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# HOW CAN BOTANICAL GARDENS SUPPORT SUSTAINABLE URBAN DEVELOPMENT? A CASE STUDY OF SHANGHAI CHENSHAN BOTANICAL GARDEN

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## ABSTRACT

This case study describes the role of Chenshan Botanical Garden in the sustainable development of Shanghai City in the last six years and provides perspectives on future plant conservation and sustainable utilization. Sustainable economic growth is demanded by regions and countries with urbanization globally. Chenshan has played an important role in the sustainable development of Shanghai as a relatively newly established botanical garden. Shanghai Chenshan Botanical Garden works closely with the local government in the “City Green Master Plan” to increase plant diversity and join in rural park projects. It also provides technical support to city construction by introducing urban horticulture and phytoremediation. More than 20% of the plants in the most urbanized and industrialized areas in China are under threat. Chenshan has collaborated with the central government and the administration of local reserves in the conservation of 14 critically endangered plant species in East China. This has made the sustainable utilization of these plants possible. Chenshan also has a strategic vision to provide people with functional food. The secondary metabolism and gene-manipulating platforms have been already implemented to develop new varieties of plants to achieve this goal. As a botanical garden, Chenshan aims to attract and educate the public with landscapes, seasonal flower shows, and cultural events. Chenshan helps visitors understand the condition of plants and the ways to protect them. These are important tasks of botanical gardens in supporting sustainable urban development.

*Key words:* Botanical garden, horticultural technique, sustainable development.

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In 2015, 17 Sustainable Development Goals and 169 targets were announced by the General Assembly of United Nations to achieve sustainable economic, social, and environmental development globally. “Protect, restore, and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss” is recorded as goal 15 (United Nations General Assembly, 2015). Several urgent targets are expected to be met before 2020, including “prevent the extinction of threatened species” and “integrate ecosystem and biodiversity values into national and local planning.”

China’s burgeoning economic growth has already shown its effects on global ecosystems and biodiversity. The urbanization of Chinese cities has abused limited natural resources in the last 30 years. Shanghai is a model city for economic development. The development of economy and urbanization has led to environmental pollution and ecological destruction in recent years. Air, water, and soil pollution has greatly affected the quality of life of residents in Shanghai. Ecologically friendly sustainable development is a vital part of city

construction and planning by the local government, with the goal of being an excellent global city by 2040. Chenshan has a simple and practical philosophy for sustainable development of the city. First, sustainable development is the responsibility of current generations. This means that the needs of future generations should not be compromised while meeting the present demands. Second, a region or country should seek development strategies without impairing the development ability of other regions or countries. Sustainable development is a strategy and an inexorable trend of global economic and social development in the near future (Griggs et al., 2013). Air, water, and soil pollution is not conducive to the sustainable development of Shanghai City. Chenshan plays a role in achieving ecologically friendly development by utilizing new technologies and transmitting scientific knowledge.

Strategic planning of sustainable development includes several important aspects, including urban green space establishment, restoration of urban ecology by plants, sustainable utilization of plants, and endangered plant conservation. It is clear that botanical gardens can be an important part of urban

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green space. Their establishment is a significant symbol of the quality of the urban ecological environment. In this article, we describe the role of Chenshan in the sustainable development of Shanghai City in the last six years and provide perspectives on future plant conservation and sustainable utilization.

#### ACHIEVEMENTS OF CHENSHAN

##### ASSISTING THE CITY CONSTRUCTION COMMITTEE TO APPLY A BETTER SUSTAINABLE STRATEGY

The Shanghai Municipal Government pays close attention to green construction during urbanization. The latest “Shanghai Master Plan (2016–2040) (Draft)” has put forward that “the forest coverage of Shanghai should increase to more than 25% by 2040, and the public green space per capita should increase to more than 15 m<sup>2</sup>” (Shanghai Local Government, 2016). These ambitious goals need creative strategies, considering the current 7.6 m<sup>2</sup> green space per capita and an area of 4.0 m<sup>2</sup> in city centers. Chenshan has already contributed in several aspects, including assistance in new green space planning, professional advice on new rural park projects, enlargement of the urban horticulture industry, and sustainable utilization of plant resources in Shanghai.

##### INVOLVEMENT IN THE NEW GREEN SPACE PLANNING AND PROJECTS

A rural park is generally defined as an urban–rural fringe with a certain greening rate and ecological characteristics, considering the natural environment as the most important highlight. The construction of rural parks has an important ecological significance. Parks can either regulate local climate by reducing wind speed and evaporation to improve the microclimate or provide ecological protection for the city to improve urban air quality and protect the surface and underground water resources. Thus, the construction of rural parks not only expands the outdoor leisure space for urban and rural residents, but also plays an important role in the ecological balance of the city. The rural park system should consist of a basic farmland, a river wetland, a natural village, an ecological forest, and historic scenes. So far, Chenshan has participated in five different projects in a suburban area of Shanghai, such as the Changing Island project and Jiading Park. In accordance with the plan of the Shanghai Rural Park Department and its functional goal, Chenshan has studied the characteristics of natural vegetation in five different areas and the principles of construction to provide

best recommendations for the construction committee of rural parks.

Chenshan is an important player in the construction of rural parks. The scientific knowledge of plant communities in rural parks is attributed to the analysis of resources regionally and the study of similar cases in other countries. Meanwhile, Chenshan has provided technical support regarding plant diversity to the urban greening plan. More than 300 new adaptive plant species have been selected, and up to 1000 plant species have been used in the city greening plan in the last 10 years, including significant plants such as rose and hydrangea.

##### SUPPORTING URBAN HORTICULTURE TECHNIQUES

The city center of Shanghai has more than 38,000 skyscrapers and other infrastructures occupying nearly 40% of the city area. It is hard to find some pieces of land to grow plants, keeping in mind all the roads and streets. The hard surfaces, such as rooftops, concrete walls, squares, and pedestrian walks, are not favorable for plant growth. Urban horticulture techniques are important approaches to convert these hard surfaces into soft areas, resulting in an improvement in environmental quality in urban areas. This conversion is of significance in Shanghai as a vital means of sustainable urban development.

A total of 70 kinds of plants have been screened to meet the greening demands in urban areas, especially those of mini shrubs and perennials, with characteristics of strong hardiness, drought tolerance, and low maintenance. A proper soil mix that is light in weight, has good drainage capacity, and has moisture retention properties is used for rooftop and container gardening. The depth of soil on a rooftop is decided by the maximum rainfall. The roots are carefully separated from the original surface to prevent roof damage. Modules are used to host vertical wall plants instead of climbing ones to create a landscape. The street tree planting needs a special kind of soil. The coarse rocks can make space for roots to breathe and endure often heavy pressure. All these strategies have been patented and are currently being used in the city. The research achievements of Chenshan have been used in all kinds of projects in the city.

##### PHYTOREMEDIATION TECHNIQUES FOR CLEANING UP SOIL AND WATER

Phytoremediation for cleaning up contaminated soil and water is an emerging technology that uses

various plants to degrade, extract, contain, or immobilize contaminants from soil and water. The technology is considered a low-cost, solar energy-driven cleanup method and has attracted immense attention recently (Gagnon et al., 2013).

The transition from scientific research to biotechnology is one important aspect of the work done at Shanghai Chenshan Botanical Garden. Three projects have been undertaken in the study of phytoremediation: (1) phytoremediation trials for heavy metal uptake by woody plants; (2) selection and performance analysis of macrophyte species for a constructed wetland at a large-scale experimentation site; and (3) ecosystem management strategies for a recreational water system. The selection of woody plants is based on the transfer rate and phytoremediation factor of some heavy metals, such as copper, zinc, and lead. The role of macrophytes in restoring constructed wetland systems and aquatic ecosystems is determined by an improvement in water quality and nutrient removal efficiency (Ladislav et al., 2013).

The results showed that faster-growing woody species had a higher efficiency of metal uptake, even if they had a lower transfer rate, such as *Cassia corymbosa* Lam. for copper and lead and *Hibiscus mutabilis* L. for zinc. The removal efficiency of total nitrogen, total phosphorus, and ammoniacal nitrogen is better in a mixed plantation of *Phragmites* Adans., *Typha* L., and *Thalia* L. than in a uniform plantation in constructed wetlands.

The present study found that the submerged plants played an important role in maintaining surface water quality because of their high efficiency in removing total nitrogen and total phosphorus. These plants accounted for more than 90% total nitrogen and 92% total phosphorus in all macrophyte harvests all year long.

The phytoremediation technologies can be used at sites with soils contaminated with copper, zinc, and lead, and also to treat eutrophication of the surface water. These technologies fully utilize the capacity of the plants for ecological restoration and environmental remediation. These techniques are being promoted in botanical gardens and city greening projects.

#### SUSTAINABLE UTILIZATION OF PLANTS AS FOOD RESOURCES

Economic growth has led to the excessive utilization of resources in Shanghai in the last 30 years. Meanwhile, the demand for better and healthier food has increased. Unfortunately, the prevalence of chronic metabolism diseases, such as type 2 diabetes, high blood pressure, and heart disease, has increased in the last 15 years. Normally,

medicines are not the first choice if symptoms are not serious, because of potential side effects and the cost of taking medication long term. Therefore, food with medicinal functions, so-called functional food, may be a better choice for many people. This has promoted a huge market in China.

Traditionally, the use of medicinal plants as functional food to fight diseases has a long history. Chinese medicine practitioners often recommend functional food to patients based on their own experience, without accurately calculating the medicinal contents in plants. Although not perfect, the effects are practically always good. Chenshan is trying to study the concentrations of medicinal components in various plants based on the metabolism platform. The target is to promote accurate utilization of medicinal plants and their products.

#### SECONDARY METABOLISM RESEARCH ON MEDICINAL PLANTS

Numerous research projects at Chenshan aim to develop new kinds of functional food to meet the current demand. This requires a detailed knowledge of the bioactive compounds, followed by studies of the pathways of metabolism and attempts to find the key regulatory genes. Finally, the genes can be manipulated with the knowledge gained, and various techniques can be used to improve the quality of plants. Efforts continue to gather information on the resources, biodiversity, geographic distribution, and phylogenetic relationships of potential plants with other plants.

The scientists at Chenshan have found that tanshinone and phenolic acids in the root of *Salvia miltiorrhiza* Bunge are effective in treating some vascular diseases (Yang et al., 2016). Comprehensive transcriptome sequencing was used to identify the enzymes and transcriptional regulators involved in the biosynthesis of tanshinone and polyphenolics and unravel the regulatory mechanisms of these active compounds (Yang et al., 2013).

Another plant, *Scutellaria baicalensis* Georgi, has been used widely as a medicinal plant for thousands of years. Flavones in *Scutellaria* L. have been reported to have pharmacological functions, such as hepatoprotective, anticancer, antibacterial, and antiviral effects. A previous study demonstrated a newly evolved pathway responsible for the biosynthesis of bioactive flavones, i.e., baicalein and wogonin. Genes that convert pinocembrin into the aforementioned bioactive flavones were also isolated (Zhao et al., 2016a). These genes were used to alternatively produce bioactive compounds from common vegetables, fruits, or microbes (Zhao et al., 2016b).

## RESEARCH ON FUNCTIONAL OILS

Tree peony oil, listed as the latest recognized plant oil, is a typical oil from woody plants in China (Yuan et al., 2014). Peony oil was approved by the Ministry of Health as a food resource in 2011 because of its medicinal function. The omega-6 to omega-3 fatty acid ratio of the peony oil is less than 1.0, which makes it valuable. It contains 26.7%–50.0%  $\alpha$ -linolenic acid, 20.8%–46.0% oleic acid, and 10.0%–38.0% linoleic acid. As an essential fatty acid for humans,  $\alpha$ -linolenic acid has many special functions, such as reducing blood lipids and blood pressure, enhancing immunity, and preventing cancer and diabetes. Dietary  $\alpha$ -linolenic acid is especially important in the development of the brain and retina. It also has an antiarrhythmic function, preventing cardiac arrest in patients with ischemic heart disease (Yu et al., 2016).

The group at Chenshan researching tree peony used omics technology to investigate peony genomics and gemplasm. Transcriptome and proteome data showed that certain genes and proteins were closely related to the biosynthesis of unsaturated fatty acids. These genes were differentially expressed at various developmental stages and in different tissues of the seed. The current focus is on the high-quality genome sequence of tree peony and the evolution of its giant chromosomes and huge genome (12 Gb in total).

## CONSERVATION OF ENDANGERED PLANTS IN EAST CHINA

East China accounts for about 7% of the country, feeding around 30% of the population in China. It is one of the most urbanized and industrialized areas compared with other regions. The landscape is isolated by cities, villages, and factories. The plants in this area are considered the most endangered, even though some national reserves have been set up in the last 20 years. It is estimated that 20% of the local plants are under threat. The situation has become worse due to population growth, resulting in a shortage of land for growing plants.

## CONSERVATION RESEARCH AT CHENSHAN

Designated as the “Conservation Center for Endangered Resource Plants of Eastern China,” Chenshan focuses on generating a reliable checklist of local plants first. Researchers are working on geological genetics, quantitative genetics, and pollination biology of some particular plant groups, such as ferns (Shang et al., 2016), orchids, and oaks (Xu et al., 2016). All these plants are important in eastern China.

## CRITICALLY ENDANGERED PLANT CONSERVATION PLANS

Chenshan also works with the State Forestry Administration (SFA) and local natural reserves to conserve critically endangered plants, such as *Carpinus putoensis* W. C. Cheng, *Abies beshanzuensis* M. H. Wu, and 14 other species. Chenshan is responsible for drafting the conservation plan for each species, including the status of the plants, propagation methods, and reintroduction to natural habitats, based on its research achievements. Chenshan voluntarily assists the reserves in conserving plants and monitors progress for SFA. Chenshan’s practice of conserving and protecting endangered plants can be adopted by other regions in China.

## CHENSHAN AS A BOTANICAL GARDEN

A botanical garden not only should be a place with beautiful landscapes and plants, but it also should have outreach programs in which people can get involved. In Chenshan Botanical Garden, visitors can understand why plants are important and what a botanical garden can do; it has become a popular destination where visitors gain knowledge of plant science.

## HIGHLIGHTS OF CHENSHAN’S LANDSCAPES

The Quarry Garden is one of Chenshan’s most beautiful attractions, covering an area of 39,000 m<sup>2</sup>. Inside the Quarry Garden, visitors have an excellent view of the garden, including a waterfall, a pit, Mirror Lake, and different kinds of plants, such as colorful shrubs (camellias, tree peonies, *Rhododendron* L., *Hydrangea* L., *Hibiscus* L., *Viburnum* L., and so on).

The conservatory at Chenshan consists of an indoor garden, a greenhouse of succulents, a greenhouse of rare and exotic plants, and an energy center, which covers an area of 21,000 m<sup>2</sup> with an exhibition area of 12,600 m<sup>2</sup>. It is the largest conservatory in China and Asia. The building was constructed in a unique shape using arc-shaped and long-span aluminum.

## CULTURAL ACTIVITIES AND EDUCATION

Chenshan international orchid shows have contributed greatly to the promotion of urban ecological civilization of Shanghai in the last several years. Thousands of rare orchids have been displayed, and many events and scientific meetings have been held during the shows to attract people and encourage them to become involved and develop a relationship with plants.

The rose is a flower with high ornamental significance. Moreover, rose cultivation in China has a long history. Chenshan organized two rose shows in 2015 and 2016 with the theme of love, where more than 800 rose cultivars were displayed, including a stunning tree rose blooming with more than 100 flowers from a single plant simultaneously.

Chenshan has successfully held lawn concerts each spring season since 2012, combining the beauty of plants and music. The concerts were co-sponsored by the classical music channel of Shanghai Radio Station, which invited orchestras from all over the world to perform.

It is understood that a botanical garden is not just a place for people to entertain and relax; it should also be an organization that has a local, national, and even an international impact. The aim of Chenshan is to serve local demands, conserve regional plants, and sustainably utilize plants by collaborating with international institutions. Chenshan makes all visitors aware of the importance of ecologically friendly sustainable development.

#### CONCLUSIONS AND PERSPECTIVES

Chenshan is a relatively young botanical garden investing its best efforts in research, conservation, and education. Its mission and strong strategic plan have guided the promised development of the garden since its opening. Support from the public, government, and employees has permitted Chenshan to play a significant role in the city's sustainable development.

Chenshan works with the local government under the City Green Master Plan. It provides technological support for phytoremediation in treating water and soil pollution. Chenshan has been credited as a close working partner of government agencies in plant conservation and sustainable urban development. The achievements and ongoing programs of Chenshan Botanical Garden confirm the vital role played by botanical gardens in modern society, which today faces many critical environmental challenges and health issues.

Chenshan will continue its work on plant science research, and goals for the coming years will include combining plant conservation and city greening in terms of choosing more suitable plant species for city greening projects. It will also examine the changing climate, because a successful greening plan for a city should have long-term benefits for the quality of life of its residents. Phytoremediation techniques will offer a way to reduce pollution and will also provide alternative options in domestic waste treatment. Chenshan will also take part in the cleaning of

Shanghai City, together with many gardens in the city. Considering that the gardens in Shanghai have already worked together for years toward the conservation of endangered plants, Chenshan will collaborate more closely with other gardens to fight against the loss of plant diversity in the future. Chenshan also has a long-term vision to provide people with healthier functional food. It has already implemented the secondary metabolism and gene manipulation platforms to develop new varieties of plants to achieve this goal. Only scientific and technical innovations can make sustainable development possible. Hence, it is necessary to understand secondary metabolism and gene functions in plants in collaboration with the international scientific community.

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