§2-5

# Physiology of radiocesium uptake by flooded rice

S. Uematsu[1, 2], H. Vandenhove[1], L. Sweeck[1], E. Smolders[2]

[1] Biosphere Impact Studies, SCK•CEN & [2] KU Leuven
suematsu@sckcen.be

FAO/IAEA-NARO Technical Workshop
17 October 2016, IAEA, Vienna

SCK•CEN ACADEMY FOR NUCLEAR SCIENCE AND TECHNOLOGY

SCK•CEN STUDIECENTRUM VOOR KERNENERGIE CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

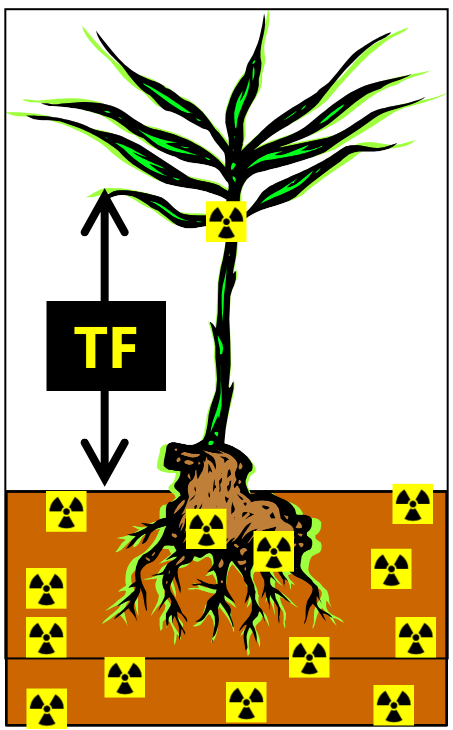
KU LEUVEN

# Long-term risks after the Fukushima accident

- Large-scale contamination of the top layer of arable soils:

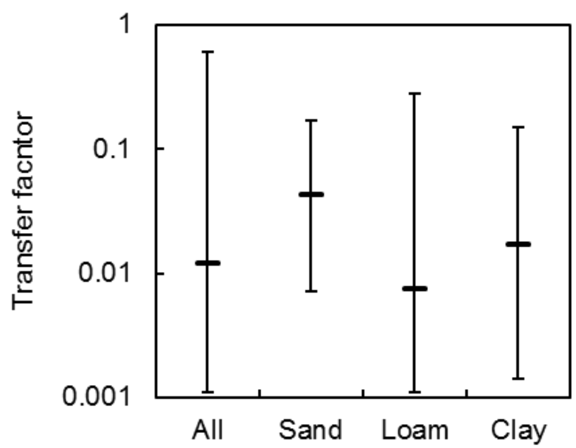
  ($^{137}$Cs + $^{134}$Cs) > 5000 Bq kg$^{-1}$ soil **75 km$^2$** (Dec 2012)

- Soil-plant radiocesium (RCs) transfer



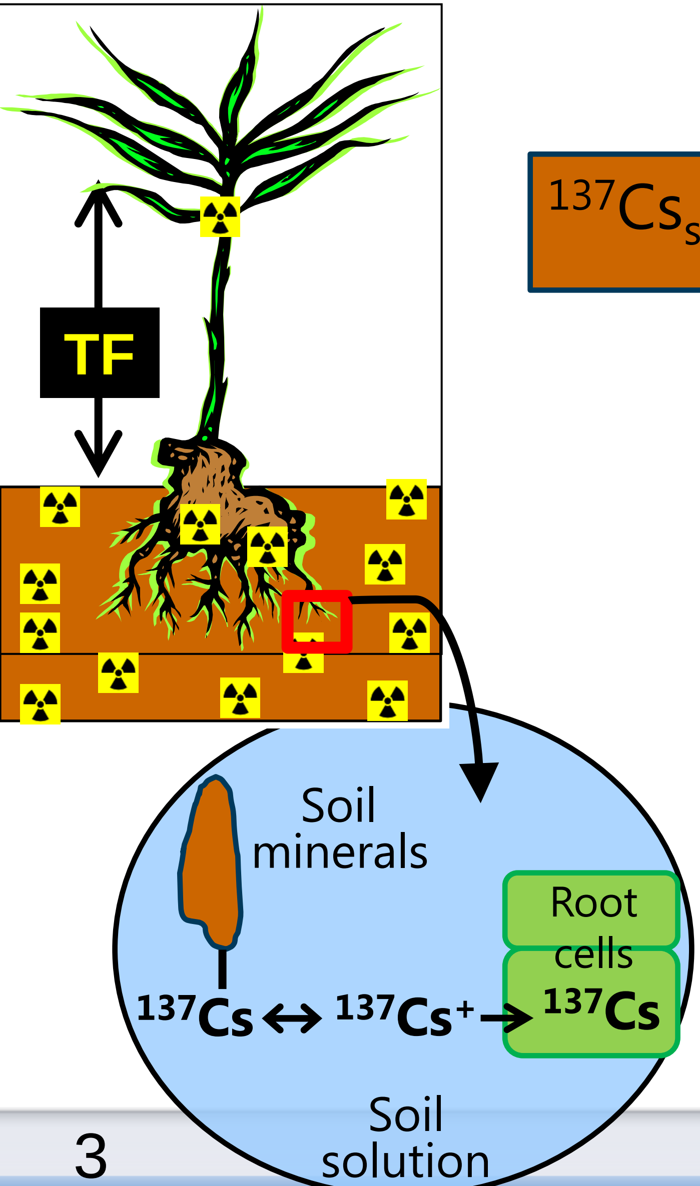

$$\text{Transfer factor (TF)} = \frac{\text{RCs in plant (Bq/kg)}}{\text{RCs in soil (Bq/kg)}}$$

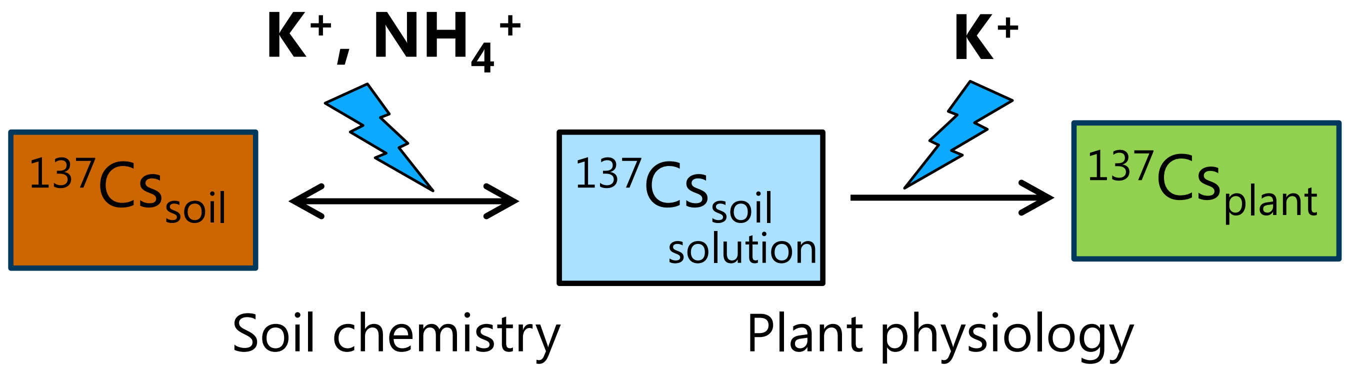
TF to brown rice




IAEA TECDOC-1616 (2009)

# Known mechanisms of RCs behaviour




- Potassium (K) plays a double and counteracting role on RCs transfer.
- $NH_4$ competes with RCs sorption in soils, does not affect plant RCs uptake.

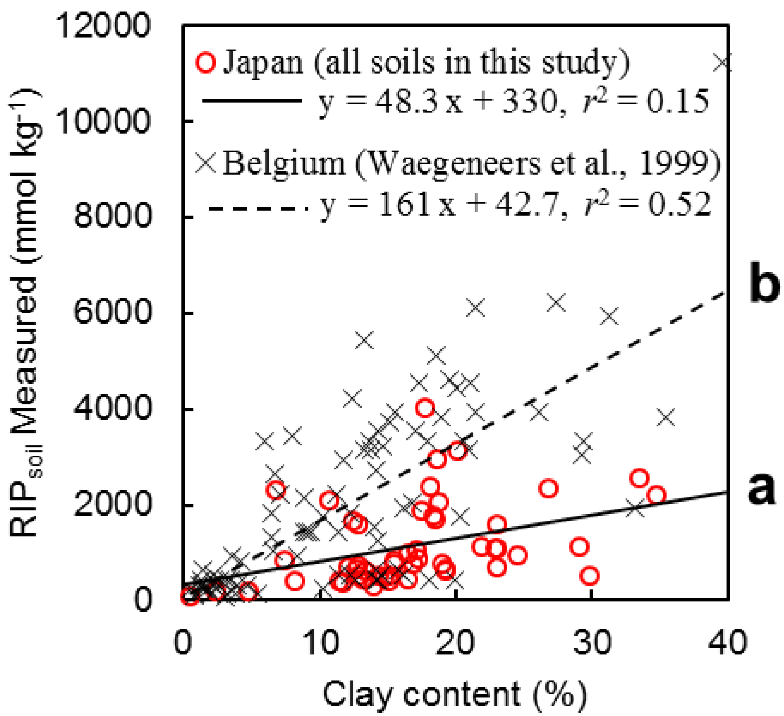
→ Existing models predict RCs transfer using soil %clay and exchangeable K for European soils and crops.

# Hypotheses & research questions

What is ‘new’ in Fukushima?

## 1. RCs sorption in soils

(soil mineralogy)

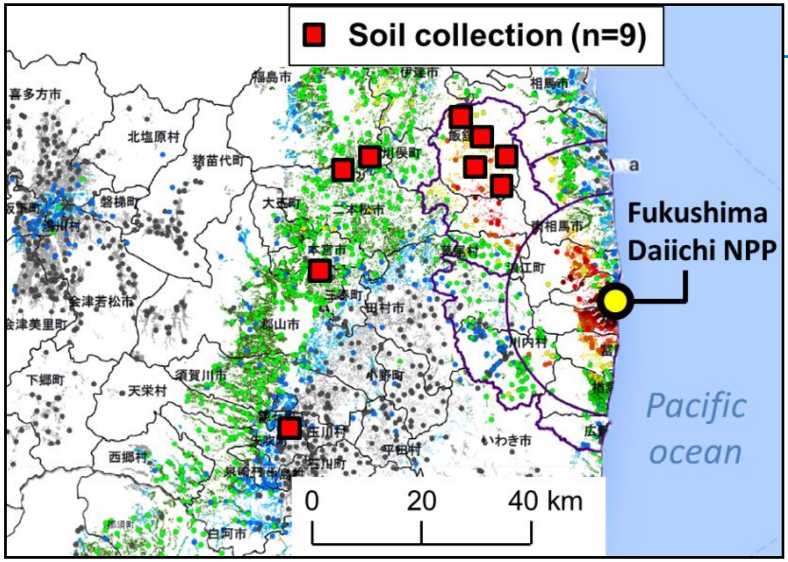



Uematsu *et al.* (2015) *Sci. Total Env.*

## 2. Rice grown in flooded soils

- Higher TF may be expected for rice than ryegrass due to the role of **$NH_4$** on mobilising RCs in soils.
- Is the mechanism of RCs transfer to flooded rice same as the mechanism known for European soils and crops?

# Potted soil transfer studies




Paddy soils ($N$=9)

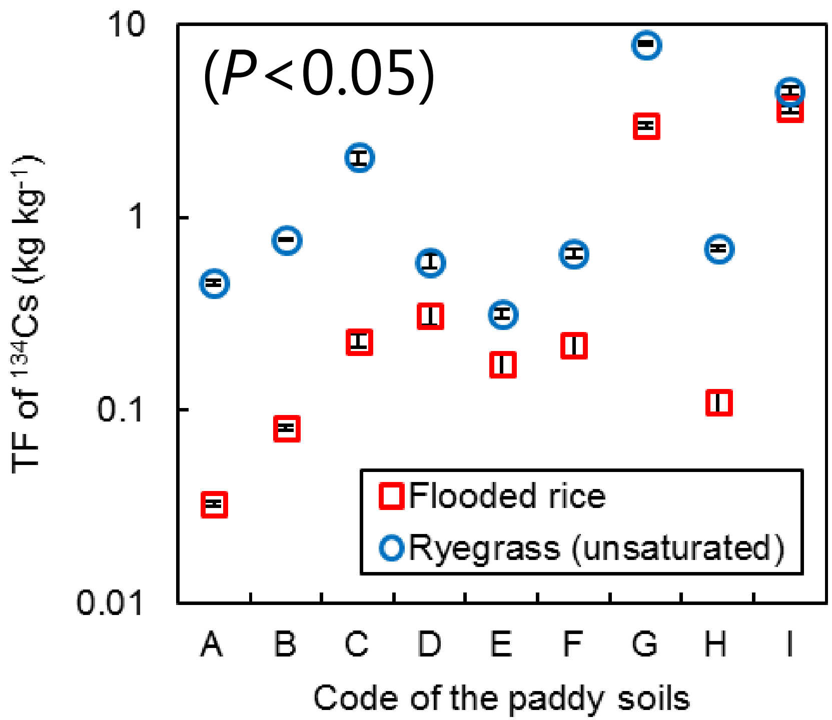
$^{134}$Cs, 4-wk incubation

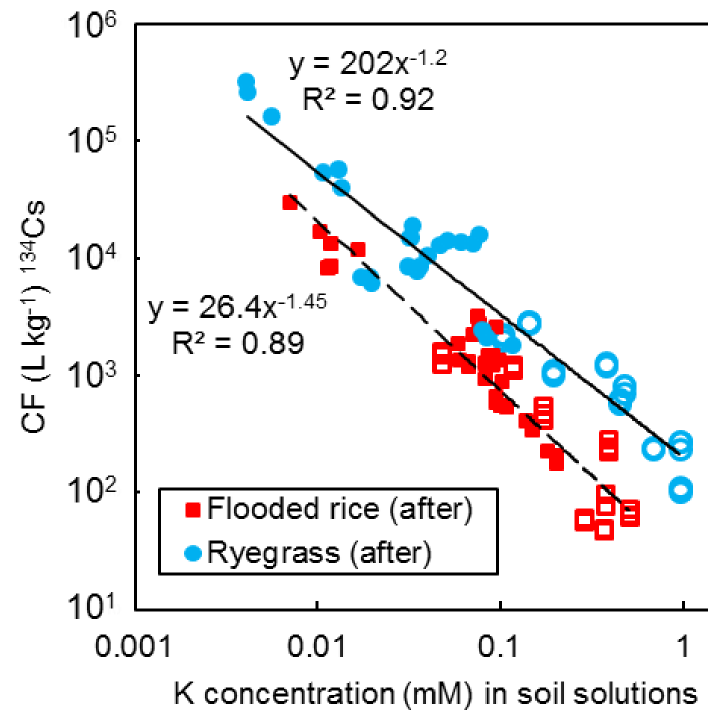
Rice growth (flooded soils)

Ryegrass growth (unsaturated soils)

- Soil and shoot analysis ($^{134}$Cs)
- Soil solution analysis ($^{134}$Cs, $NH_4$ and K)
- Soil exchangeable K and RIP

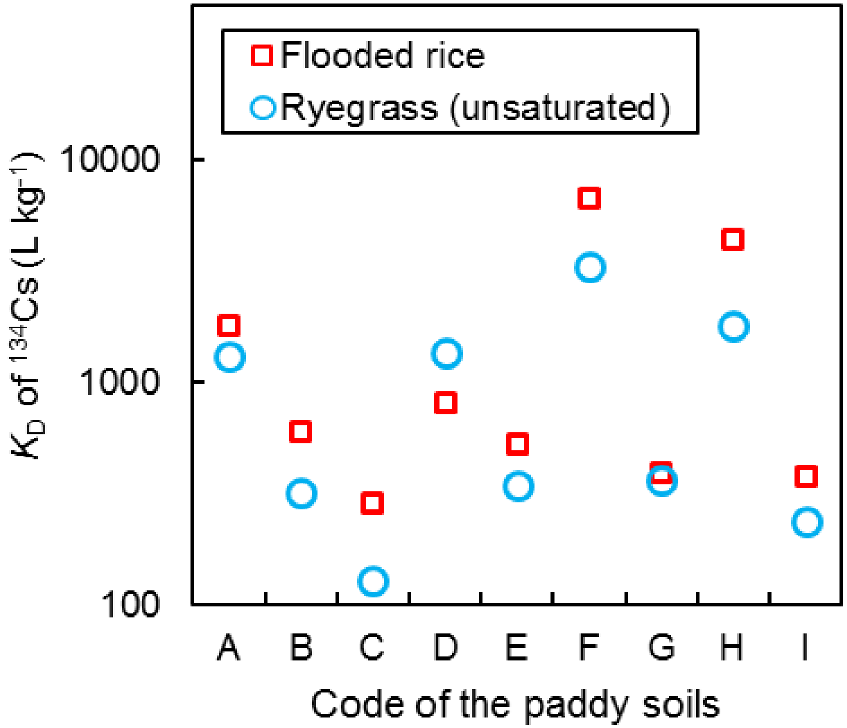
# Soil-plant transfer factor of RCs

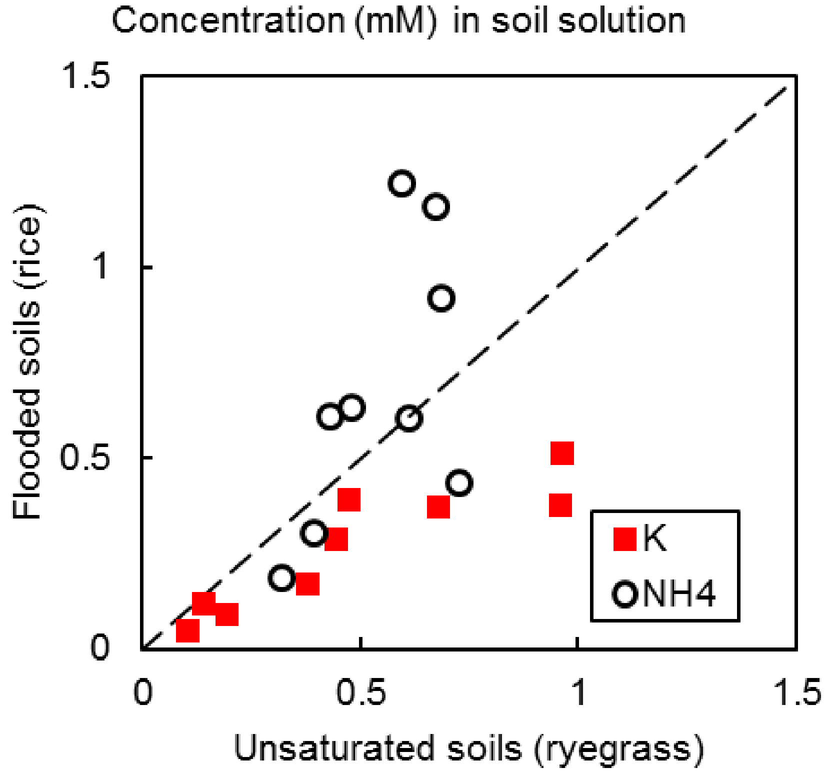



- The TF for flooded rice was significantly lower than the TF for ryegrass.
- This can be attributed to the higher root uptake of RCs and higher translocation to shoots for ryegrass than rice.

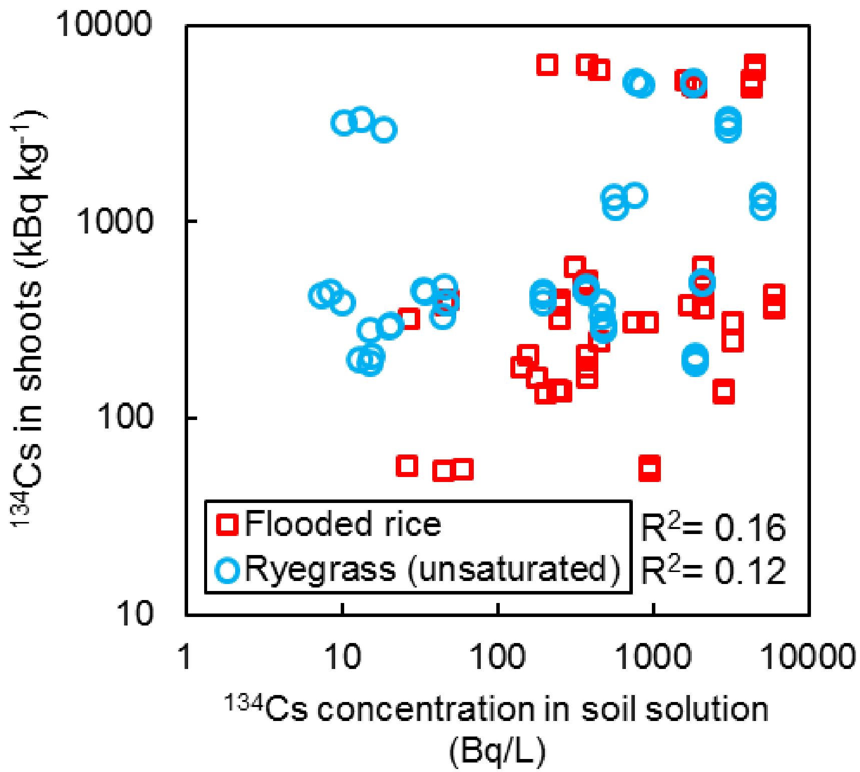
# Sorption of RCs in soils

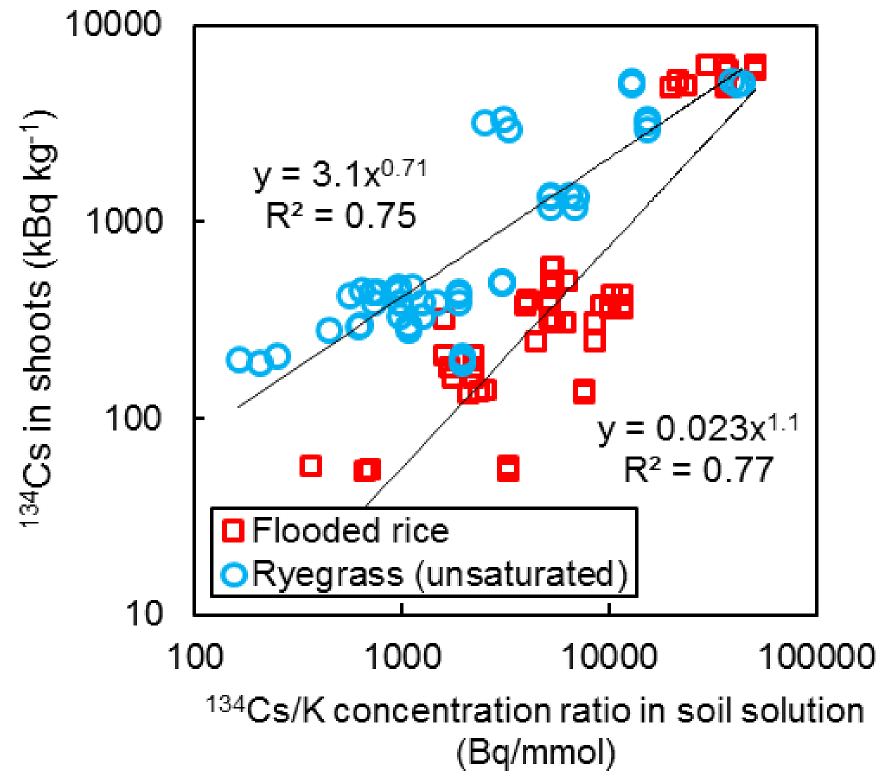



- $NH_4$ was accumulated in the flooded soils.
- Dilution of K and $NH_4$ in soil solutions in flooded soils increased the RCs sorption compared to unsaturated soils.

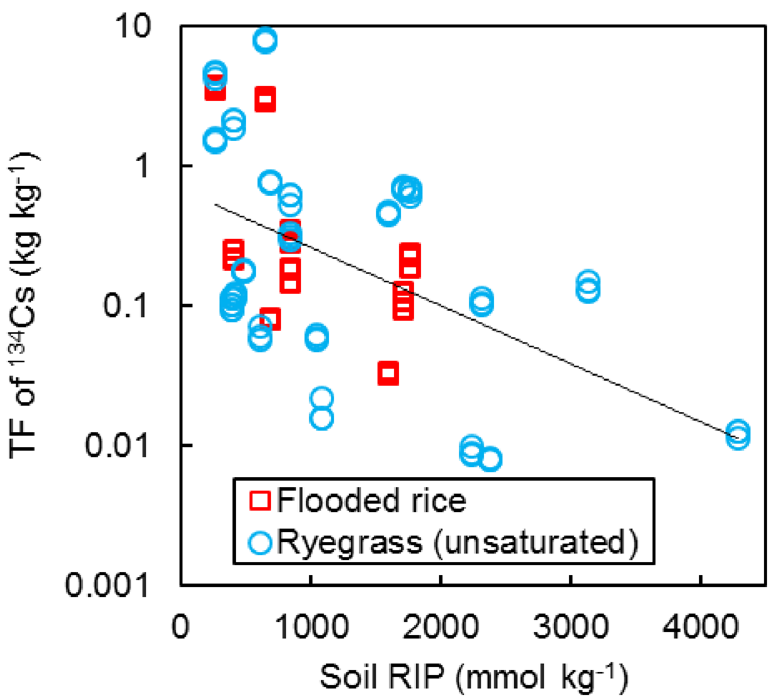
# Plant availability of RCs

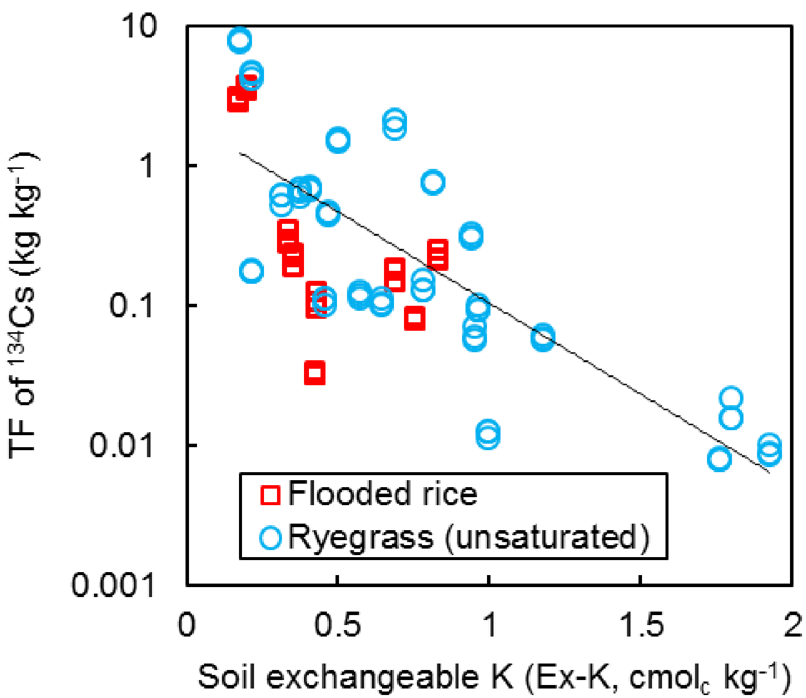



- The $^{134}$Cs concentration in the shoots was correlated to the $^{134}$Cs/K ratio in the soil solution.

# Regression model predicting the RCs transfer




$$\log(\mathrm{TF}) = 0.88 - 6.9\times10^{-4}\,\mathbf{RIP} - 2.5\,\mathbf{Ex\text{-}K} + \begin{cases} -0.33 \text{ (if } \mathbf{rice}) \\ 0.33 \text{ (if } \mathbf{ryegrass}) \end{cases}$$

($R^2 = 0.66$)

- The regression confirmed the lower TF for flooded rice compared to ryegrass ($P<0.05$).

# Conclusions and prospects

1. Flooded rice was less vulnerable for radiocesium (RCs) transfer than ryegrass, due to the lower uptake of RCs and translocation to above-ground parts by rice than ryegrass.

2. The RCs sorption in soils was more influenced by the dilution of K and $NH_4$ at saturated conditions than by the accumulation of $NH_4$ in soil solutions.

3. The existing models predicting RCs transfer for ryegrass need to be recalibrated to account for the RCs sorption in flooded soils and for the RCs root uptake by rice.

# Thank you for your attention.

**Acknowledgements**:
A PhD scholarship from the Flemish Government.
Researchers and farmers for their help in our soil sampling.

Drs. N. Yamaguchi, I. Taniyama, T. Ohkura (NIAES)

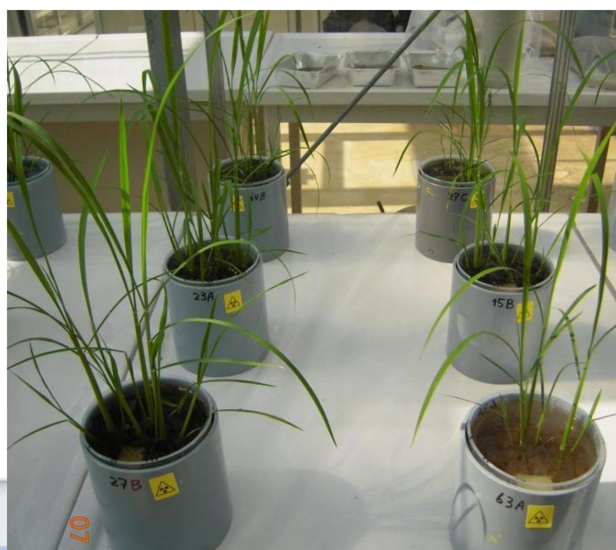
Dr. K. Noborio (Meiji Univ.)

Drs. T. Saito, K. Yoshioka, T. Saitou, I. Arakawa (Fukushima Agri. Tech. Cent.)

Dr. T. Ota (Tohoku Agri. Res. Cent.)

Drs. T. Nishimura, M. Mizoguchi, K. Nemoto, Resurrection of Fukushima (The Univ. of Tokyo)

Drs. D. Yamada, H. Harada (Livestock & Grassland Sci.)



**SCK•CEN**
Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire
Belgian Nuclear Research Centre

Stichting van Openbaar Nut
Fondation d'Utilité Publique
Foundation of Public Utility

Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSELS
Operational Office: Boeretang 200 – BE-2400 MOL

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE