Dynamics of radioactive cesium behavior in agro-environment

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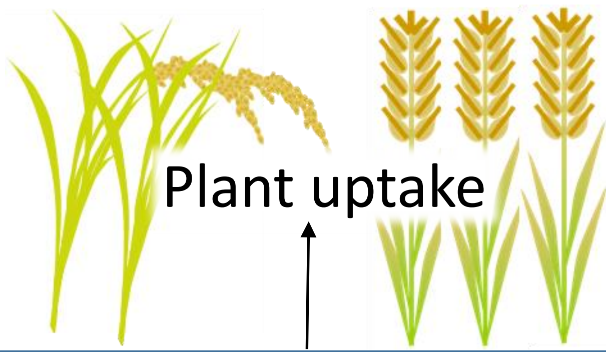
Three topics in this presentation

Radioactive cesium (RCs): $^{134}Cs + ^{137}Cs$

3. Radiocesium Interception Potential (RIP) of farmland soils



Soil to water distribution

RCs concentration in farmland soils

What causes changes in RCs concentration in farmland soils?

1. Changes in RCs concentration of farmland soils for 5 years

2. Loss of RCs from paddy fields

Criterion to decide whether or not decontamination is necessary

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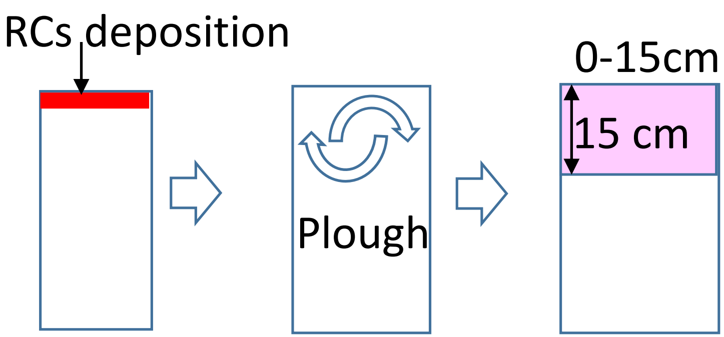
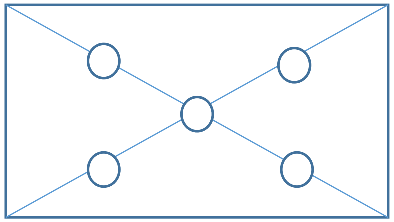
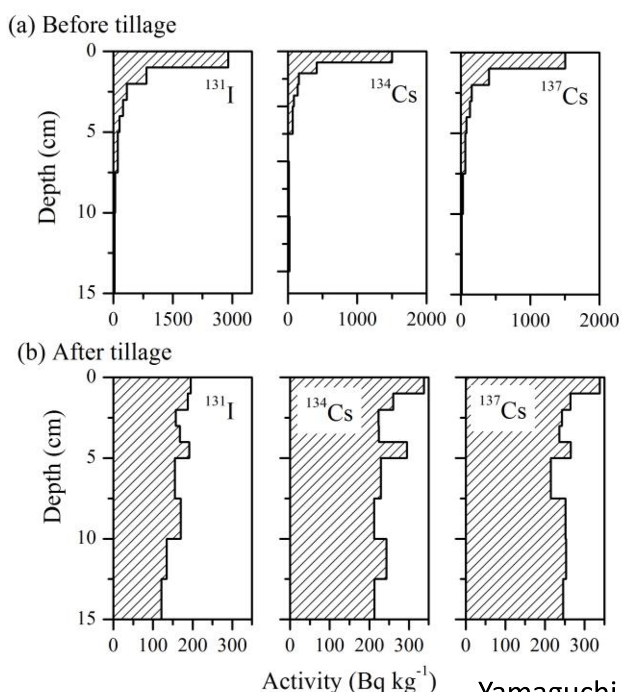
1. Changes in radiocesium concentration of farmland soils over 5 years
2. Loss of radiocesium from paddy fields
3. Radiocesium Interception Potential of farmland soils



composite sample from 5 plots in each field



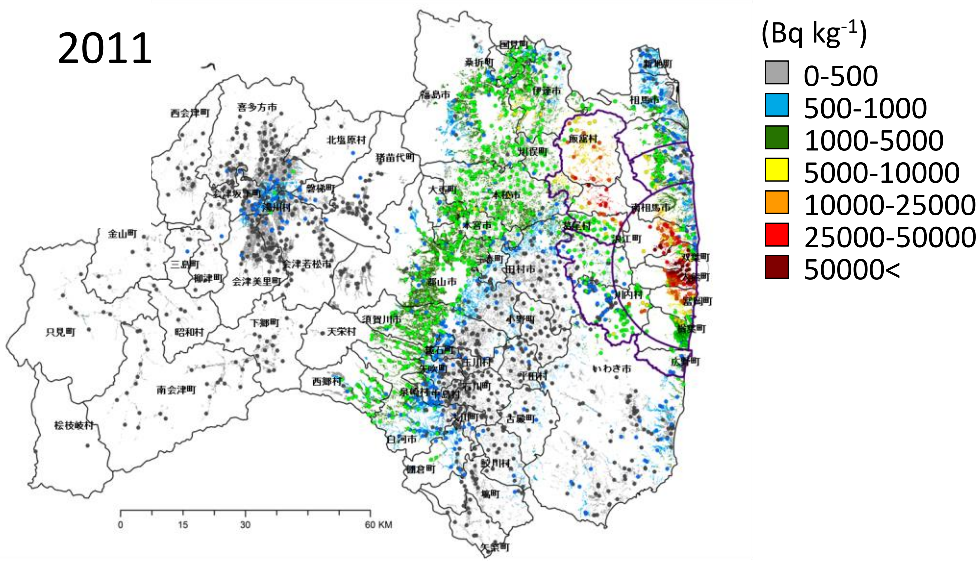
Ge detector
^{134}Cs and ^{137}Cs activity



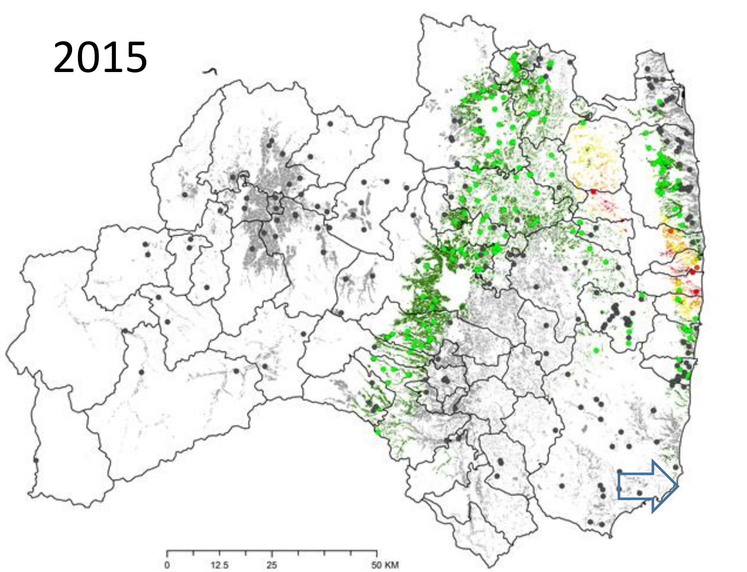
Yamaguchi et al., J. Environ. Radioactiv. (2012)

RCs distribution map of farmland soils in Fukushima

2011



2015



Technologies sorted by RCs levels in soil

RCs level in soil (Bq / kg)	**Technology**
～ 5,000	Inverting plow, reduction of RCs uptake by crop, topsoil removal (uncultivated field)
5,000 ～10,000	Topsoil removal, inverting plow, removal of soil after paddling with water
10,000 ～25,000	Topsoil removal
25,000 ～	Topsoil removal after solidification

Farmlands over 5000 Bq/kg

8900 ha (2011) ⇒ Decontamination, Radioactive decay, Erosion ⇒ 2200 ha (2015)

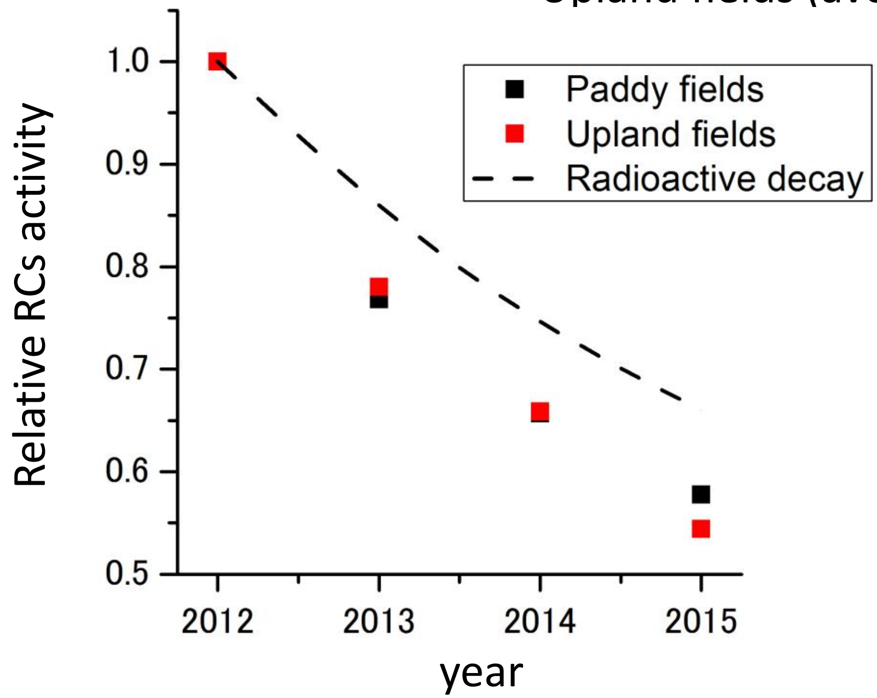
Kohyama, Takata, unpublished

RCs decrease over 5 years without decontamination

Paddy fields (average of 16 fields)

Upland fields (average of 14 fields)

$$\frac{\text{RCs concentration (Bq/kg)}}{\text{RCs concentration in 2012}}$$

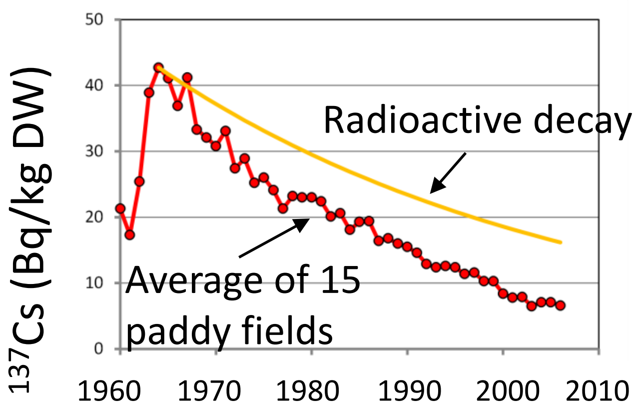


Rates of RCs decrease were typically faster than radioactive decay

Global fall-out by atmospheric nuclear weapons test

Monitoring of ^{137}Cs concentration in farmland soils for 25 years

(Komamura et al., 1999, 2004)



Effective half life of ^{137}Cs in ploughed layer

Paddy field	Upland field (wheat)
17 y (9-24 y)	17 y (8-26 y)

Rates of decrease were faster than radioactive decay ($T_{1/2}$=30.1yr)

Loss of RCs-bearing soil particles

- Wind erosion
- Surface run-off
- Downward migration

Accelerated by soil perturbation due to agricultural practices

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1. Changes in radiocesium concentration of farmland soils for 5 years
2. **Loss of radiocesium from paddy fields**
3. Radiocesium Interception Potential of farmland soils

Input

Irrigation water
Atmospheric deposition

Output

Surface drainage
Tile drainage

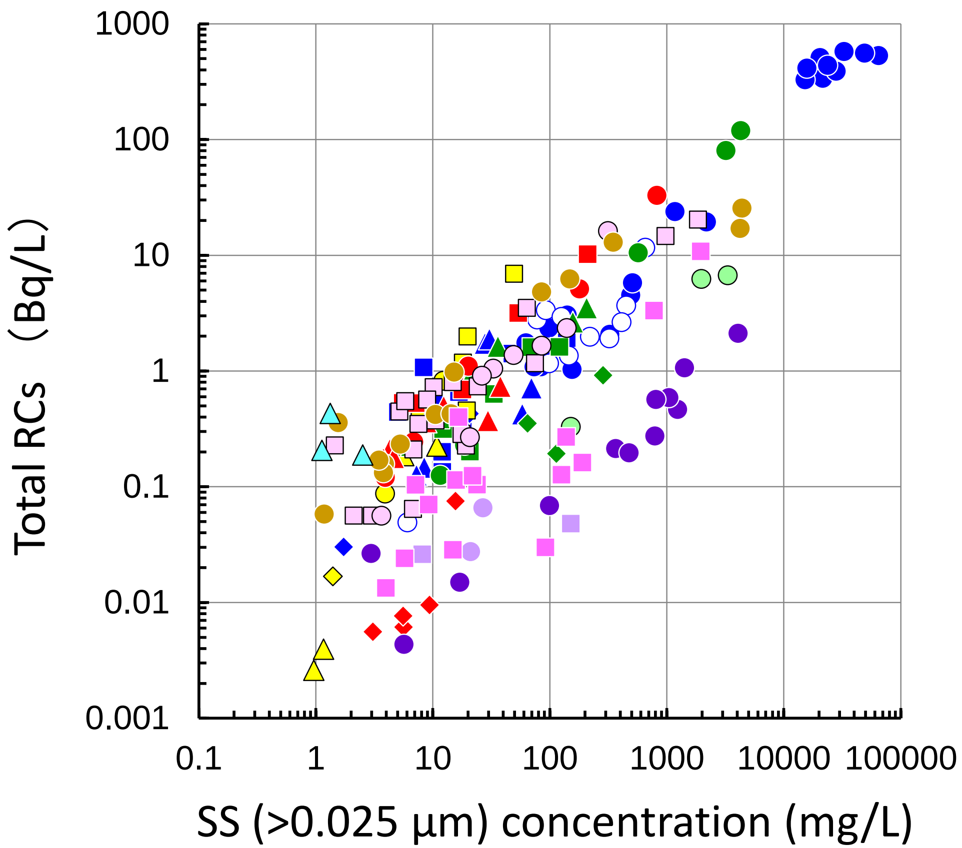
Soil perturbation event by soil puddling with irrigation water before transplanting rice seedlings

Surface drainage during puddling

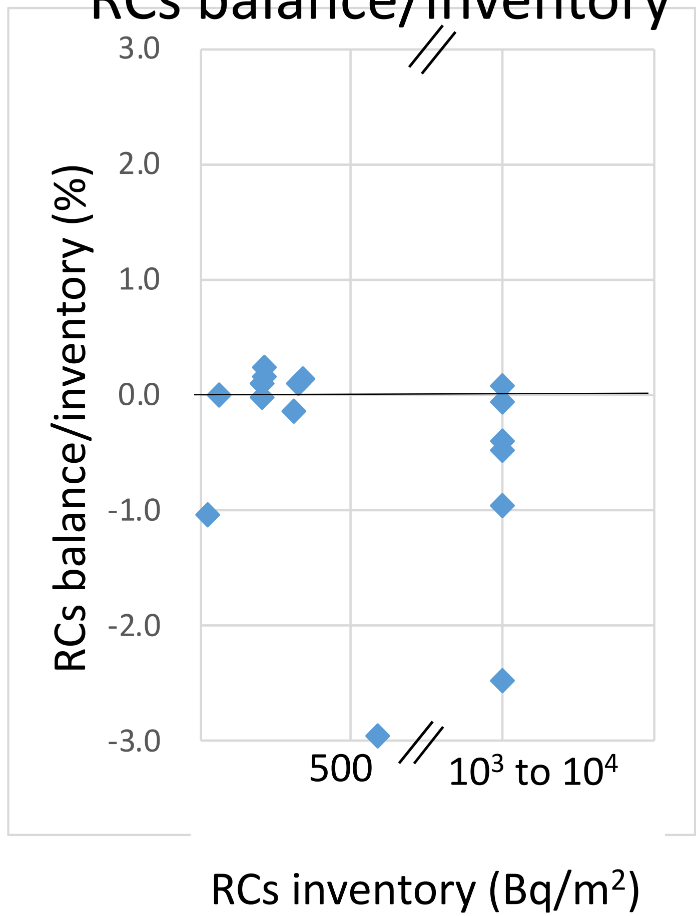
SS: 65000 mg/L

Surface drainage before transplanting (5 days after puddling)

Total RCs vs suspended solids (SS)



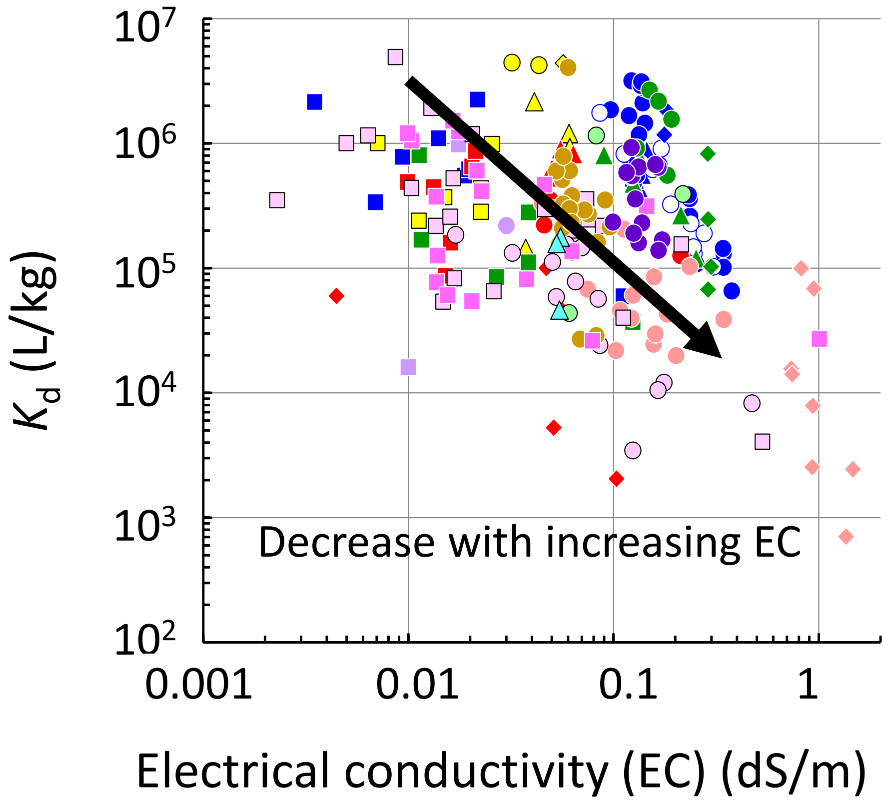
RCs balance/Inventory

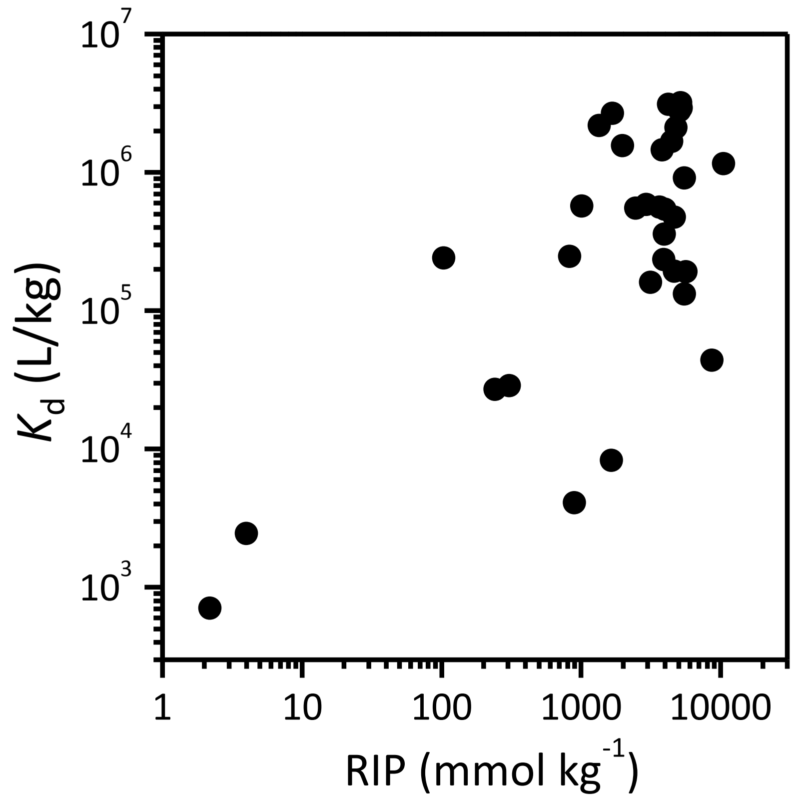


- Input and output of RCs was associated with those of suspended solids.
- RCs was lost from paddy fields at rates of less than a few % per year of the soil RCs inventory

Distribution coefficient

$$K_d\,(L/kg) = \frac{^{137}Cs\ conc\ in\ SS\,(Bq/kg)}{^{137}Cs\ conc\ in\ filtrate\,(Bq/L)}$$ ⇦ Source of plant uptake





K_d 10^3～10^7 L/kg

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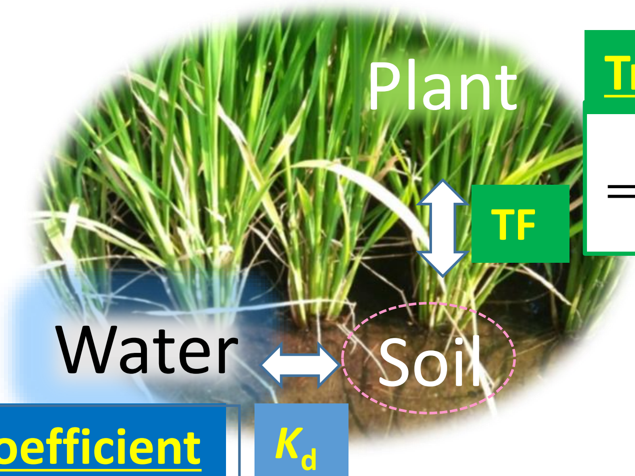
Simple and Important parameters to describe/predict RCs behavior



Transfer factor (TF)

$$= \frac{\text{RCs in plant}}{\text{RCs in soil}}$$

Distribution coefficient

$$= \frac{\text{RCs in soil}}{\text{RCs in water}}$$

- Reflect the soil characteristics of RCs adsorption
- Variable depending on water quality/plant type, growing & nutrient condition

RIP

Intrinsic parameter describing RCs mobility in soil independent of various environmental factors

Radiocesium interception potential (RIP)

Parameter to evaluate selectivity and quantity of highly selective sites for Cs sorption

Definition

$$RIP = K_c^{FES}(\text{Cs-K}) \times [\text{FES}]$$

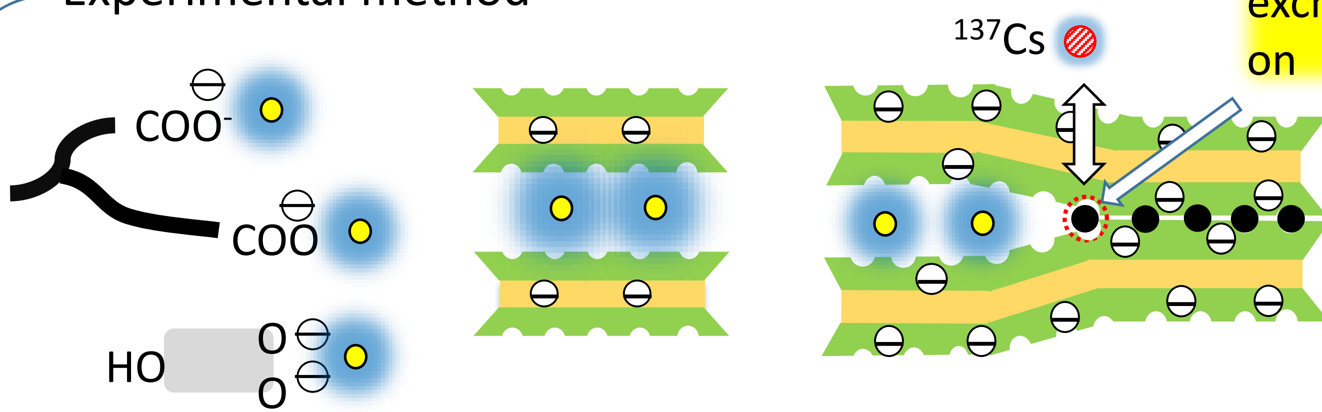
Selectively coefficient of Cs against K on FES

Amounts of FES

$$= \frac{[^{137}\text{Cs adsorbed on FES}]}{[^{137}\text{Cs in solution}]} \times \frac{[\text{K in solution}]}{\cancel{[\text{K adsorbed on FES}]}} \times \cancel{[\text{FES}]}$$

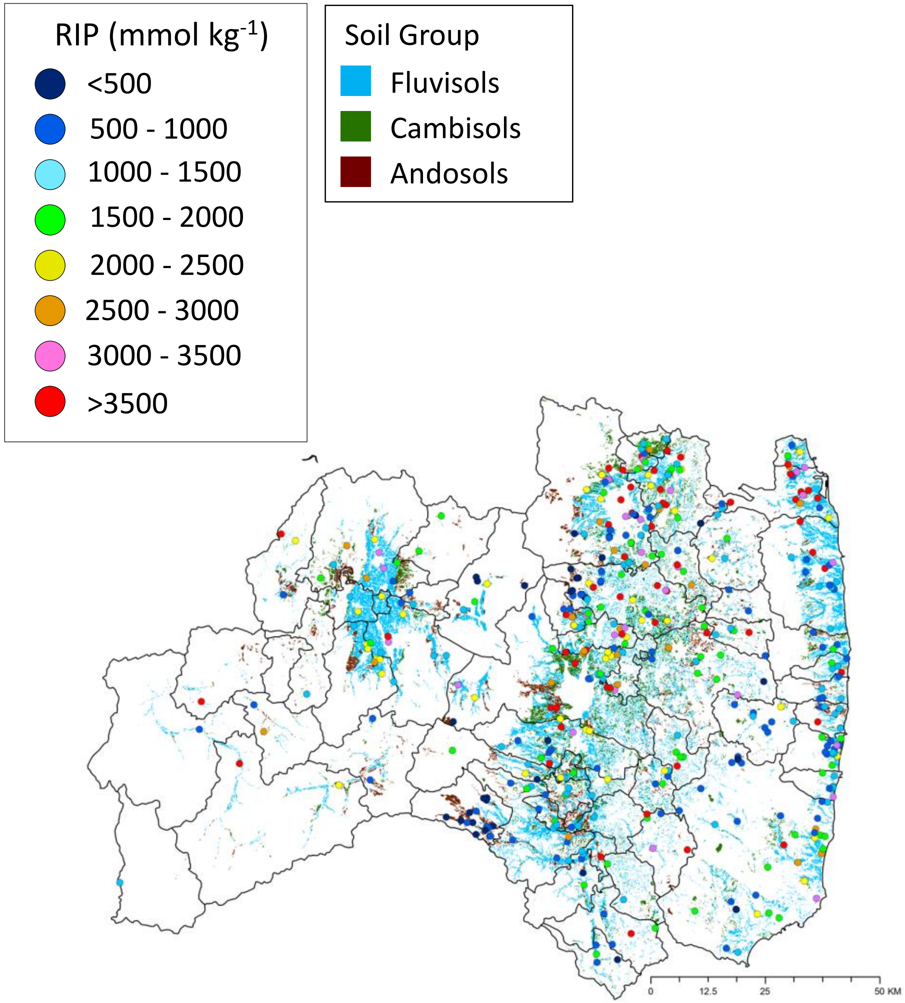
$$= K_d(^{137}\text{Cs on FES}) \times [\text{K in solution}]$$

Experimental method

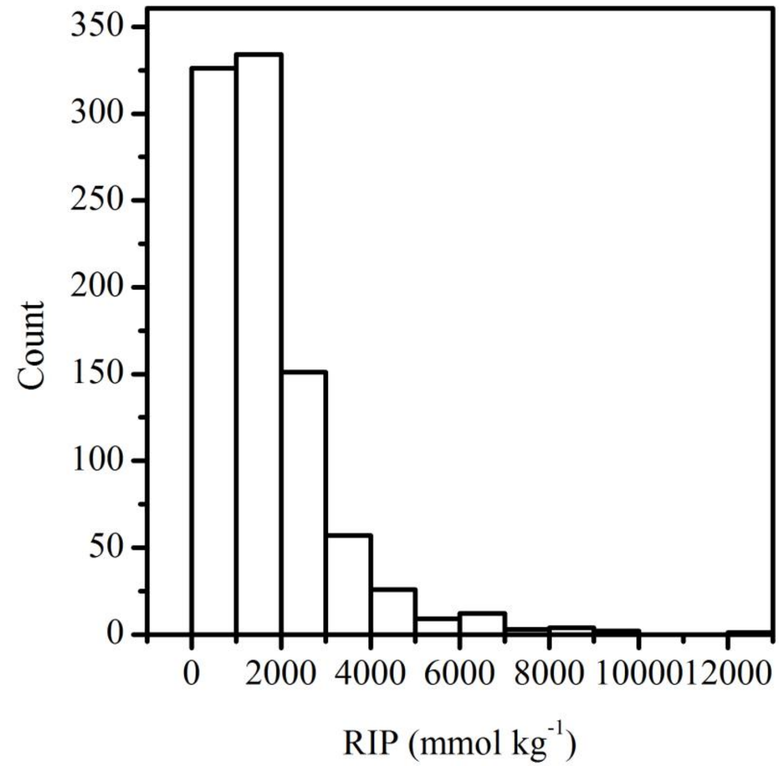


Spiked ^{137}Cs is exchanged with K on FES

- ➢ Cation exchange sites except FES → masked by Ca^{2+}
- ➢ FES → saturated by K^{+}

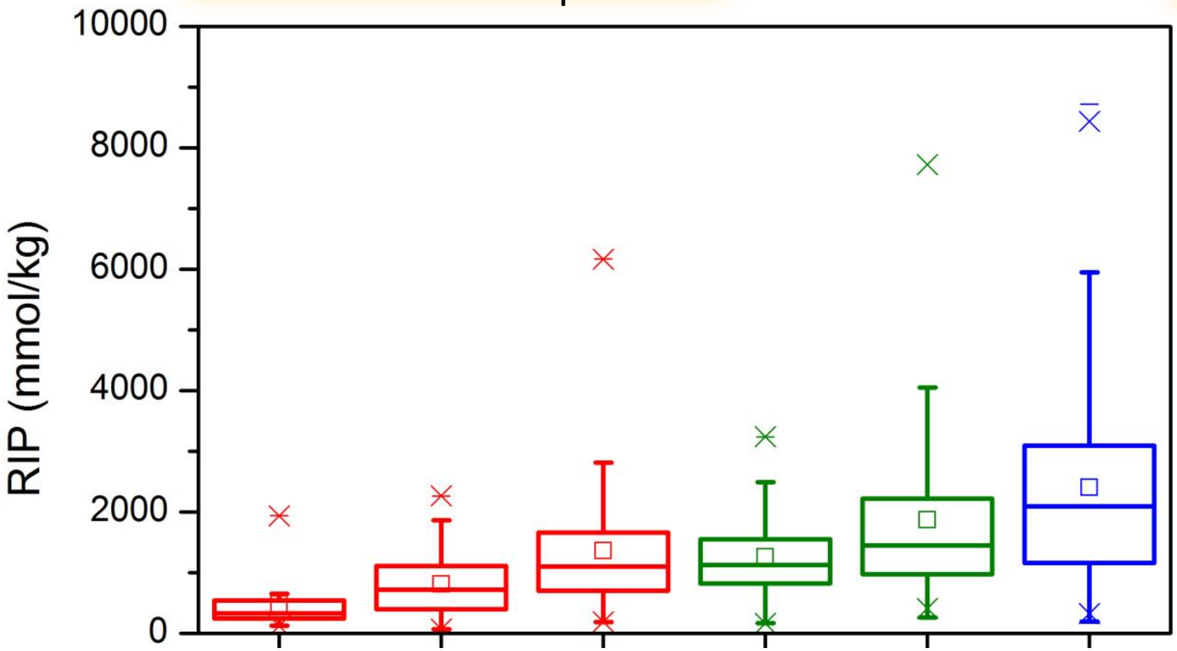


RIP distribution map



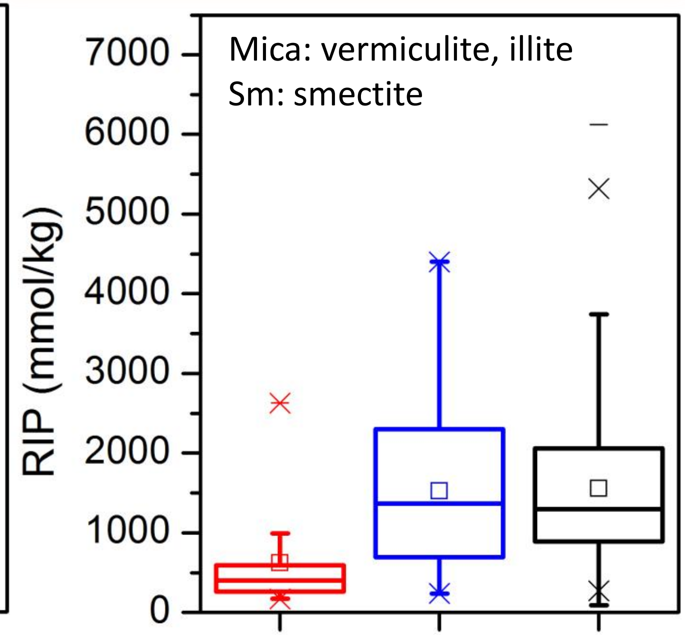
Geometric mean: 1280 ± 2.16 mmol/kg
Minimum: 73 mmol/kg
Maximum: 12700 mmol/kg
Median: 1300 mmol/kg

Soil Group



	Andosols			Fluvisols		Cambisols
TC %	>6%	3~6%	<3%	>3%	<3%	
Average	486	812	1360	1260	1870	2410
N	52	69	96	79	486	143
	a	b	c	c	d	e

Clay mineral composition



Mica	×	×	○
Sm	×	○	○
Ave	625	1530	1560
N	37	28	487
	a	b	b

Values within a column followed by different letters are significantly different according to Steel-Dwass test at $p \leqq 0.01$ for soil group and $p \leqq 0.005$ for clay mineral composition

Low RIP ⇨ Andosols, High TC, w/o crystalline clay minerals

Summary

RCs distribution map + RIP map

➡ Prediction of RCs uptake by crop

RCs concentration of farmland soil changes over time

Loss of Cs-bearing soil particles by erosion

Acknowledgement

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