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Balkan-Mediterranean
BalkanRoad

Towards farms with zero carbon-, waste- and water-footprint. Roadmap for sustainable management strategies for Balkan agricultural sector

PROJECT DELIVERABLE

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1 Extended Summary

Conventional agriculture uses chemical fertilizers and the environmental impact is poorly documented. Environmental benefits versus drawbacks of production are not well known. Life cycle assessment (LCA) is used to measure the environmental footprint and identify particular environmentaly unsustainable cultivation practices. In this LCA, we have analyzed the commonly practiced pepper production, in polytunnels, which will be compared after changes leading to increased environmental sustainability are introduced. The aim of this work is to quantify, compare and improve the environmental sustainability of typical conventional pepper cultivation system.
Furthermore, the environmental impact is assessed by life cycle analysis of a finalized product made from pepper. Analyses, were performed after the construction of a LCI database relating to the standard processes of pepper production and processing, the structure of the system, the inputs for production, and the generated waste products. Results are analysed at midpoint level in order to obtain a comprehensive overview of the environmental sustainability at current production practices.

2 Introduction

Balkan agricultural sector faces strong challenges in terms of unsustainable resources management and GHGs emissions. Recent studies have shown that agriculture and production are responsible for 10–30% of the total GHG emissions and that the effects of the production are also evident in different categories of environmental impacts, like climate change, impacts of land and water use, human- and eco-toxicological effects, eutrophication, acidification, soil fertility degradation, and landscape changes. Policy makers and private companies in various countries have recognized the need to quantify these environmental impacts and, on this basis, to identify measures for impact reduction. New legislation introduced recently started to encourage the labeling of food products with their carbon/environmental footprints. Retail companies are also joining the initiative by calculating the food products carbon footprint and communicating these to their customers. Recently, water footprint studies for agriculture and food production have also gained high interest, revealing the amounts of water consumption and the related impacts. Although some countries show positive development indicators, however the continuous economic crisis, the low level of participatory/initiatives undertaking by local/regional authorities and the lower capacity and educational level of Balkan farmers in comparison to other European farmers, inhibit the adoption of innovative approaches and conformation of Balkan agriculture to EU policies, mainly at farm/local level. In addition there are still large data gaps concerning the environmental assessment of agriculture and food production. Thus, detailed, process-based LCA data are needed to support decisions making regarding sourcing of food products, means of transportation, agricultural management, and consumer choices. The goals of the BalkanROAD project is to: 1. develop strategies, methodologies and technologies for natural resources conservation (soil, water, air), reduction of GHGs, reduction of waste generation/disposal and increase recycling/reuse ratio in farm systems environment protective practices and 2. develop a common Balkan

Protocol for the production of eco-labeled agricultural products, by putting in force sustainable practices throughout the entire production line (i.e from the field to the market) so that the final products will have measurable, comparable and ultimately the lowest possible environmental footprint.

3 Material and Methods

3.1 Study Area description - Pilot site

MOPF has selected one of the EKO-GRUP OCP company vegetable production plots to implement BalkanROAD project activities. EKO-GRUP manages most if its own vegetable in several locations within the Tikvesh region. The selected plot for BalkanROAD activities is located in Palikura village (about 10 km near town of Kavadarci). On this location EKO-GRUP OCP company grows peppers (Kapia variety) on 0,5 ha in plastic tunnels (dimensions 5,1 x 33 m) which are subject of the BalkanROAD activities, but also tomato, eggplant and garlic. Crop rotation involves mostly chickpeas and kidney beans, but oats and barley are also used for weed control.
All harvested products are transported to the EKO-GRUP OCP processing facility, located in town of Kavadarci and finalized in to a variety of jarred or bottled products. EKO-GRUP OCP processes about 70 different products made mostly from raw materials grown in own operations or in cooperation with local growers.

The main categories of products include:

- Pepper products
- Tomato products
- Eggplant products
- Chickpeas and kidney bean products
- Fruit products
- Leafy greens products

EKO-GRUP OCP sells products on both the domestic and export markets in the region, EU but also overseas markets like Canada, Australia and New Zealand.

3.2 LCA Methodology

Life Cycle Analysis (LCA) is defined as a method for compiling and evaluating all inputs, outputs and the potential environmental impact of a production system throughout its life cycle. It enables the user to measure and quantify the environmental impacts of a product (ISO, 2006a,b). Furthermore, it helps to identify hot spots where the most significant impacts occur, giving the user the opportunity to develop strategies for improving the product's environmental performance.

In respect to agriculture, LCA is a tool that can better place the ‘food miles’ concept into perspective and enables farmers and agricultural enterprises to respond to demands and awareness from consumer and environmental groups about the carbon and water footprints of agricultural products. Both environmental demands and awareness influence the way in which legislative bodies such as governments will guide the future development of agricultural and industrial food production systems.

The leading components for standardized LCA are the international standards of ISO 14040 and ISO 14044. The key methodological aspects of an LCA are summarized in the following four steps:

i) "Goal and Scope Definition",

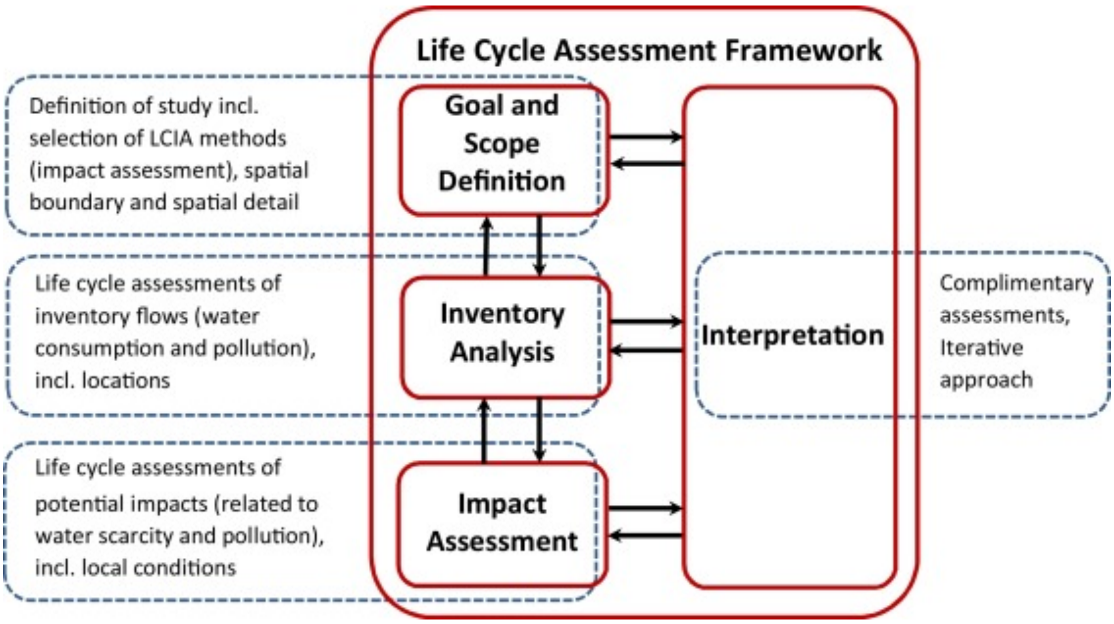
ii) "Inventory analysis",

iii) "Impact Assessment" and

iv) "Interpretation"

A schematic overview of a typical LCA is presented in Figure 1.

Figure 1 LCA steps in standardized methodology according to ISO 14040 standard



The LCA study is carried out to determine the consumption of raw materials i.e. fertilizers, pesticides, irrigation and processing water, energy and agricultural/processing waste, as well as to calculate emissions of pollutants (CO_2, CH_4, VOCs, NO_x, SO_2 etc.) to air, water and soil. In the frame of BalkanROAD, the "*current situation*" is analyzed at first, acting as a basis for undertaking performance tracking, and/or to set improvement environmental targets and monitor progress against them. It includes common farm management and normal mode of field-work processes for peppers production and processing (both cultivation and processing/post-harvest), by considering data extrapolated from the past 3 years (2015-2017) for Palikura planting site. This "*current scenario*", based on the actual current cultivation/processing and waste/by-product management practices that take place in Palikura pilot area, will be further used as the basis for comparison with the **"build up" scenario** representing alternative sustainable and plausible farm/processing and waste management options followed during BalkanROAD project.

3.2.1 Functional Unit

EKO-GRUP's jarred pepper product named "**Peppers in own sauce**" is selected as a **functional unit (FU)** in the BalkanROAD activities. Peppers grown by EKO-GRUP are used as main ingredients for this product, which contains 87% peppers, 13% sunflower oil and is seasoned with salt. The product used as functional unit is packed in **275 ml (0.275 l) glass jars with a net content of 260 g** and sealed with twist off metal lids.

In order to produce "Peppers in sauce" the harvested peppers from EKO_GRUP OCP plots are transported to the processing facility. Within 24 hours, the seeds are manually removed and the peppers are roasted in tunnel ovens using gas burners. After this, the peppers are washed and peeled in a peeling machine which uses fresh water and brushes to remove the scorched peels and clean the peppers. As next step about 70% of the peppers are placed in freezers for storage and processed later in the year, while 30% are processed after pealing. The pealed peppers are then sliced and cooked with addition of sunflower oil and salt. The cooked peppers are then filled in jars and pasteurised before the jars are labelled and included in transport packages.

The products are exported to several export destinations, including Canada via the Thessaloniki port.

As the product is made with peppers (grown on the test plot) all needed production data inputs from the test plot and processing are available in a clearly defined and measurable way. In addition, the product is made with minimum addition of additional ingredients (13% sunflower oil), packed and placed on the market in Canada via the Thessaloniki port. Therefore, this product fulfils most of the requirements for successful "cradle to grave" LCA and is selected as a Functional unit for the purpose of the LCA.

3.2.2 System Description

LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, and as a result allows selecting path or process that is more environmentally preferable. In the frame of BalkanROAD, the "cradle-to-grave" approach is used. "Cradle-to-grave" begins with the gathering data on the production of raw materials from the earth to create the product and ends at the point when the final products are finally used. At the current example aiming to establish a reliable comparison basis of the marketable products under study, an expanding "cradle-to-grave" approach is adopted in the BalkanROAD project, including the stage of distribution. In this context, the port of Thessaloniki is being used as the final destination of the LCA study, common for all the marketable products.

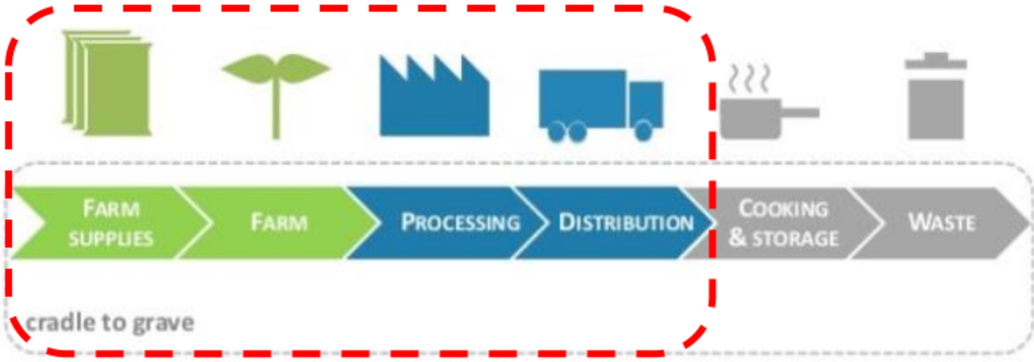


Figure 2 "Cradle-to-grave" approach in the frame of BalkanROAD project

Figure 2 shows the boundaries of conventional pepper cultivation systems and its processing in to the final product as a functional unit. The system will be then assessed against a sustainable system, defined within the Balkan ROAD project. Both systems have similar post harvesting activities, such as processing, packaging and distribution to a selected location. Sale and consumption are treated as being outside the boundaries.
The LCA starts at seedling production, seedling planting, growing and harvest of peppers and ending at pepper processing it to a final products, distributed to Thessaloniki port. All main environmentally relevant physical aspects such as farm activities, transport, processing facility activities and inputs in to the final product are included within the boundaries of this LCA.

3.2.3 Data Collection

The *Kapia* is a variety of sweet bell peppers suitable for field cultivation growing. This pepper is a native of the Balkan and Eastern Europe countries. *Kapia* peppers are in the same family as the bell pepper (C*apsicum annuum*). Plants are about 0,5m tall and produce fruits that are big, hanging and shiny and flattened with tender, juicy, sweet flavored flesh. The case study includes sustainable and conventional Kapia pepper cultivation in the central part of the Tikvesh region, near the town of Kavadarci. The study focuses to the production of a jarred pepper product named "**Peppers in sauce**" produced by EKO-GRUP company. The final product includes the farm produced peppers as main ingredients.

3.2.4 Modelling approach, Impact categories and Assigned burdens

By taking into account the phases of classification and characterization defined by the standards of ISO 14040-14044 series, the selection of impact categories can be chosen according to the goal and scope of the study. During the classification phase, each burden is linked to one or more impact categories, while in the characterization phase the contribution of each burden to each impact category is calculated by multiplying burdens with a characterization factor.

As a result, **five mid-point environmental impact categories**, defined according to the **CML 2001 (April 2013 version)**[1] impact assessment method reported by the Centre of Environmental Science of Leiden University (*Guinée et al., 2001; 2002*), as well as the impact category of the cumulative energy demand as an energy flow indicator, were considered as shown in Table 1. The CML method is selected because it is well recognized and widely used

[1] In the case of Palikura site, CML 2001 (January 2015 version) is used.

in several LCA agricultural studies for allowing clear and precise quantification of a wide range of critical impact categories related to the use of energy and application of fertilizers and pesticides with considerably lower level of uncertainty compared to end-point methods (*Cellura et al., 2012b, Perrin et al., 2014; Bartzas et al., 2015; Bartzas and Komnitsas, 2017*). In addition, CML 2001 is the only recent impact assessment method that includes a characterization factor for phosphorus.

The cumulative energy demand (CED) impact category will be also calculated based on the method proposed by Frischknecht et al. (*2005*), in order to assess the energetic performance of the corresponding agricultural production.

Table 1 Environmental impact categories with their respective units

Impact category	Acronym	Units
Acidification Potential	AP	kg SO_2-eq·FU^{-1}
Eutrophication Potential	EP	kg PO_4-eq·FU^{-1}
Global Warming Potential (100 years)	GWP	kg CO_2-eq·FU^{-1}
Ozone Depletion Potential	ODP	kg CFC-11-eq·FU^{-1}
Photochemical Ozone Creation Potential	POCP	kg C_2H_4-eq·FU^{-1}
Cumulative Energy Demand	CED	GJ-eq·FU^{-1}

4 Life Cycle Inventory (LCI)

Data collection during BalkanROAD is conducted through a survey of in-situ/field campaigns and processing of peppers in to a functional unit. This approach aims at increasing the credibility of LCA analysis (LCI), as well as at drafting conclusions relying on the local agricultural and economic conditions. As a result, a site and product specific data are obtained. The site visit on Palikura peppers planting site and the EGO-Group processing plant in Kavadarci was performed on 11 June 2018. To complete the life cycle inventory, data associated with the operations performed in the background system (agrochemicals production, fertilizers production, machinery production and transportation) were drawn from literature and other available LCI databases such as Professional and Ecoinvent (*Ecoinvent, 2015 and Thinkstep, 2014*). A structured questionnaire was used to collect data on post-harvest handling and production of the functional unit.

Table 1 Main characteristics and LCI data of *Kapia* peppers cultivation area

Life Cycle Inventories (LCI for *Kapia* peppers conventional in plastic tunnels 0,5 HA cultivation area		
Production inputs		Values
Land use m^2		5000
Mean yield in tons		25 tons
Irrigation	Drip irrigation pipes	7700 m
	Water	300 m^3 / growing season
Field operation (times)	Plowing	1
	Harrowing	1
	Hoeing	1
Weed control	Herbicides (STOMP)	3 liters
	Mechanical weeding	0

Diseases control	Fungicides (Viente trplo, tilt, armetil, fulminal)	5,5 kg
	Disinfectant	0
Fertilization	10x30x20 NPK	250 kg
	Manure	5000 kg
	Potassium ammonium nitrate	150 kg
Pest control	Insecticides (sumi alfa, nurel, aktara)	2,25 kg
Waste generation	Covering plastic	Waste generated per year 166 kg
	Crop residues	Waste generated per year 1500 kg
	Mulching film	Waste generated per year 200 kg
Transport to processing facility	Fuel	300 Liters

Table 3 Main characteristics and LCI data for the product pepper in sauce

Life Cycle Inventories (LCI for finished product) 18.750 units pepper in sauce 0,275ml jar from 25.000 kg of fresh peppers		
Production inputs		Values
Water consumption		112 m^3
LPG consumption		2.652 liters
Electricity consumption		570 kw/h
Waste generated	Organic	12.500 kg
	Inorganic	400 kg
Fuel for transport to Thessaloniki port	Liters	100 liters
Inputs	Labels	18.750 units
	Sunflower oil	1.875 liters
	Jar	18.750
	Metal lids	18.750

Farm data were obtained from a several conventional vegetable farms and which also grow Kapia peppers for more than 25 years' experience. Additional data are obtained by direct interviews with pepper growers in the neighboring regions. The gathered data represent the typical growing practices for paprika in poly tunnels used by small-scale farmers.
The gathered data were for all stages of plastic tunnel pepper growing and processed using life cycle assessment software, based on LCI databases.
Pepper processing data are obtained from the EKO-GRUP company and include all stages of the pepper processing process.

5 LCA Results and discussion

The purpose of the LCIA is to quantify the environmental sustainability of typical conventional pepper cultivation systems. In this pepper, LCA study is carried out to determine the consumption of raw materials i.e. fertilizers, pesticides, irrigation and processing water, energy and agricultural/processing waste, as well as to calculate emissions of pollutants (CO_2, CH_4, VOCs, NO_x, SO_2 etc.) to air, water and soil. In the frame of "current situation" analyses are basis for undertaking performance tracking, and/or to set improvement environmental targets and monitor progress against them (e.g. going for organic production).
One open field pepper cultivation, located in village of Palikura, was selected as case study. Life cycle assessment (LCA) is used to quantify the overall environmental footprint and identify environmental weaknesses (i.e. unsustainable practices) of the cultivation system. At this point, the results are analyzed at midpoint levels to obtain a current overview of the environmental sustainability of the system with the current practices. Results are presented for problem-oriented (midpoint) approach, using **CML (baseline) [v4.4, January 2015]**.

The product process flow taken into consideration in CML is shown on the following graph:

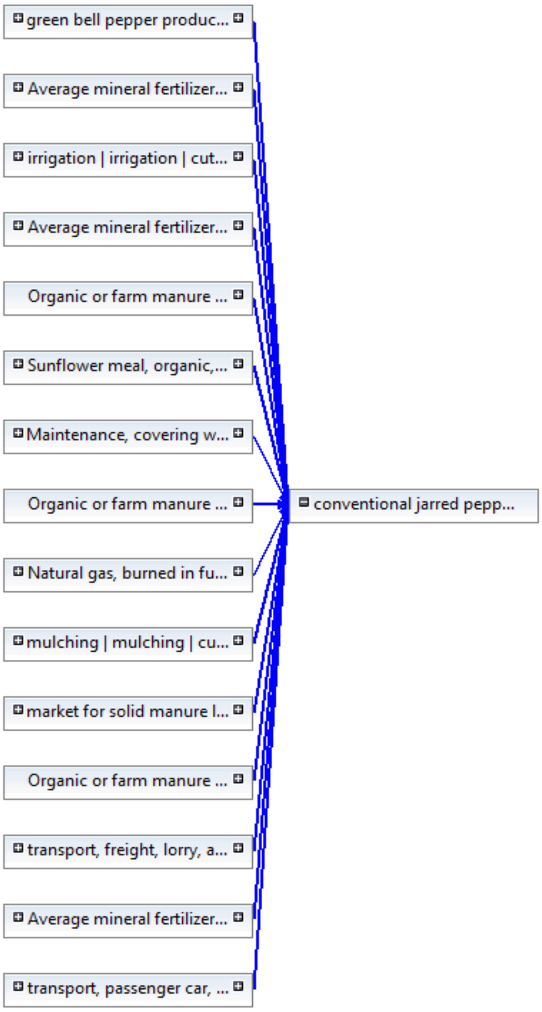


Figure 3 – Product process for conventional jarred peppers

At midpoint level, conventional cultivation shows higher environmental impact on freshwater eutrophication. This arises from the use of nitrogen and phosphorus-based fertilizers, with consequent direct emissions to the environment. The remaining impact categories are mainly affected by irrigation and water depletion. The electricity usage is also associated with the fossil-fuel-dependent Macedonian electricity mix (mainly by coal) which affect the climate change and global warming potential. Therefore, the climate change – GWP100 expressed as kg CO_2 eq. is also significantly impacted by the conventional pepper production.

LCA analysis was undertaken using Agribalyse, version 1.3. which incorporates all common life cycle inventory (LCI) datasets, including eco invent v3.2, the European Life Cycle Database (ELCD).

At midpoint level, CML uses the following 5 impact categories, which are given along with their units: 'climate change' (CC), kg CO_2 to air; 'ozone depletion' (OD), kg chlorofluorocarbon (CFC-11) to air; 'freshwater eutrophication' (FE), kg P to freshwater; 'marine eutrophication' (ME), kg N to freshwater; 'photochemical oxidant formation' (POF), kg non-methane volatile organic carbon compounds (MVOCs) to air; 'agricultural land occupation' (ALO), m^2 year of agricultural land which are in line with the proposed categories in the Guidance.

Results are expressed at midpoint level by means of a problem-oriented approach, which translates impacts into the 5 environmental themes in order to identify key issues related to conventional pepper cultivation system.
Table 4 shows the life cycle impact assessment (LCIA) results which are expressed per functional units of marketable jarred pepper in its own sauce normalized using CML (baseline) [v4.4, January 2015]'s European reference inventories.

Table 4 – LCIA results for conventional pepper production

Impact category UUID	Impact category	Reference unit	Result
721619b4-95cf-447e-9dd4-38df96f90476	Acidification potential - average Europe	kg SO_2 eq.	350.2779511
0e0bcbdc-d4cd-46c0-811c-6dc20df54629	Climate change - GWP100	kg CO_2 eq.	74559.52445
3a08605b-d7c9-4f40-a17e-74cece1dde8b	Depletion of abiotic resources - elements, ultimate reserves	kg antimony eq.	0.129356306
1080477d-1784-43c7-9a6e-b158e4a4f09b	Depletion of abiotic resources - fossil fuels	MJ	669563.851
aaa5ff8b-a60c-47ad-a74b-9d8172ee3f88	Eutrophication - generic	kg PO_4--- eq.	136.8223438
f1f73325-64c9-4668-b0c3-9babe50bb4b5	Freshwater aquatic ecotoxicity - FAETP inf	kg 1,4-dichlorobenzene eq.	21387.58327
cc4e80c6-afe6-43e3-a5b6-23962e8d99fa	Human toxicity - HTP inf	kg 1,4-dichlorobenzene eq.	27744.75272
c3829256-f575-49d4-8a48-4794e8210366	Marine aquatic ecotoxicity - MAETP inf	kg 1,4-dichlorobenzene eq.	62894024.37
6c4c343b-1140-43e4-ad21-fd3514ca5328	Ozone layer depletion - ODP steady state	kg CFC-11 eq.	0.003632039
f65587bb-c11d-4ad5-9864-22025b28a5e0	Photochemical oxidation - high Nox	kg ethylene eq.	98.58493995
ca0fb42d-5fb1-45c5-a578-2f7d396d8674	Terrestrial ecotoxicity - TETP inf	kg 1,4-dichlorobenzene eq.	613.597702

For conventional pepper cultivation, the impact category with by far the highest normalized score is 'fossil depletion (climate change). Other impact categories that contribute to the environmental footprint of conventional pepper cultivation, ordered from the highest to lowest scores, are 'freshwater eutrophication, and 'water depletion'.

The cumulative energy demand (CED) impact category was calculated based on the method proposed by Frischknecht et al. (*2005*), to assess the energetic performance of the corresponding agricultural production. The CED results for the Palikura site for conventional jarred pepper production are given in the table below.

Table 5 – CED results for conventional pepper production

Impact category UUID	Impact category	Reference unit	Result
8f51f7df-88e9-47b8-b990-7432f5c6fe2d	Non-renewable resources - fossil	MJ	712787.908
38da6014-d311-4af9-98a8-589df102c9fd	Non-renewable resources - nuclear	MJ	44117.82749
574028cd-3627-46da-8f23-eb6e7a842e75	Non-renewable resources - primary forest	MJ	20.24851378

5aae9258-1c05-494b-a019-0acaeabd3006	Renewable resources - biomass	MJ	181332.7214
9a641379-14d1-4a44-a18b-5f2d1c489a10	Renewable resources - geothermal	MJ	0.042148901
b023a3e7-5681-4b85-a1d3-118446a436fc	Renewable resources - solar	MJ	351.8669329
89a41929-0ca3-401f-8bc4-777e00e1b4da	Renewable resources - water	MJ	14093.85916
fc37fd01-6775-4928-b207-4f5a5194ef59	Renewable resources - wind	MJ	2361.424325

6 Conclusions

The present LCA study of pepper production in the Tikvesh region has enabled us to assess the environmental performance of the poly tunnel protected cultivation system. It has clearly established that fertilizer use in production generates the main environmental impact for all the categories studied, including toxicology and ecotoxicology. Differences between the traditional pepper cropping systems after changes with more sustainable practices is to be assessed after making a thorough analysis.

The environmental footprint and key environmental hotspots of poly tunnel pepper cultivation system have been identified by LCA methodology using information from a case study in Palikura planting plot (0,5ha). The main conclusions are listed below:

- At midpoint level, the highest normalized environmental impact in cultivation conventional system is in the ‘climate change (fossil depletion)’ impact category;
- Owing to direct emissions from the much greater use of chemical fertilizers, conventional cultivation attains higher score on ‘freshwater eutrophication’;
- Cumulative energy demand is also relatively high, especially from the fossil fuels.

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