Practice of desertification control in Anhan of Inner Mongolia, China

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Table of Abbreviations

APFNet	Asia-Pacific Network for Sustainable Forest Management and Rehabilitation
CAFS	Chifeng Academy of Forestry Sciences (Inner Mongolia, China)
GCA	Greater Central Asia
IPCC	Intergovernmental Panel on Climate Change
NGO	Non-Governmental Organization
OBOR	One Belt One Road Initivative
SYJFF	Sanyijing Forest Farm
UNEP	United Nations Environment Programme

Table of Boxes with English, Latin and Chinese names of plant species

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Executive Summary

This project, supported by APFNet and executed by Sanyijing Forest Farm in Aohan Banner, Inner Mongolia, China, has undertaken a trans-formative approach to desertification control, vegetation restoration, and resource utilization in sandy lands within the Greater Central Asian region. With a focus on both ecological protection and economic development, the project has established novel demonstration models for multifunctional forest benefits in semi-arid areas.

Key Achievements

1. **Innovative Forest Restoration Models**: The project introduced mixed forests instead of monocultures, showcasing 8 models that either demonstrated full afforestation, enrichment of degraded forests or restoration with forests for ornamental purposes.
2. **Restoration-Nursery Forests:** A new concept was developed whereby forests serve both ecological restoration purposes and as a nursery for income-generating tree species, such as Sugar maple, Yellowhorn, Mongolian scots pine, and Meyer's spruce.
3. **Orchard Improvements:** The project improved existing orchard yields of yellowhorn and Siberian apricot by employing advanced horticultural techniques like grafting and providing superior cultivars.
4. **Sandy Land Arboretum and Exhibition Hall**: An arboretum was built, showcasing species capable of thriving in desertified conditions, and an exhibition hall was constructed to disseminate the project's achievements to the public.
5. **Ecological, Social and Economic Benefits:** After afforestation, compared with unafforested land, the perennial plant species in project sites increased with the annual plant species decreased; the vegetation and 0-60cm soil carbon storage, soil organic matter, total nitrogen, maximum water holding capacity and water storage capacity, increased significantly, the soil wind erosion depth was reduced more than 50%. After high-yield Management, orchards increased organic matter; the soil bulk density reduced. After the high-yield management, the average fruit and seed production of Siberian apricot and Yellowhorn increased 18% and 25%. The multifunctional high-density nursery forest can increase income by $400-900 per ha. By 2023, the project areas have hosted at least 1,000 people of the Inner Mongolia Aohan manager training College, and a total of approximately 800 visitors have visited the Desertification Control Exhibition Hall.
6. **Outreach and Training**: Over 1000 professionals received training in desertification control and vegetation restoration, and the project's successes and methods were widely shared through websites, publications, and promotional films.

Lessons Learned

1. Expertise is crucial for innovation in desertification control and vegetation restoration.
2. Scientific monitoring is essential for evaluating project outcomes.

3. Learning from other successful projects is vital.
4. Post-project sustainability must be a priority to maintain and manage the project's demonstration forests.
5. Effective dissemination strategies are necessary for the models to have an impact.

Future Outlook

The now established demonstration base at Sanyijing Forest Farm is poised to be a key learning site for forestry in dry regions, with potential for scaling up the models and practices developed or introducing new models relevant for the GCA.

Tree Species for Desertification Control

Mongolian scots pine

Pinus sylvestris var. mongolica

樟子松

Mongolian scots pine is a 15-25 m high evergreen tree, native to the northeast of China. Needles 2 per bundle, blue-green, semiorbicular in cross section, with persistent sheath. Seed cones dull yellow-brown, conical-ovoid. Apophyses broadly rhombic. Seeds long winged.

It is fast-growing and adaptable, tolerating drought and sandy soils. It is thus suitable for afforestation in the sandy areas of northern of China.

(Photo: Wang Shusen)

Xinjiang's poplar

Populus alba var. pyramidalis

新疆杨

Xinjiang's poplar is a 15-30 m high deciduous tree, has a narrow cylindrical trunk and is gray-white bark that is smooth with a few cracks. Sprouts and long branches have deep palmately split leaves; the back of the blade is covered with white fluff. This variety also tends to grow in a pyramid, conical shape.

Xinjiang's poplar (Populus alba var. pyramidalis), different from the poplar trees (*Populus simonii*) planted locally in the past, is a commonly planted tree in the northwest of China due to its fast-growing nature, as well as its drought and wind resistance.

(Photo: Wang Shusen)

Yellowhorn

Xanthoceras sorbifolium

文冠果

Yellowhorn is a small 2-5 m high deciduous tree, with single-pinnate compound leaves. Between April and May, flowers arranged in panicles, with white petals with a red or yellow base and purple-red spots on the inner surface. Large capsules are produced with a tough green exterior between July and August. Seeds are round, dark brown, hard and smooth.

It is important tree for desertification control, with good drought and low temperature resistance, as well as low requirements for soil and wide tolerance of different light levels, ranging from being able to thrive in full sun to half-shade conditions. Finally, it also has beautiful flowers and edible seed oil, which has important market value.

(Photo: Wang Shusen)

Siberian elm

Ulmus pumila

榆树

Siberian elm is a 25 m high deciduous tree, with dark gray bark. Leaves are elliptical or oval-shaped. Samara, that is its fruit, is nearly circular and its flowering and fruiting period is from March to June.

Siberian elm is native to the northeast, north, northwest, and southwest of China. It is a fast-growing tree with well-developed roots and strong adaptability. Wood is hard and young fruits would be used as food source. Siberian elm is also an important tree species in urban forestry and for factory greening.

(Photo: Wang Shusen)

Chinese pine

Pinus tabuliformis

油松

Chinese pine is a 25 m high evergreen tree, native to China. Bark consists of irregular scales. Leaves are needle-shaped. Fruit is ovoid or round ovoid in shape and seed is light brown with a wing. Flowering period is from April to May, and the cones mature in October of the following year.

This native pine is a deep-rooted species that can grow in a dry and cold climate. All parts of Chinese pine have medicinal value. It ideal as a shelterbelt against wind and dust, and, as an evergreen, also makes an ideal ornamental tree and thus is suitable for planting on road sides. Its wood can be used for buildings, poles, shipbuilding, furniture, and more.

(Photo: Wang Shusen)

Chinese wild peach

Amygdalus davidiana

山桃

Chinese wild peach is a 10 m high deciduous tree. Its tree crown is spread out, with slender branches. Leaves are ovate lanceolate, with serrated leaf edges. Flowers stand solitary and open before the leaves in spring from March to April, with obovate or nearly circular pink petals. Its fruit is nearly spherical and light yellow with a thin and dry fruit flesh that is inedible and not dehiscent at maturity from July to August.

It has a high drought resistance, cold resistance and is resistant to both saline and alkali soils. It is beautiful as the wood is hard and heavy, and it can be used for various handicrafts.

(Photo: Wang Shusen)

Meyer's spruce

Picea meyeri

白杆

Meyer's spruce is a 30 m high evergreen tree, native to China. Bark is grayish brown and breaks into irregular thin pieces. Annual branches are yellowish brown with persistent bud scales that are reflexed at the base. Needles are quadrangular in shape. The cones are solitary, pendulous and their seeds have little wings.

Meyer's spruce is tolerant to shade. It can be used as industrial raw material for buildings, poles, bridges, and furniture. From an aesthetic point of view Meyer's spruce has a beautiful appearance, grows fast, and has well-developed lateral roots, making it an excellent ornamental tree species for gardens, while at the same time being able to fix soil.

(Photo: Wang Shusen)

Siberian apricot

Prunus sibirica

山杏

Siberian apricot is a 2-5 m shrub or small tree. Bark is dark gray. Leaf is ovate or suborbicular, and serrated. Flowers are solitary and open before the leaves. Its petals are white to pink. Drupe is oblate, yellow or orange red, and pubescent when fresh, thin, dry and cracking at maturity. The flowering period is from March to April, and the fruiting period is from June to July.

Siberian apricot is a important tree species along the Yellow River. It can be used for greening barren mountains, conserving water and soil. Its seed is edible and can be used as a medicine for relieving cough, reducing cholesterol levels of body.

(Photo: SYJFF)

Sugar maple

Acer saccharum

糖槭

Sugar maple is a tree native to North America. It has a rounded crown with bark that ranges from yellow brown to grayish brown. It has odd palmate leaves with five lobes and the leaves are arrange in opposite pairs. Female flowers are in panicles of 5 to 10 together and are yellow-green without petals. A pair of samaras is flat, and the two fruits spread into sharp or nearly right angles. Sugar maple flowers from April to May, and fruits in September.

Sugar maple has a broad crown and provides plenty of shade in summer, making it, together with its brilliant color display in fall, an ideal urban landscaping tree species. It can be planted on roads, parks, squares, and courtyards.

(Photo: SYJFF)

Winterberry euonymus

Euonymus maackii

桃叶卫矛

Winterberry euonymus is a small deciduous tree native to eastern Asia. Its leaves are opposite, oval or ovoid, with the margin finely serrated. Flowers are small, light white green or yellow green. The capsule is oblong heart-shaped and pink when ripe. Its seeds are brownish yellow and the aril is orange red. The flowering period is from May to June, and the fruiting period is from August to October.

Winterberry euonymus is a beautiful ornamental tree species for gardens. Its capsule is beautiful， cracking and exposing their orange red aril in autumn and winter. From an ecological point of view winterberry euonymus is very adaptable, and drought resistant, is an important afforestation species in arid and semi-arid areas.

(Photo: Wang Shusen)

Flowering plum

Amygdalus triloba

榆叶梅

Flowering plum is a small tree. The branches naturally grow as many short twigs. Its leaf is wide elliptical to obovate, with a short acuminate apex and rough or double serrated leaf edges. Its flowering and fruiting period is from April to July. Pink flowers bloom before the leaves appear. Drupe is nearly spherical, red, and has thin flesh.

With dense branches and leaves, as well as colorful flowers, flowering plum is an important ornamental shrub species for gardens, streets and roadside in northern China. It has a well-developed root system, strong drought tolerance and strong disease resistance, and is intolerant of water logging.

(Photo: Wang Shusen)

Shandong maple

Acer truncatum

元宝枫

Shandong maple is a 10 m deciduous tree. The leaf is palmate with 5 to 7 lobes. The flowers are in corymbs and form at the terminal end of a twig. Samara has two oblong wings, forming obtuse angles. It flowers in May and fruits in September.

Its shape is beautiful, with dense branches and leaves. In autumn the leaves change color (yellow, orange, and red) early and last for a long time. It is an excellent ornamental tree species planted in garden.

(Photo: SYJFF)

Goldleaf Siberian elm

***Ulmus pumila* cv. 'Jinye'**

金叶榆

Goldleaf Siberian elm is a cultivar originating from China, has a straight trunk and bright yellow leaves. It sprouts early and appears yellow.

It is an important landscaping tree species in urban and rural greening thanks to its beautifully colored leaves and can be used as street trees or shade trees.

(Photo: Wang Shusen)

Little leaf poplar

Populus simonii

小叶杨

Little leaf poplar is a 20 m high tree. Bark grayish green when young, dark gray on old trees, furrowed. leaf blade is near rhombic. Flowers open before the leaves from Mar to May. Capsule is 2-4 valved and seeds is small with hair and fruit period is from April to June.

It is a light-loving tree species. It is drought-resistant, cold-resistant, and tolerates barren or weakly alkaline soil. It can grow in sand, wasteland and loess valleys. It has a well-developed root system and strong wind resistance. It can be propagated by cuttings and sowing. It is favored by people in arid areas of China.

(Photo: Wang Shusen)

Contents

01 Introduction

1.1 Report Structure

This report primarily discussed the achievements and experience gained from two phases of the Demonstration Project of Desertification Control and Forest Resource Management and Utilization in the Greater Central Asia Region, which was supported by APFNet. Project supervision unit was Forestry and Grassland Bureau of Chifeng City, Inner Mongolia, China and Project implementation unit was Sanyijing Forest Farm, Aohan Banner, Chifeng City, Inner Mongolia, China. In this project, through the establishment of demonstration areas in Inner Mongolia, which is a part of the Greater Central Asia (GCA) region, regionally relevant restoration approaches, such as the improvement of sandy ecosystems and their sustainable management, were showcased in order to demonstrated how forests can be managed for multiple functions and ultimately produced comprehensive benefits.

This report was structured into four chapters, specifically (1) Introduction, (2) The Project, (3) Key desertification control forest restoration models, and (4) Conclusion. Chapter 1 introduced Greater Central Asia and its desertification issues, including how desertification had historically been controlled within China and at the project site in Aohan Banner, Inner Mongolia of China. Chapter 2 was about the project itself, focusing on the background information about the project and why this site was selected, project goals and key partners of the project. In Chapter 3, the most important part of this report, the key models of afforestation and vegetation restoration for desertification control were described. This included full afforestation with no prior forest, restoration models for degraded poplar forests, models to achieve higher yields in orchards, models for multi-functional high-density nursery forests, and reforestation models with a focus on landscaping. Additionally, project related project activities, such as the establishment of a sandy-land arboretum and environmental education efforts would also be described. The last chapter distilled down key achievements, lessons learned and how the project site can serve as a demonstration base for innovative anti-desertification models in the future.

1.2 Desertification in Greater Central Asia

The Greater Central Asia region, situated in the temperate zone’s arid belt of the northern hemisphere, forms a part of central Asia. It includes the economies and regions of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Mongolia and north-western China (Figure 1-1). It spans from the northwestern slopes of the Pamir Plateau in the west to the Mongolian Plateau in the east. Characterized by fragile ecosystems, the area is also globally recognized for its rich natural resources, especially fossil fuels (Han et al., 2021).

Figure 1-1 GCA and the project location (Source: China Map Publishing House, National Basic Geographic Information Center, 2022); the thick yellow area shows the GCA with Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Mongolia and north-western China; the red star

is the project site.
There are two distinct climatic regions in the Greater Central Asia. In the western belt, where the project site is a monsoon-influenced warm summer humid continental climate. This translates to summers are marked by high temperatures, humidity and rainy seasons due to the warm and humid air from the ocean. Winters, in contrast, are cold and lack precipitation due to the dry and cold air flows from the Siberian High (a massive collection of cold and dry air that accumulates in the north-eastern part of Eurasia from September until April). Aohan Banner, the project site, is gradually decreasing from south to north, with annual precipitation ranging between 310 mm and 460 mm.

The other zone is largely influenced by a cold desert or semi-arid climate, which spans large parts of the rest of the GCA, the cold season is marked by low temperatures and little rain, while high temperatures and low precipitation dominate in the warm season (Hu et al., 2014; Cao et al., 2017). The mean temperatures in winter range from -3 to -20 ℃, while mean temperatures during summer range from 20 to 40 ℃ (World Bank, 2016). The annual average precipitation in Tajikistan is 500 mm and in Uzbekistan is 250 mm (USAID, 2018).

In terms of geography, the western part of the region has a varied topography, higher in the southeast and lower in the northwest. Specifically, the Pamir Plateau of Tajikistan in the southeastern part is 4,000-7,500m above sea level and blocks the western airflow, thus trapping substantial moisture.

Large rivers supplying freshwater are comparatively sparse. For instance, in Turkmenistan, there are no other large rivers except the Amu Darya. Exacerbating this, its annual precipitation is less than 205 mm, but its evaporation is more than 2,000 mm. Thus, due to drought and little rainfall, agriculture in most of economies and regions must solely rely on irrigation from that one river, especially since it is grappling with issues of soil salinization that make it difficult to rely on ground water (Shula et al., 2015; Pu et al., 2008; O'Hara, 1997).

The oases and deserts in the northwestern part of Greater Central Asia are widely distributed across the plain basin at an altitude of 200-400 m. The general pattern is that forest and steppes can mostly be found in the mountains, while deserts, oases are located at the basins (Chen et al., 2013). In the eastern part of the region, the Mongolian Plateau is located. This plateau gradually decreases in elevation from west to east with the altitude in the western part, close to the Altai mountains, averaging 1,580 m while the eastern grasslands are at an average elevation of only around 650 m. It is mainly dominated by grassland steppes and small areas of forests, as well as shrubland (Ren, 2022). Aohan Banner, where the project is located, belongs to the transitional zone from the Yanshan Mountains to the Western Liaohe Plain. The geomorphological types include the low rocky mountains and hills of the southern Nuruhu Mountain, the central loess hills, and the northern sandy dunes (Xing et al., 2022).

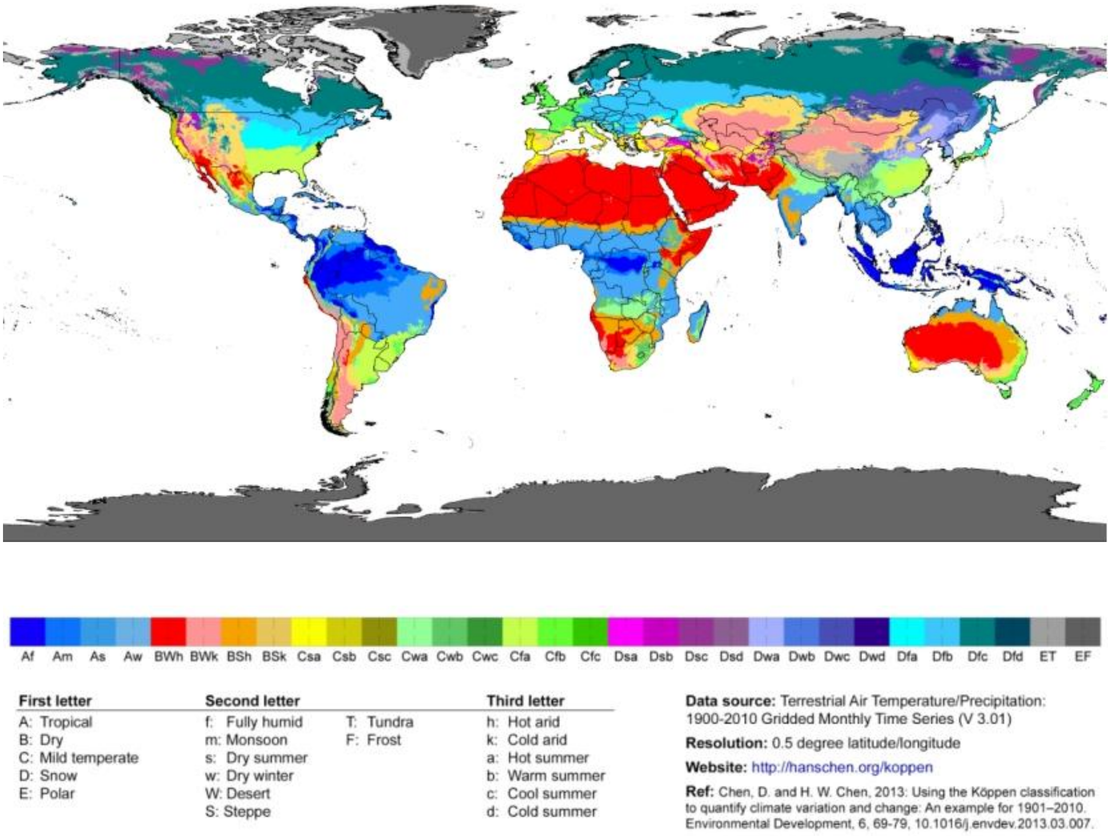

Figure 1-2 The Köppen-Geiger climate map (Hylke et al., 2018)

Human activities, particularly the consumption of fossil fuels, such as coal and oil, along with extensive deforestation and forest degradation, have led to a continual increase in greenhouse gas emissions. According to an assessment by the Intergovernmental Panel on Climate Change (IPCC), over the past century, the average global surface temperature had increased by 0.3 ℃ to 0.6 ℃, and global sea levels had risen by 10 to 25 cm. Due to climate change, glaciers in some mountainous areas of central GCA have begun to melt or even disappear, and the amount of winter snowfall had decreased as well. Consequently, river flows had diminished, adversely affecting vegetation growth, plus the availability of water for human consumption and agricultural irrigation. This in turn has negatively affected the environment and the livelihoods and health of local people (Yang, 1998).

The arid region of the GCA includes vast expanses of desert, sandy lands and the perhaps most famous desert of Asia, the Gobi. This region is naturally characterized by its aridity and lack of rain and other water resources. However, climate change exacerbated the situation. The climate here had warmed more than twice as much as that of the rest of the northern hemisphere in the past 100 years. In short, the speed and magnitude of temperature increased in this region has far exceeded the average global temperature increase (Hu et al., 2014).

Over the past 50 years, the annual average temperature in the GCA had experienced a clear upward trend. During this period, the most rapid increase occurred in winter (Figure 1-3). Spatially, the rate of warming in the northern parts of Central Asia had been greater than in the south (Chen et al., 2011 and Li et al., 2015). Furthermore, the temperature in Central Asia had been continually rising since the 1960s, surpassing the global average. Since the 1980s, the warming trend had become especially pronounced, and with a more significant temperature increase in spring. Within the GCA, Uzbekistan, Turkmenistan and southwestern Kazakhstan had warmed the most (Yao et al., 2020).

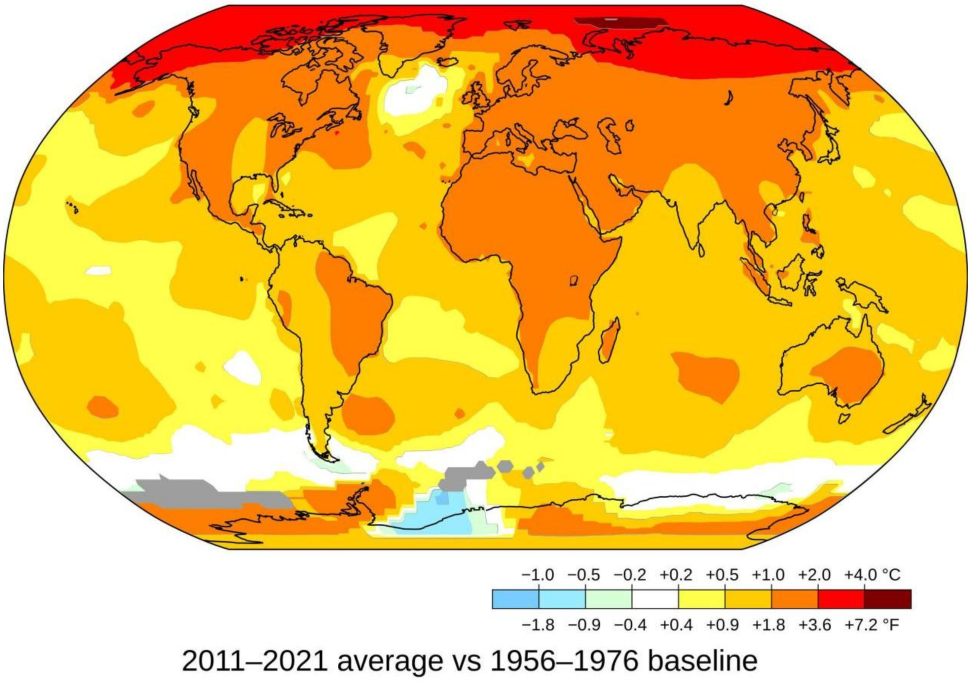

Figure 1-3 Average surface air temperatures increase between 2011 and 2021 compared to the 1956–1976 average (Source: IPCC, 2021)

1.3 Desertification Control in China

The project this report is about was, as previously mentioned, located in the Aohan Banner, Inner Mongolia of China. Thus, it may be beneficial to build up a knowledge base of previous desertification control measures in China to date, which shall be outlined.

China, like other economies and regions in the GCA, faces significant challenges with desertification. In order to address this issue, starting in 1949, China thus undertook extensive efforts in desertification control and vegetation restoration. Specifically, China started to carry on three important desertification control programs. One of the them was the Three-North Shelterbelt Program (三北防护林工程), which was initiated in 1978 and is supposed to run until 2050, making it the potentially longest-running large-scale restoration program in global history. The project area covers Northwest, North and Northeast China, overall 4,480 km from west to east and 560-1,460 km from north to south, totaling 4.069 million km^2, or 42.4% of the total area of China (Wei, 2003).

Another key anti-desertification program is the Beijing-Tianjin Sandstorm Source Control Program (京津风沙源治理工程), which initiated in 2002. The restoration area covers nearly 700 km east to west and nearly 600 km north to south in China. It targets a desertified area of 458,000 km^2 in four ecological areas, including desertified arid grasslands, sandy areas, desertified areas in the agro-pastoral transition zone, and water source protection areas (Xi, 2007). In 2002, China started also the Returning Farmland to Forest Program (退耕还林工程), which pays farmers to plant trees on their degraded farmlands instead of using them for agriculture (Tan et al., 2016). During the "Thirteenth Five-Year Plan" period, China had completed desertification control area of 10.978 million ha, built 50 desert parks, added 500,000 ha closed areas (Gu, et al. 2021).

1.4 Desertification Control in Inner Mongolia and Aohan Banner

As mentioned, the project was located in Inner Mongolia, China, and it is one of the regions most affected by severe desertification in the economies and regions of the GCA. As of 2019, Inner Mongolia had desertified land area of 59.31 million ha, accounting for 50.14% area of the Inner Mongolia region; sandification area of 39.82 million ha, accounting for 33.66%. According to statistics, compared with the fifth desertification and sandification land monitoring results in 2014, the area of desertification and sandification land in Inner Mongolia in 2023 had decreased by 1.61 million ha and 0.97 million ha respectively (Li Yanhong, 2023).

The project site in Aohan Banner is part of Chifeng City and is located at the southern edge of Horqin Sandy Land. From the early 1960s to the mid-1970s, due to a rapid increase of the population and overexploitation of land, the mobile and semi-mobile sandy land increased at a rate of 4,667 ha per year. By 1975, the area of desertified land reached 170,667 ha, accounting for 20.8% of the total area. According to the 2004 National Desertification Monitoring of China, this figure has significantly decreased, with the mobile sand area being reduced from 38,000 ha to just 3,480 ha, and the semi-mobile sandy reduced from 114,000 ha to 5,860 ha, thanks to the hard work of local people. Due to these remarkable achievements, Aohan Banner was awarded the Global 500 Roll of Honor by UNEP in 2002 (Liu, 2009). Over years of combating desertification and conducting afforestation, Aohan Banner has explored many different strategies and developed numerous effective strategies, especially when it comes to the selection of tree species, the implementation of comprehensive desertification control measures, and the application drought-resistant afforestation techniques. However, many afforestation sites were set up as monocultures and thus provided diminished ecological value (Figure 1-4).

Figure 1-4 Desertification control in Aohan Banner, Inner Mongolia of China (Photo: Bao Hong, Cheng Yingjun, 2018)

02 The Project

2.1 Introduction

Forest degradation is a concern worldwide, however, especially in the context of climate change, developing effective approaches to restore landscapes in a drying climate became a driving concern for APFNet as many of its member economies and regions in the GCA were already grappling with issues of desertification. As such, developing demonstration models that not only address desertification control but also establish diverse forests and manage them in a sustainable and integrated manner, became imperative. The key challenge was to find a location that had experience to build upon to refine existing models and was both relevant to the GCA and accessible.

2.2 Policy Context and Project Location Selection

With the acceleration of global economic integration, especially following the proposal of the One Belt One Road (OBOR) Initiative, the exchange and cooperation among China, Mongolia and other GCA economies and regions have increasingly intensified. In 2015, Inner Mongolia was included in the scope of OBOR with other 15 provinces of China, and also one of the six Chinese provinces that are located in the GCA. This made Inner Mongolia a prime region for the showcasing of demonstration models that could then be transferred via OBOR.

Additionally, as previously mentioned, Aohan Banner specifically was once one of the areas affected by the most severe desertification, most of which was successfully fixed by plentiful desertification control measures, such as afforestation, and accumulated rich experience for desertification and forest management. Still, many the remaining problems Aohan Banner is facing are similar to those of other economics and regions in the GCA: (1) Desertification of a few areas was still severe and the remaining desertified areas were difficult to restore. (2) The established forests were still not utilized in the best manner; (3) There was still a need of demonstration models showcasing desertification control, and integrated and sustainable forest management of forests in sandy ecosystems.

Figure 2-1 The officials from APFNet and the Chifeng Forestry and Grassland Administration investigated the project site (Photo: Sanyijing Forest Farm (SYJFF), Inner Mongolia, China)

Fortunately, Aohan Banner is in a prime position to address these issues and establish relevant demonstration models for the reason: (1) It was located at the southern edge of Horqin Sandy Land and iwas easily accessible with convenient transportation, making it ideal destination for international visits. (2) Its problems of desertification were representative for the GCA. (3) Aohan Banner already had relevant experiences in the long-term practice of sand control and afforestation and can build on those. (4) It had local government support and experience in international cooperation. Due to its experience, achievements and location, Sanyijing Forest Farm (SYJFF) was chosen as the demonstration sites (Figure 2-2).

2.3 Project Goals and Objectives

The Demonstration Project of Vegetation Restoration and Forest Resource Management and Utilization in the Greater Central Asian Region overarchingly aimed to plant forests for vegetation restoration in suitable desertified areas, some of which served primarily an ecological function, while others provided economic or aesthetic benefits. Additionally, existing low-value and degraded forests were to be improved to provide more resources to improve local livelihoods.

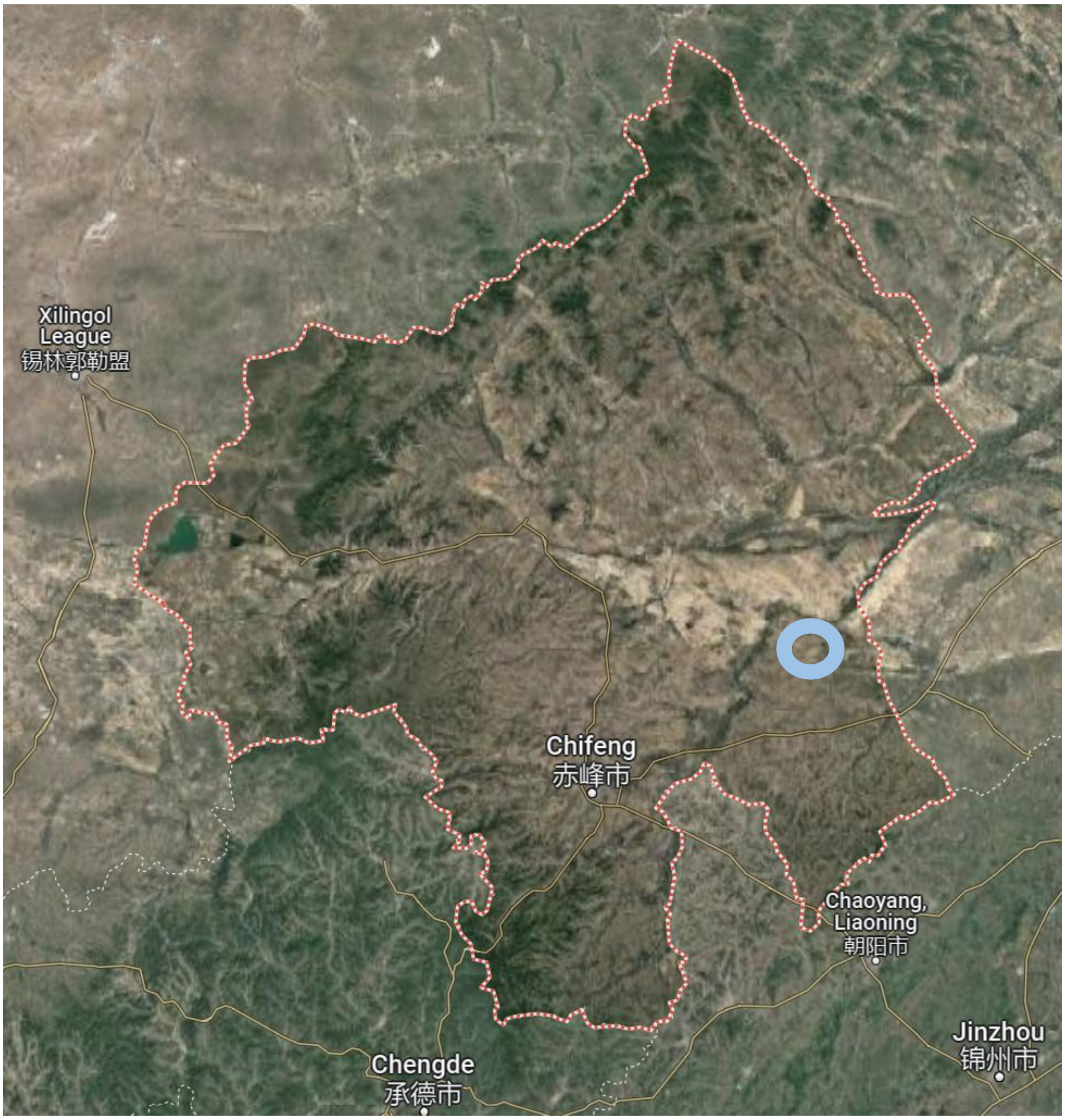

Figure 2-2 The Auhan Banner (the blue cycle) in Chifeng city (Source: google maps)

2.3.1 Phase I

In Phase I, the demonstration forests were to be established in sandy areas at Sanyijing Forest Farm. This mainly included the planting of a mixed forest of Mongolian scots pine and Xinjiang's poplar, and a mixed forest of Mongolian scots pine and Yellowhorn. In order to provide locals with a novel mean of income, the high yield management of a Siberian apricot orchard, where the fruit trees were grafted and also other techniques to achieve a for higher fruit yield were showcased. The project implementation area is 109 ha. The total project budget is US$784,500, of which US$533,200 was from the APFNet, and US$251,300 was from Sanyijing Forest Farm in Aohan Banner, Chifeng City, China. The project results mainly included that: (1) Research Report

on Typical Models of Desertification Prevention and Control in Chifeng City;
(2) Constructed 70 ha vegetation restoration demonstration forests in the sandy area; (3) Construct 39 ha economic forest demonstration base in the sandy area; (4) Trained 500 personnel, exchanged training for 20 people at home and abroad, and compiled 1 project training technical manual.

2.3.2 Phase II

Forest restoration is a long-term endeavor requiring continuous and diligent efforts, and after Phase I it was clear that there are more problems in need of feasible solutions and in some cases the results could be further improved upon. Considering the successful cooperation with Sanyijing Forest Farm in the Phase I and those gaped in knowledge, APFNet decided to carry out a second phase of this project at the same location. The project implementation area was 230 ha. The total project budget was US$1.456 million, of which US$1.148 million was from the APFNet, and US$308,000 was from the Sanyijing Forest Farm in Aohan Banner, Chifeng City, China.

In Phase II, more models, ranging from desertification control to livelihood improvement and landscape beautification were tried out. A variety of landscape forests of mixed coniferous and broad leaf trees, specifically Mongolian scots pine-Winterberry euonymus forests, Mongolian scots pine-Chinese wild peach forests, Mongolian scots pine-Shandong maple forests and, for road landscaping and protection, Mongolian scots pine-Goldleaf Siberian elm forests, were planted.

Figure 2-3 Project steering committee and inception meeting of Phase II (Photo: SYJFF)

The project results mainly included that: (1) Constructed 72.34 ha of vegetation restoration demonstration forests in semi-arid desertification areas; (2) Constructed a 10 ha sandy land arboretum; (3) Constructed 38.66 ha of low-efficiency forest transformation demonstration forests; (4) Improved the comprehensive benefits and demonstration effectiveness of the first phase project; (5) Constructed an exhibition room of 500 m^2 for desertification prevention and control achievements; (6) 600 people were trained, 32 people were exchanged and trained at home and abroad, and 1 project training technical manual was compiled.

Figure 2-4 Project meeting (Photo: SYJFF)

To improve the low-yielding existing forests, small old trees that were on the brink of dying, especially in older poplar forests, were removed and coniferous and broad-leaved mixed forests, such Chinese pine and Yellowhorn forests, Mongolian scots pine and Chinese wild peach forests and Siberian elm and Meyer's spruce forests were established in the understory. In other areas a novel scheme for livelihood improvement was tried out where seedlings for sale, such as of Sugar maple, Yellowhorn, Mongolian scots pine and Meyer's spruce, were planted. More demonstration orchards were established as well, this time piloting new fruits, such as apple and pear.

Finally, a sandy land arboretum, displaying local plant species used for desertification control was built through the project. As part of this arboretum, an exhibition hall to showcase the history of desertification control, its achievements and lessons learned in the context of vegetation restoration and integrated forest resource management and utilization in sandy land, was constructed.

2.4 Key Project Partners

2.4.1 APFNet

This project is supported by APFNet, a non-profit regional organization officially launched in September 2008. The objectives of this organization are: (1) to contribute to the efforts of member economies and organizations to substantially increase the area of restored multifunctional forests, and to contribute to the framework of multilateral aspirations and processes such as the Bonn Challenge, the UN Strategic Plan for Forests, the UN Decade on Ecosystem Restoration, and the Asia-Pacific Regional Strategy and Action Plan for Forest and Landscape Restoration; (2) to help enhance forest carbon stocks and improve forest quality and productivity by promoting the rehabilitation of existing but degraded forests and the reforestation and afforestation of suitable lands in the region; (3) to help reduce forest loss and degradation and associated greenhouse gas emissions by strengthening SFM and enhancing biodiversity conservation; (4) to help increase the socioeconomic benefits of forests in the region.

2.4.2 The Supervisory Agency

This project is supervised by the Chifeng Forest and Grassland Administration (CFGA), Inner Mongolia of China, which is mainly responsible for the city's the afforestation, grass planting and greening, desertification prevention and control; the ecological protection, construction, restoration and management of forestry and grassland; the supervision and management of wild animal and plant resources of forests, grasslands and wetlands; the science and technology of forestry and grassland; the publicity, education, external exchanges and cooperation work(CFGA, 2022).

For this project a project management office was established at the Chifeng City Forest and Grassland Protection and Development Center. Under the guidance of the APFNet and the Project Steering Committee, the office was responsible for project supervision and project management. It was accountable for ensuring the project's progress and the quality of project activities, while ensuring that funds was used in a standardized and efficient manner.

2.4.3 The Executive Agency

The project’s Executive Agency is Sanyijing Forest Farm (SYJFF). SYJFF (120°14′-120°22′ E and 42°30′-42°51′ N), founded in 2018, is located in Xiawa town the northern part of Aohan Banner in the transition zone from Yanshan Mountain to Songliao Plain on the southern edge of Horqin Sandy Land. The forest land is mainly distributed across Changsheng Town, Mutouyingzi Town, Aorunsumo Town, Xiawa Town, Niugutu Town and Huangyangwa Town of Aohan Banner. Route 111, G45 Expressway and the Beijing–Tongliao railway pass through its territory. The whole farm spans about 45 km from east to west and 120 km from north to south. It includes 4 sub-sections, which are Chenjiawazi, Xiaohezi, Heyewusu, and Sanyijing. The total areas covers 14,645 ha, including 7,556 ha of forest land, as well as 4,593 ha of other land. Among them, there are 5,225 ha of degraded forests. SYJFF currently has 109 employees.

Figure 2-5 The location of Sanyijing forest farm (green tree) (Source: google maps)

03 Key Models of Vegetation Restoration and Forest Resource Management and Utilization

Table 3-1 The main contents of Vegetation Restoration and Forest Resource Management and Utilization

Box Nr.	Items	Contents
1	Full afforestation	Mongolian scots pine and Boll's poplar mixed forest
		Mongolian scots pine and Yellowhorn mixed forest
		Mongolian scots pine and Siberian elm forest
2	Restoring Degraded Forests	Chinese pine and Yellowhorn enriched forest
		Mongolian scots pine and Chinese wild peach enriched forest
		Meyer's spruce and Siberian elm enriched forest
3	Management for Improved Yields of Orchards	High-yield management of Siberian apricot orchards
		High-yield management of Yellowhorn orchards
4	Multifunctional, High-Density Nursery Forests	Sugar maple nursery forest
		Yellowhorn nursery forest
		Mongolian scots pine nursery forest
		Meyer's spruce nursery forest
5	Ornamental Forest Restoration	Ornamental forest restoration for colorful landscapes: Mongolian scots pine, Chinese pine, Winterberry euonymus, Flowering plum or Shandong maple mixed forest
		Goldleaf Siberian elm and Mongolian scots pine Roadside landscaping mixed forest
6	Construction of the Sandy Land Arboretum	10 hectares， 40 plant species, including 24 types of trees and 16 varieties of shrubs.
7	Environmental Education	Desertification Control Exhibition Hall

3.1 Full Afforestation

In Phase I, mixed coniferous-broad-leaved forests on bare sandy land were planted, marking a departure from the monoculture plantations of the past. The reason for choosing mixed forests was that planting Little leaf poplar (*Populus simonii*) monocultures can fix local drifting sand, but the resulting forests, which colloquially had been referred to as 'the small old tree forests', provided limited ecosystem services and no economic value.

Note that in the following sections species that appear be described more extensively in the section of *Species for Desertification Control*. Novel or different management aspects will be described at length initially and then be referred back to. For similar processes either refer to the section it was first mentioned.

3.1.1 Mongolian Scots Pine and Xinjiang's Poplar Mixed Forest

The trees were planted in a grid 200×200 m with Mongolian scots pine (61 rows) inside and Xinjiang's poplar (4 rows) planted in a shelterbelt grid. The spacing of Mongolian scots pine seedling was 3×3 m. The spacing of Xinjiang's poplar seedlings was 2×4 m (Fig. 3-1).

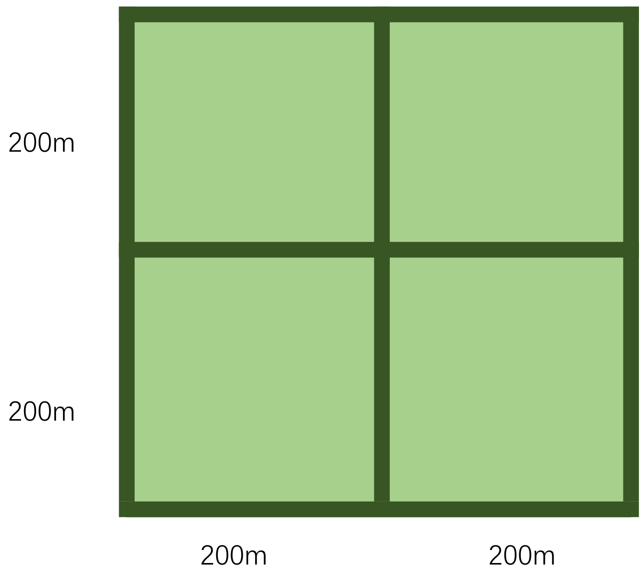

Figure 3-1 Planting scheme, the dark green is Xinjiang's poplar and the light green is Mongolian scots pine

A mechanical soil preparation method was adopted to create a level surface for the following afforestation. The soil was plowed to a depth of more than 25 cm, and a 80 cm wide and 30 cm deep ditch was dug to provide an optimal environment for seedling growth.

Potted Mongolian scots pine seedlings that were at least 4 years old with a height greater than or equal to 1 m were selected; meanwhile Xinjiang's poplar seedlings were at least 4-5 years old with a height of at least 2.5 m and a basal diameter of at least 2 cm.

Figure 3-2 Mechanical soil preparation (Photo: SYJFF)

The pine was planted in 40×40×40 cm pits as soon as the seedlings were transported. Before planting the seedling was removed from its container and put in the pit, which was then backfilled with wet soil and watered with 50 L per plant. Once the soil had settled down more soil was added to fill the pit to the general ground level[1].

The roots of the Xinjiang's poplar seedlings were soaked for 48 hours so they can absorb water. During planting the seedlings were put vertically in the 50×50×50 cm pits. Afterwards half of the pits was filled back with soil, and the seedlings were slightly lifted and watered, then the rest of the pit is filled with soil as well. The total amount of water was 50 L[2].

The seedlings were watered three times in the first year, the first time during planting in April, the second time in June or July, and the third time in August or September. In the 2nd and 3rd year the seedlings were only watered once with 50 L per pit in June or July each time. Each year the seedlings were weeded twice in a 1.5 m belt along the tree row in June and July as weeds grew fastest in these two months. Finally, they were fertilized once with 7.5 tons of manure per ha in March of the second year.

[1] This process is hereafter referred to as Planting Process 1

[2] This process is hereafter referred to as Planting Process 2

Figure 3-3 Mixed Mongolian scots pine-Xinjiang's poplar forest (Photo: SYJFF)

3.1.2 Mongolian Scots Pine and Yellowhorn Mixed Forest

The trees were planted in the grids 200×200 m with Yellowhorn (61 rows) inside and Mongolian scots pine (4 rows) planted outside (Fig. 3-4). The spacing of the Mongolian scots pine seedlings was 2 × 4 m, while for Yellowhorn it was 2 × 3 m . The ground of the Yellowhorn forest was covered with gray plastic in order to reducing weed growth, improving the ground temperature and retaining more soil moisture.

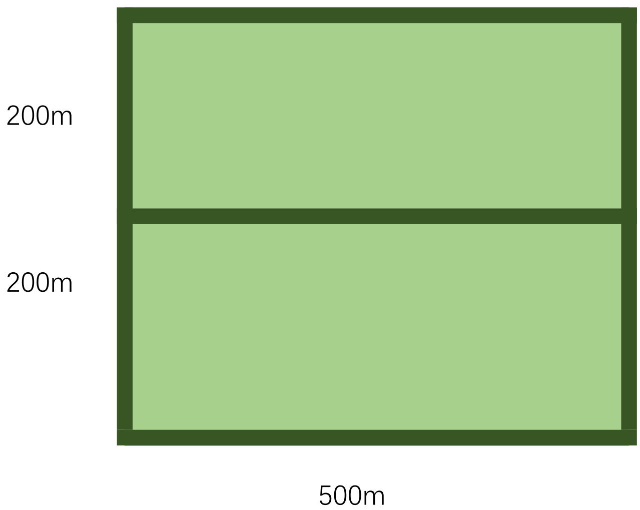

Figure 3-4 Planting scheme, the dark green is Mongolian scots pine and the light green is

Yellowhorn

Soil preparation was the same as above. The Mongolian scots pine container seedlings were over 4 years old and larger than 1 m, while the Yellowhorn seedlings were at least 1 year old and 1.2 meters high. Opposed to the pine seedlings these seedlings were bare rooted and their basal diameter was at least 0.8 cm.

Figure 3-5 Mixed Mongolian scots pine-Yellowhorn forest (Photo: SYJFF)

Mongolian scots pine was planted in 40×40×40 cm pits according to Planting Process 1. The roots of the Yellowhorn seedlings were soaked 48 hours so they can absorb water. After this their roots were dipped into a powder that promotes rooting, and planted in a pit of 40×40×40 cm according to Planting Process 2. Post-afforestation maintenance was the same as in Chapter 3.1.1.

3.1.3 Mongolian Scots pine and Siberian Elm Mixed Forest

This area was afforested with a mix Mongolian scots pine and Siberian elm a belt forest, whose seedling ratio was 2:4 (Figure 3-6). The spacing between the Mongolian scots pine and Siberian elm seedlings was 3.5×3.5 m.

Soil preparation was the same as in Ch. 3.1.1. The seedlings of Mongolian scots pine were more than 5 years old with a height of at least 1.2 m; meanwhile the seedlings of Siberian elm were around 2 years old, with a height of at least 1.2 meters and a basal diameter of at least 1 cm.
Mongolian scots pine was planted in 60×60×60 cm pits according to Planting Process 1. The roots of the Siberian elm seedlings were dipped in powder that promotes rooting, then planted in 50×50×50 cm pits according to Planting Process 2. Post-afforestation maintenance was the same as in Chapter 3.1.1.

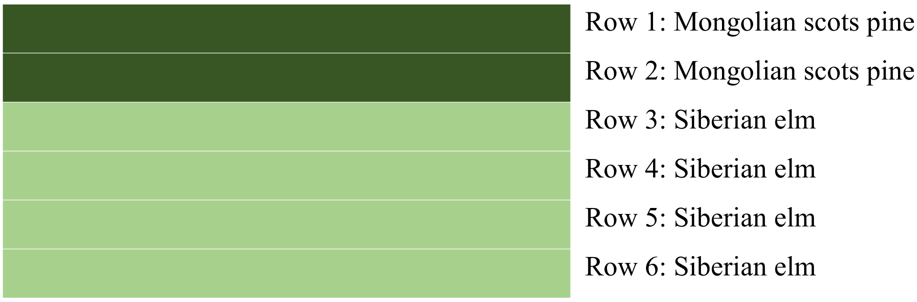

Figure 3-6 Planting scheme, the dark green is Mongolian scots pine and the light green is Siberian elm

3.1.4 Summary

Full afforestation was carried out on a large area of fixed and semi-fixed sandy land without forests. The forests used a mixed forest of evergreen coniferous trees and deciduous broad-leaved trees of different seedling ages. Due to the different lifespans, growth rates, and root distribution ranges of tree species, after years of growth, a multi-layered mixed forest of different ages can be formed, which increased the plant diversity of the artificial forest, increased the carbon sink capacity of the vegetation, and improved the soil nutrients and moisture characteristics. Compared with the previous pure poplar forest, the stability and sustainability of the ecosystem were greatly improved.

Figure 3-7 Weeding of the mixed Mongolian scots pine-Siberian elm mixed forest (Photo: SYJFF)

3.2 Restoring Degraded Forests

Between the 1960s and 1990s, Little leaf poplar (*Populus simonii*) monocultures with a spacing of

2×3 m and 2×4 m were commonly planted to fix sand at SYJFF. However, most trees in those forests grew slowly or even died due to the harsh conditions and a lack of water. Therefore, improving the structure of the forest, promoting forest growth and improving the economic benefits the forest can provide had become more and more important. In Phase II, a lot works were done to restore and improve these degraded forests.

3.2.1 Chinese Pine and Yellowhorn Enriched Forest

In the severely degraded poplar monocultures, belt thinning was conducted that took out a number of degraded and dead trees, afterwards Chinese pine and Yellowhorn were interplanted in a mixed fashion (Figure 3-8).

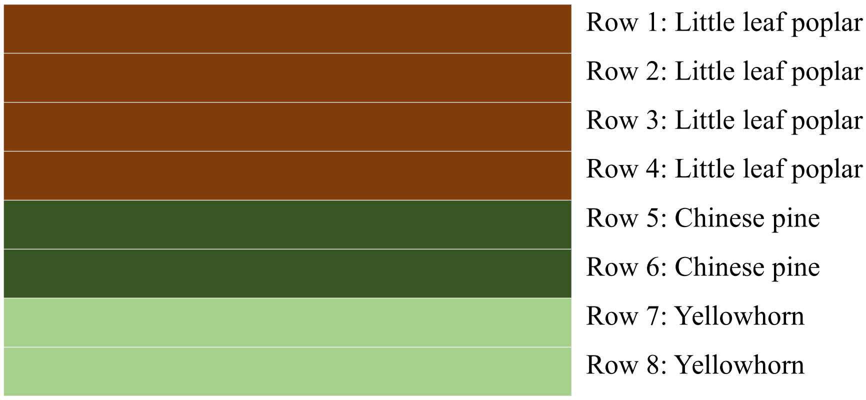

Figure 3-8 Planting scheme of Chinese Pine and Yellowhorn enriched forest

In this mixed forest of Chinese pine and Yellowhorn an equal amount of each species was planted (2 rows Chinese pine, 2 rows Yellowhorn). The spacing of Chinese pine seedlings was 2×5 m, while for Yellowhorn it was 1.8×5 m.

As with all previous afforestation, the mechanical soil preparation method was adopted to create a level surface. Each ditch was 80 cm wide and 30 cm deep. However, the soil was ploughed to a greater depth of more than 120 cm beside the poplar trees than in previous afforestation in order to be able to cut Little leaf poplar roots and in this fashion promote the growth of the newly planted trees. The seedlings of Chinese pine were more than 5 years old with a height of at least 1.5 m and with plastic containers, while the seedlings of Yellowhorn were 1 year old, and at least 1.2 meters tall, and had a basal diameter of at least 0.8 cm.

Chinese pine was planted in 60×60×60 cm pits according to Planting Process 1. The roots of the Yellowhorn seedlings were soaked in water for 48 hours, and its root systems were dipped in root improvement powder to promote rooting, then planted in 60×60×60 cm pits according to planting Process 2. Post-afforestation maintenance was the same as in Chapter 3.1.1.

Figure 3-9 Restored degraded poplar forest now intermixed with Chinese pine and Yellowhorn (Photo: SYJFF)

Under the degraded forest of Little leaf poplar (2×5m) and *Corethrodendron fruticosum* (1.5×5m) (a small sandy shrub), A row of poplar trees inter-planted with a row of Mongolian scots pine trees, and Inter-planted Chinese wild peach beside to *Corethrodendron fruticosum*. The spacing of the Mongolian Scots Pine seedlings was 2×5 m, while it was 1.8×5 m in the case of Chinese wild peach (Figure 3-10).

3.2.2 Mongolian Scots Pine and Chinese Wild Peach Enriched Forest

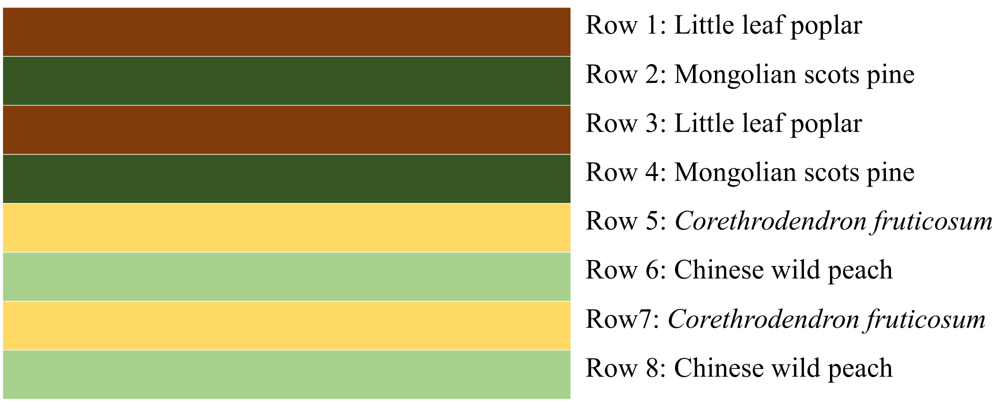

Figure 3-10 Planting scheme of Mongolian scots pine and Chinese wild peach enriched forest

Figure 3-11 Mongolian scots pine and Chinese wild peach mixed forest (Photo: SYJFF)

The same mechanical soil preparation method adopted again. The Mongolian scots pine seedlings were more than 5 years old, and their height at least 1.2 m. The seedlings of Chinese wild peach were at least 5 years old and at least 1.5 meters in size, with a basal diameter of at least 2 cm. Mongolian scots pine seedlings were planted according to Planting Process 1, while Chinese wild peach seedlings were dipped in root improvement powder and planted according to Planting Process 2. Post-afforestation maintenance was the same as in Chapter 3.1.1.

3.2.3 Meyer's Spruce and Siberian Elm Enriched Forest

Meyer's spruce and Siberian elm were selected and planted with an equal ratio in forest glades of the old poplars. The spacing of Meyer's spruce seedlings was 2×5 m, while Siberian elm was spaced at 1.8×5 m (Figure 3-12).

Soil preparation, including ditch and pit size, was the same as in Ch. 3.2.1. The seedlings of Meyer's spruce were more than 5 years old, their height ranges between 80 cm and 1 m. In contrast, Siberian elm seedlings were only around 1 year old with a height of at least 1.2 m, and a minimum basal diameter 0.8 cm. Meyer's spruce was planted according to Planting Process 1, while Siberian elm, after dipping its roots in root growth powder for promoting rooting, was planted according to Planting Process 2. Post-afforestation maintenance was the same as in

Chapter 3.1.1.

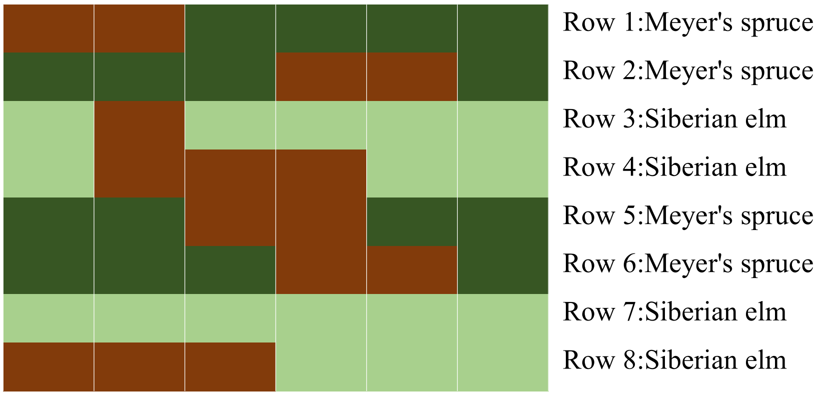

Figure 3-12 Planting scheme of Mongolian scots pine and Chinese wild peach Enriched Forest, the dark green is Meyer's spruce, the light green is Siberian elm and the dark brown is Little leaf poplar

Figure 3-13 Meyer's spruce and Siberian elm enriched forest (Photo: SYJFF)

3.2.4 Summary

The restoring degraded forests of Little leaf poplar were a very important and complicated task, because the difference of number of dead trees and growth status of living trees in different area was great. First, it was necessary to investigate the actual growth status of the original tree species in different areas. Then selected suitable afforestation model according to local conditions. In our project, we planted coniferous (Chinese pine, Mongolian scots pine, Meyer's spruce) and broad-leaved trees (Yellowhorn, Chinese wild peach, Siberian elm) between trees, rows and belts in old Little leaf poplar forest, These afforestation models improved the health of the forest while kept most original vegetation. These models improved also the windbreak and sand-fixing capabilities of the forest, increased the stability of the ecosystem, and provided a good ecological environment for the local people.

3.3 Management for Improving Yields of Orchards

The area of existing Siberian apricot and Yellowhorn orchards in local sandy land was extensive. However, most of them yielded low economic benefits due to inadequate management. The project aimed to introduce a series of techniques to improve their fruit yield and thus increased the incomes of local people. The Siberian apricot and Yellowhorn already planted for many years. We had managed the Siberian apricot orchards in Phase I and the Yellowhorn orchards in Phase II for higher yield, respectively.

3.3.1 High-Yield Management of Siberian Apricot Orchards

In Aohan Banner, the Siberian apricot orchard grew slowly and had low fruit yield, thus requiring the introduction of high-yield management measures. All branches, except for the main stems, were pruned. In May of the first three years, all new sprouts were removed. By removing branches and new sprouts the tree can focus its energy on the main stems and grafted cultivar to produce more fruit there. In May of the second year, the “Dabian” cultivar of Prunus (with higher fruit yield and better taste seed) was grafted onto the existing apricot trees using the cleft grafting technique. Typically, the grafting depth was 2-3 cm, and the grafting joint was wrapped tightly with a grafting tape to ensure a tight seal.

Figure 3-14 Pruning of Siberian apricot (Photo: SYJFF)

Under each tree, a 1.5×1.5 m square pit was dug. The trees were watered twice, first time in May of the first year, the 2nd time in March of the second year. They also were weeded one time in June every year of the first to the third year, in a radius of 1.5 m around each tree. The apricot trees were also fertilized with NPK and trace elements required for the growth and fruiting of tree.

Figure 3-15 Watering of the Siberian apricot orchard (Photo: SYJFF)

Figure 3-16 Fruit harvest in the Siberian apricot orchard (Photo: SYJFF)

3.3.2 High-Yield Management of Yellowhorn Orchards

Yellowhorn is a small native tree known for its edible oil seeds, which has important economic values, not only for culinary uses such as cooking, but also industrial uses, such as Biodiesel.

However, the tree growth at project site was previously slow and had low fruit production as no specialized management measures were introduced.

Figure 3-17 Pruning of the Yellowhorn orchard (Photo: SYJFF)

To balance fruiting and growth, and increase fruit yields, the tree branches were pruned in the first winter. Pruning in winter, when the tree was dormant, minimized stress on the tree and reduced the risk of disease infection. It also prepared the tree for vigorous growth in the spring. The cut branch notch must be smooth, and the larger wounds must be treated immediately with a protective sealant to prevent bacterial infection and help the healing process. Three to four main branches were preserved, in relation to each other fairly spreaded out to encourage high fruit production. The tree height was controlled to be around 60 cm for easy fruit picking. Dense, dead, cross, and parallel branches were cut off so that the tree crown was better ventilated and received more light. Gradually, each tree was cut to a hemispherical shape. Additionally, naphthalene acetic acid, a plant hormone, was sprayed during the blooming period to improve the fruiting rate. Maintenance measures were the same as for Siberian apricot (Ch. 3.3.1).

3.3.3 Summary

Pruning can help fruit trees form a more fruit-bearing shape; Grafting can improve the original fruit tree varieties and obtain higher yield and quality. Expanding the tree pits, watering, fertilizing can provide sufficient water and nutrients for fruit trees, promote the growth of trees and the formation of flower buds. After the high-yield management of project, the average fruit and seed production of Siberian apricot and Yellowhorn increased 18% and 25%, the seed price of the "Dabian" cultivar of Prunus was higher than original Siberian apricot.

3.4 Multifunctional, High-Density Nursery Forests

Some tree species are very popular in the local market, but need to be large enough, which are more adapted to the local environment. For this reason, the new concept of the multifunctional high-density nursery forest was invented in the project. Here, the seedlings were initially planted in 4 times the normal density and grow in real outdoor conditions. Then, within 3 years, ¾ of them would be excavated. This was possible within the first 3 years as the trees were very young and their root systems were still small, so excavation had a comparatively small effect. The remaining trees stayed on site to form forest. This was an activity of Phase II and had been tried with Sugar maple, Yellowhorn, Mongolian scots pine and Meyer's spruce.

3.4.1 Multifunctional, High-Density Sugar Maple Nursery Forest

Sugar maple is very popular in the local market due to its golden leaves in autumn. In the project, Sugar maple was planted with a spacing of 2×2 m. The final plant spacing in the nursery forest would be 4×4 m after three years.

Figure 3-18 Multifunctional, high-density Sugar maple nursery forest (Photo: SYJFF)

Soil preparation was the same as in Ch. 3.1.1. The seedlings of Sugar maple were more than 4 years old with a height of at least 1.5 m and a diameter at breast height at least 2 cm. The roots of transported Sugar maple seedlings were dipped into a powder for promoting rooting. The seedlings were planted in 40×40×40 cm pits as soon as possible according to Planting Process 2. The seedlings were watered seven times in the first year, the first 2 times during planting planting and on the 15th day after planting in April, the 3rd-6th times from May to September, and the seventh time in November. The needed amount of water every time was 30 L. Other post-afforestation maintenance measures were the same as in Chapter 3.1.1.

3.4.2 Multi-Functional, High-Density Yellowhorn Nursery Forest

The Yellowhorn was planted in a similar fashion to Sugar maple, however the spacing was denser because the Yellowhorn was smaller than Sugar maple, with a distance of only 1×1 m among the seedlings. The final plant spacing would be 2×2 m after three years.

Soil preparation was the same as in Ch. 3.1.1. The seedlings of Yellowhorn were 1 years old with a height of at least 1.2 m and a basal diameter of at least 1 cm. The roots of transported Sugar maple seedlings were dipped into a powder for promoting rooting. The seedlings were planted in 30×30×30 cm pits as soon as possible according to Planting Process 2. The seedlings were watered seven times in the first year, the first 2 times during planting planting and on the 15th day after planting in April, the 3rd-6th times from May to September, and the seventh time in November. The watering amount of each pit every time was 30 L. The post-afforestation maintenance measures were the same as in Chapter 3.4.1.

Figure 3-19 Multi-functional, high-density Yellowhorn nursery forest (Photo: SYJFF)

3.4.3 Multi-Functional, High-Density Mongolian Scots pine Nursery Forest

Soil preparation of Mongolian scots pine was the same as in Ch. 3.1.1. The seedlings of Mongolian scots pine were more than 8 years old with a height of at least 2.5 m and a basal diameter of at least 3 cm. Mongolian scots pine was planted in 60×60×60 cm pit according to

Planting Process 1. The seedlings was watered seven times in the first year, the first 2 times during planting planting and on the 15th day after planting in April, the 3rd-6th times from May to September, and the seventh time in November. The watering amount of each pit every time was 50 l. Mongolian scots pine was planted with a distance of 2×2 m. The post - afforestation maintenance was the same as in Chapter 3.4.1. The final plant spacing would be 4×4 m after three years.

Figure 3-20 Multi-functional, high-density Mongolian scots pine nursery forest (Photo: SYJFF)

3.4.4 Multi-Functional, High-Density Meyer's Spruce Nursery Forest

Soil preparation of Meyer's spruce was the same as in Ch. 3.1.1. The seedlings of Meyer's spruce were more than 5 years old with a height of at least 0.8 m. Mongolian scots pine was planted in 60×60×60 cm pit according to Planting Process 1. The seedlings were watered seven times in the first year, the first 2 times during planting planting and on the 15th day after planting in April, the 3rd-6th times from May to September, and the seventh time in November. The watering amount of each pit every time 50 l. Meyer's spruce was planted with a distance of 1.5×1.5 m. The post - afforestation maintenance was the same as in Chapter 3.4.1. The final plant spacing would be 3×3 m after three years.

3.4.5 Summary

Sugar maple is an excellent ornamental tree species with golden autumn leaves. Yellowhorn is loved by locals for its beautiful flowers, seed oil and many other uses. Mongolian scots pine and Meyer's spruce are evergreen tree species commonly used in local greening. All of them are very popular in the local tree seedling markets. According to the market tree seedling price, planting multifunctional, high-density nursery Forests, local people can increase income by $400-900 per ha.

Figure 3-21 Multi-functional, high-density Meyer's spruce nursery forest (Photo: SYJFF)

3.5 Ornamental Forest Restoration

In Phase II of the project, the reclaimed sandy zones were strategically transformed into vibrant landscapes by introducing a curated selection of trees. These included species renowned for their resilience to desertification and others chosen for their ornamental values—especially when it came to vibrant color displays in leaf. The vision was to create an ornamental forest that served multiple functions: it standed as a testament to ecological restoration efforts, it significantly uplifted the aesthetic fabric of the area, and it acted as an attraction point in the context of eco-tourism. This multifaceted forest not only contributed to environmental stability and biodiversity but also fostered a connection between people and nature, inviting visitors to experience the harmony of conservation and beauty.

3.5.1 Ornamental Forest Restoration for Colorful Landscapes

The different ornamental trees were planted in a shelterbelt grid. In the inner blocks deciduous trees like Winterberry euonymus, Flowering plum, Shandong maple were planted (one species per block) (Figure 3-22), while for the belts themselves Mongolian scots pine and Chinese pine were selected. The seedling spacing of Mongolian scots pine, Chinese pine, Winterberry euonymus, Flowering plum and Shandong maple was 3.5 × 3.5 m. Soil preparation was the same as in Ch.

3.1.1. The seedlings of all trees had to be over 5 years old. Mongolian scots and Chinese pine seedlings had to reach a height of at least 1.5 m, while the broad leaf trees had to be at least 1.8 meters tall, with a DBH of at least 4 cm. All trees were planted in 40×40×40 cm pits, the conifers based on Planting Process 1, the broadleaves based on Planting Process 2 (including the use of rooting powder). Maintenance was the same as described in Chapter 3.1.1.

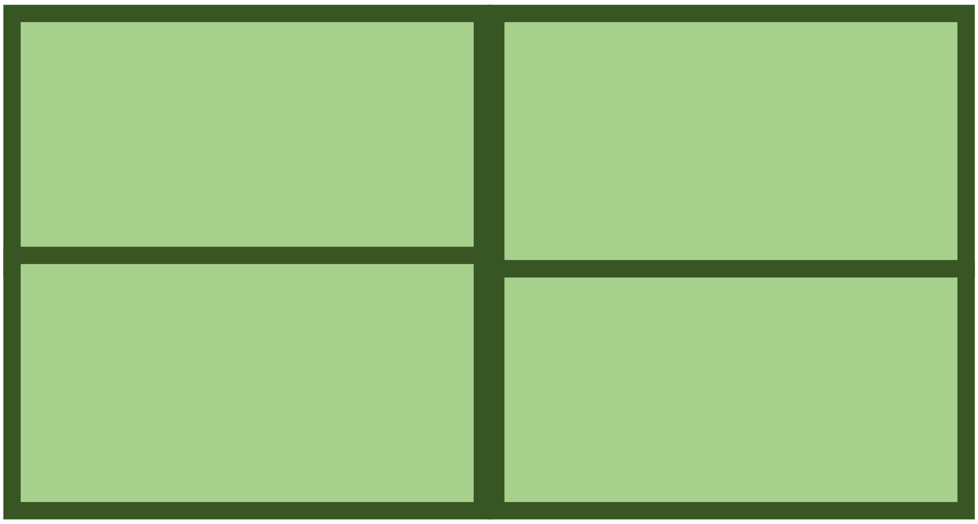

Figure 3-22 Planting design, with the dark green shelterbelt planted with Mongolian scots pine or Chinese pine and the light green blocks planted Winterberry euonymus, Flowering plum and Shandong maple

Figure 3-23 Ornamental forest of Mongolian scots pine, Chinese pine, Winterberry euonymus, Flowering plum and Shandong maple (Photo: SYJFF)

3.5.2 Roadside Landscaping Strip Restoration

The most important consideration for the selection of tree species on the sides of roads in desertified areas was their ability to reduce sand erosion that could otherwise impact road accessibility. In addition, by choosing colorful and aesthetically pleasing tree species a more beautiful landscape view can be created.

Figure 3-24 Roadside landscaping strips and a fixed sand dune in the background (Photo: SYJFF)

Mongolian scots pine and Goldleaf Siberian elm seedlings were planted next to roads where the sandy land was still semi-mobile. All of them were planted in 80×80×80 cm bio-degradable non-woven containers. The ratio of Goldleaf Siberian elm to Mongolian scots pine is 2:1, which meaned there are two rows of Goldleaf Siberian elm planted directly adjacent to the road and one row of Mongolian scots pine was planted outside facing the outer landscape and serving as a shelterbelt against wind as it retained its foliage all year round (Figure 3-24).

3.6 Construction of the Sandy Land Arboretum

The Sandy Land Arboretum, spanning 10 hectares of stabilized sandy land, was home to about 40 plant species, including 24 types of trees and 16 varieties of shrubs, which had been carefully selected for their roles in combating desertification, ability to support restoration efforts, and enhancing the landscape's beauty.

The arboretum was divided into six distinct zones: (1) trees dedicated to desertification control, which was a key component of tree use in Aohan Banner; (2) ornamental trees, showcasing that restoration and creating beautiful landscapes do not have to be mutually exclusive; (3) evergreen trees, providing year-round green cover and habitat stability; (4) a poplar tree area, continuing the longstanding tradition of using these robust trees for sand fixation in the area; (5) shrubs chosen for their effectiveness in desertification control, playing a critical part in soil conservation; and (6) ornamental shrubs, adding variety and visual appeal (Table 3-2).

The grander vision for establishing the Sandy Land Arboretum went beyond its immediate visual or ecological contributions. It served as a vital genetic reservoir, safeguarding the diversity of local species that were adapted to the harsh conditions of sandy lands. It was a living laboratory for environmental education, where students, researchers, and visitors can learn about the delicate interplay between flora and the arid ecosystem. Moreover, it was a testament to sustainable land management practices, demonstrating how once desertified areas can be restored and transformed into thriving ecosystems.

Table 3-2 Main species and areas of the Sandy Land Arboretum

Type	Area	species
Trees	Desertification control	*Xanthoceras sorbifolia, Acer mono, Acer truncatum, Elaeagnus angustifolia, Tamarix chinensis, Ulmus pumila, Salix matsudana*
	Ornamental	*Armeniaca sibirica, Euonymus alatus, Malus baccata*
	Evergreen	*Pinus tabuliformis, Pinus sylvestris var. mongolica, Picea wilsonii, Platycladus orientalis*
	Poplar	*Populus xiaozuanica cv. 'Chifengensis', Populus alba var. pyramidalis, Populus berolinensis, Populus pseudo-simonii*
Shrubs	Desertification control	*Caragana microphylla, Caragana korshinskii, Hedysarum laeve, Amorpha fruticosa, Lycium barbarum, Prunus armeniaca, Salix gordejevii, Salix cheilophila, Hippophae rhamnoides*
	Ornamental	*Ligustrum obtusefolum, Forsythia suspens, Swida alba, Rosa davurica, Amygdalus triloba, Syringa oblata, Sabina vulgaris*

Figure 3-25 Sandy Land Arboretum (Photo: SYJFF)

3.7 Environmental Education

To further share knowledge and experiences in combating desertification, the Desertification Control Exhibition Hall was built via pictures, audio and video. The shown contents of exhibition hall mainly includes: (1) Background: In the 1950s and 1960s, wind erosion and desertification were severe in the northern part of Aohan Banner. Farmland, roads, and villages were buried by flowing sand. The desertification area of the Aohan Banner was 6,300 km^2, accounting for 76% of the total land area; (2) The development history of Sanyijing Forest Farm, and its fruits and experience on desertification control; (3) Desertification combating heroes, such as Sun Jiali, Ma Haichao, Zhang Fu, Li Ru, and their touching stories how to control desertification.

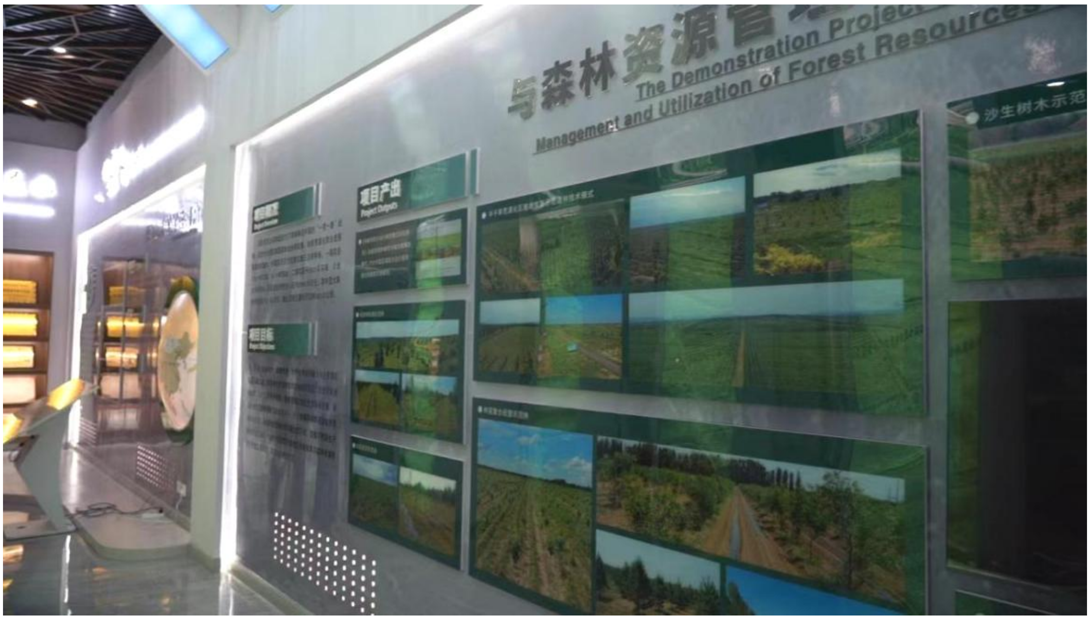

Figure 3-26 Desertification Control Exhibition Hall (Photo: SYJFF)

Figure 3-27 Visited of the Desertification Control Exhibition Hall (Photo: SYJFF)

(4) Techniques of their desertification control: researched and developed the JKL-50 furrow plow; the series afforestation techniques on drought resistance; the shelter-belt system for degraded grassland; the afforestation techniques of coniferous container seedlings; the high-yield techniques of Siberian apricots control techniques of *Didesmococcus koreanus*; dryland afforestation techniques with Poplar; close-to-nature mixed afforestation techniques, compound sand barrier techniques; shrub sustainable management techniques of *Hedysarum fruticosum*; (5) Introduction to APFNet and the Demonstration Project of Vegetation Restoration and Forest Resource Management and Utilization in the Greater Central Asian Region.; (6) International cooperation projects of SYJFF for desertification control and afforestation projects with Germany; Italy and Japan; (7) Conclusion. By 2023, approximately 800 visitors had visited the Desertification Control Exhibition Hall.

04 Conclusion

4.1 Key Achievements

Supported by the APFNet and the Chifeng Forest and Grassland Administration of Inner Mongolia, as well as executed by Sanyijing Forest Farm, a number of things had been achieved by the project:

(1) Established novel demonstration models for the restoration of desertified areas to enhance the multi-functional benefits of forests in sandy lands in semi-arid areas. Specifically, this included:

- Several full afforestation models, that, previously virtually unheard of in the area, established mixed forests instead of monocultures:
  - ✓ Mongolian scots pine - Xinjiang's poplar mixed forest
  - ✓ Mongolian scots pine - Yellowhorn mixed forest
  - ✓ Mongolian scots pine - Siberian elm mixed forest were showcased.
- Restored degraded poplar forests by introducing several next-generation species via enrichment planting, resulting in:
  - ✓ Chinese pine - Yellowhorn enriched forest
  - ✓ Mongolian scots pine - Chinese wild peach enriched forest
  - ✓ Myer's spruce - Siberian elm enriched forest
- Established combined restoration-nursery multifunctional forests, to achieve ecological restoration while earning income, a novel that had never been done before:
  - ✓ Multi-functional, high-density Sugar maple nursery forest
  - ✓ Multi-functional, high-density Yellowhorn nursery forest
  - ✓ Multi-functional, high-density Mongolian scots pine nursery forest
  - ✓ Multi-functional, high-density Meyer's spruce nursery forest

- Restored and beautified the otherwise often barren-looking landscape in a variety of ways:
  - ✓ Established an ornamental forest with Mongolian scots pine, Chinese pine, Winterberry euonymus, Flowering plum and Shandong maple species
  - ✓ Carried out roadside beautification that also fixed sand and served as a shelterbelt using Mongolian scots pine and Goldleaf Siberian elm

(2) Improved existing orchards to achieve a higher yield by introducing advanced horticultural techniques, such as grafting and providing better cultivars to use as grafting materials, specifically in:

- Siberian apricot orchard
- Yellowhorn orchard

(3) Built an showcasing of trees and shrubs that can survived in desertified land and be used, amongst other purposes fine restoration efforts.

(4) Engaged in communication efforts to increase the reach of the project:

- Built the Desertification Control Exhibition Hall to show the main achievements of this project and achievements in Chifeng to the wider public
- Set up more than 10 permanent publicity boards in the project area
- Published project materials on
  - ✓ the Aohan Banner government website
  - ✓ the Chifeng Forestry website
  - ✓ the Inner Mongolia Autonomous Region Forestry website
  - ✓ the Hongshan Evening News newspaper (China)
  - ✓ the Chifeng Daily newspaper
  - ✓ the China Green Times magazine
- Edited and issued two Chinese and English brochures, titled:
  - ✓ Typical Models of Desertification Prevention and Control in Chifeng City
  - ✓ Vegetation Restoration and Forest Resource Management in Greater Central Asia
- Produced 3 promotional videos of the project

(5) Trained over 1,000 professionals (measured in person-times). in desertification control, vegetation restoration, afforestation techniques, maintenance, pest control, and relevant standards, regulations, policies, and laws through indoor workshops and field training sessions.

4.2 Ecological, Social and Economic Benefits

The Auhan Banner project supported by APFNet had improved the local ecological environment.

Monitoring results had shown that the implementation of the project had had a significant impact on ecological service functions of sandy land in project sites. According to the monitoring results of Mongolian scots pine and Xinjiang's Poplar mixed forest, and Mongolian scots pine and Yellowhorn mixed forest in 2022-2023, after afforestation, compared with unafforested land, (1) the perennial plant species increased with the annual plant species decreased, and the species of Chenopodiaceae and Gramineae decreased with the species of Leguminosae, Asteraceae and Convolvulaceae increased; (2) the vegetation carbon storage of these forests increased by 807% (27.69 tCO_2/ha), and the 0-60cm soil carbon storage increased by 126% (2.16tCO_2/ha). The soil of these forests increased by 111% (3.86g/kg) in organic matter, 62% in total nitrogen (0.14g/kg); (3) the soil bulk density decreased by 8% (0.14g/cm^3), and the porosity and capillary porosity increased by 24% and 26% respectively, and the maximum water holding capacity and water storage capacity increased by 38% (0.08t/ha) and 33% (11.79t/ha) respectively; (4) the soil sediment contents reduced by 34% (2.33t/ha), and the soil wind erosion depth reduced by 64% (1.66 cm). According to the monitoring results of Siberian apricot orchards, after high-yield Management, (1) orchards increased soil organic matter by 25% (1.86g/kg), total potassium by 21% (2.81g/kg), and alkali hydrolyzable nitrogen by 20%. (5.87mg/kg), available phosphorus 54% (0.86mg/kg), available potassium 37% (15.95mg/kg). (2) the soil bulk density reduced by 3% (0.05g/cm^3).

Figure 4-1 Project training of the managers and workers (Photo: SYJFF)

The forest construction of roadside landscaping strip restoration improved road traffic conditions, beautified environment, and reduced and avoided the occurrence of wind-erosion and sand-buried of roads. The sandy forest landscape attracted surrounding tourists to visit, increased local income and promoted the development of related tourism industries. For example, by 2023, the project areas had hosted at least 1,000 people from the Inner Mongolia Aohan manager training College, the only manager training college in Inner Mongolia taking ecological education as its main task, and approximately 800 visitors had visited the Desertification Control Exhibition Hall.

After the high-yield management, the average fruit and seed production of Siberian apricot and Yellowhorn increased 18% and 25%, the price of the “Dabian” cultivar of Prunus was higher than original Siberian apricot. The excavated young trees in the multifunctional high-density nursery forest will be sold and can possibly increase income by $400-900 per ha according to the current market price.

4.3 The Impact and Demonstration Role of Project Implementation on Desertification Control in North-western China and GCA

General Secretary Xi Jinping always pays great importance to the ecological protection and construction of Inner Mongolia. On January 26, 2014, under temperature lower than -30 degrees, he visited the forest of Ershi Town, Aershan City, Xing'an League. On July 15, 2019, he came to Ma'anshan Forest Farm, Haraqin Banner, Chifeng city. Xi Jinping said that building ecological security barriers of the capital and the north of China had strategic significance and we must do from generation to generation.

The project models supported by APFNet in Auhan Banner for desertification control via forest restoration as well as some models for improving existing orchards in Sanyijing, provide a number of key tree species and techniques that can be used for building a multifunctional forests in sandy land in Inner Mongolia, even in north-western of China. These models also can be benefit to the economies and regions of GCA through replicating the successful experiences and technologies.

4.4 Future Outlook

On June 6, 2023, General Secretary Xi Jinping said that we would use about 10 years to build a multifunctional and stable Great Green Wall and ecological security barrier in Three Norths in a symposium in Inner Mongolia on strengthening the comprehensive prevention and control of desertification and promoting the construction of key ecological projects, such as the Three Norths, in which region, the more than 90% sand area of the Horqin and Hunshandake sand lands in Inner Mongolia as main regions of the "Three Norths" project.

Through the implementation of the Phase I and Phase II of the project supported by APFNet in Auhan Banner, Chifeng city, Inner Mongolia, the models of vegetation restoration and forest resource management and utilization have played a significant role in the sustainable development of local forest resources, the improvement of local ecological conditions and the quality of forests quality, as well as an income increase of local people. Now, Sanyijing Forest Farm has established infrastructure in the project area, including gravel road, power and water supply, and telecommunication equipment. However, there still many problems to be solved. In the future, with further support from APFNet and the Chifeng Forest and Grassland Administration of Inner Mongolia, Sanyijing Forest Farm will rely on Aohan Banner's unique natural and cultures and the world ecological honor of Global 500 Roll, adopt the measures of integral planning, construction and operation, build a large and comprehensive sandy land garden to achieving comprehensive improvement of local ecological, economic and social benefits. These further works can be used in the comprehensive prevention and control of desertification of the Horqin and Hunshandake sand lands in Inner Mongolia, and provide technological support for building a multifunctional and stable Great Green Wall and ecological security barrier that was said by Xi Jinping, General Secretary of China.

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