2nd Caesium Workshop: meeting challenges for Fukushima recovery

October 8th, 2014

Radiocesium contamination in forest ecosystems and wood

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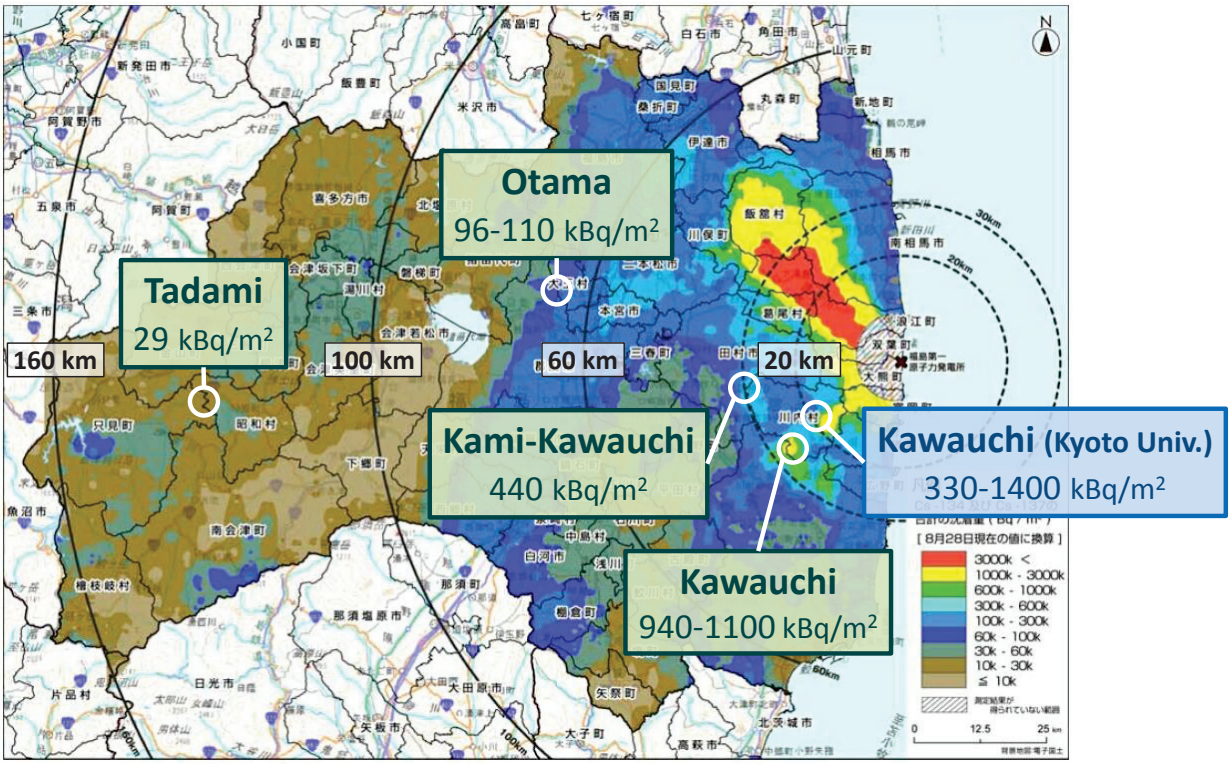
Outline

- Overview of radiocesium in Fukushima forests (**FFPRI**)
- Radiocesium distribution patterns in wood (**Kyoto Univ.**)
- Temporal change of radiocesium in wood (**FFPRI**)
- Discussion: lessons for Fukushima forest management

Research collaborators

- **FFPRI**
  Komatsu M, Akama A, Kobayashi M, Ikeda S, Saito S, Kuroda K, Takano T, Kaneko S, Kajimoto T, Takahashi M (and more)
- **Kyoto University**
  Okada N, Tanaka A, Nakai W, Takano S

Study site



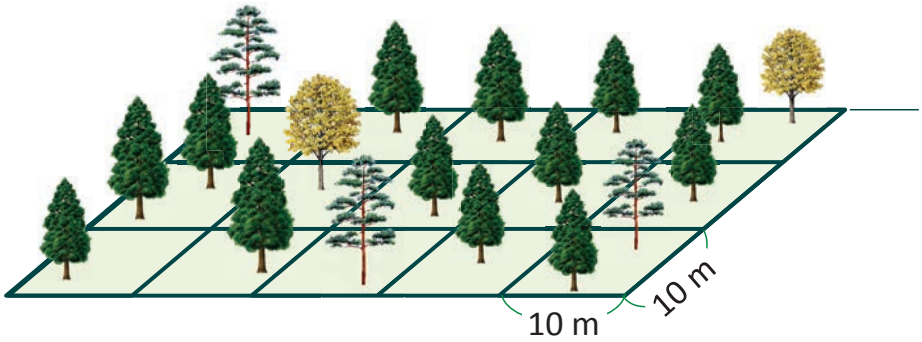
Radiocesium (134+137) deposition in August 2011 (MEXT 2011)

Study site, species and period

Area	Forest type of study site	Dominant species	Tree age (y)	Study period	Deposition* (kBq/m²)
Kawauchi	**Evergreen** coniferous	**Cedar**	42	2011-	1,100
	Evergreen coniferous	Cypress	26	2012-	970
	Deciduous broad-leaved	Oak	27	2012-	940
Kami-Kawauchi	**Evergreen** coniferous	**Cedar**	56	2011-	440
Otama	**Evergreen** coniferous	**Cedar**	42	2011-	110
	Mixed	Red pine	42	2011-	96
	Mixed	Oak	42	2011-	97
Tadami	**Evergreen** coniferous	**Cedar**	40	2011-	29
Kawauchi (Kyoto Univ.)	**Evergreen** coniferous	**Cedar**	18	2013	1,400
	Evergreen coniferous	Red pine	36-54	2012	330
	Deciduous broad-leaved	Oak	43	2012	1,200

*Radiocesium (134+137) deposition in August 2011 (MEXT 2011)

Methods



Tree census

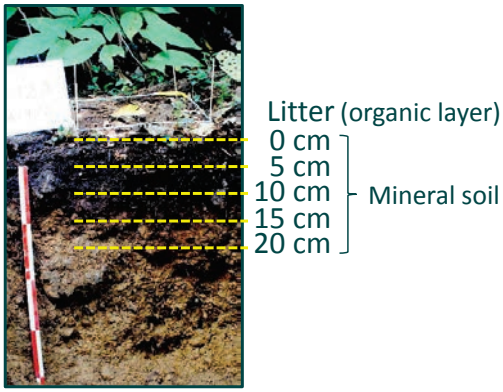
- 0.16-0.24 ha
- Size (diameter)
- Species
- Population

Tree sampling

- 3 individuals / year
  (outside of census plots)
- Leaf
- Branch
- Bark
- Wood

Soil sampling

- 12 points / year
  (inside of census plots)
- Litter
- Mineral soil
  5 cm deep at 9 points
  20 cm deep at 3 points
  (sampled every 5 cm)



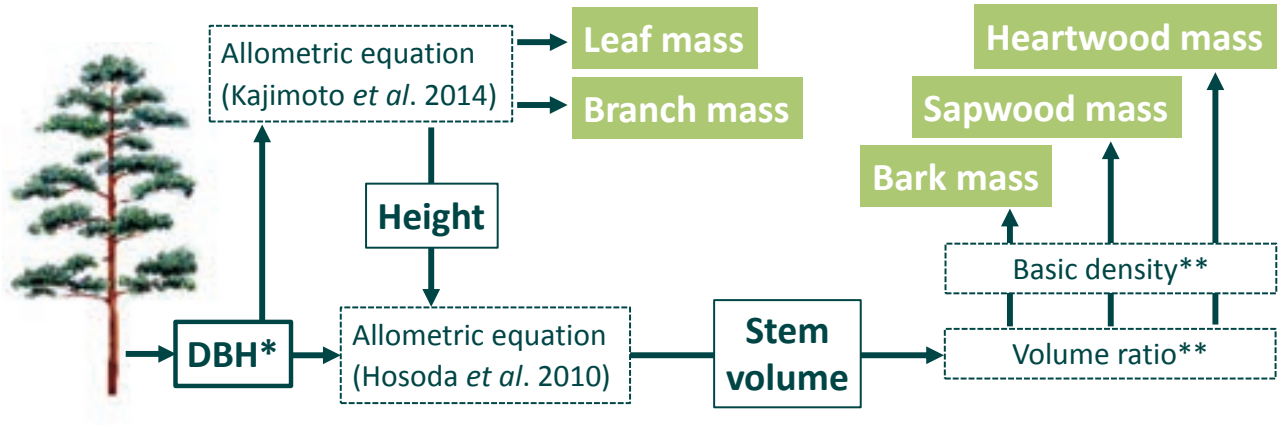
* These photos were taken at FFPRI (Tsukuba)

Methods

Measurement of radiocesium concentration (Bq/kg)

- All samples were dried and homogenized
- Radioactivity of Cs-134 and Cs-137 was measured using a Ge detector
- Radioactivity was decay-corrected to September 1st of each sampled year

Estimation of biomass in aboveground tree components (kg/m^2)



*DBH: diameter at breast height

**Mean value of sampled trees

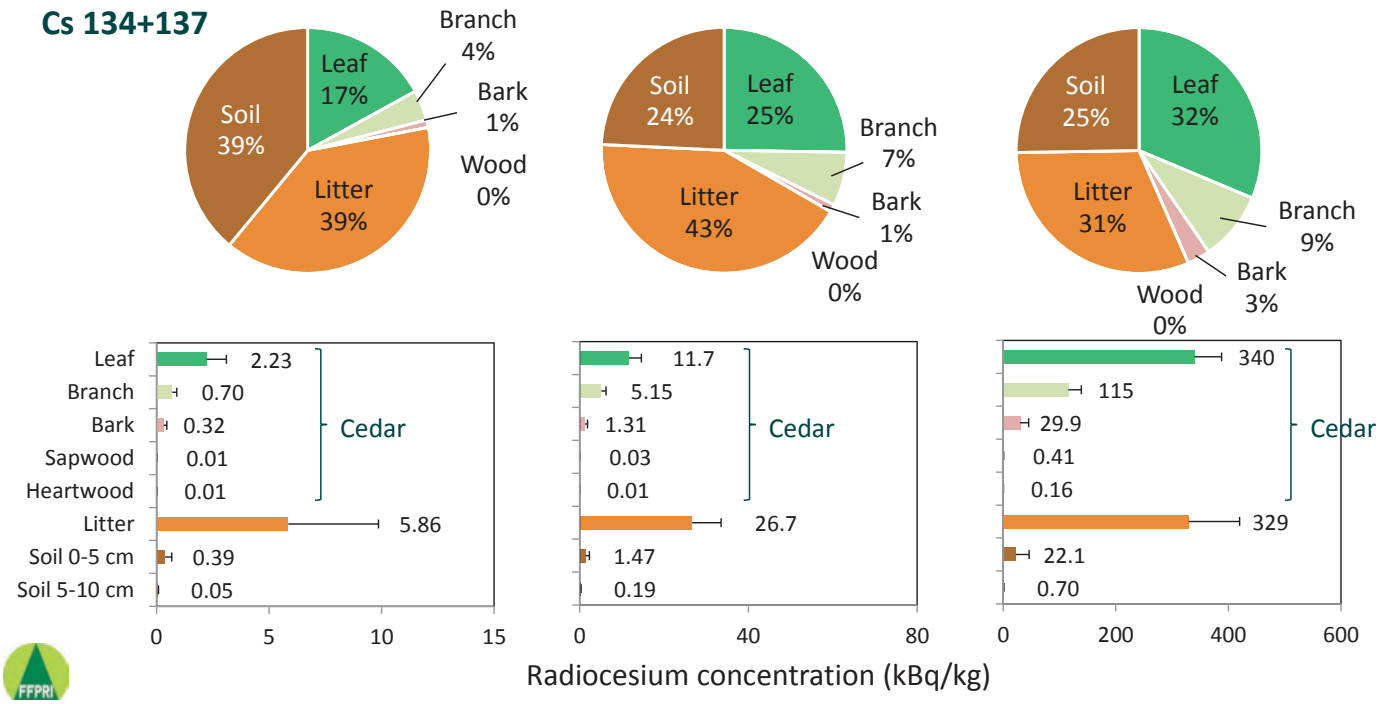
Cs distribution in forest ecosystem in 2011

Tadami
Cedar forest
20 kBq/m²

Otama
Cedar forest
106 kBq/m²

Kawauchi
Cedar forest
1,279 kBq/m²

Cs 134+137

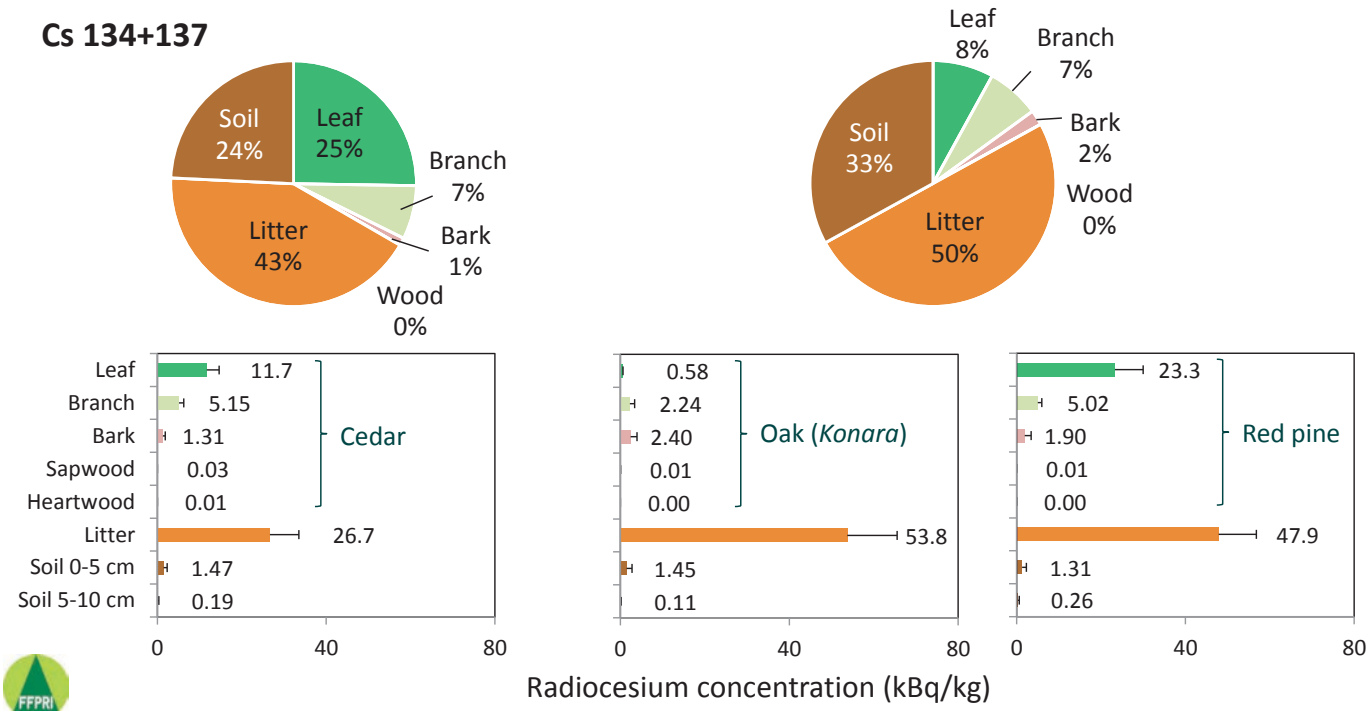


Cs distribution in forest ecosystem in 2011

Otama
Cedar forest
106 kBq/m²

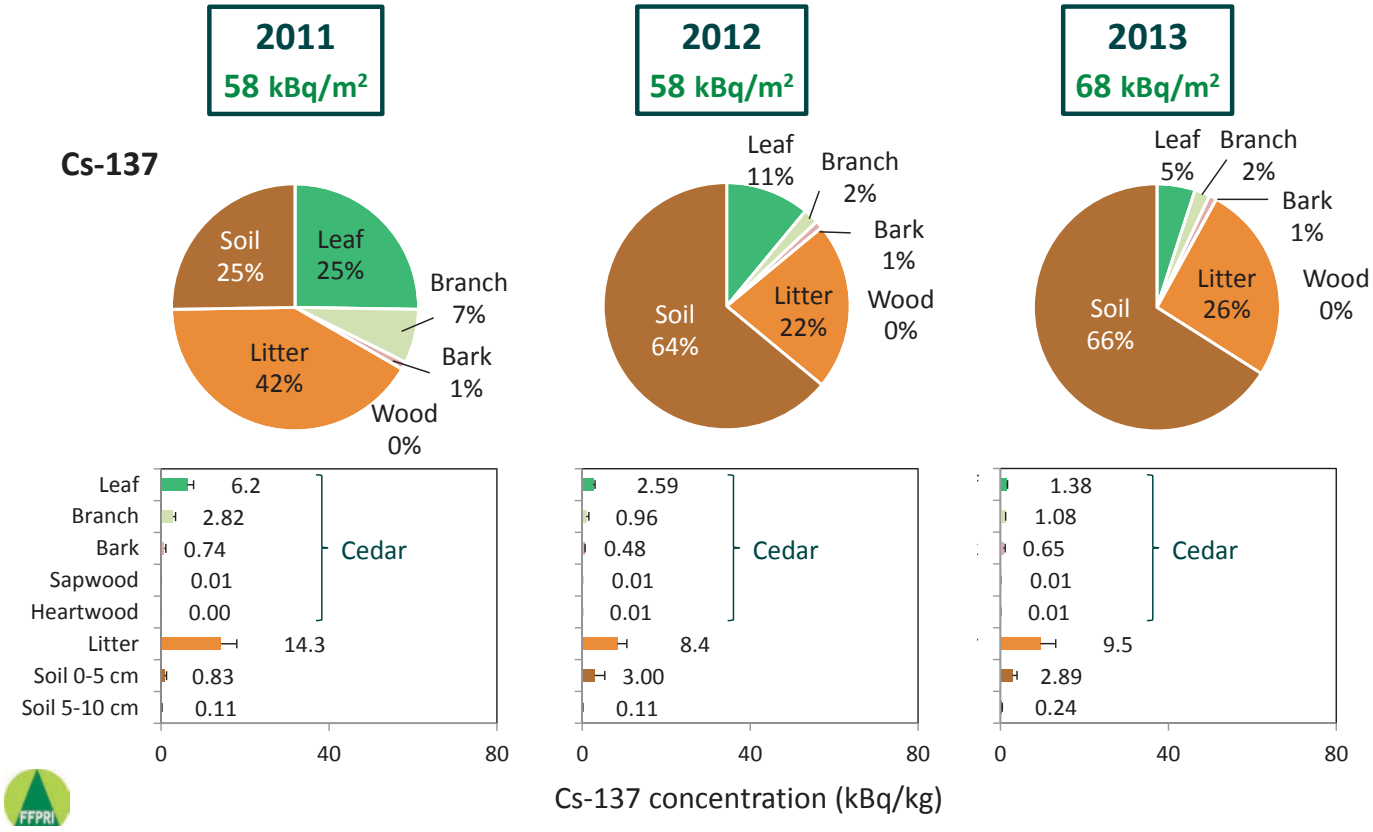
Otama
Mixed forest (oak and pine)
92 kBq/m²

Cs 134+137



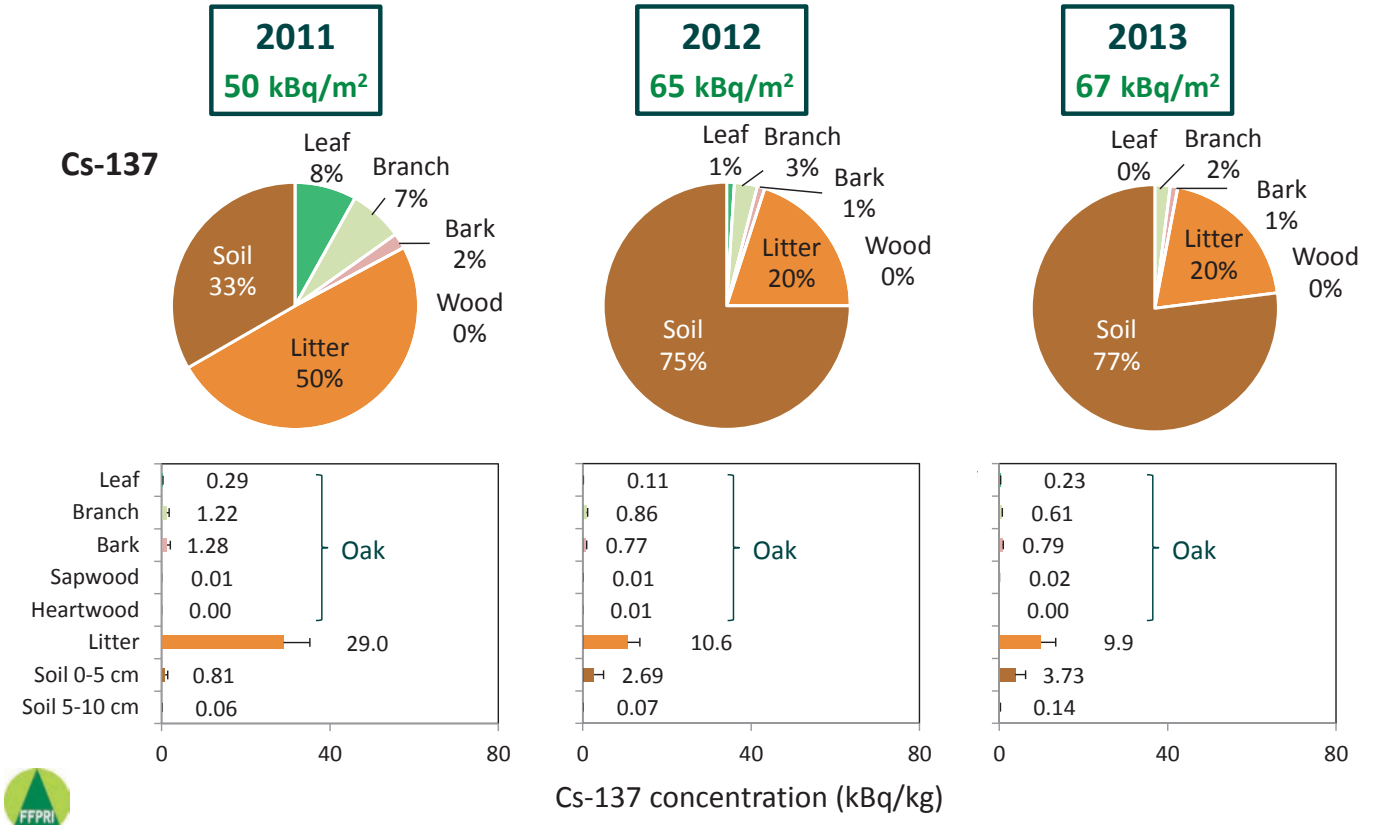
Temporal change in Cs-137 distribution

Otama - Cedar forest



Temporal change in Cs-137 distribution

Otama - Mixed forest (oak and pine)



Overview of radiocesium in Fukushima forests

- In 2011, the nearer the sites are to FDNPP,
  the more Cs distributed to tree components.
- In Sep. 2013, **more than 90% of Cs in cedar forests**
  and **more than 95% of Cs in mixed forest** were distributed in **litter and soil**.
- Because cedar's needles (leaves) have long life span (4-5 years),
  2-8% of Cs in cedar forests was still distributed in leaf in 2013.
  In several years, the distribution may become similar to that in mixed forests.

- Distribution to wood is negligible on a forest-ecosystem scale;
  however, it is quite important for wood production and utilization.
- Detailed information about Cs contamination in wood **in the early stage**
  and **in native species** (e.g. Japanese cedar) is necessary for the management.

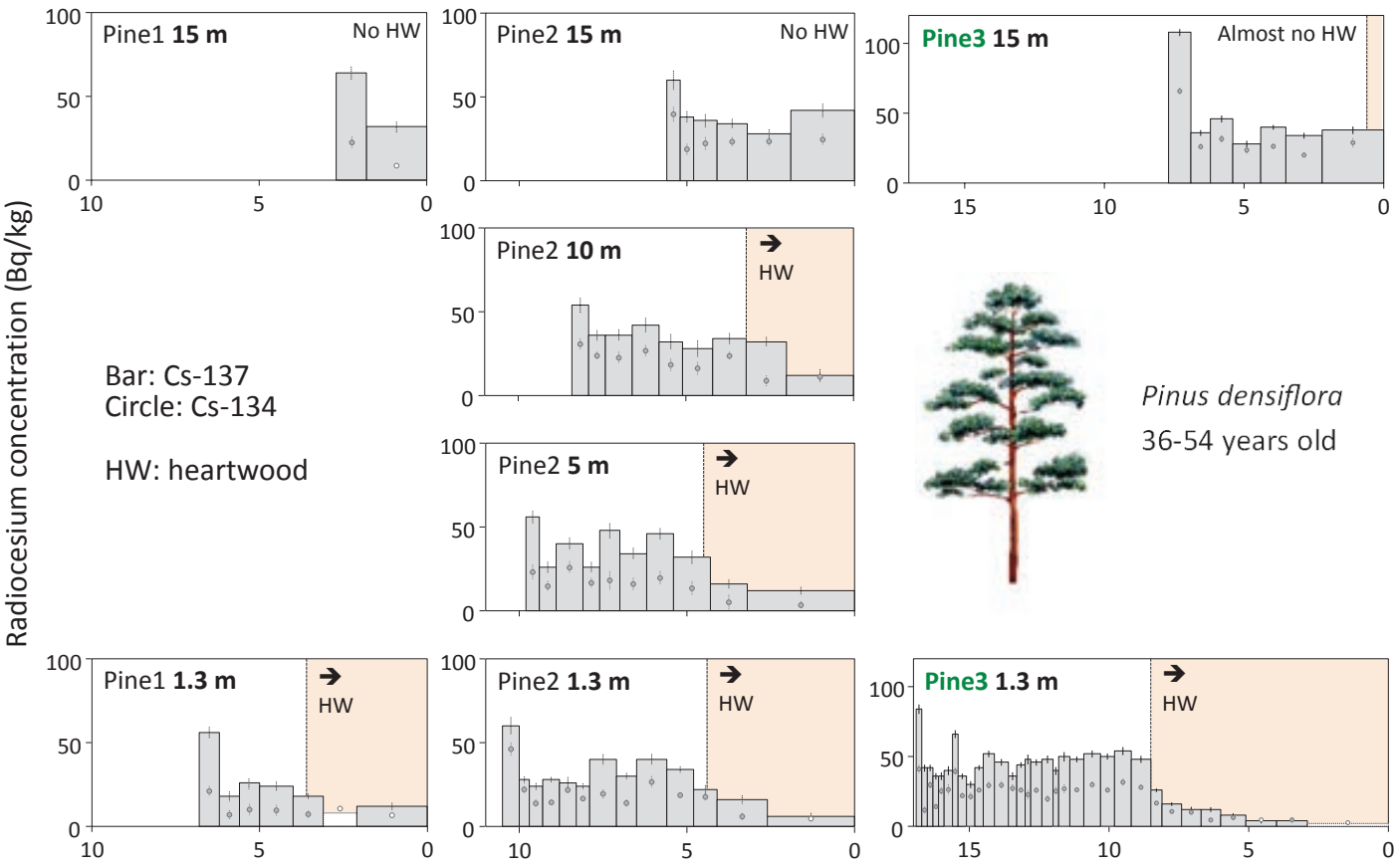
Method | Cs distribution patterns in wood

- **Species** ... Red pine (Sep. 2012), oak (Sep. 2012), cedar (Sep. 2013)
- **Sample** … Wood disks (5-10 cm thick) sampled from different heights
- **Preparation** … Wood disks were separated radially with a chisel

Wood disk of red pine

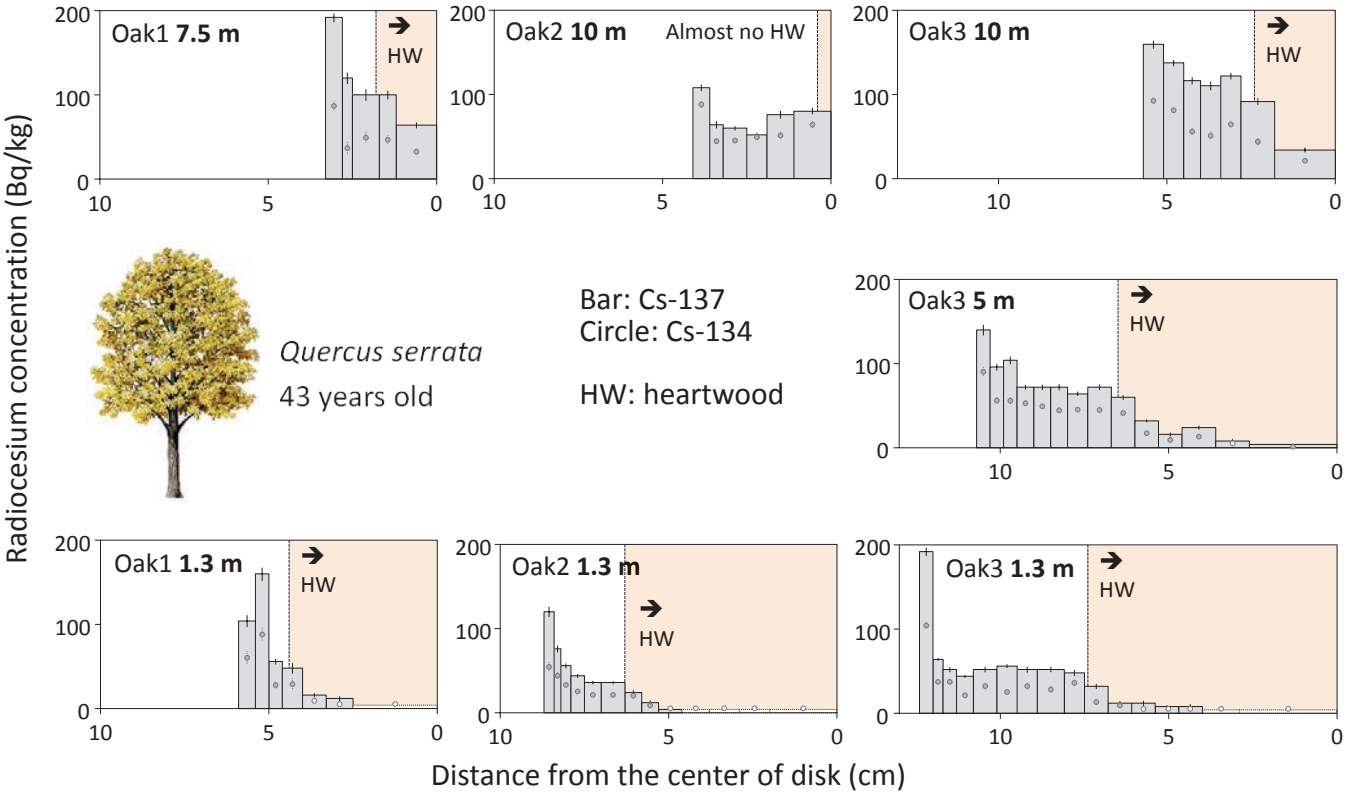
Wood disk of oak

Cs distribution in wood of red pine (Sep. 2012)



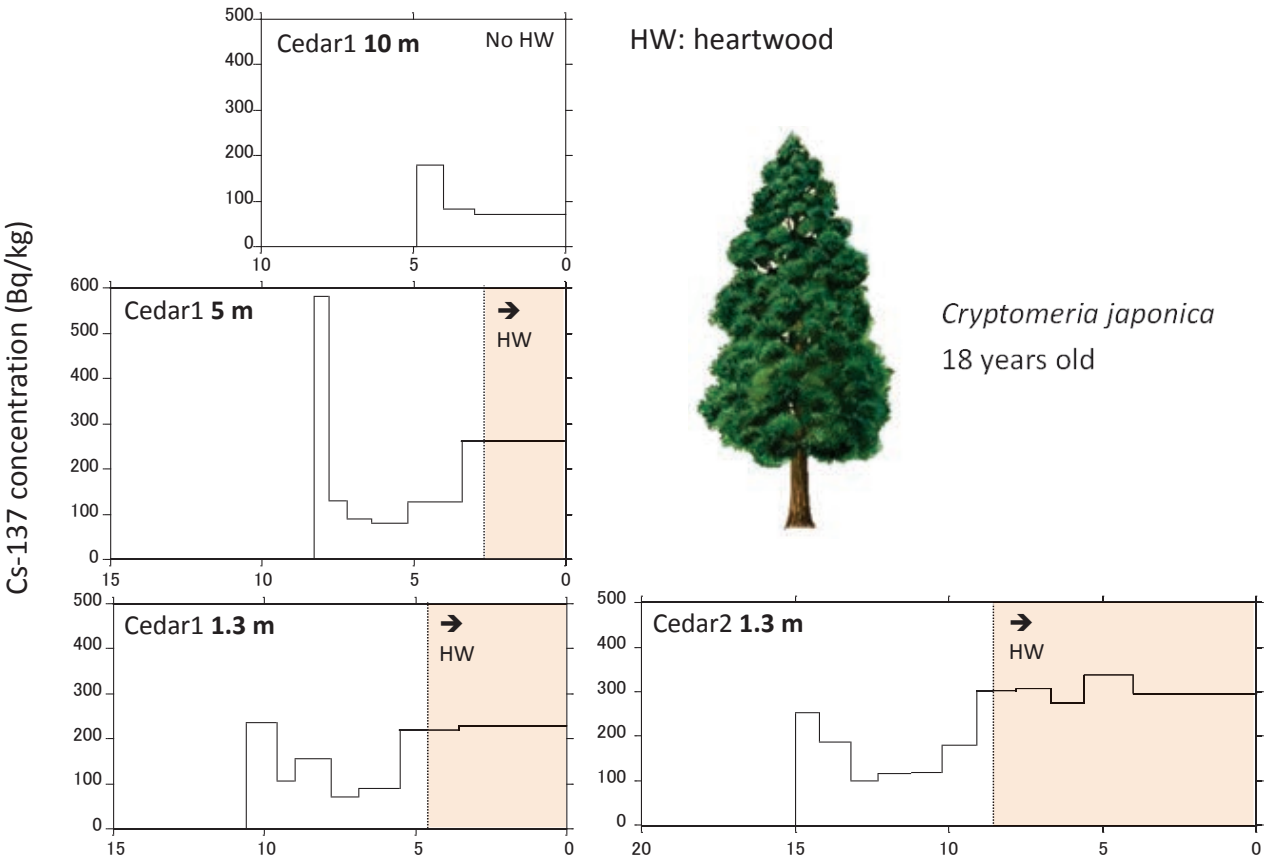
Ohashi *et al*. (2014)

Cs distribution in wood of oak (Sep. 2012)



Ohashi *et al*. (2014)

Cs-137 distribution in wood of Cedar (Sep. 2013)



HW: heartwood

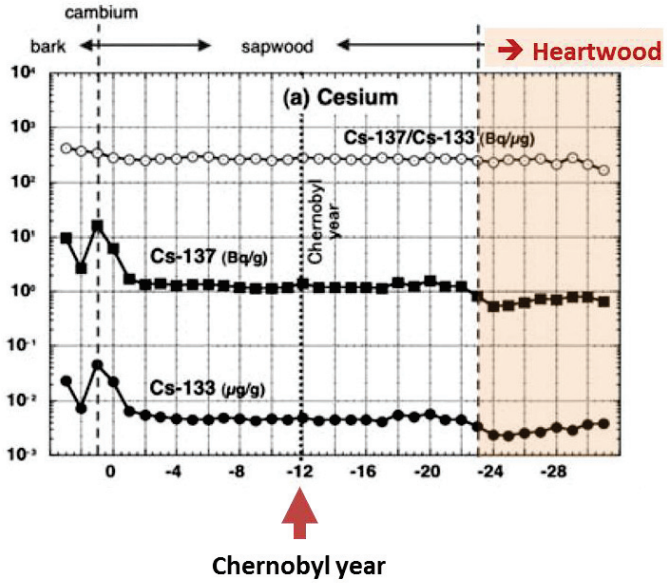
Cryptomeria japonica
18 years old

Okada *et al*. (unpublished)

Cs distribution in wood (previous studies)

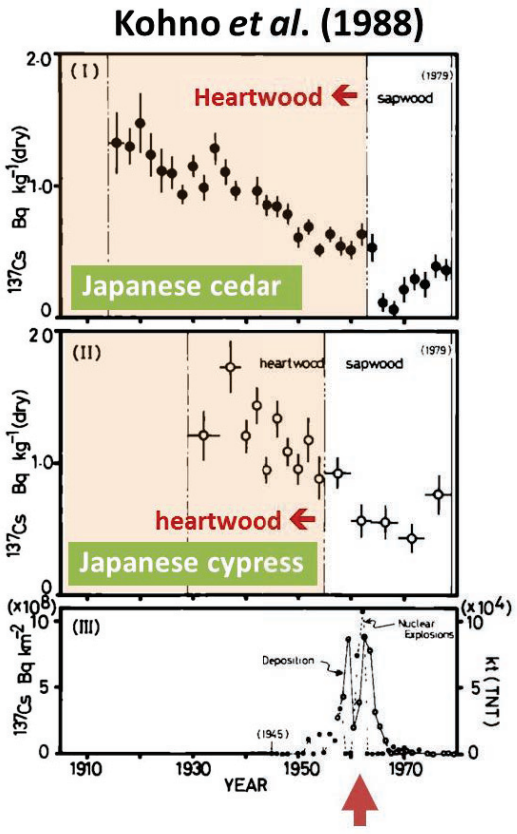
Yoshida *et al*. (2011)

Scots pine (European red pine)



Chernobyl year

Kohno *et al*. (1988)



Fallout from global weapons testing

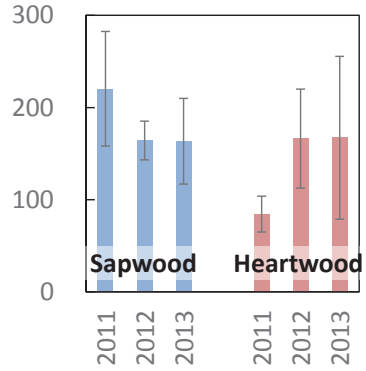
Temporal change in Cs-137 in wood

Sapwood
Heartwood

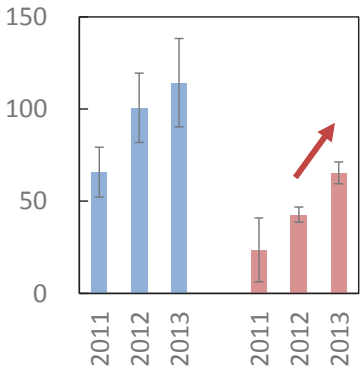
Cedar

Cs-137 concentration (Bq/kg)

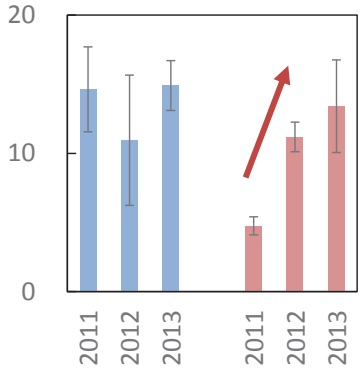
Kawauchi



Kami-Kawauchi

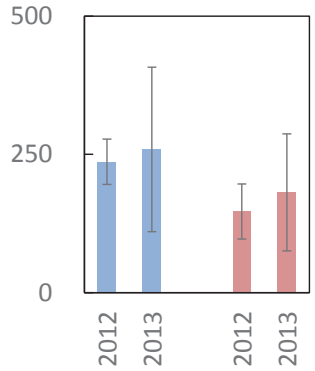


Otama

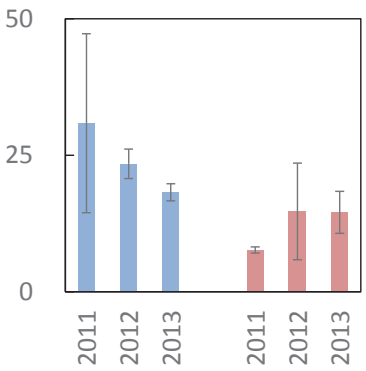


Cypress

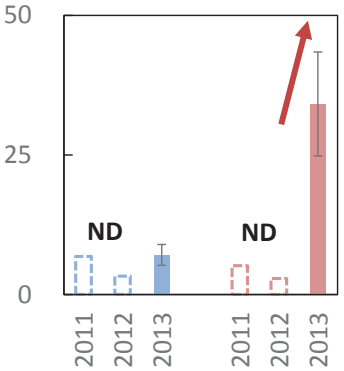
Kawauchi



Tsukuba (Ibaraki pref.)



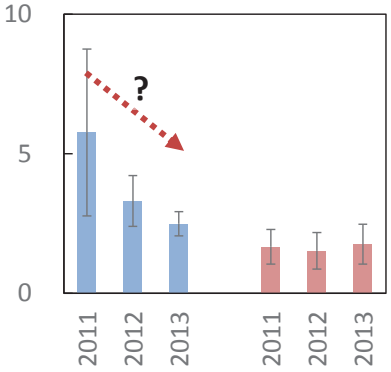
Tadami



Temporal change in Cs-137 in wood

Red pine

Otama

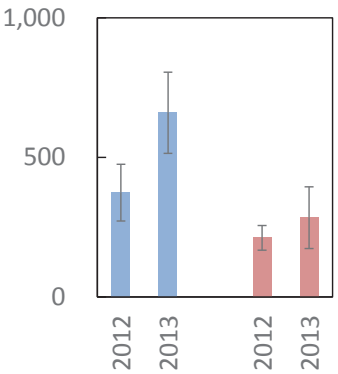


Sapwood
Heartwood

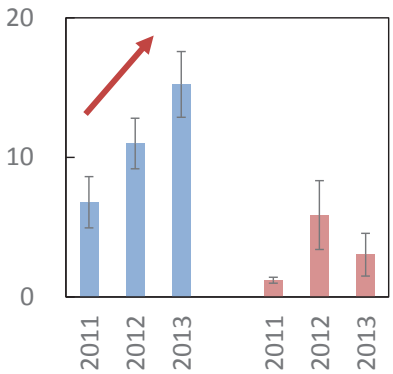
Cs-137 concentration (Bq/kg)

Oak

Kawauchi

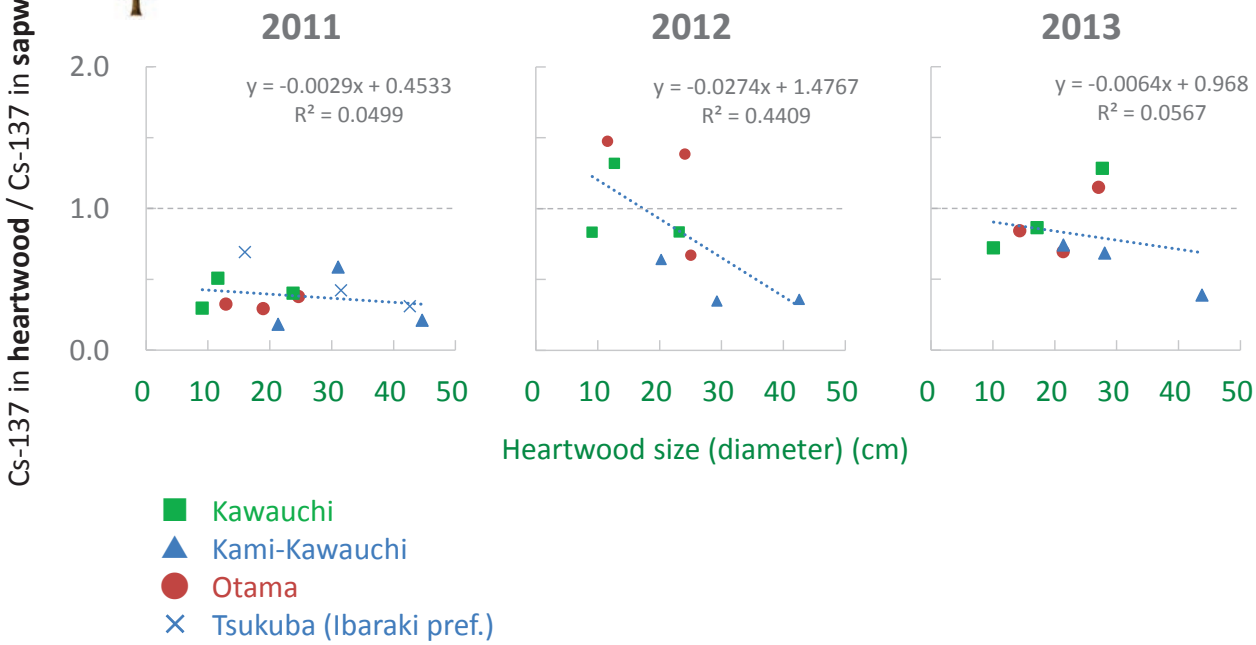


Otama



Cs transfer to heartwood

Cedar



Cs transfer to heartwood

Cypress

Red pine

Oak

Overview of radiocesium contamination in wood

Species	Cs temporal variation		Main contamination part in the future
	Sapwood	Heartwood	
Cedar *Cryptomeria japonica*	→	↗	**Heartwood**
Cypress *Chamaecyparis obtusa*	→	↗?	**Heartwood?**
Red pine *Pinus densiflora*	↘?	→	**Sapwood**
Oak *Quercus serrata*	↗	→	**Sapwood**

- Cs contamination patterns were **different among species** (and sites?)
- In small-sized cedars, Cs concentration has already been higher in heartwood than in sapwood

Related works in FFPRI

Forest

Hashimoto *et al.* (2012) The total amounts of radioactively contaminated materials in forests in Fukushima, Japan. *Scientific Reports* 2:416

Hashimoto *et al.* (2013) Predicted spatio-temporal dynamics of radiocesium deposited onto forests following the Fukushima nuclear accident. *Scientific Reports* 3:2564

Wood

Okada *et al.* (2011) Application of activable tracers to investigate radial movement of minerals in the stem of Japanese cedar (*Cryptomeria japonica*). *Journal of Wood Science* 57:421-428

Kuroda *et al.* (2013) Radiocesium concentrations in the bark, sapwood and heartwood of three tree species collected at Fukushima forests half a year after the Fukushima Dai-ichi nuclear accident. *Journal of Environmental Radioactivity* 122:37-42

Yoshida *et al.* (2014) Study on the densification of biomass containing radioactive substances: densification characteristics of woody leaves and branches. *Journal of the Japan Institute of Energy* 93:297-300

Shoot and Flower

Akama *et al.* (2013) Survey of radioactive contamination of sugi (*Cryptomeria japonica* D. Don) shoots and male flowers in Fukushima prefecture. *Japanese Journal of Forest Environment* 55:105-111

Edible wild plant

Kiyono and Akama (2013) Radioactive cesium contamination of edible wild plants after the accident at the Fukushima Daiichi Nuclear Power Plant. *Japanese Journal of Forest Environment* 55:113-118

Animal

Hasegawa *et al.* (2013) Radiocesium concentrations in epigeic earthworms at various distances from the Fukushima Nuclear Power Plant 6 months after the 2011 accident. *Journal of Environmental Radioactivity* 126:8-13

Soil

Fujii *et al.* (2014) Vertical migration of radiocesium and clay mineral composition in five forest soils contaminated by the Fukushima nuclear accident. *Soil Science and Plant Nutrition* (online)

Water

Shinomiya *et al.* (2014) Radioactive cesium discharge in stream water from a small watershed in forested headwaters during a typhoon flood event. *Soil Science and Plant Nutrition* (in press)

and more