Environmental Monitoring of Village Contaminated by Radionuclides

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ABSTRACT

On March 11, 2011, a massive earthquake struck the eastern region of Japan, causing widespread devastation. Since then, agricultural engineers throughout Japan have combined their experience and have been working on a variety of restoration projects. One such project involves the restoration of farmland contaminated by radionuclides; however, this is a new type of challenge with many unknowns. For example, do countermeasures for soil contamination exist? How should we evaluate the efficiency of the farmland decontamination efforts? We propose that it is necessary to monitor radiation continuously at points referred to as hotspots in rural areas. However, although people need an economical radiation sensor that gives a relative value, such meters are typically expensive. These high costs prompted a volunteer group to develop a pocket radiation sensor. We have also been developing a field monitoring system (FMS) for quasi-real time data collection from remote agricultural fields in Asia. In October 2011, we added this new radiation sensor to our in situ soil monitoring in Iitate, Fukushima. Here we explain the outline of an FMS with a radiation sensor. We believe that an FMS fitted with a radiation sensor is a useful tool for remediation of the radionuclide contaminated farmland.

Keywords: field monitoring system (FMS), radiation sensor, earthquake disaster reconstruction, remediation of village

1 INTRODUCTION

The massive earthquake that struck Japan on March 11, 2011 caused a serious accident at the Fukushima Daiichi nuclear power plant. As a result of the accident, farmland in several municipalities of Fukushima Prefecture was contaminated by radionuclides. Eastern Japan is now in need of extensive reconstruction and the issue of land contamination has become a serious problem. Japanese agricultural engineers are therefore currently focusing on various ways to decontaminate the farmland in these areas [1].

It is very important to determine the effectiveness of these decontamination efforts, particularly in areas referred to as hotspots. In addition to these continuous measurements, it is also important to clarify, as best as possible, the relationship between radiation levels and weather conditions, such as precipitation and wind which are known to transport radioactive materials. Further, the relationship between precipitation and the turbidity of agricultural runoff also needs to be clarified because the runoff after heavy rain contains a lot of clay particles which attract radionuclides. However, radiation meters are expensive and it is difficult for members of the general public to acquire the necessary equipment. People therefore need a cost effective radiation meter that gives a relative value, even if it is somewhat rough in accuracy. Fortunately, in order to address this need, a non-profit volunteer group recently developed a pocket radiation sensor. (see "radiation-watch.org", [2]).

We have developed a field monitoring system (FMS) for quasi-real time data collection from a remote agricultural field in Asia [3]. When we were thinking about how we, as researchers, could play an active role in the recovery from the disaster, we decided to add this new radiation sensor to the FMS. As a result, we have now been observing radiation on some of the farms in the village of Iitate in Fukushima Prefecture since October 2011.

In this paper, we provide an outline of the FMS with this radiation sensor, and discuss the potential application of the FMS.

2 FIELD MONITORING SYSTEM (FMS) WITH A RADIATION SENSOR

2.1 Component of FMS with a radiation sensor

The FMS with radiation sensor consists of three main components: A field router (FR), data logger, and soil/meteorological sensors including a radiation sensor. The function of the FR is to collect data from the data logger and then send to the data server over the internet, and the data logger stores the data measured by sensors. Figure 1 is a schematic diagram of the FMS with the radiation sensor.

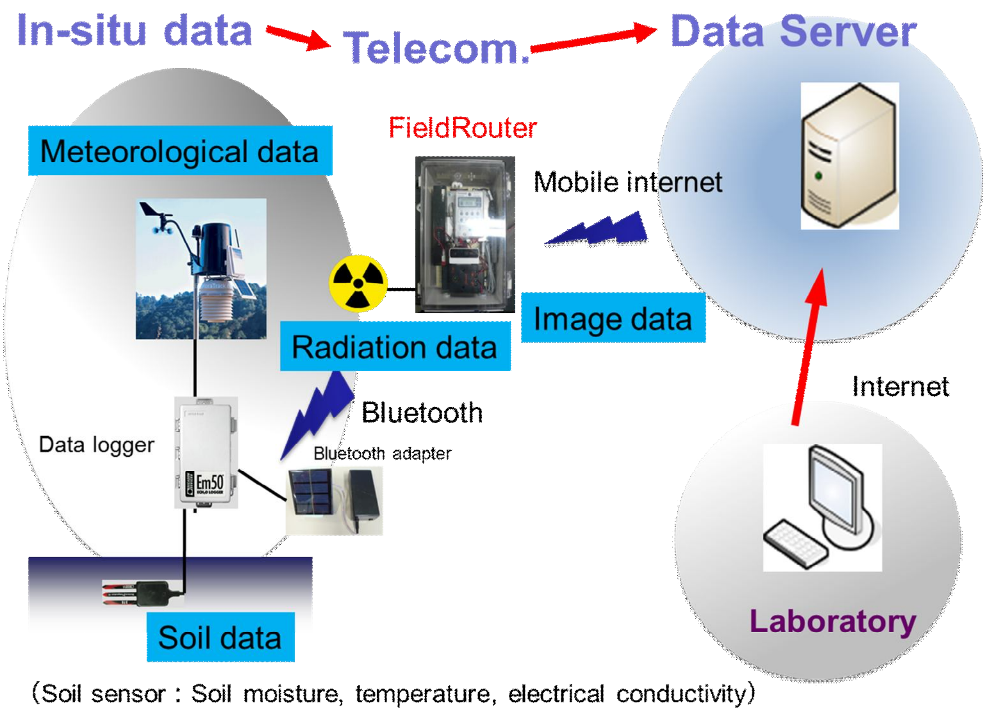

Figure 1: Schematic diagram of the Field Monitoring System (FMS)

2.2 FieldRouter (FR)

Figure 2 shows the FR. The FR mainly consists of a micro-PC, 3G/GSM USB modem, Web camera, battery, and timer in a water proof and dust-tight box. The advantages of the FR include its small power source (6 W solar panel), easy setup, cost-effectiveness (uses a cellular mobile line), ability to check the battery level remotely from the laboratory, and no data loss because the data are stored by a data logger as well as a data server. Although problems related to internet connectivity and/or electrical power occasionally arise, the data are saved and stored in the data logger.

Figure 3 is a flowchart showing the process by which the FR sends data from the field. The FR is operation at a specific, predetermined time (e.g. 12:00-12:30 JST). During this time, the FR boots up automatically and prepares to connect to the internet through the USB modem. The FR then takes a picture of the filed using the in situ Web camera and measures the radiation. The FR then collects soil and meteorological data from the data logger through a cable or via a bluetooth connection. Finally, the FR sends the collected data to the server over the 3G/GSM that is plugged into the USB modem in the micro-PC.

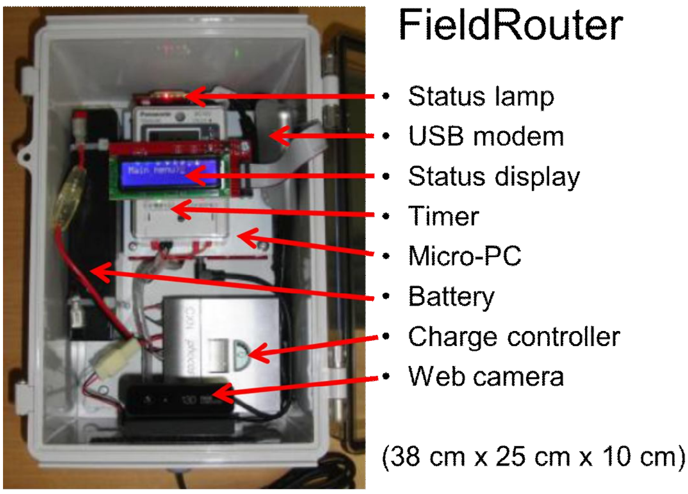

Figure 2: Component of the FR

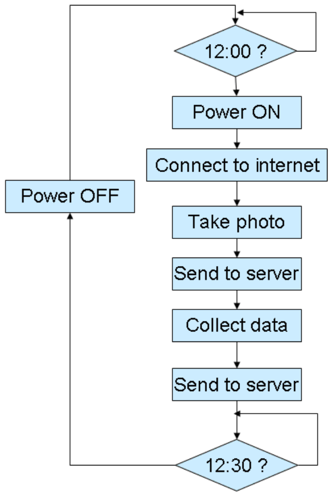

Figure 3: FR flowchart

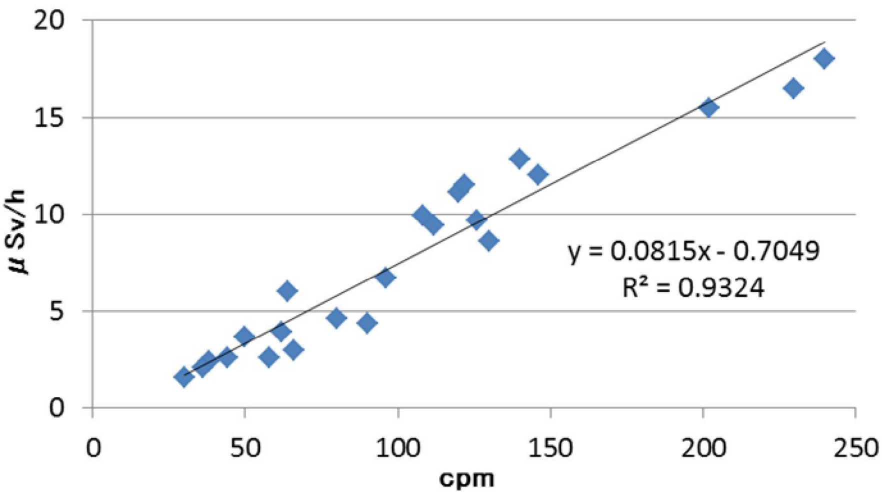

Figure 4: Calibration of a pocket Geiger sensor in Iitate village

2.3 Sensors

We used a soil sensor [4], meteorological sensors [4], and a radiation sensor [2]. For soil measurements, a Decagon soil sensor (5-TE, Decagon Devices, Inc.) measures soil moisture content, soil temperature, and soil electrical conductivity at the depth of 5 cm. For atmosphere measurements, Decagon meteorological sensors (Decagon Devices, Inc.) measure air temperature and humidity (EHT RH/Temp), precipitation (ECRN-100), solar radiation (PYR), and wind speed and direction (Davis Cup Anemometer). All of these data are collected and stored on an Em50 data logger (Decagon Devices, Inc.) at one hour intervals.

Radiation is measured using a pocket Geiger sensor [2] which uses a PIN photodiode device because it is considerably cheaper than other devices. This sensor is typically used with an iPhone, but we adapted the sensor to connect to the FMS. Figure 4 shows calibration results obtained using the radiation sensor on soil samples at hotspots in Iitate village on July 9, 2011. The results suggest that this sensor was sufficiently accurate for measuring radiation level in the field.

2.4 Installation of FMS in Iitate village

Figure 5 shows an FMS installed in Iitate village. The first FMS was installed in the garden of a house in Iitate village on October 2, 2011. The FMS measures the radiation at a height of 1.2 m above the ground at noon and sends the data to a data server in a laboratory together with image data and hourly data for meteorological parameters. Since July 2012, we have installed a total of six FMS in the village.

Figure 5: Field Monitoring System (FMS) at a garden (left), in a forest (center) and deforest area (right) in Iitate village.

3 RESULTS AND DISCUSSION

3.1 Open access FMS website

Users can access the environmental monitoring data being collected in Iitate village via the open access website “Earthquake Disaster Reconstruction Project (EDRP) by using FMS” at http://www.iai.ga.a.u-tokyo.ac.jp/mizo/edrp/index.html. A data portal page is shown in Figure 6. The page provides an overview of the FMS that are currently operational. We refer to this monitoring as “Quasi-real time monitoring” because the environmental and image data are sent at daily intervals. The letters “I” and “S” represent the transmission status of image and data logger data, respectively. The status for today and previous day are shown to the right and left sides of the picture, respectively. If both letters appear on a given day, then it means that the FR has succeeded in sending all of the data on that day. While there are some days when data is missing due to interruptions caused by inclement weather or a weak internet connection, almost all of the data will eventually be transmitted to the server over several days as they are stored on the data logger.

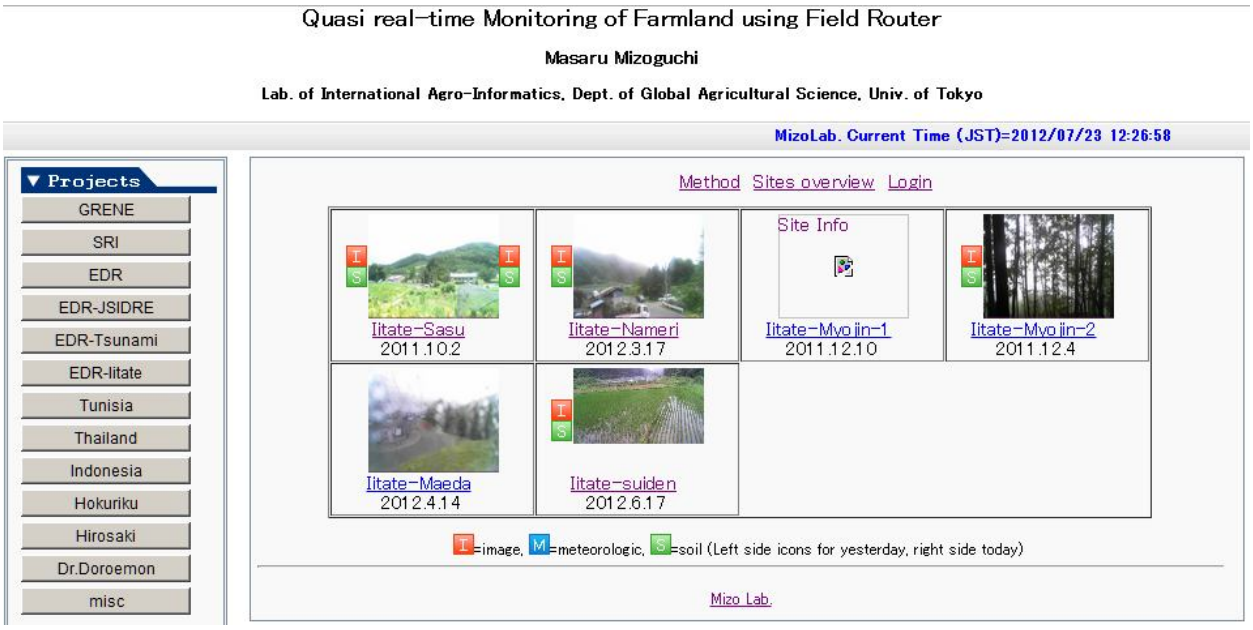

Figure 6: A data portal page for the environmental monitoring data in Iitate village

3.2 Accessing data from the website

As shown in Figure 7, users can obtain data for specific sites by clicking on a picture on the portal page. Once users download the QR-code on this page to their smartphones, they can easily access the information for that specific site from anywhere. Image data can be saved manually by right clicking of the computer mouse and then selecting "Save Image As" from the menu. Moreover, there is also the option to select between "image calendar/movie" to see the overview of images captured to date. The "image calendar/movie" link can be found above the image of the daily image.

All of the data can be downloaded from the website as numerical or graphical data. Soil and meteorological data can be accessed by clicking the "AA" or "RAW" icon located to the right of the text "EM+number" (Figure 7). Similarly, radiation data can also be accessed by selecting the icons to the right of "FriskCounter". "Phocos" contains daily information on the FR, including the solar battery power. The data is saved as a .csv file can be examined further using Microsoft Excel.

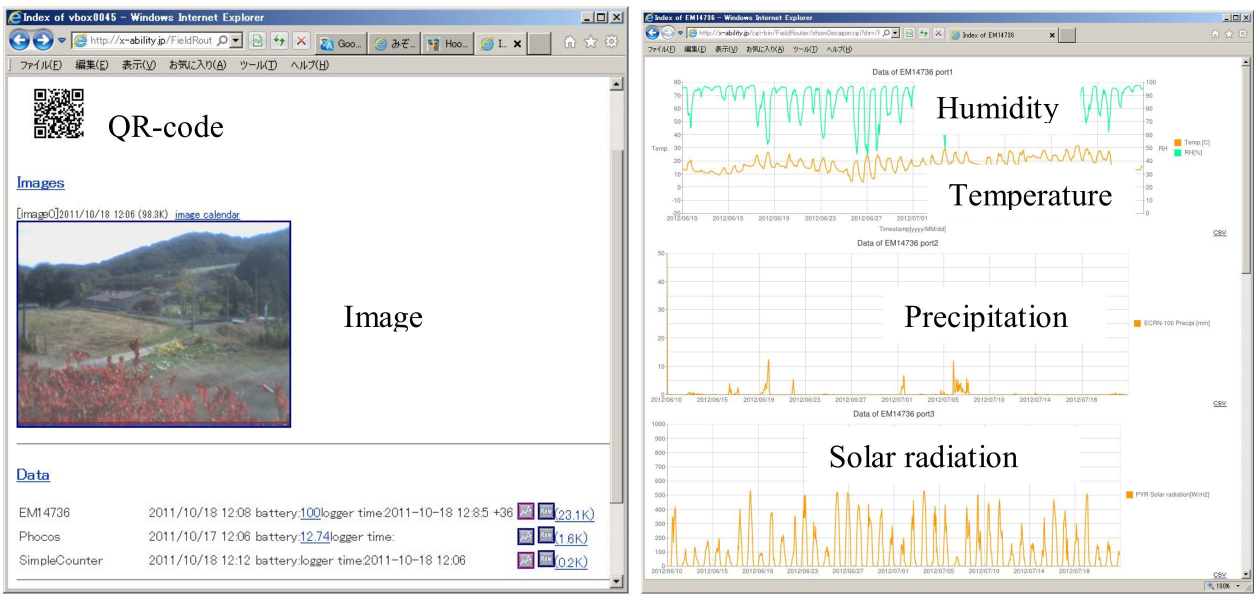

Figure 7: The portal page of the FMS (left) and meteorological data (right) at a garden in the Iitate village

3.3 Relationship between radiation measurements and meteorological data

Figure 8 shows a comparison of radiation measurements and images captured in a garden, a forest, and a deforested area from autumn to winter. Although radiation levels fluctuated daily, especially at the house, they decreased after January 20 when snow started to cover the ground. This result means that snow prevents radiation from being emitted from the ground and such an observation could only be obtained by using the FMS with a radiation sensor that captures image and radiation data every day. In addition, we also now have a lot of valuable radiation data that has been collected by the FMS with the radiation sensor. Preliminary findings of comparisons of radiation and meteorological data have revealed that radiation levels tend to be higher on fine days with low humidity.

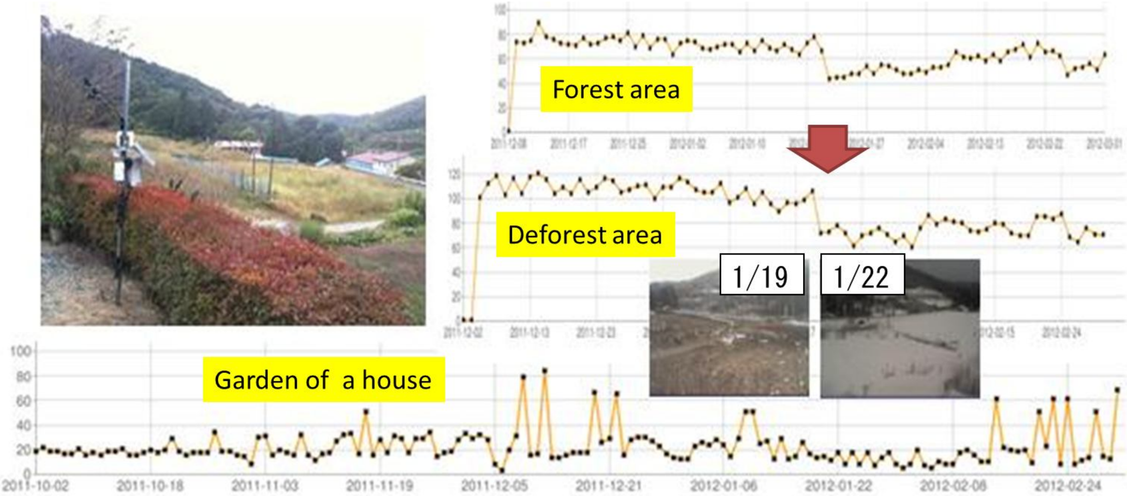

Figure 8: Comparison of radiation at three FMS sites: a garden, a forest, and a deforested area

4 CONCLUSION

The FMS fitted with a radiation sensor is useful tool for environmental monitoring of areas of farmland that Japanese engineers are currently struggling to decontaminate. We believe that the FMS may facilitate the restoration of disaster-hit areas such as Iitate village in Fukushima, Japan.

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