Challenges of Agricultural land Remediation and Renewal of Agriculture in Iitate Village by a collaboration between scholar and NPO

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The accident at TEPCO's Fukushima Daiichi Nuclear Power Plant, which occurred in March 2011, became an unprecedented nuclear disaster. As a result, the forests, agricultural lands and oceans were contaminated extensively by radioactive cesium. In Iitate Village, Fukushima Prefecture, where evacuation continued after the nuclear power plant accident, decontamination work was carried out with thousands of workers for villagers’ return in the spring of 2017.
The authors entered the village three months after the nuclear accident and have tested several ways of agricultural revitalization by developing farmland decontamination methods that farmers can clean up by themselves with collaboration of local farmers, NPO members and researchers. As a result, the rice harvested in the test field passed the official inspection of Fukushima Prefecture in 2014. Despite many efforts of local people, we have not yet succeeded to dispel the anxieties of publics who mistrust that Fukushima's agricultural crops might contain radioactive cesium. Such a so called “harmful rumor” prevents from regenerating local agriculture. In this paper, we review our challenges of agricultural land remediation and renewal of agriculture by a collaboration between scholar and NPO, and propose the scenario of rural resurrection of Iitate village.

Keywords: Fukushima, Iitate Village, collaboration, soil remediation, agriculture, forest

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Monitoring Inspection for Radiocesium in Agricultural, Livestock, Forestry and Fishery Products in Fukushima Prefecture

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The Tohoku Region Pacific Coast Earthquake, which occurred on March 11, 2011, caused an accident at the Fukushima Daiichi power station operated by the Tokyo Electric Power Company. Radioactive material, such as cesium, released by the accident spread to farmlands in Fukushima and neighboring prefectures, and contaminated the soil and agricultural products. The Ministry of Health, Labor and Welfare established a provisional regulation level of 500 Bq/kg for radiocesium in cereals, vegetables, meat, and fishery products. In April 1, 2012, a new maximum limit of 100 Bq/kg was established as a new standard of radiocesium in general food. To verify the safety of agricultural products, the Nuclear Emergency Response Headquarters have been conducting emergency environmental radiation monitoring of agricultural and fishery products (hereafter referred to as monitoring inspections). Monitoring inspections were performed before shipment of the food products. If the radioactivity detected in the food exceeded the regulation level, the government would order the municipalities to suspend the shipment or limit consumption. By the end of March 2016, approximately 500 types of foods were selected, and 100,000 samples were analyzed in total. We summarized the monitoring inspections of radiocesium concentration levels in Fukushima Prefecture for 5 years.
The ratio in which radiocesium concentration exceeded the 100 Bq/kg from March 2011 to June 2011 was 18% in agricultural products (excluding rice), 3% in livestock productions, 49% in forest productions, and 52% in fishery produced. The maximum concentration of radiocesium in this period was 84,000 Bq/kg. The high concentration value could be attributed mainly to direct deposition of the fallout on plants that had already grown at the time of the accident. If people consume vegetables, fruits, forestry products, meat, milk, and fishery products grown in Sousou area during March to June 2011, the calculated internal exposure is expected to be 0.75 mSv/year.
After June 2011, radiocesium concentration reduced drastically. Radiocesium concentration in agricultural and livestock products hardly exceeded 100 Bq/kg. Radiocesium concentrations of forestry and fishery products have been falling every year, but there were a little sample which exceeded 100 Bq/kg. In addition to the decrease in the concentration of radioactive nuclides based on the physical half-lives, tillage also contributed to the decrease in the concentrations of radioactive nuclides in plants grown in the field, because radioactive cesium is firmly attached to the clay minerals, and by mixing, the concentration of cesium decreases. Application of potassium, an element homologous to cesium, to the field is another effective tool to minimize cesium uptake in the plants.
Rice is the main staple food of the Japanese diet, and the most valuable agricultural product. In 2012, Fukushima Prefecture decided to investigate the radiocesium concentration in all rice using custom-made belt conveyor testers. Notably, rice with radiocesium concentration levels over 100 Bq/kg were detected in only 71, 28 and 2 bags out of the total 10,338,000 in 2012, 11,001,000 in 2013, 10,956,000 in 2014 respectively. Since 2015, there were no bags which with higher radioactivity than 100Bq/kg.

Keywords: Radiocesium, Monitoring Inspection, Checking all bags of rice for radiation

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Current status of reconstruction and challenges post the Fukushima disaster: Case study of Iitate Village

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Some farmers who evacuated due to the Fukushima Daiichi Nuclear Power Plant accident have resumed farming at the evacuation destination. On the other hand, many evacuees have discontinued agriculture for several reasons. Furthermore, as the number of areas where evacuation instructions have been canceled increases, new issues arise with regard to returning to the village or settlement at the evacuation destinations. This presentation considers the perspective of restarting farming and compares the current status of reconstruction of the affected farm village with that of a general rural village. Furthermore, it clarifies the challenges for future.
We investigated Iitate Village in Soma-gun, Fukushima Prefecture. The entire village was evacuated due to the Fukushima Daiichi Nuclear Power Plant accident. We conducted interviews and questionnaire surveys for farmers resuming farming at the evacuation destination and for evacuees being shifted to temporary housing. Through these surveys, we grasped the trends and intentions of farmers with regard to resuming farming as well as the conditions of temporary housing refugees.
Some large-scale farmers have resumed farming. The process of resuming farming for evacuees depends on their business contents. Floral cultivation farmers search farmland near the evacuation destinations. However, cattle breeding involves the use of a closed livestock barn. Therefore, farming can be resumed in an area where there are livestock barns. Restarting farmers use abandoned farmland and closed barn. Moreover, these farmers have high management skills and influence the community to resume farming. For example, they introduce new techniques in agriculture that were not previously used in the evacuation area.
On the other hand, most refugees placed in temporary housing have not resumed farming because these are mainly elderly people and semi-retired farmers. Thus, they do not possess management skills to secure agricultural land, work, and storage space necessary to resume farming as well as to purchase agricultural equipment.
Many farmers who have resumed farming consider returning to their villages, excluding those in the difficult-to-return area. However, they have not recover the scale of business before the accident. Further, there are no cases concerning relocation of all the living bases and farming in the evacuation destination. Many restarting farmers have chosen to continue farming both in Iitate village and at the evacuation destination.
As in many other middle and mountainous areas, Iitate Village had a declining population before the accident. In addition, Iitate Village has witnessed not only a few decades of population decline but also significant changes due to the accident. For example, vegetable gardens cannot be used for self-sufficiency around the house after the accident as used previously. Elderly people find it difficult to return to their home, and there is uncertainty concerning decontamination results. Therefore, it is necessary to consider agricultural assistance as an industrial policy to deal with issues that the policy has not covered so far.
Many issues relating to regional agriculture and community are more difficult post the accident than during evacuation. Among measures to be taken, long-term situations that consider the succession to the next generation are essential. Furthermore, researchers will need to focus on issues faced by residents over a long period of time.

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Keywords: Post the Fukushima disaster, Restarting farming

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Radiocesium runoff forms and its temporal variation at two rivers in Iitate, Fukushima

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Radionuclides were released by the accident at the Fukushima Daiichi Nuclear Power Plant, and radiocesium, ^{137}Cs and ^{134}Cs, were deposited on the soil surface. All of the residents within 50 km of the plant were forced to move. Six years after the accident, some residents are expected to return. However, decontamination efforts that remove topsoil around houses, agricultural lands, and forests requires a lot of time. Focusing on the forests, it is impossible to remove all of the topsoil, and thus estimates of radiocesium movements are needed. Radiocesium is adsorbed on soil and organic matter. Their movements would be equivalent to soil particle movements, through soil erosion and sediment transport. In this study, field monitoring was conducted to estimate radiocesium runoff from two comparative watersheds. Especially, radiocesium runoff forms and its temporal variation were focused.

The study sites were two watersheds in Iitate Village, Fukushima, Japan (Figure 1). The southern observation watershed (Hiso River watershed, 25.6 km^2) has higher radiation levels compared to the northern Mano River watershed (10.8 km^2). Forest accounts for close to 75% of the land area in both watersheds. Sediments containing radiocesium carried by runoff from surrounding lands into the rivers were monitored. A monitoring system is composed of a rain gauge, water level sensor, water velocimeter, turbidity sensor, and automatic water sampler (Figure 2).

Focusing on sediment particle size, more than 75% of the ^{137}Cs was adsorbed on finer particles such as clay, silt, and fine sand which were occupied less than 50% of suspended sediment as shown in Figure 3. Correlations between suspended sediment concentrations (SSC) with ^{137}Cs concentrations in storm waters are shown in Figure 4, and were approximately linear. These results mean radiocesium was discharged with the suspended sediment and organic matter. Comparing the two watersheds in the Figure 4, the slope of the regression line at Hiso was greater than that at Mano, which means radiocesium content in the suspended sediment at Hiso was larger than that at Mano. This also agrees with the distribution of radiocesium content in the topsoil shown in Figure 1. Comparing the slope of the regression lines from 2013 to 2016 in Figure 4, it decreased clearly with the lapse of time. The decreasing ratio for three years was 79% at Hiso and 83% at Mano. These ratios are much greater than the decay ratio of 6.7% estimated by physical half-life of radio-cesium. This high decreasing ratio might have been resulted due to the selective erosion and transportation of fine particles and organic matter in the hillslope and waterway. Monitored total amounts are summarized in Table 1. Hiso radiocesium losses were greater than those at Mano even though sediment yield was smaller, and this was due to the greater concentrations of radiocesium at Hiso. Spatially averaged ^{137}Cs contents at Hiso and Mano were 1017 kBq/m^2 and 421 kBq/m^2. Thus, decontamination of radiocesium in topsoil by natural soil erosion processes may not be effective. Focusing the form of radiocesium in the river water, most of ^{137}Cs was discharged as particulate form in the storm events. Its form accounted for greater than 95% of the total ^{137}Cs amount at both watersheds.

Keywords: Radiocesium, Sediment, Soil erosion, Fukushima

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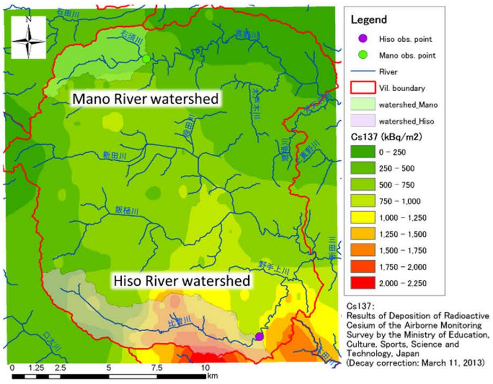

Figure 1. Study sites and ^{137}Cs levels in Iitate Village.

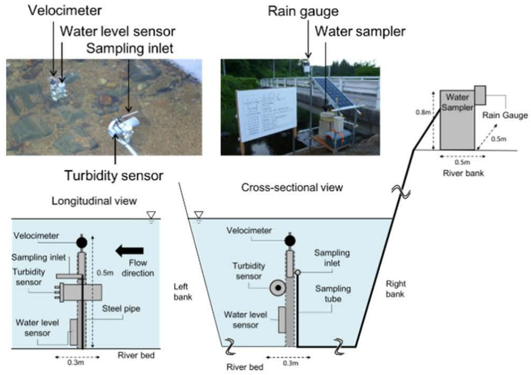

Figure 2. Instruments for field monitoring.

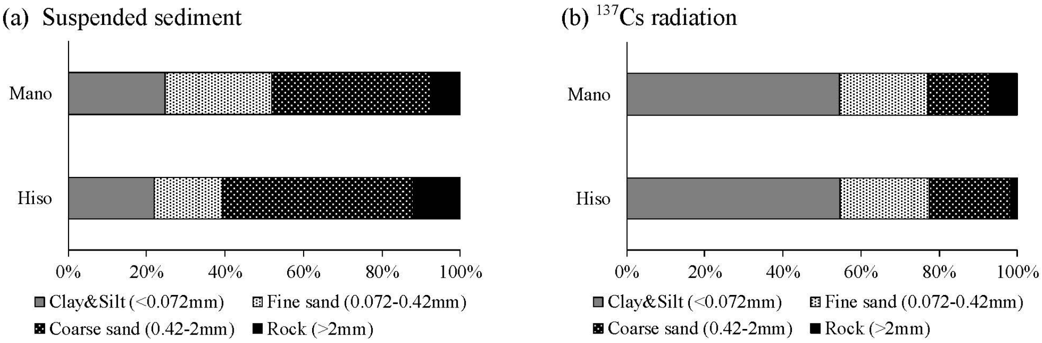

Figure 3. Ratios of each particle size in suspended sediment (a) or ^{137}Cs radiation (b) at Hiso in 2013.

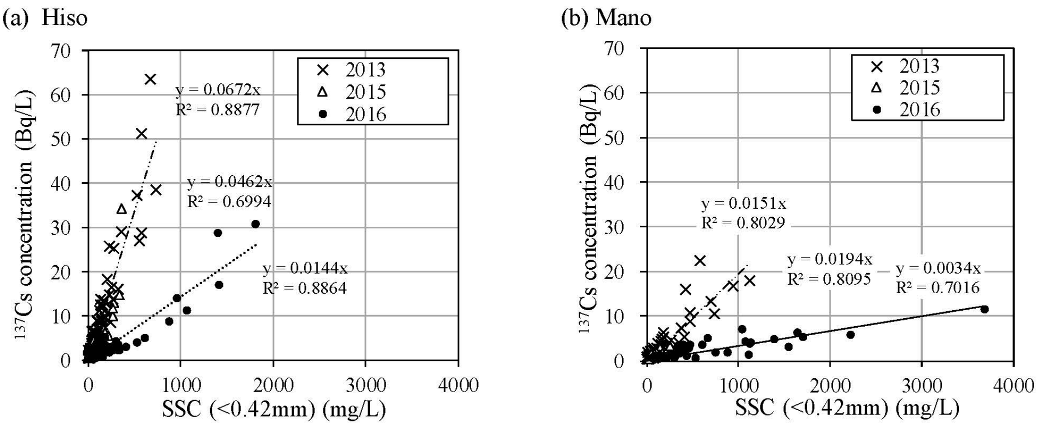

Figure 4. Relationships of SSC with ^{137}Cs concentration in the storm water at Hiso (a) and Mano (b)

Table 1. Monitored total amounts from June 2013 to December 2016.

Site	Year	Precipitation (mm)	Water runoff (mm)	Sediment yield (g/m²)	^{137}Cs runoff (Bq/m²) Storm Particulate	Storm Dissolved	Normal Particulate	Normal Dissolved	Total
Mano	2013	906	574	33	647	11	10	4	705
Mano	2014	1241	997	51	693	16	18	8	776
Mano	2015	1563	573	59 *	510 *	12	8	4	525 *
Mano	2016	1319	259	25 *	69 *	2	3	2	94 *
Hiso	2013	974	562	21	1387	26	12	5	1410
Hiso	2014	1595	1234	39	1000	21	19	8	2126
Hiso	2015	1639	753	74	2502	45	13	6	2604
Hiso	2016	1394	750	55	613	20	8	3	730

*Including missing values

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Watershed Modeling Tools for Stakeholders: Utilizing Fallout Radionuclides to Assess Sustainable Management, Climate Change, Disaster Recovery and Community Resilience

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Existing isotope techniques based on fallout radionuclides and process-based soil redistribution modeling together are complementary techniques to provide more reliable and detailed data to a broad spectrum of stakeholders with different objectives: managers of natural resources and disaster managers of contaminated soils. On the one side, utilizing process-based model approaches and fallout radionuclides of surface atomic bomb tests more than half a century ago, enable to support more detailed soil and water conservation analysis of the past and future impact studies under changes of land use and/or climate around the world. While in the latter case the main objective is the sustainable use of natural resources, the same approach can also be used to assess a variety of land management strategies with the primary goal of minimizing erosion of radiation contaminated soils and increase the deposition of contaminated sediments before they reach a water body or stream. We present techniques to develop modeling tools for stakeholders to design, verify, validate and apply models assessing soil redistribution and the return periods of extreme events for agricultural soil conservation strategies as well as recovery of radiation contaminated soils.
The Geospatial Interface for the Water Erosion Prediction Project (GeoWEPP) is a quantitative, scenario-based watershed assessment model that is used around the world. GeoWEPP utilizes Geographic Information System (GIS) data such as digital elevation models (DEM), land use/cover and soils maps to derive and prepare valid model input parameters to start site-specific soil and water conservation planning for small watersheds. At its core is the WEPP model, a state-of-the-art, continuous simulation, process-based model for small watersheds and hillslope profiles within larger watersheds that can be of mixed land use such as agriculture, forest, rangeland, etc.
In Marchouch, Morocco, an agricultural experimental site provides five parallel transects with excellent data availability and a relatively high density of derived soil redistribution points based on ^{137}Cs and ^{210}Pb techniques. These transects are ideal to verify, validate and apply the GeoWEPP watershed simulations. Using these fall out "contaminants" as soil tracers, reinforces knowledge about the agro-environmental behavior of these anthropogenic radioisotopes (especially ^{137}Cs, but also new soil tracers such as ^{239}Pu and ^{240}Pu isotopes). The technique requires selecting stable reference sites in undisturbed areas that can be used in the future as background indicator if any other radioisotopic releases of Nuclear Power Plant accident occurs.
However, such simulation tools for sustainable development of natural resources (e.g. soil and water conservation and crop yields) and disaster risk reduction (e.g. flood risk and loss of biodiversity) are rarely performed within an integrated framework to account for the interests of a much larger, diverse group of stakeholders in a community. We therefore present a methodology to integrate quantitative models to drive the analysis of the complex, interdependent processes that interact within multi-dimensional, functional systems in landscapes. Creating potentially win-win situations based on quantitative measures among a larger group of stakeholders in a watershed is an important aspect of creating long-term

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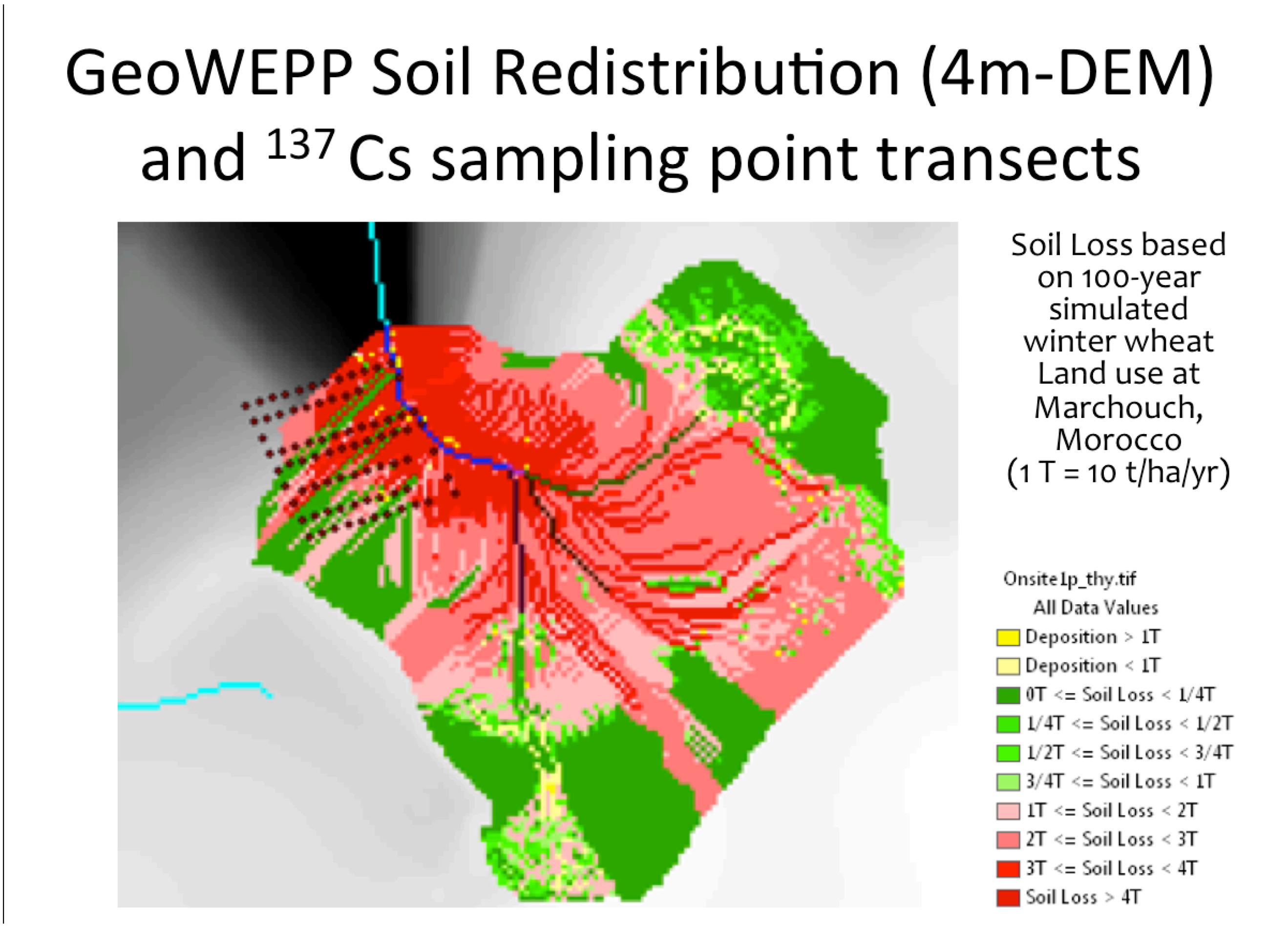
partnerships, particularly those in communities exposed to the need for natural resources development and higher risks of natural and man-made hazards (e.g. Fukushima Nuclear Power Plant Disaster). Resilience has been defined as a measure of geospatial and temporal functionality, its decay and recovery, in face of various extreme events, disasters and potential hazards. The functionality and resilience of a community are dependent on numerous components and dimensions. Seven dimensions of community resilience are represented in the holistic, interdisciplinary framework with the acronym PEOPLES: **P**opulation and Demographics, **E**nvironmental/Ecosystem, **O**rganized Governmental Services, **P** hysical Infrastructure, **L**ifestyle and Community Competence, **E**conomic Development, and **S** ocial-Cultural Capital. The '**PEOPLES** Resilience Framework' provides the basis for the integration of quantitative and qualitative models that continuously measure the resilience of communities against extreme events or disasters in any or a combination of the above-mentioned dimensions.

Keywords: soil erosion, extreme events, isotopes, disaster, radioactive fallout, community resilience



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Characteristics of water quality and stable isotopes in spring water, groundwater and artesian well at Minamisoma City and consideration of the water quality change after Tsunami.

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After the Great East Japan Earthquake occurred, the investigation near the coast area in northern part of Fukushima prefecture has been carried out to clarify the groundwater flow and residence time in this area. The measuring of EC, pH, water temperature, ORP and water sampling of groundwater, spring water and river water have been carried out several times. In this presentation, we will report the result of investigation which was carried out on December, 2016.
The investigation was carried out on 29-30 December, 2016 at Minamisoma City and Soma City. As a result of investigation of four spring sites and six groundwater sites (including the five artesian wells), the following were revealed.

1) As a result of chemical analysis for dissolved inorganic matter in spring water and groundwater, Na-(Cl+SO_4) type, Ca-HCO_3 type and Na-HCO_3 type were indicated. The spring water which shows the Na-(Cl+SO_4) type may be affected by the Tsunami. The investigation of this spring water has been performed regularly. Thus, the EC in this spring water decrease gradually (from 100 mS/m in December, 2012 to 30 mS/m in December, 2016), the influence of the Tsunami may decline. In the other sites, there is no tendency that was affected by the Tsunami.

2) If the water quality shows the Na-HCO_3 type, the groundwater flow might be more deeper and residence time might be relatively longer. In the investigation of December, 2016, Na-HCO_3 type was recognized at 2 sites (groundwater in Minamisoma City and artesian well in Soma City). Since the stable isotopes of oxygen and hydrogen in these water is relatively low, it is assumed that the recharge area is more higher latitude. As a result of calculation by using the altitude effect (δ^{18}O: -0.29‰/100 m, δD: -2.0‰/100 m), recharge area of groundwater that water quality is Na-HCO_3 type is estimated about 300 m higher than the site where the water quality is Ca-HCO_3 type.

3) There is multiple groundwater flow near the coast area of northern part of Fukushima prefecture.

4) The concentration of trace element of manganese and iron is relatively high in the part of Minamisoma. The origin of manganese and iron might be Earth (soil or rock).

5) Because of the stable isotopes of strontium are different by geology, it is highly possible to grasp the difference of recharge area of groundwater. In future, we will measure the strontium isotopes and consider about the more detailed groundwater flow.

Keywords: Minamisoma City, groundwater, spring water, artesian well, water quality, Tsunami

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Quantitative estimate of ^{137}Cs load characteristics in Kuchibuto river watershed

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^{137}Cs has major impact on the environment due to its long half-life (30.1 years). To understand ^{137}Cs load characteristics in the watershed, we estimated the effective ^{137}Cs half-life in the Kuchibuto river watershed by calculating the ^{137}Cs load in the river. Watershed area is 22km^2, elevation is from 329m to 1,050m. Annual precipitation and average temperature is 1,158mm and 14°C respectively. The research watershed was covered with forest (74%), agricultural land (17.4%) and paddy field (7.6%). And, soil types are brown forest soil (51%) and Andosol (49%).
During the period from 6 July 2014 to 24 August 2015, we measured river discharge, SS, and ^{137}Cs concentration. Utilizing measured data, we attempted to estimate the ^{137}Cs load during non-observed period. First, Soil and Water Assessment Tool (SWAT) was utilized for river discharge estimate. Model warmup period was from 2008 to 2010. For the calibration, 2000 times simulation was conducted with Latin Hyper-cubic method from 1 October 2014 to 31 May 2015. Validation was also conducted from 6 July 2014 to 30 September and from 1 June 2015 to 24 August 2015. The model performance was assessed by Nash-Sutcliff efficiency (NSE) and regression coefficient (R^2). Particulate ^{137}Cs concentration was calculated by regression curves between discharge and suspended solid (SS), and SS and ^{137}Cs concentration. Regression curves were constructed from observed discharge[m^3 s^{-1}], SS[g L^{-1}] and ^{137}Cs concentration[Bq L^{-1}], and bias was compensated. Dissolved ^{137}Cs was also calculated by using the partition coefficient which was ratio of particulate and dissolved ^{137}Cs in the river. For uncertainty analysis, 95% confidential interval of ^{137}Cs load was estimated by using the composition of Gaussian distribution of each regression curves from1 October 2014 to 31 May 2015. Discharge uncertainty was estimated by the sequential uncertainty fitting (SUFI).
During the observed period (6 July 2014 - 24 August 2015), particulate and dissolved ^{137}Cs load was calculated at 6.1×10^8 and 1.5×10^6 Bq km^{-2} and these values were equal to 0.26% and 0.00065% of total ^{137}Cs deposition on the watershed (5.13TBq, 28 December 2012 at present). Through the hydrological simulation by SWAT, total load of ^{137}Cs from 2013 to 2015 were estimated. For about the model performance, NSE and R^2 for calibration and validation were 0.75, 0.76 and 0.50, 0.54 respectively. Especially, in September 2015, large scale rainfall event(165mm day^{-1}) was occurred and this event contributed to huge amount of ^{137}Cs discharge in 2015. Annual total ^{137}Cs load excluding this rainfall event in September 2015 was 2.41×10^8 - 2.86×10^8Bq yr^{-1} km^{-2} which was equal to about 0.1% of total ^{137}Cs deposition. Otherwise, annual particulate and dissolved load including the large scale rainfall event in September 2015 were estimated at 2.41×10^8 - 6.8×10^{10}Bq yr^{-1} km^{-2} and 8.7×10^5 - 5.76×10^7Bq yr^{-1} km^{-2} respectively and these values were equal to 0.1 - 29% of total ^{137}Cs deposition in this watershed. However, it needs to be paid attention that the estimation of this huge scale rainfall might have large uncertainty because our observed period did not cover such large event. Lastly, effective ^{137}Cs half-life with consideration of ^{137}Cs load was calculated at 4.33 years according to our point estimation, and it appears that total amount of ^{137}Cs in the watershed is decreasing to 0.82% of initial ^{137}Cs amount within next 30 years. However, according to our uncertainty analysis, uncertainty range of ^{137}Cs load was crossing over 2 - 3 orders, thus, effective ^{137}Cs half-life is also probably highly uncertain. Thus, to obtain more accurate estimate, we need to improve the model performance during the extremely high flow events.

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Keywords: Fukushima Dai-ichi Nuclear Power Plant accident, Cesium137 load, SWAT

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Monitoring of radioactive Cs in stream discharge from small un-decontaminated forest in Fukushima

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Huge amount of radioactive materials were emitted by the accident of Fukushima dai-ichi nuclear power plant following to the Great East Japan Earthquake on March 2011. Five years have passed and decontamination has been proceeding at residential area and agricultural fields. Some evacuated areas are planning to accept return of former residences. However, especially in Fukushima, forest covers large area of the polluted region. A 70% of the area in Fukushima is covered by forest and most of them are still un-decontaminated. For returning village people, effects of polluted forest is important issue. From May 2016, we set monitoring and water sampling facility at the outlet of a small un-decontaminated forest. Water sampling was conducted when water level of the stream exceeded a threshold. Stream data and climate data at neighbor were transfer to the data storage by Field Reuter (X-ability, Inc.).

Water level-flow rate relationship and turbidity-suspension concentration relationship were determined, separately. Discharge of radioactive Cs was estimated by using those equations. Estimated discharge was 1470 MBq for 6 months since May till November, 2016. The number was 0.1 to 0.4% of the initial deposit (1 to 3 MBq m^{-2}) of radioactive Cs at the nuclear power plant accident on March 2011.

Suspended sediments filtered by 0.45 μm mesh membrane filters were subjected to imaging plate analysis. When suspended sediments seemed to be inorganic particles such as silt, sediments evenly contained radioactive Cs while when most of the sediments were consisted of organic matter, only several strongly radioactive Cs holding particles contributed most of radiation of the sediments. This suggested radioactive Cs in a sediment flowing a stream may variate temporarily depending on watershed conditions.

Keywords: radioactive cesium, forest, discharge

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Effects of Soil Organic Matter on Transport of Cesium in weathered granite soil

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To grasp migration of radiocesium (Cs) in soil is an important issue after the accident of Fukushima Dai-ichi nuclear power plant, Japan. The soil organic matter (SOM) is one of the components to affect Cs transport. There are two possible cases for SOM-induced Cs transport. First, SOMs in solution carry Cs to deeper soil layer. Second, SOMs sorbed on the soil solid surface inhibit Cs fixation, resulting in enhancement of Cs mobility. Cs concentrations in soil water are also one of important factors to affect Cs transport. In this study, we exprimented effects of organic matters, dissolved organic matter(DOM), humic acid (HA) and fluvic acid (FA), on the Cs transport in the soil by laboratory column experiment using different concentrations of Cs solution.
Soil sample was collected at an abandonment forest in Iitate, Fukushima, Japan. Dissolved organic matter was extracted from a litter from university forest in Chichibu, Saitama. Two Cs solutions are used, high(30mg/L) and low(1000Bq/L) concentration. High concentration solution was stable CsCl solution, and low one was extracted from organic soils in Iitate. The acrylic plastic column having a diameter of 3-cm and a length of 7-cm was used for the experiment. Two different treatments were applied for the repacked soil (control and organic adsorbed soil columns). The control soil column was prepared by repacking air dry soil sample up to 5cm of height. The organic adsorbed soil column was prepared by flowing dissolved organic matter for 24 hours to the control soil column. In the column experiment, Cs or Cs-DOM mixed solutions were applied under a constant ponding depth. Effluent Cs concentration was measured. After the transport experiments, the column was sliced in 1-cm interval and the soil at each section was used for the sequential extraction of Cs.
As a result of preliminary column transport experiment where high concentration Cs solution was applied to the 10cm long soil column, Cs accumulated within surface 4cm thick layer, while Cs mixed with DOM solution could move into 10-cm deep soil layer. Sequential extraction suggested most of Cs at deeper layer was complexed with organic matter.

Keywords: Fukushima, cesium, dissolved organic matter, humic acids, fulvic acids

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Effects of soil clay minerals on radiocesium transport in soil

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In 2011 the fallout of radiocesium, Cs-134 and Cs-137, originated from the Fukushima-Daiichi Nuclear Power Plant contaminated soils in the Pacific coast side of northern Japan. The most of the fallout-radiocesium on the soil surface was reported to be ramained in the surface layer in Fukushima Prefecture. There are two major soils with different clay minerals in Miyagi Prefecture, a northern next neighbor of Fulushima Prefecture: (1) volcanic ash origin soil with allophane found in the northern part of Miyagi Prefcture, and (2) granite origin soil with vermiculite found in the southern part of Miyagi Prefecture. Column experiments were conducted in a constant temperature room. The soils were uniformly packed in the columns and saturated with distilled water supplied from the bottom of the columns. A 160 mL of KCl solution with 1.5 kBq/kg exchangeable radiocesium was supplied with a rate of 10 mL/h from the top of the soil columns. Effluent from the bottom of each soil column was collected every two hours and analyed for the concentrations of Cs-134 and Cs-137, dD and dO-18, and KCl. After applying 800 mL distilled water with a rate of 10 mL/h from the top of the soil columns, the soil columns were disected with 1 cm thick and analyed for the concentrations of Cs-134 and Cs-137. No or less than the detection limit of Cs-134 and Cs-137 was found in the effluents of all the columns although the solution cotaining the radiocesium was completely drained out with 2 pore volumes of effluent. The distributions of Cs-134 and Cs-137 in the volcanic ash origin soil and the granite origin soil were very different. The radiocesium reached near the bottom of the column for the volcanic ash origin soil whereas the radiocesium stayed near the soil surface for the granite origin soil. This difference might be attributed to diffent clay minerals contained in the soils. Our results implied that the prediction of radiocesium transport in soil should be accounted for clay minerals.

Keywords: adsorption, advection, breakthrough curve

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Effects of inorganic amendments on radiocesium behavior in grassland soil

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The accident at the Fukushima Daiichi nuclear power plant occurred in 2011, resulting in contamination of agricultural fields by radioactive substances such as ^{137}Cs (RCs). Potassium (K) fertilization is typically considered as an effective countermeasure for reducing RCs uptake by plants. However, in case of a pasture, K fertilizer application results in increase in pasture K concentration, causing a metabolic disease for cattle known as grass tetany. Therefore, in the grassland polluted by RCs, alternative countermeasures for reducing RCs uptake are required. In this study, we investigated the effect of adsorbent applications on the RCs behavior in grassland soil.
Soil samples were taken from a grassland polluted by RCs at the surface layer (from 0 to 5cm) in Fukushima prefecture. Zeolite and weathered biotite were selected as adsorbents. The soil was adjusted to different water contents (0.86, 1.2) and the adsorbents were added at 0.5, 2.5, 5g per 50g dried soil. Incubation was conducted in constant temperature (20℃) room. Incubation duration was 7, 28 and 112 days. After that, 1M ammonium acetate with soil: solution ratio of 1:4 (dried soil: solution) was added and shaken for 6 hours. Suspension was filtered by 0.45 μm membrane filter. Cs concentration (exchangeable Cs, Ex-Cs) in the filtrates were measured by a Ge semiconductor detector.
With increasing adsorbents added to the samples, the concentration of Ex-Cs decreased where more decrease in Ex-Cs was observed for the sample at higher water content. Zeolite decreased concentration of Ex-Cs more than weathered biotite in same soil: solution ratio.
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Keywords: Fukushima, cesium, inorganic amendments

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Application of Soil Radioactivity Data to Environmental Contamination Recovery

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Response to an environmental disaster consists of three domains: Human perception of the event, the concerned environmental processes, and the data and analytical tools. Human perception of the event (cause, effect, future prediction) would affect the disaster recovery and mitigation planning. Building a proper plan requires an understanding of the physical landscape processes. To understand the landscape processes, filed data and data analysis tools are utilized. Together, these three domains combine to present a whole aspect of the disaster situation which needs to be tackled.

During the summer of 2016, soil samples were collected in a village in Fukushima, Japan for radioactivity level assessment. Following the nuclear plant accident in 2011, environmental decontamination efforts, including surface soil scraping, have been taken place in the areas affected by the radioactive fallout. In this study, based on the collected soil radiation data, the relationship among the three domains (human perception, landscape processes, and data) in case of Fukushima is analyzed.

The challenge, which soil data presents, is the inherent geological and landscape heterogeneity, movability, and its three-dimensionality. The land types of the sampling site include natural forests on hills, the foot of the forests where the ground surface was decontaminated, and a rice paddy in the lowlands whose surface soil was replaced. In an effort to identify the storage and the subsurface movement patterns of radioactivity, numerical statistical analysis and two- and three- dimensional visualization analysis are attempted.

The preliminary results indicate a few issues in the three-domain model. With regard to human perception, decision makers' perception about the land processes pose enormous effects on the later implementation of recovery measures. Physical process modeling indicates that the forests are acting as a natural storage for elevated radioactivity, although the natural storage would work differently compared with a man-made storage. As for data handling, horizontally and vertically distributed soil samples impose challenges in visualization. Still, visualization attempts show the certain radiation 'sink' areas in the landscape.

Addressing shortcomings in each domain and filling gaps in the interconnection among them would present an insight which is relevant to disaster response and recovery in general.

Keywords: radiation, radioactivity, soil, decontamination, geography, GIS

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Artificial Macropore Installation for Enhancing Vertical Transport and Fixation of Radioactive Cesium at Blueberry Farm.

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Artificial Macropore Installation for Enhancing Vertical Transport and Fixation of Radioactive Cesium at Blueberry Farm.

Keywords: artificial macropore, radioactive Cesium, infiltration

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Potential of Bioenergy Crop Production in Decontaminated Farmlands in Fukushima

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The devastating accident of Fukushima Dai-ichi Nuclear Power Plant occurred due to Great East Japan Earthquake on March 11th, 2011. The projects of remediation lands and removal of radiocesium-contaminated soil from farmlands are still ongoing. Essentially, it is an important aspect to utilize those decontaminated farmlands for local farmers and communities. In Japan, the researchers have now been seeking how to start agricultural production from decontaminated farmlands, restructuring local communities, and economic activity in Fukushima. Globally, the research regarding the renewable energy resources, for example, *Miscanthus ×giganteus*, have increased significantly. *Miscanthus × giganteus* has the high potential for a biomass energy crop, because of high biomass yield with low annual energy requirements and financial inputs, including tillage and planting practices and fertilizer, herbicide, and pesticide application. In addition, *Miscanthus ×giganteus* can growth under severe soil condition such as dilapidated land or reclaimed mine land. Under *Miscanthus ×giganteus* cultivation, their nitrogen recycles system is sufficient, because the nitrogen is recycled as it moves from the rhizosphere into the developing shoots during spring and summer, and is transferred to the rhizosphere in fall and winter. If shoots are harvested, the nutrients remain in the rhizosphere. It can be utilized for *Miscanthus × giganteus* shoot growth in the coming season. The previous research showed that the average biomass yield of *Miscanthus ×giganteus* over 6 years was 25.6 Mg ha^{-1} $year^{-1}$ in Northern Japan. In addition, our previous research revealed that carbon sequestration rates of *Miscanthus ×giganteus* were 1.96 Mg-C ha^{-1} $year^{-1}$ over the 6 years of this research trial. *Miscanthus ×giganteus* generally increase SOC stocks due to the greater carbon inputs of above- and belowground biomass and no tillage. Therefore, the objective of this research was to estimate the potential of bioenergy production thought *Miscanthus ×giganteus* cultivation in decontaminated farmlands in Fukushima, Japan. The key findings are outlined below: (1) *Miscanthus ×giganteus* can be the new insight for agricultural production from decontaminated farmlands, (2) due to the high carbon sequestration under *Miscanthus ×giganteus* cultivation, the fertility of decontaminated farmlands can be improved, (3) more field experiments need to be done in order to develop the bioenergy crop production.

Keywords: Decontaminated farmlands, Miscanthus ×giganteus, Bioenergy

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Supporting Greenhouse Cultivation Using Fertigation Control System ZeRo.agri

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In response to the request of a farmer in Iitate Village of Fukushima Prefecture in 2015, an old pipe greenhouse was refurbished and the ICT nutrient soil cultivation system "zero agri" was introduced as a prototype of the future agriculture in the village. Nutrient soil cultivation is a cultivation method in which liquid fertilizer is mixed with irrigation water and applied to plant stocks using drip irrigation tubes. Drip irrigation was first developed in Israel in the 1960s to save irrigation water. Meiji University and Routurek Networks Co., Ltd. developed the "Zero Agri" system to automate fertigation procedures in 2013 and market the system. The system consists of two components: (1) a control section and (2) a driving section. using sensors that simultaneously measure solar irradiance outside a greenhouse using a pyronometer, and soil temperature, soil moisture, soil EC (electric conductivity: strongly relates to nitrate concentration, which is a major fertilizer source) using a Hydro probe Ⅱ. Data measured by the sensors are recorded with a data logger of the control section and transmitted to the cloud over the Internet, where the amount and concentration of liquid fertilizer to be applied and the supply time are calculated based on the data acquired via the Internet. The driving section consequently controls control signal parts to open and close solenoid valves to manage liquid fertilizer application. The liquid fertilizer is supplied to the field with an infusion irrigation tube. A thermometer/hygrometer, a web camera, etc. can also be installed along with the sensors.

As daily water and fertilizer requirements of crops are proportional to the amount of solar radiation, liquid fertilizer is applied in proportion to the amount of solar radiation per time. Moreover, by separately controlling the supply amount and the concentration of the liquid fertilizer, soil moisture and soil EC become constant values. It is possible to increase the demand of water and fertilizer according to growth stages of crops, thus to cope with a decline in the water demand of crops due to increases in water infiltrated into the rhizosphere from the lower soil layers in the greenhouse. It is possible for growers to change soil moisture and soil EC by observing growing conditions of the crops. In other words, this system is semiautomatic in cooperation with growers. Since a tablet terminal is used to change control procedures, all the data are stored in the cloud, and the "experiences and feelings" of the growers are digitized. These data can be used for cultivation in the following years, or it can be provided to growers with insufficient experiences. If the system is introduced in a certain area, comparison among good and poor growers can be used to improve all the growers' skills in the whole area.

In Iitate Village, before the earthquake, agriculture, mainly rice and dairy farming, was a major industry. Although villagers will return to the village from April 2017, there is no prospect of improvement in paddy rice price once collapsed by the nuclear accident. Also, since pastures are always exposed to the risk of radioactive pollution, there is no prospect of resuming dairy farming. Furthermore, due to the restriction of the topography, there is little possibility of agriculture utilizing large-scale upland fields. In such background there is a high possibility of protected horticulture that uses greenhouses. Based on our study in Iitate Village from 2015 to 2016, we concluded that a rotation of "spring summer pepper →autumn lettuce →autumn lettuce →two winter spring transplanted spinach" was fully applicable. "Zero Agri" adequately supported a commuter farmer, who is not reside in the village, to grow crops.

Keywords: Fertigation, Greenhouse Cultivation, Control System

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