Assessment of eco-economic effects of urban water system connectivity project

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Abstract
As one of the large ecological infrastructures, the urban water system connectivity (UWSC) project is an important part of urban ecosystem construction. It is helpful for the scientific planning and construction of the project to systematically evaluate the effects. However, due to the complex and various effects of UWSC project, there is no complete effect system and quantitative method. Against this backdrop, the composition and mechanism of positive and negative effects of ecological economics of UWSC project were deeply analyzed to improve the composition system of eco-economic effects in this study. At the same time, the emergy theory was used to put forward the quantification method of eco-economic effect system. Taking the UWSC project in Xuchang as an example, its ecological, social, and economic effects were evaluated. The result showed that the average eco-economic effect of the project is 49.97 million dollars/year. Economic effect and ecological effect are significant, accounting for 82.49% and 15.89% of total effect, respectively. This study can provide reference for comprehensive and unified assessment of eco-economic effects of UWSC project.

Keywords Emergy theory · Urban water system connectivity project · Ecological economic effect · Composition system · Quantification

Introduction
River system is the carrier of water resources, the component of the ecological environment, and the foundation of economic and social development (Olaj et al. 2012). Urban development cannot be separated from the river and lake ecosystem. As an urban open space, UWSC project has eco-economic effects, such as improving water quality, providing recreational places, and increasing the value of real estate (Anderson and West 2006; Brander and Koetse 2011). It can provide good resources and ecological environment for urban development. In recent years, a large number of UWSC projects have been built all over the world, such as Boston Park system in the USA, the restoration of Bishan-Ang Mao Kio Park and Kallang River in Singapore, and the Wuhan Dadong Lake ecological water network project in China. The advantages and disadvantages of the UWSC project can be objectively assessed by analyzing and quantifying the ecological, social, and economic effects of the project, so as to carry out scientific and reasonable planning and construction of the project and realize the sustainable development of the city (Grizzetti et al. 2016).

The UWSC project connects rivers and lakes through channels and builds or expands artificial water bodies such as lakes and wetlands. It increases the water surface area, strengthens the hydraulic connection between water bodies, and produces a series of ecological, social, and economic effects (Fu 2014; Wang et al. 2011). At present, many studies have pointed out that UWSC project has a significant impact on ecology. The construction of the project not only affected regional hydrometeorological factors such as precipitation, evaporation, and temperature but also changed the connectivity pattern of river and lake systems. It helps
to improve the urban microclimate, enhance the comfort of the surrounding environment, ameliorate the water quality, and provide a high-quality place for the survival and reproduction of organisms (Bennett and Saunders 2011; Cui et al. 2017; Park et al. 2017; Qin et al. 2020; Rivers-Moore et al. 2016; Xiang et al. 2015; Yang et al. 2020b). At the same time, the construction of the project will have an impact on the economy and society. The connectivity of river and lake systems is beneficial to maintain the ecological integrity of landscape (Lane et al. 2018). The project combines local cultural characteristics to bring people spiritual enjoyment and physical relaxation. In addition, the city’s water safety has been improved after the project was completed, and people are more willing to live near the water (Asakawa et al. 2004; Volker and Kistemann 2011).

Some scholars have evaluated the water system connectivity project. Yang et al. (2019b) took the connectivity project of Tangxun Lake Group as an example to establish a comprehensive evaluation system including hydrodynamics, water quality, and social economy to select the optimal water diversion scheme. Zhang et al. (2021) proposed 15 ecosystem evaluation index systems to analyze the relationship between water system connectivity project and environmental indicators by using analytic hierarchy process (AHP). Zhu et al. (2021) used fuzzy comprehensive evaluation to quantitatively evaluate the comprehensive benefits of water system connectivity projects according to the three characteristic indexes of water system connectivity, landscape fragility, and water quality pollution. Cai et al. (2017) calculated the incremental value of ecosystem services of river connectivity project by using market valuation method and replacement cost method and proposed an optimization research method to maximize incremental value. Yang et al. (2020a) divided the water system connectivity project into four functional areas, fish pond, crab pond, reed wetland, and marsh wetland, and analyzed their ecological service value under three scenarios of low flow year, normal flow year, and high flow year. These studies mostly use fuzzy mathematical methods or external-effect internalization method to monetize non-market commodities such as ecological and social effect, but these methods are difficult to accurately measure their real value (Steinhorst et al. 2015). Emergy theory takes emergy as the benchmark and integrates the ecological economic effect into a common non-monetary unit-solar emergy joules (sej) to quantify (Liu et al. 2019b). Thus, the unified measurement of ecological economic system can be realized. Wu et al. (2018) calculated the eco-economic value of water resources in Qingyi River Basin by using the emergy method. Liu et al. (2019a) calculated the value of ecosystem services before and after dam construction using emergy theory. Wu et al. (2022) calculated the ecological environmental values inside and outside the river through the emergy method. However, there are few studies on quantifying the effect of UWSC project by using emergy method.

Based on the above problems, this paper started from the function of UWSC project and analyzed the composition system and mechanism of the positive and negative effect of project from three aspects of ecology, society, and economy. The emergy theory was introduced to put forward the emergy evaluation method of ecological economic effect system of project. It provided a new idea for quantitative analysis of UWSC project. At the same time, this paper took the UWSC project in Xuchang as an example to evaluate the eco-economic effects produced by the project, which provided a basis for the value evaluation, planning, and management of the project.

**Materials and methods**

**Materials**

**Study area**

Xuchang City (N 33°42′–34°24′, E 113°03′–114°19′) is located in the central part of Henan Province, China, covering an area of 4996 km², with an average altitude of 72.8 m. The annual average temperature of Xuchang is between 14.3 and 14.6 °C, and the annual average precipitation over the years is between 671.1 and 736 mm. The rivers in Xuchang belong to the Shaying River basin of the Huaihe River basin. There are 4 rivers with the catchment area more than 1000 km², including Beiru River, Yinghe River, Shuangji River, and Qingyi River. There are 19 rivers with the catchment area more than 100 km².

In May 2013, Xuchang municipal government carried out the UWSC project in central urban area of Xuchang City. The main measures are as follows: ① Qingyi River was connected with Xiaohong River; ② the Qingyi River was connected with Yinma River; ③ Yinma River was connected with Xueyuan River; ④ Shiliang River, Qingyi River, Beihai Lake, and Xueyuan River were connected; ⑤ the Xueyuan River was connected with Furong Lake and Luming Lake; ⑥ Xufu Canal was connected with Xiaohong River; ⑦ Furong Lake, Luming Lake, Baling Lake, and Wetland Park were built; and ⑧ the river section was dredged and supporting facilities such as green space and parks were built. Through this project, rivers and lakes were connected, resulting in a complete ecological water system. Based on field investigation and information provided by the Xuchang government, after the completion of the UWSC project, the water surface area has reached 433.33 hm², 125 hm² more than before. Combined with OSM vector data (Geofabrik Download Server) and Google Earth Remote
Sensing Image, the schematic diagram of UWSC project in Xuchang is shown in Fig. 1.

**Data sources**

The UWSC project in Xuchang was constructed from 2013 to 2015, so 2010~2012 (before the completion of the project) and 2016~2018 (after the completion of the project) were selected as the research period. The data used mainly include the original data needed to calculate the emergy index, the original data and correlation coefficients needed to quantify eco-economic effect, and solar transformity. The main data sources are shown in Table 1.

**Methodology**

**Emergy theory**

Emergy theory was established by Odom H.T., a famous American system ecologist. He defined the emergy as the amount of energy in one kind of flow or storage that contains another kind of energy. Based on emergy analysis, energy from different sources and properties can be uniformly converted into the same standard for measurement and analysis. The unified quantification of energy flow, logistics flow, money flow, and other ecological flow is realized. Any energy is directly or indirectly derived from solar energy.

**Table 1 The data sources in this study**

| Data type                                                                 | Data sources                                                                 |
|--------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Socio-economic data (industrial, agricultural and living raw data, pollutant discharge amount, finance) | Henan Statistical Bureau (2011–2019); Xuchang Statistical Bureau (2011–2019); National Development and Reform Commission (2011–2013,2017–2019); The Expenditure of Xuchang Water Source Dispatch Center |
| Natural data (precipitation, surface water, evaporation, species numbers) | Xuchang Water Conservancy Bureau (2010–2018); The Status Water Resources Evaluation Report of Qingyi River Basin of Xuchang; Hao (2018) |
| Solar transformity                                                        | Lan et al. (2002); Carey et al. (2011); Sun et al. (2019)                   |
Therefore, solar emergy is taken as the benchmark; other types of energy are converted into solar emergy through the solar transformity for unified analysis (Odum 1996). The formula is as follows:

\[ EM = \tau \times B \]  

(1)

In the above formula, \( EM \) is emergy (sej), \( \tau \) is the solar transformity (sej/J or sej/g), \( B \) is the energy or material quality (J or g).

According to emergy analysis method, the relationship between solar emergy and currency can be established through emergy/currency ratio (EDR). The emergy/currency ratio of a country (or region) is equal to the ratio of the total annual energy input in the economic system of the country (or region) to the current gross domestic product. EDR can convert the emergy of the ecological economic system into equivalent market currency value. Thus, the problem that it is difficult to uniformly measure the income of natural resources and the monetary income of economic society is solved (Lan et al. 2002).

It can be seen that emergy method is not a substitute for currency to measure economic behavior, but a perfection of traditional economic methods (Lv et al. 2021). In this paper, the eco-economic effects of UWSC project were fully considered, and a relatively scientific and perfect effect quantification system was established by using emergy method.

**The composition of eco-economic effect**

Water resources play an irreplaceable role in the development of human society and urban economy. As the carrier of water resources, the construction of UWSC project will inevitably produce a variety of effects. According to the analysis, the project increases the urban water surface area, which leads to local climate improvement, enhances biodiversity by connecting the bodies of water. It can also transport sediment, purify water quality, and protect the ecological environment health, so the construction of the project has ecological effect. The project enriches the urban landscape, increases the recreational places for residents, and strengthens the flood control ability. The research related to the project is also increasing gradually. The construction of the project promotes the social development and has social effect. The urban waterfront formed by the project has become an important position in the economic development of the city. The construction of the project enhances the value of the surrounding land and has economic effect. However, the construction of UWSC project and supporting facilities needs capital investment, and the daily maintenance of the project will also bring corresponding negative economic effect. To sum up, the positive and negative effects of ecology, society, and economy brought by the project were considered synthetically and a relatively complete system of eco-economic effect was constructed (Fig. 2).

**Emergy assessment method**

Before the completion of the project, the urban water system itself had eco-economic effects, such as regulating climate and providing recreational places. The construction of the project changed the size of these effects. In this paper, the difference in the effects size between before and after the completion of the project is taken as the eco-economic effects produced by the project.

\[ EM = EM_2 - EM_1 \]  

(2)

where \( EM \) is the effect of project (sej), \( EM_1 \) is the effect before completion of the project (sej), \( EM_2 \) is the effect after completion of the project (sej).
Emery assessment method of ecological effect

(1) Climate regulation effect The UWSC project increases the urban water surface area; water evaporation increases the air humidity, lowers the local temperature of the city, and relieves the urban heat island effect. Therefore, it can be considered that the evaporation energy of water reflects the climatic regulation ability of the project. The climatic regulation effect is calculated as (Yang et al. 2019a):

\[ EM_q = E \times S \times \rho \times G_w \times \tau_{wrt} \]  

(3)

where \( EM_q \) is the climate regulation effect (sej); \( E \) is the annual evaporation in the study area (m); \( S \) is water surface area \((\text{m}^2)\); \( \rho \) means the density of water; \( G_w \) is the water’s Gibbs free energy \((J/g)\), which equals to 4.94 (Brown and Bardi 2015); and \( \tau_{wrt} \) is the solar transformity of water transpiration \((J/J)\).

(2) Biodiversity conservation effect UWSC project is an important habitat and ecological corridor for supporting urban biodiversity, which can provide a variety of habitats for animals and plants in and around urban water bodies. As an important connecting channel of urban ecosystem network, project enhances the connectivity of ecological network system, which is conducive to energy flow and material exchange among biological species. Green Spaces around the river system also provide breeding grounds for birds, amphibians, and reptiles, thus helping to maintain the overall biodiversity of the city. Biodiversity conservation effect can be expressed by the number of species and the area of biological activity in the region, and the calculation formula is as follows:

\[ EM_B = \tau_b \times N \times R \]  

(4)

where \( EM_B \) is the biodiversity conservation effect (sej); \( \tau_b \) is the average energy transformity of biological species, which is 1.26E + 25 sej/species (Wen et al. 2005); \( N \) is the total number of biological species within the scope of the project; and \( R \) is the proportion of biological active area to global area, in which the surface area of the earth is 5.21E + 10 hm\(^2\).

(3) Sediment transportation effect The UWSC project connects independent lakes, rivers, and channels, enhancing the flow of water bodies. Sediment transportation depends on the flowing water, and the total energy of the flow at any cross-section is equal to the sum of potential energy and kinetic energy (Wu et al. 2019). Sediment transportation effect is realized by working on suspended and bedding sediment in water body. Therefore, the basic formula can be established according to the energy principle:

\[ EM_D = (P_E + K_E) \times (\theta_1 + \theta_2) \times \tau_d \]  

(5)

where \( EM_D \) is the sediment transportation effect (sej), \( P_E \) is the variation of potential energy \((J)\), \( K_E \) is the variation of kinetic energy \((J)\), \( \theta_1 \) is the bedload energy transfer coefficient, \( \theta_2 \) is the suspended load energy transfer coefficient, and \( \tau_d \) is the solar transformity of river water energy \((sej/J)\).

(4) Water purification effect Water can purify pollutants through a series of physical and biochemical reactions such as natural dilution, adsorption, diffusion, and oxidation. The self-purification function of water body ensures the recycling of all kinds of substances in the river ecosystem, effectively prevents the pollution caused by excessive accumulation of substances, and purifies and improves the water environment. The UWSC project integrates the water system in the region, promotes water circulation, speeds up water exchange, turns stagnant water into living water, and improves the pollutant purification capacity of the water system. Finally, the water environment is improved. The purification effect of water can be expressed by quantifying the amount of pollutants naturally degraded in water. The formula is as follows:

\[ EM_p = \sum_{p=1}^{n} f \times m_p \times \tau_p \]  

(6)

where \( EM_p \) is the water purification effect (sej), \( f \) is the pollutant degradation coefficient, \( m_p \) is the amount of pollutants \((g)\), and \( \tau_p \) is the solar transformity of each pollutant \((sej/g)\).

Emery assessment method of social effect

(1) Flood regulation effect The acceleration of urbanization leads to the increase of impervious underlying area. As a result, the rainwater runoff becomes more and more concentrated, the flood peak time of the river is advanced, the confluence time is shortened, and the pressure of flood control of the river is intensified. The implementation of the project can connect different water systems to play a combined effect and increase the river and lake storage capacity by restoring or building water system connection channels. When the flood occurs, we can turn harm into a benefit by flood retention and peak staggered regulation which are realized through reasonably regulating the dam and sluice in the urban river system. The project will enhance the local flood control and drainage functions of urban water systems, ensure the safety of people’s lives and property, and play a huge flood control effect. The effect can be calculated by the energy of the flood storage volume. The formula is as follows:
\[ EM_f = \tau_f \times W_f \]  

where \( EM_f \) is the flood regulation effect (sej), \( \tau_f \) represents the solar transformity of the corresponding water body (sej/m\(^3\)), and \( W_f \) is the flood storage volume in the study area (m\(^3\)), which is obtained according to the maximum storage depth and the water surface area.

**(2) Landscape and recreation effect** People’s leisure activities cannot be separated from the natural landscape, and the green space around the urban water system is generated by the combination of the natural ecosystem and the artificial construction system. With the construction of UWSC project, a variety of urban ecological landscape can be presented, which provides open places for residents to jog, relax, picnic, and other recreational activities. It brings good experience and feeling to residents, so that residents’ happiness is improved. The landscape and recreation effect of the project can be quantified by referring to the equivalent factor method proposed by Xie et al. (2015). According to the ecological service function value provided by farmland per unit area and the leisure equivalent factor of water, the landscape and recreation value per unit water area is calculated. The formula is as follows:

\[ EM_c = EDR \times V_r \times S \]  

where \( EM_c \) is the landscape and recreation effect (sej), \( V_r \) is the value equivalent of landscape and recreation per unit water area (¥/hm\(^2\)), and the leisure equivalent factor of water is 4.34, which is obtained by value equivalent table of Xing et al. (2017). \( S \) is the water area (hm\(^2\)).

**(3) Scientific research effect** Urban water ecosystem has the characteristics of complex and diverse ecological environment and rich species resources and is an important research area of ecology, hydrology, water resources, environmental engineering, aquatic biology, and fishery resources. Therefore, the UWSC project has important scientific research and cultural value. The effect of scientific research is quantified by the emergy value of related academic papers. The formula is as follows:

\[ EM_s = T \times 6 \times \tau_S \]  

where \( EM_s \) is the scientific research effect (sej); \( T \) is the number of academic papers published during the study period; each academic paper is counted as 6 pages; and \( \tau_S \) is the solar transformity of academic papers, which is 3.39E + 15 sej/P calculated by Meillaud et al. (2005).

### Emergy assessment method of economic effect

**(1) Land value increment effect** With the improvement of people’s living standards, people’s demand is constantly improving, and more and more attention is paid to the surrounding environmental quality and infrastructure supporting conditions. With beautiful scenery and fresh air around the UWSC project, it can get closer to nature and improve people’s quality of life. Because people yearn for green life and visual beauty, the demand for housing around the project increases, and the commercial value also increases accordingly. According to the research of Liang et al. (2010), after comprehensive treatment of urban rivers, 31.43% of the land value increment effect are generated by the urban water system. The calculation formula is as follows:

\[ EM_1 = Q \times 31.43\% \times EDR \]  

where \( EM_1 \) is the land value increment effect (sej) and \( Q \) is the total increment of land (¥).

**(2) Negative effect of project cost** The cost of the construction of the project and supporting facilities include labor, materials, equipment, and construction land compensation. According to the project investment, operation period, and social discount rate, the annual cost of the project can be calculated. The calculation formula is as follows:

\[ EM_c = P[A/P, i, n] \times EDR \]  

where \( EM_c \) is the negative effect of project cost (sej), \( P \) is the total investment (¥), \( i \) is the social discount rate, and \( n \) is the project operation period. According to The Economic Evaluation Standard of Water Conservancy Construction Projects, \( n \) is 25, and \( i \) is 8%.

**(3) Negative effect of maintenance** In order to ensure the healthy and sustainable development of urban water system, it is necessary to invest a lot of manpower, material resources, and financial resources in the construction and management of river courses, including cleaning work of river surface and river bank, inspection and improvement of water quality, and dredging of river. Increasing the financial expenditure of the city is the negative effect of the UWSC project, which can be calculated by the emergy consumption of the invested labor and equipment. The calculation formula is as follows:

\[ EM_m = G \times EDR \]  

where \( EM_m \) is the negative effect of maintenance (sej) and \( G \) is the annual expenditure of project maintenance (¥).
Results and discussion

Quantification of eco-economic effects of UWSC project in Xuchang

(1) Quantification of emergy index

According to the emergy calculation method mentioned above, the average EDR of Xuchang from 2010 to 2018 was calculated, which equals 1.67E+7 sej/¥. According to the method of Lv (2009), solar transformity of surface water body in Xuchang is represented by the ratio of total emergy of precipitation to surface runoff, which is 5.93E+11 sej/m³. 

(2) Quantification of ecological effects

The ecological effects of project in Xuchang include climate regulation effect, biodiversity conservation effect, sediment transport effect, and water purification effect. The project is located in the plain. Because of the small difference of terrain and the small amount of sediment, the effect of sediment transport was not calculated here. The ecological effects of the project were calculated as follows:

① Climate regulation effect: The solar transformity of surface water in Xuchang calculated in this paper is regarded as the \( \tau_{wt} \). Combined with Formula (3), \( EM_q \) was obtained.

② Biodiversity conservation effect: According to a species survey in Qingyi River Basin, the species number did not change after the project was completed, but the area of biological activity changed. Combined with Formula (4), \( EM_B \) was obtained.

③ Water purification effect: According to Xuchang Water Conservancy Bureau (2010–2018), the main water pollutants in the study area are ammonia nitrogen (NH₃-N) and chemical oxygen demand (COD). According to the results of Zhang et al. (2015), The degradation coefficients of NH₃-N and COD are 0.18/d and 0.15/d, respectively. Based on Formula (6), \( EM_p \) can be obtained.

The ecological effect before and after the completion of the project can be obtained by referring to the calculation method and data above, and the calculation results are shown in Table 2.

Table 2. Assessment of ecological effects of project in Xuchang (E+18 sej)

| Items  | 2010 | 2011 | 2012 | 2016 | 2017 | 2018 |
|--------|------|------|------|------|------|------|
| \( EM_q \) | 2.19 | 2.02 | 1.34 | 2.45 | 2.88 | 2.00 |
| \( EM_B \) | 16.85 | 16.85 | 16.85 | 23.69 | 23.69 | 23.69 |
| \( EM_p \) | 5.13 | 8.24 | 8.07 | 9.21 | 8.04 | 7.50 |

(3) Quantification of social effects

The social effects of project in Xuchang include flood regulation effect, landscape and recreation effect and scientific research effect. The social effects of the project were quantified as follows:

① Flood regulation effect: According to The Flood Control Plan of River System in Xuchang, the maximum storage depth can be obtained. Based on Formula (7), \( EM_f \) was calculated.

② Landscape and recreation effect: According to the equivalent factor method, \( V_e \) is obtained. Combined with Formula (8), \( EM_e \) can be calculated.

③ Scientific research effect: According to literature data retrieval, the number of relevant literatures was obtained. Based on Formula (9), \( EM_s \) can be calculated.

In summary, the social effects before and after the completion of the project can be obtained, as shown in Table 3.

(4) Quantification of economic effects

The economic effects of project in Xuchang include land value increment effect, negative effect of project cost and negative effect of maintenance. The economic effects were calculated as follows:

① Land value increment effect: The project is located in Weidu District and Jian’an District. Land value increment is mainly reflected in housing sales. Combined with Formula (10), \( EM_l \) can be calculated.

② Negative effect of project cost: The total investment data are provided by the government. Based on Formula (11), \( EM_c \) was calculated.

③ Negative effect of maintenance: In order to ensure the normal operation and management of the water system, there are management and maintenance expenses every year. Based on Formula (12), \( EM_g \) was calculated.

The calculation results of economic effects before and after construction are shown in Table 4.
Results and analysis

According to the above calculation results, the average effects of 2010–2012 and 2016–2018 were respectively used as the effects before and after the completion of the project. According to Formula (2), the eco-economic effect of UWSC project in Xuchang was obtained (Table 5).

(1) According to Table 5, the average effect of UWSC project in Xuchang is 49.97 million dollars/year. The project has produced a huge eco-economic effect and has made contributions to the economic growth of the area, the improvement of residents’ material and spiritual enjoyment, and the improvement of the ecological environment. Lee and Jung, (2015) calculated the ecological benefits of the Cheonggyecheon Urban River Restoration Project in Seoul, South Korea, and calculated that the project benefits were negative every year. It showed that the evaluation of project benefits should not only include the ecological benefits. Economic and social benefits are equally important.

(2) Based on Fig. 3, among the eco-economic effects of the project, the economic effect accounts for the largest proportion, accounting for 82.49% of the total effect. This is mainly due to the large land value increment effect. It showed that the project makes the surrounding land more valuable. Liang et al. (2010) evaluated the comprehensive benefits of the transformation and restoration project of urban river and concluded that the surrounding land appreciation benefits accounted for 95.75% of the total benefits. It can be concluded that a good water environment can indeed promote the development of the surrounding economy and have a non-negligible impact on all industries. The proportion of engineering ecological effect is 15.89%. It showed that the impact of the project on the ecological environment...
in this area cannot be ignored, and it is necessary to adopt scientific methods to quantify. The ecological and social effects are far lower than the economic effect, which indicated that the water system connectivity project, as an urban ecosystem, has a far greater impact on the economy than other impacts due to the large human disturbance factors.

(3) According to Fig. 3 and Fig. 4, among the ecological effects of project, the effect of biodiversity conservation is the highest, which is $6.83 \times 10^{18}$ sej. It showed that this project can provide a good place for energy flow and material exchange among species. Holgado et al. (2020) studied the urban water system under four different circumstances and found that all of them had a good effect on biodiversity conservation, which is consistent with the results of this paper. The social effect is the smallest in eco-economic effects, accounting for only 1.62%. In the social effect, the flood regulation effect is the largest, which indicated that the project has flood control and drainage function, and provides security for the safety of residents’ lives and property. In the economic effect, the cost of management and maintenance increases, which is reasonable because the construction of the project leads to the increase of human and material resources input.

## Conclusions

As an urban eco-hydraulic project, the UWSC project not only can regulate climate, protect biodiversity, transport sediment, purify water quality, but also have the effects of flood regulation, landscape and recreation, scientific research and land value increment. However, the negative effect cannot be ignored. Therefore, the scientific assessment of the project is conducive to a comprehensive understanding of its ecological, social, and economic effects and provides data support for the sustainable development, research, and protection of the project. Based on emergy theory, this paper analyzed the construction and evaluation methods of eco-economic effects of the project and took UWSC project in Xuchang as an example to evaluate. The results showed that the average effect after the completion of the project is 49.97 million dollars/year, which has brought huge effect for the urban ecological construction and economic and social development of Xuchang. However, since the Xuchang Project was completed at the end of 2015, there is only 3 years of data available for research so far, so the trend of effect change cannot be analyzed yet. In addition, most of the solar transformities are based on the previous results, and the solar transformity of Xuchang City need to be studied further.

## Author contribution
All authors contributed to the study conception and design. Conceptualization: Cuimei Lv. Methodology: Cuimei Lv and Huali Liao. Formal analysis and investigation: Minhua Ling. Writing—original draft preparation: Cuimei Lv and Huali Liao. Writing—review and editing: Cuimei Lv, Huali Liao, Zening Wu and Denghua Yan. Funding acquisition: Minhua Ling. Resources: Denghua Yan. Supervision: Minhua Ling and Zening Wu. All authors have read and agreed to the published version of the manuscript.

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## Data availability
All data and materials support our published claims and comply with field standards.
Declarations

Ethics approval  Informed consent

Consent to participate  Informed consent

Consent to publish  Informed consent

Competing interests  The authors have no relevant financial or non-financial interests to disclose

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