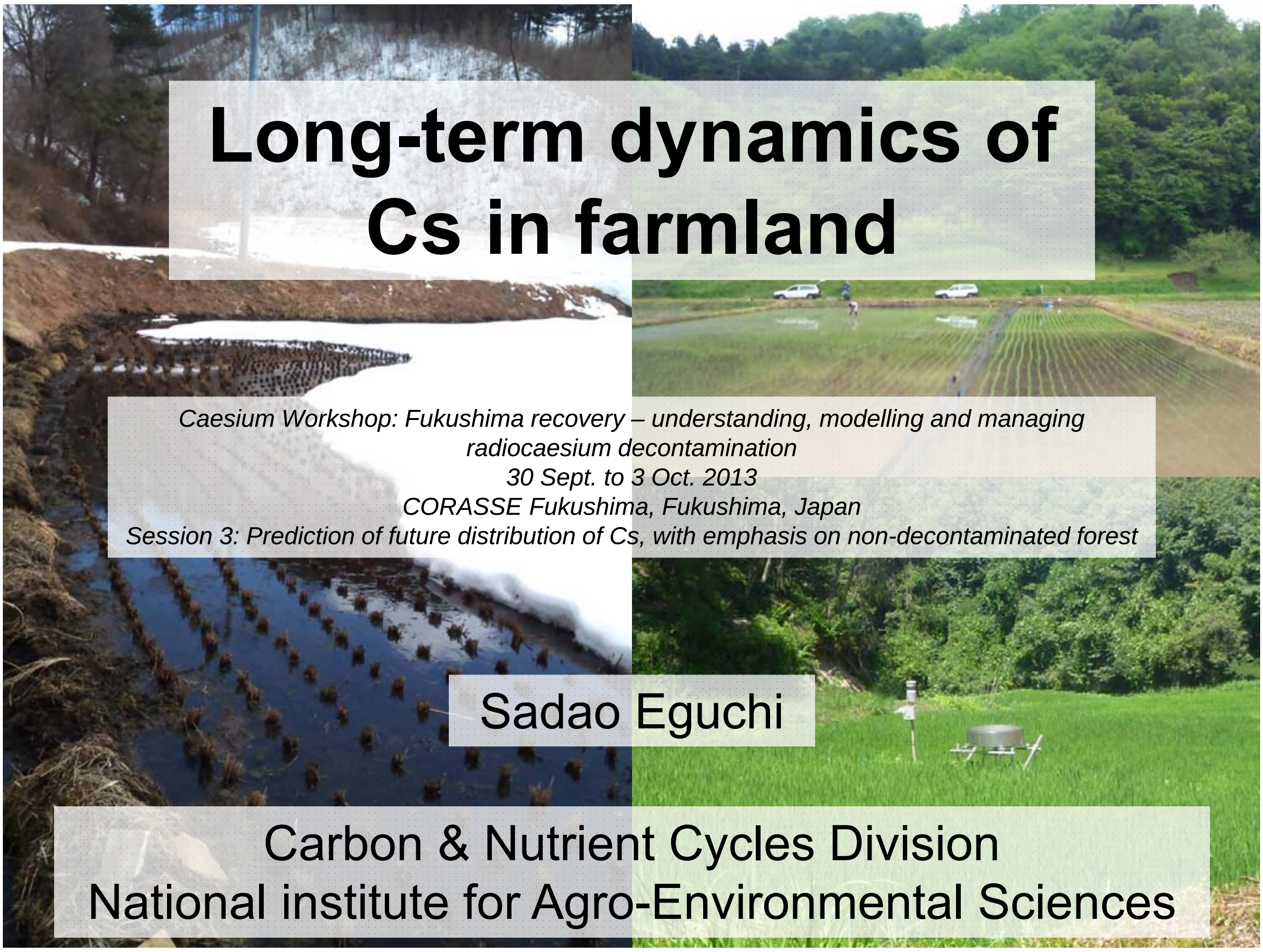
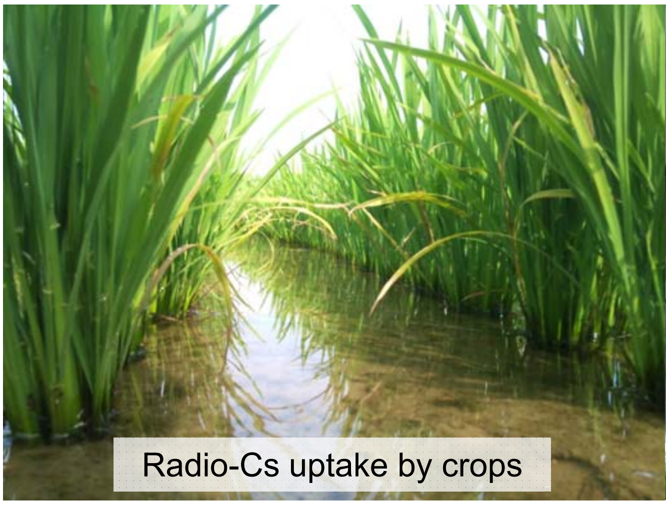


Long-term dynamics of Cs in farmland

Caesium Workshop: Fukushima recovery – understanding, modelling and managing radiocaesium decontamination
30 Sept. to 3 Oct. 2013
CORASSE Fukushima, Fukushima, Japan
Session 3: Prediction of future distribution of Cs, with emphasis on non-decontaminated forest

Sadao Eguchi

Carbon & Nutrient Cycles Division
National institute for Agro-Environmental Sciences



Radio-Cs uptake by crops

Radio-Cs discharge from farmland

→ Recharge to other environments

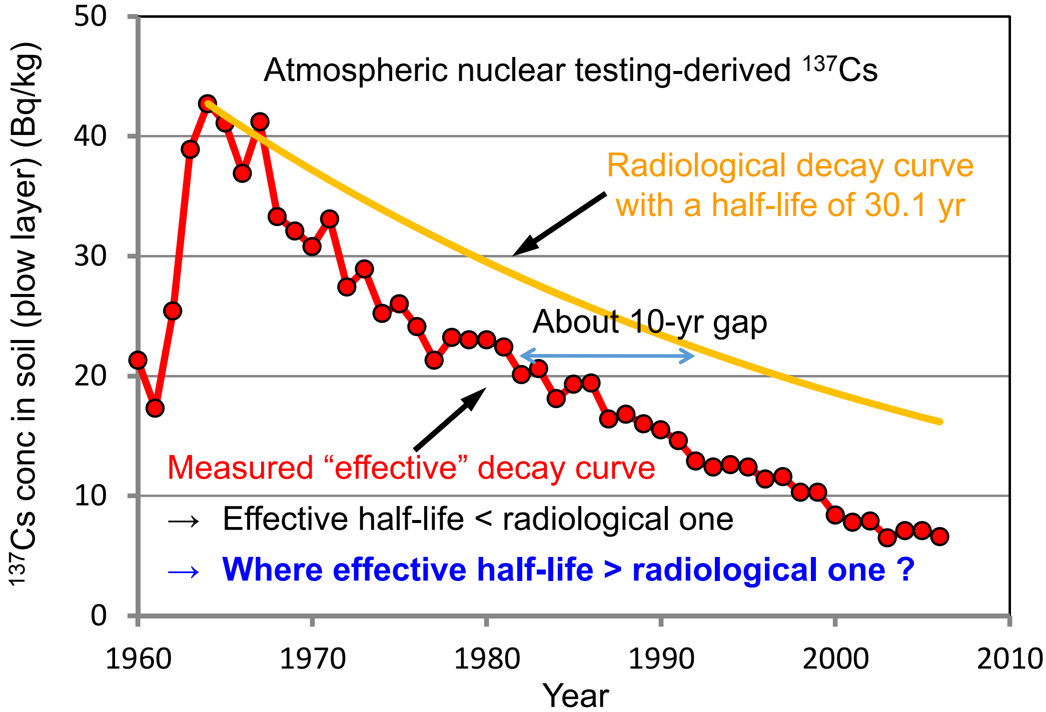
11 March 2011 TEPCO-NPP accident → Radio-Cs emitted to environment
Brown rice produced in cropping lands in 2011 >500 Bq/kg (0.2% of total)
“Yatsuda” (rice paddy fields located at narrow, gentry sloping, small valleys)

Cause: Soil properties？ Fertilizer？ Some other agricultural management？
Irrigation water Cs？ Fallen leaves Cs？ Atmospheric deposition Cs？

→ Understanding watershed-scale dynamics of radio-Cs is indispensable for explaining or predicting crop radio-Cs uptake in a farmland

Global fallout ^{137}Cs conc in farmland soil

Average for 15 rice paddy fields in Japan



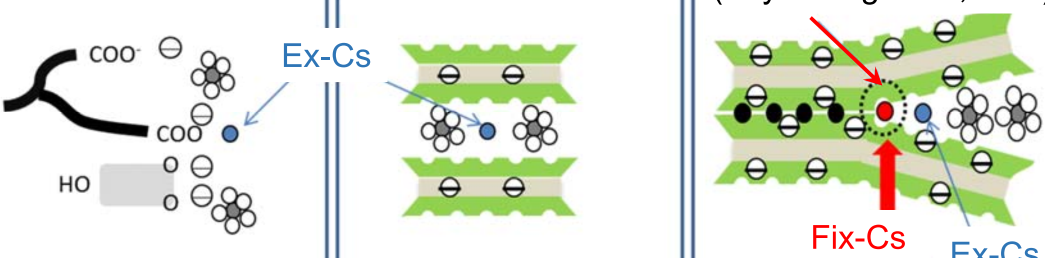
Distribution & characteristics of radio-Cs in soil

1) Living or dead organisms: Emit soluble Cs by mineralization
2) Soil liquid (dissolved form): Easily absorbed by crops
3) Soil solid (exchangeable or fixed form): See below

a) Weakly adsorbing sites (rapid reaction): Very easily desorbed by other cations

b) Strongly adsorbing sites (rapid reaction): Exchangeable with other cations

c) Fixing sites (slow reaction): Very difficult to be desorbed by other cations (frayed edge site, FES)



a) e.g., Humic substances -COOH, Clay minerals edge -OH

b) e.g., Smectite

c) e.g., Weathered mica Vermiculite, Illite

Modified from Yamaguchi (2012)

Quantifying high affinity of $^{137}Cs^+$ to FES

Radiocaesium Interception Potential

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

Selectivity coefficient of Cs to K for FES (≒1000)

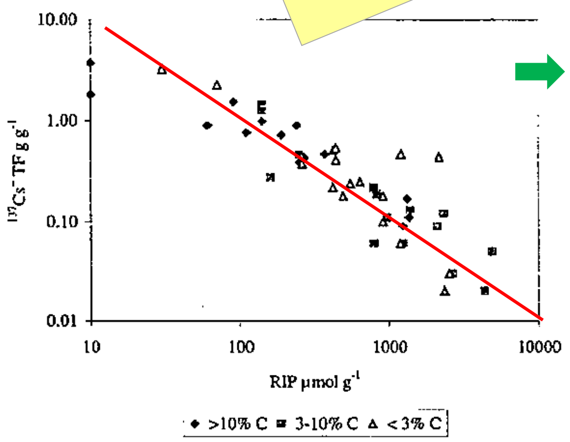
Amount of FES per 1 kg soil

Measurement:
Mask negative charges other than FES by high conc Ca^{2+}
→ Add K^+ to adsorb to FES
→ Competitive adsorption between radio-Cs^+ & K^+

Cremers et al. (1988) Nature

Log TF vs log RIP relationship

Negative relationship between TF and RIP
One-order small RIP → One-order large TF

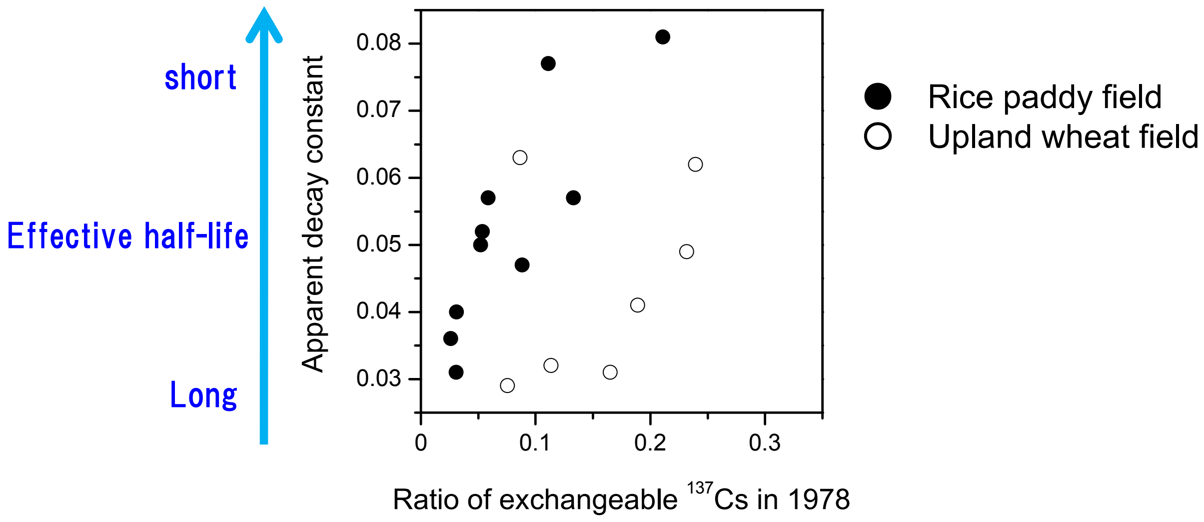


Ryegrass grawn in ^{137}Cs-amended soils with different RIP

FIGURE 2. Log−log plot of rhizospheric $^{137}Cs^+$ transfer factor (TF) versus the radiocesium interception potential (RIP) in soil. The different symbols refer to the different categories of carbon content.

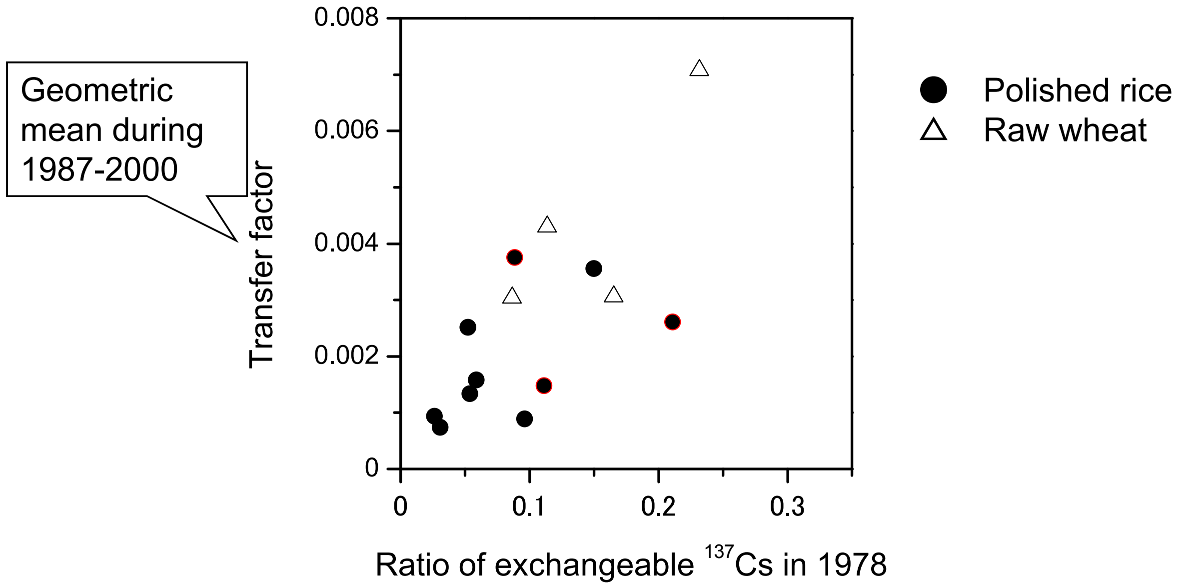
Delvaux et al. 2000. Environ Sci Technol

Ex-^{137}Cs/total-^{137}Cs ratio affects effective half-life of ^{137}Cs



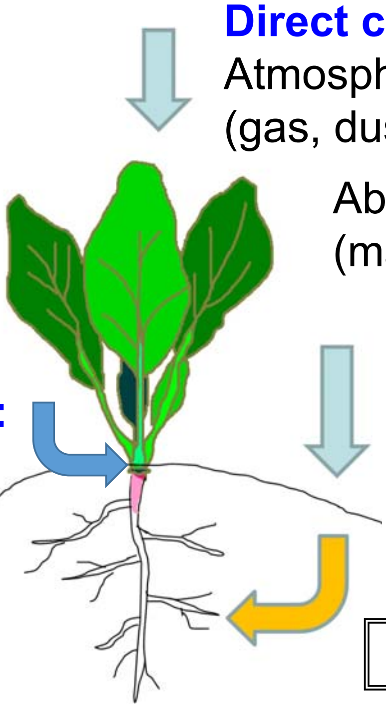
- Effective half-life of ^{137}Cs in farmland soil decreases with ex-^{137}Cs/total-^{137}Cs ratio
- Effective half-life of ^{137}Cs in rice paddy fields is shorter than upland wheat fields

Ex-^{137}Cs/total-^{137}Cs ratio affects TF



TF increases with ex-^{137}Cs/total-^{137}Cs ratio

Direct & indirect crop contamination



Direct contamination:
Atmospheric dry & wet deposition
(gas, dust, rain drop, mist, etc.)

Absorption by leaf, stem, etc.
(mainly via stomata)

Mixed-type contamination:
Absorption by stem base from irrigated water (ponded water in paddy field)

Indirect contamination:
After deposition to soil
Absorption by root from soil

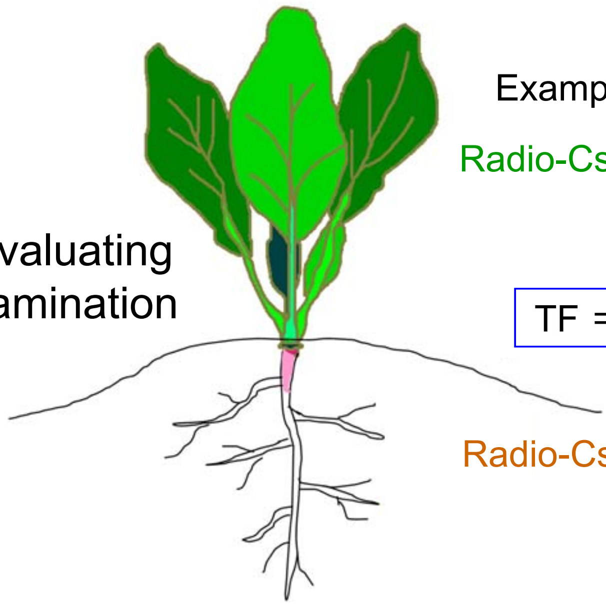
Continue for a long time

Transfer factor (TF) from soil to crop

$$TF = \frac{\text{Radionuclide concentration in crop body (Bq/kg)}}{\text{Radionuclide concentration in soil (Bq/kg)}}$$

For estimating radio-Cs conc in crop body from that in root zone soil

Method for evaluating indirect contamination



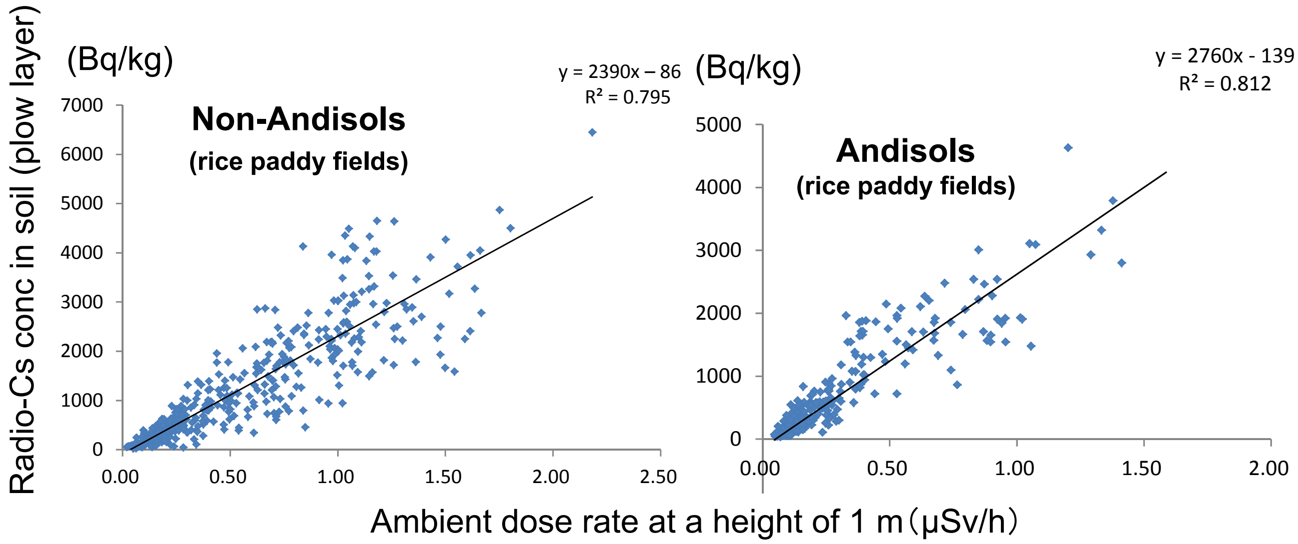
Example:

Radio-Cs conc in edible portion
500 Bq/kg

TF ＝ 500/5000 ＝ 0.1

Radio-Cs conc in root zone soil
5000 Bq/kg

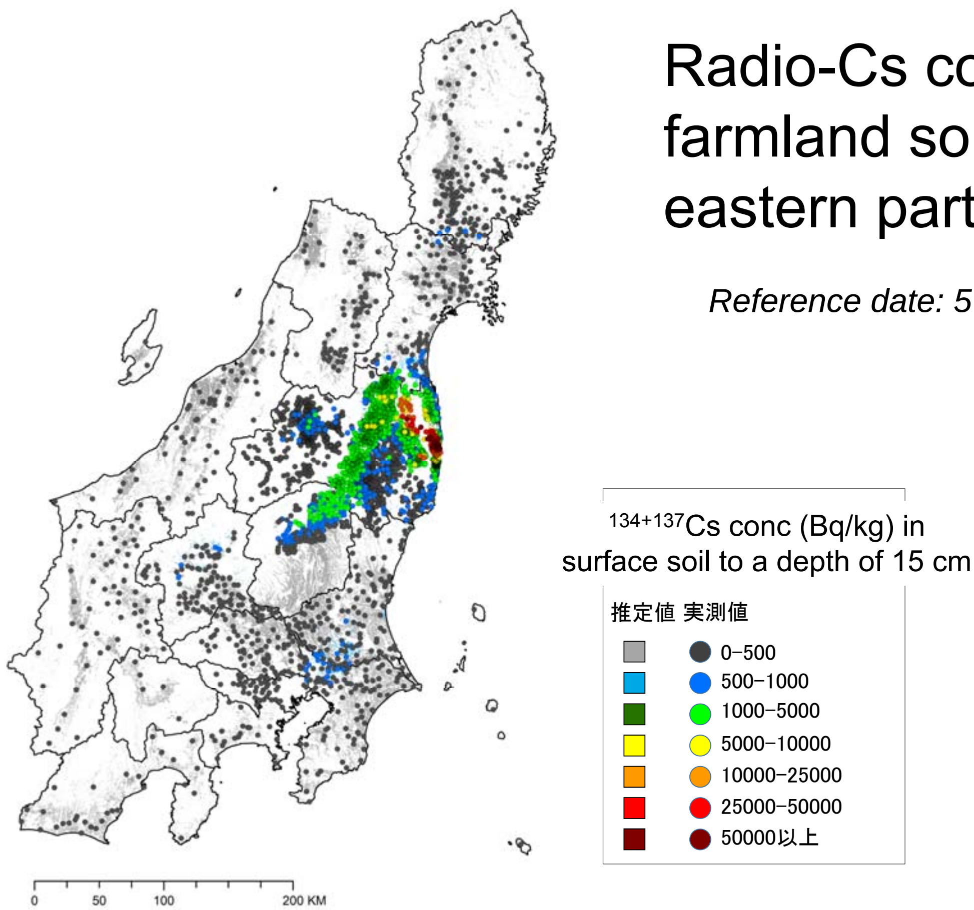
Radio-Cs conc in soil vs ambient dose rate



MAFF (2012)

Radio-Cs conc in farmland soil in eastern part of Japan

Reference date: 5 November 2011

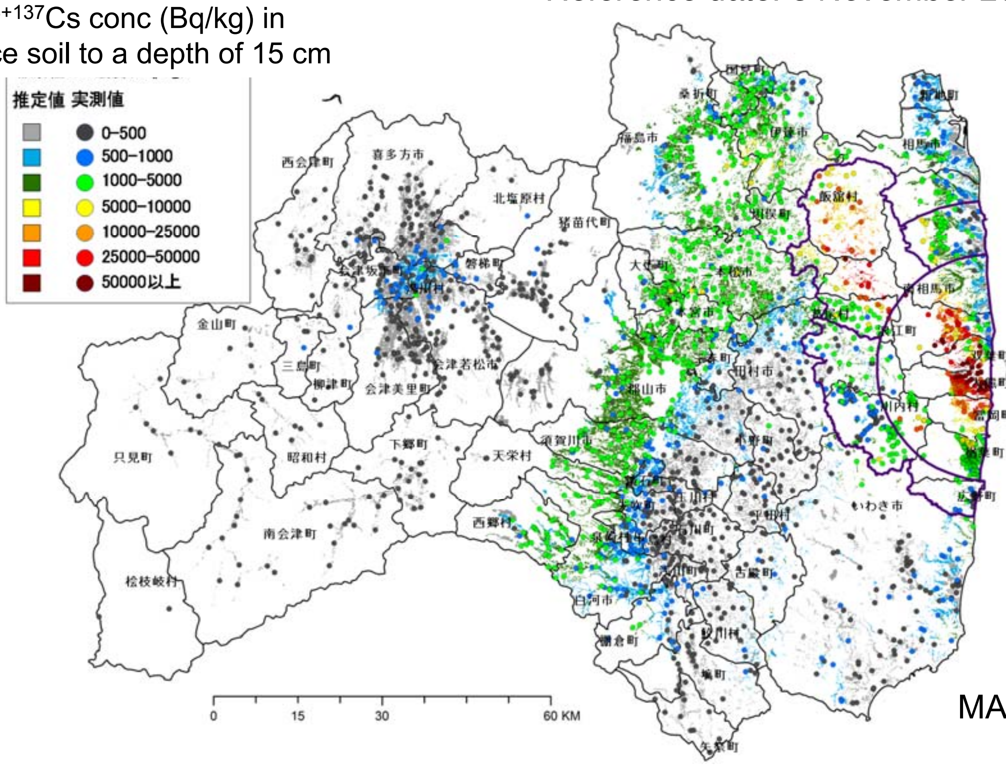


MAFF (2012)

Radio-Cs conc in farmland soil in Fukushima

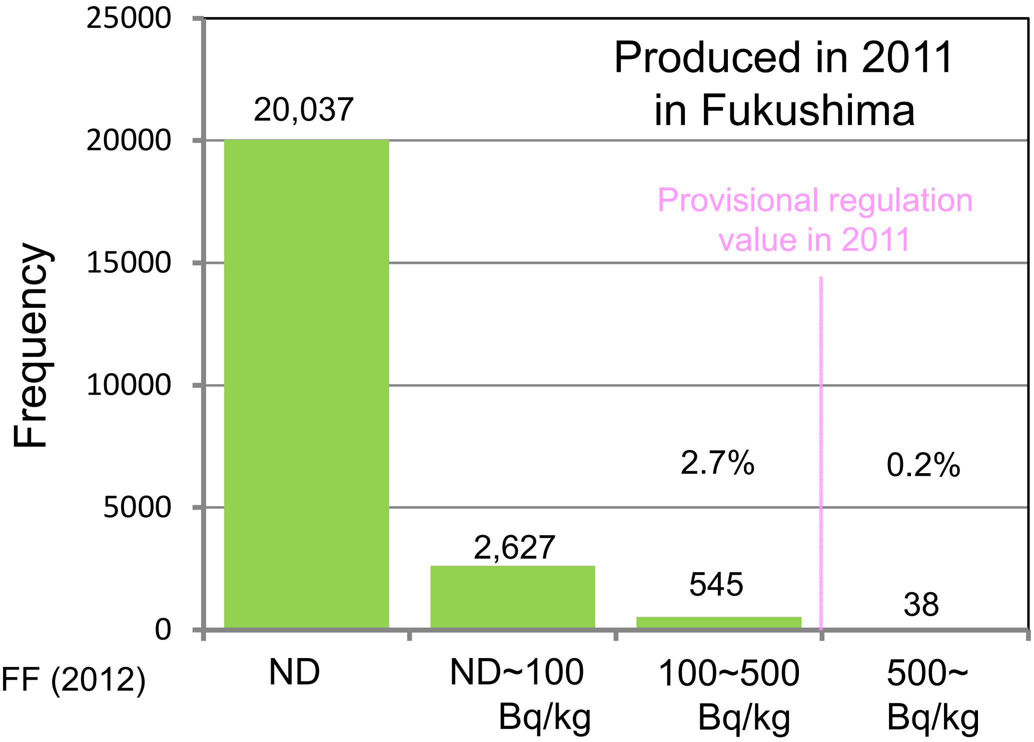
Reference date: 5 November 2011

$^{134+137}Cs$ conc (Bq/kg) in surface soil to a depth of 15 cm



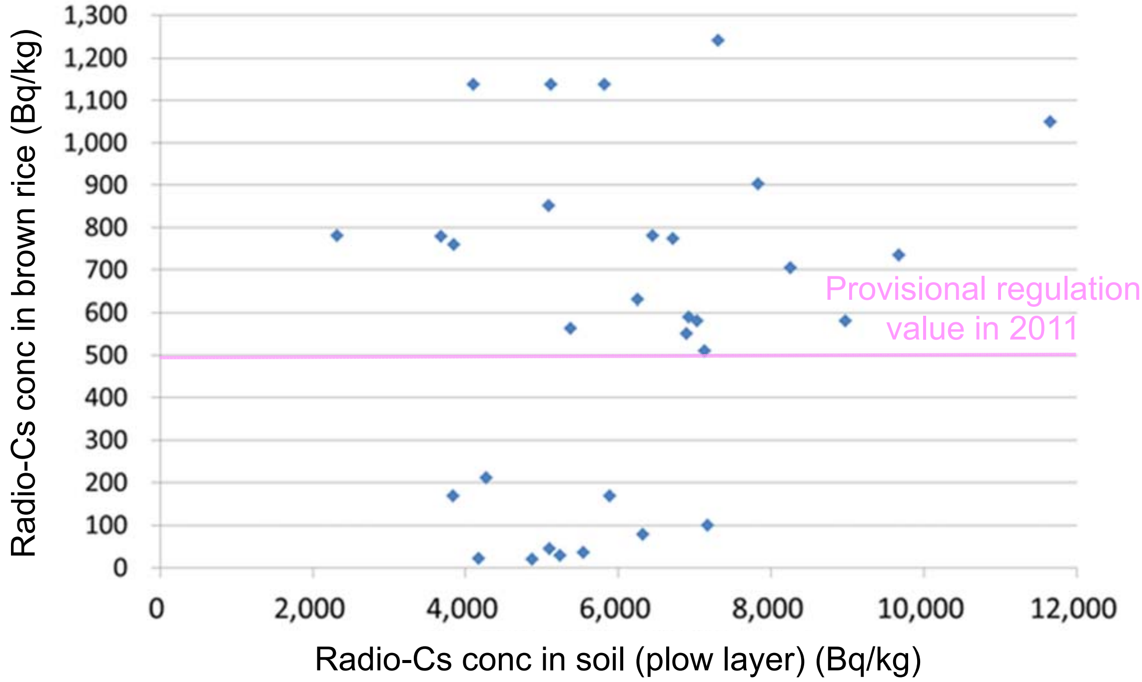
MAFF (2012)

Frequency distribution of radio-Cs conc in brown rice



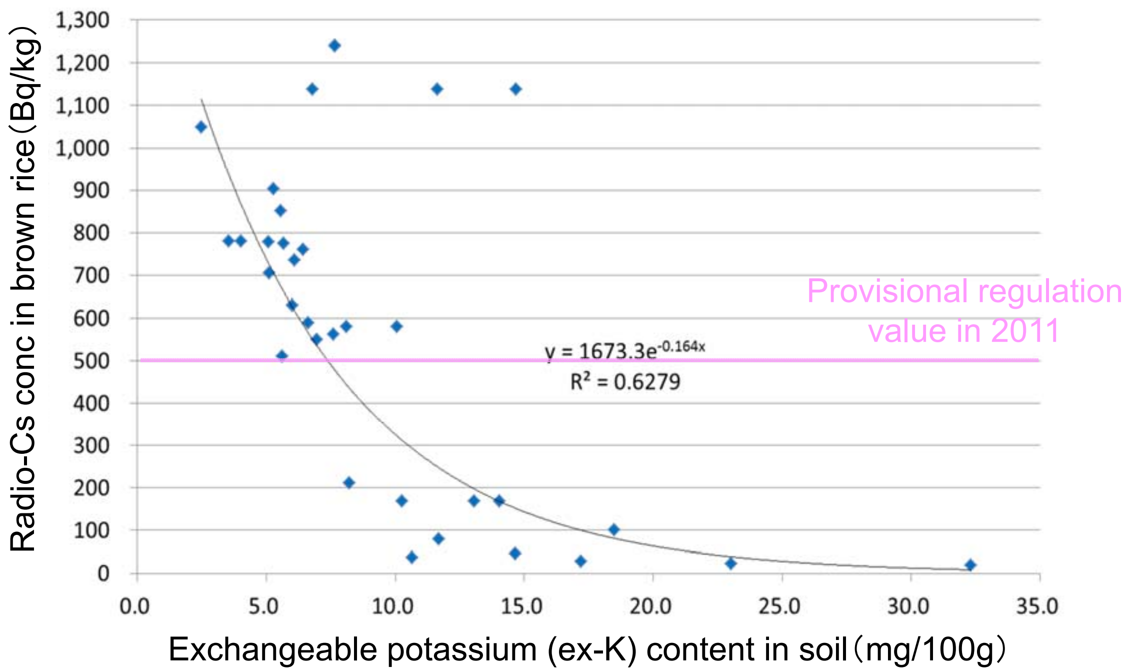
MAFF (2012)

Radio-Cs conc in brown rice vs that in soil



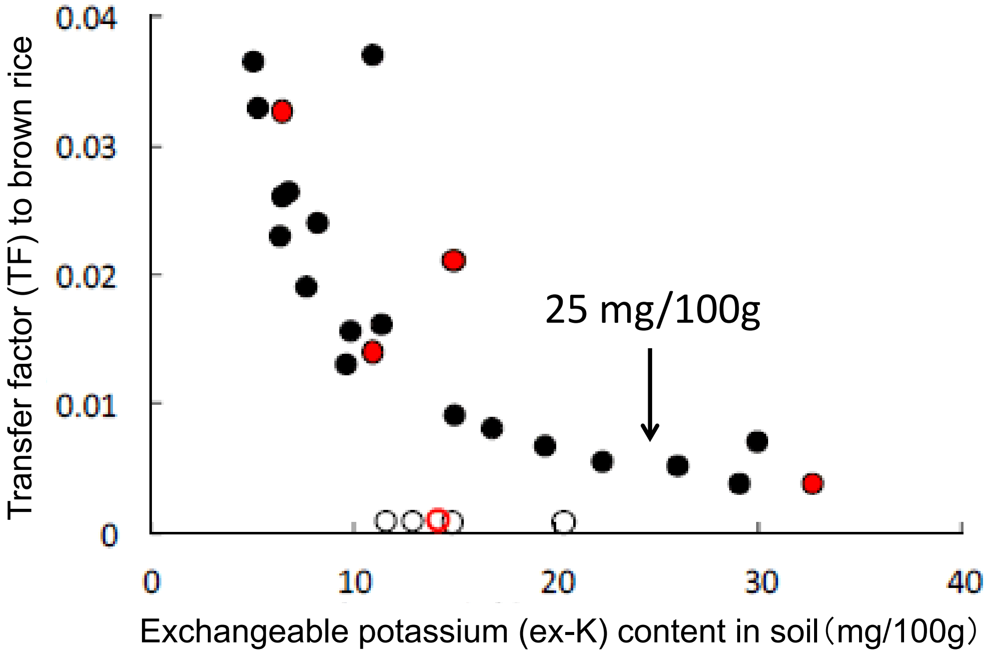
Fukushima Prefecture et al (2011)

Soil ex-K mitigates radio-Cs conc in brown rice



Fukushima Prefecture et al (2011)

Soil ex-K mitigates TF to brown rice



NARO (2011)

National Institute for Agro-Environmental Sciences NIAES

Radio-Cs monitoring at Farmlands in Fukushima

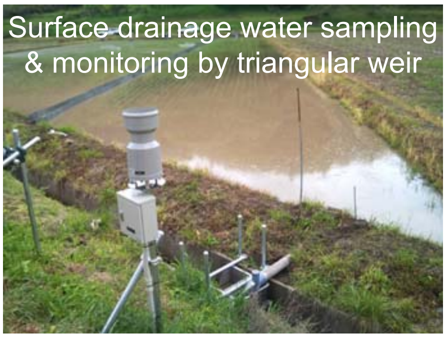
Dry & wet deposition sampler (right) & rain gauge (left)

Radio-Cs monitoring at farmlands in Fukushima

Rice paddy, upland vegetable, orchard, grassland, non-cropping rice paddy fields, etc.

Irrigation water supplied from mountain stream, spring water, large-scale irrigation system

Separate dissolved & suspended radio-Cs by filtering with a pore size of 0.025 μm



Tile drainage water sampling & flow meter

Agriculture effects on riverine radio-Cs discharge

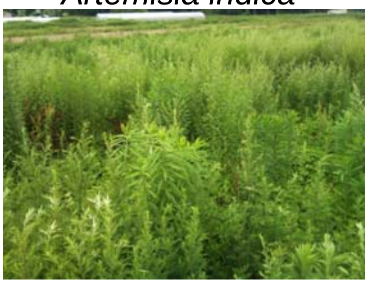
Cropped watershed

Uncropped watershed (prohibited)

Paddy rice / soybean

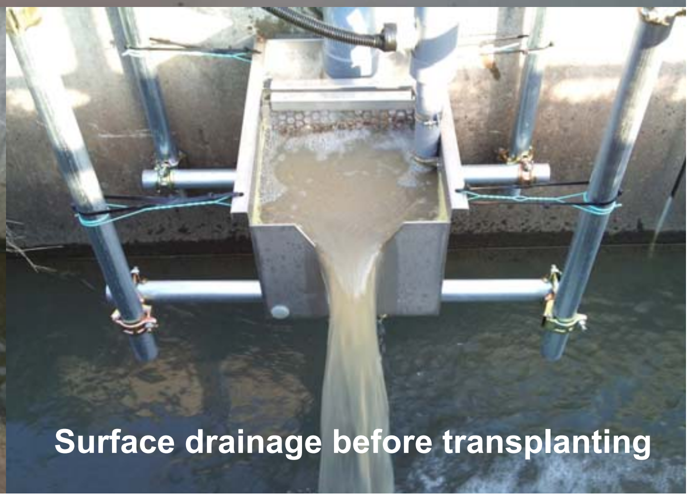
Solidago altissima

Artemisia indica



Agricultural activities in rice paddy fields

Surface drainage during puddling



Surface drainage before transplanting

Summary～Current research needs

1. Effective half-life of radio-Cs in farmland soil (about 16 yr for paddy soil) is shorter than that of radiological one
2. Exchangeable K (>25 mg/100 g) in paddy soil mitigates radio-Cs conc in brown rice (TF <0.01)
3. Radio-Cs recharge & discharge in farmland (rice paddy environment) occur mainly in suspended form
4. Dissolved radio-Cs is trace <1 Bq/L; however, its effect on crop radio-Cs uptake (in edible portion) is unclear
5. Farmland to watershed-scale models should include dissolved & adsorbed radio-Cs in soil & water, organic matter decomposition, time-dependent fixation, etc.

NEW http://aerap.dc.affrc.go.jp/

Ｗｅｂサイト「農業環境と放射能汚染」のご案内

トップページ

このウェブサイトは、土、水および農作物などの農業環境の放射能汚染に関連する調査・研究成果や関連情報を提供するものです。放射能汚染についての多岐にわたる情報を集約・整理して、分かりやすく伝えることを目指しています。

＊サイトの活用法＊

- 行政・研究機関から発信される新着情報
- 放射能と農業に関する研究会の開催情報
- 放射能汚染対策研究の成果情報
- 放射能と農業についての用語集
- 研究会要旨集や一般図書・パンフレット
- 国際機関の新着情報や資料
- 放射能研究に関する写真
- その他、放射能と農業の情報収集に役立つリンク先

研究成果

放射能汚染と農業に関する研究成果を、農環研、農研機構、放医研、原研、日本分析センター、福島県農総セ、東大など国内研究機関より収集。これらを研究対象ごとに分類し、カテゴリー検索が可能。

17のカテゴリー

「土壌」「水」「降下物」「穀物」「野菜」「果樹・樹園地」「畜産」「分析法」「モニタリング」「除染」「動態」「移行係数」「外部被ばく」「セシウム」「ストロンチウム」「ヨウ素」「その他核種」

「土壌」を検索すると　課題名、年、機関、代表者、文献名などの情報掲載。

用語集

放射線測定器や除染技術などの放射能汚染と農業に関する101の用語を、写真を用いて解説。

刊行物

一般図書、ガイドライン、研究報告書、シンポジウム要旨集など。

関連リンク

農業環境における放射性物質の情報収集に役立つリンク先を整理。

国際情報

IAEA、ICRPなどの国際機関が発行する資料など。

新着・イベント情報

行政・研究機関の新着情報とイベント開催案内。

ギャラリー

除染作業や放射線測定などの写真。