Life Cycle Assessment of Urban Farming Production in Aquaponic

Life Sciences und Facility Management
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Thesis goals

In the context of this thesis a comprehensive life cycle assessment of products from the UrbanFarmers pilot site „UF001 LokDepot“ was conducted. The results were compared with data from the literature, the most relevant environmental factors were identified and recommendations for the improvement of the eco-balance were developed accordingly.

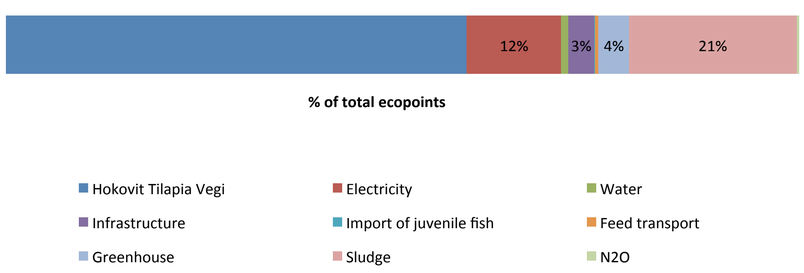
Material and Methods

The LCA was modeled with the software SimaPro 7.3.3 and Ecoinvent database 2.2.
The environmental impact was calculated per kg produce (functional unit = 1 kg of vegetables or fish). For the impact assessment the following methods were used: Cumulative Energy Demand, CML Baseline 2001, Global Warming Potential and the Method of Ecological Scarcity.
The analytical framework includes environmental impacts of the products up to the farm gate („cradle-to-gate“). Upstream processes such as exploitation of resources for animal feed or greenhouse material as well as for production are taken into account. The transport to the consumer, packaging material and disposal of fish or vegetable waste are not considered.

Results

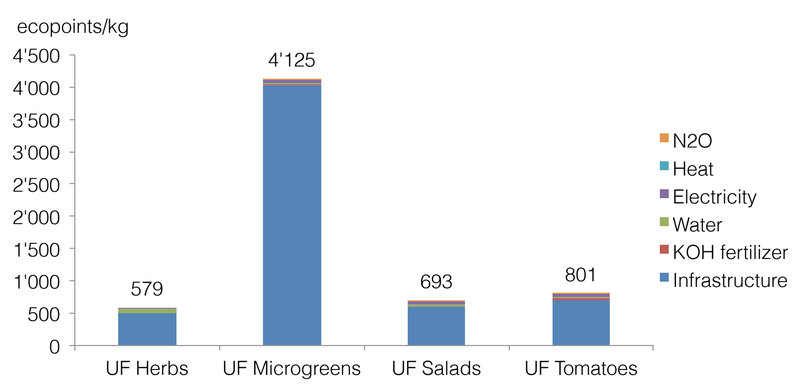
Ecological Scarcity

Ecopoints (UBP) per kg fish



- Feed, sludge and electricity cause 58%, 21% and 12% of the 9‘951 UBP
- Soybean meal makes up 69% of UBP of the feed
- Filtered solids (sludge) have a high nitrogen content and in the beginning were discharged into the sewerage, thus the high environmental impact
- Electricity from non-renewable energy sources used for the production of fish tanks, greenhouses and so on lead to environmental pollution

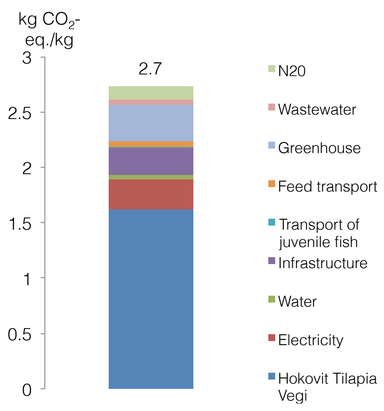
Ecopoints (UBP) per kg vegetables



- The greenhouse is the cause for 80% of UBP
- The production of steel and aluminum generates large emissions of CO2 and particulate matter
- The use of coal or nuclear energy for steel and aluminum production also leads to a high environmental impact

Global Warming Potential

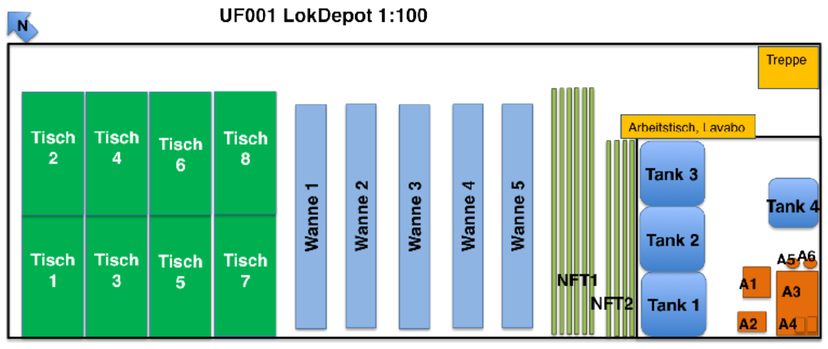
kg CO2 equivalents per kg fish



- Feed leads to 1.69 kg CO2 equivalents or 57% of the total
- For the greenhouse and infrastructure the energy (coal or nuclear) for the production is the most important Global Warming factor

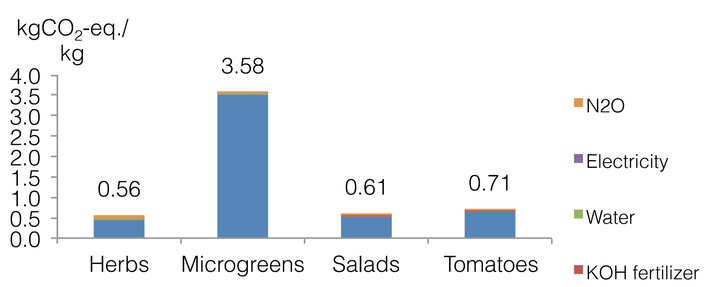
UF001 LokDepot

UrbanFarmers is a spin-off of the ZHAW Wädenswil. The system in the greenhouse at UF001 LokDepot in Basel has been in operation since mid-December 2012. Since January 2013 produce has been harvested and sold. During the first year 918 kg tomatoes, 1200 kg lettuce, 55 kg microgreens, 450 kg herbs and 900 kg fish were produced.



Tables 1-2	Microgreens	A1	Separation of solids
Tables 3-4	Herbs	A2	Drum filter
Tables 5-8	Salad	A3	Biofilter
Troughs 1-5	Troughs for tomatoes	A4	Oxygen generators
NFT 1-2	Channels for salad	A5	Water purification
Tank 1-4	Fish tanks	A6	Oxygen pump

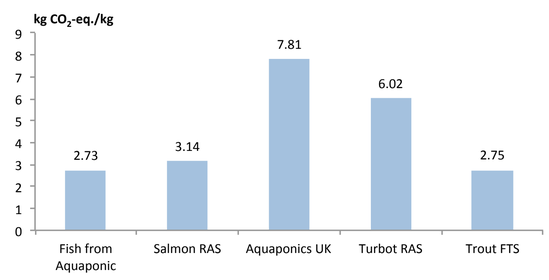
kg CO2 equivalents per kg vegetables



- The biggest Global Warming Potential emanates from the infrastructure (80-98%), due to emissions from the production of steel and aluminum
- Nitrious oxide (N2O) arises from fish excrement, which serves as nutrients for the plants

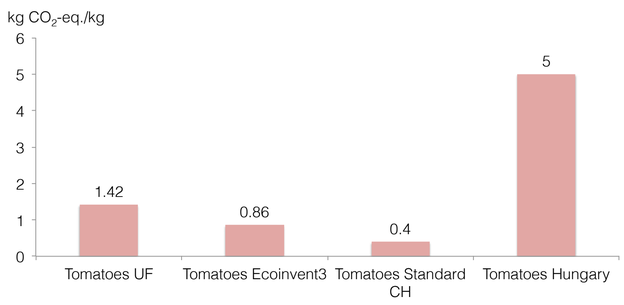
Compared literature Global Warming Potential

Global Warming Potential of aquaculture systems in kg CO2 equivalents.



- For Aquaponics UK: 71% from energy consumption, 16% from feed and 12.5% from infrastructure
- Trout in flow-through-system (FTS): 73% from feed, 15% from energy consumption and 9% from infrastructure
- Aquaculture of turbot in a recirculating system (RAS): 32% from feed, 7% from infrastructure and 61% from energy consumption
- Salmon in a recirculating system: 75% from feed, 5% from infrastructure, 13% from energy consumption and 7% from use of chemicals

Global Warming Potential of tomato cultivation in kg CO2 equivalents



- In an average cultivation process in Switzerland the greenhouse accounts for 70% (Egloff, 2013)
- In the tomato data set from Ecoinvent 3 the use of machines for fertilisation, planting and weed control has the biggest impact
- The most important factor for tomatoes in a greenhouse in Hungary (Torrellas, 2012) is the air conditioning, especially heating with natural gas. Additionally, infrastructure (15%, 0.75 kg CO2 eq.), pesticides (15%) and fertilisation (10%) are important

Aquaponic - How and why?

An aquaponic system combines a recirculating aquaculture system and hydroponic production of plants. Through the feed or fish waste respectively, nutrients enter the water. Solids are filtered before the water is pumped into a biofilter. Nitrifying bacteria convert ammonium, which is harmful for fish and can‘t be taken up by plants, into nitrate. Nitrogen in the form of nitrate can then be taken up by the plants. This process has an additional cleaning or filtering effect. Finally, the water is pumped back to the fish (Rakocy, 2006). The water goes through this process several times a day and on average remains in the system for about 2 weeks. Thanks to the circulation and biofiltration environmentally harmful effluent from the fish production can be avoided and drinking water can be conserved. At the same time synthetic fertilisers can be saved. The filtered solids or sludge respectively, can be composted and used as fertiliser in agricultural production (van Rijn, 2013).

Life Cycle Assessment?

A life cycle assessment lists all the environmental pollution that is caused by a product throughout its life span. The method records all significant environmental impacts from exploitation of the resources through to the production and use of a product up to its disposal (BAFU, 2007).

Discussion

Positives

- District heating from waste incineration does not cause environmental pollution.
- The electricity mix from the IWB is made up 100% from renewable sources. The average Swiss electricity mix leads to 4-5 times higher Global Warming Potential.
- UBP (ecopoints) of fish and meat products are between 15‘000 - 35‘000 UBP, fish from the UrbanFarm has just under 10‘000 UBP (Stucki & Jungbluth et al. 2012)
- Further comparisons with data from literature show that products from the UrbanFarmers facility achieve good results

Potential improvements

- Use of recycled steel and aluminum results in a 50% lower Global Warming Potential.
- Intensification of cultivation in hydroponics improves the environmental performance per kg produce, since the greenhouse is the most important factor.
- 50% of the UBP are caused by the feed, of which soybean meal makes up 70%
- Alternative protein sources could be fly larvae (FiBL trial) or potato proteins (a waste product of potato starch production).
- The sludge causes 15% of the UBP per kg fish. Composting and re-utilisation as fertiliser could also reduce this impact.

Conclusion

Cultivation in Aquaponic in the UrbanFarmers facility is promising from an LCA perspective. The proximity to the consumer, the absence of fertilisers, pesticides and large machines gives this production type advantages compared to conventional methods. A point of concern is the high electricity consumption and the required heat. Depending on the energy sources the environmental impact is suddenly much larger. For vegetable crops a reduction of the greenhouse share and in aquaculture a replacement for soy in the feed are the most promising possibilities for improvement.

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