Toward Establishment of Japan-Korea Long-Term Forest Hydrological Research Network

Otsuki, Kyoichi
Associate Professor, Faculty of Agriculture, Kyushu University, Fukuoka, Japan

Ogawa, Shigeru
Professor, Faculty of Agriculture, Kyushu University, Fukuoka, Japan

Kume, Atsushi
Assistant Professor, Faculty of Agriculture, Kyushu University, Fukuoka, Japan

Kumagai, Tomo'omi
Assistant Professor, Faculty of Agriculture, Kyushu University, Fukuoka, Japan

ABSTRACT : In this paper, the status of forest and forestry together with the trend of forest hydrology in Japan are firstly overviewed for the mutual understanding between the Japan Society of Hydrology and Water Resources (JSHWR) and the Korean Water Resources Association (KWRA). Then, Long-Term Ecological Research recently introduced in Asia is briefly explained, and the establishment of Japan-Korea Long-Term Forest Hydrological Research Network is proposed.

1 INTRODUCTION

Japan is called as *Midori no Retto,* literally translated as the Green Archipelago. As shown in the name, Japan is one of the most broadly forested countries in the world, where the forest cover runs up to 68%. Almost all the resources had been supplied from forests since ancient times, but most materials from forests have been replaced by imported or artificial ones in connection with economic growth and technological development in recent years. A decrease in timber self-sufficiency ratio from 94.5% in 1955 to 19.2% in 1999 implies this trend. Then, the public interest and expectations toward forests have become more diverse and more articulate. To correspond to the current state, the Forestry Basic Law enacted in 1964 was revised as the Forest and Forestry Basic Law in 2001, in which multi-functional roles of forests become predominant. However, environmental data in forests have been still insufficient, and the integrated data and analysis of forest environment have been strongly required.

In such a background, interdisciplinary studies on forest environment have been gradually spread, and movements toward establishment of interdisciplinary long-term ecological researches have arose. Hydrological process will be a core issue among these studies because water cycle is one of the most influential process in the environment. However, hydrological database system has not been established nor utilized as compared with meteorological database. To overcome this situation, the Mountainous Watershed Catalog and Database Research Group was established in the Japan Society of Hydrology and Water Resources (JSHWR) in May, 2000. Collaboration in the activity with the Korean Water Resources Association (KWRA) is recommended to widen the usefulness of the catalog and database system. Moreover, establishment of Japan-Korea long-term forest hydrological research network is highly recommended to enable comparative studies not only in hydrology but also other related fields such as ecology and geochemistry, deepen our environmental knowledge and enhance the environmental management.

In this paper, firstly the status of the forest management along with the trend of forest hydrology in Japan are introduced for the mutual understanding between JSHWR and KWRA. Then, Long-Term Ecological Research recently introduced in Asia is briefly explained, and the establishment of Japan-Korea long-term forest hydrological research network is proposed.

2 FOREST AND FORESTRY IN JAPAN

2.1 Physical features of Japan

2.1.1 Location

Japan is a crescent-shaped archipelago extending along the eastern coast of the Asian continent. It stretches about 3,000 km long from 45°33'N, 153°59'E to 20°25'N, 122°56'E. It consists of four main islands of Hokkaido, Honshu, Shikoku, Kyushu and many other small islands with a total area of 377,873 km^2.

2.1.2 Topography

Almost 75% of the land is mountains and hills covered by forests, and about 24% of the land is flat. In central Japan, there are numbers of high mountains of the 3,000 meter range. Several mountain ranges act as the backbone of the archipelago. They are associated with volcanism, and there are some 265 volcanoes, of which many are still active. Thus, catastrophic earthquakes and eruptions have occurred regularly throughout Japanese history.

Rivers in Japan are mostly short and swift flowing. The longest river, the Shinano River, is about 367 km long. Most streams rise in the mountains, run across narrow strips between mountains and sea not distant therefrom. Flooding, debris flows and landslides frequently occur in rainy season and typhoon season, which are closely related to the forest management.

2.1.3 Climate

The climate of Japan is diverse in location but featured by dynamic changes in weather and distinct seasons (see Fig.1). It is significantly affected by the elements of 1) the wide range of latitude, 2) latitudinal position receiving numerous fronts, 3) the location on the east edge of the Asian Continent, 4) the mountainous topography throughout the country, and 5) the surroundings with deep seas having various currents.

Southwestern Japan has long, hot summers and short cool winters. Northern Japan experiences short, warm summer and long, cold winter. In the coastal areas of central Japan, winter is cool and summer is hot. The mountains running through the center of the islands protect the lee side from the effects of the monsoons, effectively creating two climatic regions; the Sea of Japan side and the Pacific Ocean side. The Sea of Japan side is featured by heavy snowfall in winter and year-round humidity, and the Pacific Ocean side is featured by low winter precipitation and dry winter. Annual rainfall throughout Japan is high (generally between 1,000 and 25,00 mm). With these pluvial features, Japan has an average annual precipitation of 1,750mm, almost twice as high as the world average. Almost whole the country has annual precipitation more than 1,000mm.

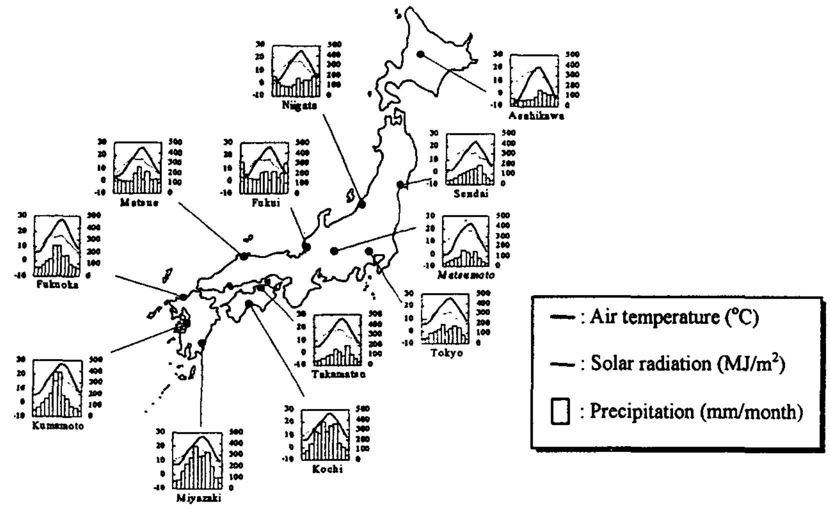

Fig.1 Climate in Japan (Otsuki, 2001)

2.1.4 Soils

Soils in Japan are formed under the influence of the environment of temperate humid climate, islands, volcanes, high steep mountains and short steep rivers. Forest soils in Japan are classified into seven soil groups (Podzol, Brown Forest Soil, Red-Yellow Soil, Black Soil, Dark Red Soil, Glay, Peat) and immature soil. About 75% of the forest soil is Brown Forest Soil. Brown Forest Soil is distributed throughout the country except Ryukyu chain. Black Soil are mainly distributed in the area covered by volcanic Kuroboku (Ando). Podzol are located in alpine and sub-alpine zones.

2.2 Forests in Japan

In Japan, forest covers about 25.1 million hectares in 1999, which is about 68% of the land. Of the entire forested area, natural forests and plantation forests cover 13.4 million hectares (53%) and 10.4 million hectares (41%) respectively. Of the entire forested area, national forests cover about 7.8 million hectares (31%), municipal and prefectural forests make up about 2.7 million hectares (11%) and private forests is 14.6 million hectares (58%). The current growing stock is about 3.5 billion m^3 with an average annual growth of about 80 million m^3 consisting mainly of planted forest.

2.2.1 Natural forests

The distribution of the forest zones in Japan is determined primarily by temperature because the rainfall is generally sufficient.

Thus the distribution corresponds well with latitude and elevation (see Fig.2). There are five major natural forest zones:

Rainforest (sub-tropical)

Rainforests in Japan are restricted to the southwest islands of the Ryukyu chain. The dominant species of these forests are similar to the evergreen broadleaf forest of western part of Japan, but floristic elements from the Asian continent, southern China, the Philippines and Indonesia are also found.

Evergreen broadleaf forest (warm temperature/hill)

Evergreen broadleaf forests are distributed in the northern islands of Ryukyu chain and lowlands of Kyushu, Shikoku and southern Honshu. They are floristically and biogeographically unique. These forests are restricted to Japan, the southern coast of the Korean peninsula, and central and southern China. They differ from European and North American forests of the same climatic zone featured by dry summer and rainy winter. They are dominated by evergreen oaks with thick glossy leaves. Major species include *Quercus*, *Cyclabalonopsis*, *Castanopsis*, *Machilus* and *Cinnamomum*. The forests are layered, multi-aged, with the leaves concentrated in the upper crown.

Deciduous broadleaf forest (cool temperatute/mountain)

Deciduous broadleaf forests are distributed in highlands of Kyushu, Shikoku and souther Honshu, lowlands of northern Honshu and south to the central Hokkaido. Major species are beech (*Fagus crenata*) and oak (*Quercus mongolica* var. *grossesrrata*). Although beech forests predominate in Honshu, the species composition differs between the Sea of Japan side and Pacific Ocean side. In the Sea of Japan side, *Fagus crenata* is predominate in association with *Quercus mongolica* var. *grossesrrata*, *Acer japonicum* and *Betula maximowicziana*. In the Pacific Ocean side, *Abies* and *Fagus japonica* is predominate in association with *Quercus serrata*, *Carpinus laxiflora* and *Carpinus tschonoskii*.

Evergreen coniferous forest (subalpine)

Evergreen coniferous forests are distributed in the sub-alpine zones of northern Honshu and Hokkaido and lowlands of eastern Hokkaido. In some zone, deciduous birch (*Betula ermanii*) also grows. Major species are *Abies* and *Picea*. These forests are similar to other sub-alpine forests in the northern hemisphere.

Shrub/tundra forest (alpine)

Shrub/tundra forests are distributed in the alpine zones of northern Honshu and Hokkaido. There are only low trees such as *Pinus pumila*.

2.2.2 Plantation Forests

Plantation forests are a significant and important in Japan. Reforestation has a long history in Japan. Major species are sugi (*Cryptomeria japonica*), hinoki (*Chamaecyparis obtusa*) and matsu (*Pinus* species). Plantations now occupy about 41% of the total land area, the majority of which were planted after World War II. Initially, plantations were established for protection purposes as well as timber production. Recently the roles of forests have expanded to include wind control near coasts, fish breeding habitat, scenic reserves and recreation areas.

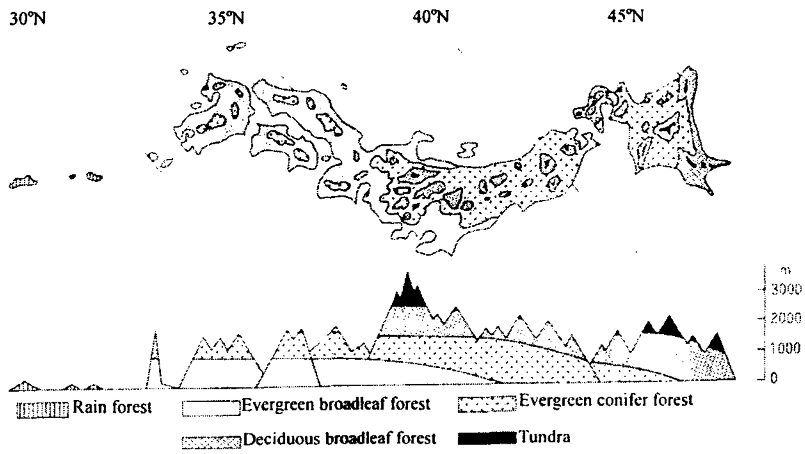

Fig.2 Distribution of natural forest in Japan (Tadaki, 1992)

2.3 Current State of Forest Management in Japan

2.3.1 After the Forestry Basic Law

Various measures under the Forestry Basic Law enacted in 1964 have increased forest resources as well as wood supply capability. However, the scale of forest management size has not expanded; 94% of forest owners have less than 20 hectares of forest. Moreover, the demand has shifted drastically from domestic timber to imported timber; the self-sufficiency ratio was fallen to 19% in 1999. Wood demand has declined and forest-products prices have been stagnant for a long time. There are approximately 6,000 forestry enterprises of log production and silviculture. Sixty four percent of them are private, and many of them are small and weak in management. Forestry employees has been decreasing (70,000) and getting older (29% are older than 65 years old). Improvement of forestry came to a standstill and the forestry and wood industry became stagnant.

The public demands for forests have become diversified and specific such as a growing expectation for recreation, the conservation of the natural environment, and the mitigation of global warming. Forests of 8.87 million hectares are designated as Protection Forests for securing water resources, preventing natural disasters, preserving living environment and so on (see Table 1). It should be noted that almost 90% of the Protection Forests are designated for securing water resources and preventing sediment discharge, thus highly related with hydrology and water resource management.

Table 1 Area of Protection Forest in Japan (1,000 ha)

Category	National forest	Private forest	Total
Securing water resources	3,291	3,096	6,387
Preventing sediment discharge	783	1,320	2,103
Others 15 categories	429	554	983
Total (some are categolyzed more than one)	4,503	4,970	9,473
Actual total	4,209	4,658	8,867

2.3.2 Reform of national forest management to create "forests for the people" in 1998

The national forests, approximately 20% of the land and about 30% of the entire forest area, are mainly located in the backbone mountain ranges or upstream water reservoir areas. In order to manage the national forests as "common assets of the nation, with the people's participation, for the sake of people", laws concerning the reform of national forests was enacted in 1998, which include a shift to social-benefit-oriented forest management, the establishment of a simple and efficient operation system through the streamlining and cutting back of organizations and personnel.

By the reform, the national forests for social objectives were enlarged from 50% to 80% of total national forest area. These objectives include 1) water resource management, soil conservation, and sheltering, 2) conservation of ecological, cultural, historical, recreational and spiritual values, and 3) sustainable use of wood resources.

2.3.3 Revision of the Forestry Basic Law as the Forest and Forestry Basic Law in 2001

The Forestry Basic Law enacted in 1964 was revised as the Forest and Forestry Basic Law in July, 2001. The backgrounds of the former and new policies are compared in Table 2. The philosophy of the new policy is to fulfill the multi-functional role of forests by the "sustainable forest management". Directions of the new policy are as follows (Forestry Agency, 2001)

Fulfillment of the multi-functional role of forests

In order to maintain soundness and vitality of forests, and to meet public demands toward forest management according to forest classifications, introduction of long-term cyclical forest management, constant implementation of forestry works including thinning of plantation forests must be promoted.

Promotion of cyclical use of forest resources

In order that forestry will be able to continue to be responsible for the maintenance of forests as well as the sustainable use of forest resources, fostering work force capable of effective and stable forest management, intensifying forest works and management, securing and developing employees must be promoted.

Vitalization of mountain villages

In order that mountain villages will be able to play an important role in creating safe and prolific national land, while utilizing local resources, mountain villages need to be vitalized by creating and securing diverse job opportunities, by improving of living conditions and by promoting interchange activities with cities.

Setting the objectives of forest management and use of forest resources

In order to stabilize the supply of wood products with reliable quality, increasing efficiency of distribution system through information technology and utilizing local timber must be promoted for the wood industry to contribute to the cyclical use of forest resources in future.

Table 2 Comparison of background of the former and new forest policies

	Background of the former Forestry Basic Law	Background of the new Forest and Forestry Basic Law
Demand for wood	Wood supply did not meet the increasing demand by the economic growth.	80% of wood is imported and domestic supply has been decreasing.
Public demand for forests	Immediate action for enlargement of wood supply and stabilization of the price was required.	Demand for multi-functional role of forest has been increasing
Forest management	Development of deep undeveloped forests and enlargement of plantation forests was conducted to increase wood supply.	Implementation of thinning of plantation forests and promotion of long-term cyclical forest management are required.
Forest owner	Ambition of forest owners for plantation and wood production was vital in accordance with the vigorous demand for wood	Decreasing profitability of forestry and generation shift has lost interest of forest owners toward forestry.
Social-benefit of forests	Social-benefit of forests was considered to be involuntarily obtained by the forest management to promote forestry.	Possibility of harm to social-benefit of forests by non-thinning plantation forests and non-planted cutovers has emerged.

3 TREND OF FOREST HYDROLOGY IN JAPAN

Hydrology was established as a modern science based on the measured data in late 17th century. Since then, the contents of hydrology had gradually expanded. They were rapidly enlarged in 1990s when global environmental problems and scarcity of water resources became worldwide issues to be tackled, which stimulated to establish the Japan Society of Hydrology & Water Resources (JSHWR) in 1988.

The contents of forest hydrology have been widening in accordance of the changes of the forest management as well as the above-mentioned movement. Since 68% of the land is covered by forests, almost all the hydrological events are somehow related to forests, and a large number of hydrological studies is closely related to forests.

Forest hydrology was initiated in Germany and France when forest observatories was set in 1860s (Fukushima, 1992). In 1899, the measurement of discharges from two watersheds having different vegetation cover started in Switzerland. Referring to this experiment, experimental watersheds were set in Ohta and Kasama within the Tokyo Forest District in 1904, which is the beginning of forest hydrology in Japan. The University of Tokyo established a experimental watersheds in Ashiyatsu in the Chiba Experimental Forest in 1913 (Kuraji, 2001). The former National Forest Experimental Station initiated the measurement of discharge in the Tatsunokuchi experimental watersheds in 1937.

Other organizations have also started forest hydrological measurement since the International Hydrological Decade (IHD) was initiated in 1965. The Japanese Forestry Science and The Japan Society of Erosion Control Engineering were the major societies to conduct forest hydrology at this stage. However, the other societies dealing with hydrology also studied hydrological cycles of forests because most of the land was covered by forests in Japan. Common objectives in these studies were to qualitatively evaluate the hydrological functions of forests; whether forests conserved water resources or not, and whether forests prevent flood or not . Principal interest was put on the relation between rainfall and discharge.

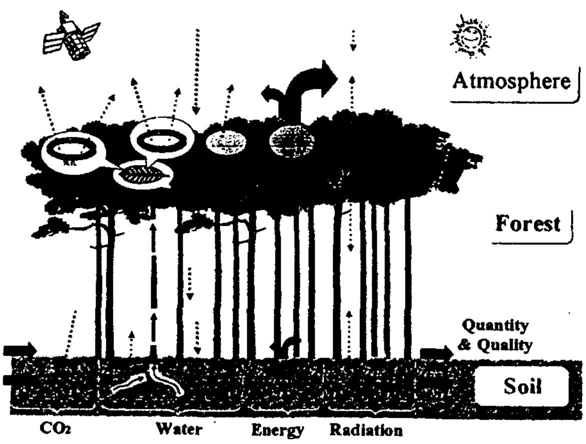

Fig.3 Current contents of forest hydrology in Japan

Since 1980s, hydrological elemental process such as evapotranspiration, soil water movement (infiltration, throughflow and subsurface flow), and overland flow have been studied in various hydrological societies. In forest hydrology, water movement within the canopy such as interception, stemflow and throughfall have also became spotlighted. At the same time, studies on water quality in the hydrological cycle emerged.

In 1990s, Soil-Plant-Atmosphere-Continuum (SPAC) models were introduced, which required physiological measurements and knowledge. Remote sensing analysis has became widely used in forest hydrology because of its capability of simultaneous and large-scale measurement on the complex terrain of mountains. Flux measurements obtaining fluxes of CO_2, sensible heat and latent heat have been spotlighted because of the global warming, which required eco-physiological knowledge.

4 NEEDS FOR INTERDISCIPLINARY STUDIES *–Long-Term Ecological Research–*

As mentioned above, forest hydrology has become more diversified, and ecology, physiology, meteorology, soil physics, remote sensing and other environmental sciences become parts of forest hydrology. The importance of ecology has greatly enhanced in recent years, and ecology become inevitable science to deal with various environmental issues. Thus, the relation between forest hydrology and ecology become especially tight.

4.1.1 International Long-Term Ecological Research (ILTER)

The U.S. National Science Foundation established the U.S. Long-Term Ecological Research (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.

4.2 Korea Long-Term Ecological Research (KLTER)

Korea has established the national Korean LTER (KLTER) Network in 1997, and become a member of ILTER Network (Kim *et al.*, 2002). There are three official research sites in mountainous forests (Kwangnung Experimental Forest, Mt. Kyebangsan Forest and Mt. Keumsan Forest) and eight potential sites. The detail information of the sites is obtained from http://klter.kookmin.ac.kr/intro/klter_data.htm. The major objectives of the KLTER are to investigate the dynamics of structure and function of ecosystem related to the changes of environment.

KLTER intensively held LTER meetings (East Asia-Pacific Regional ILTER Workshop in 1998, 3rd East Asia-Pacific LTER Conference in 1999 and Korea-China Joint Serminar on Ecosystem Research and Sustainable Management in 2000). However, KLTER is still under development (Kim *et al.*, 2002). The internet information on KLTER (Kim *et al.*,2002) implies that hydrological research may not be sufficiently involved in KLTER activities.

4.3 Japanese Long-Term Ecological Research (JLTER)

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. One hundred twelve research sites have been registered for the LTER, and they are listed in the URL of http://ecology.kyoto-u.ac.jp/jlter/inventory/list.htm. In Japan, the number of the research sites are abundant compare with 24 sites in the U.S.LTER and 11 sites in the KLTER. The Japanese research sites are rather small and investigations in the sites are conducted individually or by a small group with small fund whereas many researchers, technicians and students are intensively investigate in a few large scale sites in the U.S.LTER Network.

Honma (2001) summarized the characteristic of the status of the activities toward LTER in Japan as follows:

- A great number of research sites are densely distributed within a small land.
- There are many sites having same purposes.
- Continual fund is scarce.
- Continual research is difficult because of too many moves of the researchers.
- Methods of measurement within the sites of same purpose are not yet standardized.
- Network among the research sites is scarce.
- Research supporting system such as database and technicians is infirm.
- There are many single purpose research sites, and it is difficult to develop interdisciplinary researches.

Honma (2001) establish the network of the researchers who investigate beech with about 20 researchers and 17 sites in Japan. The network called as Nutwork started investigation of beech with the same method followed by the same manual, and the data have been stored in a same format. Their work enable the comparative studies and the group has obtained many useful results and knowledge. However, since their work has conducted mainly by individual researchers, it has been very difficult to maintain the long-term research as shown in Table.3.

Table 3 Changes of the numbers of researchers and sites in the Nutwork (Honma, 2001)

(a) Number of researchers

Fiscal year	No of researchers	Non-move	Newly joined	Move once	Move twice
1993	20				
2001	24	7	4	6	7

(b) Number of sites

Fiscal year	No of sites	Non-move	Newly joined	Change researcher	Discontinue
1993	17				
2001	21	5	4	5	7

4.4 University Experimental Forests as potential sites for JLTER

Honma (2001) suggested to use the university experimental forests distributed country wide for LTER effectively. 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, which would be LTER Network in future. The one is the Phenology Observation Network in which tree phenology has been observed in 22 forests in 12 universities. The other is the Database of Acidic Deposition in which water quality of rainfall and stream flow have been observed in 15 forest watersheds in 14 universities. In the both projects, observations have been conducted in a same manner under the unified manual. The databases have been opened through internet:

Phenology http://www.hkuf-unet.ocn.ne.jp/phenology/kekka.html
Acid Rain http://pc3.nrs-unet.ocn.ne.jp/~zenen/wg.html

There are 74 experimental watersheds in 29 university experimental forests. Among these watersheds, Tokyo University Forest in Aichi has the longest history. There are four experimental watersheds having the area of 14~110ha. Discharges have been observed for about seventy years, and the data have been published since 1930. All the raw data have been carefully stored, and saved in microfilm. Discharge ledgers calculated from water levels have been stored in two places (Kuraji, 2001). Although they have lead the hydrological observation of the experimental watersheds in university experimental forests, the hydrological observation network has not been formed.

5 LONG-TERM FOREST HYDROLOGICAL RESEARCH NETWORK

Meteorological observation network has long history and wide spread in the world. In case of Japan, there are almost 150 standard meteorological station and about 1,300 Automated Meteorological System (AMeDAS) stations managed by the Japan Meteorological Agency. The facilities, instruments, elements, method and database have been strictly followed by the guidelines, and accuracy and homogeneity of the data have been highly maintained. Their data are sold by the Japan Meteorological Business Support Center through on-line system or various off-line system such as CD-ROM, FD, MO and MT.

Hydrological observation network has not yet standardized compared with the meteorological network. Ministry of Land, Infrastructure and Transport are the main organization to conduct hydrological observation in Japan. Some of their data have been presented through internet http://wdb-kk.river.or.jp/zenkoku/.

Although the above mentioned data are useful and valuable, the data in the mountainous area are too scarce to understand the ecosystem in detail. Thus, establishment of long-term forest hydrological research network including mountainous area is strongly required. In United States, these network has already established and data are freely presented. In the U.S. LTER, such data are freely supplyed through internet http://lternet.edu/data/. 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 http://www.nwrc.ars.usda.gov/databases/index.html. To meet the demand in establishing the long-term forest hydrological research network and open the database in Japan, the Mountainous Watershed Catalogs & Database Research Group in JSHWR initiated the preparation with other scientific groups related to hydrology in 2000. It is a great opportunity to cooperate in this work with KWRA in this early stage of preparation. It will be a great first step to conduct a cooperative forest hydrological research between JSHWR and KWRA.

6 CONCLUSION

In this paper, the status of forest and forestry together with the trend of forest hydrology in Japan are briefly overviewed. The Japanese forests had been extensively conserved by some regulations and plantation. They seemed to be most severely devastated in the postwar days of World War II about 50 years ago. Under the Forest Law and the Forestry Basic Law as well as the Erosion Control Law, intensive plantation has been conducted and the forests have been successfuly recovered. It has led Japan to be one of the most broadly forested countries within 50 years. Moreover, the disasters of flood and landslides have been reduced due to the afforestation on the vulnerable sloping wildlands. However, although about 68% of the land has become forested, self-sufficiency of industrial wood has decreased to about 19% and forestry industry has been stagnant. On the other hand, public demand for forests has gradually changed and diversified such as growing expectation for recreation, the conservation of the natural environment, and the mitigation of global warming, etc. Accordingly, forest policy has drastically changed from production of forest products to fulfillment of multi-functional role of forests in a sustainable way. The role and system of the National Forest was changed in 1998, the Forestry Basic Law was revised as the Forest and Forestry Basic Law in July 2001, and the Forest and Forestry Plan is established in October 2001. Consequently, we are just in the midst of the turning point of the forest management in Japan. What we should notice is that the role of hydrology and water resource management are greatly enhanced by this reform.

Forest hydrology has become more diversified, thus interdisciplinary researches have been widely conducted. In recent years, ecology, physiology, meteorology, soil physics, remote sensing and other environmental science become part of forest hydrology. However, hydrological database system has not been established nor utilized as compared with meteorological database. To overcome this situation, the Mountainous Watershed Catalog and Database Research Group was established in JSHWR in May, 2000. Collaboration in the activity with the KWRA is recommended to widen the usefulness of the catalog and database system. Moreover, establishment of Japan-Korea long-term forest hydrological research network is highly recommended to enable comparative studies not only in hydrology but also other related fields such as ecology and geochemistry, deepen our environmental knowledge and enhance the environmental management.

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