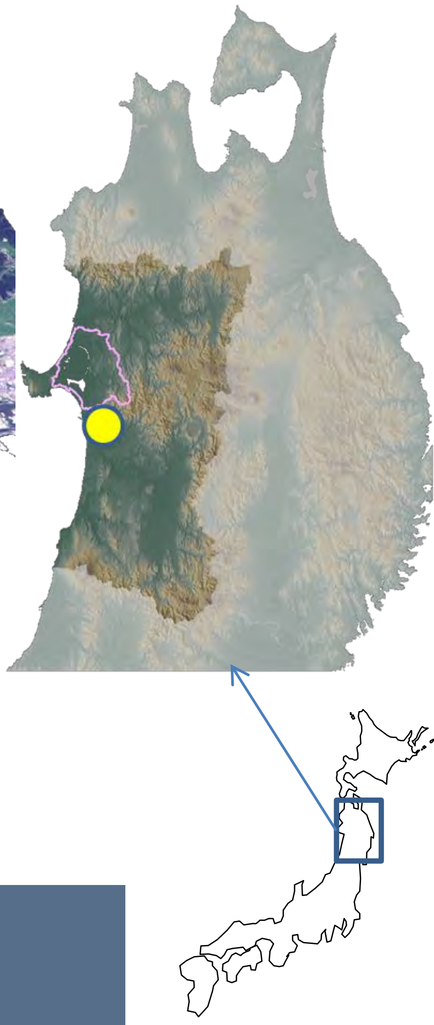
Soil functions as Natural Resource for the Bioeconomy: A case study in a catchment

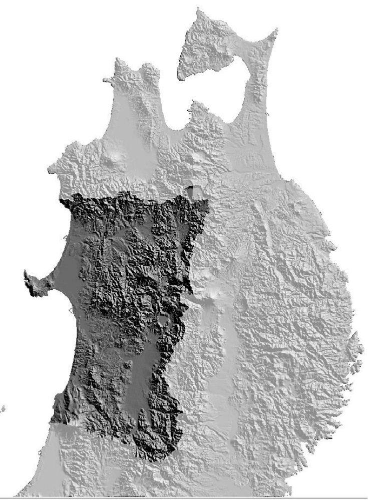


Akita Prefectural University
(Hayakawa Atsushi, 早川 敦)

Japan Society for the Promotion of Science JSPS Bonn Office at Japanese-German Center Berlin, 2022.5.20-21

Akita

秋田



Area

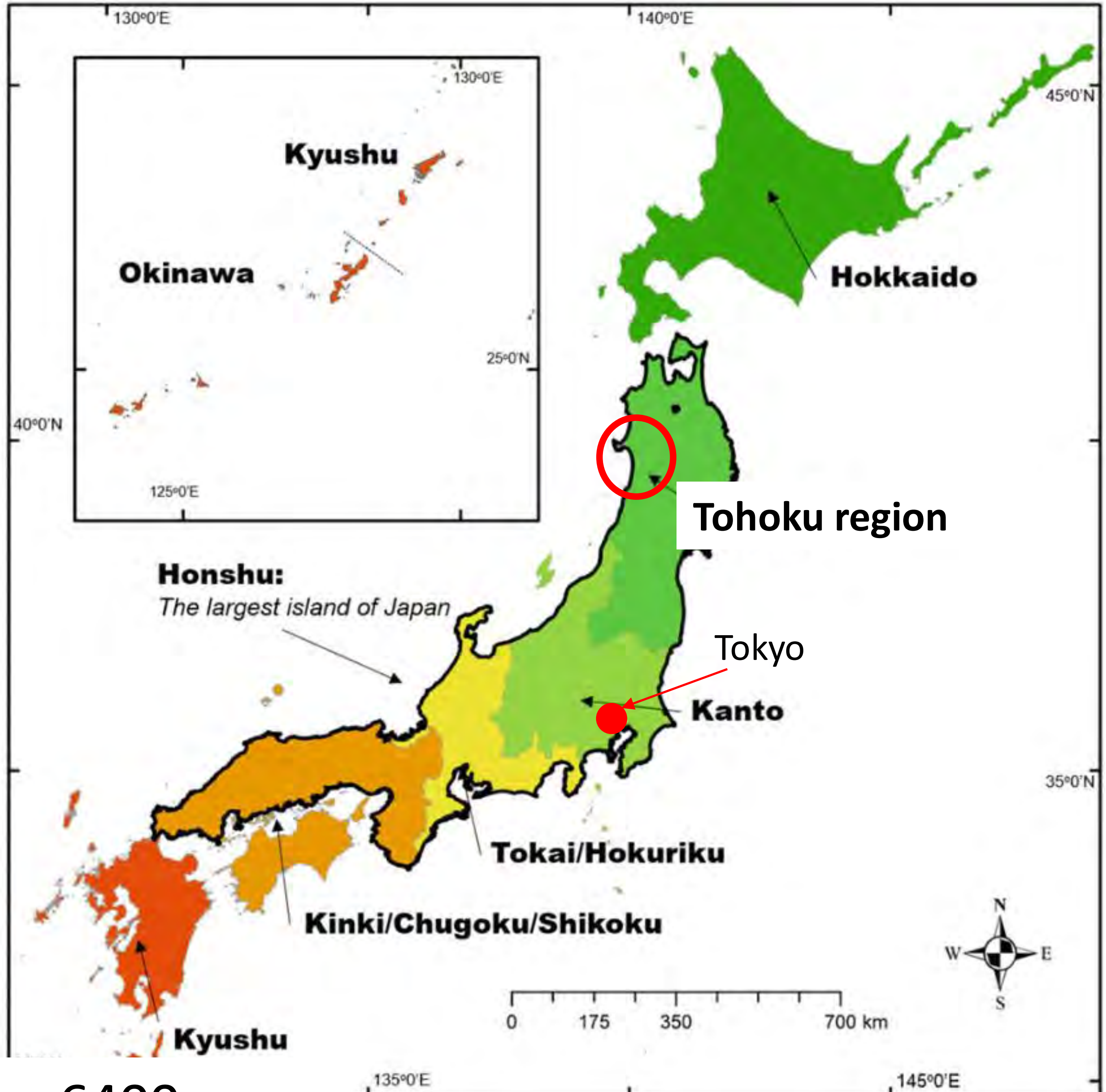
11637 km^2

Population

0.93 mil.

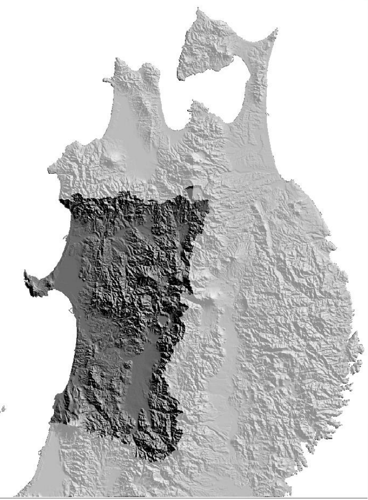
Population density

80 person/km^2 << 6400 (Tokyo)



Akita

秋田



Annual Temp.

12℃

Annual Precip.

1600 mm

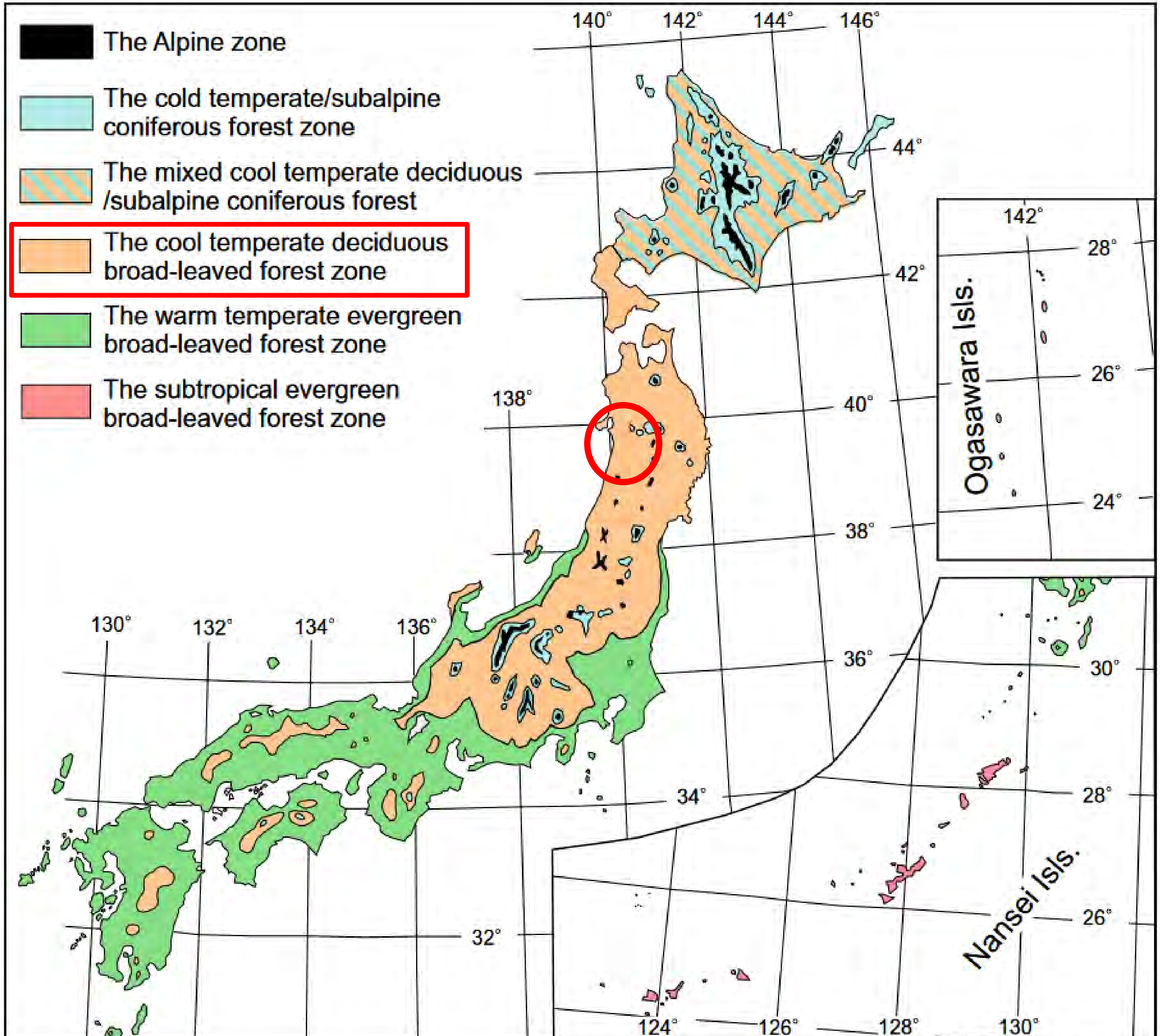
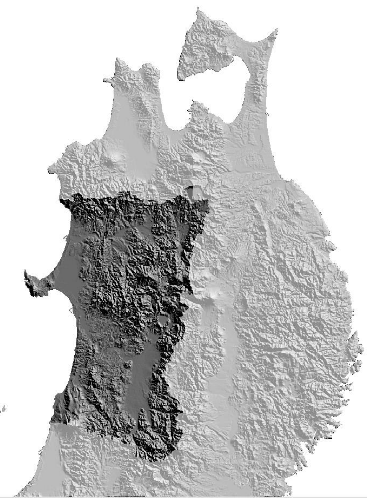
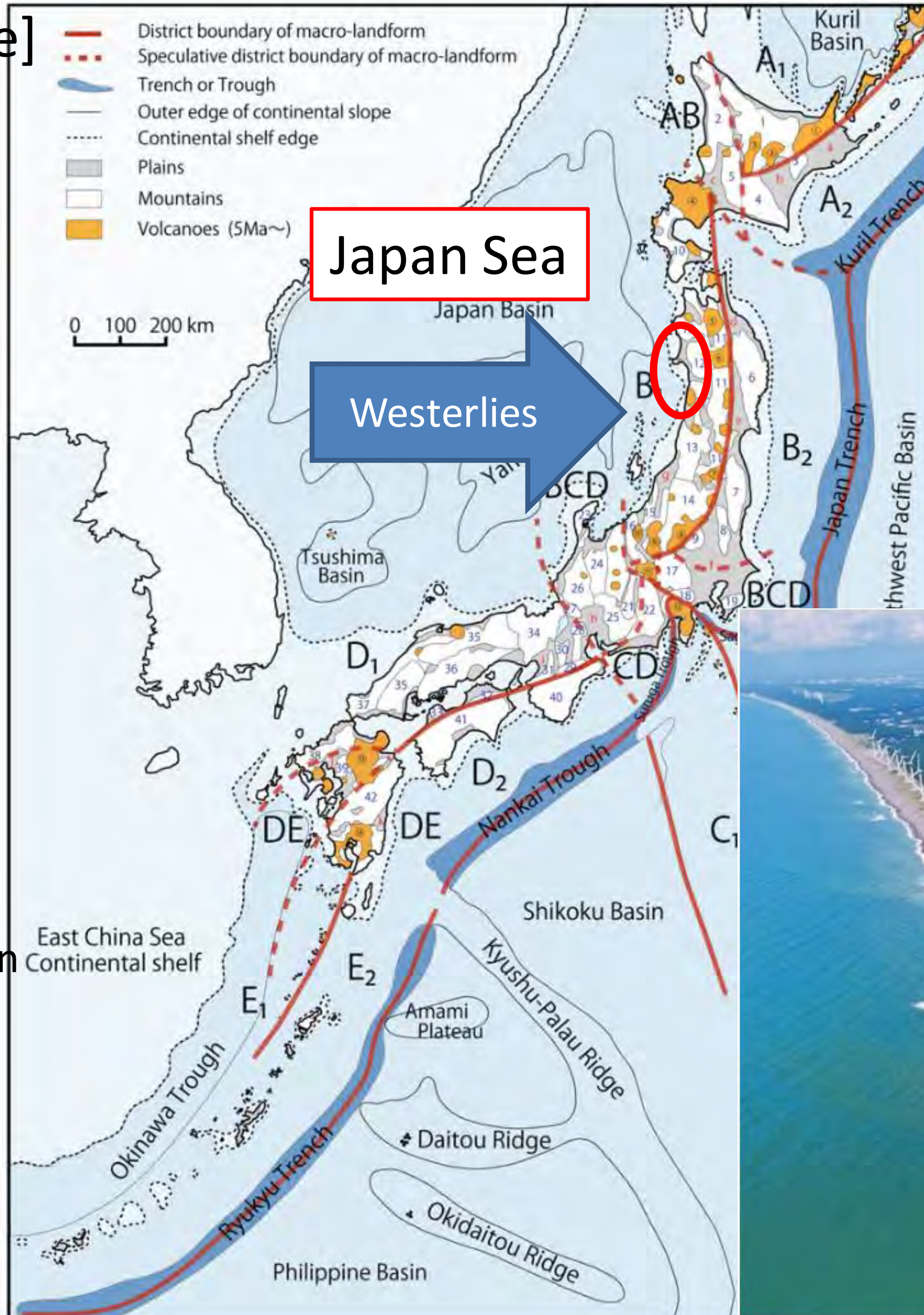


Fig. 2.27 Vegetation map of Japan. Redrawing of the vegetation map of Japan (Yoshioka 1973). We added the map in subtropical area and partially changed the forest distribution of the original map (Figure supplied by Tetsuya Sano)

[Natural Resource]

Akita





Wind power generation

2nd largest

in Japan

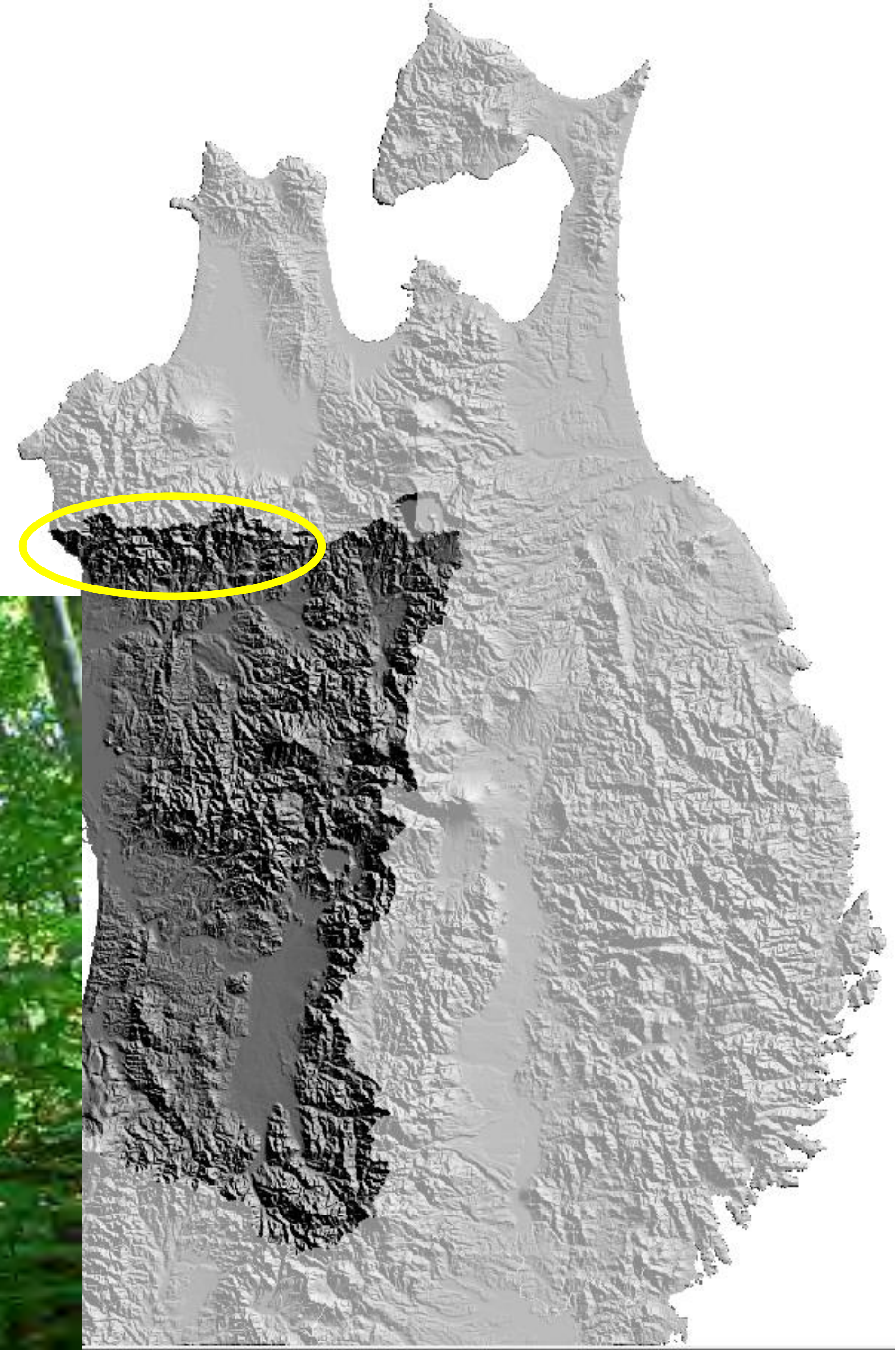
[Natural Resource]

Akita

白神山地

Shirakami Sanchi

UNESCO World Heritage sites

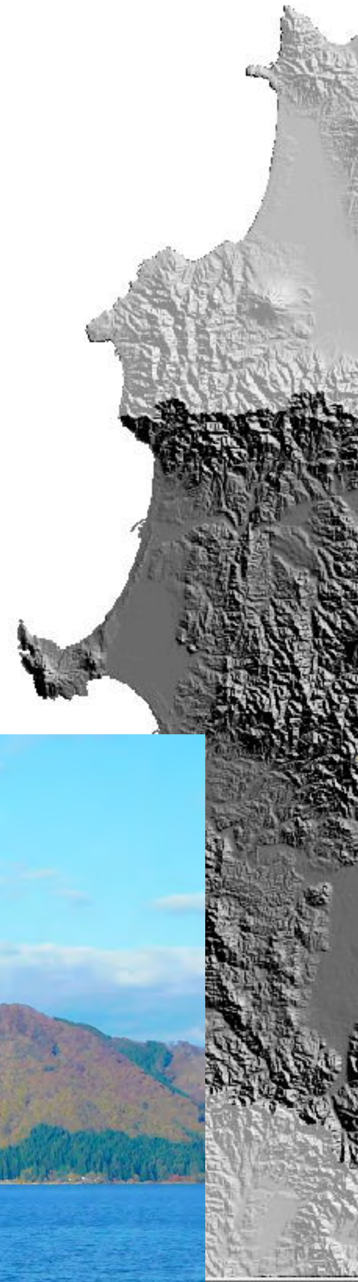


[Natural Resource]

Akita

田沢湖

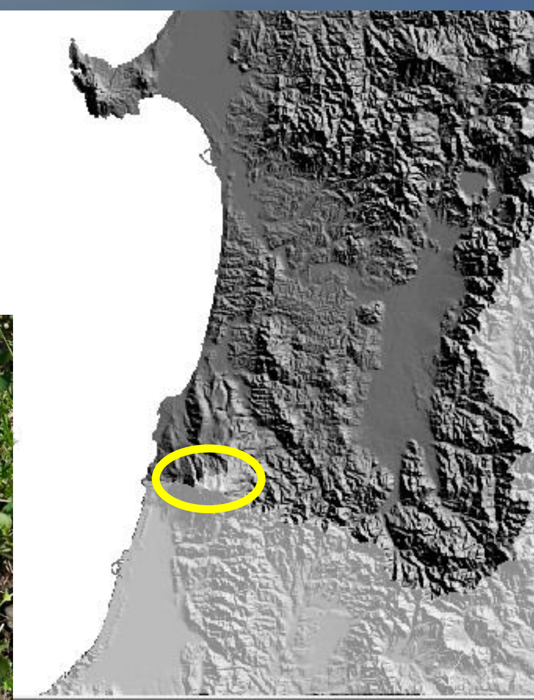
Lake Tazawa



[Natural Resource]

Akita

鳥海山
Mt. Chokai



• Rice is the main agricultural production in Akita

88% of cropland area

http://www.machimura.maff.go.jp/machi/contents/05/index.html




[Cultural Service]

Akita

なまはげ

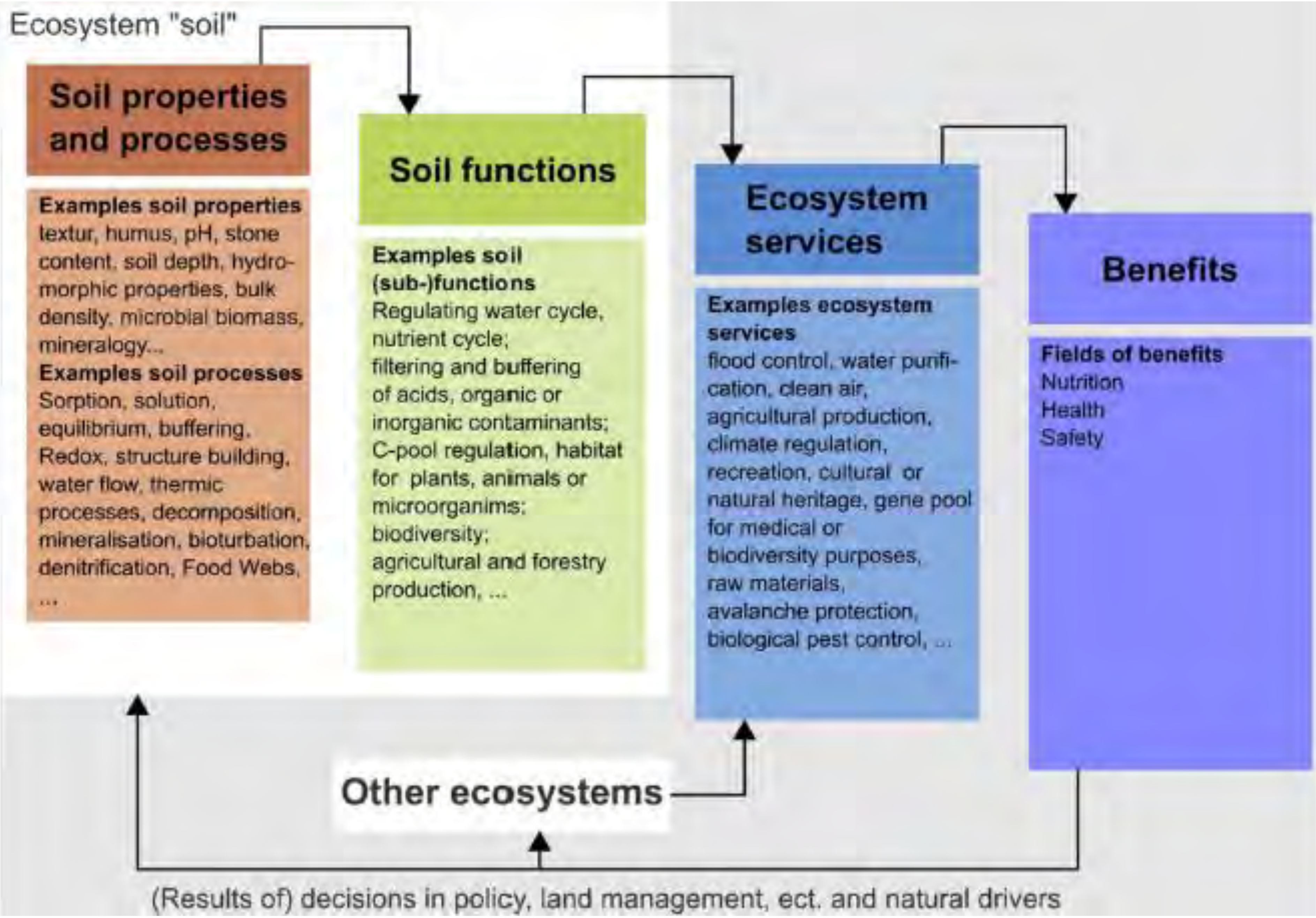
Namahage

Akita original “god”, not “ogre”

鬼ではなく，神様です！

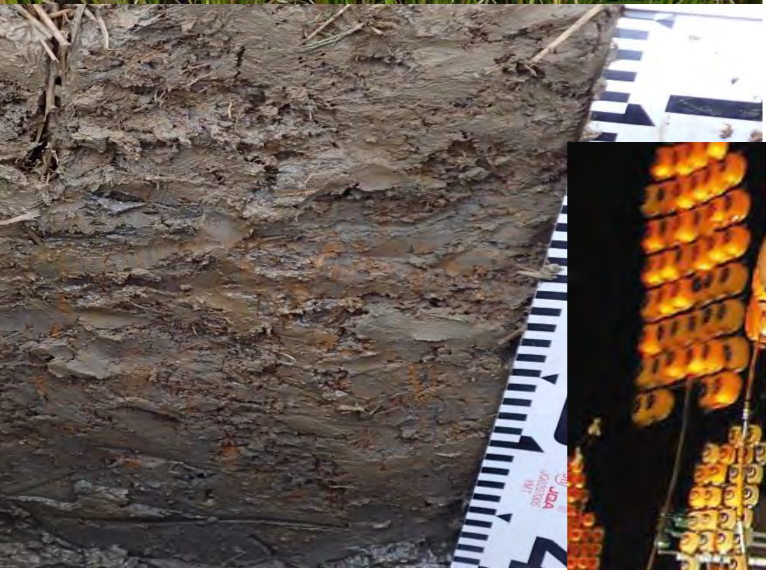
In 2018, Namahage is recognized by UNESCO as Intangible Cultural Heritage List


角館やま行事
鹿角　花輪ばやし
柴灯まつり
横手　かまくら祭り
西馬音内盆踊り
土崎港
曳山まつり
土崎神明社例祭



Greiner et al., 2017

[Soil functions and cultural Service]



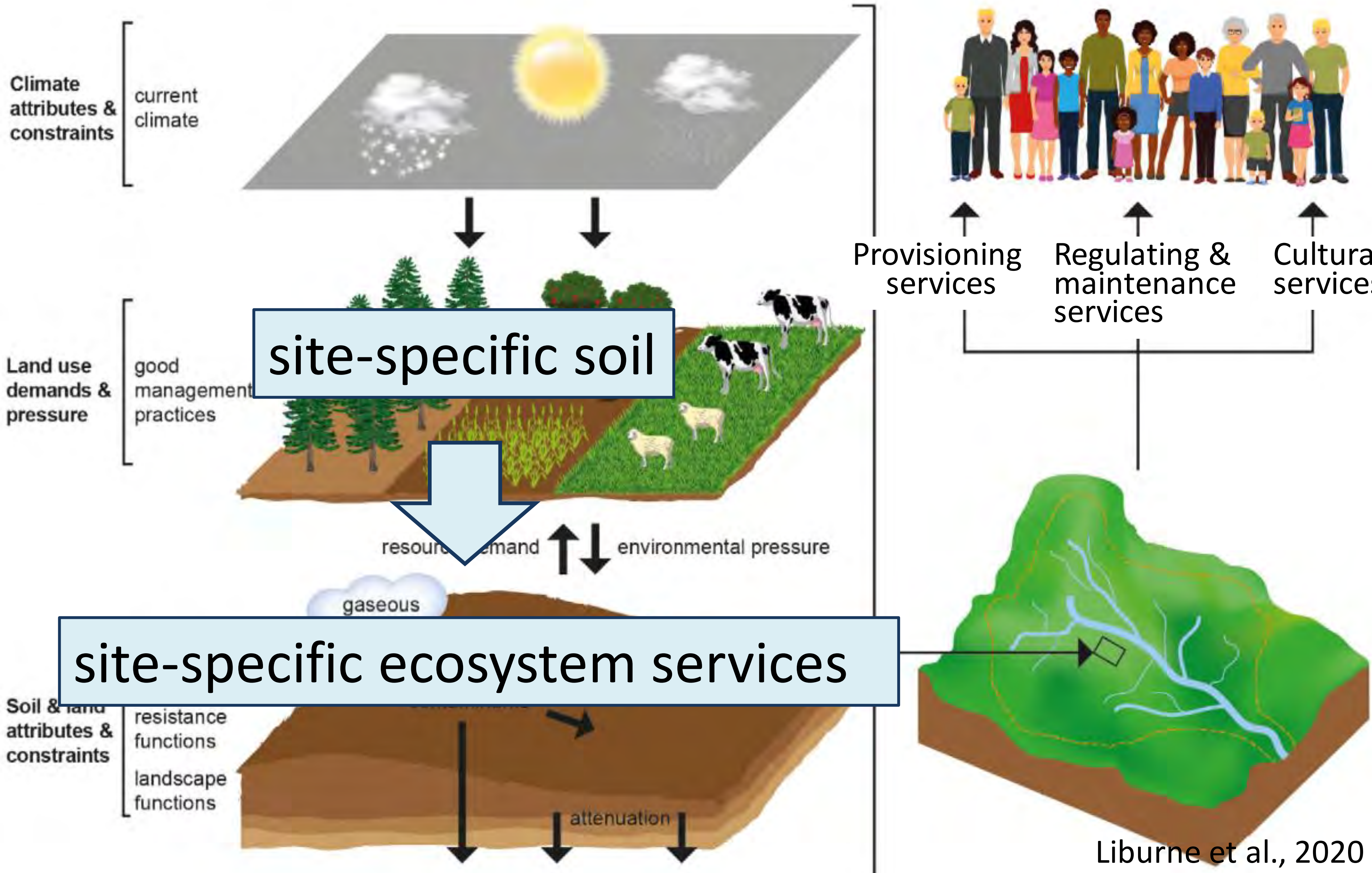
Good soil, water, air
Good management

↓

Good harvest
Good health, culture

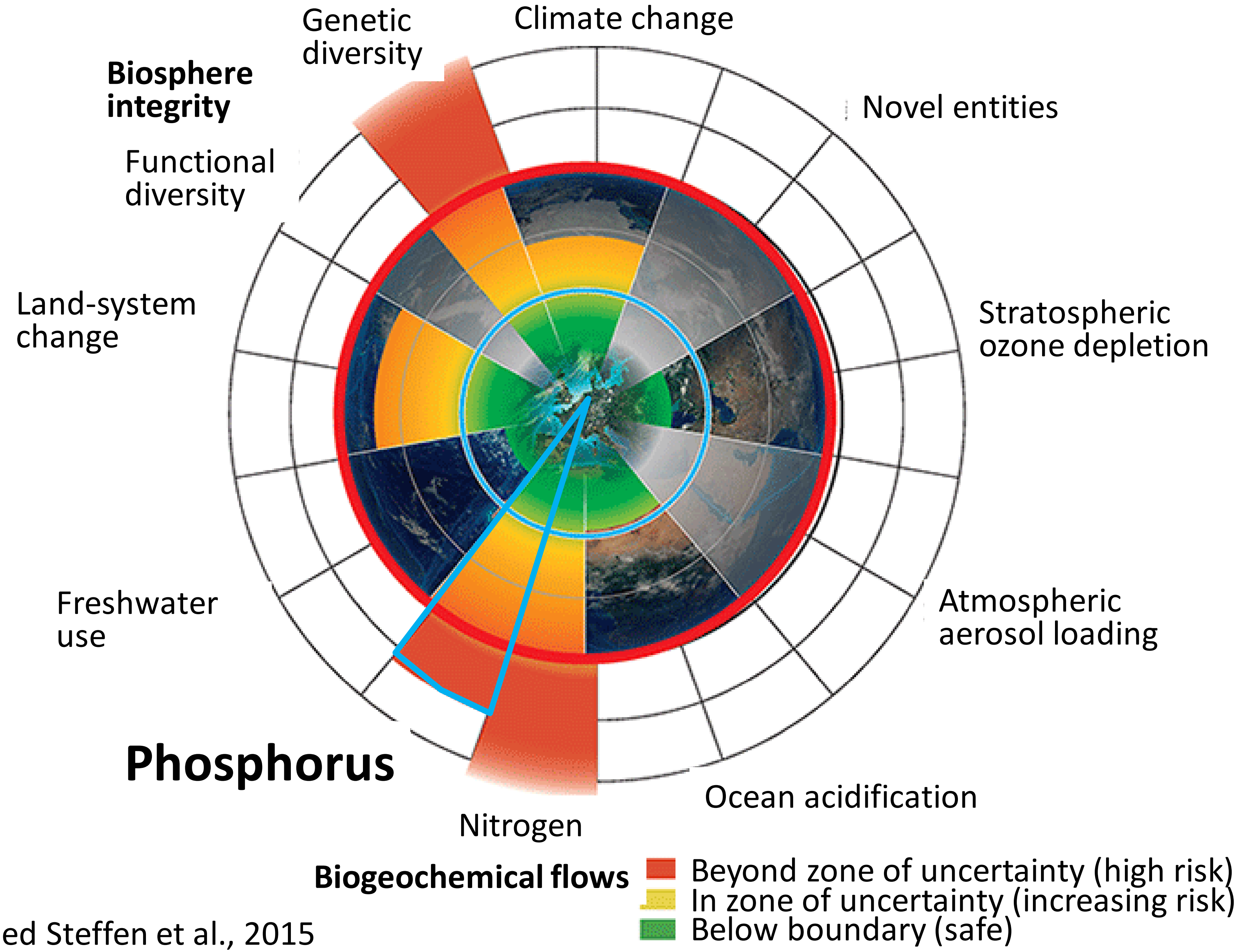
Kanto Festival
竿燈まつり
the event to pray for a good harvest

Ecosystem services are determined by spatially different soil functions in region.



Liburne et al., 2020

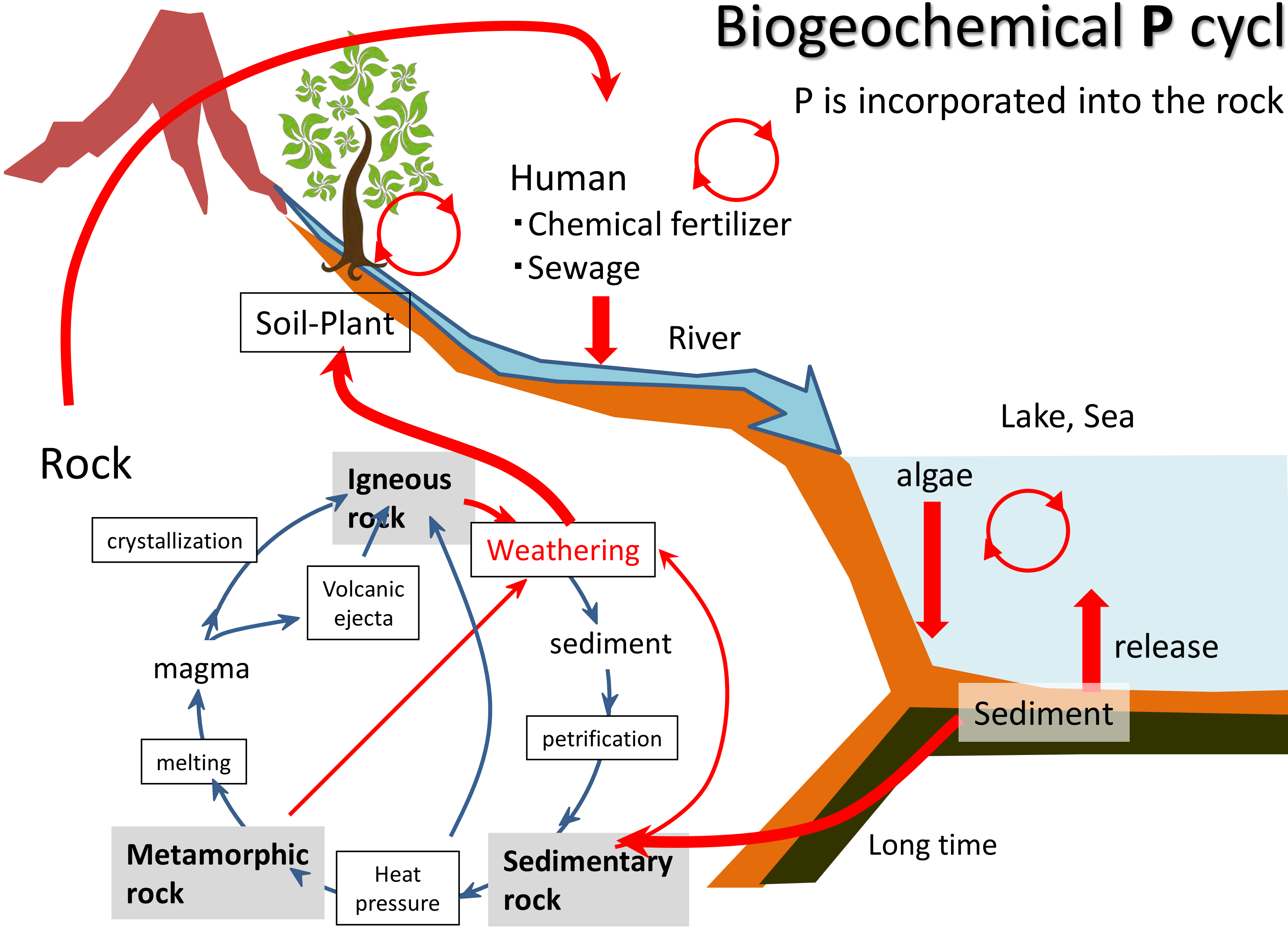
The phosphorus (P) cycle is deemed to be over the safe limit



Modified Steffen et al., 2015

Biogeochemical **P** cycles

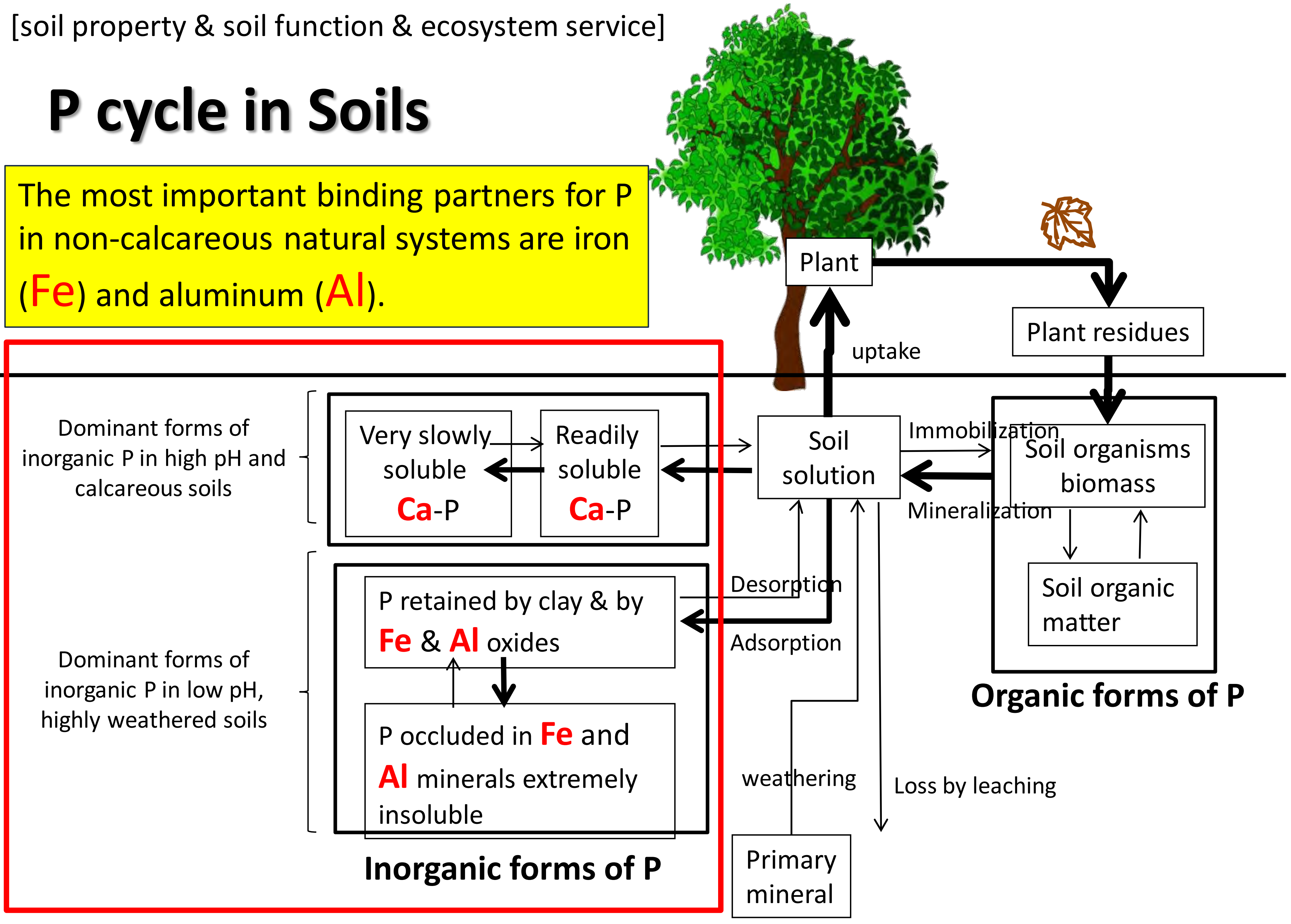
P is incorporated into the rock cycle



Biogeochemistry, p. 586

P cycle in Soils

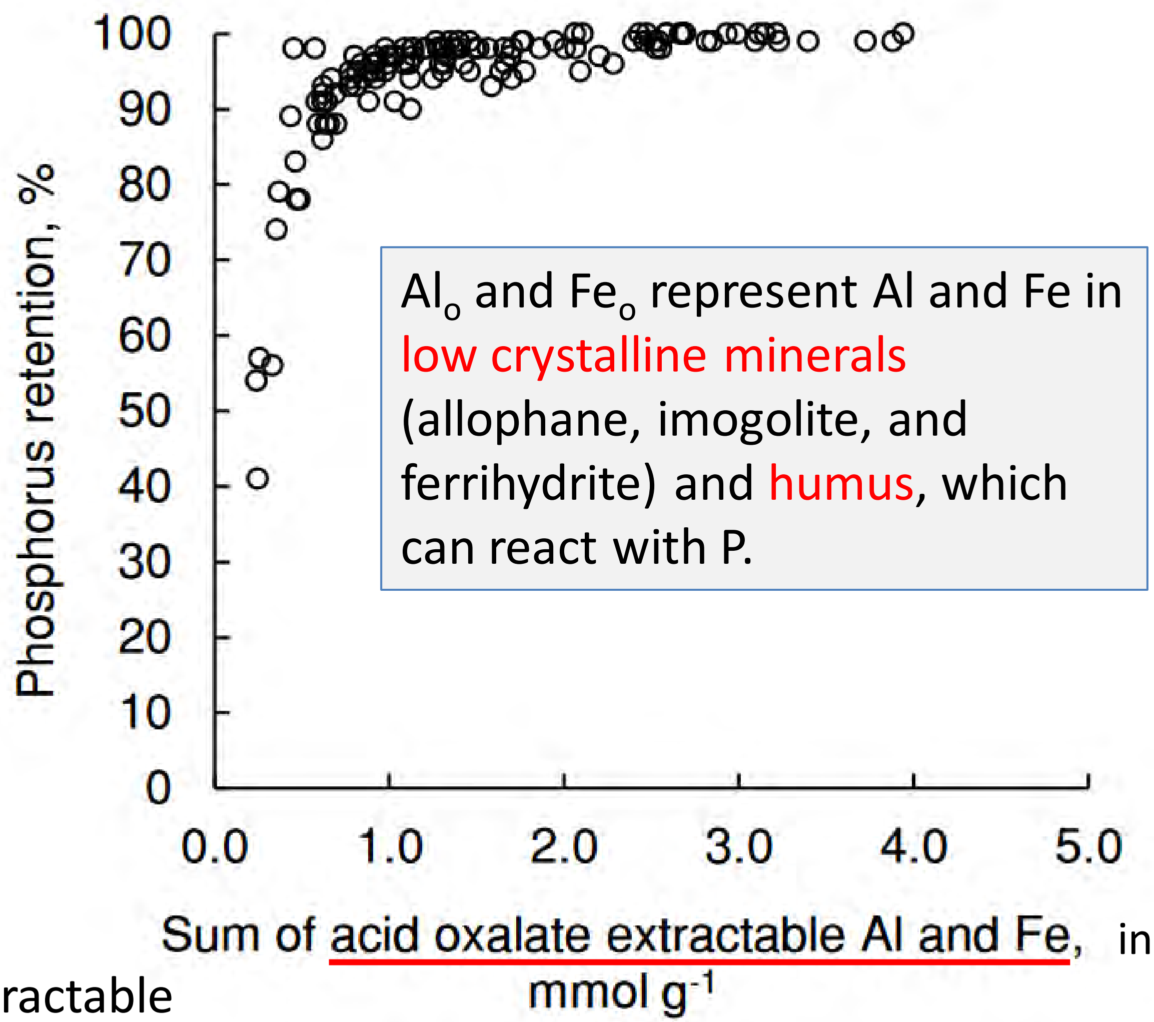
The most important binding partners for P in non-calcareous natural systems are iron (Fe) and aluminum (Al).



Modified Brady &Weil (2008)

[soil property and soil function]

Soil P is tightly retained by Al and Fe oxides [key soil process]



in soil

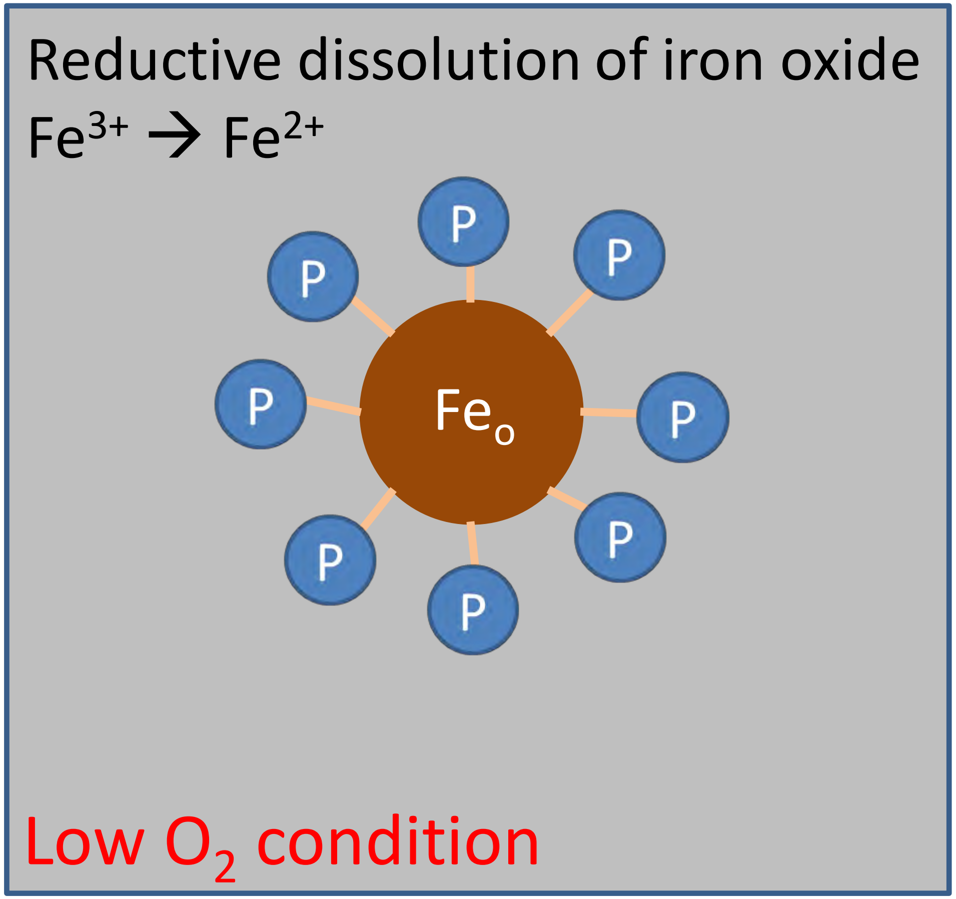
[key soil property]

Acid oxalate extractable
Al (Al_o)
Fe (Fe_o)

Shoji et al. (1985), Ito et al. (1991), Wada (1986)

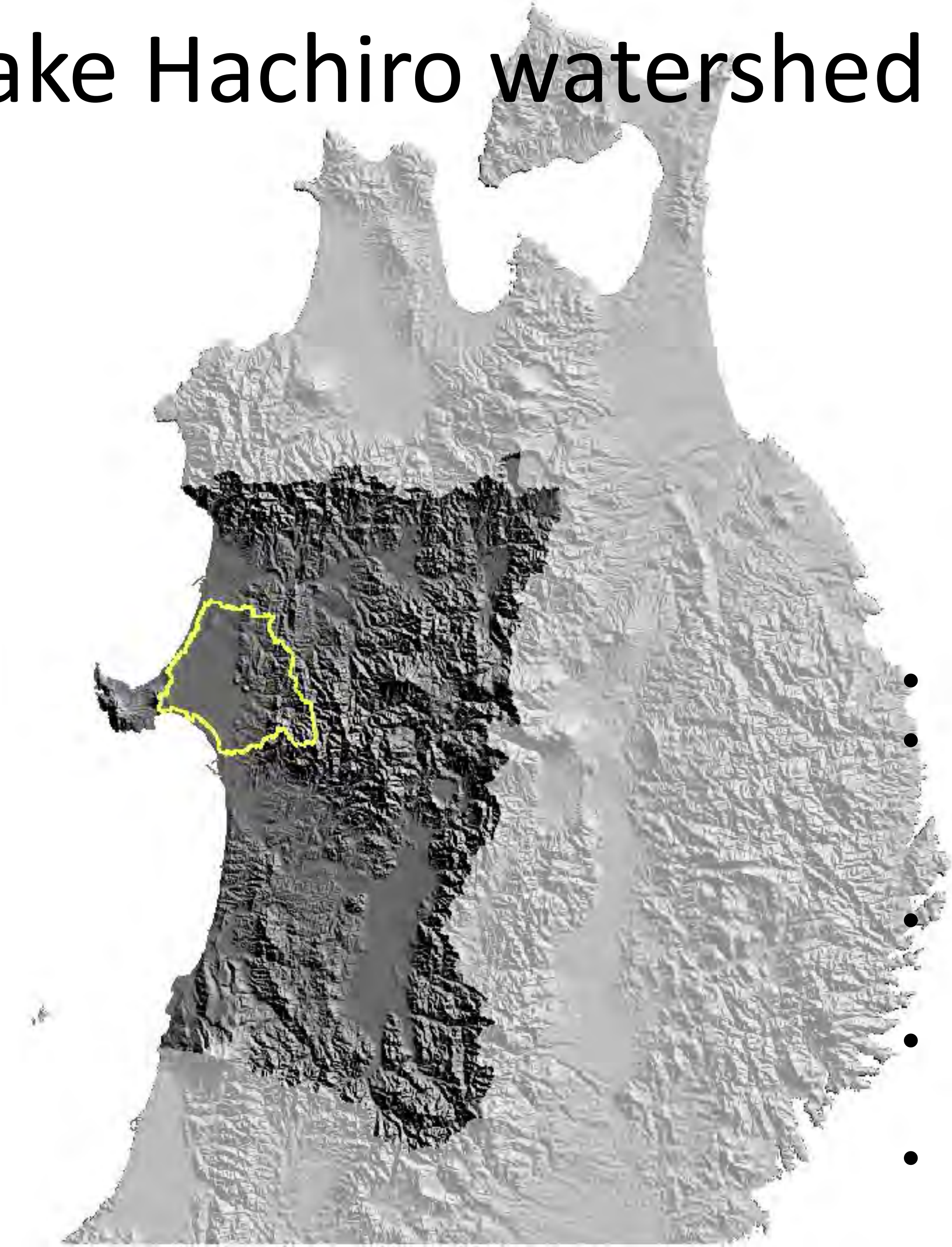
[soil property and soil function]

P can be released from Fe-P in anoxic condition [key soil process]



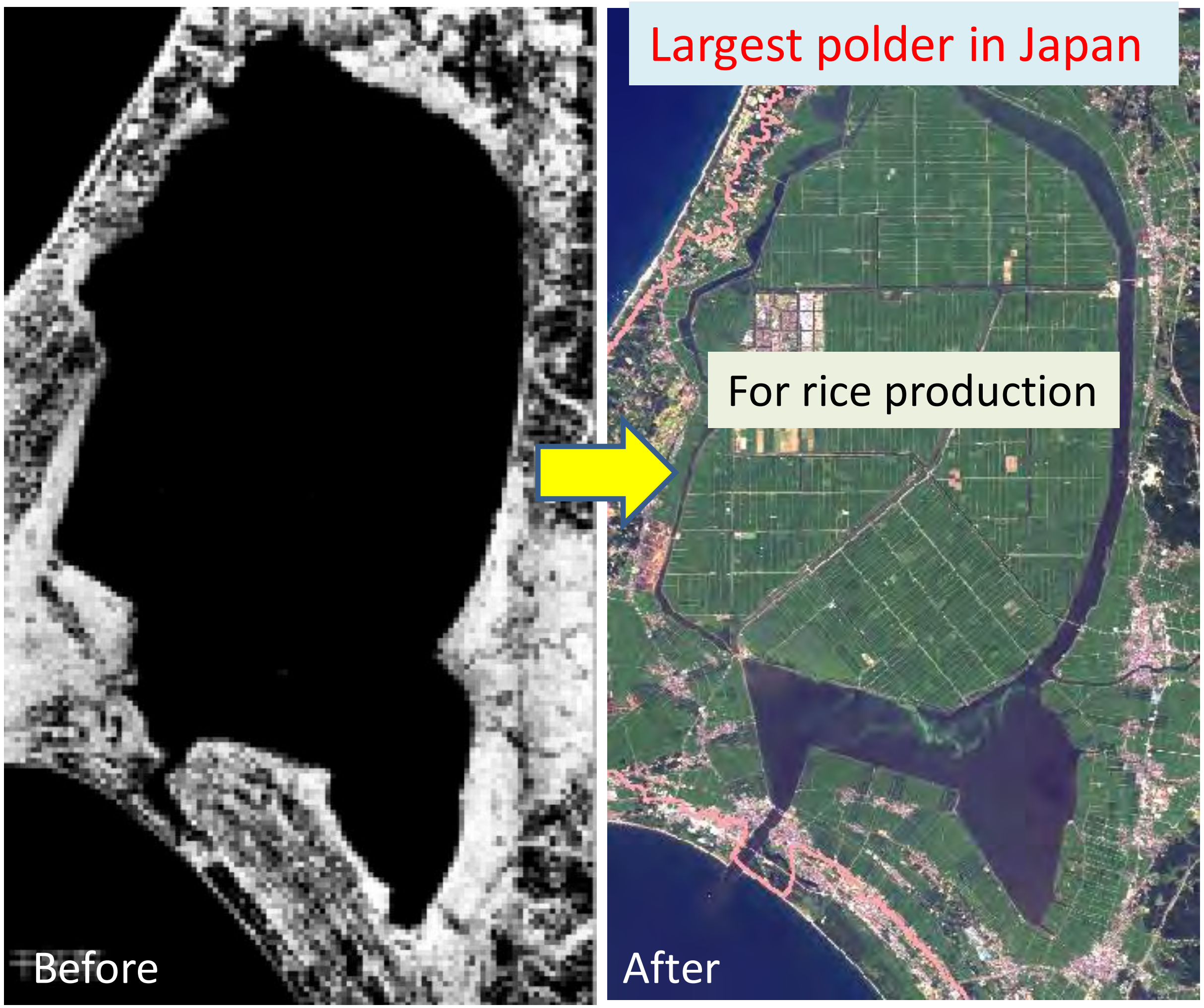
Al-P don’t release P even in anoxic condition.
Because Al don’t affect redox reaction.

Lake Hachiro watershed



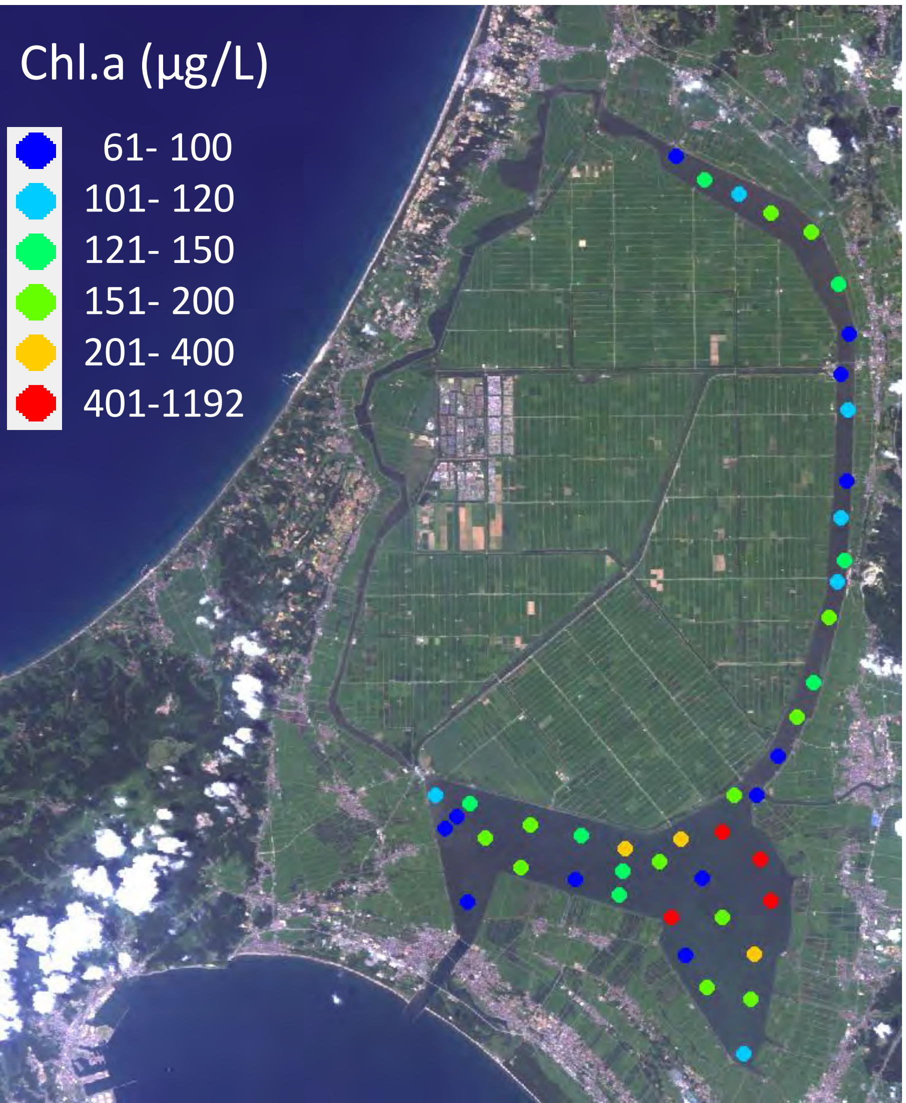
- Total Area: 904 km^2
- Lake area: 47 km^2
  - Water depth 3 m
  - Residence time : 30-40 days
- Topography
  - elevation -5 - 1030 m
- River
  - About 20
- Human
  - 80,000 (90 person/km^2)

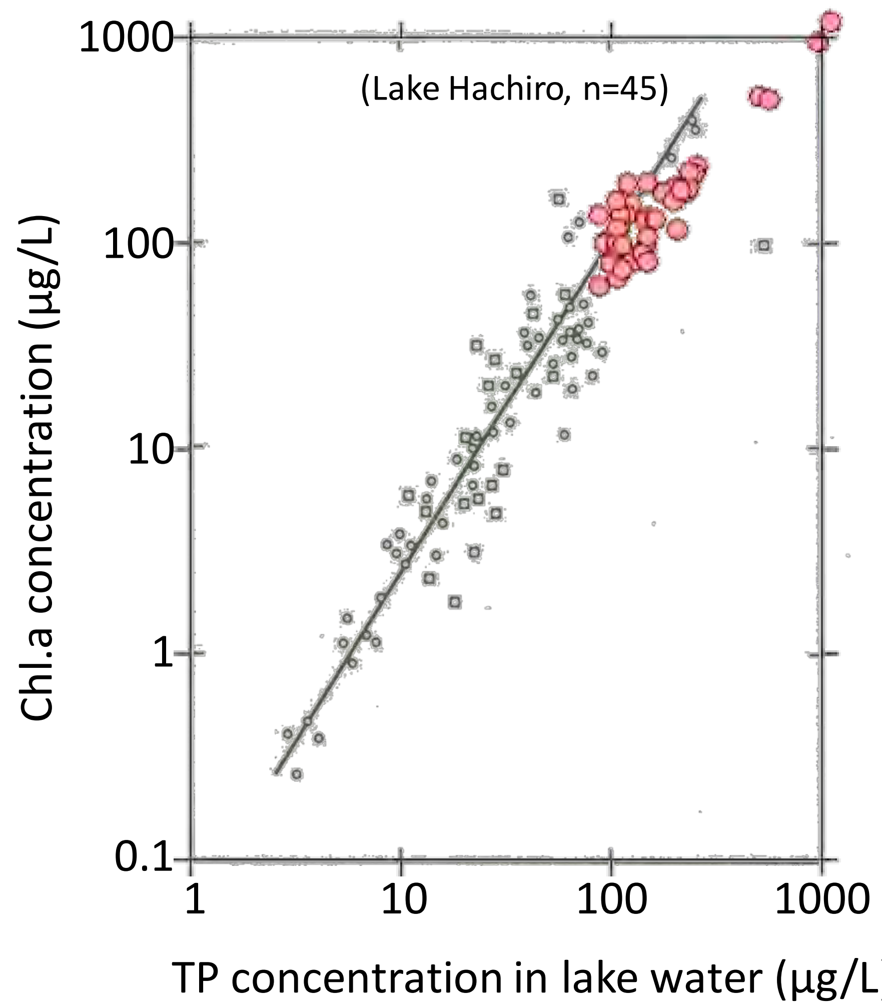
[landscape management] Land Reclamation



Hachirogata was once the second-largest lake in Japan, with a total area of 22,024 ha. However, a severe food shortage after World War II, the lake underwent extensive reclamation in 1966. About 80% of lagoon area changed to land after the big project.

Why is P concentration so high in Lake Hachiro?





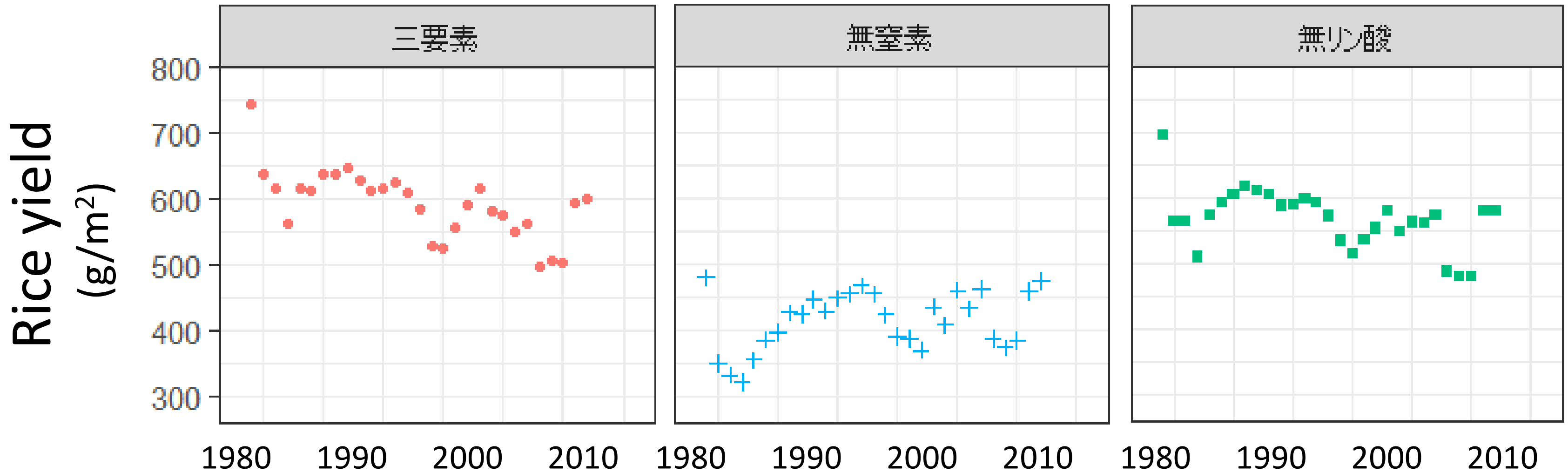
Horne and Goldman (1994) Limnology

[soil property & soil function & ecosystem service]

High yield of paddy rice with no P fertilizer in the soil.

Why? Soil function?

(+N, +P, +K) (-N, +P, +K) (+N, -P, +K)

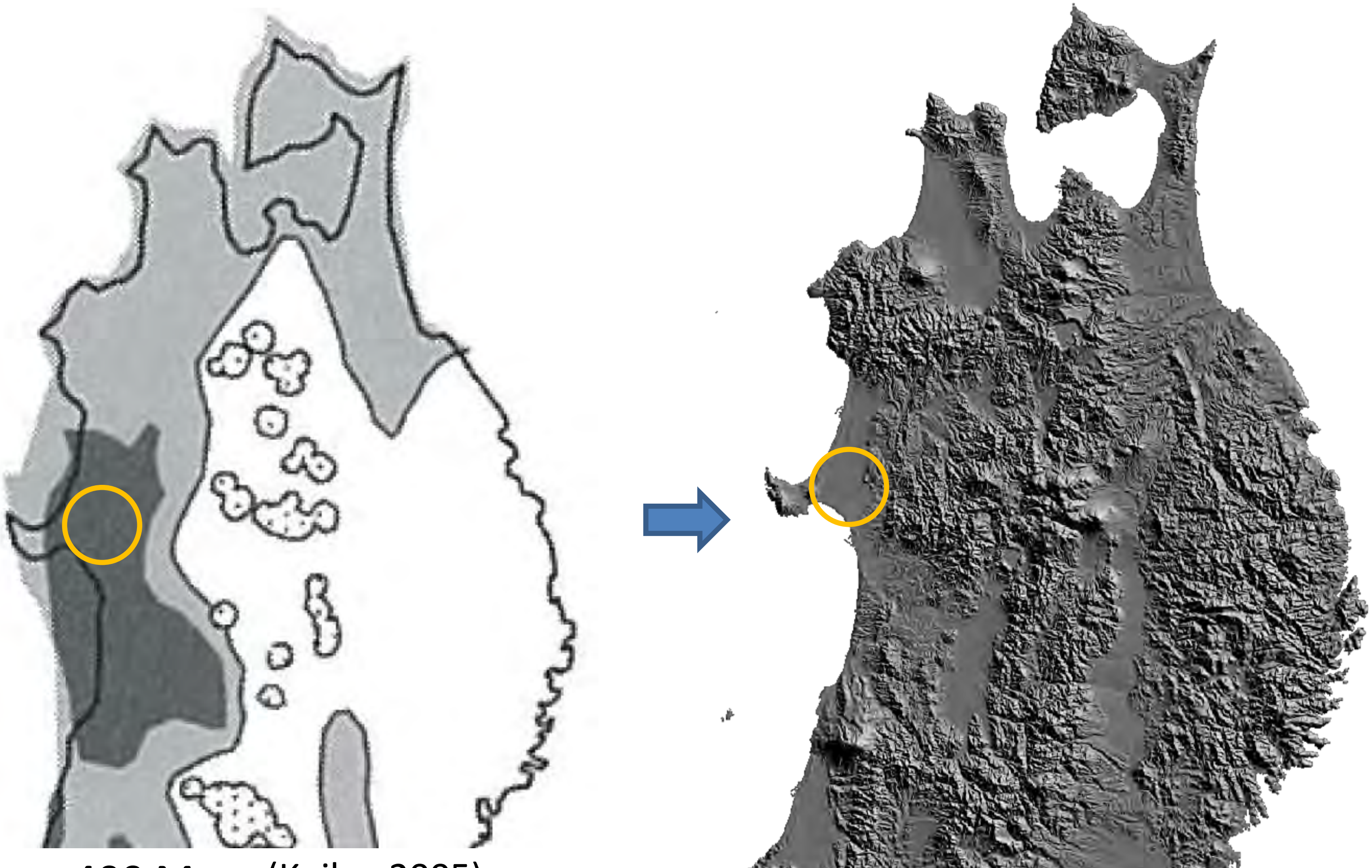


100% 71% 96%

Ito (2009)

Why is P so high in the Lake Hachiro watershed ?

Geo-history? → Natural resource? Soil function?



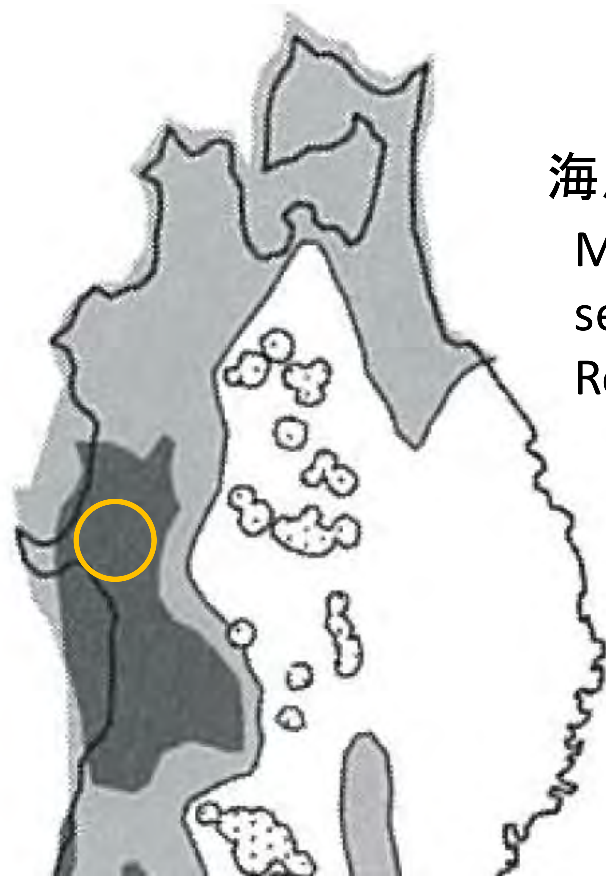
400 Ma (Koike, 2005)

Coastal Akita was submerged beneath the sea during the Neogene period

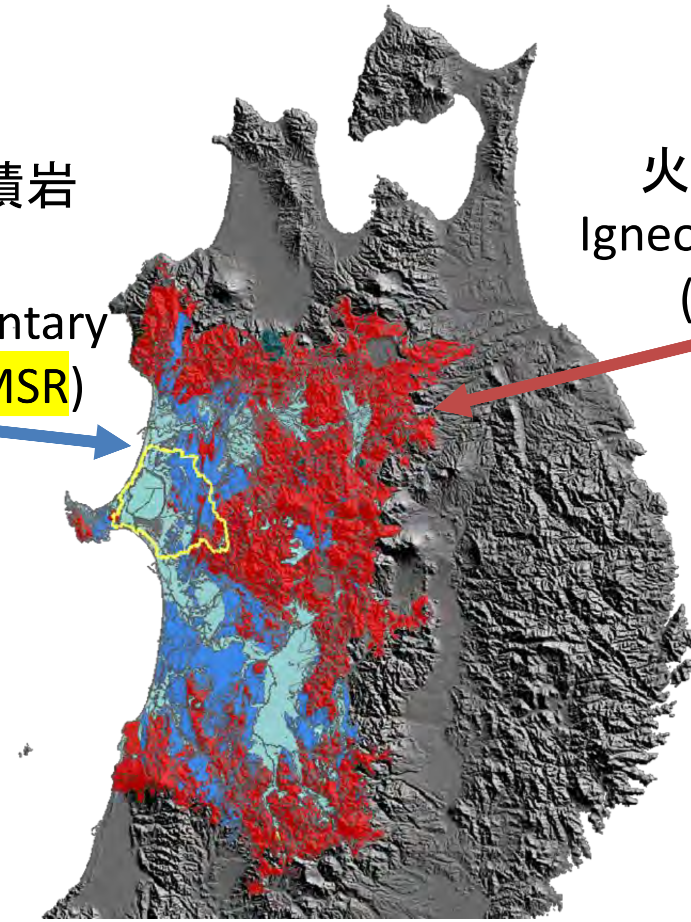
(Shiraishi and Matoba, 1992).

Why P is so high in the Lake Hachiro watershed ？

Geo-history? → Natural resource? Soil functions?



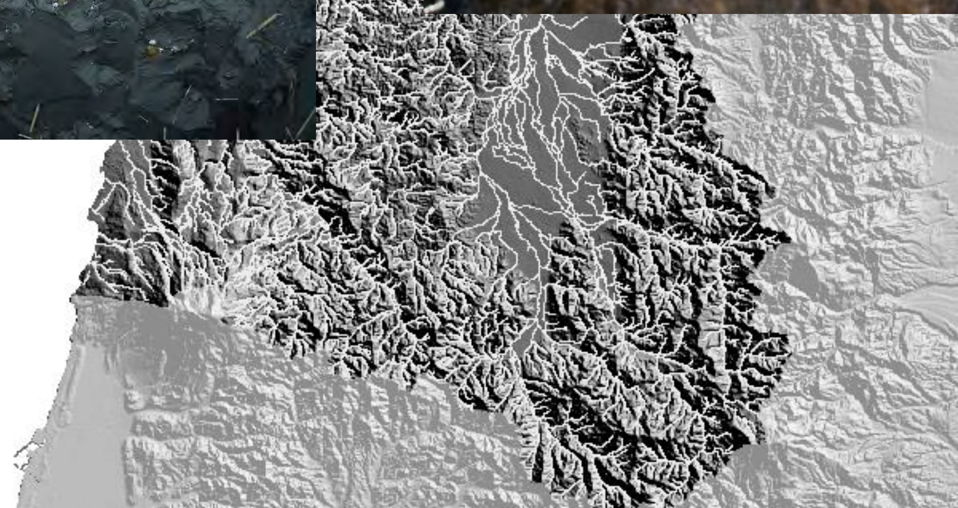
400 Ma (Koike, 2005)



Coastal Akita was submerged beneath the sea during the Neogene period (Shiraishi and Matoba, 1992).

[Landscape function]

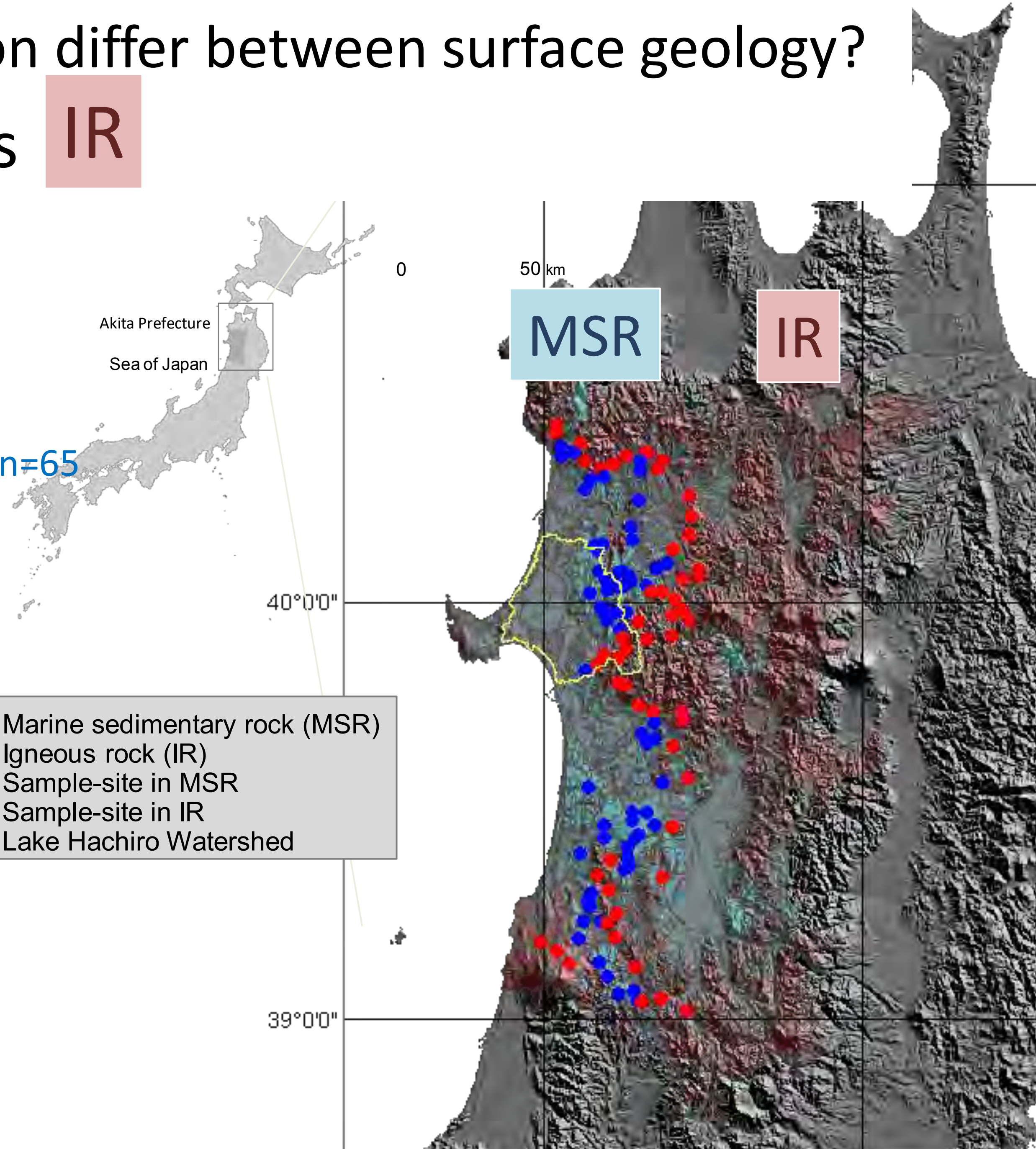
River connects land to sea and transports soil to down stream.



[Natural resource]

Stream P concentration differ between surface geology?

MSR vs IR



Catchment

- All forest catchments
- Marine sedimentary rock (MSR), n=65
- Igneous rock (IR), n=54

Geography and Topography

- Catchment size (p =0.572)
  - MSRs: 181 ha
  - IRs: 190 ha
- Elevation ($p < 0.01$)
  - MSRs: 176 m
  - IRs: 372 m

Climate

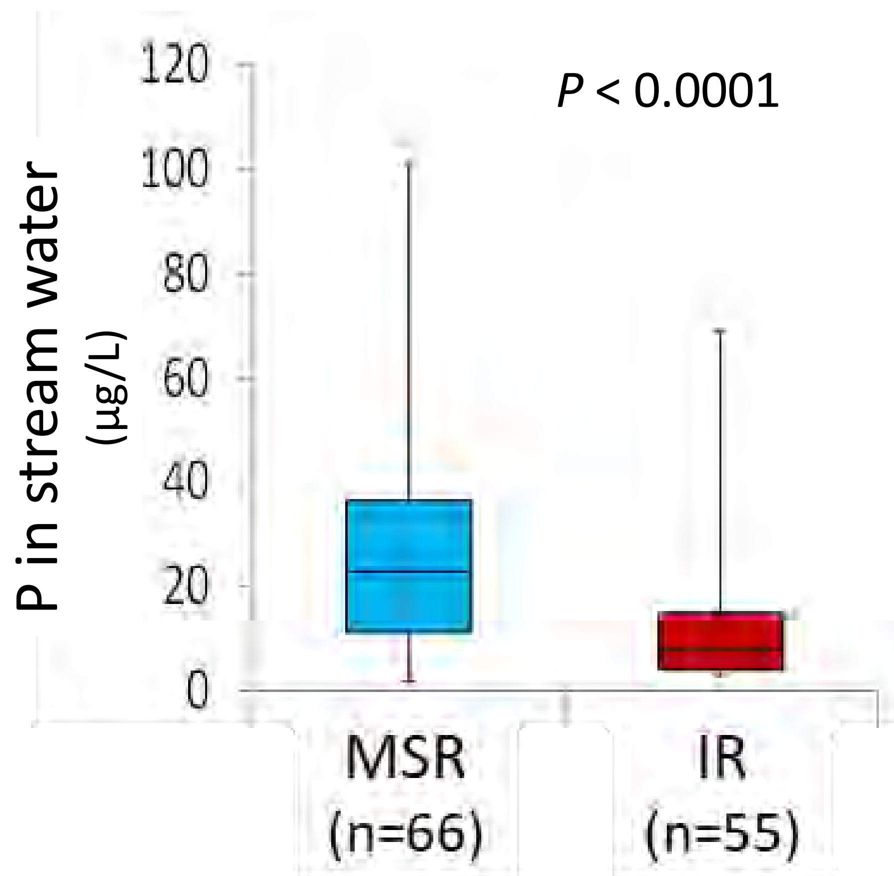
- Annual temp.: ca.11.7℃
- Precipitation: ca. 1700 mm

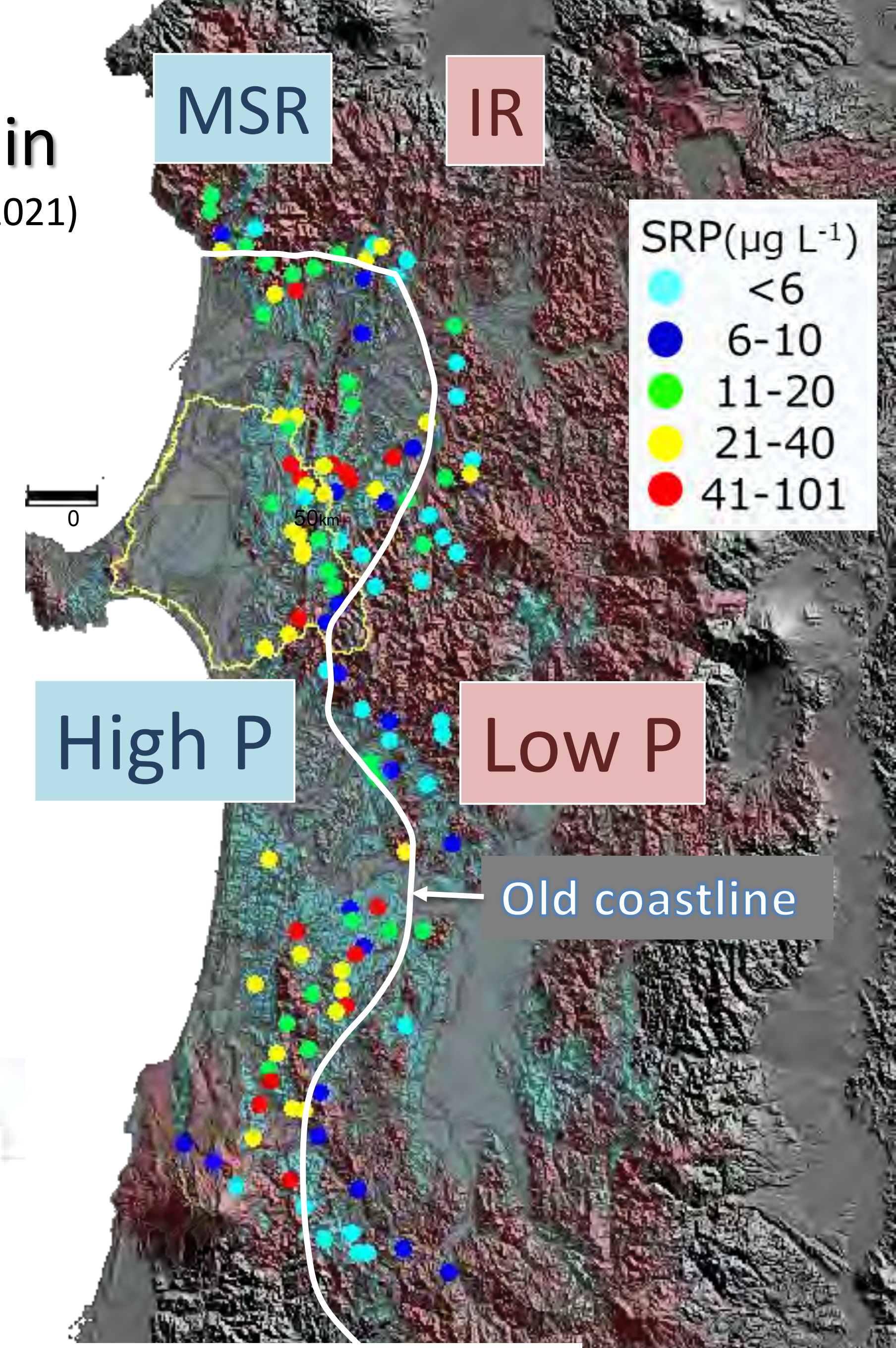

Natural stream
MSR vs IR
▪Sediment Fe_o, Al_o
▪Sediment P (Fe-P, Al-P)
< 2 mm

[Natural P resource]

P conc. in stream water is higher in MSR.

Hayakawa et al. (2021)

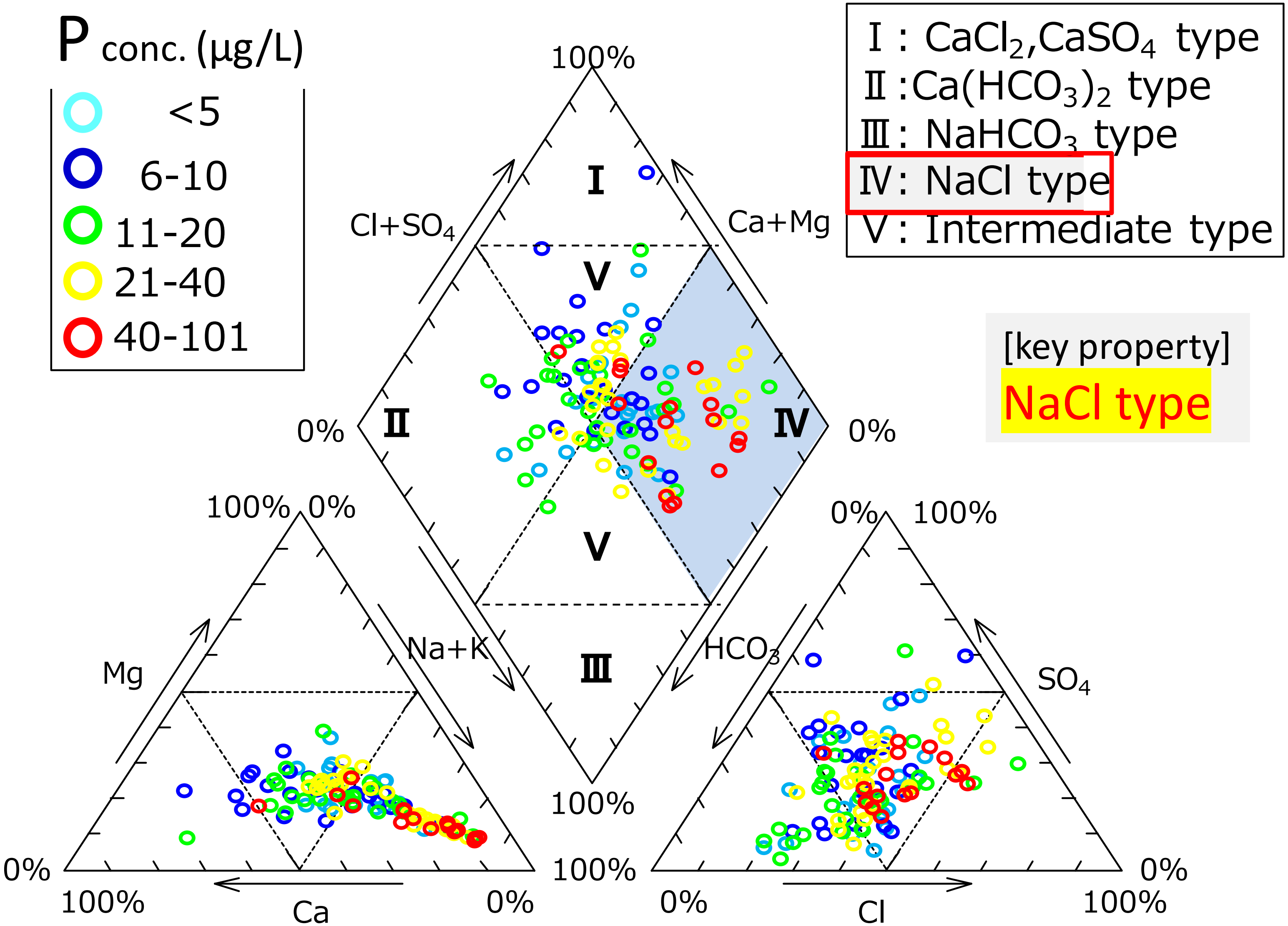




Stream P concentration in natural forested catchments in coastal Akita.

Water type in higher P conc. is "NaCl type"

Hayakawa et al. (2021)



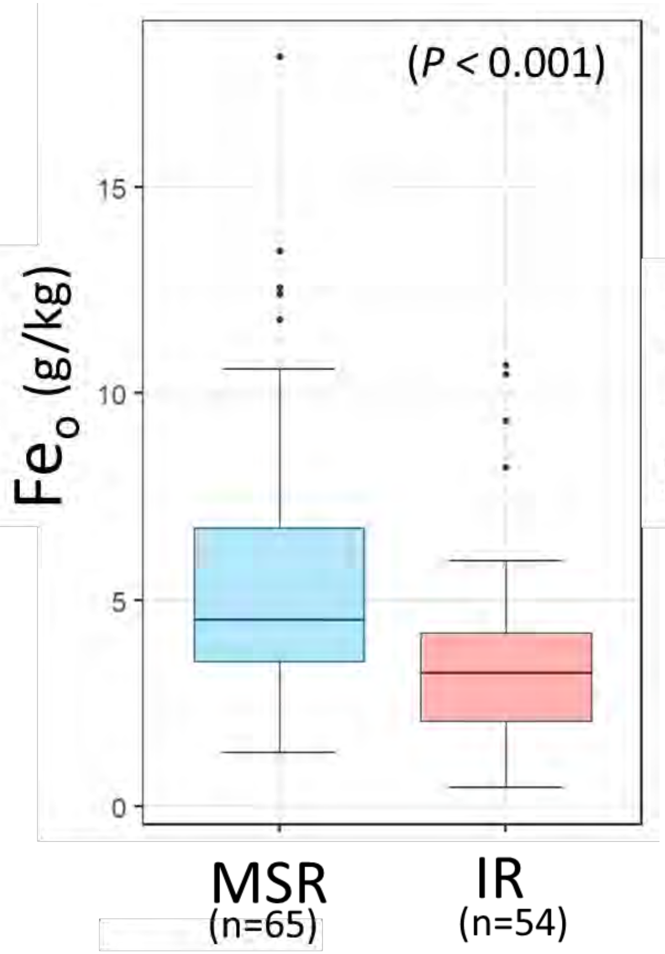
[key property]

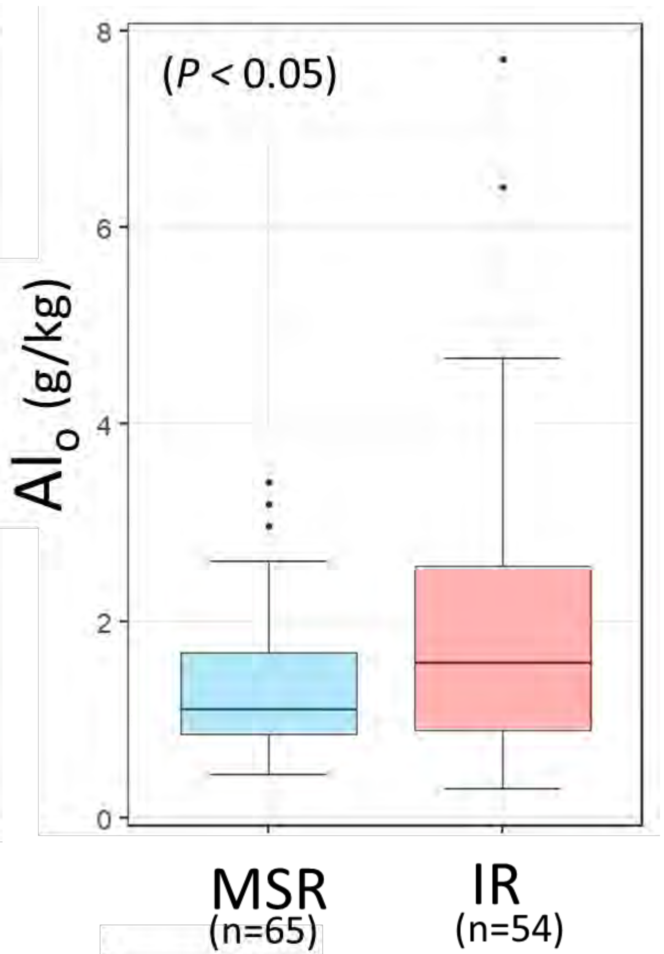
NaCl type

Classification of stream water quality by Piper diagram

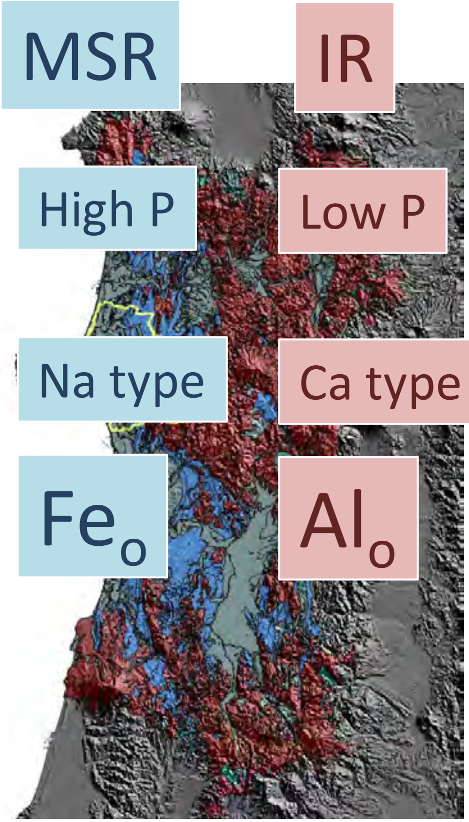
[Site specific soil property]

MSR has higher Fe_o. P retention process can be different between surface geology.





Fe_o and Al_o contents in streambed sediments

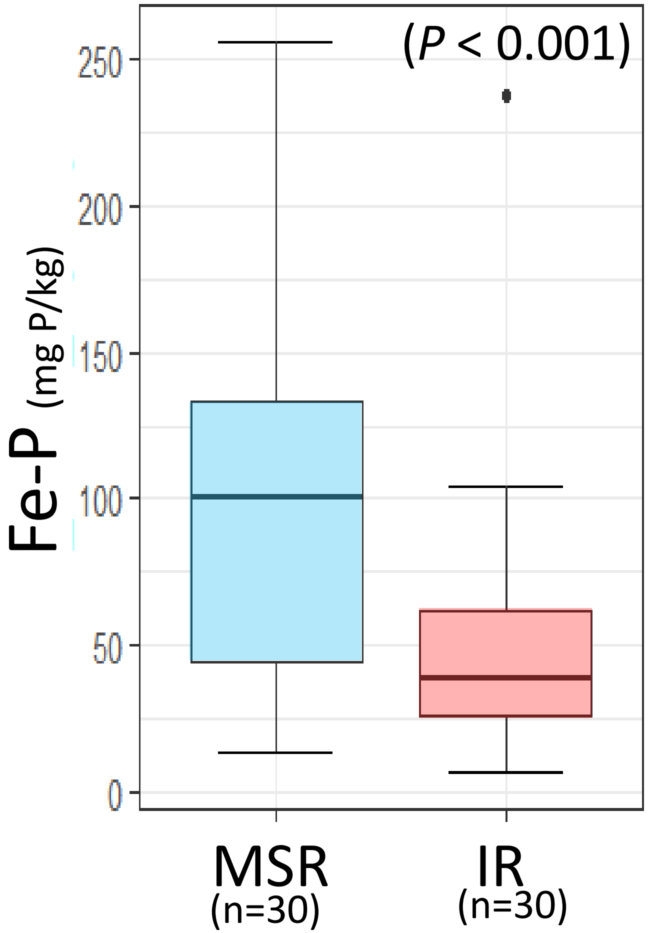


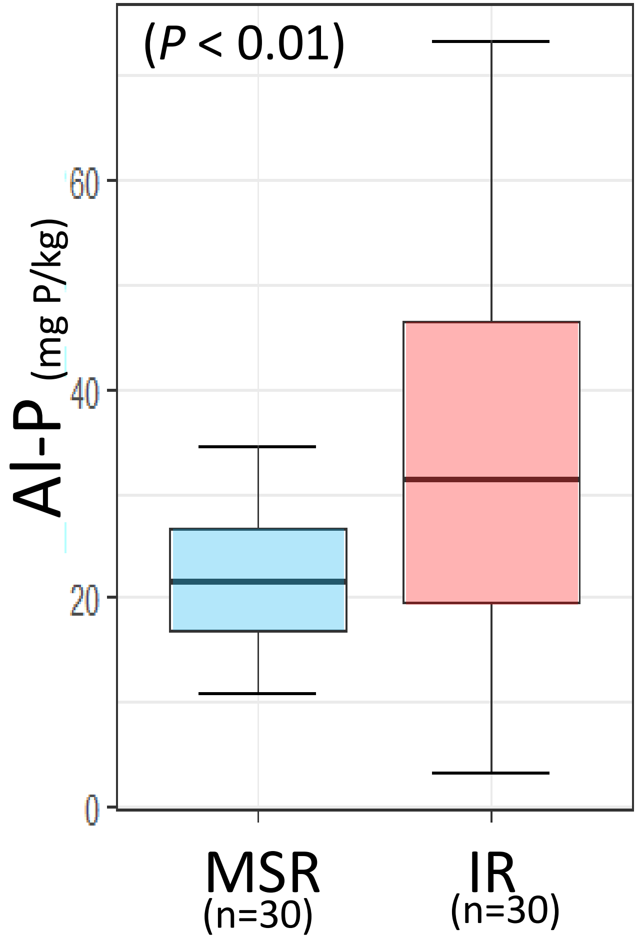
Streambed sediment

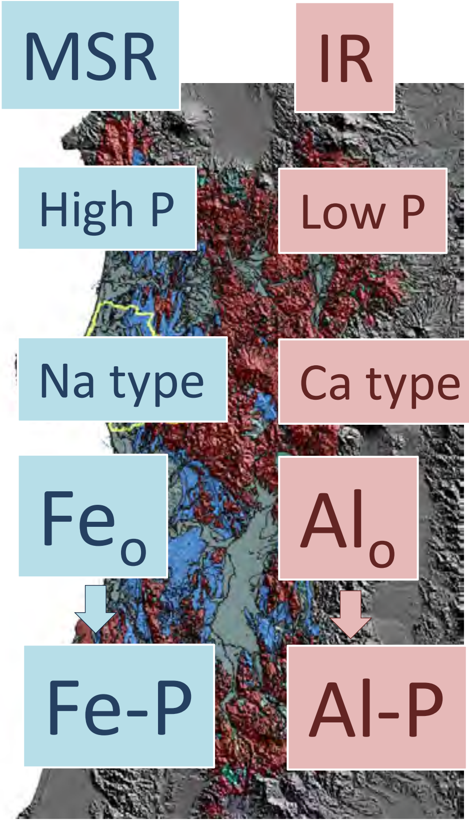
[Site specific soil property]

Fe-P is a main P fraction in MSR sediments

Likely controlled by Fe_o



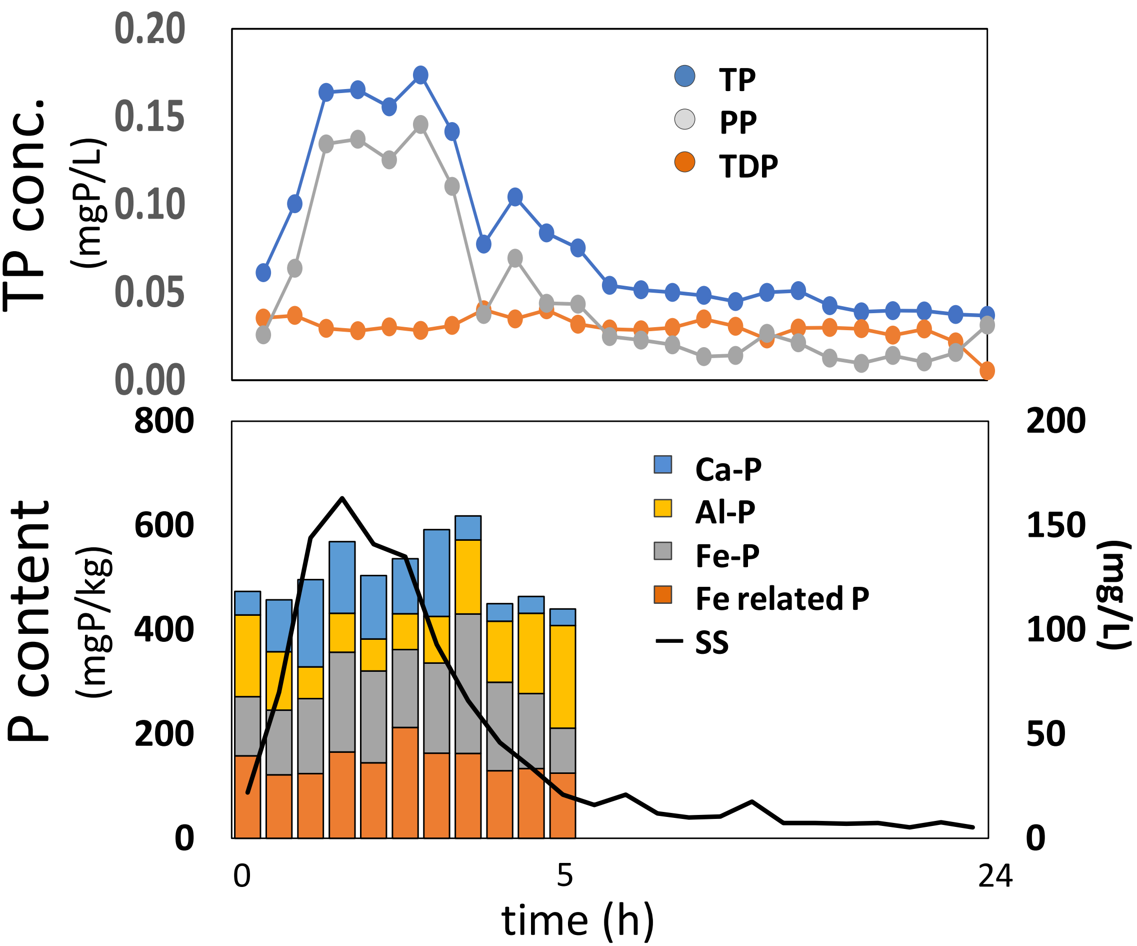


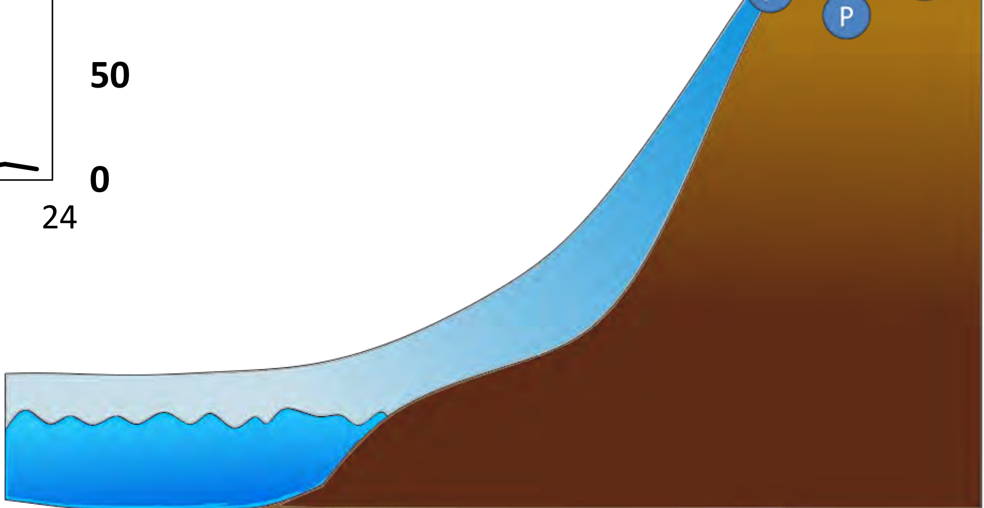


Streambed sediment

[landscape function]

During storm in MSR catchment, river transports soil with Fe-P to the down stream.



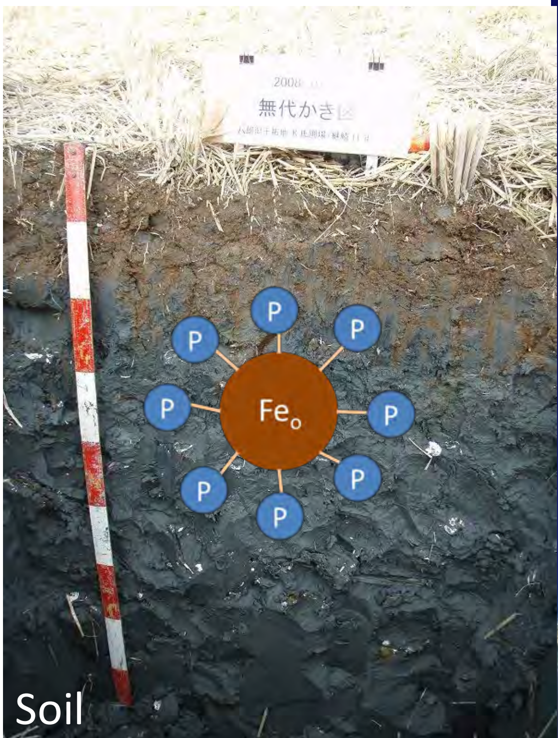


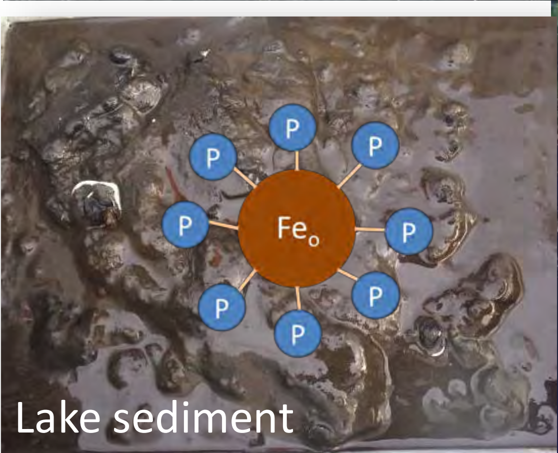
70% of TP is Fe-P

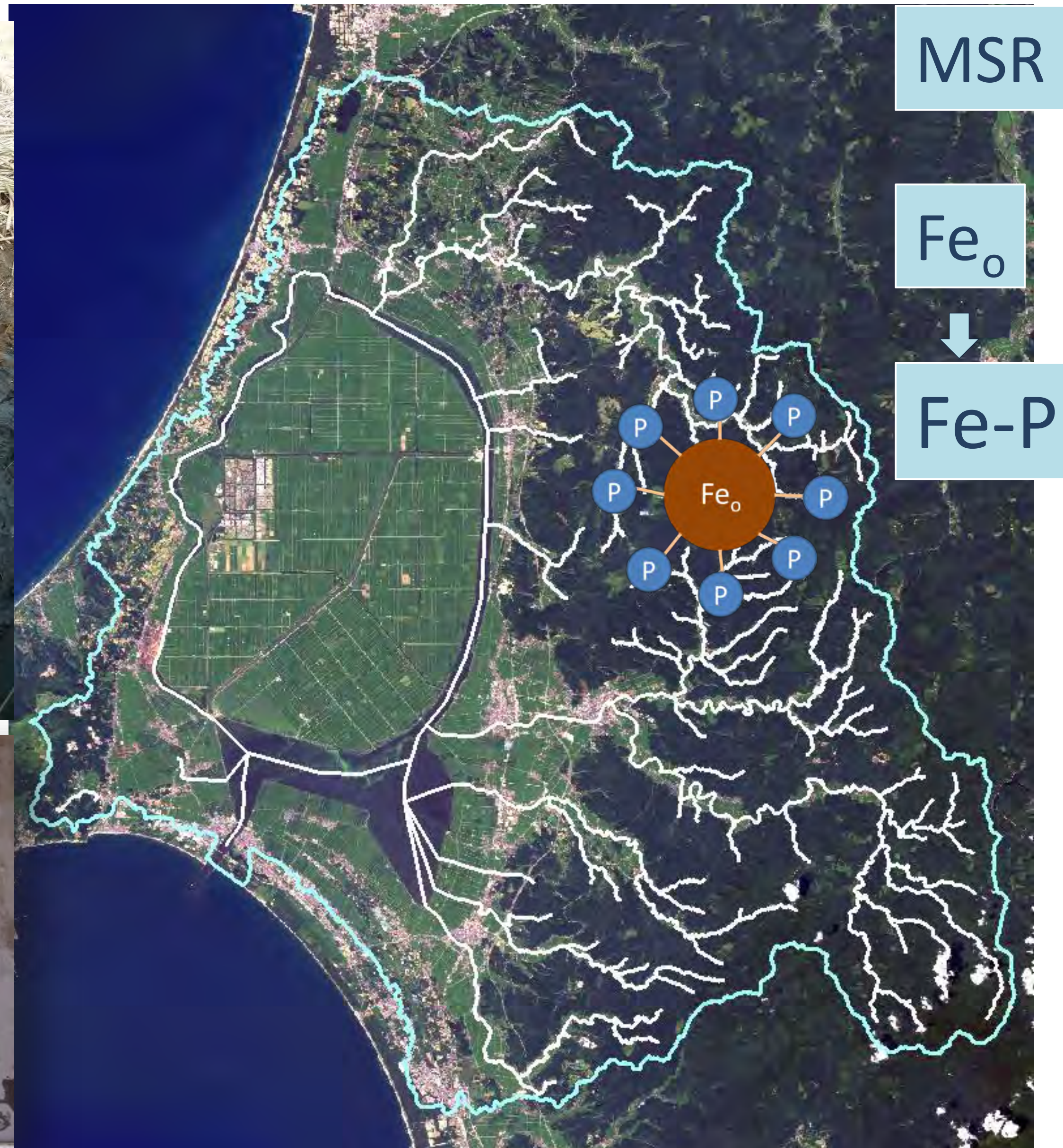
(Minato et al., 2020)

[landscape function]

The transported soil deposits in the alluvial plain and lake.

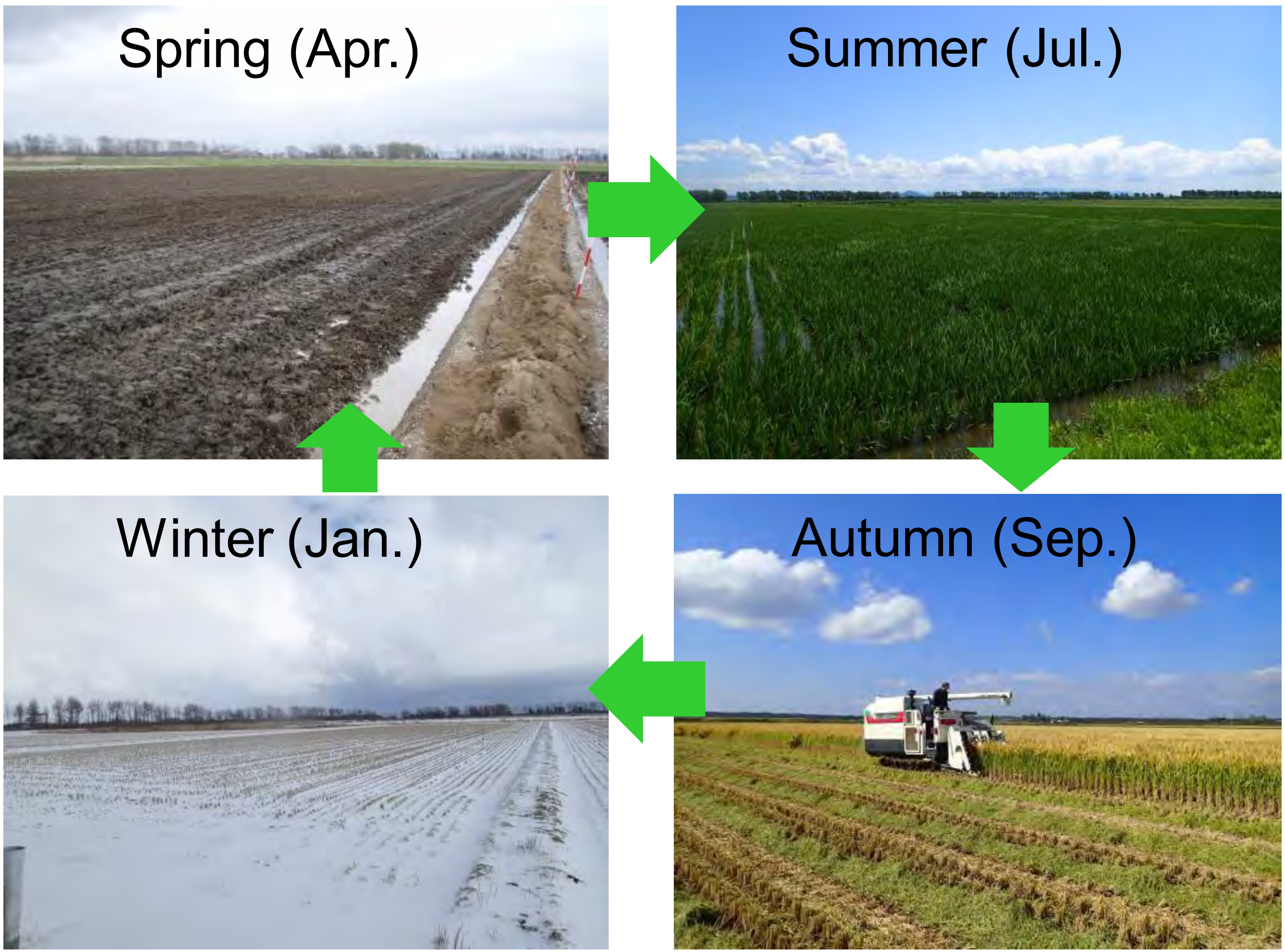






• Seasonal rice cultivation pattern in cool-temperate region

Single cropping for one year／1年1作



(photo: Takakai)

[Soil management]

Submerging & Paddling (May)／湛水と代かき

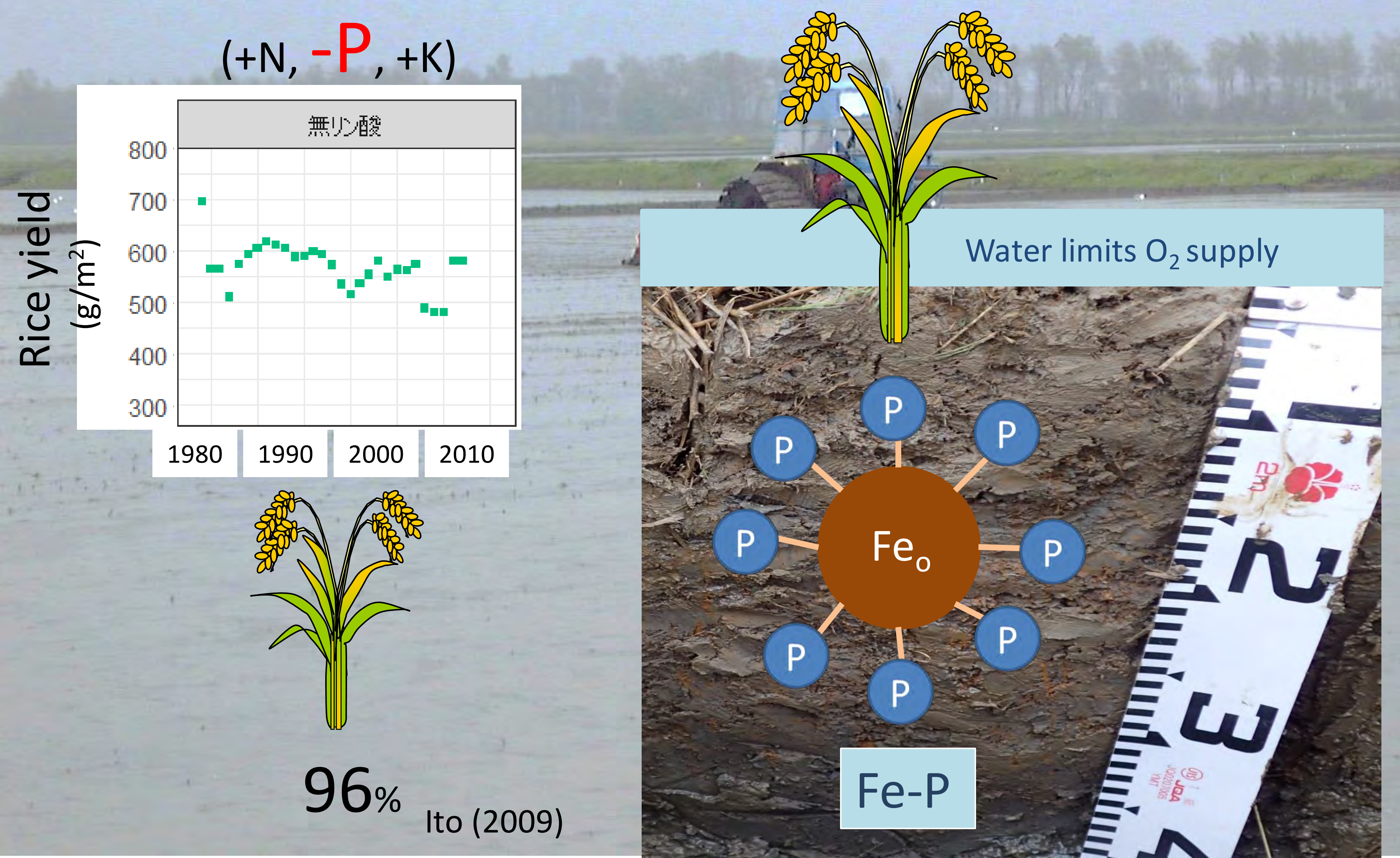
Wet tillage in paddy

[Object]

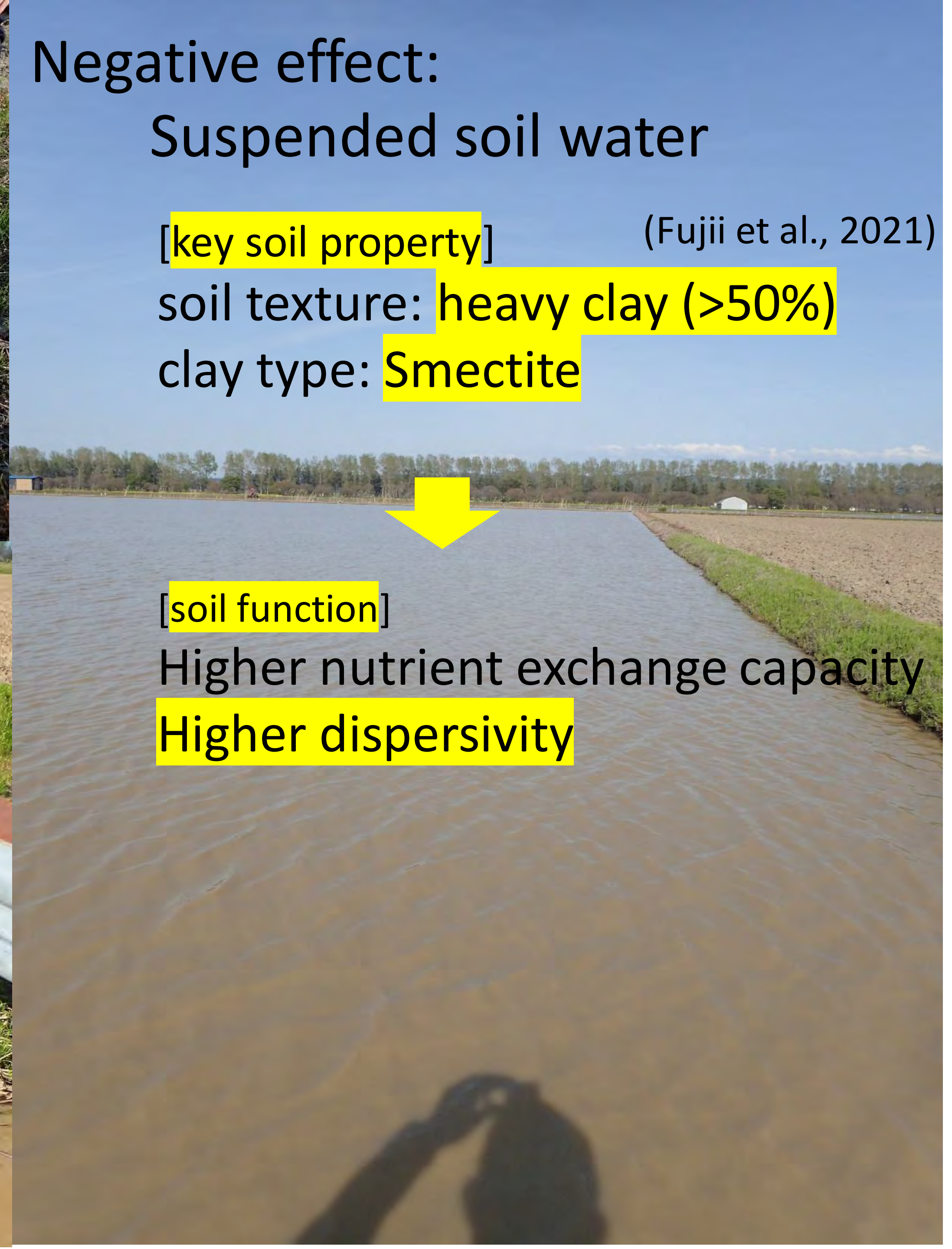
For flattening soil, planting, fertilizer mixing, water retention, weeding…

[soil management & soil function & ecosystem service]

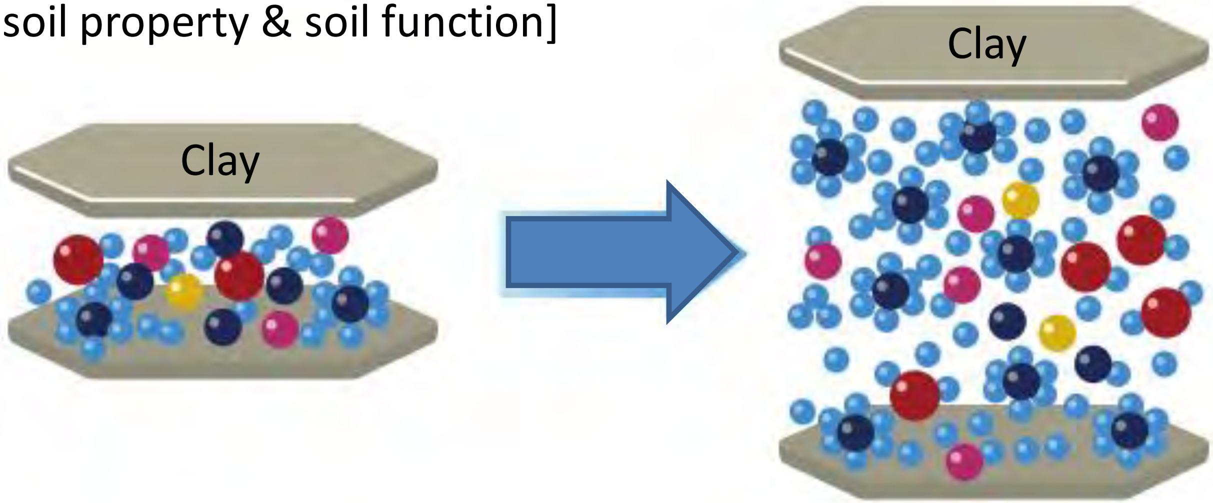
Surface water limits O_2 supply to soil, causing P release from Fe-P.




Drain before planting


Negative effect:
Suspended soil water
[key soil property] (Fujii et al., 2021)
soil texture: heavy clay (>50%)
clay type: Smectite
[soil function]
Higher nutrient exchange capacity
Higher dispersivity

[soil property & soil function]



Dispersivity of soil

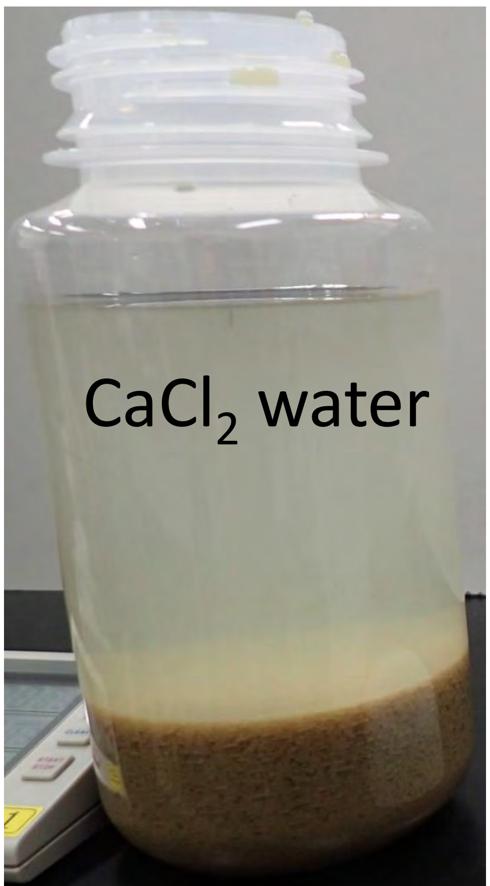
[Key properties]

Clay type: Smectite
Water type: NaCl

↓

Higher dispersion

$Na^{+} > K^{+} > Mg^{2+} > Ca^{2+} > Al^{3+}$



[Soil property & Soil management & Landscape function]

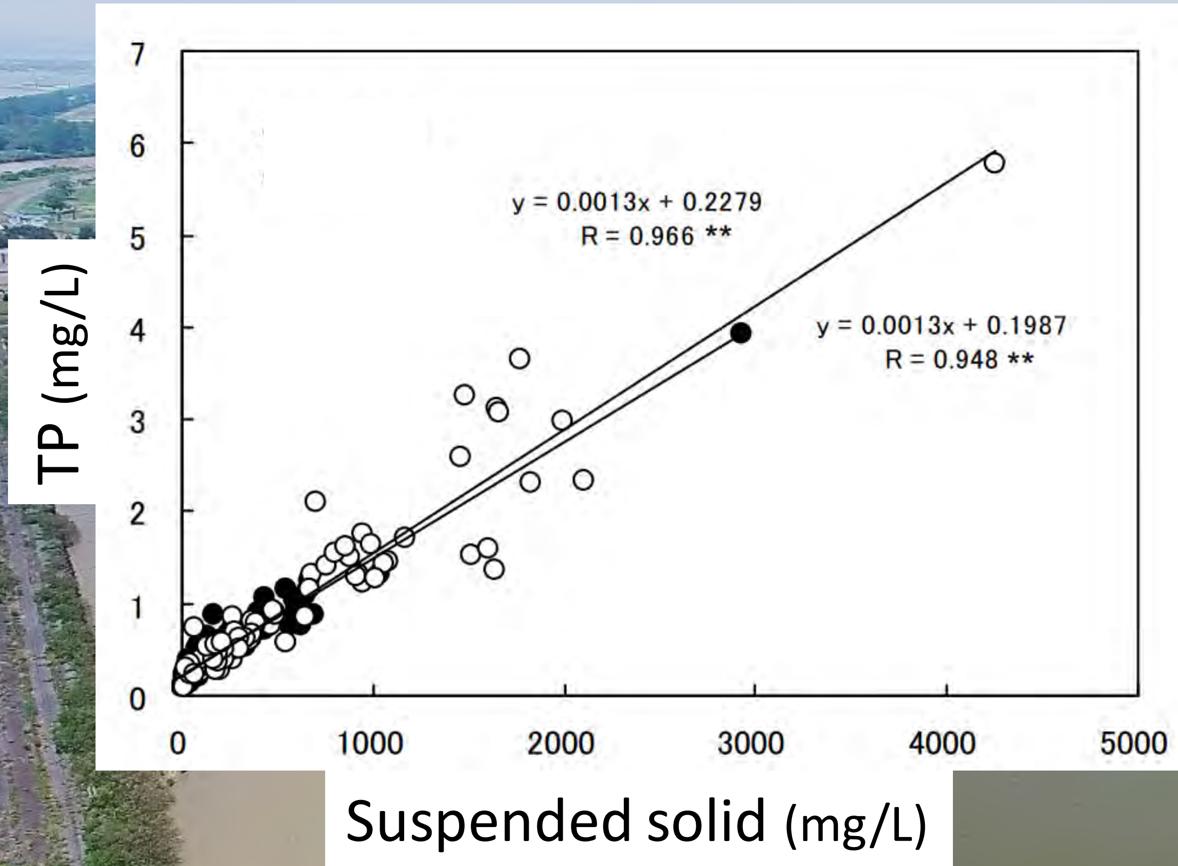
Drain water transports soil from paddy field to the lake

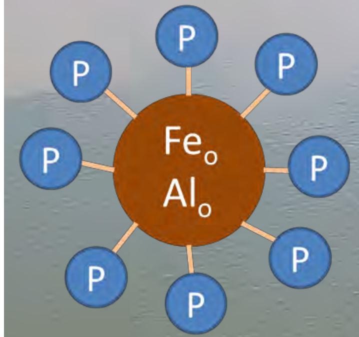
Loss of precious soil
もったいない
“MOTTAINAI”

→ Decrease P use efficiency

[Soil property & Soil management & Landscape function]

Suspended soil is accompanied with P

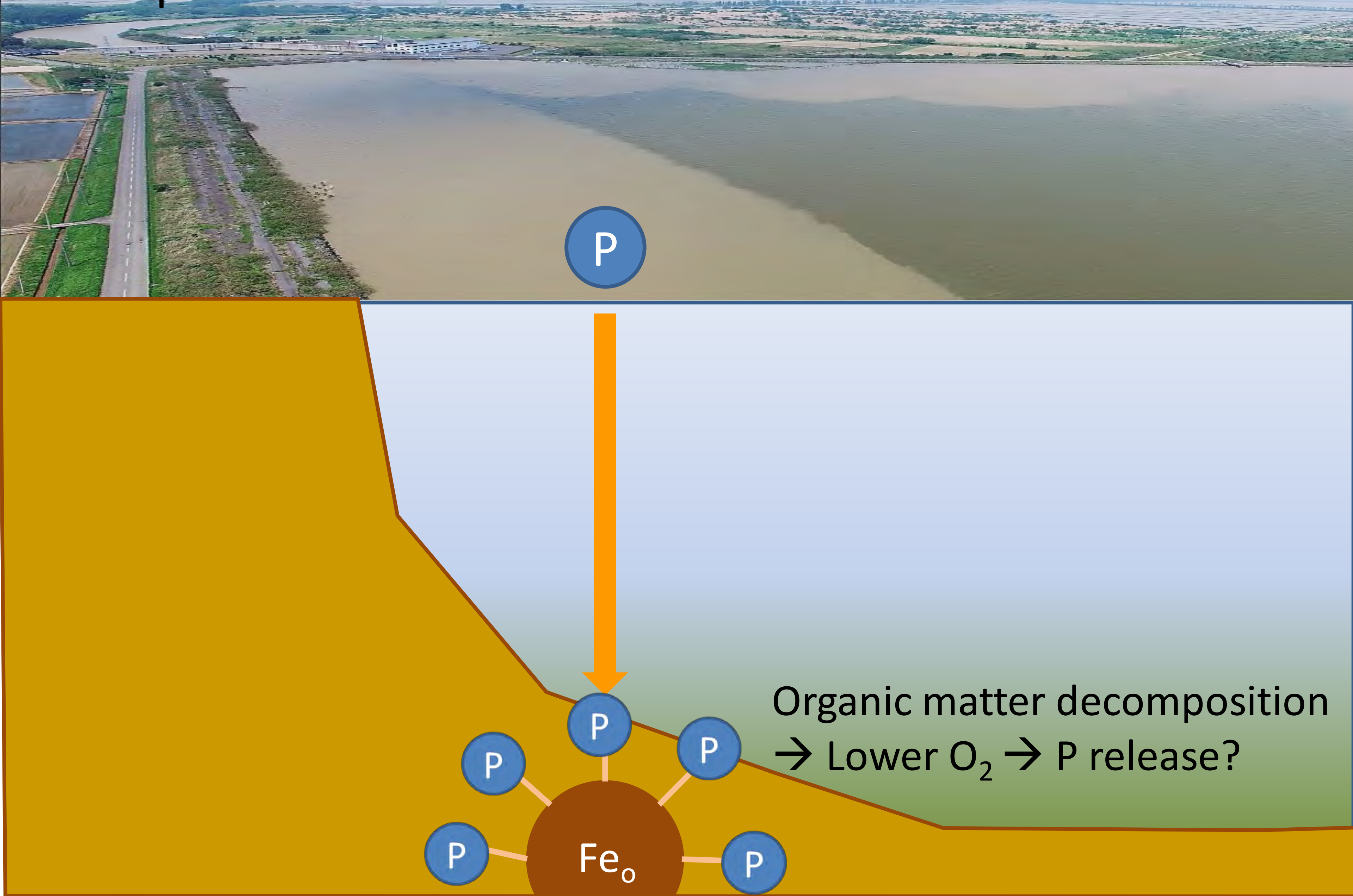




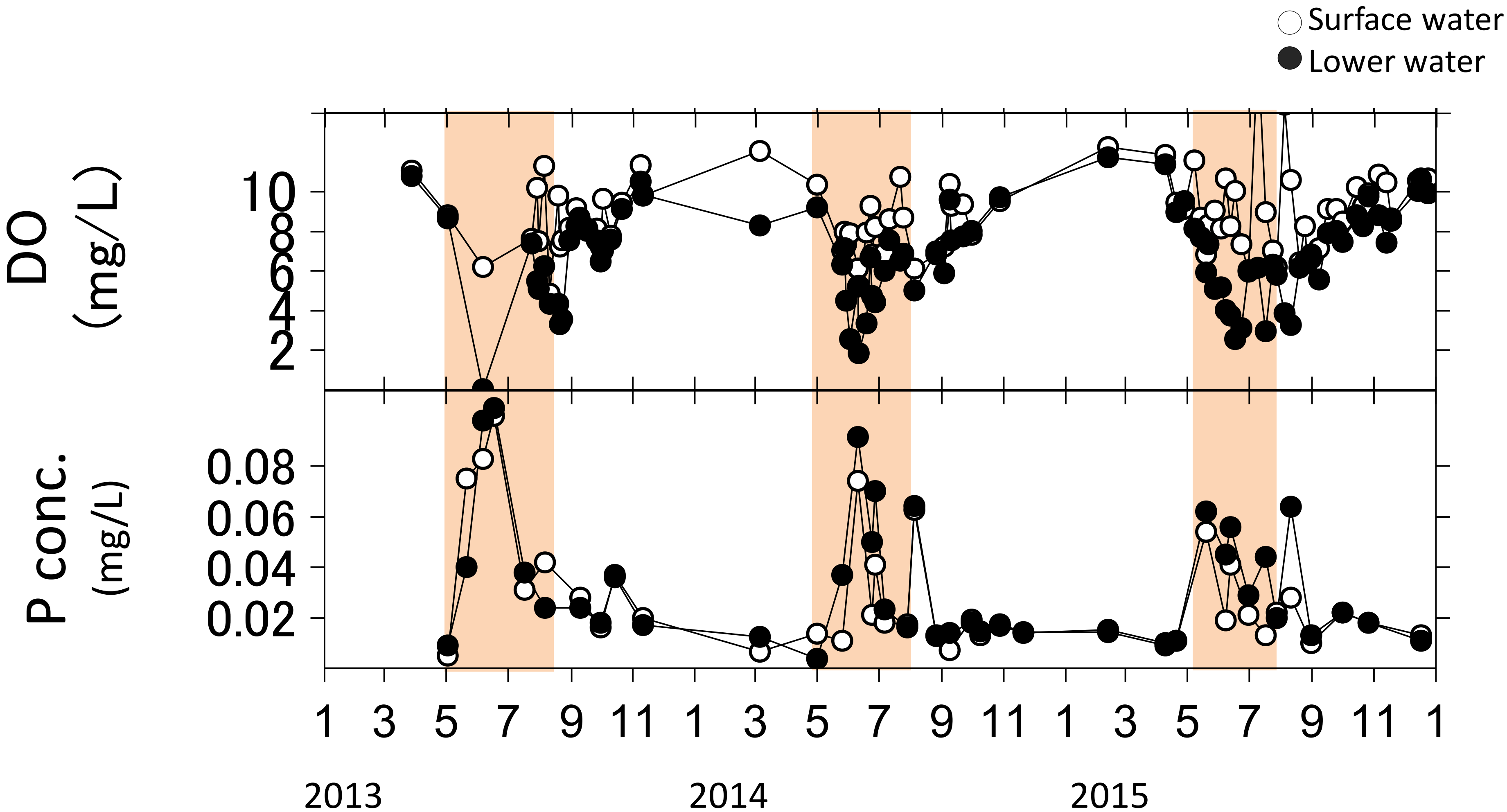
(Kaneta, 2006)

[Landscape function & soil function]

Soil deposits on the bottom of the lake and can release P



P conc. in the lake water increase during summer as dissolved O_2 (DO) decrease.



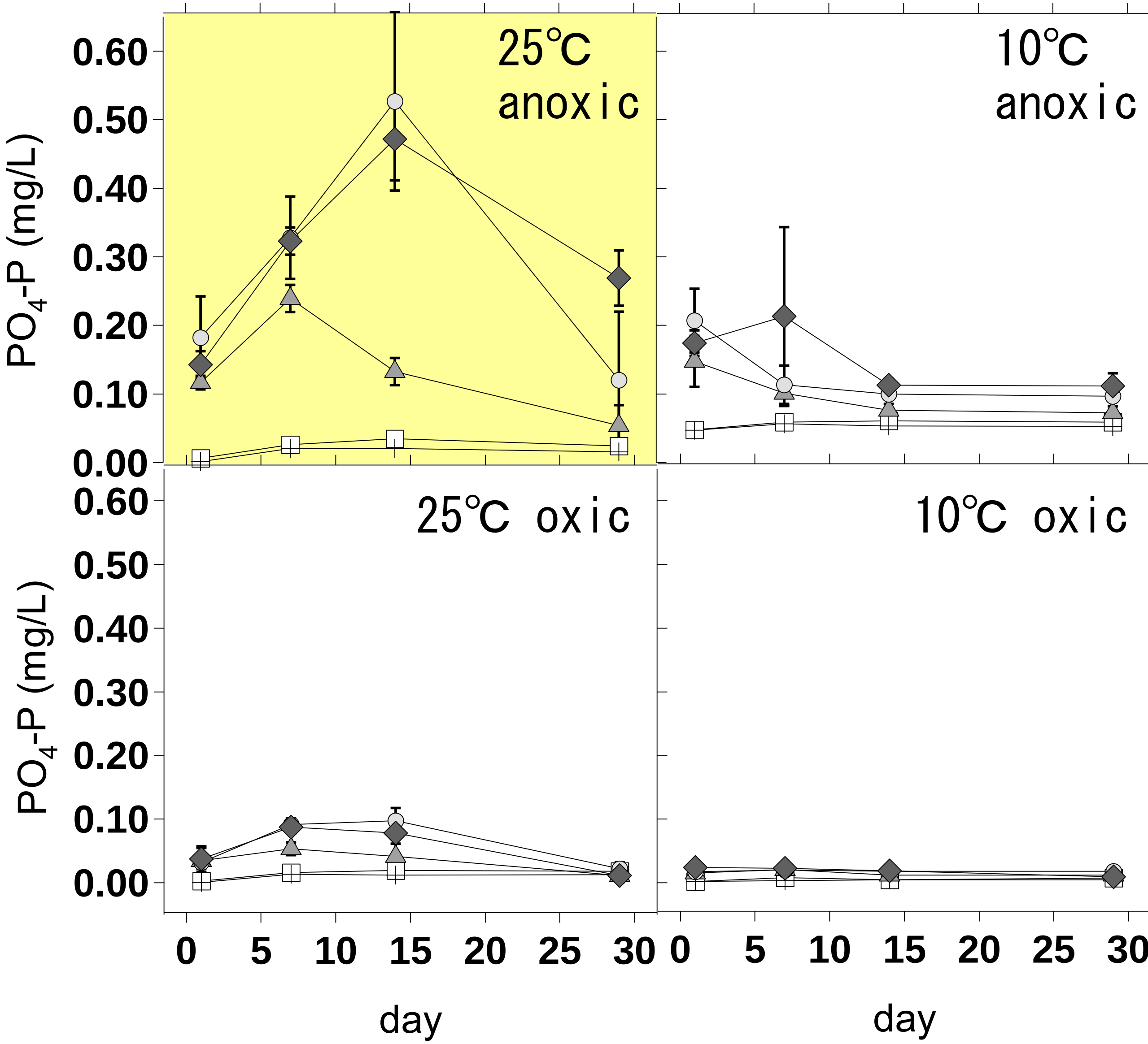
(Hayakawa et al., 2016)

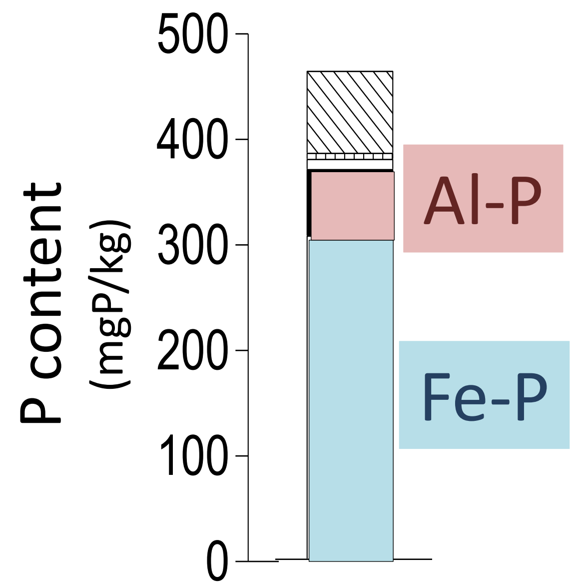
[Soil function]

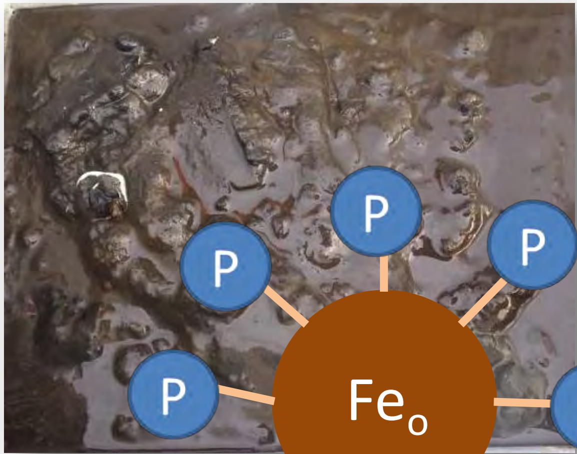
P is released at 25℃ in anoxic condition

especially from sediment with higher Fe-P content.

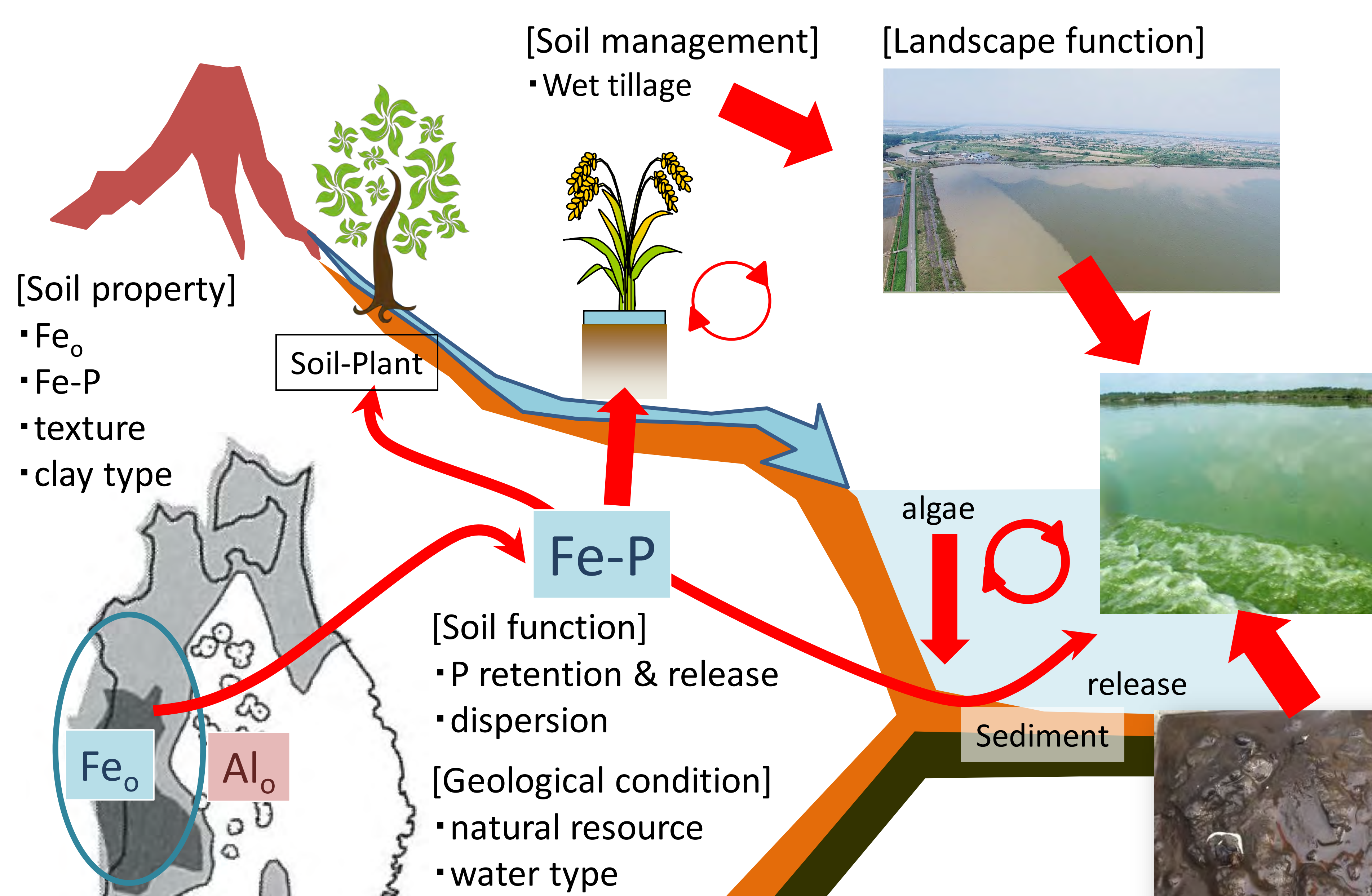
(Hayakawa et al., 2015)



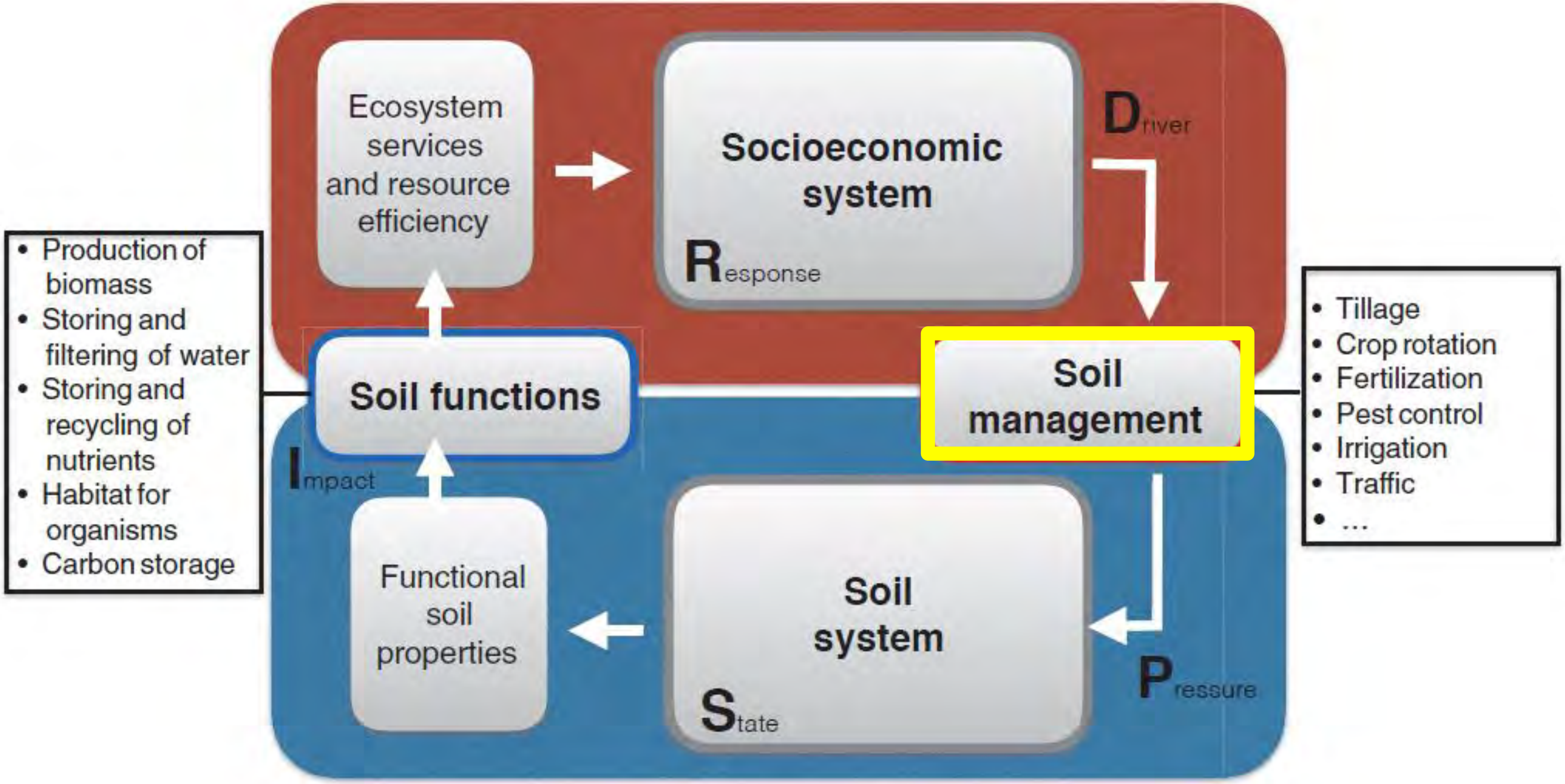




[Brief summary] Site-specific soil properties & functions and their controls of biogeochemical P cycles in coastal Akita



How can we manage soil and P?

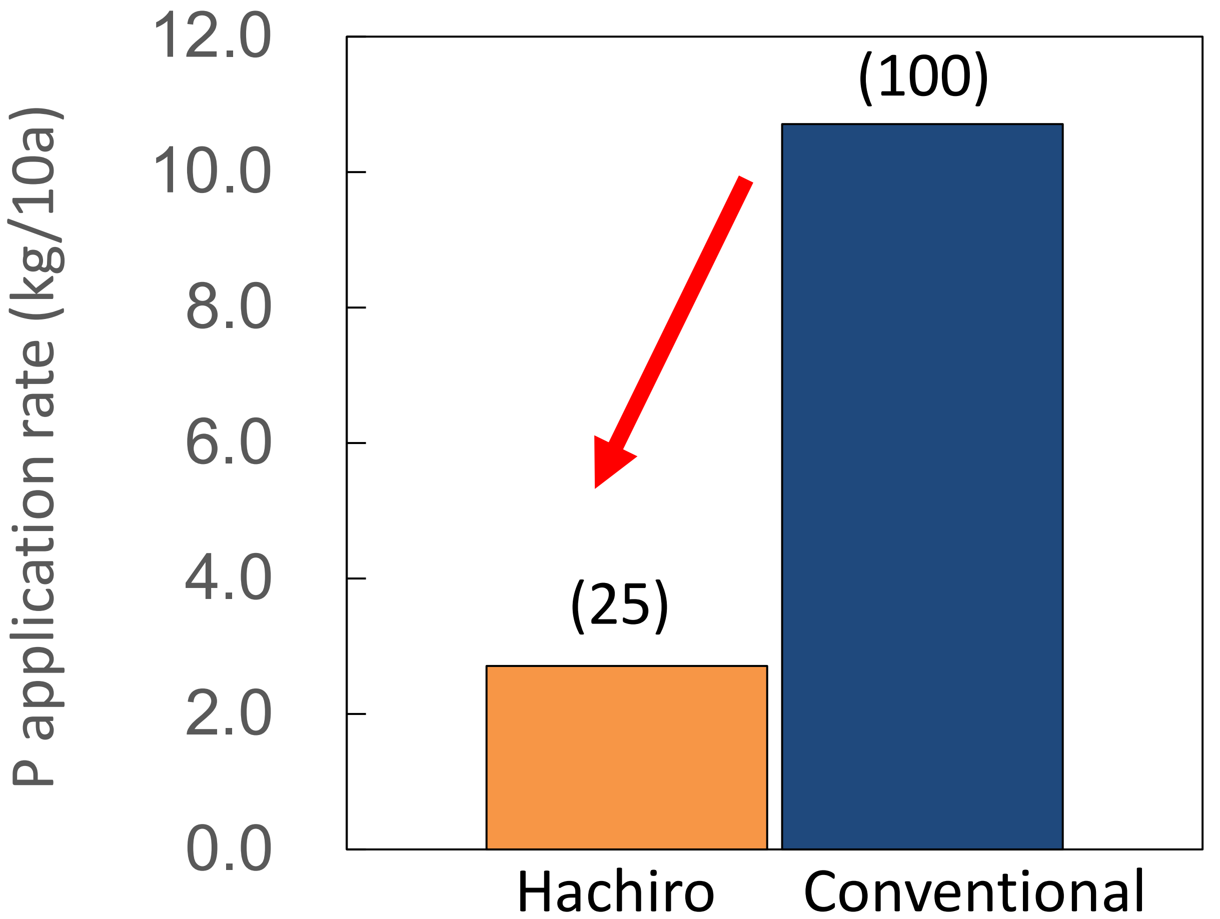


(Vogel et al., 2018)

[Soil management]

Reducing P fertilizer input based on the soil function.

→ Increase P use efficiency

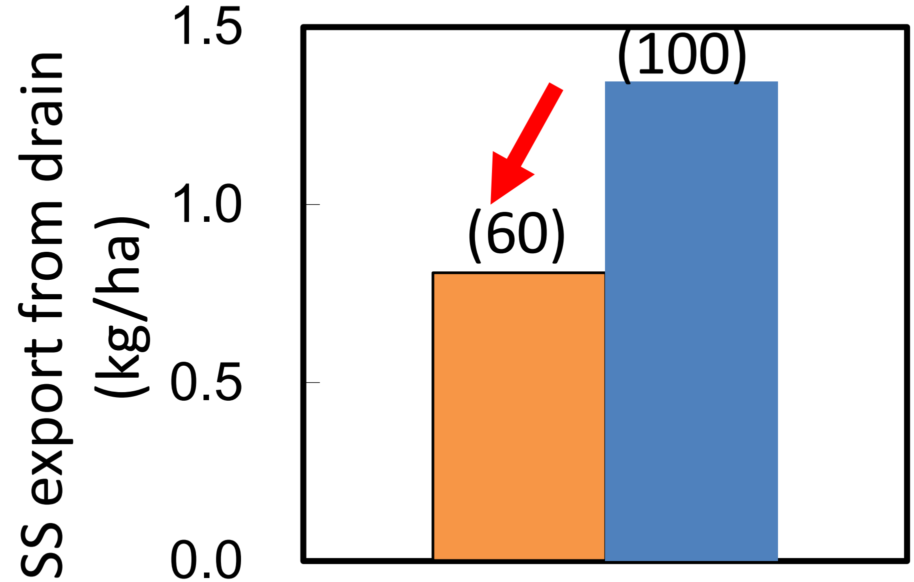


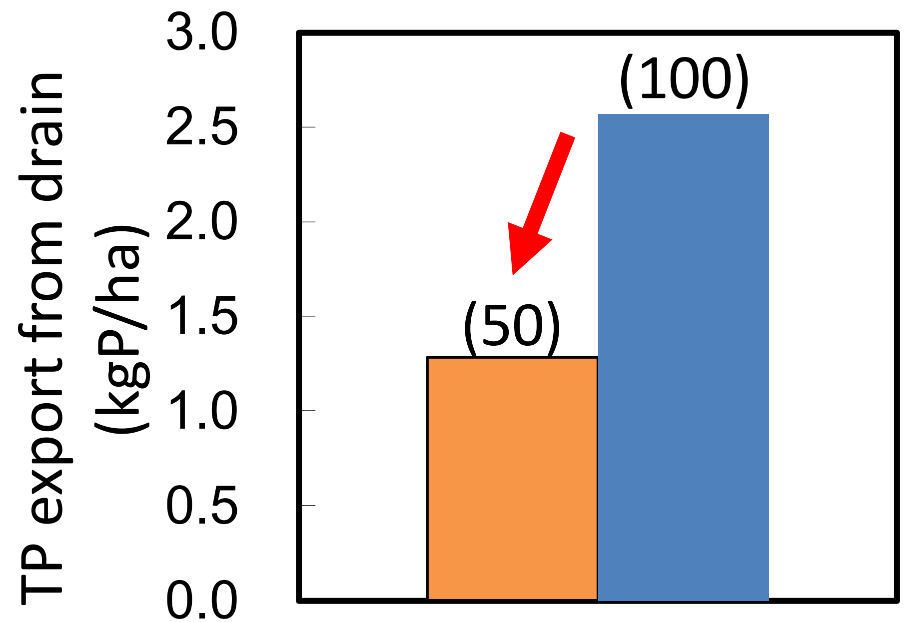
Reduced fertilizer brings not only economical benefits to farmer but a reduction of environmental pressure.

(Ogata village, 2006)

[Soil management]

No-paddling can decrease soil dispersion and P export.





(Kaneta et al., 2007)

[Soil management]

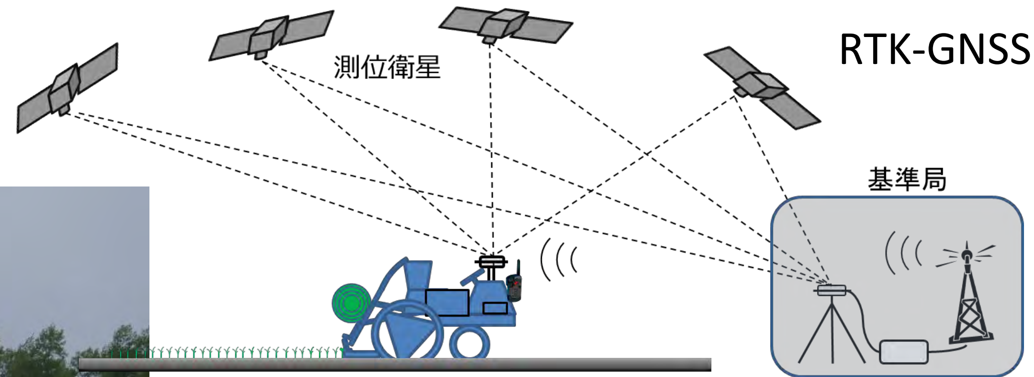
No-paddling management needs new equipments (high cost).

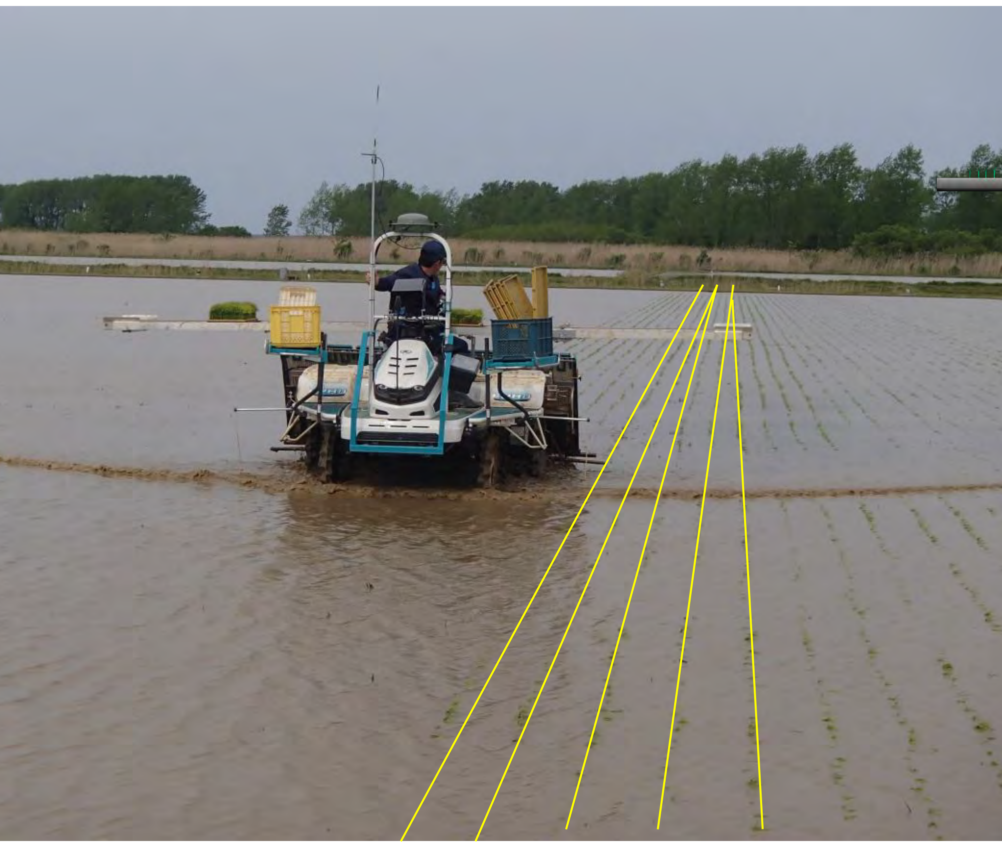
It has little effect on rice yield (same as conventional).
But, there are few benefits for farmers.

4.2% of paddy area (Akita Prefecture, 2021)

[Future management]

No-drain planting by smart agriculture



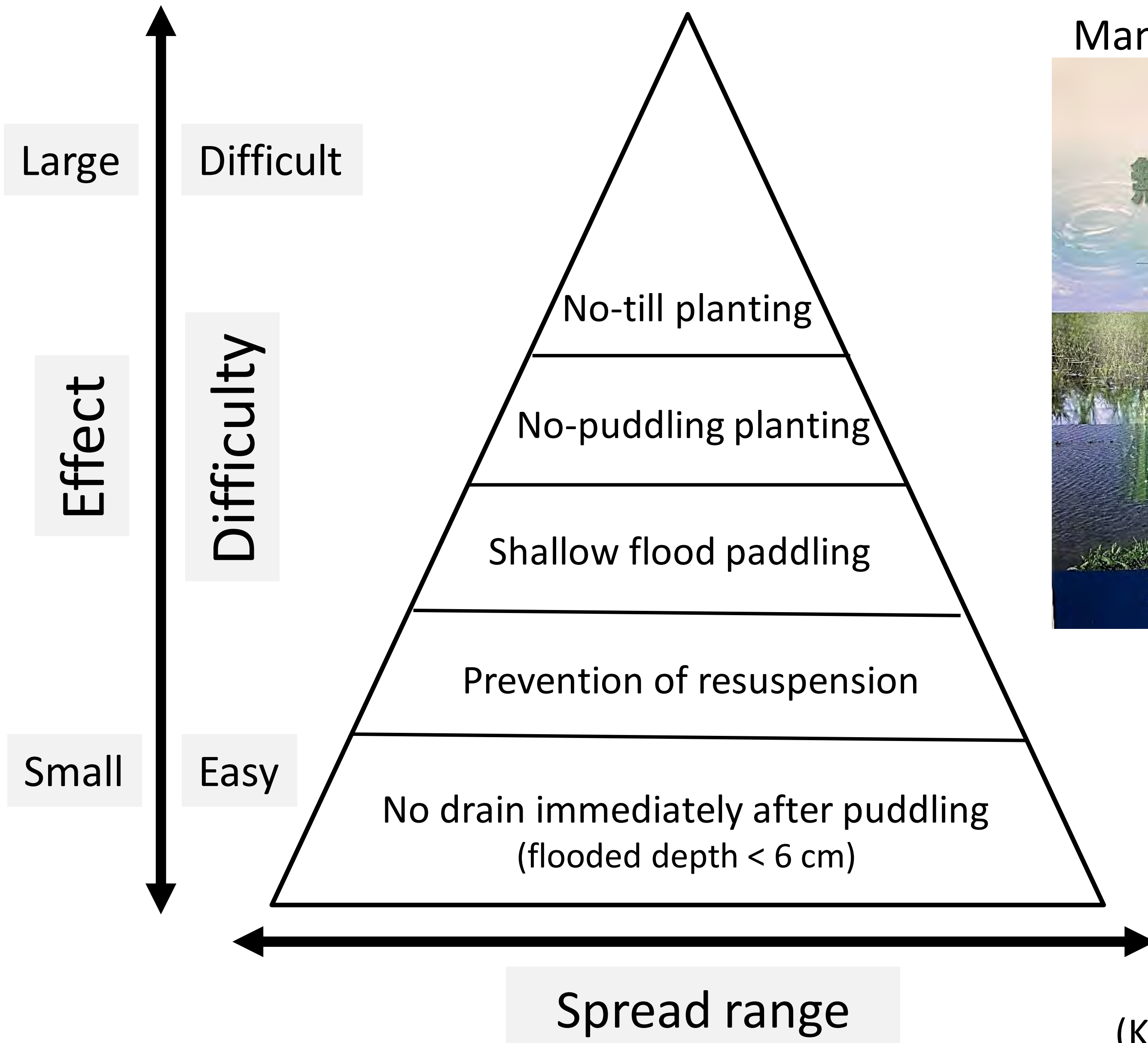


P export reduced by 50% per year

(Kondo et al., 2019)

This system can be an automatically planting by without drain.

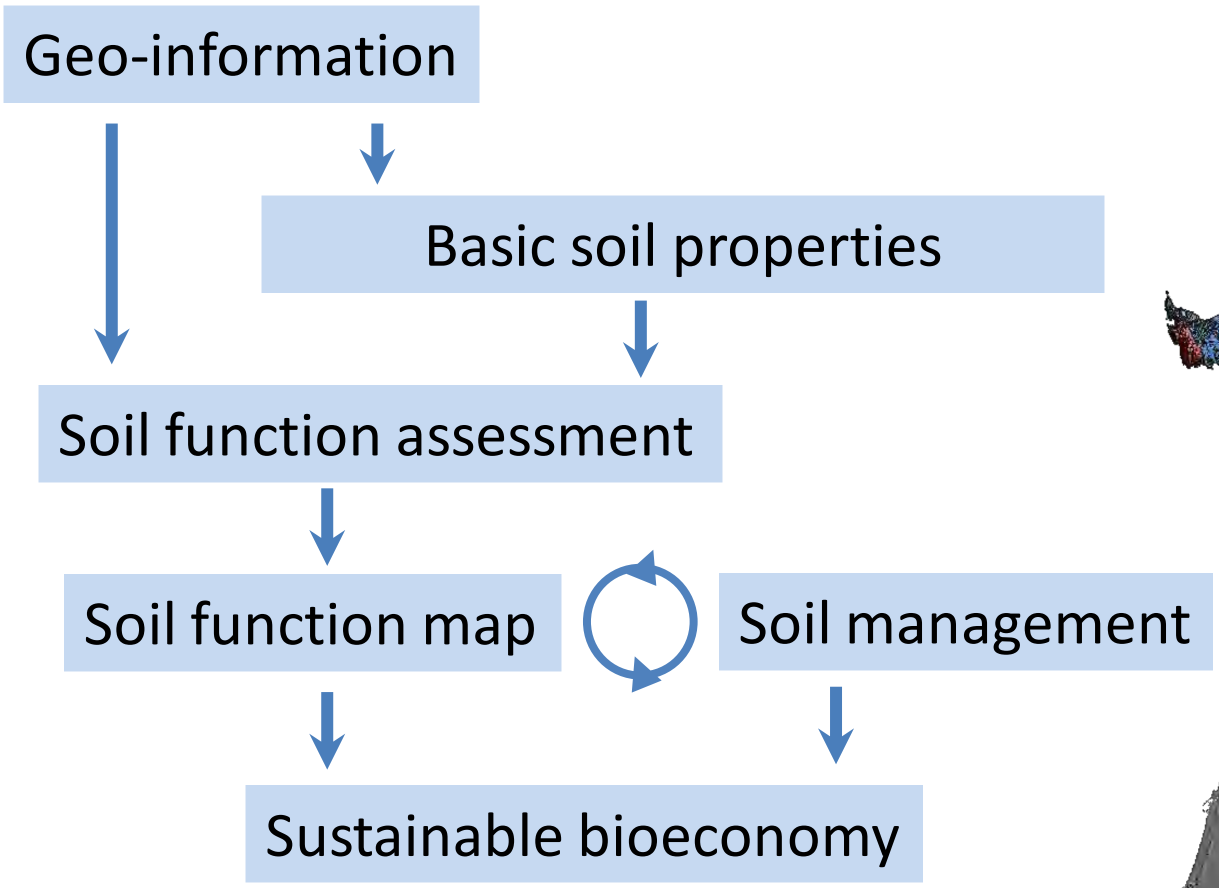
Effect and difficulty of technique for suppressing suspended solids

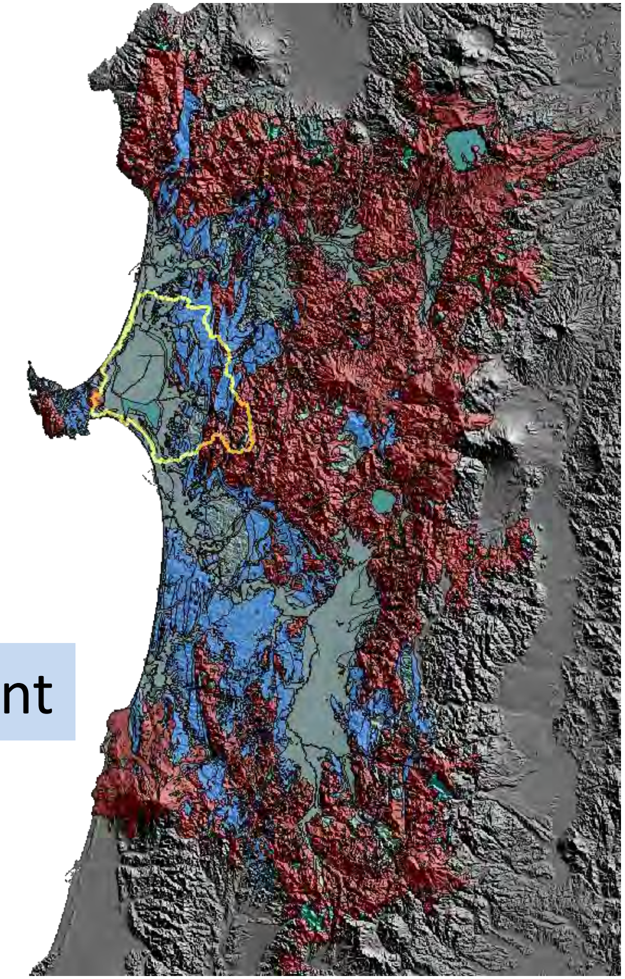


Manual for farmers

(Kaneta et al., 2016)

[Conclusion]
Toward for sustainable bioeconomy





・Spatial assessment of site-specific soil function is required for sustainable bioeconomy.

・Basic research on the natural resource of soil functions and its management that enable the sustainable agriculture in landscapes will more need towards for the bioeconomy.