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Case Report

Ecological dredging and landscape transformation: A sustainable approach to enhancing urban green spaces and forest ecosystems in Xianyang Lake

Xinhui Ding[1,*], Yuanhui Yu[2], Xiaoying Liu[3], Guangquan Liu[3], Xiao Feng[1], Jiayu Wu[1], Jing Cheng[1]

[1] College of Geography and Environment, Xianyang Normal University, Key Laboratory of Environmental Evolution and Ecological Restoration of Weibei Arid Plateau, Xianyang 712000, China
[2] Yellow River Conservancy Technical Institute, Kaifeng 475004, China
[3] China Institute of Water Resources and Hydropower Research, International Research and Training Center on Erosion and Sedimentation, Beijing 100048, China
*** Corresponding author:** Xinhui Ding, dingxh@xync.edu.cn

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Abstract: In order to address severe siltation and enhance urban green spaces in Xianyang Lake, the research offers a sustainable solution by proposing an innovative integration of ecological dredging and landscape transformation. The key findings are as follows: Firstly, an ecological dredging mechanism was established by directly transporting sediment from Xianyang Lake to its central greenbelt, reducing dredging costs and environmental impact while creating a sustainable funding cycle through revenue from eco-tourism activities. Secondly, the landscape artistic conception of the central greenbelt was significantly improved by leveraging the natural distance between the lakeshore and the greenbelt, offering diverse viewing experiences and enhancing the cognitive abilities and urban life satisfaction of tourists. Thirdly, the project demonstrated substantial economic and social benefits, including revenue generation from paid activities like boat tours, increased public awareness of biodiversity through ecological education, and improved community well-being. The central greenbelt also enhanced the urban environment by improving air quality, mitigating the "heat island effect," and providing habitats for wildlife. This integrated approach serves as a model for sustainable urban development, offering valuable insights for cities facing similar ecological challenges. Future research should focus on long-term monitoring to further evaluate the ecological and socio-economic impacts of such projects.

Keywords: ecological dredging; landscape transformation; urban green spaces; sustainable forestry; Xianyang Lake

1. Introduction

With rapid urbanization, the expansion of urban construction land has posed significant challenges for urban planning and environmental management. One of the most pressing issues is the limited availability of urban green spaces. Green spaces, including forests, parks, and water bodies, are essential for maintaining ecological balance, improving air quality, and providing recreational areas for urban residents [1–3]. However, the increasing demand for urban development has led to the reduction of natural green spaces, resulting in ecological fragmentation and loss of biodiversity [4,5]. In this context, landscape transformation has emerged as a crucial strategy to address these challenges by integrating ecological, aesthetic, and socio-economic goals [6–9].

Urban green spaces have gained prominence due to their role in supporting biodiversity and ecosystem services. Recent studies highlight the importance of

integrating ecological restoration into urban planning to address habitat loss and fragmentation caused by urbanization [10–12]. For example, research on urban grassland restoration suggests that decreasing management intensity and using native species can significantly enhance biodiversity. Additionally, studies have shown that urban forests provide numerous ecosystem services, such as nutrient cycling, climate regulation, and mental health benefits [13]. However, there are still gaps in understanding the long-term impacts of restoration efforts, especially in tropical regions [14]. In China, urban green space research has also made significant progress. Studies have focused on the optimization of urban green space design through user satisfaction research, emphasizing the importance of walkability, accessibility, and environmental equality [15,16]. In addition, research on post-industrial landscapes has highlighted the transformation of abandoned areas into green spaces, emphasizing the need for public participation and historical preservation [17]. For example, in the context of Xianyang Lake, severe siltation has led to the degradation of the central greenbelt, characterized by overgrown weeds and a lack of aesthetic and ecological value [18]. Traditional siltation management methods, such as dredging and disposing of sediment in distant locations, are costly and environmentally impactful [19–22]. Therefore, innovative approaches like integrating ecological dredging with landscape transformation are being explored to address these challenges.

Landscape transformation is not only about enhancing the visual appeal of urban areas but also about creating multifunctional green spaces that can support ecological processes and provide ecosystem services [23,24]. By repurposing underutilized or degraded areas, such as silted lakes and abandoned lands, cities can expand their green infrastructure without compromising urban development needs [25–28]. This approach can significantly increase urban green areas, improve microclimates, reduce air pollution, and enhance biodiversity [29,30]. In the case of Xianyang Lake, an innovative solution that integrates ecological dredging with landscape transformation aims to convert the central greenbelt into a sustainable urban forest ecosystem. By utilizing dredged sediment as a substrate for planting native and ornamental trees, shrubs, and flowers, the central greenbelt can be transformed into a multifunctional space that enhances ecological and aesthetic value. The transformed greenbelt can serve as a recreational area for residents, a habitat for wildlife, and a source of economic revenue through eco-tourism and sustainable management [31–33]. This approach aligns with the principles of sustainable forestry by promoting the sustainable use of natural resources, enhancing ecosystem services, and fostering ecological resilience.

This study explores how landscape transformation can be used as a tool to address the dual challenges of urban green space limitations and siltation management. By transforming the central greenbelt of Xianyang Lake into a sustainable urban forest ecosystem, we aim to demonstrate the potential of integrating ecological restoration with urban planning to achieve both environmental and socio-economic benefits. This approach aligns with global trends in urban ecological restoration and highlights the importance of creating multifunctional green spaces that support biodiversity and human well-being.

2. Study area and methods

2.1. Study area

The Weihe River (34°20′02″ N–34°22′15″ N, 108°30′18″ E–108°42′30″ E), known as the mother river of Xianyang, is a significant waterway that carries a high sediment load and experiences high flood peaks with large volumes during the flood season. Before the renovation, the riverbed of the Weihe River in the urban area of Xianyang was overgrown with weeds and severely polluted by litter, significantly impacting the urban ecological environment. In response to these challenges, the Xianyang Municipal Government initiated a comprehensive ecological and landscape renovation project for the Weihe River in 2003 [18], aiming to establish a modern garden-style eco-tourism zone along its banks. As part of this project, Xianyang Lake (34°19.7′ N–34°20.1′ N, 108°42.5′ E–108°42.8′) was created as an artificial lake on the renovated urban section of the Weihe River. It serves both as a tourist attraction and an ecological showcase. The lake, which spans approximately 1.24×10^6 m^2, was formed by using a rubber dam to retain water on the north side of the river, while the south side functions as a flood discharge channel. This design not only regulates the urban climate and improves the ecological environment but also provides recreational and aesthetic value. Currently, the sediment in Xianyang Lake primarily originates from the flood discharge of the Wei River during the flood season (**Figure 1**). Given its relatively low pollution level, priority should be given to utilizing the dredged sediment from Xianyang Lake for ecological and landscape purposes [13]. The overall landscape of Xianyang Lake, however, lacks distinct characteristics and bears many similarities to other scenic spots in China. This presents an opportunity to integrate sustainable forestry practices into the management of Xianyang Lake, transforming it into a unique and multifunctional urban green space that supports biodiversity, enhances ecosystem services, and promotes eco-tourism.

Figure 1. Close-up view of the greenbelt and sediment deposition after flood discharge in the Xianyang Lake.

2.2. Methods

Inspired by the method of managing West Lake recorded by Su Shi in "Biography of the Six Wells in Qiantang" [34,35], this paper proposes a study on enhancing the landscape aesthetics of the central greenbelt in Xianyang Lake based on the concept of ecological dredging. This study aligns with the principles of sustainable forestry by promoting the sustainable use of natural resources and enhancing ecosystem services. The use of dredged sediment for landscape transformation not only reduces waste but also supports the growth of native and ornamental plants, fostering biodiversity and ecological resilience. Additionally, the integration of cultural and ecological elements in the landscape design aims to create a unique and multifunctional urban green space that supports both environmental and socio-economic.

The first step involves using ecological dredging technology to remove the nutrient-rich silt deposited at the bottom of Xianyang Lake and transport it into the central greenbelt. This method not only addresses the issue of sediment accumulation but also provides a valuable substrate for landscape transformation. Following the dredging process, flowers and trees with distinct seasonal characteristics will be planted in the greenbelt. This strategy ensures that the area offers diverse and attractive scenery throughout the year, engaging visitors' senses of vision, smell, and hearing. The planting design leverages the natural distance between the lakeside and the greenbelt to create spaces that highlight the artistic beauty of the landscape. To further elevate the aesthetic and cultural value of the greenbelt, the design will incorporate elements of traditional Chinese landscape aesthetics, inspired by the successful transformation of West Lake. This includes creating scenic views that harmonize natural and cultural elements, providing visitors with a unique and immersive experience. By enhancing the landscape aesthetics and cultural appeal of the greenbelt, the study aims to attract more tourists to participate in paid activities such as lake tours. The revenue generated from these activities will be reinvested in the ecological dredging and maintenance of Xianyang Lake, establishing a long-term, self-sustaining management mechanism (**Figure 2**).

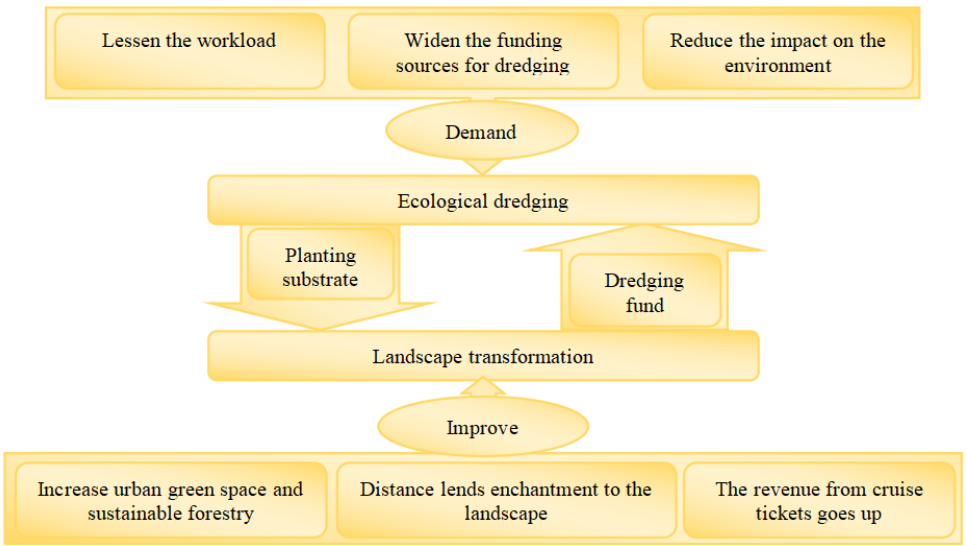

Figure 2. Roadmap for the landscape planning of the central greenbelt based on the ecological dredging concept.

Maps and illustrations for this study were created using Adobe Photoshop CS6 and Adobe Illustrator 2022, respectively. The maps provided a detailed spatial representation of Xianyang Lake and its surrounding areas, while the illustrations were used to visualize the proposed landscape design and transformation concepts.

3. Results

3.1. Ecological dredging of Xianyang Lake and renovation of its central greenbelt

Dredging is a key aspect of river and lake management. To achieve environmentally friendly, efficient, clean, and thorough dredging results, it is crucial to scientifically select dredging techniques. The primary methods for removing silt from rivers and lakes include underwater dredging technology and dry dredging technology. As environmental protection becomes increasingly important, both methods emphasize minimizing environmental impact during construction. In practice, dry dredging is generally not used in urban rivers to protect the residents' living environment. However, underwater dredging can be easily disrupted by large underwater debris, such as dead wood and plastic waste. Furthermore, underwater dredging often results in silt with high water content, which requires a large disposal site if not dewatered. Finding a suitable storage site for dredged material in urban areas with extensive hardened surfaces is a significant challenge. This study innovatively proposes to directly dispose of the silt accumulated in Xianyang Lake into its central greenbelt (**Figure 3**), thereby minimizing the dredging workload, reducing the impact of silt transportation on the urban environment, saving dredging costs, and not disrupting people's enjoyment of the other scenic spots in the lake area.

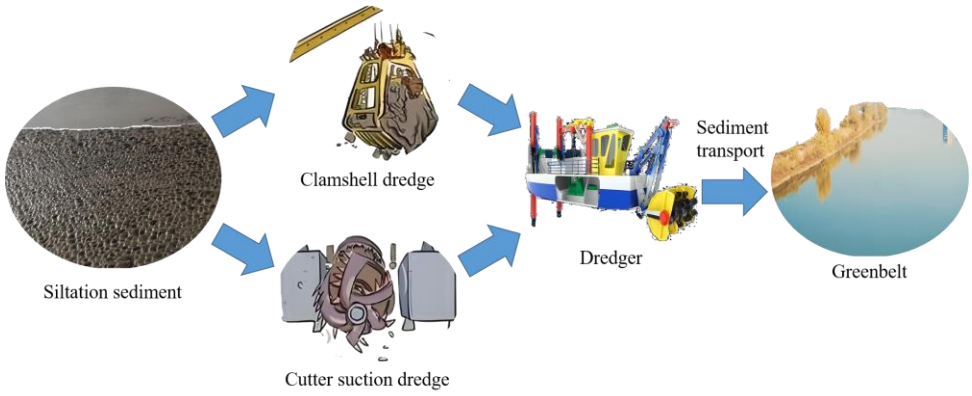

Figure 3. The illustration of ecological dredging process for Xianyang Lake.

The greenbelt in the center of Xianyang Lake is presently overrun with weeds and shrubs, resulting in poor aesthetic appeal. To improve this situation, firstly, an assessment will be conducted based on the growth status, ornamental value, and ecological function of the existing plants within the greenbelt. Plants that are diseased, weak, lack ornamental value, or have weak ecological functions will be removed. Subsequently, new plant species that are highly adaptable, highly ornamental, and capable of enriching the landscape will be introduced. A diagram illustrating the landscape layout is provided (**Figure 4**). Specifically, since the main viewing area is

on the north side, the south inner side of the greenbelt will be planted primarily with suitable evergreen low shrubs, such as Boxwood, Japanese Andromeda, Euonymus fortunei, Nandina domestica, and Sabina chinensis, to form a dark backdrop for the greenbelt. On the north side, plants such as Cherry Blossom, Tulip, Hyacinth, Winter Jasmine, Rose, White Calla Lily, Salvia splendens, Chrysanthemum, Begonia semperflorens, Dianthus, Coreopsis, and Wintersweet will be planted in an alternating pattern to enhance the layered landscape of the greenbelt and ensure good ornamental effects throughout the seasons. Lighting equipment will be added to the north side of the greenbelt to showcase a unique landscape at night.

Figure 4. Landscape design sketch of the central greenbelt in Xianyang Lake.

3.2. Mechanism of landscape artistic creation in the central greenbelt of Xianyang Lake

Based on the widely accepted aesthetic concepts such as “everyone has the desire to appreciate beauty” and “distance lends enchantment to the view”, a flower belt that can be admired in all seasons is created in Xianyang Lake, enhancing its attractiveness for people to enjoy the scenery. A natural aesthetic distance is formed between the flower belt and the lakeside, allowing visitors to view the flower belt from afar on the lakeside, overlook it from the gallery bridge, or admire it while cruising on a boat, thereby enriching their viewing experiences (**Figure 5**). Standing on the 1- or 2-floor of the gallery bridge, people can overlook the central flower belt from different angles, and the mobility of the boats also enables them to appreciate the magnificent scenery of the flower belt from various distances. Similarly, walking along the lakeside, people can smell the fragrance of flowers across the lake and hear the chirping of birds in the woods, enriching their sensory experiences. The diverse ways of enjoying the scenery allow people to experience the artistic conception of “the lake reflecting the flowers, and the flowers highlighting the clarity of the water” while having fun, thus achieving the purpose of physical and mental pleasure.

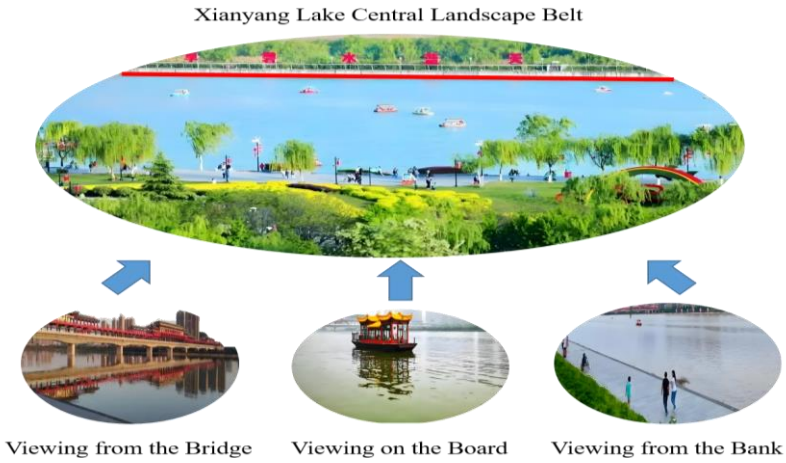

Figure 5. Touring ways of the central greenbelt in Xianyang Lake.

The lake forms a natural barrier between visitors and the central green belt, creating the distance that is necessary for appreciating the beauty of the scenery. When the central green belt forms a flower wall, it is fully exposed to the visitors. The flower belt on the opposite shore presents a magnificent beauty, and with the change of seasons, it adds a sense of variety to the beauty. Its reflection in the water enriches the layered beauty of the landscape. The flower belt on the opposite shore and the lake constitute the basic elements that create the artistic conception. Changes in the time of day, the backdrop of wind, rain, frost, and snow, as well as the embellishment of the sun, moon, and stars, all contribute to the creation of a variety of beautiful scenic conceptions.

The creation of artistic conception follows a certain path and requires a medium for transmission or enhancement, such as the reflection of water, the blowing of wind, or the placement of stones and sculptures. Landscapes with artistic conception should be ever-changing. The more varied a landscape is, the more likely it is to evoke artistic conception. In the process of perceiving artistic conception, it is best for people to engage multiple senses, such as seeing the reflection of flowers in water, hearing the chirping of birds in the forest, and smelling the fragrance of flowers from afar. Through the involvement of vision, hearing, and smell, people discover the charm of nature. Therefore, the perception of artistic conception by people necessitates the variety of landscapes and the engagement of multiple senses, gradually enhancing their ability to perceive artistic conception.

3.3. Impacts of the central greenbelt of Xianyang Lake on urban ecological environment

The central greenbelt of Xianyang Lake not only enhances the urban landscape value but also significantly improves the city's ecological environment (**Figure 6**). Through extensive vegetation cover, it effectively absorbs carbon dioxide from the air and releases oxygen, reducing urban air pollution, such as dust and harmful gases, and thereby markedly improving the city's air quality. The plants in the greenbelt release water through transpiration, helping to lower the ambient temperature and increase air humidity, thus creating a more pleasant climate for the city. This improvement in microclimate plays a vital role in mitigating the urban "heat island effect".

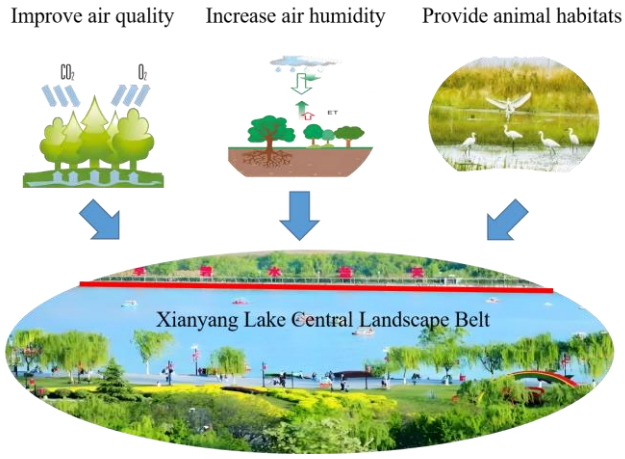

Figure 6. Impacts of the central greenbelt in Xianyang Lake on the environment.

The central greenbelt of Xianyang Lake provides migration corridors and habitats for birds and other wildlife, thereby promoting the protection of urban biodiversity. The rich vegetation and ecological landscape within the greenbelt create a favorable living environment for wildlife. Connected with surrounding landscape projects, the central greenbelt of Xianyang Lake forms a large urban ecological leisure park that integrates ecology, landscape, and recreation, providing citizens with beautiful venues for leisure and entertainment.

To further enhance the ecological and functional benefits of the greenbelt, sustainable management practices have been implemented. These practices include the establishment of a flower base within the greenbelt, which serves as a cultivation area for precious flowers and trees. This not only enriches the biodiversity of the greenbelt but also provides a source of native and ornamental plants that can be used for restoration and enhancement projects. The cultivation of these plants is carried out using sustainable methods, such as organic fertilization and water-saving irrigation techniques, to minimize environmental impact and ensure long-term ecological health. Additionally, the flower base acts as an educational and recreational space, allowing visitors to learn about plant conservation and sustainable gardening practices. Through these integrated sustainable management strategies, the central greenbelt of Xianyang Lake continues to provide multiple ecological, social, and aesthetic benefits to the city and its residents.

4. Discussion

4.1. Establishment of an ecological sediment dredging mechanism for Xianyang Lake

Ecological dredging refers to the process of dredging without damaging the surrounding environment, achieving good dredging results with minimal investment and workload. During the dredging process, emphasis should be placed on protecting the lake's ecosystem by adopting ecologically friendly dredging methods, such as biological methods, to minimize damage to the ecological environment. Deribe et al. [36] believes that ecological concepts should be integrated into the process of river sediment removal, and an ecological dredging industry chain should be established on

this basis. To ensure the scientificity and effectiveness of the dredging work, Lee et al. [37] and other researchers argue that river restoration requires the use of "3S" technology to study river ecological functional reconstruction on a large scale. Based on individual practice, Li et al. [38] summarizes that sewage interception, river dredging, waste management, and river water utilization are the most effective measures for comprehensive river pollution control. The dredged sediment should be utilized reasonably, such as for the construction of landscape islands or the reinforcement of middle partition walls, to achieve resource recycling. This study proposes to clean up the dredged sediment in the central greenbelt of Xianyang Lake, enhancing the landscape's artistic conception to attract tourists to participate in paid activities such as boating, with the resulting revenue being reinvested in the dredging project. This forms a closed loop for sediment reuse, promoting long-term harmonious development between ecology and economy.

4.2. Utilization of the landscape artistic conception in the central greenbelt of Xianyang Lake

As an important component of the city's ecology and landscape, the central greenbelt of Xianyang Lake primarily contributes to enhancing the city's image and reputation, promoting eco-tourism development, and fostering a sense of belonging and happiness among citizens through the utilization of its landscape artistic conception [39]. The exquisite scenery and beautiful environment within the greenbelt add a unique charm to Xianyang Lake, making it a landmark area of the city.

Leveraging the stunning landscape of the greenbelt, the Xianyang Lake scenic area can vigorously develop eco-tourism projects, such as paid boat tours, allowing tourists to deeply experience the natural beauty of the greenbelt while also stimulating the development of surrounding industries like dining and lodging. The central greenbelt of Xianyang Lake provides a place for citizens to get close to nature and relax. They can take walks, stop and admire the view, and enjoy the tranquility and comfort brought by nature, thereby enhancing their sense of belonging and happiness towards the city.

The creation of a landscape artistic conception in the central greenbelt of Xianyang Lake has significant implications for other landscape transformations, primarily in two aspects: (1) "Blank Space" in Landscape Design: Drawing from Chinese traditional garden art, the greenbelt incorporates "blank spaces" that allow tourists to appreciate the landscape from an overall perspective to the details and then revert to the overall view. This technique enhances the multi-dimensional charm of the landscape's artistic conception. (2) Integration of Scenic Elements: The combination of beautiful scenery with water features, such as the lake and surrounding vegetation, elevates the quality of the landscape and enriches visitors' experiences [39]. This integration of multiple scenic elements creates a more immersive and aesthetically pleasing environment [40]. By combining sustainable management practices with thoughtful landscape design, the central greenbelt of Xianyang Lake serves as a model for urban ecological restoration and sustainable development, contributing to both environmental health and social well-being.

4.3. Ecological and economic benefits analysis of the central greenbelt of Xianyang Lake

The designed landscape of Xianyang Lake's central greenbelt has multifaceted economic and social impacts on the citizens, fostering both economic growth and community well-being. The central greenbelt attracts tourists through paid activities like boat tours, lakeside dining, and accommodation, generating revenue that supports ecological dredging and maintenance. This, in turn, creates a sustainable funding cycle and employment opportunities in the landscaping, tourism, and education sectors. The enhanced aesthetics and ecological value of the greenbelt improve Xianyang's image, potentially increasing property values and attracting further investment, which boosts the local economy. By establishing a flower base within the greenbelt to cultivate precious flowers and trees, the initiative enriches biodiversity and provides native and ornamental plants for urban greening projects. This reduces costs for external plant sources and creates economic value through sustainable landscaping.

The greenbelt offers a tranquil space for citizens to relax, walk, and connect with nature, enhancing their sense of belonging and happiness, and fostering a stronger community identity. The multifunctional space, equipped with walking paths, birdwatching points, and educational signs, encourages physical activities like walking and jogging, promoting health and reducing stress. Regular ecological education activities, such as plant identification lectures and sustainable gardening workshops, raise public awareness of biodiversity and environmental management, encouraging sustainable practices among citizens. The integration of traditional Chinese landscape aesthetics into the greenbelt's design provides unique cultural experiences, enriching citizens' understanding of local heritage and enhancing their appreciation of natural beauty.

By combining economic benefits with social well-being, the designed landscape of Xianyang Lake's central greenbelt serves as a model for urban ecological restoration and sustainable development, contributing to both environmental health and community prosperity.

Future research should focus on long-term monitoring of the transformed greenbelt using technologies like remote sensing and GIS to evaluate ecological impacts and the effectiveness of ecological dredging techniques in different environments. Economic sustainability studies are needed to analyze cost-benefit ratios and explore funding mechanisms such as public-private partnerships and green bonds. Research should also assess the revenue potential of eco-tourism and the economic benefits of improved urban environments. Social impact assessments should measure public satisfaction, recreational use, and the role of green spaces in enhancing community cohesion. Strategies to increase public engagement and education in ecological projects should also be explored.

5. Conclusions

In response to the severe siltation of Xianyang Lake, limited urban disposal space, significant and difficult-to-source funds for dredging, as well as the lack of artistic conception in the lake's greenbelt landscape and poor tourist experience, this study innovatively proposes a landscape renovation and enhancement model for the

central greenbelt of Xianyang Lake, incorporating the concept of ecological dredging. The main achievements are as follows:

(1) An ecological dredging mechanism for Xianyang Lake sediment has been established. Firstly, the silt accumulated in Xianyang Lake is directly dredged and disposed of in its central greenbelt, providing soil substrate for the vegetation transformation of the greenbelt. Then, by creating an artistic conception within the central greenbelt landscape to attract tourists to participate in paid tour projects, the revenue generated is in turn used to fund the sediment dredging project of Xianyang Lake. The establishment of this dredging mechanism has reduced the dredging workload, minimized the impact of sediment transportation on the urban environment, saved dredging costs, and ensured that people can still enjoy other landscapes in the lake area.

(2) The artistic conception of the central greenbelt landscape in Xianyang Lake has been created. Initially, the natural distance between the lakeshore and the central greenbelt was utilized to create a readily perceptible landscape artistic conception. The renovated central greenbelt offers more diverse tour options, such as boating to view flowers, gazing at the flower belt from the shore, and overlooking the flower belt from a bridge. Instead of the monotonous activity of boating for entertainment, people now enjoy boating to appreciate the beautiful scenery and get closer to the natural water area. The renovated landscape, by creating scenic spots full of artistic conception in different seasons, guides people to enhance their cognitive abilities regarding landscape artistic conception, thereby improving their sense of happiness in urban life.

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