

Soil Salinity After Deforestation and Control by Reforestation in Northeast Thailand

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ABSTRACT

Salt accumulation in sandy soils after the clearance of the native vegetation in Phra Yun, Khon Kaen was investigated in order to clarify the process of salinization and to identify methods of control.

Deforestation changes the balance between rainfall and evapotranspiration, resulting in the increase of percolation and seepage water. Saline seepage water induces salinization in the foot slopes and the low-lying lands.

Salt-affected soils displayed mottlings in the upper part of the profile in connection with the elevation of the groundwater table in the rainy season. In these soils, salt reached the surface through the upward movement of saline water mainly at the beginning of the dry season. Salt could also be easily leached out to the subsoil with rainwater.

Accumulation of salt on the soil surface in the dry season was associated with the elevation of the groundwater table to a critical level at the end of the rainy season and continuity of capillary pores above the groundwater level.

To control salt accumulation, the planting of eucalyptus trees which led to the lowering of the groundwater table was found to be effective in preventing saline seepage water from reaching the low-lying lands.

Introduction

Soil salinization is one of the serious constraints on crop production in Northeast Thailand, where soils strongly to slightly affected by salinization are present. Some of them are barren and abandoned. Presently salinized lands are estimated to cover approximately 17% of the region (Arunin, 1987).

Saline soils are distributed mostly as spots in the depressions or the low-lying lands. It is currently recognized that salt does not originate from the rock salt beds, but from salt-bearing red siltstone and sandstone, i.e. the upper clastic member of the Mahasarakham Formation (Sinanuwong and Takaya, 1974; Takaya *et al.*, 1984).

However, soil salinization has expanded in recent years in the Northeast. According to Arunin (1987), an additional 18% of the region may become salinized. This phenomenon can not be attributed solely to geological factors. It is assumed that various human activities have enhanced the salinization process.

Mitsuchi *et al.* (1989) reviewed the natural and artificial causes of salinization. Among the various artificial causes, salinization caused by deforestation may be widespread. Indeed, the native vegetation has been cleared to make room for arable land for the past 40 years,

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due to the rapid increase in population (Table 1). At present, there is no room left for expanding farmlands in the Northeast.

Deforestation changes the balance between rainfall and evapotranspiration, resulting in the elevation of the groundwater table due to the increase of percolation and seepage water. Saline seepage water induces salinization in the foot slopes and the low-lying lands (Tuckson *et al.*, 1982; Arunin, 1983; Mitsuchi *et al.*, 1989), as shown in Fig. 1. As for the improvement of salinized lands, reforestation with eucalyptus trees could be effective (Arunin, 1983; 1989).

Due to the limited amount of information on this aspect, in the present study, the process of salinization caused by deforestation was analyzed and the effect of reforestation with eucalyptus trees on the control of salinization was evaluated.

Table 1 Changes in the forest land and the arable land area, and the population in Northeast Thailand since 1950

Year	Forest land		Arable land		Population (x1,000)
	Area (x1,000ha)	%	Area (x1,000ha)	%	
1950	10,435	61.8	4,356	25.8	6,764
1962	7,762	46.0	4,227	25.0	9,560
1973	5,067	30.0	7,836	46.4	13,396
1978	3,122	18.5	7,888	46.7	15,494
1982	2,589	15.3	*8,858	*52.5	*18,100

* Data in 1985.

Source: Association for International Cooperation of Agriculture and Forestry (1983), Present situation and near future of Northeast Thailand; Overseas Agricultural Development Association (1989), Monthly Bulletin Overseas Agricultural Development News, 6; Thai Royal Forest Department, Table on comparison of forest land in northeastern Thailand estimated from landsat imageries in 1978 and 1982.

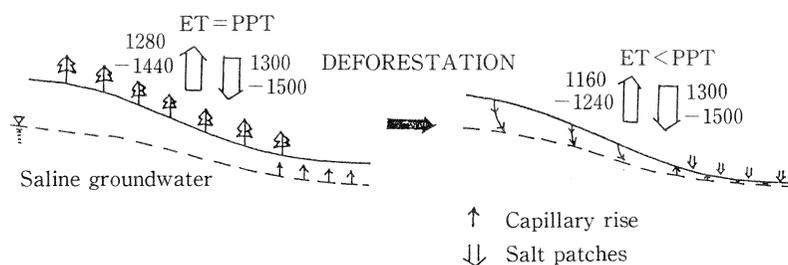


Fig. 1 Salinization caused by the clearance of the native vegetation.

General description of the Northeast

Northeast Thailand is a saucer-shaped plateau, bordered to the North and the East by the Mekong River, to the West by the Phetchabun Mountain Range and to the South by the Phanom Dong Rak Mountain range (Fig. 2). Structurally the plateau's interior is not really a plateau but consists of two basins separated by the Phu Phan Mountain Range, with the Sakon Nakhon Basin in the North and the Korat Basin in the South. Except for the Phu Phan Mountain Range, the land surface of the region is predominantly characterized by a gently undulating landscape. The average elevation of the interior of the region is about 170m above sea level. The plateau is drained by three main rivers; the Mun and the Chi for



Fig. 2 Location of the study area in Phra Yun, Khon Kaen.

the Korat Basin, and the Sri Song Khrum for the Sakon Nakhon Basin.

According to the Köppen's climatic classification, the Northeast belongs to the Tropical Savanna Climate, type "Aw", with a distinct dry season. In the Northeast dry and rainy seasons alternate from November to April and May to October, respectively. Based on the climatic data collected over a period of 30 years (1951 to 1980) in Khon Kaen, the mean annual rainfall is 1,197 mm and the mean annual temperature 27.7°C (Royal Meteorological Department, 1982).

In the Northeast, the natural vegetation consists of dry monsoonal forest, with a predominance of a mixture of deciduous and dipterocarp trees. However, forests in the region have been rapidly cleared to make room for arable land, as mentioned above. At present, most of these newly opened lands have been abandoned due to various constraints such as salinization.

The study area

The two districts, i.e. Ban Bo Yai and Ban Phra Yun, with salt-affected lands distributed in the Phra Yun Division, Khon Kaen Province, which are located about 30km southwest from Khon Kaen city, were selected for the study (Fig. 2).

In both districts, forests were cut down to make room for arable land about 30 years ago. After land clearance, farmers introduced upland crops such as kenaf and cassava in the higher lands and lowland rice in the lower lands. However, crop yield gradually decreased due to soil salinization associated with the elevation of the groundwater table and eventually some of the places became barren and abandoned.

In both districts, *Eucalyptus camaldulensis* was planted on the convex slopes at or near the top of a hill where salinity was not severe, namely in Ban Bo Yai from 1984 to 1987 and in Ban Phra Yun in 1985 and 1989 (Fig. 3 and 4). Soils strongly affected by salinization are distributed in the low-lying lands where the saline groundwater accumulates.

Procedures

Fifteen sites were selected in Ban Bo Yai (Fig. 3) and fourteen sites in Ban Phra Yun (Fig. 4). At each site, the depth of the groundwater level was measured using a piezometer and the groundwater sample was collected for the measurement of EC. In Ban Bo Yai, soil samples at depths ranging between 0 and 200cm from the surface were also taken with an auger for the measurement of EC (soil : water = 1 : 5). In Ban Phra Yun, the sites, B8 and B11 were

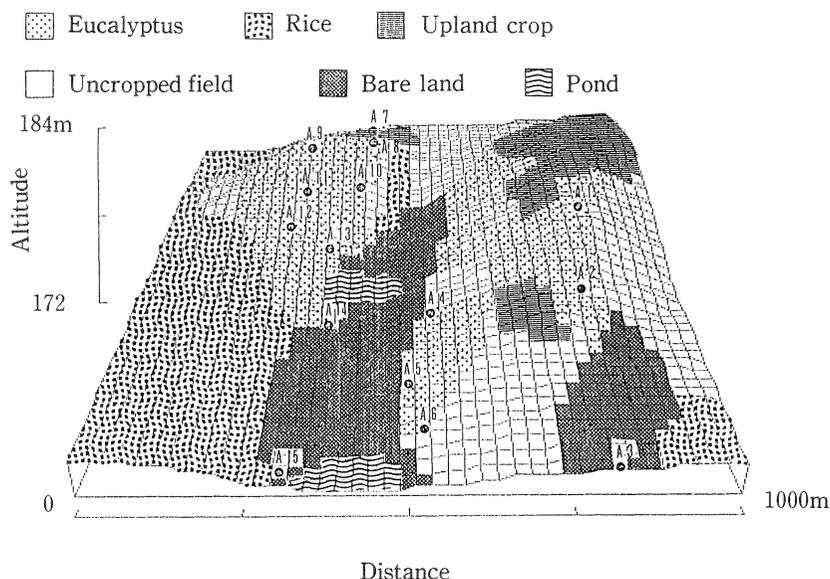


Fig. 3 Land use map in Ban Bo Yai district, showing the study sites, A1 to A15.

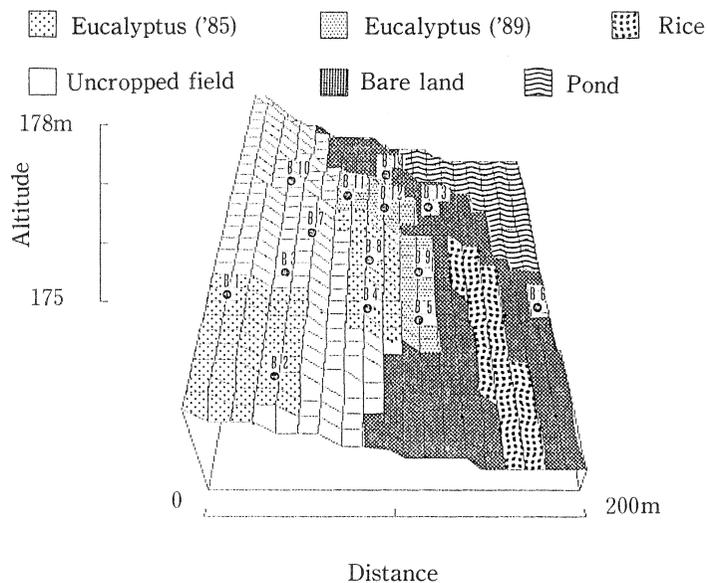


Fig. 4 Land use map in Ban Phra Yun district, showing the study sites, B1 to B14.

selected for the measurement of the soil water suction at the depths of 10, 30, 50, 70, and 100cm below the surface by using a tensiometer from the end of the rainy season to the middle of the dry season. These investigations were carried out over a period of about 2 years, i.e. February 1988 to February 1990 in Ban Bo Yai and about four months, i.e. October 1989 to February 1990 in Ban Phra Yun.

In addition to the above surveys, the two sites, i.e. A3 and A14 in Ban Bo Yai were chosen to open a pit and to describe the profile. The core and disturbed samples were also taken from each of the horizons for the analysis of the physical properties, i.e. pF-moisture characteristics, three phase distribution, and particle size distribution. Except for these sites, the profile of each site was described using an auger in both districts.

Morphological characteristics

The salt-affected soils in both districts generally exhibited a thick sandy surface layer overlying a loamy to clayey subsoil layer (Fig. 5 and 9). These soils displayed common to many yellowish to brownish mottles in the pinkish subsoil, reflecting the saturation with groundwater and the development of a reduced state in the rainy season. The appearance of the mottlings was related to the groundwater level in the rainy season, as described below.

Soils distributed in the upper part of a hill in Ban Bo Yai which were not affected by salinization had a very thick sandy layer, 80cm or more (Fig. 5). At many of the sites, common mottle distribution was found in layers at a depth of 130cm or more. However, judging from the present groundwater level, the depth of the layer with common mottle distribution was close to the surface. According to the data recorded previously in Ban Bo

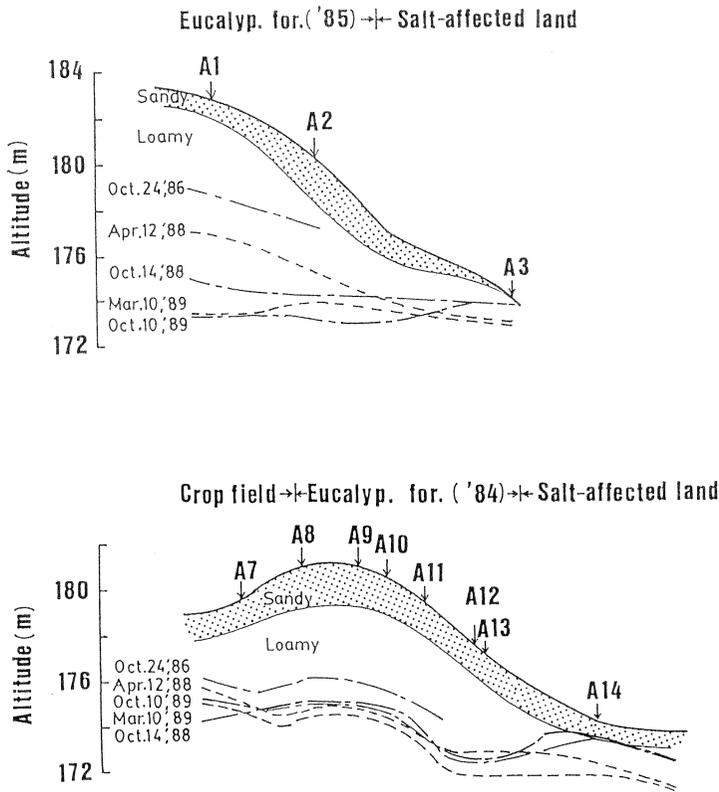


Fig. 5 Cross sections between the A1 and A3 sites (upper) and between the A7 and A14 sites (lower), showing the lowering of the groundwater level after reforestation with eucalyptus trees and the soil stratigraphy in Ban Bo Yai district.

Yai, the groundwater level which used to be higher had been lowered significantly after the plantation of eucalyptus trees (Fig. 5). Especially at the A1 and A2 sites in Ban Bo Yai, the lowering of the groundwater level became significant after the plantation of eucalyptus trees in 1985. Therefore, the mottles observed in the shallower part may have been formed in the past when the groundwater level was higher.

Factors controlling the seasonal movement of salt

1 Elevation of the groundwater level

In the case of A3 which is a site strongly affected by salinization in Ban Bo Yai, the seasonal movement of salt was clearly observed within the soil profile (Fig. 6).

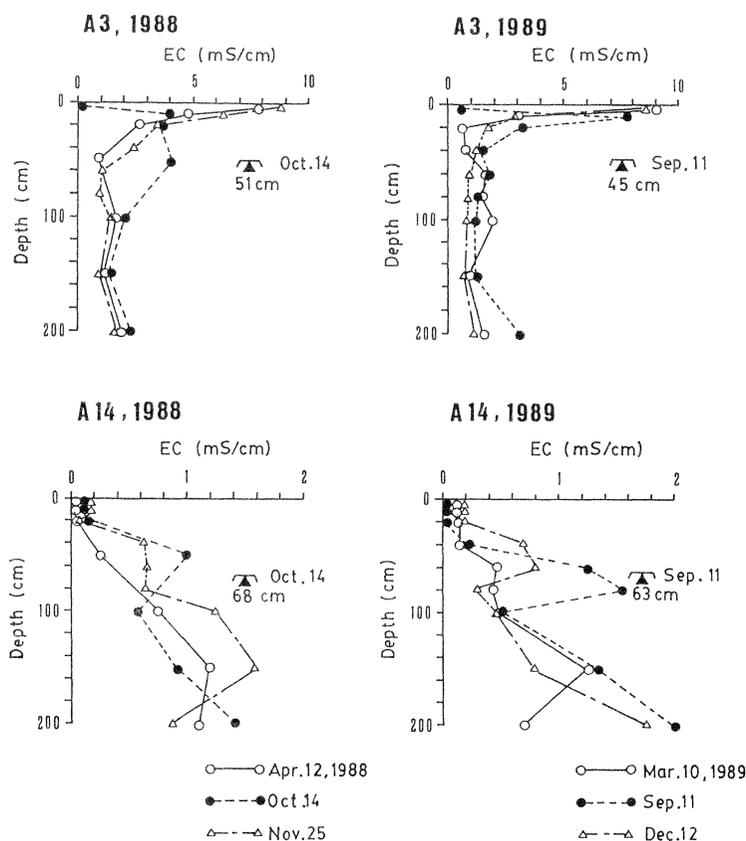


Fig. 6 Seasonal movement of salt within the soil profile at the A3 and A14 sites in Ban Bo Yai district in 1988 and 1989.

During the long sunny period of the dry season, a salt crust was formed on the soil surface. The EC value of soil became the highest, about 8 to 9mS/cm at the 0 to 5cm depth and markedly decreased to 1 to 2mS/cm at the 100 to 200cm depth, indicating an accumulation of salt at the surface (April 12, 1988). However, the EC value readily fell to 0.2mS/cm at the 0 to 5cm depth and rose to about 4mS/cm at the 10 to 50cm depth due to the leaching of salt from the soil surface with rainwater, when the groundwater level rose to the 51cm level at the end of the rainy season (October 14). On November 25, at the very

beginning of the dry season, the EC value of the surface soil again became the highest within the profile, presumably due to the capillary rise of salt, followed by drying from the soil surface.

Salt distribution in the layers between the 100 and 200cm depth, was rather uniform throughout the year, since this part always remained below the groundwater table during the year ; the lowest groundwater level was found at the 120cm depth at the end of the dry season (April 12, 1988).

A similar seasonal movement of salt was observed in 1989.

As for the appearance of mottlings in connection with the groundwater level in the salt-affected sites in both districts, the depth of the layer with common mottle distribution was highly correlated with the shallowest groundwater level at the end of the rainy season in 1989 ($r=0.846$), as shown in Fig. 7. Based on this Figure, it appears that when the groundwater

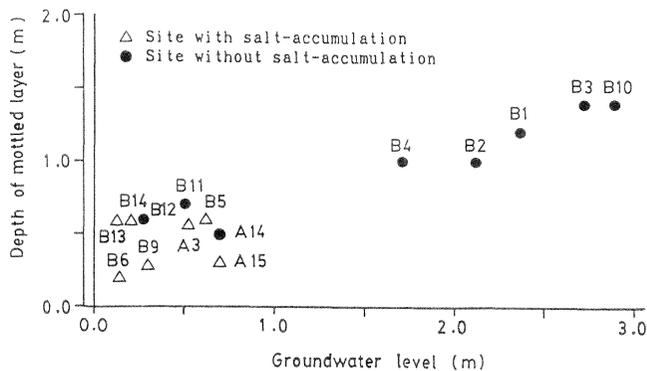


Fig. 7 Relationship between the groundwater level at the end of the rainy season in 1989 and the depth of the layer with common mottle distribution.

level rose to less than 70cm from the surface, soil salinization was likely to occur.

2 Continuity of capillary pores

In the case of the A14 site which is also located on low-lying land, the distribution pattern of salt was quite different from that at A3 (Fig. 6). The EC value of soil at the 0 to 20cm depth was less than 0.2mS/cm throughout the year. Below the 20cm depth, the EC value gradually increased with the depth. At the end of the rainy season (October 14), the EC value at the 50cm depth near the groundwater level became higher than in the dry season. A similar trend was observed in 1989.

The absence of salt accumulation at the soil surface during the dry season may be due to the interruption of the upward movement of water which may be caused by the discontinuity of the capillary pores between the surface and the subsurface horizon, although the groundwater table reached a depth of 70cm.

As shown in Fig. 8, the pore space at the surface of A14 which is dominated by coarse pores, more than 0.05mm in diameter, or non-capillary pores accounted for nearly 80% of the total porosity. The capillary pore space was remarkably lower at the surface than at the subsurface. In the case of A14, the sandy surface layer played a significant role in breaking the continuity of capillary pores. Thus, the interruption of the continuity of capillary pores may be a very effective method to prevent the accumulation of salt on the soil surface. In contrast, in the case of A3, the capillary pore space was relatively uniform in the surface to the third layer. Since the groundwater level at the end of the rainy season was observed at

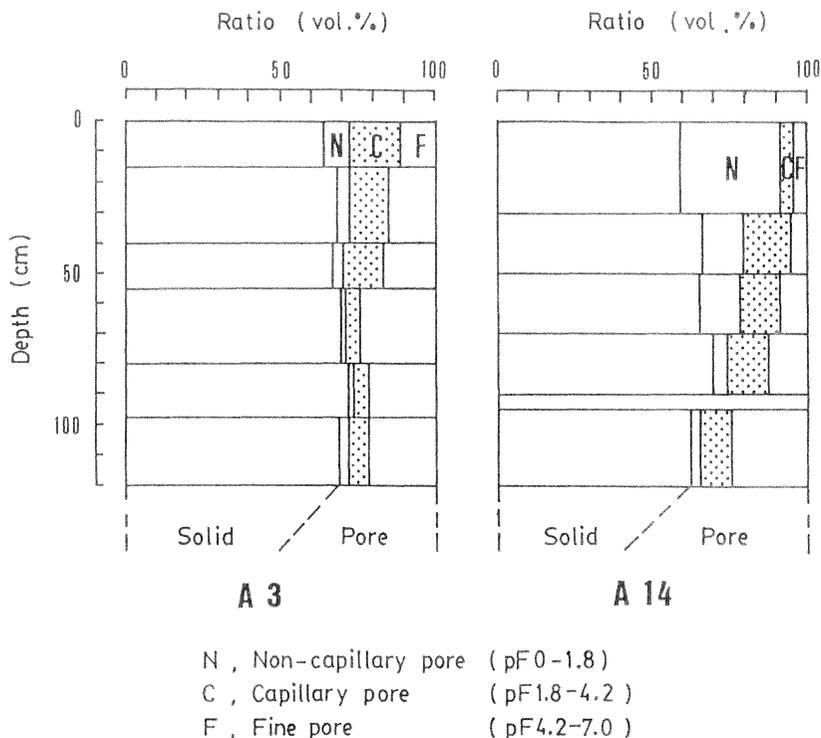


Fig. 8 Solid and pore-size distribution of the salt-affected soils at the A3 and A14 sites in Ban Bo Yai district.

the third layer, saline water could easily reach the surface.

Hence, in addition to the elevation of the groundwater table to a critical level at the end of the rainy season, it is considered that the uniformity of the capillary pore space above the groundwater table may be another factor controlling salt accumulation on the soil surface.

On the other hand, all the sites in the middle part and top of a hill always showed much lower soil EC values, less than 0.1mS/cm within the profile throughout the year. In these cases, the saline groundwater table with an EC value of 10 to 30mS/cm for groundwater, was so deep that salt could not reach the soil surface by capillary rise.

Effect of reforestation with eucalyptus trees

As already mentioned, after reforestation with eucalyptus trees, the groundwater table became lower in Ban Bo Yai. Moreover, based on the data of the groundwater level and the soil moisture in Ban Phra Yun, the effect of the plantation of eucalyptus trees was even more significant.

Based on the contour lines of the groundwater level above sea level on 16th October, 1989, the next day after the last heavy rain which occurred from October 12 to 15 (total rainfall 96mm), the groundwater level inside the eucalyptus forest was much lower than that in the surroundings in Ban Phra Yun (Fig. 9). Especially, the higher groundwater level at B9 than at B8 against the topographical position indicated that the water movement to the low-lying land was prevented. This phenomenon must be ascribed essentially to the higher evapotranspiration rate inside the eucalyptus forest than in the surroundings. In this connection, the rise of the groundwater level at B8 inside the eucalyptus forest after the last

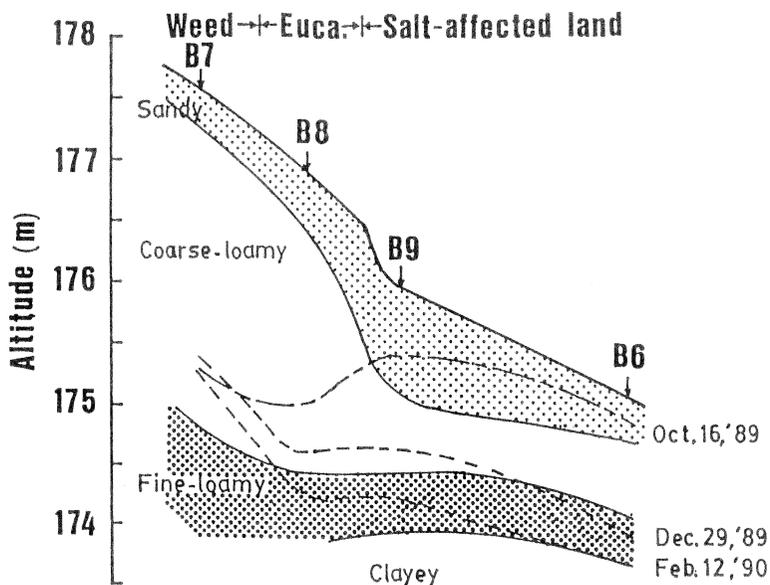


Fig. 9 Distribution of the groundwater table in Ban Phra Yun district on 16th October, 1989.

heavy rain was not as evident, although the groundwater level at the other sites had markedly risen (Fig. 10).

The soil moisture suction rapidly increased at B8 inside the eucalyptus forest planted in 1985 after the last rainfall due to the relatively high evapotranspiration rate (Fig. 11). Especially, the suction at the depth of 30 to 70cm was always higher than that in the other parts after early November, 1989 and in early January, 1990 it already reached $-600\text{cmH}_2\text{O}$, i.e. $\text{pF } 2.8$, equivalent to the moisture corresponding to the rupture of the capillary bond. This may be associated with the root distribution of eucalyptus trees. In other words, eucalyptus trees were able to utilize the soil moisture effectively.

By contrast, at B11 inside the eucalyptus forest planted in 1989 which was located at nearly the same altitude as that of B8, the moisture suction gradually increased within the profile except for the surface (Fig. 11). At B11 even in the middle of February, the value ranged from about -80 to $-300\text{cmH}_2\text{O}$, indicating a higher moisture content than at B8.

Conclusions

Based on the above results, the following conclusions were drawn.

Salinization after deforestation is essentially controlled by two factors; groundwater table shallow enough to induce a capillary rise in the rainy season and continuity of capillary pores above the groundwater level. Thus, the control of salinization can be achieved by acting on either factors.

Covering the soil surface with sandy materials, i.e. mulching, may be effective for interrupting the continuity of the capillary pores. However, the effect may not be lasting, if the groundwater table continues to rise. In this regard, the planting of eucalyptus trees may enable to prevent salinization, since the saline seepage water was prevented from reaching the low-lying lands, due to the very high transpiration rate of eucalyptus trees. In this connection, planting of eucalyptus trees should begin at the top and middle part of a hill, where saline seepage water originates. This is the optimum strategy to ameliorate the salt-

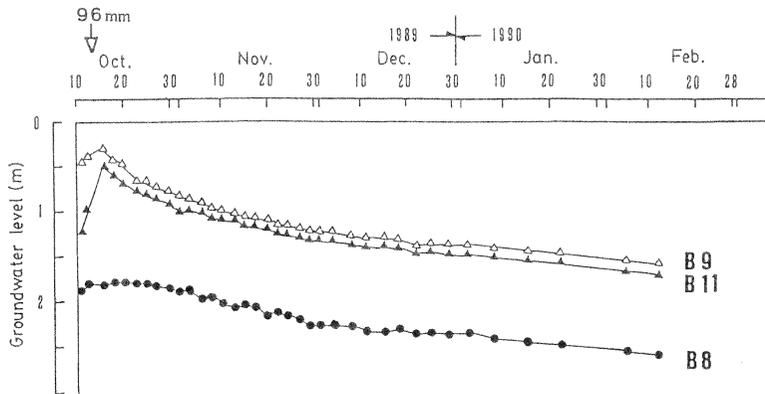


Fig. 10 Fluctuations of the groundwater level at the B8, B9, and B11 sites in Ban Phra Yun district from the end of the rainy season to the middle of the dry season.

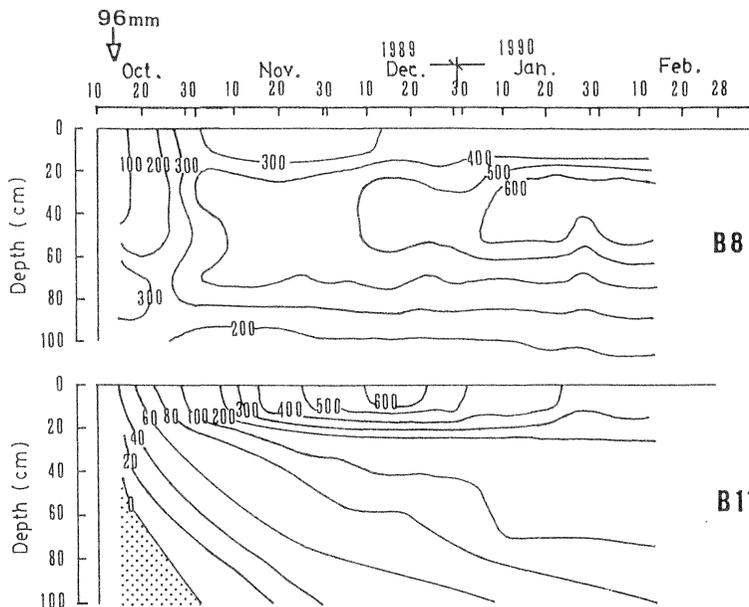


Fig. 11 Changes in the soil moisture suction within the soil profile at the B8 and B11 sites in Ban Phra Yun district.

Note: Figures indicate the soil moisture suction in cmH_2O and parts of shading represent the saturated condition with water.

affected soils. However, further studies are required to provide the most efficient design for reforestation with eucalyptus trees.

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