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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
Conv.	Conventional production
EC	Ecuador
Femto	one billiarth (10^{-15})
FT	Fair Trade
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 Netherland
Opt.	Optimised production
P_2O_5	Phosphorpentoxid (unit of measurement for phosphate content in fertilizers)
PDF	Potentially disappeared fraction
tkm	Ton kilometres

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Executive Summary

The present study determines the environmental impacts of the production of five different cut roses: conventional roses from Ecuador, average and Fairtrade roses from Kenya and conventional roses and roses from optimised production from Holland. The agricultural production in the country of origin, the packaging of the roses and their transport to Switzerland are taken into account.

For conventional and average roses, the key figures for agricultural production were compiled from literature data. The key data on the agricultural production of Fairtrade roses and on roses from optimised production in Holland were collected directly from producers by means of a questionnaire.

Roses from Kenya have the lowest or one of the lowest impact of all environmental impacts analyzed, except for the water scarcity footprint, where they exhibit the highest values. The Fairtrade roses from Kenya show similar environmental impacts as average Kenyan roses. In terms of amount used, pesticide use is lowest for Dutch roses. In Kenya, Fairtrade roses have a lower pesticide use than average roses. However, the amount used does not reflect the effect of the pesticides in the environment and therefore does not indicate the environmental impact.

Energy use for greenhouse heating for the roses produced in the Netherlands and *air transport* for the roses cultivated overseas dominate the environmental impacts of cut roses. Direct water consumption, nitrate emissions of the rose production overseas and the production of the packaging material are important for individual environmental impacts.

Greenhouse gas emissions from air transport of roses from overseas are four to six times lower than those from heating the greenhouses in the Netherlands, even though the increased greenhouse effect of aircraft emissions is taken into account.

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 sources for greenhouse heating. The objectives of the Dutch producers in this respect have not yet been implemented. If Dutch production were to be converted to renewable energy sources, it could possibly do better than the roses flown in.

For Kenyan roses, water use is a critical issue. As a result of the high water scarcity in this country, measures to reduce water demand and increase water efficiency are central. Possibilities are e.g. the collection of rainwater or the recycling of used water.

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.

Overall, it can be stated that Fairtrade standards not only enhance social justice, but can also contribute to the reduction of the environmental impacts of rose production. For

measurable effects across all environmental impacts, we recommend that the relevant standard requirements be specifically strengthened. One possibility would be the mandatory use of closed-loop systems to reduce fresh water requirements.

1. Introduction

1.1. 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 conventional cut roses from Ecuador, average and Fairtrade cut roses from Kenya (using five different Fairtrade certified farms as an example) and conventional cut roses from Holland is to be carried out. The analysis should take into account both rose production in the country of origin and the packaging and transport of roses to Switzerland. In addition to the conventional variant for cut roses from Holland, a variant with optimised production in terms of energy consumption is to be calculated.

1.2. Objectives

The aim of this study is to determine the environmental impacts of cut roses from Holland, Kenya and Ecuador. 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 five production systems are calculated: conventional roses from Ecuador, average and Fairtrade roses from Kenya and conventional roses and roses from optimised production in Holland.

2. Data basis and key figures

2.1. Investigated production systems and data basis

Tab. 2.1 shows an overview of the investigated production systems and the data used for the life cycle inventories of rose production. For the conventional and average roses, the key figures for agricultural production were compiled from literature data. The key data on the agricultural production of Fairtrade roses and on roses from optimised production in Holland were collected directly from the producers by means of a questionnaire. Five companies were surveyed for the Fairtrade roses, the data on Dutch roses from optimised production came from one producer.

Tab. 2.1 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**
Conventional roses Holland	NL conv.	Torrellas *et al.* 2012 Pesticides: CBS Nether-lands	Good
Average roses Kenya	KE av.	Oulu 2015 Consuming water use: Mekonnen & Hoekstra 2010	Middle
Conventional roses Ecuador	EC conv.	Derived from Torrellas *et al.* 2012 und Franze & Ciroth 2011 Water use: Knapp 2016	Bad
Fairtrade roses Kenya	KE FT	Own survey	Good
Optimised roses Holland	NL opt.	Own survey, supple-mented with information from Torrellas *et al.* 2012	Middle - Good

* The assessment of data quality refers to the representativeness of the data for the respective production system

2.2. Key figures conventional roses

The production data for the roses grown in the Netherlands stem from Torrellas et al. (2012) with additional information from Montero et al. (2011). They refer to a typical rose production system in the Netherlands with current agricultural practices. Pesticide use was taken from the Central bureau for statistics (CBS) in the Netherlands[1]. The production data for the average Kenyan roses are derived from Oulu et al. (2015). This study was conducted at Nini Flowers farm located at the shores of Lake Naivasha in Kenya. The data was, depending on availability, sourced either from the records held by Nini Flowers or directly measured and/or observed and refer to the yearly averages from 2002 to the latest available figures of 2011. Additionally, the data was verified by the study leader to represent an average of Kenyan production. It is known to the authors that Nini farm is also a Fairtrade farm, however the data from Oulu et al. (2015) is the most reliable about rose production in Kenya and there were no other studies available with an adequate level of detail and similar credibility. Therefore, the average data of Oulu et al. (2015) was chosen to represent average Kenyan production. For Ecuador, no detailed

1 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 24.4.2018

study with production data was available. Therefore, most of the data were estimated based on Torrellas et al. (2012) and the relationship between the production in the Netherlands and Ecuador from Franze & Ciroth (2011).

Tab. 2.2 shows an overview of the analysed production systems. All roses are grown in greenhouses. In the Netherlands, Venlo greenhouses made of a metal structure and glass walls with a life span of 15 years are used. The roses are grown in trays filled with rockwool and have a life span of about 4 years. In Kenya and Ecuador, the greenhouses are made of a steel structure with a plastic cover. The lifespan of the steel structure is also 15 years, whereas the plastic cover is replaced every two years. The roses are planted directly into the soil and have a life span of about 7 years. The lifespan of Ecuadorian roses was approximated with the life span of Kenyan roses.

In the Netherlands, bundle roses are produced. As no information on the weight of the roses was available, it was approximated with the weight of the Kenyan roses (25 g per stem). In a year, about 276 flowers per m^2 can be harvested. In Kenya, 261 stems with a weight of 25 g are produced per m^2 and year. Ecuador produces particularly large and high-quality roses with a weight of about 76 g per stem. The roses produced in Ecuador are single roses. These are longer-stemmed, therefore heavier and of higher quality than the bundle roses produced in the other systems. As they are grown at high altitudes, they grow slower than the roses in the Netherlands and Kenya. With a growing cycle of about 15 weeks versus typically 8 weeks for roses grown at sea level[2], it was assumed that they deliver about half of the yield of Kenyan roses[3]. As a product, single and bundle roses are not directly comparable.

All roses are irrigated with a drip water irrigation system. In the Netherlands a closed-loop system is used, whereas in Kenya and Ecuador, there is no closed loop.

[2] https://www.ft.com/content/eb5114d6-d846-11e4-ba53-00144feab7de, last visited on 23.04.2018

[3] Although Kenyan roses are grown at about 1500 m. above sea level, they were chosen as a reference system because of the similar cultivation system.

Tab. 2.2 Key data on the production systems of conventional/average roses in Holland, Kenya and Ecuador

		NL conv.	KE av.	EC conv.
Type of production		Heated greenhouse, glass	Greenhouse unheated, plastic	Greenhouse unheated, plastic
Number of plants per square metre	Plants/m^2	8.3	6.5	6.5
Life span of rose plants	Year	4.0	7.0	7.0
Yield	Flowers/m^2*year	276	261	130
Weight per flower	g/Flower	6.0	25.0	75.5
Proportion of substrate-based systems	%	100%	0%	0%
Type of substrate		Rockwool	-	-
Irrigation system		Drip irrigation, closed circuit	Drip irrigation	Drip irrigation
Origin of water for irrigation		Rainwater tank & groundwater	Lake Naivasha	River water

Tab. 2.3 shows the key production figures for the conventional resp. average rose production in the Netherlands, Kenya and Ecuador. Since most of Ecuador's production data has been estimated, only the primary data of the Netherlands and Kenya are described in detail.

Tab. 2.3 Use of production resources per harvested rose in conventional/average rose production in Holland, Kenya and Ecuador

		NL conv.	KE av.	EC conv.
Seedlings	#	0.008	0.003	0.003
Substrate amount	g	4.53	0	0
Energy needs				
Electricity	kWh	1.04	0.004	0.37
Natural gas	m^3	0.37	0	0
Diesel	l	0	0.00094	0.00094
Petrol	l	0	0.00001	0.00001
Fertiliser Use				

		NL conv.	KE av.	EC conv.
N	g	0.42	0.48	0.84
P_2O_5	g	0.10	0.16	0.20
K_2O	g	0.46	0.32	0.93
Pesticides Use				
Insecticides	g	0.005	0.032	0.015
Fungicides	g	0.033	0.146	0.098
Herbicides	g	0.001	0.000	0.002
Acaricide	g	n.a.	0.935	n.a.
Nematicides	g	n.a.	0	n.a.
Auxiliary materials	g	n.a.	n.a.	n.a.
Material Greenhouses				
Aluminium	g	0.8	0	0
Steel structure	g	3.2	1.0	1.0
Plastic sheeting (LDPE)	g	0	0.5	0.5
Glass sheet	g	2.9	0	0
Polyesters	g	0.3	0	0
Concrete	m^3	1.0E-06	1.7E-07	1.7E-07
Watering				
Water demand	l	3.3	12.3	18.1
thereof rain water	l	1.7	0.0	0.0
Consuming use	l	1.6	5.1	7.5
Waste material				
Biowaste	g	1.33	0.91	0.91
Plastic	g	0.24	1.00	1.00
Substrate	g	4.53	0	0
Effluent water	l	0	7.2	10.7

In the Netherlands, the greenhouse is heated which leads to a relatively high energy consumption. They use a combined heat and power (CHP) system for the production of thermal energy and electricity. As the own production cannot fully cover the electricity demand, the remainig power is drawn from the grid.

In Kenya, the energy consumption is much lower, even though there is some use of diesel and petrol for in-farm transports, which is not the case for the Netherlands. Fuel consumption for rose cultivation in Ecuador is assumed the same as in Kenya.

The use of nitrogen fertilizer per flower harvested in the Netherlands and Kenya is quite similar, whereas in Kenya more phosphorus, but less potassium fertilizer is used. The total use of pesticides per flower harvested is higher in Kenya. Especially the use of miticides (80 % of total pesticide application) is very high. In Holland, no miticides are used. Fungicides make up the highest proportion with 85%.

Water demand in Kenya is nearly four times higher than in the Netherlands. The data about consumptive water use for Kenyan roses stems from Mekonnen & Hoekstra (2010) and amounts to 5.1 kg per rose harvested. For the closed-loop system in Holland only the ground water used was included in the consumptive water use. This resulted in a consumptive water use of 1.6 kg per rose harvested. The water demand of Ecuadorian rose stems was estimated based on Knapp 2016 and is 50 % higher than the one of Kenyan roses. For the consumptive use, the same share as for the Kenyan roses was assumed (41 %).

2.3. Key figures Fairtrade roses

The production figures for Fairtrade roses in Kenia were collected directly from producers for Max Havelaar with a questionnaire. Five producers have been contacted which all filled in the questionnaire. Their 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 presented in Tab. 2.4 and Tab. 2.5 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 average plant density is 7.6 plants/m^2. The rose plants have a life span of 6.3 years. The yield is 135 roses/m^2 and thus lower than in the average production in Kenia and is close to the yield in Ecuador[4]. The plants are directly planted into the soil. All producers use drip irrigation systems with mostly surface water, but also some groundwater and rainwater is used.

[4] 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.

Tab. 2.4 Key figures on the Fairtrade production system and average roses from Kenya

		KE FT	**KE av.**
Type of production		Plastic tunnel with metal tubes, non-heated	Plastic tunnel with metal tubes, non-heated
Number of plants per square metre	Plants/m^2	7.6	6.5
Life span of rose plants	Year	6.3	7.0
Yield	Flowers/m^2*year	135	261
Proportion of substrate-based systems	%	0	0
Irrigation system		Drip irrigation	Drip irrigation
Origin of water for irrigation		Mostly surface water, some ground- and rain-water	Surface water (lake Naivasha)

As the greenhouses are not heated, the energy demand per flower harvested is low. Electricity is the most important energy source. The electricity demand is higher than in average Kenyan production and close to the one in Ecuador.

The use of nitrogen und phosphorus fertilizer is generally higher than in average production, whereas the use of potassium fertilizer is rather lower. However, most of the Fairtrade farms indicated the quantities of fertilizer and not the amount of nutrients used. These were derived from the average nutrient content of the fertilizers. However, if farms use fertilizers with a lower nutrient content, the quantities of nutrients used are overestimated.

Pesticide use was reported in detail. The use of fungicides and insecticides is higher than in conventional production in Holland, but lower than in average / conventional production in Kenya and Ecuador with a similar yield. The different quantities of fertilisers and pesticides used are likely to be related to local conditions such as soil conditions and pest pressure or different management strategies. A striking feature is the high variability in the quantities used between the individual farms: For pesticides, a factor of 5 is between the farm with the lowest and the one with the highest input, for fertilizers even factors of 35 (N fertilizer) to 50 (P fertilizer). However, these values have practically no influence on the level of environmental impact, as those are dominated by other parameters (see Chapter 3).

Tab. 2.5 Use of production resources per Fairtrade and average rose harvested from Kenya

		KE FT	KE av.
Seedlings	#	0.011	0.003
Energy needs			
Electricity	kWh	0.025	0.004
Natural gas	m^3	0.0001	0
Diesel	l	0.0002	0.00094
Petrol	l	0.00003	0.00001
Fertiliser Use			
N	g	1.29	0.48
P_2O_5	g	0.38	0.16
K_2O	g	0.29	0.32
Pesticides Use			
Insecticides	g	0.010	0.032
Fungicides	g	0.036	0.146
Herbicides	g	0.000088	0.000
Acaricide	g	0	0.935
Nematicides	g	0.000211	0
Auxiliary materials	g	0.025	n.a.
Material Greenhouse			
Metal structure	g	0.972	1.0
Plastic sheeting (LDPE)	g	1.098	0.5
Watering			
Water demand	l	12.0	12.3
Consuming use	l	4.6	5.1
Waste Material			
Biowaste	g	22	0.91
Plastic	g	0.0097	1.00
Cardboard	g	0.0015	-
Empty chem. containers	g	0.0308	-
Effluent	l	1.55	7.2

2.4. Key figures roses from optimised production in Holland

In the optimized Dutch production, the same Venlo greenhouses as in the conventional Dutch production are used (Tab. 2.6). They also use rockwool as substrate for the roses. The life span amounts to seven years and the harvest is with 300 flowers/m^2*a a bit higher than in conventional Dutch production. The plant density of the roses was approximated with data from conventional production. For irrigation, a closed-loop system fed with filtered rainwater is used. Additionally, some tap water is used for the buckets in which the roses are transported to the point of sale.

Tab. 2.6 Key figures for the production systems optimized and conventional rose production in Holland

		NL opt.	**NL conv.**
Type of production		Heated greenhouse, glass	Heated greenhouse, glass
Number of plants per square metre	Plants/m^2	8	8.3
Life span of rose plants	Year	7.0	4.0
Yield	Flowers/m^2*year	300	276
Proportion of substrate-based systems	%	100	100
Irrigation system		Stone wool	Stone wool
Origin of water for irrigation		Drip irrigation, closed circuit	Drip irrigation, closed circuit
Number of plants per square metre		Rainwater tank	Rainwater tank & groundwater

Tab. 2.7 shows the key production figures for the rose production from optimized production in the Netherlands. The amount of seedlings was taken from the conventional rose production in the Netherlands. According to the information obtained from the producer the amount of substrate used is much lower than in the conventional Dutch system. As for the conventional production, natural gas is used for heating the greenhouses and generating electricity. As the combined heat and power system does not produce enough electricity to cover the demand, the missing quantity is drawn from the national grid. Compared to the conventional Dutch system, less natural gas is used and more electricity is drawn from the grid. The amount of nitrogen and potassium fertilizer used is 50 % higher than in the conventional Dutch system, the amount of posphorus fertilizer used even nine times higher. On the other hand, the use of pesticides is lower than in the conventional Dutch system (-55 % for fungizides, -83 % for insecticides). Fungicides also make up the largest share of the pesticies applied (94 %).

Tab. 2.7 Use of production resources per harvested rose from optimized and conventional production in Holland

		NL opt.	**NL conv.**
Seedlings	#	0.008	0.008
Substrate	g	0.067	4.53
Energy needs			
Electricity	kWh	1.07	1.04
Natural gas	m^3	0.20	0.37
Fertiliser Use			
N	g	0.61	0.42
P_2O_5	g	0.92	0.10
K_2O	g	0.69	0.46
Pesticides Use			
Insecticides	g	0.001	0.005
Fungicides	g	0.015	0.033
Acaricide	g	0	0.001
Nematicide	g	0	n.a.
Auxiliary materials	g	0.0001	n.a.
Material greenhouse			
Aluminium	g	0.8	0.8
Steel structure	g	3.2	3.2
Plastic sheeting (LDPE)	g	0.0	0
Sheet glass	g	2.9	2.9
Polyesters	g	0.3	0.3
Concrete	m^3	1.00E-06	1.0E-06
Watering			
Water demand	l	0.133	3.3
Consuming use	l	0.125	1.6
Waste Material			
Biowaste	g	1.33	1.33
Plastic	g	0.24	0.24

		NL opt.	NL conv.
Substrate	g	0.067	4.53

2.5. Packaging

The amount of packaging material and the energy use for the cooling rooms stem from Franze & Ciroth (2011) for the conventional Dutch roses and from Oulu (2015) for the average Kenyan roses. In the absence of other information, the data for Kenyan roses have also been adopted for the conventional roses from Ecuador. For the Dutch roses from optimized production, only the packaging materials were known. The data about the amount of packaging and the electricity used for the cooling rooms were taken from the conventional Dutch roses. For the Fairtrade roses, detailed information from the producers was available.

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 paper. Then the bouquets are boxed into a paperboard container. Tab. 2.8 shows the amount of packaging material used for each system.

Tab. 2.8 Amount of packaging material used for one packaging unit containing 25 bouquets à 20 roses

		EC conv.	KE av.	KE FT	NL conv.	NL opt.
Plastic	g	250	250	465	0	1250
Paper	g	0	0	8	1250	0
Cardboard	g	1910	1910	1267	3125	3125
Electricity for cold rooms	kWh	2.6	2.6	4.7	12.5	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.

2.6. Transport

Overseas transports are made by air. Delivery from the farm to the airport and from the airport in Holland to Switzerland is by refrigerated truck. The distances were determined using the EcoTransIT calculator[5]. Tab. 2.9 shows an overview of the means of transport used and the transport distances taken into account.

Roses from Kenya are shipped from Jomo Kenyatta International Airport in Nairobi, roses from Ecuador from the Aeropuerto Internacional Mariscal Sucre in Quito.

Tab. 2.9 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**	**EC**
Farm - Airport of origin	Refrigerated truck	-	90	50
Airport of origin - Schiphol Airport (NL)	Aircraft	-	6772	9657
Schiphol Airport (NL) resp. Farm (NL) - Distribution Center Aalsmeer (NL)	Refrigerated truck	169	8	8
Distribution Center Aalsmeer (NL) - Zürich (CH)	Refrigerated truck	778	778	778

2.7. Background data

The background data for the processes downstream of agriculture (packaging, transport) are based on the KBOB Life Cycle Assessment database DQRv2:2016 (KBOB et al. 2016) and mobitool v2.0 (Stolz et al. 2016). This includes current data on flight transports from Messmer et al (2016).

2.8. 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 (2013)
- Water scarcity due to the consumptive use of freshwater resources according to AWARE (Boulay et al. 2017; regionalized evaluation)

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

- Biodiversity loss through land use according to Chaudhary et al. (2015; regionalized evaluation)
- Terrestrial eutrophication according to Seppäla et al. (2006)
- 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 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 vapour trails generated by aircraft, the induced clouds and the water vapour emitted is 0.95 kg CO_2-eq. The global warming potential of CO_2 emissions from burning kerosene by aircrafts is thus 1.95 kg CO_2-eq/kg.

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.

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. Terrestrial eutrophication primarily takes into account ammonia and nitrogen oxide emissions into the air. 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 over-fertilisation 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 one hand, there were no data availabe on the active pesticide ingredients used in the conventional rose production systems. On the other hand, the active pesticide ingredients used in the fairtrade production and the optimised production in Holland are only partly covered by USETox. Aditionally, 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 8.4.0 (PRé Consultants 2017).

3. Results

3.1. Overview

In the following subchapters, the results for the seven environmental indicators analysed are shown: Cumulative energy demand in subchapter 3.2, greenhouse gas emissions in subchapter 3.3, water scarcity footprint in subchapter 3.4, biodiversity loss in subchapter 3.5, terrestrial and aquatic eutrophication in subchapter 3.6 and 3.7, respectively, and pesticide use in subchapter 3.8. All results are shown per bunch of 20 roses.

The results are shown for the three stages agricultural production, packaging and transport. The agricultural stage includes the growing and harvesting of the roses with the associated consumption of resources and the associated 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 until Switzerland (Zurich).

3.2. Cumulative energy demand

The non-renewable cumulative energy demand is between nearly 90 MJ (roses KE) and almost 600 MJ (conv. roses NL) per bunch of roses.The energy demand of the conventional roses from the Netherlands is 6.5 and 1.8 times higher than the energy demand of the roses from Kenya and Ecuador, respectively (Fig. 3.1). This is due to the energy demand for greenhouse heating in the Netherlands. In the optimized rose production in the Netherlands, the energy requirement for greenhouse heating per rose is 35 % lower than in the conventional Dutch production, which is the main reason for the lower non-renewable energy demand of the optimized production in the Netherlands.

For the roses from Ecuador and Kenya, the main contributor to the non-renewable energy demand is the air transport to Europe. The higher contribution of the air transport from Ecuador is due to the higher weight of the roses as well as the longer distance to Europe, which requires more air transport services. Also the contribution of the agricultural production is higher for the conventional roses from Ecuador, than for those from Kenya. This is due to the lower yield in Ecuador (in terms of roses per ha and year).

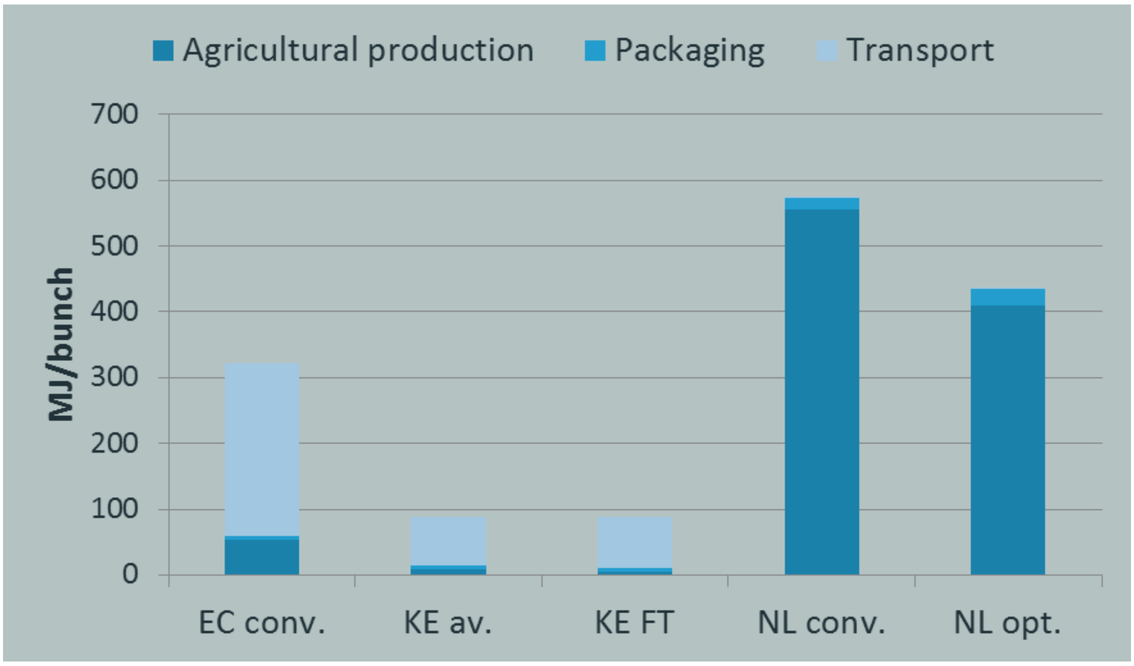

Fig. 3.1: Cumulative energy demand, non-renewable according to Frischknecht et al. (2015) of the five different bunch of roses analysed

The total energy demand of the Fairtrade and average roses from Kenya is the same. While the energy demand due to agricultural production is about 60 % lower, the roses are a bit heavier. They therefore need more transport services, which outweighs the lower demand during agricultural production.

3.3. Greenhouse gas emissions

The greenhouse gas emissions per bunch of roses are between 7 kg CO_2 eq (KE) and 37 kg CO_2 eq (NL conv.). They show a similar picture like the cumulative energy demand (Fig. 3.2). The greenhouse gas emissions of the conventional roses from Ecuador are 1.5 times lower, the greenhouse gas emissions of the average and fairtrade roses from Kenya 5.5 times and 5.4 times lower respectively than the ones from the conventional roses grown in the Netherlands. The greenhouse gas emissions from the roses from optimized production in the Netherlands are 30 % lower than the ones from the conventional roses from the Netherlands. The high greenhouse gas emissions of the roses from the Netherlands are due to the combustion of natural gas for heating the greenhouses. For the roses from Ecuador and Kenya, the transport causes most greenhouse gas emissions. Again, the emissions during the agricultural production of the Fairtrade roses are lower than during the production of the average Kenyan roses, but this is outweighted by higher emissions during transport. The higher greenhouse gas emissions from Ecuadorian roses are due to their higher weight and longer transport distances (transport) and the lower specific yield in terms of roses per hectare and year (agricultural production).

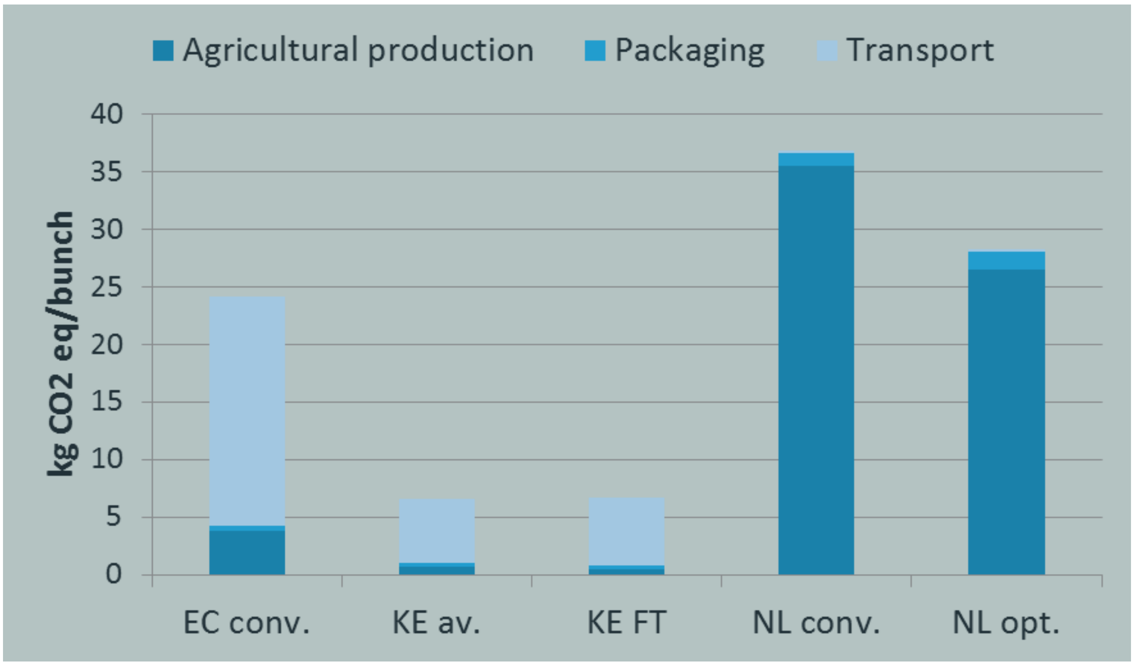

Fig. 3.2: Greenhouse gas emissions according to IPCC (2013) of the five different bunch of roses analysed

3.4. Water scarcity footprint

The water scarcity footprint is between 1 and 2.3 m^3 water equivalents per bunch of roses. Average roses from Kenya exhibit the highest water scarcity footprint, followed by the Fairtrade roses from Kenya (-4 %) and the conventional roses from Ecuador (-11 %; see Fig. 3.3). The water scarcity footprint of the roses from the Netherlands is about half as high as the water scarcity footprint of the roses from Kenya. For all roses, the agricultural stage is the dominant contributor to the water scarcity footprint.

The high water scarcity footprint of the Kenyan roses is a consequence of the high water scarcity in this country. The conventional roses from Ecuador consume most water for irrigation (unweighted water consumption of 7.5 l per rose). The average roses from Kenya consume 5.1 l per rose for irrigation and the conventional roses from the Netherlands only 1.6 l. 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 generation for greenhouse heating (above all cooling in hardcoal power plants, which make up 17 % in the electricty mix of the Netherlands).

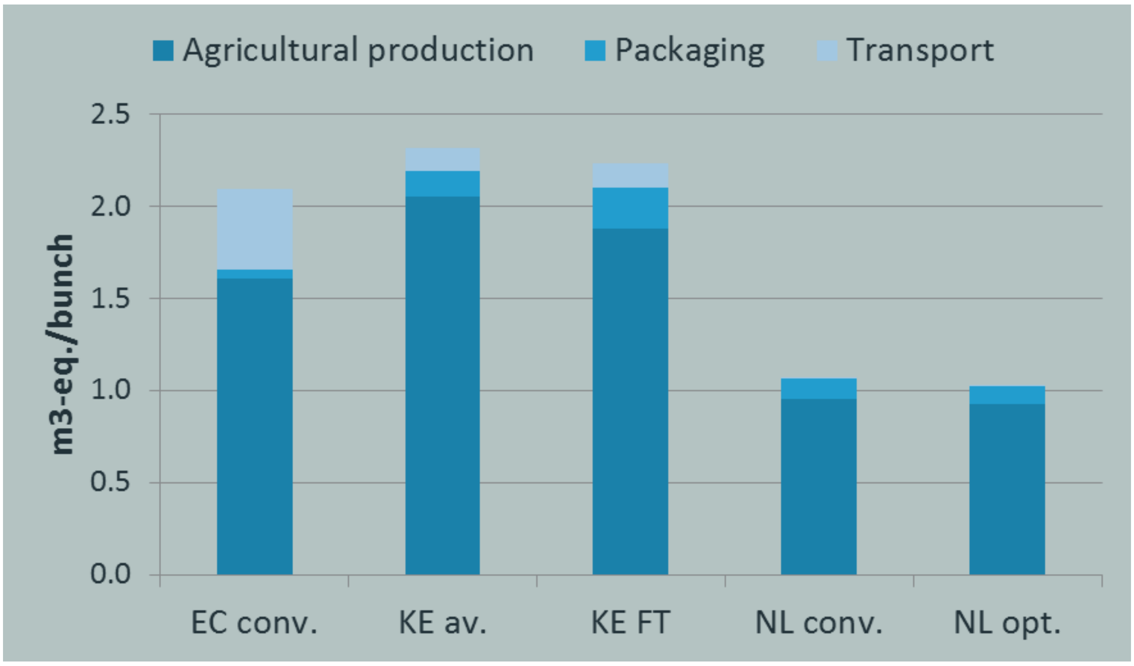

Fig. 3.3: Water scarcity footprint according to AWARE (Boulay *et al.* 2017) of the five different bunch of roses analysed

With 4.6 l per rose the Fairtrade roses from Kenya have a slightly lower water consumption for irrigation than the average Kenyan roses. The main reason for this lower consumption is the use of recycled waste water and rain water for irrigation. The total (consumptive and non-consumptive) water use for irrigation is with 12.0 l per rose practically the same as the average Kenyan roses (12.3 l per rose). The higher contribution of the packaging stage is due to the higher electricity use for the cooling rooms and the relative high share of water power in the Kenyan electricity mix. However, there is a high variability in the energy demand for cooling between the five Fairtrade farms analysed. The higher average power consumption is mainly due to one farm that consumes a very high amount of electricity for cooling. If this farm is not taken into account, there are no differences in electricity consumption for cooling between average and Fairtrade roses.

The relative high contribution of the transport stage for the Ecuadorian roses is again due to their higher needs in transport services because of their higher weight. The water emissions occur during the operation of the aircraft and during kerosene production.

3.5. Biodiversity loss

This indicator quantifies the long-term potential loss of species through human land use compared to natural areas (see also Subchapter **Fehler! Verweisquelle konnte nicht gefunden werden.**).

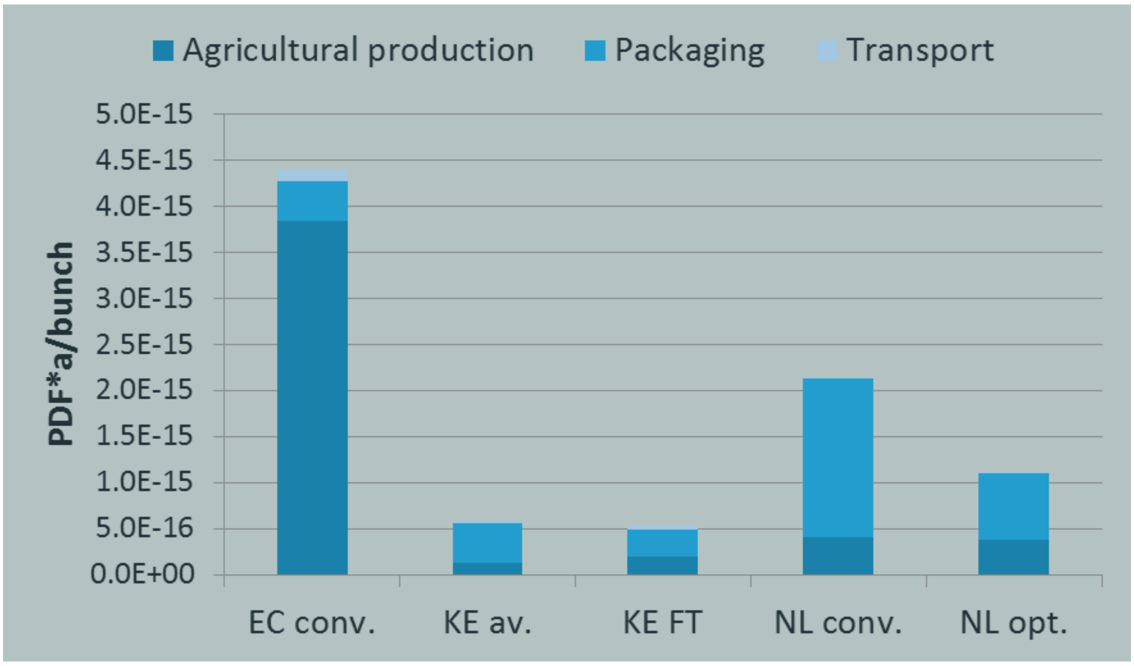

Fig. 3.4: Biodiversity loss of through land use according to Chaudhary et al. (2015) of the five different bunch of roses analysed

The biodiversity loss through land use lies between 0.5 and 4.4 femto-PDF*a per bunch of roses and is highest in Ecuador (Fig. 3.4). The impact of the conventional roses in the Netherlands is about half as high, the impact of the roses from optimized production in the Netherlands about four times lower and the impact of the roses from Kenya seven to eight times lower. The high impact of the Ecuadorian roses is firstly due to the low yield in this country, which leads to a three times higher land occupation per rose in Ecuador than in the other countries. Secondly, the potential species loss is particularly high in Ecuador: one square metre year of land used in Ecuador has a 13 times higher impact on biodiversity than one square metre year used in Kenya. This could be due to a higher (initial) biodiversity in Ecuador (and thus a higher loss potential) or more endemic species in that country (and thus a higher weighting of the area used).

For all other roses analysed, i.e. the kenyan and dutch roses, the impacts of the agricultural stage are very small. Packaging contributes most to biodiversity loss, mainly caused by the managed forests which deliver the wood for the cardboard packaging.

3.6. Terrestrial eutrophication

The terrestrial eutrophication (over-fertilization, see also Subchapter **Fehler! Verweisquelle konnte nicht gefunden werden.**) is between 0.11 and 0.39 molc N equivalents per bunch of roses (see Fig. 3.5). Also for terrestrial eutrophication, the roses from Ecuador exhibit the highest impact. The terrestrial eutrophication of the conventional roses from the Netherlands is 2.3 times lower, the one of the roses from optimized production from the Netherlands 2.7 times lower. The average and Fairtrade roses from Kenya exhibit a 3.5 and 3.2 lower impact respectively than the roses from

Ecuador. For the roses from overseas, the transports are the most important contributor. This is due to nitrogen oxide emissions during air transport to Europe. For the roses from the Netherlands, the agricultural stage contributes most to the terrestrial eutrophication. Most important are the nitrogen oxide emissions from the natural gas burnt in the combined heat and power unit as well as from electricity generation for the national grid mix.

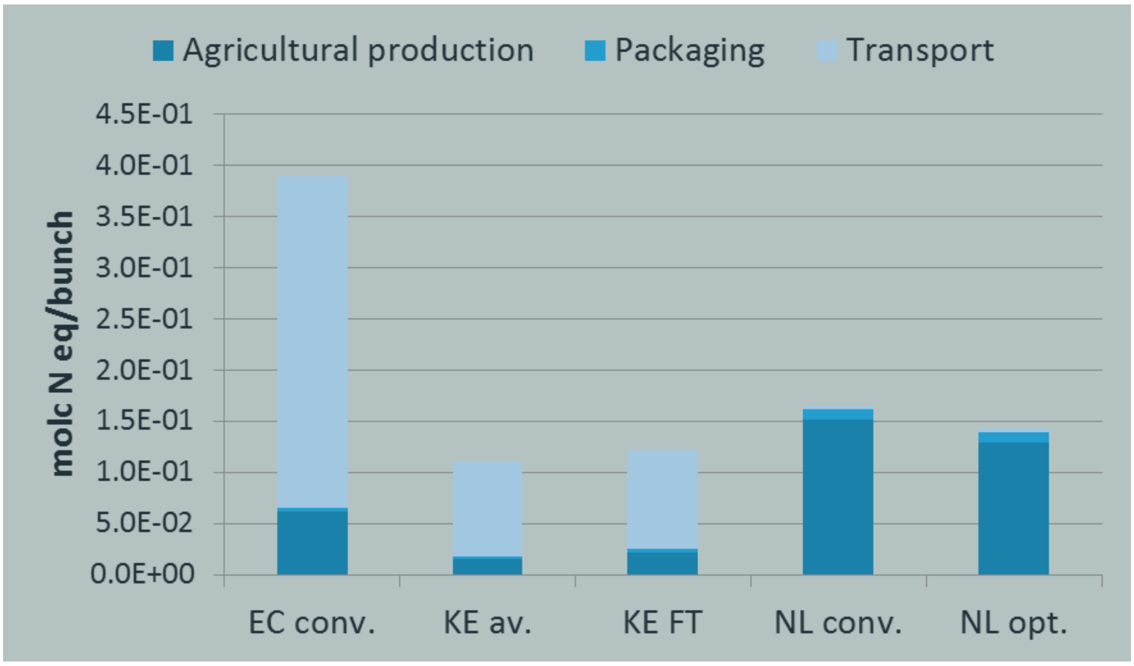

Fig. 3.5: Terrestrial eutrophication according to Seppäla et al. (2006) of the five different bunch of roses analysed

3.7. 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 **Fehler! Verweisquelle konnte nicht gefunden werden.**).

The roses from the Netherlands exhibit the highest freshwater eutrophication impact (see Fig. 3.6). The impact of the roses from Ecuador is three times, the impact of the average and Fairtrade roses from Kenya 16 and 19 times lower, respectively.

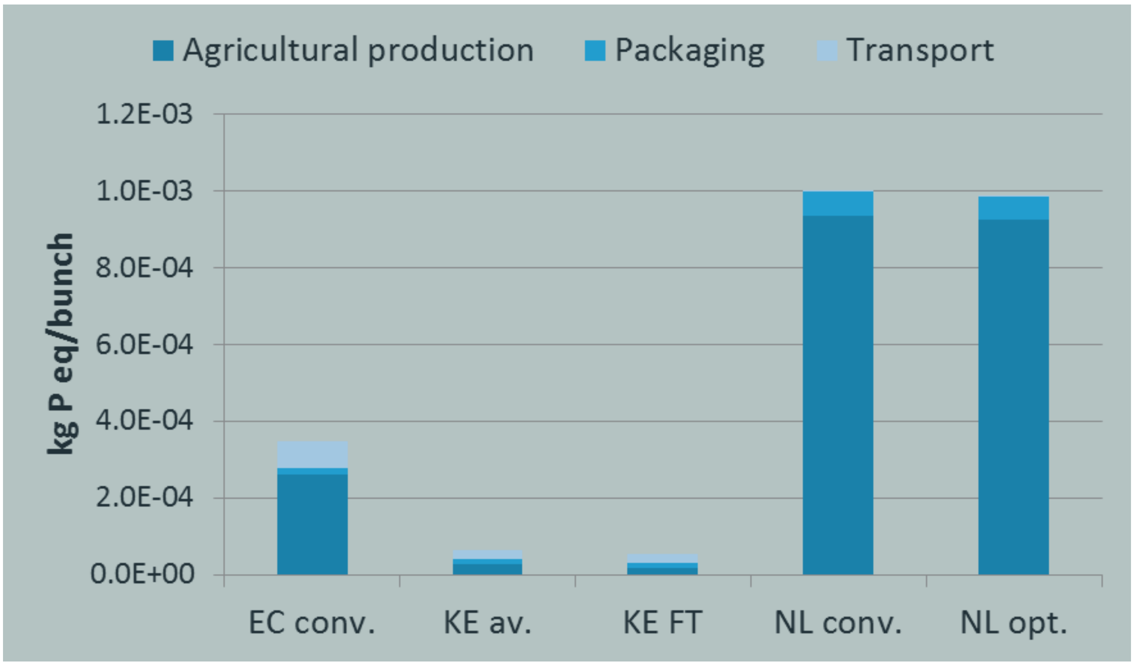

Fig. 3.6: Freshwater eutrophication according to ReCiPe (Huijbregts et al. 2016) of the five different bunch of roses analysed

Again, the agricultural stage is most important for the roses from the Netherlands, Ecuador and to a lower degree also the average roses from Kenya. For the roses from Ecuador and 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).

The roses from Ecuador exhibit the highest marine eutrophication impact (Fig. 3.7). The impact of the conventional roses from the Netherlands and the average roses from Kenya is nearly three times lower, the impact of the Fairtrade roses from Kenya is more than two times lower. For the roses from the Netherlands and Kenya, the agricultural stage is most important. 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 Kenia, 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 – the fertiliser input per hectare is similar for both systems. The Ecuadorian roses with a even lower yield exhibit slightly higher nitrate emissions than the Kenyan Fairtrade roses. These are exceeded by emissions from air transports, which are the most important contribution to marine eutrophication for roses from Ecuador.

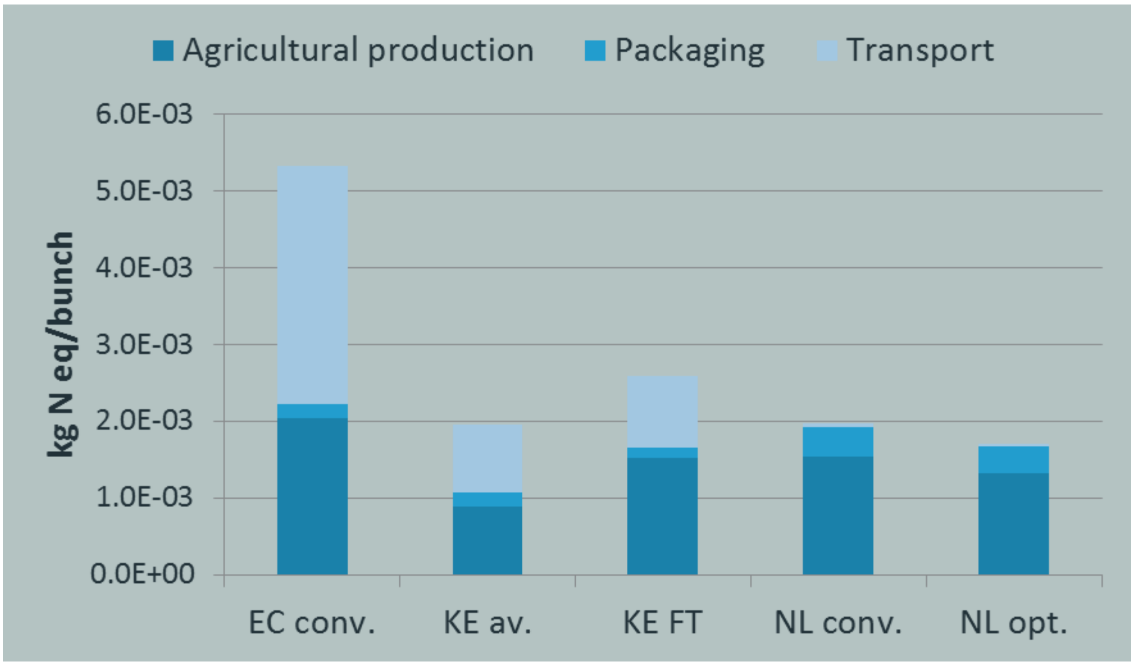

Fig. 3.7: Marine eutrophication according to ReCiPe (Huijbregts et al. 2016) of the five different bunch of roses analysed

3.8. Pesticide use

Regarding pesticide emissions, detailed information on the active ingredients used were only available for the Fairtrade roses from Kenya and the roses from optimised production from the Netherlands. For the other roses, only the total amount of insecticides, herbicides and fungicides used is known (Fig. 3.8). In all systems, the use of fungicides is highest, followed by the use of insecticides. Herbicides are only used in minor quantities. The producers of the average roses in Kenya and the roses from optimized production in the Netherlands reported not to use herbicides.

Overall, the amount of pesticides used is highest for the average roses produced in Kenya. They use 6.4 times more insecticides and 4.5 times more fungicides than the conventional roses grown in the Netherlands. The conventional roses produced in Ecuador are in between. As the amount of pesticides used in Ecuador was scaled from the amount of pesticides used in the Netherlands, the use of insecticides, fungicides and herbicides is consistenly three times higher than the use in the Netherlands. The Fairtrade roses grown in Kenya use significantly less pesticides than the average roses grown there. The use of insecticides is almost 70 % lower, the use of fungicides 75 % lower. For both systems, the use of miticides was known too (not shown in Fig. 3.8), of which the Fairtrade roses use 97 % less than the average roses from Kenya. The roses from optimized production in the Netherlands use the least amounts of pesticides. They use 83 % less insecticides and 55 % less fungicides than the conventional Dutch roses.

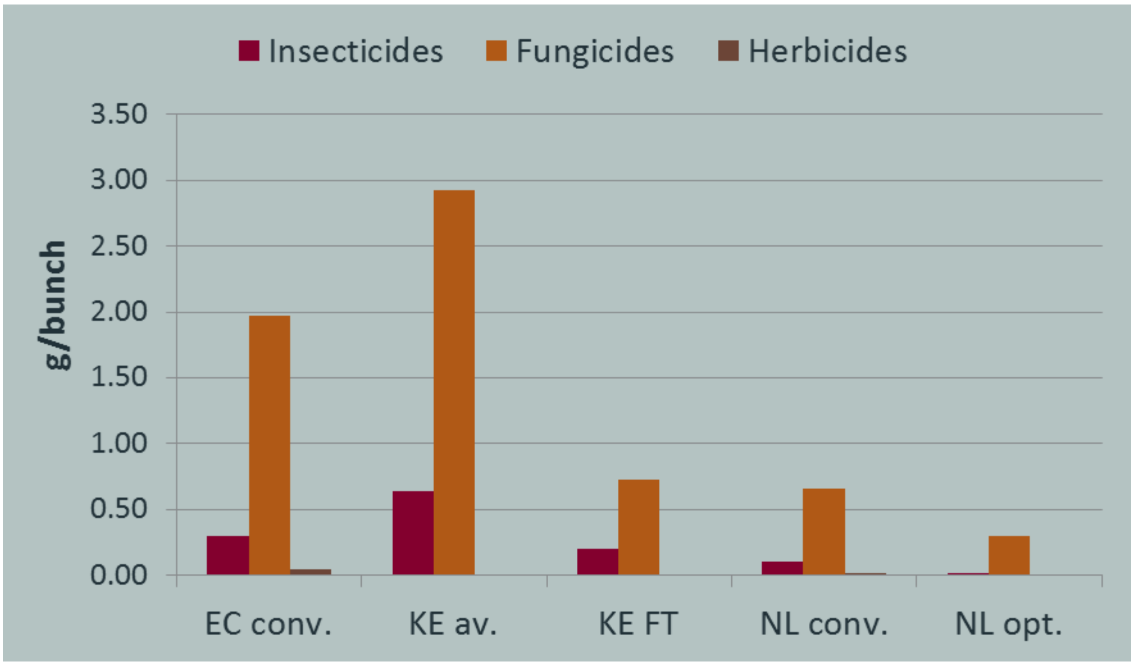

Fig. 3.8: Amount of insecticides, fungicides and herbicides used of the five different bunch of roses analysed

As a restriction, it must be said that it is unclear whether the figures for average roses in Kenya refer to the quantity of active ingredients used or the total quantity of pesticides. If they refer to the total amount of pesticides used, the amount of active ingredients could be about 30 % to 60 % lower. This would result in lower amounts used than the roses from Ecuador, but still higher than the Fairtrade roses from Kenya and the roses from the Netherlands.

However, the total amounts as reported here do not say anything about the potential adverse environmental impacts of individual pesticides and their damage potential for non-target organisms.

4. 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.

The life cycle inventory of the Dutch roses bases on recent, detailed high quality primary data. Data on pesticide use was taken from national statistics. The data can be judged as representative for current rose production in the Netherlands. For the average roses from Kenya, production data represent a ten years average of one farm, which were cross-checked with findings from other similar or comparable studies and literature. The farm analyzed is typical for rose production systems in Kenya. However, in view of the great variability in the production data of different rose producers, a large number of producers would be necessary to obtain a statistically representative sample. Another limiting effect has the age of the data. The source used is based on surveys conducted between 2002 and 2011. Any technical optimizations of the last 10 years are therefore not reflected. For Ecuador, no primary data was available. The production figures have usually been extrapolated from data about rose cultivation in other countries (Kenya, Netherlands) and are therefore subject to a high degree of uncertainty.

The key figures for the agricultural production of Fairtrade roses and the roses from optimized production in the Netherlands were collected directly from the producers by means of a questionnaire. For the Fairtrade roses, data from five producers were available. In view of the great 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 amounts of active ingredients used in pesticides. The production figures for the optimized production in the Netherlands represent the situation of one specific producer.

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 and Ecuador, waste water is sometimes collected in dumps, where it is naturally purified and then released to the environment. This waste water 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 quantified and thus were not taken into account.

Overall, it can be said that high quality, primary data has been used for the average roses from Kenya and the Netherlands as well as the Fairtrade roses from Kenya and the roses from optimized production from the Netherlands. Especially the most important parameters (greenhouse heating, means of transport and transport distances) are subject to a low degree of uncertainty. In this regard, the comparison can therefore be regarded as reliable. For other production parametes, the age of the production data of the Kenyan roses has a limiting effect. The differences in pesticide consumption e.g. could also be due to the different age of the data sets.

For the conventional roses from Ecuador, no primary data has been obtained and the comparison very much depends on the assumptions about the yield and weight of the roses from Ecuador. For reliable statements, accurate data on these parameters should be available. The present results can only give an indication of the direction in which the results could go and must therefore be treated with the utmost caution. In addition, the roses from Ecuador are of a different quality than the other roses considered and are therefore not directly comparable as a product.

The results for the Fairtrade roses refer to ground planted, open loop systems. In Kenya there are also Fairtrade farms with closed-loop systems that grow on substrates. However, these were not taken into account in the present study.

5. Conclusions

The most important production parameters are *energy use* 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. Exceptions are the water scarcity footprint, where direct water consumption plays the dominant role (especially in countries with a high water scarcity); marine eutrophication, where fertilizer use and the related nitrate emissions of the rose production overseas are also important; and biodiversity loss, where the production of the packaging material dominates except for roses produced in Ecuador.

Roses from Kenya are the benchmark. Roses from this country have the lowest or one of the lowest environmental impacts for all indicators analyzed. The Fairtrade roses from Kenya show similar environmental impacts as average Kenyan roses. In terms of amount used, pesticide use is lowest for Dutch roses. In Kenya, Fairtrade roses have a lower use than average roses. However, the fact that this comparison was based on a relatively small sample has a restrictive effect. Since the variability between the individual producers is very large, a much larger sample would have to be used for statistically significant statements.

Overall, it can be stated that Fairtrade standards not only enhance social justice, but can also contribute to the reduction of the environmental impacts of rose production. For measurable effects across all environmental impacts, however, the relevant standard requirements should specifically be strengthened. The great variability between the individual producers indicates that there is optimization potential. One possibility would e.g. be the mandatory use of closed-loop systems to reduce fresh water requirements. Targeted improvements for the producers with the highest environmental impacts would have the most positive effect.

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.

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). 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 sources for greenhouse heating. The objectives of Dutch production in this regard have not yet been achieved. If Dutch production were to be converted to renewable energy sources, it could possibly do better than the roses flown in.

For Kenyan roses, water use is a critical issue. As a result of the high water scarcity in this country, measures to reduce water demand and increase water efficiency are central.

Possibilities are e.g. the collection of rainwater or the recycling of used water (closed-loop-systems).

When interpreting the results, we have to have in mind that the roses assessed differ in their size and weight. The longer-stemmed and higher quality roses of Ecuador are three times heavier than the Kenyan and the Dutch roses. The weight ratio also reflects the respective qualities and prices of the roses. The Ecuadorian farms achieve a significantly higher price for their high-quality, long-stemmed roses. These are sold individually, while roses from Kenya and Holland are sold in whole bouquets. The products are therefore not the same and a direct comparison is only possible to a limited extent. Referring the environmental impacts to one kilogram or one Swiss franc of roses would change most of the results in favor of the Ecuadorian roses.

Additionally, the roses assessed are of different quality and prices and therefore do not represent exactly the same product.

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A. Appendix

A1 Pesticide use

Table A.1 Use of pesticides per bunch of roses and in percent of the conventional roses in the Netherlands in the different production systems analysed.

		Conv. Roses EC	**Av. Roses KE**	**MH Rosen KE**	**Conv. Roses NL**	**Opt. Roses NL**
Insecticides	g/bunch	0.298	0.63	0.197	0.099	0.016
	%	300%	639%	199%	100%	17%
Fungicides	g/bunch	1.967	2.93	0.729	0.656	0.292
	%	300%	446%	111%	100%	45%
Herbicides	g/bunch	0.041	0.00	0.002	0.014	0
	%	300%	0%	13%	100%	0%

Table A.2 Detailed list of active ingredients used per rose for the fairtrade roses in Kenya

Insecticides total	g/rose	0.009867012
1,4-Benzenedicarbonyl dichloride	*g/rose*	*0.000456333*
Acephate	*g/rose*	*0.003818683*
Azadirachtin	*g/rose*	*7.07673E-05*
Buprofezin	*g/rose*	*0.000690177*
Cypermethrin	*g/rose*	*1.23101E-08*
Cyromazine	*g/rose*	*2.10151E-07*
Deltamethrin	*g/rose*	*0.000550832*
Dithianone	*g/rose*	*0.002376734*
Fipronil	*g/rose*	*1.61512E-05*
Imidacloprid	*g/rose*	*0.001014886*
Indoxacarb	*g/rose*	*0.000242378*
Lambda-cyhalothrin	*g/rose*	*0.000173468*
Methoxyfenozide	*g/rose*	*0.000199276*

Profenofos	*g/rose*	*1.23101E-05*
Pymetrozine	*g/rose*	*0.000176187*
Tebufenozide	*g/rose*	*6.86079E-05*
Fungicides total	g/rose	0.036467486
Azoxystrobin	*g/rose*	*0.000154376*
Benzoic acid	*g/rose*	*0.000208941*
Bupirimate	*g/rose*	*0.003192343*
Carbendazim	*g/rose*	*3.40383E-05*
Chlorothalonil	*g/rose*	*0.001332911*
Cymoxanil	*g/rose*	*0.000122717*
Cyprodinil	*g/rose*	*0.000400525*
Difenoconazole	*g/rose*	*1.15389E-05*
Dimethomorph	*g/rose*	*0.000327109*
Dodemorph	*g/rose*	*0.005402924*
Fluazinam	*g/rose*	*7.27427E-06*
Fludioxonil	*g/rose*	*5.66584E-07*
Folpet	*g/rose*	*0.000751514*
Fosetyl-aluminium	*g/rose*	*0.001551568*
Iopromide	*g/rose*	*0.000333963*
Iprodione	*g/rose*	*0.002220608*
Kresoxim-methyl	*g/rose*	*0.000145212*
Mancozeb	*g/rose*	*0.013700179*
Metalaxil	*g/rose*	*1.30222E-05*
Metalaxyl-M	*g/rose*	*0.00011183*
Propamocarb hcl	*g/rose*	*0.003420601*
Propineb	*g/rose*	*0.000679032*
Pyrimethanil	*g/rose*	*0.001542351*
Thiabendazole	*g/rose*	*1.88128E-06*
Thiophanate-methyl	*g/rose*	*1.62535E-05*
Triflumizole	*g/rose*	*0.000520351*

Triforine	*g/rose*	*0.000263855*
Herbicides total	g/rose	8.79631E-05
Glyphosate	*g/rose*	*8.79631E-05*
Miticides total	g/rose	0.002206365
Hexythiazox	*g/rose*	*0.002206365*
Nematicides total	g/rose	0.000210785
Biocides total	g/rose	0.000210785
Beneficial organisms total	g/rose	1.317632427
Wetter and adjuvants total	g/rose	0.024670044

Table A.3 Detailed list of active ingredients used per rose for roses from optimized production in the Netherlands

Insecticides total	g/rose	0.001
Azadirachtin	*g/rose*	*0.001*
Fungicides total	g/rose	0.015
Bupirimate	*g/rose*	*0.000*
Kresoxim-methyl	*g/rose*	*0.000*
Dodemorph	*g/rose*	*0.014*
Herbicides total	g/rose	0
Miticides total	g/rose	0
Nematicides total	g/rose	0
Beneficial organisms total	g/rose	0
Wetter and adjuvants total	g/rose	0.0001

A2 Treeze

A2.1. *Company description*

Treeze Ltd was founded on 1.11.2012 by Dr. Rolf Frischknecht. The team is specialized in life cycle assessment and its application in product development, environmental management of companies and organizations, policy making, training and research. The service is characterized by fairness, excellence and independence. „treeze“ symbolizes the process trees within LCA-modeling. The name stands for „towards resource and energy efficiency and zero emissions“, goals to which LCA can contribute significantly. Martina Alig, Philippe Stolz and Laura Tschümperlin are working for treeze Ltd.

Treeze and its employees have extensive experience in the collection of life cycle inventory data, in life cycle assessment case studies and research projects in the energy, transport, buildings and housing, information technology and food and nutrition sectors, in the design, development and implementation of life cycle assessment databases, and in the management of complex life cycle assessment data projects with several project partners. Many of our projects are characterised by a high degree of innovation, complexity and practical suitability. Since the publication of the first life cycle assessment database at ETH Zurich in 1994, Rolf Frischknecht has been commited to transparency and reproducibility. For more information, please visit our website www.treeze.ch

A2.2. *Staff*

Dr. Rolf Frischknecht is managing director of treeze and of the Swiss platform “life cycle assessment data in the construction sector”. He studied civil engineering at the Swiss Federal Institute of Tech¬no¬logy (ETH) in Zurich. Between 1990 and 1997 he worked at the Department of Ener¬gy Technology at ETH Zurich on me¬tho¬dology, data collection and data ma¬na¬ge¬ment related to Life Cycle Assessments of energy systems and was responsible for the deve¬lop¬ment of the first version of an Internet-based LCA database. He wrote his Ph.D. on life cycle inventory analysis and decision making. In 1998 he founded ESU-services and was its ma¬naging director until 2012. He was leading the ecoinvent projects, with the aim to design, build-up, introduce and operate a large web-based LCA database. From 2005 to 2008 he was director of the ecoinvent Centre, maintaining and further extending the ecoinvent data¬base. He is guest author in scientific journals and invited keynote speaker at international con¬feren¬ces. Rolf Frischknecht is co-chair of the flagship project "global guidance on environmental impact assessment indicators" of the international UNEP SETAC life cycle initiative, member of the international advisory council of the ecoinvent Centre and management board member of the society of the Swiss LCA discussion forum. He teaches LCA on bachelor and master level at ETH Zürich. He is subject editor LCI methodology and databases of the “International Journal of LCA” (Springer publishing), and member of the öbu, the sustainable business network, of the Society of Environmental Toxicology and Che¬mistry (SETAC), the Swiss Engineers and Archi¬tects Association (SIA) and the Association of German Engineers (VDI).

Martina Alig is project manager at treeze. She has distinctive competencies if the field of agricultural life cycle assessment. She assesses food, feed and other agricultural products and advises companies such as retailers on making environmentally sound decisions. She compiles emission factors for product ranges and has extensive expertise in the calculation of regionalised water stress and biodiversity impacts. She analyses consumption patterns of Swiss households and uses environmentally extended input-output tables to determine their environmental footprints. Martina Alig also conducts reviews of product LCAs according to KBOB and DIN EN15804. Martina Alig joined treeze in September 2016, after having worked at Agroscope’s life cycle assessment group for nine years. She holds a Master in Environmental Sciences from ETH Zurich. During her Master’s thesis, she assessed the sustainability of smallholders in Côte d’Ivoire.