Construction of observation network and future prediction method for advanced control of forest water resources focusing on adjustment to climate change (Abstract of the Interim Report)

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1. Introduction

Forests cover about two-thirds of Japan's land surface, and usually occupy the mountainous upstream area in Japan. Thus, forests are expected to perform the functions of water flow control such as decreasing flood peak, preventing drought and of protection of water quality. The functions related to forest hydrologic cycle may change in near future due to forest harvests and forest decline caused by climate change and/or vegetation senescence. We should estimate the impacts with high accuracy through scientific verification and prepare for what will happen. Thus it is necessary to conduct long-term and continuous observation of water cycle in forests over a wide area and intensive analysis based on the datasets obtained.

2. Research Objectives

To establish the scientific basis for estimations of the effect of forest managements and climate change on forest hydrologic processes, we aim to build an observation network for investigating and monitoring changes in the water cycle and meteorological/environmental factors in and around forest ecosystems, covering various climate patterns and forest management histories from Hokkaido to Kyushu Islands, Japan. We also object to develop some tools to interpret and estimate the change of quantity and quality of water discharge from forests under some possible conditions, and seek to share the techniques of observation and estimation with local governments and developing countries.

3. Research Methods

To achieve the objectives above, observations of precipitation (P) and water discharge (Q) were conducted throughout Japan, including long-term sites and newly registered forest watershed sites. Collections of precipitation and stream water were also conducted continuously to analyze water quality. Observations of solar radiation, temperature, and humidity were started at each site and compared with other external data sources based on AMeDAS etc. to understand the characteristics of the observed values in the mountainous watersheds. In addition, evapotranspiration, stable isotopes in precipitation and stream water, and SS (suspended solid) concentration were measured at intensive observation sites. The observation data were arranged and incorporated into the database which was renewed with link of P and Q database and water quality database.

Information on observation sites and vegetation histories were re-organized and published: These data were applied for long-term and wide-area analysis as follows: Long-term changes in water use efficiency and water loss due to forest growth, aging, and increases in carbon dioxide concentration were investigated with using stable isotopes in tree rings. Also, the impact of clearcutting on water discharge were compared over a wide area with consideration of its recovery processes. Temporary impacts and its duration of thinning on water quality and forest transpiration were estimated. Focusing on atmospheric nitrogen loading, we investigated its long-term variation and analyzed its impact on stream water quality.

Using the observed data as validation values, a generic model was experimentally applied to evaluate and predict the water cycle in mountainous forest watershed. Using the SWAT model, water discharge from forested watersheds was simulated across Japan and its applicability to mountainous watersheds was carefully examined.

For Akita Prefecture and Okinawa Prefecture, joint observation researches and data analyzes were conducted with supporting their presentation and sharing methods and techniques of observation. In Cambodia, where joint observations had been conducted, mutual exchanges were resumed.

4. Results and Discussions

The database was re-established on more stable basis including 11 observation sites across Japan with linkage of *P*, *Q* and water quality. Previously obtained data were rearranged and published as research record (e.g., Tamai et al., 2020, Kubota et al., 2023) and newly analyzed data were added to it. Histories of data acquisition, vegetation and instruments at each site were published on the web and an international journal (Shimizu et al., 2021) for data users' accessibility. Measured meteorological factors were verified by comparison with external data, and direct measurements of *P* and solar radiation were found to be particularly important and should be measured with *Q*.

It was suggested that increase of water use efficiency as carbon dioxide increase, the old age and reduced density of trees caused slight decrease of evapotranspiration in 80-years forest watershed without any cutting (Kubota et al., 2021). The impact of clearcutting on *Q*. was relatively long (typically 10 years or more) and the recovery process appeared different between coniferous and broadleaf forests. Meanwhile, the observation result suggests that transpiration rates in planted forests after thinning were restored in about 3 years because of improved light condition of the remained trees.

The dissolved ion analysis quantitatively indicated that accumulation of excessive nitrogen loading on forests close to large cities induced high discharge of NO_3^- ion: NO_3^- concentration in stream water was generally larger when it was closer to the large city (Ito et al., 2021). Further, our observation suggested that in addition to nitrate nitrogen, ammonia nitrogen has been an important factor at least since 2000 to count nitrogen loading from the atmosphere. The impact of thinning on water quality was mainly due to soil surface erosion from the work roads, and it still continued for several years (Shinomiya et al., 2020).

The daily basis *Q* from a forested watershed was generally well reproduced by applying SWAT (Soil & Water Assessment Tool) across Japan: This result suggested that SWAT, which has been developed mainly aiming to apply for a watershed containing mixed land use on gentle terrain, but can be applied to relatively small forested watersheds on steeply rolling terrain. However, the optimized parameters in SWAT deviated from the measured soil physical properties which implied that the SWAT sub-model for water discharge from small steep forest is necessarily improved.

Cooperative observation and analysis with Akita and Okinawa Prefectures promoted and their presentation of research results were supported. The above study of changes in transpiration due to thinning was conducted jointly with Akita Prefecture. Technical training was provided for researchers in Okinawa for particle size analysis of eroded soil. In Cambodia, hydrological instruments had deteriorated under the corona virus pandemic situation, but we were able to repair and reconfigure these instruments and re-establish a joint observation system for the forest water cycle.

We will continue to make progress in these efforts, accumulate data on the water cycle process in forests, and conduct wide-area assessments.

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