

Biological Models for Protecting Different Land Use in Arid Areas China

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Abstract. There are more than 750 counties in 13 provinces and autonomous regions constituting 30% of China lands which are facing serious problem of desertification. These areas are mainly distributed in arid, semi-arid and dry sub-humid areas in the western part of Northeast China, North central china and most of northwest china. Biological methods are the ultimate way for drift sand stabilization and a fundamental approach for the development and proper utilization of desert. There are 12 deserts in two physiographical situations (hilly and low land situations) where some successful biological methods for combating desertification have been documented. These methods were used on the basis of land use and the best plant species which are suitable for these harsh conditions. The land uses that are suffering most from desertification are agricultural areas, highways, railways, roads, cities, industrial places and mining areas. The important plant species used for combating desertification are *Hedysarum laeve*, *H. scoparium*, *Amorpha fruticosa*, *Lespedeza bicolor*, *Caragana microphylla*, *C. korshinskii*, *Artemisia halodendron*, *A. sphaerocephala*, *Astragalus adsurgens*, *Ulmus pumila*, *Hippophae rhamnoides*, *Haloxylon ammodendron*, *Calligonum mongolicum*. Transplanted seedlings, direct sowing, use of cutting, and air seeding techniques were used for greening areas degraded by wind and water erosion. Different models have been applied for protecting agricultural areas, cities, highways, railways and roads, industrial or mining and reservoir properties. Some successful models which have been employed are shelter forest system in oases, shelter system for sand fixation in agricultural areas, transportation, industrial or mining and reservoir properties.

Keywords: China desert, Biological methods, Plant species.

Introduction

Chinese people are unremitting in their efforts to struggle against the adverse effects of desertification. Some available measures to fix shifting sands in the different regions have been created by Chinese scientists through the successive implementation in such major ecology restoration projects as the Three North Regions Shelterbelt Construction Project and the National Action Program to Combat Desertification.

Effective progress in the aspects of re-vegetation, rangeland improvement and soil and water conservation have been made in the affected areas. Some acceptable and practical techniques, successful demonstrations and rich experiences as well as extension service models to combat desertification and manage dry lands have been developed at community, local and national levels. For instance, the techniques of dune fixation and sand stabilization with biological and mechanical measures along railways, highway and at mining facilities have been created. The techniques of air-seeding of bushes and grasses to re-vegetate shifting sand lands were used. The technical measures of rice cultivation with under-soil plastic mulching in dune areas and countermeasures to implement the integrated management of watershed were also applied. The traditional skill of rational rotation grazing system and the determination of rangeland quality and carrying capacity were employed. The approaches to develop fodder farms and high efficiency grazing land and public awareness rising of shed-feed animal raising and the development of eco-farms were used for improving vegetation cover. According to the demand for development of national economy of China, appropriate balance should be kept among agriculture, forestry and pasture. The arrangement of plantation place generally isn't effected by grass and shrub vegetation, so afforestation should be arranged according to the technical requirement. Biological methods

are the ultimate way for drift sand stabilization and a fundamental approach to the development and proper utilization of desert (Yaolin and Jihe, 2005). The measures used to fix sands in China can be classified into two types: One is to protect the extant vegetation on the sand dunes or where such vegetation has deteriorated to plant trees, shrubs and grasses. This type is called a biological methods or plant measure for desert control. Another is the mechanical measures.

In this paper, some successful biological methods proposed by Chinese scientists for protecting the properties will be summarized. Different methods would be suitable for protecting various kinds of desert features and also, for different properties.

General biological characteristics of plant species

Artificial plantations of trees, shrubs and grass are the most effective measures to stabilize mobile dunes and fix shifting sands in arid and semi-arid regions for protecting village and agricultural properties. The methods used in plantation for fixing sands are:

- Plantations of trees, shrubs and grasses in the inter-dune and low-lying lands; Shrubs that have a high resistance to wind erosion are planted in the front or middle part of windward slopes of dunes.
- Cuttings of species there are drought-resistant in sandy soil such as *Salix* spp., *Artemisia* spp. And *Calligonum* spp. are planted in the leeward slopes of sand dunes to fix the sand surface of dunes. This plantation is characterized by non-irrigation and quick growth with production of fodder for livestock and fuel wood (Youlin *et al.*, 2005).

Species selection

Natural conditions in various desert areas are quite different and they are a key to select suitable species based on local conditions. So, the selection of species is the key for successful artificial

afforestation. If the suitable species are not selected, not only it will be a failure for afforestation and lead to the waste of labor, material and money, but also the land potential will not be taken into effect due to the bad growth of trees on it. When selecting suitable species, the following items should be taken into consideration:

- 1) Selecting the species which grow well from nearby area.
- 2) Selecting local species.

3) Selecting the species with high economic values.

4) Selecting the species that are strong in sand fixing.

There are 4 main factors effecting the selection of desert plants including zonal, temperature, ecological series and sand dune sectors. There are some series of plant species which are suitable for different desert types (Table 1).

Table 1. Suitable Plant Species for Different Desert Types

Desert type	Suitable Species
1 Desert	<i>Populus euphratica</i> , <i>Populus alba</i> var. <i>pyramidalis</i> , <i>Populus gansuensis</i> , <i>Reaumuria soongorica</i> , <i>Elaeagnus angustifolia</i> , <i>Caragana korshinskii</i> , <i>Hedysarum scoparium</i> , <i>Haloxylon ammodendron</i> , <i>Calligonum</i> sp, <i>Tamarix</i> spp. <i>Artemisia arenaria</i> , <i>Zygophyllum xanthoxylum</i> and <i>Atraphaxis bracteata</i> .
2 Sand dunes	<i>Haloxylon ammodendron</i> Bge., <i>Tamarix ramosissima</i> Ledeb., <i>Hedysarum scoparium</i> Fisch.et Mey., <i>Caragana korshinskii</i> Kom, <i>Calligonum arborescens</i> Litv., <i>C. caput medusa</i> Schrenk and <i>C. mongolicum</i> Turcz.
3 Arid area	<i>Haloxylon ammodendron</i> , <i>Hedysarum scoparium</i> <i>Caragana korshinskii</i> .
4 Semi arid area	<i>Salix matsudana</i> , <i>Populus canadensis</i> , <i>P. simonii</i> , <i>P. nigra</i> var. <i>italica</i> , <i>P. alba</i> var. <i>pyramidalis</i> and <i>P. nigra</i> var. <i>thevestina</i> .

(a) In the steppe desert area.

Hedysarum laeve, *Amorpha fruticosa*, *Lespedeza bicolor*, *Caragana microphylla*, *Artemisia halodendron*, *Astragalus adsurgens*, *Ulmus pumila*.

(b) In the steppe and desertified steppe areas

Hedysarum laeve, *Hedysarum scoparium*, *Artemisia sphaerocephala*, *Astragalus adsurgens*, *Caragana korshinskii*, *Hippophae rhamnoides*.

(c) In the arid areas

Haloxylon ammodendron, *Calligonum mongolicum*, *Hedysarum scoparium*, *Artemisia sphaerocephala*.

Important treatments for different seeds, sowing period, sowing rate and sowing methods are necessary. The sowing rate for

different plant species with seed quantity are recommended by the scientists for planting at deserts of China (Table 2).

Table 2. Sowing Rate of Several Main Sand-Holding Specie

Species	Seed quantity per mu(kg)	Species	Seed quantity per mu(kg)
<i>Haloxylon ammodendron</i>	1.5 – 2	<i>Tamarix</i> spp.	0.5 – 0.7
<i>Elaeagnus angustifolia</i>	20 – 30	<i>Calligonum</i> spp.	10 – 12
<i>Hedysarum scoparium</i>	10 – 12	<i>Nitraria tangutorum</i>	10 – 12
<i>Caragana korshinskii</i>	13 - 15	<i>Artemisia arenaria</i>	0.5 - 1

Biological Models for protecting different land uses

The integrated shelter system that consists of 3 parts fixing sand belt for preventing wind erosion on the periphery of oasis, stocking sand belt for breaking wind and stopping the shifting sand along the edge of oasis and forest network within oases for protecting the farmland. This model is the cardinal pattern of shelter system for sand harm in China. Usually, the shrub and grass belt is (300-500) m wide. The purpose of closing the area is to protect the land surface from wind erosion, and to stop shifting sand. The shrub and grass belt is a first defense for protecting the oasis. Establishing the shrub and grass belt is a pioneering measurement for the establishment of the whole system because shrub and grass belt can be established easily and it can take into effect rapidly. At the beginning, after the completion of an integrated system, the shrub-grass belt can stop drifting sand; resist the wind erosion, protecting the young trees used in the system, and the free belt. Generally, the sand-stocking and sand-fixing forest belts are the second defense ranging from (200-

300) m to 1000m wide in the forward region of dunes where a great number of shifting sands can encroach on oases; it is (50-100) m wide in the sections where shifting sands are close to oases and the trees can be planted at the feet of sand dunes; it is (30-50) m wide in the sections where farmland adjoins semi-fixed dunes; and it is (10-20) m wide in the sections where sand source is not rich. There are some example models for protecting oases (Ming, and Yaolin, 2006).

Comprehensive control of shifting sand in Xishawo, Minqin County

Closing the fixed and semi-fixed dunes constituted by the sand mounds covered by *Tamarix laxa* and *Nitraria tangutorum* (Fig.1). Close to farmland, the belt is formed for protecting natural vegetation. In the section attaching to mobile sand dunes on the periphery of closing belt, Russian olive and poplar are planted as patches in lowlands among dunes to encircle the dunes, clay or wheat straw barriers are constructed in grid or line and *Haloxylon ammodendron* is planted within barriers on dunes.

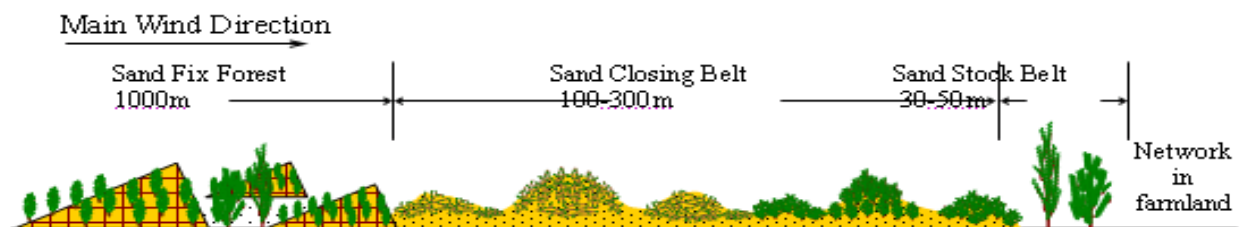


Fig. 1. Shelter System in Xishawo Minqin County

Comprehensive control of shifting sand in northern bank of Heihe River in Gaotai County

Sand-stocking forest belts with 12-16m width per belt are planted with trees (*Populus gansuensis* and *Elaeagnus angustifolia*) in the sand area close to farmland; there is an interval of 10m between neighboring belts (Fig. 2). Forest multi-belt for stocking sands is planted with trees and shrubs along the foreword

line of mobile dunes. Based on the construction of sand barriers, shrub forest for fixing shifting sands is planted with *Haloxylon ammodendron* and *Calligonum spp.* on mobile sand dunes within 100m out of sand-stocking forest belt (Fig. 3). Combined with the placement of sand barriers, sand-closing belt for rehabilitating natural vegetation whose width is (200-500) m is placed on the periphery of sand-fixing belt.

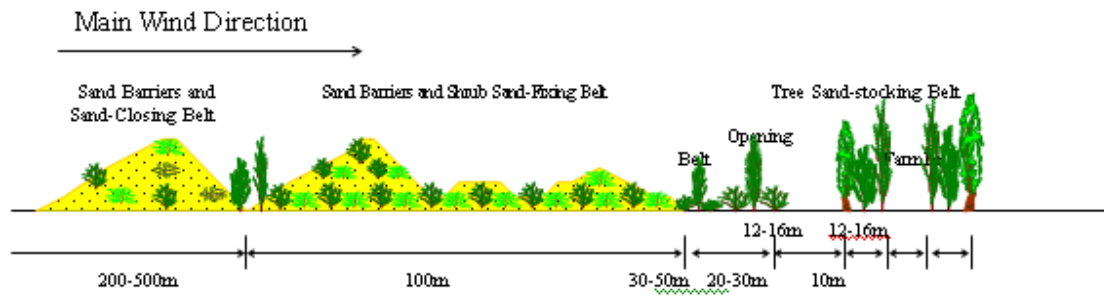


Fig. 2. Comprehensive Shelter System in Jiuba, Gaotai County

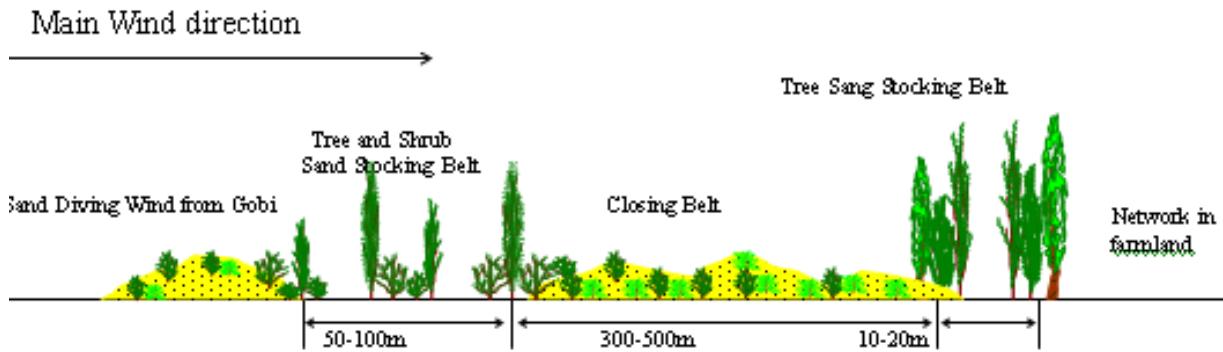


Fig. 3. Comprehensive System for Near Aydingkol Lake, Turpan County

Throughout diverting water in autumn and summer to irrigate the land and afforest outside of sand-closing belt, the forest belt that is disposed in multi-belt and where wide rows alternate with narrow rows for stocking blown sand is planted with trees (*Populus alba* var. *pyramidalis*, *Elaeagnus angustifolia*, *Ulmus pumila*,

etc.) and shrubs (*Tamarix spp.*) on it. Shelter forest systems of oases in sandy desert include closing belt for grasses (shrubs) established with front line of mobile dunes, land-break and sand-stock forest belt along the edge of oases and forest network in farmland in oases. (Fig. 4).

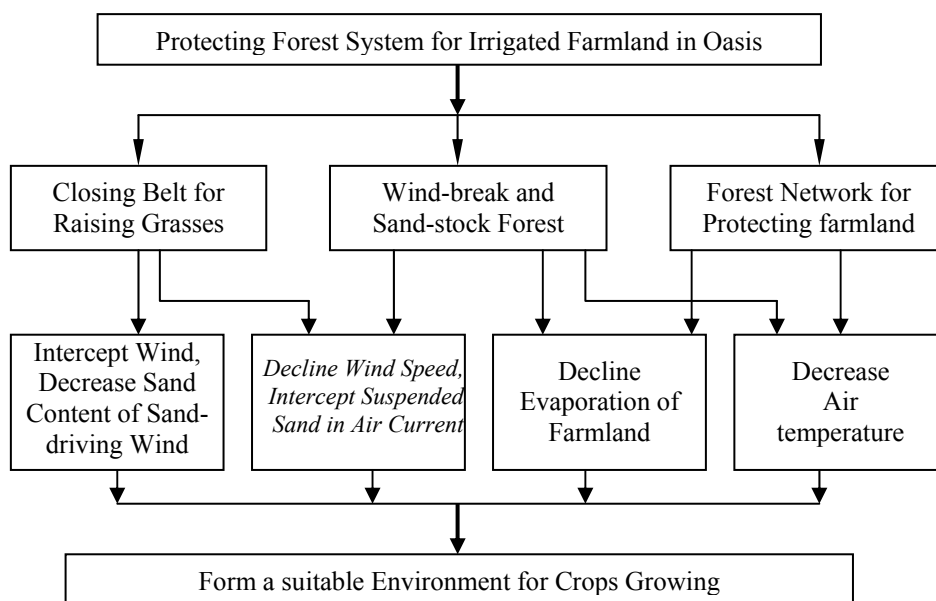


Fig. 4. Shelter Forest System in Oases

Planting forest on lowlands

This measure is common in Mu Us sandy land called as “blocking shifting sand dune in front and dragging it from behind”. Wushenzhao lain in the north of Mu Us sandy land is taken as an example here.

The concrete method is to take the trees as major species for afforesting in lowlands among shifting sand dunes called as “blocking shifting sand dunes in front”, breaking up and surrounding mobile sand

dunes and planting sand-fixing plants on lower(1/3) part of windward slope of the dune to form “dragging dune from behind”. The middle and upper parts of wind ward are eroded by wind constantly, the height of dune declines constantly, even a concave is formed by wind erosion in former upper part of dune and at this time, sand-fixing plants are planted on the concave (Fig.5). This continues till whole sand dune becomes even.

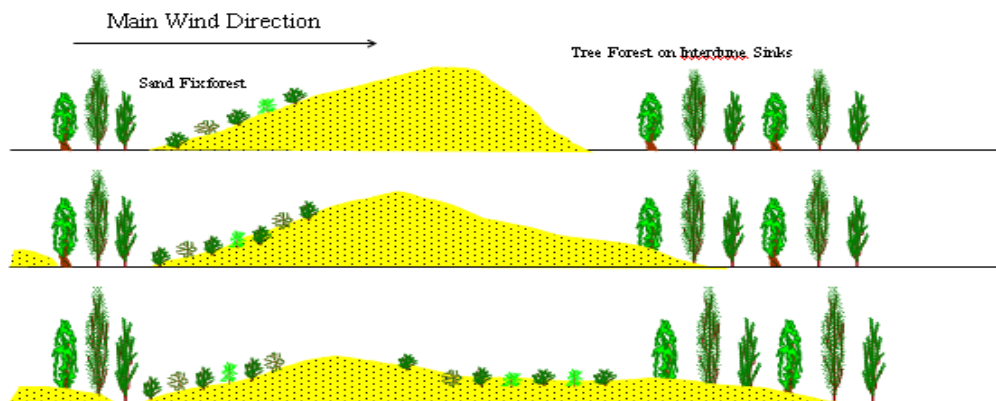


Fig. 5. Blocking Shifting Sang Dunes at Front and Dragging at back in Wushenqi

In general, this process takes about 5 years, thus the coverage of controlled sand land could be increased to over 50%, so far as shifting sand is stabilized. What is worth mentioning especially is that aerial sowing has achieved successfully on Mu Us Sandy lands and the coverage reaches 50-60% after 4-5 years of sowing. This is an event of important practical significance to improve the sand control work in semiarid area of China.

Trees in combination with shrubs to control shifting sand

It is adopted that tree patches are planted on sinks between dunes, simultaneously with planting sand binders (mainly shrubs) on sand dunes and later building pine (*Pinus sylvestris* var. *mongolica*) grove to form woodlands in Horqin sandy land. Experience of Zhanggutai district in

Liaoning province shows that measures for arresting mobile sand dunes include the following: first, the belts of *Artemisia halodendron* samplings or the cuttings of *Salix gordejvii* are planted on the middle-lower part of windward slope to prevent wind erosion, *Lespedeza davurica* or *Caragana microphylla* may be used for the same purpose, then, sand-fixing plants should be cultivated when the dune top is leveled off. After about 3 years, when the sand surface is relatively stabilized, it is the high time to plant *Pinus sylvestris* var. *mongolica* between shrubs or herbs on the sand.

The shifting sand dunes in Zhanggutai district are transformed into the fixed sand land of *Pinus sylvestris* var. *mongolica* grove with the measures aforementioned (Fig. 6).

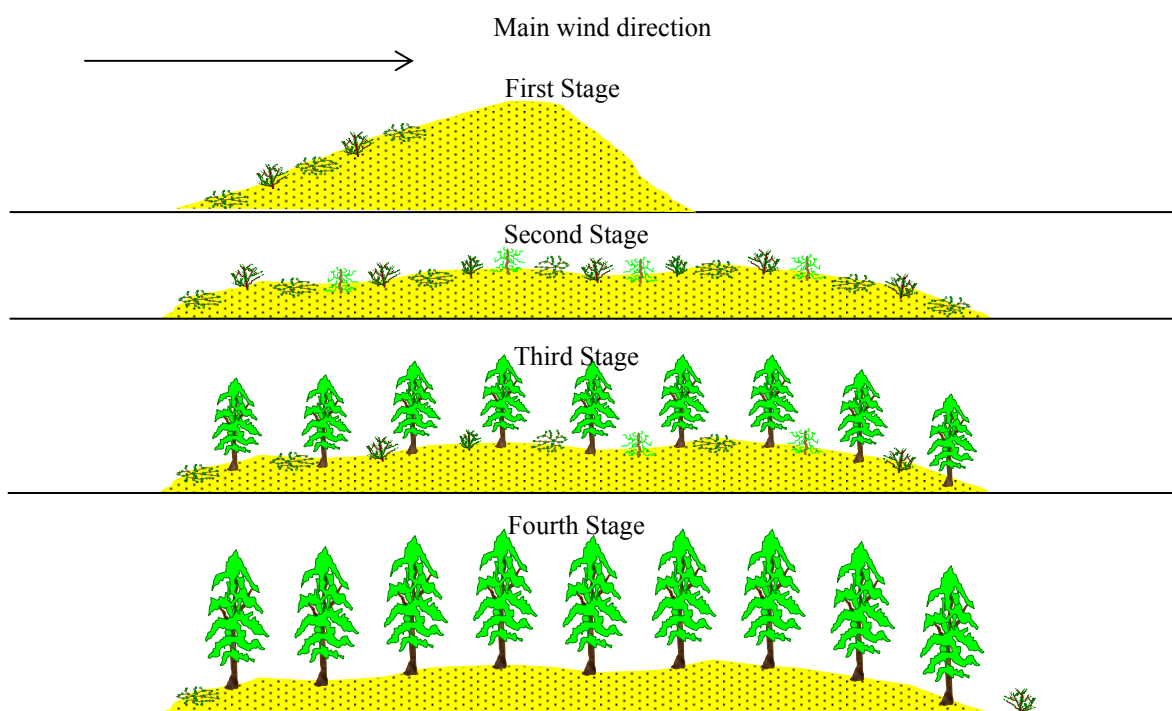


Fig.6. Sand-fixation and Afforestation on Shifting Sand Dunes in Zhanggutai

Suitable Biological Models for Protecting Transportation Properties

There has been experienced in managing sand dunes along both sides of transport lines including railways and highways and protecting railroad beds from wind erosion and sand accumulation. This action will guarantee the safe operation of transportation.

The biological approaches are widely used for stabilizing shifting sands along railways/highways in the sandy deserts and other affected regions of Northern China.

Which are as follows?

Revegetation along railways/highways without irrigation for controlling sand encroachment and sand accumulation, and plantation of trees or shrubs along railways and highways to decrease wind velocity and increase roughness of surface to prevent the traffic lines from sand disasters. Such examples are available at Shapotou Station, Zhongwei Country, Ningxia Hui Autonomous Region and

Cross-Taklimakan Desert Expressway, Xinjiang.

As an initial step to fix shifting sands, some measures for planting vertical mechanical barriers were adopted to prevent dune surface from sand transport and dune movement in given cases. There are two types of sand barriers which are composed of vertical barriers consisting of tree branches and straw checkerboards in a square formation. The tree-branch vertical barriers are (1-1.5) m high and the wheat straw checkerboards are 1m×1m with (15-25) cm height.

After the mobile sand dune surfaces are stabilized with the above mentioned checkerboards, some selected species which were tested for more than ten years are transplanted from nurseries. The transplants are wrapped with dried plant branches to deter grazing and protect against wind. These newly planted biological complexes are fenced for years to avoid animal trampling, to increase the silt crust on vegetated dune surface and slow down the wind velocity.

There are some railways and highways intersecting desert regions. In order to guarantee the operation of railway and highway communications in the desert, besides selecting ideal routes, available measures should be taken in the light of different conditions. Establishing protective systems in the form of sand-stocking, sand-fixing and sand-transporting along the sides of road is usually adopted for the control of sand harms. So-called "stocking" is to erect artificial sand barriers in a little further place out of road on the windward side of road to stock shifting sands; "fixing" is to adopt engineering measures in combination with plantation sand binder on the sand dunes close to road along sides of road to stabilize the surfaces of dunes; "transporting" is to build streamline section for highway, sand guiding bank, sand transportation bank or shallow trough to promote wind velocity and prevent or lessen sand accumulation. These measures are applied according to different natural conditions and types of sand harms.

Control of Sand Harms along Railway in Semi-Desert Region

For railway lines running through the border zone of semi-desert where shifting sand dunes stretch and undulate, e.g. the Zhongwei-Gantang section of Baotou-Lanzhou Railway on the southeastern fringe of the Tengger Desert, besides providing gravel protection on the slopes of road and gravel platforms on both sides of road for transporting sand and checking the advance of sand dunes, there are protective belts built to form a protective system in combination of "sand-fixing, sand-stocking and sand-transporting" on both sides of road in proportion to the yearly advance rates of sand dunes. In this case, there have been built a 500m wide belt on the side of main wind direction and a 200m wide belt in the secondary wind direction which widespread straw checkboard sand barriers (1m×1m) with planting sand-fixing plants in grids (Fig.7). Above-mentioned measures are adopted extensively in this section to guarantee the smooth operation of railway in the desert.

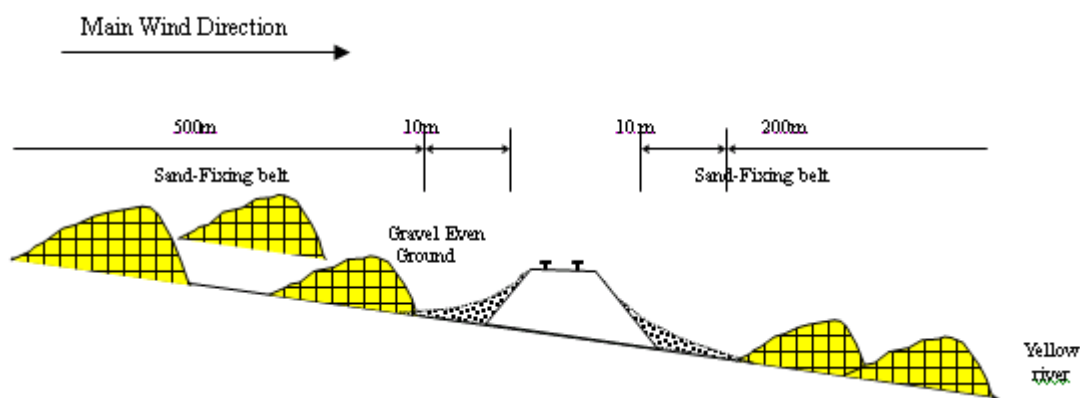


Fig. 7. Structure of Comprehensive Protection System in Shapotou Section of Baotou Lanzhou Railway Line

Control of the harms of sand driving wind from Gobi along railway lines

For railway lines running through arid zone and Gobi where sand-driving wind constitutes a serious menace, the Yumen section of Lanzhou-Xinjiang Railway is in such a case that the sand-stocking is taken as main protective measure. In order to

play the sand-stocking function of shelter forest belt, multi-belt disposal of forest belts and opening belt are a choice. At wind gaps where sand drift is strong, 2 to 3 rows of sand barriers should be placed in front of the shelterbelt to block the sand drifting (Fig. 8).

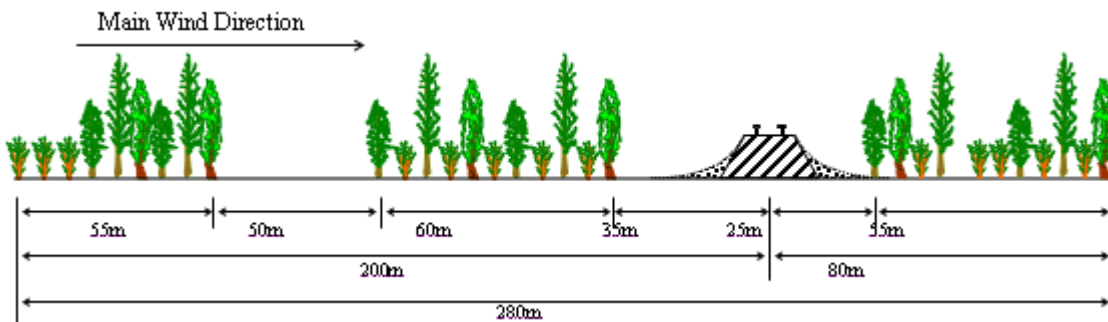


Fig. 8. Structure of Sand- breaking Forest Belt

Control of sand harms along railway line in dry steppe

There are some railway lines running across mobile sand areas and fixed and semi-fixed sand dunes in steppe, e.g. Dahushan-Zhengjiatun line through Horqin Sandy Land. The railway line where mobile sand dunes prevail, the poplar is planted on sinks between dunes and flat sand lands with planting sand binder (e.g.

Salix gordejvii, *Artemisia halodendron*, *Caragana microphylla*, etc.) The shelter belt on the windward side is 200m wide and divided into 3 forest belts with width of 25m per belt of first to fourth forest belts, 40m of fifth from road bed, and distances of 15m between neighboring belts. The widths of (600-700) m are on windward sand and (300-400) m on leeward side as closing belt (Fig.9).

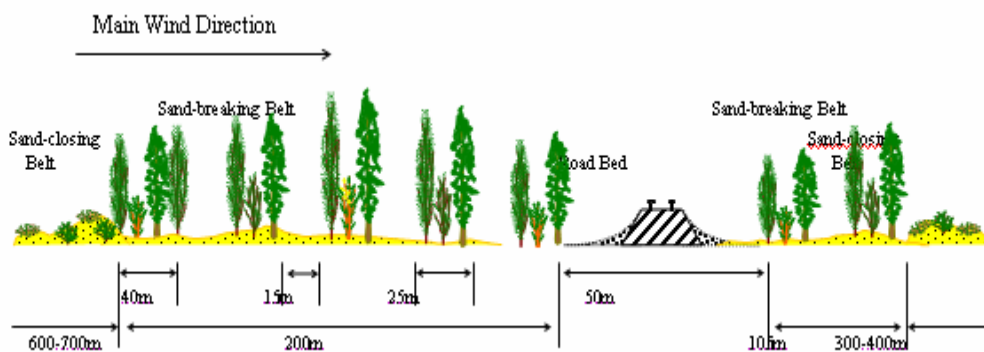


Fig. 9. Structure of Shelter Belts in Ganqika Section of Dahushan-Zhangjiatun Railway Line

Control of Sand Harms along Highways

For highways that pass through desert areas where the conditions are favorable for sand-fixing plants to grow, measures such as planting road protective forest belts along the line and fixing sand dunes by planting shrubs (*Artemisia ordosica*, *Salix psammophilla*, etc.) should be adopted and properly combined. For sectors of fixed and semi-fixed sand dunes, the best and easiest way is to fence off the dunes to grow grasses and forests. This method has been widely adopted on most highways in Mu Us Sand Land.

The sectional pattern of roadbed (Fig.10). Adapts the areas where sand source is rich

and shifting sand dunes prevail. The wind-leading panel is constituted by two posts erected at the shoulder of highway on the windward side of highway, cross stays and panel made of board or reed. The panel is planted in erection or fore-inclination (the angle of inclination is 60°-80°). There is a wind exit between the ground and the panel. The recommended width of a panel is 1.5-2.0m, and the recommended height of the wind exit is 1-1.5m. The experimental data of wind tunnel on wind-leading panel show that the proper ratio of width of panel to the height of wind exit is 1 to 0.7 as a whole.

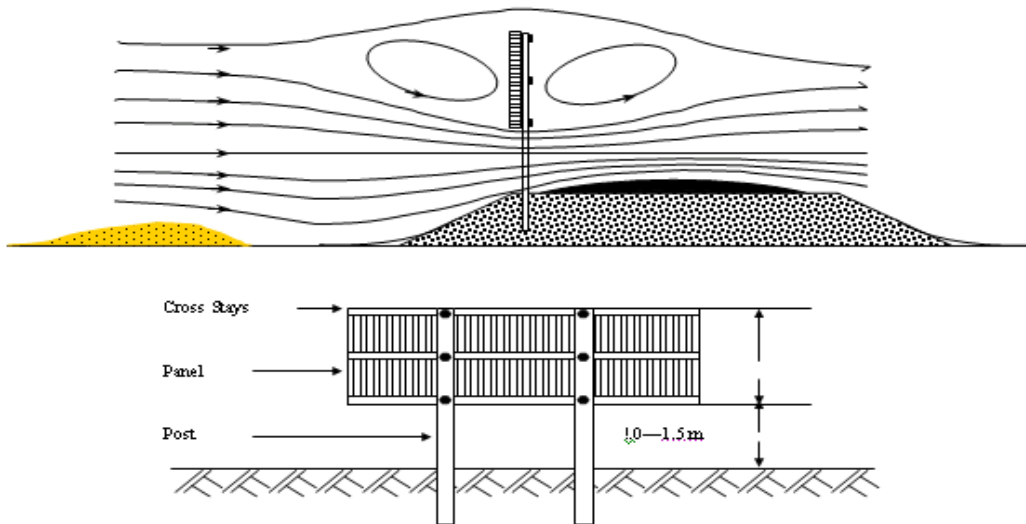


Fig. 10. Structure and Placement of a Wind-leading Panel

The best and easiest way is to establish an engineering protective system in combination of “fixing, stocking and transporting”. The comprehensive protective system is disposed by erecting several rows of standing sand barriers as outmost sand-stocking belt on the windward side of highway to check the shifting sand, then, placing the straw-checkerboard sand barriers of (100-200) m width and planting sand-holding species such as *Haloxylon ammodendron*,

Calligonum mongolicum, etc. As sand-fixing belt is to stabilize mobile sand dunes and lessen the strength of blown sand and paving flat belt is close to roadbed for streamlining the section of roadbed so that shifting sand in non-accumulation passes over the road surface.

Adopting above engineering protective system (Fig. 11) on Ruoqiang-Qiemo Section of Qinghai-Xinjiang highway and Urumqi-Yining highway has been achieved successfully.

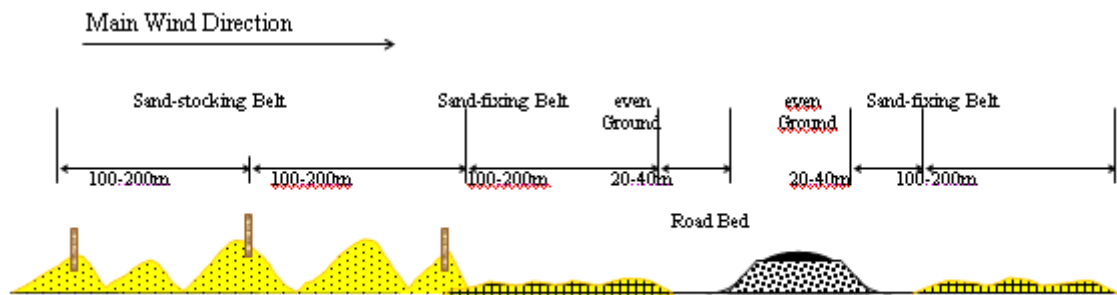


Fig. 11. Comprehensive Shelter System on Two Sides of a Highway

Control of Sand Harms around Factories or Mines

The control of sand harm around Jilantai Salt Lake is taken as an example here. The Jilantai Salt Lake lies in the southwest part of Ulan Buh Desert around which the shifting longitudinal dunes and sand mound covered by *Nitraria tangutorum*

prevail. The northwest is the main wind direction in this area. The area covered by sand reached to 10.8 km² making up 29% of the total salt lake area which was 37 km² in the light of an investigation (1983). In view of this situation, comprehensive shelter system around the Lake has been

established. The measures adopted are as follows.

Enclosure method for protecting factories

In the spring of 1984, the wire fence of 27 km length was installed and the closed area reached to 16 km². An investigation in 1985 showed that the vegetation coverage of the closed area increased from 20% to 39.4%; the sand quantity (0-10 cm above ground surface) in the air current in the closed area compared to the check plot, decreased by 75%. A great amount of sand was kept in the closed area. Adopting the sprinkler irrigation to reclaim the surface of sand dunes of this area could improve the rehabilitation and regeneration of vegetation cover in closed area.

Adopting engineering measure

The clay checkerboard barriers (1×1m) should be built at the feet of mobile longitudinal dunes close to the Lake, and combined with closing and protecting natural vegetation and establishing artificial vegetation to form the blocking shifting sand in front and cut off the sand source from behind to stop the encroachment of blown sand to the Lake.

Planting sand-fixing forests

Sand-fixing forests were planted on the area where original natural vegetation and terrain were not disturbed, in the light of the principle of "planting suitable trees in accordance with local natural conditions". After two and a half years, the vegetation coverage reached to 45%. On the contrary, when sand-fixing forests were planted on the sand land formed by leveling off the sand mounds covered by *Nitraria tangutorum* the vegetation coverage only reached 27.5% during the same period.

Watering shifting sand dunes through sprinkler in winter

The surface of sand dunes was frozen after irrigation by sprinkler; as a result the wind erosion and movement of sand dunes were avoided. In addition, the water content in

the sand dunes was ideal for afforestation of next spring. The comprehensive protective measures have been carried out in Jilantai Salt Lake since 1984. The average annual amount of sand (1984-1986) entering the Lake had been decreased by 908,000 m³ (from 1275,000 m³ to 367,000 m³) compared to 3 years before 1984.

Control of Sand Harms to Reservoirs

The control of sand harms to Jiefang Village Reservoir in Jingta County of Gansu Province is taken as an example. The Jiefang Villgae Reservoir adjoins Baishuiquan Desert on the west, northwest and north. The northwest is the main wind direction. The Baishuiquan Desert encroaches upon the Reservoir and constantly fills the sand into the Reservoir. The annual amount of sand entering into the Reservoir reaches to 300,000m³. The shelter system around the Reservoir is necessary to be established. 3 rows of standing sand barrier with an interval of 3-6m were set up between the neighboring barriers on the part of windward slope (2/3 up the windward slope) of fourth barchan chain (from the Reservoir) 1,300 m away from the Reservoir. The windward slope became steeper after a wind season. The bare sand surface on the windward slope (down 2/3 the windward slope) was paved with gravels from sinks between the dunes to form a permanent artificial sand-accumulating bank by which shifting sand was piled up and the sand source was cut off.

Conclusion

According to China's country paper to combat Desertification, published by CCICCD in 1997, the affected lands are mainly distributed in arid, semi-arid and dry sub-humid areas in the western part of Northeast China, North central China and most of northwest China. China and her people have a long history to combat desertification, especially since the foundation of New China. The government

is concerned about desertification and effective efforts have been made for combating desertification. Some acceptable and practical techniques, successful demonstrations and rich experiences as well as extension service models to combat desertification and manage dry lands have been developed at community, local and national levels. At present, at the periphery of sandy desert and Gobi areas, sand encroachments have been controlled and local ecological restoration and environment protection have been obviously promoted in many regions, social economy has been coordinately developed and local people's living standard has been greatly improved. Some successful biological measures were suggested for combating desertification in different land uses such as agricultural areas, highways, railways, roads, cities, industrial factories and mining areas. Suitable plant species were chosen on the basis of their capabilities in these kinds of harsh environments. Plantation techniques and the seed treatments like sowing, seedling and air seeding were successfully used for protecting the properties of people

that are living in the desert areas of China. Shelter belt systems and practical models for the hilly and flat desert areas are applied.

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