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

福島県農畜水産物の放射性セシウムに関するモニタリング調査について
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.

キーワード：放射性セシウム、モニタリング調査、全量全袋検査
Keywords: Radiocesium, Monitoring Inspection, Checking all bags of rice for radiation

福島第一原発事故避難地域の営農再開の現状と将来　飯舘村を事例に
Current status of reconstruction and challenges post the Fukushima disaster: Case study of Iitate Village

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福島第一原子力発電所事故で避難を余儀なくされた農家には，避難先で営農再開をしている方々がいる。一方，様々な理由で不本意ながら農業から切り離されてしまった避難者も多い。さらに，避難指示を解除される地域が増加すると共に，村への帰還，避難先での定着等さまざまな選択がなされ，新たな課題も出現している。そこで，本発表では，多くの地域で避難指示が解除され村の再建が始まっているなか，営農再開という視点から，被災農村の位置づけを中山間地域農村一般との対比の中で検討し，将来への課題を明らかにすることを目的とする。本発表では，福島第一原子力発電所事故で全村避難を強いられている福島県相馬郡飯舘村を事例に，避難先で営農再開している農業者や仮設住宅への避難者に対して発表者らが実施した聞き取り調査，アンケート調査から営農再開農家や仮設住宅避難者の動向と意向を把握した。

これまで，避難先で営農を再開してきたのは，大規模に営農してきた農家がほとんどである。彼らが避難先のどこで営農再開したか，その過程には経営内容により相違がある。花卉栽培は避難先の周辺で花卉栽培のハウスを建設できる農地を探した例が多い。それに対して，肉牛飼育は廃業して空いている畜舎に入居している例が多く，そのような畜舎がどこにあるかで再開先が決まる傾向にある。このような営農再開者を受け入れた地域の側にとっては，これまで地域内に不足していた経営能力の高い農業者が遊休化していた農地や畜舎の利用を進めてくれることになり，参入は歓迎されている。遊休農地・施設の利用だけではなく，地域にとってこれまでにない作目が導入されることになるなど，地域によい刺激を与えている営農再開者も多い。

一方，仮設住宅への避難者は，ごく一部の例外を除いて営農再開していない。仮設住宅への避難者は高齢者が中心であり，地域農業の担い手の位置にある方は少なかった。そのため，営農再開するために必要な農地や作業・保管スペースの確保，農機具の購入をするだけの経営力がないからである。

避難指示解除後に向けての対応については，帰宅困難区域の出身者を除くと，多くの営農再開農家が帰還を検討し，実際に準備を進めている例も多い。しかし，帰村当初から避難前の経営規模を回復する例はなく，また避難先から生活拠点や営農の全てを一度に移転する事例も少ない。しばらくは飯舘村と避難先の二重生活・両方での営農を継続することを選択している営農再開農家が多い。

飯舘村も多くの中山間地域農村と同様，避難前から人口動態は減少傾向にあった。しかし，全村避難とそこからの帰還は，人口減少を数十年先取りしただけではない変化を地域にもたらしている。例えば，屋敷周りにある自給目的の菜園は通常の農村であれば，高齢者が最後まで耕作を続ける対象となる空間であるが，飯舘村ではむしろ，帰村が困難な高齢者の存在，除染結果に対する不安なども含め，自力で営農再開を図ることが産業的な利用以上に困難であることが予想される。産業政策としての農業支援だけではなく，これまで政策が対象としてこなかった部分での対応が必要になることも考慮しなければならない。

地域農業やコミュニティに関する課題は，むしろ避難解除後の方が困難なものが多い。対策についても，次の世代への継承を視野に入れた長期的なものをも考えるべきである。そこに関わる研究者にとっても，住民の意に寄り添いながら長期にわたって関係を続けることが必要であろう。

キーワード：福島第一原発被災地の将来、営農再開
Keywords: Post the Fukushima disaster, Restarting farming

福島県飯舘村の2河川における放射性セシウム流出の形態と経年変化
Radiocesium runoff forms and its temporal variation at two rivers in Iitate, Fukushima

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2011年3月の東日本大震災の影響で発生した福島第一原子力発電所の事故により，大量の放射性物質が飛散し土壌などに吸着した．中でも放射性セシウム137（^{137}Cs）は半減期が約30年と長く，土壌中の粘土鉱物や有機物に吸着しやすい性質を持っている．土壌に吸着したCsは河川に流出，湖沼や海洋に輸送されると考えられる．事故周辺地域では健康被害や農林水産物に長期にわたる影響が出ることが懸念されるため，流域におけるCsの動態をモニタリングすることは必須である．既往の研究では，河川水の懸濁物質（SS）濃度とCs濃度の関係性が確認されているが，懸濁態，溶存態等の輸送形態や経年的な流出量の変化に着目した研究は少ない．そこで本研究では，Csの土壌沈着量が異なる福島県飯舘村の2河川を対象とした現地観測を実施し，流域からのCsの輸送形態や流出量の経年変化について考察することを目的とした．

福島県飯舘村の北部に位置する真野川，南部に位置する比曽川を対象流域とした（Figure 1）．帰還困難区域を含んでいる比曽川流域では，土壌へのCs沈着量が真野川流域より大きい．両地点に各種計測機器を設置し，雨量，水位，流速，濁度の連続測定と採水を行った（Figure 2）．観測期間は2013年6月～2016年12月である．降雨時に採水した約1Lの試料は目開き0.42mmのふるいを通過する試料としない試料に分け，それぞれ孔径1μmのガラス繊維濾紙で吸引濾過し，SS濃度およびCs濃度（降雨時懸濁態）を測定した．なお，一部の試料は2mm，0.42mm，0.072mmのふるいを用い，粒度別に分けて測定した．また，無降雨時に約20Lの採水を行い，ガラス繊維濾紙で吸引濾過し，SS濃度およびCs濃度（無降雨時懸濁態）を測定した．さらに，降雨時と無降雨時の採水試料の濾液を蒸発乾固させ，Cs濃度（降雨時溶存態，無降雨時溶存態）を測定した．

降雨時の懸濁態試料における^{137}Cs線量の粒径別割合をFigure 3に示した．粘土やシルトなど粒径の小さいものほど^{137}Cs線量が高く，粘土，シルト，細砂成分で約70%以上を占めた．
比曽川および真野川における粒径0.42mm以下のSS濃度の関係をFigure 4に示した．土壌へのCs沈着量が大きい比曽川の方が近似直線の傾きが大きかった．また，近似直線の傾きを比較すると，2013年～2016年の間で明確に減少している．このことから，SSに吸着している^{137}Csは年々減少しており，減少率は3年間で79%以上と物理的半減期に基づいた3年間の減少率6.7%と比較し，非常に大きかった．これは雨水に流されやすい細粒成分や有機物に吸着した^{137}Csから選択的に流出したことによると考えられる．

^{137}Cs流出量を算出した結果をTable 1に示した．降雨時懸濁態での流出割合は，どの年も両河川で95%以上と最大であった．一方，無降雨時の^{137}Cs流出量は微少となった．また，降雨時，無降雨時それぞれで懸濁態の割合より溶存態の割合が小さかった．各流域における4年間の総^{137}Cs流出量は比曽川で6.9 kBq/m^2，真野川で2.1 kBq/m^{2}であり，土壌沈着量の平均値（比曽川：1017 kBq/m^2，真野川：421 kBq/m^2）と比較すると非常に微少であった．

以上のことから，放射性セシウムの流出は，降雨時懸濁態の流出成分が大部分を占めており，細粒成分や有機物に吸着して流出する割合が高いことが分かった．土壌の沈着量に対してCs流出量は微少であり流域内にほとんどが残存している状況下で，Cs流出量は自然崩壊による減少よりも著しく減少した．これは雨水に流されやすい細粒成分や有機物に吸着したCsから選択的に流出したことによると推察される．

キーワード：放射性セシウム、土砂、土壌侵食、福島
Keywords: Radiocesium, Sediment, Soil erosion, Fukushima

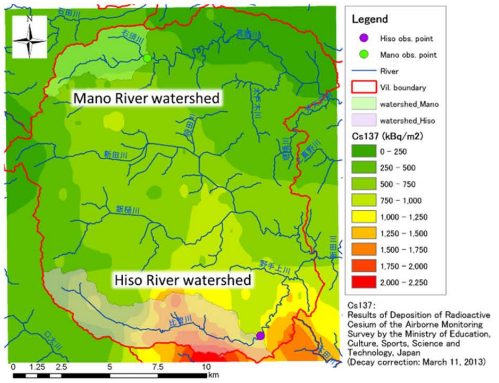

Figure 1. Study sites and ^{137}Cs levels in Iitate Village.

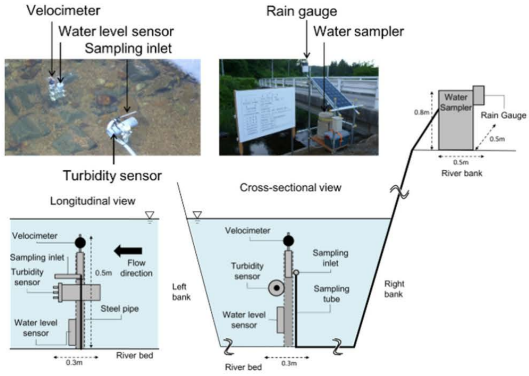

Figure 2. Instruments for field monitoring.

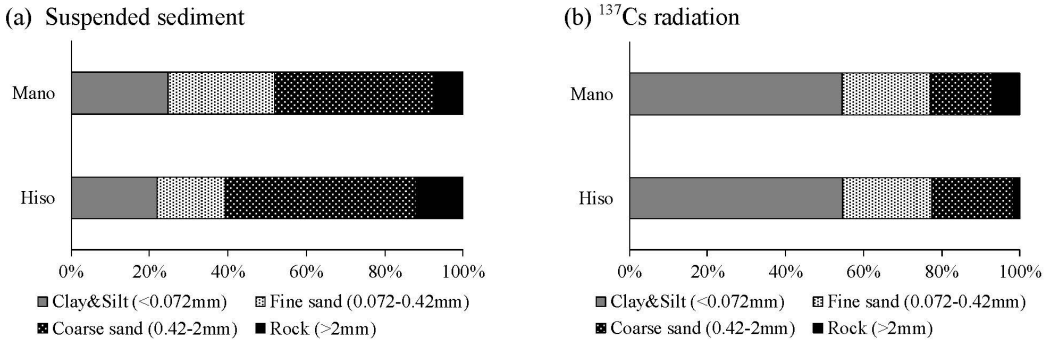

Figure 3. Ratios of each particle size in suspended sediment (a) or ^{137}Cs radiation (b) at Hiso in 2013.

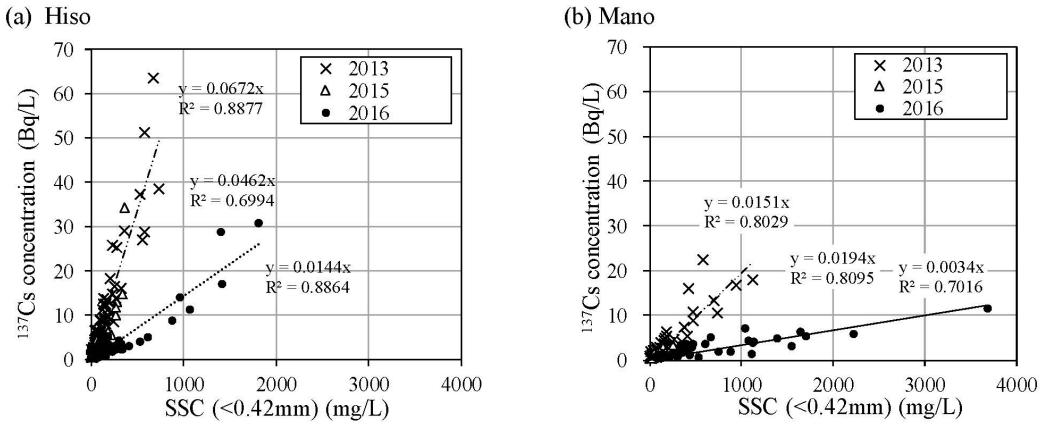

Figure 4. Relationships of SSC with ^{137}Cs concentration in the storm water at Hiso (a) and Mano (b)

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

Site	Year	Precipitation (mm)	Water runoff (mm)	Sediment yield (g/m^2)	^{137}Cs runoff (Bq/m^2)				
					Storm		Normal		Total
					Particulate	Dissolved	Particulate	Dissolved	
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

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

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