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Effectiveness of Environmental Restoration Induced by Various Trials for Preventing Desertification in Horqin Arid Land, China – Straw Net Method (Part 1) –

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The quicksand phenomenon is one of the big factors of desertification. This report introduced straw net method which is one of the effective methods for stabilizing quick–sands. This method is to cover the sand dune with straw nets with square circumference of about 1 m. Height of straw fence is about 10–20 cm from soil surface and the depth is about 10–30 cm. Grass seeds are sprayed after construction of the nets. In some cases, young trees such as pine and yellow willow are planted.

At first this method was adopted as the way of protecting a road, a railway from the flow dune in Horqin arid land. Nowadays this method has become popular and widely used for the fixation of the flow sand and for recovering the vegetation, in arid area China.

The merits of straw nets on protecting desertification can be pointed as follows. First, the flow sand can be stabilized by the wind–proof effects. Second, the natural material of straw which are an agricultural by–product can be procured in the farm village in the spot. Third, the technique to construct nets is easy. Fourth, the prompt effect after establishment can be expected. Fifth, grass and trees are fixed at the short time by harvesting the snow and rainfall as natural water to the root zone.

The new evaluation of straw nets is the effects on the microclimate modification such as lowering air temperature, increasing the air humidity and lowering soil temperature. These environmental modifications are effective for the prompt germination of the seed and nursing vegetation growing.

As mention above, this straw net method is effective for the sand dune fixation and the vegetation recovering.

INTRODUCTION

Desertification is a degradation phenomenon on the arid land and the half arid land which is caused by that the various artificial factors to support a change of the environ-

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ment of the nature such as the climate and a human activity by twine complicatedly. The environment change accompanies the vegetation degeneration, or the disappearance, the loss of the land productivity, and so on. The changes of the ecological environment bring the declination of the regional economy seriously. The vegetation restoration by the area which faces to make a desert in this way is the urgent problem which is common to the human race. When seeing the area which faces the development of desert at the earth scale, it is equivalent to one fourth of the world land area and about 900 million people undergo the influence, after the report in United Nation's desertification environment investigation in 1990 (Jiang *et al.*, 2002).

China which is the investigation area of this research is nominated for one of "the country where the crisis of developing a desert is very serious". A desert zone in China is mainly distributed between north latitude 37–47° and the total area is 1,270,000 km^2 and this accounts for about 13% of the country total area. In recent years, the scientist in China is reporting that the desert increase reaches to 246,000 ha every year (Zhu, 1985). Especially, the development of desert is conspicuously observed in the drought area and the grassland area in Horqin arid land which is the investigation area located in the Chinese northeast part.

Horqin arid land is the mixed zone of the agriculture and livestock–raising in the north of China and this area is counted to one of the typical desert developing zones. The range of the zones spread to 3 Ministries, Inner Mongolia, Jilin and Liaoning, and the total area is about 62,100 km^2. Rapid degeneration of the vegetation began at the same time of the 1960s when the food production increase policy began. As a result, the desertification area. which contains an investigation area reached 43.6% of the total area (Jiang *et al.*, 2002).

Before the desert development have begun, Horqin arid land was covered with a thin wood and the grassland with rich water resource. After the 1960s, addition to the natural drought and gale tendency, over cutting the tree, over cultivation land and over pasturage caused the increase of the desertification. The ecological environment in the concerned area which was under the fragile ground environment primarily degenerated rapidly and to make a desert progressed. As a result, except for the part of the Horqin natural grass land which is left at present, a lot of areas were changed into arid soil.

In Horqin arid land, it is executing the planting trees of the green tract of land recovery projects which was taken in from the 80s, too, effectively whereas the difficulty which hinders planting trees plan on the desert, too, exists. In one of the big factors is a quicksand phenomenon by the wind, especially, in the investigation area of this research, as for selected Horqin arid land, a lot of dunes are formed by quicksand. The research and the development of the fixation method of the quicksand which are appropriate to bring big hindrance to the vegetation restoration, i.e. the planting trees plan promotion and the planting trees technology method on the dune are made the urgent and moreover most important problem.

In Naiman area which is situated on Horqin arid land, the restoration of the ecology environment is tried with various vegetation recovery methods of construction implemented. This paper introduces about the straw net planting trees method of construction and the effect which is especially tried on the flow dune.

GENERAL CONDITION OF THE INVESTIGATION AREA

Geographical conditions

Horqin arid land is spreading to the range of north latitude 41°41′–47°39′ east longitude 116°21′–123°43′ and altitude 178.5 m (TongLiao)–631.9 m (Wudan). The scale of this arid land accounts for 12% of the total area of Inner Mongolia. Arid land is widely distributed mainly until it leads to the Daxinanlin cordillera on the alluvial plain on the parched branch coast of down stream of the Xiliao river, in the northern part on it. The administrative district is consisted of seventeen small districts in the Inner Mongolia, eastern part in the two Ministries in Jilin, and three Ministries in Liaoning. Most of the sand areas are distributed over the Tongliao area and the Chifeng area (Fig. 1). Especially, about 65% of sandy soil exists in the Tongliao area. This area is the main food production base in the Inner Mongolia constituency. The main products are maize (about 40% of the cultivated area), sorghum (about 30%), paddy rice (about 30%), wheat, beans, sunflower and so on.

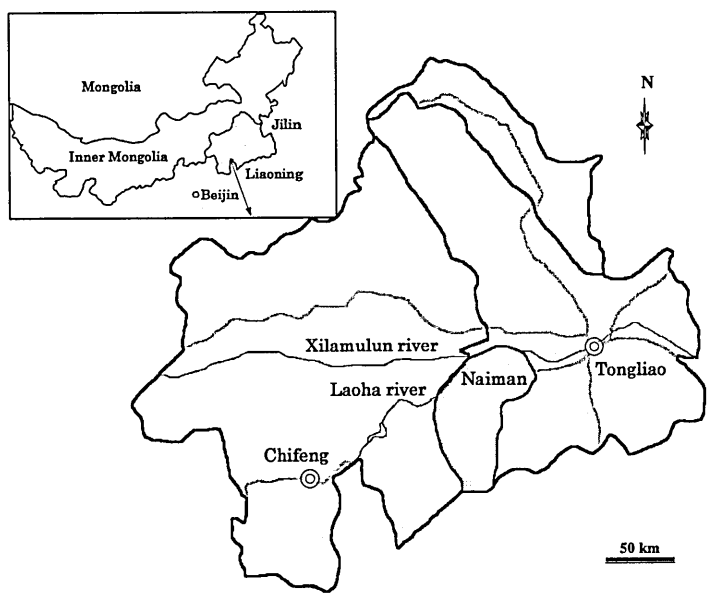


Fig. 1. Horqin Arid Land.

Weather conditions

The climate of the investigation area is crossing from the temperate zone to the sub arctic zone and the half humid zone, and the natural conditions are strongly influenced in the Mongolia high atmosphere pressure. The average evaporation quantity in a year of this area is 1,700–2,400 mm, the relative humidity is 50–55% and the annual duration of sunshine are about 2,900–3,100 hours. The average temperature in a year of this area is

5.2–6.4 °C, the maximum temperature is 39 °C, a minimum temperature is –29.3 °C and the duration of accumulated temperature more than 10 °C is 3,000–3,200 hours. The amount of rainfall in southern and eastern parts is larger than in the northern and western parts. The variation of the amount of annual rainfall is large (Liu *et al.*, 2003).

The monthly average of the number of the days when gales blow and the temperature of the main area in Horqin arid land were shown in Table 1 and 2. In July, average temperature exceeds 23.6 °C every year. The average temperature from November to March of the following year is equal to or less than 0 °C and the ground freezing depth in this period reach to more than 1 m. Also, the annual average wind velocity is 3.5–4.5 m/s. In the season of the winter and the spring, the northwest or the north wind blows strongly and reaches 31 m/s at the maximum. It is called as gale when the wind velocity is equal to or more than 17 m/s with the disaster wind.

The average grain diameter of the sand which composes the surface of Horqin arid land is small with 0.01–0.5 mm, the cohesion of earth particle, too, is weak, the wind sand

Table 1. Wind conditions in central Horqin Arid Land.

Name of the area	Naiman	Kailu	Tongliao
Average wind velocity in spring (m/s)	4.4	5.2	4.6
The annual average number of gale days (d)	22.4	25.2	27.5
Maximum number of gale days within a year (d)	45.0	42.0	48.0
Month	Average number gale days		
1	1.6	1.4	1.0
2	1.6	1.5	1.3
3	3.5	3.9	4.1
4	4.9	5.4	7.3
5	4.0	5.6	6.1
6	1.2	1.7	2.2
7	0.3	0.8	1.4
8	0.3	0.4	0.7
9	0.6	0.4	0.6
10	1.2	1.6	1.6
11	1.9	1.7	1.6
12	1.4	0.7	0.8
Percentage of gale days from Dec. to May	75.9	73.4	72.3

Gale: Wind speed more than 17 m/s. (Mcience and technology literature report, China 2001).

Table 2. Monthly average temperature in central Horqin Arid Land (°C).

Name of	Spring			Summer			Autumn			Winter		
the area	3	4	5	6	7	8	9	10	11	12	1	2
Naiman	-1.6	8.2	16.5	20.9	23.6	21.7	15.8	7.6	-2.5	-10.7	-13.1	-9.8
Kailu	-2.6	7.8	16.0	21.0	23.9	22.1	15.7	7.0	-3.5	-11.7	-14.7	-10.8
Tongliao	-2.8	7.6	15.9	21.0	23.7	21.9	15.4	6.9	-4.0	-12.9	-15.3	-11.7

(Jiang *et al.*, 2001)

phenomenon occurs easily in the weak wind and has an influence on the change of the landform (Zhao *et al.*, 1998; Jiang *et al.*, 2002). The average grain diameter of wind sand in this area is 0.1–0.25 mm. Wind sand begins to move at about 4–5 m/s wind speed (Table 3).

The area of Horqin arid land is so wide that the distribution of rainfall isn't uniform. The annual average rainfall reaches about 340–400 mm and 70% of the annual rainfall centers mainly in the summer (Table 4).

Table 3. Relationship between sand-raising wind speed and diameter.

Particle diameter of sand grains (mm)	Wind velocity at height 2 m (m/s)	Wind velocity at height 10 m (m/s)
0.1–0.25	4.0	5.5
0.25–0.50	5.6	7.7
0.50–1.00	6.7	9.2
>1.00	7.1	9.8

(Zhang *et al.*, 1991)

Table 4. Seasonal precipitation and its percentage in whole year in central Horqin Arid Land.

Weather station	Position	Annual precipitation (mm)	Spring		Summer		Autumn		Winter	
			precipitation (mm)	%	precipitation (mm)	%	precipitation (mm)	%	precipitation (mm)	%
Naiman	42°14′N, 120°19′E	366	43.9	12.1	255.6	70.5	56.7	15.7	6.2	1.7
Kailu	43°36′N, 121°17′E	338.8	37.2	11.0	244.6	72.2	52.9	15.6	4.2	1.2
Tongliao	43°36′N, 122°16′E	394.7	47.7	12.1	272.1	68.9	67.0	17.0	7.8	2.0

(Jiang *et al.*, 2001)

Distribution of the dune and quick-sands

The big desert zone spreads from east to west about 400 km length. The inclination descends in the southeast gently from the western side to the opposite stair stepping and extends to the flat area. The characteristic of the landform in this area is that the low land area spread between the dune and the sand ridge regularly. The surface of the earth is mainly the desert which was covered with thick gravel stone and breccias. However, as for the western central part, the fixation dune, the flow dune and the half flow dune spread, as for the alluvial plain in the central part, sandy soil and a dune are regularly distributed mainly and as for the eastern part, the quick-sands having to do with a fleck which are due to the wind exist among the fixation dune groups with big area. As for the shape of the flow dune, the half-moon-type pattern and the irregular dune range mutually and it is as much as 10 m but the height of the dune is generally composed by the dune with 20–30 m in the maximum and with various shapes.

The sandy soil grain diameter analysis at three points of study area was shown in Fig. 2. Soil in this area was composed of the minute particle equal to or less than 1 mm. No difference between the three points were observed. According to this, about 40% was

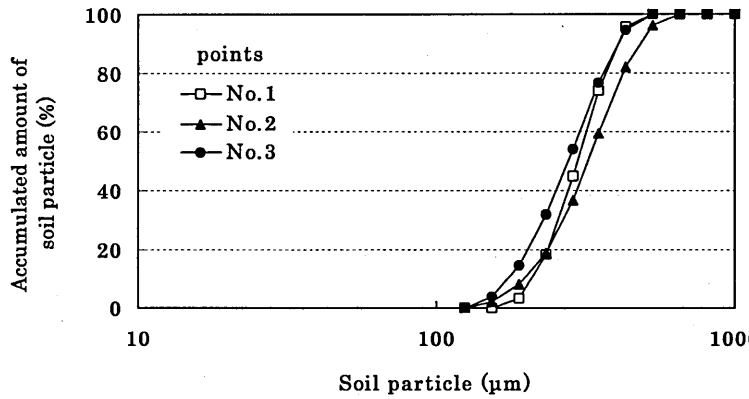


Fig. 2. Soil particle characteristic of sand soils in Horqin Arid Land.

fine sand and 60% of the remainder was fault sand. The results can be confirmed by the investigations of Zhao *et al.* (1998).

Soil moisture conditions

Generally, the ground water level is said to exist within 4 m from the surface. At flow sandy dune area, the percolation speed of soil water is about 0.01 cm/s. The change of the

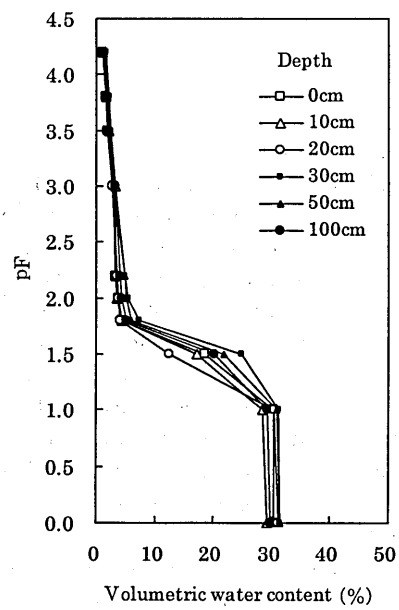


Fig. 3. Soil water characteristic curve.

ground holding water quantity in the sand layer of 0–3.0 m is low. The volumetric soil moisture in the surface layer, 0–5.0 cm, is about 1% and in the layer deeper than 5 cm is between 2–5%. At fixated sand dune, the ground holding water quantity in the sand layer of 0–3.0 m is large comparatively. In the early spring, water quantity range in 1–3% and 4–5% in rainy season. However, high soil moisture tendency is relatively admitted by the replenishment of ground water and the rainfall on the low land among the dunes. It was observed to reach 23.3% at the maximum.

Fig. 3 shows the soil moisture characteristic curves of one of the sand dune in the study area. Field capacity (pF 1.8) is observed as about 6%. Saturated water content is about 30%. Only small differences were observed between the 6 depths.

STRAW NET CONSTRUCTION

Because the grain diameter of sand on the dune is small, sandy soil moves easily by the small wind speed. Therefore, the fixation of quick–sands becomes a big problem. Straw net method is the most typical method for stabilizing the flying sand. This method is applied for the construction of important facilities, the road, railway and so on, against the harm of flying sand on the dune. This way is one technology for the fixation of quick–sands and planting trees in the dune are done at the same time.

The method for constructing the straw net is as follows. First, it draws a line with about 1 m length and width with grid array format to the surface of dune, and bury straws along the line with quadrangle exposing reeds about 10–20 cm above the ground level (Fig. 4). On the dune surface, this is developed as "the basis method of construction" about the early stage step of the vegetation projects.

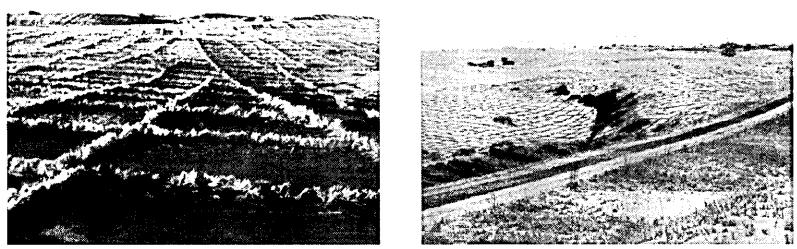


Fig. 4. The structure of straw net in early stage.

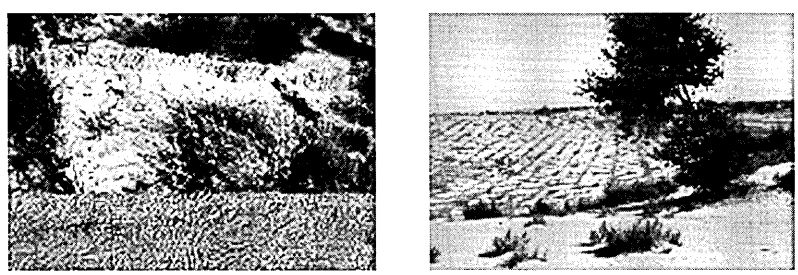


Fig. 5. The structure of straw net in early stage.

Wind velocity near the surface of the earth is eased by this, and the movement of sand is fallen. To fix a dune, seed, pine, yellow willow are planted inside the straw net after construction (Fig. 5). Sand is stabilized by the straw nets and grass.

EFFECT OF STRAW NETS ON SAND DUNE STABILIZATION

Preventing the flying sand

Typical model on the wind-proof effect of the straw net development is shown in Fig. 6 (Tusboi, 1974). The wind which is blowing in the parallel to the ground rises near the fence of straw, through the top of the big whirlpool which occurred in the rear of the fence of straw, it descends along the back edge of the whirlpool and the wind becomes level again. The wind which passed the fence of straw was being right-angled becomes the weakest of several times of places of the height of the fence of straw and after that, it recovers gradually. The wind-proof effect of straw net becomes the best at the length about 5 times of height from the fence which was exposed on sand. The measurement of the wind velocity shows that the change of the wind velocity is occurred with in 30 times of the height of the fence as shown in Fig. 7 (Tusboi, 1974). The range of the wind-proof

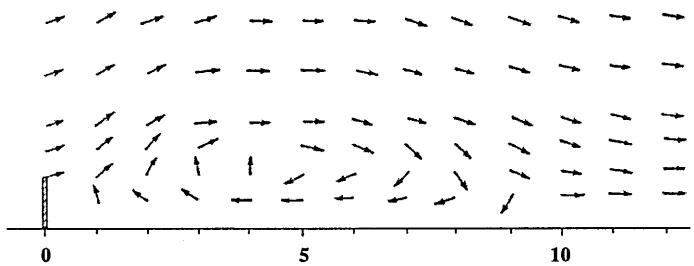


Fig. 6. The direction of the wind distribution in the perpendicular section behind the wind-proof (Tani *et al.*, 1958).

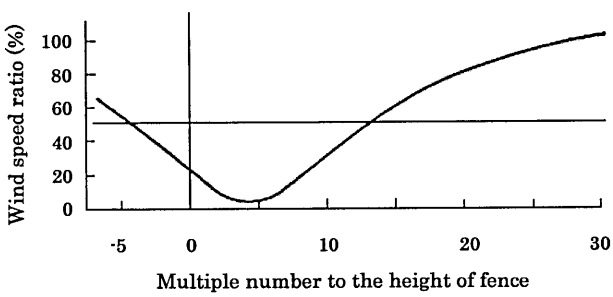


Fig. 7. The wind speed in the perpendicular section in front and behind of the wind-proof fence (Tani *et al.*, 1958).

effect becomes large when the direction of the wind is perpendicular to the fence of straw. It is possible to evaluate how the wind velocity is weakened in straw net.

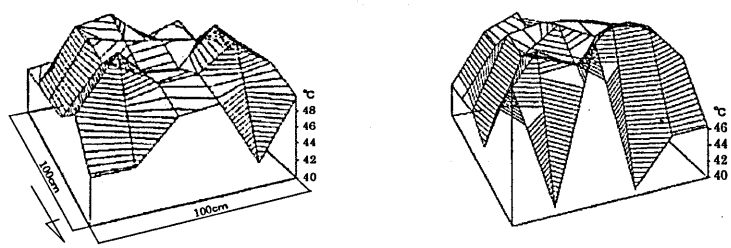
In the area of the fixation sand where straw net method of construction was done, the wind velocity declines by about 76.3% and quicksand quantity is restrained by equal to or less than 0.28% (Liu and Zhang, 1997).

Han and Chen (1993) also reported that the amount of quicksand quantity by the straw nets with 15–20 cm height from the sand surface is only one thousandth of the non straw nets sand dune.

Modification of the microclimate

To lay straw in sand and to increase a surface area are effective for changing the heat environment. Fig. 8 shows the surface temperature in a straw net measured with the infrared thermometer. The height of the plant is about 60 cm. Isotherm lines are displaying every 0.5 °C. Fig. 8 (a) is the temperature in a net with one plant in a central part. In the plant growth ward, the hollow part of the temperature decline is admitted at the center caused by the plant shade. Fig. 8 (b) is the temperature in a net with non plant. The straw temperature shows about 10 °C lower values than that of the sand surface. The straw exposed above the ground has an effect on modifying the temperature by exchanging heat between air and straw. The straw nets which used in this way could admit the effect on modifying the temperature. Also, the decline of the wind velocity by the straw net influences the decline of the ground temperature and the decrease of the evaporation quantity, and these phenomena will effective for saving soil water consumption.

On the other hand, fog and snow which is carried by the wind will contribute for sandy soil to replenish moisture.



(a) Planted (b) Non-Planted

Fig. 8. Sand surface temperature in the straw net treatment.

Soil improvement and vegetation recovery

The effect of straw nets construction on stopping quick–sands has been proved empirically. Additionally, the straw nets play a role of the moisture supply to sand soil. This is effective for the prompt germination of the grass. Inside of the straw net, plants can expand their roots up to about 30 cm depths without irrigation (Li *et al.*, 2000).

After two years from construction, the straw nets decay and improve the chemical and physical conditions of soil. According to the experiment at the area seeded of *Caragana microphylla* inside of straw net, the increase of the organic materials and the resolvable N, P, K contents were admitted in the surface layer of 0–10 cm (Kawanabe and Bao, 2000). Long term investigation during 35 years after construction of straw nets, plant species increased at maximum 23 kinds (Cao and Liu, 1998).

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