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Improvement Effect of Semi-Arid Land Afforestation on Soil Environment

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Abstract: Carbon fixation by afforestation in semi-arid land has been proposed as one of the most promising countermeasures against the global warming issue. Our demonstration area for carbon fixation suffered some serious problems, such as salinization and water logging, which we attempted to solve. We tried to reduce the groundwater level by taking advantage of the transpiration of planted trees. The two sites used were identified as D-low and D-high. In this study, the transpiration of planted trees, soil water change, and groundwater level were measured. *E. sargentii* and *E. occidentalis* were considered to be optimum. From the analyses of the groundwater and soil water contents, water was found to gather at the D-low site. However, analysis of the Neutron Moisture Meter (NMM) data indicated that the volumetric water content did not rise. Through the transpiration of planted trees, groundwater was absorbed via tree roots located in deep soil. Thus, the groundwater level was expected to decrease, but this decrease was prevented by the collected water. On the other hand, due to afforestation at the D-high site, where it was difficult for water to gather, a decreasing tendency in the amount of groundwater was clearly shown by the volumetric water content. Furthermore, the precipitation water trickled down through the soil surface layer, which was expected to mitigate the salt accumulation in topsoil. Soil improvement effects by afforestation, i.e., desalination and the prevention of water logging through the transpiration of planted trees, were confirmed in our research area.

Keywords: Afforestation, Carbon fixation, Groundwater, Salinization

1. Introduction

Global warming has become one of the most serious environmental problems. The main cause is the increment in the amount of carbon dioxide in atmosphere. As a promising countermeasure, carbon fixation by afforestation in arid and semi-arid areas has been proposed (Yamada *et al*., 1999; Kojima *et al*., 2006). An afforestation experiment was also conducted at a farm (named Martin's Farm) in a semi-arid land of Western Australia as a case study. The location (UTM data) of this farm, scale, and annual precipitation are shown in **Figure 1**. In this research area, the original native forest had been felled, and the land had been turned into farmland. As a result, transpiration per unit area had decreased, and the groundwater level had risen. Thus, there are currently some serious problems, such as salinization and water logging. In this research, two sites, identified as the D-low and D-high sites, were selected for comparison. The D-high site is shown in the upper area of Figure 1. The D-low site is shown in the lower area of Figure 1. In this research, we attempted to lower the groundwater level through the transpiration of planted trees. We aimed to achieve both the improvement of the agricultural conditions and carbon sequestration by afforestation.

2. Materials and Methods

The transpiration of planted trees, soil water content, and groundwater level were measured. Comparing the measured data, the influence of afforestation in the research area was evaluated. Below is an explanation of the objectives and installation position of each measurement item.

2.1. Transpiration

We selected four tree species as candidates for afforestation: *Pinus radiata*, *Eucalyptus sargentii*,

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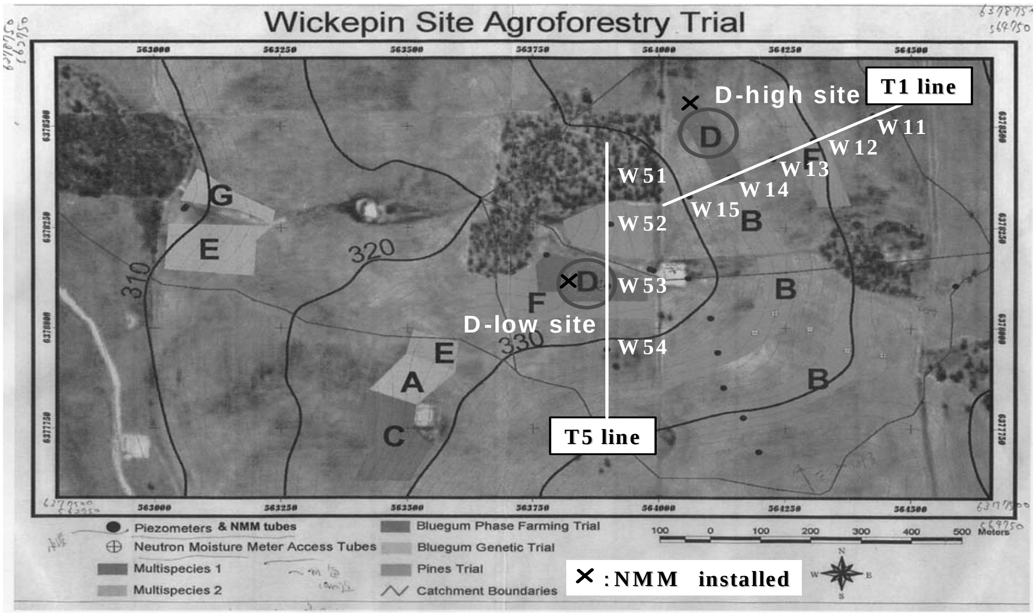

Fig. 1. Martin's Farm (annual mean precipitation; 314mm: S32.46˚; E117.40˚).

Rainfall ave	P. radiata	E. sargentii	E. globulus	E. occidentalis
average [m3/(d･tree)]	0.82×10^{-2}	1.31×10^{-2}	0.74×10^{-2}	1.22×10^{-2}

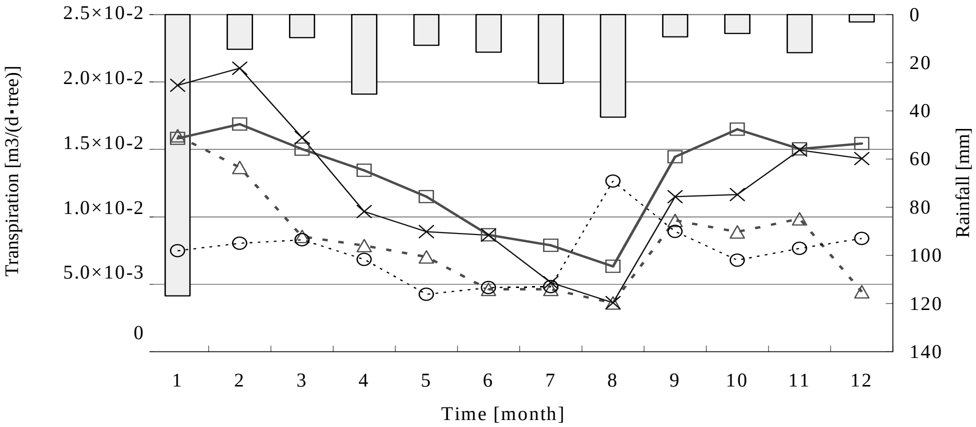

Fig. 2. Comparison of the transpiration amount of trees in 2006.

Eucalyptus globules and *Eucalyptus occidentalis*. Thermal Dissipation Probes (TDP) were installed to measure the transpiration rates in their trunks in our research area (D-high and D-low). Data of TDP were measured every 30 minutes for three samples per tree species. Trees were planted at 3 m intervals within the rows, giving an initial stocking of 1111 trees/ha in June 2000. TDP data were analyzed, and transpiration rates were compared among four species for optimum tree species selection. Data from January 2006 to December 2006 were available.

2.2. Groundwater level

Piezometers were installed at the points indicated by W11-W54 in Figure 1. In this study, the T1 and T5 lines were selected for analysis because they were across the D-high and D-low sites. The data obtained in 2005 were available.

2.3. Soil water content

Data from Neutron Moisture Meter (NMM) probe tubes installed at two sites (D-high and D-low, as shown in Figure 1) were analyzed, and the characteristics of the land and soil water content change at five points in depth (30 cm-270 cm) were discussed. These data were measured twice a year and averaged. The data from March 2002 to December 2004 were available.

3. Results and Discussion

3.1. Transpiration

E. sargentii and *E. occidentalis* were considered to be optimum tree species because their transpiration rate was larger than that of other species (**Fig. 2**). Their transpiration rate was around 1.20×10^{-2} [m^3/(d･tree)].

3.2. Groundwater

Results of the groundwater level are shown in **Figures 3** and **4**. As also shown in Figure 1, the distance from W54 across the D-low site and that from W15 across the D-high site are shown in the x-axis of Figures 3 and 4.

Figure 3 indicates that the groundwater level is high at the D-low site. Thus, the D-low site was found to be easily salinized and water-logged. This could be because the D-low site was located near a creek, where it was easy for water to gather.

At the D-high site, it was found that the soil surface was far from the groundwater level. **Figure 5** indicates that the groundwater level slowly decreased at the D-high site.

3.3. Soil water content

Results of the soil water content are shown in **Figures 6** and **7**. At the D-low site, the results indicated that the soil volumetric water content remained stable for all of five points in depth. The analysis of Piezometer data (Fig. 3) indicated that the soil water content might have risen due to the groundwater level; however, no clear effect from the groundwater level was found from the data in Figure 5. At the D-high site, the volumetric water content decreased at all five observation points. Moreover, the measured value of the soil water content was not found to be affected by the groundwater level as measured by the piezometer.

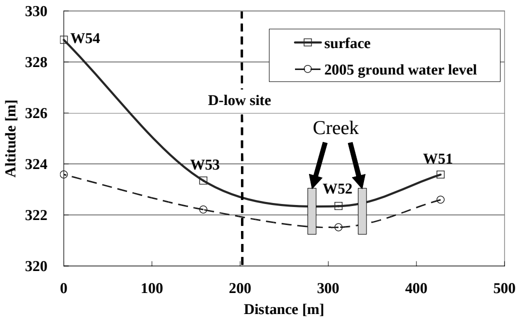

Fig. 3. D-low site groundwater data.

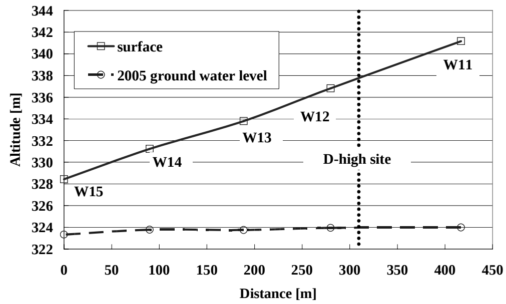

Fig. 4. D-high site groundwater data.

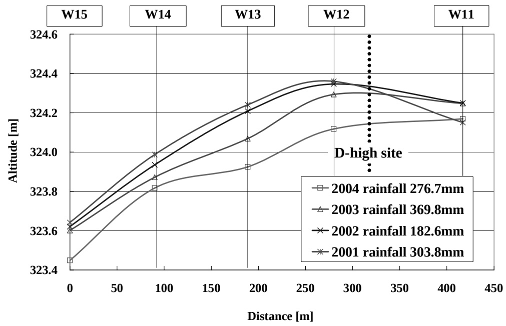

Fig. 5. Changes in the groundwater level at the D-high.

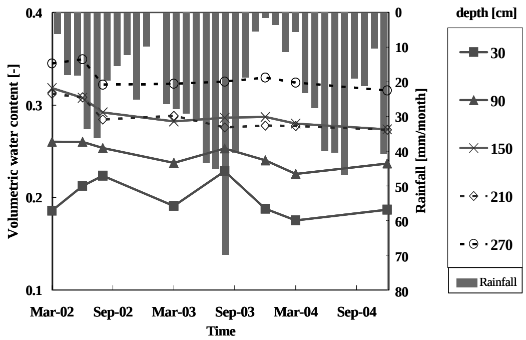

Fig. 6. Variation of volumetric soil water content measured by NMM in D-low site.

4. Conclusions

4.1. D-high

The D-high site was characterized by a deep groundwater level, i.e., 12 meters deep from the soil surface. The surface altitude of the D-high site was high; thus, water hardly collected at the D-high site. The analysis of NMM data pointed to a decreasing tendency with time in the volumetric water contents. Soil improvement effects, i.e., desalination and the prevention of water logging through the transpiration of planted trees, were confirmed in our research area. Finally, the hydrological mechanism of the improvement effect by afforestation was explained.

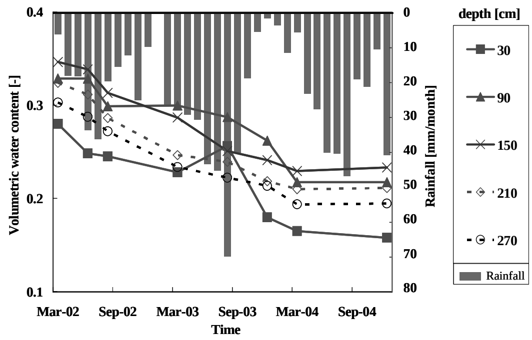

Fig. 7. Variation of the volumetric soil water content measured by NMM at the D-high site.

4.2. D-low

The D-low site was characterized by a high groundwater level. In addition, water was found to gather at the D-low site. However, analysis of the NMM data indicated that the volumetric water contents did not rise. This contradiction is explained as follows. Through the transpiration of planted trees, groundwater was absorbed via the roots of trees located in the deep soil. The groundwater level at the D-high site slowly decreased, while that at the D-low site remained almost constant. However, the groundwater level at the D-low site is expected to decrease in the near future. Furthermore, the precipitation water which trickles down through the soil surface layer was expected to mitigate the salt accumulation at the topsoil. Thus, salt in the top soil was considered to move down to the root zone and to be leached out by groundwater. Soil improvement effects, i.e., desalination and the prevention of water logging through the transpiration of planted trees, were confirmed in our research area.

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