学位（博士）論文要旨

Evaluation of Human Impacts on Groundwater Resources in Mountainous Catchments, Western Japan

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論文の要旨

The long-term cumulative effect of increasing urbanization, population and climate change on watershed hydrology has altered the spatial availability of groundwater resources in many regions. In recent years, demographic trends have led to concerns on how population growth will affect water resources. In many Asian and Western countries, population densities are declining despite global population growth with a significant increase in the proportion of the elderly. With an increasing number of citizens over 65 and many cities experiencing depopulation, Japan has experienced this demographic change faster than most Western and Asian countries. Despite these social changes, it still faces serious environmental problems related to groundwater quality and quantity.

Population growth and increasing economic condition have led to the continuous expansion and transformation of many Japanese's mountainous rural catchments with associated groundwater resource problems. Despite the significant impact of urbanization (population growth) on groundwater resources, most studies have focused on qualitative, regional impact, with little attention given to the combined effects of social and environmental issues on groundwater resources in mountainous rural catchments. Therefore, understanding how environmental and social aspects affect groundwater resources is crucial. This study provides insight into groundwater resource degradation resulting from an aging and depopulating society, as well as the effects of urbanization and climate change.

Examining the effects of population aging and depopulation on groundwater nitrate contamination in an island with intensive citrus cultivation, we compared two neighbouring villages and watersheds with similar social aspects. The northern village (Kubi) has a slightly higher average farmer age of 76 years, and a decreasing rate of farmland over the last 10 years spanning from 2005 to 2015 of 46%, compared to the eastern village (Ocho) with an average farmer age of 73 years and a decreasing rate of 37% during the same period.

Despite a population of 830 in Ocho, twice that of Kubi, higher mean concentrations of NO_3^-−N were recorded in Kubi village (6.55 mg/L) than in the Ocho area (4.75 mg/L). Nitrate contamination sources were associated with land use and social aspects such as aging and depopulation, with Kubi experiencing higher leaching due to the substantial use of chemical fertilizers by more aged farmers.

Similarly, the hydrochemistry and dual isotope approach were used to evaluate groundwater

contamination status in the Saijo River basin. Results showed that, calcium (Ca_2^+) and bicarbonate (HCO_3^-) were the most abundant cation and anion respectively, and the major water type in the study area was Ca–Mg–HCO3. Inferred from contamination sources in the basin using $\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$ measurements, it indicated two major contamination sources with values characteristic for nitrate derived from nitrification of soil organic nitrogen and nitrate derived from animal wastes or human sewage in two distinct zones. Despite agricultural activities in the study area, no evidence of nitrate originating from synthetic fertilizers in the groundwater was found.

Furthermore, the spatial variation in groundwater recharge under the influence of urbanization and climate change was investigated using SWAT (Soil and Water Assessment Tool) over three decades. The findings indicate a substantial impact on the water balance over the past 30 years due to changes in land use associated with urbanization. Notably, there has been a significant 25% reduction in the mean annual groundwater recharge, decreasing from 184.5 mm in the 1980s to 120.2 mm in the 2000s. Rice paddies were identified as major recharge zones, exhibiting the highest recharge compared to forest and residential areas. Higher rainfall interception by forest canopy were responsible for the lower recharge values observed at forested sites. Predicted scenarios highlight a substantial decrease in groundwater recharge over the next 30 years by 29% due to future climate change. These findings could contribute to the improvement of land and water resource management if utilized by decision-makers, planners, and managers in the region.