

Riverside Restoration Through Ecological Landscape Design

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Abstract

Riverside regional landscape have been the most representative and valued part of human-dominated landscape for thousands of years. With the development of social economy and the enhancement of urbanization, riverside areas in landscape are facing a variety of issues: the ecosystem of the riverside is being destroyed; the reconstruction of the riverside is blind and utilitarian; river-side public space is getting smaller and smaller. Therefore, how to restore the riverside landscape has become a hot topic in the field of landscape architecture today. Furthermore, the phenomenon of “the same model of face” is staged in riverside area landscape. In order to effectively solve the challenges that landscape of riverside area facing, the riverside restoration by ecological landscape design was proposed by many scholars. The study will compare 3 studies of riverside restoration, to find the effective and reasonable ecological landscape design strategies for riverside restoration.

Keywords

Riverside landscape; Ecological landscape design; Riverside restoration.

1. INTRODUCTION

River have been a valued part of human-dominated landscapes for thousands of years [1] because it provides various services, from water resource to recreation, and to support habitats for plants and animals [2]. Riverside is a term for land and river interface as a unique city's space and is an important nature geographical element in urban landscape, as well as an important ecological corridor. However, the rapid social development has brought many environmental problems on riverside while improving the economy, such as: the destruction of the natural environment, the waste of natural resources, the imbalance of the ecosystem, etc [3]. The riverside area as the main gathering place for citizens has also encountered many severe challenges. Rivers are gradually becoming place to discharge sewage due to people blindly pursuing economic benefits and weak environmental awareness, a large amount of rubbish was thrown into river, people cut forests uncontrollably and reclaimed land from rivers, resulting in massive of soil erosion and damage to the riverside ecosystem [4]. In order to effectively solve these issues that riverside area facing, the ecological landscape design for restoring riverside area is one of the alternative solution. Its can largely alleviate the environmental problems of riverside, and improve the ecological quality of riverside.

2. LITERATURE REVIEW

2.1. Ecological Landscape Design

Ecological design refers to the relationship between human and nature in a coordinated manner. It is necessary to consider not only the comfortability of people in the environment,

but also the coordination between the site and the natural environment if ecology is applied to landscape design. This is a comprehensive design concept and method [5]. Landscape ecology was defined that “the study of the structure, function and change in a landscape [6]” by Richard Forman and Michael Godron (1986). Thus “ecological landscape design is based on an ecological understanding of landscape which ensures a holistic, dynamic, responsive and intuitive approach. It is responsive because it develops from a realization of the constraints and opportunities of context whether natural, cultural or a combination of both [7]”. Ecological landscape design is not a new concept. The first book that highlight the importance of riverside restoration by ecological landscape design was Ian McHarg’s *Design with Nature* in 1969, and taking the riverside landscape design in Pototomac River as an example, it showed how to restore the riverside though the combination of nature and ecology [8]. Engineers (1988) pointed out that “the ecological environment, spacial characteristics and historical culture of the riverfront area should be taken seriously” [9]. Yu (1998), a famous professor in Beijing University, explained that “the riverside area is an ecological sensitive area that contains diverse species and complex ecosystem from the perspective of landscape ecology [10]” in his book entitled *Landscape: culture, ecology and perception*. As ecological landscape design has received more and more attention in the field of riverside landscape, scholars and designers began to apply the concept of ecological landscape design in riverside restoration. The landscape renewal design of Clyde River-side in Scotland is one of the typical riverside restoration cases of ecological landscape design, it is designed for restoration from ecological environment, historic relics and urban context [11]. Bruns (2007), a Landscape planning Professor, pointed out that the effect of ecological landscape design is not immediate, it may be implemented after 10 years or 20years [12]. A research by Liu (2009) studies that applying the concept of ecological compensation design to the landscape reconstruction of urban disused area, which has an important reference for the application of ecological compensation design in landscape design [13]. Zhen (2011) conducted a study in ecological landscape design of old urban riverside area, proposed that 3 strategies including ecological compensation, historical context compensation and transportation system compensation, which provided a new idea for restoring river-side area [14]. A comprehensive guideline has been suggested by Kalantari (2015) who identified the ecological issues of the Tajan Riverside from literature, observation and interview with experts. The guideline consists of principles and methods that may be useful for the ecological restoration of the riverside [15].

2.2. Ecological Restoration

Ecological restoration of riverside is method of using the principles of ecosystem to restore dam-aged riparian ecosystems. Linking ecological research and restoration is essential for riverside restoration. This method can not only rebuild healthy ecosystem on riverside, repair and strengthen the main functions of river ecosystem, but also coordinate and maintain the cycle of ecosystem on riverside [16]. Due to severe floods in the history, people have made great efforts in the development of riverside flood prevention measures, thus restoration techniques of riverside were gradually improved. Traditional idea of riverside protection is mainly stone and concrete, which have damaging effects on ecological by isolating the material exchange between soil and water [17]. Natural ecological restoration methods can be adopted in riverside area with low requirements for flood control [18,19,20,21]. Plants are selected to be planted on the riverside, the roots and stems of the plants can protect the riverside area, which can also play a role in flood control. Moreover, soil and bioengineering method can also be used in recent years. This method is the use of living plant materials to construct structure that prevent soil erosion and provide stable living habitats on riverside, it was applied to a riverside restoration project in Shanghai of China, and achieved a positive results [22]. engineering ecotypes restoration methods are commonly used on riverside areas where severe soil erosion occurs

and flood control is more demanding [23,24,25], e.g., gabion or stakes are set at the foot of the slope, and combine vegetation with reinforced concrete on the slope. Non-biological hydrophilic materials with high water permeability can be used after the riverside is restored, since they not only meet the requirements of filtration, but also provide habitat conditions for the growth of aquatic plants and animals. A successful case is the riverside restoration of the Crow Creek located in US. This approach was used in the project and achieved a good results [26]. With the improvement of people's awareness of ecological protection, some new restoration methods of riverside which meet variety of requirements (i.e. ecological health, flood control, ecological landscape, etc) have been applied. Park's (2013) research explained that it is essential to build ecosystem information that can be used for reference in order to achieve the success of riverside ecological restoration. A reference ecosystem can provide a clear depiction of the objects of the riverside restoration project, thus the study found out a restoration models of riverside vegetation from the Bongseonsa stream, which retain an integrate riverside area [27]. Ecological restoration in urban riverside design has been suggested by Lu(2013), in the project of Jiangdongzhi River in Guangzhou, he suggested restoring the riverbank and controlling flood in three areas: eco-design of revetment, recovery of diversity in river channel and vegetation recovery [28]. Jiang(2015) took the tributary of Daling Riverside in the arid vegen of Liaoning Province as the research object, proposed a mathematical method for comprehensive assessing the structure and function of river ecosystem, then this method was used to evaluate the structure and function of river-side ecosystem, and some measures and suggestions for restoration of riverside ecosystem were arisen [29]. Lange(2015) conducted a new design process for restoring the small urban riverbank, the model-based design, the model-based design can not only analyze the defects in river morphology and establish new habitat information, but also help to estimate the temporal availability of high quality habitat [30]. Zhao(2015) applied three ecological restoration technologies, namely water self-restoration, biological floating island and ecological slope protection, to the urban cannal restoration project, which provide valuable reference for the sustainable construction of urban canal [31]. Chou(2016), in his research on successful riverside restoration in dense urban area, highlighted that people's positive attitudes towards riverside restoration were mainly related to landscape aesthetics and recreational value, the findings revealed that using the project of the Cheonggyecheon stream in South Korea as a framework for riverside restoration seems effective in providing local people with an example of riverside restoration, based on aesthetic and recreational improvement [32]. A study by Tian(2016) showed that riverside restoration has become the focus of urban development planning and watershed management. Three typical revetment(original revetment, natural revetment and hybrid revetment) are used in riverside restoration projects, and provide planting suggestions for each area. The aim of the study is to provide a feasibility reference for the restoration of riverside area [33]. Mi(2018) pointed out that the main reason riverside pollution is industrial waste water and domestic sewage, using plants to purify the riverside, so as to establish a good ecosystem is one of the most important content of riverside landscape construction. In addition, the author also puts forward a combination of ecology and humanity to maintain the aesthetic of the riverside landscape, and achieve the vision of symbiosis between human and nature [34]. Ma(2019) took the Dongping river in Foshan as an example, according to the various degrees affected by floods and tides, the conceptual model of the hierarchical design was proposed, and used engineering, ecological and landscape methods to restore the riverside natural habitat [35]. Urban riverside will cause damage to the riverside ecological environment while preventing floods. In order to improve the functions of urban riverbanks in flood control, ecological services and environmental quality, the theory of resilient landscape restoration was proposed, this theory can be used in three strategies(softening, yielding and compound) to achieve a balance between flood control and landscape [36].

3. THE RIVERSIDE RESTORATION BY ECOLOGICAL LANDSCAPE DESIGN

3.1. San Antonio Riverside

San Antonio River is located in South Texas, U.S., and it is a river less than 2m wide. However, it is a life-saving water resource in the Texas Plains, and treasured extremely by people. The San Antonio River has been flooded many times in history, especially after a deadly flood in September 1921 caused millions of dollars in economic losses and 50 deaths. The facilities of flood control for the river was designed and built by the U.S. army corps of engineers in 1968, and although it has been effective in controlling flooding for more than a decade, it has been dull, visually unappealing, and the quality of habitat is poor [37]. To improve the urban environment, the San Antonio River Oversight Committee was built by the San Antonio municipal government, the San Antonio River Authority and citizens' organizations to lead the renovation project of San Antonio River to restore it to its former state.

3.1.1 Ecosystem Restoration

Based on the principles of river geomorphology and hydraulics, the current river was reconstructed, and the river was restored to the form close to the natural river course by widening the river course and increasing the bend degree of the river bed. At the same time, the erosion of the riverbank and the threat of flood were effectively reduced. In addition, plants in riverbed can form shading surface on the water surface and reduce average water temperature, which is conducive to maintaining high oxygen content in the river, promoting plant growth and improving habitat. Maintain habitats of fish and wildlife to ensure the diversity and integrity of the ecosystem.

3.1.2 Planting Design

The original trees should be retained as much as possible. The new trees and shrubs are mainly native species, such as American Redbud, Cedar and Elm. The planting areas are covered with native grass species, such as Grama. The planting of plants in the riverside area should meet the conditions such as water passage capacity and safety of the river, instead of reducing the flood discharge capacity of the river.

3.1.3 Transportation System Design

According to the general plan, the reconstructed road system will supplement the original road and replace some roads. To adjust the road for the improved river course, a 15-mile continuous and complete riverside walk and bicycle path was established. Set the viewing platform and picnic area on the site with better river landscape, and combine the water body to design diversified leisure ways.

3.2. The Fish-birds Riverside of Yantai

The fish-birds River is located in Yantai city, Shandong province, China. connecting the mountains in the south and the seaside in the north with a total length of 22.5km. The river was originally a clear river, however, in previous years, due to the development of the middle and lower reaches of the river, a large number of trees were cut down, the river channel silted up, overgrown with grass, and the ecosystem was severely damaged. With the enhancement of people's awareness of environmental protection, the Yantai municipal government began to build the fish-birds River in 2010, restore its ecological landscape system, rationally protect and utilize natural resources within the region, and enhance the ecological value of land around the riverside.

3.2.1 Ecology Restoration

The flood discharge function of the fish-birds River deep water area is retained, the original riverbank is lowered below the water surface, and the shallow wetland landscape is created in the flood discharge buffer area. It gives enough space for water flow, meets the functional

demand of flood discharge, and recovers the wetland ecological landscape. The green path of different sizes of natural ecology becomes the breeding habitat of various creatures, forming a rich ecosystem. At the same time, the fish-birds River after restoration has the function of rainwater filtration and purification, which can permeate, regulate and purify the rainwater runoff of green land and surrounding areas, restore the natural circulation of water through natural infiltration, and make it a buffer zone between the city and natural wetland, forming a filter membrane between the city and nature. In addition, permeable pavement design is adopted in the site to form a good stormwater treatment system.

3.2.2 Plant Selection

On both sides of the river bank, the original plants are kept, with local tree species as the keynote tree, such as locust, elm, white wax, sequoias, willow, cherry, etc. The plants with rich leaf color and high ornamental value are selected as the backbone tree species to form the riverside landscape with distinct seasonal changes. At the same time, the succession rules of aquatic plants and plant communities were taken into consideration, and wetland plants such as Gramineae, Legume and Compositae were added to form a diversified community structure and create valuable habitat environment for plants and animals.

3.3. Bachuan Riverside

Bachuan river is located in Tongliang city of Chongqing in China. The whole river runs through Tongliang city, from Shuang river into Huanyuan river. The main river is about 11.3 kilometers long. With the development of society, the surrounding of the Bachuan river is heavily urbanized, with large areas of residence, restaurants and factories clustered on both sides of the river. A large number of riverside plants are reduced because of the serious urbanization around riverside, and the healthy circulation and habitat are damaged, which the habitat of plants and animals are separated, isolated and destroyed. Due to the destruction of Bachuan riverside was getting worse, people began to restore the riverside. However, most of the transformation process ignored the natural environment and ecological balance of river, designer transforms the natural river bank into stone or concrete artificial revetment, although this path seems to consider flood management, it cause great damage to the river's ecosystem, the self-purification capacity of river is reduced, followed by the disappearance of habitats of animals and plants.

3.3.1 Transportation

The transportation system is an important system connecting various landscape elements[38]. The design of the riverside transportation system respects the change of topography. The characteristics of the current topography should be kept, and the artificial change of topography should be weakened. At the same time, the material of the road is selected for permeable and environment-friendly, which reflects the application of the concept of ecological compensation

3.3.2 Wetland Ecosystem

Wetland ecosystem is rich in flora and fauna ,and it has significant role in the maintenance of bio-logical balance. At the same time , the operating cost of artificial wetland is low and the management is easy, so its environmental and economic benefits are very significant [39]. The compensation design of the wetland ecosystem should be based on botany and river ecology, considering the problem of wetland clogging, it is best to combine with sand filtration, oxidation, flocculation and sedimentation in artificial wetland. In addition, some plant species with strong purification ability and easy management can be selected.

3.3.3 Buffer Zone

The buffer zone is a transitional zone between water and land, the lined adjacent river ecotone has a obvious edge effect in the ecosystem, and the role of the buffer peak [40]. at the same time it plays an important role in flood detention, soil erosion prevention, and degrade

environmental pollution [41]. The buffer zone can be designed into three areas. The area closest to the river channel is area A, which is mainly decorated with deciduous trees and shrubs. Area A is designed to ensure the stability of the riverside ecosystem and riverbank soil. Area B is outside area A, which is mainly decorated with trees and shrubs with landscape effects. The function of zone B is to increase the appreciation of riverside space under the premise of protecting soil and water and ecology. Zone C is the furthest part of the buffer zone, which is mainly equipped with various herbaceous plants. Its function is to purify rainwater and absorb pollutants from surface runoff, which can be designed as gardens or lawns.

4. SUGGESTION

Table 1. Comparison of three studies

	San Antonio riverside	Fish-birds riverside	Bachuan riverside
Issues	The river environment and riverside landscape are damaged	Economic development	The excessive exploration
		cause destruction of riverside ecosystem	The ecological environment of the riverside is damaged.
Ecological Measures	The principle of river geomorphology	Landscape ecology principle Energy-saving	Use materials that are permeable Provide condition for habitats of wildlife
	Reduce the impact of water erosion	Create the ecological island chains	Provide buffer zone
	Use low-flow sites		Protect and enhance
	Design node spaces	Rainwater circulation	for water quality
Planting	Original trees	Keep original vegetation	Keep the natural form of riverside Maintenance the riverside with plants
		Local trees	Chose native plants
Design	Add native trees	Increase wetland plants	Water infiltration with vegetation

In order to identify issues of riverside, three riversides restoration projects were selected and compared based on the similar background and issues of riverside. These projects are: San Antonio Riverside in United States, Fish-birds Riverside of Yantai and Bachuan Riverside of Tongliang in China (Table 1).

Three of main problems of riverside are encroaching and damaged on riverside, river pollution and low percentage of green space by three cases study and comparison. According to the results, several ecological landscape strategies are recommend for restoring riverside, these strategies could be divided into 3 categories through three main problems(Table 2).

Table 2. Ecological landscape strategies recommendations of riverside restoration

Issues	Ecological Landscape Strategies
Encroaching and damaged on riverside	Substitute natural riverside form for hard riverside
	Provide buffer zone
	Maintenance the riverside with plants Use materials that are permeable
	Link isolated spots in riverside
River pollution	Water infiltration with plant vegetation
	Sewage treatment
	Rainwater circulation
Low percentage of green space	Retention with existing plants
	Chose native plants
	Establish wetland as habitats

5. CONCLUSION

Riverside is an important part of the river ecosystem. A good riverside ecosystem can not only help increase biodiversity and reduce river pollution, but also bring benefits to society and economy[42]. With rapid urbanization, riverside ecosystem has been seriously damaged in many ways, and the important function of the riverside has been diminished. Facing increasingly complex ecological problems, this article studies and compares 3 riverside restoration cases with similar background, to find effective ecological landscape design strategies for riverside restoration. These strategies are essential for the protection of riverside along the river and the restoration of ecological balance. The research only focuses on the ecological restoration of the riverside. Future research can focus on improving the sustainable riverside landscape and restoring the historical context of riverside. I hope that these restoration strategies will provide new idea and references for the construction of riverside landscape

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