Environmental Impact Indicators and Mining Method

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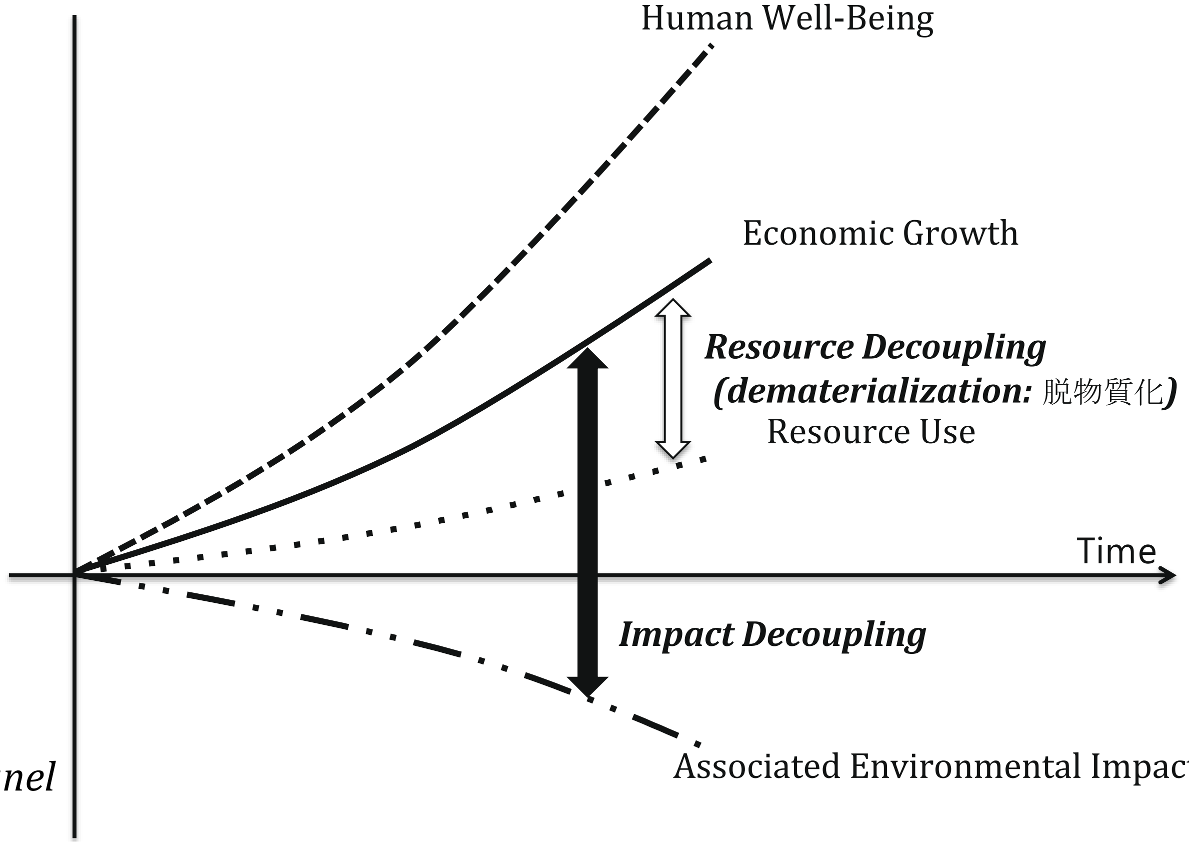
Background: Increasing attention onto mining environmental impacts

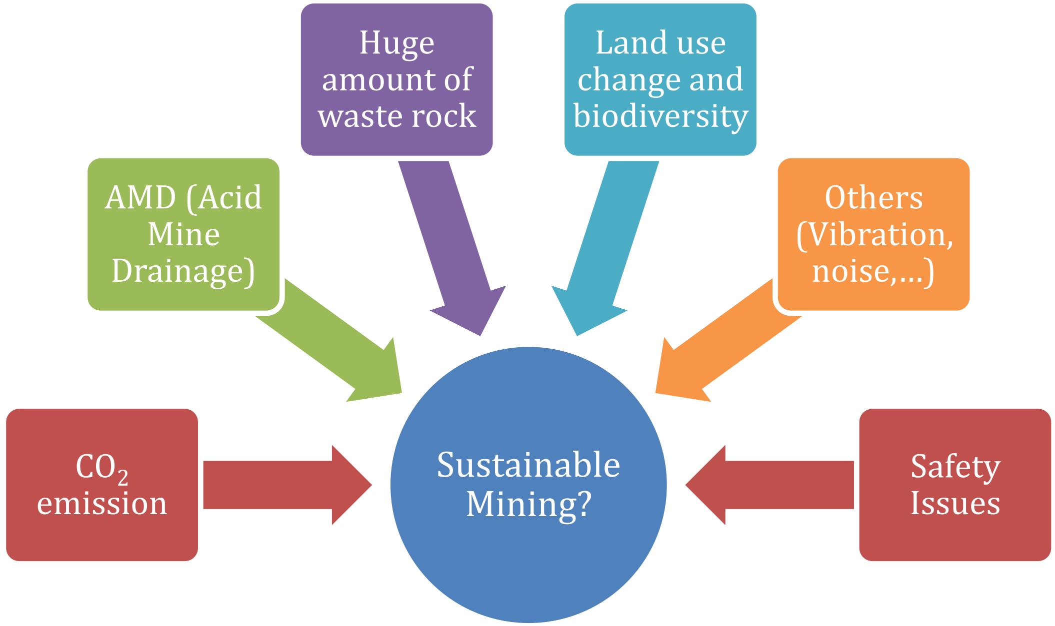
Resource Efficiency & Sustainable Resource Use/Management?

So many people have interests in mining's environmental impact. Then, <u>we'd better be equipped with the idea of how to measure it and communicate with **non mining related** people</u>? If there is any **indicator**, which can summarize the impacts, it would be useful.



UNEP International Resource Panel Decoupling Report

Mining and Environment: How to measure it?



Comparison of multiple case for same mining method is relatively easy.
But how about comparing open-pit mines against block-caving mines?

	CO_2	AMD	Waste	Land use change	Others & Safety
Open-pit	Trucks Haulage	Site-dependent (surface & underground water)	A lot	Huge	?
Underground	Conveyor or other Haulages		Not much	Small?	!

Objective of this study

<Motivation & Research Questions>

- Difference between two mining methods
  - CO_2 emission: Different sources, need to be analyzed
  - AMD, vibration, noises: More site specific
  - Waste Rocks & Land-use change: Obviously ***<u>"OP>UG"</u>***
- But really large scale underground mining is more environmental friendly mining method?
  - Honestly, I don't know.

<Objective>

- Explore whether there is any good *indicator, to measure the mining environmental impacts* reflecting the different *<u>mining methods and site specific environment</u>*.
  - Case study: Open-pit vs Block Caving
  - Indicators: TMR, CO_2 emission, Ecological Footprint (and land use change)

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Copper Mines	Environment	Method
Mine A	Forestry	Open Pit
Mine B	No Green	Open Pit
Mine C	No Green	Block Caving

METHODS & RESULTS

Indicators: TMR (Total Material Requirement)

Not every material-flow-based indicator measures environmental pressure. A precondition is that it always addresses physical interaction between the environment and the human sphere. In other words, it is a matter of system-boundary definition. (*Bringezu et al. 2008*)

TMR=DMI(Direct Material Input) + Hidden Flows
In the case of mining, not only ores but also waste rocks are included. In short, TMR is the weight of everything we excavate.

TMR in mine site can measure the size of our activities in the sense of the intervention onto environment by us, while at least this gives some ideas on the amount of waste rocks.

Indicators: CO_2 emission

Of course, CO_2 emission is not an indicator but just an inventory. However, this is one important inventory item, which we don't know how much it is going to be changed by mining method therefore analyzed here.

Source of the CO_2 emission at mine site

Surface mine		Block Caving	
Truck & other Haulage	Crushing (Mill)	Underground Haulage (i.e.) LHD)	Crushing (Mill)

CO_2 emission tool for mine site: **MLED***

* *Adachi and Mogi, Journal of Life Cycle Assessment, Japan (2006 in Japanese)*

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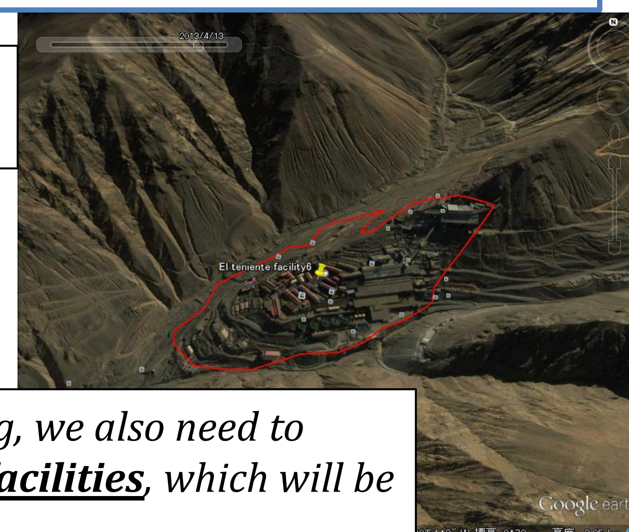
Land Use Change

- ✓ Method: Satellite Image Analysis
  - ✓ In the case of mine A, which is located in a forestry area, bare land was detected using data from the red spectral band. Boundaries between bare and vegetated land were delineated by density slicing (Yamano et al., 2006) using threshold values determined by the Threshold Selection Method from Gray-Level Histograms of Otsu (1979).
  - ✓ For mine A and B, the boundaries are defined manually by authors.
  - ✓ Enclosed boundary lines, extracted based on these threshold values, were converted to polygons. The polygon areas were then calculated using ArcGIS version 10 (ESRI, Redlands, USA).
- ✓ Data: Landsat imagery (cloud-free)

*In open-pit mining, the largest Built-up land is the one for the "**pit**."*



*Even in the case of block-caving, we also need to evaluate **the area of related facilities**, which will be counted as Built-up land.*

Indicators: Ecological Footprint

- EF analyzes our footprints in the following six land use categories
  - Built-up land
  - Forest land
  - Fishing Ground
  - Grazing Land
  - Cropland
  - Carbon Footprint
- Our objective is to analyze the footprint of the mining activity. Therefore we limited our analysis to ***built-up land*** only.
- Built-up lands for mining activities may be a good indicator of mining's impacts onto local ecosystem.

EF (Continued)

$$\boldsymbol{EF_{L,N} = A_L \times EQF_L \times YF_N}$$

Where

- ✓ A: the demanded area for the concerned activity for the land use type L
- ✓ EQF: equivalence factor, which is weighting factor between the land types.
- ✓ YF: yield factor, which is another weighting factor for country N to adjust the difference between countries.

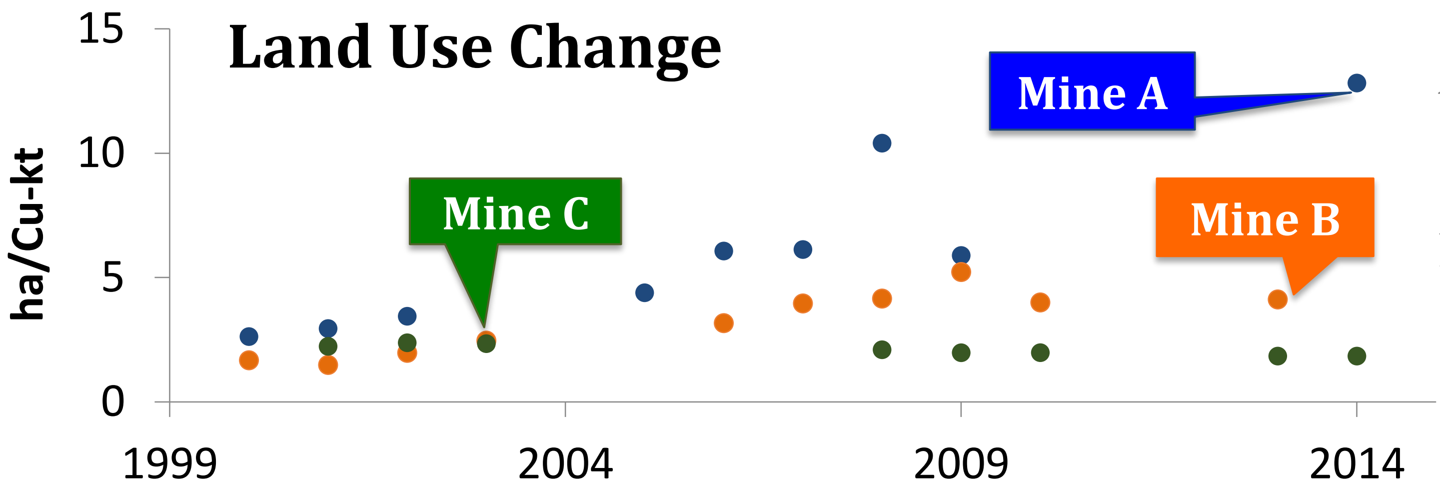
Problems in EF with existing factors.

- ✓ EQF prepared by GFN (Global Footprint Network) <u>assumes Built-up Land is located in an area, which **previously was cropland**</u>.
- ✓ However, <u>mine sites may locate various types of lands</u>.
- ✓ Also, GFN's land use consists of 6 and are not sufficient to reflect the local environment well.

We re-estimate EQF with NPP following Venetoulis and Talberth (2008).

- ✓ We <u>assumed **mine sites' EQFs are equal to nearest land types'**.</u>
- ✓ 6 is not sufficient!; 13 land use types are prepared.

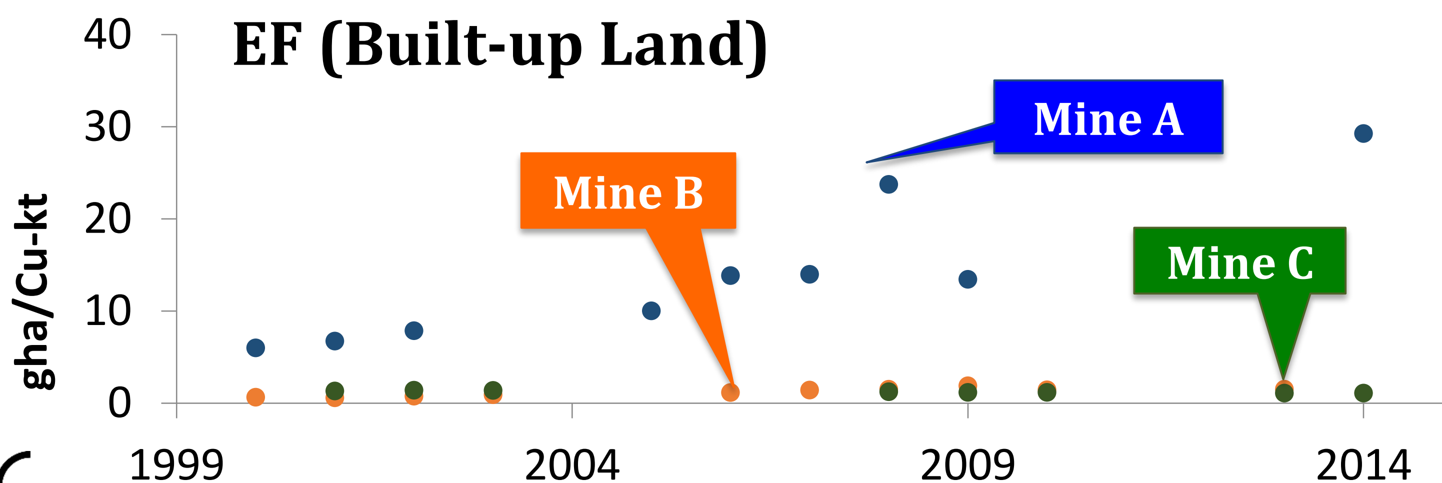
Result: Land Use Change and EF (Built-up land)



A@ 2014 is

3 times

larger than B @ 2013



A@ 2014 is

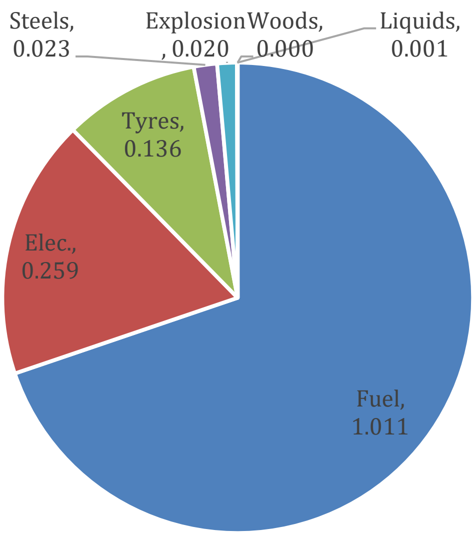
20 times

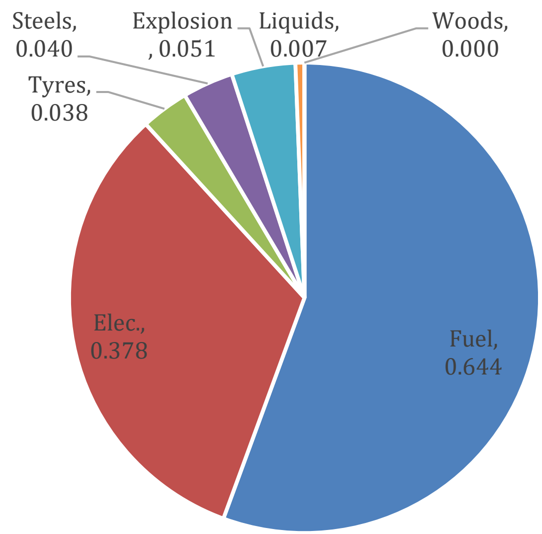
larger than B @ 2013

Result: CO_2 emission and TMR

	CO_2 emission	TMR
Mine A	2.32 [CO_2 –kg/Cu-kg]	N/A
Mine B	1.38 [CO_2 –kg/Cu-kg]	348.98 [kg-TMR/kg-Cu]
Mine C	1.16 [CO_2 –kg/Cu-kg]	139.85 [kg-TMR/kg-Cu]

CO_2 emission details for mine B and C





- ✓ Even though all inputs' rucksacks are accounted for TMR estimation, almost all of them are waste rocks, which were governed by grade and waste/ore ratio.
- ✓ Regarding CO_2, mine A is located in a more mountainous area, which may force more energy consumption therefore more emission.
- ✓ Mine B and C show similar values, though the details are different.

Conclusions

CO_2 emissions

- Reflecting some details of operation

TMR

- Works as pressure indicator to the environment and also reflecting volumes (3D)

Land Use Change

- Area indicator (2D). Nice counterpart for TMR?

EF (Build up land)

- Area indicator, considering local environment.

	Mining Method	Local Environment	AMD	Dynamic (not-static)
CO_2	○: OK	△: Reflect some?	×: No	×: No
TMR	○: OK	×: No	△: Possibility?	×: No
Land Use	×: not suitable UG	×: No	×: No	○: Yes
EF (BUL)	△: not suitable UG	○: Yes	×: No	○: Yes

Conclusions

CO_2 emissions

- Reflecting some details of operation

TMR

- Works as pressure indicator to the environment and also reflecting volumes (3D)

Land Use Change

- Area indicator (2D). Nice counterpart for TMR?

EF (Build up land)

- Area indicator, considering local environment.

✓ EF (Built-up land) showed some potential. Though, the factors prepared by GFN are not useful for this kind of microscopic analysis, therefore we need some adjustment.
✓ TMR could be nice complement for EF (Built-up Land) because of its 3D nature.
✓ CO_2 emissions give you some idea on operation.
✓ Dynamic aspects of mining are not well reflected in most indicator. (EF does.)

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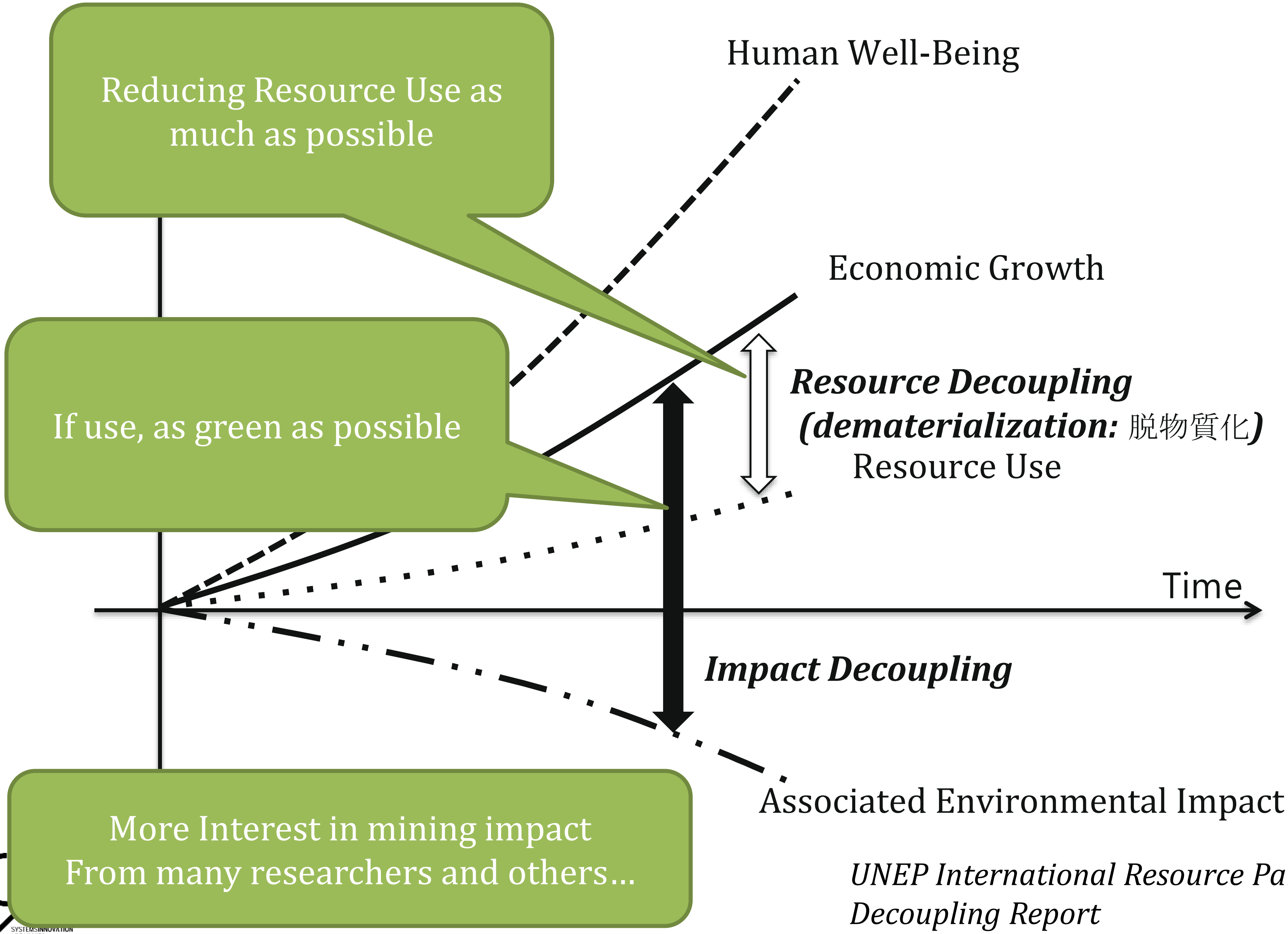
THAT'S ALL. THANKS FOR LISTNING.

SUPPLEMENTARY SLIDES

Sustainable Resource Use/Management



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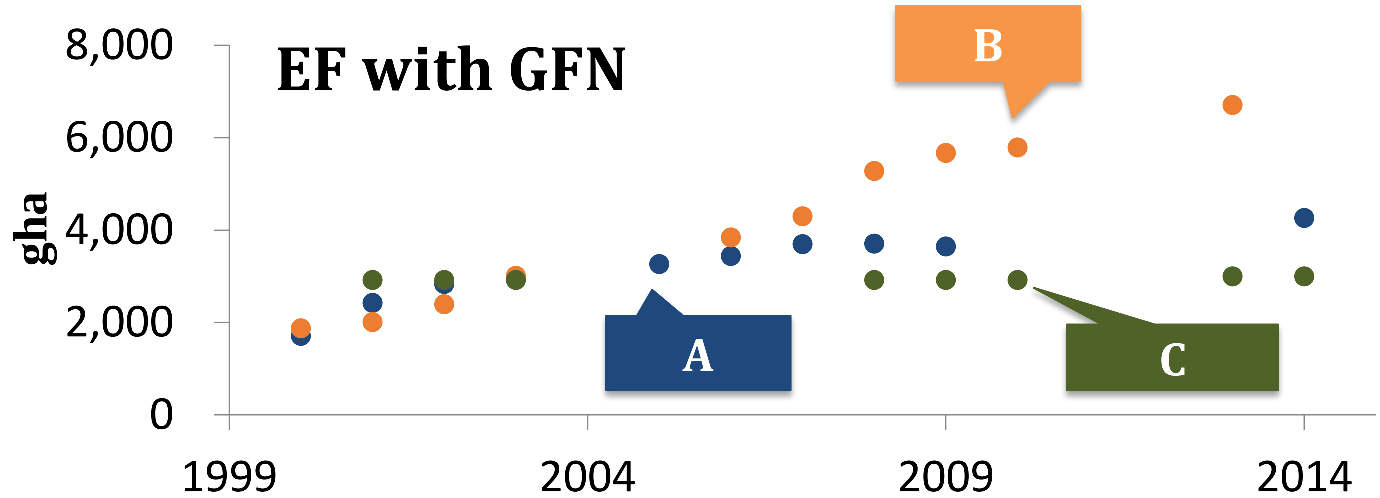
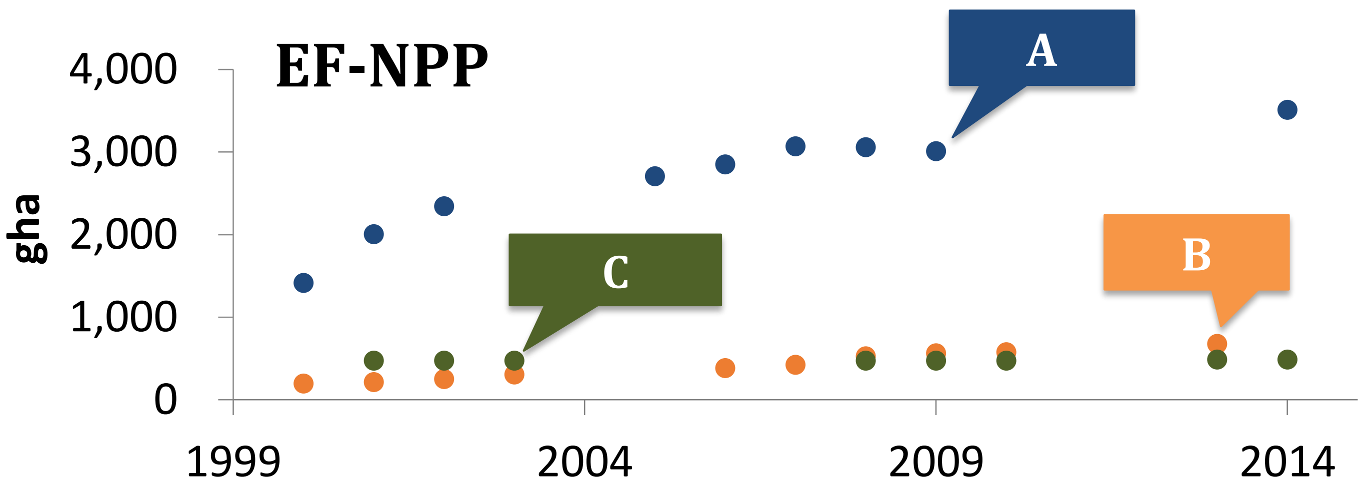
Validation:
EF with Global Footprint Network factors vs this study





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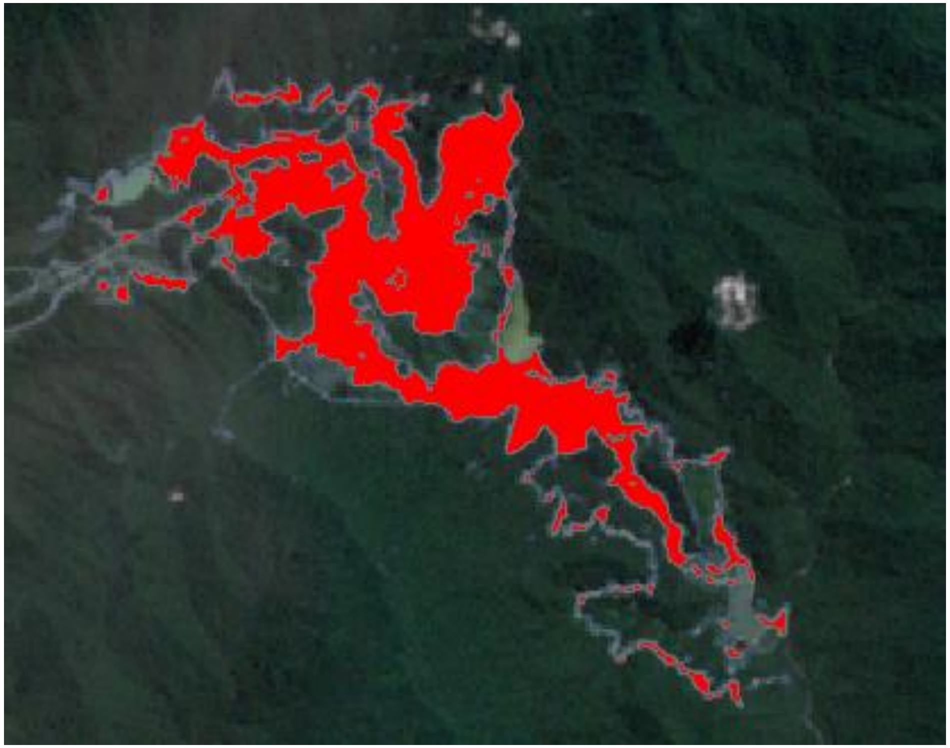

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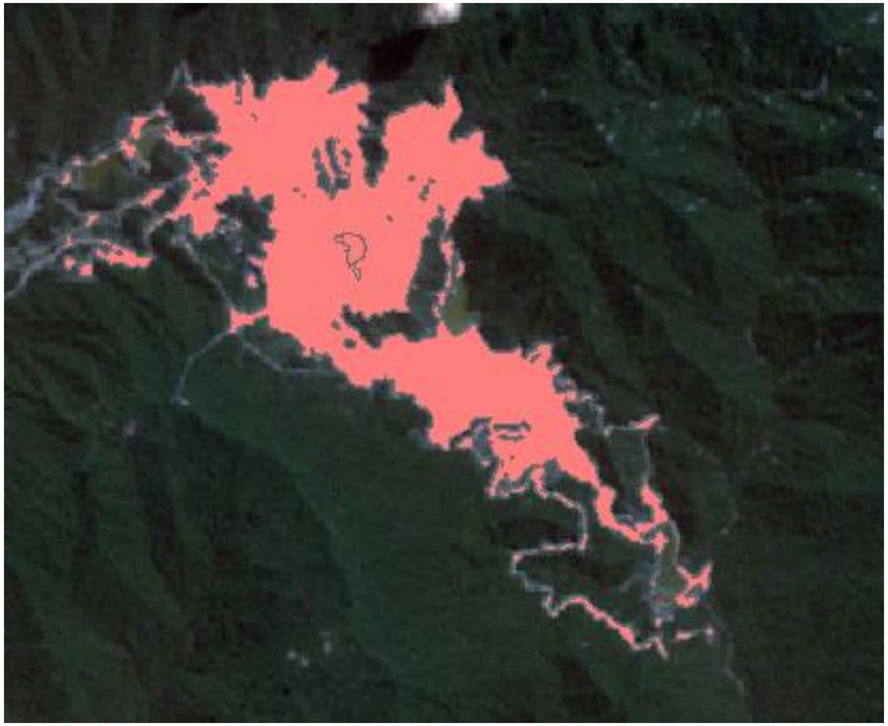

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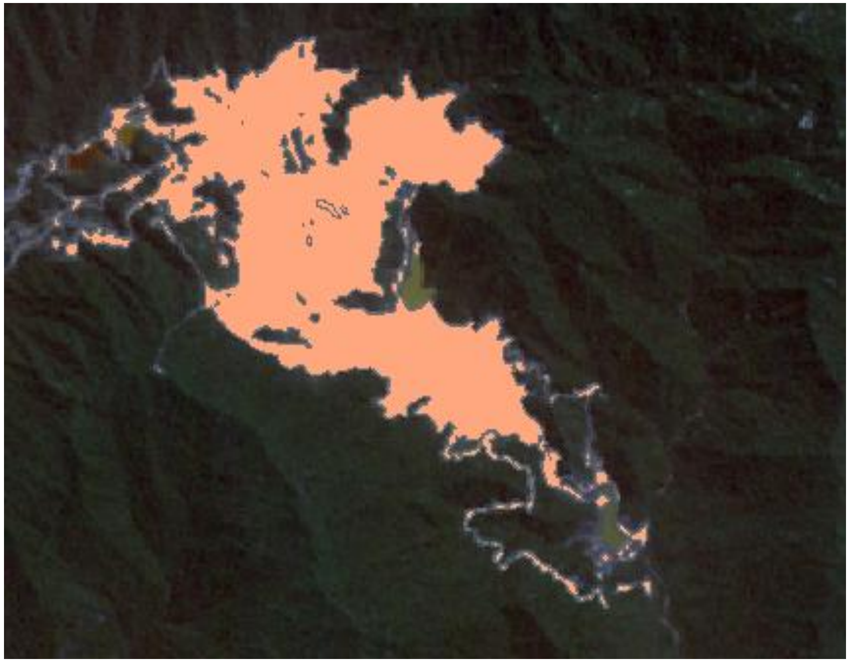

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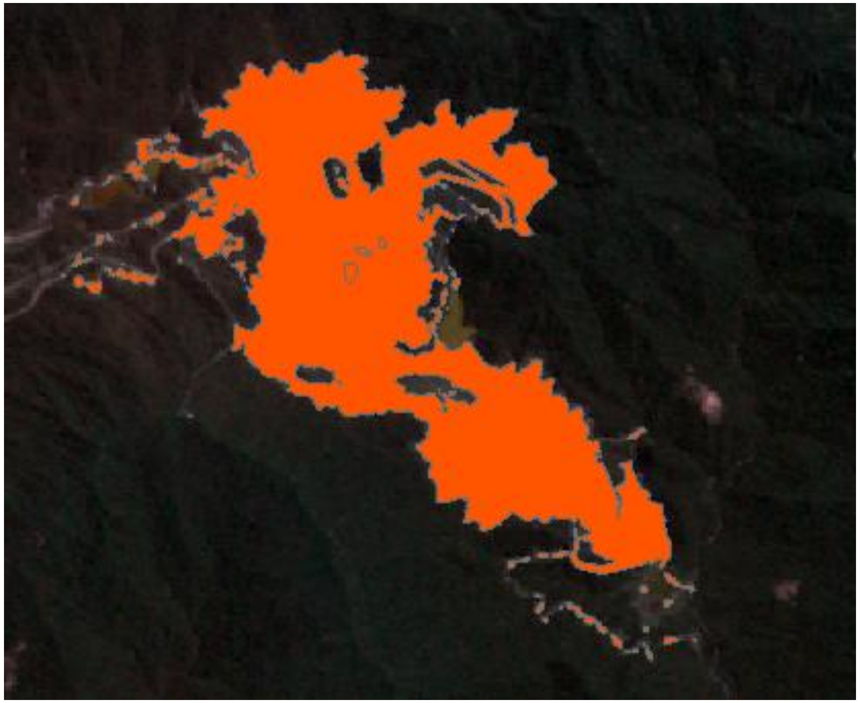

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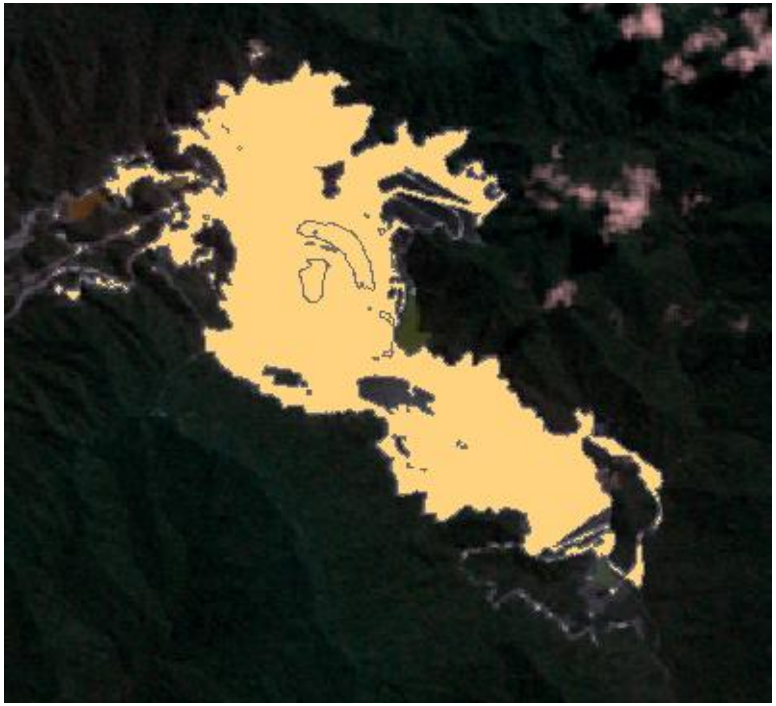

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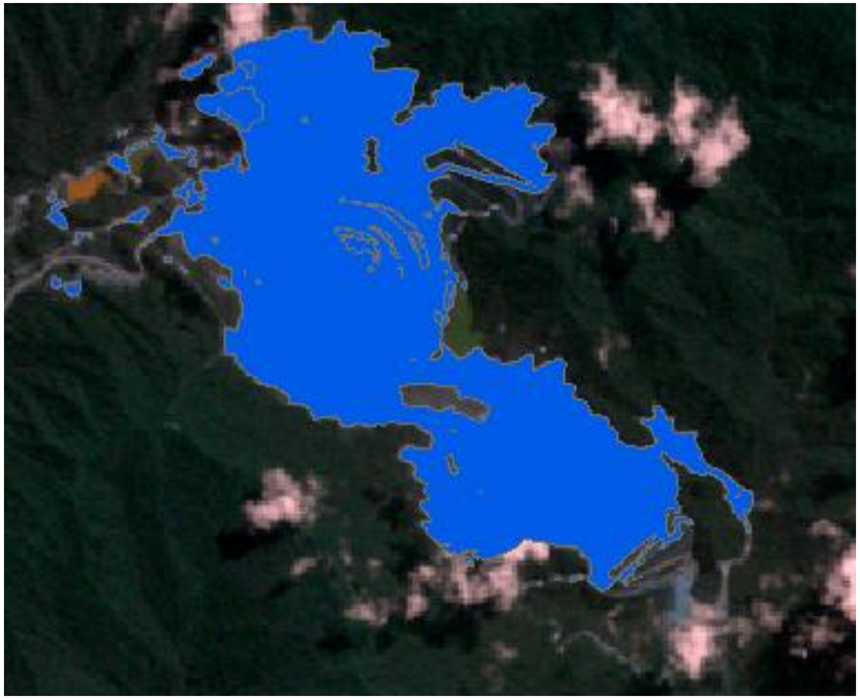

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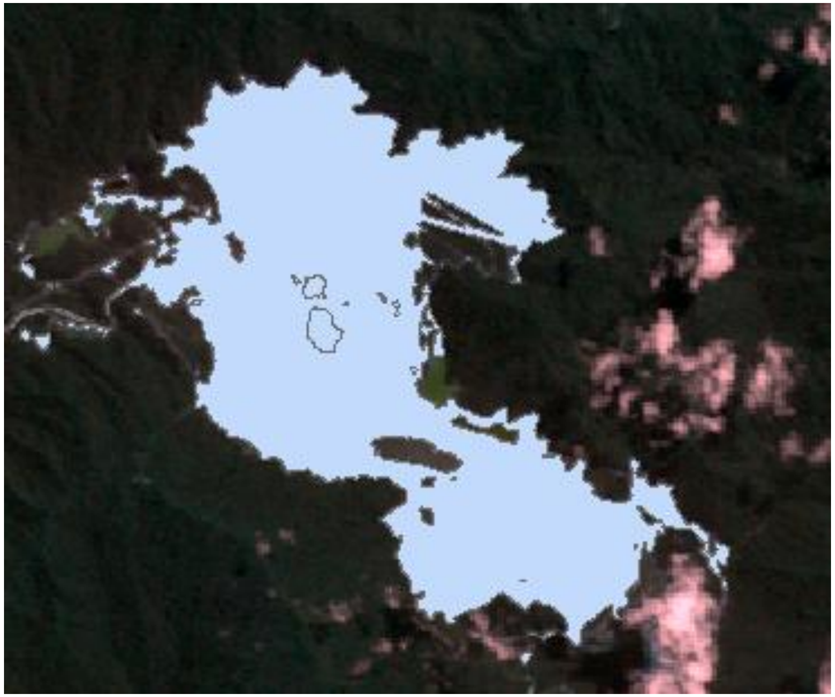

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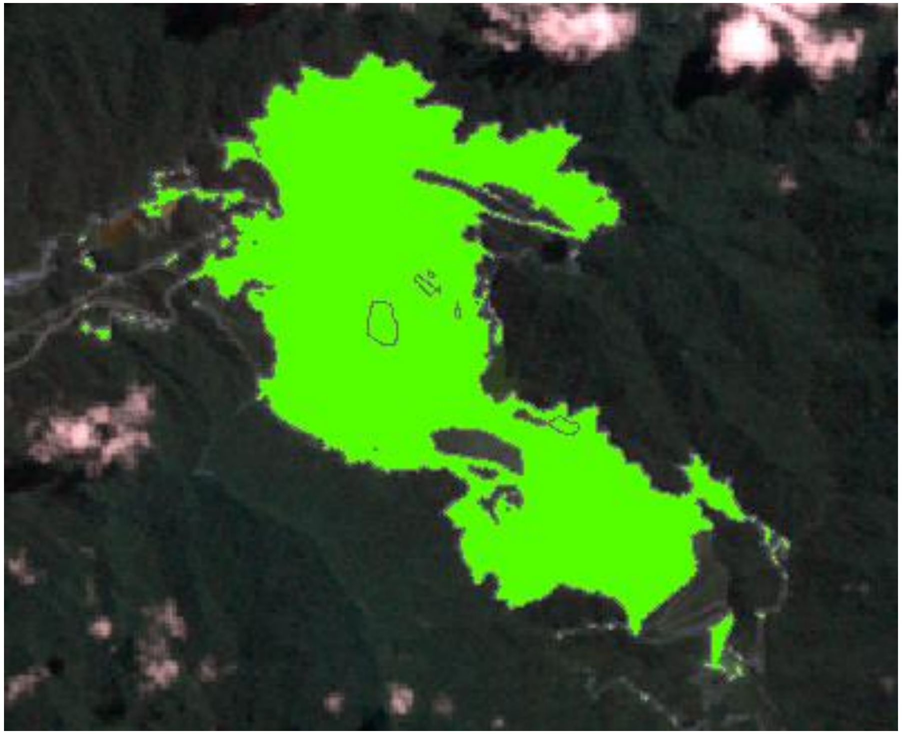
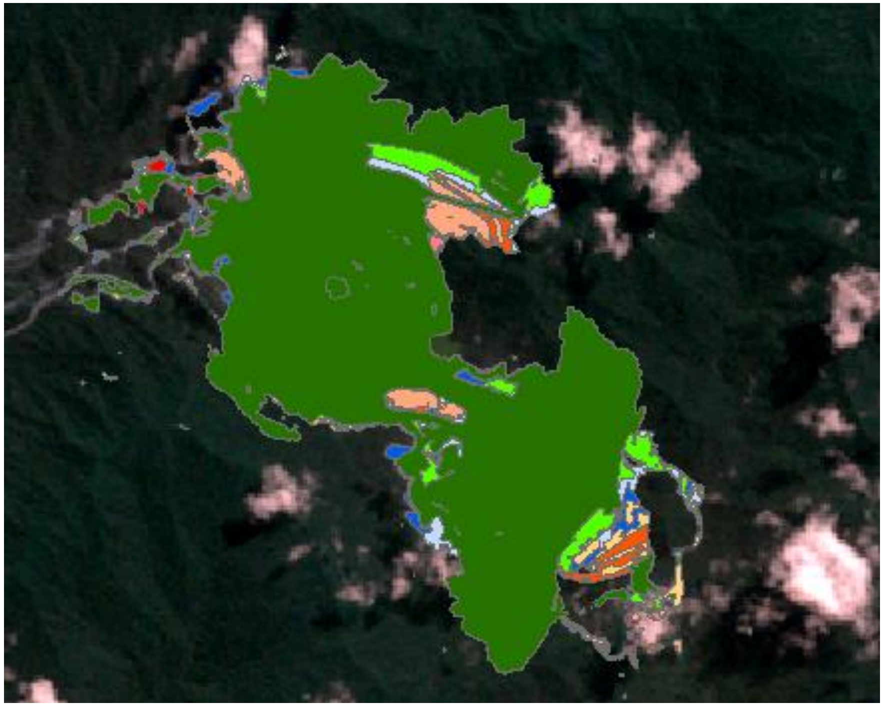
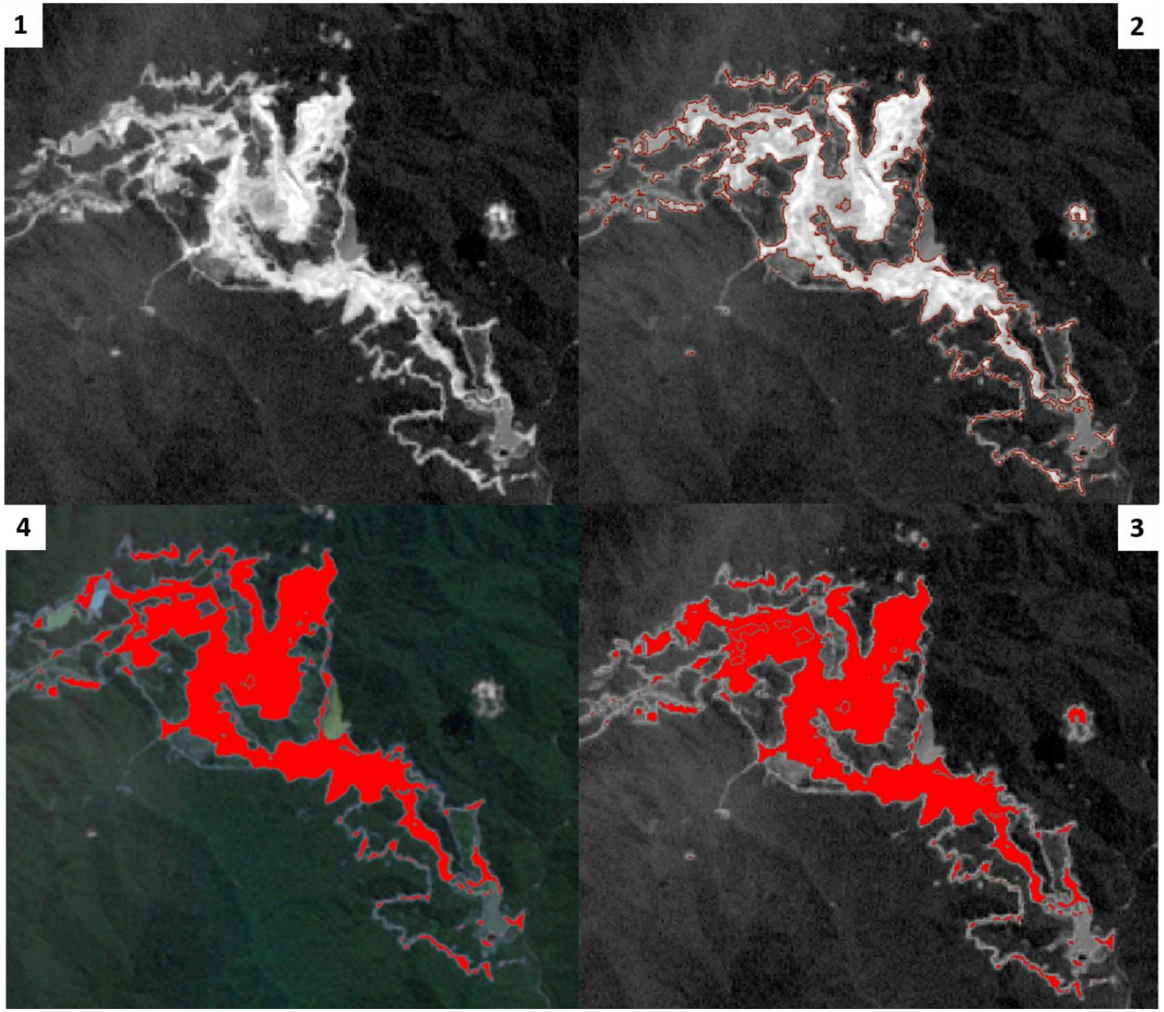


2014-5-7

2000-2014



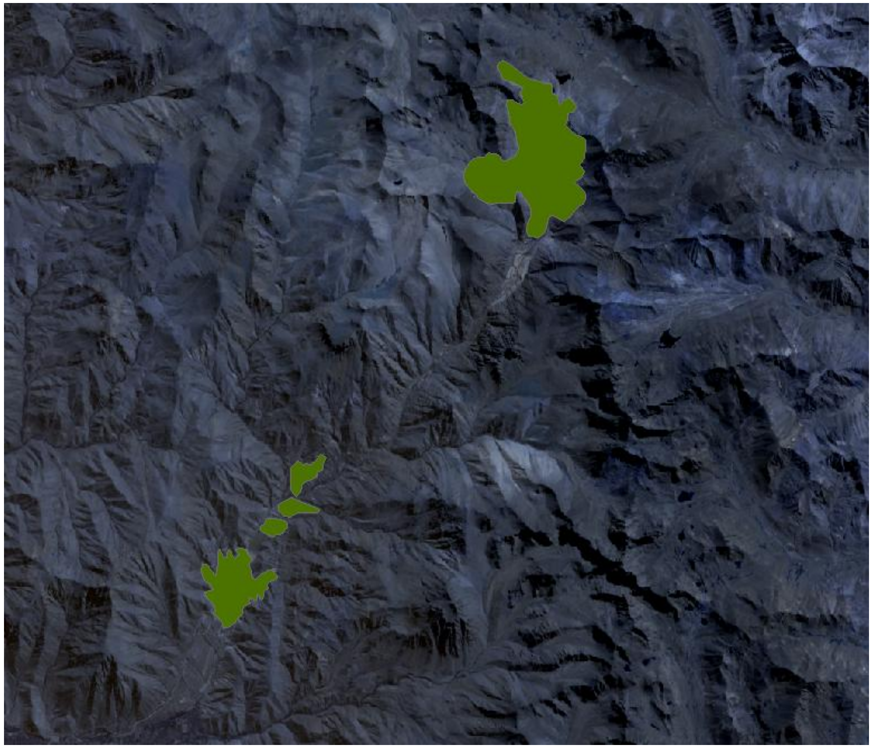
鉱山Aのポリゴン作成手順



鉱山Aのポリゴン作成の手順

鉱山B、鉱山Cの面積測定

鉱山B



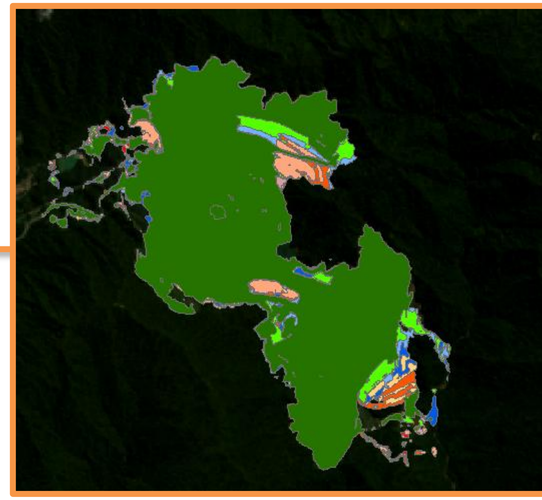
鉱山Bポリゴン

鉱山B、Cでは周辺環境に植生が存在しておらずしきい値の設定

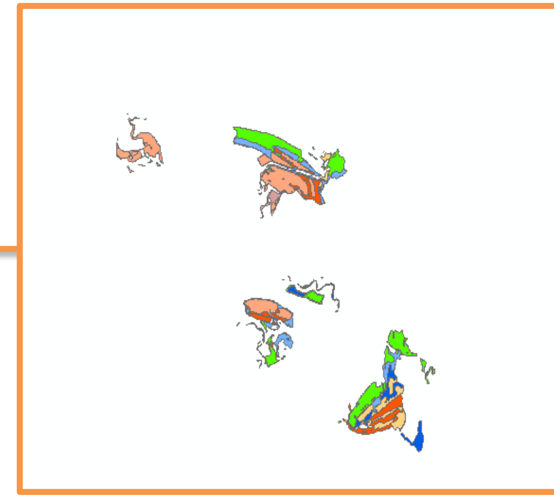
が困難であった。そのため面積の過大評価とならぬように注

鉱山Aの緑化面積の測定

鉱山A,2014



ポリゴンの重ね合わせ



各年の緑化箇所

①各年の画像を古いものを下にして重ね合わせた。
②目視で確認した緑化箇所と一致したことを確認した
③各年の緑化箇所を切り取った

ある年では裸地の部分が2014年には植生が回復していることが確認出来る。この面積を緑化面積とした。

鉱山Aの緑化箇所の確認

緑化箇所を目視による確認を行った