Hydrological aspects of a non-managed artificial forest watershed of *Chamaecyparis obtusa* Endl.

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ABSTRACT: In this report, we first introduce the plan of the Japanese Council of University Experimental Forests to establish Long-Term Forest Hydrological Network, and propose the cooperation between Japan Society of Hydrology and Water Resources (JSHWR) and Korean Water Resources Association (KWRA) to fulfill the plan. Then we introduce our hydrological researches conducted in a non-managed artificial forest watershed of Kyushu University Forests in 2002. Though hydrological phenomena have not sufficiently investigated, we introduce the hydrological aspects obtained in 2002 to initiate cooperative researches on Forest Ecosystems with KWRA.

1 INTRODUCTION

It has been widely recognized that forest ecosystems contribute environmental conservation and remediation since global environment problems emerged in late 20th centuries. And now policies, educations and researches on forest are at the turning point worldwide. In Japan, the Forestry Basic Law was reformed as the Forest and Forestry Basic Law in 2001, and the multi-functional roles have become the core of the law since then. However, platforms for forest ecosystem researches have not yet sufficiently established. Thus promotions of interdisciplinary researches on forest ecosystems based on a long term monitoring become an urgent task.

Korea has already initiated Long-Term Ecological Researches (LTER) on forest ecosystems since 1997: Kwangnung Experimental Forest, Mt. Kyebangsan Forest and Mt. Keumsan Forest. Korea Forest research institute (KFRI) has principally managed these LTER sites. Forest Hydrology Laboratory of KFRI have conducted long-term hydrological monitoring in eight mountainous watersheds in various parts of Korea including the Kwangnung Experimental Forest, and published the hydrological dataset of these watersheds (Jeong et al., 2002). Among them, integrated hydrological researches have been conducted in the Kwangnung Experimental Forest (Kim et al., 2002).

On the other hand, in Japan, systematic long-term forest hydrological researches at the Forest Experimental Stations of Forestry Agency ceased in late 20th century. Thus the Japanese Council of University Experimental Forests is going to establish Long-Term Forest Hydrological Network (Ogawa et al., 2002). In this report, we first introduce the plan and propose cooperation between Japan Society of Hydrology and Water Resources (JSHWR) and Korean Water Resources Association (KWRA) to fulfill and extend the plan. Then, we introduce our hydrological researches conducted in Kyushu University Forests. Though hydrological phenomena have not been sufficiently investigated, we introduce the hydrological aspects obtained in 2002 to initiate cooperative researches on Forest Ecosystems with KWRA.

2 PROPOSAL OF LONG-TERM FOREST HYDROLOGICAL RESEARCH

Human may have kept the memories of benefits from forests since ancient times, and reflected how much we have damaged forests in recent centuries. We accordingly tend to or would like to believe that forests give us abundant benefits, and respect forests as the land to be fostered and conserved. However, we do not have sufficient data to prove these benefits and lead how to foster forests with producing resources and promoting the social benefits. Although we must not evaluate the benefits of forests from a single point of view, we have responsibility to monitor ecosystems of forests and open them to the public. Among many factors existed in the ecosystems of forests, water circulation is the predominant factor because it is most influential process in the ecosystem. However, forest hydrological monitoring systems are scarcely distributed and forest hydrological database has not yet established.

Recognizing the importance of ecosystem in recent years, ecological research networks have been widely spreading worldwide. Since they could be useful models for forest hydrological research network, we herein introduce the International Long-Term Ecological Research (ILTER), and the activities of environment monitoring conducted by the Japanese Council of University Experimental Forests. Based on these backgrounds, we propose to establish the Long-Term Forest Hydrological Research Network and link it with Korean hydrological research network.

2.1 International Long-Term Ecological Research (ILTER)

The U.S. National Science Foundation established the U.S.LTER program in 1980 to support research on long-term ecological phenomena in the United States. The U.S.LTER now has 24 LTER sites. In 1993, the U.S.LTER Network held a meeting on international network in long-term ecological research to meet the demand in assessing and resolving complex environmental issues. In the meeting, the establishment of International LTER (ILTER) Network was decided. The mission of the ILTER network is as follows (ILTER, 2001):

- ➢ Promote and enhance the understanding of long-term ecological phenomena across national and regional boundaries;
- ➢ Promote comparative analysis and synthesis across sites;
- ➢ Facilitate interaction among participating scientists across disciplines and sites;
- ➢ Promote comparability of observations and experiments, integration of research and monitoring, and encourage data exchange;
- ➢ Enhance training and education in comparative long-term ecological research and its relevant technologies;
- ➢ Contribute to the scientific basis for ecosystem management;
- ➢ Facilitate international collaboration among comprehensive, site-based, long-term ecological research programs; and
- ➢ Facilitate development of such programs where they currently do not exist.

Twenty-one countries have established formal national LTER programs and joined the ILTER network in 2000. Japan is still in process of developing the national LTER. The LTER Sub

Committee was formed in the Ecological Society of Japan in 1999, and has been preparing to establish the Japanese LTER (JLTER) Network.

2.2 Environmental Monitoring conducted by University Experimental Forests

There are 27 universities having university forests, in which the total number of research forests are 81. The Japanese Council of University Experimental Forests has been conducting two joint projects. The one is the Phenology Observation Network Project in which tree phenology has been observed in 22 forests in 12 universities. The other is the Material Dynamics Monitoring Project in Forested Watershed in which water quality of rainfall and stream flow have been observed in 15 forest watersheds in 14 universities.

The later was initiated to continue at shortest 50 years. For the comparative study, observations have been conducted in a same manner under the unified manual. The database of acid rain and the list of experimental watersheds have been opened through Internet (in Japanese).

- Acid Rain Data : http://pc3.nrs-unet.ocn.ne.jp:591/juef_data/Acidopen/Start.htm
- Watershed Catalog : http://forester.uf.u-tokyo.ac.jp/~kuraji/univ_for_exp_list.htm

2.3 Proposal to establish Long-Term Forest Hydrological Research Network

Although the above-mentioned data are useful and valuable, the data in the mountainous area are still too scarce to understand the ecosystem in detail. Thus, establishment of long-term forest hydrological research network is strongly required. In United States, these networks have already established and data are freely presented. In the U.S.LTER, such data are freely supplied through Internet. The United States Department of Agriculture presents the various hydrological data (precipitation, snow, discharge, soil water, climate, etc.) observed for 34 years in the Reynolds Creek Experimental Watershed through Internet.

To meet the demand in establishing the long-term forest hydrological research network and open the database in Japan, the Mountainous Watershed Catalog & Database Research Group in JSHWR initiated the preparation for the catalog and database with other scientific groups related to hydrology in 2000. The Japanese Council of University Experimental Forests is also preparing the fourth stage of the Material Dynamics Monitoring Project in Forest Watersheds. To extend the project as the forth stage, the following objectives are formed:

1) clarify the dynamics of water, energy and material in each forest watershed,
2) compare the dynamics with other forest watersheds and clarify the characteristic depend on the botany, geology, geography and climate,
3) construct the environmental database network with other monitoring database downstream, clarify the dynamics in river system, and evaluate the effect of forests,
4) internationally link the database network with other environmental database networks such as ILTER.

To accomplish these objectives, a core project of long-term & large area material dynamics in forest and three sub projects to

1) analyze the conservational function of water quantity and quality of forest,
2) open the database and link with other forest environment monitoring system such as ILTER,
3) link the monitoring database with other monitoring systems down stream such as Meteorological Database and River Water Level & Quality

are formed. These processes are for the Japanese Council of University Experimental Forests project, but essential for forest hydrology in general. Consequently, we propose the cooperation between JSHWR and KWRA to fulfill the plan and extend this approach worldwide.

3 HYDROLOGICAL ASPECTS IN NON-MANAGED ARTIFICIAL FORESTS

One of the greatest problems in the forest and forestry in Japan is how to manage the ill-managed artificial forests. We then installed an experimental forest watershed in a non-managed artificial forest of *Chamaecyparis obtusa* Endl. in Fukuoka Experimental Forest of Kyushu University Forests in 2001.

3.1 Study site

The study site introduced in this paper is the Ochozu Experimental Watershed, which was reinstalled in 2001. It is located about 15km east of Fukuoka city. It is a mountainous watershed within No.4 forest section of the Fukuoka experimental forests of Kyushu University Forests.

Topographical features of the watershed are as follows:

Area	: 9.5ha
Length of the main stream	: 265m
Width of the watershed	: 179m
Slope of the stream	: 0.22
Average slope	: 0.37

The major bed rock is a chlorite schist and the major soil is a Yellow-Brown Forest soil. The watershed consists of artificial forests of *Chamaecyparis obtusa* Endl. of 50 years old along the stream and various secondary grown broad-leaf forests in the middle and upper parts of the slope. The artificial forests of *Chamaecyparis obtusa* Endl. have not managed except that a small portion was thinned. Thus the canopy of the artificial forests is closed and the vegetations of the forest floor are scarce.

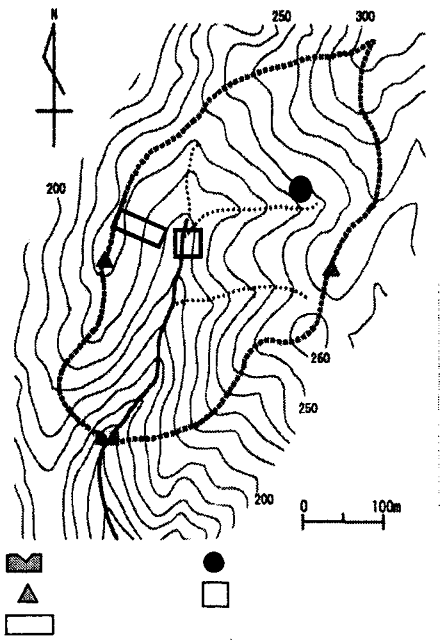

Fig.1 Ochozu experimental

3.2 Hydrological cycle

3.2.1 Method

Precipitation, wind speed, wind direction, air temperature, relative humidity and solar radiation have been measured in openings at both east and west ridges of the watershed.

A weir is installed at the outlet of the watershed, and the water level has been measured by float sensor and hydraulic pressure sensor. Discharge has been measured manually several times a month.

Soil water content and matric potential have been measured at the west slope of the central watershed. The slope is divided into a riparian zone (LP), a foot of the slope (LT), a middle part of the slope (M) and a upper part (H) of the slope.

Pipe flow has been measured near the upper stream of the watershed.

3.2.2 Result and Discussion

Precipitation and Discharge

Fig.2 shows the precipitation and discharge from the watershed. Annual precipitation and discharge in 2002 were 1,384mm and 653mm respectively. The annual precipitation was about 350mm less than the average year value of 1,632mm. It was due to the drought during summer from June to August; total precipitation in summer was 306mm, which was 420mm less than the average value. Thus base flow from June to November had considerably reduced compared with the one from January to May. Base flow had gradually increased since the middle of December.

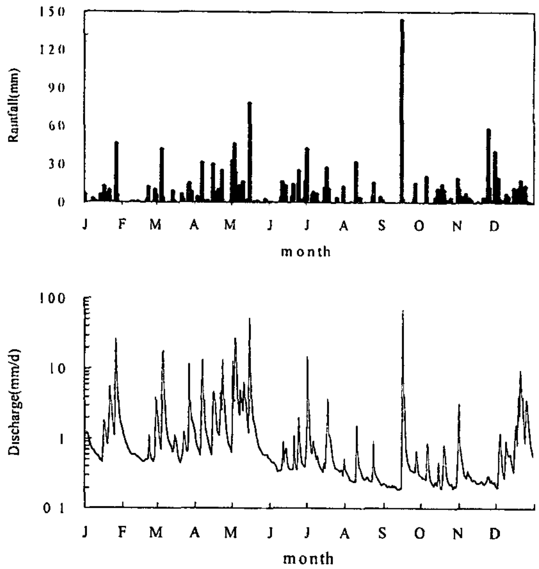

Fig.2 Precipitation and discharge in 2002

Soil matric potential

Soil moisture at the riparian zone (LP) was nearly saturated in most of the time. However, it considerably reduced from mid-August to mid-September, which indicates entire watershed became quite dry in this period.

Soil moisture at the foot of the slope (LT) became gradually dry, but soon saturated after rain. It was considerably dry in August-September and November.

Soil moisture at the middle and upper part of the slope (M&H) was considerably dry in most of the times. Even when the soil moisture at LT became saturated from mid-September to early November, the soil moisture at the M&H was kept dry. It became near saturation when rain continued in winter.

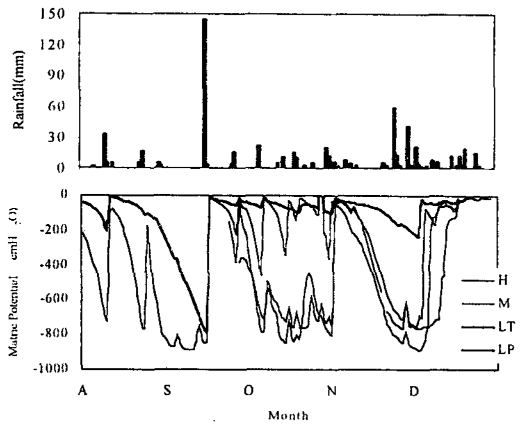

Fig.3 Precipitation and soil matric potential

Relationship between soil moisture and pipe flow

Pipe flow observation was started in late September. Pipe flows were observed four times from October to December when soil moisture at the entire part of the slope was almost saturated: once in November and three times in late December.

Pipe flow appeared only when the discharge from the watershed was more than 4000*l*/10min.

Relationship between soil moisture and evapotranspiration

Evapotranspiration were estimated by the short-term water-budget method. It increased from February to July, and then decreased gradually from September to December. But it considerbly decreased in August. The period when evapotranspiration were depressed was when the soil moisture at riparian zone became dry.

3.2.3 Discussion

It reveals that soil moisture distribution at the slope has close relationship with the discharge, pipe flow and evapotranspiration of the watershed.

3.3 Rainfall under the canopy

3.3.1 Method

Throughfall (*TF*) and stemflow (*SF*) of *Chamaecyparis obtusa* Endl. have been measured since October 2001.

The gross rainfalls (*Pg*) were measured by the tipping bucket raingauges installed at the openings of the ridges. To obtain the continuous long-term dataset, four automatic logging tipping bucket raingauges (TF: 2, SF: 2) were installed within the observation plot located in the central part of Ochouzu experimental watershed (Fig.1). The throughfalls were spatially varied. Therefore, the tipping bucket raingauges data were converted to throughfall by taking account of the average values of 25 storage raingauges. The stemflow also varied with the tree size. This effect can be expressed by funneling ratio (*FR*), which explains the stemflow generation in terms of total basal area at breast height (*BA*) (Vavier, 1993). *BA* and *FR* within this observation plot was 0.403 m^2 and 25.1 respectively. These values were used to estimate the average stemflow.

3.3.2 Results and discussion

Fig. 4 shows the relations of throughfall and stemflow with gross rainfall. Both throughfall and stemflow can be expressed by the linear equation.

$$TF = 0.764\,Pg - 0.949 \quad (R^2 = 0.986) \qquad (1)$$

$$SF = 0.167\,Pg - 0.239 \quad (R^2 = 0.941) \qquad (2)$$

The ratio of canopy interception rapidly decreased with the gross rainfall (Fig.5). Therefore, the contribution of canopy interception to the water cycle in this watershed should be significantly

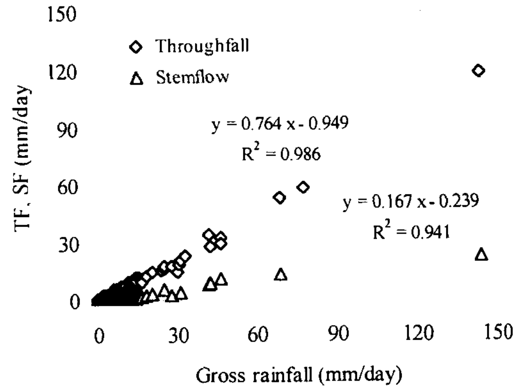

Fig.4 Relations of *TF* and *SF* with *Pg*

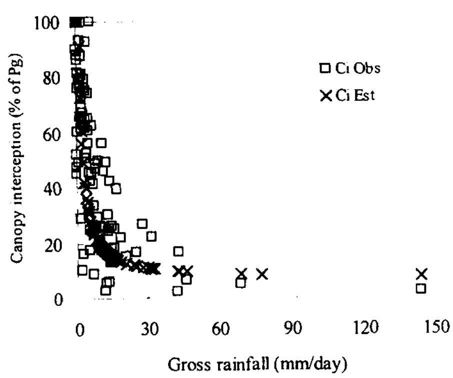

Fig.5 Relations between *Ci* and *Pg*

varied with gross rainfall conditions.

Fig.6 shows the monthly canopy interception from November 2001 to October 2002. It shows that the monthly canopy interception varied 5.9 ~ 40.1 % of gross rainfall. It should be emphasized that the canopy interception ratio during the summer drought from June to August in 2002 was the considerably high, which indicate that the dense canopy due to non-thinning may increase the evaporation (interception) loss in drought period.

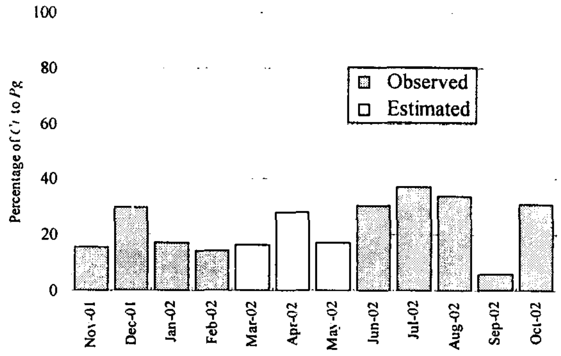

Fig.6 Percetage of *Ci* to *Pg*

3.3.3 Discussion

The amount of observed annual gross rainfall was 1343.8 mm (2001/10/25 ~ 2002/10/24), whereas throughfall and stemflow were 867.0 mm (64.5 % of gross rainfall) and 180.8 mm (13.5 % of gross rainfall) respectively. Thus, the annual rainfall interception loss by the canopy in this stand would be 296.0 mm (22.0 % of gross rainfall). Hattori *et al.* (1982) measured the rainfall interception at the 29-year-old *Chamaecyparis obtusa* Endl. stand in Ibaragi prefecture, Japan. They showed that the annual ratios of throughfall, stemflow and canopy interception to gross rainfall were 67.7 %, 11.0 % and 21.3 % respectively. The values obtained in this study agreed well with the results of this previous study. However, to predict the interception loss in this watershed more accurately, we have to carry out further research by taking into account the effect of micrometeorological conditions.

4 CONCLUSION

One of the greatest problems in the forest and forestry in Japan is how to manage the ill-managed artificial forests. Although it is time to harvest the trees planted after World War II, large number of the trees have not yet harvested nor properly managed. We have not experienced such dense ill-managed artificial forests in our history. Thus integrated researches on the forest ecosystem not only for natural forest but also artificial forests are strongly required.

The researches in the Ochozu Experimental Forest have been still developing. We have also conducted the nutrients balance (Nagafuchi et al., 2002) and will start measuring stem water dynamics, energy balance, transpiration and photosynthesis within 2003. We have gradually found the links of these factors. It must be difficult to find appropriate artificial forest management to fulfill profitable production and environmental conservation, but it is the task of our generation to initiate integrated long-term ecological researches for the next generation. Fortunately, there are time lags in the situations of forests in Japan and Korea, and comparative studies between Japan and Korea will greatly contribute to strategies of proper forest management for both countries. The hydrological working group of the Japanese Council of University Experimental Forests will establish the hydrological monitoring network in basin scale to find the roles of mountainous forests on the hydrological cycles and related environmental issues. We believe these activities will be a milestone to establish cooperative researches on long-term forest ecosystem researches between Japan and Korea.

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