8–10 Effects of Forests on ^{137}Cs Behavior in River Catchment

—Development of a Watershed Model Combined with ^{137}Cs Migration in a Forest—

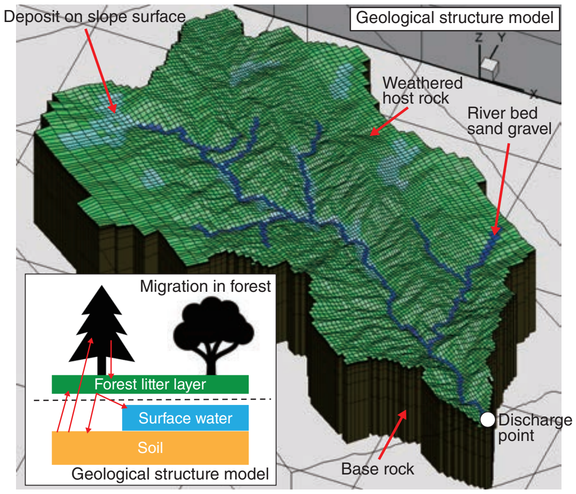

Fig.1 Three-dimensional structural model of the area and ^{137}Cs migration in a forest
GETFLOWS creates a three-dimensional model of the subsurface based on geological structures and a two-dimensional model of the surface based on elevation to simultaneously simulate surface water and groundwater. Based on the obtained hydrological cycle, GETFLOWS simulates the sediment and ^{137}Cs transport in the surface layer, as well as ^{137}Cs migration in the forest to predict ^{137}Cs dynamics in the environment.

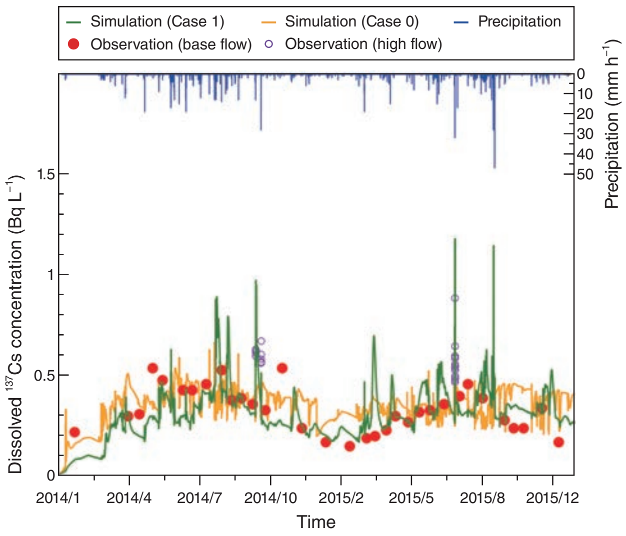

Fig.2 Simulation results of the dissolved and particulate ^{137}Cs in river water
Case 0 was simulated assuming adsorption–distribution equilibrium for dissolved and particulate ^{137}Cs, and Case 1 was modeled by considering trees and forest litter layers and linking the transfer within the forest to the watershed. Specifically, we modeled the availability of dissolved ^{137}Cs, originating from organic matter decomposition and from the forest litter layer, to enter the river water due to an increase in the water level.

Since approximately 70% of the ^{137}Cs from the accident at TEPCO's Fukushima Daiichi Nuclear Power Station is present in forested areas that are not decontaminated, it is important to understand how ^{137}Cs moves from forests to rivers to predict the ^{137}Cs concentrations trends in agricultural crops and freshwater ecosystems. In particular, it is necessary to understand the behavior of not only particulate ^{137}Cs but also dissolved ^{137}Cs in river water, which is highly bioavailable. In a previous study, we simulated water, sediment, and ^{137}Cs transport using a watershed model GETFLOWS for the upstream region of Ohta River (Fig.1); 99% of this region comprises forested area. By comparing the measured and simulated results, we inferred that the dissolved ^{137}Cs discharges in the forest are influenced by organic matter; in other words, the dissolved ^{137}Cs is leached from the forest litter layer and discharged into the river. In this study, we incorporated the phenomena of ^{137}Cs transfer in forests and dissolved ^{137}Cs leaching from organic matter into the GETFLOWS model and compared the simulations with measurements to better understand the phenomena of discharge of dissolved ^{137}Cs into rivers.

First, we confirmed the reproducibility of the model with respect to flow rate, sediment discharge, and dissolved ^{137}Cs at the discharge point shown in Fig.1. We then modeled the transfer of ^{137}Cs within the forest and among three-dimensional structural models shown by the red arrows in Fig.1 (inset). We simulated the concentration of dissolved ^{137}Cs in river water at the runoff point shown in Fig.2 for the period January 2014–December 2015, depending on precipitation. Case 0 represents the results of a previous study*, and Case 1 represents the results of this study. The results of simulation Case 0 (—), which assumes adsorption–distribution equilibrium (i.e., the dissolved and particulate ^{137}Cs instantly adsorb and desorb in a certain ratio), are consistent with the measured dissolved ^{137}Cs concentrations during base flow (0.14–0.53 Bq/L, mean: 0.32 Bq/L). However, the results did not fully reproduce the increase in dissolved ^{137}Cs concentration during high flow (○) and the seasonal fluctuations (●), such as high levels in summer and low levels in winter. When the model was simulated by incorporating the transfer of ^{137}Cs in forests and its dissolution from organic matter (—), these two trends of change was reproduced, albeit with some discrepancies between the measured and simulated values (correlation coefficients with measured values for cases 0 and 1 were −0.33 and 0.62). In other words, the dissolved ^{137}Cs is considered to have leached from the forest litter layer and discharged into the river.

We will continue to clarify the mechanism of dissolved ^{137}Cs leaching from the forest litter layer into rivers through river surveys and laboratory experiments to predict the decreasing trend of ^{137}Cs concentration in the future and to evaluate countermeasures.

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* Sakuma, K. et al., Applicability of K_d for Modelling Dissolved ^{137}Cs Concentrations in Fukushima River Water: Case Study of the Upstream Ota River, Journal of Environmental Radioactivity, vols.184–185, 2018, p.53–62.

Reference
Sakuma, K. et al., Watershed-Geochemical Model to Simulate Dissolved and Particulate ^{137}Cs Discharge from a Forested Catchment, Water Resources Research, vol.58, issue 8, 2022, e2021WR031181, 16p.