

Siting Green Infrastructure: Synthetical Solutions for Leading the Oasis City's Sustainable Development In Wuyi New Town

Jie Ren, School of Architecture, Tsinghua University, China

1. Introduction

As a popular framework for smart growth and conservation, urban green infrastructure aims at constructing a natural support system in urbanized areas through protecting nature resources and considering social, economic and cultural elements. The formation and stability of this green framework could not only guarantee the security and stability of ecological environments, but also offer a basic ecological security pattern and development control framework and finally provide a foundation for city's future resilient development.

Owing to the particular conditions of oasis cities, the stability and security of ecological environment seem to be quite more crucial especially when dealing with urban sustainable development. This article showcases how Wuyi New Town constructed its sustainable developing strategy by the strategic method of green infrastructure.

2. Background

Wuyi new town, covering 11.2sq km, is located in the north foot of Tianshan Mountain in the western arid land of China, about 26km from west of downtown Urumqi (Figure 1, Figure 2). In order to meet the need of the ecological and sustainable development, protect the regional ecological safety, and guide urban future rational special expansion, the idea of green infrastructure was presented at the beginning.



Figure 1 Location of research site



Figure 2 Research areas

2.1 The formation of the idea of green infrastructure

2.1.1 The constrain of ecological environment: important oasis areas in the north foot of Tianshan Mountain

The Tianshan Mountain lies in the north of Xinjiang and it is the largest mountain range located in Central Asia. Owing to the difference of topographic slope and the distribution of rainfall, the north foot of Tianshan Mountain forms a special MODS (mountain-oasis-desert system) ecological pattern, that extends roughly north-south and distributes layered (Figure 3). Among those three systems, the oasis regions in the north foot of Tianshan Mountain are the key factors of maintaining the ecological safety of Tianshan Mountain, and Wuyi new town is just in the core region of the oasis.

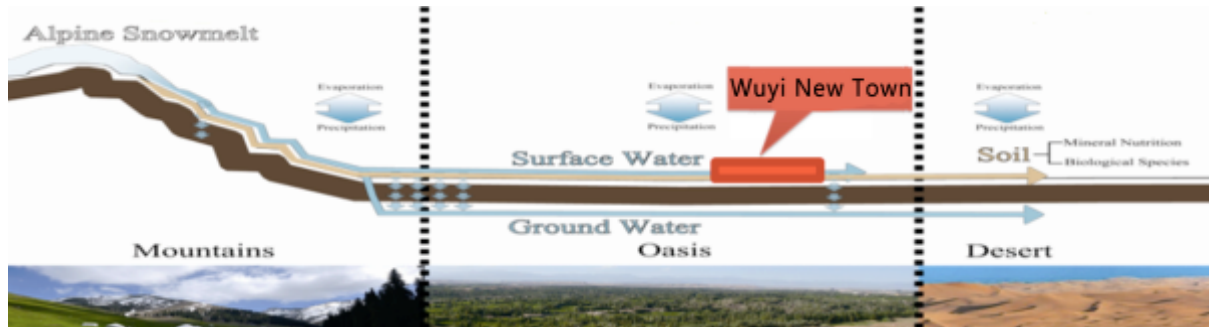


Figure 3 MODS system: Mountain-Oasis-Desert

Recent years, because of entering into the phase of rapid urbanization, the amount of urban construction lands of Wuyi new town have experienced a significant increase. The urban layout pattern has moved from “punctate distributed layout” which is single axis-based on main traffic lines, towards “multi-point and multi-axes” network layout” gradually, while interfered many ecological elements’ north-south circulation seriously and leading to a sharp increase of the fragment of regional ecological landscape. Meanwhile, owing to the continued expansion of large scale land reclamation and unreasonable farming practices, the resource of surface water and ground water have been overexploited, and caused more serious phenomenon of funnel-shaped ground water.

Under the background of increasing changes of ecological pattern in north foot of Tianshan Mountain, it is important and crucial to pay attention to the building of ecological environment and the construction of rational urban green space in order not only to curb the oasis degradation, prevent the desert southward and maintain the stability of regional ecological patterns, but also promote the sustainable expansion of Wuyi new town’s future urban space.

2.1.2 The need of urban development: the key location of regional economic development

Wuyi new town located in the northwest of Urumqi downtown, the east of Changji downtown, the north of Diwobao International Airport and the middle of Urumqi-Changji economic integration, and it owns better advantages of location and resources (Figure 4). However, for now, because of the constrains from economic structure and political system, there existed some issues which could not been ignored maybe hinder the future urban development. Meanwhile, seen from the point of the development of Bingtuan Area and the update of regional future development, it further reinforced the sustainability of development path and the important role of city’s function.

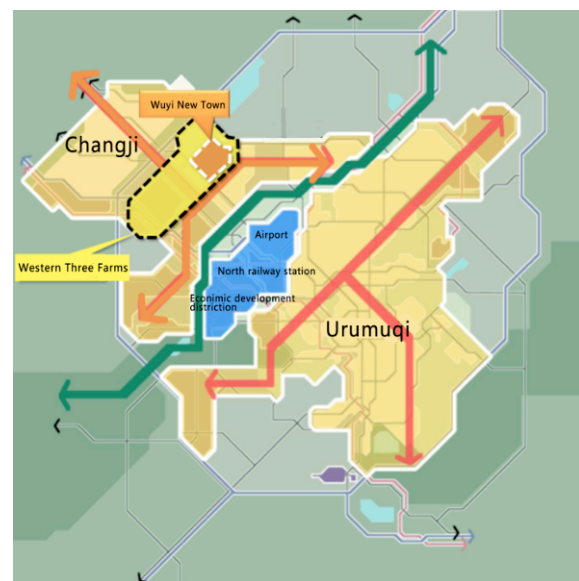


Figure 4 Regional future development layout

2.2 The constrains and challenges of green infrastructure planning

2.2.1 Serious degradation of vegetation and relative shortage of water resources

Wuyi new town is located in semi-arid continental climate regions with an average annual evaporation of 1787mm, which is 9.77 times than the rainfall, and the problem of water scarcity is very prominent. Meanwhile, as some other oasis cities, Wuyi new town is also exposed to a multitude of conundrums on natural environment deterioration, such as dry weather, dust storm, inadequate green areas, soil depletion, vegetation degradation, etc. At the same time, owing to the relatively limited water environmental capacity, Also, because the whole area's water environmental capacity is relatively limited, the phenomenon of sandy soil and the soil with low organic matter is also going to be troubleshooting. So, the reasonable construction of region's green space is particularly important.

2.2.2 Sandstorm impact on the town significantly

Wuyi new town lied in the "Qitai-Shihezi hot wind zone" with frequent sand blowing weather which not only reduced the air cleanliness, but also affected the local crop production and the life of local residents seriously. Since the dust weather, the process of Wuyi new town's urbanization will experience an exchange from the pattern of "farm-protective forest network" to the pattern of "town-green space". Therefore, rely on the current situation of vegetation, how to enhance the protective capability of green space from the level of spatial arrangement and vegetation choice is also a problem this green infrastructure planning will face.

2.2.3 The construction of urban green land needs to be improved

The construction of Wuyi new town's green land is still in its infancy. There is only one current agricultural sightseeing garden for urban residents' daily recreation and the other main form of green land is protective green land, including current road protective forest and farmland shelter forest network. In addition, the types of vegetation are still in limited and the form of greening is relatively simple, that make the size and quality of green space and the future need of urban development both have large gaps.

2.2.4 The promotion of agricultural landscape faces challenge

Agriculture has been not only a basic industry of Bingtuan but also the regions of north foot of Tianshan Mountain. After a long period of development, agriculture has been a typical type of landscape and important landscape resources that could embody and strengthen the geographical characteristics. However, the agriculture's character of large consumption of water seems to contradict the ecological safety of those oasis regions seriously.

Hence, during the process of changing from traditional agriculture to modern agriculture, It also seems to be an challenge for Wuyi new town to extend the characteristics of agricultural landscape properly, enhance the overall efficiency of agriculture and reshape the regional landscape.

2.3 The core content of green infrastructure planning

On the one hand, green infrastructure emphasizes an interconnected network of green open spaces; on the other hand, it is more a method of land preservation, the green space network it formed could not only offer a framework for urban future development in foresight, but also present a path to guide both urban future development and the greening of other municipal infrastructure systems.

Therefore, during the research of green infrastructure of Wuyi new town, the contents from above two aspects have been documented into three facts: the construction of green space system, the setting of urban development path and the guidance of municipal infrastructure.

In addition, because of the convenient regional traffic conditions and abundant resource superiorities, in the future, Wuyi new town will also undertake a pivotal role in regional development. The ecology, security and sustainability of oasis city are emphasized during the planning progress of Wuyi new town from government decision-making, innovative

planning conceptions, and technological means to practical approaches. Basing on the core idea of maintaining and enhancing the regional ecological environment mostly, the conception of green infrastructure was presented to guide Wuyi new town's sustainable development. As a city's natural service system, Wuyi new town's green infrastructure aims at exploring a planning and design operation mechanism, and forming the "Wuyi Model" that features rational and efficient oasis city development.

3. Green infrastructure planning in Wuyi new town

3.1 Basic concept: using green infrastructure to guide urban development

3.1.1 Green infrastructure first

At the beginning of the design, the concept of treating natural environment and green space as one part of urban infrastructure to be constructed first was been determined. It emphasized a comprehensive analysis of current land resources and the synthesis of society, economy, ecology and some other factors. It claims to delimit the boundary of preserved land first and finish the planning formulation before new land allocation. Through protecting the rationality and integrity of green land system, it could guarantee the continuity of the natural and biological processes, while reserving sufficient development space and providing the possibility of high efficient land preservation and development, and enhancing land's natural service capability and urban resilience to natural disasters.

3.1.2 Not only emphasis on green indicator, but also eco-efficiency

Although owned favorable regional advantages and resource endowment, Wuyi new town experienced a relatively fragile ecological natural environment because of the affection of oasis climate. Therefore, it is crucial to pay attention to the capability of natural service, enhance the attention to green space and strengthen natural spaces' important role in urban sustainable development. Basing on the emphasis of protecting green indicator, this planning paid more attention to the interconnection and ecological efficiency of green land. Through the construction of perfect network of green space systems, those green land space not only could been seen, but also could been used and enhanced the ecological efficiency of green land fundamentally.

3.1.3 Full recognition of the economic contribution value of green spaces

On the basis of full recognition and emphasis of the comprehensive benefits that urban green land could produce, building a sound green infrastructure network and improving ecological environment dominated by efficient management of green land could make the environmental advantages convert into economic advantages, which will led Wuyi new town's future economic development. At the same time, urban environment with high quality will also help enhance the city's image and visibility, then further promote the city's tangible and intangible asset value.

3.1.4 The combination of passive preservation and positive development

The planning emphasized the combination of passive preservation and positive development, that is to form a network which addressed both the protection of green space and urban development, and this protective overall green network could draw a boundary for urban future development and require future development activities carried out within this boundary. Yet, this mode is not to place land preservation in opposition to land development, it stressed a transformation from a simple only protection of green space to a much systematic and guiding overall urban development network through the consideration of future development, urban expansion and some other development planning.

3.2 Multi-layered research perspectives

In the case of Wuyi new town, in order to improve the veracity and comprehensiveness of the planning, the research prospect of green infrastructure was expanded to a larger medium-level of Wuyi Farm and a macro-level of Western Three Farms (Figure 5), and those

three different spatial levels corresponded to the microscopic specific design methods, the formation of medium planning countermeasures and the construction of macroscopic strategic guidelines, respectively.

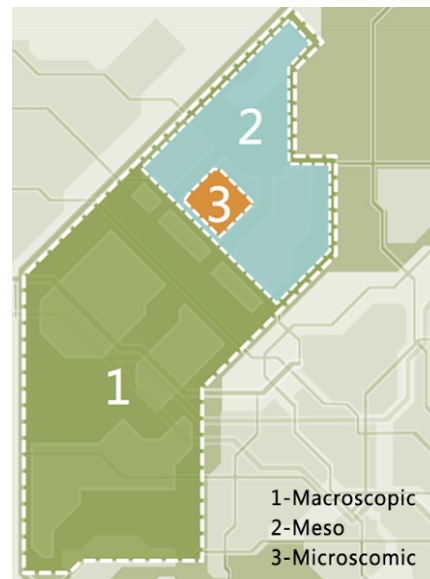


Figure 5 The mode of planning levels

Sheet 1 The relationship between three research levels

Research Level	1. Macroscopic	2.Middle	3.Microsmic
Research Area	Western Three Farms (including Wuyi Farm, Sanping Farm and Toutunhe Farm)	Wuyi Farm	Wuyi New Town
Land Area (Km)	181.2	61.2	11.3
Planning Content	The construction of macro strategic guidance	The formation of medium planning countermeasures	The realization of micro design measures
The Key Point of Planning	<ol style="list-style-type: none"> 1. Proposed the guiding ideology of green infrastructure 2. Constructed strategic structure of regional green infrastructure 3. Presented guiding overall strategy (including green space and infrastructure) 	<ol style="list-style-type: none"> 1. The planning countermeasures of green space 2. The planning countermeasures of infrastructure 	<ol style="list-style-type: none"> 1. The design measures of green space 2. The design measures of infrastructure

3.3 Strengthen the construction of ecological green space

3.3.1 The ecological strategy of green space in macro Western Three Farms

The macro-level research determined the idea of using green infrastructure to guide urban development and five basic principles about valuing the ecological benefits, advocating green infrastructure advance, combining the passive protection and positive development, realizing the economic value of green space, and compromising the urban public space and green space. Under this planning conception and principle, the macroscopic green infrastructure system was constructed through collecting and analyzing the oasis's special natural conditions and the other social, economic and cultural elements, And this system offered a strategic framework for the whole Western Three Farms' spatial development and land layout. Meanwhile, the overall strategy about green space, urban development and urban infrastructure were defined in the meantime.

(1) The functional diversification of green land

According to western three farms' current developing situation and its development goals in 12th Five-Year Plan, at first, the project made three east-west agricultural landscape belts based on produce function, which are mainly composed of forestry, vegetables and fruit, respectively. Those three landscape belts were urban delicate agriculture oriented which featured in ponds leisure, flowers economy and farmhouse experience, and aimed at forming a big scale farm landscape with both productive and entertainment. Second, on the basis of meeting with the need of bit lines and safety requirements of municipal pipeline corridors, the project separated those regions by five green land corridors. Those corridors were mainly used of country parks with strong public participation and public activities. The design proposed for a subject of plant cultivation and used the large-scale farming of sunflowers, lavenders, canola flowers and some other landscape plants to extent the beauty of agricultural landscape while kept the balance of the flexibility of space usage and the low maintenance costs. Besides, as the balance space of urban construction and nature protection, those five green country parks would also accomplish a great deal in the safety of storm water for the function of storing water (Figure 6).

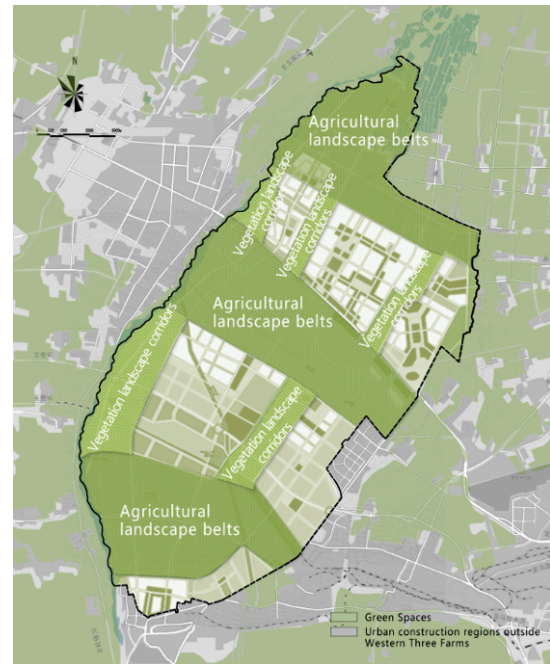


Figure 6 The strategic framework of green infrastructure in Western Three Farms

(2) The features of landscape

The project adjusted the original planting mode of Western Three Farms, combined the original topography and morphology of Western Three Farms, and then used the landscape effects of special flowers and shrub plants to create a flat open landscape.

3.3.2 The planning countermeasures of green space in medium Wuyi Farm

The medium-level confirmed the specific countermeasures, like specific location, control range and main function of green infrastructure system of Wiyi Farm.

(1) The refinement of green spatial structure

This level emphasized its connection with macro level, and it added a next level of green belt to perfect the overall green spatial structure. Through the formation of a number of park zones, it connected all the parks, ecological corridors, green belts and some other large green space, kept the continuity of the green land in Wuyi Farm, boosted ecological factors penetrating to urban regions step by step, and finally improved the natural environment and micro climate.

(2) Keep the ecology and versatility of green land

Firstly, as urban agricultural ecological corridors, there was a need of promoting the transformation of agriculture structure through strengthening the construction of agricultural water-saving facilities and building high efficient ecological agriculture systems, marked by

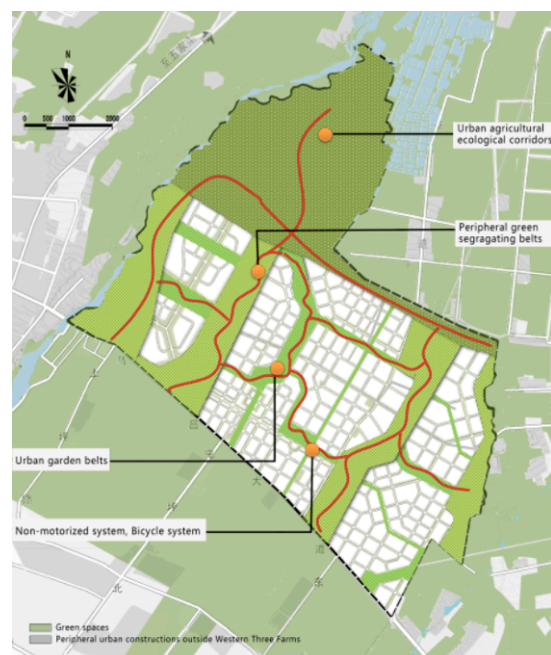


Figure 7 The spatial layout of green infrastructure in Wuyi Farm

ecological green agriculture, tourism agriculture, modern high-tech agriculture and so on. Secondly, for the peripheral green belts, it should strengthen the green construction of current villages, roads and some other constructions, control the construction strength, move away the construction projects which were heavy impact on environment gradually and do ecological restoration. Meanwhile, the project promoted an agricultural forest mode of "big grids, wide belts" in green belts' upwind regions to build a source of oxygen and a protection from sands. Finally, all the urban park belts should pay much attention to ecology first and highlight the ecological function of water-saving and protection against wind during the choose of plants and planting methods. In addition, based on those urban park belts, it constructed more connective pedestrian systems and exercise biking systems.

3.3.3 The design measures of green space in micro Wuyi New Town

In the micro-level of Wuyi new town, green infrastructure system became not only green space system but also a basic functional carrier which could coordinate multiple urban infrastructure, such as open space system, transportation system, water supply and drainage system, under the principle of "green".

(1) Adaptive vegetation choice

Because the special climatic conditions in Urumqi, it was crucial to choose proper vegetation to adapt such middle temperature and drought environment.

The regions around the east, south and west of Wuyi new town were both country green ways and the fields of those regions were relatively fertile and owned a large proportion of arable land. In the future, the productive ways would be dominated by agroforestry which were mainly protection forestry of "narrow belts and small grids" with part small economic trees and timber forest. By doing so, it maintained the safety of regional ecological system. The green ways inside Wuyi new town were all urban green ways and road greening were important part of urban green ways, that they own significant role of decreasing dust, replenishing groundwater, improving outdoors' high temperature in summer, purifying the appliance of city and some other aspects. In the tree species selection, elm, maple and conifer were the main kind owing to their long-life, less flower drop and better effect in the development of desert and temporary development.

(2) Strengthen the ecology of green land

In the design of green space, proper allocation of different vegetation was significant measures for improving the ecological efficiency of green land. Firstly, the design used large areas of large arbors and shrubs in green ways inside city. On the one hand, by doing so, intensive big crested species could enhance light shielding effect and reduce urban green ways' wind speed (green ways could reduce wind speed between 35% and 75% [1]); on the other hand, transpiration could enhance the air humidity of around regions (The air humidity around green ways are about 10%-20% higher than that around urban district. The air humidity of big parks could be about 27% higher [2]), form pressure differences between green ways and urban constructions, and then improve the circulation of air humidity and ameliorate air condition.

For arbors and shrubs, the lawn has a better performance of dust extraction. The complexity of the combination of above three will directly affect ecological benefits of dust extraction, wind-resistant and noise canceling, and the more complicated combination, the higher ecological efficiency. When the width of the combination of arbors, shrubs and lawns achieved 3 to 70 meters, the noise would be reduced between 3.7 to 7.5DB(A). Therefore, it was important to pay attention to the structural equilibrium of those three vegetation in Wuyi new town's plant arrangement.

(3) The effective integration of urban public space

The goal of green infrastructure system in Wuyi new town was not only connecting constructions and natural environment, but also offering urban residents more comfortable, convenient and efficient urban public service through giving ecological green land more active roles. Hence, this design corrected the problem of considering and planning green land systems and urban public space systems separately, and it considered those two

aspects together to set proper comprehensive parks, community parks, topic parks and green areas nearby street to meet the need of urban function.

The combination of city green ways, parks, squares and green land formed Wuyi new town's public open space system. It not only offered ecological securities for Wuyi new town, but also supplied the possibility of peoples' high usage of green land through injecting many kinds of urban functions in green land.

(4) The reasonable convergence of urban public service facilities

The urban green public service systems were mainly composed of Bingtuan-level facilities, New town-level facilities and residential facilities. Based on the formation of green infrastructure network, this planning ensured residents can have green space within 500 meters. Meanwhile, it distributed urban public service facilities along main roads and important green corridors to improve the convenience of peoples' daily usage of public service facilities and formed urban green public service facilities network systems.

3.4 Construct a low-impact water environment

Wuyi new town's distribution of vegetation has closing relationship with the water level and water quality of regional underground water. Hence, under limited water resource, it was significant to guide rainwater, enhance the water storage ability of regional soil and improve vegetation's ability to survive.

3.4.1 The building and control of urban rainwater network

(1) Rainwater network

There were no rain drainage facilities in Wuyi new town and the rainwater usually evaporated or flowed to low lands along roads. This design emphasized the artificial guidance of rainwater and claimed to use green land's ability of water content and water storage to amplify rainwater's infiltration time and infiltration areas. Meanwhile, under the basic principle of respecting site's original hydrological direction, this design complied with natural original context and formed drainage direction of main north-south and accessory east-west. It combined the artificial water channels and natural water channels, and enhanced their benefits.

(2) Rainwater control

Forest infiltration and drainage systems: combined with the construction of road protection belts, this planning formed artificial channels to collect rainwater from roads and residential areas by two levels. At the same time, all the forest infiltration and drainage systems were made of natural stones to enhance their ability of infiltration.

The control of rainwater in residential areas: set sunken green land to centralize rainwater and form rain gardens that could infiltrate water and decrease the concentration of initial rainwater's pollutant by the ways of plant purification.

The control of rainwater in public space: built water collection and water infiltration facilities in densely public buildings. In addition, used porous pavement on ground parking lots, sidewalks and new roads to increase rainwater's infiltration rate and reduce runoff coefficient. The treatment of excessive rainwater: firstly, used forest infiltration and drainage systems to absorb parts of excessive rainwater. Then, through organized control and whole-process monitor of excessive rainwater's surface runoff, when faced with extreme rainfall, the traffic measures of restricting access roads will ensure city's water safety.

(3) Rich green land's function

The project used green land's interior function, like grass swale system, detention system and low-lying permeable landscape, to change traditional mode of drainage rainwater and chose more natural ways to manage rainwater.

Firstly, the pebble grass swale systems were used to collect and purify rainwater. Then, based on the network of green ways, grass swale systems were made to form region's ecological basis. Finally, lots of "green pots" were constructed to replace the structure of "single line" through comprehensive detention (small wetlands). In most part of site, it chose traditional gravel basin-shaped depression. In the other urban central park and ecological demonstration garden, it used wetland detention and shallow swamp detention owing to

their higher demand of water and the ecological demonstration effect. Besides, the project also used large amount of low-lying permeable landscape to reduce surface runoff and replenish urban groundwater source.

(2) Efficient urban sewerage system

Current urban sewerage was discharged through original open trench and closed canal and there was no perfect drainage facilities that caused serious pollutant for downstream water and its surrounding soil. According the characteristics of climate and terrain conditions in Wuyi new town, the design emphasized the combination of current terrain and the usage of natural line, and used the method of gravity flow. By doing so, it saved the length of pipes with large diameter and constructed a concise layout of drainage pipes.

(3) Strengthen the reuse of recycle water

According to the types of land use, it determined the main application of recycle water to be the supply of landscape water (water for amusement in urban park) and urban common use water (irrigated water, washing closets of some public buildings, cleaning roads and washing cars). On the sequence of usage, it gave priority to irrigated water, then the supply of landscape water, finally the washing closets.

4. Conclusion: Taking green infrastructure as synthetic solutions for leading the oasis cities' sustainable development

As on kind of complicated work, the theoretical research of green infrastructure integrated landscape ecology, conservation biology, regional planning, geography and many other subjects. In addition, it also followed some basic principles, such as connectivity-emphasized, preservation parallel with development, planning and preservation first, important public investment and some others.

The ecology, security and sustainability of oasis city are emphasized during the planning progress of Wuyi new town from government decision-making, innovative planning conceptions, and technological means to practical approaches. Basing on the core idea of maintaining and enhancing the regional ecological environment mostly, the conception of green infrastructure was presented to guide Wuyi new town's sustainable development. As a city's natural service system, Wuyi new town's green infrastructure aims at exploring a planning and design operation mechanism, and forming the "Wuyi Model" that features rational and efficient oasis city development.

When facing the particular environmental conditions of oasis, the green infrastructure of Wuyi new town turned out to be an effective planning strategy to ease environmental pressure, adjust the ecological benefit of urban vegetation and balance the environmental capacity and city's sustainable development.

Endnotes:

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