The 6th International Conference on Life Cycle Management in Gothenburg 2013

# DEVELOPMENT GLOBAL DAMAGE FACTORS OF RESOURCE CONSUMPTION

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*Keywords: Mineral resource; Damage function; Impact assessment; Biodiversity; Fossil fuel*

## ABSTRACT

Resource consumption causes destruction of nature by mining and economic damage by resource depletion. To evaluate these damage, we need Life Cycle Impact Assessment (LCIA) indicators.

In this study, we developed grovel LCIA damage factor of resource - consumption. We evaluated damage of biodiversity, primary production and human economy. By using some static data, we made damage factor of resources extracted in each country. Then, by using international trade data, we made damage factors of resources consumed in each country. This method will contribute to LCIA of resource consumption around the world.

## INTRODUCTION

Resource consumption causes destruction of nature by mining and economic damage by resource depletion. Also integration and comparison these damage with other environmental damage are highly concerned. To evaluate these damage, we need Life cycle Impact assessment (LCIA) indicator. Though some methods are proposed(Watando, 2012, Vieira, 2012), no method contains both environmental and economic damage. In Japan, previous study developed damage factors for Japanese resource consumption. This result was published as part of LIME2 (Itsubo and Inaba, 2010).

In this study, we expanded geographical boundary to the world and recalculated damage factors for many resources extracted in each country. We evaluate three impact category related to resource consumption, “Social assets”, “Net Primary production (NPP)” and “Expected Increase in Number of Extinct Species (EINES)”. Additonaly, by using international trade data, we made damage factors for resources consumed in each country. However, we introduced only damage factors of each extracting countries because of space limitation.

## METHODS

Characterization factor of resource depression

The framework of evaluation was shown in Fig.1. We chose “inverse of reserve (1/R)” as characterization factor(midpoint) which directly refer to the resource depletion. We used the data of mine production and reserve of each mineral from “Mineral Commodity Summaries 2010 (MCS2010)”(USGS, 2011) and other statics (British Petroleum, 2011).

Additionally, we chose characterization factor for fossil fuel was “Lower Heating Value (LHV)”. This is the good factor when we focus on the problem of energy.

Characterization factor of natural destruction

We chose “the area of land transformation” as characterization factor of destruction of nature. We made mining model in Fig.2 and Eq. (1) and estimated the area of land transformation for mining and wasting. This is one of the inventory analysis for mineral consumption.

We set parameters of each resource from some statics such as USGS(2012). We reflect a difference in mining type(surface or underground mining), orebody thickness of each resource in each country. Additionally, some mineral such as rare earth are extracted from same ore. So we allocated the transformed area to each resource on the basis of ore grade.

$$
\begin{aligned}
A &= m_i \times \frac{1}{C_i} \times \frac{1}{G_i} \times \frac{1}{D_i} \\
&+ \left( m_i \times Oo_i \times \frac{1}{go} \times \frac{1}{Ho} + m_i \times Ot_i \times \frac{1}{gt} \times \frac{1}{Ht} \right) \\
&\cong \underbrace{m_i \times \frac{1}{C_i} \times \frac{1}{G_i} \times \frac{1}{D_i}}_{a} + \underbrace{m_i \times O_i \times \frac{1}{g} \times \frac{1}{H}}_{b} \qquad (1)
\end{aligned}
$$

A : Area of land transformation [m2]

mi: Weight of metal content of mineral i [t]

Ci: Ore grade of mineral i

Gi: Specific gravity of mineral i

Di: Orebody thickness of mineral i [m]

Ooi: Weight ratio between metal and overburden [t/tmetal]

Oti: Weight ratio between metal and tailing [t/tmetal]

Oi: Weight ratio between metal and overburden + tailing

=Hidden flow [t/tmetal]

g: Density of overburden and tailing [t/m3]

H: Height of overburden and tailing [m]

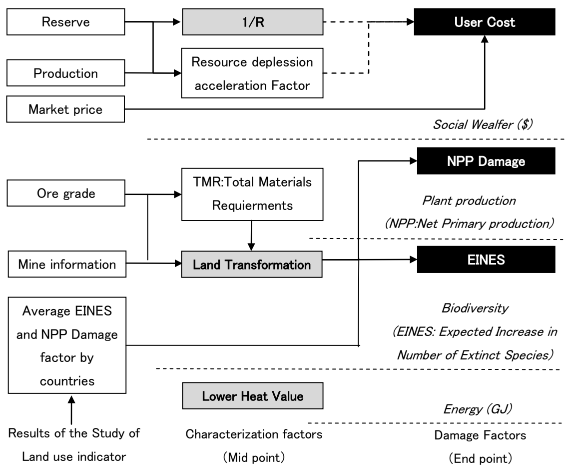


Fig.1 Framework of evaluation of resource consumption

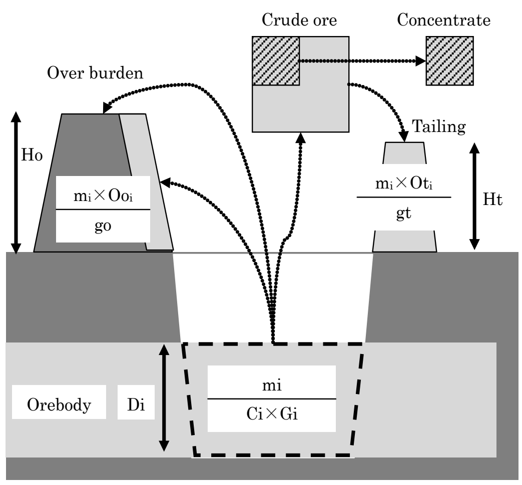


Fig.2 The model of the area of land transformation

Damage factor of social asset
We used "User cost" as the damage factor of social asset. User cost presented by El serafy(1989) was the investment to keep constant income after mining. It is equal to the cost to prepare the resource depletion. User cost was calculated by Eq. (2). The market value of each metal in *MCS 2010* and other statics was used.

Damage factor of primary production
The primary production means the plant growth from photosynthesis. We considered primary production because it is essential for ecosystem as if money in human society. In the resource consumption, the damage of "Net Primary Production (NPP)" was calculated by multiplying the area of land transformation by the average NPP loss of each country. A detailed discussion of the method to calculate average NPP loss will be published by our project soon.

Damage factor of biodiversity
We chose "Expected Increase in Number of Extinct Species (EINES)" as the indicator of biodiversity. In the resource consumption, the EINES was calculated by multiplying the area of land transformation by the average EINES of each country. As well as NPP loss, a detailed discussion of the method to calculate average NPP loss will be published by our project soon.

## RESULTS

We calculated all characterization factors and damage factors.

In the impact of social asset, the damage factor of gold is the highest. User cost of consuming 1 metric ton gold is 23 million US-$. This is more than four times larger than that of platinum or palladium. On the other hand, User cost of consuming 1 metric ton iron was only 12 US-$. Lithium has the smallest economic damage because of its huge reserve.

The NPP loss per unit of resource consumption was shown in Fig.3. In this figure, a point means a damage factor of one country. At almost all resources, differences between extracting countries are less than 10 times. Countries with rich nature such as Indonesia and Brazil have bigger damage factors. The result indicates the mining of Gold, platinum, palladium has a million times NPP loss of Iron. The grade of minerals is dominant on the difference between minerals.

The EINES per unit of resource consumption was similar to NPP loss. Because both of them are proportionate to the area of land transformation.

## DISCUSSION

The damage factor of social asset, user cost was the cost to compensate future generation for a resource. This method assumed that the human economy can continue after the resource depletion. The user cost consider longer period than that of the surplus cost. Additionally, both of them could not consider the stock and recycling of the mineral. So an user of these factors should be careful this difference.

A few methodologies directly treated the land use by resource consumption. It may be the matter of inventory analysis, but we hope more discussion and information about the association between the resource consumption and land transformation in terms of LCIA.

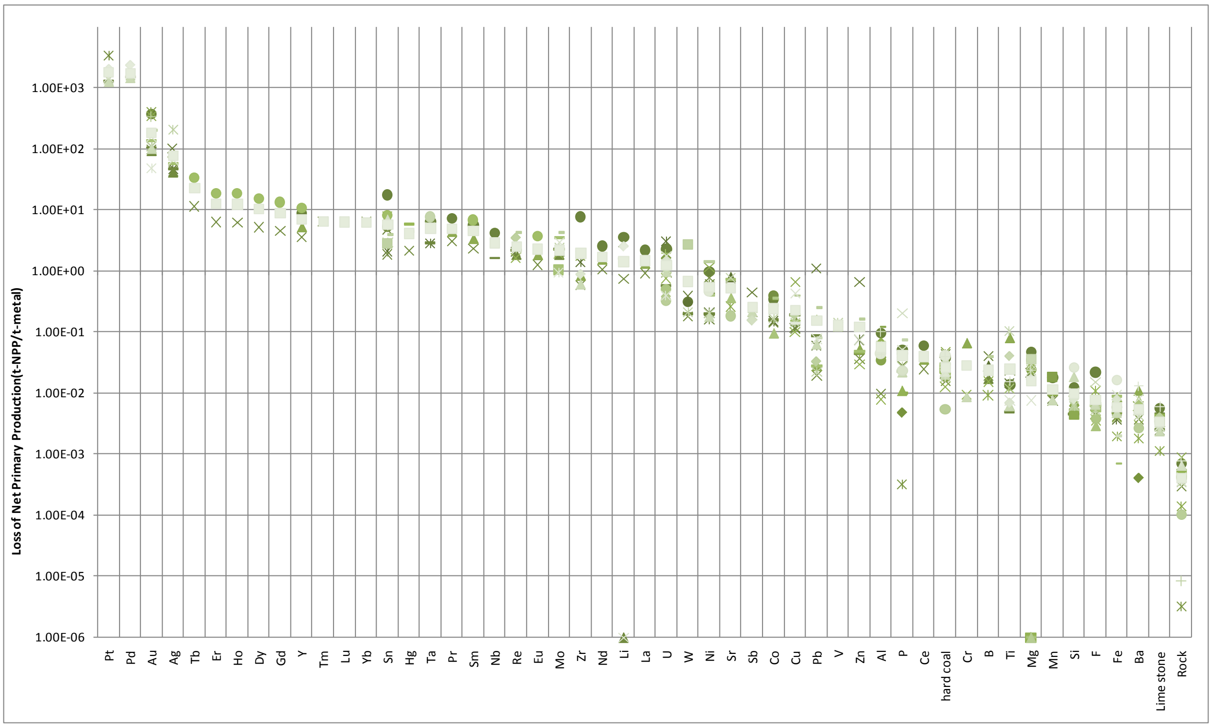


Fig.3 The damage factors of primary production of each extracted country

## CONCLUSIONS

We developed grovel LCIA damage factor of resource consumption. We made damage factor of resources extracted in each country and resources consumed in each country. Our damage factors of NPP and biodiversity have differences between extracting countries. The differences between countries are less than 10 times at the damage factor of NPP. We hope this method contribute to LCIA of resource consumption around the world.

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