Mitigation of radioactive cesium transfer from soil to plant

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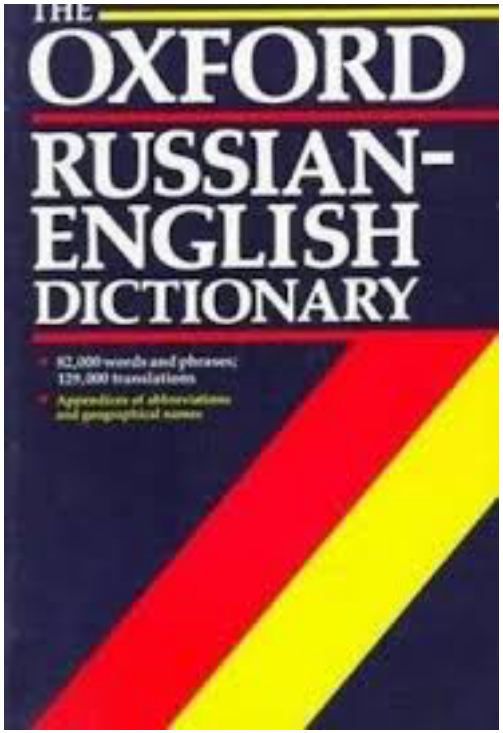
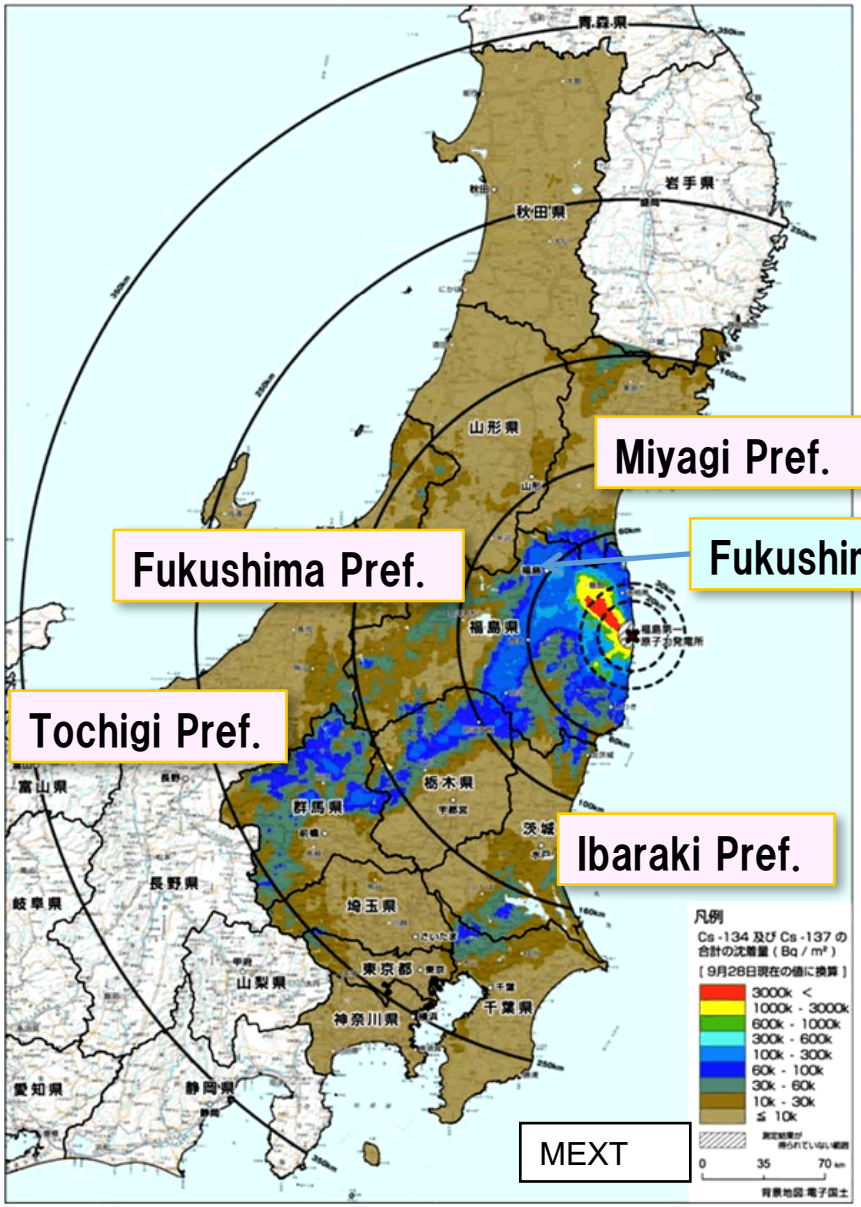
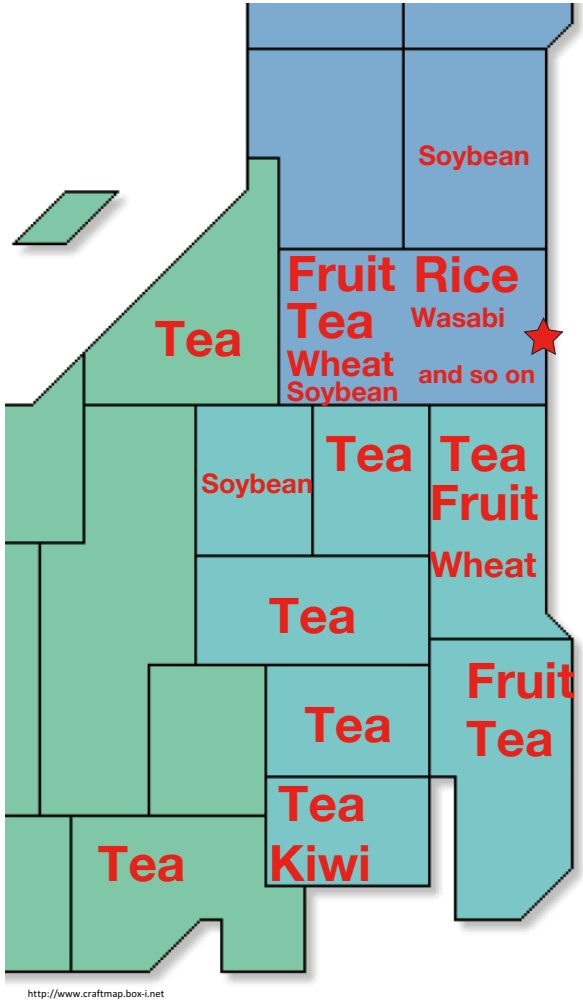

THE
OXFORD
RUSSIAN-
ENGLISH
DICTIONARY

Distribution of Radioactive Cesium

文部科学省による新潟県及び秋田県の航空機モニタリングの測定結果について（文部科学省がこれまでに測定してきた範囲及び新潟県及び秋田県内の地表面へのセシウム134、137の沈着量の合計）



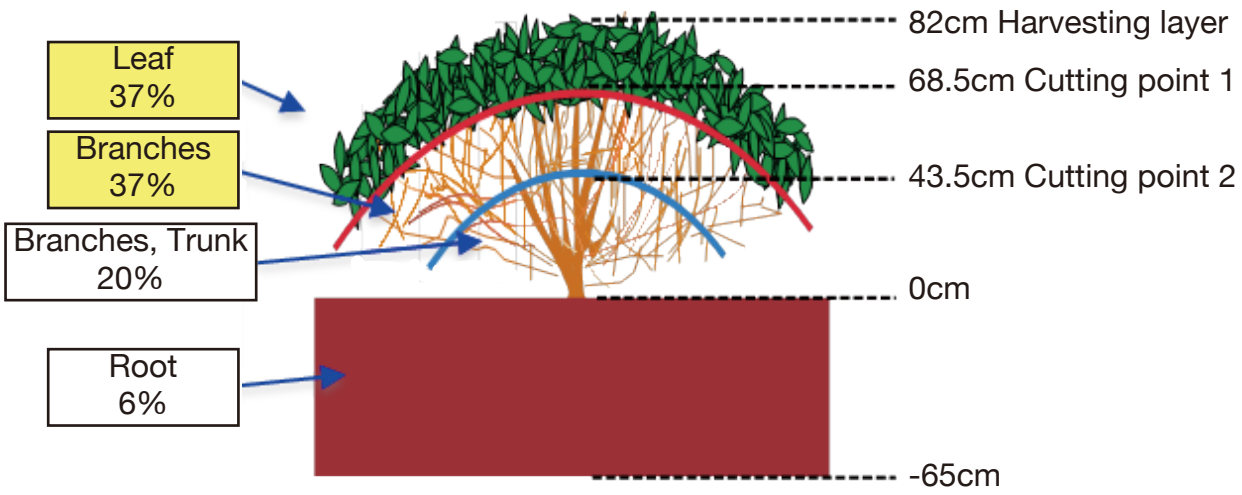


http://www.city.iruma.saitama.jp/kankou/genkinairuma.html

View of Tea tree in Tokyo (March)

View of Persimmon tree in Fukushima (March 2nd)

Decontamination of tea trees

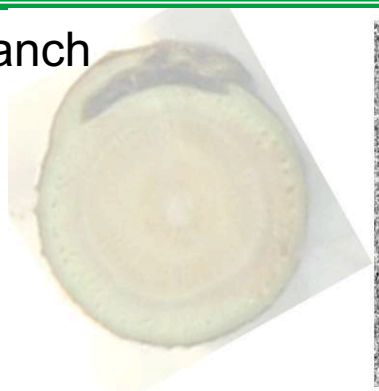


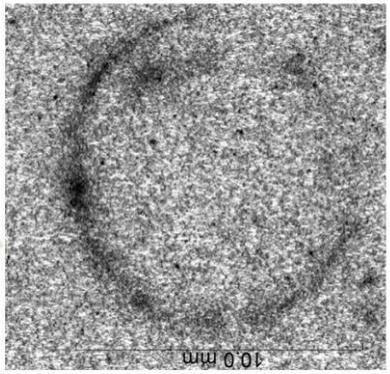
- **74 % of the radioactive cesium is found over cutting point 2. Most effective method is to cut off the leaves and branches over cutting point 2.**

(Kanagawa Pref.)

NARO Institute of Vegetable and Tea Science

Section of peach branch





Radioactivity image by imaging plate

Trunk of peach tree

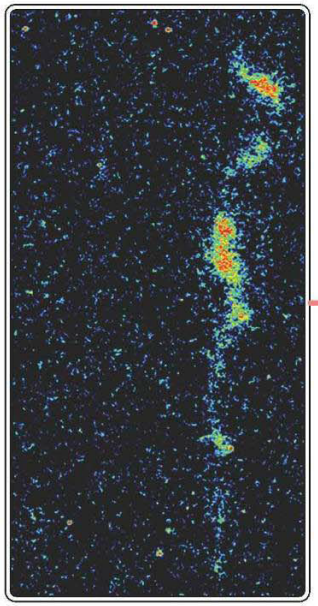


Image of radioactivity distribution by IP

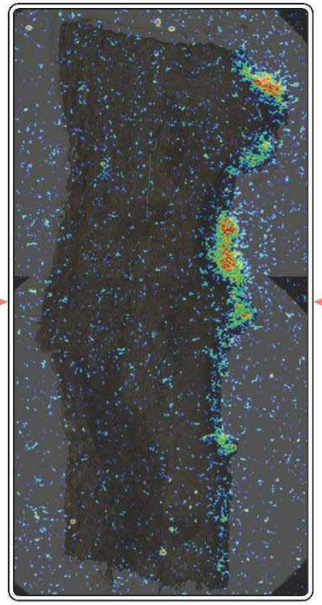


Image of superposition

Image of optical micro-scope

http://www.a.u-tokyo.ac.jp/rpjt/event/2012120802-slide.pdf

Fukushima Agricultural Technology Center

Bark removal / high pressure water cleaning

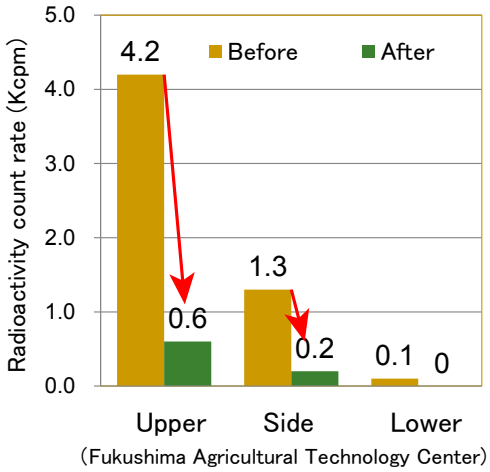
By hand

High pressure washer

Peach, Apple,
Persimmon, Grape,
Pear…

5 to 10 hours for 10 a orchard with 1,000 to 3,000 liter of water

http://item.rakuten.co.jp/hana-online/shibugaki_atago/



Decontamination of pair tree by scraping off the bark of pair treee

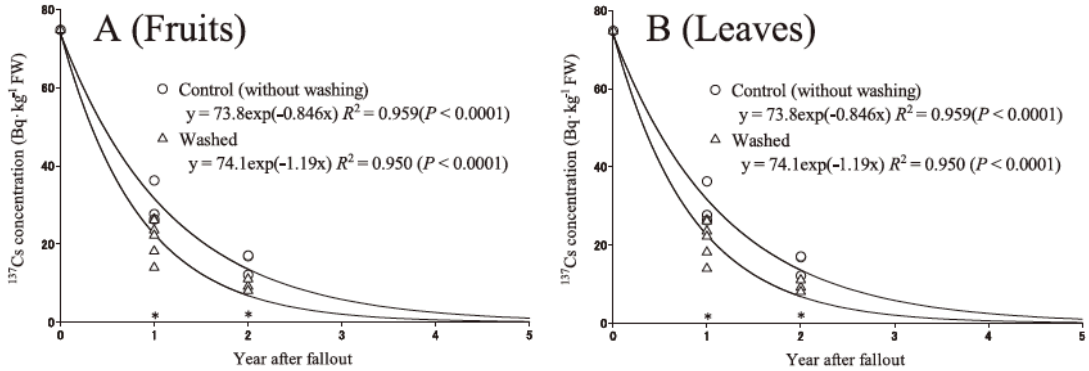


Fig. 2. Comparison of the exponential equation model of temporal changes in ^{137}Cs concentration in Japanese persimmon fruits (A) and leaves (B) by bark-washing decontamination. The equation was deduced by the least-squares method, using fruit (A) and leaf (B) data at harvest. Data for 2011 were from one sample combining five trees prior to washing. Data for 2012 were from three control trees and six washed trees. Data for 2013 were from three trees of each treatment in 2013 in Japanese persimmon 'Hachiya'. * and ** indicate significant difference between treatments at $P < 0.05$ and 0.01 by t-test.

View of typical field area in Fukushima (March 2011)

Field condition at the event

Paddy fields were before tillage. Seedling for transplanting did not start yet.

Upland fields were before tillage except for Winter wheat and pasture.

http://www5b.biglobe.ne.jp/~jakot/hhy_3/

Rice production

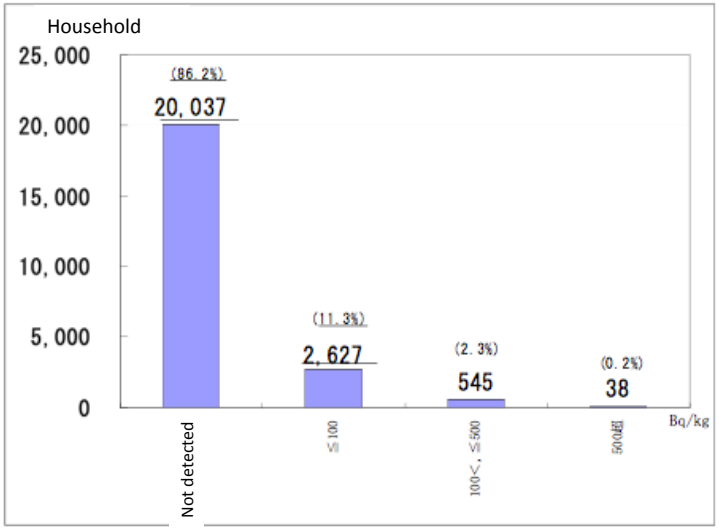
Seedling is prepared in greenhouse in April.
Paddy field is prepared in May.

Rice production is the major concern to farmers, consumers, and authorities.
Based on literature surveys only limited number of information can be obtained.
(Tensho et al. 1959, 1961, Tsumura et al. 1984, Yonezawa and Mitsui 1965)

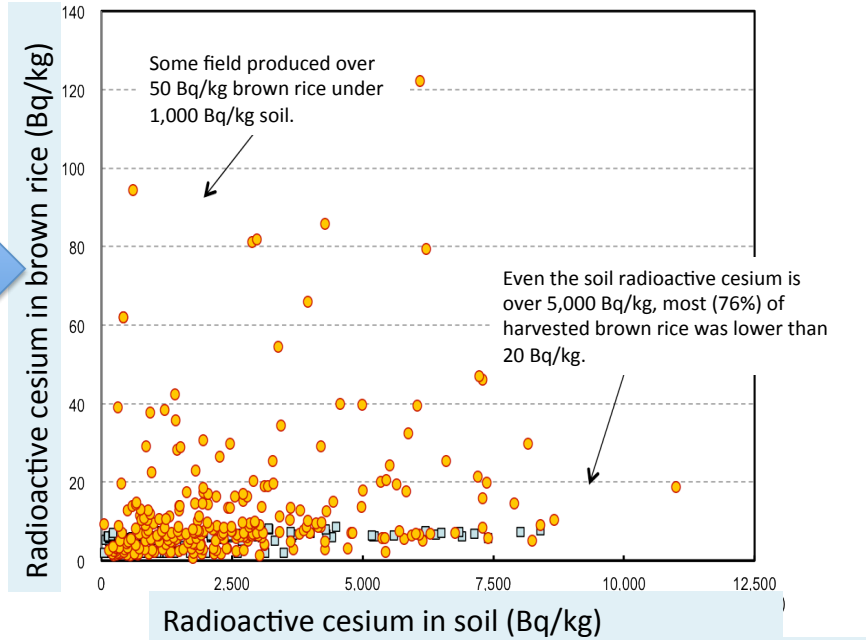
Based on the survey, the highest transfer factor of rice was determined as 0.1 and as the provisional regulation value for rice was set to 500 Bq/kg in 2011, Those field with radioactive cesium content lower than 5,000Bq/kg, were allowed to plant rice.
(The standard value was set to 100 Bq/kg from 2012)

TF = 0.1, Soil radioactive Cs < 5,000 Bq/kg means Brown rice radioactive Cs < 500 Ba/kg

$$\text{Transfer factor (TF)} = \frac{\text{radioactive Cs content of Brown rice}}{\text{radioactive Cs content of soil}}$$



Radioactive cesium concentration of brown rice grown in Fukushima Prefecture, cultivated in 2011 outside of Special Decontamination Area (Fukushima Pref. 2012.)

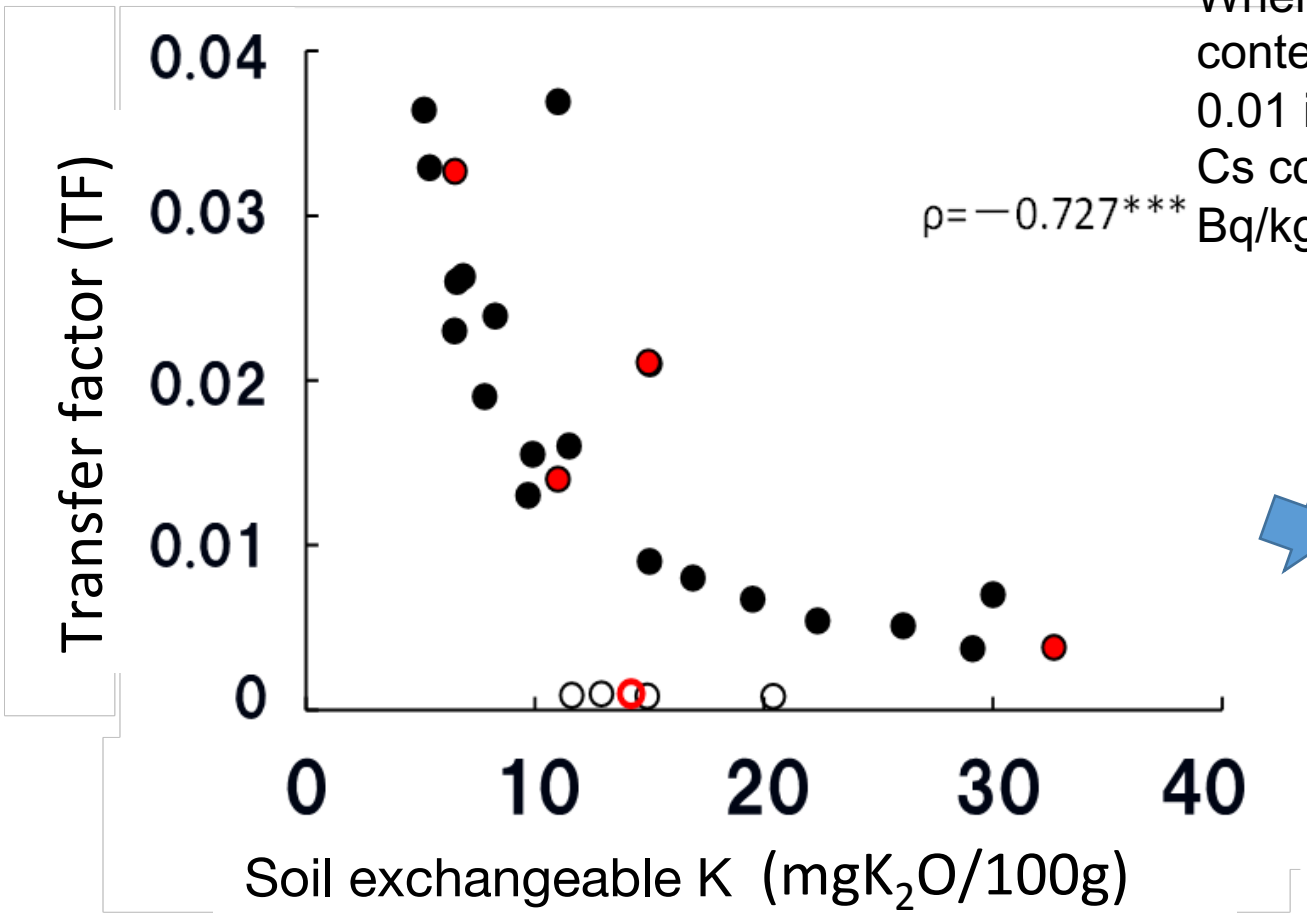


(MAFF, Fukushima Pref)

Mitigation of Cs transfer to brown rice by potassium(K)

Transfer factor is negatively correlated with Soil exchangeable K.

TF= Radioactive Cs content in plant / Radioactive Cs content in soil



When the soil radioactive Cs content is 5,000 Bq/kg, TF 0.01 indicates the radioactive Cs content of brown rice is 50 Bq/kg.

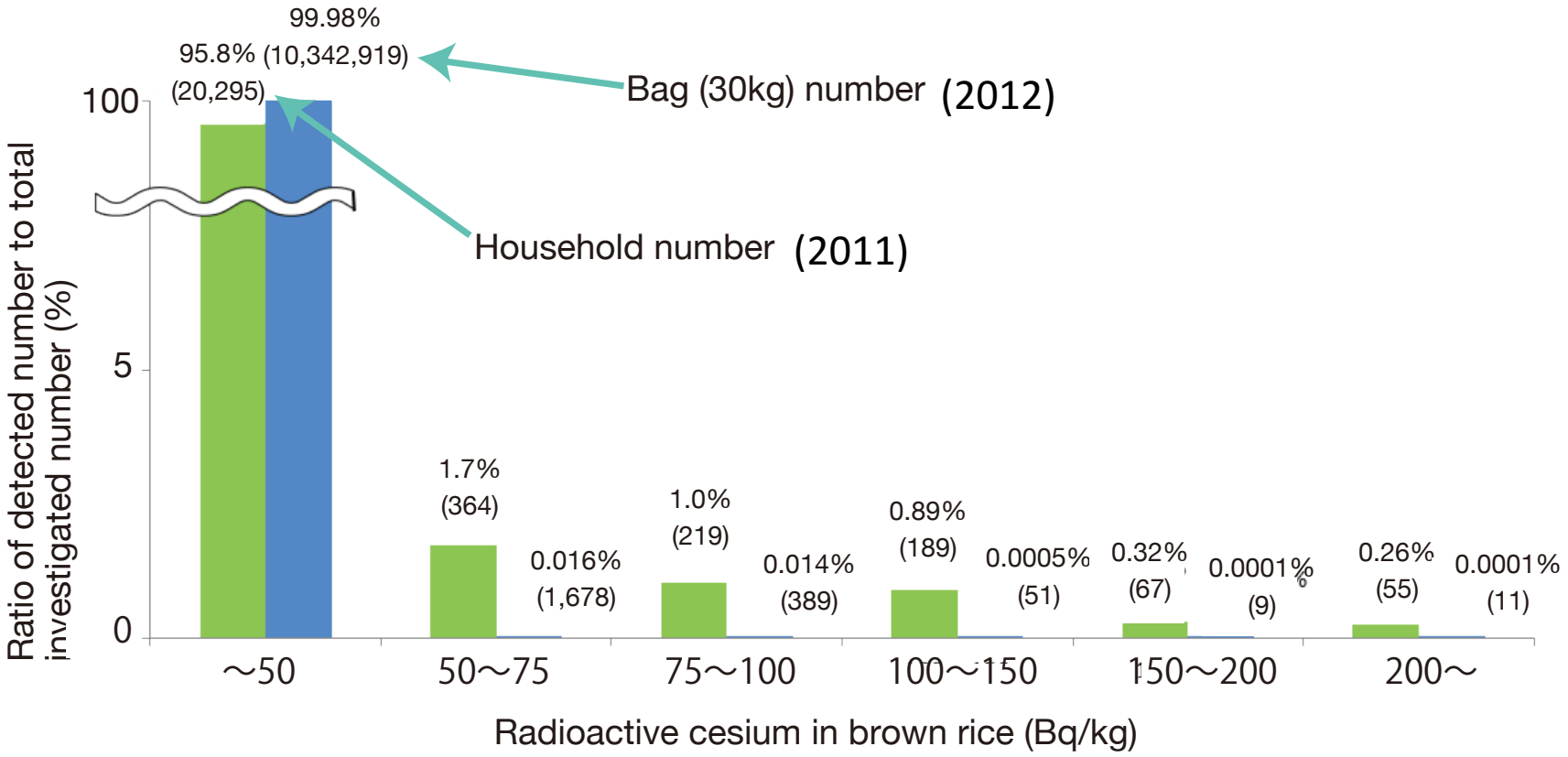
Soil exchangeable K is set to 25 mgK_2O/100g

Used for the guideline of rice cultivation in 2012

http://wwwcms.pref.fukushima.jp/download/1/youinkaiseki-kome130124.pdf

Mitigation of Cs transfer to brown rice by K

Screening inspection is conducted on all rice bags produced in Fukushima prefecture since FY 2012.



In 2012, 71 bags out of 10,342,919 bags were over 100 Bq/kg (0.0007%).

Decontamination of K application

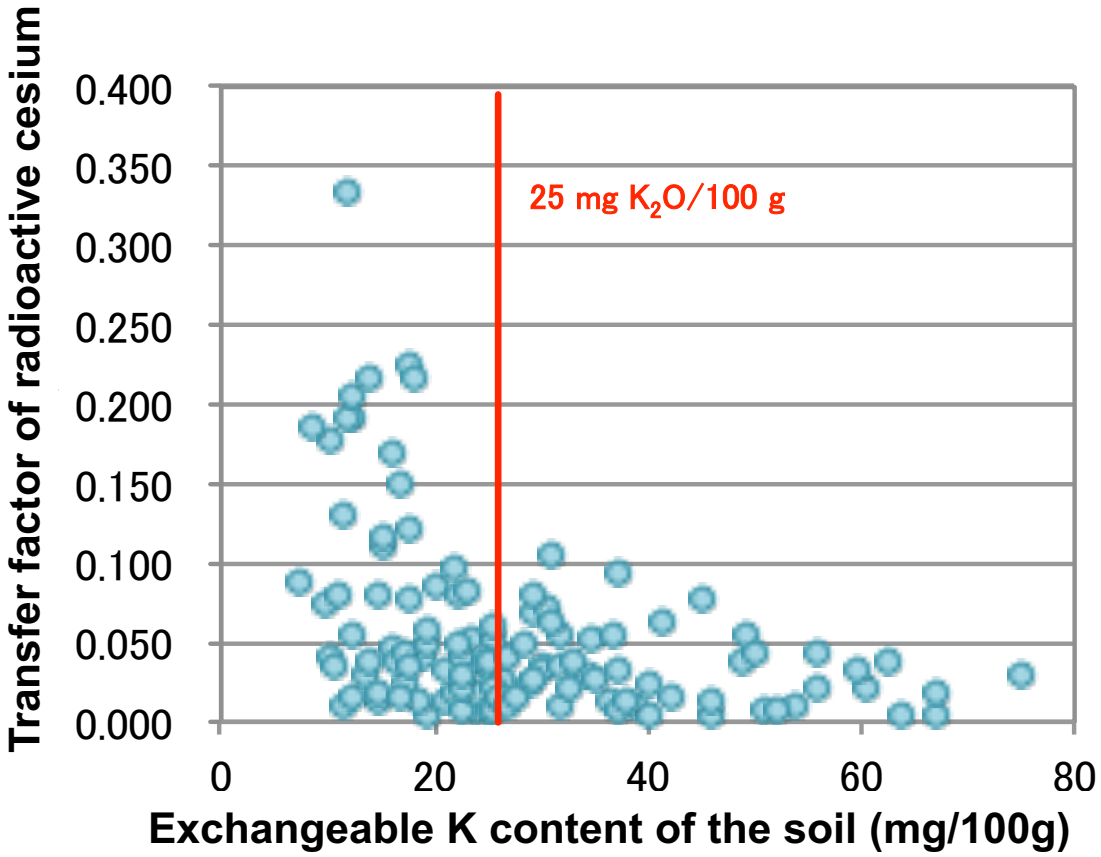
Changes of the radioactive Cs concentration of brown rice after 2011.3.11 (30kg bag) (Fukushima prefecture)

		≤ 50 Bq/kg	51–75 Bq/kg	76–100 Bq/kg	100 Bq/kg <	Monitored number
FY 2011	actual no.	20,295	364	219	311	21,189
	ratio (%)	95.78%	1.7179%	1.0336%	1.4677%	100%
FY 2012	actual no.	10,343,548	1678	389	71	10,345,686
	ratio (%)	99.98%	0.0162%	0.0038%	0.0007%	100%
FY 2013	actual no.	10,951,351	492	323	28	10,952,194
	ratio (%)	99.99%	0.0045%	0.0029%	0.0003%	100%
FY2014	actual no.	11,014,636	1	1	2	11,014,640
	ratio (%)	100%	0.00001%	0.00001%	0.00002%	100%
FY 2015	actual no.	10,498,325	4	0	0	10,498,329
(2016.10.01)	ratio (%)	100%	0.00004%	0	0	100%

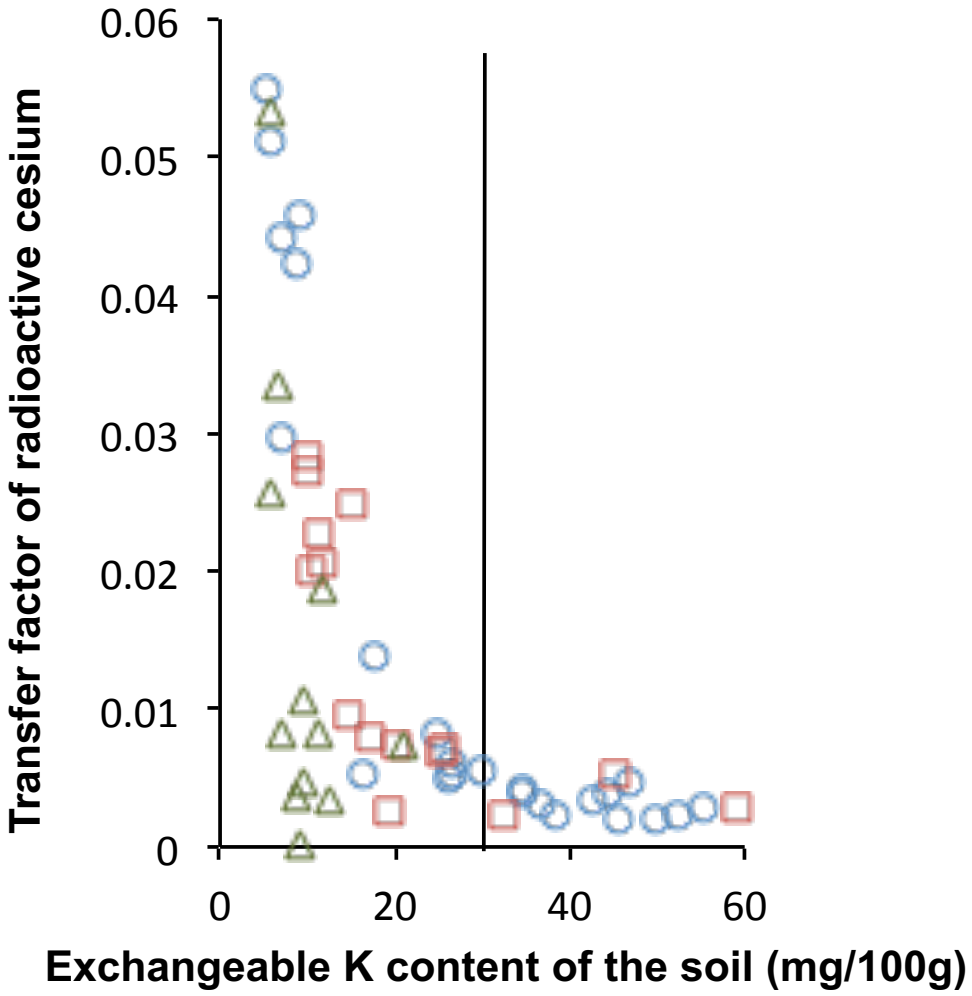
A total of paddy fields under usage.

But this does not mean that it is free for cultivation of rice in Fukushima.

Soybean


Transfer factor of radioactive cesium
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
25 mg K_2O/100 g
0
20
40
60
80
Exchangeable K content of the soil (mg/100g)

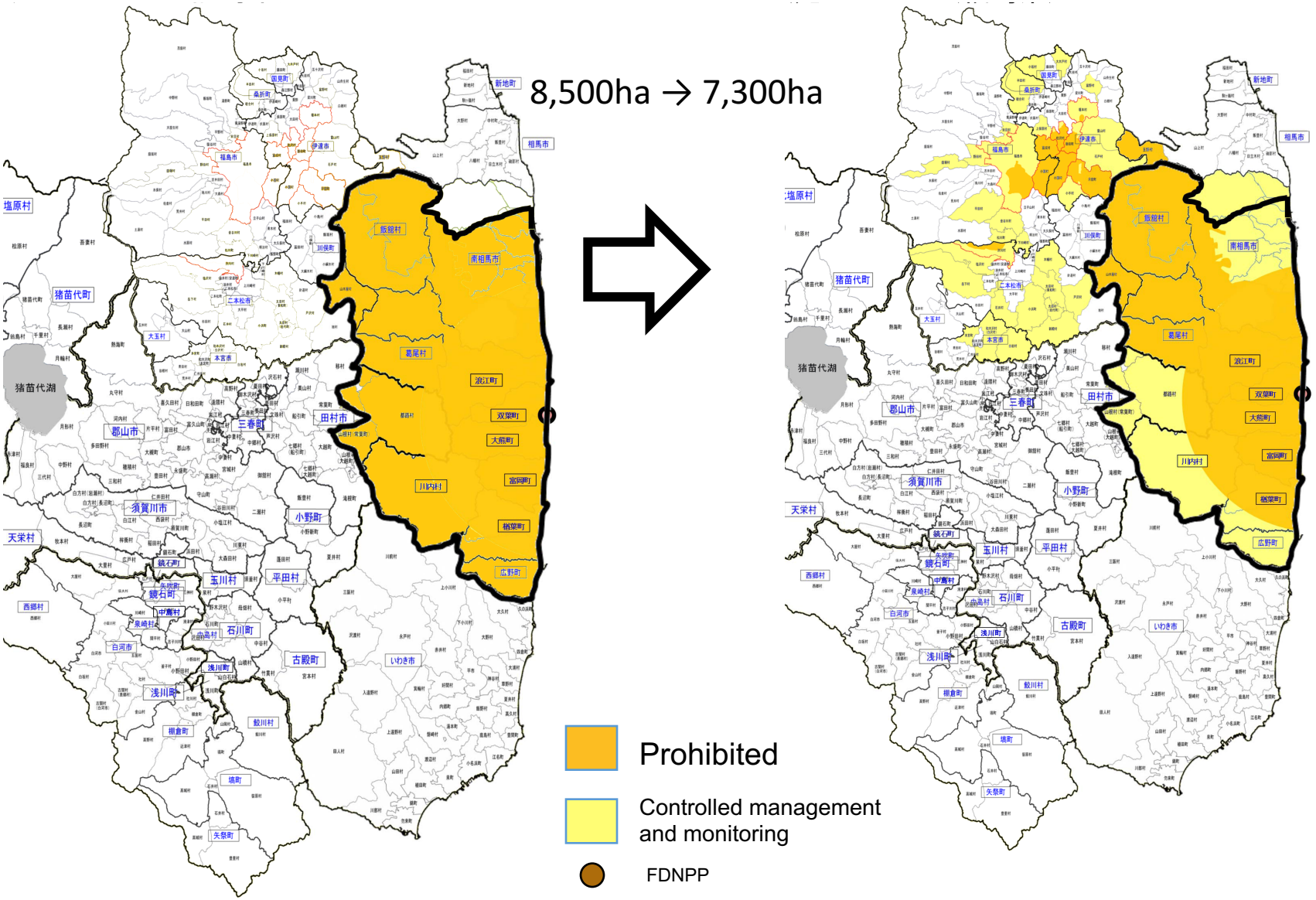
Buckwheat


0.06
0.05
0.04
0.03
0.02
0.01
0
Transfer factor of radioactive cesium
0
20
40
60
Exchangeable K content of the soil (mg/100g)

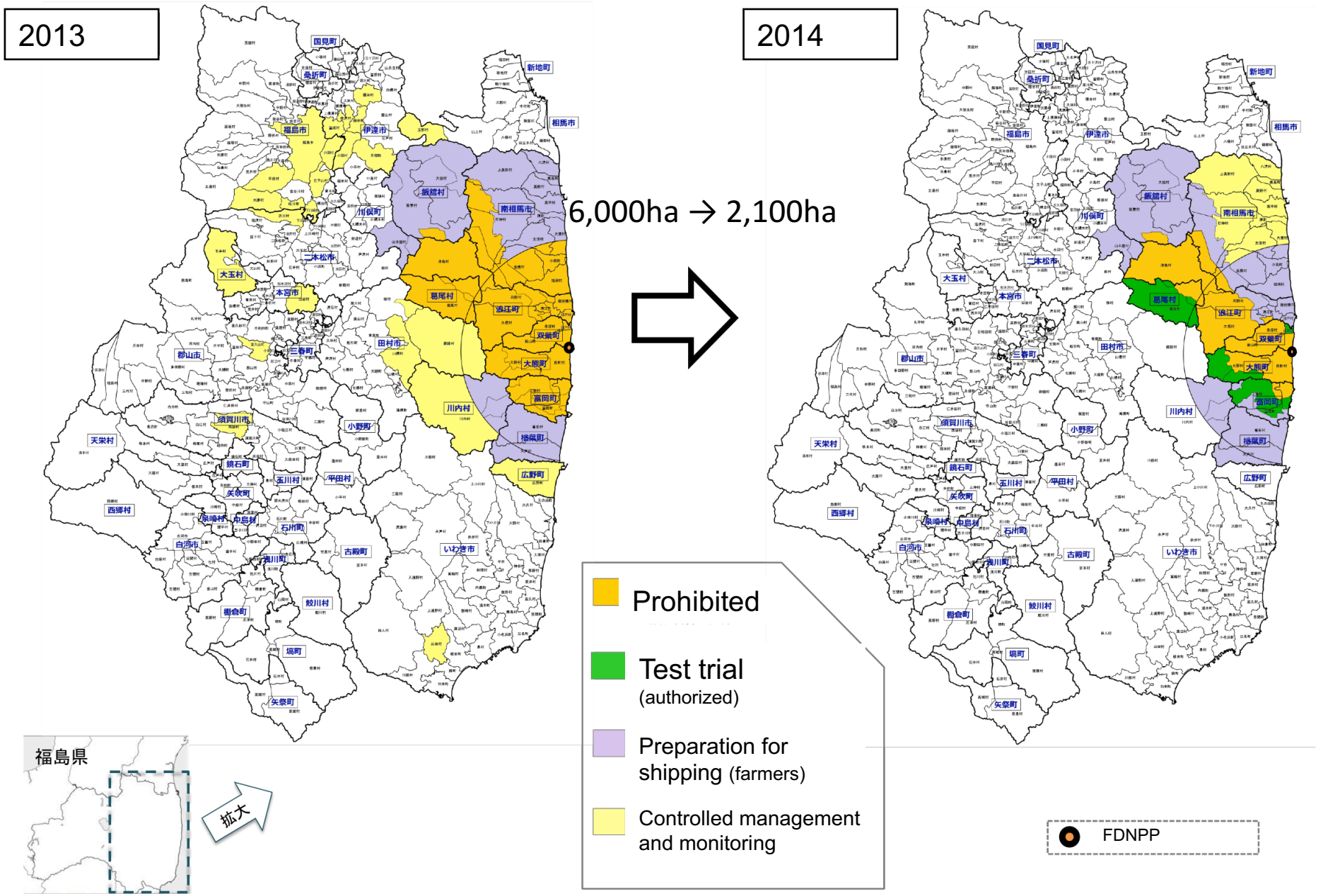
Restricted area for rice production (2011, 2012)

2011

2012



Restricted area for rice production (2013, 2014)

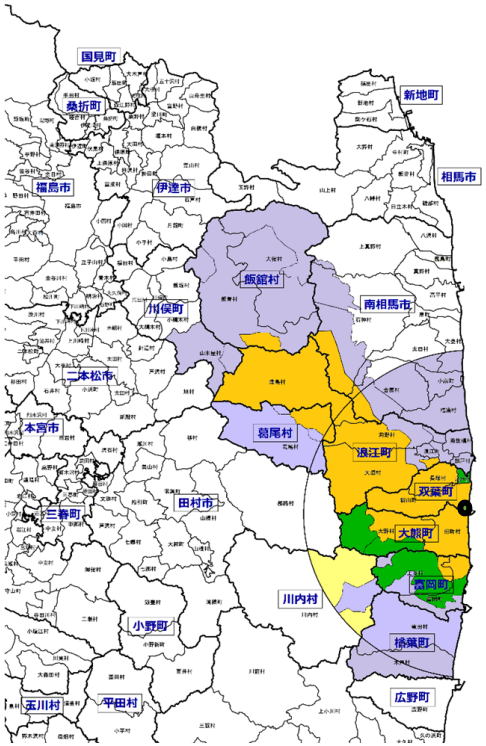


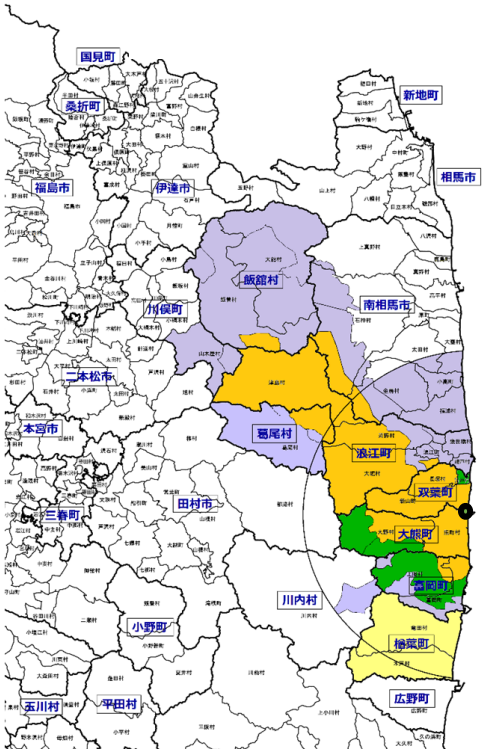
Restricted area for rice production (2015, 2016)

2015

2016

2,100ha → 2,100ha





- Prohibited
- Test trial (authorized)
- Preparation for shipping (farmers)
- Controlled management and monitoring
- FDNPP

福島県

拡大

（MAFF）


CAT


Paddy field is used to collect
removed topsoil from other paddy
field.

10m x 10m x 5cm x ca 1.0 g/cm3 = ca. 5 ton

Neighboring mountainous soil (mainly degraded granite rock) is used for dressing.

1) Poor fertility
2) Remained radioactivity
3) Management of field until the initiation of agriculture is required

Chemical properties of additional soil

Location	Sample number	Total N (%)	Humus content (%)	pH (H_2O)	Exchangeable K (K_2O mg/100g Soil)	Available P (P_2O_5 mg/100g Soil)	CEC (me/100g Soil)
Iitate, Komiya	1	0.02	0.1	6.5	7	10	7
Iitate, Komiya	2	0.03	0.5	6.4	5	15	5
Iitate, Komiya	3	0.04	0.9	6.3	8	16	6
Iitate, Kusano	4	0.01	0.2	6.7	5	16	4
Iitate, Kusano	5	0.02	0.1	6.7	4	16	5
Iitate, Kusano	6	0.02	0.4	6.7	6	20	5
Iitate, Nagadoro	7	0.02	0.2	6.8	5	21	4
Iitate, Nagadoro	8	0.02	0.2	6.5	5	18	5

Tohoku Agricultural Research Center, NARO, Naigai Corp.

Low fertility
Soil erosion
Invasion of weed
Invasion of wild animals
▪
▪

Once again

Decontamination DOES NOT MEAN complete removal of radioactive materials from the field.

It is barely achieved to control the radioactive Cs content in the food under the standard limit by applying surplus amount of potassium fertilizer.
（Countermeasure for mitigation of radioactive Cs should CARRY ON till the soil radioactive Cs content decrease sufficiently)

Risk occurs in a complex manner. It is necessary to comprehensively consider about soil, water, secondary fall out, etc.

Disaster strikes when you least expect it
(Torahiko Terada, 1878-1925)

Acknowledgements

NARO

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農工研		若杉晃介
中央研		小林有一
中央研		飯嶋渡
中央研		長坂善禎
東北研	福島	竹倉憲弘
畜草研	那須	天羽弘一
畜草研	那須	阿部佳之
農工研		吉本周平
農工研		人見忠良
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中央研		横江未央
東北研	福島	申　文浩
東北研	福島	太田健
畜草研	那須	栂村恭子
中央研		高橋茂
中央研		百瀬浩
中央研		仲谷淳
作物研		近藤始彦
果樹研		草塲新之助
野茶研	金谷	野中邦彦
畜草研	那須	井出保行
畜草研	那須	小林真
畜草研	那須	秋山典昭
畜草研	那須	天羽弘一
畜草研	那須	下田勝久

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食総研		等々力節子
食総研		内藤成弘
食総研		奥西智哉
食総研		濱松潮香
東北研	福島	小林浩幸
東北研	福島	村上敏文
作物研		石川淳子
畜草研	那須	渋谷岳
畜草研	那須	進藤和政
畜草研	那須	平野清
畜草研	那須	須永義人
畜草研	那須	住田憲俊
畜草研	那須	山田大吾
畜草研	那須	阿部佳之
食総研		木村啓太郎
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中央研		竹内正彦
作物研		後藤明俊
野茶研	金谷	廣野祐平
畜草研	那須	小島陽一郎
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東北研	福島	松波寿弥
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東北研	福島	好野奈美子
中央研		髙木恭子
中央研		若林正吉
食総研		八戸真弓
果樹研		松岡かおり

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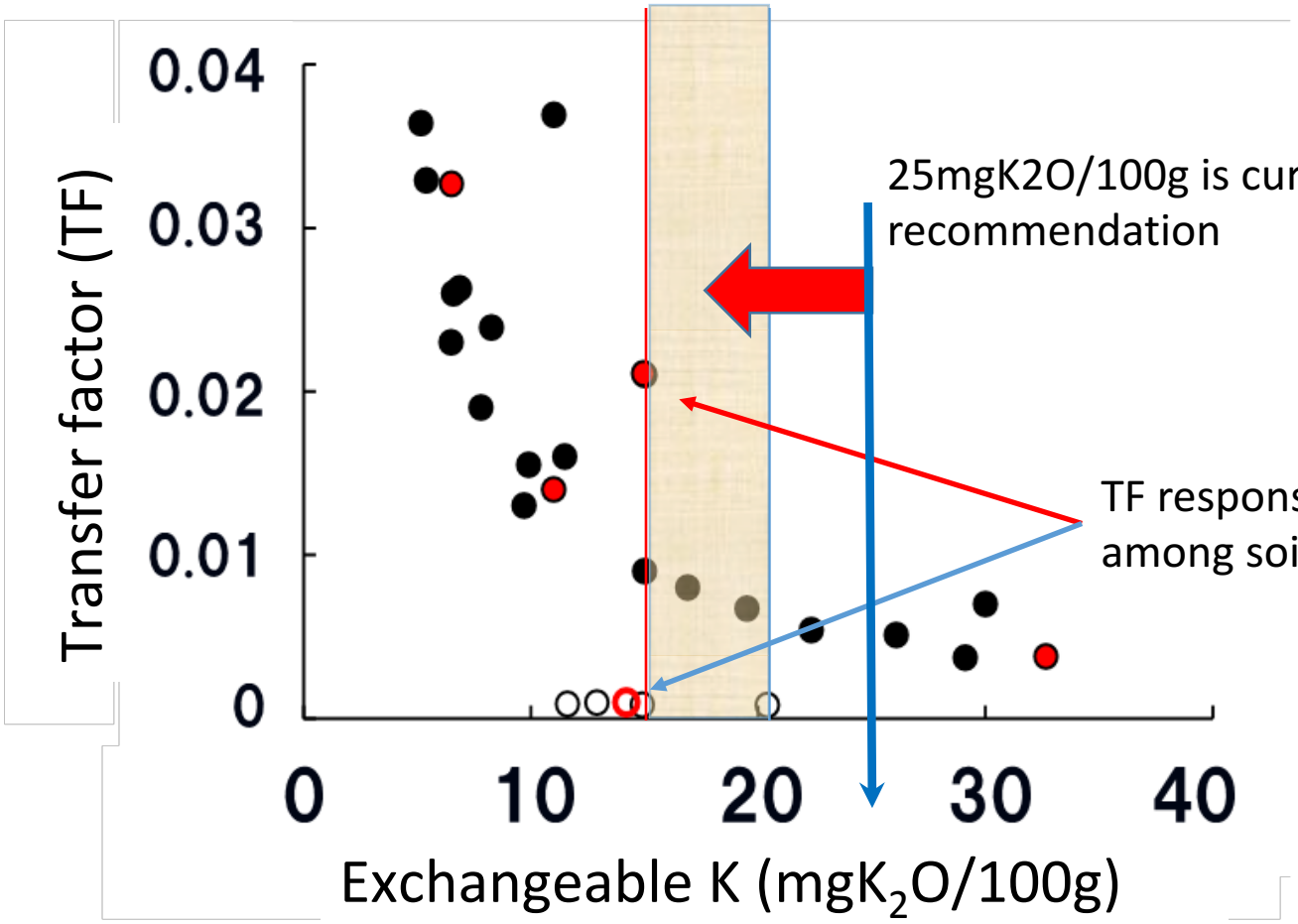
Farmers

Financial supports from
MAFF, MEXT, MOE

Additional slides for answers to queries

Appropriate amount of K application.

Standard fertilization level for potassium is 15-20mgK_2O/100g.



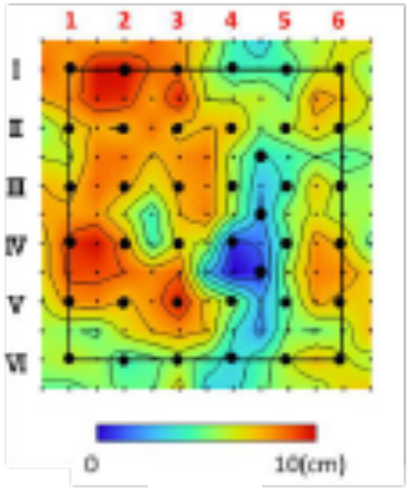
Soil(Bq/kg) x TF < 100(Bq/kg) The uppermost TF value is 0.02, then the soil should be lower than 5,000 Bq/kg.

Top soil removal does not mean complete removal of RCs

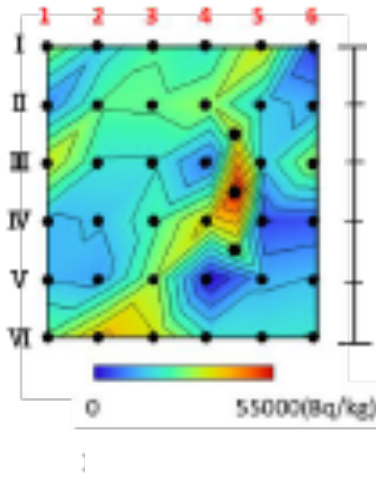
Unevenness of RCs contamination level even in a single plot of field.
Unevenness of the form of RCs fall out (soluble form, aerosol, Cs ball…)
Unevenness of penetration?

Top soil removal (5cm) is not enough to remove all the contaminants.

Soil height (cm)

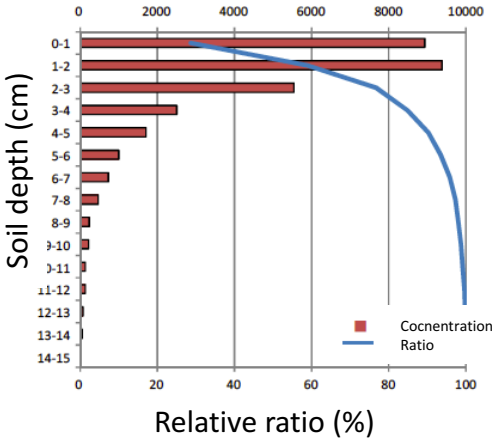


RCs concentration (Bq/kg)

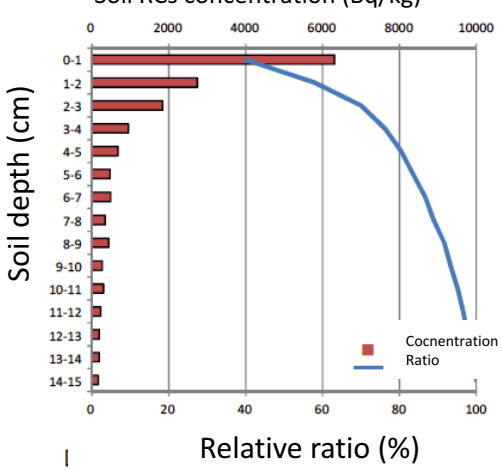


Furuta et al. (2014)

RCs distribution in Field A



RCs distribution in Field B



Saito (2014)

Unevenness of radioactive Cs contamination in a field

Based on instruction, 5 cm top soil removal then 5cm clean soil apply. How this happen?

Instruction for decontamination of agricultural field (Ver. 8)

Top soil removal→Soil dressing→Adjust surface height as original→Recovering fertility→Transfer the field to the farmers.

Instruction for decontamination of agricultural field in Namie town (2015)　The depth of surface soil for removal is 5 cm in average.