# Integrated Forest Management for Miyun Reservoir Watershed

Beijing Forestry Society

Since 1955

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# 1. Overview of Miyun Reservoir Watershed

The Miyun Reservoir, located in the north of Beijing's Miyun District, was built in the 1960s, with a design capacity of 4.37 billion $m^3$. The Reservoir receives water from the Chao River and the Bai River. It has a total watershed area of 15,788 $km^2$, 2/3 of which spreads in the counties of Guyuan, Chifeng, Chongli, Huailai, Xuanhua, Fengning, Luanping, Xinglong and Chengde, within Chengde City and Zhangjiakou City of Hebei Province. The remaining 1/3 is located in the districts of Miyun, Yanqing and Huairou of the Beijing Municipality.

Figure. 1-1 Miyun Reservoir

## 1.1 Natural Conditions

### 1.1.1 Topography, Rock and Soil

The Miyun Reservoir Watershed, located in Northern Beijing and Hebei Province's Zhangjiakou and Chengde areas, is within the region where the Yanshan Mountains and the North China Plain meet. Mountainous areas account for over 80% of the Watershed area. The Watershed is Beijing's important water source and ecological conservation area. In the mountainous areas, main rock types include granite, limestone, sandstone, conglomerate, feldspatite, and quartzite, etc. Through the long course of history, those rocks have developed into loose pieces of gravel and particle, forming residual soil, deluvium and sediment.

Due to the scattered topography and complicated rock types, in the Watershed area, there is great variability in soil type, soil depth and distribution. Main soil types include leached cinnamon soil, mountain cinnamon soil and mountain brown soil, etc. After the Miyun Reservoir was built, the water level in downstream areas significantly decreased and moisture soil gradually changed into cinnamon soil. In the Watershed, soil fertility is low. In the mountainous areas, the soil depth is around 20-60 cm, and in the soil there is a high proportion of gravel and the bottom part is mainly a gravel layer or mother rock.

### 1.1.2 Climate

The Miyun Reservoir Watershed is within the semi-humid and semi-arid temperate continental monsoon climate zone, with a dry and cold winter, a hot and rainy summer, and a warm and

moderate spring and autumn. The annual precipitation is around 400-630 mm, most of which occurs from July to September accounting for 70% of the total. Northwest wind prevails in winter.

### 1.1.3 Vegetation

Vegetation in the Miyun Reservoir Watershed is called temperate deciduous broad-leaved forest, or summer green forest. Type, distribution and growth of vegetation are closely related to elevation, slope and soil, and are influenced by human activities.

In the hilly areas with an elevation of less than 800 meters, type and distribution of plants are mainly influenced by slope. In mountainous areas with an elevation of more than 800 meters, vegetation is less influenced by human activities.

For decades, there has been large-scale afforestation initiatives in the Watershed. Nowadays, massive plantations of various forest types have formed, which are mixed with natural vegetation, laying a good foundation for close-to-nature plant community.

## 1.2 Beijing's Water Resources & Miyun Reservoir Watershed

### 1.2.1 Beijing's Most Important Water Source

#### Water Shortage in Beijing

The North China area, where Beijing is located, faces shortage and unevenness of precipitation. The record high of annual precipitation was 1,406 mm (in 1959) and the record low was only 242 mm (in 1869). Beijing is a megacity with sever water shortage, with an per capita available water of only 300$m^3$, about 1/8 of the national average and 1/30 of the world average, far below the limit of internationally recognized per capita of 1000$m^3$. With population expansion and socio-economic development, there is an increasing demand for water resources, and water shortage and water security have gained more attention.

According to analysis, for the year 2020, if the precipitation is around the average, Beijing's available water is 4.038 billion $m^3$ and the water demand is around 6.469 billion $m^3$, so there is a shortage of 2.376 billion $m^3$; if this year is a dry year, the available water for Beijing is 3.379 billion $m^3$ and the water demand is still around 6.469 billion $m^3$, so there is a shortage of 3.09 billion $m^3$. From the above analysis, we can see the water crisis in Beijing.

## Decrease of Water Supply from Two Main Reservoirs

The Miyun and Guanting Reservoirs provide 90% of Beijing's surface water, with an average annual supply of 1 billion $m^3$. Around 80% of Beijing's drinking water is from the Miyun Reservoir (before the North-south Water Diversion Project). Due to issues such as increase of water use in upstream areas and recent droughts, there has been gradual decrease of water inflow to the two reservoirs. In the middle of the $20^{th}$ century, the annual inflow to the two reservoirs was once up to over 3 billion $m^3$, which however decreased sharply to only 1.2 billion $m^3$. Specifically, the annual inflow to the Guanting Reservoir decreased from 1.9 billion $m^3$ in the 1950s to 0.4 billion $m^3$ in the 1990s. The annual inflow to the Miyun Reservoir Watershed decreased from 1.2 billion $m^3$ in the 1950s to 0.8 billion $m^3$ in the 1990s. In the extremely dry year of 1999, the inflow to the Miyun Reservoir was only 0.08 billion m3. Due to various reasons, the trend of decrease in the water flow for the two reservoirs is irreversible.

## Groundwater Overdraft

Beijing is a city which heavily depends on groundwater. Around two thirds of total water supply of the city is from groundwater. As there is insufficient surface water, groundwater has been over used for a long time. In recent years, annual water pumped from underground is around 2.6-2.7 billion $m^3$, with an annual overdraft of 0.1 billion $m^3$. Overuse of groundwater has also caused geological and environmental problems. Beijing's ground water level has declined year by year and a lot of springs have also dried up. Compared with 1960s, there is a decrease of ground water storage of 5.8 billion $m^3$ in Beijing's plain area. Meanwhile, overdraft of groundwater caused seepage pits and polluted water may infiltrate into the ground water. There has been an increase of mineral components in the groundwater, causing water quality problems.

## Water Pollution

According to surveys, Beijing's total discharge of wastewater was around 1.01 billion tons. Specially, there was 0.882 billion tons from households and 0.128 billion tons from industry. Water quality of lakes and rivers in the city also shows signs of decline, and eutrophication has been worse. Although water quality of source water for drinking from the Miyun Reservoir has been fine and suitable for drinking, the water quality of the Guanting Reservoir has been not satisfactory with too much TN and TP. Since the year 1997, the Guanting Reservoir has not been used as source for drinking water. Eutrophication has also been a problem in the Miyun Reservoir Watershed in recent years.

### Miyun Reservoir's Role with South-North Water Diversion

As Beijing is not able to solve the problem of water shortage, China initiated the South-North

Water Diversion Program. However, this initiative cannot meet Beijing's water demand in short time, and in dry years, the role of the Miyun Reservoir in water supply will still be significant. Water quality of the Danjiangkou Reservoir, which is the source of the South-North Water Diversion, is relatively satisfactory, and meets the national Ⅱ standard for surface water. Nevertheless, there are still concerns that there may be risks of water pollution in certain periods. Also, the water tariff for household water use may also increase after the North-South Water Diversion Program. Overall, in terms of water quality and quality as well as water tariff, the Miyun Reservoir will still play a unique role for Beijing.

## 1.2.2 Water Protection Forests

### Ecological Problems in Miyun Reservoir Watershed

The Miyun Reservoir is the most important water source for the city of Beijing, proving water for production and household use. It is also significant in drought and flood periods, thus holds an important role in Beijing's sustainable development. Extending lifespan of the Reservoir, sustaining its water quantity and water quality, is a priority in safeguarding Beijing's water security. However, in reality, there are multiple ecological problems or risks, including conventional challenges such as water and soil erosion, sedimentation and mud-rock flow, and new challenges such as droughts and decreased inflow brought about by climate change. There is also pollution from industry, households and agriculture, and eutrophication due to economic activities.

As rainfall in this area mainly occurs in summer and slopes are usually steep (area with slope large than 35°accounts for 16.7%; area with slope between 25-35°accounts for 44.2%, and area with slope between 15-25°is 19.9%), continuous rainfall may cause landslide, mud-rock flow and torrential flood, which are the major natural disasters in this area. In the Watershed, content of nitrogen and phosphorus from household and industrial wastewater discharge and farmland runoff has been gradually increasing, leading to decline of water quality to national III level in certain areas and in certain periods. All those ecological problems are connected to water protection forests to various degrees.

#### Multiple Ecological Functions of Water Protection Forests

The relationship between water protection forests and the Miyun Reservoir Watershed's water quality and quantity is believed to be very complicated. Over the years, researchers have conducted massive research and their findings show that forest vegetation plays a role in water or watershed conservation through multiple hydrological processes. Forest crown can retain (around 20%±7%) rainfall, which reduces rainfall erosion and soil erosion; interaction of raindrops

and forest crown also change chemical composition of rainfall. Ground cover is also important for water conservation, retaining rainfall and reducing the speed of surface runoff. It can also protect soil and filter sentiment. In general, a ground cover of over 60% can guarantee that there is no significant soil erosion.

The forest soil layer is the main part in forests' hydrological processes. Forests can increase soil's porosity and infiltration, and change runoff generation and proportion of runoff components, reducing surface runoff and increasing soil water storage. This increases interflow and groundwater flow, reduce flood peak and increase flow in dry periods. Forest ecosystems can also significantly improve water quality, through filtration, absorption and exchange. Therefore, restoring and increasing forest vegetation is essential for safeguarding the Miyun Reservoir's water supply function.

**More Forests Needed for Miyun Reservoir Watershed**

In dry areas with serious water shortage, the general belief is that increasing forest vegetation will mean more evapotranspiration leading to more water consumption and less watershed water yield, which has been much discussed domestically and worldwide. However, research on the case of the Miyun Reservoir Watershed shows that, the economic benefits of forests' water purifying capacity is far more than the economic loss of water consumption from forest evapotranspiration. Therefore, forests consuming water should not be an excuse to go against increasing and restoring forest vegetation.

# 1.3 Miyun Reservoir Watershed Problem Analysis

## 1.3.1 Water Quantity

The Chao and Bai Rivers, and 11 rivers and 1,606 streams in Beijing are the main water source for the Miyun Reservoir (and the Huairou Reservoir). Statistics show that overall inflow of the Miyun Reservoir reduced sharply in the 1980s, with an annual average of 0.6 billion $m^3$, only half of that of 1960s and 1970s, the reasons behind which include reduce of precipitation and retaining of water for use in the upstream areas.

In early 1980s, in the catchment of the Miyun Reservoir (especially in Hebei Province), industrial and agricultural production expanded, and their demand for surface and ground water increased rapidly. Between 1978 and 1986, within the catchment in Hebei Province, 49 small and medium-scale reservoirs, and many large wells and ditches were built. As around 66% of the catchment area of the Reservoir is in Hebei Province, in normal years, available water from Hebei to the

Reservoir is relatively little.

Inflow to the Miyun Reservoir is mainly from the catchment area in Beijing (around 4,500 $km^2$ ). The annual total average precipitation of this area is around 2.8 billion $m^3$. The total annual inflow to the Miyun Reservoir is estimated at around 1.09 billion $m^3$, and an average of 0.9 billion $m^3$ is from areas within Beijing. In 1980s, as total precipitation in Beijing was also very low, annual inflow from Beijing to the Reservoir was around 0.55 billion $m^3$, accounting for 92% of the total annual inflow (0.6 billion $m^3$) to the Reservoir.

Overall, to safeguard Beijing's water security, it is essential to increase and protect forest resources and build relevant water resource facilities, to make good use of precipitation; to improve waste water treatment and recycling; to mobilize the public to save water resources. In the long run, to solve the problem of water shortage, the South-North Water Diversion Program is also necessary.

## 1.3.2 Water Quality

Water quality of the Miyun Reservoir shows signs of decline. The Beijing part of the Miyun Reservoir Watershed covers three districts and 30 townships. The Reservoir's 1st Level Protection Area and 2nd Level Protection Area are all within Beijing's Miyun District, and the 3rd Level Protection Area is within Beijing.

The 1st Level Protection Area directly surrounds the Reservoir and covers an area of 14,000 $hm^2$; the 2nd Level Protection Area covers an area of 40,000 $hm^2$, and this area has high population density and complicated human activities. This area has the most influence for the Reservoir's water quality and thus holds much more importance for watershed conservation. It is the main area of water pollution and is the priority area for integrated watershed management. In the catchment in Beijing, most of the villages and rural residents are within the 1st and 2nd Level Protection Areas. Local residents' production activities and daily life are closely connected with water quality and quantity of the Miyun Reservoir. Around 95% of the source of pollution is within those two areas.

The 3rd Level Protection Area is the main source of water (85% of total precipitation within the catchment in Beijing) in Beijing for the Reservoir. This area is the main target for forestry development in Beijing. The Natural Forest Protection Initiative is also carried out within this area.

### 1.3.3 Source of Pollution

Main source of pollution includes point source pollution and non-point source pollution. With economic development, there had been more factories in the catchment of the Reservoir. Since 1970s, measures have been taken to close, merge or convert some factories with high pollution. Non-point source pollution is mainly resulted from use of chemicals and pesticides in farmland and fruit orchards.

Population density in the catchment is relatively high and the population is still increasing. Some local areas are also developing tourism. Human activities are producing various wastes. In some villages, household waste water and daily garbage are discharged or dumped directly into or near water courses without any treatment, which will be washed away into the rivers during the flood season, causing water quality problems. This is even worse in Hebei Province's Chicheng and Luanping Counties.

The mining industry is another non-point source pollution causing loss of vegetation and water and soil erosion. To protect water source for the Miyun Reservoir, Beijing has closed the mining industry but mining is still in operation in some areas in Hebei Province.

# 2. Forest Resources in Miyun Reservoir Watershed

## 2.1 Forests within Beijing

The Miyun Reservoir Watershed's Beijing portion covers Miyun District, Huairou District and Yanqing District. Forest vegetation in those three districts are mainly plantations from 1960s to 1980s. Those plantations are basically ecological non-commercial forests, and most of which are further categorized as water protection forests or soil conservation forests. They are mainly located near the Reservoir and along the Chao River, the Bai River, their tributaries and catchments. The forests are playing important roles in water conservation, soil conservation, wind prevention and sand fixation, air purification and other ecological functions as well as recreation and other cultural functions.

However, due to historic reasons and natural restrictions, plantations in Beijing are dominated by middle and young-aged forests which accounts for 80% of the total forest areas. Most of the plantations (especially, conifer forests) are monoculture. In particular, *Platycladus orientalis* and *Pinus tabuliformis* forests account for a large proportion of the conifer forests. Forests consisting of only one tree species and simple stand structure may lead to slow growth, low efficiency in soil nutrient cycling, and forest stands are less steady and have low biodiversity. Those forests have low capacity for water and soil conservation.

The main tree species used in the Watershed in Beijing for plantations are mainly *Platycladus orientalis*, *Larix principis-rupprechtii*, *Pinus tabuliformis*, and other conifer species. Over the years, there has been lack of tending and thinning and other management measures on middle and young-aged forests, therefore, forest stands have very high density and low growth, and most of them are not of multiple structure. Forest fire, pests, diseases and other risks are very high.

## 2.2 Forests within Hebei Province

The Miyun Reservoir Watershed's Hebei part covers Zhangjiakou City's 5 counties (i.e. Guyuan, Chicheng, Chongli, Huailai and Xuanhua) as well as Chengde City's 4 counties (Fengning, Luanping, Xinglong and Chengde). Forest vegetation is basically plantations from the 1960s and afterwards.

In the Watershed area in Hebei Province, there are large areas of natural secondary forests and

plantations of good structure and biodiversity, playing important roles in ecological protection and watershed conservation. However, in certain areas, there are certain plantations with large monoculture conifer forests, featuring high density and simple structure. Meantime, forest cover in Hebei is still relatively low.

Over the past 10 years, due to the national strategy of Beijing-Hebei-Tianjin Coordinated Development, the Central Government and the Beijing Municipal Government have been supporting Hebei's Zhangjiakou and Chengde areas in increasing water protection forests. The Beijing Municipal Government have been providing funding for these two cities in Hebei to plant more trees in the Watershed area for 10 years in a row, and has achieved much success.

## 2.3 Problem Analysis

The Miyun Reservoir Watershed is located in the rocky mountainous area in North China. The natural and geographical conditions are less favorable. For example, the area with soil depth of less than 30 cm accounts for 70% of the total Watershed, which causes problems for afforestation as tree survival rates are very low. There are still large areas of barren mountains awaiting afforestation or mountain closure. Also, existing forests face problems of simple structure, uneven distribution, lack of tree species diversity and decline in genetic quality, which restricts the forests from fully displaying their functions. Therefore, tending and managing of existing forests are still among the main targets for watershed management.

## 2.4 Forests' Hydrological Benefits

Forests in the Miyun Reservoir Watershed are mainly performing the functions of water conservation, increasing soil's water storage, preventing soil erosion, reducing flood peak and purifying water quality, etc.

# 3. Livelihoods in Miyun Reservoir Watershed

Research and practices in the Miyun Reservoir have been focused on how to improve restoration and management of forest vegetation as well as enhance watershed management. Another priority is about improving local livelihoods. A win-win situation in which watershed conservation and local livelihood are both improved has been a much discussed topic.

## 3.1 Existing Problems

For many years, to protect Beijing's source of water, local rural residents in the Miyun Reservoir Watershed have been restricted from many production activities and many industries have been closed. Income gaps between upstream rural areas and downstream urban areas have been wider. Local residents have limited livelihood options. Most young and middle-aged residents go and work in large cities as migrant workers, leaving elders and kids behind in rural villages. To achieve sustainable watershed development, there must be more livelihood options for local residents.

## 3.2 Solutions

### 3.2.1 Payment for Watershed Services

Beijing initiated the Rural Water Use Association and the Water Warden System. The Association is responsible for securing rural water security, watershed conservation, waste water treatment, water use management and water course management, etc. Villages in the Watershed area in Beijing have several water wardens each who are paid to carry out water use related responsibility. Funding is provided by the Beijing Municipal Government, from the water resources fee paid by urban residents. Through this method, rural residents in the upstream Watershed area get economic compensation for watershed conservation.

Beijing also developed a new mechanism for local forest management, forest warden team, who takes forest management and related work as a major means of living. This mechanism has achieved great success in improving forest management and improving local livelihoods. Funding is provided by the Beijing Municipal Government and local district governments.

### 3.2.2 Forest Landscape Restoration & Livelihood Improvement

From 2007 to 2011, the Beijing Forestry Society (BFS) and International Union for Conservation Nature (IUCN)'s China Office initiated the "Livelihood and Landscapes Strategy (LLS)" project in two sub-catchments of Hebei Province's Fengning County and Beijing's Miyun District, respectively, also applying the Forest Landscaping Restoration (FLR) concept.

These projects were committed to identifying and developing technical solutions for FLR in the Miyun Reservoir Watershed. They involved the consideration of both economic needs and ecological capacity to realize the multiple benefits of sustainable development. The LLS project worked to renovate the traditional household hypocaust, a brick bed for house heating widely used in rural areas of northern China, aiming to increase its energy efficiency and reduce damage to riparian forests due to firewood harvesting. There was also outreach effort to educate residents on environment-friendly and energy-efficient improvements in their daily life, in addition to the training for implementing forest management practices, operating small treatment facilities and renovating the hypocaust.

These efforts played an important role in moderating conflicts between watershed conservation and economic development in the Miyun Reservoir Watershed. The projects developed a new mechanism for local forest management, the forest warden team. The team employed forest wardens to whom forest management and related work are their primary source of income. A competitive wage was paid with funding initially from the projects. The team will then realize the goal of sustaining itself as more income streams flow from the high quality forest due to effective management activities. Wood harvesting, for example, was a main income source for the team and local community. Compared with the conventional forest wardens paid by the Beijing Municipal Government, the new forest warden teams had a younger age structure and better knowledge and experience in forest management. As a result, these teams were able to perform more skilled tasks such as targeted thinning and pest and disease control, compared to simple and repetitive tasks such as patrolling for forest fire prevention.

# 4. Management of Forests in Miyun Reservoir Watershed

Since 2000, along with economic development and more environmental concern, there have been more efforts in forest management in Beijing in the Miyun Reservoir Watershed. Beijing has launched several large-scale forest management programs and initiatives in the Miyun Watershed, including the Tending of Young and Middle-aged Forests, Forest Health Management, the Sino-German Cooperation Miyun Watershed Management and Close-to-Nature Forest Management. Those programs have improved management of the water protection forest in the Watershed, and enhanced forest stands and their structure.

The following part of this chapter will elaborate close-to-nature forest management and its application in the Miyun Reservoir Watershed.

## 4.1 Introduction of Close-to-nature Forest Management (CFM)

### 4.1.1 CFM Overview

Close-to-nature Forest Management (CFM) is a forest management system which builds on forest ecosystem's stability, biodiversity, multi-functions and buffering capacity. It takes forests' whole life cycle as the design units. The main technical measures include marking of target trees and thinning of competitor trees as well as promoting natural regeneration. The ultimate objectives include permanent forest cover, multi-functional and high-quality forests.

The concept was proposed by German foresters in the late 19$^{th}$ century. It evolved from the religious belief that human beings and other living creatures are created by God and that they should live in harmony. The concept implied that human beings should also consider for the ecosystems, for wildlife and other creatures, it has gradually developed into theory related to managing forest. In 1970s in Europe, due to natural disasters, large areas of planted forests were destroyed, which made people think how to manage forests in a manner that is close to what nature would do.

## 4.1.2 Theoretical Basis for CFM

**Epistemology**

After experiencing flood, drought, sand storm and other natural disaster resulted from deforestation, and after realizing the economic and ecological impacts of large-scale monoculture conifer forests, people realized that it was time to rethink forests, and to reconsider the relationship between human beings and nature. The important turning point for people to develop the concept of close-to-nature forest management was when people realized that human beings should be humbler and should respect and treat nature well, to go with instead of going against nature.

**Ecosystem Theory**

Forests are important part of the terrestrial ecosystem, forests' soil and biodiversity being two key factors. CFM theory believes that soil is connected with geology, climate and vegetation, and the humus layer soil contributes most to the terrestrial ecosystem. Close-to-nature forests with good combination of tree species and good structure will maintain and improve humus layer's development, which will facilitate succession of the whole forest ecosystems.

Biodiversity is another important factor of the terrestrial ecosystem. Trees and other creatures in forests can form food chains which further develop into a food web. The structure will improve decomposition of organic matters and forming of humus, etc. Biodiversity is closely related to forest composition and its structure. Good combination of tree species and good forest structure will enhance biodiversity of an area.

The key to CFM is to adjust and manage species in the forests and their structure, and further maintain forests' natural dynamic succession. Good forest structure can be achieved through reasonable management planning and operation measures, which is technically key to CFM.

## 4.1.3 CFM in Practice

Over the years, there have been environmental problems such as air pollution, water shortage and forest degradation, etc. CFM has been introduced from Germany into Beijing to solve those problems.

### 4.1.4 Technical CFM Issues in Beijing

**Biotope Analysis and Mapping**

The biotope map is related to forest landscape ecology. It is a professional map showing organisms in certain areas, and their categories, distribution and development trends. It is usually based on topographic maps and site visits. It is a technical tool for close-to-nature forest management and stand improvement.

**Management Objectives and Forest Development Types**

Forest development type is a CFM model that combines potential natural forest vegetation & their succession progress with economic needs and technical feasibility of forest management. It is based on people's understanding of the site conditions, species characteristics, and other forest natural features. It is a forest model between planted forests and natural forests. The key is optimal combination of natural possibility and human needs. A good design of forest development type has high demand for techniques and data base. It is important to propose an ideal forest model, but it is also essential to propose necessary management measures to achieve this model.

**Operation System for Target Trees**

The target trees are usually those large-size trees and those dominant trees that grow fast. The operation system has the assumption that if a plantation is adjusted to a close-to-nature structure, the stand volume per unit should be double or more.

The system is target-tree oriented. It divides trees into several categories, and also involves design of thinning and regeneration improvement. The design is based on the trees' competition for factors such as light, water and nutrient. The categories include target trees, competitor trees, special target trees and ordinary trees. Forest operation usually includes marking of target trees, tending of forest stands, thinning of competitor trees, natural regeneration or enrichment planting.

**Vertical Structure Oriented Life Cycle Management**

From the natural and ecological perspectives, a forest's establishment and succession both reflect its dynamic periodic trends, which should be considered during the forest life cycle management planning. There should be a good understanding of forest succession, characteristics, and possible type classification, before designing CFM operations.

From the perspectives of forest management in Beijing, the forest succession and management process are divided into five stages, i.e. forest establishment stage, competitive growth stage, quality selection stage, close-to-nature forest stage and permanent forest stage. In all stages, species composition and forest stands' vertical structure are constants that are observable in the life cycle of forests.

Compared with traditional forest management, CFM operation systems have following advantages:

- Main management targets are indigenous trees. CFM will ensure that there will be no early-stage forest degradation or outbreak of pests and diseases;
- CFM facilitates natural regeneration. Natural regeneration keeps occurring in small areas;
- CFM uses forests' whole life cycle as the planning time unit;
- CFM refers to site conditions, indicator plants, forest succession stages, and potential native plants, to design and adjust forest structure and management measures;
- CFM marks target trees and implements tending management of individual trees, to achieve maximum average growth of high-value trees (target trees);
- CFM uses selective thinning based on analysis of forest stand structure and competition relationship, to achieve improved forest stand quality;
- CFM tries to analyze various ecological and economic impacts of management measures, to ensure that the designed operation system is optimal;
- There will be monitoring and assessment of forest growth and health conditions at regular intervals.

### 4.1.5 Application of CFM in Beijing

The concept of CFM was adopted in the Technical Guideline on Tending of Ecological Non-commercial Forests in Mountainous Areas in Beijing, with the aim to convert the monoculture conifer forests into close-to-nature uneven-aged

broadleaf-conifer mixed forests. In the Guideline, tending principles, measures and methods all refer to CFM. For example, the Guidelines encourages growth of trees, shrub and grass that are not disturbing target trees, to facilitate multiple-layered forests. It also encourages protection of seedling trees from natural regeneration, uneven-aged forests, and more openings in the forests and maintaining natural vegetation in forest gaps.

Since 2002, CFM demonstration areas were established in Miyun District, Yanqing District, Changping District, Badaling Forest Farm and Xishan Forest Farm. In an area of 5,583 $hm^2$, target trees were marked and competitor trees thinned.

From 2002 to 2004, according to CFM principles, tending of about 1.43 million mu (1 mu=1/15 ha) of middle and young-aged forests were conducted, to adjust stand density and improve stand structure.

## 4.2 Sino-German Cooperation

### 4.2.1 Overview

The Sino-German Financial Cooperation Project Watershed Management on Forest Lands Beijing was implemented from 2009 to 2017 by the Beijing Municipal Bureau of Forestry and Parks. Project sites are located in Beijing's four districts of Miyun, Huairou, Changping and Yanqing as well as Hebei Province's Fengning County.

The project aimed to improve and sustain the water protection function of forests and small water bodies in the Miyun Reservoir Watershed using CFM and ecological restoration of small water bodies. The project had several innovations. It was based on inter-regional (Beijing and Hebei Province) and cross-sectoral (forestry and water) cooperation; it applied CFM based on local conditions and realities; it implemented ecological restoration of small water bodies using bio-engineering measures. In 1,180 stands in 104 villages of 31 townships in 5 districts, CFM was conducted on an area of 156,000 mu.

The project's forest management activities have the following characteristics. Forest stands are the basic unit for management. 10-year forest management and operation planning was developed based on management urgency, frequency and intensity; individual trees are management targets. Target trees and competitor trees are selected, and competitor trees are later thinned; the project developed several

technical guidelines; the project also implemented good monitoring and management systems.

### 4.2.2 Experience and Lessons learned

**Inter-regional and Cross-sectoral Cooperation**

The Beijing Municipal Bureau worked with Hebei Province's Fengning County Forestry Bureau in planning, implementation and monitoring of forest management in Fenning County, and worked with Beijing Water Authority and water authorities in five project districts on ecological restoration of small water bodies.

**Participatory Planning**

The project initiated participatory planning during forest management planning. The key was to give local villagers a say in project management. There were door-to-door interviews and consultations to collect local villagers' thoughts and opinion.

**Development of Technical Documents**

The project developed several technical guidelines, including the Guideline on Participatory Planning for Forest Management, the Guideline on Planning for Forest Management, the Guideline on Monitoring for Forest Management, etc. The project outputs were summarized and the Technical Guideline on Close-to-Nature Forest Management were developed and became a Beijing local standard in 2012, which promoted application of CFM in broader areas in Beijing

**Technical Training**

The project conducted over 20 training sessions on participatory forestry planning, financial management, forest management planning and monitoring.

**Multi-level Monitoring and Assessment**

During project implementation, a three-level monitoring and assessment, covering project site self-assessment, random check by the project monitoring center, and double check by the project management office and international experts, was established.

### 4.2.3 Impacts

**Improved Ecological Environment.**

After implementation of the project, forest stand structure and biodiversity in the project sites improved. In particular, there are more natural regeneration of elms, basswoods, maples and other indigenous broad-leaved tree species.

**Local Participation Awareness**

Through participatory planning and management, local residents were involved in project decision and implementation, and their awareness of protecting local environmental improved.

**Improved Local Livelihoods**

Local residents were involved in project implementation and they received incomes. The project built bridges, roads and other infrastructure, to facilitate local people. Residents involved in forest management activities got an average of 4,000 RMB (30% of their total annual income) per person each year. In addition, improved small water bodies also led to development of eco-tourism in local areas.

## 4.3 Forest Management for Different Forest Types

By establishment, Beijing's forests can be divided into plantations and secondary forests. The following part of this chapter will elaborate CFM for forest types of these two origins.

### 4.3.1 *Pinus tabuliformis* Plantations

**Stand Overview**

*Pinus tabuliformis* is one of the most widely distributed tree species in mountainous areas in Beijing. The total area of *Pinus tabuliformis* stands is around 68,905 $hm^2$, with a stand volume of around 1.95 million $m^3$. There are natural secondary forests and plantations for this species, with a total area of 62,364 $hm^2$ for plantations.

*Pinus tabuliformis* plantations mainly distributed in the hilly and mountainous areas with an elevation between 100m to 1000m, mostly on shady or semi-shady slopes. In hilly areas with very low elevation, the plantations are mostly monoculture, with little mixture with other species; in mountainous areas, *Pinus tabuliformis* usually

mix with other species such as oaks, poplars and basswood, etc.

*Pinus tabuliformis* plantations in Beijing are mostly 10 years to 50 years old. Crown closure is between 0.5-0.9 with average height of 8-16m and average DBH of 15-25cm. Early plantations are now in semi-natural status, with invasion of oaks and other indigenous species.

**Forest Functions**

*Pinus tabuliformis* plantations in mountainous areas in Beijing are basically ecological non-commercial forests. They are used for water conservation, soil conservation, wind prevention and sand fixation, or special purposes (recreational forests, etc.). Plantations in very good site conditions may also be used for timber production. According to current conditions and management objectives, *Pinus tabuliformis* plantations can be divided into three main categories, namely protection type, landscape type and hilly-area sunny slope type.

**Management of Protection Type**

- **Stand Features**

Protection type *Pinus tabuliformis* plantations are usually found in remote mountains with an elevation of more than 400m, or on shady slopes in hilly areas with an elevation of less than 400m, mostly far away from villages and scenic areas. Forests are mainly for ecological protection; normally, forest crown is close to closure, with a few gaps or openings; tree height differentiation is obvious. Average stand height is up to 6m and average DBH up to 10cm; there are young seedlings growing under forest crown, and there are high invasive broad-leaved tree species in forest gaps; there are various degrees of stand density. Some stands can be not dense (crown closure less than 0.7, and density less than 80/mu), some normal (crown closure around 0.8, and density around 80-100/mu), some dense (crown closure around 0.9, and density around 100-120/mu), and some very dense (crown closure more than 0.9, and density more than 120/mu).

Figure. 4-1 Marking of Target Trees

- **Management Objectives**

Forest management for this type of plantation is to sustain and improve forest

stands' stability, resistance and biodiversity, to enhance forests water conservation oriented multi-functions.

- **Management Measures**

Thinning

Select and mark target trees, competitor trees and special target trees, and then log out competitor trees. For stands of medium density (crown closure around 0.8 and density around 80-100/mu), there will be thinning once or twice in 10 years; for dense stands (crown closure around 0.9 and density around 100-120/mu), there will be thinning twice or three times in 10 years; for very dense stands (crown closure more than 0.9 and density more than 120/mu), based on stands' average height, there will be thinning three times in 10 years.

Figure. 4-2 Plantation after Thinning

Improving natural regeneration

Protect natural regenerated indigenous species under forest crown, especially seedlings of those dominant community species. Tending measures include building weirs, cutting shrub and fencing, etc.

Protecting debris, humus and soil

Debris from forest management will be crushed and put back on the ground. Thinning operation will try not to disturb ground vegetation and young seedlings or trees.

Enrichment Planting

In large forest gaps and openings where there is not enough natural regeneration, enrichment planting of indigenous broad-leaved trees (such as ash) can be implemented, to facilitate crown closure and forming of a mixed forest.

To enhance forest stands' protection function, attention should also be paid to improve the proportion of broad-leaved trees, to protect and nurture young broad-leaved trees originated from natural seeding, to covert the stands from a single layer to multiple layers consisting of uneven-aged trees, shrub and grass.

**Management of Landscape Type**

- **Stand Features**

This type of forest stands is usually found in favorable sites. Normally, forest crown is close to closure, with a few gaps or openings; tree height differentiation is obvious. Average stand height is up to 6m and average DBH up to 10cm; there are young shade-tolerant trees and seedlings originated from natural seeding growing under forest crown, and there are also broad-leaved tree species from natural seeding found in forest gaps; forest stands are healthy, with various landscape, species or color, or such potential; there are needs or better landscape, if the forest stands are near roads, residential areas or scenic areas.

- **Management Objectives**

Forest management of this type is to improve stand structure, to increase species diversity, especially to add color trees and shrub, to improve landscape and forest stands' recreation function, also considering other functions.

- **Management Measures**

Figure. 5-3 CFM in Favorable Site Conditions

Management activities mainly include selecting and marking of target trees, competitor trees and special target trees, and thinning of competitor trees. Ideal crown closure is designed to be between 0.6 and 0.7. Natural regenerated indigenous species under forest crown, especially seedlings of those dominant community species, will be protected, by building weirs, cutting shrub and fencing, etc. Forest operation will not disturb ground vegetation or young seedlings. Proportion of broad-leaved trees will be gradually increased. Young broad-leaved trees from natural seeding (including dominant community species, color tree species, species that bloom in spring or autumn, and other ornamental plants), will be protected and nurtured.

In large forest gaps and openings (especially close to roads or rest areas) where there is not enough natural regeneration, enrichment planting of indigenous broad-leaved trees (especially those broad-leaved trees with flowers and leaves of high landscape value in spring and autumn) can be conducted, to facilitate crown closure. For forest stands where there will be forest recreation activities, pruning, cutting of shrub and nurturing of herbaceous plants can be implemented, to improve forest stands'

accessibility and landscape value. In areas much frequented by visitors, thinning intensity can increase. Garbage bins, publicity signs, benches, signs and other supporting facilities can be set up.

**Hilly-area Sunny Slope Type**

- **Stand Features**

Stands are usually found on sunny or semi-sunny slopes with thin soil. As site conditions are less favorable, tree height and growth are both very low. Forest structure is less favorable, in lack of mixture with broad-leaved tree species; forest ecosystem function, biodiversity and recreation functions are also to be improved.

- **Management Objectives**

Forest management of this type is to transform forest stands in a close-to-nature manner. Trees with less favorable growth conditions will be thinned out. Replanting and reseeding of indigenous broad-leaved tree species will be conducted, to improve stand structure. The designed objectives include water conservation and soil conservation.

- **Management Measures**

Management measures include selecting and marking of target trees, competitor trees and special target trees, and thinning of competitor trees; building of weirs for target trees, and pruning if there are dead or dying branches; Natural regenerated indigenous species under forest crown, especially seedlings of desired broad-leaved tree species originated from natural seeding will be protected, by building weirs, cutting shrub and other tending measures. In forest gaps and openings, there will be replanting or reseeding of indigenous broad-leaved tree species (such as *Quercus variabilis* and *Acer truncatum*, etc.) of 15-20/mu.

## 4.3.2 *Platycladus orientalis* Plantations

**Stand Overview**

*Platycladus orientalis* is widely distributed in mountainous and plain areas in Beijing. The total area of *Platycladus orientalis* stands is around 115,000 $hm^2$, with a stand volume of around 0.894 million $m^3$, including a total area of 87,000 $hm^2$ for plantations.

This species is resistant to drought and other less favorable conditions. Raising seedlings is less complicated and survival rates for rare-root planting is also very high. It is widely used in afforestation, especially in less favorable sites, such as hilly sunny slope with thin soil, in the past 20 years. It spreads the mountainous areas in Beijing, becoming the most widely distributed plantation species. However, as *Platycladus orientalis* stands mostly consists of young trees and the density is very high, the total volume of standing trees is very low, accounting for only 6% of that of the total of plantations in Beijing.

*Platycladus orientalis* plantations are a main conifer species grown in mountainous areas of low elevation in Beijing. They are playing important roles in water and soil conservation, wind prevention and sand fixation as well as landscaping. However, most of the plantations are monoculture, with high density, simple structure and local stand stability, with high rick of pests, diseases and forest fire.

**Forest Functions**

*Platycladus orientalis* plantations found in mountainous areas in Beijing are mainly for two function categories. One is for protection, which covers water conservation, soil conservation, wind prevention and sand fixation as well as air purification. The other is for landscaping, including barren mountain landscaping, and recreation. For management purposes, *Platycladus orientalis* plantations can be divided into three main categories, namely protection type, landscape type and low-value type.

**Protection Type**

- **Stand Features**

*Platycladus orientalis* plantations are usually distributed in mountainous areas with low or medium elevation, or far away from villages and scenic areas; forest crown is close to closure, and there are forest gaps or openings; stand height is up to 4m and tree DBH above 8cm; tree height differentiation is obvious; there are seedlings or young trees of shade-tolerant species growing under forest crown; most plantations are monoculture with high density.

Stand density can be not dense (crown closure less than 0.7, and density less than 80/mu), normal (crown closure around 0.8, and density around 100-200/mu), dense (crown closure around 0.9, and density around 200-300/mu), and very dense (crown closure between 0.9 and 1, and density more than 300/mu).

- **Management Objectives**

Forest management for this type of plantation is to covert monoculture to mixed forests, to improve stand structure and age structure, to improve the debris layer and soil fertility, to optimize stand density, ultimately to improve forests' protection functions.

- **Management Measures**

Select and mark target trees, competitor trees and special target trees, and then log out competitor trees. For stands of medium density (crown closure around 0.8 and density around 100-200/mu), there will be thinning once or three times in 10 years; for dense stands (crown closure around 0.9 and density around 200-300/mu), there will be thinning twice or three times in 10 years; for very dense stands (crown closure between 0.9 and 1, and density more than 300/mu), there will be thinning three times in 10 years.

Figure. 5-4 Plantation after Thinning

If there are more than two trees in one tree pit, or tree clusters, only one tree with good growth conditions will be remained and others will be removed; Natural regenerated seedlings of broad-leaved tree species originated from natural seeding will be protected, by building weirs, cutting shrub and other tending measures; if there is in lack of natural seeding or regeneration, replanting of indigenous broad-leaved species such as *Quercus variabilis* can used planted in forest gaps. Attention should also be paid to protect debris, shrub and grass.

**Landscape Type**

- **Stand Features**

*Platycladus orientalis* plantations of this type are usually along roads and easy to see. Site conditions are relatively good and stands also in good conditions; forest closure is more than 0.7; tree height is more than 4m and DBH more than 8cm; there are indigenous broad-leaved species originated from natural seeding in forest gaps; mostly monoculture with very high density.

- **Management Objectives**

Forest management of his type of plantation in a CFM manner is to improve stand structure and density, to increase species diversity, to improve forest landscape and forest stands' recreation function.

- **Management Measures**

Select and mark target trees, competitor trees and special target trees, and then log out competitor trees. thinning will only be conducted in those stands with a crown closure of more than 0.7.

Figure. 5-5 Plantation after Thinning

If there are more than two trees in one tree pit, or tree clusters, only one tree with good growth conditions will be remained and others will be removed; Natural regenerated seedlings of broad-leaved tree species originated from natural seeding will be protected, by building weirs, cutting shrub and other tending measures.

In forest gaps and openings, it is suggested to plant broad-leaved tree species or shrub, with ornamental value (spring flowers and autumn leaves); in recreation forests, pruning and shrub cutting can be used to improve forest stands' accessibility.

**Low-Value Type**

- **Stand Features**

This type of forest stands is monoculture with very high density and low stability. Crown closure is less than 0.5; site conditions are less favorable, such as hilly sunny or semi-sunny slope; forest structure is simple (single layer and even-aged), in lack of mixture; there are great risks of forest fire, pests and diseases; forest landscape is less favorable; there is less diversity of shrub and grass species, and not enough seedlings from natural seeding.

- **Management Objectives**

Forest management of this type is to convert the monoculture into mixed forests by adjusting stand density, removing less favorable trees, and replanting broad-leaved indigenous trees in forest gaps and openings.

- **Management Measures**

Management measures include selecting and marking of target trees, competitor trees and special target trees, and thinning of competitor trees; for stands with very high density, special efforts are needed to determine number of thinning in 10 years; If there are more than two trees in one tree pit, or tree clusters, only one tree with good growth conditions will be remained and others will be removed; In forest gaps and openings, there will be replanting or reseeding of indigenous broad-leaved tree species (such as *Quercus variabilis* and *Quercus mongolica*, etc.) of 15-20/mu.

### 4.3.3 *Rarix pricipis-rupprechtti* Plantations

**Stand Overview**

*Rarix pricipis-rupprechtti* is mainly distributed on shady and semi-shady slopes in mountainous areas with medium and high elevation (1,100-1,700m). The total area of *Rarix pricipis-rupprechtti* stands is around 9,270 $hm^2$, with a stand volume of around 0.458 million $m^3$. The unit stand volume is 45.14 $m^3$/ $hm^2$. *Rarix pricipis-rupprechtti* has the highest growth indicator among all plantation tree species.

Almost all *Rarix pricipis-rupprechtti* forests in Beijing are plantations, with the exception of a few natural trees in the Baihuashan area with high elevation. The plantations are around 40 to 50 years old, mature or close to mature. Forest stands are protected in good conditions, nearly close-to-nature stand structure. There is mixture with local broad-leaved species. There is not much shrub under forest crown. There are various degrees of stand density and growth conditions also vary.

**Forest Functions**

*Rarix pricipis-rupprechtti* plantations are used for water conservation, soil conservation, wind prevention and sand fixation, air purification and biodiversity conservation, etc. In the long run, timer production can also be considered in good sites. Management is mainly for ecological protection.

**Stand Feature**

Forest crown is close to closure, and there are forest gaps or openings; stand height is up to 6m and tree DBH above 10cm; tree height differentiation is obvious; there are seedlings or young trees of shade-tolerant species growing under forest crown; there are patches of indigenous broad-leaved trees surrounding forest gaps.

Stand density varies. Some stands are not dense (crown closure less than 0.7, and

density less than 80/mu), some normal (crown closure around 0.8, and density around 100-200/mu), some dense (crown closure around 0.9, and density around 130-160/mu), and very dense (crown closure between 0.9 and 1, and density more than 160/mu).

**Management Objectives**

Forest management is mainly to improve stand stability, diversity and resistance, to enhance stands' ecological protection capacity.

**Management Measures**

Select and mark target trees, competitor trees and special target trees, and then log out competitor trees. For stands of medium density (crown closure around 0.8 and density around 100-200/mu), there will be thinning twice in 10 years; for dense stands (crown closure around 0.9 and density around 130-160/mu), there will be thinning twice or three times in 10 years; for very dense stands (crown closure between 0.9 and 1, and density more than 160/mu), there will be thinning three times in 10 years.

For natural regenerated indigenous broad-leaved trees, especially dominant community species, measures such as building weirs and shrub cutting will be taken to facilitate their growth; attention will also be paid to protect indigenous broad-leaved trees and shrub as well as debris, to promote multiple-layer forest stands.

### 4.3.4 *Quercus* Forests in Mountainous Areas

**Stand Overview**

*Quercus* species in mountainous areas with medium and high elevation in Beijing mainly include *Quercus mongolica*, *Quercus wutaishanica*, and *Quercus aliena*, etc. They are the main forest type for zonal vegetation and a climax community in forest succession in mountainous Beijing. Mountainous *Quercus* species are widely distributed in Beijing's districts of Huairou, Yanqing, Miyun, Mentougou an Fangshan, with a total area of 108,700 $hm^2$. They can be found in areas with elevation between 500-1,800m, especially on shady and semi-shady slopes with elevation of 8,00-1,200m. Most *Quercus* forests in Beijing were natural forests and there were a few plantations. Existing *Quercus* forests are mostly secondary forests established after harvesting, usually 30-50 years old. Crown closure is between 0.6 and 0.8. In different sites, *Quercus* species may also be mixed with other species.

**Forest Functions**

*Quercus* forests in mountainous areas in Beijing are performing multiple functions, including water conservation, soil conservation, carbon sequestration, biodiversity conservation, landscape recreation, scientific research, etc.

After many years of forest management, *Quercus* forest stands have been improved. Most stands have good density and trees are growing well. For some stands, there is good mixture of *Quercus* and other conifer species. However, there are some stands of monoculture originated from coppice, with very high density. Those stands are called low-efficiency forests and are in need of better management. According to stands' functions and management objectives, *Quercus* forests can be divided into two types, the protection type and low-efficiency type.

**Protection Type**

- **Stand Features**

*Quercus* stands usually consist of only *Quercu*s species or *Quercu*s species mixed with *Pinus tabuliformis*; forest crown is close to closure, but there are still some gaps; stand height is up to 6m and tree DBH up 10 cm; tree differentiation is obvious; There are various degrees of stand density. Some stands' density is normal (crown closure around 0.8, and density around 40-80/mu), some dense (crown closure around 0.9, and density around 80-120/mu), and some very dense (crown closure between 0.9 and 1, and density more than 120/mu).

- **Management Objectives**

Forest management of this type is mainly to adjust stand density and structure, to improve stands' ecological protection functions, such as water conservation, soil conservation, carbon sequestration and biodiversity conservation, etc.

- **Management Measures**

Select and mark target trees, competitor trees and special target trees, and then log out competitor trees. For stands of normal density, there will be thinning once or twice in 10 years; for dense stands, there will be thinning twice or three times in 10 years; for very dense stands, there will be thinning three times in 10 years.

For mixed *Quercu*s and *Pinus tabuliformis* stands, special attention is needed to maintain reasonable mixture; for natural regenerated young *Quercu*s trees from natural seeding, and other indigenous broad-leaved trees, measures will be taken to

facilitate their growth; attention will also be paid to protect shrub (especially flowering shrub), grass and debris, to maintain biodiversity.

**Low-efficiency Type**

- **Stand Features**

Stand crown closure is usually more than 0.7. Stands are in shrubby cluster, originated from coppice; Stand density is very high, more than 2,000 $hm^2$; Tree form and height-diameter ratio are less favorable; Stands have low ecological and other multiple functions.

Figure. 5-8 Marking of Target Trees

- **Management Objectives**

Management of this type is to adjust stand density and structure, to convert coppice to arboreal forest, to improve species mixture and stand quality.

- **Management Measures**

Select and mark target trees, competitor trees and special target trees, and then log out competitor trees. For stands with density of more than 2,000/$hm^2$, there will be thinning once or twice in 10 years; for stands with density of less than 2,000/$hm^2$, there will be thinning once in 10 years.

For natural regenerated young *Quercu*s trees from natural seeding, and other indigenous broad-leaved trees, measures such as building weirs and cutting shrub will be taken; attention will also be paid to protect shrub (especially flowering shrub), grass and debris, to maintain biodiversity.

## 4.3.5 *Populus davidiana* Secondary Forests

**Stand Overview**

*Populus davidiana* forests are usually secondary forests established on sites where *Pinus tabuliformis* or *Quercus mongolica* were deforested. They are widely distributed in Beijing in shady, semi-shady and semi-sunny slopes with elevation of 800-1400m or in valleys with good site conditions. The total area is 194,000 $hm^2$.

Crown closure is up to 0.7. Stand average height is 15m average DBH 20-25cm. *Populus davidiana* may be mixed with other broad-leaved trees or shrub.

**Forest Functions**

*Populus davidiana* is a pioneer tree species during vegetation rehabilitation after original vegetation was destroyed. It provides a basis for forest succession. It has good adaptability but does not live long. It has been used for firewood for many years. Most *Populus davidiana* forests are originated from coppice. *Populus davidiana* forests are important in soil conservation, carbon sequestration and biodiversity conservation. Better management can improve forest stands' multiple functions, especially water conservation capacity.

**Stand Features**

Forest crown is close to closure, but some stands have low crown closure; stand height is up to 6m and tree DBH up 10 cm; there are seedlings of shade-tolerant tree species growing under forest crown.

There are various degrees of stand density. Some stands' density is normal (crown closure around 0.8, and density around 40-80/mu), some dense (crown closure around 0.9, and density around 80-120/mu), and some very dense (crown closure between 0.9 and 1, and density more than 120/mu).

**Management Objectives**

Forest management of *Populus davidiana* is mainly to log competitor trees, to improve stand structure (tree species structure and age structure, etc.), and to improve stands' water conservation capacity.

**Management Measures**

Select and mark target trees, competitor trees and special target trees, and then log out competitor trees. For stands with normal density, there will be thinning twice or three times in 10 years when the density should be 0-20/mu; For dense stands, there will be thinning three times in 10 years when the density will be 0-20/mu; for very dense stands, there will be thinning three times in 10 years when the density will also be 0-20/mu. Special attention should be paid to avoid large forest gaps in case that there will be more coppice.

Natural regenerated *Quercus mongolica* from natural seeding, and other valuable indigenous broad-leaved trees, should be protected; If natural regeneration from natural seeding is not enough, there can be replanting of *Quercus* species (such as *Quercus mongolica*) in forest gaps; special attention will also be paid to protect shrub (especially flowering shrub), grass and debris, to maintain stands' multiple structure

and biodiversity.

### 4.3.6 *Betula platyphylla* Secondary Forests

**Stand Overview**

*Betula platyphylla* is mainly distributed on shady, semi-shady, sunny and semi-sunny slopes with elevation of 1,200-1,600m. The total area is around 11,700 $hm^2$. Most *Betula platyphylla* forests are natural secondary forests. Crown closure is around 0.7. Average tree height is 11m and average DBH is 12 cm. Forest stands are mostly 30-50 years old. Monoculture dominates, but there is also mixture with *Populus davidiana*, *Quercus mongolica* and *Rarix pricipis-rupprechtti*.

**Forest Functions**

*Betula platyphylla* is a pioneer tree species for secondary forests, with good natural regeneration. *Betula platyphylla* forests are also used mainly for water and soil conservation and biodiversity conservation. *Betula platyphylla* has high landscaping value. *Betula platyphylla* forests are special landscape in suburban areas.

**Stand Features**

Forest crown is close to closure. There are various degrees of density in some stands; stand height is up to 6m and tree DBH up to 10cm; there are species such as *Quercus mongolica* and *Rarix pricipis-rupprechtti* scattered in the stands; there are natural regenerated seedlings of shade-tolerant species (such as *Quercus mongolica*) originated from natural seeding.

There are various degrees of stand density. Some stands' density is normal (crown closure around 0.8, and density around 40-80/mu), some dense (crown closure around 0.9, and density around 80-120/mu), and some very dense (crown closure between 0.9 and 1, and density more than 120/mu).

**Management Objectives**

Forest management is mainly to improve stand structure and density to improve stands' ecological and landscaping functions.

**Management Measures**

Select and mark target trees, competitor trees and special target trees, and then log out competitor trees. For stands with normal density, there will be thinning once or

twice in 10 years when the density should be 35-55/mu; For dense stands, there will be thinning twice or three times in 10 years when the density will be 50-60/mu; for very dense stands, there will be thinning three times in 10 years when the density will be 60-70/mu.

Natural regenerated *Quercus* from natural seeding, and other valuable indigenous broad-leaved trees, should be protected; If natural regeneration from natural seeding is not enough, there can be replanting of species such as *Quercus mongolica* and *Pinus tabuliformis* in forest gaps; special attention will also be paid to protect shrub (especially flowering shrub), grass and debris, to maintain stands' multiple structure and biodiversity.

# 5. APFNet Funded Forest Management

The project named Rehabilitation and Management of Degraded Forests in Miyun Reservoir Watershed Beijing was funded by APFNet and implemented by the Beijing Forestry Society from July of 2015 to June of 2018, adopting CFM concepts to manage about 283 ha of forests in threes sites of Shichangyu, Shitanglu and Maoshigou in Miyun Districts.

In the first project year, the project team gathered available literature on forest management, and conducted bio-physical and socio-economic surveys in project sites. Data on vegetation, soil, land ownership and other basic information were obtained. Boundaries for forest management for the three project sites have been identified. A participatory land use planning was later conducted in three project sites. Current land use conditions were investigated. Based on the survey results of the participatory land use planning, 10 forest management plans (2016-2020) for the three project sites were developed.

Based on the forest management plans, training manuals on forest management, forestry community development were developed. Specifically, the manual on forest management covers sustainable forest tending and management related planning, development of plans, implementation, technical measures and operation standards as well as management techniques of main forest types in Beijing; the manual on forestry community development includes sustainable timber collections, energy-efficient brick-beds, management of *Juglans regia* and *Castanea mollissima*, treatment of wastewater and garbage classification, etc. 6 training sessions on forest management and community development were conducted during project implementation for a total audience of over 400 persons/time.

Forest management in Shichangyu project site mainly targeted for *Pinus tabuliformis* plantations and shrubland. Main management activities in *Pinus tabuliformis* plantations include marketing of target trees and competitor trees as well as thinning of competitor trees; in shrubland, indigenous broad-leaved tree species *Quercus variabilis* and *Acer truncatum* as well as conifer species *Pinus densiflora* var.zhangwuensis was replanted; a total of forest operation paths of 8km was built to facilitate forest management activities.

Forest management in Maoshigou project site was mainly for *Pinus tabuliformis* plantations, include marketing of target trees and competitor trees as well as thinning of competitor trees, and pruning; 1km of forest operation paths was built. In

Shitanglu project site, forest management was mainly for *Pinus tabuliformis* and *Platycladus orientalis* plantations. Management measures include marketing of target trees and competitor trees as well as thinning of competitor trees, and pruning, building of tree weirs, and replanting of indigenous broad-leaved trees such as *Quercus mongolica*, *Cotinus coggygria* and *Acer truncatum*.

# 5.1 Forest Management Plans

Three 10-year forest management plans were developed for the three project sites. The Shitanglu project site was located within the 1st-level protection area of the Miyun Reservoir, and the Maoshigou project site within the 2nd-level project area. The Shichangyu project site is also within the greater conservation area of the Miyun Reservoir.

## 5.1.1 Purposes

The forest management plans were developed according to relevant national and municipal technical requirements on forest management, and also adopting concepts and techniques of close-to-nature forest management. Considering the importance and representativeness of the three project sites, the three plans accommodate local site conditions, to improve forests water conservation and soil conservation capacity as well as carbon sequestration and other multiple functions.

## 5.1.2 Principles

The following principles were considering during development of the forest management plans. Sustainability, science-based management, easy operation, people-oriented (local people participation), stable forest structure and biodiversity, improved landscape value, coordinated conservation and management, efficiency.

## 5.1.3 Guidelines

The Chinese Forest Law, Beijing Municipal laws, regulations and technical guidelines were referred to during developing the management plans.

### 5.1.4 Procedures

There were four steps for developing the plans, namely collecting baseline data, site investigation, public consultation and expert consultation.

### 5.1.5 Project Site Natural Conditions

The three project sites are all located in Beijing's northeast district of Miyun, where the Miyun Reservoir is located. The annual average precipitation in Miyun District is around 661.3mm, and most of the rainfall occurs from June to September each year. Vegetation in Miyun District varies in different areas due to soil type, soil depth, elevation, slope and human activities.

In the Shichangyu project site, forestland is collectively owned by the local village. Forest cover is around 60.56%. The APFNet project demonstration area covers a total area of 101.6ha of con-commercial forests including 46.1ha of *Pinus tabuliformis* plantations and 55.5ha of shrubland.

In the Shidongzi administrative village, where the Maoshigou project site is located, the total forest land is 1,058.48ha. Main tree species include *Pinus tabuliformis*, *Platycladus orientalis* and *Robinia pseudoacacia*. The APFNet project demonstration area mainly include threes stands of *Pinus tabuliformis*.

In the Shitanglu project site, the local forested land is 1,027ha and forest cover is around 80%. Most of the forests are plantations established between 1980s/1990s and 2006. In the *Platycladus orientalis* plantations, many pits have several trees grew together or in clusters, and many trees had multiple stems. In some cases, young trees were overgrown by shrub and grass. There was an urgent need for thinning or tending cutting, pruning, shrub cutting, coppice removal and other measures. There were various degrees of forest density and not much tree species density. There were many forest gaps, and enrichment planting could be used to change stand density and species composition.

Common problems in the three sites included unfavorable forest structure (most forests were monoculture consisting of one main tree species), high stand density (especially coniferous forests, density is usually more than 80/mu, with high risks of pests, diseases and snow damage), evenness in forest age structure (around 80% is middle and young-aged stands), lack of enough multiple functions (cultural functions, etc.), lack of science-based forest management.

The APFNet project adopted CFM concepts, through thinning of competitor trees, to promote growth of target trees and desired natural regenerated young trees, to improve forest health. It also took replanting, reseeding and other tending measures to foster a multiple-layer uneven-aged conifer broad-leaved mixture structure of water protection forests.

## 5.1.6 Management Evaluation

Water conservation and soil conservation are the main functions of forests in the three project sites.

**Management Objectives**

By end of the 10-year forest management period, the *Pinus tabuliformis* and *Platycladus orientalis* plantations will have favorable stand structure and improved ecosystem functions; through replanting, reseeding and other tending measures, the shrubland will develop into shrub-tree mixed land consisting mainly of indigenous species; forest cover increases in three sites. Forest density reduces, and evapotranspiration and crown retention also reduce to increase water yield.

In 10-year forest management period, through thinning of competitor trees, growth of target trees will improve (no competition of crown and root system) and stability also improve (height/diameter less than 0.7). There will be more light in the forest and natural regeneration will be enhanced; color trees and broad-leaved trees will be planted in forest gaps, to improve landscaping values.

**Forest Management Details**

The APFNet project demonstration area in Shichangyu covers a total area of 101.6ha of 9 con-commercial forest stands, including 46.1ha of *Pinus tabuliformis* plantations and 55.5ha of shrubland (Figure. 5-1).

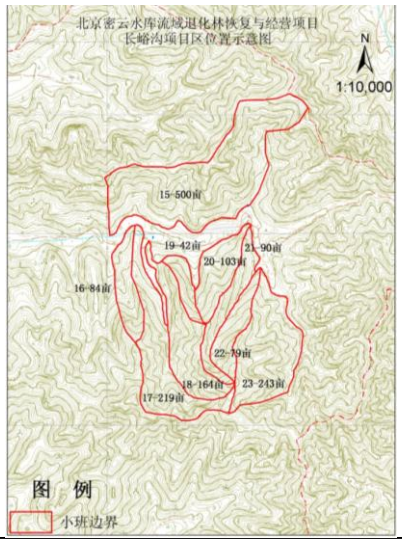


Figure.5-1 Forest Stands in Shichangyu

In the Maoshigou project site. Forest management was planned for three *Pinus tabuliformis* plantations with a total area of 30.68ha (see Figure. 5-2).


Figure.5-2 Forest Stands in Maoshigou


Figure.5-3 Forest Stands in Shitanglu

In the Shitanglu project site, forest management of 8 stands with a total area of 151.2 ha (mainly *Pinus tabuliformis* and *Platycladus orientalis* plantations) were planned (see Figure. 5-3)

## 5.2 Shrubland Management

Regeneration is the main measure for restoring forest vegetation, and it is very important for improving forest stand quality and adjusting tree species structure. In shrubland, the project implemented the measures of replanting and reseeding.

### 5.2.1 Replanting

Replanting was used to develop the shrubland into a shrub-tree mixture of conifer and broad-leaved species. Replanting in shrubland was mainly done in the Shichangyu project site in 2016, and maintenance was done in following years.

Based on shrub height and density, ground preparation was conducted to remove shrub and herbs in certain areas, to improve planting survival rates. Main seedlings used include *Quercus variabilis* and *Acer truncatum* as well as conifer species *Pinus densiflora* var.zhangwuensis (height more than 0.3m). Planting density is 60/mu.

### 5.2.2 Reseeding

Reseeding was also mainly done in the Shichangyu project site in 2016, and maintenance was done in following years. Selected seeds were from *Quercus*

*mongolica*, *Quercus variabilis* and *acer truncatum*.

## 5.3 Management of *Pinus tabuliformis* and *Pladycladus orientalis* plantations

For each stand, during the forest management planning period, there was effort to identity stand details (location, area, establishment type, soil, elevation, slope, soil type, etc.), conditions before operation (age, crown closure, species composition, average DBH, height, volume, etc.) and desired stand conditions after operation (age, crown closure, species composition, average DBH, average height, etc.)

When selecting target trees in *Pinus tabuliformis* and *Platycladus orientalis* plantations, tree viability, establishment type, age and external damage, etc. must all be considered. There were normally 20 target trees selected per mu.

Competitor trees are those causing disturbance to the growth of target trees. They are relatively close to target trees and have direct influence on target trees. Example, their crowns are disturbing crowns of target trees. The number of competitor trees is decided by crown closure and stand density.

After competitor trees are selected and marked, they will be thinned out by chainsaws. The stump height will not be above 5cm. During thinning, attention should be paid to not cause damage to other trees.

## 5.4 Pruning and Other Measures

Pruning and other tending measures such as building weirs, shrub cutting were also taken, to retain rainfall and small surface runoff.

## 5.5 Operation Paths

Forestry infrastructure is necessary for sustainable forest management. Forest operation paths are basic for managing and protecting forest resources. In the tree project sites, efforts were made to build or widen operation paths to facilitate forest management activities.

When building forest paths, considerations were given to connect paths with firebreak and patrolling road systems, to avoid high-value forest areas and buffers as

well as sensitive areas, and to avoid causing damage to ground vegetation and natural landscape.

## 5.6 Supporting Measures

### 5.6.1 Law and Policy

During project implementation, relevant national and municipal laws and regulations were strictly followed and referred to.

### 5.6.2 Technical Support

The project executing agency has close cooperation with experts from research institutes and technical sectors, to provide technical, management and monitoring expertize needed for implementing the project.

### 5.6.3 Management and Supervision

Forest management activities were carried out in the three project sites with strong process management, checking, reporting and external supervision.

### 5.6.4 Forest Protection

Special attention was paid to avoid forest fire. Staff and contracted labors were allocated in the project for patrolling and monitoring fire risks. During replanting and reseeding, efforts were made to select seedlings and seeds that are pests and diseases resistant, to avoid outbreak of pests and diseases.

### 5.6.5 Technical Training

The project adopted CFM concepts and techniques which are not very familiar to forestry practitioners. Indoor training session and outdoor on-site practice helped forestry practitioners and local residents who were involved in forest management activities of this project to have better understanding of CFM as well as pruning, ground preparation, seeding and planting, etc.

# 5.7 Impacts of Forest Management

## 5.7.1 Ecological Impacts

Management of the low-efficiency shrubland and the *Pinus tabuliformis* and *Platycladus orientalis* plantations, has improved stand structure. Forests' water conservation capacity has improved. Biodiversity also improved as there more natural regeneration of indigenous species, etc.

## 5.7.2 Social Impacts

Forest management has facilitated growth of certain medicinal herbs which local residents collect for use by themselves or selling to others. The participatory forest management process and relevant training have improved local residents' awareness and capacity.

## 5.7.3 Economic Impacts

Forest management and other activities in the three project sites provided local forestry community residents with direct and indirect work opportunities. Forest management has improved local landscape and eco-tourism and employment opportunities.

## 5.8 Eco-orchard Management

*Juglans regia* and *Castanea mollissima* are two main economic tree species in projects sites. Traditional management of these two species involved using of pesticide and herbicide, which causes water quality problems for surface water. The project demonstrated eco-orchard management, by introducing better quality seedlings and grafting techniques as well as training on better management.

Figure.5-4 Training on Grafting

# 6. Eco-tourism Planning for Long Mountain Valley

A master plan of eco-tourism has been developed for the Long Mountain Valley in the Shichangyu project site.

## 6.1 Overview

Long Mountain Valley (a small natural village) is located within the Shichangyu project site in Miyun District. It is easily accessed by highway. There are only 13 residents left in the village, and most of them are seniors with limited income options.

The village has very unique natural landscape. There are large areas of *Pinus tabuliformis* and *Platycladus orientalis* plantations as well as *Juglans regia* and *crataegus pinnatifida* forests. Forest cover is high, but due to thin soil on slopes, tree growth is less favorable. There is some abandoned farmland along roads and paths.

The village still maintain traditional local country characteristics, with very special stone buildings and stone walls.

## 6.2 Guidelines and Principles

### 6.2.1 Guidelines

The natural and municipal governments have been emphasizing harmony between nature and human beings, valuing nature and protecting nature. Improving rural development and local livelihoods has also been on the high agenda of the Beijing Municipal Government. In developing eco-tourism in Long Mountain Valley, the project executing agency has been always rearing in mind the importance of protecting the integrity of local landscape.

### 6.2.2 Principles

Locality. Utilize local landscape in a reasonable way without causing damage to

landscape integrity, and also respect and explore local culture, to build a demonstration area for forest therapy, experience, education, etc.

Sustainability. Science-based use of current resources, by protecting and restoring local resources.

People-oriented. Introduce concepts of forest education and forest therapy, etc. to improve human beings' contact with nature, and improve forests' multiple functions for human beings.

## 6.3 Masterplan

The master plan divides the area into four zones and functions, namely forest therapy, forest education and experience, farming practice exhibition, and forest research and demonstration.

Figure. 6-1 Eco-tourism Masterplan

### 6.3.1 Forest Therapy

Forest therapy is a concept originated from Germany and further developed in Japan and South Korea. The practice of forest therapy is believed to improve people's mental and physical health. Developing forest therapy have many benefits, such as enhancing forests' multi-functions, providing a platform for forestry to cooperate with other sectors, boosting local forestry and economy, and promote employment. Forest therapy can also contribute to environmental conservation, by encouraging more people to go to forests and experience the nature.

The APFNet project and other counterpart projects have established trails of different levels, yoga and Tai Ji platforms, and together with other supporting infrastructure and facilities for forest therapy activities. Through training sessions organized by the project, professional forest therapists were trained and are capable of carrying out forest therapy activities in Long Mountain Valley. A number of forest therapy events have been organized for different target groups in the site.

### 6.3.2 Forest Education and Experience

Forest education and experience has been a focus of the project executing agency in the past decade, for which the main venue had been urban parks. Since the project initiation, facilities such as a handicraft workshop, Hawthorn platform, persimmon garden and trails were built. Courses and programme for forest education and experience for the site were also developed.

Currently, forest education and experience activities organized in the site have been also connected with tree-planting and other events.

### 6.3.3 Agricultural Practice

The project restored abandoned local farmhouse and yard, and also added up traditional stone mills, cellar and garden plots, which together with a number of terraces along main education and experience trails, form the basis for agricultural experience for urban citizens.

### 6.3.4 Forest Research

The project executing agency has implemented a number of research projects in the project site. Those projects cover forest carbon and landscape restoration. It is expected that there will be more research program coming up, such as on organic compost and biomass fuel.

## 6.4 Eco-tourism Training

Based on the training manual on eco-tourism (forest therapy, forest education and experience) developed by the project, training sessions were organized for an audience of over 100 persons/time.

Figure.6-2 Eco-tourism Training

# 7. Suggestions for Forest Management

## 7.1 Water Protection Forest & Payment for Watershed Services

### 7.1.1Water Protection Forest

Suggestions include to improve techniques on water protection forests, to establish a comprehensive network for research and monitoring, to research on main tree species and forest types' water related parameters, to research on how forests can filter farmland pollutant, to develop eco-friendly orchard management models and valuing eco-products, to quantifying hydrological impacts of different management measures, to develop process-based forest hydrology models to assist decision-making, to value forests and their multiple functions, and to develop technical standards for managing water protection forests.

### 7.1.2 Evaluation of Ecological Benefits of Forests

In China, 30% of forests is categorized as public non-commercial forests by law. There are supporting measures and policy for compensation for forest ecological benefits, and the compensation is accommodated in public financial budget. However, the current compensation is mainly in the form of subsidies for planting, tending, protection and management and the subsidies are not very high.

Beijing developed a new mechanism for local forest management, forest warden team, who takes forest management and related work as a major means of living. This mechanism has achieved great success in improving forest management and improving local livelihood. Funding is provided by the Beijing Municipal Government and local district governments.

In compensation for ecological forests, Beijing has been the pioneer in China. However, there is still much room for improvement. In some sense, this mechanism is similar to a poverty-reducing model. It fails to maintain a long-term stable professional team. There has been much discussion on introducing a market-oriented and professional team.

From the perspective of forest quality, ecological protection forests are playing a positive role, but commercial forests might cause damage to water quality through

over use of chemicals and pesticide. Reducing use of chemicals and pesticide may result in less products and income. In this sense, orchard farmers should be compensated for their economic loss. However, there is a long way in include orchards into the compensation mechanism. The demonstration of eco-orchards could be scaled up and other mechanism innovations also needed.

### 7.1.3 Inter-regional Cooperation

Two thirds of the Miyun Reservoir Watershed is within Hebei Province. Efficient and effective watershed conservation in the upstream can guarantee water quality and quantity for Beijing. Beijing needs to take financial and technical measures to support upstream watershed areas and local livelihoods.

Beijing has been compensated Hebei in certain ways in the past years. Restoring and managing water conservation forests can be a main topic of cooperation between Beijing and Hebei. It is suggested that Beijing can help manage water protection forests in Hebei Province, based on Beijing's many years of experience, through technical and financial aid. An inter-regional network for planting, management and monitoring is also suggested. To improve livelihoods in Hebei Province, it is suggested that Beijing nurtures and encourages a market that favors green and eco-products, such as fruits, etc.

### 7.1.4 Legislation

Some developing countries have already developed laws, regulations on water protection zones and zoning, etc. The Chinese Water Law also calls for regulations on protection zones for source of drinking water.

Beijing's local regulations on water source protection needs to be improved. It is suggested that when revised the Beijing Regulations on Protection and Management of the Miyun and Huairou Reservoirs need to encourage increase of forest cover restricting farming activities in the 1$^{st}$-level Protection area, and also to provide local residents with certain compensation for reducing or stopping farming activities. In addition, considering that protecting source of water is a long-term mission. It is suggested that in the future reform of the water tariff can consider increased cost for water protection.

## 7.2 Management of Quercus Species

### 7.2.1 Overview of Quercus Species in Beijing

Main *Quercus* species in Beijing include *Quercus Variabilis*, *Q. acutissima*, *Q. alien, Q. dentate*, *Q. mongolica*, and *Q. liaotungensis*.

### 7.2.2 Value of Quercus Species

From the ecological perspective, *Quercus* species have strong root system and are good at soil fixation and soil conservation. They are also fire and wind resistant. *Quercus* species have strong coppicing ability, and can grow even after fire burning. They are priority species for fire protection forests and mixed forests.

*Quercus* species are also a favorable tree used for plantations with the main function of water conservation. *Quercus* leaves fall on the ground, good for soil fertility, forming a thick layer of leaves underneath which the soil contains rich organic matters and soil is less compressed. It is estimated that 92% of rain falling in *Quercus* forests will infiltrate in the soil and surface runoff is only 6%. Therefore, *Quercus* species are important in Beijing for water and soil conservation.

*Quercus* forests are also important for maintaining and enhancing biodiversity, being important habitats, providing source of food such as flowers and fruits for many insects, birds and small animals who also bring many new seeds. The debris and humus layer is a good environment for undergrowth plants and fungus.

### 7.2.3 Protection and Management

Currently, several *Quercus* species have been listed as priority species for plantations. Nevertheless, there are some challenges. On one hand, *Quercus* species grow slow in the early stage, and this is one reason that they are not selected for planting. On the other hand, there are not much research on genetic breeding, afforestation techniques and forest management.

To effectively protect current *Quercus* forests, it is suggested to implement strict mountain closure and target tree tending measures, to conduct a detailed survey on current *Quercus* resources, to carry out research on different species' suitability for different sites conditions and trials on relevant afforestation (planting and seeding),

and to conduct research on species breeding, cultivating and stand improvement, etc.

# Reference

王彦辉. 北京市密云库区水源保护林的建设和管理. 2006.10

段淑怀. 北京水源涵养林对水源保护的作用. 2006.10

于志民. 密云水库流域可持续发展对策研究

北京林学会. 密云水库流域“森林景观恢复与生计改善”项目——2007-2011 年度项目总结

陆元昌. 近自然森林经营工作报告. 2006.12

胡永. 北京市“近自然森林经营”实施情况报告. 2006.11

崔国发等. 2008. 北京山地植物和植被保护研究. 北京: 中国林业出版社. 74-82.

王小平, 陆元昌, 秦永胜. 2008. 北京近自然森林经营技术指南. 北京: 中国林业出版社. 29-38, 66-78.