環境放射能研究所

INSTITUTE OF ENVIRONMENTAL RADIOACTIVITY

Canopy interception and retention of Fukushima Dai-ichi derived radiocaesium on three coniferous and two deciduous tree species

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Presentation outline

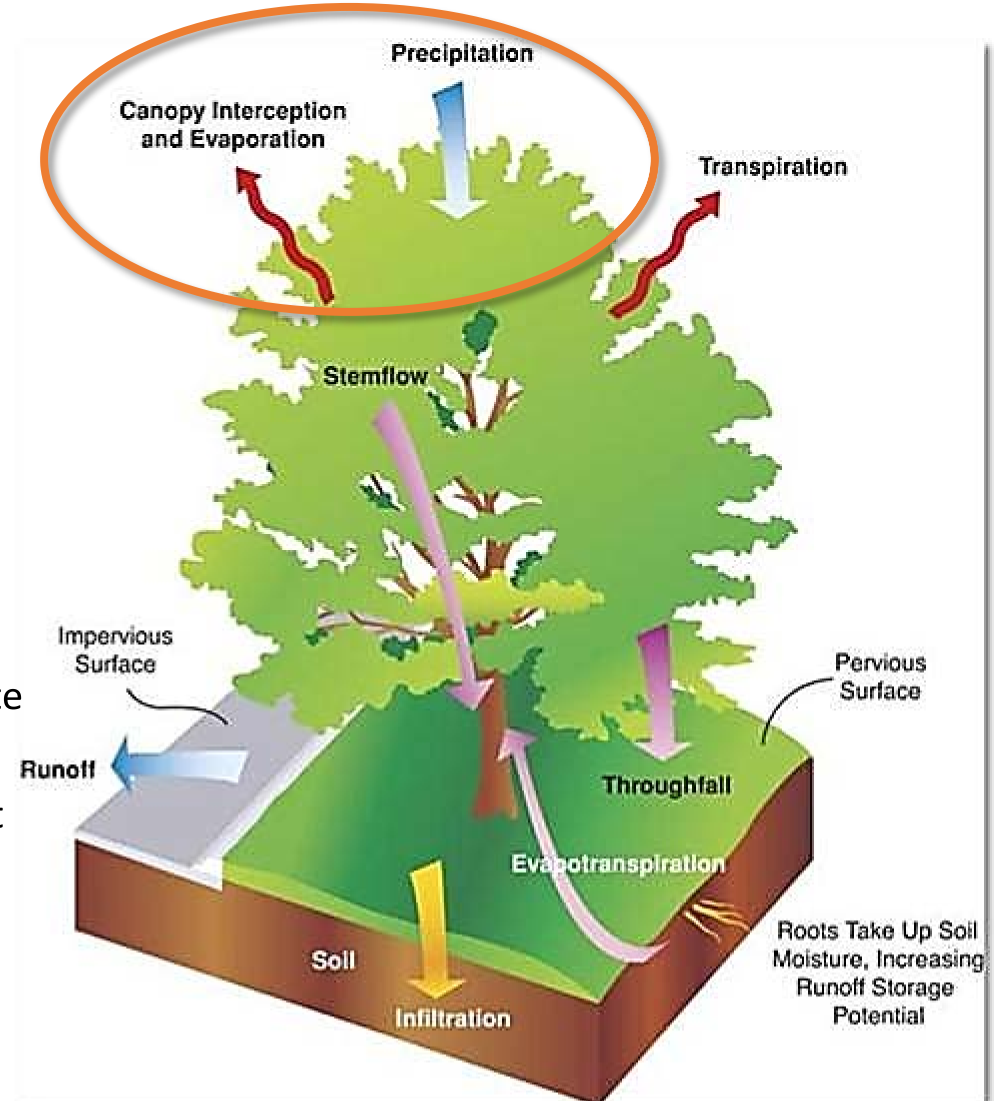
- **Purpose**
- **Materials and Methods**
- **Results and discussion**
- **Conclusions**

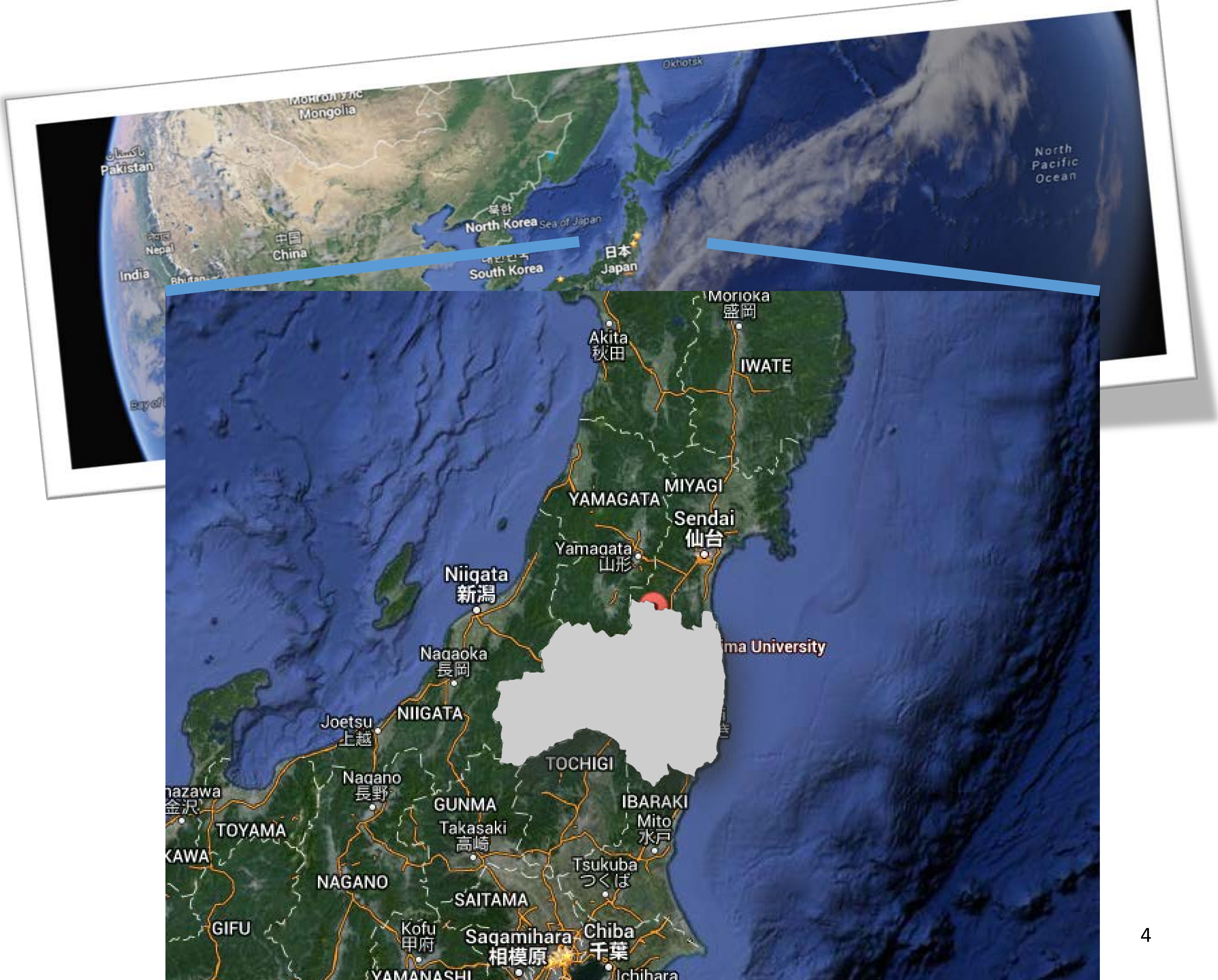
Purpose

To analyse canopy interception and retention of Fukushima Dai-ichi nuclear power plant (NPP) derived radiocaesium (^{134}Cs and ^{137}Cs).

Relationships between

- The effects of stand characteristics (tree species, age, openness, etc.) on canopy interception and retention, in-forest dose rate and its temporal changes.
- The effect of deposition type (fraction of wet and dry deposition) on canopy interception and retention, in-forest dose rate and its temporal changes.
- Calculation of aggregated transfer factors.

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Materials and Methods

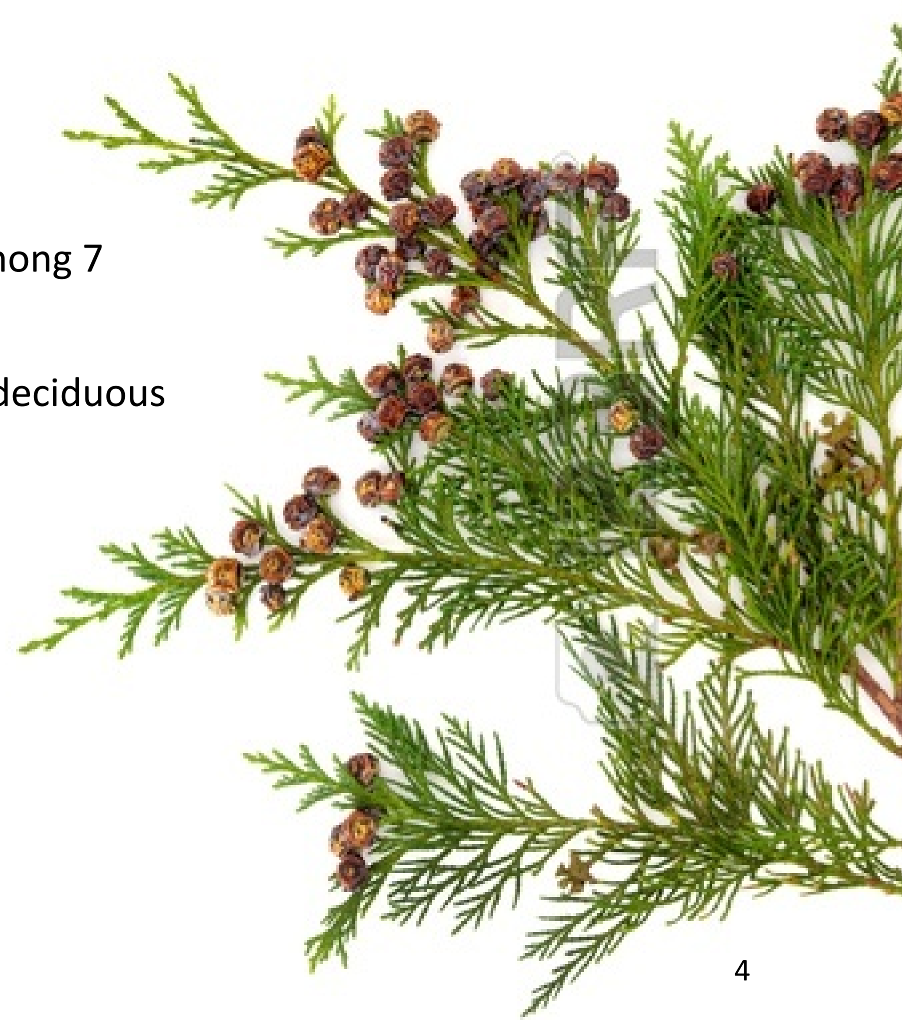
Study site

- Measurements of radioactivity concentration of radiocaesium, ambient dose rate, and sampling of plants and soils.
- Humid subtropical climate, mountain area in western part have continental climate.
- Average annual total rainfall 1250 mm, mean air temperature 12°C.
- Area 13 783 km^2 of which 9 361 km^2 forest.
- Dominating tree species: Japanese cypress, Japanese cedar and different types of broadleaf trees.
- Soil type is andosol and brown forest soil.
- First radionuclide fallout on 15 and 16 March 2011, as wet deposition.
- Continuation of fallout on 20 and 21 March 2011.
- Totally 4 300 km^2 area was contaminated by radiocaesium.

Materials and Methods

Investigated tree species

- Approximately 170 measuring points distributed among 7 different tree species.
- 2 main groups; evergreen species (coniferous) and deciduous (broadleaf).
- Age of trees were in general 50 years.
- Tree species in this investigation were:
    - Japanese cedar, スギ (**Cj**)
    - Japanese red pine, アカマツ (**Pd**)
    - Japanese cypress, ヒノキ (**Co**)
    - Beech mixture, ブナミックス (**F**)
    - Oak mixture, オークミックス (**Q**)



Materials and Methods

Dataset

- Different datasets were used in the study.
    - Monitoring data of forest contamination by the Ministry of Agriculture, Forestry and Fisheries (MAFF) in 2011 and 2014.
    - Yearly monitoring data of forest contamination by Fukushima Prefecture from 2011 and onward.
    - Fallout map of Fukushima Dai-ichi NPP accident derived radiocaesium (3rd airborne gamma ray monitoring survey) by the Nuclear Regulation Authority.
    - Distribution map of wet and dry radiocaesium deposition (Gonze *et al*., 2014; WSPEEDI simulations (Terada *et al*., 2012)).

Materials and Methods

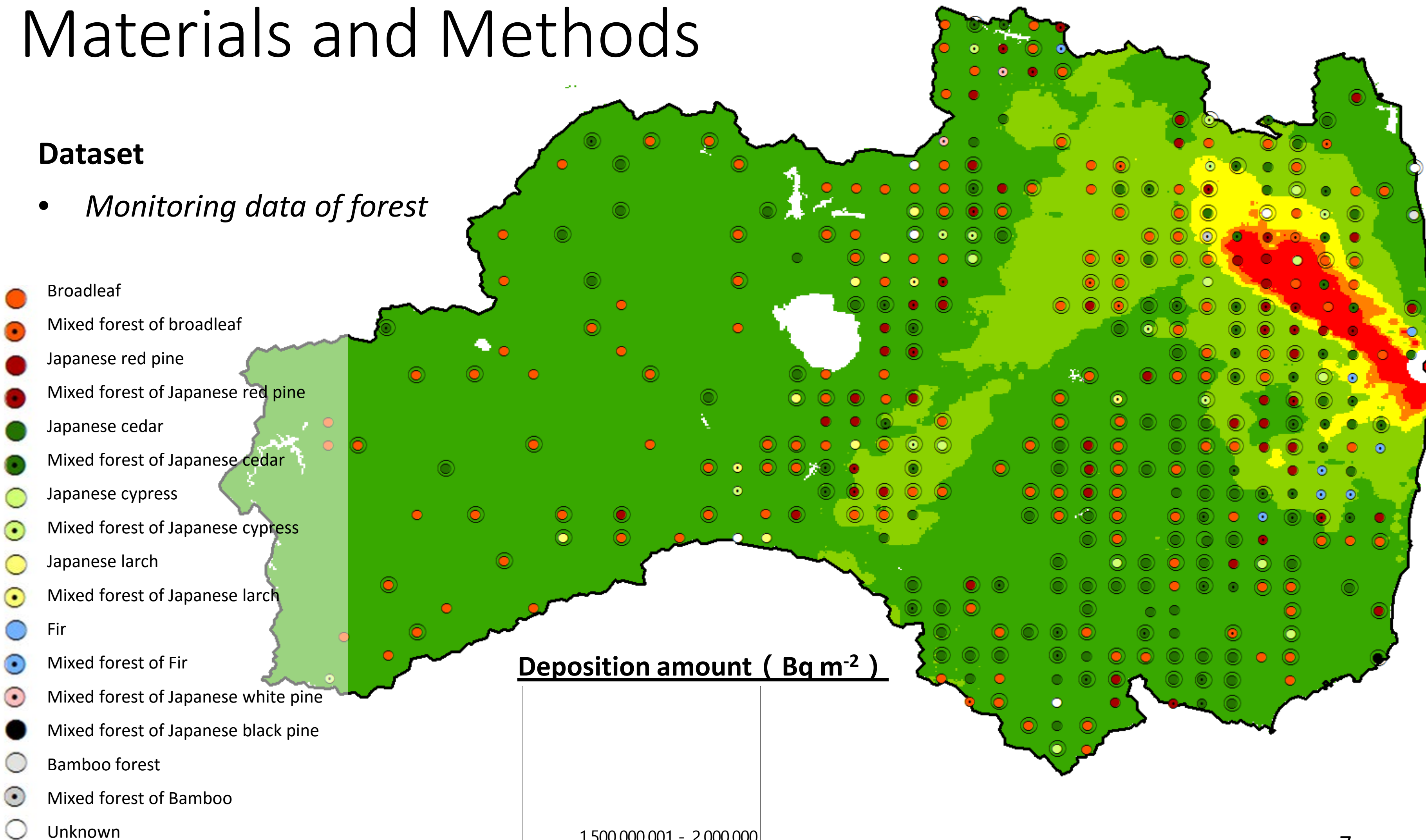
Dataset

- *Monitoring data of forest*
  - MAFF survey of measurements in Fukushima Prefecture.
  - September to November 2011 and September to November 2014.
  - Radioactivity concentration of ^{134}Cs and ^{137}Cs in litter layer, soil and trees (only ambient dose rate for trees).
  - Fukushima Prefecture monitoring in 2014 on concentration of radioactivity in different plant parts of trees (Japanese cedar, Japanese cypress and Japanese red pine).

Materials and Methods

Dataset

- *Monitoring data of forest*



Materials and Methods

Dataset

- *Monitoring data of forest*

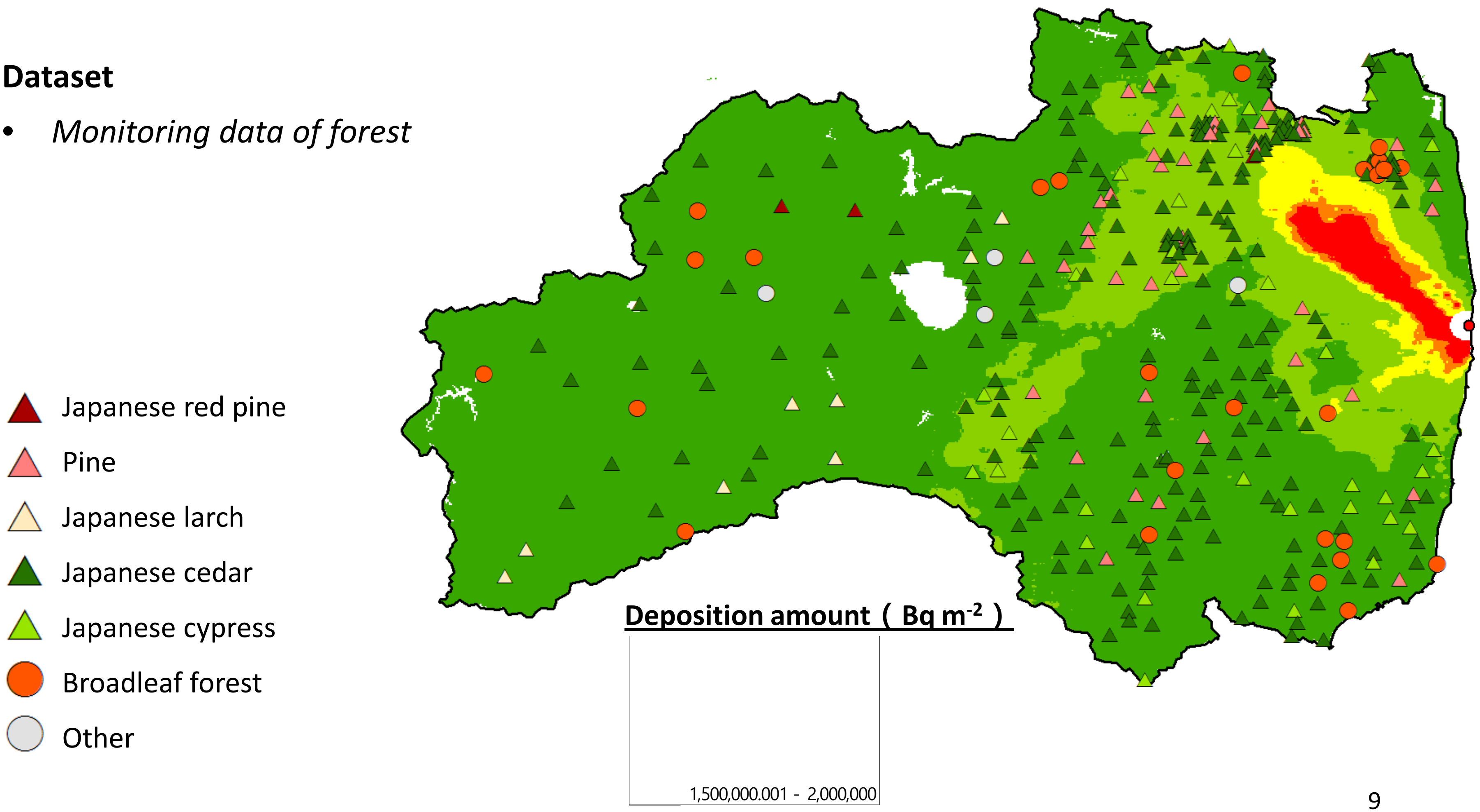
Training in the forest

Bench mark

Materials and Methods

Dataset

- *Monitoring data of forest*



Materials and Methods

Dataset

- *Fallout map of radiocaesium*
  - Airborne gamma ray monitoring surveys regularly since April 2011.
  - In this study the 3rd airborne gamma ray monitoring survey was used.
  - Estimation of deposited radioactivity concentration of ^{134}Cs and ^{137}Cs was derived by extracting these numbers using the multi values (spatial analyst) using ArcGIS 10.2.2.

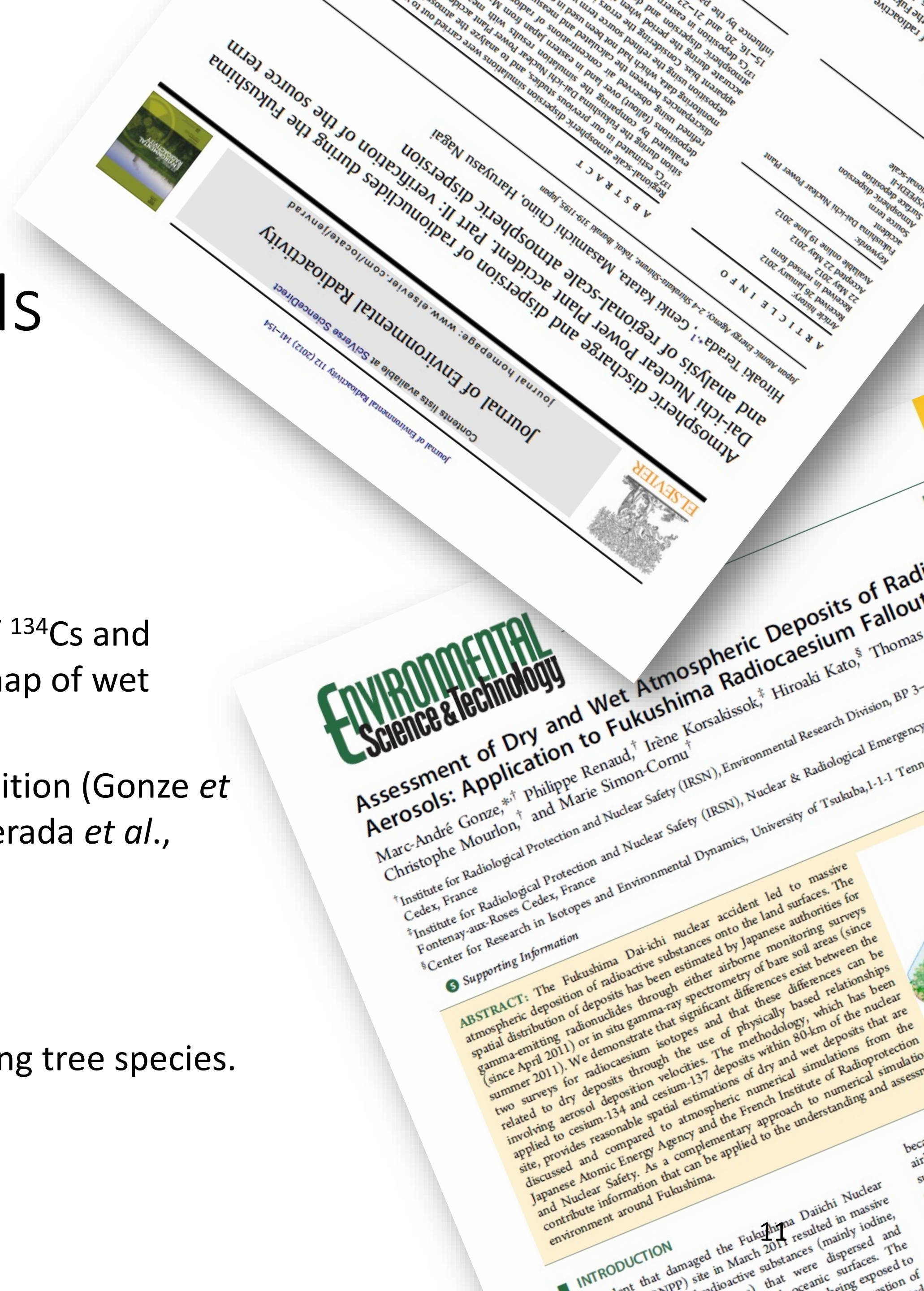
Materials and Methods

Dataset

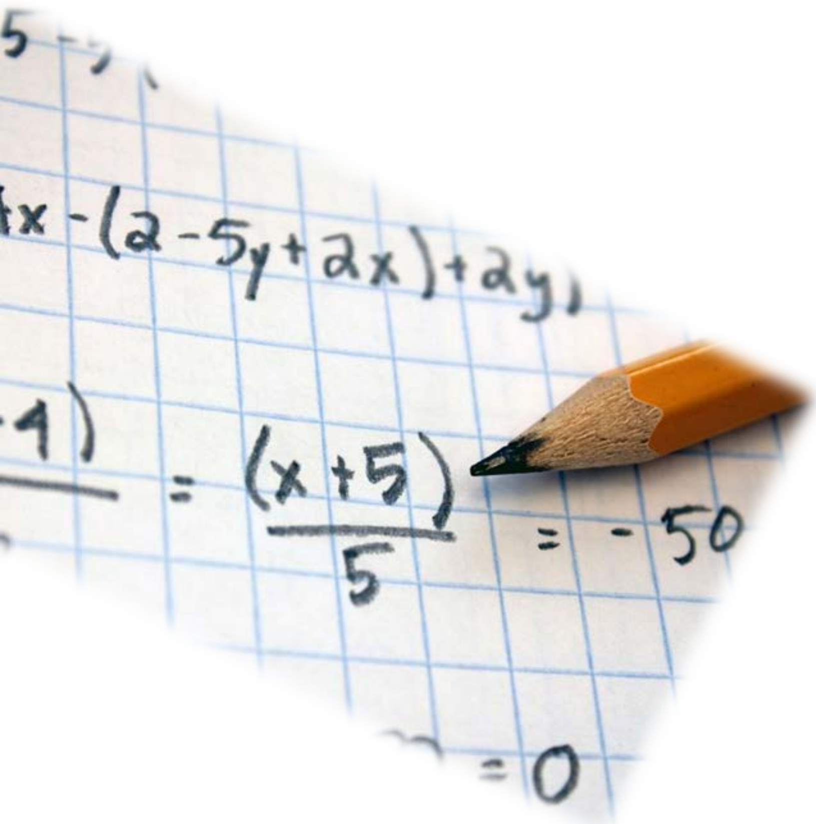
- *Distribution map of dry and wet deposition*
    - Distribution of dry and wet deposits of ^{134}Cs and ^{137}Cs estimated by using distribution map of wet deposition.
    - Distribution map of dry and wet deposition (Gonze *et al.*, 2014) and WSPEEDI simulations (Terada *et al.*, 2012)).

Data processing

- Data divided in different categories depending tree species.
- Four different groups of species mixtures.



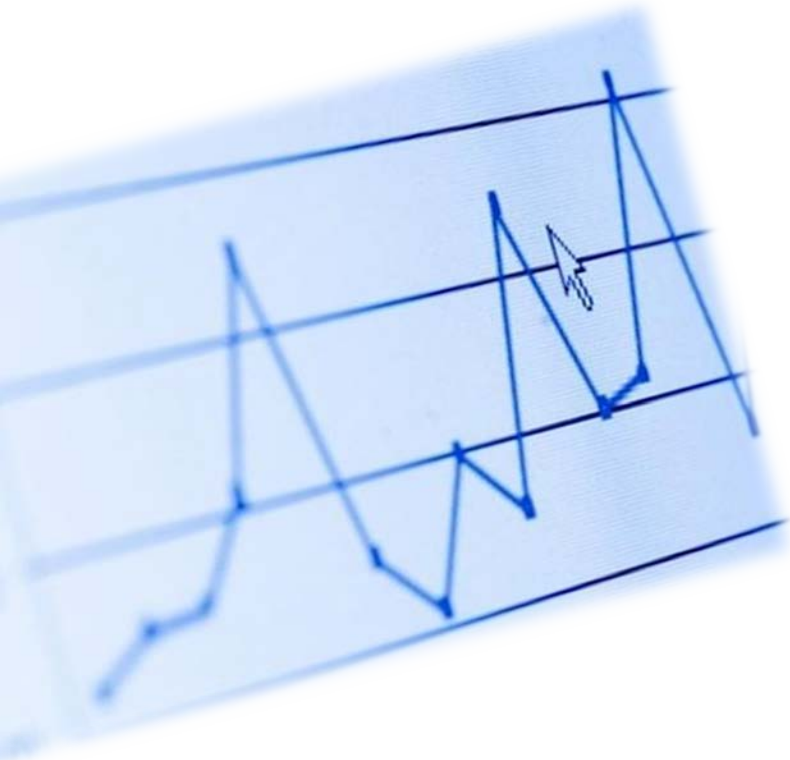
Materials and Methods



Calculations

- Interception and retained fraction *(f_R)* = radioactivity concentration in the standing plant directly after deposition (A_i) divided with the estimated total amount of radioactivity concentration deposited (A_t).
- Aggregated transfer factor (T_{ag}, $m^2\ kg^{-1}$) = radioactivity concentration in plant parts (A_c) divided with the estimated total amount of radioactivity deposited (A_t).

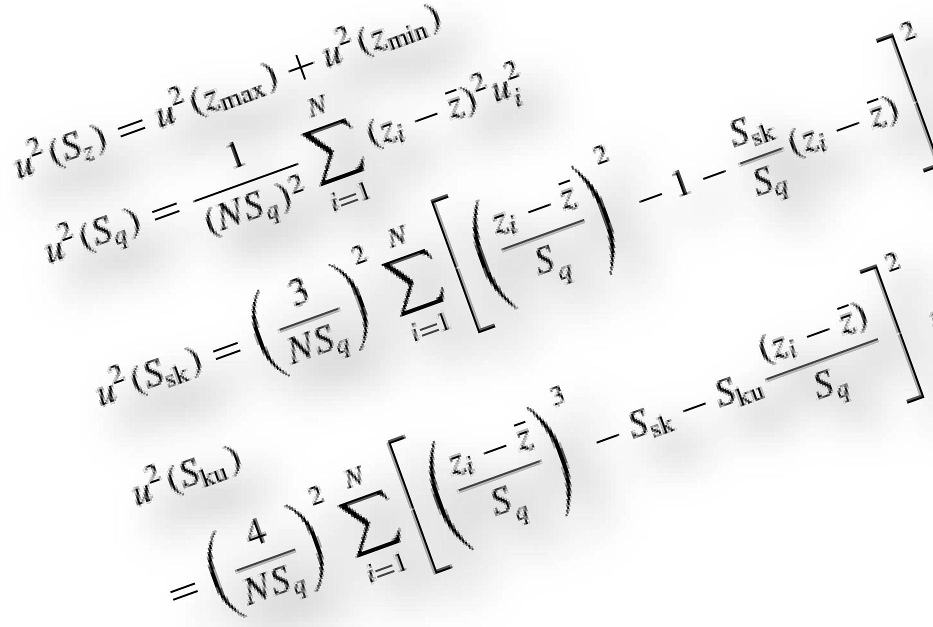
Materials and Methods



Statistics

- Firstly, to determine whether interception types affected the interception on trees, interception of dry and wet deposition from linear regression plotted against the interception.
- Secondly, the interception from the linear regression plotted against the radioactivity concentration, to determine whether the radioactivity concentration affected the interception.
- Thirdly, to determine whether different tree species affected the interception.

Materials and Methods



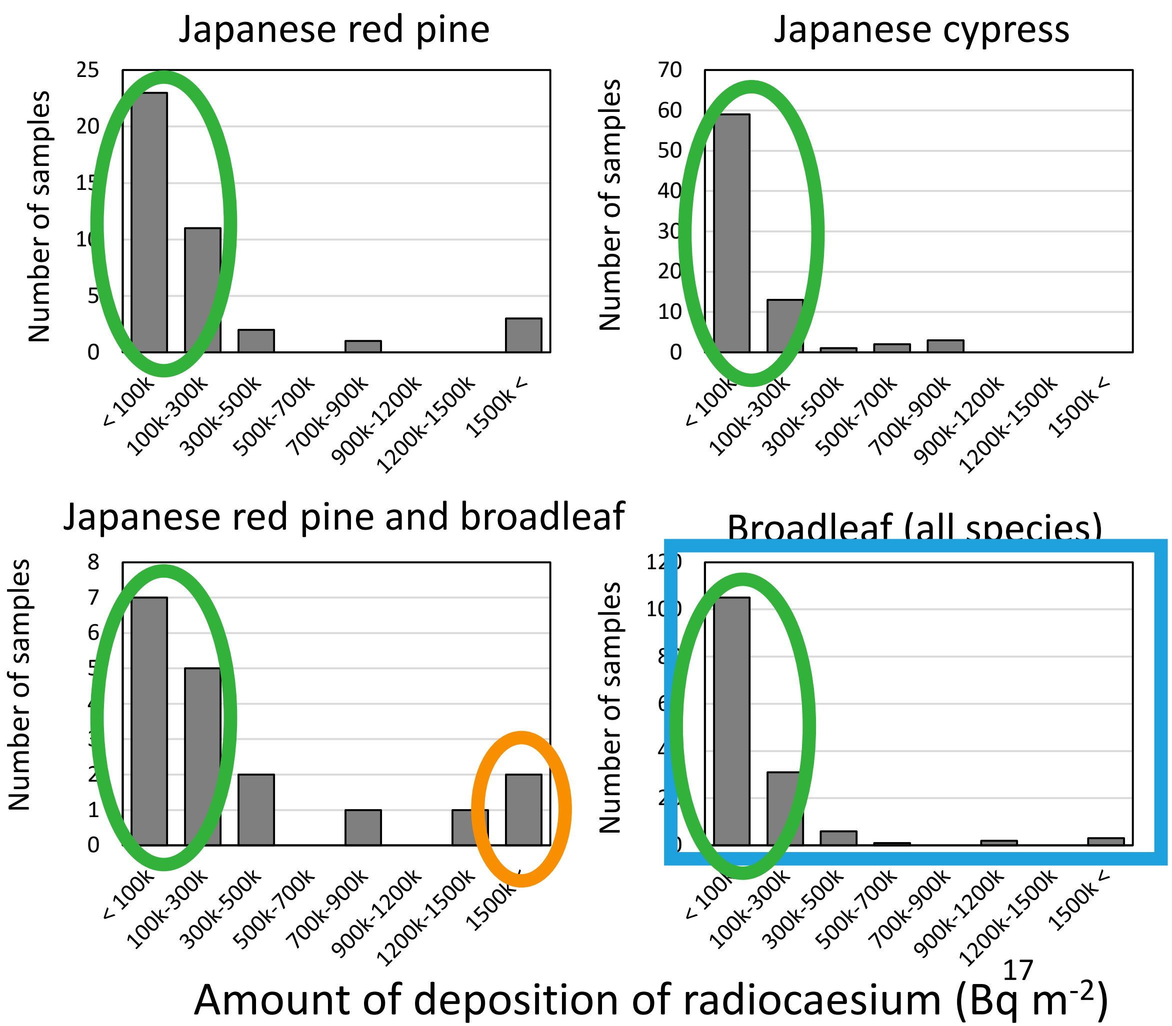
Uncertainties in this study

- Uncertainties estimated with the method described by the Guide to the Expression of Uncertainty in Measurement (GUM).
- Uncertainties presented as the combined standard uncertainty $u_c(y)$ for radioactivity concentration in litter and soil, for the estimation of the radioactivity concentration in trees.
- The combined standard uncertainty U was presented for f_R and T_{ag} as a 95% confidence interval.

Results and discussion

The number of deposition points

- Most tree samples in the lower part of the radioactivity deposition.
- Broadleaf have most sampling points in the lower part of the radioactivity deposition.
- Japanese red pine and broadleaf-group had quite many samples in the very high radioactivity group.



Results and discussion

Interception and retention of ^{134}Cs and ^{137}Cs

- Highest average estimated intercepted and retained radioactivity concentration was for Beech tree, they also had the highest estimated deposited radioactivity concentration.

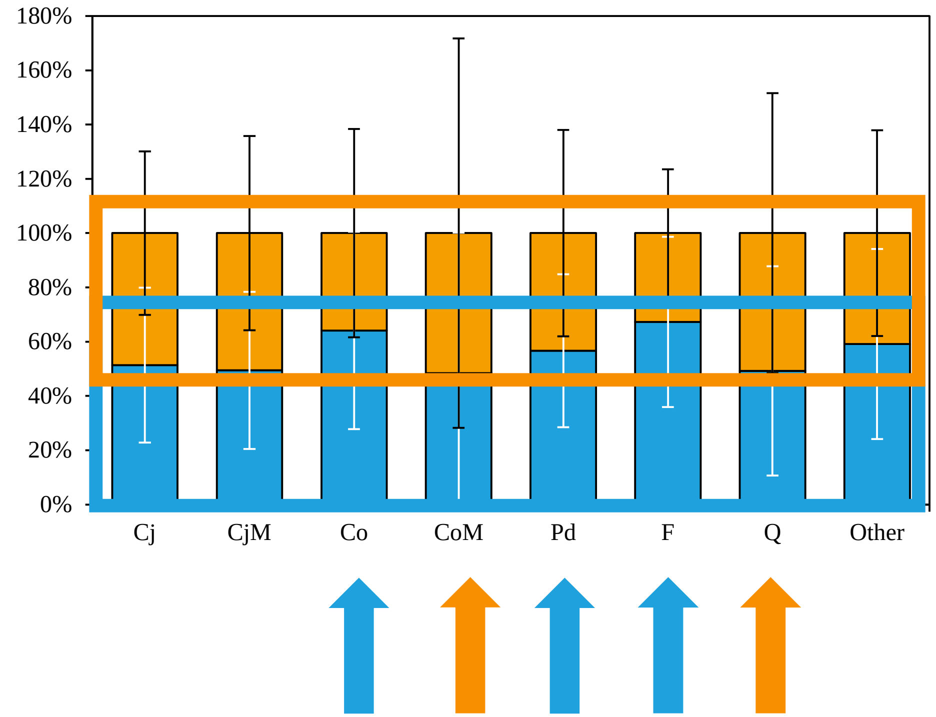
- Lowest average estimated intercepted and retained radioactivity was for Japanese cedar, however they also had the lowest estimated deposition radioactivity concentration.

- To be able to estimate the amount of ^{134}C and ^{137}Cs intercepted and retained the interception and retention fraction (f_R) was used.

Results and discussion

Interception and retention of ^{134}Cs and ^{137}Cs cont.

- In general, both dry and wet deposition contributed more or less the same to the interception and retention. Exception i.e. for Japanese cypress, Japanese red pine and Beech tree mixture.
- Highest average f_R-values for both ^{134}Cs and ^{137}Cs were for coniferous tree, Japanese cedar mixture.
- Lowest average f_R-values for both ^{134}Cs and ^{137}Cs were for Japanese cypress mixture.
- The f_R-values was higher for ^{134}Cs in all tree species, except for Japanese cypress mixture.

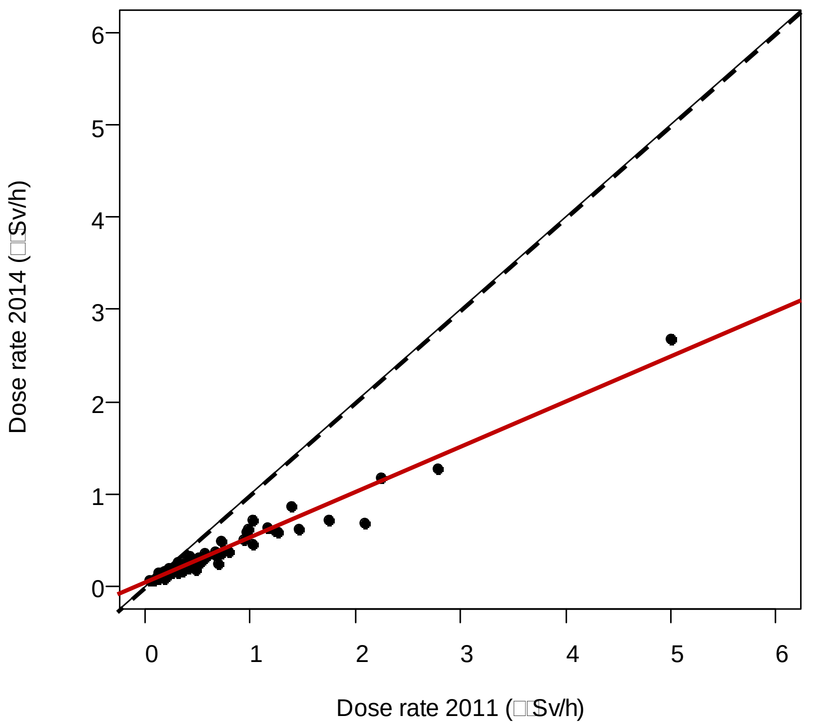


Results and discussion

Ambient forest dose rate

- 6 to 8 months after Fukushima Dai-ichi NPP accident, average ambient dose rate highest in Beech mixture. Explained by high deposition radioactivity concentration.
- Lowest average ambient dose rate in Japanese cedar tree, they had lowest deposition radioactivity concentration.
- Ambient dose rate decreasing from 2011 to 2014 for all tree species.

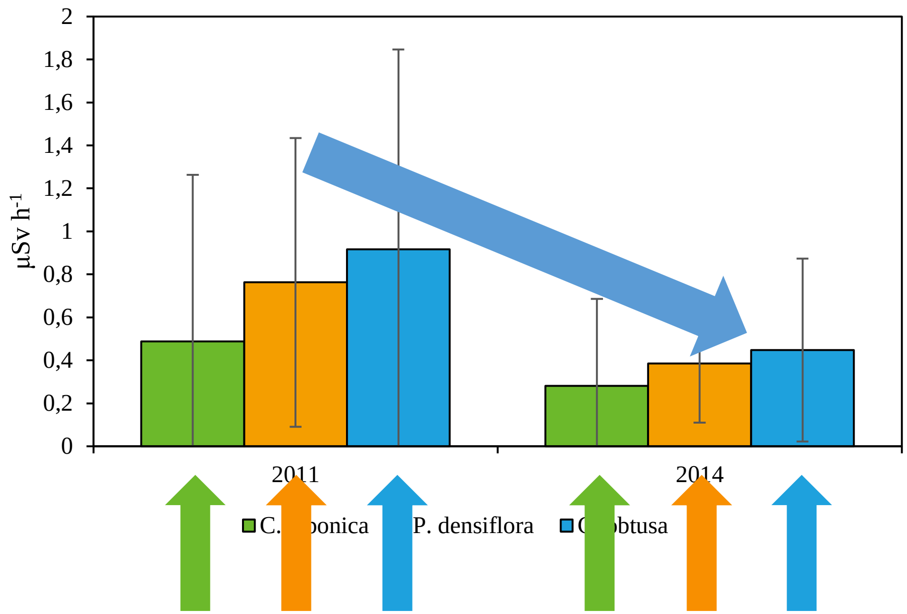
Dose rate 2011 vs. Dose rate



Results and discussion

Ambient forest dose rate cont.

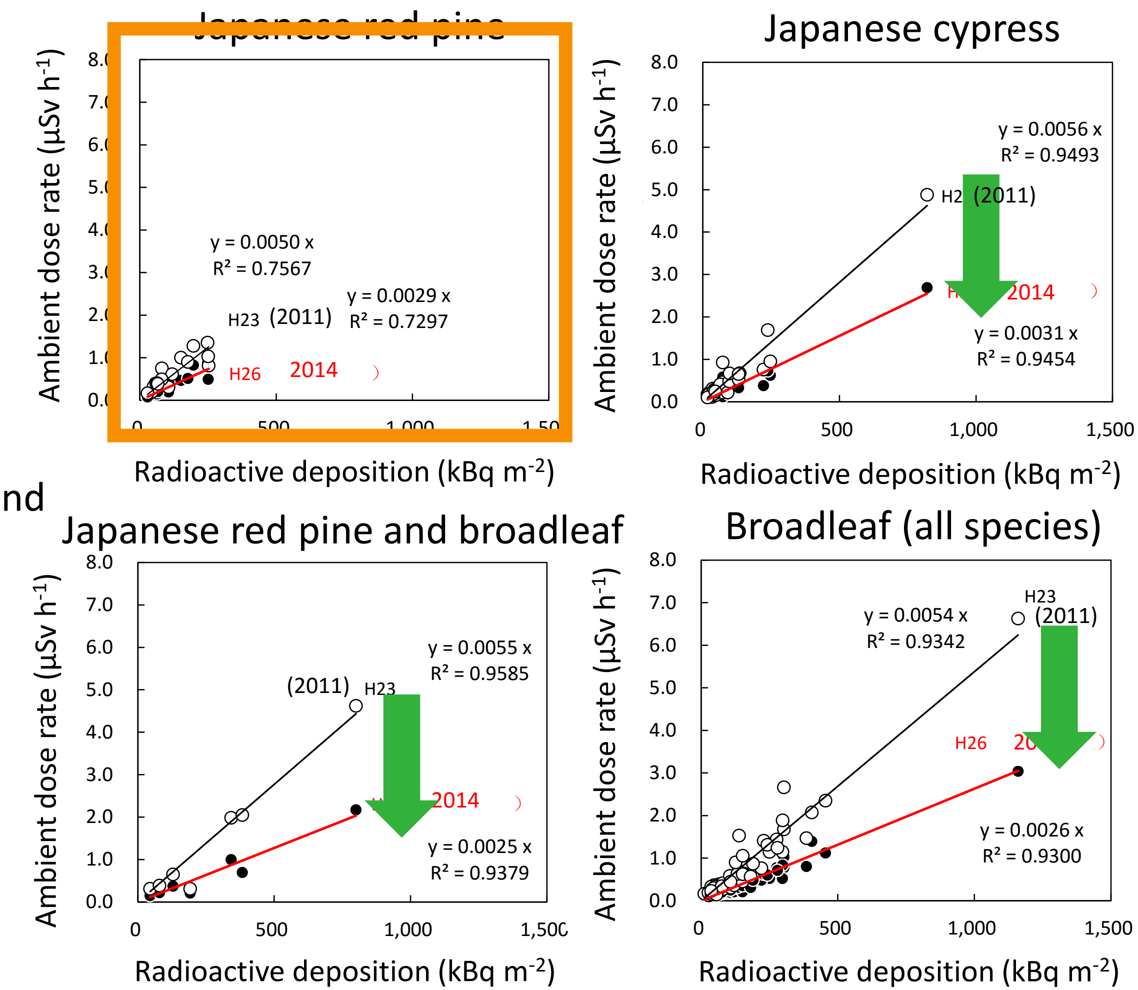
- For coniferous trees, the lowest ambient dose rate was found for Japanese cedar following by Japanese red pine.
- Highest ambient dose rate for coniferous trees was found for Japanese cypress.
- There was a reduction of the ambient dose rate from 2011 to 2014, for all the coniferous tree species.



Results and discussion

Ambient forest dose rate cont.

- The relationship between the amount of radioactive deposition and the ambient dose rate.
- The slope of the relationship between the deposition amount and the ambient dose rate.
- Reduction of ambient dose rate was significant. However, less for Japanese red pine.



Results and discussion

Ambient forest dose rate cont.

Broadleaf
(2011-12-01)

Physical decay

This project results
(MAFF re-measurement point)

Japanese red pine

J. red pine and broadleaf

Japanese cedar

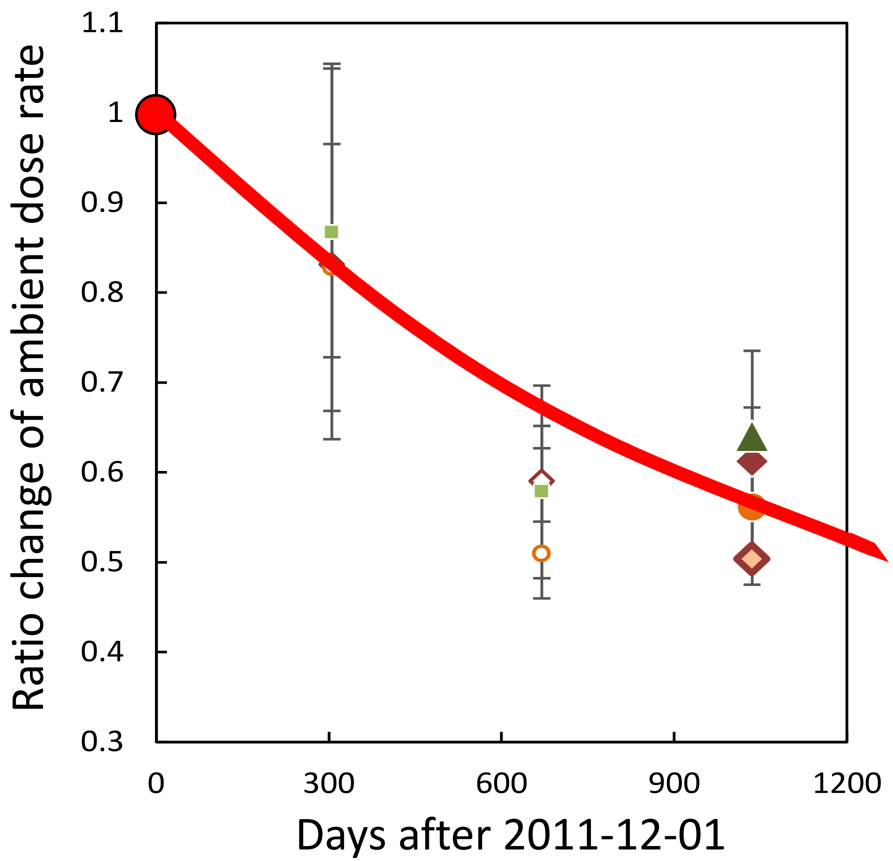
Broadleaf

Fukushima prefecture data

Japanese red pine

Japanese cedar

Broadleaf



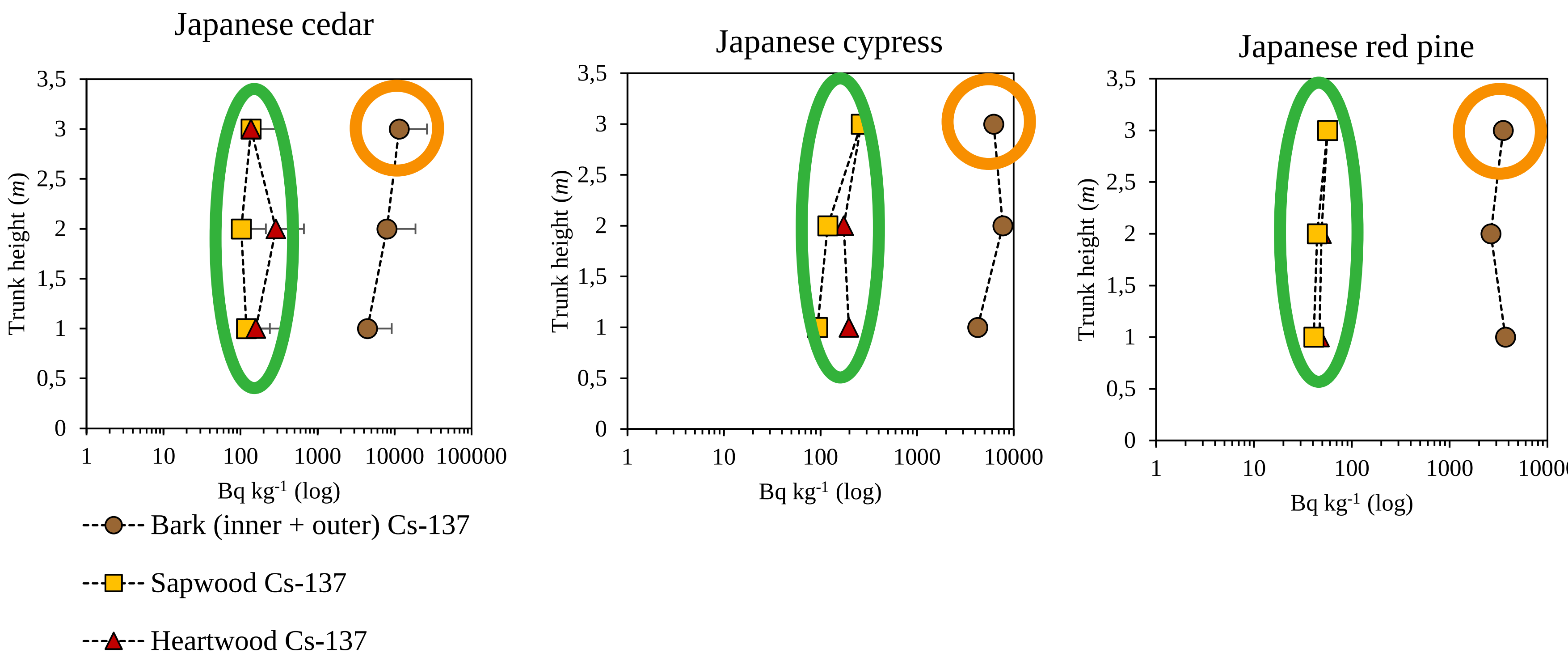
Results and discussion

Ratios between ^{134}Cs:^{137}Cs

Specie	Est. deposited	Est. in tree
Japanese cedar tree	0.95 ± 0.00	1.14 ± 0.29
Japanese cedar tree mixture	0.95 ± 0.00	1.06 ± 0.12
Japanese cypress tree	0.95 ± 0.00	1.11 ± 0.17
Japanese cypress tree mixture	0.95 ± 0.00	1.29 ± 0.40
Japanese red pine tree	0.95 ± 0.00	1.16 ± 0.34
Beech tree mixture	0.95 ± 0.00	1.08 ± 0.08
Oak tree mixture	0.95 ± 0.00	1.06 ± 0.11
Other tree mixture	0.95 ± 0.00	1.16 ± 0.20

Results and discussion

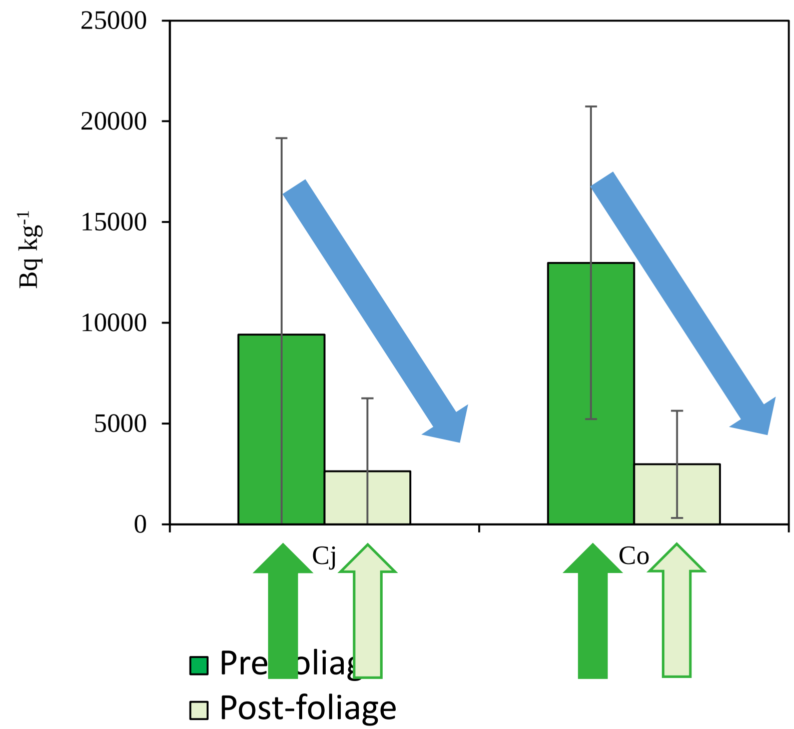
Radioactivity concentration of ^{134}Cs and ^{137}Cs in different plant parts



Results and discussion

Radioactivity concentration of ^{134}Cs and ^{137}Cs in different plant parts cont.

- Radioactivity concentration in pre-foliage (old foliage) was highest in Japanese cypress and somewhat lower in Japanese cedar.
- For post-foliage (new foliage) highest radioactivity concentration was in Japanese cedar following by Japanese cypress.
- There was a much lower radioactivity concentration in post-foliage compared to the pre-foliage for both tree species.

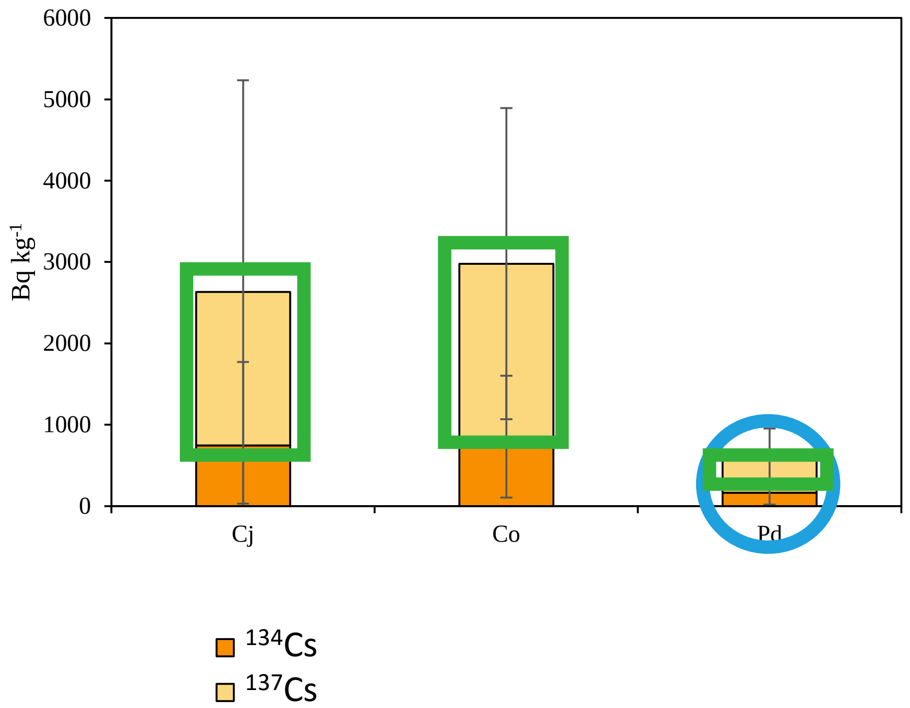


Results and discussion

Radioactivity concentration of ^{134}Cs and ^{137}Cs in different plant parts

- For post-foliage the lowest radioactivity concentration was found for Japanese red pine.

- For all tree species a higher contribution of ^{137}Cs radioactivity concentration was found than for ^{134}Cs. This can be related to the much shorter half-life for ^{134}Cs than for ^{137}Cs.



Results and discussion

Radioactivity concentration in soil and litter layer of ^{134}Cs and ^{137}Cs

- The forest soil had a higher radioactivity concentration then the forest litter layer had.
- The radioactivity concentration was higher both in soil and in litter layer for deciduous tree stands than for coniferous tree stands.
- Highest radioactivity concentration in soil was found for Japanese cypress tree mixture and lowest in Japanese cedar stands as well in Japanese cedar stands.

Results and discussion

Aggregated transfer factors (T_{ag}, m^{2} kg^{-1} × 10^{-3}) of ^{134}Cs and ^{137}Cs in plant parts of trees

Plant part	Japanese cedar tree		Japanese cypress tree		Japanese red pine tree	
	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs
Bark 1 m	22.6 ± 18.6	26.0 ± 21.4	14.3 ± 6.8	16.4 ± 7.7	17.4 ± 5.8	20.1 ± 6.1
Bark 2 m	37.5 ± 41.6	43.5 ± 49.0	30.4 ± 24.8	35.4 ± 30.1	11.2 ± 3.5	13.1 ± 4.0
Bark top	59.2 ± 51.0	67.7 ± 58.1	30.5 ± 35.6	35.5 ± 42.4	16.3 ± 11.7	18.8 ± 13.7
Sapwood 1 m	0.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5	0.6 ± 0.6	0.2 ± 0.1	0.2 ± 0.1
Sapwood 2 m	0.4 ± 0.4	0.5 ± 0.5	0.5 ± 0.4	0.6 ± 0.5	0.2 ± 0.1	0.2 ± 0.1
Heartwood 1 m	0.7 ± 1.1	0.7 ± 1.3	0.3 ± 0.3	0.2 ± 0.2	0.1 ± 0.0	0.1 ± 0.0
Heartwood 2 m	1.1 ± 1.5	1.3 ± 1.7	0.3 ± 0.3	0.3 ± 0.4	0.2 ± 0.1	0.2 ± 0.1
Sap- and Heartwood top	0.7 ± 0.6	0.6 ± 0.7	0.7 ± 0.6	0.9 ± 0.7	0.2 ± 0.1	0.2 ± 0.1
Pre-foliage	34.3 ± 15.5	39.0 ± 17.7	33.4 ± 22.3	37.9 ± 24.1	*	*
Post-foliage	9.5 ± 10.5	11.0 ± 12.1	9.2 ± 9.2	10.5 ± 10.8	1.6 ± 0.9	1.9 ± 1.0
Litter layer	169.9 ± 117.4	197.0 ± 140.0	98.8 ± 54.7	115.1 ± 63.0	117.3 ± 51.8	137.9 ± 61.3
Soil	10.1 ± 8.7	11.9 ± 9.9	4.4 ± 2.9	5.3 ± 3.2	4.1 ± 2.0	4.9 ± 2.3

Conclusions

1. Highest intercepted and retained factor of radioactivity concentration, found for coniferous trees.

2. Both wet and dry deposition contributed more or less the same to the interception and retention.

3. Ambient dose rate decreasing from 2011 to 2014 for all tree species.

4. There was a much lower radioactivity concentration in post-foliage compared to pre-foliage for Japanese cypress and Japanese cedar.

5. The forest soil had a higher radioactivity concentration then the forest litter layer had.

Thanks to…

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