Effect of Degradation of Forest Land on Erosion and Infiltration Capacity of Soil

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Abstract

Agricultural activities in forest land may not only cause top soil erosion but also reduce the infiltration capacity of soil through the changes of the conditions of the soil surface. In this study the effects of forest stand formation and crop cultivation on soil erosion were examined in a prospective site for agroforestry in Luzon island, the Philippines. Also the influences of stand growth and differences in land-use types on the infiltration capacity of soil were examined in reforestation sites. The amount of sediment deposited on slopes which were covered with different types of vegetation after 170㎜ precipitation occurring once was as follows : bare land, about 2.8 ton/ha ; ginger field, 2.0 ton/ha and young forest and grassland, 0.3～0.8 ton/ha. The soil erosion rate tended to increase with the increase of rainfall, especially in the case of bare land. On the other hand, the infiltration capacity of the top soil in forest land under different conditions was as follows : bare land with annual burning, 100 ㎜/hr and less ; grassland or man-made young forest, 200～500㎜/hr, and natural forest or man-made forest with ten years old stands, 500㎜/hr and over. The infiltration capacity generally tended to increase in a natural forest or old man-made forest compared with young forest or bare land. It was confirmed that the activities of earthworms in the soil of forest land led to a porous structure and played an important role in the increase of the infiltration capacity of the soil surface.

Introduction

Forest land shows a higher capacity for soil and water conservation than other kinds of land use. Therefore if forest land is converted into other land uses, soil erosion is likely to be promoted. Especially burning and agricultural activities in forest land may cause soil erosion and also reduce the infiltration capacity of soil through the changes in the conditions of the soil surface. Erosion results not only in the transport of top soil and land degradation which leads to the decrease of the productivity of upland farming, but also in the sedimentation or siltation of river beds, lakes, and reservoirs. Since human life and property may become damaged, the impact on the nation's economy is very serious.

In the tropics, due to both population pressure and shortage of food, people's demand for land is increasing rapidly. The population pressure results in the conversion of forest land into agricultural land. More forest land and grassland are being cleared for food production and then exposed to soil erosion. In recent years, agroforestry has developed rapidly and may contribute to the solution of the problems mentioned above. However the functoin of agroforestry for soil and water conservation has not been fully clarified. Therefore it is important to evaluate the effects of various types of agroforestry systems on soil erosion, runoff of surface water and infiltration capacity of soil.

The purpose of this paper is to present experimental data on the effects of forest stand formation, for-

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est floor vegetation and crop cultivation on top soil erosion and infiltration capacity of soil which were examined in a prospective site for agroforestry and afforestation in Luzon island, the Philippines. These results were obtained from experiments carried out in 1990 and 1991 under the cooperative research program between the Tropical Agricuture Research Center, Japan, and the University of the Philippines at Los Banos (UPLB), The Philippines.

Methodology

1 Measurements of surface water runoff and soil erosion

Measurements of surface water runoff and soil erosion were performed in the Makiling Experimental Forest of UPLB and in the demonstration farm at the UPLB campus from August to September 1990. Experimental plots measuring 1m×2m were set up in areas with different vegetation covers for the analysis of runoff surface water and soil erosion. The plots were bound by GI-sheets (iron plates) buried at a depth of about 10 cm to prevent the inflow of surface water runoff into the plots or outflow from the plots. In the lower parts of the plots, plastic drums with a 48-liter capacity were placed. The amount of surface water runoff and eroded topsoil was measured with the drums after each heavy rainfall. After the measurement of the amount of runoff water in the drums, the water was stirred until the sediment or soil particles were completely mixed with the water. Thereafter, samples of 1-liter of water were collected form the stirred water. Filter paper and funnel were used to filter the soil particles from the water samples. The filtered sediment or soil particles were oven-dried and weighed.

In parallel with the measurement described above, the amount of daily rainfall and that of rainfall during several days were measured at the UPLB campus and in the Makiling Experimental Forest. A long term automatic recording rain gauge which was set up at the UPLB cumpus was used for measuring the daily rainfall. The rainfall during several days was measured after each storm or rain event using a non-automatic recording rain gauge which was set up beside the plots in the Makiling Experimental Forest. The location of the rain gauge was about 1.5km SW of the Yamashita historical monument, in Los Banos, Laguna. The altitude of the rain gauge site was about 240m above sea level.

The plots in the Makiling Experimental Forest consisted of anabiong (*Trema orientalis*) forest, kakawate (*Gliricidia sepium*) forest, cogon (*Imperate cylindrica*) grassland, ginger field and bare land (no vegetation). The anabiong and kakawate forests were man-made young forests. The vegetation condition of each plot is shown in Table 1. The slope gradient was 25° and the slope faced the SSE.

The plots of the demonstration farm at the UPLB campus consisted of a soybean field, mungo bean field, paayap field and bare land. The slope gradient was 20° and the slope faced the WNW. The treatments on each experimental site were replicated two times.

2 Measurement of infiltration capacity of soil

Measurement of infiltration capacity of soil was performed in Carranglan, the RP-Japan afforestation project site from March to April 1991. A simple plastic tube 110㎜ in inside diameter was used for measuring the infiltration capacity of soil. The method of measurement was as follows. First, the tube was

Table 1 Vegetation condition in each plot in the Makiling Experimental Forest (measurements were performed in August 25, 1990)

Plot	Height (m)	D. B. H (cm)	Density (no/ha)	Age (year)
Anabiong forest	3.75	4.35	10,000	3
Kakawate forest	3.77	2.87	10,000	3
Cogon grassland	0.50	—	268,770	—
Ginger field	0.25	—	40,460	—
Bare land	—	—	—	—

put into the soil at a depth from 45mm to 50mm. Then 400ml (42mm) of water was gently poured into the tube so as not to disturb the soil surface and the infiltration rate (time until infiltration of poured water) was measured. Such an operation was repeated five times. Finally, 2,000ml (210mm) of water was introduced.

In this study, the infiltration rate of 210mm of introduced water (IR for 210mm) was considered to reflect the infiltration capacity of the soil. Five tubes were installed in every plot.

Results and discussion

1 Characteristics of rainfall

Rainfall is an important factor for soil erosion. The rainfall data recorded around the research area

Table 2 Characteristics of rainfall during the experimental period (July 18 to September 3, 1990, UPLB Campus)

Period of total rainfall	Rain days (day)	Rainfall (mm)	Remarks
July 18-31	9	92.5	
August 1-31	21	271.0	
September 1-3	1	39.0	
July 18-September 3	31	402.5	
Maximum daily rainfall		87.0	August 24, 1990
Maximum hourly rainfall		23.0	August 24, 1990
Maximum 30-min. rainfall		13.0	September 1, 1990

Table 3 Several-day period of rainfall during the experiment

Date of measurement	Interval (days)	Rainfall(mm) Campus*	Rainfall(mm) Forest**
1990-8-14	4	22.0	29.0
16	2	10.5	14.0
18	2	32.5	51.8
20	2	45.0	57.3
23	3	18.0	38.7
25	2	89.5	162.8
27	2	35.5	66.9
9-3	8	43.0	91.2
Total		296.0	511.7

* UPLB campus

* * Makiling Experimental Forest

Table 4 Runoff rate in each plot

Plot	Total* (%)	Maximum* (%)
Bare land	19	36
Ginger field	18	42
Kakawate forest	13	28
Anabiong forest	13	32
Cogon grassland	9	16

* Period : from August 11 to September 3, 1990
with total rainfall of 512mm.

in the past, however, involved only daily rainfall. Table 2 summarizes the characteristics of the rainfall measured with a long term automatic recording rain gauge which was set up at the UPLB campus during the research period from July 18 to September 3, 1990. Heavy rainfall with maximum hourly amount of 23mm and 30-minute rainfall of 13mm (shower in the tropics) took place during the period.

Table 3 shows the amount of rainfall during several days from August 11 to September 3, 1990 at the UPLB campus and in the Makiling Experimental Forest. The amount of rainfall was always larger in the Makiling Experimental Forest than at the UPLB campus.

2 Runoff of surface water

Table 4 shows the runoff rate in each plot in the Makiling Experimental Forest. The runoff rate is the percentage of runoff against rainfall. Bare land gave the highest rate of 19% followed by the ginger field with 18%, the kakawate and the anabiong forests with 13% and the cogon grassland with 9%. It is interesting to note that the runoff rate in the cogon grassland was lower than that of the young forest, presumably because the high density of root system of cogon grass may increase the permeability of the top soil.

3 Soil erosion

a) Types of soil ersion

Types of soil erosion observed in the research area included rainsplash erosion, sheet erosion, rill

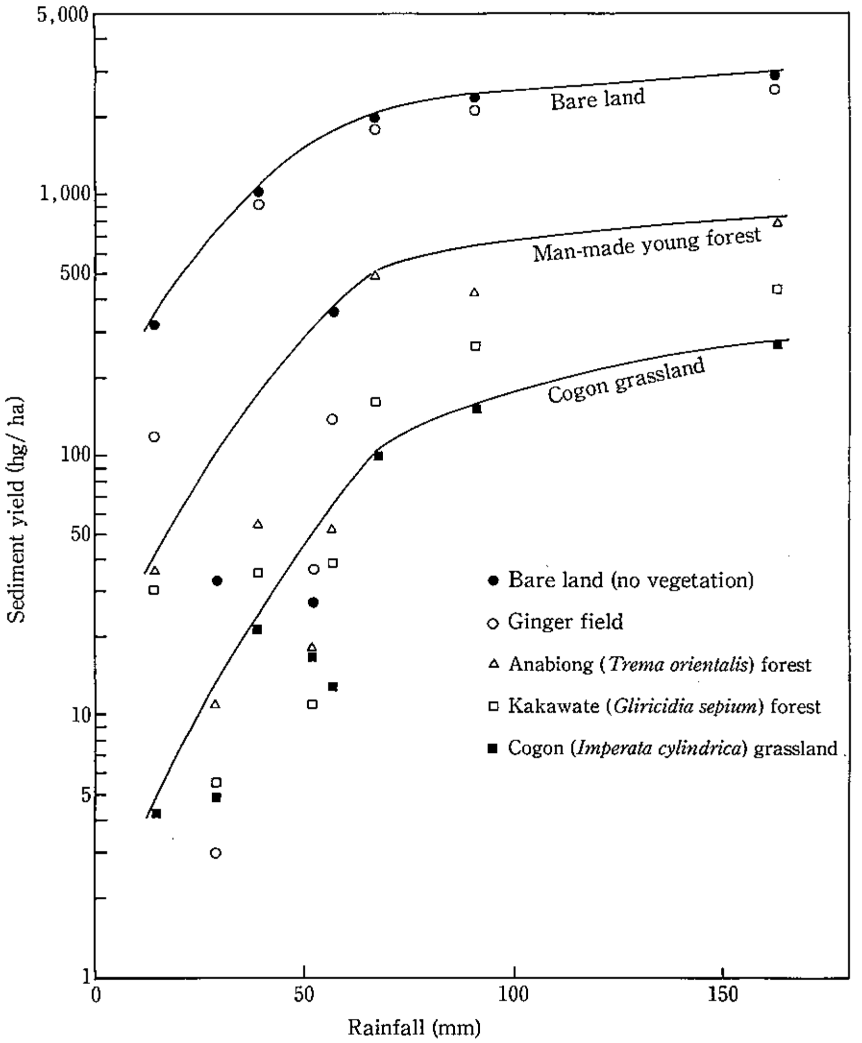

Fig. 1 Relationship between rainfall and sediment yield.

wash erosion and gully erosion.

Rainsplash erosion consists of the spattering of soil particles resulting from the impact of raindrops. Many marks caused by the spattering of soil were found on the wall of the GI sheet which was used for measuring soil erosion and also many soil columns were formed on the soil surface. These phenomena reflected the severity of the spattering action of raindrops.

Sheet erosion consists of the gathering and washout of soil passing through a sheet flood over a smooth slope.

Rill wash erosion is represented by the removal of soil by flowing water from a small channel. Average size of rill channels developed on the slope of a corn field in one season was 26.4cm in width and

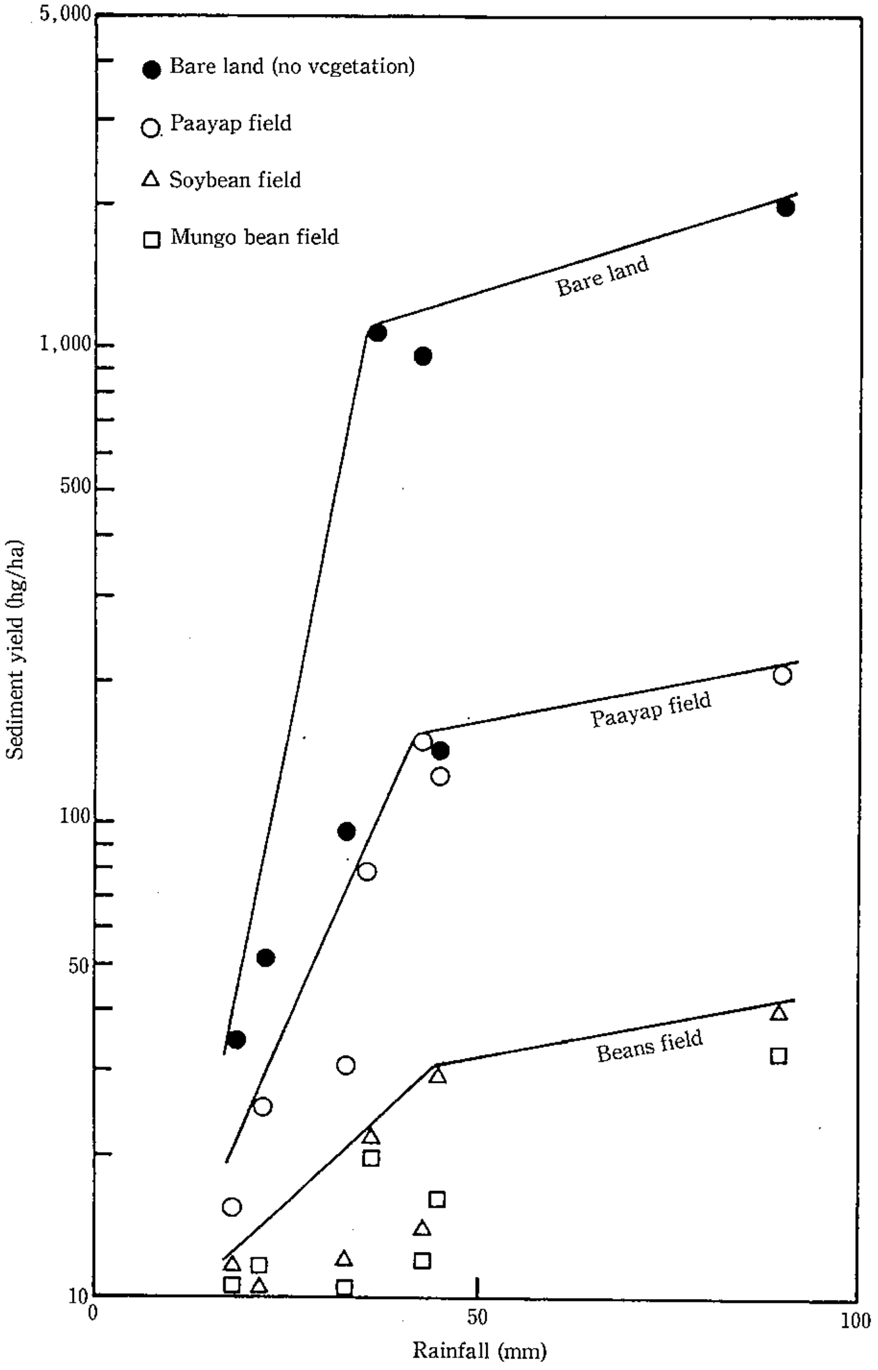

Fig. 2 Relationship between rainfall and sediment yield.

13.9cm in depth in the lower part of the slope and 20.0cm in width and 9.3cm in depth in the upper part of the slope. The length of the slope was about 50m and the slope gradient about 25°.

Gully erosion which is an advanced stage of rill wash erosion is characterized by the removal of soil and other materials from larger channels compared with rill. The end of the gully channels was sometimes connected with a creek.

b) Sediment yield associated with soil erosion

Figure 1 shows the relationship between rainfall (㎜) and sediment yield (kg/ha) in each plot in the Makiling Experimental Forest. There was a positive correlation between rainfall and sediment yield. As in the case of surface water runoff rate, the erosion rate was high for the bare land and the ginger field while low for the cogon grassland. The total amount of sediment yield on bare land and the ginger field during the period August 11 to September 3 was 9,204kg/ha and 7,610kg/ha followed by the anabiong forest with 1,942kg/ha, the kakawate forest with 965kg/ha and the cogon grassland with 851 kg/ha. The higher erosion rate of the anabiong and the kakawate forests than that of the cogon grassland, was attributed to the fact that since the forests were very young, the litter layer and net system were not yet developed while the cogon grass covered the ground completely at a high density. In bare land and in the ginger field, both rainsplash and sheet erosion may be related to soil erosion, while in the young forest and the cogon grassland, sheet erosion rather than rainsplash may be related to erosion.

Figure 2 shows the relationship between rainfall (㎜) and sediment yield (kg/ha) in each plot in the demonstration farm at the UPLB campus. There was a positive correlation between rainfall and sediment yield. The total sediment yield on bare land was by far the highest amounting to 5,812kg/ha fol-

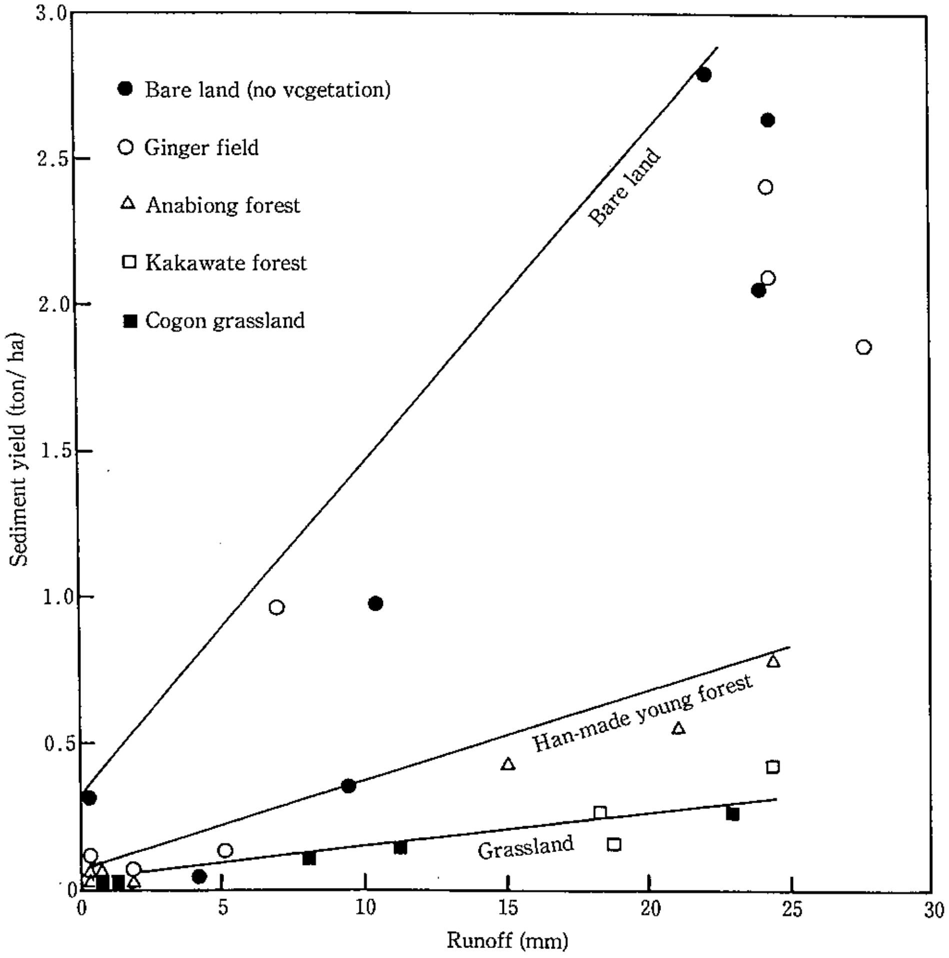

Fig. 3 Relationship between runoff and sediment yield

lowed by the paayap field with 642kg/ha, the soybean field with 128kg/ha and the mungo bean field with 111kg/ha. The sediment yield was reduced when the soil surface was covered with a dense vegetation canopy because the impact of rain splash or sheet erosion was attenuated. For example, since the culm of soybeans and mungo beans assumed a multistoried shape compared with paayap, the sediment yield in the soybean and the mungo bean fields was lower than that in the paayap field.

c) Relationship between runoff and sediment yield

Figure 3 shows the relationship between the amount of runoff (mm) and sediment yield (ton/ha) in each plot in the Makiling Experimental Forest. There was positive correlation between these paramenters. It was evident that the sediment yield in bare land and the ginger field in which the density of the culms is low was susceptible to the effect of runoff water.

4 Infiltration capacity

Figure 4 shows the relationship between the amount of introduced water (mm) and the infiltration rate (mm/ha) in each plot in Carranglan. There was a negative correlation between these parameters. The rate

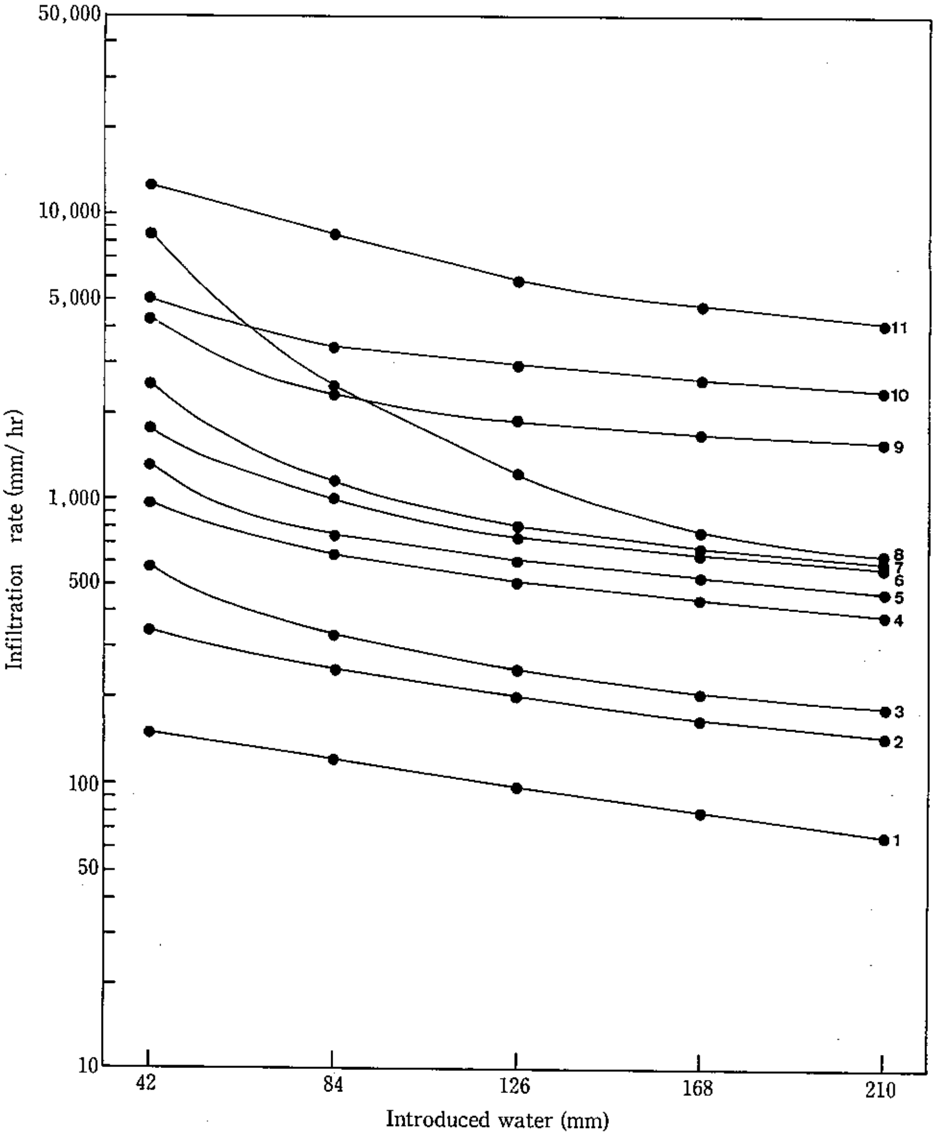

Fig. 4 relationship between introduced water and infiltration rate.
Note : characteristics of each plot are shown in Table 5.

was higher at the beginning and then it decreased gradually with time along with the introduction of water. This phenomenon was attributed to the saturation of soil with water or to the clogging of the pores with soil materials.

Figure 5 shows the relationship between IR' (㎜/hr) and the infiltration capacity (㎜/hr). Here, the IR' is the balance between the infiltration rate when 168㎜ (IR for 168㎜) and 210㎜ (IR for 210㎜) of water was introduced, respectively. As already mentioned, in this study the infiltration rate corresponding to the introduction of 210㎜ of water (IR for 210㎜) was considered to be the infiltration capacity. There was

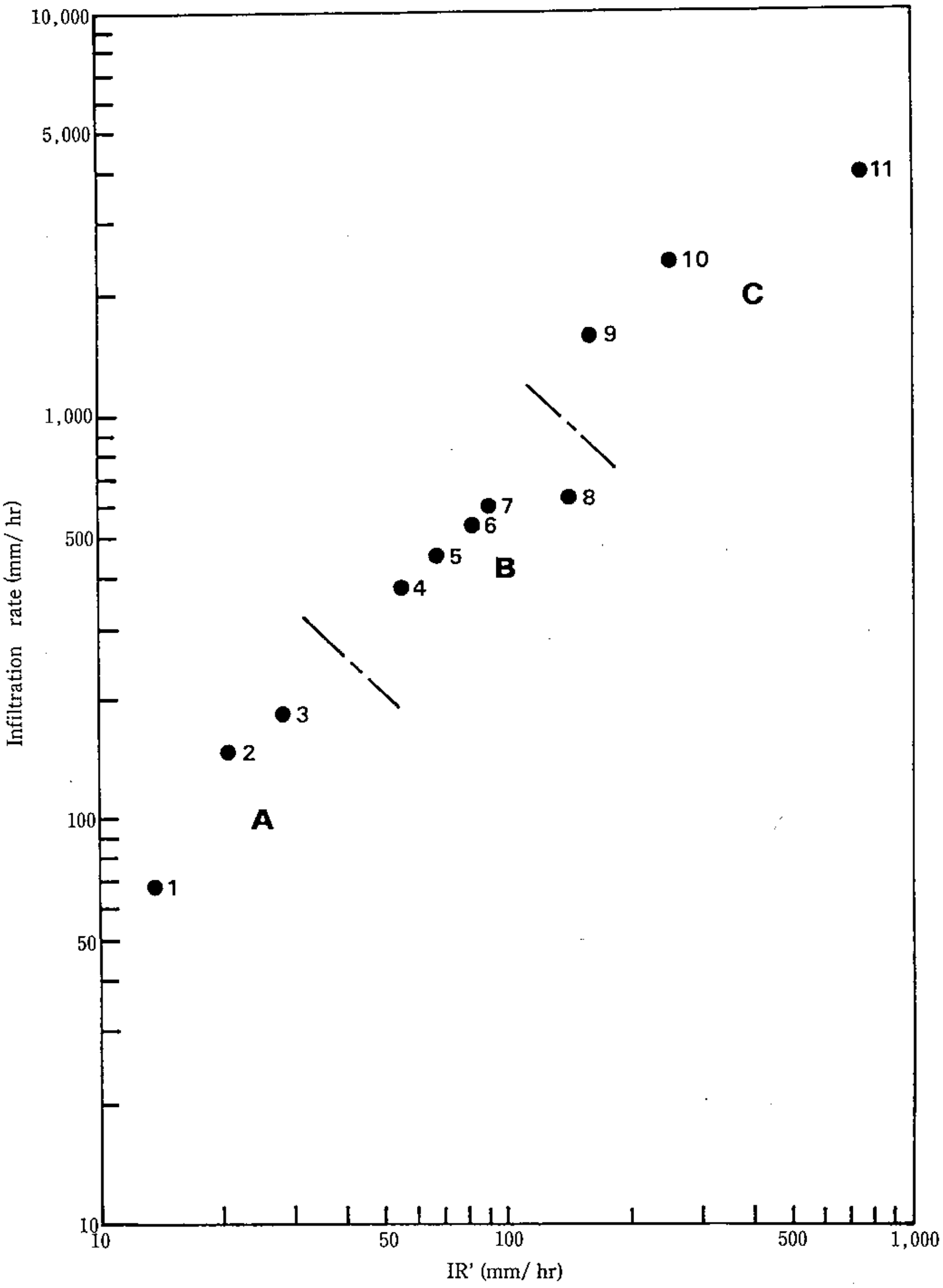

Fig. 5 Relationship between IR′ and infiltration capacity.
Note : characteristics of each plot are shown in Table 5.

Table 5 Site conditions of each plot

Group	Plot	Remarks
A	1	Bare land. Frequent burning. Burned in April, 1990 and March, 1991.
	2	Grassland. Occasional burning. *Imperata cylindrica, Thema triandra, Saccharum spontaneum.*
	3	Man-made forest. Burned in April, 1990. 4-years old *Acacia auriculiformis.*
B	4	Man-made mixed forest. 12 years old *Pinus kesiya.* Interplanted with some species of dipterocarps (2 years old).
	5	Man-made forest. 8 years old teak (*Tectona grandis*).
	6	Man-made forest. 10 years old *Gmelina arborea.*
	7	Natural forest. 15 species of trees.
	8	Man-made forest. 13 years old pure pine (*Pinus caribea*).
C	9	Man-made forest. 10 years old *Acacia auriculiformis.* Natural regeneration (seedling) of *A. auriculiformis.*
	10	Man-made forest. 10 years old *Acacia auriculiformis.* Thick litter and well-developed root system on the forest floor. Soil showed many holes caused by the activity of earthworms.
	11	Natural forest. 11 species of trees. Soil showed many holes caused by the activity of earthworms.

a positive correlation between IR' and the infiltration capacity. As shown in Figure 5, the infiltration capacity of each plot was divided into three groups. The infiltration capacity of group-A was 200㎜/hr and below, that of group-B ranged from 400 to 700㎜/hr, and that of group-C was 1,500㎜/hr and over.

The characteristics of 11 plots under various site conditions are shown in Table 5. Group-A corresponded to the sites which were affected by burning. Group-B included mainly the man-made young forest 8~12 years old. The major characteristics of Group-C were observed in the forest floor which exhibited a thick deposit of litter and organic matter, a well-developed root system and many holes and scats caused by earthworms. Repeated burning may have reduced the infiltration capacity of the soils through the changes in the physical properties of the soil surface which became tight. On the other hand, even in the man-made forest, according to the development of the forest environment, the physical properties of soil showed a transition to a porous structure which contributed to the increase of the infiltration capacity and soil and water conservation. These data emphasize the beneficial effect of afforestation on degraded forest land.

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