ESTIMATION OF SOIL FREEZING DATE IN IITATE VILLAGE, FUKUSHIMA USING REMOTELY MEASURED AIR TEMPERATURE

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Abstract Soil freezes in the winter of Iitate Village in Fukushima Prefecture. When soil freezes with an appropriate depth, it seems to be a perfect timing for removing the soil surface layer that contains most of radiocesium fallout. We monitored air- and soil-temperatures at 20 different places all over Iitate Village so that we may estimate soil freezing date to start radiocesium-contaminated-soil removal operation. Cumulative air temperature below zero was calculated for a reference site. At the reference site, soil freezing was detected using a soil moisture sensor installed at 5cm deep because the dielectric constant of ice was similar to that of soil particle.

Introduction Most of radiocesium released from Fukushima Daiichi nuclear power plant has been accumulated in the topsoil within 5 cm. In Iitate village, the soil freezes during the winter. The frozen soil is as hard as asphalt and farmers could easily strip the frozen soil using a backhoe (Fig.1). In field experiments of January 2012, we confirmed that the level of radiation in the ground surface reduced from 1.28 to 0.16 μSv/h on stripping the frozen paddy soil. This drastic reduction in the radioactivity level indicated that the radiocesium in the topsoil could be removed by stripping the frozen soil. This simple method exploits a natural process. The difficulty with this method was predicting the timing of stripping frozen soil for districts which are different in climatic condition. Therefore, it was necessary to predict the optimum thickness of frozen soil before stripping.

Fig.1 Field experiments of January 2012 at Sasu district

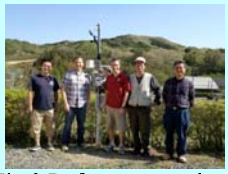

Fig.3 Reference weather station at Sasu district

Fig.2 Location of measuring sites of air temperature

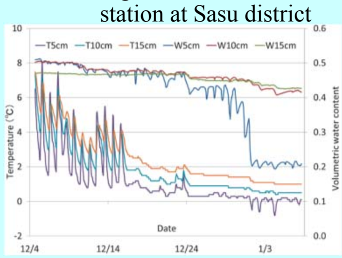

Fig.4 Changes in the soil temperature and soil moisture.

Theory Freezing depth can be predicted by a modified Stefan's formula (Mizoguchi, 2013).

$$z = \sqrt{\frac{2\lambda}{\rho_i \theta L}\int T\,dt}$$

$$z = \alpha\sqrt{F}$$

sub-zero air temperature: T (°C)

freezing index: $F = \int T\,dt$

empirical constant: $\alpha = \sqrt{\frac{2\lambda}{\rho_i \theta L}}$

Method We monitored air- and soil-temperatures at 20 different places all over Iitate Village (Fig.2) so that we may estimate soil freezing date. Cumulative air temperature below zero was calculated for a reference site in Sasu district (Fig.3). At the reference site, soil freezing was detected using a soil moisture and temperature sensor installed at 5cm (Fig.4).

Results Parameters are determined by using measured soil temperature and soil moisture of reference site in Fig.4.

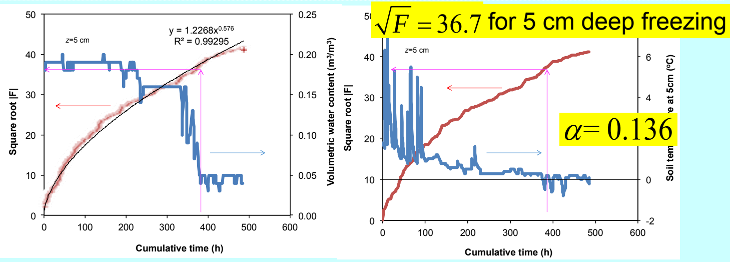

Fig.5 Square root |F| is determined from the first freezing time at 5 cm.|

Discussion A ratio of Square root |F| at each place to reference site (Fig.6) gives contour map of characteristic of reginal soil freezing from which we can estimate the optimum soil freezing date (Fig.7).

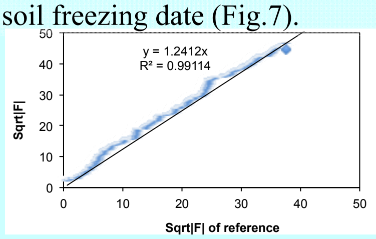

Fig.6 Calculation of regional characteristic

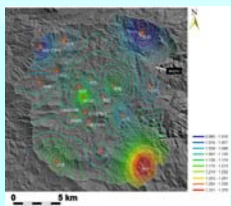

Fig.7 Contour map of characteristic of reginal soil freezing

Conclusions (1) A simple modified Stephan equation proposed by Mizoguchi (2013) may predict freezing date at remote location with a reasonable accuracy. (2) A numerical simulation model would be a useful tool for fine tuning the method. (3) Further work is a definite need.

Acknowledgments

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