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Development of Ecological Scarcity Japan

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Abstract

The ecological scarcity method Japan was developed through the adaptation of the most recent Swiss eco-factor 2006 method. It includes elementary flows and environmental impacts such as nitrate emissions to ground water, pesticides, land use, and fresh water, in addition to climate change, ozone depletion, and so on.

The life cycle inventories of five different crops grown in Japan, conventional and a improved cultivation, are introduced. The life cycle inventories include the field cultivation processes, production of agricultural machines and materials used and refer to 1 kg of fresh matter crops. The impact assessment is carried out with the ecological scarcity Japan method. Ammonia, greenhouse gases and phosphate are important pollutants.

It is concluded that the improved cultivation can contribute to a reduction of the environmental load of Japanese agricultural activities. The eco-factors developed so far will be further refined and complemented with eco-factors of further pollutants and resources.

Keywords: ecological scarcity, distance to target, life cycle impact assessment, agricultural production, biofuels

1. Introduction

The Swiss ecological scarcity method is based on the distance to target principle. A critical flow is deduced for every substance where legislative guidelines or political goals exist. The current flow corresponds to the actual situation. The calculation of the eco-factor is determined by setting the current flow into relation with the critical flow.

Simplicity and transparency of the eco-factor calculation on one hand, and direct derivation from political targets on the other are this method's strength. The use of political targets is the main difference to damage oriented approaches such as the Lime method or the eco-indicator 99. As a consequence, eco-factors can only be determined for substances with an applicable political target.

There is a main advantage for companies to use the ecological scarcity method. It measures the ecological performance of a company (or its products) with reference to the political agenda of the country or region. In the case of a company this information can be more valuable and relevant than a damage oriented assessment. Furthermore the concept can be used to establish an ecological scarcity method valid for other nations or political entities. Several nations, for example Japan (JEPIX, [1]), have adopted the methodology in the past and are calculating own eco-factors based on their national environmental situation and legislation.

The ecological scarcity method Japan [2] is being developed through the adaptation of the most recent Swiss eco-factor 2006 method. Its purpose is to assess biofuel production and biomass utilization in Japan and thus it includes elementary flows and environmental impacts such as nitrate emissions to ground water, pesticides, land use, and fresh water, in addition to climate change, ozone depletion, and so on, although the method is in general applicable to life cycle impact assessment of Japanese products and services.

2. Methods: the Ecological Scarcity Formula

2.1 The Formula Representation

The formula representation that was used in the former two editions of the Swiss ecological scarcity method and the JEPIX method [1, 3, 4] is slightly changed (see formula (1)).

$$EF = 1EP \cdot \underbrace{K}_{\substack{\text{Characterisation}\\ \text{(optional)}}} \cdot \underbrace{\frac{1}{F_n}}_{\text{Normalisation}} \cdot \underbrace{\left(\frac{F_a}{F_k}\right)^2}_{\text{Weighting}} \cdot \underbrace{c}_{\substack{\text{Constant}\\ \text{(1e12 EP/a)}}} \tag{1}$$

EP:	eco-points (the unit)	F_a:	actual flow
K:	characterisation factor	F_k:	critical flow
F_n:	normalisation flow	*c:*	constant (10^{12})

It allows for a more powerful interpretation. However, from a mathematical point of view the new representation (1) is only a conversion, leading to identical eco-factors as the previous one.

2.2 Characterisation, Normalisation and Weighting

The characterisation term improves the transparency of applying such factors. Characterisation was implicitly used in the previous versions (e.g. global warming potential) but is only now made explicit. The explicitly separated but optional characterisation term is in line with the impact assessment procedure according to the ISO standards. Normalisation is done with the current flow as suggested by the ISO standard 14044. The weighting factor is determined independently of the normalisation and is the square of the ratio between current annual emissions and the political targets in Japan.

The new formula allows to address regional or national differences combined with a Japanese perspective. Normalisation values represent the annual Japanese situation, whereas the actual and critical flows used in the "weighting" term are those of the region or nation of interest. This is particularly important with regard to water use, which shows high regional differences in scarcities (see for instance [5]).

3. Japanese Eco-Factors

3.1 Overview

In the first phase of the co-operation Japanese tentative eco-factors are established for the following pollutants and resources:

Emissions to air:

- CO_2 and further greenhouse gases
- ozone depleting substances
- nitrogen oxide, particulate matter, NMVOC, and sulfur dioxide
- ammonia
- dioxins

Emissions to surface water:

- phosphorous
- nitrogen
- organic matter (BOD/COD)

Emissions to ground water:

- nitrate

Emissions to soil:

- heavy metals
- plant protection products

natural resources:

- land use
- water use

In the following we shortly describe the eco-factors of a few selected substances.

3.2 Climate Change

The different greenhouse gases are characterised with the help of the global warming potentials published by IPCC [6]. Japan emits about 1'374 mio. tons of CO_2-eq per year. Japan intends to reduce the emissions of greenhouse gases by 25 % (until 2020; base year 1990) and by 60 to 80 % on a long-term (until 2050; base year 2007). We use the long-term perspective and chose a reduction factor of 70 % compared to the situation in 2007. This results in an eco-factor of 8 eco-points per kg CO_2.

3.3 Particulate matter

The annual emissions of particulate matter in Japan amounts to 192'000 tons, whereof motor vehicles emit 79'000 tons per year. Japan aims at reducing the traffic related emissions of particulate matter by 92 % until 2015 (compared to 2000). Hence, the critical flow is about 131'000 tons per year. The eco-factor of particulate matter is 13'000 eco-points per kg PM10.

3.4 Non methane volatile organic carbon (NMVOC)

The different organic substances are characterised with the photochemical oxidant creation potential (POCP). The annual NMVOC emissions in Japan amount to 1.64 mio. tons (2006). The Japanese Air Pollution Control Law defines a reduction of 30 % as compared to the emissions in the fiscal year 2000, resulting in a critical flow of 1.26 mio. tons per year. The eco-factor is 1'900 eco-points per kg average NMVOC.

3.5 Nitrogen and Phosphorous emitted to surface water

The situation in major Japanese lakes and bays is taken into account. Currently about 360'000 tons of nitrogen and 21'000 tons of phosphorous are emitted annually. On average, the concentration of both nitrogen and phosphorous in lakes and bays is about 15 % above the values stated in the Environmental Quality Standard of Japan (lakes) and the critical load defined by the Japanese Government (bays). This results in annual critical flows of about 320'000 tons nitrogen and 18'000 tons phosphorous. The eco-factors of nitrogen and phosphorous are 3'600 eco-points per kg N, and 64'000 eco-points per kg P, respectively.

3.6 Plant protection Products

The different plant protection products are characterised with their effectiveness. The effectiveness is expressed by the reciprocal value of the standard dose, the latter being reported in kg active ingredient per hectar. The average standard dose of plant protection products applied in Japan is 13.4 kg/ha. In the fiscal year 2004 about 63'000 tons of plant protection products were used. Japan aims at a reduction by 30 % compared to the situation in 1990/1992. This results in a critical flow of about 62'000 tons per year. The eco-factor of an average plant protection product is 17'000 eco-points per kg PPP.

3.7 Further eco-factors

The current tentative set of eco-factors will be further refined in the course of the second phase of the project, during which additional eco-factors will be established.

4. Japanese agricultural products

4.1 Overview

Main industrial crops in Japan – sugar beet, potato, sorghum, sweet potato, and sugarcane – can also be used as feedstocks for ethanol production and the production may cntribute to regional revitalization. However, the production potentials as feedstocks have not yet been assessed. Thus, this paper clarifies the potentials through the comparisons between conventional and improved cultivation practices.

4.2 Functional unit

All assessments are based on annual data and 1 kg of fresh matter crops are selected as functional units. Sugarcane is cultivated in the cycle of spring planting and ratooning through a few years, hence the results obtained for the entire cycle were averaged out.

4.3 System boundaries

We adopted cradle to gate LCA in our study, which includes machinery operation, transport in the farm, direct field emissions, and materials such as chemical and organic fertilizers, agricultural chemicals, and plastics. The upstreams of these processes are also included as the background system. Energy conversion, transportation of crops out of the farm, distribution, and fuel consumption are excluded in this analysis, as well as the input of construction materials.

4.4 Data quality considerations

NARO LCI is used for the assessment which is a Japanese database in progress focusing on agricultural sectors. As for cultivation technology, we identified the processes of each crop on the basis of the prefectural recommendation or the field experiments at national or prefectural agricultural research institutes.

5. Preliminary Results

5.1 Overview

The assessment of the life cycle inventories of five different crops is performed with the ecologica scarcity Japan. Tab. 1 and 2 show the results of the assessment of conventional and improved cultivation, respectively.

There are considerable differences between the different crops. Sugar beets, sorghum, and sweet potatoes show the highest impacts, whereas the impacts of potatoe and sugar cane are substantially lower.

The difference between conventional and improved cultivation varies between the crops. It is as low as 2 % in the case of sugar beets but may reach more than 60 % in the case of sugare cane.

The main pollutants determining the environmental impacts are ammonia (to air), greenhouse gases (N_2O, CO_2, and CH_4), phosphate (to water), particulate matter, nitrogen oxides, sulfur dioxide and zinc (to soil), see Fig. 1 and 2. Neither emissions to ground water (nitrate) nor resources (land use or water use) show up in the top 15 substances and contribute negligibly.

Table 1: Environmental impacts of selected Japanese agricultural products (*conventional* cultivation), assessed with ecological scarcity Japan

eco-points/kg	potatoes	sorghum	sugar beets	sugar cane	sweet potatoes
air	1.4	9.5	9.4	3.0	8.2
surface water	0.7	0.6	1.6	0.3	0.6
ground water	0.0	0.0	0.0	0.0	0.00
soil	0.2	0.1	0.1	0.1	0.2
resources	0.0	0.0	0.0	0.0	0.02
total	**2.3**	**10.2**	**11.1**	**3.4**	**9.0**

Table 2: Environmental impacts of selected Japanese agricultural products (*improved* cultivation), assessed with ecological scarcity Japan

eco-points/kg	potatoes	sorghum	sugar beets	sugar cane	sweet potatoes
air	1.2	6.2	9.2	1.1	7.5
surface water	0.6	0.3	1.5	0.1	0.0
ground water	0.0	0.0	0.0	0.0	0.0
soil	0.1	0.0	0.1	0.1	0.1
resources	0.0	0.0	0.0	0.0	0.0
total	**1.9**	**6.5**	**10.9**	**1.3**	**7.6**

After this overview, a detailed analysis is carried out for the two crops potatoes and sugar beet.

5.2 Potatoes

Total eco-point of potatoes shows the smallest value among crops in conventional cultivation and second smallest in improved cultivation. It is smaller by around 20 % in improved cultivation compared to conventional. Both abbreviation in cultivation procedure and increase of yield by breeding are considered to contribute to this decrease. By compartments, eco-point of air emission is the largest, however, it is smaller compared to other crops. Emission to air accounted the major share in total eco-point over all crops.

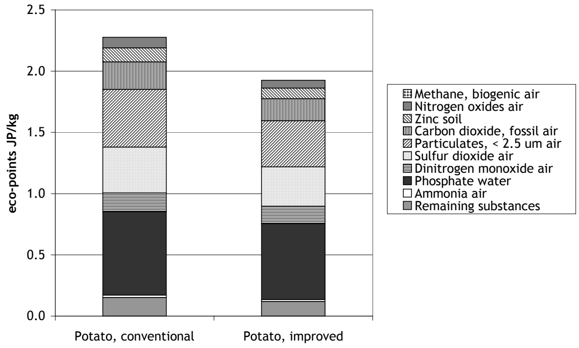

Fig.1: Environmental impacts of 1 kg of potatoes (conventional and improved) grown in Japan, assessed with ecological scarcity Japan

5.3 Sugar beet

Total eco-point of sugar beet is the largest. Most of them comsisted of emission into air and is also the major difference between sugar beet and potatoes. In terms of technology, large amount of compost is applied in cultivation of sugar beet and no compost in potatoes. Considering total tendency, the amount of compost input is supposed to have a large contribution to the environmental impact. However, further analysis is needed to clarify this question. The difference in eco-point between conventional and improved technology is small. One of the reason is supposed that the effect of breeding in sugar beet is not increasing its yield but increasing its sugar content. Hence, the effect for decreasing environmental impact does not appear because the assessment is based on the weight of crops.

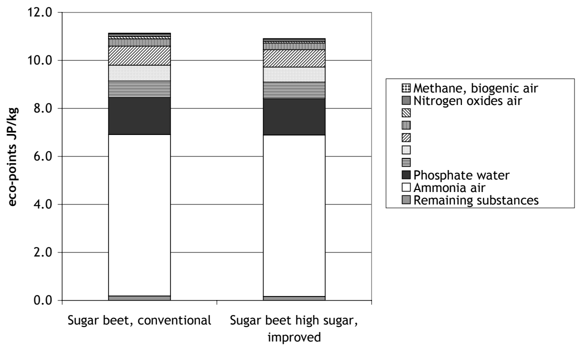

Fig.2: Environmental impacts of 1 kg of sugar beet (conventional and improved) grown in Japan, assessed with ecological scarcity Japan

6. Conclusions and outlook

The assessment of the life cycle inventories of five different crops is performed using the Ecological Scarcity Japan. Environmental impact largely differ by crops, in particular emissions into air. Improving cultivation technology has effects to decrease environmental impacts by from 2 to 60 %.

During the second phase of the research project, further eco-factors are being established, ranging from further air and water pollutants such as heavy metals and radionuclides, further resources such as primary energy carriers, and selected wastes.

7. Acknowledgement

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