Catchment scale Radiation monitoring in Fukushima area following the Fukushima Daichi Nuclear Power Plant accident

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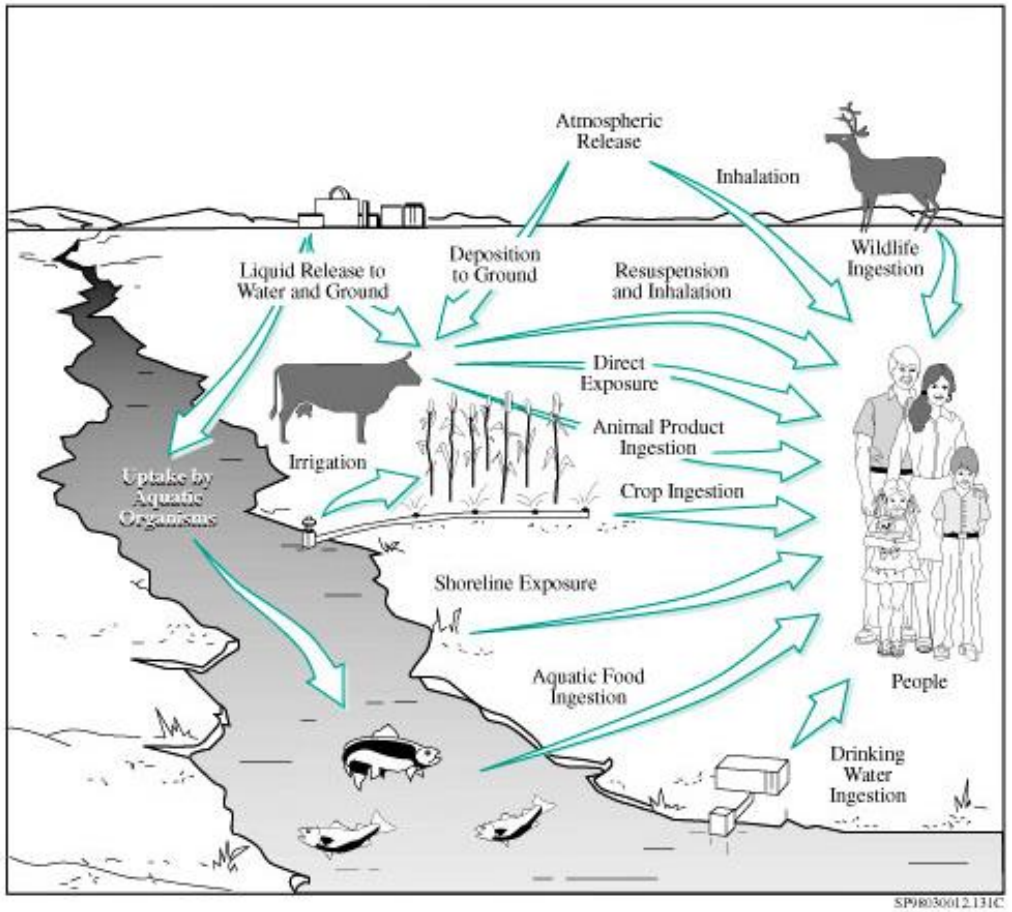
Introduction

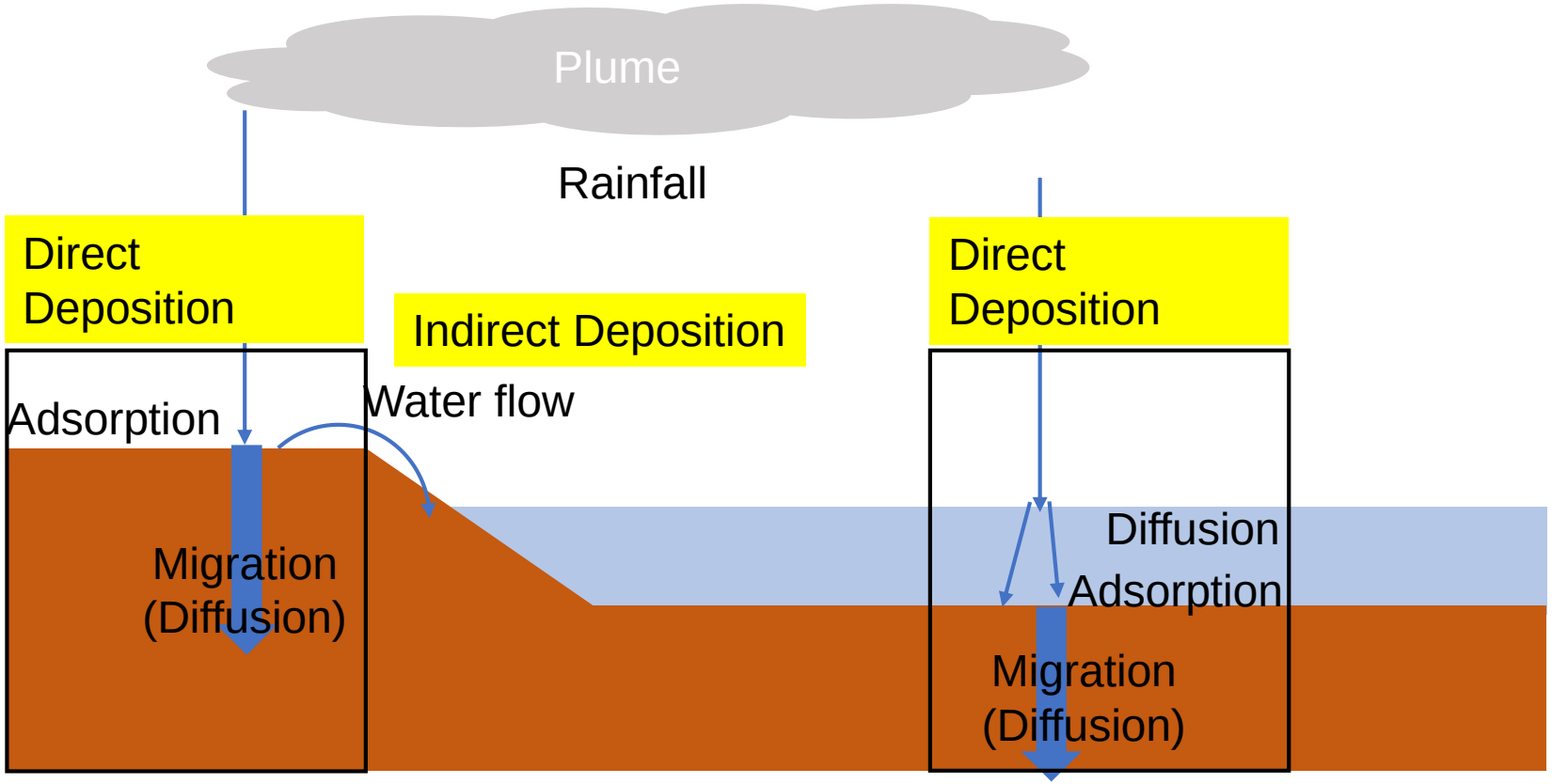
Radiation exposure pathways



https://www.learner.org/courses/envsci/visual/visual.php?shortname=exposure_pathways

Introduction

How radioactive cesium deposited and migrate in terrestrial environment?



Introduction

Objectives of our work

- Monitor the radioactive contamination in terrestrial area by analyzing horizontal and vertical distribution of air dose rate and Cs-137 inventory on soil catchment in different elevation and land use.
- Analyze the migration of Cs-137 in terrestrial area and accumulation of Cs-137 into lake/reservoir sediment

Field survey in Hibara Lake area

Sampling

*) Soil concentration data is as of March 11, 2012, Source: http://ramap.jmc.or.jp/map/eng/

Sampling Area

- About 100 km from FDNPP
- 10.8 km^2 surface area, 12 m averaged depth and 0.83 year retention time
- Samples were taken on August 8-9, 2016.

Sampling

Results

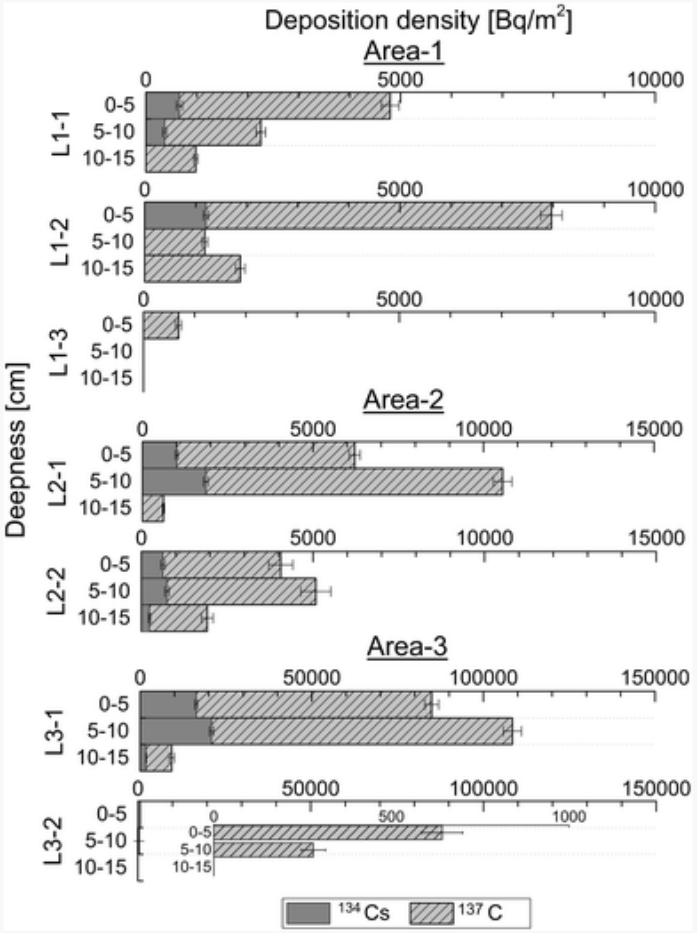


Fig. 2
Depth profile of deposition densities (Bq/m²) of ^{134}Cs and ^{137}Cs in sediment, which are decay corrected at sampling day, August 8, 2016

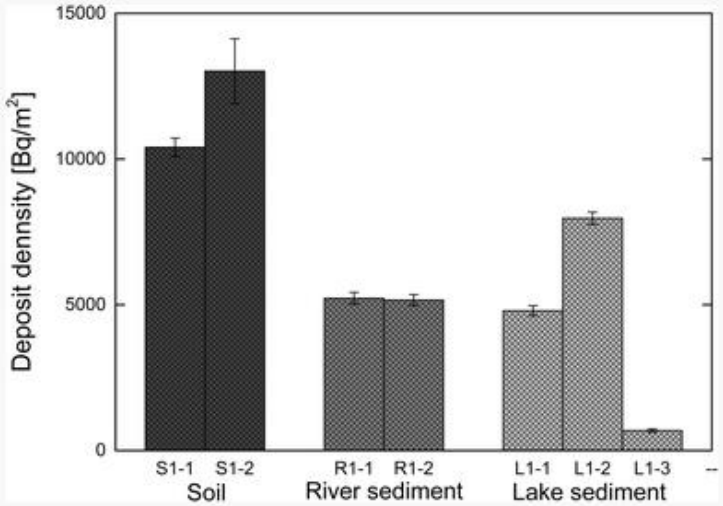


Fig. 3
Deposition densities (Bq/m²) of ^{137}Cs in surface (0–5 cm) of soil in surrounding area, river sediment and lake sediment in Area 1 (flat area), which are decay corrected at sampling day, August 8, 2016

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Results

Table 3 Activity concentration of ^{134}Cs and ^{137}Cs on sand fraction and silt and clay fraction of lake sediment and soil

Sample		Deepness (cm)	^{134}Cs				^{137}Cs			
			Sand		Silt and clay		Sand		Silt and clay	
			2 mm–70 μm		< 70 μm		2 mm–70 μm		< 70 μm	
			Bq/kg	Error	Bq/kg	Error	Bq/kg	Error	Bq/kg	Error
Lake sediment	L1-1	0–5	19	1	190	20	81	6	1880	220
		5–10	ND		81	7	16	1	440	50
		10–15	ND		42	4	26	2	660	80
	L1-2	0–5	23	2	56	5	86	7	700	70
		5–10	ND		ND		14	1	100	10
		10–15	ND		ND		37	4	110	10
	L2-1	0–5	15	1	20	1	100	10	250	20
		5–10	18	1	31	2	91	6	330	30
		10–15	ND		ND		12	1	73	8
	L2-2	0–5	27	2	ND		150	10	400	40
		5–10	29	1	44	5	190	10	700	60
		10–15	12	1	11	1	60	4	160	10
	L3-1	0–5	210	10	1460	60	1110	30	19,730	850
		5–10	270	20	1680	70	1450	40	21,060	890
		10–15	90	5	410	20	1020	40	6650	300
	L3-2	0–5	ND		ND		50	6	1450	180
		5–10	ND		ND		13	2	130	20
		10–15	ND		ND		6.8	0.9	90	10
Soil	S1-1	0–5	18	2	39	3	120	10	530	50
		5–10	ND		ND		10.1	0.8	37	4
		10–15	ND		ND		ND		60	7
	S1-2	0–5	84	7	130	10	820	70	1760	180
		5–10	7	1	15	2	86	8	66	7
		10–15	96	4	160	10	860	70	2370	260

Radioactivity was corrected at sampling day, August 8, 2016. ND shows Not Detected. Sample L1-3 is not measured due to its low bulk concentration of radioactive cesium. Calculated detection limit is 3.8 and 5 Bq/kg for ^{134}Cs and ^{137}Cs, respectively. [36]

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Field survey in Ogi reservoir area

Measurement and sampling

- Ogi reservoir, inside 20 km zone
- 4.2 km^2 area of reservoir.
- Sampling was conducted on 15-16 March 2018.

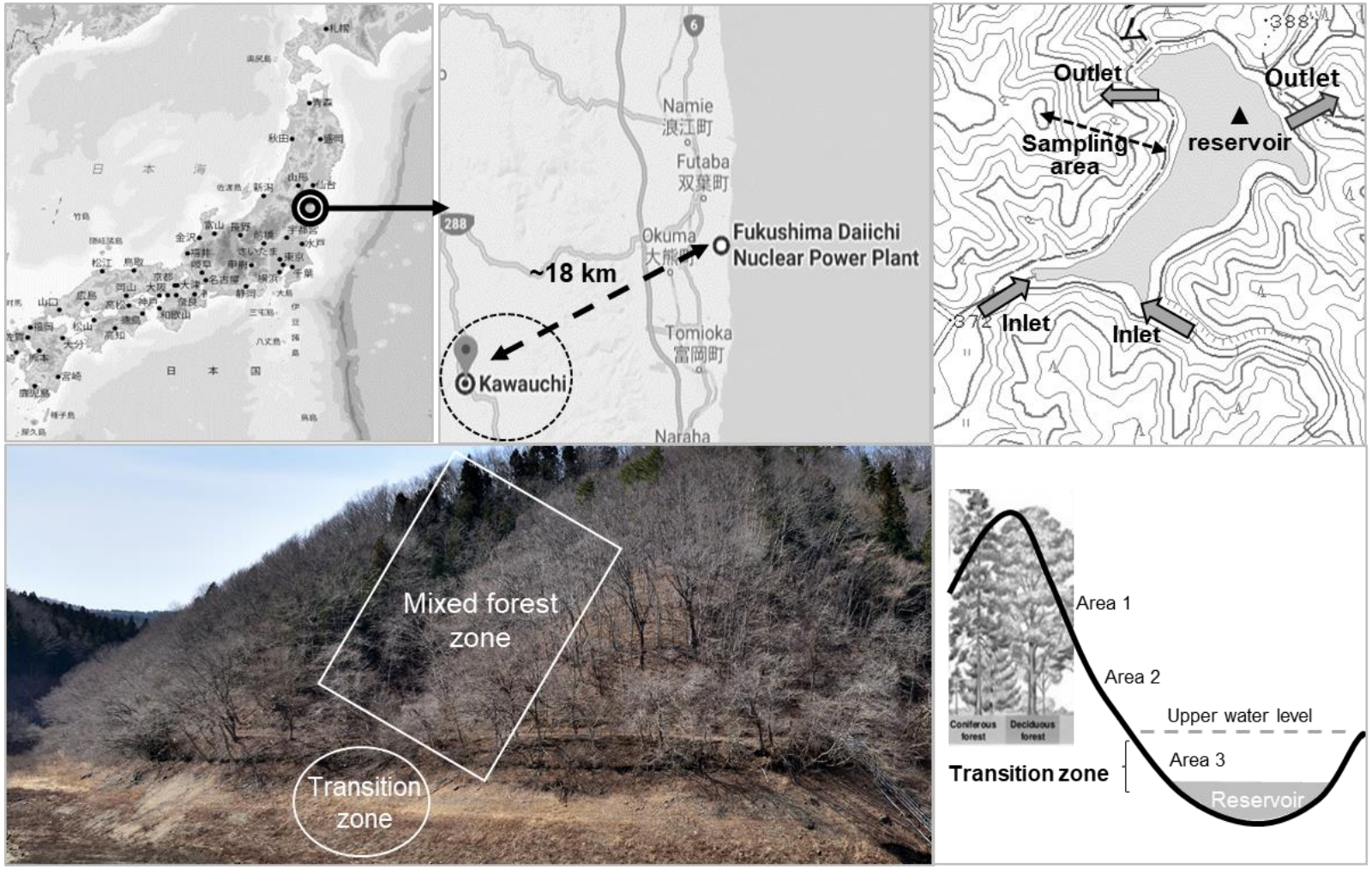

Fig. The study area, Ogi reservoir catchment, Kawauchi village, Fukushima.

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Measurement and sampling

Unpublished work

Measurement and sampling

Results

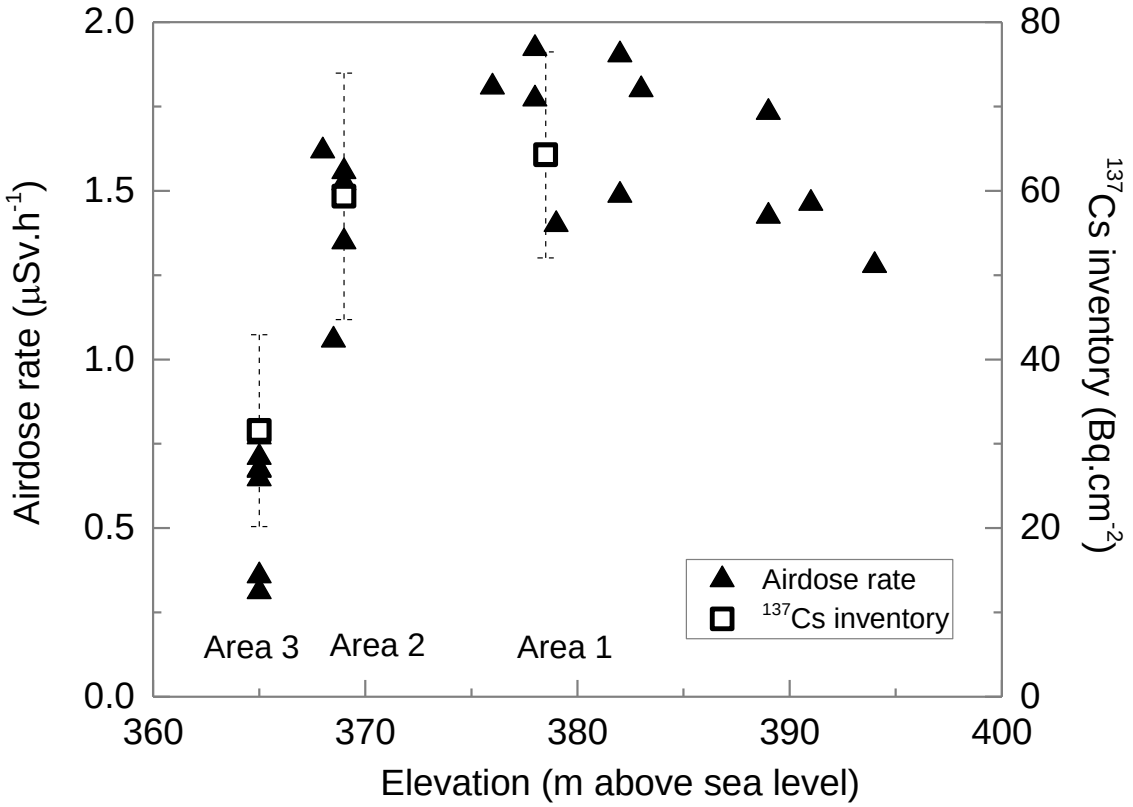

Fig. Air dose rate, ^{137}Cs iventory and area elevation of the catchment.

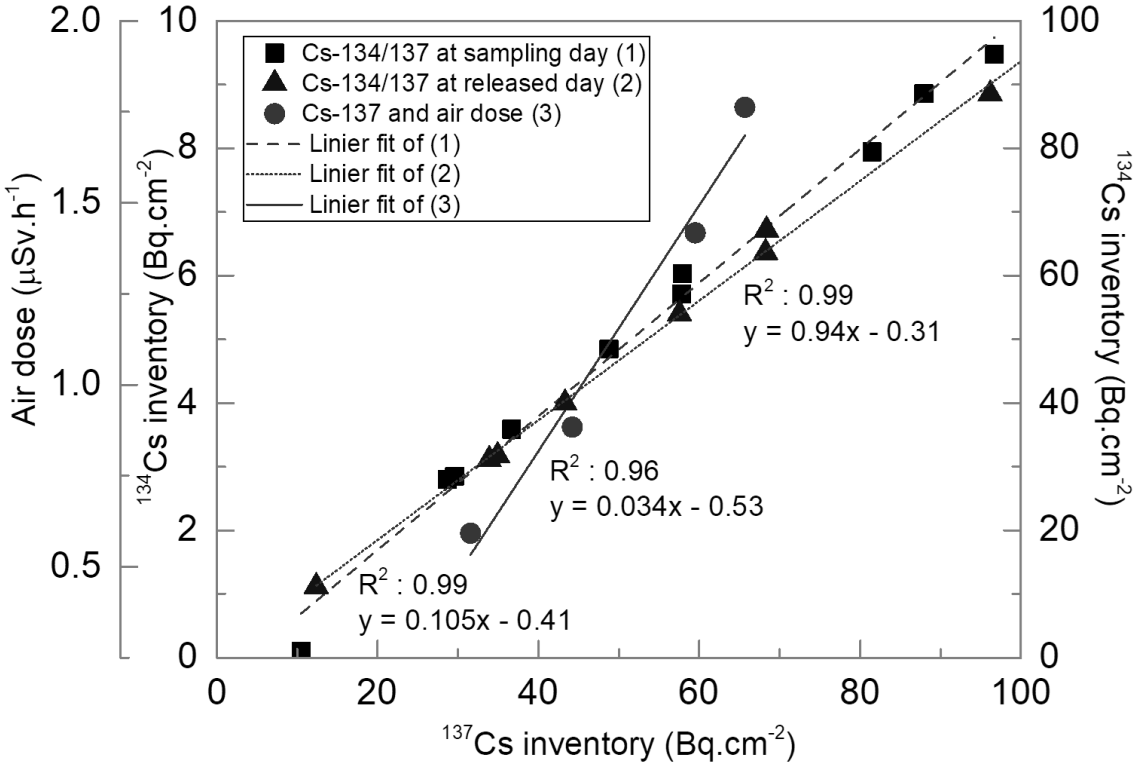

Fig. ^{137}Cs and ^{134}Cs inventory decay corrected at sampling and released day, and air dose rate (µSv·h^{-1}).

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Results

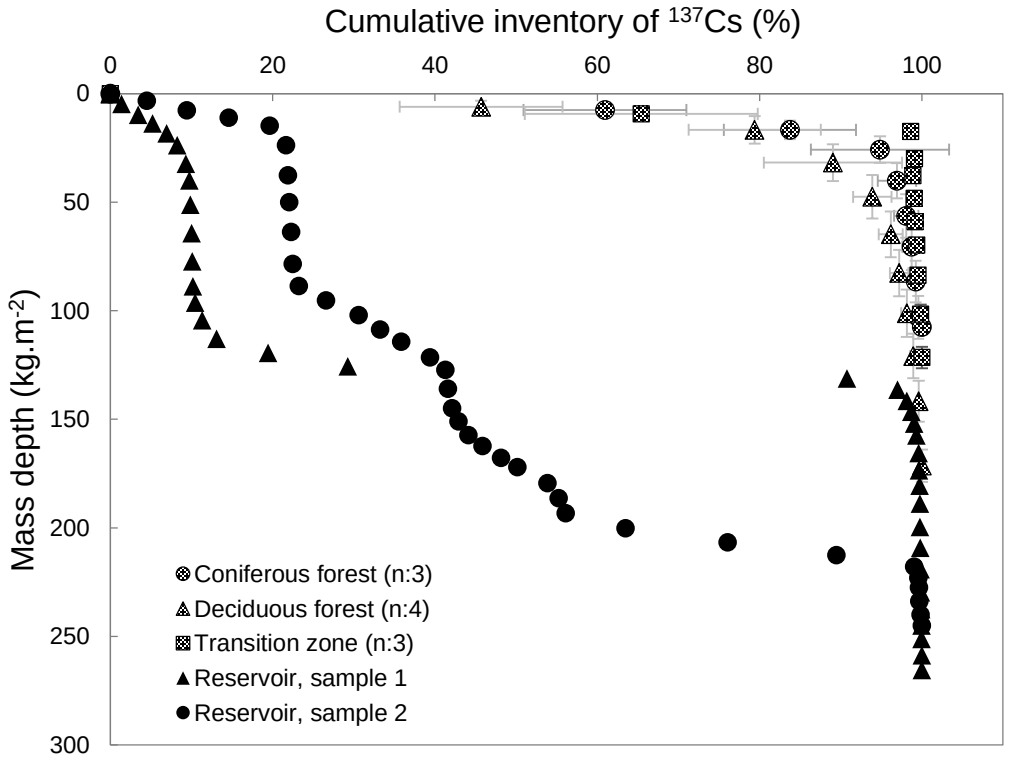

Fig. Vertical profile of ^{137}Cs cumulative inventory of soil catchment and reseroir sediment. Each increment equals to 1 cm and 2 cm depth for sediment and soil, respectively.

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Results

Table. Data of ^{137}Cs in soil, sediment and its ratio between the previous studies and the present study. The ^{137}Cs deposition density value is decay corrected to each sampling date.

Water body	Type	Location	Area (km^2)	Deposition density in surrounding soil ($Bq.cm^{-2}$)	Deposition density in sediment ($Bq.cm^{-2}$)	^{137}Cs soil to sediment ratio	Sampling date	References
Oyado	Irrigation pond	Nihonmatsu city, 40~50 km from FDNPP	0.001	36	8	4.39	July, 2011	Yoshimura et. al., 2014.
Takayashiki			0.001	32	42	0.75		
Neppami-Ike		Kawamata town, 40~50 km from FDNPP	0.002	35	7	5.29	August, 2011	
Matsuzawakami-ike			0.009	21	8	2.75		
Suzuuchi	Irrigation pond	Okuma town, ~10 km from FDNPP	0.004	640 ± 220	1300 ± 650	0.49 ± 0.30	July, 2016	Wakiyama et. al., 2017
Funasawa			0.011	290 ± 90	890 ± 630	0.33 ± 0.25		
Inkyozaka			0.007	210 ± 110	160 ± 67	1.31 ± 0.88		
Kashiramori			0.008	90 ± 4	110 ± 46	0.82 ± 0.34		
Hibara	Lake	Yama gun, ~100 km from FDNPP	10.8	0.3 ± 0.15	1.2 ± 0.5	0.25 ± 0.23	August, 2016	Basuki et. al., 2018.
Ogi	Reservoir	Kawauchi village, ~18 km from FDNPP	4.2	54 ± 10	102 ± 57	0.53 ± 0.31	March, 2018	Present study

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Results

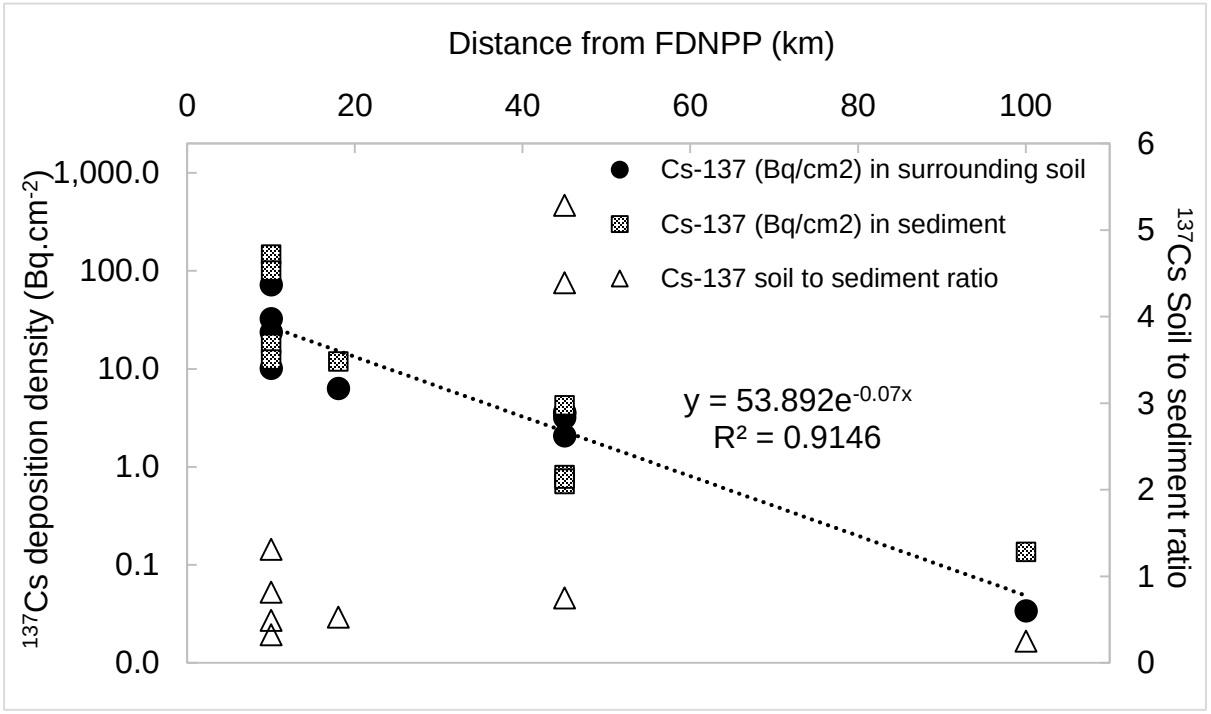

Fig. Location dependency of ^{137}Cs deposition density in soil and sediment. The data are decay corrected to the released day.

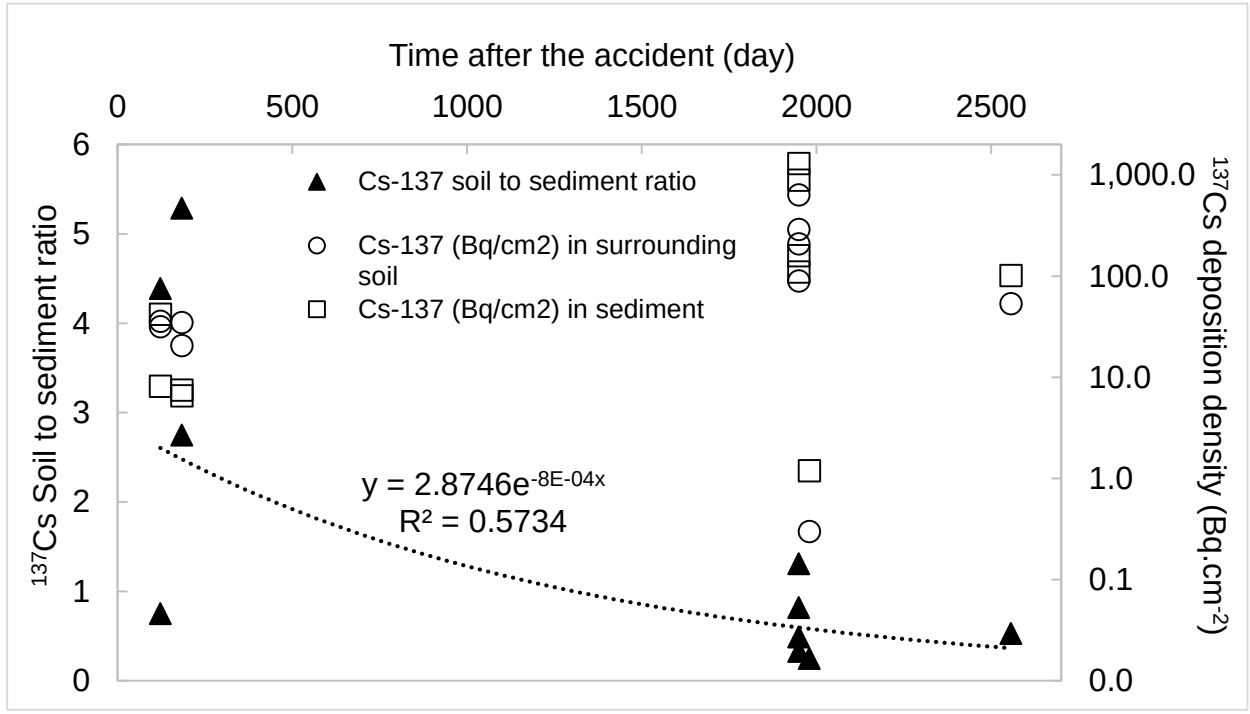

Fig. Time dependency of ^{137}Cs soil to sediment ratio. The data are decay corrected to the samping day

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Results

Table. Physicochemical property of surface soil catchment (0-2 cm depth)

Soil type	Sample (*n*)	Bulk density ($g \cdot cm^{-3}$)	pH (H_2O)	OM fraction (%)	Size fraction <75μm (%)	Exchangeable cation ($cmol\ kg^{-1}$)				CEC ($cmol\ kg^{-1}$)	Base saturation (%)
						Na^+	K^+	Mg^{2+}	Ca^{2+}		
Coniferous forest soil	3	0.37±0.11	4.34±0.15	37.47±15.94	20.99±6.86	0.19±0.03	0.40±0.09	0.52±0.14	4.45±0.85	82.12±17.32	6.77±1.77
Deciduous forest soil	4	0.30±0.14	4.52±0.19	40.11±14.94	17.67±4.21	0.14±0.01	0.50±0.07	0.65±0.11	8.29±1.21	77.26±25.23	12.39±4.34
Transition zone soil	3	0.46±0.09	4.73±0.04	19.00±2.88	66.09±7.17	0.23±0.07	0.28±0.02	0.35±0.02	4.50±0.20	58.74±7.55	9.12±1.23

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Conclusions

- The air dose rate in forest area catchment inside 20 km zone still much higher than the reference dose.
- The sediment vertical profile showed the accumulation of ^{137}Cs in sediment. The low value of radiocesium soil to sediment ratio provided the evidence of radiocesium accumulation in the sediment from the catchment.
- We showed land used type (forest area) and slope of area were important in Cs-137 migration.
- The physicochemical property of the forest surface soil could be a possible factor of high retention of radioactive contaminant in the steep slope forest zone.
- We showed the distance dependence of radioactive contamination (Cs-137 inventory) of catchment area and time dependence of Cs-137 in soil and sediment ratio.