Effectiveness of Environmental Restoration Induced by Various Trials for Preventing Desertification in Horqin Arid Land, China : Development of Wind Shelter Forest (2)

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Effectiveness of Environmental Restoration Induced by Various Trials for Preventing Desertification in Horqin Arid Land, China – Development of Wind Shelter Forest (Part 2) –

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The objective of this study is evaluating the effect of the wind shelter forest on the mitigation of the intrinsic environment and the improvement of the soil characteristics. First, the field investigation is conducted to clarify the method of the development of the wind shelter forest in the study site, Naiman. It is clear that the process of the development of the wind shelter forest is planned, considering the geographic and climate conditions in the study site. The micrometeorological observation is conducted at the wind shelter forest and the bare field in the study area. In the wind shelter forest, the air temperature decreases, and the relative humidity increases, comparing with the bare field. The experiments on the soil physical and chemical characteristics are conducted to evaluate effect of the wind shelter forest on the soil improvement. At the wind shelter forest, the improvement of the soil water retention can be obtained, comparing with the value at the bare field. The soil chemical characteristics at the wind shelter forest, including organic matter content, cat ion change capacity (CEC), pH, and EC, are improved comparing with the value of the bare field.

INTRODUCTION

The desertification has intensified in northern China because the micrometeorological environment here is affected by the change of climate and the lack of the development plan (Li *et al.*, 2003). The afforest started in 80' aims to prevent the soil degradation caused by desertification and mitigate the intrinsic environment (Koizumi, 2000). However, Horqin sandy land has spatial changes of geographical and social conditions. The adoption of appropriate afforest technique is important, considering the various geographical and social conditions (Li *et al.*, 1994; Koizumi, 2000).

Development of the wind shelter forest is adopted as the methods of the afforest and mitigation in the arid area. The evaluation of the wind shelter forest effect on the crop production was studied by Zhang *et al.* (1997). However, the micrometeorological

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mitigation by the wind shelter forest has not been evaluated yet.

The objective of this study is evaluating the effects of the wind shelter forest on the micrometeorological environment and the soil characteristics. First, the field investigation is conducted to clarify the actual method of the development of the wind shelter forest in the study site, Naiman, which is located in Inner Mongolia constituency. Next, the field observation is conducted to evaluate the effect of the wind shelter forest on the mitigation of the intrinsic environment and the improvement of the soil characteristics.

STUDY SITE

The effect of the wind shelter forest is evaluated in Naiman. The study site is located at the southeast of Inner Mongolia constituency (E 120° 19' 40"–121° 35' 40", N 42° 14' 40" –43° 32' 20"). In the study area, the water resource provided by the river is abundant, and the groundwater level is high, and the soil is fertile.

The climate at the study site categorized as the semi–arid area. Fig. 1 shows the monthly average of the precipitation and pan evaporation. This figure indicates that the precipitation shows maximum value, 54.4 mm, in August. This value is equal to 25.5% of the annual precipitation. The pan evaporation is high from April to September as shown in Fig. 1, and the total amount of pan evaporation is equal to 80% of the annual pan evaporation. The annual precipitation is 11% of the annual evaporation. Fig. 2 shows the monthly average of the temperature and wind velocity. The annual average temperature is 7.5 °C.

The intrinsic soil texture at the study site is classified as the sandy loam. The ground surface is generated by aeolian sand, and the wind erosion often happens, because the average grain size of the ground surface is relatively small (0.01–0.5 mm) and the flocculation is low. The geographical feature at the study site is classified as fixed sand

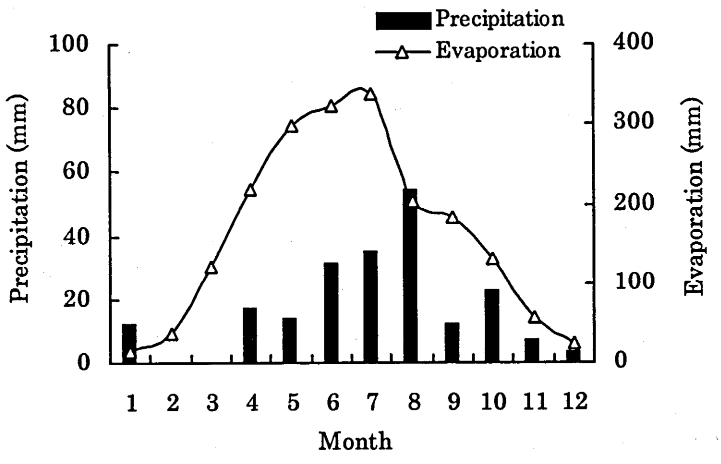


Fig. 1. Monthly changes of precipitation and pan evaporation (2000).

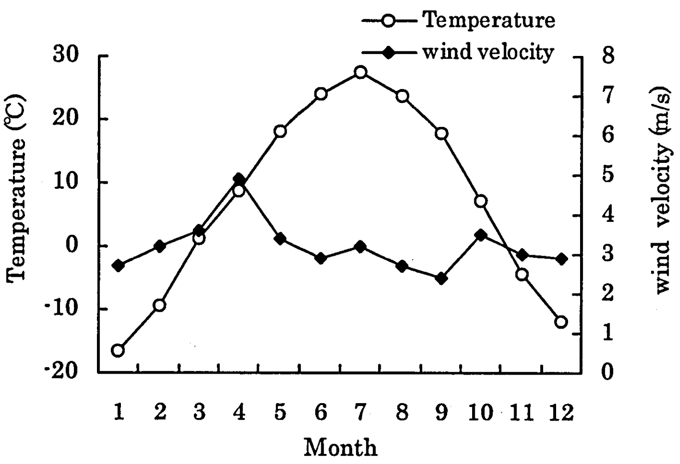


Fig. 2. Monthly changes of temperature and wind velocity (2000).

dune, semi–fixed sand dune, mobile dune, and steppe. Aeolian sand damages to the crop growing and the production. To prevent this damage, the wind shelter forest is adopted at the study site.

DEVELOPMENT OF WIND SHELTER FOREST

In the study area, the wind shelter forest is developed for the protection of the farmland against the aeolian sand and prevention of the wind erosion. The wind shelter forest generally consists of the shrubs or trees, and is developed to protect the farmlands against the aeolian sand, and to prevent the farmlands from the wind erosion. Additionally, the wind shelter forest has multifunction, including aeolian sand control in the roads, mitigation of the intrinsic environment, fixing the dune, and so on. The wind shelter forest developed at a right angle to the wind direction is effective for protection against wind.

The wind shelter forest at the study site is developed for the mitigation of intrinsic environment, and improvement of the agricultural productivity under the environmental and economic policy in China. The process of wind shelter forest development can be summarized as follows:

Selection of the shrubs and trees

The types of the shrubs and trees for the wind shelter forest in the arid area should be selected, considering the drought, salt, heat, and cold tolerance. At the study site, the wind shelter forest is important timber resource, used as the fuel and feed. Recently, the demand of the multi–use timber resource is increasing. At the study site, Poplars are most used for the wind shelter forest, considering these factors. Poplars are well–growing, and adapted to the micrometeorological environment at the study site.

Poplars have high drought tolerance, and soil improvement effect by humus of fallen leaves. Additionally, *Pinus sylvestris var.*, *Ulums propinqua*, *Caragana microphylla*, *Amorphy fruticosa*, *Astragalus adsurgens*, and *Agropyron cristatum* are used for the wind shelter forest development.

Planning of the wind shelter forest

At the study site, to imitate primeval forest, the wind shelter forest is developed, using tree, shrub, and grass. The development of the wind shelter forest is planned, considering the geographical condition. The scale of the wind shelter forest can be classified as large and small scales.

The schematic view of a large scale wind shelter forest is shown in Fig. 3. The main wind shelter belts are composed of the trees. The main wind shelter forest, which is 500 m width, crisscrosses at intervals of about 4500 m. In the main wind shelter belts, *Populous simonii* or *Salix gordejevii* are planted. In the area surrounded by the main wind shelter belts, which is 100 ha, the sub wind shelter belts are developed by the *Salix gordejevii* or *Caragana microphylla*. The sub wind shelter belts are 100 m width and cross at a right angle at intervals of about 1100 m. At a small part surrounded by the sub wind shelter belts, the ground surface is covered by the grass. The small part is used as the farmlands, and the wells are dug as the water resource.

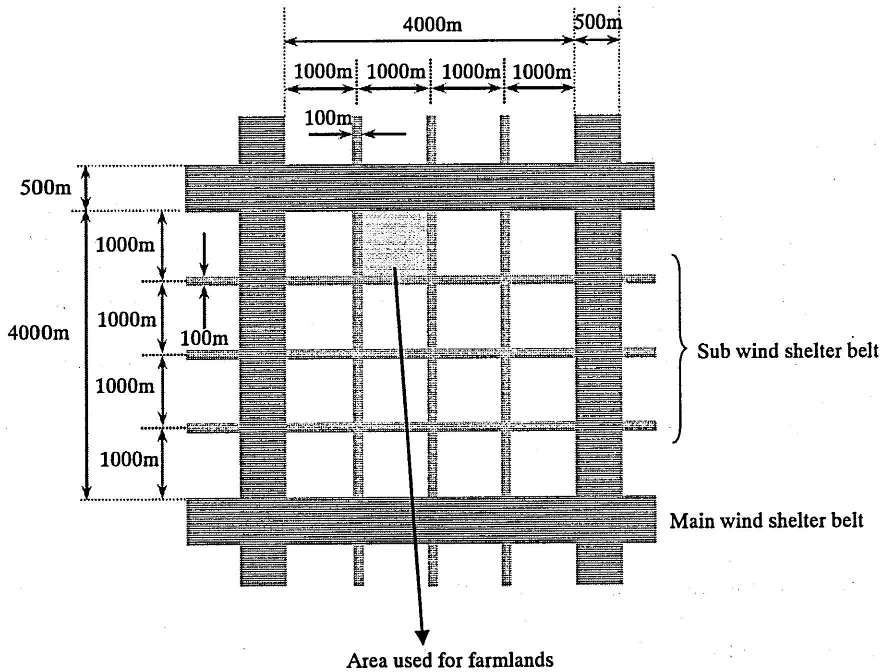
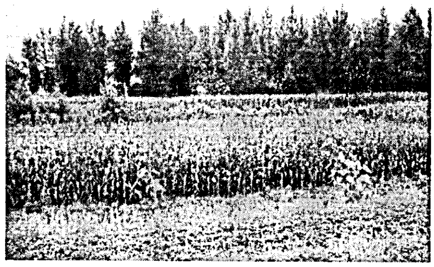


Fig. 3. Arrangement of a large scale wind shelter forest.

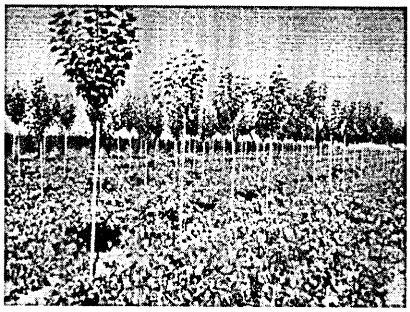
(a) Wind shelter forest planting

(b) Wind shelter forest at middle stage

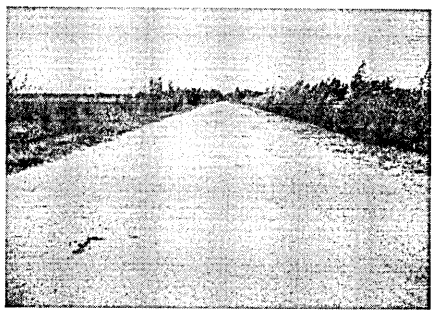
(c) Wind shelter forest at final stage



(d) Wind shelter forest adjacent to the farmland



(e) Intercrops in the young wind shelter forest



(f) Wind shelter forest along a road

Fig. 4. Various conditions of wind shelter forest.

A small scale wind shelter forest is composed by the sub wind shelter belts. The width of the sub wind shelter belts is generally about 100 m, however, the width of the sub wind shelter belt is changed, considering the geographic condition, from 200 m to 500 m.

Process of the development of the wind shelter forest

The first step of the development of the wind shelter forest is the selection of the types of the trees, shrubs, and grasses. The types of the plant are selected, considering not only the cultivation conditions, including climate and soil characteristics, but also the transportation. The ditches for planting are arranged by the excavator, the holes with a 0.6–1.0 m diameter and a 0.3–0.8 m depth are dug. The irrigation and fertilizing are conducted in the holes, and the young plants lopped off are planted in the hole. The surface irrigation is adopted for the target of 90% plant growing.

To prevent the aeolian sand efficiently, the trees and shrubs in the main and sub wind shelter belts are planted at intervals of 2 m times 2.5 m, and arranged in the hounds tooth check. In the farmland, which is located in the small part shown in Fig. 3, the shrub is planted relatively densely, because the site for the wind shelter forest is limited. Some small parts are used for farmland to cultivate bean, grass, and so on. The various conditions of the wind shelter forest are shown in Fig. 4.

WIND SHELTER FOREST EFFECT ON THE INTRINSIC ENVIRONMENT

Reduction of the wind velocity

The wind shelter forest reduces the wind velocity, and changes the wind direction. The effect of the reduction wind velocity of the wind shelter forest depends on its

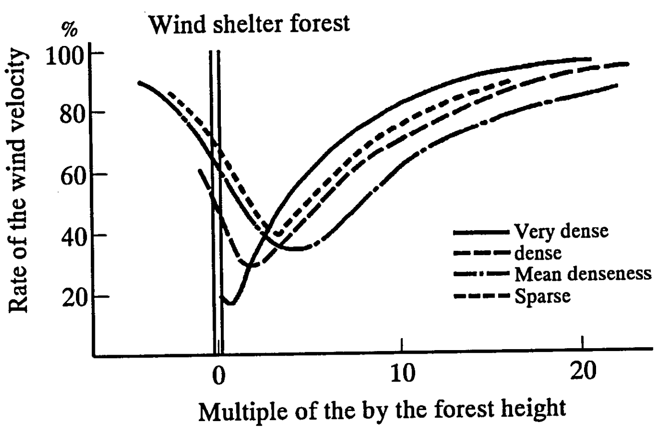


Fig. 5. Relationship between the effect of the wind velocity reduction and the various ranks of the denseness in the windbreak forest (height 1.4 m) (Naegeli, 1946).

denseness. The relationship between the effect of the reduction wind velocity and the denseness in the wind shelter forest is reported by Tsuboi *et al.* (1974). The 100% denseness means that the there is no gap in the wind shelter forest. The effect of the reduction wind velocity increases in proportion to the denseness when the denseness is from 0% to 80%. The effect of the reduction wind velocity does not change with the denseness of the wind shelter forest.

Fig. 5 shows the relationship between the effect of the wind velocity reduction and the various conditions of the denseness in the wind shelter forest reported by Tsuboi (1974). This figure indicates that the wind shelter forest with the mean denseness is most effective to reduce the wind velocity, and the effectiveness of the wind velocity reduction decreases with the upward distance above the wind shelter forest. The 75% wind velocity is reduced on the wind shelter forest, and the wind velocity reduction decreases at 25%. However, Luo *et al.* (1998) reported that the effect of the wind velocity reduction changes variously with the upward distance. The denseness and the height of the wind shelter forest should be taken into account for the wind shelter forest development.

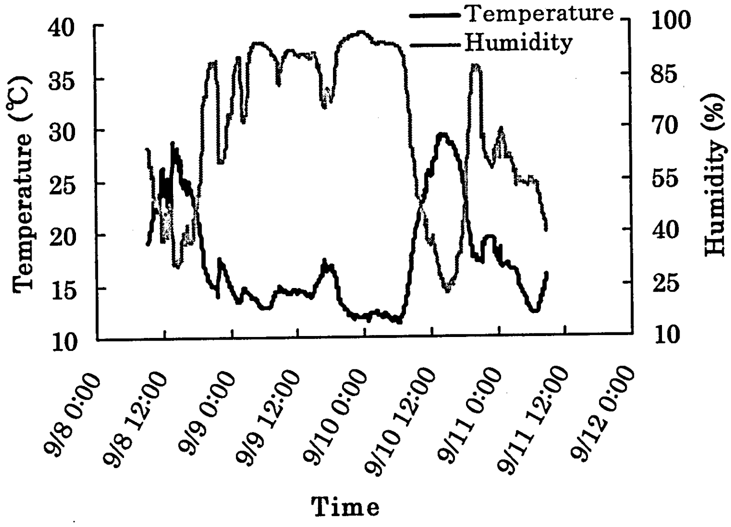
Mitigation of the micrometeorology

The reduction of the wind velocity affects on the micrometeorological environment in the wind shelter forests. To evaluate the effect of the wind shelter forest on the micrometeorological environment, the field observation is conducted at the wind shelter forest and the bare field. Fig. 6 shows the air temperature and relative humidity measured at the wind forest and the bare field every 10 minutes. At the wind shelter forest, the maximum and minimum air temperatures are 28.5 °C and 11.4 °C, respectively. On the other hand, the maximum and minimum air temperatures at the bare field are 32.5 °C and 12.4 °C, respectively. The relative humidity at the wind shelter forest is higher than the value at the bare field. The maximum difference of the relative humidity between the wind forest and bare field is 10%. These results are caused that the solar radiation is intercepted by the wind shelter forest canopy.

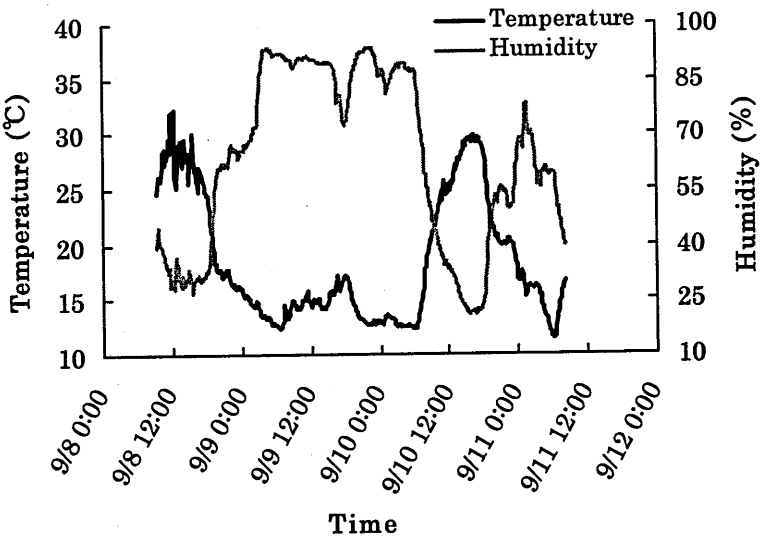
Fig. 7 shows the profiles of the soil temperature measured at the 0, 10, and 30 cm depth at the wind shelter forest and the bare field. These results indicate that the soil temperature at the bare field changes drastically, comparing the measurement at the wind shelter forest. The maximum soil surface temperature at the bare field is 34 °C. On the other hand, at the wind shelter forest, the maximum soil surface temperature is about 21 °C, and the difference of the soil surface temperature is over 10 °C.

Soil chemical and physical characteristics

To evaluate the effect of the wind shelter forest on the soil improvement, the soil characteristics are experimented. Fig. 8 shows the soil water characteristic curve estimated using the wind shelter forest soil and the bare field soil. The surface layer at the wind shelter forest shows the high water retention. The water retention by the soil at the wind shelter forest gradually decreases with the ground depth. At the bare field, the soil water characteristic curves in all depths shows similar profile. These results are caused that the water loss by soil surface evaporation is reduced because the solar radiation is intercepted by the forest canopy and the irradiance on the soil surface at the

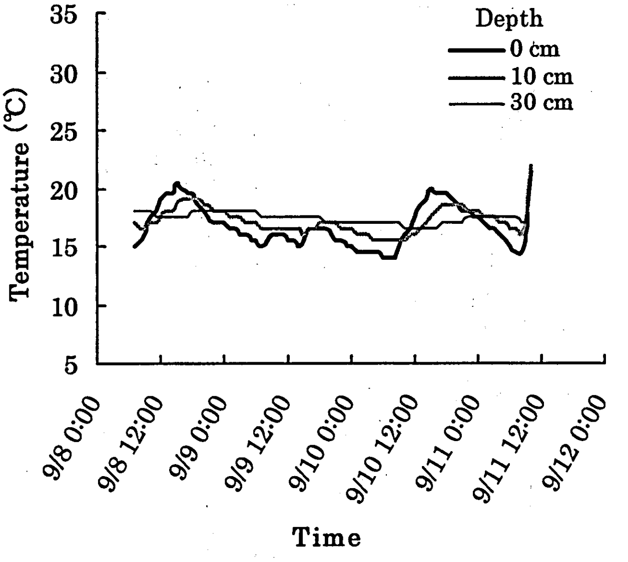


(a) Wind shelter forest

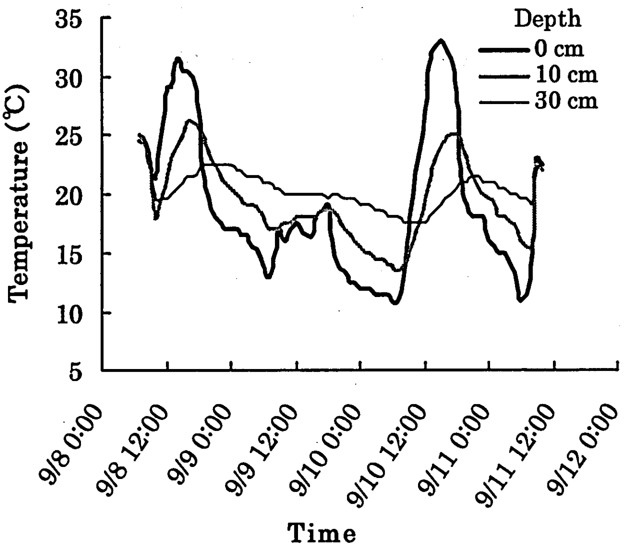


(b) Bare field

Fig. 6. Diurnal changes of the air temperature and relative humidity measured at the wind shelter forest and the bare field.



(a) Wind shelter forest



(b) Bare field

Fig. 7. Diurnal changes of soil temperature measured at the wind shelter forest and the bare field.

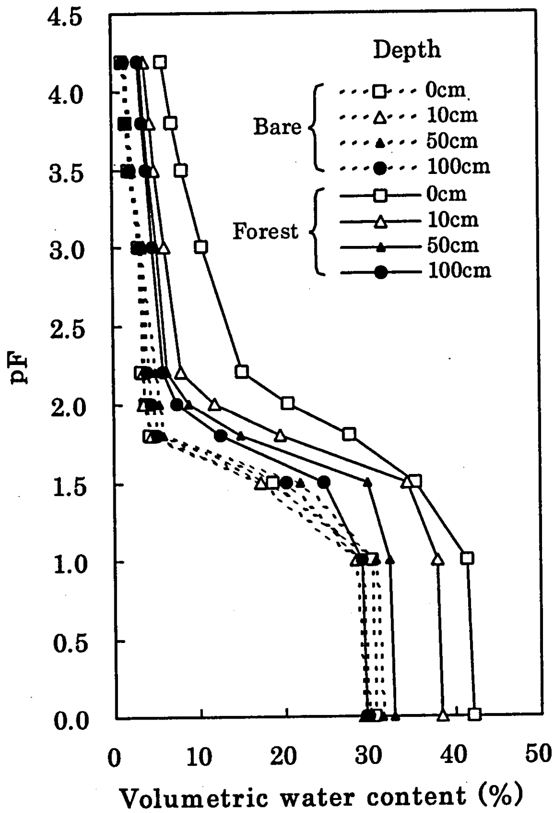


Fig. 8. Soil water characteristic curves.

wind shelter forest decreases, comparing at the bare field.

Table 1 shows the soil chemical characteristics, including organic matter content, cation exchange capacity (CEC), pH, and EC at the wind shelter forest and the bare field. The soils at the wind shelter forest and bare field are sampled at 10 cm depth. The value of the organic matter content at the wind shelter forest is four times as large as at the bare field, and CEC at the wind shelter forest shows high, comparing at the bare field. These results are caused that the fallen leaves from the wind shelter forest. The improvement of CEC at the wind shelter forest could improve the intention of the fertilizer. The differences of pH and EC between the wind shelter forest and the bare field are not marked. The result of pH experiment indicates that the soils at the wind shelter forest and the bare field can be classified as the alkaline soil. EC in the wind shelter forest decrease slightly, comparing with the value of the bare field.

Table 1. Soil physical and chemical characteristics.

Land use (Depth: 0–10 cm)	Water content (Air dry) (%)	Organic matter content (%)	CEC (meq/100g)	EC (mS/cm)	pH
Windbrake forest	0.69	0.67	6.9	0.012	8.87
Bare sand	0.36	0.14	3.3	0.030	9.31

Note: EC values are measured with 1:5 dissolusion method

CONCLUSIONS

To evaluate the effect of the wind shelter forest on the micrometeorological environment and the soil characteristics, the experimental study is conducted in Naiman. First, the method of the development of the wind shelter forest is investigated in the study site. It is clear that the process of the development of the wind shelter forest is planned, considering the geographic and climate conditions.

The micrometeorological observation is conducted at the wind shelter forest and the bare field in the study area. In the wind shelter forest, the air temperature decreases, and the relative humidity increases, comparing with the bare field. The diurnal change of soil temperature is mitigated, especially the soil surface temperature is much lower, comparing the value at the bare field.

The experiments on the soil physical and chemical characteristics are conducted to evaluate effect of the wind shelter forest on the soil improvement. At the wind shelter forest, the improvement of the soil water retention can be obtained, comparing with the value at the bare field. The results are caused that the water loss by soil surface evaporation is reduced because the solar radiation is intercepted by the forest canopy and the irradiance on the soil surface at the wind shelter forest decreases. The soil chemical characteristics at the wind shelter forest, including organic matter content, cation change capacity (CEC), pH, and EC, are improved comparing with the value of the bare field. These results are caused that the fallen leaves from the wind shelter forest. The mitigation of the micrometeorological environment affects on the soil chemical characteristics, because the microorganism decomposing the organic contents in the soil has relation to the micrometeorological factors. These results indicated that the improvement of the soil chemical characteristics and water retention by the soil should be continued by cultivation of the deep root crops, supply of the organic matter, soil improvement, and so on.

The various effects of the wind shelter forest on the intrinsic environment are clarified in this study. In the development of the wind shelter in the arid area, the geographical and land use conditions should be taken into account to increase the wind shelter forest effect.

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