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学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Studies on spatial and temporal analysis of hydrological ecosystem services in watershed
（流域における水文学的生態系サービスの時空間解析に関する研究）

Watershed ecosystem provides various ecosystem services for human well-being. Some of the ecosystem services especially for provisioning and regulating services closely relates to hydrological and biogeochemical processes such as water quantity and quality in the watershed. The understanding impacts of land-use and climate changes on those hydrological ecosystem services are important and not well understood yet. Furthermore, the effective conservation planning of ecosystem services and risk analysis under land-use and climate changes are also still unknown. In this study, the following research questions were developed: (1) How do the hydrological ecosystem services of watershed change temporally and spatially? and (2) What are driving factors for those changes in the hydrological ecosystem services and their conservation priorities? To address these questions, this study was conducted in Teshio river watershed in northern most of Hokkaido, northern Japan by applying a physical based watershed model in the watershed (The Soil and Water Assessment Tool: SWAT model), economic assessment approaches, empirical land-use change model (Conversion of land use and its effects, CLUE model), climate change data based on general circulation model, zonation model and risk assessment model.

Simulated water yield and their conservation priorities fluctuated in the watershed spatially and temporally according to the spatial distribution of the topography, land-use and soil type, and seasonality of climate condition. The spatial pattern of priority for water resources was different from that of economic value of the water supply for irrigation, electricity production and household usage. It was suggested that water in riparian flat area is potentially available for future water resources.

The simulation using SWAT model indicated that land-use change from current paddy field to farmland resulted to decrease the sediment, total nitrogen (N) and total phosphorous (P) exports from watershed due to the alteration of hydrological processes and nutrient cycling of the watershed ecosystem. It was suggested that higher nutrient uptake by crops and less nutrient mineralization by soil microbes, reduced nutrient leaching from soil, and lower water yields on farmland contributed to the changes of those water qualities under the land-use

change. On the other hands, the climate changes increased the sediment and nutrient (N and P) exports especially during the snowmelt and rainy seasons. The annual water yield, sediment and nutrient exports also increased under climate change scenarios. The climate changes were projected to have greater impacts on water quantity and quality than those of land-use changes. The sediment and nutrient exports were mainly occurred from agricultural land under all scenarios of climate and land-use changes, suggesting that riparian zones and adequate fertilizer management would be a potential mitigation strategy for reducing these negative impacts of land-use and climate changes on water quality.

The risk analysis model was applied to assess the economic and environment risks under multiple land-use and climate scenarios. The gross margin and net return for crop production predicted using governmental statistics was used as parameters for economic risk. The simulated total N and total P exports from agricultural land was used as parameters for environment risk. Under current climate condition, the land use dominated by farmland provided lower cost and higher crop yield than the land use dominated by paddy filed. The higher economic and environmental risks were both predicted in land use dominated by paddy field. Increase of temperature and precipitation increased crop yields under all three climate changes, resulted to decrease the economic risk. The increase of temperature and precipitation also enhanced microbial nutrient mineralization, water discharge, sediment transports and nutrient leaching to river, resulted to increase the environmental risk. It was suggested that the larger climate change for farmland increased the economic risk than small climate change due to the decrease of crop yield.

The spatial assessment of conservation priority for hydrological ecosystem services was applied using multiple climate and land-use scenarios. Under specific land-use and climate changes, the water yield, inorganic-N, inorganic-P and sediment retentions increased due to the higher precipitation and temperature. However, the organic-N and organic-P retentions decreased because the increase in temperature accelerated microbial mineralization of organic matter. The higher water yield was distributed in the northern watershed due to more precipitation and substantial snowpack. Priority areas for conservation of six ecosystem services associated with water, sediment and nutrients under land-use and climate change scenarios concentrated in north (providing water yield), southeast (providing sediment, organic-N and organic-P retentions), southwest (providing inorganic-N and inorganic-P retentions) of watershed, relating to the watershed topography and land-use patterns. The priority areas for water yield, sediment, organic-N and organic-P retentions are traded off against priority areas for inorganic-N and inorganic-P retentions.

Base on above findings, spatial conservation prioritization and risk analysis of hydrological ecosystem services help producers and watershed managers to measure the tradeoffs between environmental protection and economic development under land-use and climate changes.