DOI: 10.34355/CRiES.U.Tsukuba.00206
Supplemental report

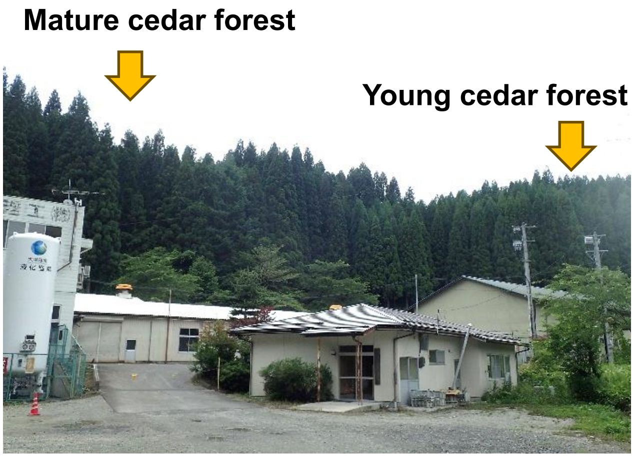
Site Description

Location: Notoriba-yama, Yamakiya, Kawamata Town, Fukushima Prefecture (N37.58575, E140.69066)

Altitude: 530 m

Mean slope: 25°

Dominant vegetation: *Cryptomeria japonica* (15-year-old plantation as of 2011)



Picture 1 Mature and young cedar forest sites (July 2, 2017)

Picture 2 Inside the young cedar forest (August 9, 2023)

Picture 3 Sampling plot (July 2, 2011)

DOI: 10.34355/CRiES.U.Tsukuba.00206
Supplemental report

Soil profile

Soil group: Non-allophanic Andsol (Soil Classification System of Japan), Aluandic Andsol (WRB)

Basement rock: Metamorphic rocks (Mesozoic Early Cretaceous Aptian - Albian)

Parent material (landform covered material): Volcanic ash, Metamorphic rocks

Mode of deposition: Eolian, Creep

Rock outcrop: None

Horizon	Depth (cm)	Horizon boundary	Color (moist)	Soil texture	Rock fragment	Soil structure	Hardness (mm)*	Al
A1	0-14	Wavy Diffuse	10YR2/2	CL	None	CR, M, F	8	+
A2	14-46	Wavy Diffuse	10YR2/3	CL	None	SB, WE, F-M	10	+++
BA	46-55	Wavy Gradual	10YR3/3	CL	None	SB, WE, F-M	15	+++
Bw1	55-68	Wavy Gradual	10YR3/4	L	Φ1-10cm SA, SL, M	SB, WE, F-M	15	++
Bw2	68-80	Smooth Gradual	10YR4/6	L	Φ1-10cm SA, SL, C	SB, WE, F-M	19	++
Bw3	80-100+		10YR4/6	L	Φ1-10cm SA, SL, C	SB, WE, F-M	14	++

*Measurement values using soil hardness tester (DIK-5553).

DOI: 10.34355/CRiES.U.Tsukuba.00206
Supplemental report

Table 1 Chemical properties of soil profile.

Horizon	Depth (cm)	pH H_2O	pH KCl	pH NaF	TC (g kg^{-1})	TN (g kg^{-1})	C/N	Exchangeable cation ($cmol_{(c)}$ kg^{-1})				CEC ($cmol_{(c)}$ kg^{-1})	BS (%)
								Na^+	K^+	Mg^{2+}	Ca^{2+}		
A1	0-14	4.72	4.03		82.0	6.31	13.0	0.10	0.10	0.81	3.34	45.9	9.5
A2	14-46	4.88	4.14		48.8	3.09	15.8	0.01	0.09	0.17	0.68	36.5	2.6
BA	46-55	4.81	4.09		33.3	2.07	16.1	0.02	0.09	0.07	0.35	30.5	1.7
Bw1	55-68	4.89	4.02		19.0	1.16	16.3	0.01	0.17	0.12	0.40	24.0	2.9
Bw2	68-80	5.00	3.94		6.75	0.42	16.2	0.01	0.13	0.16	0.53	21.1	3.9
Bw3	80-100+	5.05	3.90		4.25	0.26	16.1	0.01	0.17	0.37	0.55	16.3	6.7

TC, total carbon content; NC, total nitrogen content; CEC, cation exchangeable capacity; BS, base saturation.

Table 2 Extractable Al, Fe and Si of soil profile.

Horizon	Depth (cm)	Extractable Al, Fe, Si (g kg^{-1})							Al_o+1/2Fe_o (g kg^{-1})	Al_p/Al_o	(Al_o-Al_p)/Si molar ratio	Fe_o/Fe_d
		Al_o	Fe_o	Si_o	Al_p	Fe_p	Al_d	Fe_d				
A1	0-14	14.0	6.19	2.30	11.6	4.92			17.1	0.82	1.12	
A2	14-46	16.5	7.79	3.22	11.5	5.91			20.4	0.70	1.61	
BA	46-55	12.5	7.11	2.42	8.79	5.38			16.0	0.71	1.58	
Bw1	55-68	8.57	5.52	1.51	5.84	3.68			11.3	0.68	1.88	
Bw2	68-80	4.22	3.87	0.56	2.91	2.07			6.2	0.69	2.45	
Bw3	80-100+	2.98	3.22	0.34	2.07	1.69			4.6	0.69	2.76	

Al_o, Fe_o, Si_o, oxalate-extractable Al, Fe, Si; Al_p, Fe_p, pyrophosphate-extractable Al, Fe; Al_d, Fe_d, dithionite-citrate extractable Al, Fe.

DOI: 10.34355/CRiES.U.Tsukuba.00206
Supplemental report

Table 3 Physical properties of soil profile.

Depth (cm)	Three phases distribution (Volume %)			Micropore (Volume%)	Macropore (Volume%)	Bulk density (g cm^{-3})	Specific Gravity (g cm^{-3})	K_{20} (cm s^{-1})
	Solid	Liquid	Gaseous					
5-10	13.0	33.0	54.0	63.3	23.7	0.37	2.81	1.14×10^{-1}
15-20	17.8	40.4	41.8	68.9	13.2	0.49	2.72	3.97×10^{-2}
25-30	16.9	37.5	45.7	71.3	11.8	0.47	2.81	3.43×10^{-2}
35-40	20.3	44.6	35.2	68.7	11.0	0.57	2.82	1.16×10^{-2}
45-50	22.1	47.9	30.0	67.5	10.4	0.60	2.70	5.00×10^{-3}
55-60	24.4	47.2	28.4	65.2	10.4	0.68	2.79	7.04×10^{-3}
65-70	24.7	43.7	31.6	66.0	9.2	0.69	2.81	4.71×10^{-3}
75-80	26.9	44.2	28.9	62.2	10.9	0.78	2.88	2.53×10^{-3}
85-90	30.2	43.1	26.7	59.6	10.3	0.84	2.80	1.89×10^{-3}
95-100	31.2	43.2	25.6	58.9	10.0	0.87	2.80	1.95×10^{-3}

K_{20}, saturated hydraulic conductivity converted at 20°C.

Table 4 Particle size distribution

Horizon	Depth (cm)	Coarse sand (%) 0.2-2 mm	Fine sand (%) 0.063-0.2 mm	Silt (%) 0.002-0.063 mm	Clay (%) <0.002 mm
A1	0-14	23	20	31	26
A2	14-46	24	19	36	21
BA	46-55	22	21	38	19
Bw1	55-68	23	25	39	13
Bw2	68-80	28	26	35	11
Bw3	80-100+	18	15	53	13

DOI: 10.34355/CRiES.U.Tsukuba.00206
Supplemental report

Vertical distribution of Cs-137 concentration

The vertical distribution of Cs-137 concentration in mineral soil layers without litter layer was fitted using the following equation (Takahashi et al., 2019).

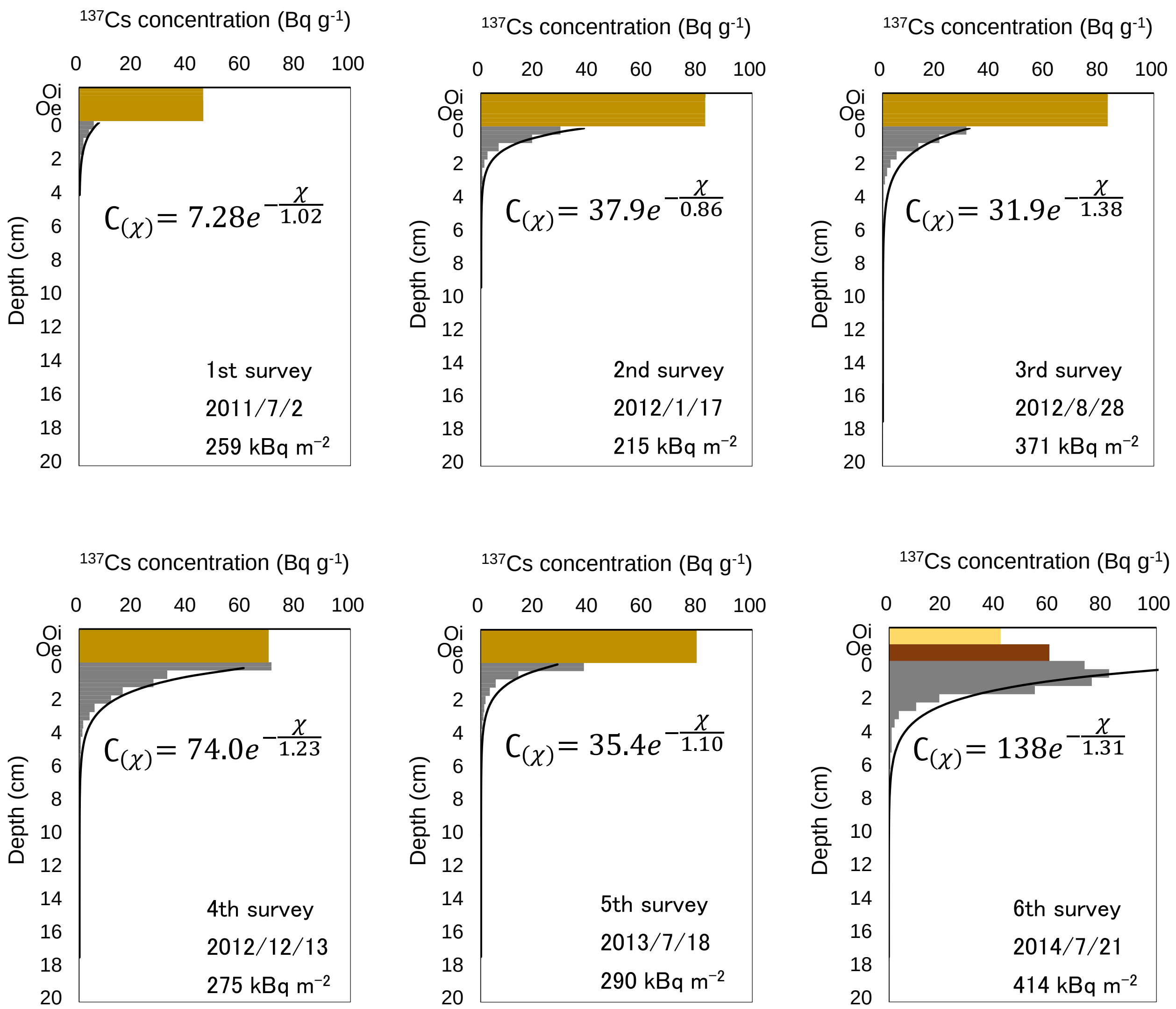
$$C_{(\chi)} = C_{(0)} e^{-\frac{\chi}{\alpha}} \qquad \cdots(1)$$

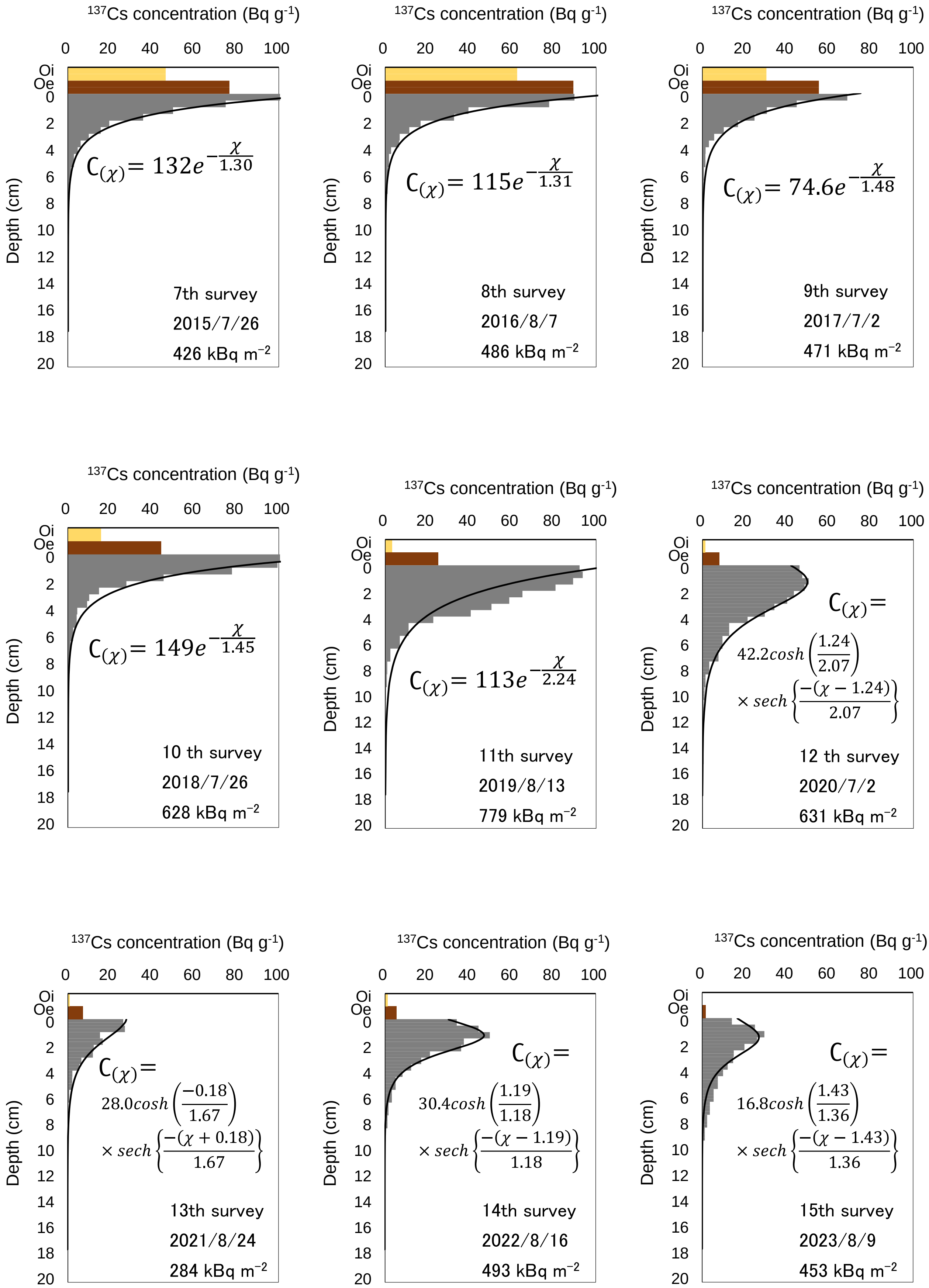
where $C_{(\chi)}$ and $C_{(0)}$ are the Cs-137 concentration (Bq kg^{-1}) at depth χ (cm) and χ=0, respectively. The parameter α (cm) is the relaxation depth (cm), indicating the necessary distance which $C_{(0)}$ decreases to 1/ e(≒1/2.7).

If the maximal Cs-137 concentration in the soil shifted progressively to deeper layers with time, an analytical function was defined on the basis of the hyperbolic secant (sech) and hyperbolic cosine (cosh) functions as follows (Matsuda et al., 2015).

$$C_{(\chi)} = C_{(0)} cosh\left(\frac{\chi_m}{\alpha}\right) \times sech\left\{\frac{-(\chi-\chi_m)}{\alpha}\right\} \qquad \cdots(2)$$

where X_m is the depth at which the cesium-137 concentration reaches its maximum.




137Cs concentration (Bq g-1)
Depth (cm)
Oi
Oe
$C_{(\chi)} = 132e^{-\frac{\chi}{1.30}}$
7th survey
2015/7/26
426 kBq m-2
$C_{(\chi)} = 115e^{-\frac{\chi}{1.31}}$
8th survey
2016/8/7
486 kBq m-2
$C_{(\chi)} = 74.6e^{-\frac{\chi}{1.48}}$
9th survey
2017/7/2
471 kBq m-2
$C_{(\chi)} = 149e^{-\frac{\chi}{1.45}}$
10 th survey
2018/7/26
628 kBq m-2
$C_{(\chi)} = 113e^{-\frac{\chi}{2.24}}$
11th survey
2019/8/13
779 kBq m-2
$C_{(\chi)} = 42.2cosh\left(\frac{1.24}{2.07}\right) \times sech\left\{\frac{-(\chi - 1.24)}{2.07}\right\}$
12 th survey
2020/7/2
631 kBq m-2
$C_{(\chi)} = 28.0cosh\left(\frac{-0.18}{1.67}\right) \times sech\left\{\frac{-(\chi + 0.18)}{1.67}\right\}$
13th survey
2021/8/24
284 kBq m-2
$C_{(\chi)} = 30.4cosh\left(\frac{1.19}{1.18}\right) \times sech\left\{\frac{-(\chi - 1.19)}{1.18}\right\}$
14th survey
2022/8/16
493 kBq m-2
$C_{(\chi)} = 16.8cosh\left(\frac{1.43}{1.36}\right) \times sech\left\{\frac{-(\chi - 1.43)}{1.36}\right\}$
15th survey
2023/8/9
453 kBq m-2

DOI: 10.34355/CRiES.U.Tsukuba.00206
Supplemental report

References

Matsuda, N., Mikami, S., Shimoura, S., Takahashi, J., Nakano, M., Shimada, K., Uno, K., Hagiwara, S., Saito, K., 2015. Depth profiles of radioactive cesium in soil using a scraper plate over a wide area surrounding the Fukushima Dai-ichi Nuclear Power Plant, Japan. J. Environ. Radioact. 139, 427–434. https://doi.org/10.1016/j.jenvrad.2014.10.001

Takahashi, J., Onda, Y., Hihara, D., Tamura, K., 2019. Six-year monitoring of the vertical distribution of radiocesium in three forest soils after the Fukushima Dai-ichi Nuclear Power Plant accident. J. Environ. Radioact. 192, 172–180. https://doi.org/10.1016/j.jenvrad.2018.06.015

Acknowledgments

This study was supported by the Commission Study of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) FY 2011–2012; Nuclear Regulation Authority (NRA) FY 2013–2014; Japan Atomic Energy Agency-funded FY2015–2023; JSPS KAKENHI Grant-in-Aid for Early-Career Scientists (20K19951).