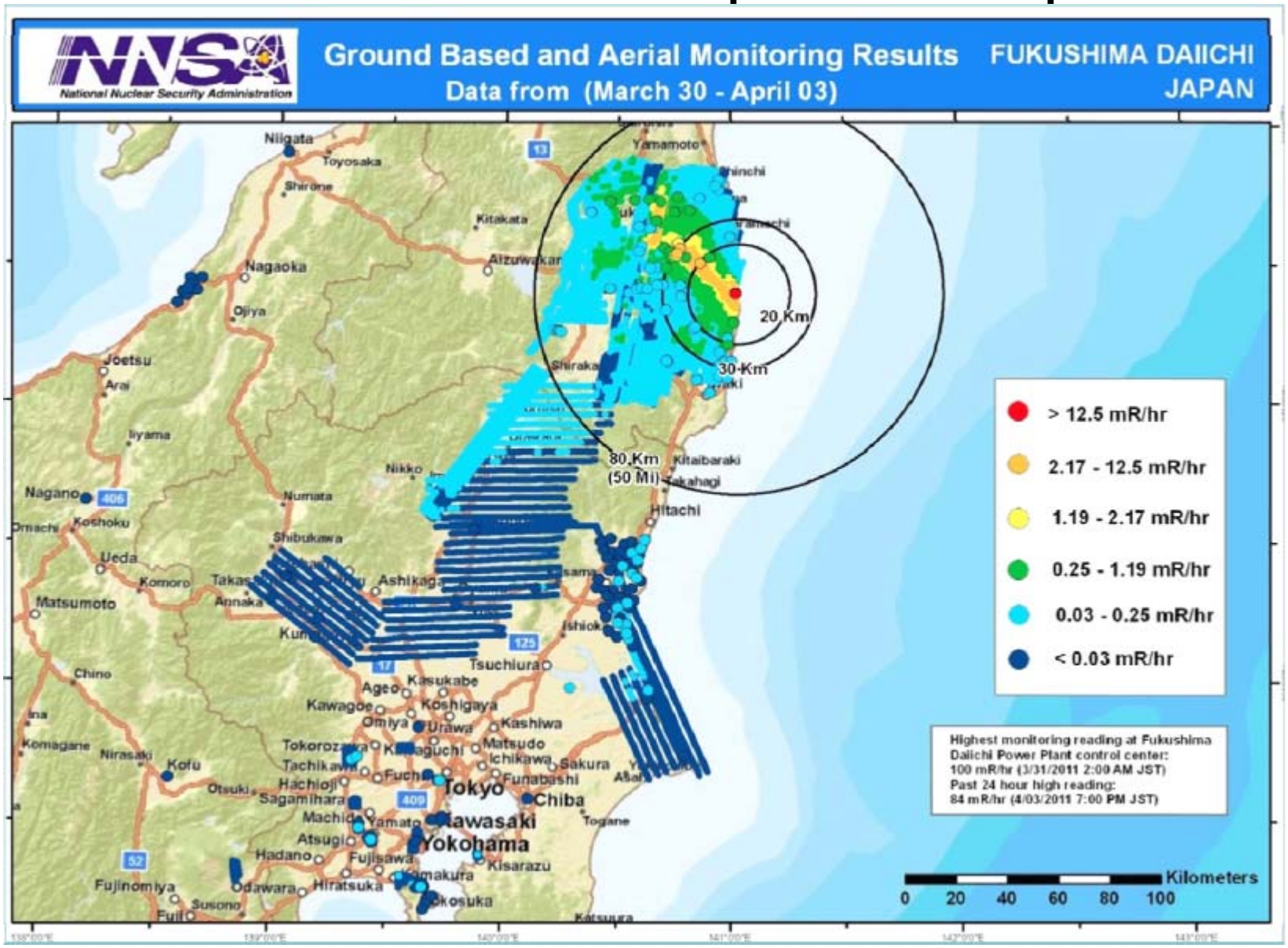
Radioactive fallout removal from the surface soils by enhancing vertical transport with artificial macropores

Yasushi MORI*, Atsushi SUETSUGU
Department of Environmental & Life Sciences, Okayama University, JAPAN
Eiko INAO
Miyagi Prefectural Institute of Agriculture & Horticulture, JAPAN
Kosuke NOBORIO
Graduate School of Agriculture, Meiji University, JAPAN

Background

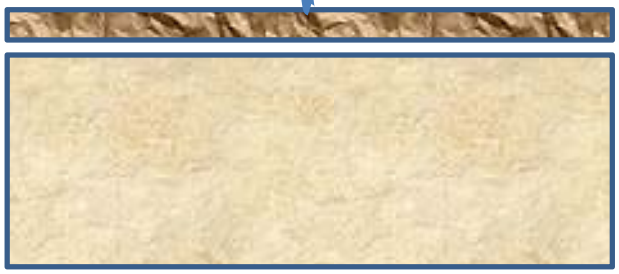
3.11 the Great East Japan Earthquake



Background

Possible technique for reducing radiation levels at the surface soil

Stripping

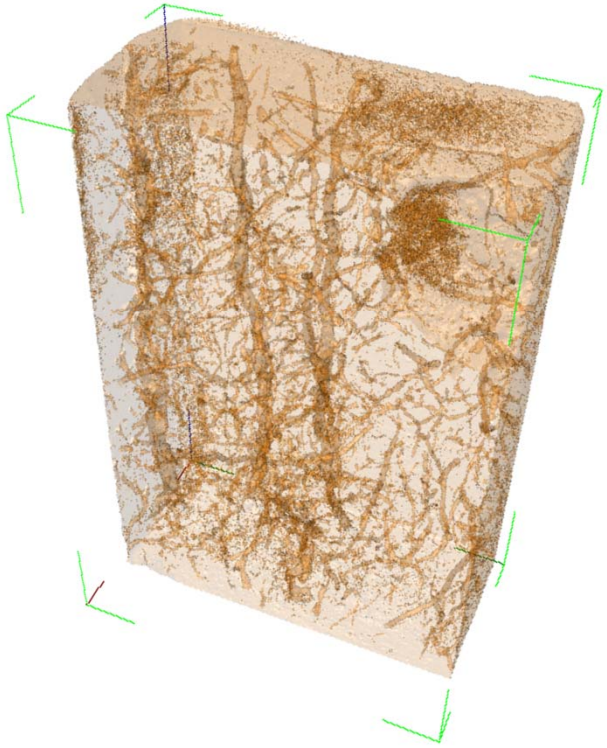


waste soil disposal
Limited to wide, flat area

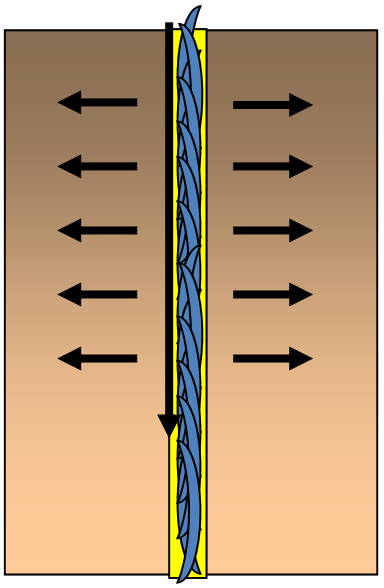
Turn over

Theory

Enhancing vertical infiltration at ill-drained soils

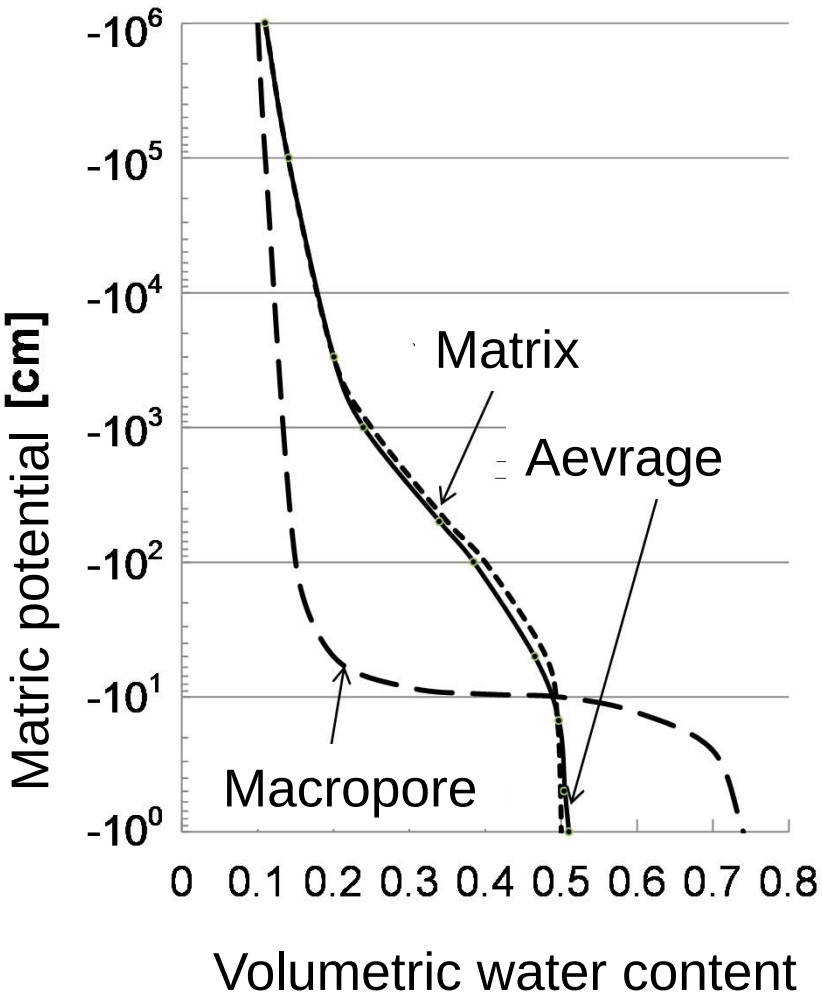


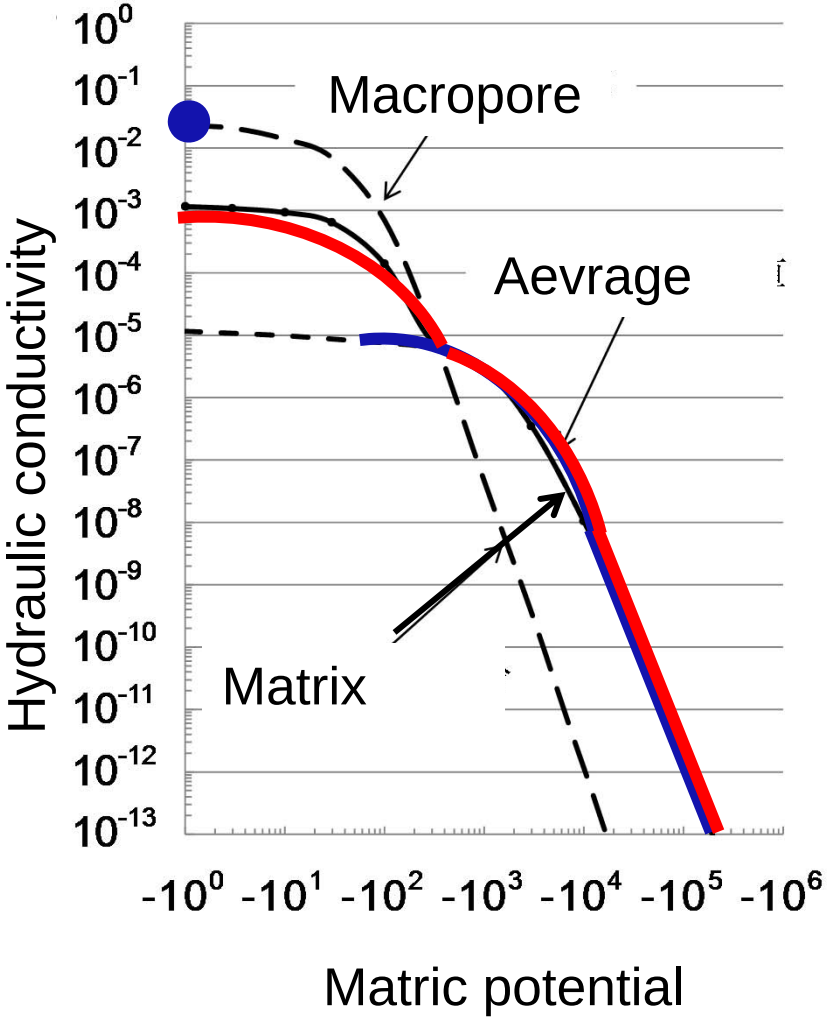
Microfocused X-ray CT
（inspeXio SMX-90CT, Shimadzu）
90kV 2mA



Artificial Macropore

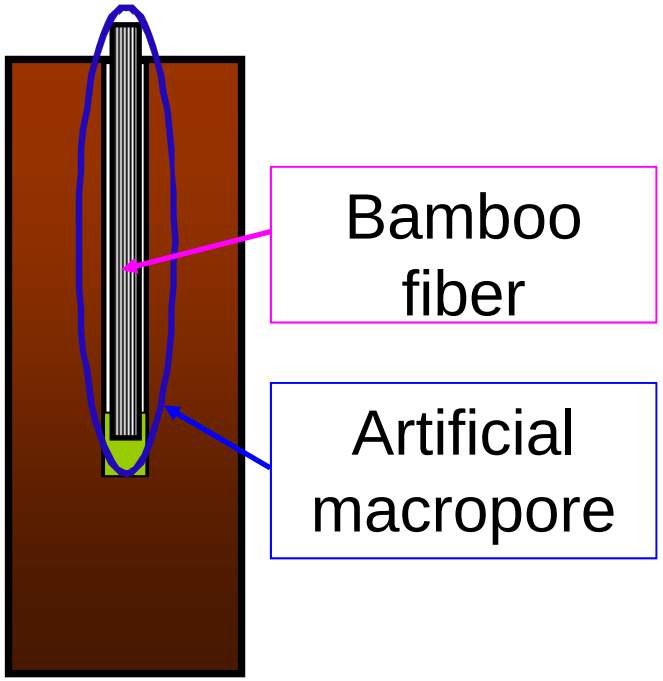
Hydraulic properties of Artificial macropore





Objectives

Artificial macropore → Enhanced infiltration



Structure of artificial macropore

Our previous studies have revealed the effectiveness of artificial macropores on rainfall infiltration and subsurface storage of organic matters.

The artificial macropore system can be made by drilling and insertion of fibrous materials (e.g., bamboo fiber) to avoid clogging.

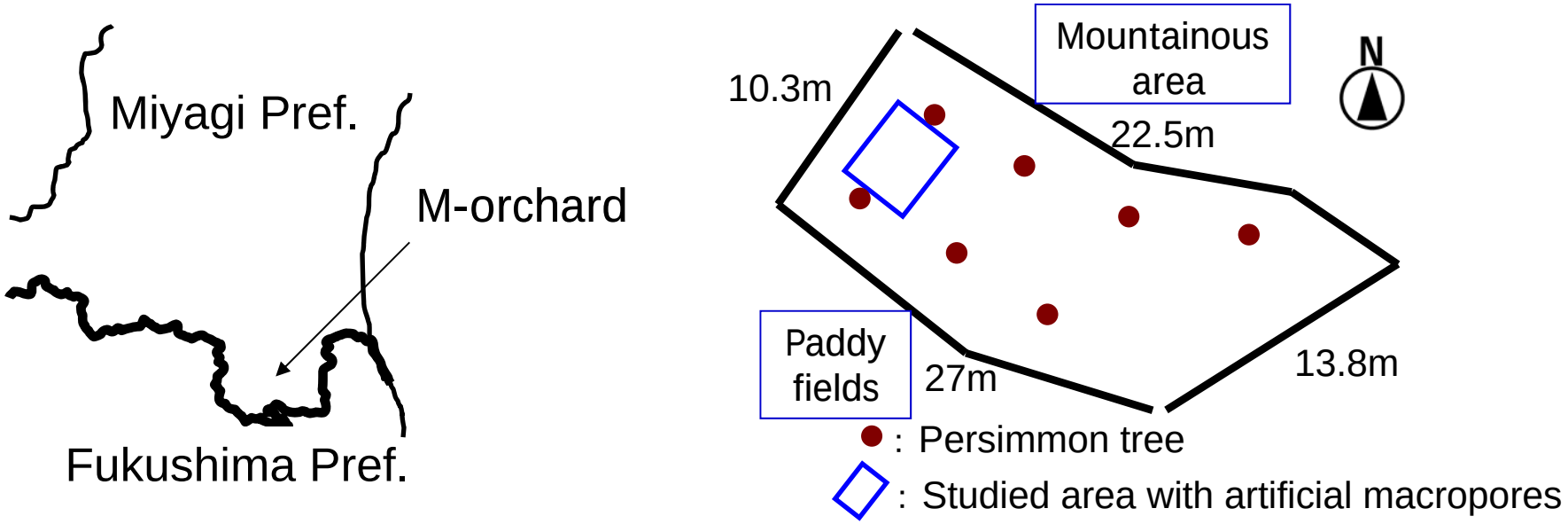
The objectives of our study is conducting a set of on site & column experiments to establish a technology for immediate removal of radioative Cesium fallout in forested areas through artificial macropore systems.

Materials and Mathods

Study site

Date of investigation
5/29/2012, 9/25/2012

M-region orchard (persimmon) at the southern part of Miyagi prefecture



Saturated hydraulic conductivity of surface soils ranged from 2.51×10^{-6} to 3.02×10^{-5} cm s^{-1}. We expected to remove soluble surface fallout through reclamation of drainage efficiency.

Materials and Mathods

Artificial Macropore

Materials and Mathods

Procedure of soil core sampling

M Orchard (persimmon), Miyagi prefecture, September, 2012

20 cores were sampled

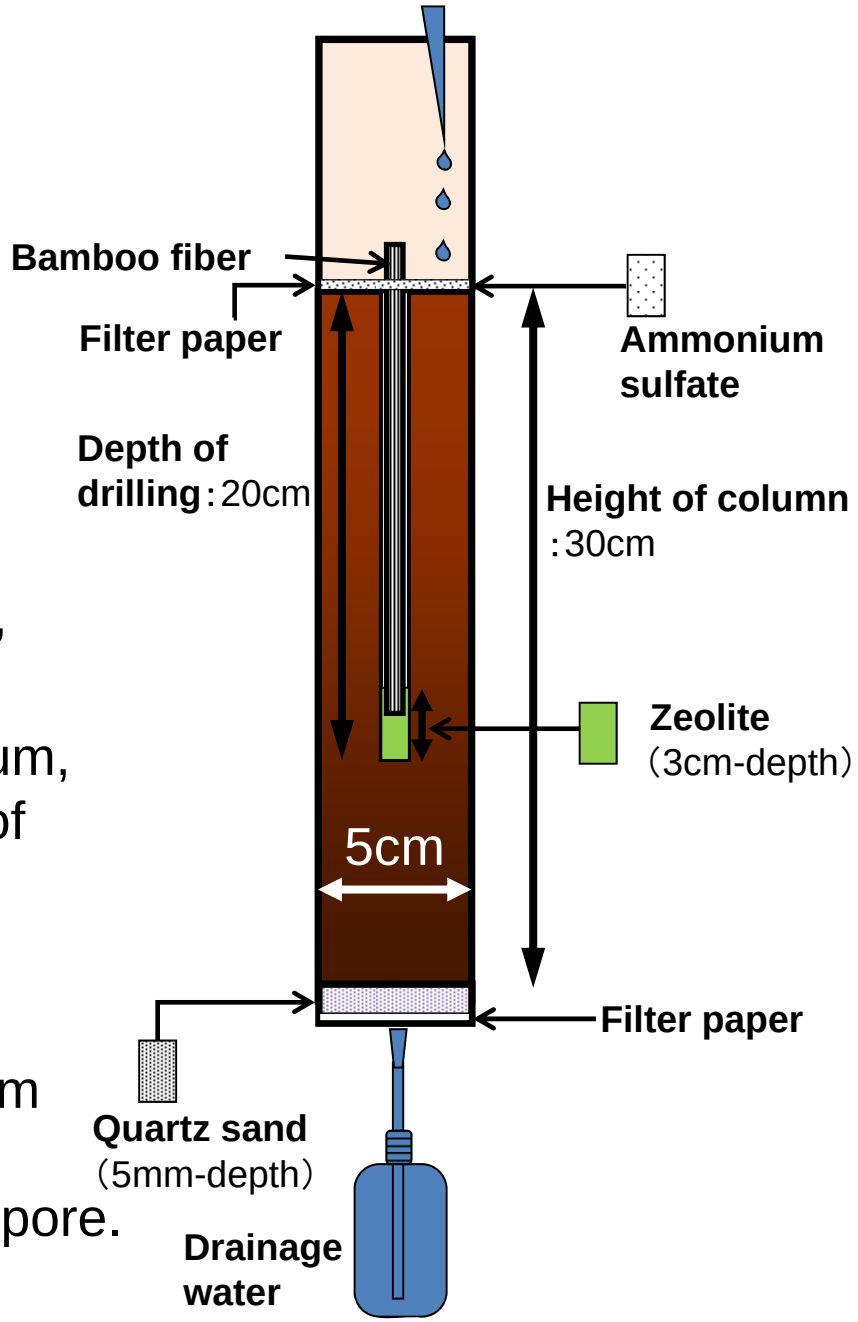
Materials and Mathods

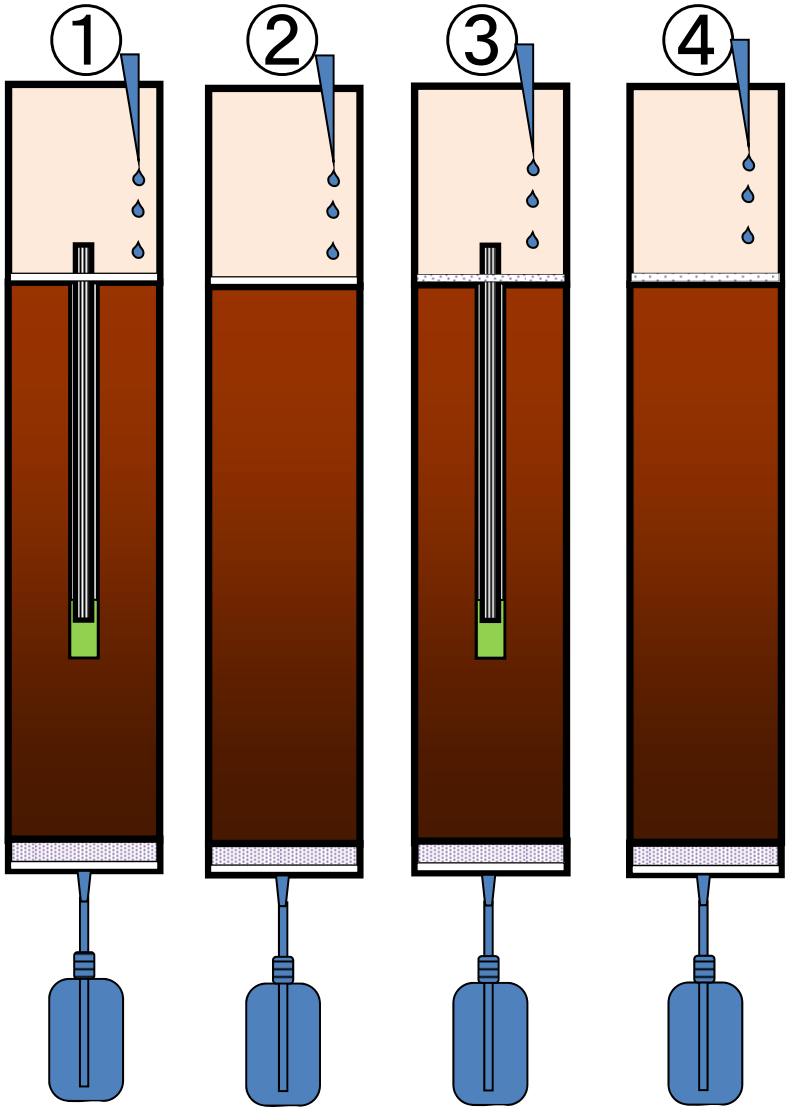
Column Experiment

We conducted a column experiment for a precise quantification of radiocesium migration through the artificial macropores,

For solubilization of immobilized radiocesium, ammonium sulfate was applied at the top of soils. Other chemicals were not chosen to minimize toxic effects on plants.

To avoid excessive migration of radiocesium into groundwater, a synthetic zeolite was applied at the bottom of the artificial macropore.





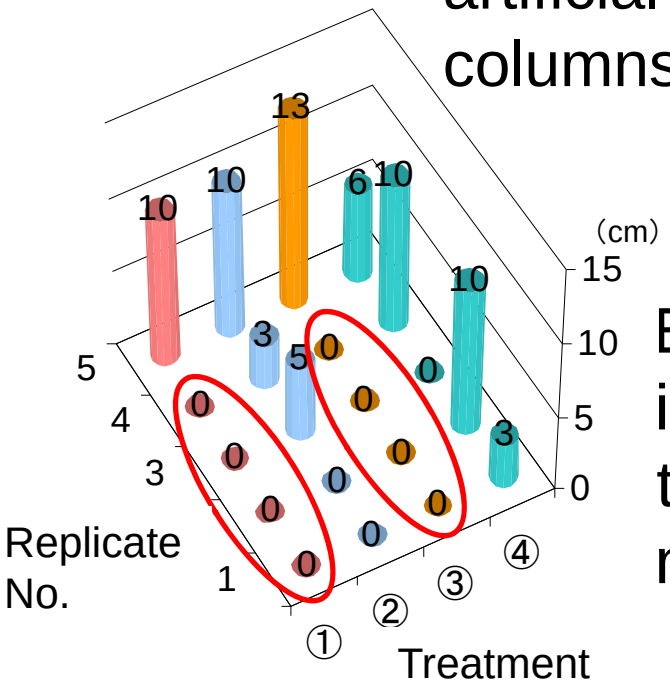
① with artificial macropore
② without artificial macropore
③ with artificial macropore & ammonium sulfate
④ without artificial macropore & ammonium sulfate

4 treatments × 5 replicates total 20 columns
Frequency of irrigation : twice per week
Amount of irrigation : 50 mL
Period of irrigation : 1 month

Results

Ponding depth（cm）

No ponding water was developed on the artificial macropore columns (①, ③).



Enhanced infiltration by the artificial macropore

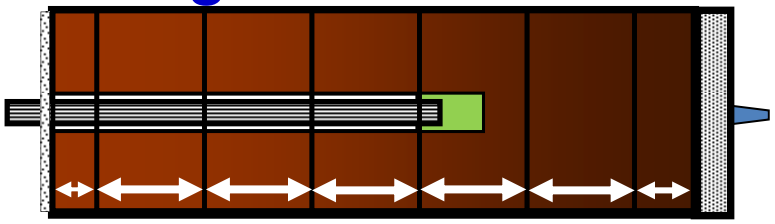
Radioactivity of drainage water in every column was below the detection level, which confirms elimination of excessive leaching of radiocesium into groundwater.

Results

Measured at Miyagi Prefectural Institute of Agriculture & Horticulture
Date of investigation:
11/12/2012～11/16/2012

Method of radioactive Cesium detection

①Cutting the column



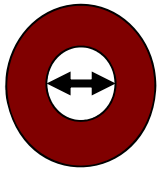
2cm 5cm 5cm 5cm 5cm 5cm 3cm
1st 2nd 3rd 4th 5th 6th 7th

Column cutter

②Filling the detection vessel

● **Hollowing around the macropore**

diameter : ca.2cm



By hollowing (concentric) sampling at 2-cm diameter, we compared the concentration of radiocesium between inner- and outer-part of each column.

③Sample weighing

④Detection of radiocesium

Results Radioactive Cesium detection

(averaged values of triplicated samples)

unit : Bq kg^{-1}

With macropore Without ammonium sulfate			Without macropore Without ammonium sulfate	With macropore With ammonium sulfate			Without macropore With ammonium sulfate
layer	inner	outer		layer	inner	outer	
1st	1910	1847	2133	1st	1543	1813	1793
2nd	119	165	61	2nd	133	234	90
3rd	ND	26	ND	3rd	ND	40	ND

1st layer : 0～2cm, 2nd layer : 2～7cm, 3rd layer : 7～12cm

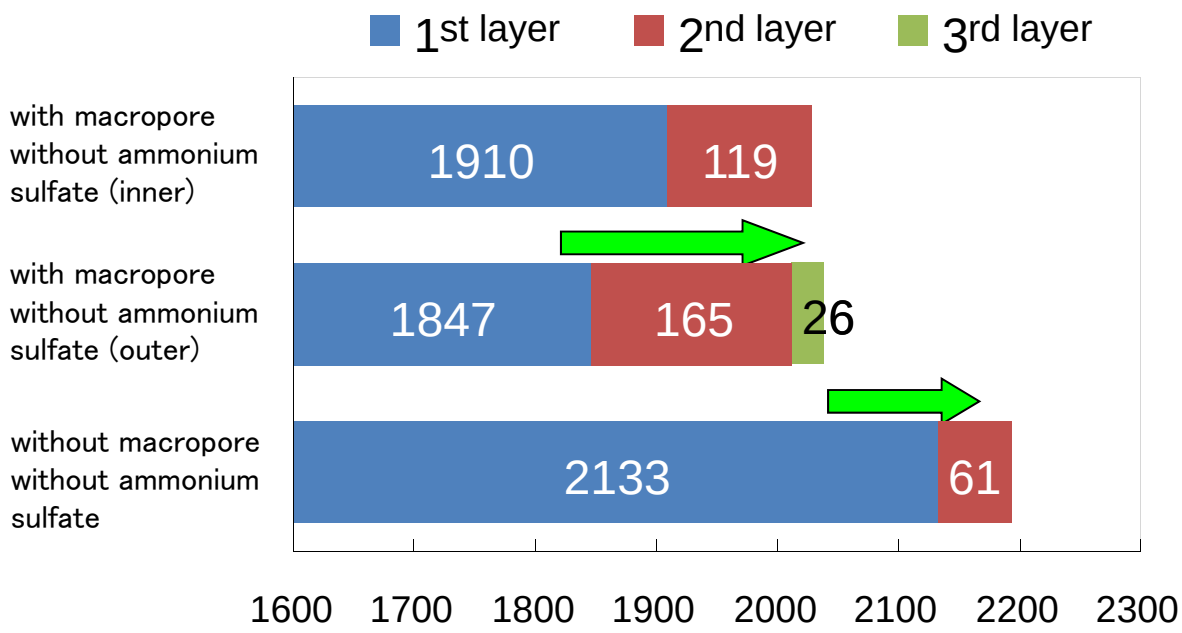
Ratios of 2nd-layer/1st-layer were increased by the artificial macropore & ammonium sulfate treatments.

Significant amount of radioactive fallout at this orchard could be solubilized & mobilized through the artificial macropore system.

Results

Effect of the artificial macropore

unit : Bq kg^{-1}



The artificial macropore promoted radiocesium migration into deeper layer.

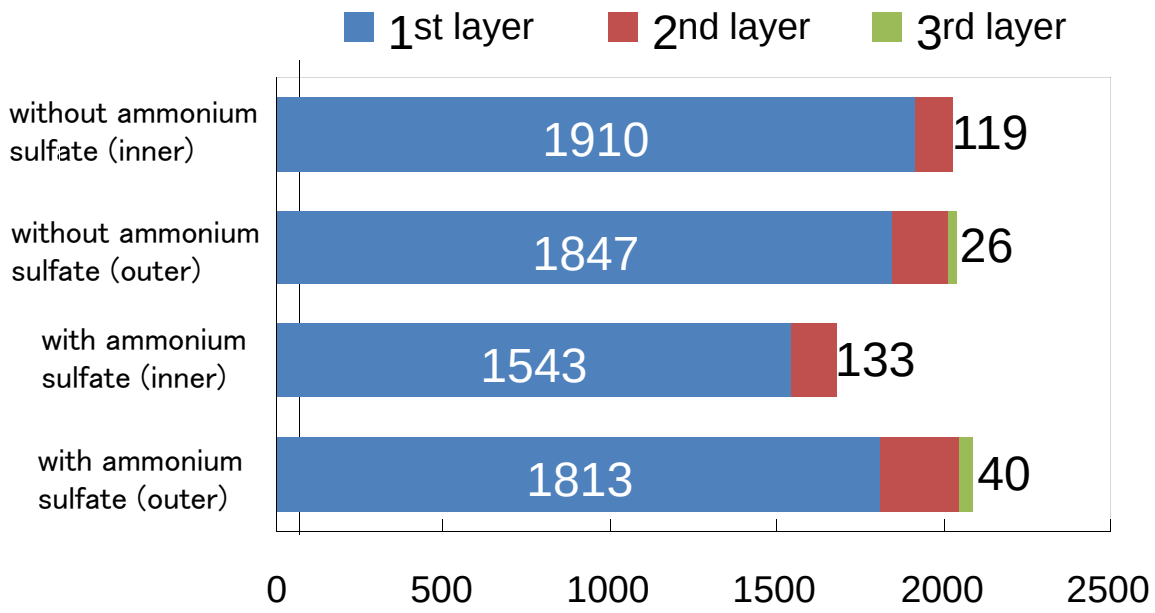
The large amount of organic matter in the orchard soils has enabled the migration of weakly-bound radiocesium through the artificial macropore.

The artificial macropore system was efficient in reducing surface fallout of radiocesium at organic-rich forested sites.

Results

Effect of ammonium sulfate

unit : Bq kg^{-1}



Ammonium sulfate solubilized & mobilized a portion of retained radiocesium.

The artificial macropore system could be optimized by applying cesium solubilizers.

Results

Summary

・Field experiments showed that radioactive Cesium was slightly decreased by artificial macropore.
・Column experiments showed that artificial macropore system could improve ill-drained soils.
・Artificial macropores greatly transported radioactive Cesium when compared with no macropore columns.
・Ammonium sulfate slightly improve mobility of radioactive Cesium.

Why was Cesium moved/transported, which is usually reported to be strongly bonded to soil surface?
We could say,
・Some of the radioactive Cesium would be weakly bonded at the surface soils, probably to organic matter.
・so there is still something we can do about solute transport.
・however, we also need to recognize that time is limited.

Results

Conclusion

An application of the artificial macropore system to radioactive Cesium removal from land surfaces could be advantageous over some conventional technologies, such as surface soil strip or turn over.

because of less amount of wastes, smaller size equipment, lower cost, easier installation, and moreover, wider range of application for complex land shapes (e.g., forests, inclined sites).

Because it is pilot study now, more field application needs to be done to figure out its strength and weakness.

Acknowledgment

- Agricultural workers at M-region Miyagi.
- Agricultural Improvement Staff, Miyagi.

This work was partially supported by

- Funding Program for Next Generation World-Leading Researchers (NEXT Program) (JSPS) 2010-2014
- Research for Promoting Technological Seeds (JST) 2009
- Grant-in-Aid for Scientific Research (JSPS) 2006-2008