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Evaluating of the effect of thinning on suspended sediment runoff in a cypress and cedar plantation forest using Fukushima-derived Cs-137,Cs-134 and Pb-210ex

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Introduction

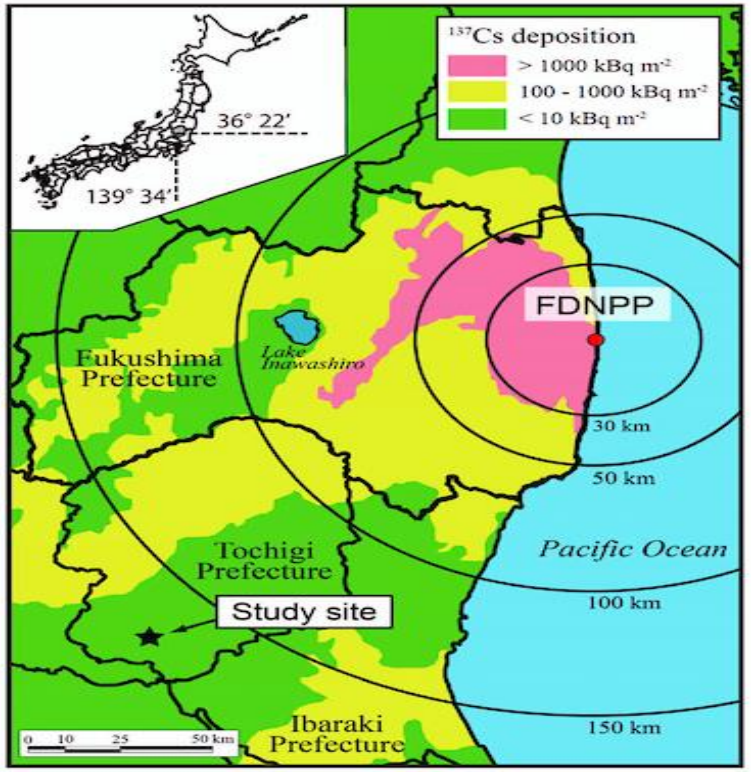
Thinning cause the increase of the sediment erosion by soil disturbance with establishing skid trail and dragging timber. Eroded sediment can flow into the river and float as a suspended sediment(SS), which result in downstream water pollution. To detective the movement of sediment, radioactivity was used because radioactive combined with sediment Strongly. Cs-137(half-life 30.2 year) and Pb-210ex had been used as very popular tracers. Those radioactivity show characteristic depth distribution. It is useful to follow soil movement more detail. But now, the research using Cs-134 as a tracer is nothing. Cs-134(half-life 2 year) exist shallower depth than Cs-137 and Pb-210ex(Teramage et al, 2011). Using by Cs-134 will be useful to know soil movement more.

In 11th March 2011 in japan, Fukushima Daiichi Nuclear Power Plant Accident occurred and Cs-137 and Cs-134 deposited 8kBq/m^2 and 7.5kBq/m^2 in Mt.Karasawa, Tochigi prefecture(Kato et al, 2012).

So, Cs-137 and Cs-134 from Fukushima Daiichi Nuclear Power Plant can be applied as a tracer.

From the viewpoint of the forest management, monitoring a series of changes of soil erosion in the long-term is necessary.

But now, we don't have research examined a series of change of SS's amount and production source from pre- to post thinning in long term .



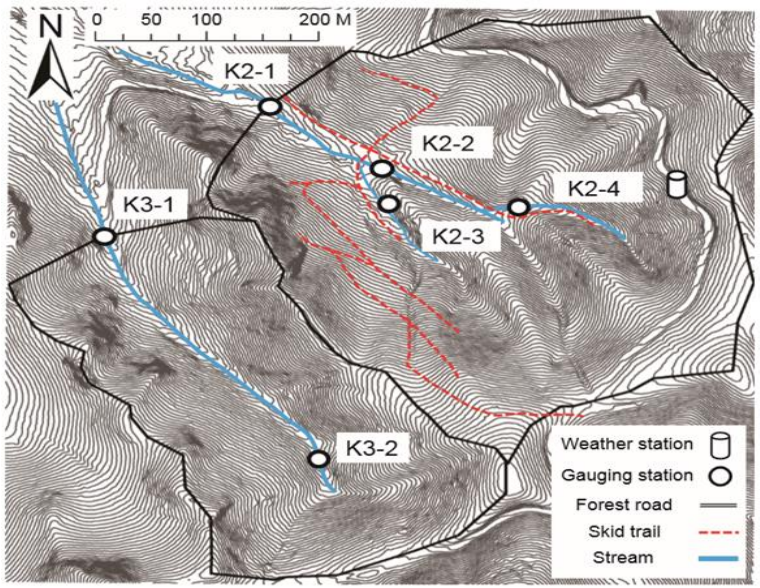
Cs-137 deposition (Kato et al, 2012)

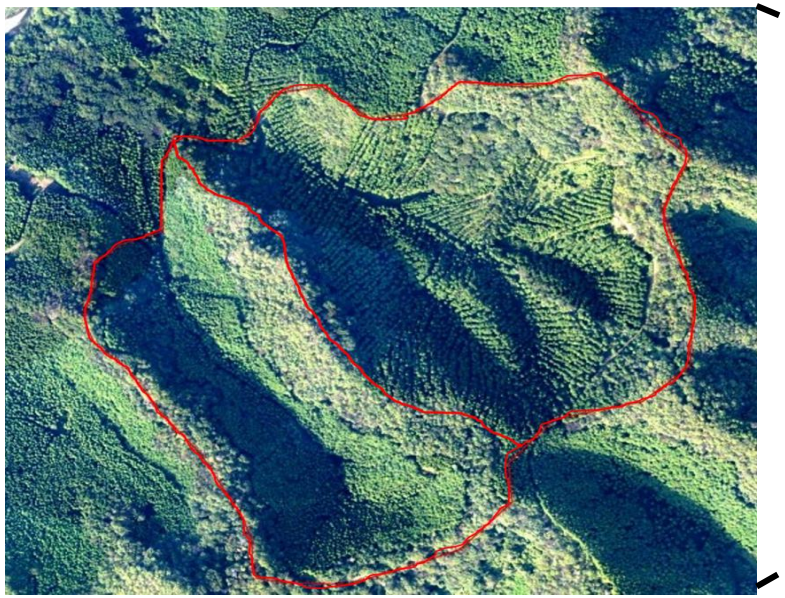
Objective

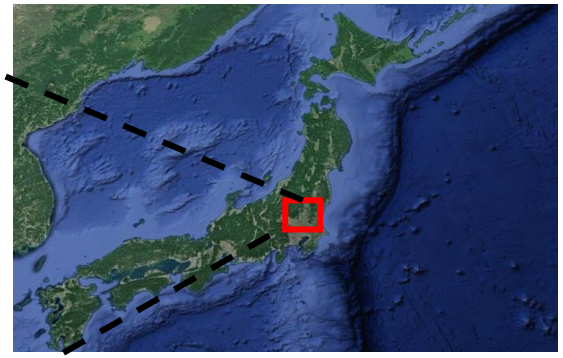
・Focus on the long term observation of SS activity from pre- to post thinning(after 8 years) with using a radionuclides which is derived from Fukushima Daiichi nuclear powerplant(Cs-137, Cs-134) and natural radionuclide(Pb-210ex).

Study site- Mt.Karasawa in Tochigi prefecture, Japan

180km southwest of Fukushima Daiichi nuclear power plant
Initial deposition amount of Cs-137, Cs-134: 8kBq/m^2 and 7.5kBq/m^2

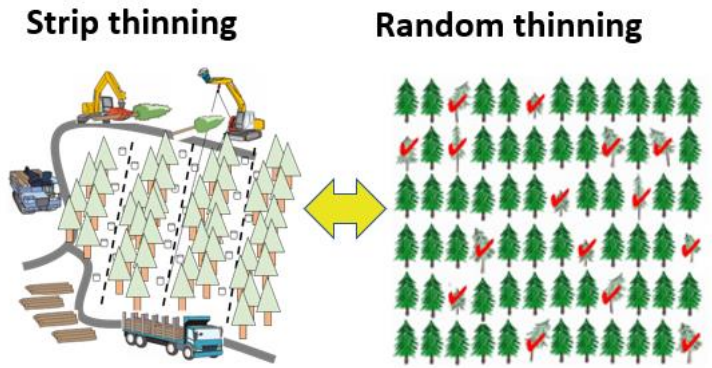






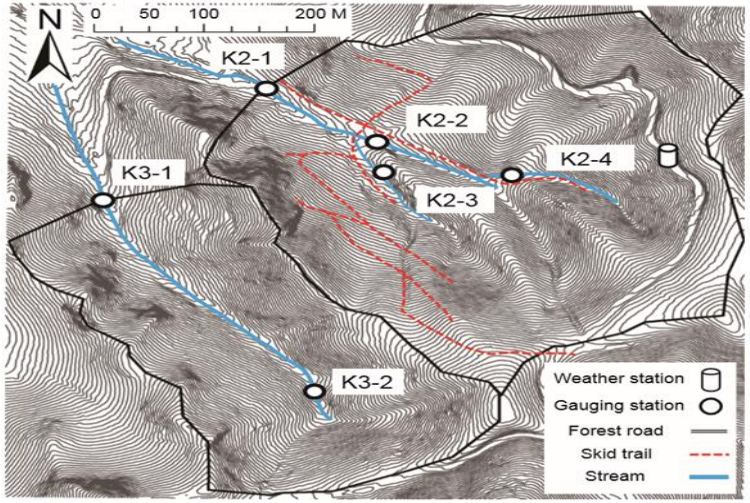
Catchment	K2	K3
Catchment area	17.1ha	8.9ha
Type of thinning	Strip thinning	Random thinning
Thinning period	Jul-Nov, 2011	Jan-Mar, 2013
SS sample point	4 point	2 point
Turbidity censor	K2-1	K3-1

Difference between thinning type



Managed with machine Create a lot skid trail	Choose and Cut the poor growth tree
Efficiently	Take cost
Heavy soil disturbances	Less soil disturbances

Field measurement and sampling



River installation

Soil sampling

Total observation period : Aug, 2010 – Aug, 2019
Discharge : Stream(@K21-K32) Aug, 2010 – Aug, 2019
hillslope(@K22,K24,K31) Aug 2010-may 2013

Sampling : ・Suspended sediment(@K21-K32) Aug, 2010 – Aug, 2019
・Sediment source hillslope, skid trail, forest road, stream bed 2010 – 2015, 2019

Analyzing method : Finger printing

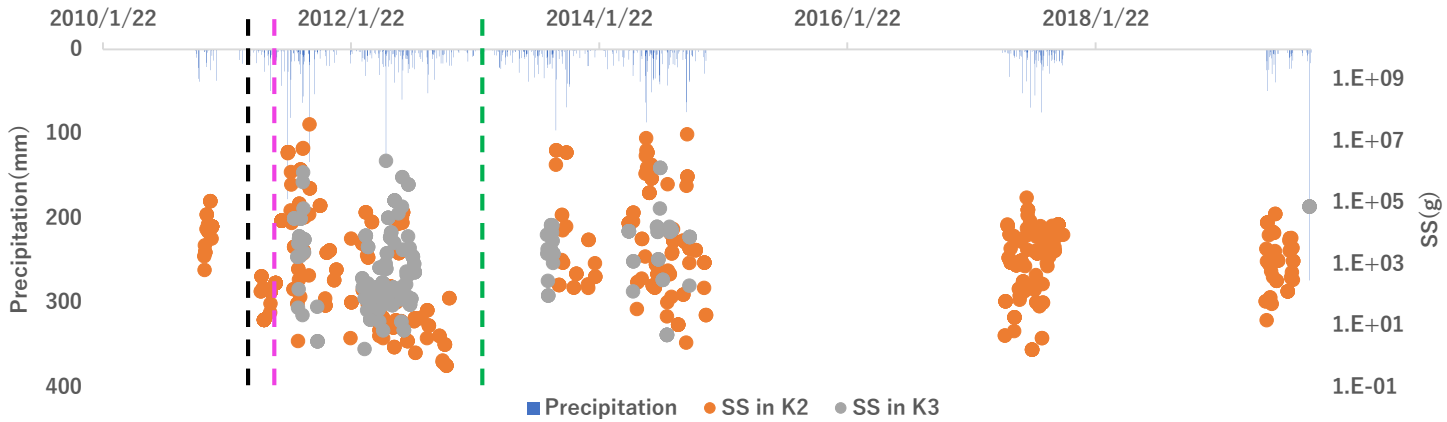
- **Measuring of the radionuclides activity Cs-137,Cs-134,Pb-210ex by gamma-ray detector**
- **Applying Mixing model analysis**
  SS is assumed a mixture of several sources
- **Estimate the contribution from hillslope and streambed**

$$\sum_{j=1}^{m} a_{i,j} \cdot x_j = b_i$$

$$\sum_{j=1}^{m} x_j = 1 \quad \text{with} \quad x_j \geq 0$$

bi: the value of tracer property i (i = 1 to n) in SS
aij: the value of tracer property I in source type j ((j = 1 to m)
Xj: the unknown relative contribution of source type j to SS
M: the number of source type
***n*: the number of tracer properties**

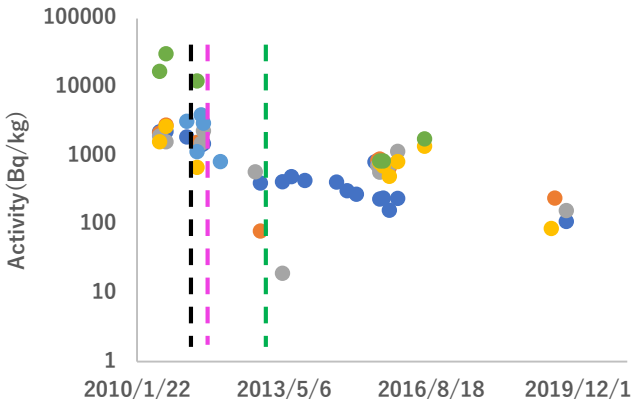
Observation of Precipitation and SS amount



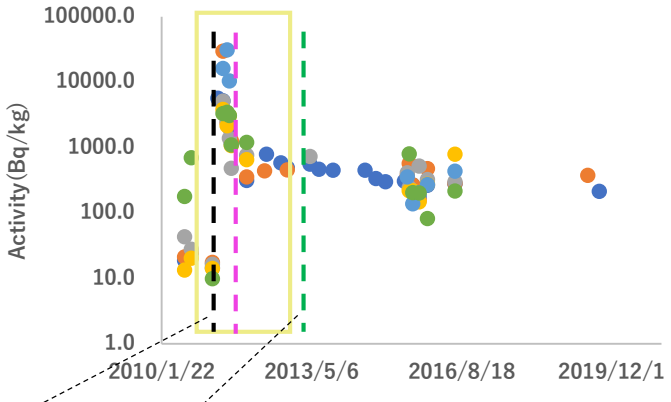
- **SS yield in K2 increase rapidly in during thinning and continued to decrease in post thinning**
- **SS yield in K3 didn't show remarkable increase.**
- **Cs-137 and Cs-134 in SS decreased right after FDNPPA**

Measuring Radioactivity

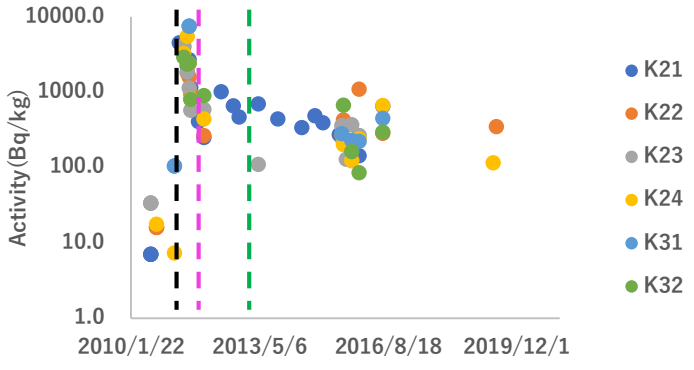
Activity in SS



Activity of Pb-210ex in SS



Activity of Cs-137 in SS



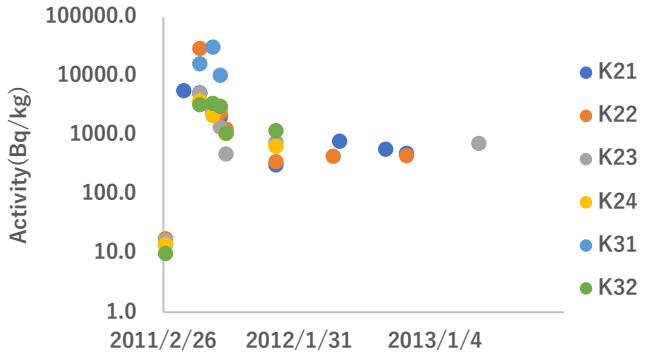
Activity of Cs-134 in SS

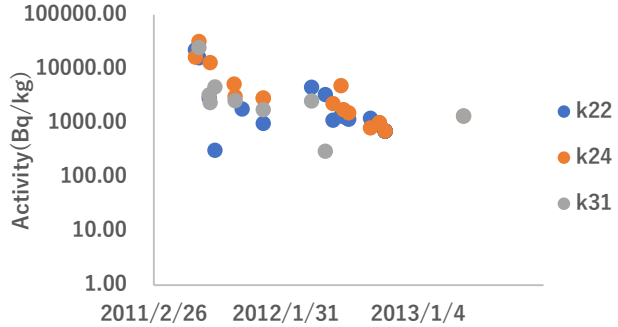
:FDNPPA

:Strip thinning

:Random thinning

Comparing value of Cs-137 between SS and hillslope

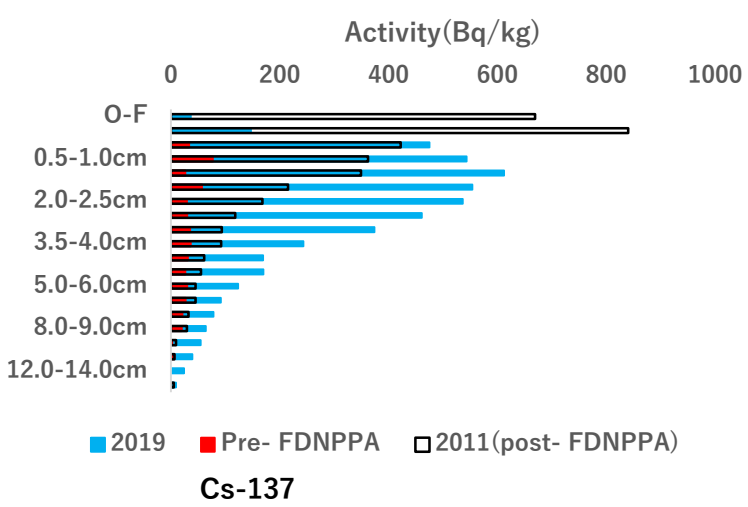




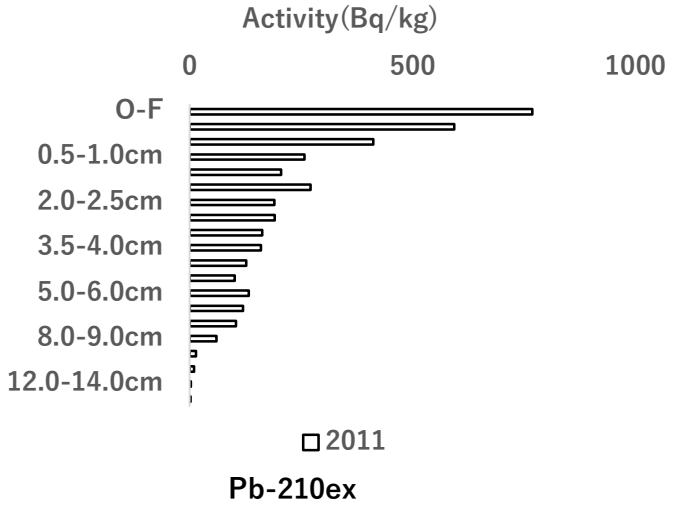
Cs-137 and 134 show decreasing rapidly decrease in Hillslope and SS.
It supposed to unstable surface sediment in forest floor eroded after FDNPPA.

Measuring Radioactivity

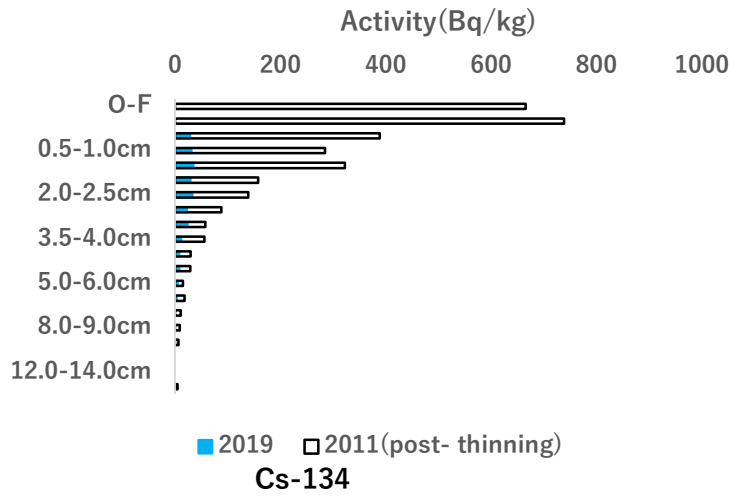
Activity in soil of sediment source



Cs-137



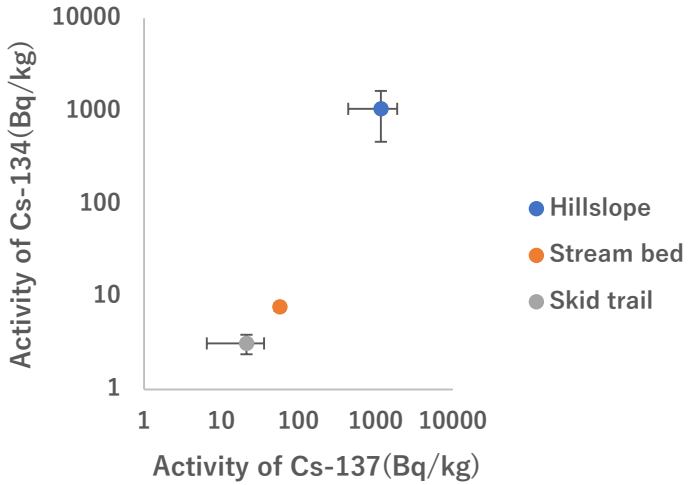
Pb-210ex



Cs-134

Depth distribution in undisturbed soil Cs-137, Cs-134 : 2011 (teramage et al, 2011)

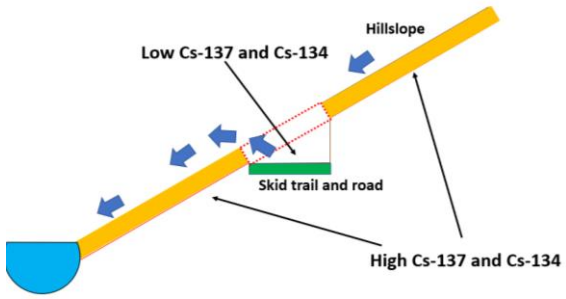
Depth distribution
Cs-137<Pb-210ex<Cs-134



Stream bed

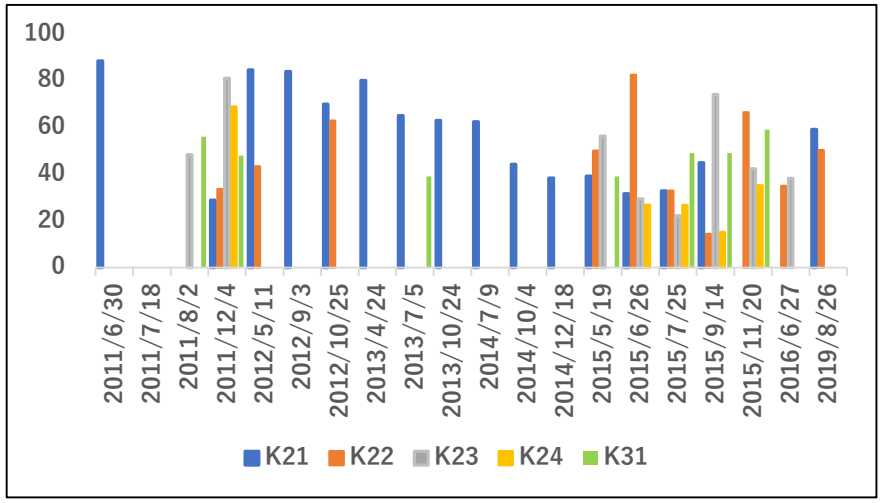
Hillslope

Skid trail

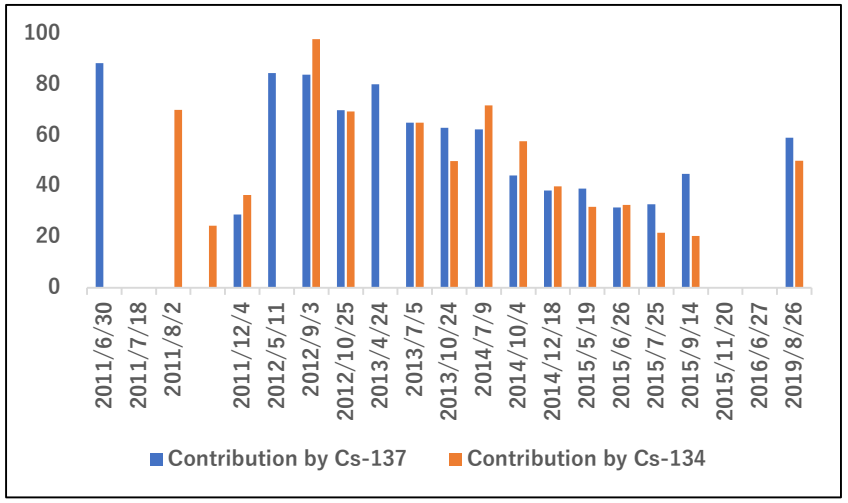


Hillslope shows the highest value and stream bed show low value. skid trail also show low value because surface soil was scraped by machinery in thinning .

Contribution from hillslope to SS



Contribution from hillslope to SS estimated by Cs-137



Contribution from hillslope to SS in K2 estimated by CS-137 and Cs-134

- **Contributions from hillslope decreased after thinning in K21&K24.**
- **In K22, K23 and K31 still show high contribution from hillslope some years after thinning**
- **Contribution from hillslope dramatically decreased during thinning. It supposed that soil eroded from hillslope and passed skid trail or contributed from timber carry-out trace. Mizoguchi et al.(2018) reported that soil erosion was caused by penetration loss in timber carry-out trace. Timber carry-out trace can be predicted to show low Cs-137 value.**
- **Contribution from hillslope estimated by Cs-137 and Cs-134 show similar value.**
- **But contribution estimated by Cs-134 tend to show higher value than Cs-137**

→Soil may come from about 0-2.5cm in forest floor

Discussion

- **Strip thinning tend to produce more soil erosion from forest floor because of soil disturbance by constructing skid trail than random thinning operation in thinning period.**
- **After thinning, strip thinning more effective to suppress the soil erosion from forest floor than random thinning.**

Future study

Perform more detailed analysis using production source estimation using hysteresis analysis based on the relationship between flow rate and suspended sediment concentration

Reference

- Teramage at al 2014. Vertical distribution of radiocesium in coniferous forest soil after the Fukushima Nuclear Power Plant accident : Journal of Environmental Radioactivity 37-45
- N. Martinez et al 2008. Uncertainty assessment in suspended sediment fingerprinting based on tracer mixing models: a case study from Luxembourg : IAHS Publ. 325
- Mizokuchi et al 2018. Short-term effects of different thinning methods on surface soil erosion of a hinoki (Chamaecyparis obtusa) plantation : Japanese Journal of Forest Environment 60:23—29, 2018
- Kato et al 2012. Interception of the Fukushima reactor accident-derived ^{137}Cs, ^{134}Cs and ^{131}I by coniferous forest canopies : Geophysical research letter : Volume 39 issue 20