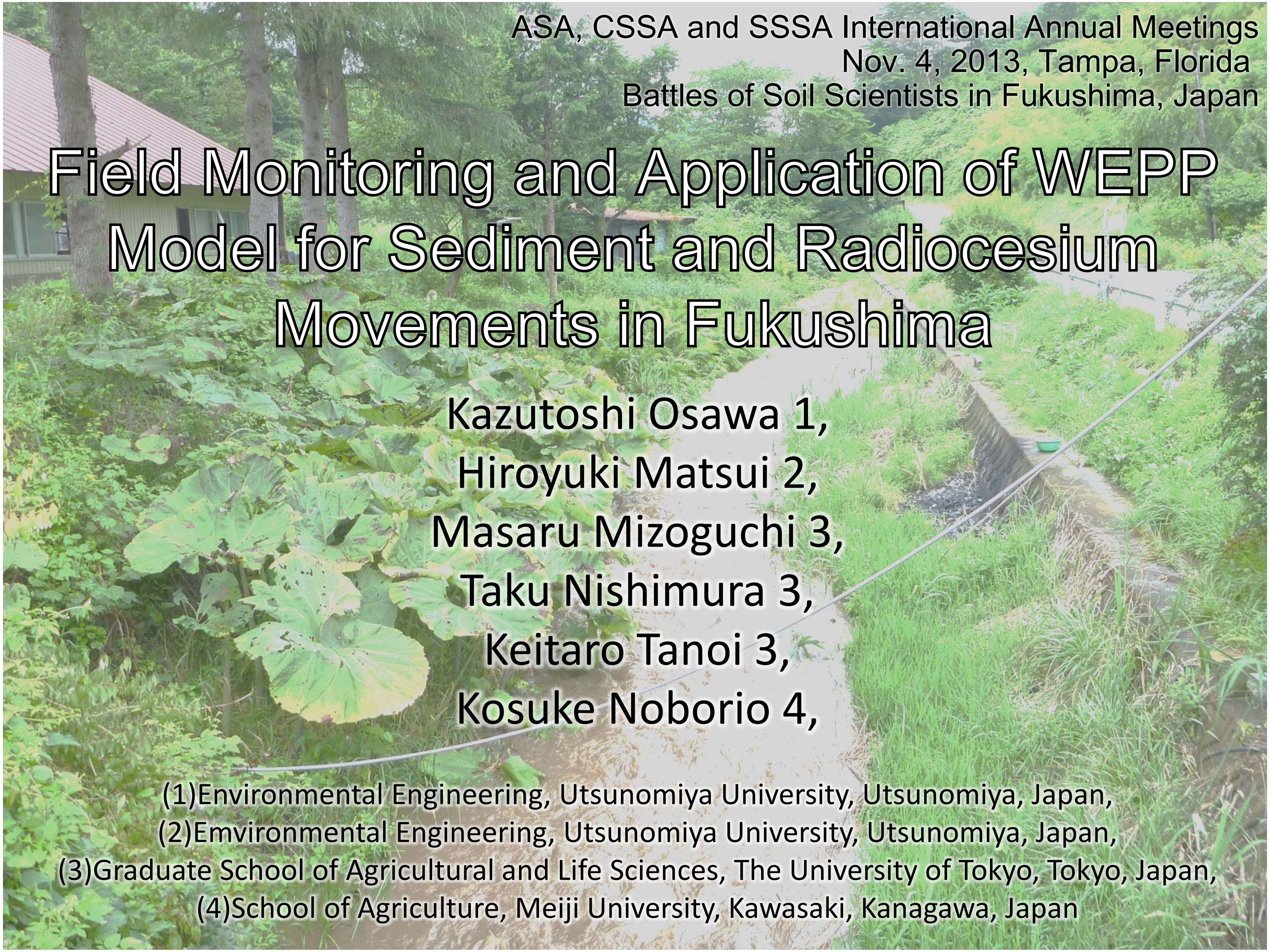


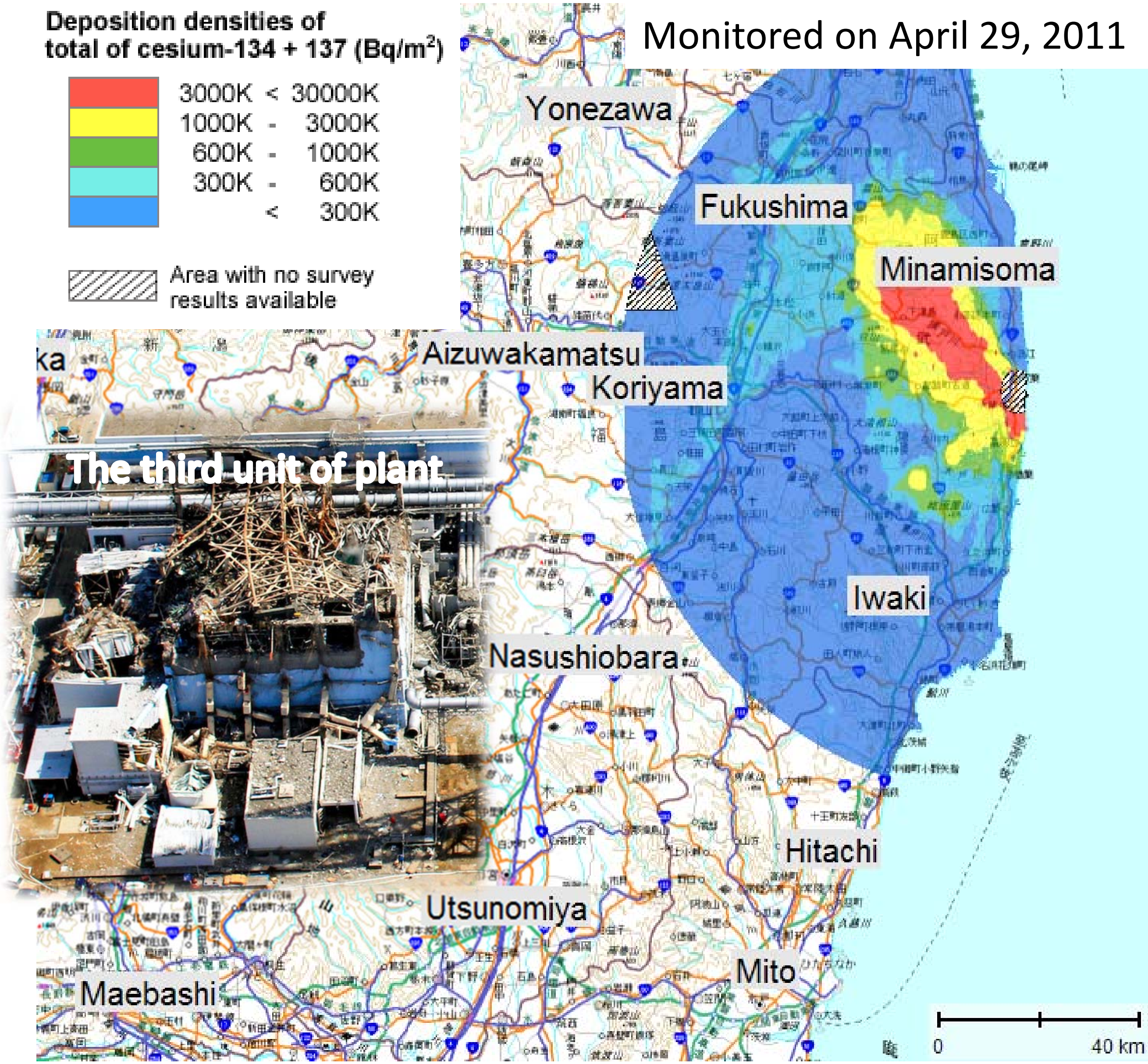
ASA, CSSA and SSSA International Annual Meetings
Nov. 4, 2013, Tampa, Florida
Battles of Soil Scientists in Fukushima, Japan

Field Monitoring and Application of WEPP Model for Sediment and Radiocesium Movements in Fukushima

Kazutoshi Osawa 1,
Hiroyuki Matsui 2,
Masaru Mizoguchi 3,
Taku Nishimura 3,
Keitaro Tanoi 3,
Kosuke Noborio 4,

(1)Environmental Engineering, Utsunomiya University, Utsunomiya, Japan,
(2)Emvironmental Engineering, Utsunomiya University, Utsunomiya, Japan,
(3)Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan,
(4)School of Agriculture, Meiji University, Kawasaki, Kanagawa, Japan

Accident of the Fukushima Daiichi Nuclear Power Plant



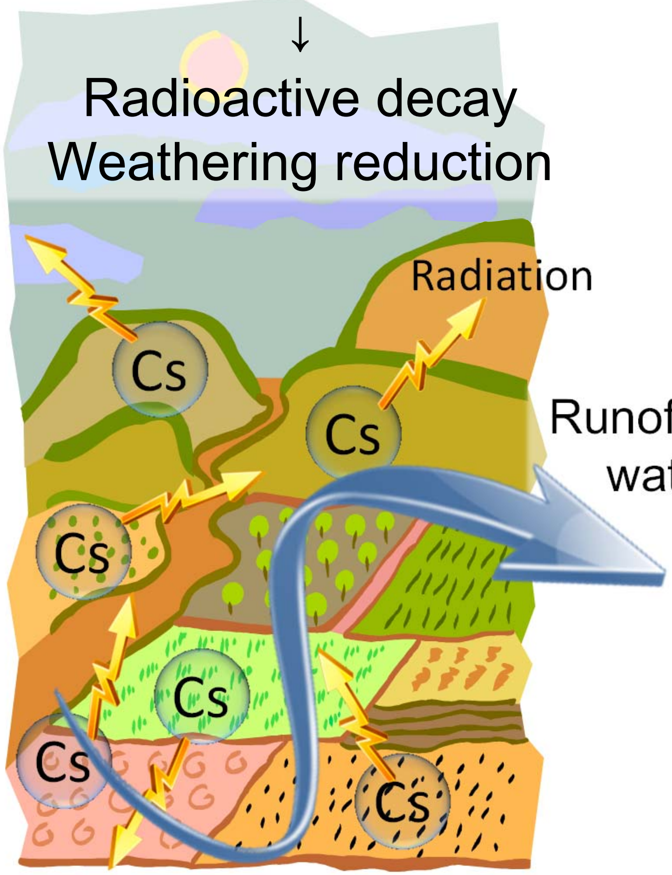
Nuclear Regulation Authority, Japan

Fukushima contaminated with radionuclides fallout by the accident of the Fukushima Daiichi Nuclear Power Plant.

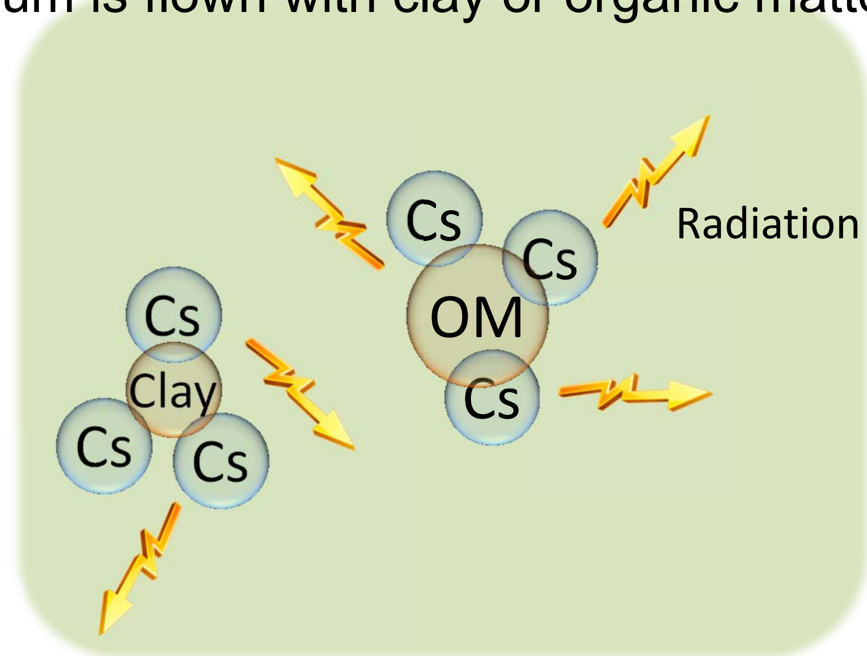
Radiocesium deposited on the ground surface.

Objectives

Contaminated top soil
with cesium
↓
Radioactive decay
Weathering reduction



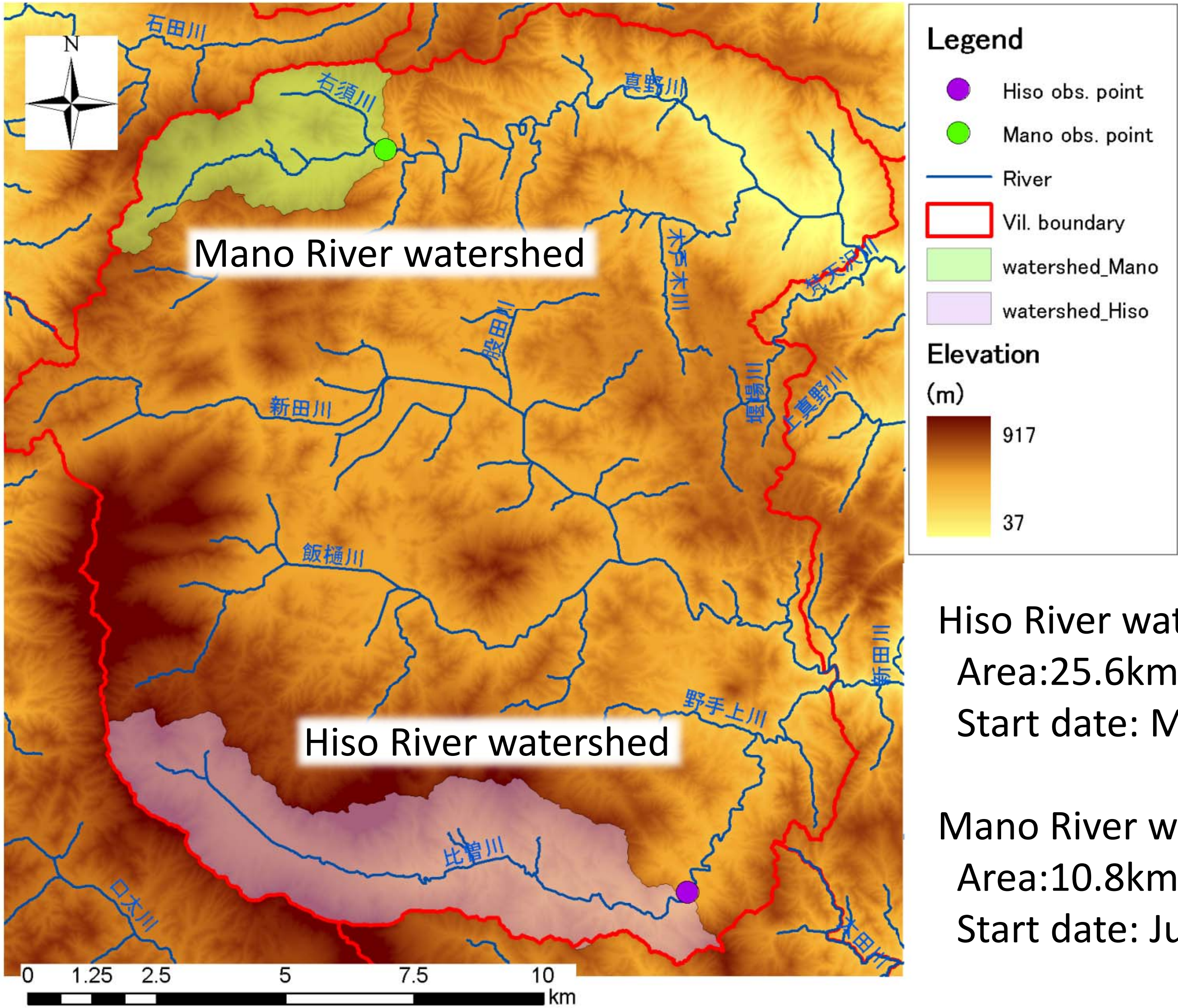
Focusing on the weathering reduction,
cesium is flown with clay or organic matter



First objective :
Field monitoring for radiocesium runoff from watersheds

Second objective :
Numerical simulation of sediment and radiocesium movements

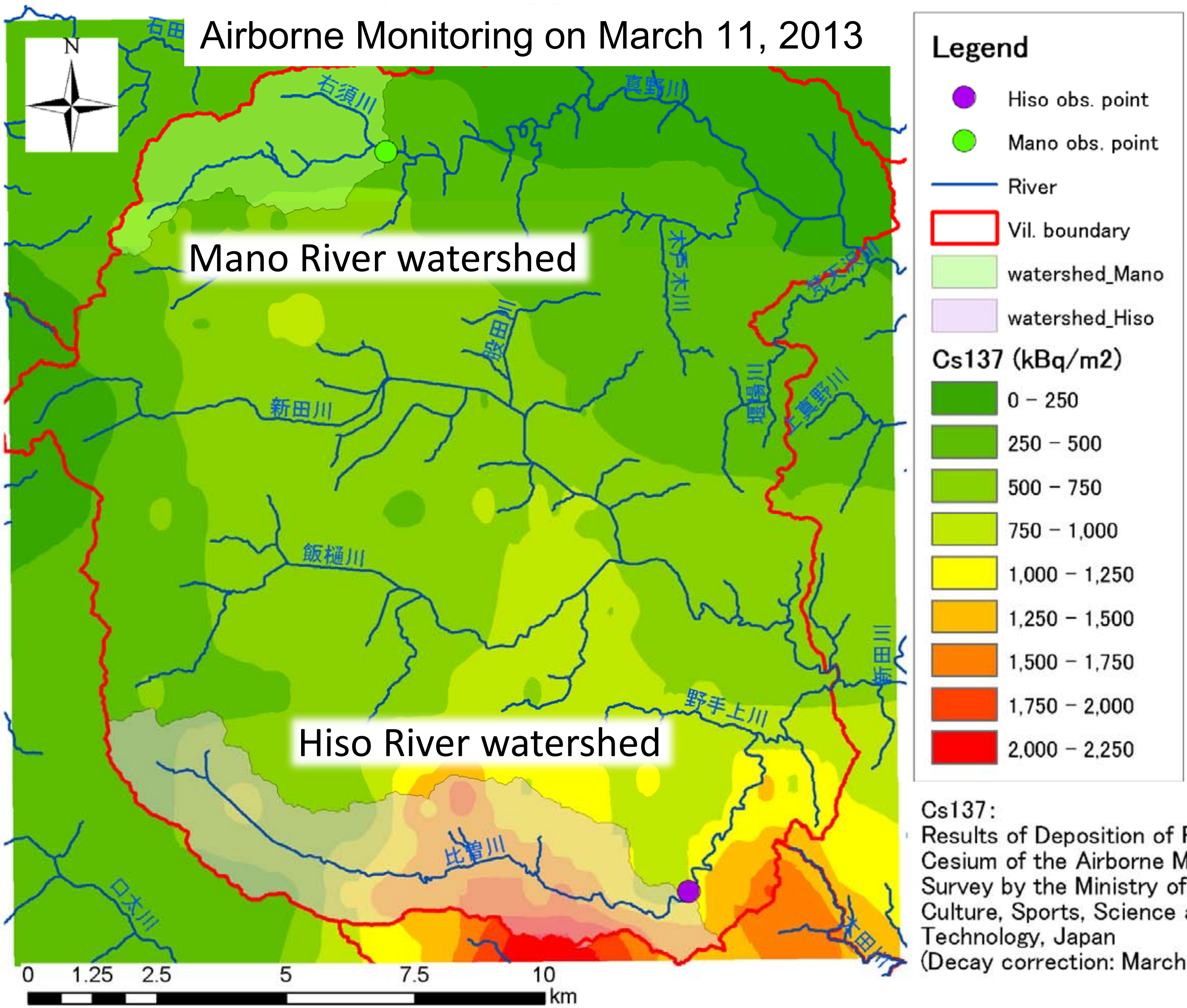
Location of field monitoring watersheds in Iitate Village



Hiso River watershed:
Area:25.6km^2
Start date: May 12, 2013

Mano River watershed:
Area:10.8km^2
Start date: June 2, 2013

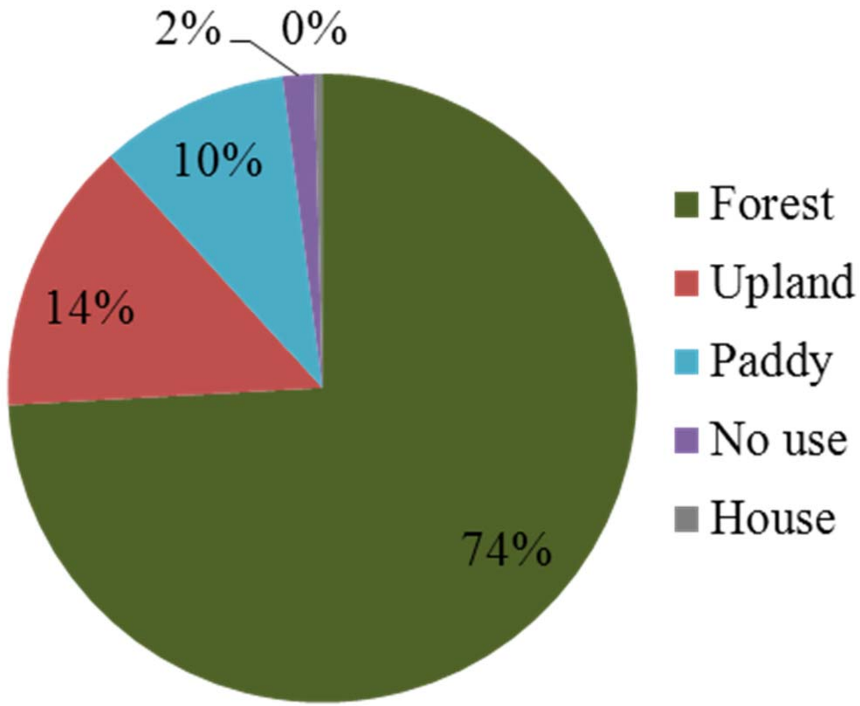
Distribution of radiocesium in Iitate Village, Fukushima



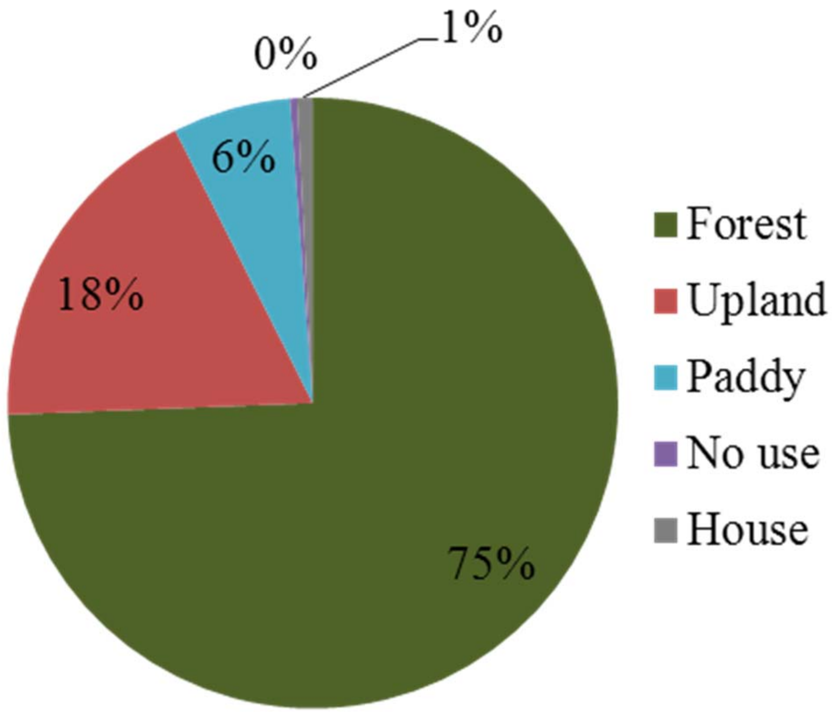
Cs137:
Results of Deposition of Radioactive Cesium of the Airborne Monitoring Survey by the Ministry of Education, Culture, Sports, Science and Technology, Japan
(Decay correction: March 11, 2013)

Landuse

Hiso River watershed
Area:25.6km^2

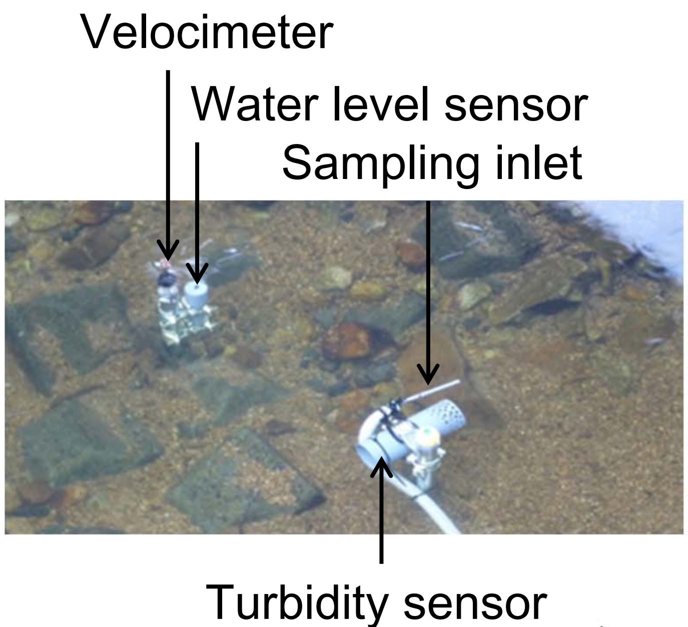


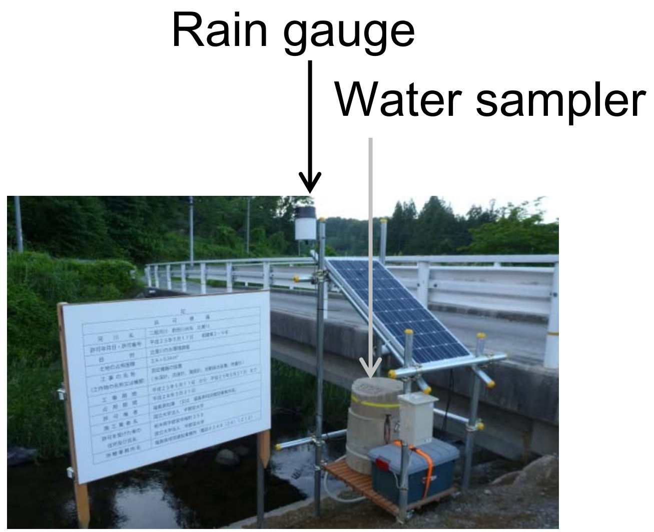
Mano River watershed
Area:10.8km^2

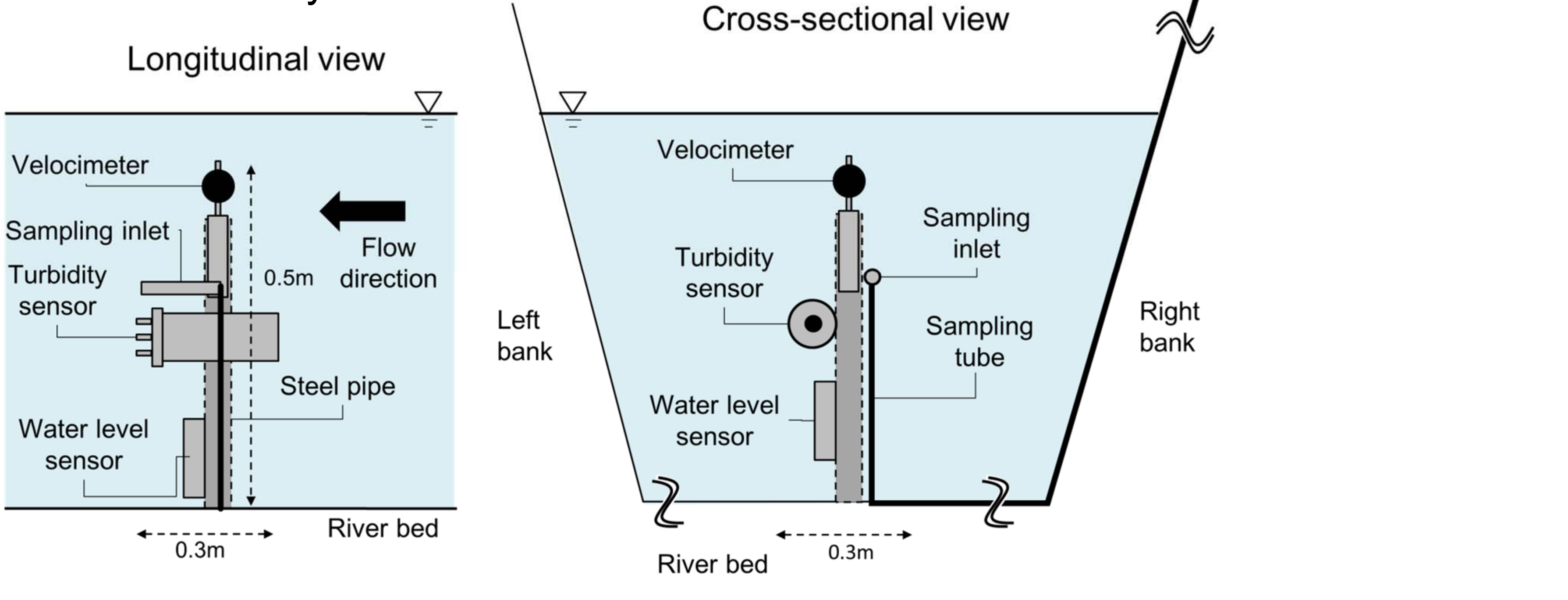


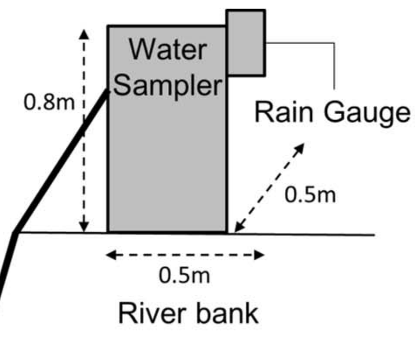
Both watershed, forest account for close to 75%
→ Difficult to do the decontamination work such as taking top soil away in these mountainous area.

Instruments for field monitoring

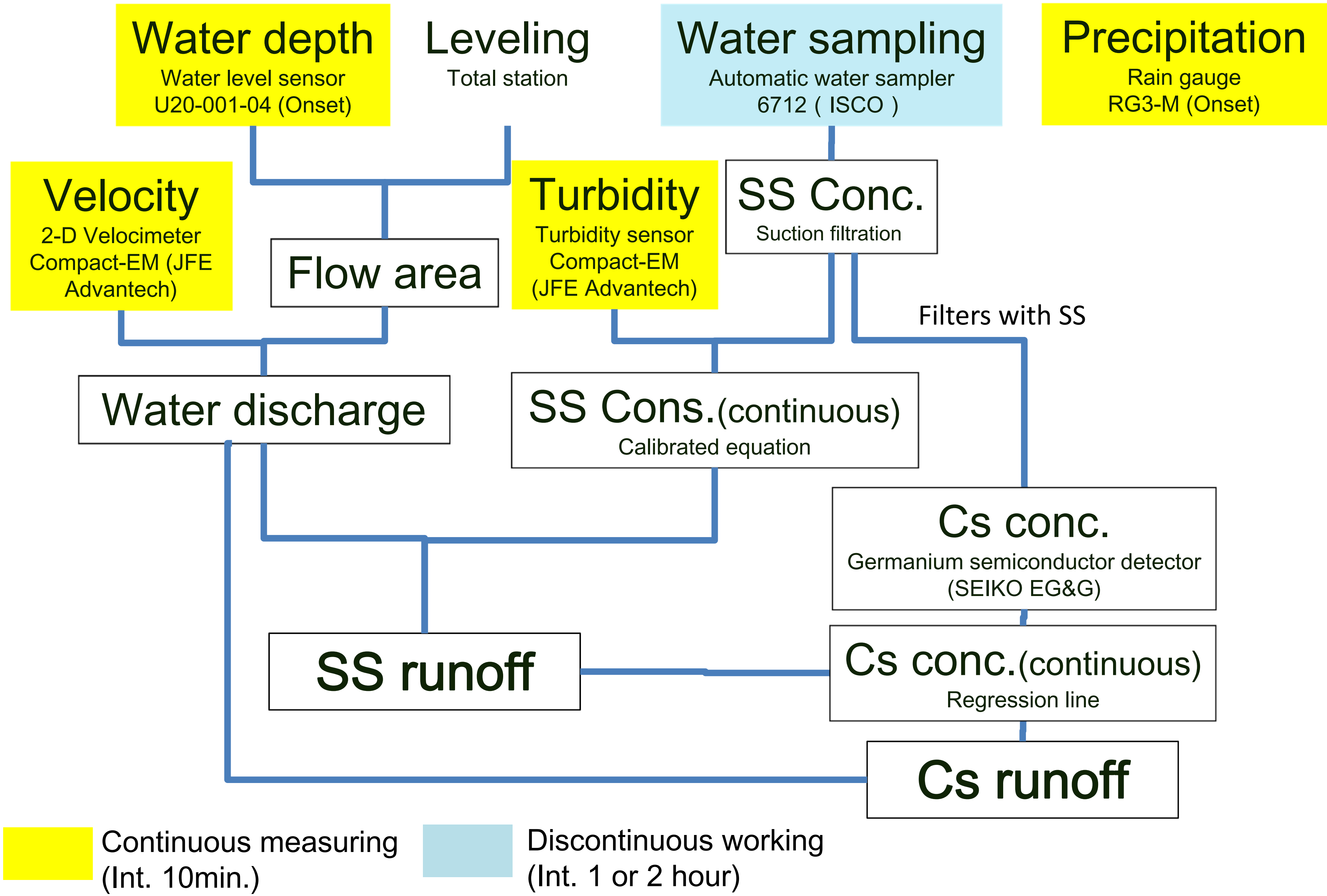






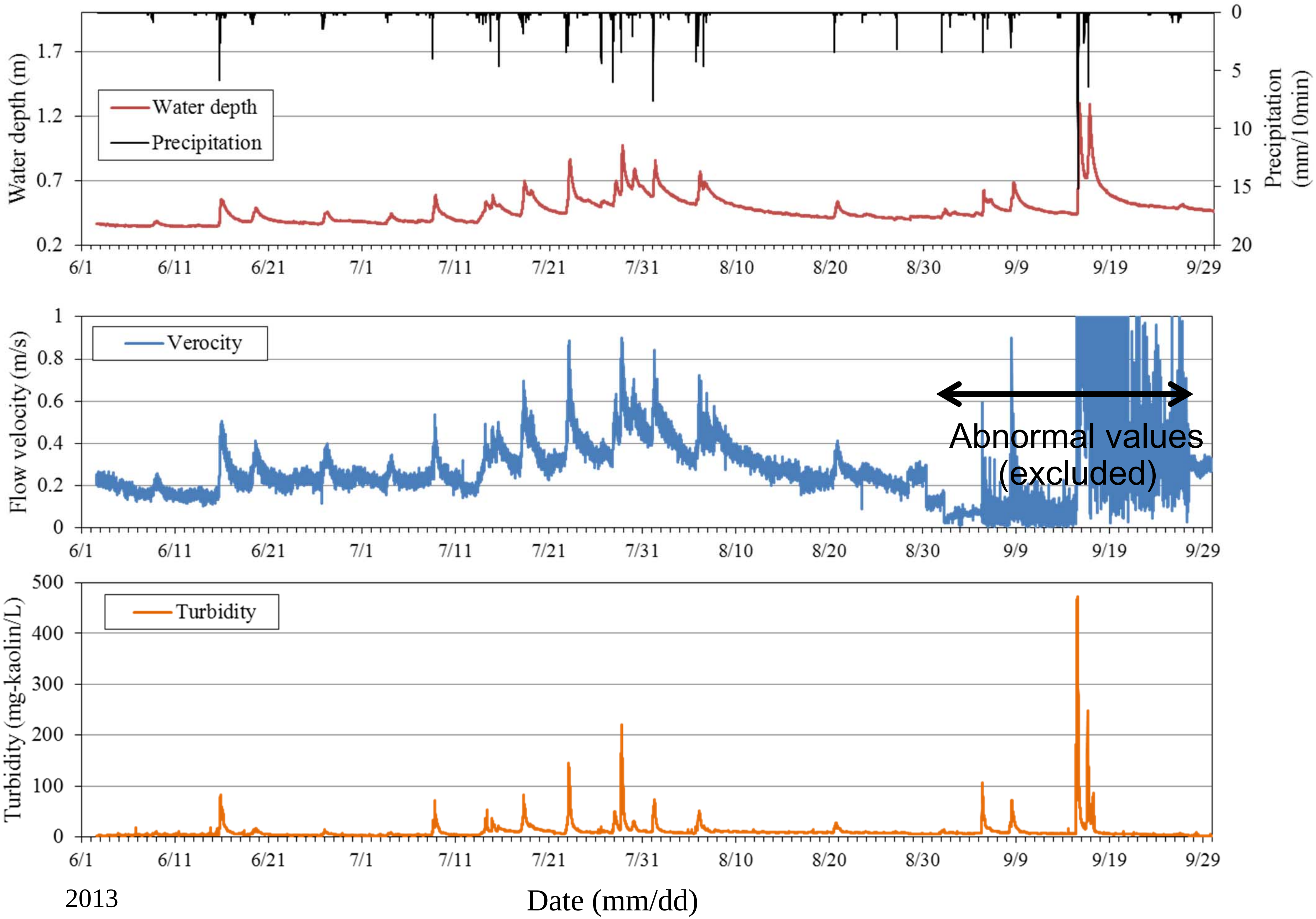


Methodology for field monitoring

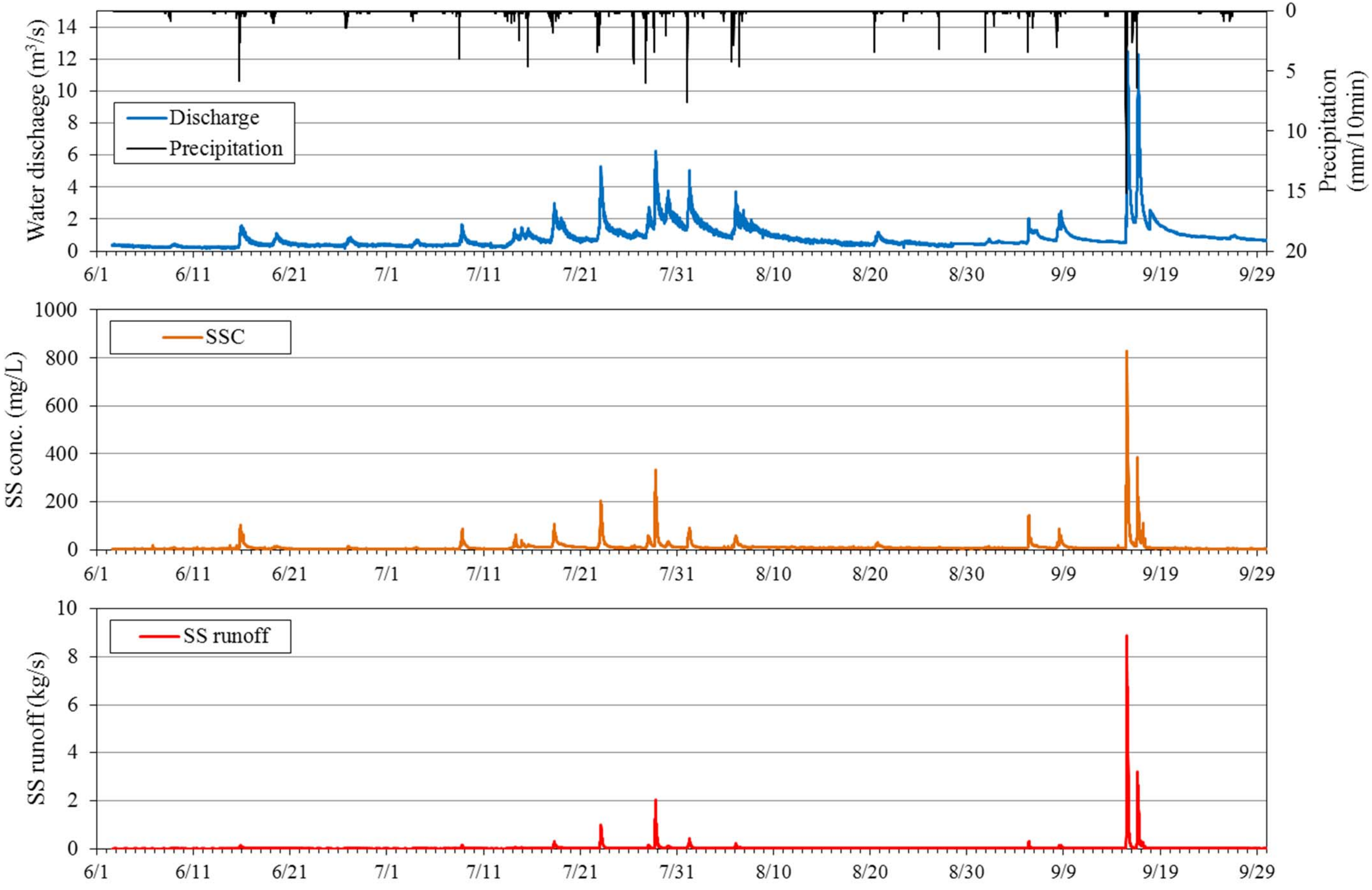



Hiso River monitoring point on Sep. 2013
Storm by a typhoon
Hiso River watershed
Flow direction
GARDENWATCHCAM 2013/09/12 10:00:19

Observed results (Hiso River) Raw data



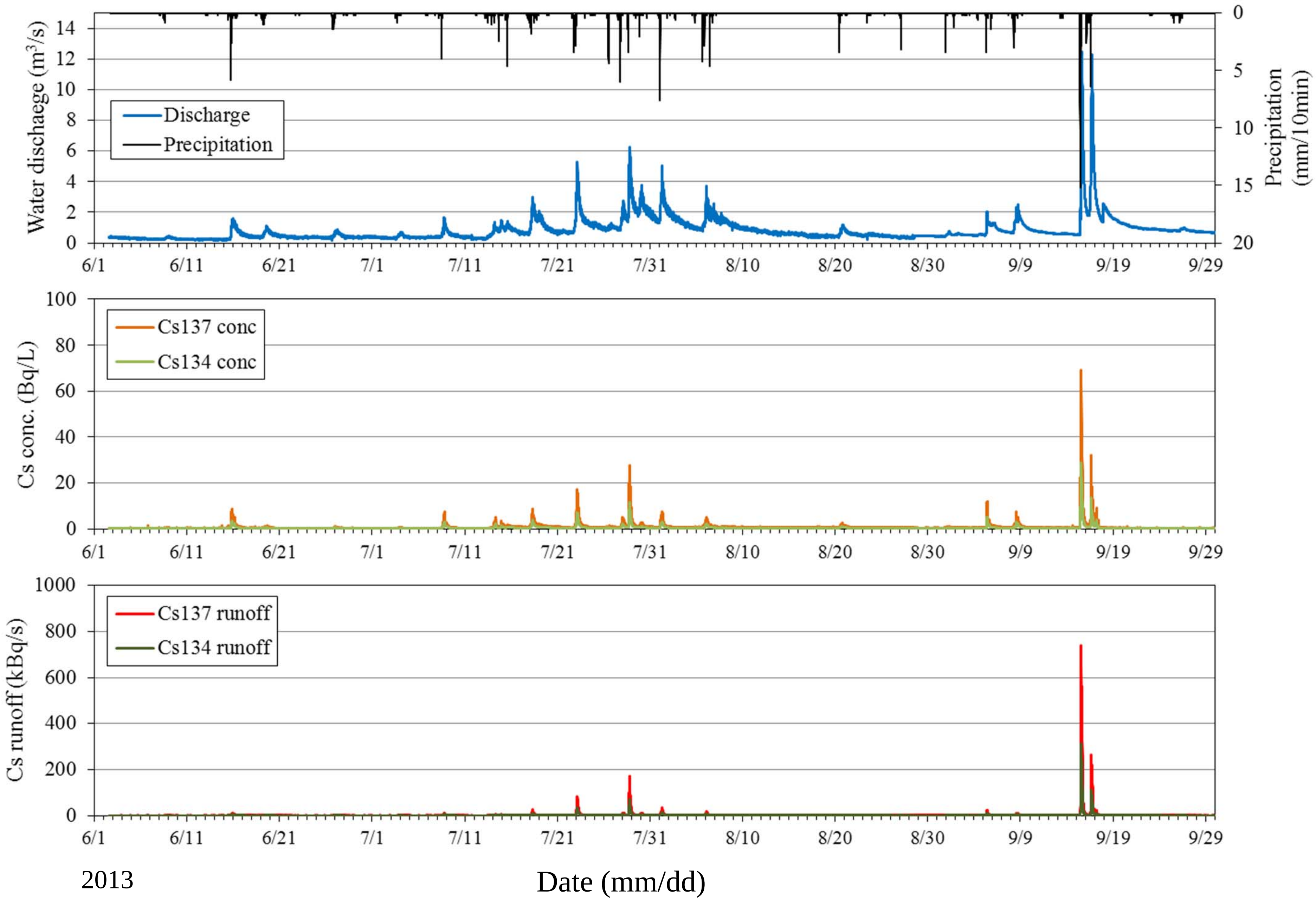
Observed results (Hiso River) Water discharge and SS



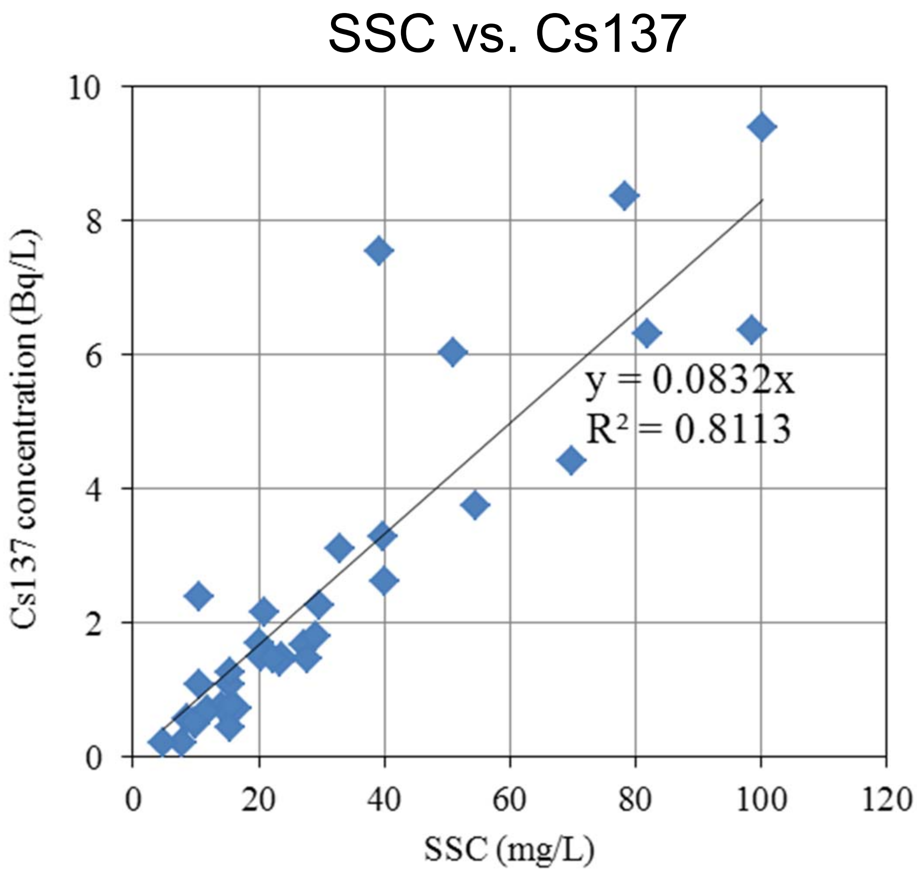
2013

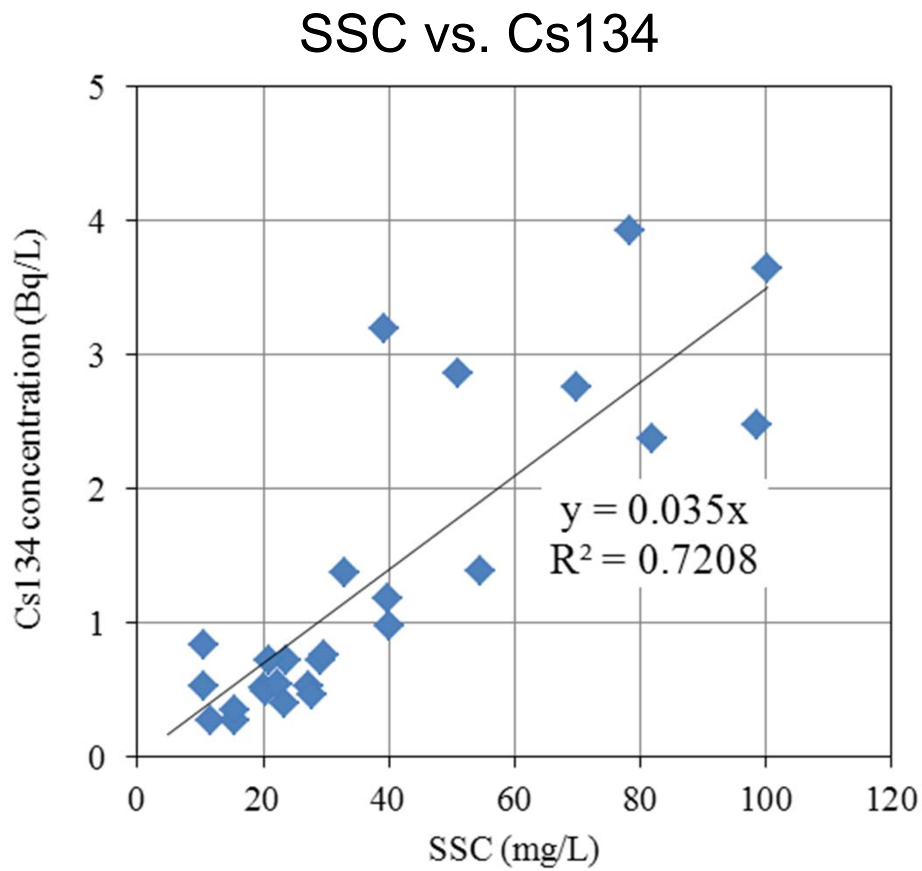
Date (mm/dd)

Observed results (Hiso River) Water discharge and Cs



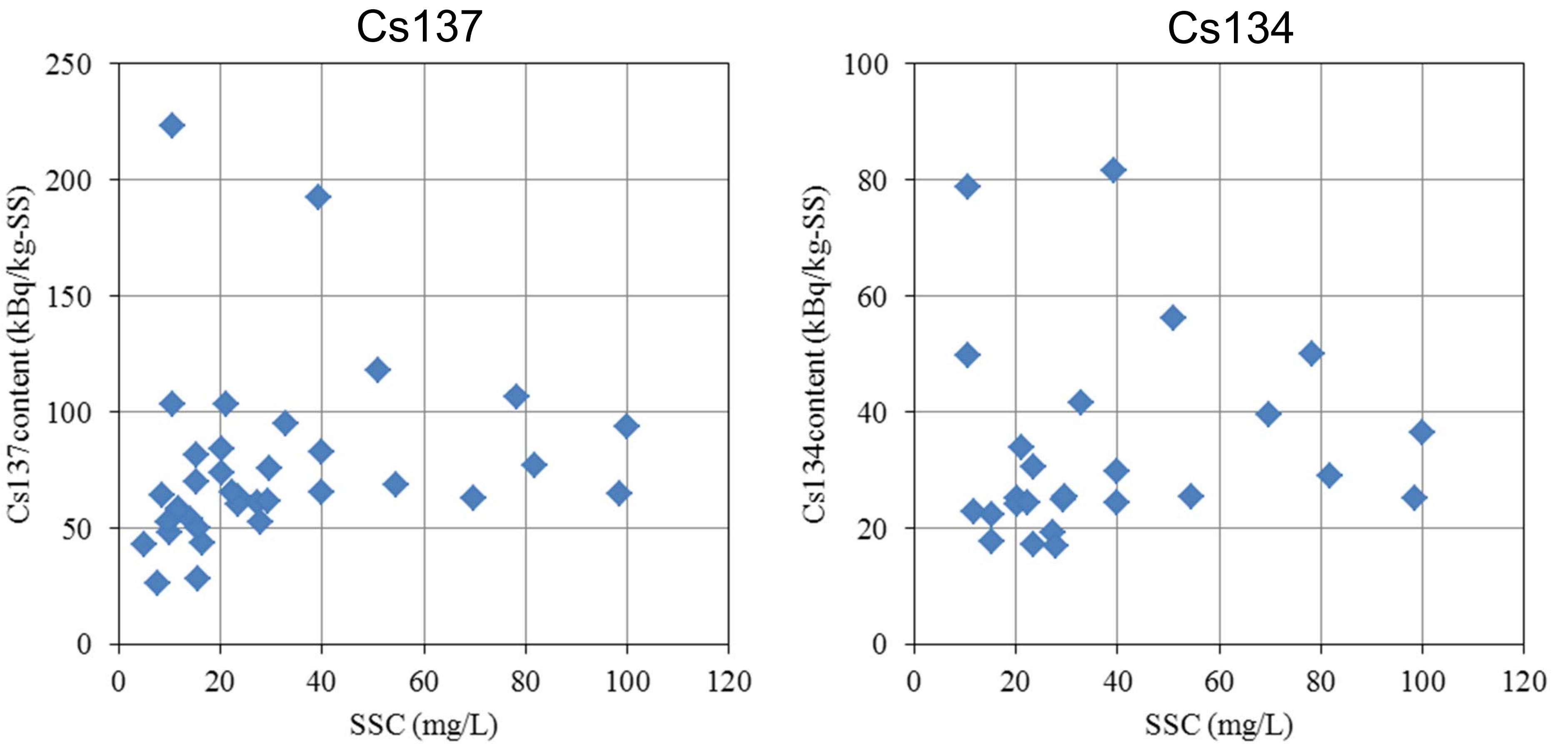
Relationships between SSC with Cesium conc.(Hiso)





Relationships were approximately liner
→Cesium is attached with suspended sediment and organic matter
Ignition loss (fraction of OM) was about 30%
Particle size distribution was
<2μm (Clay): 3-4%, 2 to 50μm (Silt):75-83%, 50μm – 2mm (Sand): 14-22%

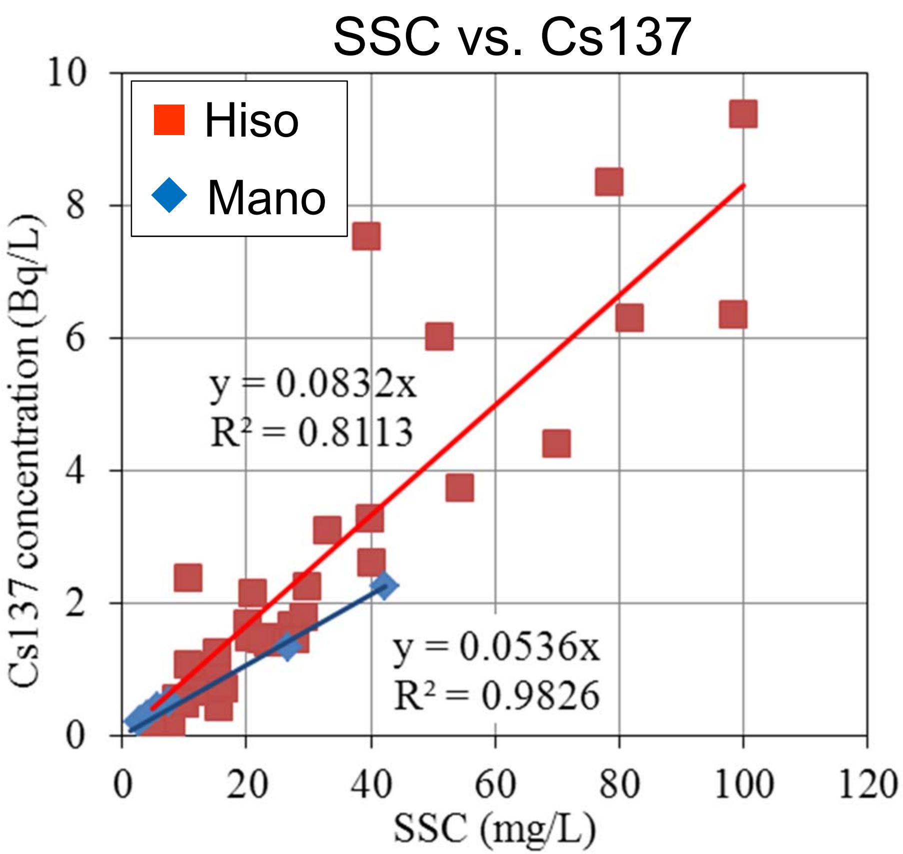
Cesium content in suspended solids (Hiso)

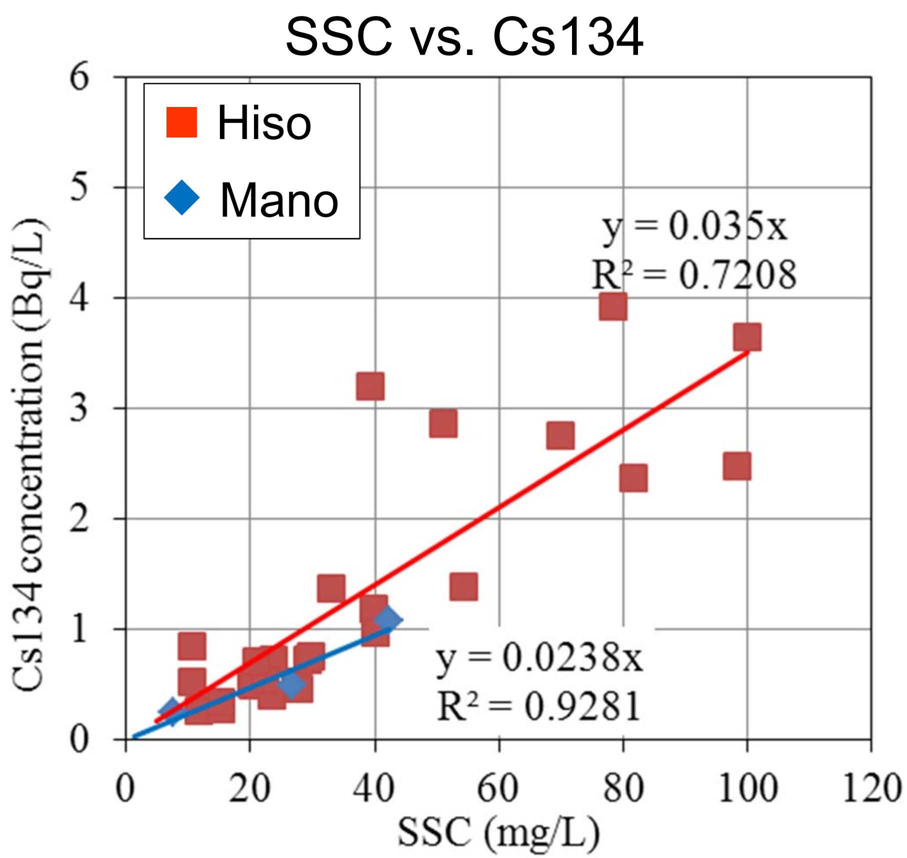


Average of Cs137 content was 76 kBq/kg-SS and that of Cs134 was 34 kBq/kg-SS.
These values were twice larger than the content of the top soil around this watershed.
→It may be the enrichment effect.
Referring from official reports*, these values were 5 times larger than the content of other rivers in Fukushima.

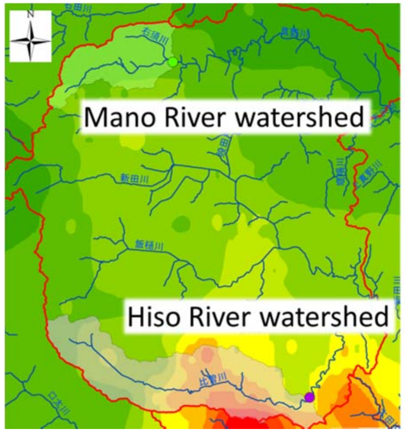
*Japan Atomic Energy Agency (JAEA) reports, 2013

Cesium concentrations of two watersheds

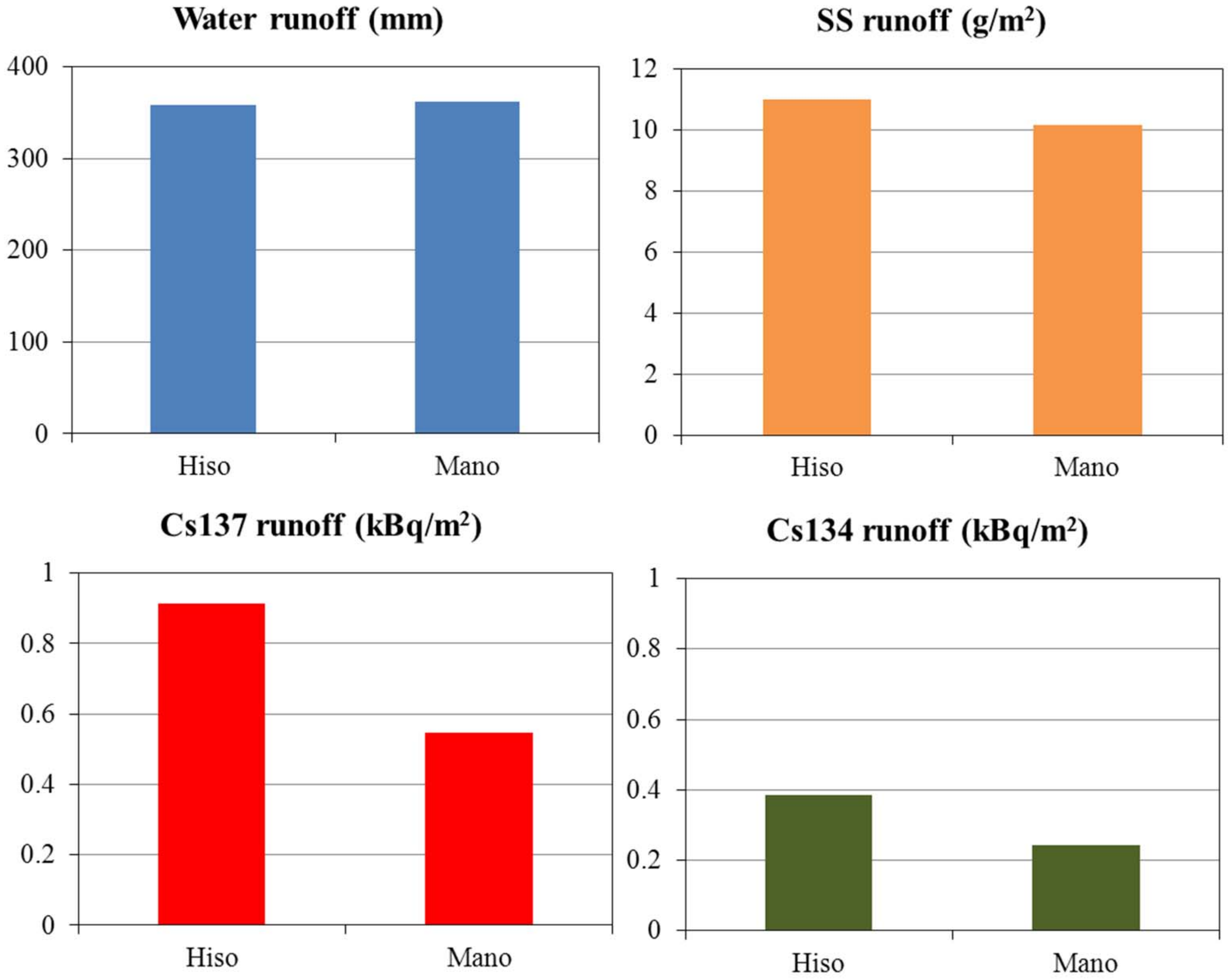




Slope of Mano was smaller than that of Hiso
→ Surface soil Cs contents were different



Total values of two watersheds



Water runoff and SS runoff were almost same.
Cesium runoffs at Hiso were larger than that in Mano.
Cesium runoffs were very small comparing with reported cesium radiation of 250 – 2000 kBq/m^2. → Weathering reduction of cesium is not effective.

Water Erosion Prediction Project (WEPP)

Developed by USDA National Soil Erosion Research Laboratory (NSERL) in 1989 as a hillslope erosion model.
In 1995, the model was expanded to the watershed scale.

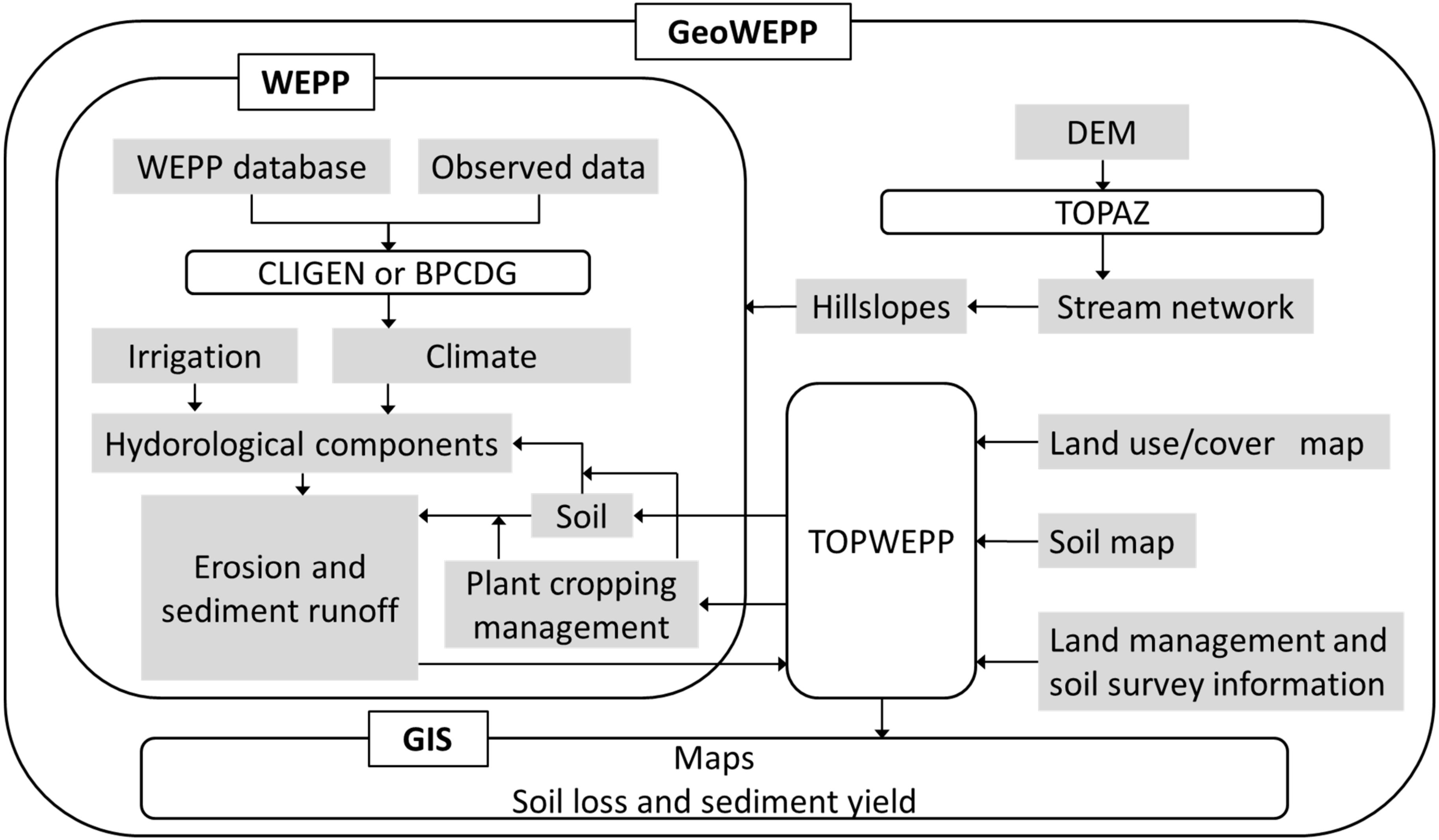
Process-based model

Erosion, climate, hydrology, daily water balance, plant growth, residue decomposition, etc.

Different from the USLE, the WEPP model was constructed for the purpose of estimating soil loss at every rainfall event.

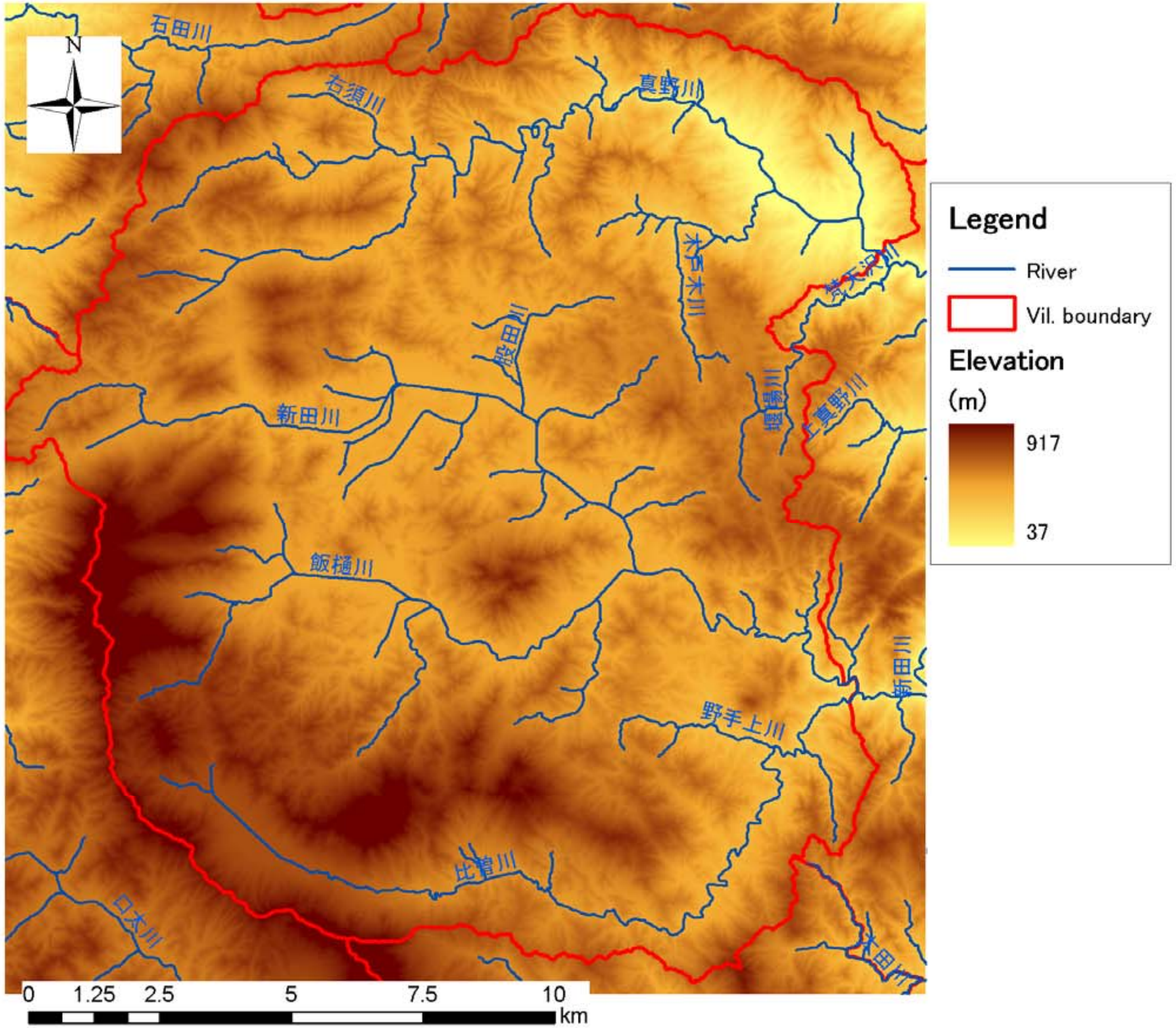
Geo-spatial interface for WEPP (GeoWEPP)

Developed by Renschler in 2001.
WEPP ver.2012.800 and GeoWEPP for AecGIS 9.X were used.



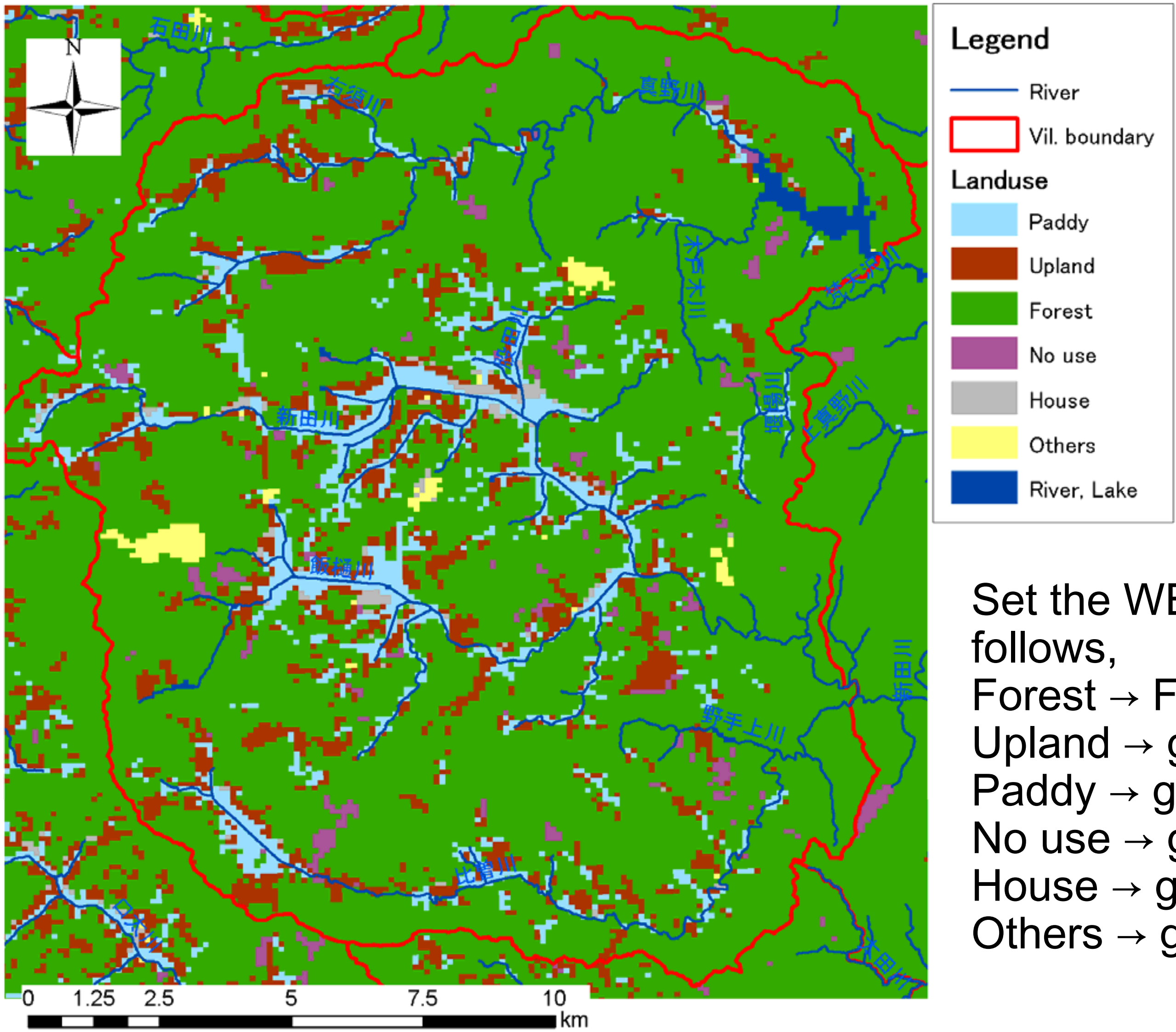
Preparing GIS data (DEM)

10×10m grid, Geospatial Information Authority of Japan



Preparing GIS data (Landuse map)

100×100m grid, National Land Numerical Information, Ministry of Land, Infrastructure, Transport and Tourism, Japan



Set the WEPP management as follows,

Forest → Forest (default)

Upland → grass (default)

Paddy → grass (default)

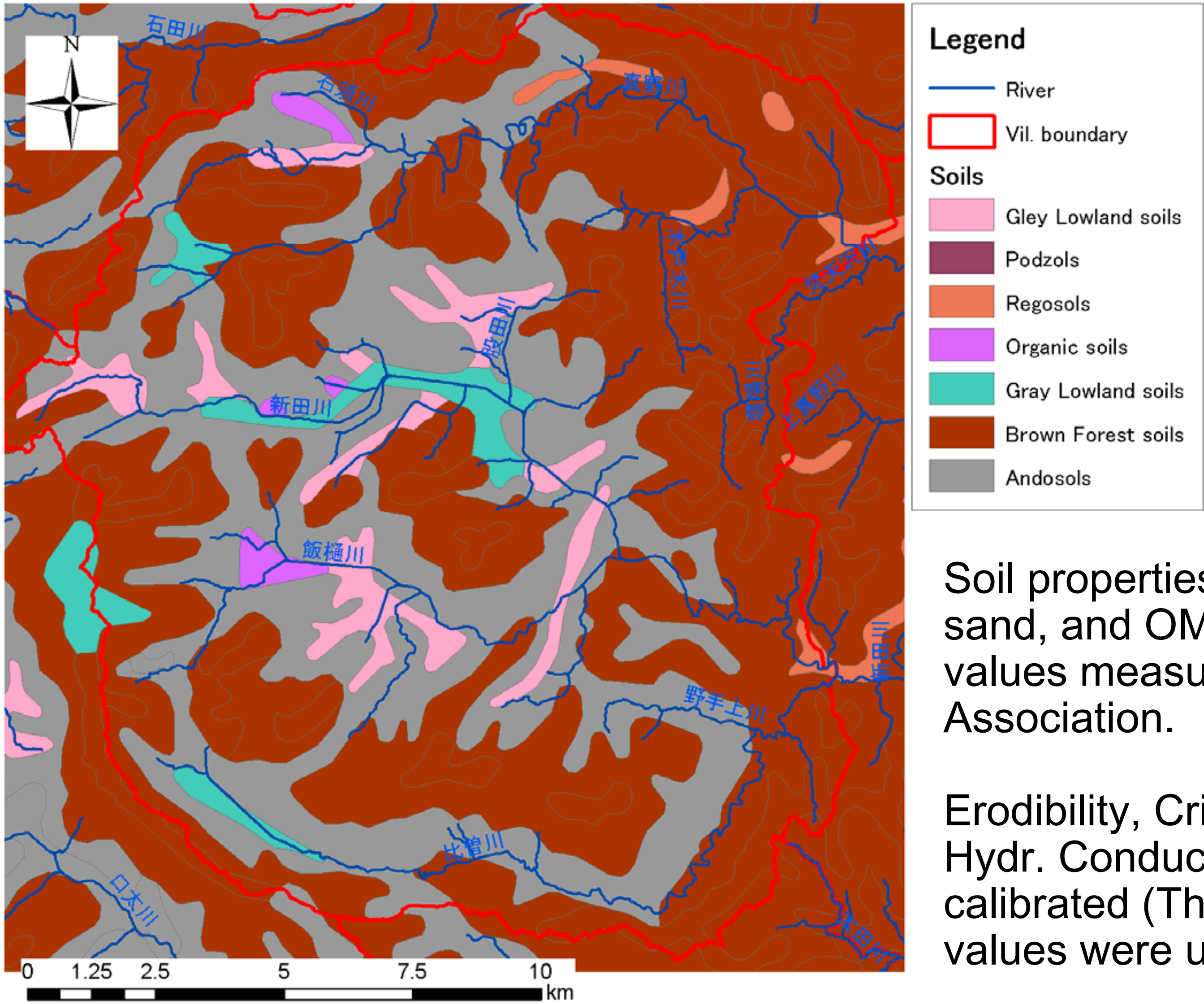
No use → grass (default)

House → grass (default)

Others → grass (default)

Preparing GIS data (Soil map)

Soil map (1:50,000), National Land Numerical Information, Ministry of Land, Infrastructure, Transport and Tourism, Japan



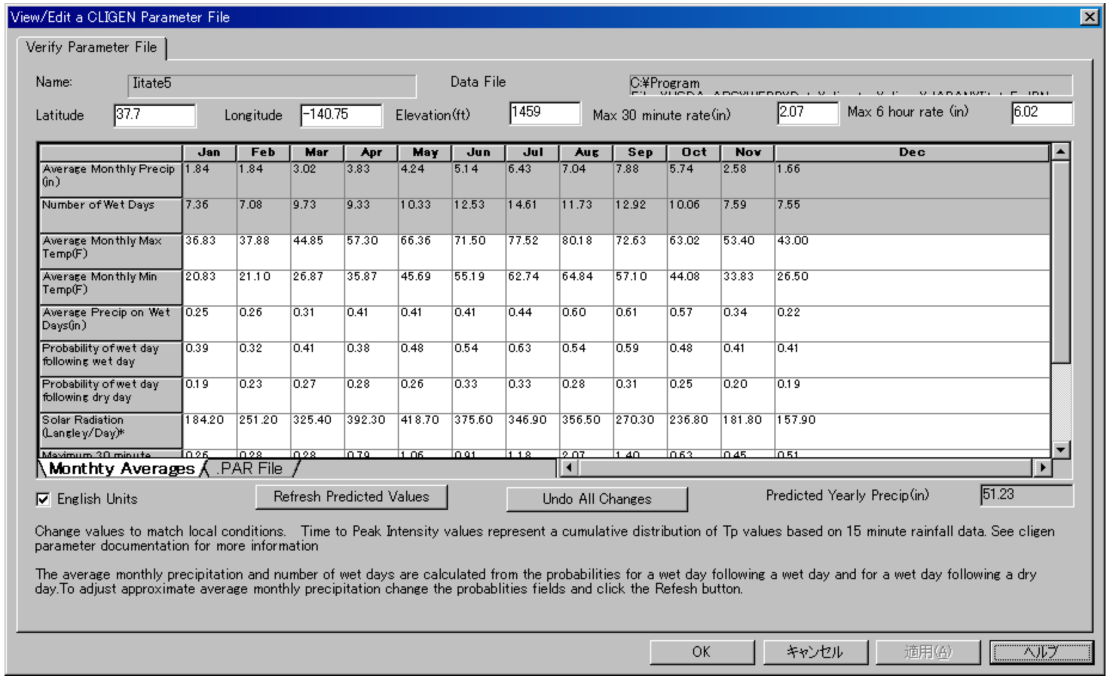
Soil properties (fraction of clay, sand, and OM etc.) were used the values measured by Japan Soil Association.

Erodibility, Critical shear, and Eff. Hydr. Conductivity were not calibrated (The model calculated values were used).

Preparing climate data

Observed by Japan Meteorological Agency (JMA)
Daily climate data in Fukushima City for 30 years
Sub-daily precipitation data in Iitate Village for 15 years

→ CLIGEN PAR File



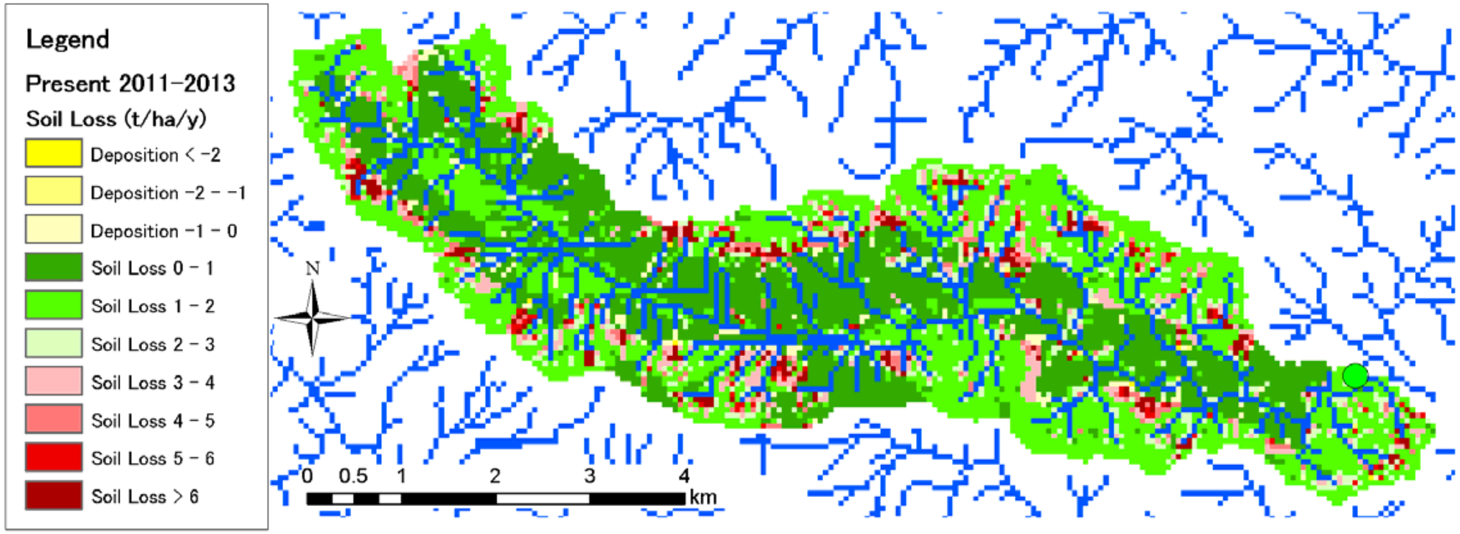
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Precip (in)	1.84	1.84	3.02	3.83	4.24	5.14	6.43	7.04	7.88	5.74	2.58	1.66
Number of Wet Days	7.36	7.08	9.73	9.33	10.33	12.53	14.61	11.73	12.92	10.06	7.59	7.55
Average Monthly Max Temp(F)	36.83	37.88	44.85	57.30	66.36	71.50	77.52	80.18	72.63	63.02	53.40	43.00
Average Monthly Min Temp(F)	20.83	21.10	26.87	35.87	45.69	55.19	62.74	64.84	57.10	44.08	33.83	26.50
Average Precip on Wet Days(in)	0.25	0.26	0.31	0.41	0.41	0.41	0.44	0.60	0.61	0.57	0.34	0.22
Probability of wet day following wet day	0.39	0.32	0.41	0.38	0.48	0.54	0.63	0.54	0.59	0.48	0.41	0.41
Probability of wet day following dry day	0.19	0.23	0.27	0.28	0.26	0.33	0.33	0.28	0.31	0.25	0.20	0.19
Solar Radiation (Langley/Day)*	184.20	251.20	325.40	392.30	418.70	375.60	346.90	356.50	270.30	236.80	181.80	157.90
Maximum 30 minute	0.26	0.28	0.28	0.79	1.06	0.91	1.18	2.07	1.40	0.63	0.45	0.51

Daily climate data in Iitate Village from 2011 to 2013 observed by JMA
Sub-daily precipitation data in each watershed from 2011 to 2013 observed by us

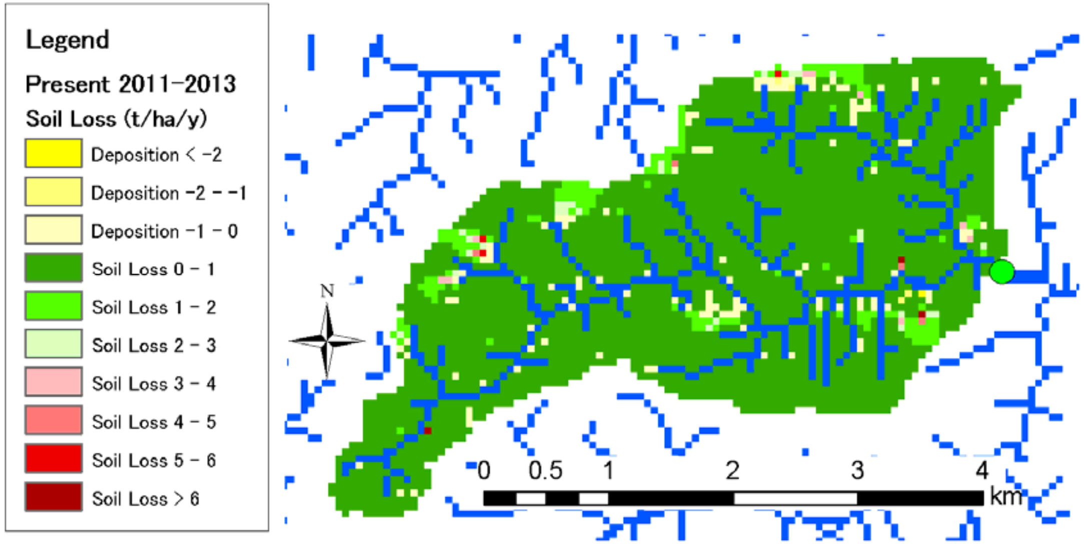
→ Actual Daily Data from 2011 to 2013 was generated using CLIGEN Ver.5.X

Calculated soil loss and deposition

Result of Flowpath method in Hiso (Soil loss in each cell can be calculated)



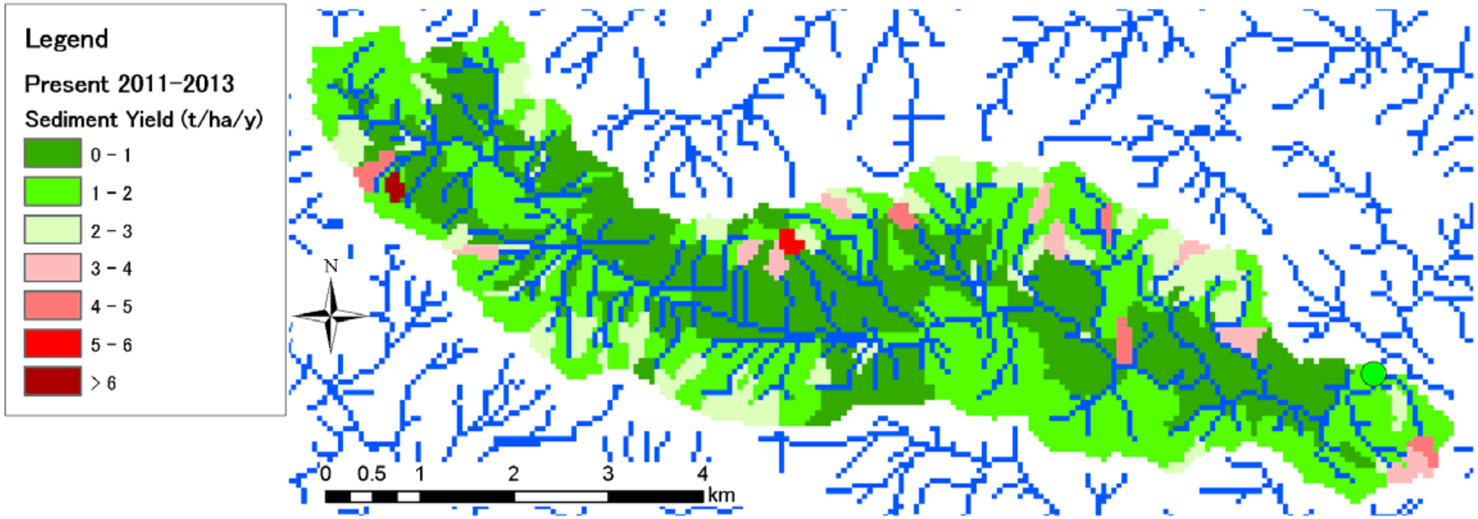
Result of Flowpath method in Mano (Soil loss in each cell can be calculated)



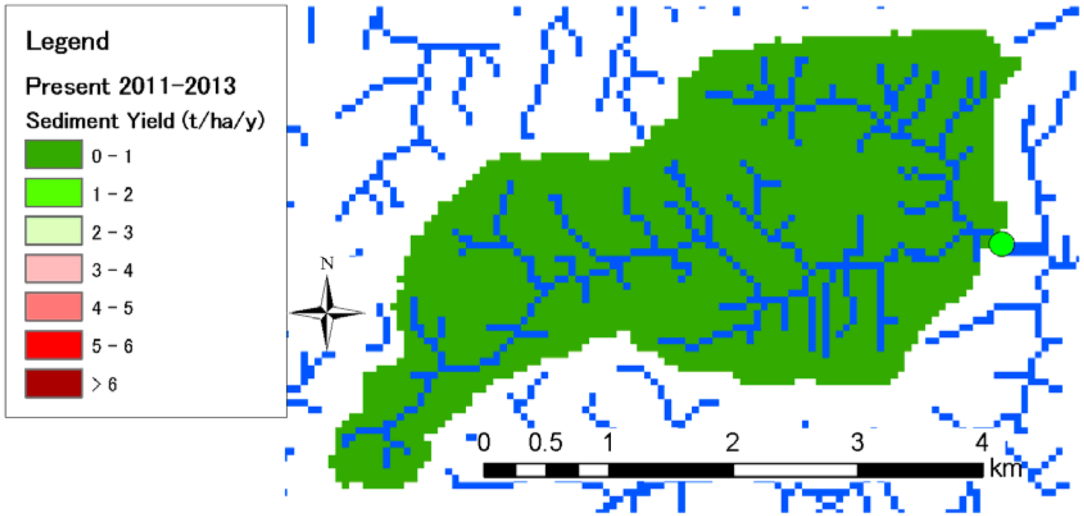
The amount and place of soil loss or deposition can be calculated.

Calculated sediment yield

Result of Watershed method in Hiso (Sediment yield in each hillslope can be calculated)

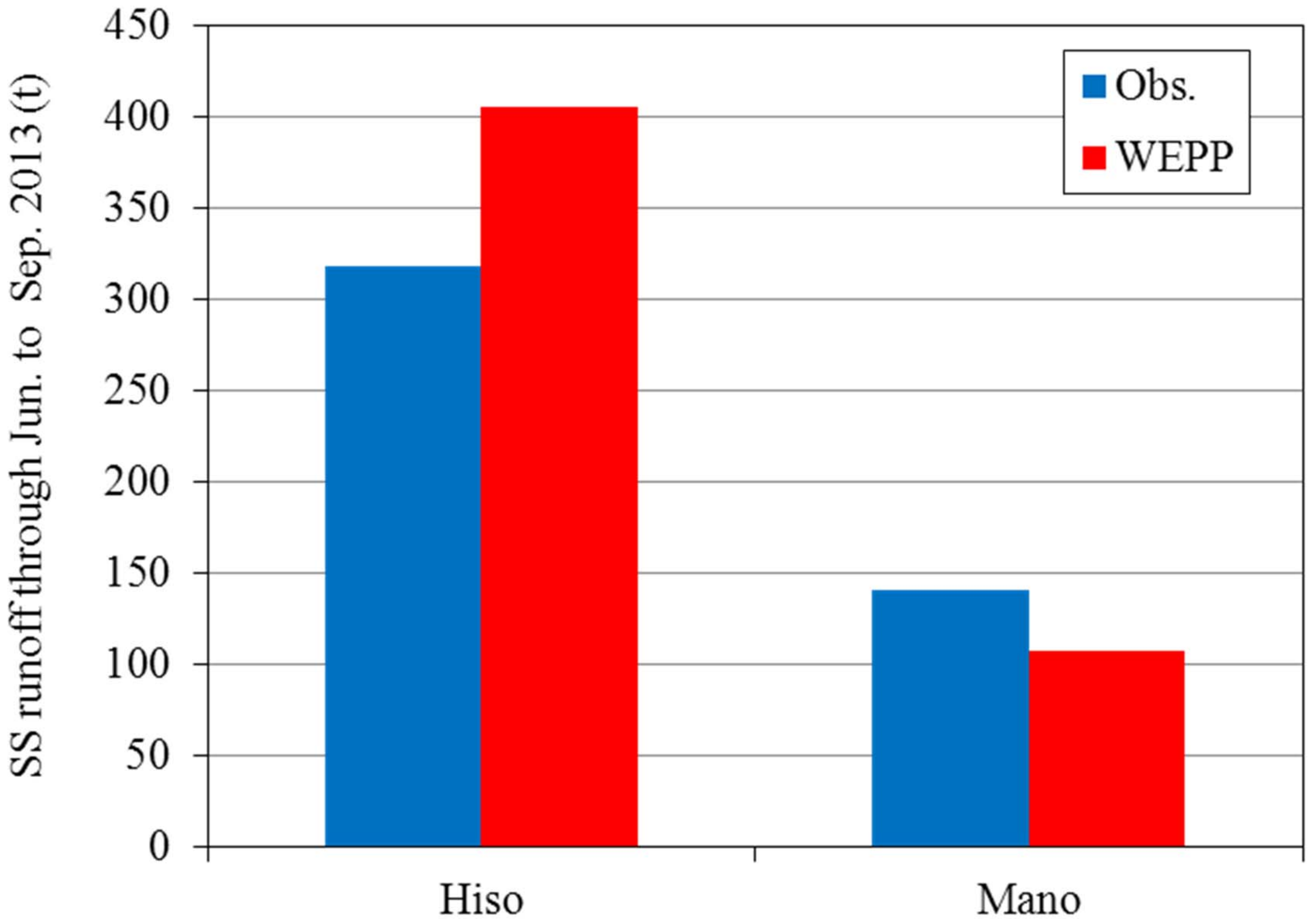


Result of Watershed method in Mano (Sediment yield in each hillslope can be calculated)



Sediment yield in Mano was smaller than that in Hiso.
It is mainly due to the difference of slope angle.

Calculated sediment runoff and observed one

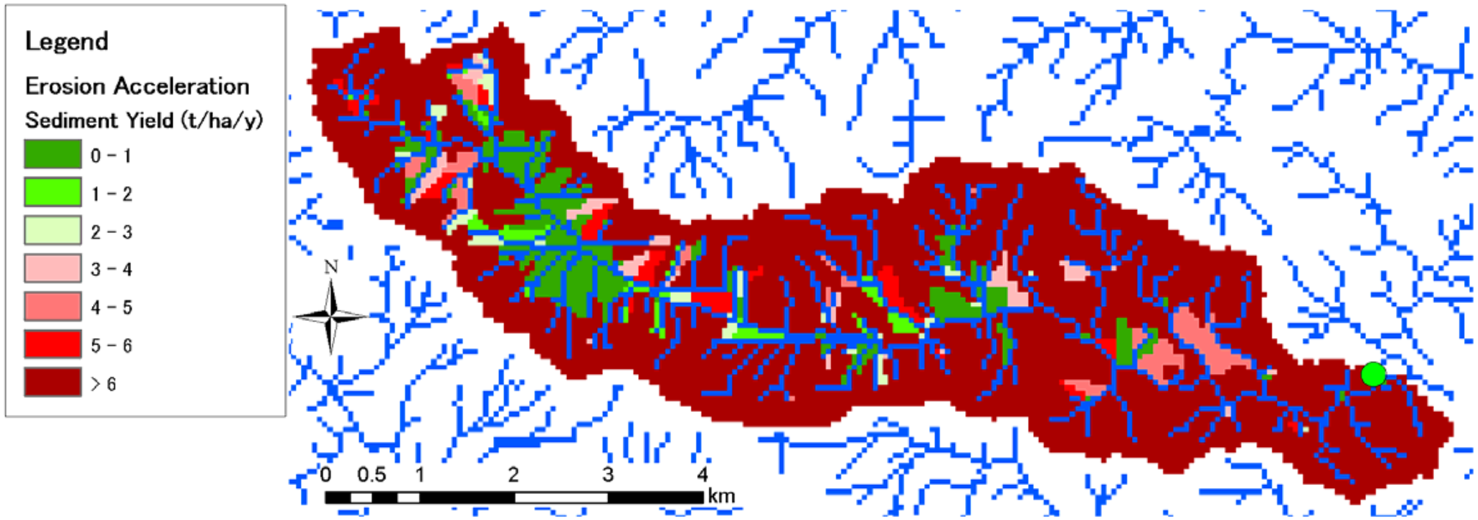


Total sediment runoff at outlet for observed 4 months (Jun. to Sep.,2013).
The calculated sediment runoffs were in approximate agreement with observed.

Simulation of the effect of cutting vegetation

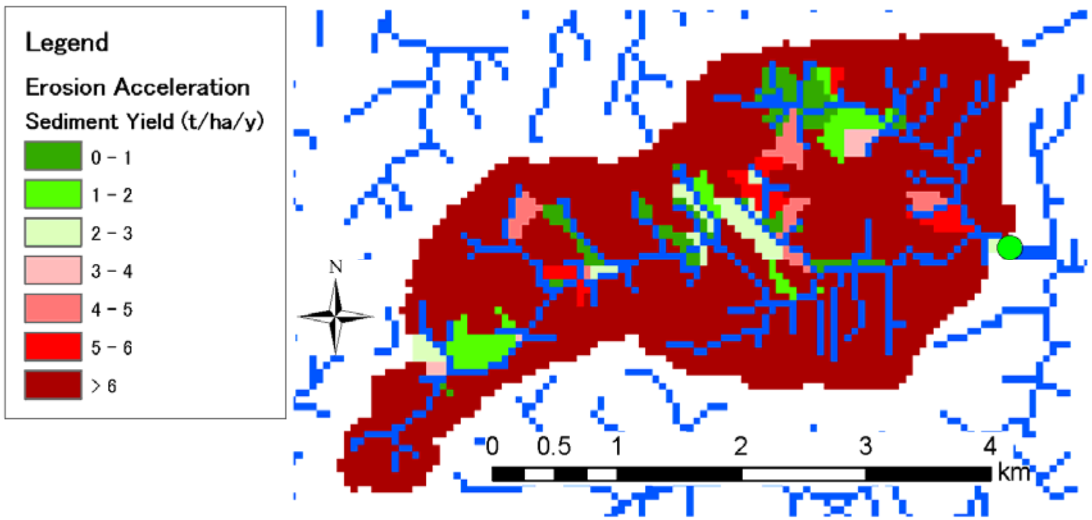
Trees and grass were cut on all of forests and grass lands.

Result of Sediment yield in Hiso



Average:
118 t/ha/y

Result of Sediment yield in Mano



Average:
108 t/ha/y

Soil erosion was accelerated dramatically.

Estimation of cesium movements in a watershed

$$Cs_y = \frac{Cs_d \cdot Sed_y}{BD \cdot dep}$$

Cs_y: cesium erosion rate (Bq/m^2/y)
Cs_d: cesium radiation (Bq/m^2)
Sed_y: sediment yield (g/m^2/y)
BD: soil bulk density (g/m^3)
dep: layer depth of cesium existing (m)

In this study, we assumed

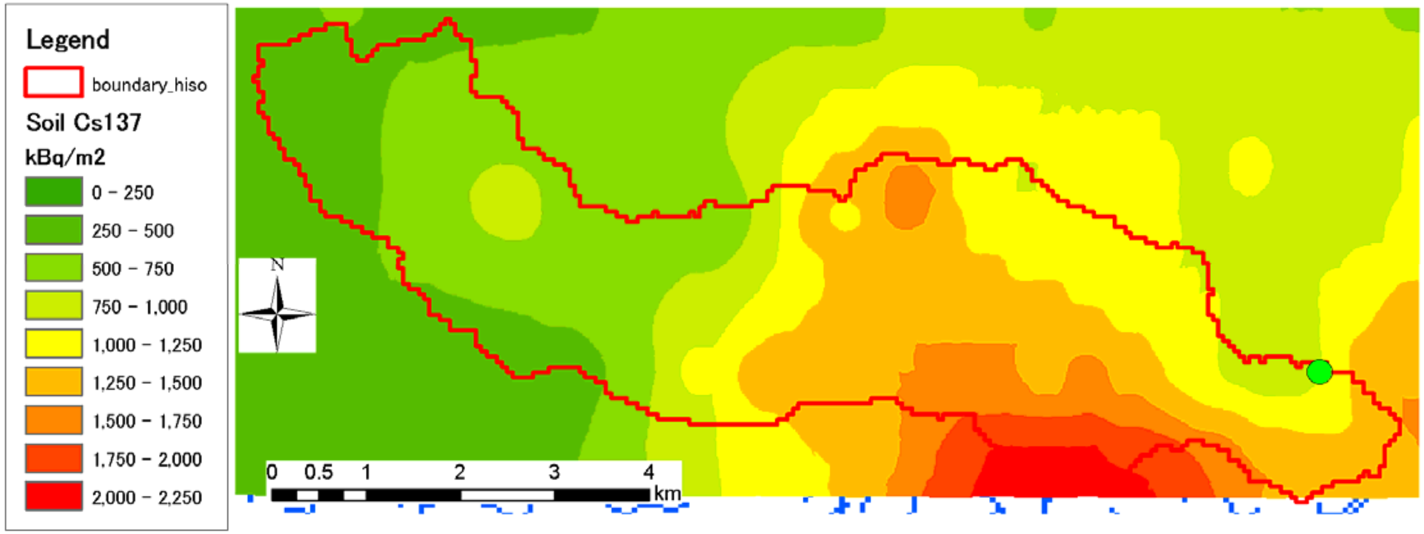
bulk density is 1.0 g/cm^3 → $BD = 1 \times 10^6$(g/m^3)

cesium is existing uniformly within 0 to 5cm layer

→ $dep = 0.05$(m)

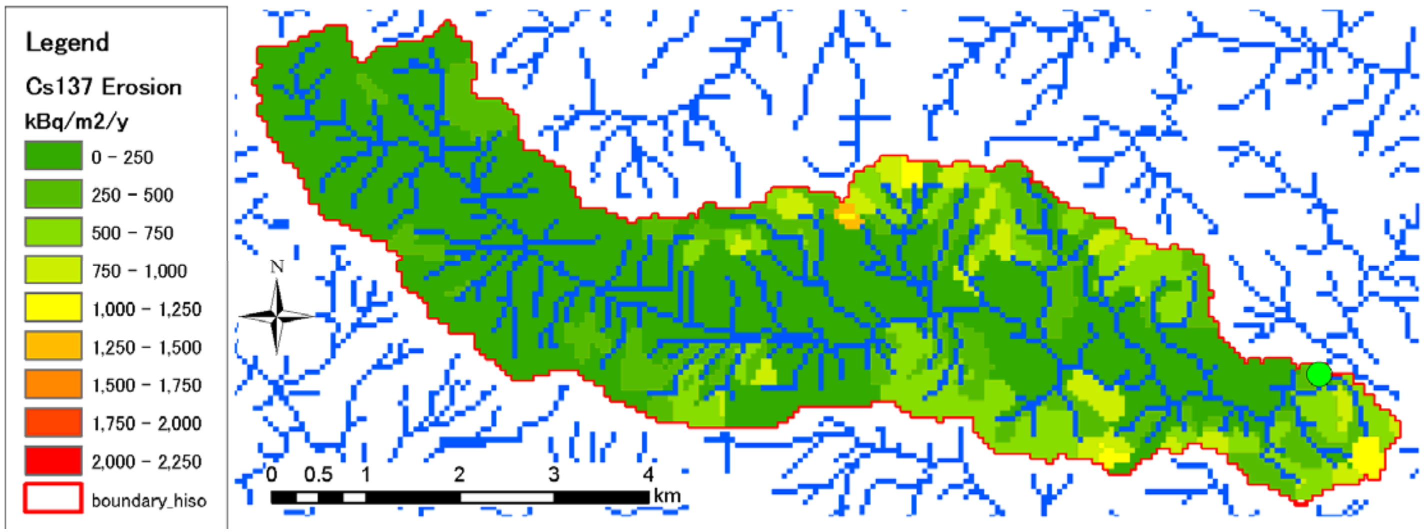
Calculated result of Cesium erosion (Hiso)

Distribution of Cs137 radiation (Monitored on March 11, 2013)



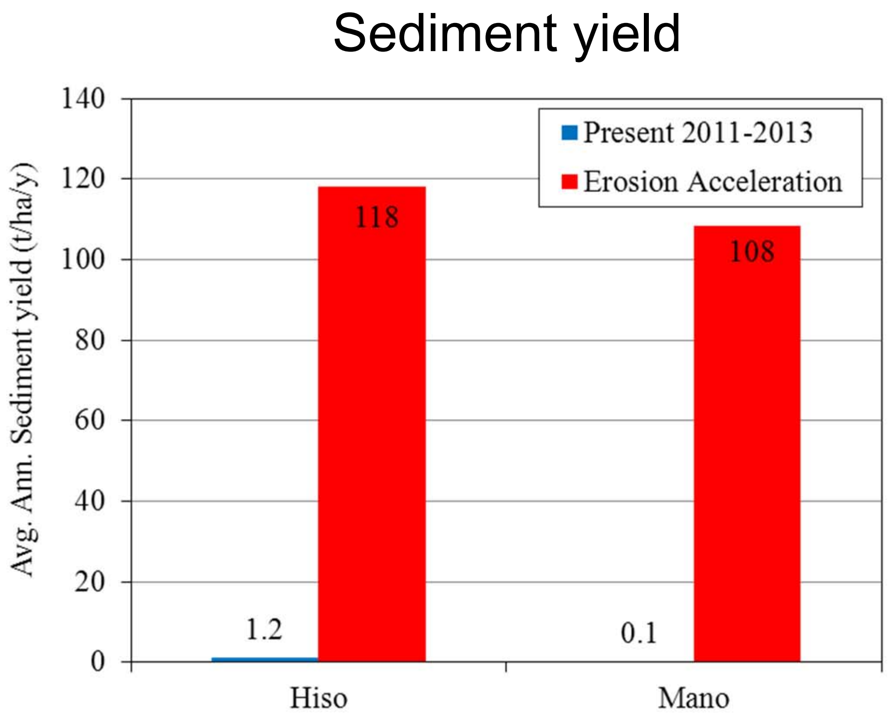
Average:
1021 kBq/m^2

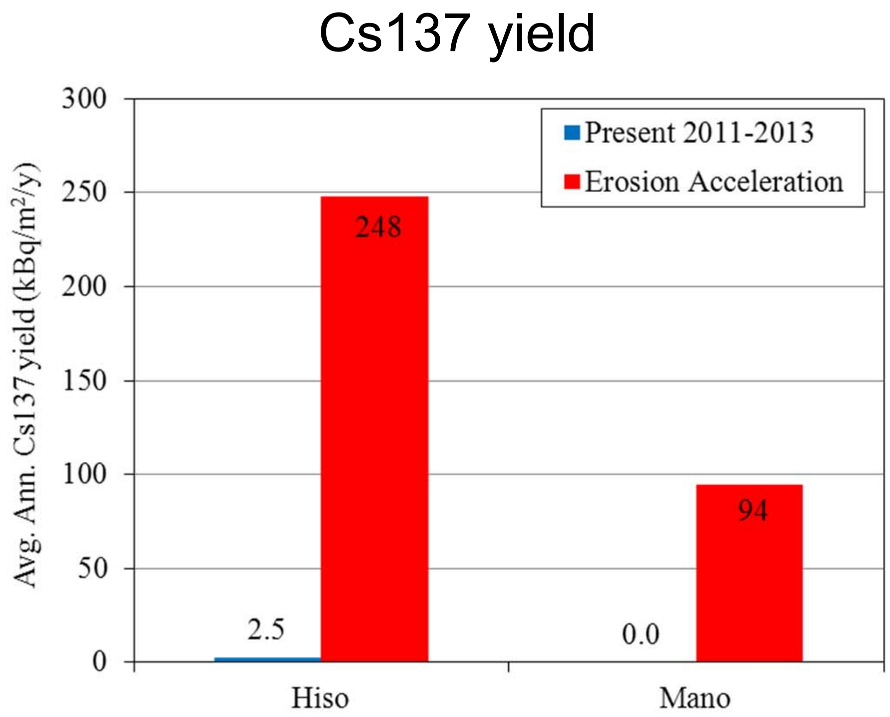
Distribution of calculated Cs137 erosion (Erosion acceleration scenario)



Average:
248 $kBq/m^2/y$

Hillslope sediment yield and cesium yield





Present case will not expect cesium yield.
→ It can be considered that there is no effect of spreading of cesium in downstream area.

Cutting vegetation case will accelerate cesium yield.
→ Practical management plan and sedimentation technique will be required for safety and effective decontamination.

Conclusions

- Monitoring system for sediment and radiocesium runoff was developed.
- Relationship between suspended sediment conc. and radiosesium conc. was almost linear. Radiocesium were flown with suspended sediment and organic matter.
- Radiocesium runoff was very small comparing with deposition density. Weathering reduction of sesium would not be effective.
- WEPP/GeoWEPP model was employed to estimate sediment and radiocesium movements. Accuracy was satisfactory.
- WEPP/GeoWEPP model estimated the much amount of cesium erosion under the case of cutting trees and grass.


Thank you very much
for your kind attention