity footprint is expressed in equivalents of potentially globally disappeared species years per 1000 trillion species (femto-PDF·a). It covers the main cause of species loss, land use. Other drivers of biodiversity loss, such as climate change and nitrogen and pesticide inputs, are not taken into account.

The categories "water consumption" and "biodiversity loss" were considered on a regional basis, i.e. the national shortage situation and the national impacts of land use were taken into account. This means, for example, for the water footprint, that one litre of water consumption in Holland, a country with low water scarcity, is rated less strongly than one litre of water consumption in Kenya, a country with a comparatively higher water scarcity.

For the impact category terrestrial acidification, the acidification potential of pollutants in the atmosphere and the soils are quantified and expressed in SO_2-equivalents. Terrestrial acidification impairs the growth of a plants that do not tolerate a lower ph-value.

Eutrophication is also known colloquially as "overfertilisation" and refers to the input of nitrogen into the environment. This causes a wide range of problems. Depending on the place where the eutrophic effect takes place, different indicators are distinguished. Marine eutrophication quantifies the amount of nitrogen that potentially enters the oceans through the emission of nitrogen compounds into water, air and soil and contributes to overfertilisation there. Freshwater eutrophication refers to phosphorus emissions which contribute to the overfertilisation of inland waters.

The calculation of the aquatic ecotoxicity and human toxicity according to USETox (Rosenbaum *et al.* 2008) was omitted, as this evaluation would only have provided an incomplete picture of the environmental impact. On the one hand, data on the active pesticide ingredients used are incomplete. On the other hand, the active pesticide ingredients used in the Fairtrade production are only partly covered by USETox. Additionally, there were only very rough assumptions available on the fate in the environment of the pesticides applied.

The calculations were made with the software SimaPro 9.3.0.3 (PRé Consultants 2021).

4 Results

4.1 Overview

In the following subchapters, the results for the seven environmental indicators analysed are shown: Cumulative energy demand in subchapter 4.2, greenhouse gas emissions in subchapter 4.3, water scarcity footprint in subchapter 4.4, biodiversity loss in subchapter 4.5, terrestrial acidification and aquatic eutrophication in subchapter 4.6 and 4.7, respectively, and pesticide use in subchapter 4.8. All results are shown per bunch of 20 roses.

The results are shown for the three stages of agricultural production, packaging and transport. The agricultural stage includes the growing and harvesting of the roses with the associated consumption of resources and emissions. The packaging stage includes the cooling of the roses after harvest as well as the production of the packaging material. The transport stage includes all transports from the farm to Switzerland (Zurich).

4.2 Cumulative energy demand

The non-renewable cumulative energy demand is between 19 MJ (roses KE FT ship) and 414 MJ (NL av.) per bunch of roses. The energy demand of the average roses from the Netherlands is 6.4 and 22 times higher than the energy demand of the Kenyan roses transported by air and by ship, respectively (Figure 1). This is due to the energy demand for greenhouse heating and artificial lighting in the Dutch production. Fairtrade certified producers do not heat their greenhouses and they do not use lighting to grow their plants. The energy demand of Fairtrade roses transported by ship is 70% lower than the one of the Fairtrade roses transported by air.

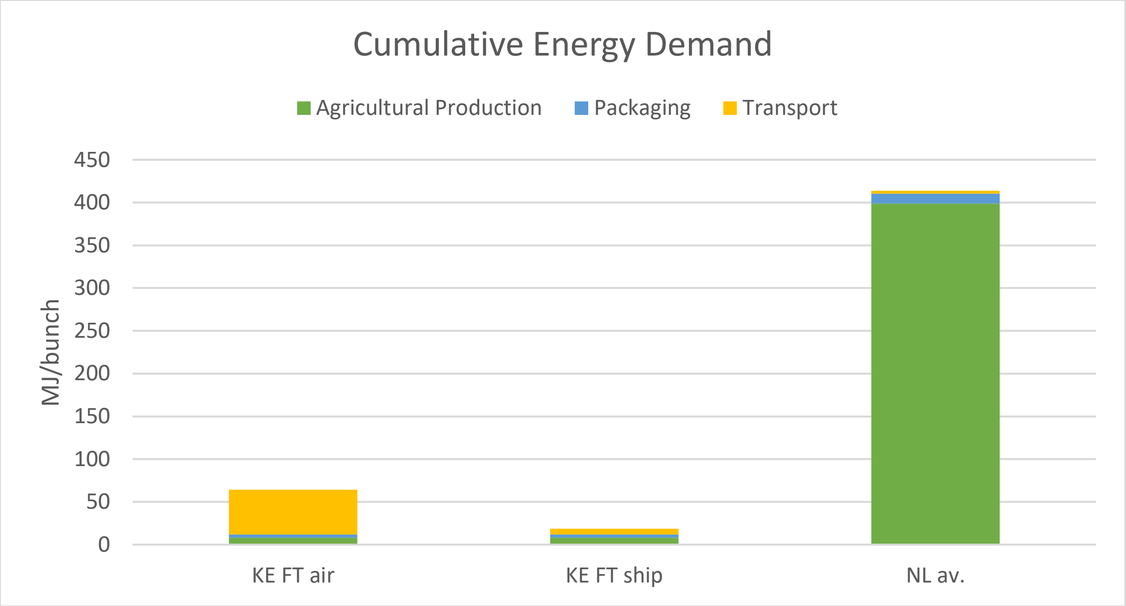

Figure 1: Cumulative energy demand, non-renewable according to Frischknecht et al. (2015) of the different bunch of roses analysed

4.3 Greenhouse gas emissions

The greenhouse gas emissions per bunch of roses are between 1.2 kg CO_2-eq (KE FT ship) and 27 kg CO_2-eq (NL av.) (Figure 2). The greenhouse gas emissions of the Fairtrade roses transported by air are 2.9 times and the roses transported by ship 21.4 times lower respectively than the average rose production in the Netherlands. The reasons are similar to those of the cumulative energy demand. The high greenhouse gas emissions per bunch of roses produced in the Netherlands result from the high energy demand, caused by the combustion of natural gas and the electricity consumption for artificial lighting. Kenyan roses do not require greenhouse heating leading to much lower greenhouse gas emissions from the agricultural production.

For the roses from Kenya transported by air, the transport causes most greenhouse gas emissions. The emissions during the agricultural production of the Fairtrade roses are low. The GHG Emission of Fairtrade roses transported by ship are 86% lower than the Fairtrade roses transported by air.

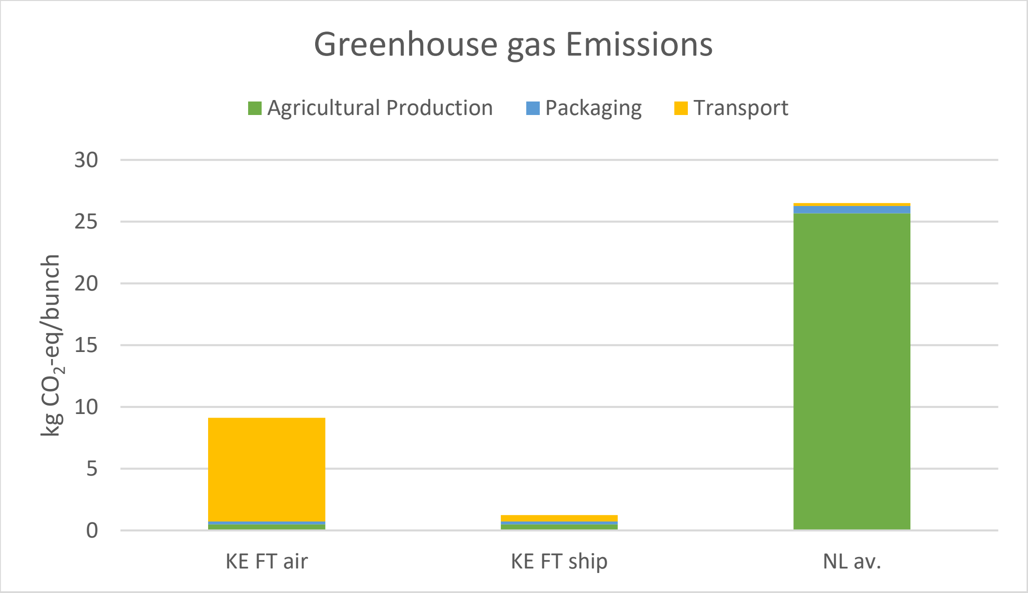

Figure 2: Greenhouse gas emissions according to IPCC (2021) of the different bunch of roses analysed.

4.4 Water scarcity footprint

The water scarcity footprint is between 2.8 and 7.9 m^3 water equivalents per bunch of roses. Roses produced in the Netherlands exhibit the highest water scarcity footprint, followed by the Fairtrade roses transported by air (-64%) and the Fairtrade roses transported by ship (-65%) (Figure 3). For all roses, the agricultural stage is the dominant contributor to the water scarcity footprint. The Fairtrade roses from Kenya consume 3.4 times more water for irrigation than the average roses from the Netherlands. This low consumption is due to the reuse of water in the closed-loop system and the use of rainwater for irrigation.

For the Dutch roses, the biggest contribution to the water footprint stems from electricity and heat generation for greenhouse heating (above all cooling in hard coal power plants, which make up 17 % in the electricity mix of the Netherlands[8]). However, these values come with a high degree of uncertainty because the amount of water that is returned to a river after cooling in the power plants is unknown. In case water is returned, the water scarcity footprint is reduced.

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[8] Share of coal according to KBOB et al. (2022). This might not consider the most recent consumer mix. However, data from the IEA (2022) show that the share of fossil-based electricity has not decreased significantly.

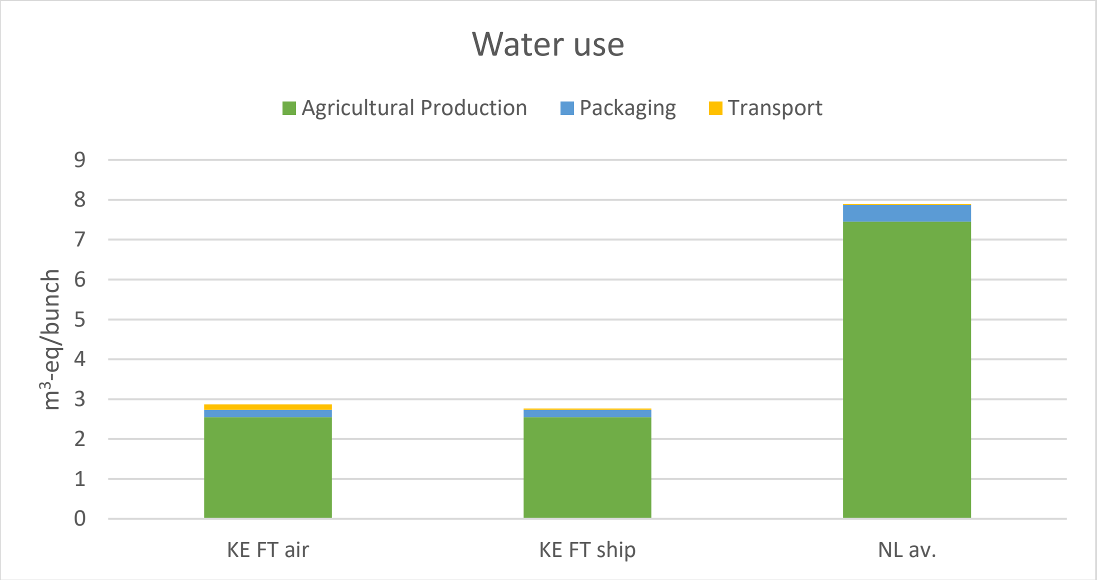

Figure 3: Water scarcity footprint according to AWARE (Boulay *et al.* 2017) of the different bunch of roses analysed.

4.5 Biodiversity loss

This indicator quantifies the long-term potential loss of species through human land use compared to natural areas (see also Subchapter 3.8).

The biodiversity loss through land use lies between 7.9 and 16.9 femto-PDF*a per bunch of roses and is highest in the Netherlands (Figure 4). For Fairtrade roses, the impact of the agricultural stage is rather small. Packaging contributes relatively much to biodiversity loss, mainly caused by the managed forests which deliver the wood for the cardboard packaging. However, a comparison of the impact of packaging material is difficult, since the data source and actuality vary between the different systems.

The transport of the roses causes on average around one third of the total biodiversity loss. The impact comes mainly from the standard fraction of biodiesel[9] used in transports by lorry. This is the main reason for the higher impact of Fairtrade roses transported by ship compared to the transport by air. The distance to the port is longer than the distance to the airport, leading to a higher diesel consumption for the transport by ship.

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[9] The applied generic emission factor for road transport considers an average diesel blend with a share of biofuel of 5%. The used factor is not country-specific and does not necessarily reflect the biofuel use in the regarding country.

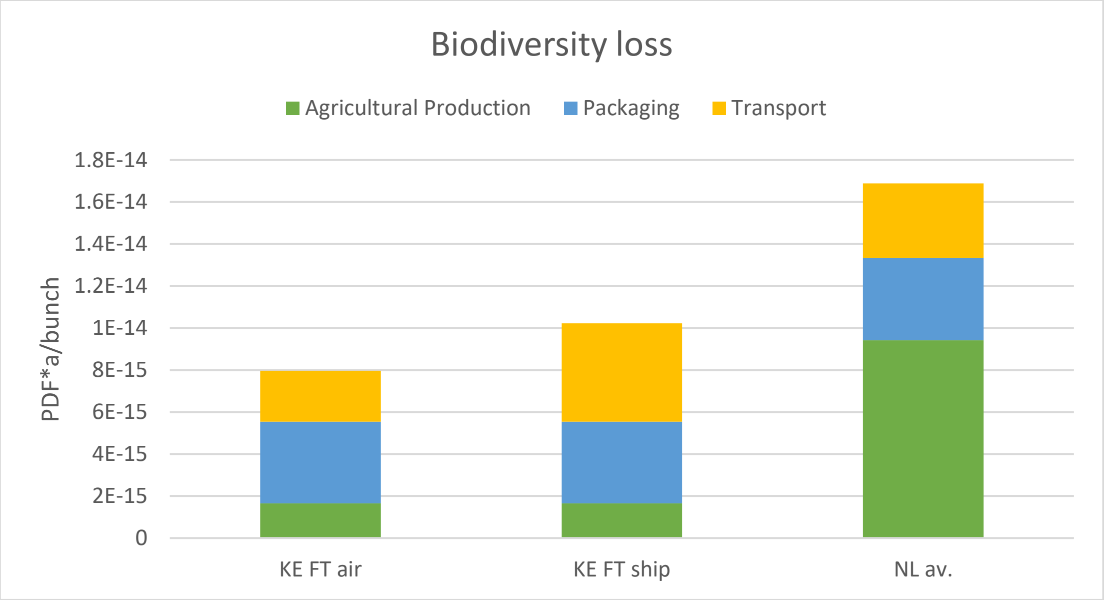

Figure 4: Biodiversity loss through land use according to Chaudhary et al. (2015) of the different bunch of roses analysed

4.6 Terrestrial acidification

The terrestrial acidification is between 0.006 and 0.026 kg SO_2 equivalents per bunch of roses (see Figure 5). For terrestrial acidification, the roses from the Netherlands exhibit the highest impact. The terrestrial acidification of the average roses from the Netherlands is 2.2 times higher than the Fairtrade roses transported by air and 4.3 times higher than the Fairtrade roses transported by ship. For the roses from overseas, the transports are the most important contributor, where the acidification potential of flight transport shows to be 2.5 times higher than the transport by ship. For the roses from the Netherlands, the agricultural stage contributes most to the terrestrial acidification. Most important are the sulfur dioxide and nitrogen oxide emissions from fossil fuel combustion for transport and heat generation and from electricity generation from fossil sources for the national grid mix.

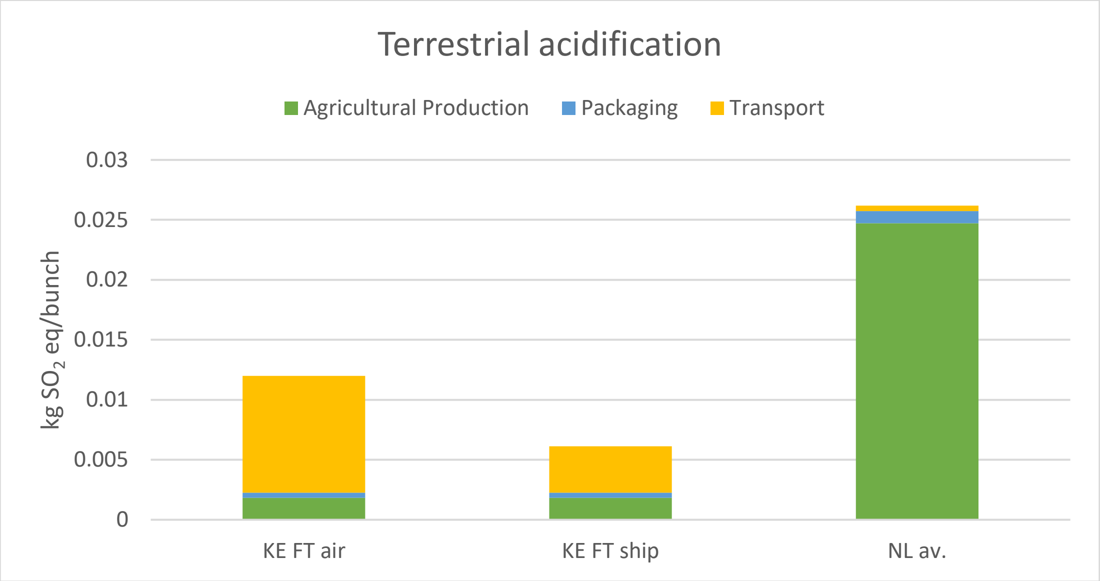

Figure 5: Terrestrial acidification according to ReCiPe (Huijbregts et al. 2016) of the different bunch of roses analysed.

4.7 Aquatic eutrophication

The aquatic eutrophication is divided into freshwater eutrophication and marine eutrophication. In freshwater eutrophication, phosphorus emissions in freshwater bodies are taken into account, in marine eutrophication nitrogen reaching the oceans (see also Subchapter 3.6).

The roses from the Netherlands exhibit the highest freshwater eutrophication impact (Figure 6). The impact of the Fairtrade roses from Kenya with air transport and with ship transport are 14 and 18 times lower, respectively.

Again, the agricultural stage is most important for the roses from the Netherlands and Kenya. For the roses from the Netherlands, the contribution is caused by phosphate emissions related to the production of the electricity used. For the Kenyan roses, the electricity demand is very low and does not contribute much to the aquatic eutrophication. Most important are phosphate emissions during the production of the inputs used respectively due to disposal processes to landfills (emissions due to leachate).

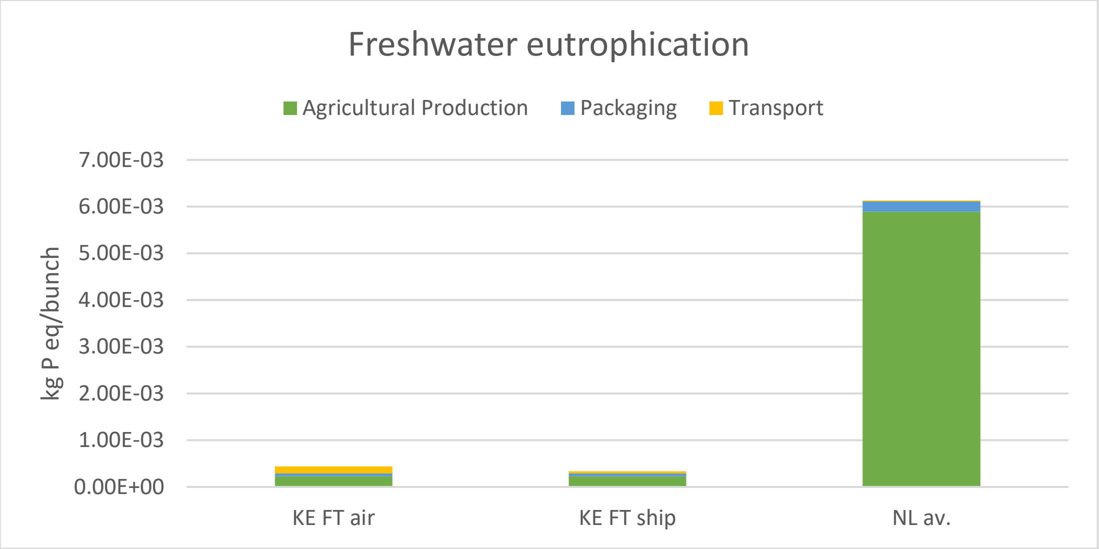

Figure 6: Freshwater eutrophication according to ReCiPe (Huijbregts et al. 2016) of the different bunch of roses analysed.

The roses from the Netherlands exhibit the highest marine eutrophication impact (Figure 7). The impact of the Fairtrade roses with air transport is 19% lower and the Fairtrade roses transported by ship are 31% lower than the Dutch average roses.

The agricultural stage is most important for the marine eutrophication. In the Netherlands, this is due to nitrogen emissions related with electricity generation and during the combustion of natural gas for heating the greenhouses. For the roses from Kenya, the nitrate emissions during cultivation (due to nitrogen fertilizers used) are most important. These are higher for Fairtrade roses. The reason for that is the lower yield of the Fairtrade roses despite the high fertilizer input.

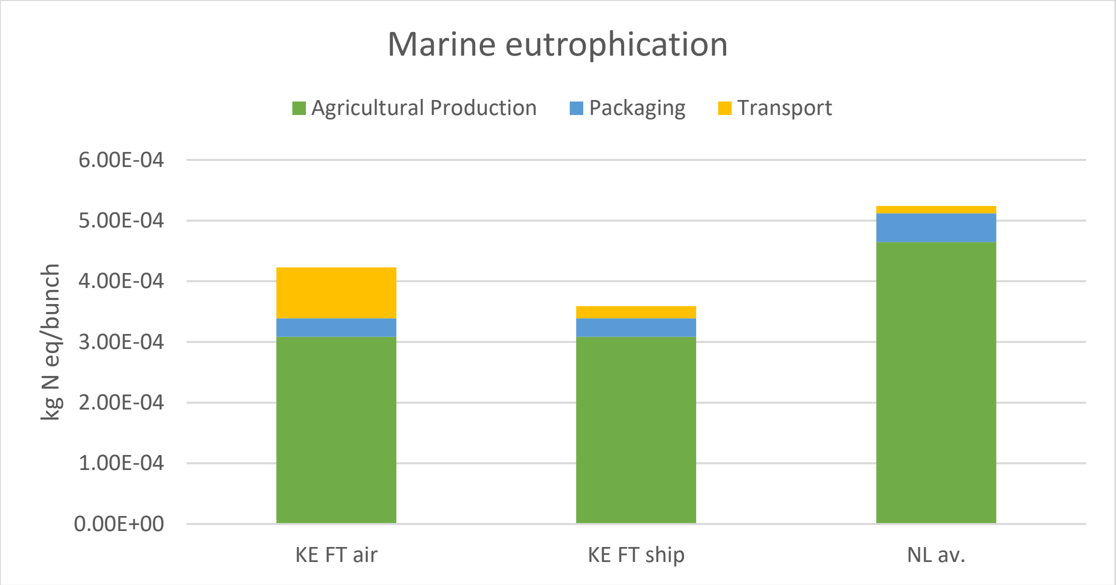

Figure 7: Marine eutrophication according to ReCiPe (Huijbregts et al. 2016) of the different bunch of roses analysed.

4.8 Pesticide use

For the different growing systems, the total amount of insecticides, herbicides and fungicides were reported or were taken from national statistics (Holland). For the Fairtrade roses pesticides have been reported as unspecified crop protection agents, hence no detailed information on type of pesticide was available. The results are presented in Figure 8. In Dutch rose production, the use of fungicides is highest of all known pesticides, followed by the use of insecticides. Overall, according to the national statistics the average pesticide use in Dutch rose production has been reduced in the past years.

The amount of pesticide used is highest for the roses produced in Kenya. The pesticide use according to the national Dutch statistics is significantly lower. For both systems, the quantity is reported in amount of active ingredients used. However, a comparison between the two systems is difficult since the type of pesticides used in the Fairtrade production systems is not known.

The total amounts as reported in Figure 8 do not say anything about the potential adverse environmental impacts of individual pesticides and their damage potential for non-target organisms.

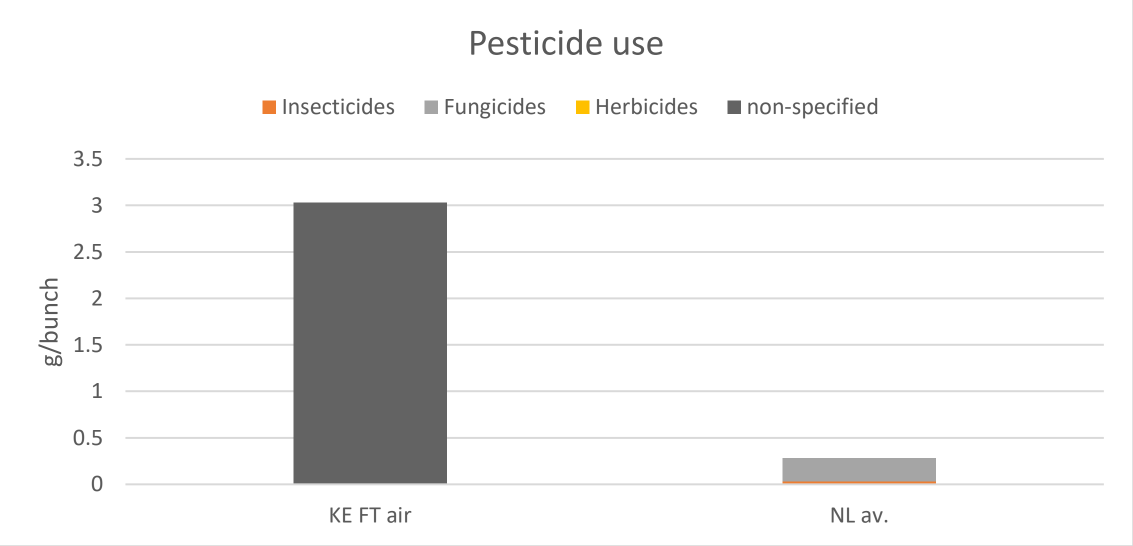

Figure 8: Amount of insecticides, fungicides, herbicides and unspecified crop protection (non-specified) used of the bunch of roses from Kenya and the Netherlands.

5 Discussion

5.1 Data Quality

The reliability of the life cycle assessment of roses depends on the quality of data used to represent cultivation (production), packaging and logistics. The data used in this study is of mixed provenience and thus of mixed quality. For the Dutch roses, high quality primary data from a comprehensive study from 2019 was used, while for the Fairtrade roses primary data from a 2022 survey of five farms were used.

The life cycle inventory of the Dutch roses bases to large parts on the primary data from the 2019 study. However, the available most current data did not fully cover the required information, but reliable data from literature as already used in Alig & Frischknecht (2018) was available to complete the inventory. Data on pesticide use was taken from national statistics, reflecting the national average of roses in greenhouse horticulture in 2020. The use of average data on fertilizer input might lead to an underestimation of the nutrient requirements because of the highly intensive production system using artificial lighting are above average for cut flower production. Aside from this, the data can be judged as representative for the production of the two rose species in the Netherlands. However, no statement about the variability between different producers or between rose different species can be made.

The variation of the average Dutch rose production system which uses geothermal heat as described and analysed in Appendix A1 is a fictive variant where electricity and heat consumption have to be considered as an estimate. No specific data on rose production using geothermal heat was available. Geothermal energy as well as district heat from waste incineration or biomass are already used as a heat source, certain producers also use renewable electricity. In addition to the exact amount of electricity and heat used, the energy source chosen also has a major impact on the results, e.g. the use of heat from waste incineration or biomass combustion, as well as the use of electricity from renewable energy sources would significantly change the results. The chosen scenario can be described to be very conservative.

The key figures for the agricultural production of Fairtrade roses were collected from the producers using the HortiFootprint Calculator. For the Fairtrade roses, data from six producers (Fairtrade certified) were available, where one producer was excluded from the evaluation because the size of the farm and the production volume was not available. In view of the variability in their data, a much larger number of producers would be necessary to obtain a statistically representative sample. The average of the five farms should, however, represent Fairtrade production by and large. The greatest uncertainty exists with regard to the nature of unspecified fertilizer and crop protection. Also, because the data of unspecified fertilizer used is reported per kg of product and not in active ingredients, it is difficult to compare to other systems. It would therefore be advisable to improve the data collection procedure and distinguish between the different types of fertilizers/pesticides and the amount of fertilizer/pesticides and active ingredients applied.

The use of post-harvest chemicals was not considered in this study. Data was only available for the Fairtrade roses in Kenya and were highly variable. Therefore, no reliable statement on the use of post-harvest chemicals was possible.

In Kenya, wastewater is sometimes collected in dumps, where it is naturally purified and then released to the environment. This wastewater is very likely to contain nutrients from the fertilizers and traces of the pesticides used, which are consequently also released to the environment. Within this study, these effects could not be quantified and thus were not taken into account.

The data basis for the packaging material differs between the Dutch and Fairtrade roses. For the Dutch roses, the data on packaging material and electricity consumption in cooling rooms stem from Franze & Ciroth (2011) and do not necessarily reflect the most recent state of packaging standards. For the Fairtrade roses, the amount of packaging material stems from the 2022 surveyed producers. Therefore, differences in the amount of packaging material used and the resulting differences in environmental impact from the packaging my results from the different data basis. More recent data on packaging for the Dutch roses would be needed to better compare the two production systems.

There were no specific data available on sea transport of roses. The results reflect a generic assessment of the impact of refrigerated products by container ship, possible specific prerequisites for the long-term transport of roses were not considered. Sea transport might e.g. lead to higher waste shares, for which no public data was available. Considering the comparably low impact regarding greenhouse gas emissions and cumulative energy demand from roses produced in Kenya and transported by sea freight, a system with a higher waste share of e.g 20% would still indicate a benefit compared to the transport by air. However, indicators where the agricultural stage plays a major role in Kenya (e.g. water scarcity) show a greater sensitivity to changes in the waste rate during transport.

Overall, it can be said that high quality, primary data has been used for the average roses the Netherlands as well as the Fairtrade roses from Kenya. Especially the most important parameters (greenhouse heating, means of transport and transport distances) are subject to a low degree of uncertainty. For these reasons, despite the differences in the type of data basis, the comparison can be regarded as reliable.

5.2 Comparison to previous study

This study is based on the previous study by Alig & Frischknecht (2018) and is aimed at providing updated information on the environmental impacts of cut roses from Holland and Kenya. Compared to the study conducted in 2018, the background data of the KBOB Life Cycle Assessment database has been updated as well as the impact assessment methods for greenhouse gas emissions. Changes in environmental impacts therefore stem not only from changes in production impacts but also from updates in background data and evaluation methods. The results of the two studies are therefore not directly comparable. The following section indicates the most relevant changes in the data basis and the impact assessment.

Data for the Fairtrade roses produced in Kenya has been collected directly from producers for both studies. Therefore, the amount of material inputs can be compared, which can explain parts of the changes in environmental impacts. The amount of electricity needed has decreased by 12%. Also, the amount of nitrogen and phosphorus fertilizer has decreased by 20% and 6% respectively. In contrast, the amount of potassium is 4 times higher compared to 2018. For the packaging, the amount of plastic needed has decreased by more than 30%, while the amount of cardboard has increased 1.9 times.

Regarding the impact assessment the most pronounced change occurred regarding the transport emissions of Fairtrade roses transported by air. The main reason therefore lays in a significant increase of the accounted global warming potential of CO_2 in the stratosphere.

For the Dutch system, the primary data on production inputs is based on a different data source than in 2018 and covers a different sample. Compared to the energy consumption per stem in the production of conventional roses in the study from 2018, gas consumption in the recent study is 43% lower and electricity consumption 3% higher, but very similar to the gas consumption in the optimized production system in the study from 2018, despite the comparably larger weight of the two rose species assessed. The indicated fertilizer input is significantly lower, but as already stated in section 3.2, fertilizer input reflects the average input for cut flowers and might be underestimated considering the highly intensive production system and can therefore not be directly compared. The use of pesticides in the Dutch system is lower compared to the input data in 2018. The national statistics since 2012 shows yearly variation in pesticide use, but with a decreasing trend. However, no comparison of the active agents has been made.

6 Conclusions

The most important production parameters are *energy use* (electricity and natural gas combustion) for heating the greenhouses for the roses produced in the Netherlands and *air transport* for the roses cultivated overseas. Those two parameters determine practically all environmental impacts analyzed. Even regarding the water scarcity footprint and biodiversity loss, where the impact from electricity generation exceeds the impact from direct water consumption.

Fairtrade roses from Kenya are the benchmark. Roses from this country show comparatively lower environmental impacts for all indicators analyzed. The roses transported by sea freight show the least environmental impact, where the benefit from this transport system is greatest when considering greenhouse gas emissions or cumulative energy demand.

Greenhouse gas emissions from air transport of roses from overseas are significantly lower than those for heating the greenhouses in the Netherlands, even though the increased greenhouse effect of aircraft emissions is taken into account. Since the two parameters 'energy demand for greenhouse heating' and 'air transport' completely dominate the results of this comparison, the comparison of rose production in heated greenhouses in other European countries with unheated production in other East African countries are likely to be similar. It can be stated that ship transport would certainly improve the overall environmental footprint except for the impact on biodiversity from roses produced overseas and should be established as a transport mode.

For the Dutch roses, a significant increase in the energy efficiency must be reached in order to reduce energy demand to a similar level as the roses from Kenya. Another option is to switch to renewable energy for greenhouse heating. However, the calculated scenario for growing roses using a heat pump showed an overall highly negative environmental impact (see Appendix A1), particularly also leading to higher greenhouse gas emissions (see Figure A.2). It can be concluded that considering the current national electricity mix in the Netherlands using renewable electricity is a prerequisite when switching from natural gas to heat pump but also indispensable to reduce emission from the electricity consumed from artificial lighting. Additionally, the use of other renewable heat sources (e.g. from biomass) or waste heat should also be examined in order to reduce the consumption of fossil energy.

A possible measure to further minimize the environmental impacts of cut roses is the optimization of the packaging (reduce material weight, use of recycled carton/paper). In comparison to the Fairtrade production assessed in 2018 the amount of plastic for packaging has been reduced in the Kenyan production systems. However, a reduction of paper and cardboard would further improve resource consumption and transport weight.

For Kenyan roses, water use is a critical issue. As a result of the generally high water scarcity in this country, measures to reduce water demand and increase water efficiency are central. Even though water scarcity may vary greatly from region to region, efforts to reduce fresh water requirements, e.g. with the collection of rainwater or the recycling of used water (closed-loop-systems) would improve the environmental impact.

In terms of amount used, pesticide use is much lower for Dutch roses compared to the Fairtrade roses. However, the fact that this comparison was based on a relatively small sample and the nature of the pesticides used for Fairtrade roses is unknown, has a restrictive effect. Since the variability between the individual producers is large, a much larger sample would have to be used for statistically significant statements.

When interpreting the results, we have to have in mind that the roses assessed differ in their size and weight. The Dutch roses have a much higher weight than the Kenyan roses. Generally, both roses are used to sell bouquets of roses and a comparison between the two system is therefore possible. However, the most common size of the bouqets of the two Dutch species is not known. Additionally, the roses assessed are of different quality and prices and therefore do not represent exactly the same product. Referring the environmental impacts to one kilogram or one Swiss franc of roses would change the results in favor of the Dutch roses.

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A1 Variation Dutch roses with geothermal heat

A1.1. Data basis and key figures

As a variation of the average production system in the Netherlands, a production system that uses geothermal heat for production was investigated. The key figures for production, packaging and transport are the same as for the average Dutch production (see chapter 3), only the energy sources for heat differ (see Table A.1).

Since no data was publicly available, a fictive example has been assessed based on the total energy use in the average roses from Holland. Different from the average Dutch system, the greenhouses in this scenario cover its heat demand using geothermal heat. To calculate the scenario, the heat and electricity demand covered by burning natural gas in the CHP are substituted by heat from a borehole heat pump and electricity from the national grid. This leads to a higher consumption of electricity from the grid compared to the average production system. Additionally, the electricity consumption of the heat pump is also assumed to be covered with electricity from the grid.

Table A.1: Use of production resources per harvested rose in the investigated production systems

		NL av.	NL av. RE
Energy needs			
Electricity purchased	kWh	1.143	1.632
Electricity purchased from renewables	kWh	0	0
Heat purchased	kWh	0	1.468
Natural gas	m^3	0.210	0
Diesel	l	0	0
Petrol	l	0	0

A1.2. Results

Cumulative energy demand

The Dutch system using geothermal energy shows a high non-renewable energy demand (Figure A.1). In the scenario no gas is burned in CHP on site for the production of heat and electricity. The electricity demand for artificial lighting as well as the electricity consumption of the heat pump is fully covered by electricity from the grid, where the Dutch electricity mix contains a large share of energy from fossil sources such as coal and gas. Additionally, energy losses from the electricity grid and heat network lead to an increase in the overall energy demand compared to the average Dutch production.

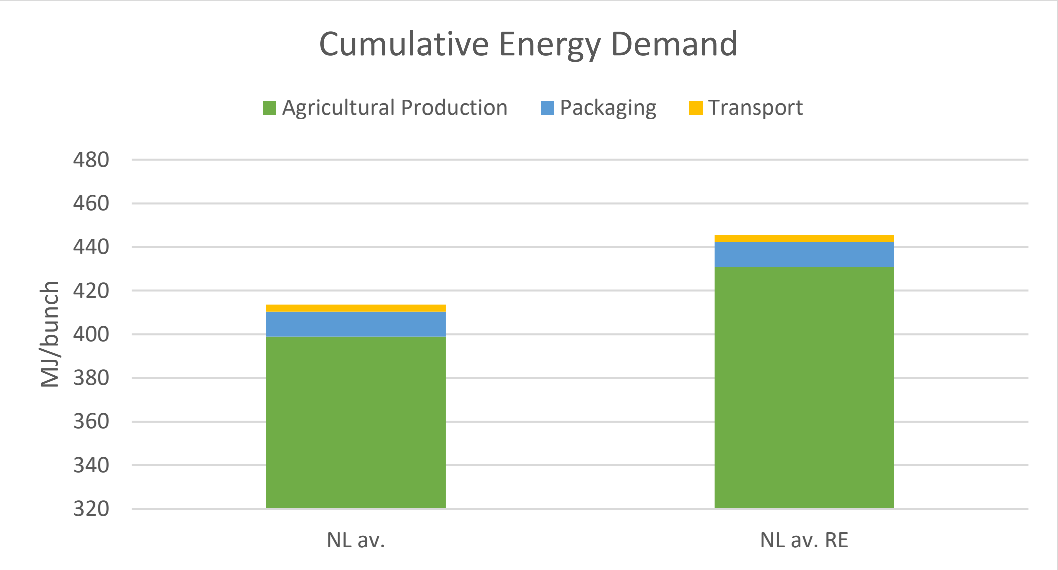

Figure A.1: Cumulative energy demand, non-renewable according to Frischknecht et al. (2015) of the two Dutch scenarios.

Greenhouse gas emissions

Similar to the cumulative energy demand, the Dutch system using geothermal energy shows higher greenhouse gas emissions than the average system (Figure A.2). Beside of the electricity consumption from the heat pump no electricity is generated from an on-site CHP and therefore the overall amount of electricity drawn from the national grid is higher than in the average production system, where the Dutch electricity mix contains a large share of energy from fossil sources such as gas and coal.

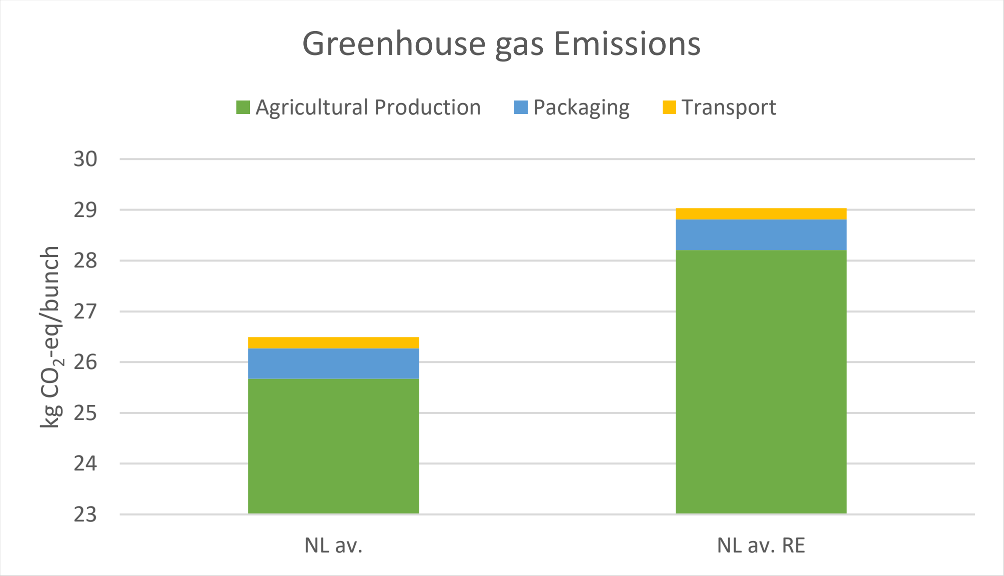

Figure A.2: Greenhouse gas emissions according to IPCC (2021) of the two Dutch scenarios.

Water scarcity footprint

For the Dutch roses, the biggest contribution to the water footprint stems from electricity and heat generation for greenhouse heating (above all cooling in hard coal power plants, which make up 17 % in the electricity mix of the Netherlands). However, these values come with a high degree of uncertainty because the amount of water that is returned to a river after cooling in the power plants is unknown. In case water is returned, the water scarcity footprint is reduced. This high contribution of the electricity generation to the water footprint is also the reason, why the roses heated with renewable heat have a higher water footprint, because the total electricity consumption of this system is higher (Figure A.3).

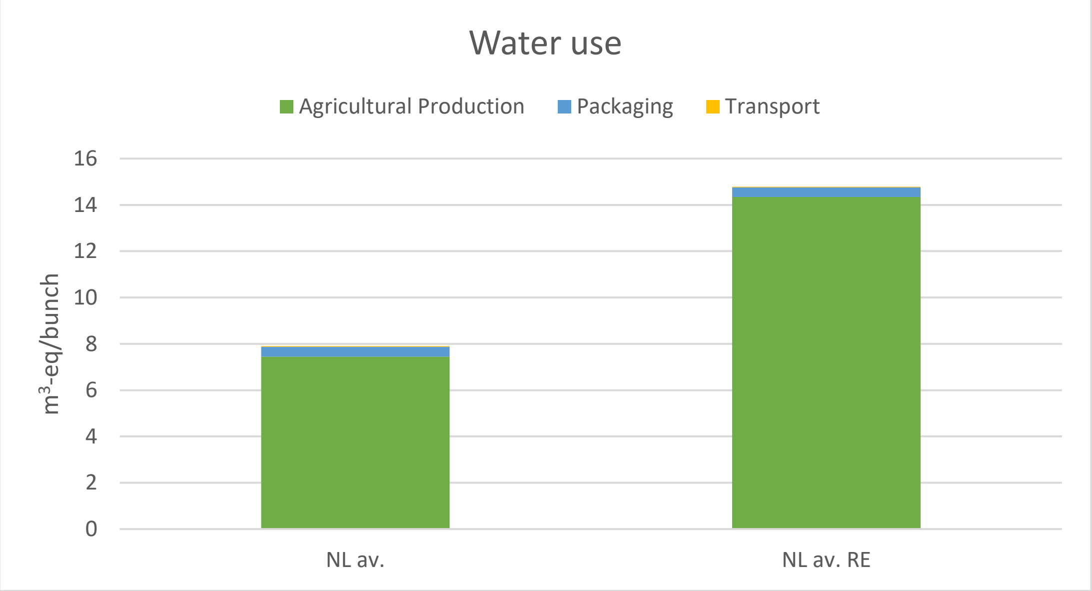

Figure A.3: Water scarcity footprint according to AWARE (Boulay et al., 2017) of the two Dutch scenarios.

Biodiversity loss

The impact on biodiversity of the roses produced with geothermal heat from the Netherlands is 25% higher than the average Dutch roses (Figure A.4) again due to the higher energy demand compared to the average Dutch roses.

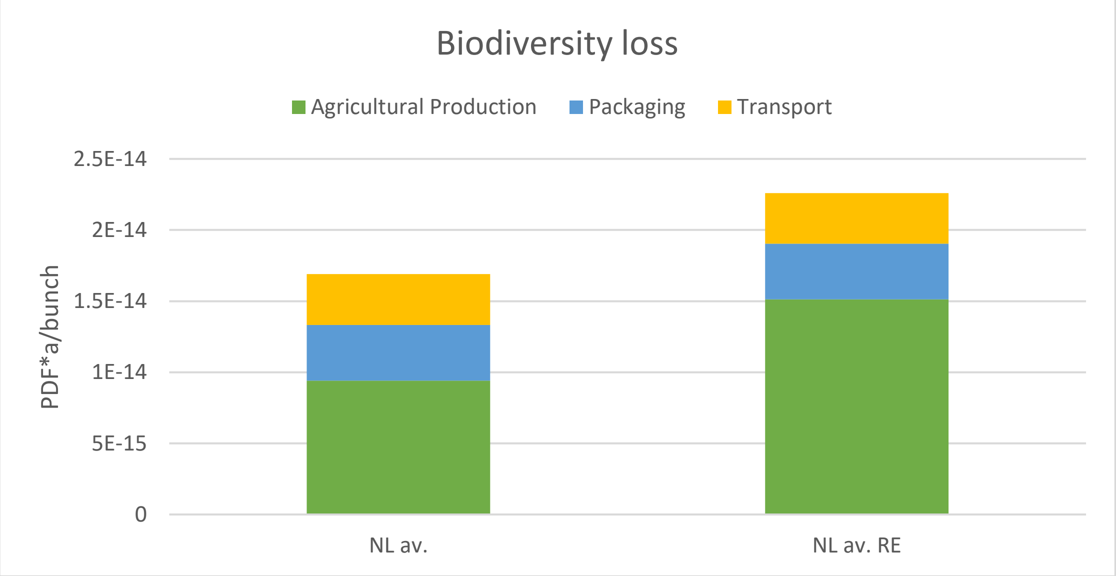

Figure A.4: Biodiversity loss through land use according to Chaudhary et al. (2015) of the two Dutch scenarios.

Terrestrial acidification

For the roses from the Netherlands, the agricultural stage contributes most to the terrestrial acidification. Most important are the sulfur dioxide and nitrogen oxide emissions from fossil fuel combustion for transport and heat generation and from electricity generation from fossil sources for the national grid mix. This is also the reason why the Dutch roses produced with geothermal heat exhibit higher terrestrial acidification due to the higher electricity consumption (Figure A.5).

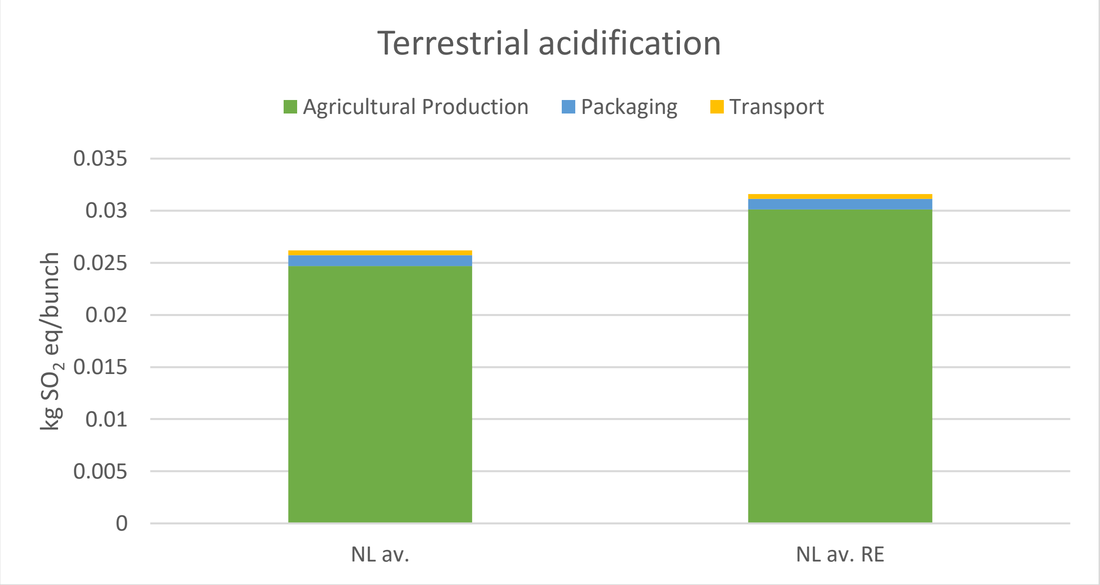

Figure A.5: Terrestrial acidification according to ReCiPe (Huijbregts et al. 2016) of the two Dutch scenarios

Aquatic eutrophication
Again, the higher electricity demand of the roses produced with geothermal heat leads to almost double the amount of aquatic eutrophication compared to the average Dutch roses (Figure A.6). The main impact stems from the phosphate emissions related to the production of the electricity used.

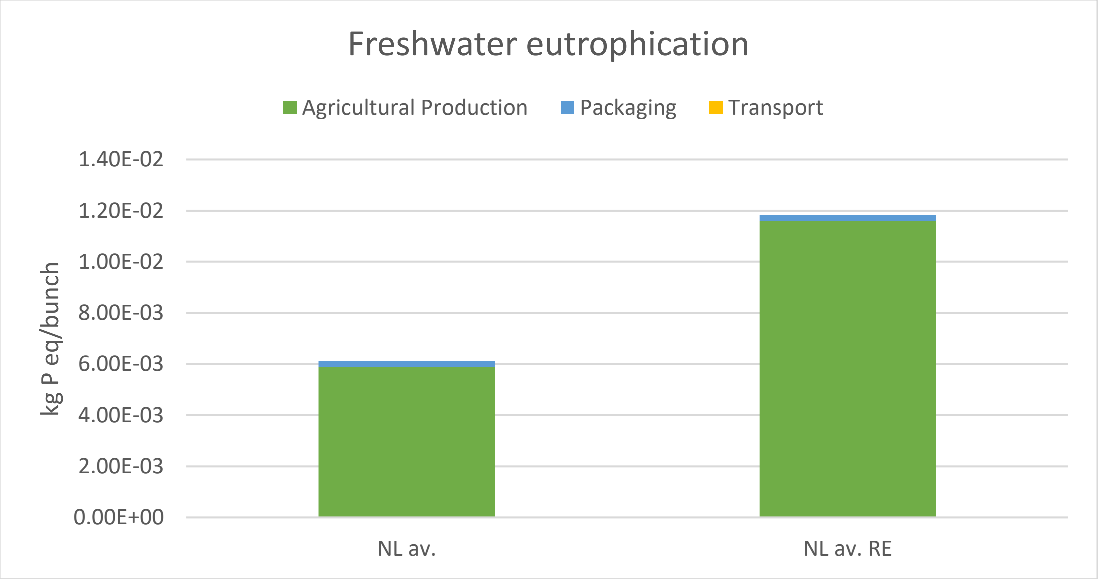

Figure A.6: Freshwater eutrophication according to ReCiPe (Huijbregts et al. 2016) of the two Dutch scenarios.

Marine eutrophication is about 1.7 times higher for the roses produced with geothermal heat compared to the average Dutch roses (Figure A.7), the main reason being the higher electricity needs of the renewable scenario, leading to higher nitrogen emissions.

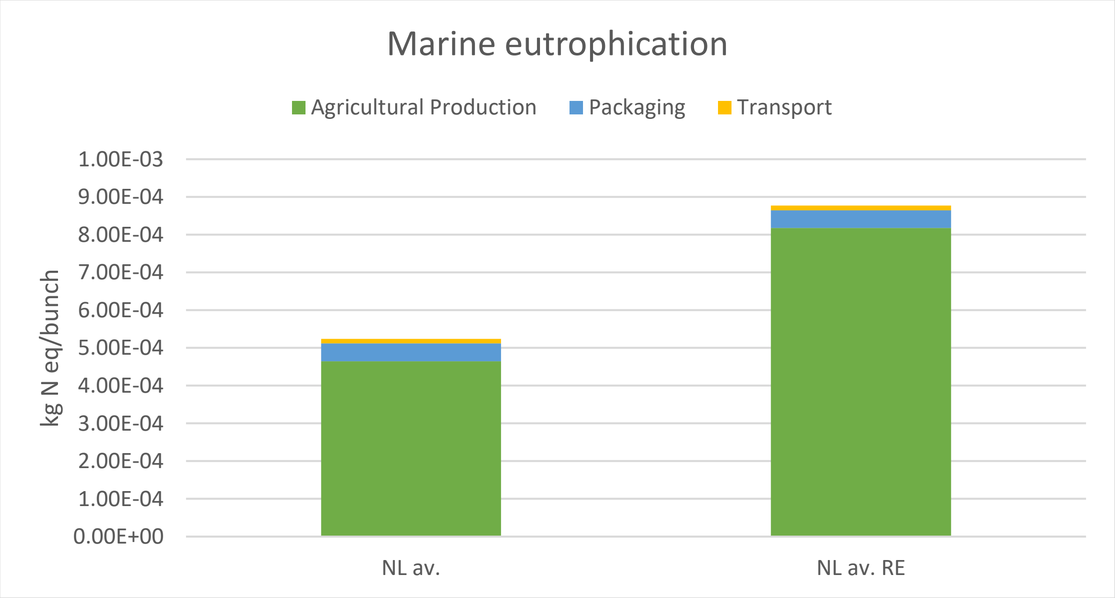

Figure A.7: Marine eutrophication according to ReCiPe (Huijbregts et al. 2016) of the two Dutch scenarios.

Pesticide use

The pesticide use of the roses produced with geothermal heat does not differ from the pesticide use of the average Dutch roses.