Asia-Pacific Network for Sustainable Forest Management and Rehabilitation

Demonstration of vegetation restoration and management and utilization of forest resources in the Greater Central Asia

(Chifeng site)

Study Report on Typical Models of Sand Prevention and Control in Chifeng

Chifeng Forestry Science Research Institute

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Contents

1. Project background

Land desertification has become one of the global environmental and resource problems of the 21st century, which involves over 100 countries in all the continents and there are about 2 billion people under the threat. The desertification in China features of larger area, wider distribution and severe harm, being the most serious natural disasters and major environmental problems to restrict the sustainable development of economy of the country.

In the process of combating desertification, after decades of exploration and effort, China has embarked on a modernization journey of harmonious coexistence between man and nature, and has embarked on a road of combating desertification with equal emphasis on ecology and economy, sand control and poverty alleviation. A reliable and replicable ecological restoration sample is provided for the world.

With the acceleration of global economic integration, especially since the birth of the Silk Road Economic Belt initiative proposed by Chinese President Xi Jinping, the exchange and cooperation between China and the countries in Central Asia, including Mongolia Republic, is becoming increasingly active. To actively respond to the “Belt and Road” strategy, to promote the coordinated development of forestry in countries in the Greater Central Asia region and to jointly accelerate the green development process, in 2017 the Asia-Pacific Network for Sustainable Forest Management and Rehabilitation started up the project “Demonstration Project of Vegetation Restoration and Management and Utilization of Forest Resources in Greater Central Asia”. Sanyijing Forest Farm of Aohan Banner in Chifeng Municipality of Inner Mongolia was selected as a project area in China. Taking desertification prevention and control, vegetation restoration, and the sand industry as its focus, the project aims at building a forestry demonstration zone with various advanced mature technologies to facilitate the regional vegetation recovery, to develop multi-functions and comprehensive benefits of forests, to ease and make responds to the global climate change, to combat desertification and improve ecological environment, to increase the living condition of farmers, and in the end to set typical examples of vegetation restoration and management and utilization of forest resource in similar regions of the Greater Central Asia.

The preparation of the “Report on the Typical Models of Desertification and Control in Chifeng” is one of the project activities. The main purpose is to comprehensively summarize the typical models of desertification in Chifeng, and to provide theoretical basis and field cases for desertification control in the Greater Central Asia region. Entrusted by the project management and construction unit, Chifeng Forestry Science Research Institute undertook the work of “Study on the Typical Model of Sand Prevention and Control in Chifeng”. Under the guidance of the Desertification

Research Institute of the Chinese Academy of Forestry and with three years' hard work, the sand control models are comprehensively sorted out, representative demonstration zones for comprehensive control of desertification are selected. The advanced and mature sand comprehensive management optimization models suitable for different regions have been refined through data collection and field research, and 2 to 3 advanced models which are selected for demonstration and promotion. It provides theoretical basis and technical support for sand control under similar site condition, and provides a typical demonstration model for vegetation restoration and sustainable management of forest resources in Greater Central Asia.

2. Current status of sand prevention and control in Chifeng

2.1 Brief information of Chifeng

Chifeng Municipality locates in mid-eastern Inner Mongolia, adjacent to Tongliao Municipality in the east, bordering on Chaoyang Municipality of Liaoning Province in the southeast, on Chengde Municipality of Hebei Province in the southwest, and connecting with Xilingole League in the northwest. Its geographic coordicates are between the north latitude 41°17 '- 45°24' and the east longitude 116°21 ' - 120°58'. Its land area is 90,021.22 km^2 with the widest distance of 375 km from the east to the west and the longest 457.5 km from the north to the south.

Figure 1 Location of Chifeng

2.1.1 Topography and landform

It locates in the northern wing of the Yanshan Mountains and the southern section of the Greater Hinggan Mountains, in the transition zone from Inner Monglolian Plateau to Song-Liao Plain. In its north lies the southern section of the Greater Hinggan mountains. Qilaotu Montain and Nuluerhu Mountain, which are the northern part of Yanshan Mountains, lie in its west and south. In its middle part cross by Hunshandak Sandy Land and Kerqin Sandy Land. The terrain slopes downward from west to east, embraced by mountains in the north, west and south, with the highest elevation of 2,067m and the lowest 260m. The landform varies as the Greater Hinggan Mountains, Yanshan mountains, Inner Mongolian plateau, Hunshandak Sandy Land and Kerqin Sandy Land, in forms of the mid-height mountains, high plains, lava plateau, low hills, sand dunes.

2.1.2 Climate

It is in the temperate semi-arid continental monsoon climate zone. The winter is long and dry cold. Rain concentrates in summer. There is little rain or snow in spring but more wind and sand. The annual average precipitation is 350mm but the annual evaporation is 2,000 to 2,300mm. The annual average temperature 6℃ with the extreme highest 42.5℃ and the extreme lowest -45.5℃. The effective accumulative temperature is 2,200℃ to 3,200℃. The annual average wind speed is 3m/second with the gale days over 8-grade for 50 to 60 days per year on average.

2.1.3 Soil

The northern and northeastern parts of Chifeng are chestnut soil belts, the southern part is basically black loam, loess and cinnamon soil belt, and the northwest and mid-eastern parts are sandy soil belts. The main soil types (sub-categories) include: loess, sandy soil, dark chestnut soil, cinnamon soil, gray cinnamon soil, brown soil and pale black soil, as well as cultivated tidal soil and salinized tidal soil.

2.1.4 Vegetation

The complexity of topography, climate and hydro-geological conditions in Chifeng determines the diversity of its vegetation types. And also, due to the grounding of the plant flora in North China, Northeast China and Mongolia, various flora is mutual penetrative in the territory and the vegetation composes in complex and transitional natures. The main vegetation types from north to south include mountainous forest vegetation, low hilly vegetation, meadow vegetation, sand dune shrub and grassland vegetation and deciduous broad-leaved forest belt.

2.1.5 Hydrology

There are many rivers in Chifeng, covering the four river basins of Xiliaohe River, Neiluhe River, Luanhe River and Dalinghe River. With a total length of 10,188.9km, the area of Xiliao River Basin is 77,790.59km^2, accounting for 86.4% of the total land area of Chifeng, including four water systems in the basin, namely Laohahe River system, Xilamulun River system, Xinkaihe River system and Jiaolaihe River system.

2.1.6 Socio-economic profile

As of 2018, there are 4.315 million residents in the municipality with 943,000 Mongolian population. The urban population accounts for 49.38% of the total. The GDP of the municipality was RMB 140.68 billion, of which the primary industry increased by RMB 28.06 billion. The per capita disposable income of urban residents was RMB 31,931, and that of rural residents was 11,373 yuan.

The traffic is accessible. There are the state-owned railway Jingtong line and Yechi line, and the local railway Jitong line across the east to west. There are national highway roads 305, 306, 303, 111, and inter-provincial highway road across the territory. But the traffic conditions in remote mountainous areas, sand areas, and forest areas are relatively poor.

2.2 Sand prevention and control status

2.2.1 Overview of sand prevention and control in Chifeng

The desertification types in Chifeng are mainly the desertification by wind erosion, that by water erosion and that by soil salinization, among which, 89.7% belongs to the desertification by wind erosion. The activities to combat desertification started as early as 1950s in three stages: the first is the extending stage from 1958 to 1978. The sand area increased from 1.0824 million hm^2 to 2.4257 million hm^2. The reason is the predatory reclamation farming in extensively cultivating with little yield and the ever-increasing livestock, plus some human activities such as cutting trees and raking-up firewood, which caused the grassland degradation; the second is the stand-off stage from 1978 to 1999.With the development of society and economy, the activities of mining and road construction was increasingly more, which caused the extensive destruction of surface vegetation and resulted in the increase of desertified area by wind-erosion. On the other hand, with the implementation of the national ecological environment protection measures, especially in 1994 Chifeng being identified as "the National Pilot and Demonstration Zone for Desertification Reform" by the State Forestry Ministry, some infrastructure constructions, mainly including the small watershed management and sand combating, were implemented. And the pace for afforestation and sand combating accelerated significantly; the third is the containment stage since 2000. Relying on the implementation of some national key

ecological projects, including the 3-north shelter-belt system construction, farmland conversion to forest program, and the Beijing-Tianjin sandstorm source control program, the desertified areas decreased significantly. A foundation framework to establish the ecological barrier in Chifeng has been built up. The initial effect can be seen in 2014. According to "the national 5th census on desertification and land sandification", the desertified area in Chifeng has reduced to 1.8869 million hm^2. From 1994 to 2014, the total desertified area reduced by 776,900 hm^2 at a reduced rate of 29.17%, with a reduction of 38,900 hm^2 per year on average.

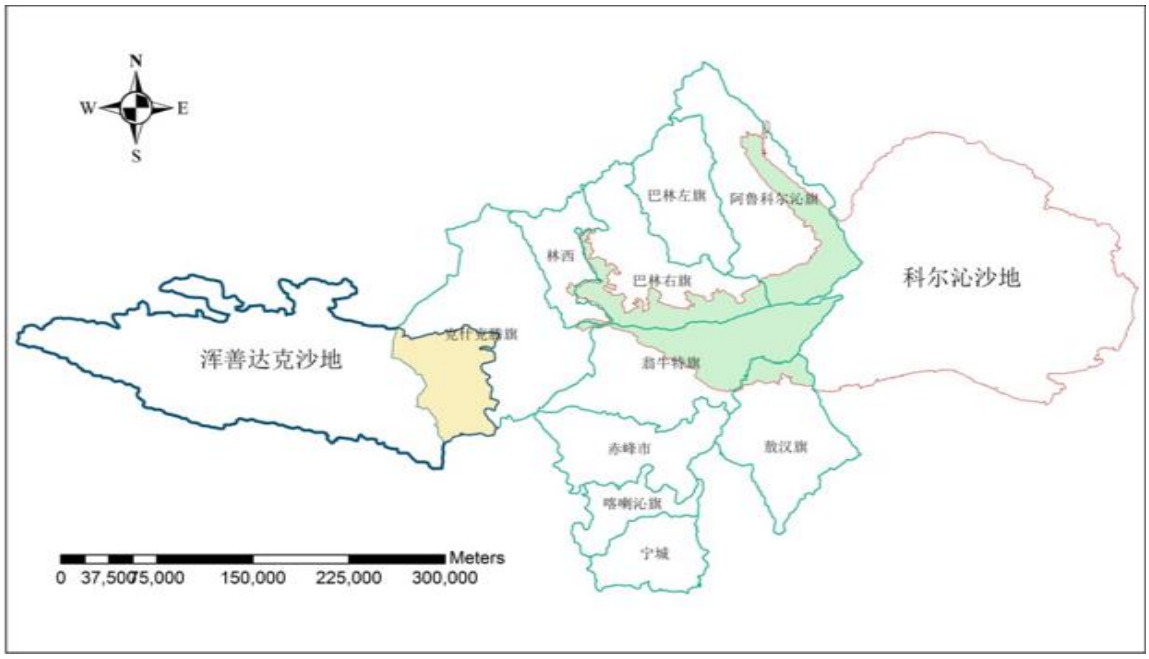

Figure 2 Sandy land distribution in Chifeng

2.2.2 Statistics on desertified land change in different years

Table 1 Statistics of Changes in Kerqin Sandy Land and Hunshandake Sandy Land in Chifeng from 1994 to 2014

Unit:10 thousand hm2

year	Sandy Land	Total area	Of which				
			fixed	Semi-fixed	shifting	Sand expose	Sandisfield cultivated field
1994	Kerqin	169.34	84.61	34.39	19.67	0.00	30.66
	Hunshandak	97.04	61.41	2.41	0.09	0.33	32.80
2004	Kerqin	129.27	101.60	10.58	13.95	1.08	2.06
	Hunshandak	62.23	52.64	8.65	0.91	0.00	0.03
2009	Kerqin	127.94	101.99	11.69	11.38	1.08	1.79
	Hunshandak	62.04	52.77	8.37	0.87	0.00	0.03

2014	Kerqin	127.27	101.99	11.69	10.72	1.08	1.79
	Hunshandak	61.42					

Table 2 Statistics of Desertification Land Changes in Chifeng from 1994 to 2014

Unit:10 thousand hm2

	total	fixed	Semi-fixed	shifting	Sand expose	Sandisfield cultivated field
1958	108.24	52.57	31.53	24.15		
1978	178.39	96.95	43.37	38.07		
1991	242.57	147.07	66.67	28.83		
1994	266.38	146.02	36.80	19.77	0.33	63.46
2004	191.50	154.24	19.22	14.86	1.08	2.09
2009	189.97	154.75	20.06	12.26	1.08	1.82
2014	188.69					

The statistical analysis from table one and two is based on the "national 4th census on desertification and land sandification" of 2009, which shows that the area of the shifting sand (dune) is 122,600 hm^2, accounting for 6.45% of the total desertified land; the semi-fixed sand (dunes) is 200,600 hm^2, accounting for 10.56%; the fixed sand (dunes) is 1,547,500 hm^2, accounting for 81.46%; the area of field with exposed sand is 10,800 hm^2, accounting for 0.57%; and the desertified cultivated field is 18,200 hm^2, accounting for 0.96%.

2.3 Sand prevention and control experience and practices in Chifeng

Since the 1950s, Chifeng people have carried out long-term unremitting and arduous efforts to fight against desertification passing through 3 stages: the first stage is the hard start in the 1950s and 1960s of establishing state-owned forest farms and voluntary afforestation by the masses, the second stage is the wide spread in the 1970s to 1990s of organizing masses assembly campaign to rehabilitate mountains and sand, the third stage is the rapid development since 2000 of the fast development of some big national projects, such as Beijing-Tianjin sand source control project, land conversion project. In this stage, the desertified land is significantly reduced, and great achievements have been made in desert prevention and control.

2.3.1 Strengthen organization and leadership

Chifeng has attached great importance to sand prevention and control. In 1999, it took

the lead in setting up a basic strategy of “build an ecological municipality” in the prefecture-level municipalities across the country, and has adhered to the basic policy and carried forward the government’s glorious tradition of “drawing the blueprint one term after another” to conduct the ecological construction and sand combating. All governments at different levels include sand combating into the annual work performance assessment to the party and government leaders. The target management responsibility system has been respected. A specialized organization is established. The publicity and mobilization work has been strengthened. The work pattern for sand combating has formed with the party committee and government taking the lead, the departments giving close cooperation, and the whole society taking active participation, which guarantees the smooth conduct of the sand prevention and control. In 2016, the document “Opinions on Further Strengthening Forestry Ecological Construction and Protection Work”, was issued to further clarify the working concept and the objectives of forestry construction, sand prevention and control of the municipality in new situation.

2.3.2 Improve the policy mechanism

In recent years, the municipality has responded to the new situation, gradually improving and innovating the policy mechanism for sand combating. In the construction mechanism, 3 construction management modes have been comprehensively promoted, namely the “project bidding for afforestation”, the “contracting for afforestation” and the “applying compensation after the acceptance of plantation”, which has effectively improved the quality of ecological construction projects and investment benefits. In engineering planning, we changed the old practices in small and scattered scale, contrarily, we break the boundaries of townships and villages, break the boundaries of various projects. We highlight the scale effect and integrate all projects, which reduced the construction costs. In terms of organizational form, with the deepening of the rural household contract system, the pasture land rights system, and the reform of the collective forest rights system, the professional construction teams are organized to conduct the rehabilitation for the areas of relatively concentrated in large-scale and with difficulty, while the benefits are distributed to households then; the small area with less difficulty are rehabilitated by individuals; which can also be transferred to capable companies or individuals in modes of “company (large household) + base + farmer” or “the cooperatives + bases + farmers” to promote the construction. In terms of capital investment, we have changed old modes only depending on project capital and financial input. On the contrary, we actively expand the financing channels by PPP mode, from financial funds, input from companies, large households and cooperatives, forming a new investment pattern with investment from governments and financial capitals and social capitals. These measures fully mobilize the social capitals in the ecological construction, which

not only achieved the purpose of intensive management, but also fulfilled the overall promotion and scale rehabilitation.

2.3.3 Put focus on both ecology and economy

In the process of sand prevention and control, Chifeng proposes the development idea of "industrialization of ecological construction and ecologicalization of industrial construction", guiding the sand prevention and control with industrialization ideas. We put the ecological construction and local economy development on the same consideration with the improvement of the production and living conditions and the improvement of people's income, explore a successful road to increase green in the sand and increase the income of farmers and herdsmen, to realize the transformation from taking ecological benefits as the main target to taking ecological the priority and meanwhile highlighting the economic benefits. Since "the 12th Five-Year Plan", we have attached equal importance to both ecological and economic construction with vigorous adjust of the structure of forest categories and tree species and promotion of 5 engineering, namely, the demonstration of comprehensive management of desertification land, high-efficiency and high-yield economic forest, building of Mongolian pine forest, building of woody oil trees, the transformation for low-yield and low-efficiency apricot trees. The comprehensive benefits of sand prevention and control have been achieved.

2.3.4 Adhere to scientific governance

Chifeng established a graded training system in multi-form and multi-level with multi-content for forestry technical training, to comprehensively improve the management level and professional quality of technical personnel, and the technical capabilities of the farmers and herdsmen at the grassroots level. During "the 12th Five-Year Plan" period, we organized more than 200 training sessions, trained 65,000 technical personnel. Each year, we focus on the construction of the key demonstration engineering of sand control demonstration, economic forests, and building of Mongolian pines, playing a leading and example role on technology, quality, mechanism, and efficiency. In view of the actual drought in successive years, the series of drought-resistant afforestation technique has been promoted and applied, such as, seedling root moisture, water-splitting before planting, water-saving irrigation and planting with container seedling, which has made a stable increase of the survival rate, and an increase of the quality of the engineering.

2.3.5 Insist on strict protection

In the process of preventing and controlling desertification, Chifeng has always put ecological protection in a prominent position, insisted on combining rehabilitation with

natural restoration, and formulated the “Regulations on the Ban Grazing and Rest Grazing and the Balance of Grass and Livestock in Chifeng”. The system of closure and banned grazing, shed feeding, and seasonal grazing has been fully implemented. It is required that the ban on grazing throughout the year should be respected in the agricultural areas, semi-agricultural and semi-pastoral areas. And the grazing ban system must be strictly followed in areas of the national key ecological project, nature reserves, ecological immigration area, enclosure area, severe desertified and degraded and ecologically fragile areas. To consolidate the results of sand prevention and control, measures on forest land management are strengthened, implement the "County-level Outline of Forest Land Protection and Utilization Plan “is carrying on, the forest and grassland fire prevention work is strengthened, the forest disease and pest forecasting and control is strengthened, the illegal occupation of forest land is strictly prohibited.

3. Investigation on sand prevention and control in Chifeng

3.1 Overview of the two major Sandy Lands

3.1.1 Kerqin Sand Land

Kerqin Sand Land locates in the middle and east of chifeng, covering Alukerqin Banner, the south of Balinyou Banner, the eastern half of Wengniute Banner and the north of Aohan Banner. Its area covers 127.27hm^2. The Kerqin Sandy Land is in the ecologically fragile belt of the agro-pastoral transition zone of the semi-arid area in northern China. The climate change and human activities cause the deterioration of the ecological environment. It formed high sand dunes, low and undulant sand and low-sand between dunes. The most significant feature of this landform is the wide coverage of sand layer and wide-open lowland between dunes, which is a terrain composition of dunes and low sand. The relative height of the dunes is about 10m, some as high as 20-30m.The relative height of the low and undulant sand is 3-5m.

The representative plants of Kerqin Sandy Land are elm (*Ulmus pumila*), wildapricot (*Armeniaca sibirica (L.) Lam*), *Caragana korshinskii Kom*, *Hedysarum fruticosum Pall.var. Leave (Maxim.) H. C. F*, yellow willow (*Salix gordejevii Y.L. Chang et Skvortsor*), *Artemisia salsoloides Willd*, *Artemisia frigida Willd*, *Leymus chinensis (Trin.) Tzvelev*, *Eragrostis pilosa (L.) Beauv*, *Salsola collina*, etc.

The main body of Kerqin Sandy Land is in a semi-arid area with an average precipitation of 300-400mm, concentrating in 3 months from July to September accounting for 70%-80% of a year.

3.1.2 Hunshandak Sandy Land

Hunshandake Sand Land is one of the 10 big deserts and sandy lands in China. 20% of its area, which is 61.42hm^2, is in Keshketeng Banner, which occupies 31.4% of the total land area of the banner. The sandy Land appears mostly in fixed or semi-fixed dunes in

shapes of ridge or chain, and some in crescent, spreading from north-west to south-east. The height of dunes is 10-30m, and there are many low sands between dunes, mostly composed of pale-yellow silty sand. 98% of the Sandy Land is the fixed or semi-fixed sand, while only 2% is shifting sand. However, with the rapid grassland degradation and desertification, the dynamic changes of desertification are mainly the expansion of shifting dunes, the expansion of semi-fixed dunes and the reduction of fixed dunes; the landscape formation with the solidified sand broad-leaved forest, the solidified of sand open forest, the sand bushes, the sand grass woods, the sand half-shrub and half-sagebrush, and the shifting sand dunes or bare sands.

The representative plants of Hunshandak Sandy Land are Mongolian pine, Caragana, Hedysarum, wild apricot, *Artemisia salsoloides Willd*, *Artemisia frigida Willd*, *Euphorbia humifusa Willd, Salsola collina*, *Suaeda glauca,Cleistogenes squarrosa (Trin.) Keng etc.*

The area belongs to the mid-temperate continental climate, with an annual average temperature of 1.5 °C, an extreme maximum of 35.9 °C, and an extreme minimum of -36.6 °C. The annual rainfall is 365.1 mm, concentrating in July, August and September accounting for 80-90% of a year. The frost-free period of the year is 104 days, and there is a 180 days snow and ice period in winter.

3.2 Lay-out the sample plots

Data (books, documents, operational designs) collection and on-the-spot investigations were conducted on the two Sandy Lands through consultation and investigation. And based on the basic factors such as the sandy land type, the sand control technology, the rehabilitation effectiveness, and the rehabilitation duration, the representative demonstration zones for comprehensive sand prevention and control are selected, 35 sample plots and comparison plots are laid out (as shown in Table 3). In March to April 2018, experiments on wind speed and sand collection was done on weather-forecasted 5-class wind days. In August 2018 and 2019, experiments on biomass measurement were done. And measurement for soil bulk density was done by cutting method, for soil moisture content by oven-drying method, for soil organic matter by potassium dichromate - thermodilution method, for soil PH value by potentiometry, and for soil texture by sieving method.

Table 3 Lay-out the sample plots for sand prevention and control in Chifeng

No.	code	location	GPS points	elevation（m）	year	Original staus	Total area	measures

1	A-1	Alukerqin-Aladimangha	43°46′18.46″ 120°35′41.36″	297	2010-2014	Semi-fix,shifting	100000mu	Closure,ariel seeding, dibble seeding-fine
2	A-2	Alukerqin-Aladimangha lane	43°50′17.64″ 120°44′20.33″		2010-2014	Gentle sand		Plant seedling-caragana
3	A-CK-1	Alukerqin-Nantugurige	43°26′5.66″ 120°2′8.86″	292		shifting		CK measure on slope
4	A-CK-2	Alukerqin-Nantugurige	43°26′4.49″ 120°2′9.72″	382		shifting		CK measure on slope
5	A-3	Alukerqin-Qinghezi		338	2010-2014	Semi-fix,shifting	100000mu	Closure,ariel seeding, dibble seeding-ordinary
6	Y-1	Balinyou-Baorige V.	43°27′44.38″ 118°36′0.93″	694	2004	fixed	150000mu	Dibble seeding by line-small caragana
7	Y-2	Balinyou-Baorige V.	43°25′13.6″ 118°31′53.69″	727	2011	fixed	SGAP	Plant seedling-small caragana
8	Y-3	Balinyou-303road	43°31′4.55″ 118°28′33.54″	664	2017	Bare sand	3115	Physical sand barrier
9	K-1	keshketeng-Dahaolaigou	43°13′06″ 117°26′06″	1149	2003	Hunshadak-fixed		closure
10	K-CK	keshketeng-shimenzi	43°11′34.67″ 117°22′28.42″	1261				CK- no measure
11	K-2	keshketeng-shimenzi	43°11′41.30″ 117°22′19.89″	1261	2012	Half-shady slope-sunny slope		Live sand barrier-seabuckthorn,artimesia-fine-ordinary
12	K-3	keshketeng-Xiaaobao	43°8′31.14″ 120°2′8.86″	1260	2014-2015		6000mu	Live sand barrier-sowing seed-small caragana+hedysarum

13	K-4	keshketeng-jingpeng	43°16′33.29″ 117°31′30.58″	1080	2015	fixed	100000 mu	Pure Mongolian pines
14	AO-1-Z	Aohan-Zhisha F.F	42°48′59.42″ 120°19′1.66″	389	1974-1980	Middle part fixed	4000	Pure Mongolian pines
15	AO-2-Z	Aohan-Zhisha F.F	42°48′6.63″ 120°17′57.46″	391	2009			closure
16	AO-3-S	Aohan-sanyijing	42°42′37.41″ 120°16′17.56″	411	2017	fixed		Misure forest
17	AO-4-ao	Aohan-aorunsumo	42°54′46.64″ 120°5′14.98″	423	2003	No caragana		Live sand barrier-small caragana-caragana
18	W-1	Wengniute-songshushan-Yuan	42°58′28.1″ 119°26′26.52″	711	2018		800mu	Gauze sand barrier
19	W-2	Wengniute-songshushan-Yuan			2018		plan3000	Degradable fibre sandbag
20	W-3	Wengniute-xianghao road	43°6′44.43″ 119°6′50.00″	584	2015			checkerboard—yellow willow
21	W-4	Wengniute-xianghao road	43°4′27.82″ 119°11′25.33″	579	2015		over200000	Degradable fibre sandbag
22	W-5	Wengniute-wulanaodu	42°59′19.75″ 119°36′24.95″	506	2012			Live sand barrier--upper: yellow willow+caragana;lower: yellow willow+hedysarum
23	W-CK	Wengniute-Yulong sand lake	43°8′27″ 119°4′29″	701		shifting		CK measure no effect
24	AO-5-C	Aohan-chenjiawazi1	42°35′46″ 120°23′57″	456		fixed		By belt

25	AO-6-C	Aohan-wenjiawazi2	42°35′18″ 120°24′12″	479		fixed		By sheet-mixture
26	AO-7-S	Aohan-sanyijing1	42°44′20″ 120°18′17″	434	2010	fixed		mesh
27	AO-8-S	Aohansanyijing2	42°44′05″ 120°18′16″	435	2010	fixed		grid
28	AO-CK-1	Aohan-kuntouling1	42°57′0″ 120°4′5″			shifting		CK measure no effect
29	AO-CK-2	Aohankuntouling2	42°55′1″ 120°0′41″			shifting		CK measure no effect
30	Y-4	Balinyou-east of provincial road	43°31′23″ 118°56′14″	689		fixed		Dibble seeding by line-small caragana
31	Y-5-1	Balinyou-chagan1-shabutai	43°41′7.93″ 118°24′56.22″	781	2012	Gentle sand	utilization	2017 level cutting
32	Y-5-2	Balinyou-chaga2-shabutai				Gentle sand		2017、2018 level cutting
33	Y-6	Balinyou-xilamulun v.	43°24′50.06″ 118°90′77.16″	561			Oat grass	Artificial plant grass
34	Y-7	Balinyou-jigeqili	43°14′25.16″ 118°57′6.02″	533			Enclosed pasture	Enclosed pasture in sand
35	W-6	Wengniute-buliyan V.	43°10′51.01″ 119°8′58.77″	549	2006	Semi-shifting	Ariel seeding	Ariel seeding recovery

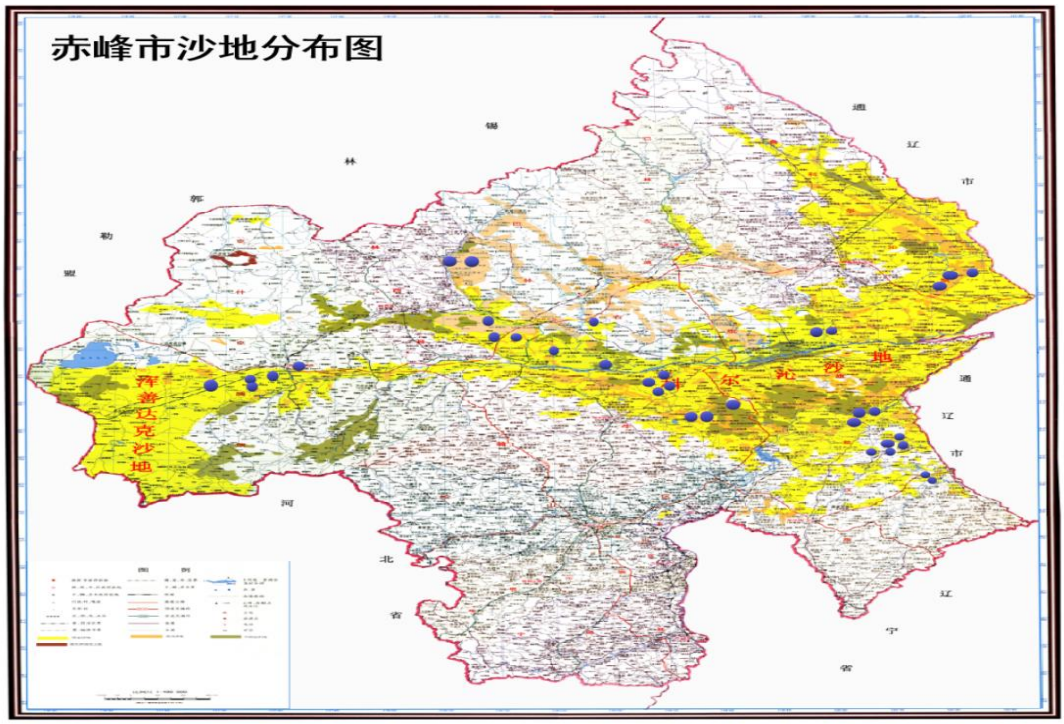

Figure 3 Sample plots distribution of sand control models in Chifeng

4. Models for sand prevention and control

Based on the interviews, field investigations and in-door analysis, research on the technical points, social influences and cost analysis, etc. for the comprehensive rehabilitation of the trial and demonstration zone is conducted. With the analysis to their advance, mature and representative, some models are initially refined, namely, sand control models of physical sand barriers, composite sand barriers, closure plus artificial measure for enrichment, artificial planting trees, sustainable management for the sandy vegetation. 1 to 2 cases are selected from the advanced, mature and typical models to provide theoretical basis and technical support for sand control in Kerqin Sandy Land and its similar areas, and provide typical demonstration for vegetation restoration and sustainable management of forest resources in Greater Central Asia.

4.1 Sand control model with physical barriers

4.1.1 Model Features and functions

The materials used for the physical barrier can be various on the local resources, no need for any processing and low cost, such as grass, branches, clay, sandy gravel etc., but perishable and no long-lasting, so need to plant other trees. The purpose is to increase the roughness of the surface, change the acting force of wind and the landform, to achieve the results for windbreak and sand stop, vegetation restoration and environment. This model is suitable for the shifting or semi-fixed sand, whose basic technique is to set up square or line sand barrier with crop straw, grass or

branches on the mobile sand dunes to stop the shifting sand, and then plant trees or grass in the grid.

4.1.2 Main technical measure

(1) the checkerboard sand barrier

In spring or autumn, plant wheat straw or corn stalk on the shifting sand by grid or by line. Barrier by lines can be set up in reverse wind area or one-way wind area, with barrier vertical to the main wind direction; grid can be set up in multi-directional wind area or in big area of mobile dunes. The grid size is 2×2 m, straw bury as deep as 30-40cm, leave 20cm above the ground level.

Figure 4 Checkboard set-up 2012

After the establishment of the sand barrier, trees can be planted among barriers on right time. Yellow willow, Caragana Fabr. or Mongolian pine can be planted on the windward section in the barriers with various spacing according to the different size of the grids. The cuttings, which plant in spring, should be cut in March, and then store-bury with wet sand and plant when raining; while in autumn the cutting can be cut when planting. The length of the cutting should be 40cm. The dry sand layer should be cleared when digging holes for planting. The depth of the hole should keep the top of the seedling or the cutting at the ground level after planting.

The established sand barrier should be strictly protected without human or animal damage. 5 years later, the yellow willow and Caragana can be given a level-cutting according to the vegetation restoration

(2) gauze sand barrier

The material used to build the sand barrier is anti-aging and insect-proof PE (Polyethylene) nets, or namely PE anti-aging and insect-proof nets with mesh size 1.0-2.0mm. The gauze should be 50-60cm wide and 50-100m long. The barrier should be set up by belts of 4-6m or by squares in various size according to the rehabilitation demands of the shifting sand and the slope degree of shifting dunes.

On the surface of shifting sand, the positioning wires should be first laid out, then put the gauze just on laid-out wire position, press the center part of the gauze down to the depth of 10-15cm with a rectangular flat shove until the two sides of the gauze upright, forming a barrier around 10cm at height. On gentle shifting sand, just lay the gauze

forming barriers; on the slope less than 10°, the barrier can be set up on the lower-middle part (about lower two-thirds part); no need to set up barriers on the dune top.

（3）the degradable fiber sandbag

Figure 5 Degradable sand bag barrier

The material of the polylactic acid fiber sandbag barrier is mainly the tapaioca starch (Manihot esculenta Crantz), which produces small molecule lactic acid by microbial fermentation, then go through the process of polycondensation and liquation, and then spin into long filament with machine as a new kind of polymer cylindrical tube barrier material. It is a kind of new polymer material of completely degradable.

Take 15m-long of polylactic acid fiber tube fabric and then slip over a 70cm-long PVC plastic pipe of diameter at 63mm (or 75 mm), then tie a knot at the end opening. Fill the dry sand in from the other end opening, tightly hold the PVC pipe and lift the pipe to make the filled-in sand slip down to the knotted end of the tube fabric (cylinder tube outer material), then lay the tube fabric with compacted sand on the surface.

4.1.3 Technical legend

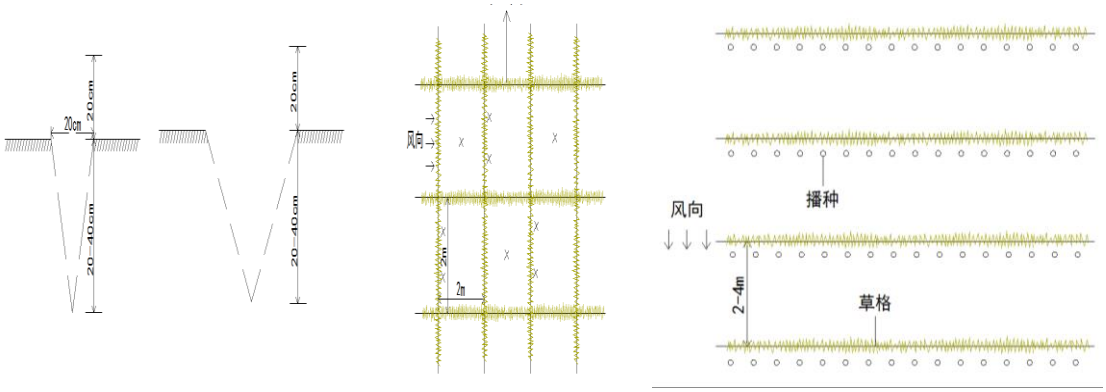

Figure 6Technical legend

4.1.4 Efficiency of the model

Within the barriers built with wheat straw or corn straw, trees or grass can be planted. And 3 years later, the straws become manure after decomposition, and provide nutrition for the vegetation; the vegetation restoration in the grid will help the sand fixation, prevent sand dunes from bury grassland, farmland, and infrastructure etc., reduce wind erosion, improve ecological environment. The effect for sand fixation and

Figure 7 Gauze sand barrier in Wengniute Bannner

sand combating is good.

Take the sample plots of Wudan Town-Yunhao Road in Wengniute Banner as an example: a shifting sand land between on north latitude 43°6′44.43″ and east longitude 119°6′50.00″, the altitude about 580 m; measures taken in 2015 with checkerboard 2×2m, and a yellow willow in the grid; the survey in September 2018 shows that he average height of yellow willow is 112 cm with crown 95×94 cm, *Artemisia scoparia* and *Echinochloa crusgalli (L.) Beauv.* appeared, the barrier is faintly visible, it has become a fixed sand with coverage 33%. For the comparison of the collected test index please see Table 4.

Table 4 Effect comparison for physical sand control model

Sample plot code	Sand type	technics	year	No.of species	biomass (kg)	Dominant species	Reletive coverage of dominant species(%)	Heigh of dominant species(m)	pH of soil	Soil bulk density(g/cm3)	Soil moisture content(%)
W-3	shift	pgysical-checkerboard	2015	2	121.49	Yellow willow	33.78	1.12	7.5	1.816	3.335

W-CK	shift			1	36.36	Agriophyllum squarrosum	100	0.175	7.46	1.93	0.05
W-4	shift	Degradable fibre sandbag	2015	6	grass 193.18	Mongolian pine	1.3	0.95	7.63	1.811	0.3615
W-1	shift	Gauze barrier	2018	3	grass 61.2	Mongolian pine		0.76	7.65	1.58	0.6345

Sample plot code	Soil organic(g/kg)	Weather report wind scale	Average wind speed(m/s)				Top wind speed(m/s)				evaporation(mm)
			20cm	60cm	100cm	140cm	20cm	60cm	100cm	140cm	
W-3	2.0759	5 级	3.4	5.1	5.7	5.4	9.4	9.8	8.5	9.4	322
W-CK	1.9308	5 级	4.7	10.5	7.6	11	10.9	17	13.7	13.9	
W-4	3.298	5 级	3.4	4	4.7	5.4	7.6	8.1	11.5	9.4	
W-1	4.208										

Figure 8 Effectiveness of checkerboard sand barrier in Wengniute Banner

Table 4 shows in the test demonstration zones with measures of checkerboard, gauze sand barrier and degradable fiber sand bag, the factors of the species composition, PH value, soil moisture content, and soil organic matter content increase. The relative coverage of the dominant communities and the soil bulk density reduce. The wind speed at different height reduce by one time to the comparison area. The effectiveness by the 3 models is shown below:

4.2 Sand combating model with complex barriers

4.2.1 Model Features and functions

To rehabilitate mobile dunes in arid and semi-arid area, select shrub of good germination, high economic value and strong regeneration ability, easy to form the plant regeneration sand barrier. This model can fulfill the function of stop sand moving and wind erosion in a short time, but also fulfill natural regeneration, avoid from

Figure 9 Effectiveness of degradable fiber sand bag barrier in Wengniute Banner

rebuilding every few years of the ordinary barrier. The species selected can be used either as forage or industrial raw material, whose advantages are renewable, sustainable, economic and practical, the restriction is the narrow selection of species. This model is suitable for the shifting or semi-fixed sand, whose basic technique is to use the plant regeneration characteristics, by cutting, soaking, deep-bury, tread down and refill, to set up barrier on the wind slope of dunes, take measures to promote the growth of shrub, and reach the purpose of sustainable fixation of the sand.

4.2.2 Main technical measure

The renewable characteristics of the psammophyte can be used when set-up the physical barriers, i.e. put renewable plant materials (live barrier) in the physical barriers, forming a composite barrier. It has a function of high-vertical-type physical barrier to stop wind and sand, change the wind force and micro-landform.

Select 1 to 2 years old yellow willow cuttings with the stem base diameter at 0.8cm, and 1-year-old *Hedysarum* cuttings with dipping treatment for no less than 24 hours.

On the windward slope of the shifting dunes, plant yellow willow cuttings on the main belts and *Hedysarum* on the side belts, plant 80cm deep for yellow willow and 60cm deep for *Hedysarum*, leaving 20cm above the ground level for both. The spacing can be 50-100cm in a grid of 4×4-6 m, add with between strains with Artemisia and branches in between. The advised ventilation coefficient is 0.2-0.3.

Figure 10 Composite sand barrier

The establishment can be done in late September to early November (before freezing) or in March in spring. At first prepare cuttings and other materials, then start the construction: first lay wires along the positioning points, second clear dry sand layer along the wire, third dig ditches of 30cm deep, then dig planting pits according to the planned spacing of 30-50cm (30cm for *Hedysarum*), then plant the cutting just clinging on to one pit side with 3 per cuttings per pit, then backfill with the wet sand of another pit, tread down the sand in the pit by two times and then add some filling materials in the ditch, and finally refill wet sand and tread down.

A full closure should be done during the first 3 years. 3 years later the cuttings of yellow willow and *Hedysarum* can be cut and used, 5 years later the level cutting can be done.

4.2.3 Technical legend

4.2.4 Efficiency of the model

The complex model solves the problem difficult to rehabilitate the mobile dunes, with which the effect can be reached for quick vegetation recovery and protection. It is a model of fast rehabilitation, good effect, easy operating and low cost to combat shifting or semi-fixed sand.

Take the sample plots in Wulanaudu village of the Wengniute Banner as an example, where is on the north latitude 42°59’19.75’’ and the east longitude 119°36’24.95’’. The area is a semi-shifting sand at an altitude of about 500 m. The construction started in

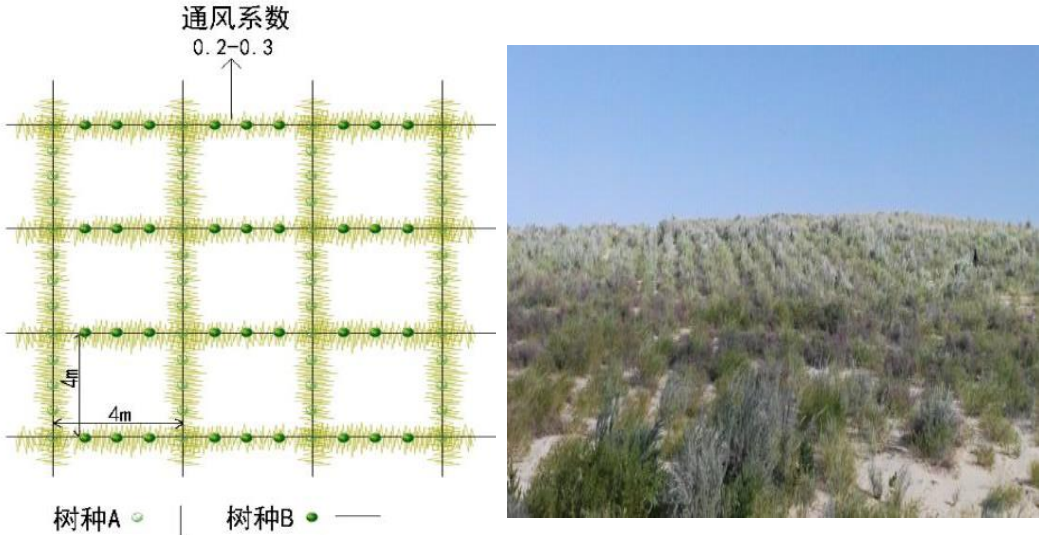

Figure 11 technical legend of composite sand barrier

2012 by checkerboard of 4 × 4 m, planting with central cuttings of yellow willow and *hedysarum* in middle part and of *Caragana* and yellow willow in upper part, keeping the porosity degree at 0.2-0.3. According to the survey in September 2018, the average height of the yellow willow in the middle is 92cm with a crown width of 125×116cm; the average height of *hedysarum* is 98.6cm with a crown width of 119×114cm; the average height of *Caragana* is 72cm with a crown of 38×34cm; the barrier can be visible with careful recognition; no growing of herbal plants. For the comparison of the collected test index from 2018-2019 please see Table 5.

Table 5 Effect comparison for complex sand control model

Sample plot code	Sand type	technics	year	No.of species	biomass (kg)	Dominant species	Reletive coverage of	Heigh of dominant species(	pH of soil	Soil bulk density(g/c	Soil moisture conten

							dominant species(%)	m)		m3)	t(%)
W-5	shift	Compound	2012	3	36.84	Small caraga	100	1.81	7.53	1.754	3.006
W-CK	shift			1	36.36	Agriophyllum	100	17.5	7.46	1.93	0.05
Sample plot code	Soil organic(g/kg)	Average wind speed(m/s)				Top wind speed(m/s)				evaporation(mm)	Weather report wind scale
		20cm	60cm	100cm	140cm	20cm	60cm	100cm	140cm		
W-5	0.2975	3.37	4.2	4.72	4.67	5.1	8.5	8.8	14.9	263	5
W-CK	1.9308	4.7	10.5	7.6	11	10.9	17	13.7	13.9		5

This model is widely used in the Sino-German financial cooperation Afforestation Project in Chifeng. Table 5 shows the factors of the species composition, PH value, and soil moisture content increase. The relative coverage of the dominant communities is the same with advantage species of shrub at height of 1.8m. The soil bulk density reduces which maybe affect by the sandy land site-condition. The wind speed at different height reduce by 2 times to the comparison area. The effectiveness is shown below:

Figure 12 Effectiveness of composite sand barrier

4.3 Model of closure plus artificial measures for enrichment

4.3.1 Model features and functions

This is one of the important measures for ecological construction by manual seeding or planting after closure to cultivate the trees, shrub and grass. It can facilitate more stable forest ecological system than the pure artificial plantation. It has become an effective method in sand area to cultivate forest. This mode is conductive to natural recovery, and the recovery can be accelerated with artificial interference, while the artificial interference must be adapted to local conditions. This model is suitable for the semi-fixed sand, whose basic technique is to select some area with good plant growing condition for closure, then plus with manual seeding, planting and aerial seeding, and taking measures of guarding, grazing and collecting ban, which will leave chances for the vegetation for recovery and growth.

Figure 13 Closure technology

4.3.2 Main technical measure

(1) Enclosure Technology

This is one of the important measures for ecological construction by manual seeding or planting after closure to cultivate the trees, shrub and grass. It can facilitate more stable forest ecological system than the pure artificial plantation. It has become an effective method in sand area to cultivate forest. This model is suitable for the semi-fixed sand, whose basic technique is to select some area with good plant growing condition for closure, then plus with manual seeding, planting and aerial seeding, and taking measures of guarding, grazing and collecting ban, which will leave chances for the vegetation for recovery and growth.

Full closure: it means that at the beginning of the closure, all the human activities, which are no good for the growth of trees and grass, should be banned, including reclamation, grazing, firewood and grass collecting. The closing and banning period can be determined according to the forest establishing term and the standard of the improvement of the sandy soil.

Half-closed: that is to close seasonally and close by the type of the plant species. Seasonally closing is to open in certain seasons (usually the dormancy period when plants stop growing) under the precondition of no influence for the recovery of forest vegetation, the local people can be organized to graze, collect firewood and grass, and other operations within the scope of plan and design; closing by plant species is to preserve and protect the promising plant species, but people are permitted for firewood and grass collecting.

Rotation closing: it is to line out a certain area from the closed area for people to collect and graze on the premise without influence for trees and grass enrichment and

Figure 14 Recovery technology by manual seeding

sand fixation, which is suitable for the rotation grazing of pasture.

Closure methods

A. Artificial guarding: The guarding area for each forest guard is 100-300hm2.

B. Set up fence: in pastoral area and half-rural and half pastoral area, or in other areas with more livestock. The physical fence is built with chain-link net, barbed wire, earth or stone wall, or opening ditches; the biological fence is to plant some thorny shrub such as seabuckthorn (*Hippophae rhamnoides)* and Russian olive (*Elaeagnus angustifolia L.)*.

(2) Recovery technology by manual seeding

This is the activity to sow the seeding materials into certain depth of soil at right time with certain quantity and manners. Choose the species of resisting wind erosion and sand bury, easily germinating once there is moisture, immediate rooting and with

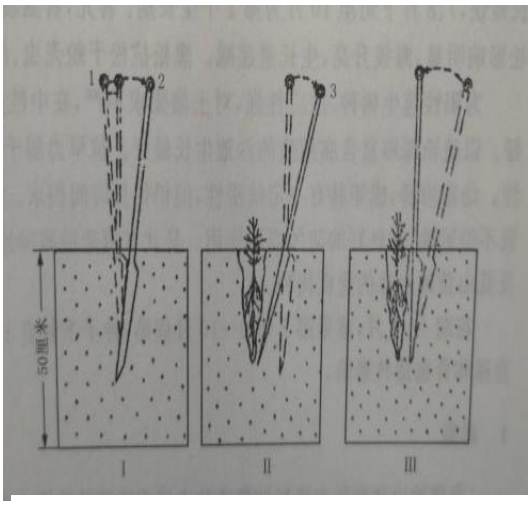

Figure 15 Recovery technology by artificial planting

strong adaptability, such as *Caragana*, *Hedysarum* etc. The suitable seeding time for *Caragana* is the raining season latest by late July, whose seeds should keep in warm water of 30℃ for 12-24 hours; the seeding season for *Hedysarum* is June, 111 pits for one mu, with band-belt tractor for direct seeding, site prepared by belt of 1.5m wide for 4 seeding lines, leaving 2.5m wide space in between. On the shifting sand, Hedysarum seeds can be sew by broadcast sowing, dibbling and drilling with amount of 6 kg/hm^2.

（3）Recovery technology by artificial planting

Take seedlings as the planting material to help vegetation recovery by artificial planting.

Choose 1-2 years old bare-root shrub seedlings of drought resistance and sand fixation, such as Hedysurum, big Caragana and *Caragana microphylla*, and 1-4 years old bare-root or container seedlings of Mongolian pine, poplar (*Populus L.*) and Russian olive, and cuttings select strong 2 to 3 years old ones with the diameter of the small end larger than 0.7cm and 60-80cm long.

It should be noted that abundant water is demanded before seedling lift, measures of covering with wet soil or heeling-in should be taken after lifting, dipping before delivery. The seedlings should be heel-in deep when download at the site; dipping is needed before planting. And plant shrub deep to the wet sand layer in cluster for and 2-4 seedlings per cluster. Usually the planting season is the early spring or the raining season. For planting Hedysarum and Caragana in the raining season, the seedlings can be lift during planting. Then the next step is to strengthen the management with measures of level cutting, thinning, tending , and activities like disease and pest control etc.

（4）Recovery technology by aerial seeding

This is to use aeroplane to sow seeds evenly on the sand, covered the seeds by the natural wind and then germinate, take root, grow with raining.

Figure 16 Recovery technology by aerial seeding

This method should select relatively concentrated sandy areas or degraded or sandified grassland with inconvenient transportation, wide-space between dunes. The area should not be less than 5,000 mu, the suitable sowing area of which should be over 70% of the seeding area; the area with a relative height more than 15m should be below 10%, with a vegetation coverage of 5-10%, groundwater level of 3-5m, annual precipitation of about 300mm, and the dune density below 0.6.

Before sowing, some activities should be done in advance, including site visit, planning and design. Make a planning of the main aerial seeding belt which is almost horizontal to the main wind direction, set up stakes for navigation, draw up the aerial seeding operation map (1:10,000) and the location map of sowing area (1:200,000), and formulate the desigh instruction.

Select the coating seeds of sand plants of high utilization value mixed with multi-effect compound agents, such as *Artemisia ordosica Krasch.*, *Astragalus adsurgens Pall.*, *Hedysarum Laeve*, *Hedysarum scoparium Fisch.et C.A.Mey.*, *Melilotus officinalis (L.) Pall.*. The aerial seeding can be done from the late May to mid-June. The direction of seeding belt should keep consistent with the main wind direction. The length of the seeding belt bases on the principle that the maximum load of an aeroplane for one navigation. Each seeding range should be 50-100m wide, the number of the sown seed per unit area should be no less than 50% of the design, and the accuracy of the sown seeds should be more than 85%. There will be a 15% overlap area on both sides of the seeding belt. Based on the practical experience, the demanded amount per mu for Hedysarum seeds is 0.225kg, for small Caragana seeds is 0.225kg, for Artemisia seeds is 0.3kg, with a mixture of 3:3:4. After seeding, it should be closed for 5 years, adding with interfering measures of protection, beating up and replanting or re-seeding and thinning. The measure of level cutting or grazing can be done 7 years later in the area with good recovery.

4.3.3 Technical legend

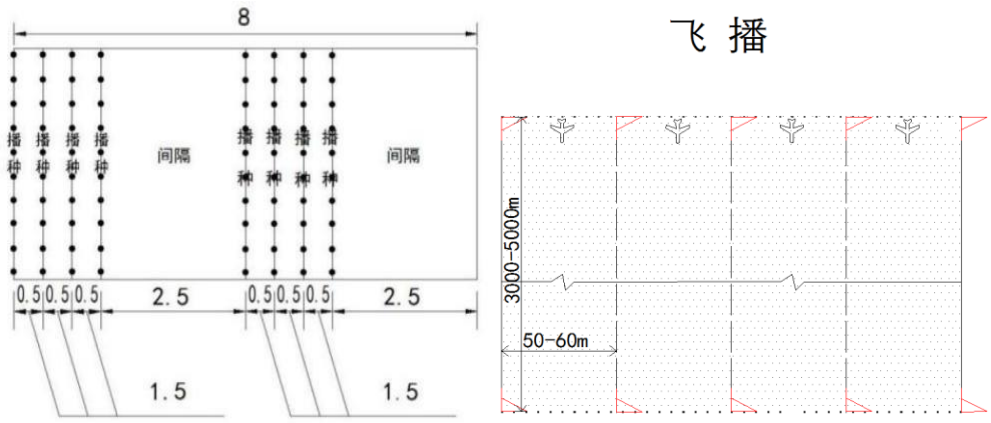

Figure 17 Technical legend for aerial seeding recovery

4.3.4 Model Effectiveness

The closure can not only fix sand, but also can help the recovery of degraded forest and grassland in large area. Most are compound storied forest composed of a variety of trees, shrub and grass, or natural vegetation composed of variety shrub and grass. This type of vegetation has stable structure, has the capacity to cultivate target trees, form forest and increase vegetation. The successful establishment of the closure will be greatly significant for the rare species resources protection, for soil fertility improvement, pests and diseases spread, ecological improvement and vegetation recovery construction.

Take the sample plots set up in Bolig Village of Balinyou Banner, at north latitude 43°27′44.38″ and east longitude 118°36′0.93″ with an elevation 690 m, as an example: it is flat gentle sand conducted seeding in 2004 in 4 lines of 3m wide and with interval 1m between lines. According to the survey made in September 2018, the average height of *Caragana* is 138cm with the crown of 154×154cm; the shrub cover is 14.7%, and there are herbal grass of 10 species with a coverage of 11.37%. For the comparison of the collected index from the demonstration area see Table 6.

Table 6 Effectiveness comparison of closure plus artificial measure for enrichment

Sample plot code	Sand type	technics	Area(mu)	year	No. Of species	biomass (kg)	Dominant species	Relative coverage of dominant species	Heigh of dominant species(m)	pH of soilSoil	bulk density (g/cm3)	Soil moisture content (%)

								(%)				
A-2	Flat sand	Plant seedling		2010-2014	8	582.97	caragana	9.8	1.93	7.49	1.752	4.746
A-CK	shift				1	122.44	salsola	100	0.2	7.42	1.927	6.229
Y-1	fixed	Manual seeding	150000	2004	11	5626.92	caragana	91	1.38	6.67	1.89	3.219
K-1	fixed	closure		2003	12	851.02	Wild apricot	5.5	1.47	6.49	1.776	7.724
Y-6-M	fixed	Manual seeding	20000	2019	1	2100	Oat grass	100	0.43	6.89	1.75	4.1
k-ck	shift			2017	1	54.1	Yellow willow	31.98	0.57	7.26	1.865	6.093
W-6	Semi-shift	Ariel seeding	7000	2007	12	537.62	Yellow willow	0.29	2.5	7.36	1.87	2.85
W-CK	shift				1	36.36	chapon	100	0.175	7.46	1.93	0.05

Sample plot code	Soil organic(g/kg)	Weather report wind scale	Average wind speed(m/s)				Top wind speed(m/s)				evaporation(mm)
			20cm	60cm	100cm	140cm	20cm	60cm	100cm	140cm	
A-2	9.7116	4	2.5	2.95	5	5.42	4.4	6.1	7.4	10.5	345
A-CK	0.6958	4	5.33	5.73	7.55	6.77	7	7.1	9.8	10.5	
Y-1	3.8101	4	2.52	2.8	2.97	3.07	5.4	5.2	5.4	5.3	341
K-1	10.7167	5	0.63	1.45	3.48	3.92	2.3	2.8	6.4	7.4	338
Y-6-M	2.7638										
k-ck	2.2058	5	7.9	7.78	10.35	11.32	12.5	11.2	17	16	
W-6	1.1674										322
W-CK	1.9308	5	4.7	10.5	7.6	11	10.9	17	13.7	13.9	

This model is most widely used in Chifeng. Table 6 shows among the demonstration areas taking models of closure technology, recovery technology by manual seeding, recovery technology by manual planting and recovery technology by aerial seeding, there is only one comparison area for the species composition, while there are 8 to 12 the demonstration areas. The soil bulk density reduces. Except that the soil organic matter content in some individual sites is lower than the comparison sites, the rest factors are all better than the comparison sites. Especially for the closure technology, the withered litters increase after years' closure, the organic matter content increase obviously. The wind speed at different height reduce by 1 time to the comparison area,

Figure 18 technology of aerial seeding

Figure19 technology of manual planting

Figure 20Technology of closure

Figure 21 Technology of manual seeding

even reduce by over 2 times at 60cm height. The effectiveness is shown below:

4.4 Sand combating model by artificial plantation

4.4.1 Model features and effectiveness

In consideration with the features of strong wind, dry climate and poor soil, and the practical problem of poor afforestation survival on the sandy land, artificial plantation technology should be applied to plant trees, shrub and grass on the sandy land, making maximal use of the natural resources of light, heat and water. The establishment can fulfill the function of windbreak and sand-fixation, but also has the capacity of fast-grow, high-yield and good quality. The advantage of the model is to consider both ecological benefits and economic benefits, but the anti-drought technology need to consider when afforestation. This model is suitable on the fixed sand, flat sand land with potential of sandification. Its technical route is to take measures of manual seeding, artificial plantation on the basis of maintain the existing vegetation, with the technical methods of watering before and laminating after planting, seedlings/cuttings/seeds storage under low temperature waiting for rain, planting with container seedlings, deep planting, and pile up soil around the planted for drought resistance etc. A characteristic windbreak and sand-fixation forest can be established in the agro-pastoral transition zone.

4.4.2 Main technical measure

This technically requires the scientific afforestation according to the forest ecological adaptability and growth regulations, using to plant timber forest, protection forest, firewood etc.

4.4.2.1Afforestation configuration models commonly used in Chifeng

(1) Protection Forest Network Configuration Model

It is usually built around farmland, pasture, economic forest, and flat sandy land. The trees are usually evenly distributed with the purpose to form a good agro-ecological environment, to release natural disasters, to adjust microclimate, to retain water and soil and slope, and to maximize the overall economic benefit of the land. It can integrate tree belts of the fields, along the two sides of highways and rivers, and village greening. It is promoted the reasonable mixing of multiple tree species and multiple layers, to change the situation of single tree species, to achieve the forest follows the water, the forest follows the road, the combination of tall trees with small shrub, the combination of forestry with agriculture, the combination of forestry with fruit, the combination of timber-use with economy.

The size of squares varies with belt spacing, which is restricted by tree species, height growth and harmful wind. The main forest belt is perpendicular to the main harmful wind direction, and the side forest belt is perpendicular to the main forest belt. The main and side belts cross and form a square with an area about 13hm2 and the max. 20hm2 and a density of 830 to 2500 plants / hm2.

Generally, a design takes narrow belt and small square with poplar and Mongolian pine as main species. The spacing between the main forest belts is 200 to 400m, the spacing between the side forest belts is 400 to 500m. The controlled area within the square is between 16 to 20hm2, and that in severely affected area by wind and sand is between 6to 13hm2. Main belt is usually 4 to 6 lines, side belt is 2 to 4 lines.

(2) Single belt configuration model

It refers to the forest belts built with the protection function around the settlements, factories and reservoirs, or along road, river and canal, and the front belt of sand. They are mostly strips. In order to achieve reasonable configuration and combination of the forest belts, canals and roads, tree belts are planted based on canals and roads, making tree belts, canals and roads are on parallel, that is to say, where there are canals, where there are tree belts, and so for roads.

Tree species selection follows the local climate and site condition by mixture of trees with shrub, between broad-leaf or conifer with broad-leaf, and mixture by lines or by plants; mostly plant with seedlings or cuttings by 2 to 3 rows according to the width of roads or 1 row along narrow road; the spacing between plants is 1 to 2m × 2 to 3m, and not below 1 to 1.5m for conifer trees; most take the compact structure. The establishing of road protection forest requires site preparation when planting, and much careful site preparation is required in poorer sites.

(3) Two-row one belt configuration model

It is a typical agro-forestry compound management used for sand fixation under the same planting density with 2 rows as 1 belt, planting in small plant and row spacing and big belt spacing for inter-cropping of low crops and perennial forages.

Take 2-row one belt configuration at a density in the belt: plant spacing 1 to 2m, row spacing 2 to 3m, and belt spacing 4 to 10m. On the basis of site preparation by opening ditches, commonly used supporting technology include seedling soaking for afforestation, earth-up drought-resistant pile after planting. Mostly take the configuration of 2 × 5 × 10m , giving edge-line growth advantage effect by making full use of sunlight and heat conditions to promote growth of trees.

The commonly used tree species are poplar, Mongolian pine, Caragana, wild apricot, etc.

(4) Mixture of multi-species configuration model

A single species is tried, but the growth appears weak after a stage of lush growth; at the first stage of afforestation, a mixture of drought-resistant and pioneer species, which are adaptable to moving sand and arid environment, is selected to establish forest stand of 2 or more tree species or of different life forms. It can form a forest

stand structure of multiple layers or of thick canopy, to improve the effect of sand fixation and stand stability.

At present, the mixture types in Chifeng include mixture between main tree species, mixture of main tree species with accompany tree species, mixture of main tree species, accompany tree species with shrub tree species, mixture of conifer with broadleaf tree species, etc. For example, the mixture types suitable for sandy land include mixture of elm with caragana, Mongolian pine with poplar, poplar with shrub (Hedysarum, seabuckthorn). suitable mixture methods should be decided after the selection of main species, which can include: ① the mixture between plants (mixture by rows) is to mix 2 or more species with each other in the row; ② the mixture between rows (mix by every other row) is to mix 2 or more species by every other row; ③ the mixture by belt is to plant one species in 3 neighboring rows, and then change another species for another 3 neighboring rows; ④ the mixture by plot (group) is to plant one species in a plot of regular or irregular, to configure with another plot of another species. The plot mixture is a suitable to use in undulant sand, while the mixture between plants, between rows and between belts are suitable to use in flat sand.

(5) Pure forest configuration model

Pure forest is composed of a single tree species or of multiple tree species, for which of multiple tree species, the forest santd must be constituted by over 65% of one species (that is the dominant tree species). Select tree species, which are easy to grow straight and strong trunk, with stable growth, and with strong natural pruning ability, such as Mongolian pine, poplar, etc., to cultivate fast-growing and high-yield timber, short-cycle industrial-use and economic-use timber, and small and medium diameter wood. The technology used for the model in the whole process from planting, silviculture, felling to utilization is single and also easy for management. the technology is single and easy to manage and so on. This model can be applied in areas with extremely severe site-condition (such as inter-dune sand). It is widely used except a disadvantage of being vulnerable to pests and diseases.

4.4.2.2 Site preparation

Plant on fixed sandy land with good vegetation coverage. Do site preparation by cave-shape or by mechanical ditch-opening. The specification for cave-shape depends on the size of the seedling, and that for ditch-opening requires 80 to 100 cm wide and 40 to 50 cm deep. Planting generally follows the site preparation, for areas with little wind erosion can do site preparation in advance.

4.4.2.3 Planting

Planting of bare-root seedlings is mainly including broad-leaf trees like poplars and elms. When planting, first pay attention to the seedlings moisturizing. it must be planted on the wet sand layer at a depth greater than 45cm, and which for big seedlings should be 80cm deep or more. The top-shoots of poplar seedlings should be cut before or after planting, painting with paints at the cut and whitening the trunk below 1.3m. Shrub should be planted in bunch with 2 to 4 plants per bunch. The afforestation technology of watering before planting and laminating after should be used in the planting, which is good for contain water and secure the survival of the seedlings.

The mechanical planting is used on the flat sand, which can do a series of activities at once including ditch-opening, planting, backfill and tread down, and require deep planting, wet sand keep in the ditch, keep moisture and tread down steadily.

Planting with container seedlings is mainly for the conifer trees and partly for sandy shrub by deep bury or apply water-retaining agent in the pit. The small seedlings of conifer trees need to live through winter with soil-cover for the first 1 to 2 years.

Planting time is in early spring or rainy season. Container seedlings are generally planted in the rainy season.

4.4.2.4 Tending and guarding

The weeding should be carried out according to the specific conditions of the afforestation site. The weeding range should not be too big. The weeding for seedling planting should do around the planting pits, no weeding for planting with laminating. Seeds sowing is generally 20 to 30 cm wide to the seedlings with weeding for 2 to 3 years for 1 to 2 times per year. In addition, proper pruning should be done for tree species. Level cutting can be done for shrubs once every 3 to 5 years, which can promote the renewal and rejuvenation of the shrub, also can obtain some economic benefits by taking cuttings as fuel-wood, timber or forage.

4.4.3 Technical legend

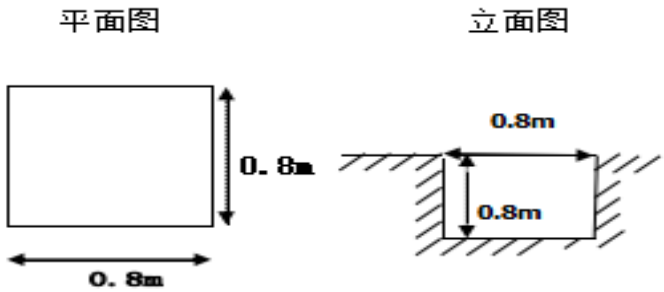

Figure 22 Legend for site preparation

4.4.4 Efficiency of the model

The establishment of artificial plantation combine the trees, shrub with grass, which not only increases the vegetation coverage, improves the efficiency of land use, reduces the wind erosion, enhances the ability to withstand natural disasters, but also promotes the increase the income of farmers and herdsmen with considerable economic benefits.

Take the sample plot of Sanyinjing Forest Farm inAohan Banner as an example, which is a fixed sand at the latitude is 42°35’18’’ and the east longitude is 120°24’12’’ with the altitude about 480m. It constructed in 2006 in mixed forest of 2×5m with 2 rows of poplar and 2 rows of Mongolian pines with 1 year old seedlings of poplar and 3 years old container Mongolian pine. The survey made in March 2019 shows that the average height of poplar is 5.79m, the DBH 10.2cm, and the crown 219×196cm; the average height of Mongolian pine is 4.45m, the DBH 6.2cm, and the crown 192×185cm. For the comparison of the collected index from the demonstration area see Table 7.

Table 7 Effectiveness comparison of manual planting and seeding model

Sample plot code	Sand type	area	year	No.of species	biomass (kg) herbal	Dominant species	Relative coverage of dominant species(%)	Heigh of dominant species (m)	pH of soil	Soil bulk density (g/cm3)	Soil moisture content(%)	techniqu e
AO-1-Z	Mid-fixe	4000	1974-1980	17	188.2	Mongolian pine	60.5	1.93	7.71	1.837	3.247	Palnt by sheet
AO-CK	shift			11	854.97	caragana	76.49	1.13	7.68	1.927	3.87	comparison
AO-5-C	Fix-flat		2008	9	157.97-草	poplar	59.25	9.47	8.36	1.42	7.8078	Plant by 2 lines as 1 belt
AO-6-C	Fix-flat		2006	7	102.95-草	Poplar,Mongolian pine	57.81	5.79/4.45	8.19	1.31	13.9948	Plant by mixture

Sample plot code	Weather report wind scale	Average wind speed(m/s)				Top wind speed(m/s)				evaporation(mm)	Soil organic(g/kg)	
		20cm	60cm	100cm	140cm	20cm	60cm	100cm	140cm			
AO-1-Z	4 级	4.93	4.78	5.97	6.23	8.1	9.1	10.2	9.5	407	2.1106	
AO-CK	7 级	13.35	13.78	15	13.13	20.1	22.2	18.9	19		1.1915	
AO-5-C	5 级	2.62	3.03	3.42	3.37	5.4	5.4	6.8	7.1		8.74	
AO-6-C	5 级	1.25	1.1	1.57	1.55	3	3.4	4.7	4		10.28	

Table 7 shows that the demonstration areas with measures of 2-row 1-belt configuration, multi-species mixture configuration and belt configuration. The sandy land in Aohan Banner all under control. Aerial seeding was taken in the comparison areas, where dominant shrub has formed. The species composition increases after years' rehabilitation. The soil bulk density reduces. According to the analysis of wind speed, the instantaneous wind speed of the comparison area reached 22.2 m/s.

Figure 23 2-row 1-belt

Figure 24 Mixed forest

Figure 25 Shelter belt

Figure 26 Pure forest

Figure 27 Square

Figure 28 Square

4.5 The sustainable management model of psammophytic vegetation

4.5.1 Features of the model

After the establishment the sandy vegetation community and keeping relatively stable, according to the biological and ecological characteristics of main species, the methods of cutting, level cutting for rejuvenation, transformation for quality improvement and reforestation are taken under the premise of no damage to the ecological benefits. It is a good method to make good use of the sandy vegetation, and also to make the vegetation group keep exuberant vitality, thus to realize the sustainable management. This measure is applicable to the vegetation types of relatively stable sandy vegetation establishment.

4.5.2 Main technical measure

(1) Grass closure construction on the sandy land

Line up a certain range or size of the pasture for closure and enrichment, or to keep the pasture production stable and high-yield through measures of reseeding, irrigation, soil preparation, fertilizer supply etc., all of which is for the grazing or harvesting grass

Figure 29 Grass closure technology in Balinyou Banner

under the plan within the closed area.

The closure should be selected in the area with thick soil layer, good moisture condition, good terrain condition and easy wind proof. Build fence to close up as the grass closure. Taking grass as the main point, combining with water, grass, trees and machine together to improve grass with water, protect grass with trees, and promote the growth of the grass with mechanical sowing; build shelter-belt forest, each big belt-square just matches with a grass closure, combining with the protection forest, timber forest and cash trees together with the forest area occupying 7-10% of the area; some water conservancy measures should be taken according to actual situation; some machines can be used for forage harvesting, processing and drying.

According to the local nature situation and the local economy, it is necessary to reasonably use the land of the grass closure. The shape of the grass closure should be closed into a square or rectangle, which is easy for fence building and rotational grazing. The grazing lane should be short as far as possible with reasonable set-up of the livestock shed and drinking points.

(2) Sustainable Management technology of psammophytic vegetation

It refers to the people take research and utilization of the regeneration capacity of the psammophytes under the precondition of not affecting its general growth, which can meet people's demands of the time to the plant resources, and will also not affect the need of our later generations. There are mainly several modes for the utilization:

Shrub cutting processing for utilization: cut by belt which is vertical to the main wind direction. The first cut is permitted for 5m wide with an interval of 10m, the second cut next year select the belt of the same direction with the previous year on the same side also for 5m wide, and take the same method in future years. The level cutting can be done every 3 years. The cutting period can be the same time with silage corn when leaves are not fallen yet, cutting on the bottom. The cutting can be processed by a shredder machine and then can be used as forage or make into silage or mixed with corn silage. The cuttings can also be compressed into molding fuel of density 0.8g/cm3.

Figure 30 caragana cutting

High-yield technology: for the low-efficiency forests, some measures should be taken to improve the stand quality and strength the development of the trees through grafting and intensive management, and finally transform the forest into multi-functional forest with windbreak and sand-fixation, and with ecological, conservation and economic functions. The quality improvement mainly targets on the low-efficiency apricot trees to exchange the bad quanlity with the good. The flowering period of the apricot which will be used for grafting should be 5 days later than the wild apricot, which can increase the fruit setting rate by 2.41 times and the grafting survival rate is over 95%. The measures for quality and efficiency improvement include strengthen soil, fertilizer and water management by building square tree planting-holes, applying organic fertilizer, watering and weeding, manage tree structure by open pruning, and

Figure 31 Grafting technology

disaster prevention and control technology by painting white, insects' control, fire

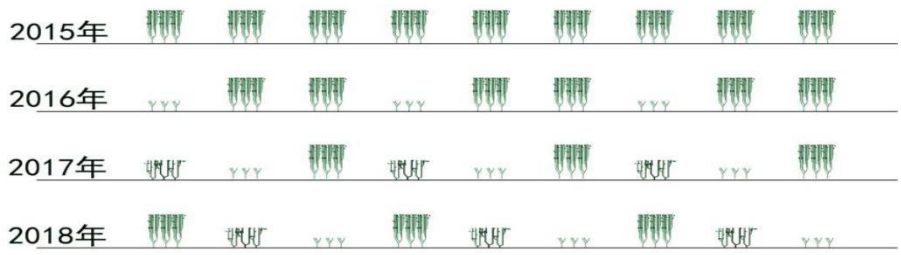

Figure 32 Technical legend for shrub cutting

control and guarding.

Update orderly: take clear cutting or selective cutting for sheet trees and belt trees under the plan for update, to achieve the continuity and sustainability of the forest for windbreak and sand-fixation.

Rotation: for the grass land of very old, conduct rotation by belt in a certain range.

Landscape utilization: According to the ecological landscape of sand area, conduct orderly development and utilization, to create a comprehensive tourist area for viewing, leisure, entertainment and vacation, etc.

4.5.3 Technical legend

4.5.4 Efficiency of the model

Taking Caragana as an example, the biomass per mu with big density is 1500-2000kg (fresh), that with small density is over 500kg, which can basically settle the current feed-livestock conflict, and on the other hand, promote the green organic food production and process into solid biological fuel. Through improve quality and update in order, it can achieve the efficiency of windbreak and sand-fixation, and also increase the economic benefits, and also promote regional economic sustainable development; it can boost people's enthusiasm to combat sand, accelerate the speed of sand control and ecological restoration; it can fulfill the everlasting being and the sustainable management of green mountains.

This model is mainly used in projects that are sustainable, recycling and orderly updated. Take the sample plot of Chaganmulun village of Balinyou Banner, a fixed sand on the North latitude 43°41′7′′ and the East longitude 118°24′59 " with an elevation of about 760 m, as an example. In 2012, Mechanical seeding of Caragana was conducted by belt of 1.5m wide of 4 lines with an interval between belts of 2.5m. The survey did in June 2019 shows that the average growth of Caragana is 129.3cm of the level-cutting height with a crown of 90×69cm in 2016, that is 71.2cm of the level-cutting height with a crown of 72×51cm in 2017, and that is 23cm with a crown of 36×32cm in 2018. For the comparison of the collected index of 2019 from the demonstration area see Table 8.

Figure 33 Shrub cutting in Balinyou Banner

Table 8 Effective comparison for psammophytic vegetation management

Sample plot code	technics	Sand type	year	No.of species	biomass (kg)	Dominant species	Relative coverage of dominant species(%)	Heigh of dominant species (m)	pH of soil	Soil bulk density (g/cm3)	Soil moisture content (%)	Soil organic matter(g/kg)
A-CK	compare	shift		1	122.44	Salsola collina	100	0.2	7.42	1.927	6.229	0.6958
Y-5-2	Sustainable development	Flat sand	2016	15	586.01	caragana	46.4	1.05	7.31	2.05	3.45	2.8071
Y-7	Grass closure construction	fixed	1998	13	1219.22	Silage corn	5.91	2.5	7.62	1.5	4.52	3.2436

This model mainly takes grass closure technology and psammophytic vegetation sustainable management technology, suitable for engineering projects for sustainable management, recycling utilization and orderly update. Table 8 shows that the species composition increases significantly, the relative coverage of the dominant communities decreases, the soil organic matter content increases, the height of dominant species is very clear. The effectiveness of this model under different patterns is as follows:

Figure 34 Quality improvement for wild apricot

Figure 35 Baiyinaobao Nature Reserve in Keshketeng Banner

Figure 36 Sand industrial products in Chifeng

Figure 37 Yulong Sand-Lake Tourism Spot in Wengniute Banner

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