Environmental System Analysis for Horticultural Crop Production

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Keywords: Life Cycle Assessment, environmental impacts, horticultural production systems

Abstract

In this paper a simplified Life Cycle Assessment for the evaluation of environmental impacts of horticultural production systems is presented. Two production systems with different production intensities (outdoor cropping, protected cultivation in a greenhouse) have been investigated with respect to the environmental impact associated with these production systems. In the open field production system the transport processes on-field and field-to-farm are contributing most to the environmental impact. In closed greenhouse production systems the lighting and heating processes are dominating the environmental impact. The system analysis performed in this study allows for the identification of those process steps in horticultural production that are major contributors to environmental impact. Therefore, the results can help the growers to improve the environmental performance of their production system.

INTRODUCTION

During the last years, there has been an increasing public concern regarding food safety and quality as well as regarding the environmental risks and impacts associated with agricultural or horticultural production processes. In the future the growers are expected to report on the environmental impacts of their production systems and activities. While maintaining the productivity of their production systems, they simultaneously need to reduce environmental impacts.

The traditional crop production strategies were concentrated on the single criterion of maximum production. Modern crop production systems must take into account the environmental impacts as well. Due to these more consumer- oriented strategies the interpretation of quality is changing. In addition to the product quality the process quality, and in particular the environmental impacts associated with the production processes, becomes more and more important. However process quality standards are not established yet and for an implementation of such standards it is necessary to obtain detailed information about the processes and the associated environmental impacts.

PROCESS QUALITY EVALUATION

Life Cycle Assessment (LCA) is a suitable technique for assessing environmental aspects and potential impacts associated with a product or a process. A LCA study is a standardized methodology where all extractions from the environment and emissions to the environment are determined, if possible in a quantitative way. LCA regards the whole life cycle of a process or a product from cradle to grave and assesses the potential impacts on natural resources, on natural environment and on human health accordingly (de Haes and Wrisberg, 1997). The methodology has proven to be a useful tool to trace environmental impacts and to improve the environmental performance of production systems by quantifying the relevant impacts according to single process steps (Schlauderer et. al. 2002).

AIM OF THE RESEARCH

In this study two production systems of practical vegetable growers with different production intensities (outdoor cropping of bunched onions and radish, protected cultivation of tomatoes in a greenhouse) have been investigated in order to study the environmental impacts associated with these production systems. For the evaluation of environmental impact a simplified life cycle assessment approach has been used. Such a system analysis should help to identify major contributors to the environmental impact and to find opportunities to improve the environmental aspects of products or processes.

EVALUATION OF THE ENVIRONMENTAL IMPACTS

One of the first steps in such a Life Cycle Assessment is the Life Cycle Inventory Analysis (LCIA), where the relevant inputs and outputs have to be determined for all the different production steps. Unit process steps have to be defined for the whole production chain that represent the smallest portions of a product system for which data are collected (ISO, 1997). In table 1 the analyzed production systems, the unit processes, the system boundaries and the data sources analyzed in this study are summarized.

For an evaluation of these production systems with different production intensities, different environmental impacts as well as different functional units (production area, yield, volume of sales) have to be taken into account. The environmental impact is divided into different impact categories, like cumulative primary energy demand, global warming potential, ozone depletion, etc. The functional units are the basis to which the impact of a product or a process is related to.

In the impact assessment phase, the detailed data collected in the inventory are assigned to the environmental impact categories. Every input and output defined in the LCIA is placed into one or more impact categories. Then the potential environmental impacts associated with each unit process is calculated. Therefore each input and output in the LCIA is placed into one or more impact categories. In study presented, the two impact categories ‘cumulative primary energy demand’ and the ‘global warming potential’ were considered initially.

RESULTS

A LCA allows for the identification of weak points of an entire production system. In the LCA performed in this study, major contributors to the different environmental impact categories could be identified. A weak point analysis for the investigated outdoor cropping system is shown in figures 1 and 2. The environmental impact can be assigned to the demand of resources (material or energy), to different process steps, and to the different products. During the cultivation of bunched onions the highest environmental impact - expressed as cumulative primary energy demand - is caused by field-farm transport processes in form of fuel consumption. With regard to material consumption, however, the process steps of fertilizing and plant protection cause the major contribution due to fertilizer and pesticide production. Additional demand for material by machinery and tractors are of minor importance. Therefore, there is a great potential for increasing the ecological efficiency by optimizing the transport system.

In figure 3 the influence of the selected functional unit on the results is illustrated. For the area as the functional unit, bunched onions have a higher environmental impact than radish. On the other hand, considering the environmental impact in relation to the yield (presented as 10.000 bunches), figure 3 reveals a higher impact of radish compared to bunched onion. This higher environmental impact of radish is even more pronounced with respect to the volume of sales as the functional unit.

These results show that an evaluation of the environmental impacts strongly depends on the selected functional unit. For an objective evaluation of the environmental impacts that are related with a chosen production system, several functional units have to be taken into account. The choice of the functional unit depends also on the interested parties. E.g. the environmental impact related to a specific area could be relevant to governmental authorities, while consumers might be more interested in a relation of this impact to the product itself.

As shown in figure 4, in the greenhouse production system a large portion of the environmental impact is related to the greenhouse material itself. In comparison to the lighting and heating process, however, all other effects can be almost neglected. The cumulative primary energy demand for this process is more than fifty times higher than for all the other processes. Regarding the impact category global warming this ratio is reduced to a factor of 10 (not shown). Accordingly, in this production system a high potential for increasing the ecological efficiency can be identified in energy saving cultivation strategies (figure 5).

CONCLUSION

The presented study shows that in the open field system the transport processes on the field (during harvesting) and the field-farm transport have larger effects on the studied environmental impact categories. Consequently a high potential for optimizing the process chain can be found in new transport concepts. The response of crop yield in open production systems is more subjected to uncontrollable variations due to weather and disease than in closed production systems. This leads to several input and output factors to the cropping system, which are either non-controllable or have at least non-controllable emissions. Therefore additional impact categories such as water quality (nitrate leaching) or soil function (e.g. coil compaction) have to be taken into account for an objective evaluation. Due to the high spatial variability of such parameters the data collection in open field production systems is by far more difficult.

For closed production systems most environmentally important data can be supplied automatically by the controlling computer, if suitable software is available. Energy or water consumption could be measured and documented. The same is true for spraying or fertilizing. Non-controllable emissions to the environment are mainly caused by technical deficiencies or hazards, which can be estimated with a sufficient accuracy (Meyer 2000). However, the total amount of emissions associated with the production systems can be much higher in closed systems than in open systems. In closed production systems with artificial lighting and heating these processes are clearly dominating the studied environmental impact categories.

The results show that the method of LCA can be a valuable means to identify the production steps with the highest environmental impacts during the whole production chain. The results from such a systems analysis can help the growers to improve the efficiency of their operations. The input costs of the production processes (machinery, water, fertilizers, pesticides and energy) are a significant portion of the overall farm operation costs. Thus a more efficient use of environmentally sensitive inputs can reduce both the production costs for the farmer as well as the environmental risks or impacts.

However the collection and evaluation of data is a highly labor and therefore cost-intensive task. If results are to be gained on farm level the data collection and evaluation has to be simplified as much as possible. Advances in information technology and automation in the recent years led to the opportunity to realize on-site information management solutions that can meet even the specific demands of generally small-sized horticultural companies (Bauersachs 2002).

Literature Cited

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Tables

Table 1. Description of the investigated production systems.

	open field production system	**heated greenhouse production system**
general remarks	- 50 ha - cultivation of radish and bunched onion - radish repeated three times on the same area	- 3 ha - year round cultivation of tomatoes - supplementary light - heating - soilless cultivation - cultivation on rock-wool Grodan substrate
unit processes	- tillage - fertilization - sowing - irrigation - plant protection - harvest - field-farm-transport	- greenhouse (material) - heating (gas) and artificial lighting - plantation and materials - fertilization and irrigation - harvest and cleaning
system boundaries	not considered are: - processing and market preparation (washing and sorting) - transport to the retailer - disposal (e.g. Grodan substrate) and composting of plant materials	
data sources	- data from vegetable production farms - data from the vegetable experimental station “Staatliche Lehr- und Forschungsanstalt Neustadt, Germany” - data of the “Kuratorium für Technik und Bauwesen in der Landwirtschaft” (KTBL) - Global Emission Model for Integrated Systems (GEMIS)	

Figures

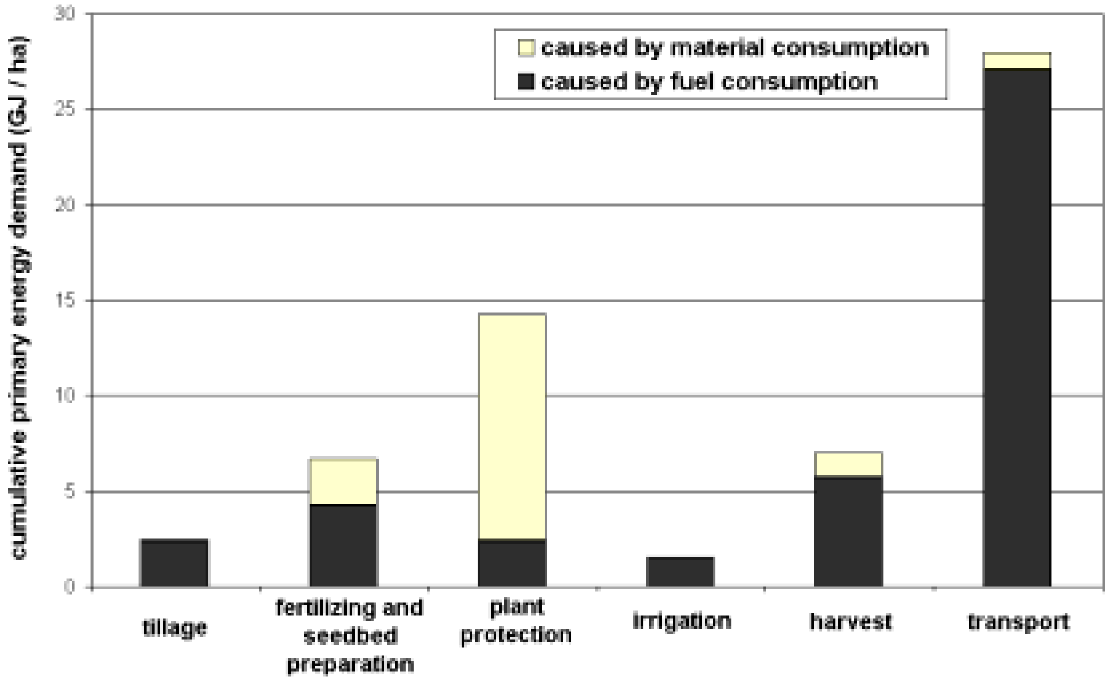

Fig. 1. Weak point analysis for the cultivation of bunched onion in the analyzed production system.

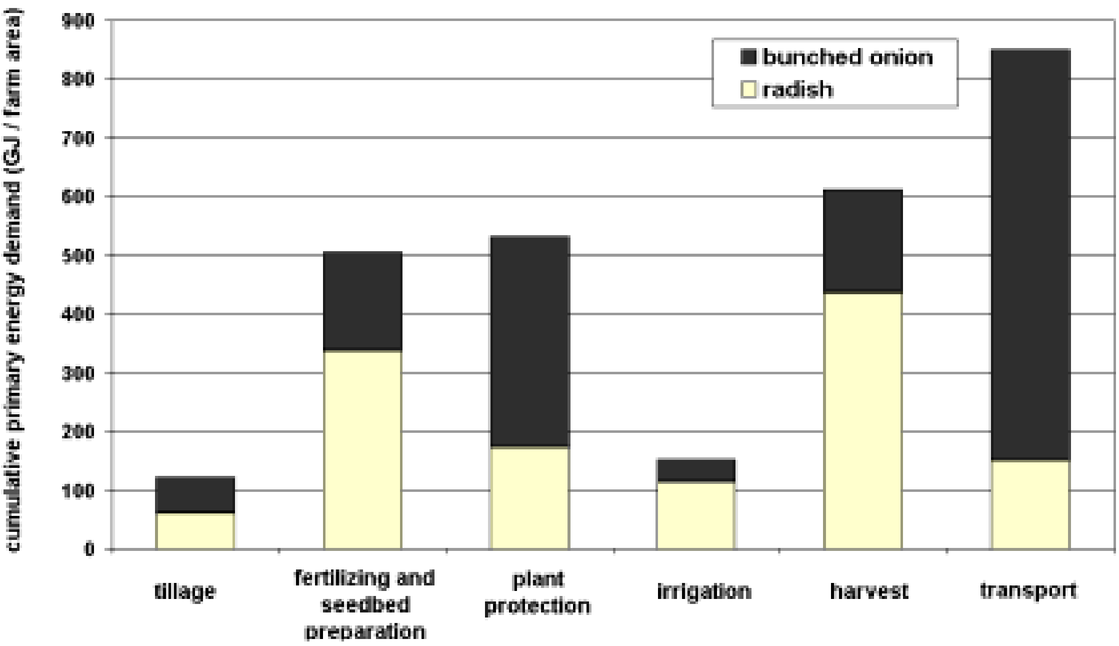

Fig. 2. Weak point analysis on farm level.

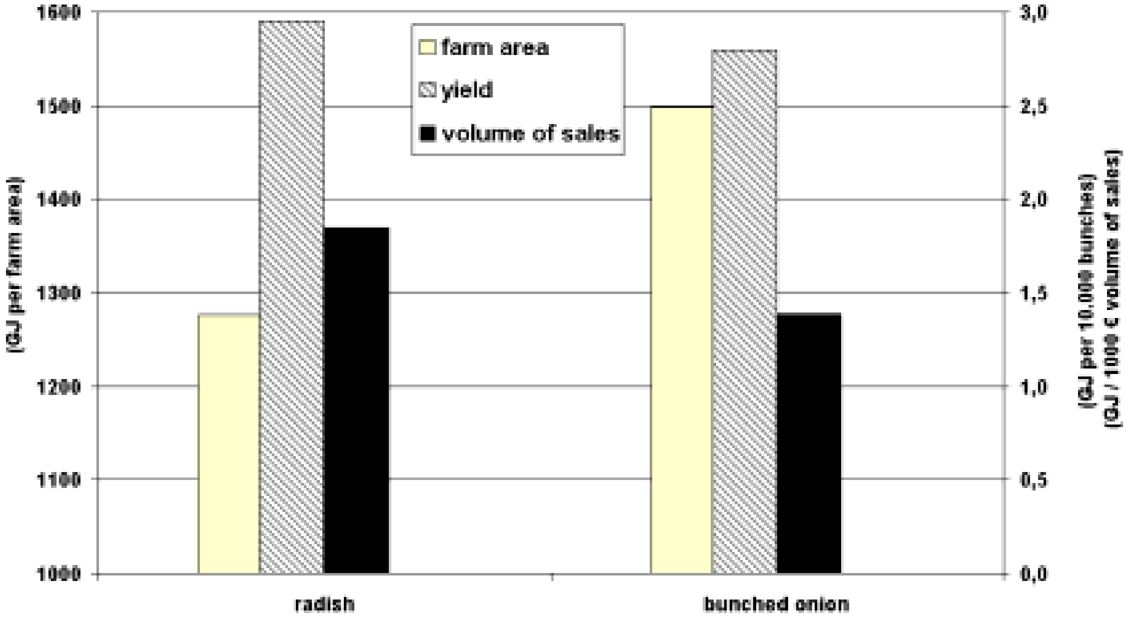

Fig. 3. Influence of the selected functional unit on the results.

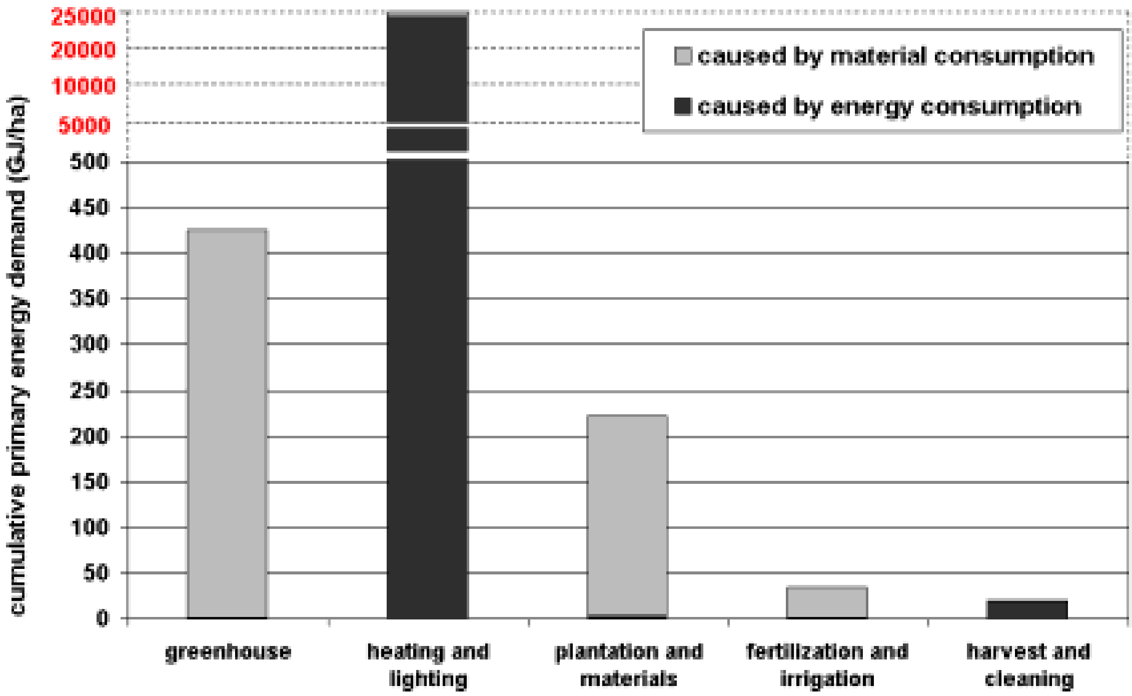

Fig. 4. Weak point analysis for the cultivation of tomatoes in a heated greenhouse production system.

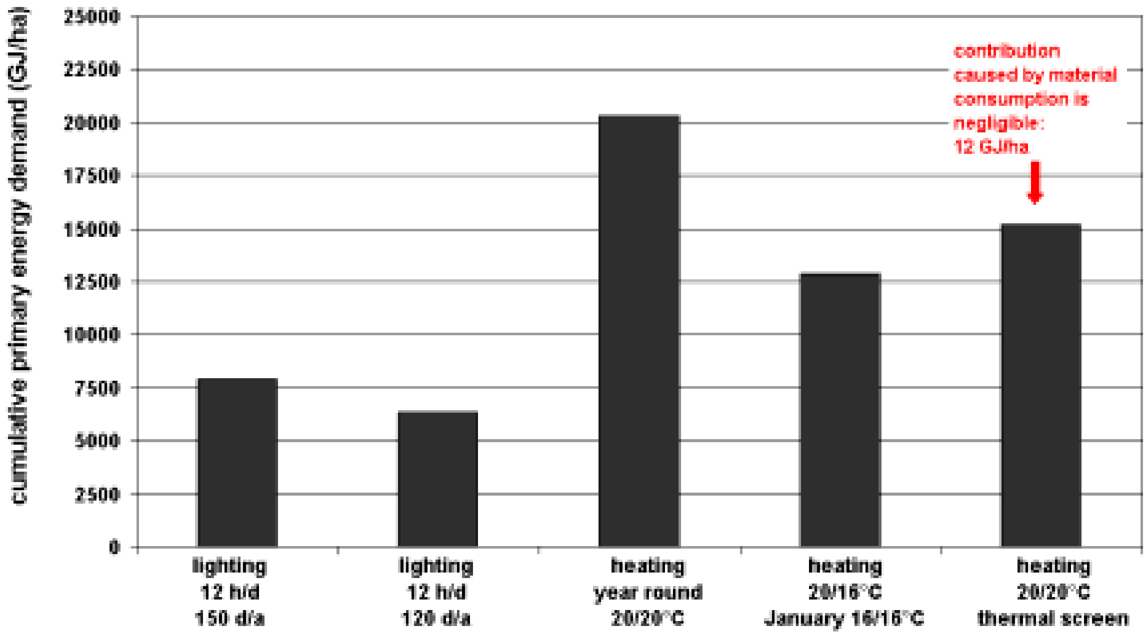

Fig. 5. Cumulative primary energy demand for different lighting and heating strategies.