Application of GeoWEPP Model to Assess Water and Sediment Discharge in Multi-scale Forested Mountain Watersheds: Agatsuma River Basin, Japan

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ABSTRACT OF DISSERTATION

Dissertation Title	Application of GeoWEPP Model to Assess Water and Sediment Discharge in Multi-scale Forested Mountain Watersheds: Agatsuma River Basin, Japan （異なる流域面積を有する山地森林流域における水・土砂流出評価への GeoWEPP モデルの適用: 吾妻川流域の事例）
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Abstract of Dissertation

Soil erosion is the process of detachment and transportation of soil and minerals, and soil erosion modeling has been utilized to predict soil erosion. Several studies utilized Universal Soil Loss Equation (USLE), a widely used empirical model, to predict the sediment yield in steeply forested watersheds in Japan. However, the USLE cannot assess the sediment yield in mountainous regions, since it has spatial and temporal limitations. USLE is limited by hillslope scale and annual soil erosion predictions. Moreover, the USLE cannot represent process in a catchment area. Process-based soil erosion models are often used to assess water and sediment dynamics in watersheds, instead of a simple combination of USLE and channel networks. The validation of physical processes implemented in a process-based model would allow for further applications.

GeoWEPP is the geospatial application of the Water Erosion Prediction Project (WEPP), a soil erosion and sediment yield prediction based on process based-models. Although there are other models, the spatial and temporal applicability of GeoWEPP is suitable for the subwatersheds in Agatsuma, which has a relatively small area (< 100 km^2). Nevertheless, the variation of watershed properties in a large area results in inaccurate runoff and sediment yields predictions. Moreover, the previous studies of WEPP/GeoWEPP were conducted in a relatively small area. Soil erosion based on process-based models have broad applications since these models have spatiotemporal capabilities and require minimum calibration. Despite this, the process-based model needs to be evaluated before being applied in Japan.

The objective of this research was to assess the application of GeoWEPP as a process-based model in the forested mountainous watersheds of Japan. Multi-scale watershed simulation using GeoWEPP was conducted to assess water discharge and sediment yield.

The study site was Agatsuma watershed (711 km^2), located in Gunma Prefecture, Japan. The watershed had various types of land cover which were dominated by diverse forest and mountain areas. This study consists of several steps. First, observational data was processed to develop continuous daily discharge and sediment yields. Discharge data from Murakami point was processed to generate daily discharge by a rainfall-runoff model. Discharge rates and suspended sediment (SS) concentrations from 100 subwatersheds were utilized to develop the SS rating curves, classified by forest coverage. Second, a sensitivity analysis on hydrological processes and sediment yield was conducted. The hydrological processes were used to analyze the water balance, with a focus on the discharge and evapotranspiration on the hillslope scale. Discharge and sediment yield comparison analyses were also conducted relative to the forest coverage and area size of the watershed. Third, GeoWEPP was applied, separating the hillslope and watershed simulations. Hillslope

simulation was used to validate sediment yield on the plot scale. Meanwhile, the watershed simulation was utilized to analyze sediment yield with regards to the forest percentage and area.

The watershed simulation was conducted comparing area and forest coverage on 20 subwatersheds with accompanying data from numerous field observations, in order to validate the applicability of GeoWEPP. In addition, watershed area simulations were conducted at 5 subwatershed ranges from 0.7 km^2 to 59.65 km^2 in high forest coverage subwatersheds. Meanwhile, a simulation of stream order by area was conducted in two high forest subwatershed which had a range of 80.5 % - 97.27 % forest coverage.

The GeoWEPP discharge result in different forest coverage percentages agreed with the rainfall-runoff model. This is an indication that GeoWEPP can predict sediment discharge in forests. The GeoWEPP watershed simulation by forest coverage, when compared with SS yields, shows that GeoWEPP slightly overestimates yield in high forest coverage watersheds. The parameter settings corresponding to actual conditions and processes enabled the reproduction of water and sediment dynamics. For surface runoff and subsequent surface erosion in hillslope sections, the introduction of a restrictive layer and evapotranspiration rate optimization were critical for reproducing hydrological processes. The depth to non-erodible layer parameter, which varies with time and cannot be obtained from the actual depth of bed material, governed the overall sediment discharge at the study site.

The assessment of water and sediment discharge in hillslope and subwatershed simulation was successful in the multi-scale GeoWEPP simulation. The hillslope simulation in 6 land cover plot types showed that both the water and sediment discharge comparison between the observational results and WEPP agree. The GeoWEPP watershed simulation by area size showed good results as well. The water and sediment discharge on the plot scale indicate low contribution to sediment yield. The sediment discharge result would improve by

using more rigorous input data. In high forest watersheds, channel soil loss contributes significantly to the sediment yield. The positive trend of channel soil loss by area size was influenced by the channel properties in each stream order. Initially, sediment yields are especially large in larger watersheds. The spin-up processes may be needed to remove the initialization process for several years. Therefore, GeoWEPP watershed simulation should eliminate initialization years as a spin-up process in order to obtain better results in large forested mountain watersheds.

GeoWEPP successfully reproduced the sediment discharge in subwatersheds of varying size, topography, and land use (forest coverage percentage). The parameter settings need consideration before running simulations, such as hydrological processes in hillslope sections and sediment storage in channel sections. In forested mountain watersheds, the restrictive layer in hillslopes is critical to producing discharge, while in the channel sections, the depth to non-erodible layers play an important role in the sediment yield result, as well in the stream order and bed material.