Environmental Impact in Process Tomato Integrated Production

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Abstract. In modern agriculture, the energy that is consumed in every stage of production can be divided in direct (e.g. fuels and lubricants) and indirect (e.g. machinery embodied energy, materials and agrochemicals etc). This energy consumption can be examined further in environmental level as environmental impact. Environmental impact regards to the CO_2 that is emitted during the production process and contributes in a negative way to the environment. CO_2 can be emitted directly by fuels and lubricants that are used from tractors or other farm machinery and indirectly by any material application, machinery embedded energy and many other field inputs. In this paper, the environmental impact of industrial tomato production in kg of CO_2 per kg of product is analyzed and estimated. There is a range in the environmental impact in the 9 different case studies from 0.0606 to 0.1256 kg CO2/kg of tomato.

Keywords: energy, environment, CO_2, carbon footprint.

1 Introduction

It is crucial before the establishment of a perspective crop to evaluate the energy consumption and/or the environmental impact. The environmental impact can be estimated either as carbon footprint or as CO_2 emissions. Carbon emissions are connected directly to the energy consumption. Barber suggested that there is a direct relationship between energy and carbon content. Furthermore, analyses the main carbon indicators that are involved in agriculture process from different inputs (Barber A, 2004). Lal has estimated the carbon emission from different field operations (Lal R., 2004).

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It is important to evaluate crops regarding their carbon emissions and the environmental impact. Karakaya et al. are assessed the carbon dioxide emission during production of the fresh and the processed tomatoes (paste, peeled, diced, and juiced) (Karakaya and Özilgen, 2011).

In this paper, an estimation of the carbon dioxide emissions in industrial tomato integrated production process is examined, including both in-field and logistics operations in 5 case studies. Furthermore, the main carbon inputs are determined and assessed.

2 Materials and Methods

The main parameters-inputs to the examined system correspond to machinery, materials and fuels. Regarding the operations that taken into account in the presented system are the main operations implemented in the cycle farm-field, the in-field operations and those in the cycle field-factory. As computational tool, MatLab Mathworks© was used. A computational model was created to include and calculate all the carbon inputs with high accuracy. The model based on literature data, commercial sources and real farmers' data. The operations that implemented can be divided into the in-field operations and the logistics operations.

2.1 In-field operations

In-field operations can be divided depending on whether there is a material that is held (e.g. fertilization) or not (e.g. disk-harrow). In both cases, the input carbon elements that have to be estimated are the fuel and lubricants factor, the labor factor, and the machinery embodied factor, while in the case of material handling operations the material carbon factor has also to be estimated. The key factor for the former case is the working time in the field under question while for the latter case the key factor is the quantity of the material that is applied or placed in the field.

For each individual operation the estimation of the working time takes place. The working time of a field operation includes the effective in-field operation time (the time that a machine produce work) and the non-effective time (that includes times for loading/unloading - in the case of the material-handling operations, machinery adjustment and time that is allocated for headland turns). The relation between the effective and non-effective time is described by the term of "time efficiency", which represents the ratio of the time a machine is effectively operating to the total time the machine is committed to the operation (Hunt, 1995). Based on the time efficiency the field capacity (ha/h) can be estimated by taking into account also is calculated by using the operating speed (Km/h), the rated width of the implement (m), and a unit conversion factor. For the calculation of operational capacity data from ASABE standards for the field efficiency for each operation and the average operational speed are used (ASAE 2003).

For the fuel consumption estimation the equation provided in ASABE standards for the typical fuel consumption of an agricultural machine is used:

$2.64 + 3.91 - 0.203\sqrt{738X + 173}$ (l/KW h) (where X is the ratio of equivalent PTO power required by an operation to that maximum available from the PTO (ASAE 2003)). Using the fuel energy content (diesel for the particular case), the working time, the tractor power and the fuel emissions factor, the fuel emissions input is calculated for the particular field operation.

The lubricants consumption is estimated using the equation provided in ASABE standards for typical agricultural machinery diesel engines: $0.00059P + 0.02169$ (l/h) (ASAE 2003). Using the appropriate lubricants energy content, the working time, the power of the tractor and the lubricant emissions factor, the lubricants emissions input is calculated for the particular field operation.

Labor factor is taken into account that does not contribute to the total emissions calculation.

Embodied emissions factor regards the emissions that have been produced during the whole production process of each machinery system, tractor and implement. This factor, multiplied by each corresponding machinery weight, the total consumed emissions for the construction, transportation and maintenance of each farm implement's whole lifetime (from ASABE standards) will be extracted and using the working time the proportional embodied machinery emissions input for each field operation is calculated.

In the case of field operations involving material handling, beyond the above mentioned inputs, the material emission inputs (propagation means/ fertilizers/ agrochemicals) should be calculated also given their necessary quantity for each case and the emissions factor for the material production.

2.2 Farm-field transportation

The transportation cycle farm-field-field is taken into account in every field operation. The calculation of emissions produced for this transport varies if the operation that is going to be implemented includes material application (fertilizer, agrochemical, etc.) or not. In both cases the main inputs correspond to fuels, lubricants and embodied energy even though the parameters that are taken into account are different.

For material operations, in fuels emissions input estimation contribute the fuel energy content, the fuel consumption/trip, the number of trips, the wagon maximum volume (in case of planting), the tanker maximum weight (in case of fertilization and agrochemicals spreading) and the fuel emissions factor. In lubricants energy input estimation, the lubricant energy content, the tractor power, the number of trips, the distance farm-field, the average road speed are taken into account and the lubricant emissions factor. In embodied energy input contribute the embodied energy of tractor and wagon/tanker, their estimated lifetime, their weights, the number of trips, the distance farm-field, the average road speed and the embodied emissions factors.

On the other hand, regarding farm-to-field logistics operations that correspond to only machinery transportation, only one return trip per operation is taken into account in the cycle farm-field-farm and there is no material emissions input.

2.3 Field-Factory transportation

This transport regards the energy inputs during the transport of the harvested product from field to storage-processing facilities. In fuels emissions input calculation are taken into account the fuel energy content, the factor X, the tractor power, the in-field capacity of harvesting, the field area, the fuel consumption per trip, the number of trips the wagon full volume and the fuel emissions factor. Lubricants energy input calculation depends on the lubricant energy content, the tractor power, the in-field capacity of harvesting, the field area, the number of trips, the cycle time, the time needed to fill a wagon and the lubricant emissions factor. Regarding the embodied emissions inputs calculation is based on the embodied energy of tractor and wagon, their estimated lifetime, their weights, the cycle time, the time needed to fill a wagon, the in-field capacity of harvesting, the field area and the embodied emissions factor.

3 Results

Five case studies of industrial tomato farmers from Thessaly area in a whole production period were selected. The main figures of each case studies are shown in Table 1.

Table 1. Main figures in 5 case studies

	Area (ha)	Distance Farm-Field (km)	Distance Field-Factory (km)	Emissions Rate (kg CO2/kg product)
1	6.83	4	43.5	0.0606
2	3.24	4	57.1	0.0926
3	3.00	4.4	84.8	0.0910
4	2.48	6	14.3	0.0995
5	1.65	4.5	78.9	0.1256

Each field operation that is implemented from every farmer is examined and analyzed. It's taken into account that tomato is planted in small seedlings. The system boundary determined from the moment that tomato plants are planted until the final tomato product will be harvested and transported to the processing factory.

In Fig. 1 the total emissions consumption for the whole production process in 5 case studies is presented.

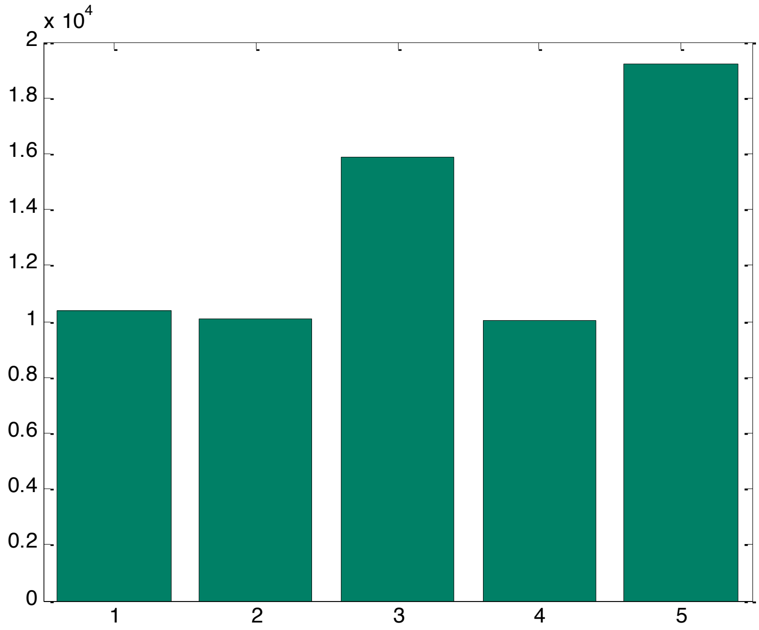

Fig. 1. Total emissions in kg CO_2 per ha for the 5 fields regarding the whole production process

In Fig. 2 the emissions produced for the different field operations in case study 1 is shown.

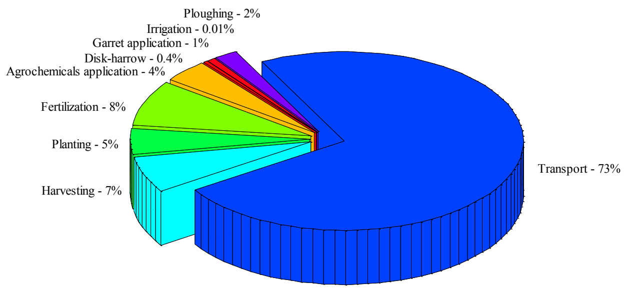

Fig. 2. Emissions per field operation in case study 1

4 Discussion

In this paper the assessment of CO_2 emissions produced during a whole production period in industrial integrated tomato fields was presented. Every field operation was analyzed under specific mathematical models in order that these field systems will be optimized in future. Finally, the total produced emissions per kg of produced product were extracted.

These results can be used in a wider research in emissions rate assessment for the total supply chain production - transport - industrial tomato processing - transport.

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