Comparison of Soil Surface Evaporation between Natural Broad-Leaved Forest and Artificial Needle-Leaved Forest*

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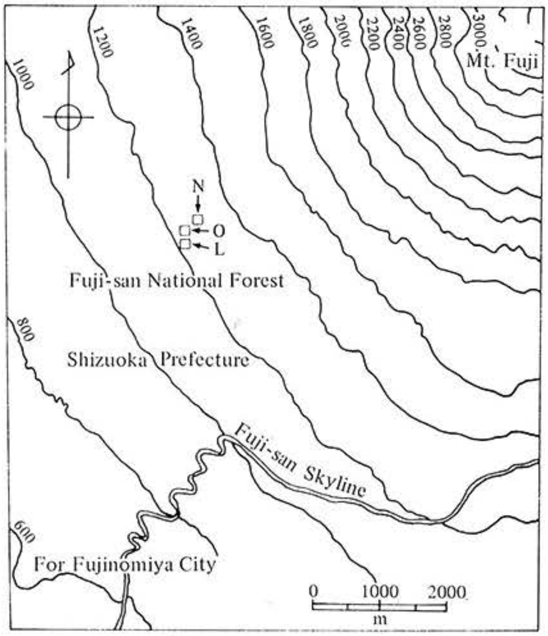
Introduction

A series of experiments have been in progress to make clear changes in hydrological process caused by conversion of the forest management type from natural broad-leaved forest to needle-leaved forest planted after the clear cutting of the former, in the national forest at the foot of Mt. Fuji. In that study, experimental plots for both the forest management types were set up, and interception, ground-rainfall, soil moisture, transpiration rates, etc. were measured.

As a part of that study program, the authors attempted to compare the amount of evaporation between natural broad-leaved forest and artificial needle-leaved forest. For the measurement of evaporation, two experimental plots; one in the natural broad-leaved forest (hereafter referred to the plot L) and the other in artificial needle-leaved forest (the plot N) were set up (Plate 1). In addition, an observation field which serves as the standard for the comparison was set up in an open space in newly planted forest after the clear cutting.

Description of the study site

In the Mt. Fuji national forest, an area locating southwest (Fujinomiya-city, Shizuoka Prefecture) of Mt. Fuji was selected as the study site, because natural forest and artificial forest (after clear cutting) are present side by side in this area. The area is 1,250–1,300 m above sea level, and has annual



L : Natural broad-leaved forest
N : Artificial needle-leaved forest
O : Observation field

Fig. 1. Location of experimental sites

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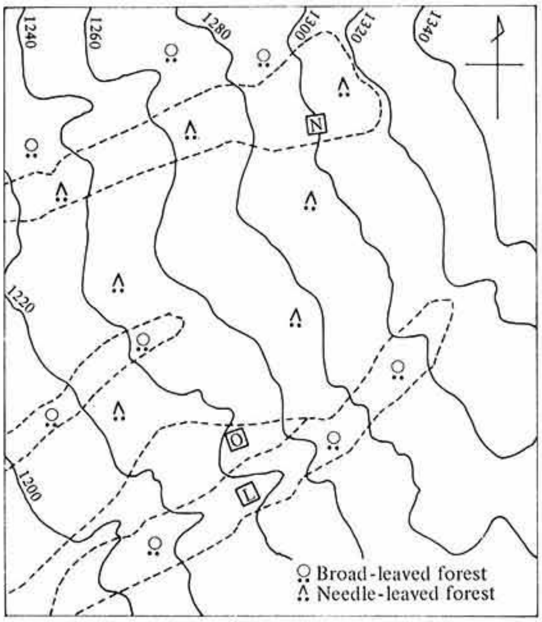


Fig. 2. Experimental plots (N and L) and observation field (O)

Table 1. Some factors of each experimental plot

Factors	Experimental plots	
	L	N
Vegetation type	Natural broad-leaved forest	Artificial needle-leaved forest
Main tree-species	Mizunara, *Quercus crispula*	Hinoki, *Chamaecyparis obtusa*
Stand age (years)	10—130	40
Growing stock (m^3/ha)	215	257
Slope bearing	NW	W
Inclination angle(°)	28	22

precipitation of about 2,000 mm (data of a near rain-gauge station[5]). The vegetation zone of this area belongs to the transitional region from the mountain zone to the subalpine region, based on climatic conditions of the area (Figs. 1 and 2). Broken lines in Fig. 2 show subcompartments of silviculture in the national forest.

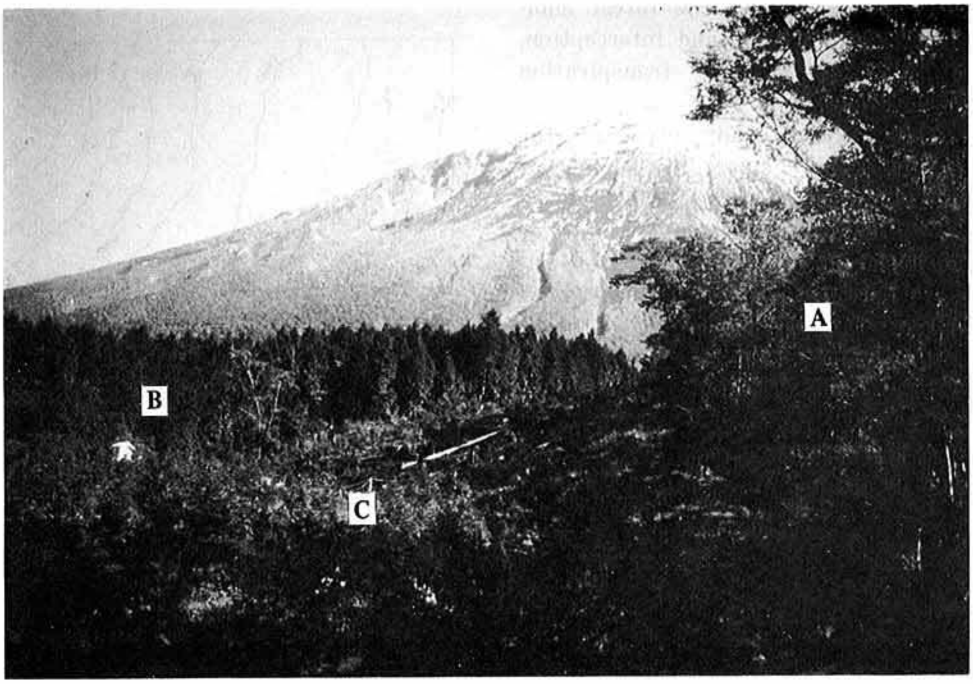


Plate 1. Experimental plots
A : Natural broad-leaved forest (plot L),
B : Artificial needle-leaved forest (plot N),
C : Observation field in an open space of newly planted forest after clear cutting.

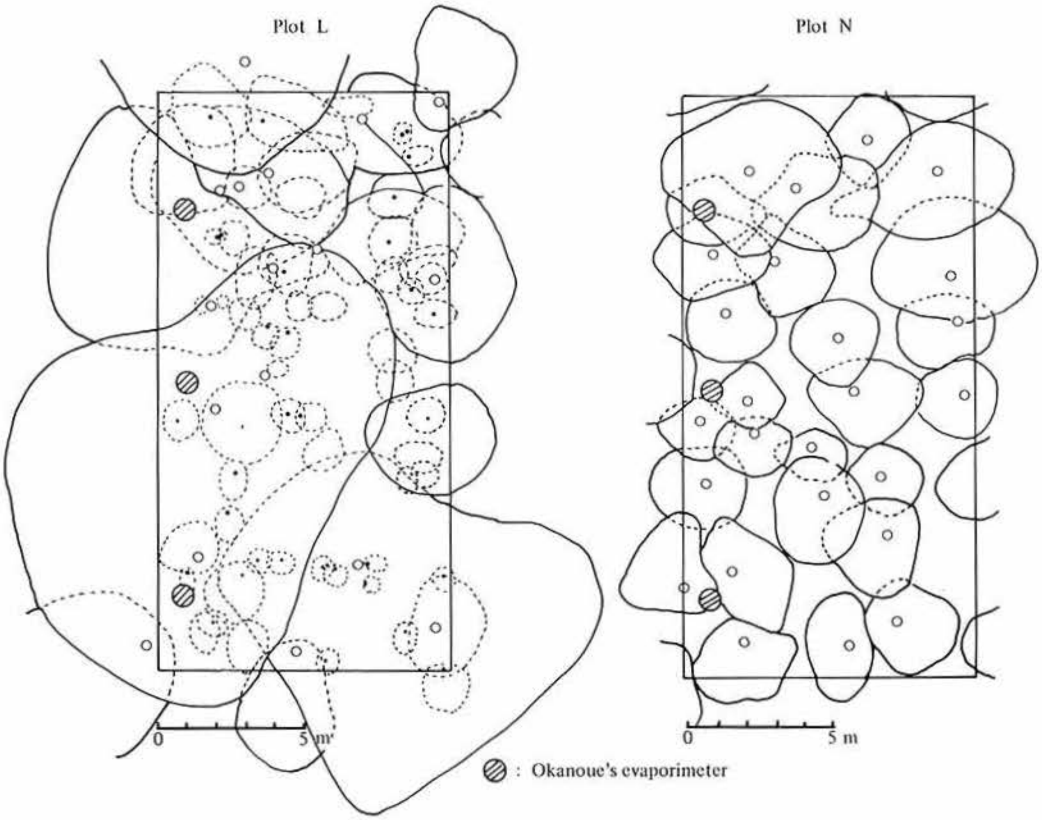


Fig. 3. Crown projection of the plots L and N

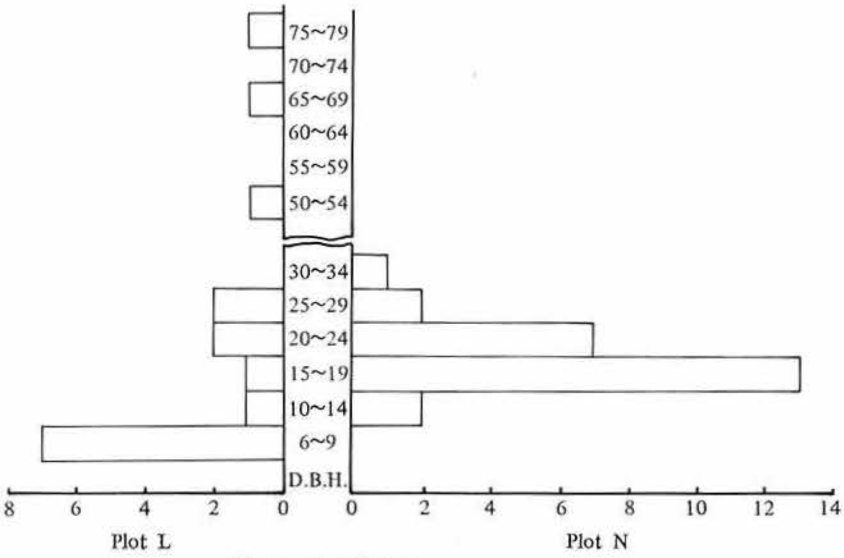


Fig. 4. D. B. H.-class distribution of the plots

Surface geology consists of ejecta of volcanic eruption of Mt. Fuji, and the soil belongs to Darkbrown forest soils.

In the plot L, mizunara (*Quercus crispula* Blume) and buna (*Fagus Crenata* Blume) of 10–130 years old are major, while in the plot N, 40 years old hinoki (*Chamaecyparis obtusa* Sieb. and Zucc.) and urajiromomi (*Abies homolepis* Sieb. and Zucc.) are major, as shown in Plate 1 and Table 1. Their crown projection and the number of trees for DBH classes are given in Figs. 3 and 4, respectively.

Experimental methods

1) Okanoue's evaporimeter

For the measurement of soil surface evaporation in mountain forest, a method using a micro-lysimeter (15–22 cm in height and 11–17 cm in diameter), which is placed in soil and its weight is measured[1,2], etc. is attempted as a trial. However, in the present experiment, the simple integrating evaporimeter[4] (hereafter referred to Okanoue's evaporimeter) was used.

The structure of this evaporimeter given in Fig. 5 and Plate 2 is self-explanatory. The chamberland bacterial filter (70 mm in length and 16 mm of diameter, L-1 type) serves as the surface for evaporation, and is connected to a plastic bottle, through a plastic pipe. At the basal portion of the pipe, a special device to prevent rain water from entering into the bottle is installed. It is a glass tube (3.5 mm of inside diameter), which has two blocks of cigarette filter and a drop of mercury (2 mm in thickness) placed above the lower block.

Now, the whole system of the evaporimeter is filled up with distilled water. Whenever the evaporation takes place from the bacterial filter, water in the bottle enters into the pipe to offset evaporated water, passing through the interface between mercury and glass tube wall. When it rains, mercury acts as a valve to prevent rain water invasion. It is necessary to confirm such a function of this device with a water-sprinkling test, before the evaporimeter is used in experiments.

This evaporimeter can be assembled easily when its parts are available.

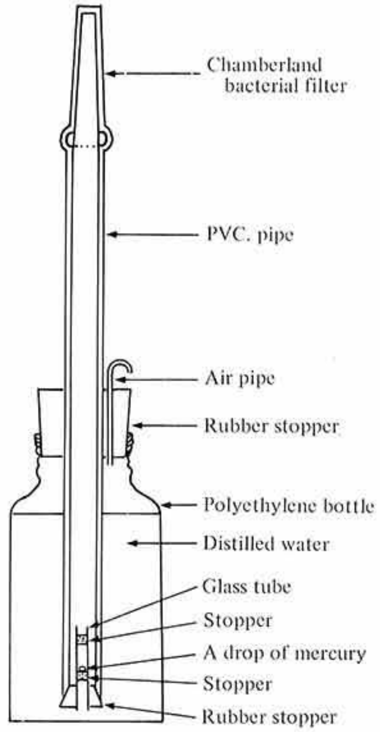


Fig. 5. Structure of the Okanoue's evaporimeter

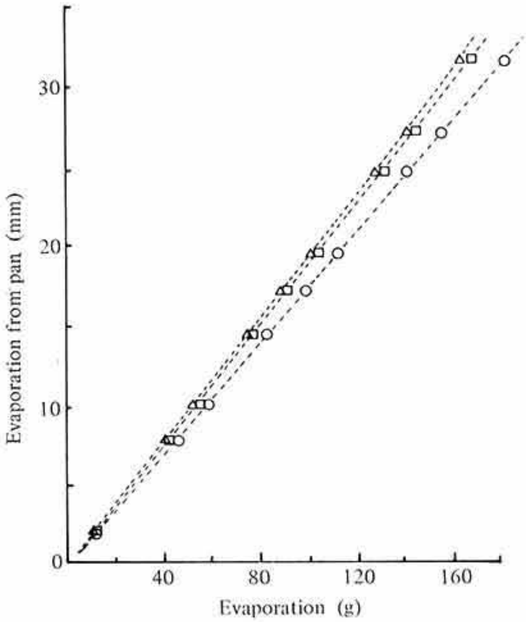
2) Installation of the evaporimeters

As shown in Fig. 3, the evaporimeter was installed at three sites on a slope (20 m) of the experimental plot. Average of values at three sites was taken as the value for the plot. The evaporimeter is placed on a supporting board so as to keep the evaporation surface (bacterial filter) at 30 cm above the ground surface. The amount of evaporation was measured by weighing the evaporimeter every week using a balance (sensitive to 1 g). In winter, no measurement was done, because freezing was expected.

3) Calibration between the Okanoue's evaporimeter and evaporation pan

With the Okanoue's evaporimeter, the amount of evaporation is expressed by the decrease of water (in g). To convert this value to water height (mm), the calibration

Plate 2. Okanoue's evaporimeter
A : Okanoue's evaporimeter
B : Rain guage



△ : The evaporimeter used in the plot N
○ : The evaporimeter used in the plot L
□ : The evaporimeter used in the observation field

Fig. 6. Relationship between evaporation from the pan and that from the Okanoue's evaporimeter

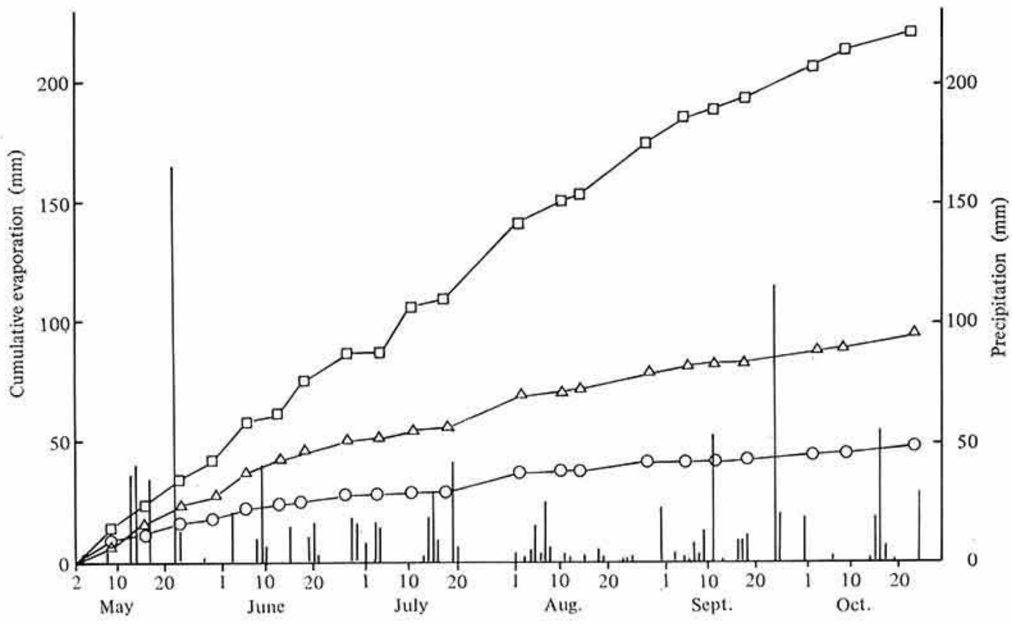
graph of evaporation pan (20 cm diameter and 10 cm depth, cupper made pan) was prepared. The measurement was made in a glassroom of a phytotron at the temperature of 25°C/20°C (day/night) and humidity of 75%. An evaporation pan was surrounded by three evaporimeters, and the average of values shown by three evaporimeters was obtained. The amount of evaporation/day was 2.5 mm with the pan, while it was 13.6 g (averaged) with the Okanoue's evaporimeter. The relation between both values expressed linear regression (Fig. 6). However, some difference in regression equations was observed due to individuality of the evaporimeters used. Hence, the calculation of water height (mm) from the values of evaporimeters was made using the regression equation specific to each evaporimeter.

Results and discussion

The period of observation was 175 days from May 2 to October 24, 1987. Fig. 7 shows cumulative evaporation (mm) in the plot N, plot L, and in the observation field, together with the amount of daily precipitation[5].

As compared with the cumulative evaporation of 223 mm in the observation field, the plot N showed 95 mm and plot L only 49 mm. These values are 41.5% and 24.0% of the value in the observation field. Thus, the evaporation in forest was remarkably less than that in the open space (observation field). Particularly, that of the plot L was about 50% that of the plot N. During the long rainless period from July 17 to August 2, the evaporation in the observation field showed a peak (2.1 mm/day in average of the period). During that period, the plot N and the plot L showed 0.9 mm/day and 0.5 mm/day, respectively. The percentages of these values to 2.1 mm/day were approximately similar to the percentages shown with the cumulative evaporation of the whole observation period as shown above.

Fluctuation of soil moisture (at the depth of 0–40 cm)[6] indicates that the rate of soil moisture fluctuation against the amount of precipitation is 30–40% in the plot L while it is 70–80% in the plot N. It shows less soil moisture fluctuation in the plot L.



△, ○, □: See Fig. 6.

Fig. 7. Cumulative evaporation from each experimental plot

Meteorological factors which are generally recognized to be concerned with evaporation, such as solar radiation, air temperature, humidity and wind velocity, are considered to act toward the suppression of evaporation in the forest. For example, solar radiation is reduced by the closure of tree canopies and, as a result, the mean daily air temperature becomes lower than that outside the forest. Furthermore, tree trunks resist against wind and reduce wind velocity.

Since the net radiation is considered to represent the combined effect of these meteorological factors, listed above, upon the evaporation in forest, Hattori[2] measured the net radiation on the forest floor as well as above the canopy of planted forest of hinoki (*Chamaecyparis obtusa* Sieb. and Zucc.) (29 years of age), and reported that the former was about 15% of the latter. Because the forest type of the plot N in our experiment resembles that of the forest used by Hattori for his study, the net radiation on the forest floor of the plot L is supposed to be further less.

Furthermore, it seems that the difference in the amount of evaporation between the plot N and plot L is caused by different stand composition. Namely, the plot N is even-aged, uniform hinoki forest, showing 6 m of the height of the first main branches, but without under stories trees. On the contrary, the plot L is compound storied forest, composed of the upper layer, second layer and under stories trees. This structure seems to be the main factor reducing evaporation. It must be noted here that the evaporation measurement was made during the growing period. In winter, needle-leaved forest continues to exert the covering effect, whereas broad-leaved trees shed their leaves. Although the amount of evaporation in winter is supposed to be extremely small, comparison of the evaporation throughout the year may be necessary from the standpoint of water loss from forest land.

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