Detailed Economic Analysis

Project Number: 52025-001
September 2020

Proposed Loan
People's Republic of China: Yunnan Sayu River Basin Rural Water Pollution Management and Eco-Compensation Demonstration Project

CURRENCY EQUIVALENTS

(as of 5 August 2020)

Currency unit	–	yuan (CNY)
CNY1.00	=	$0.1434
$1.00	=	CNY6.9736

ABBREVIATIONS

ADB	–	Asian Development Bank
COD	–	chemical oxygen demand
EIRR	–	economic internal rate of return
FSR	–	feasibility study report
kg	–	kilogram
NPS	–	nonpoint source
NH_3-N	–	ammoniacal nitrogen
O&M	–	operation and maintenance
PRC	–	People’s Republic of China
TN	–	total nitrogen
TP	–	total phosphorus
YREB	–	Yangtze River Economic Belt
WTP	–	willingness-to-pay
ZCG	–	Zhaotong City Government

NOTE

In this report, “$” refers to United States dollar.

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A. Introduction

1. The economic analysis completes least-cost and benefit–cost analyses on proposed outputs. Analyses have been conducted in accordance with the Asian Development Bank's (ADB) Guidelines for the Economic Analysis of Projects (2017).[1]

2. The Zhaotong City Government (ZCG) of Yunnan Province has requested ADB funding for the Yunnan Sayu River Basin Rural Water Pollution Management and Eco-Compensation Demonstration Project. The project will demonstrate the ADB value additions through the following components: (i) strengthening wastewater management and pollution control with innovative technologies and arrangements; (ii) improvement of water resources management with innovative information technologies; (iii) establishment of eco-compensation mechanism; and (iv) strengthening of education, capacity, and public awareness for water pollution management.

B. Macro-Economic Context

3. The Yangtze River Economic Belt (YREB) covers nine provinces and two specially administered cities in the Yangtze River Basin. It accounts for over 40% of the population of the People's Republic of China (PRC) and has 40% of the freshwater resources. It also serves as the drinking water source for 400 million people, provides 60% of the total fisheries production, has 20% of the total wetland area, and contributes about 45% of the PRC's economic output. The YREB has been earmarked as one of the three key growth engines to ensure the PRC's future economic development.[2]

4. The YREB has benefitted from extensive development since 1990s, particularly in the delta area. Yet, economic growth in the middle and upper reaches of the Yangtze River Basin is lagging and below its potential capacity. The middle and upper reaches of the Yangtze River Basin still face significant development challenges because of (i) slow transformation for green development and economic diversification; (ii) limited integration of waterways, ports, and intermodal logistics; (iii) increasing pollution and pressure on natural resources; and (iv) weak institutional coordination for strategic planning.[3] The YREB faces a growing imbalance between economic achievements and the quality of the environment. For example, since 1980, water pollution in the Yangtze River Basin has risen by 73% because of the discharge of waste,[4] soil erosion which is critical in small watersheds, and the agricultural-related nonpoint source (NPS) pollution.[5]

5. To address these challenges, the Government of the PRC formulated the YREB Development Plan, 2016–2030,[6] which stipulated the prioritization of ecological protection and promotion of green development as the guiding principle for the YREB development.[7] In this

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1 ADB. 2017. *Guidelines for the Economic Analysis of Projects,* Manila.

2 The other flagship projects are the Belt and Road Initiative and the Beijing–Tianjin–Hebei Integrated Regional Development Strategy.

3 ADB. 2016. *Yangtze River Economic Belt Environmental Protection and Rehabilitation Project—A Preliminary Study*. Consultant's report. Manila (TA 9044-PRC).

4 The upper and middle reaches of the Yangtze River Basin account for 80% of the YREB's total wastewater discharge, and the tributaries have the worst water quality in the basin. Among the rural villages in the YREB, about 40% do not have garbage collection facilities; and about 80% lack basic sewage treatment.

5 Every year, the Yangtze River Basin loses 2.24 billion tons of soil, damaging 67,000 hectares of farmlands due to soil erosion.

6 Government of the PRC. 2016. *Outline of the Yangtze River Economic Belt Development Plan, 2016–2030*. Beijing.

7 Green development aims to (i) change the traditional development model to a sustainable development model, (ii) address the challenges of rapid urbanization, and (iii) serve as a guide to socioeconomic development.

connection, ADB and the government have agreed to adopt a framework approach, providing about $2.0 billion of funding in the YREB during 2018–2020 to strategically program ADB's lending support for development initiatives in the YREB with priority given to the following four areas: (i) ecosystem restoration, environmental protection, and water resources management; (ii) green and inclusive industrial transformation; (iii) construction of an integrated multimodal transport corridor; and (iv) institutional strengthening and policy reform.

C. Sector Context

6. Zhaotong City of Yunnan Province has been selected to demonstrate water pollution reduction in the Sayu River Basin. Zhaotong has one district, one county-level city, and nine counties, out of which one district and all counties are nationally designated poverty district and counties. Zhaotong has 1,336,700 poor people, the largest poor population in Yunnan. The Sayu River is a tertiary tributary of the Yangtze River, with length of 186 kilometers. The Sayu River Basin, at 3,558 square kilometers, is an important area for ecological protection in the upper Yangtze River Basin. Currently, it is the only centralized drinking water source in Zhaotong. Urban drinking water is primarily provided from the Yudong Reservoir that was constructed in 1998. Water in the Sayu River Basin, including the Yudong Reservoir, is currently polluted due to (i) discharge of waste in the Sayu River Basin; (ii) high sediment runoff into the Sayu River due to soil erosion; and (iii) the agriculture-related NPS pollution. In many locations in the Sayu River, the water quality is worse than Class III of the national standard which is unfit for drinking.[8] Local people living around the Sayu River Basin, particularly women and the poor, suffer from water pollution.

7. Rural domestic wastewater, solid waste, and human and animal wastes pollute the water in the Sayu River Basin due to inadequate waste management. Rural domestic wastewater and solid waste contribute to 27% of the chemical oxygen demand (COD), 9% of the total nitrogen (TN), 16% of the total phosphorus (TP), and 22% of the ammoniacal nitrogen (NH_3-N) in the Sayu River.[9] Human and animal wastes contribute to 39% of the COD, 25% of the TN, 52% of the TP, and 48% of the NH_3-N in the Sayu River (footnote 9). Since forest coverage in the Sayu River Basin is only 30.2% due to expansion of farmlands which is quite smaller than 60%−70% appropriate for centralized drinking water sources, soil erosion is quite serious in the basin. About 57.9% of the Sayu River Basin is soil erosion area which provides 1.1 million tons of soil every year. High sediment runoff caused by soil erosion currently contributes to 34% of the COD, 21% of the TN, 11% of the TP, and 18% of the NH_3-N in the Sayu River (footnote 9). Water in the Sayu River Basin is further deteriorated by the agriculture-related NPS pollution due to inadequate waste management systems, uncontrolled fertilizer release, and outdated production systems. Agriculture-related NPS pollution (e.g., farmland solid waste and fertilizer) contributes to 45% of the TN, 21% of the TP, and 12% of the NH_3-N in the Sayu River (footnote 9). It also contributes to climate change through direct and indirect emission of greenhouse gases. This situation may be aggravated by intensified and more frequent rainfall events induced by global climatic changes which contribute to soil erosion and flashing of agriculture-related pollution to water systems.

8. There is a lack of capacities for planning and financing water pollution reduction activities in a holistic manner. There is also insufficient public awareness of water pollution problems, particularly interlinkages between household and economic activities and water quality. As

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8 As per the PRC's Environmental Water Quality Standard (GB 3838-2002).

9 China Urban Construction Research Institute Limited. 2018. *Application of ADB Loan: Yunnan Sayu River Eco-Compensation Demonstration Project−Project Proposal*. Beijing. General Report of the Zhaotong Yudong Reservoir Water Resources Protection Special Remediation Plan, 2015.

Zhaotong is considered a poor city, there is an urgent need for a sustainable financing mechanism for investments to address water pollution in a sustainable manner.

9. In 2006, the ZCG established a fund for ecological restoration and remediation of the primary and secondary water source protection areas of the Yudong Reservoir. The ZCG provided CNY3 million to the fund every year from 2006 to 2014. Since 2015, CNY17 million has been provided to the fund every year.[10] The fund is used to improve the environment and water quality in the Sayu River Basin through river protection and waste management. The ZCG would like to expand and improve their current approach, incorporating international good practices for sustainable financing mechanisms; and scaling up current investments in line with the central government's current push for rural vitalization.[11] In 2018, the ZCG established a district- and county-level horizontal (i.e., between same levels of local governments) eco-compensation mechanism, which consists of 14 horizontal eco-compensation agreements for 17 river sections crossing borders of Zhaotong's one district, one county-level city, and nine counties.[12]

10. In February 2018, the State Council of the PRC promulgated a policy on rural vitalization as a driver for the PRC's modernization goals and building a moderately prosperous society. The policy targets the establishment of an institutional framework by 2020, the modernization of rural areas by 2035, and the beautification of the countryside by 2050. The local governments will formulate and start the implementation of their plans aimed at improving public services and promoting environmental protection during 2018–2022. Yunnan, particularly Zhaotong, will be in the priority of the government for this policy implementation.[13]

D. Rationale

11. The project will (i) reduce water pollution sources in the Sayu River Basin through (a) waste management, (b) solid waste management, (c) pilot eco-villages to reduce emission, (d) wetlands construction to reduce the NPS pollution, (e) afforestation, and (f) promotion of low-emission agriculture; (ii) protect water resources in the Sayu River Basin from pollution through (a) construction of ecological embankments, (b) establishment of a river protection model using an intelligent cloud platform river information management system in collaboration with the existing river chief system of the PRC, and (c) establishment of smart water integrated management platform; (iii) establish eco-compensation mechanism for the Sayu River Basin to improve financial flows and incentives for conservation and restoration; and (iv) strengthen education, capacity, and public awareness for water pollution management.

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[10] CNY8 million from the ZCG, CNY5 million from the Zhaoyang District Government (ZDG), CNY2 million from the Ludian County Government (LCG), and CNY2 million of water resources utilization fees from the downstream Baoho hydropower station every year. Zhaoyang District and Ludian County are in Zhaotong City, and the ZDG and LCG are the implementing agencies of the project (Table 3).

[11] For example, the existing fund is mainly used for the land acquisition and resettlement; and do not provide local people in the Sayu River Basin with incentives for water source protection.

[12] Each agreement is for 1−3 river sections crossing the border either between the district and a county or between two counties. Compensation is paid based on water quality at the border. Of the 14 agreements, one is for the Longshu River in the Sayu River Basin and two other rivers outside the Sayu River Basin, which was signed by the ZDG and LCG, the implementing agencies of the project (Table 3). Each of them provides CNY2.0 million every year; and CNY2.4 million and CNY1.6 million are allocated to the upstream LCG and downstream ZDG, respectively. At the border of Zhaoyang District and Ludian County, water qualities of the Longshu River and two other rivers in the Sayu River Basin are measured every month (36 monitoring data/year). Every year, CNY2.4 million multiplied by the ratio of monitoring data number which did not meet the standard agreed between the LCG and ZDG is deducted from the LCG and added to the ZDG.

[13] State Council of the PRC. Policies: Latest Releases.

12. Project outputs and detailed activities are in Table 1.

Table 1: Project Outputs and Detailed Activities

Outputs	Detailed Activities
Output 1: Wastewater management and pollution control in the Sayu River Basin strengthened	**1.1 Waste management** **1.1.1 Centralized wastewater management system** Installation of wastewater collection pipes and construction of three pump stations (capacities of 333.86 m^3/day, 631.85 m^3/day, and 63.55 m^3/day for 30 m, 40 m, 15 m pumping up, respectively). Operation of a WWTP in Shuimo Town in Ludian County. **1.1.2 Distributed wastewater management system** Operation of 19 existing treatment facilities, construction of 25 treatment facilities, installation of wastewater collection pipes, and establishment of intelligent cloud platform information management systems for 43 out of 44 treatment facilities. **1.1.3 Animal feces management** Installation of manure collection tanks at 17,323 households (one tank for each household). **1.2 Solid waste management** Construction of three solid waste transfer stations (capacities of 20 tons/day, 20 tons/day, and 35 tons/day). Construction of two garbage pyrolysis facility (capacities of 70 tons/day and 20 tons/day) with automatic monitoring and warning systems (for SOx, NOx, temperature, etc.). Provision of bins (138), trash cans (2,086), compression trucks (11), hook-arm garbage trucks (8), detachable container garbage trucks (4), electric tricycles (168), and mobile compression dustbins (8). **1.3 Pilot eco-villages to reduce emission** In six natural villages, including 1,718 households and 7,045 people in three administrative villages in the Ludian County and Zhaoyang District in Zhaotong City; (i) development of basic infrastructure (permeable pavements and green space, drainage systems, public eco-toilets, ecological riverbank, etc.); (ii) training on garbage classification, recycling, reduction of resource use and waste stream (including phasing out of single-use plastics and replacing them with locally sourced reusable and compostable products); (iii) education at schools to promote garbage classification, recycling, reduction of resource use and waste stream; (iv) development of an environmental health management system, including institutional development (establishment of designated cleaning teams and designated environmental supervision groups, including their training; establishment of awarding program; etc.); and (v) publicity to promote garbage classification, recycling, reduction of resource use, and waste stream; and introduce activities by special cleaning teams and special environmental supervision groups. **1.4 Wetlands construction to reduce nonpoint source pollution** Construction of six new wetlands: (i) new wetland area of 86.92 mu with treatment capacity of 1,577.97 m^3/day (wastewater: 136.81 m^3/day; rainwater: 1,441.15 m^3/day); (ii) new wetland area of 113.76 mu with treatment capacity of 3,783.49 m^3/day (wastewater: 255.94 m^3/day + 2,000 m^3/day [from WWTP]; rainwater: 1,527.55 m^3/day); (iii) new wetland area of 115.02 mu with treatment capacity of 1,201.33 m^3/day (wastewater: 168.85 m^3/day; rainwater: 1,032.48 m^3/day); (iv) new wetland area of 50.81 mu with treatment capacity of 941.49 m^3/day (wastewater: 112.05 m^3/day; rainwater: 829.44 m^3/day);(v) new wetland area of 189.03 mu with treatment capacity of 2,773.07 m^3/day (wastewater: 310.67 m^3/day; rainwater 2,462.40 m^3/day); and (vi)

Outputs	Detailed Activities
	new wetland area of 14.93 mu with treatment capacity of 980.31 m^3/day (wastewater: 153.46 m^3/day; rainwater: 826.85 m^3/day). **1.5 Establishment of quantifiable soil and water conservation model** Afforestation of 4,627.58 mu and perennial herb planting of 6,726.19 mu. Construction of irrigation facilities and 19 ponds for perennial herb planting. For establishment of quantifiable soil and water conservation model, four afforestation patterns and bare ground were selected for each of 15-, 25-, and 35-degree slopes (15 patterns in total). For each pattern, four monitoring areas were selected (60 monitoring areas in total). Effects of afforestation on soil and water conservation will be estimated using existing model. After that, effects of afforestation on soil and water conservation will be actually measured at the 60 monitoring areas; and based on the measured data, the model will be revised. It is expected to take about 10 years to get data adequate to revise the model. However, tentatively improved model will be presented by the project completion or project completion report preparation at latest. **1.6 Promotion of low-emission agriculture** Development of a formula to estimate necessary fertilizer volume, integration of water and fertilizer to reduce fertilizer use, reduction of pesticides, controlled fertilizer release, increase of organic fertilizer application, construction of composters, use of animal feces for farming to realize circular agriculture and zero emission, construction of ecological drainage ditches, construction of a gridded surface source pollution monitoring platform, establishment of organic vegetable brand, establishment of a green and organic apple brand, improvement of soil sampling and testing, etc. in demonstration zone and points.
Output 2: Water resources management in the Sayu River improved	**2.1 Establishment of smart water integrated management platform** Installation of (i) three water quality monitoring stations; (ii) four water level and video monitoring stations; (iii) four 360-degree video monitoring stations at newly constructed wetlands; (iv) two 360-degree video monitoring stations at the two constructed garbage pyrolysis facilities; (v) one 360-degree video monitoring station at the existing WWTP in Shuimo Town; (vi) two 360-degree video monitoring stations at two of the 44 wastewater treatment facilities; (vii) three 360-degree video monitoring stations at the three pilot eco-villages; (viii) 60 360-degree video monitoring stations at river entry points into the Yudong Reservoir; and (ix) seven rainfall stations for seven main rivers flowing into the Yudong Reservoir. Establishment of smart water integrated management platform by integrating these monitoring facilities with the existing irrigation area information system for real-time monitoring and actions in the event of water quality deterioration. **2.2 Establishment of river protection model** Construction of 98.3 km ecological embankments. Establishment of a river protection model which links the existing river chief system in the PRC, a real-time water quality monitoring system (a subsystem of the smart water integrated management platform), and facilities to protect rivers from pollution (e.g., ecological embankments).
Output 3: Eco-compensation mechanism for the Sayu River Basin established	**3.1 Establishment of eco-compensation mechanism** Implementation of the eco-compensation agreement between the Zhaoyang District (downstream) and the Ludian County (upstream). Establishment and implementation of new town- and township-level horizontal eco-compensation mechanisms between four towns and two townships in Zhaoyang District and Ludian County with six agreements.

Outputs	Detailed Activities
	Establishment and implementation of a Yudong Reservoir eco-compensation fund (long-term platform for proactive management of the Yudong Reservoir water quality). Beneficiaries pay into the funds and the government covers up the fund. The fund can be used to leverage other finance sources.
Output 4: Education, capacity, and public awareness for water pollution management strengthened	**4.1 Capacity development of government staff for rural water pollution management and eco-compensation** Training, workshops, domestic study visits, and overseas study visit and training (but requirements for implementation of international training are becoming strict) for rural water pollution management and eco-compensation; with assistance from consultants to be recruited during project implementation. **4.2 Education of students for rural water pollution management and eco-compensation** Periodical special lectures at schools, study visits for students, etc. **4.3 Public awareness raising** Public awareness raising through publicity, handbook, brochure, media, internet, campaigns, etc. **4.4 Dissemination and replication of project initiatives** Dissemination and replication of water pollution management and eco-compensation demonstrated under the project to other areas of the PRC and also other countries through workshops, publications, disclosure of project information on website, submission of papers to academic societies, application for a model project for eco-civilization, application for award programs, etc.

km = kilometer, m = meter, m^3 = cubic meter, *mu* = Chinese unit of measurement (1 *mu* = 666.67 square meters), NO_x = nitrogen oxide, PRC = People's Republic of China, SO_x = sulfur oxide, WWTP = wastewater treatment plant.
Source: Asian Development Bank.

E. Methodology

13. **Parameters and assumptions.** The following assumptions apply to all analyses:
(i) Economic benefits and costs are based on a domestic price numeraire in the first quarter 2019 prices.
(ii) Capital costs are based on engineering cost estimates.
(iii) Capital costs include physical contingencies of 5%; but not price contingencies, interest during construction and depreciation.
(iv) Project costs and benefits are estimated on a with- and without-project basis.
(v) Residual asset values are treated as benefits at the end of the project life.
(vi) Traded outputs are valued at cost-insurance-freight border prices adjusted for transport cost differentials and converted to economic prices using a shadow exchange rate factor of 1.023. Non-traded outputs are valued at domestic market prices.
(vii) A shadow wage rate factor of 0.85 is used to convert the financial wage rate to an economic opportunity cost of labor.
(viii) The real opportunity cost of capital is normally assumed to be 9% for Output1 and 6% for Output 2 due to the environmental focus of Output 2.[14]
(ix) Project costs and benefits are evaluated over a 20-year period, following project commissioning.

[14] Asian Development Bank. 2017. *Guidelines for the Economic Analysis of Projects*. Manila.

14. Sensitivity tests include (i) 10% increase in capital costs, (ii) 10% increase in O&M costs, and (iii) 10% decrease in benefits. Where appropriate, tests also included a reduction in population growth; a simultaneous increase in capital and operation and maintenance (O&M) costs; and a reduction in benefits. Sensitivity indicators and switching values were calculated.

15. **Project costs**. The estimates of base costs for capital investments and annual O&M costs were obtained from a feasibility study report (FSR) for the project. The average annual O&M cost for all components, following project completion, is estimated to be 1.1% of the project investment cost. The economic costs include (i) capital costs of civil works, equipment, materials, land acquisition and resettlement, physical contingencies; and (ii) the cost of O&M, including the cost of asset repair and maintenance. The overall project investment cost is CNY1,615.5 million ($231.7 million), with an economic cost of CNY1,495.0 million ($214.4 million).[15] The estimated costs are shown in Table 2.

Table 2: Summary of Investment Costs
(CNY '000)

Item	Financial[a]	Economic[b]
A. Investment Costs		
1. Wastewater management and pollution control in the Sayu River Basin strengthened[c]	725,038	661,699
2. Water resources management in the Sayu River improved[c]	632,360	588,799
3. Eco-compensation mechanism for the Sayu River Basin established	118,056	109,169
4. Education, capacity, public awareness for water pollution management strengthened; and project management	139,997	135,318
Total Project Cost	**1,615,451**	**1,494,985**

CNY = Chinese yuan.
[a] Financial cost exclude financing charges during implementation.
[b] Economic costs exclude price contingencies and financing charges during implementation.
[c] Cost of the output subject to the economic evaluation.

16. **Output 1: Wastewater management and pollution control in the Sayu River Basin strengthened—Reduce water pollution sources.** Detailed activities for this output are in Table 1. Costs of this output includes operation, repair, and maintenance costs for facilities constructed for the output.

17. Valuation of benefits realized by villagers receiving new services from this output will be based on willingness-to-pay (WTP) for new wastewater and solid waste management services. A benefit transfer approach is applied to solid waste management services, and the WTP questions are included in a household questionnaire for valuation of wastewater management services.

18. An analysis is completed for health benefits for villagers based on a benefit transfer analysis of avoided costs (D, Appendix 3). The estimated annual benefit per household is CNY 660. This measure of benefit is not included directly as it will entail double counting with the villager WTP for wastewater management which should include the value placed on improved health as well as other benefits such as convenience and cleanliness of the village environment. Health benefits are considered here because villagers are not likely well informed about health benefits. Estimated annual solid waste and wastewater benefits per household sum to CNY 400 or 61% of the health benefits expected due to the project investments. Based on this finding, we include only 1/3 of estimated health benefits in the analysis, CNY220/year, this amount reflects the difference

[15] Cost of components that were subject to the economic evaluation. Excludes price contingencies and financing costs.

between estimated WTP and avoided health costs.

19. Downstream urban residents who rely on the Yudong Reservoir for water supply will also benefit from improved water quality. Valuation of this benefit is also based on the WTP using a benefits transfer approach. This benefit is apportioned across Outputs 1 and 2 which both benefit reservoir water quality.

20. Benefits from investments in wetlands and forests include ecological goods and services other than water quality enhancement. These benefits are valued using unit values derived from published research.

21. Both the wetland and afforestation components include agricultural elements and alternative agricultural practices are a primary focus of the pilot and demonstration projects. Benefit analysis would normally account for impacts on net farm incomes based on results a crop budgeting exercise. However, sufficient data were not available to support this type of analysis.

22. **Output 2: Water resources management in the Sayu River improved.** Detailed activities for this output are in Table 1. The primary beneficiaries will be downstream urban residents relying on the Yudong Reservoir for water supply who benefit from improved water quality. Valuation of this benefit, as noted above, is based on the WTP using a benefits transfer approach. The total benefit is allocated to Outputs 1 and 2 in proportion to loading reductions.

23. **Output 3: Eco-compensation mechanism for the Sayu River Basin established.** Detailed activities for this output are in Table 1. This output deals with a financing mechanism to transfer costs among sectors of society, and no benefit assessment is called for.

24. **Output 4: Education, capacity, and public awareness for water pollution management strengthened; and project management.** Detailed activities for Output 4 are in Table 1. Economic evaluation was not completed for Output 4 and project management.

F. Demand Analysis

25. Population growth will influence capacity designs for wastewater and solid waste management facilities. The FSR assumes near-term natural population increase rate of 0.5% and long-term population natural increase rate of 0.4%. These assumptions imply population increases of 2.5% from 2020 to 2025 and 4.1% from 2025 to 2035, or a 6.7% increase from 2020 to 2035.

26. Actual rural population growth in Zhaotong from 2012 to 2017 was 1.6%. A decline in rural population has also occurred at the provincial scale over the past 10 years from 2007 to 2017, amounting to an annual rate of change of 1.7%. However, urban populations increased over the same period at a rate of 7.0%.

27. The rural population decline would suggest that population could be assumed constant for purposes of capacity design. However, other factors affect the capacity decision. For wastewater management services, water usage and wastewater discharge are expected to increase as rural populations acquire improved water supply and wastewater management services. Over the forecast period, this increase in generation of wastewater per capita is expected to be 33% in towns and 34% in villages. Similarly, per capita solid waste generation is expected to increase 71% in villages (from 0.35 kilograms [kg]/person/day to 0.60 kg/person/day); but only 4.2% in towns (from 1.20 kg/person/day to 1.25 kg/person/day).

28. Changes in per capita demands for service are the principle driver for decisions about wastewater and solid waste management facilities' capacities. For this reason, the impact of population growth assumptions is not critical. For example, in the case of a wastewater treatment plant in Ludian County, the assumed future wastewater influent volume is assumed to be 39% greater than current levels of wastewater generation; and population growth accounts for less than one fifth of this increase. Considering the inherent uncertainty in this kind of projection, the relatively small discrepancy between actual and assumed changes in rural populations is not critical.

29. Based on the preceding evaluation of population growth, rural populations are assumed to remain unchanged over the forecast period and urban populations are assumed to increase at an annual rate of 2%. These conservative assumptions provide a basis for benefit calculations.

G. Least-Cost Analysis

30. The least-cost analysis uses a life-cycle cost approach where data permit to compare costs of design options over a 25-year period of operations. Costs included in the analysis are base costs and the O&M costs. Net present values are used as summary measures of cost effectiveness. A discount rate of 6% is the assumed social opportunity cost.

31. Findings are summarized below. Several comparisons are qualitative in nature based largely on technical considerations.

32. **Centralized wastewater management.** The least-cost option is recommended by a design institute which prepared the FSR.

Table 3: Options for Centralized Wastewater Management
(CNY million)

Option	Capital cost	Annual O&M	NPV	Least cost option	Preferred option
Collect wastewater and convey to existing WWTP in Ludian County using two pumping stations	3.659	0.0732	4.12	✓	✓
Collect WW and convey to existing WWTP in Ludian County using a single pumping station	4.091	0.0946	4.74		
Construct a new WWTP in Xinjie Town in Ludian County	4.935	0.0820	5.37		

CNY = Chinese yuan, NPV = net present value, O&M = operation and maintenance, WWTP = wastewater treatment plant.

33. **Wastewater pipe material.** Qualitative analysis leading to a choice of polyvinyl chloride and high-density polyethylene pipe materials. The choice reflects current industry practice with concrete pipe being used only for very large transmission mains that are not required in this project.

Table 4: Options for Pipe Materials

Option	Capital Cost[a]	Lifespan, Year[b]	Comments	Preferred Option
Reinforced concrete pipe	Lower	100+	Heavy, more difficult to transport and install Higher surface roughness increases head loss Prone to leakage Only available in larger diameters (600+ mm)	
HDPE pipe	Higher	100	Light weight, easier to transport and install Low surface roughness reduces head loss Not prone to leakage Flexible, good seismic performance Only available in smaller diameters	✓ (small lines into households)
PVC pipe	Higher	100	Light weight, easier to transport and install Low surface roughness reduces head loss Not prone to leakage Flexible, good seismic performance Available in larger diameters	✓ (larger collection and transmission pipes)

HDPE = high-density polyethylene, mm = millimeter, PVC = polyvinyl chloride.
[a] Actual unit costs and OM costs not provided by a design institute which prepared the feasibility study report.
[b] Values shown are based on a literature search. Actual lifespans depend on local conditions and the quality of installation.
Source: Asian Development Bank.

34. **Distributed wastewater management.** The least-cost option is recommended by the design institute.

Table 5: Options for Distributed Wastewater Management
(CNY million)

Option	Capital Cost*	Annual O&M[a]	NPV	Least-Cost Option	Preferred Option
	(CNY ‘000)				
Solar powered A2O process	120.0	4.4	165.1	✓	✓
MBR process	150.0	12.5	289.5		
Oxidation ponds and artificial wetlands	300.0	2.5	312.6		

A2O = Anaerobic-Anoxic-Oxic, CNY = Chinese yuan, MBR = membrane bioreactor, NPV = net present value, O&M = operation and maintenance.
[a] Evaluated at a capacity of 10 cubic meters/day.
Source: Asian Development Bank estimates.

35. **Animal feces management.** Choice reflects technical feasibility related to the nature of existing farm operations.

Table 6: Options for Animal Feces Management

Option	Cost*	Comments	Preferred Option
Septic tank	Medium	Applicable to small-scale farming minimal land requirement Simple decentralized system managed by farmer Lower yield of fertilizer results in lower environmental and on-farm benefit	✓
Biogas fermentation	Low	Applicable to small- and large-scale farming minimal land requirement More complex centralized system managed by farmers or technical support staff Higher yield of fertilizer results in higher environmental and on-farm benefit	Not feasible because farms are too disbursed
Bio-ferment for organic fertilizer production	High	Applicable to small- and large-scale farming large land requirement Complex centralized system requiring professional management Higher yield of fertilizer results in higher environmental and on-farm benefit	Not feasible because farms are too disbursed

36. **Solid Waste Management**

Table 7: Options for Solid Waste Management
(CNY million)

Option	Capital Cost*	Annual O&M[a]	NPV	Least-Cost Option	Preferred Option
	(CNY '000)				
Pyrolysis	285.0	0.068	269.7		✓
Incineration	350.0	0.100	331.4		
Sanitary Landfill	225.0	0.075	213.2	✓	Land availability for a new landfill is very uncertain. Costing does not account for decommissioning cost.

CNY = Chinese yuan, NPV = net present value, O&M = operation and maintenance.
[a] Evaluated at a 1.0 ton unit capacity.
Source: Asian Development Bank.

37. **Artificial wetlands.** The least-cost option must be used where the project uses basic farmland since it is the only option that is compatible with ongoing crop production as required by regulation. The highest-cost option is preferred otherwise because of its ecological benefits and its capacity to accept and treat higher flows and contaminant concentrations. It may well be the least-cost option if compared in terms of cost per kg of contaminant removed.

Table 8: Options for Artificial Wetlands

Option	Capital Cost[a]	O&M Cost (% of capital)[a]	Comments	Least-Cost Option	Preferred Option
Surface flow	Low (A)	1%	Can accept a low hydraulic load (<0.1 m^3/m^2/day) and lower influent contaminant concentrations Lowest contaminant removal efficiencies (e.g., 30% to 50% TP removal) Suitable for production of wetland food crops Medium biodiversity	✓	✓ (used on basic farmland which must remain in an agricultural use)
Horizontal sub-surface flow	Medium (20% above A)	3%	Can accept a medium hydraulic load (<0.5 m^3/m^2/day) and higher influent contaminant concentrations Good contaminant removal efficiencies (e.g., 60% to 75% TP removal) Not suitable for production of wetland food plants Medium biodiversity		
Vertical flow	High (50% above A)	5%	Can accept a high hydraulic load (<1.0 m^3/m^2/day) and higher influent contaminant concentrations Good contaminant removal efficiencies (e.g., 60% to 85% TP removal) Not suitable for production of wetland food plants Medium biodiversity		
Composite	High (50% above A)	3 to 5%	Can accept a very high hydraulic load (<3.0 m^3/m^2/day) and higher influent contaminant concentrations Best, contaminant removal efficiencies vary with hydraulic load Not suitable for production of wetland food plants High biodiversity		✓ (Preferred for non-agricultural land due to its capacity to accept higher influent loadings)

m^2 = square meter, m^3 = cubic meter, O&M = operation and maintenance, TP = total phosphorus.
[a] Unit costs were not provided by the design institute.
Source: Asian Development Bank.

38. **Ecological embankments.** Gabion baskets are preferred based on their technical performance.

Table 9: Options for Ecological Embankments

Streambank Protection	**Capital Cost** (CNY/m)	**Least-Cost Option**[a]	**DI choice**	**Comment**
Poured concrete	2,344	✓		Sever local environmental impact. Rigid structure prone to damage due to flood flows and subsidence.
Gabion basket	3,345		✓	Gabion baskets have a much better environmental performance due to their permeability and capacity to support vegetation. They are also easier to adapt to local conditions and more durable.

CNY = Chinese yuan, DI = design institute, m = meter.
[a] Operation and maintenance costs were not provided by the DI; and so, the least-cost option is not entirely clear. The poured concrete revetment may require higher maintenance costs since it is inflexibility makes it more vulnerable to damage during high flows.
Source: Asian Development Bank.

39. **Afforestation.** The planting design uses a range of alternative species based on suitability to local soil and topographic features. Selection of plants is therefore based on technical considerations.

H. Benefit–Cost Analysis

40. Net present values and economic internal rates of return (EIRR) were calculated for Outputs 1 and 2 using the methods and parameters discussed above. A summary of results is provided in 10. For the base case analysis, all outputs have an EIRR above 6%. The overall project EIRR is 10.2%.

Table 10: Summary of the Economic Evaluation

	EIRR (%)	**NPV** (CNY '000)
Overall project	10.2	344.74
1. Wastewater management and pollution control in the Sayu River Basin strengthened	12.2	183.33
2. Water resources management in the Sayu River improved	8.1	161.41

CNY = Chinese yuan, EIRR = economic internal rate of return, NPV = net present value.
Source: Asian Development Bank estimates.

41. Sensitivity analysis was undertaken to test the sensitivity of the estimated EIRRs of the proposed outputs to adverse changes in key variables and to confirm their economic viability under unfavorable conditions. Four risks are considered: (i) an increase of 10% in capital cost; (ii) an increase of 10% in the O&M costs; (iii) a 10% decrease in benefits; and (iv) a combination of tests (i), (ii), and (iii). A summary of sensitivity tests for the overall project are provided in Table 11. EIRR exceeds threshold targets for all tests except for test 4.

Table 11: Sensitivity Test Results—Overall Project

Sensitivity Test	EIRR (%)	NPV (CNY '000)	Sensitivity Indicator	Switching Value (%)
Base case	10.2	344.7		NA
1. Increase investment cost 10%	9.5	269.1	0.72	18
2. Increase operating cost 10%	10.1	331.2	0.12	105
3. Reduce benefits 10%	9.3	221.1	0.92	(13)
4. Combination of 1, 2, and 3	8.5	1431.9	1.70	NA
5. Reduce growth 10%	10.0	314.75	0.20	(60)

( ) = negative value, CNY = Chinese yuan, EIRR = economic internal rate of return, NA = not applicable, NPV = net present value.
Source: Asian Development Bank.

42. Detailed results for individual outputs are presented below. Cash flow projections for the base case EIRR calculations are provided in the appendix.

43. **Output 1.** Results of the economic evaluation for this output are provided in 0. The EIRR exceeds 9% for all tests.

Table 12: Economic Evaluation—Reduced Water Pollution Sources

Item	**EIRR** (%)	**NPV** (CNY million)
Base case	12.2	183.3
1. Increase investment cost 10%	11.3	143.3
2. Increase operating cost 10%	12.0	171.6
3. Reduce benefits 10%	11.0	113.1
4. Combination of 1, 2, and 3	10.0	61.3
5. Reduce growth 50%	12.0	169.1

CNY = Chinese yuan, EIRR = economic internal rate of return, NPV = net present value.
Source: Asian Development Bank estimates.

44. **Output 2.** Results of the economic evaluation for this output are provided in Table 13. The EIRR exceeds 6% for all tests. This result is highly uncertain since only water quality benefits apply to this component. The current analysis assigns 41% of these benefits to the output based on estimated pollutant loading reductions.

Table 13: Economic Evaluation—Protection of Water Resources from Pollution

	EIRR (%)	**NPV** (CNY million)
Base Case	8.1	161.4
1. Increase investment cost 10%	7.5	125.8
2. Increase operating cost 10%	8.1	159.7
3. Reduce benefits 10%	7.5	107.9
4. All 3 cost/rev impacts	6.9	70.6
5. Reduce growth 50%	8.0	145.7

CNY = Chinese yuan, EIRR = economic internal rate of return, NPV = net present value.
Source: Asian Development Bank estimates.

I. Poverty Impact Analysis

45. The economic benefits generated from the project will be allocated to stakeholders, as shown in Table 14. The distribution of costs and benefits among stakeholders relies on estimates of incremental benefits and cost generated by the main project outputs. All financial and economic benefits and costs are expressed in present value terms (9% discount rate). The total net benefit is estimated to be CNY1,707 million. Based on the proportion of poor beneficiaries for each project output, the total benefit accruing to the poor is estimated to be CNY547 million; and the poverty impact ratio is calculated as 0.32.

Table 14: Benefit Distribution and Poverty Impact Analysis (CNY million)

Present Value (at 6%)	**Financial NPV**[a] (1)	**Economic NPV**[a] (2)	**Difference** (2)-(1)	**Distribution of Benefits/Costs**			
				Consumers	**Construction Labor**	**Government /Economy**	**Total**
Benefits	0.0	1,046.1	1,046.1	1,046.1			1,046.1
Revenue	0.0	0.0	0.0	0.0			0.0
Intangible benefits		1,046.1	1,046.1	1,046.1			1,046.1
Costs	1,023.0	908.7	(115.1)		(2.7)	(112.4)	(115.1)
Capital	746.4	715.3	(31.1)			(31.1)	(31.1)
O&M	132.1	131.1	(1.0)			(1.0)	(1.0)
Taxes	80.2	0.0	(80.2)			(80.2)	(80.2)
Unskilled labor	64.9	62.2	(2.7)		(2.7)		(2.7)
Net benefits	(1,013.7)	137.4	1,161.2	1,046.1	2.7	112.4	1,161.2
Proportion of poor[b]				0.32	0.50	0.32	
Net benefits to the poor				**334.8**	**1.4**	**36.0**	**372.1**
Poverty impact ratio							**0.32**

( ) = negative value or amount, CNY = Chinese yuan, NPV = net present value.
[a] Measured as NPV at 9%.
[b] Based on social impact assessment in benefiting villages.
Source: Asian Development Bank estimates.

PRICE CONVERSION FACTORS

Shadow exchange rate factor

The standard conversion factor is set at 1.023 based on the Asian Development Bank's calculations.

Unskilled labor

The calculation of a conversion factor for unskilled labor could not be completed due to time and data limitations. A factor of 0.85 was assumed based on estimates of this factor in recent projects completed in the People's Republic of China.

ECONOMIC INTERNAL RATE OF RETURN

Table A2-1: Output 1—Reduce Water Pollution
(CNY '000)

				Project EIRR	12.22%
				NPV	508,060
Year	**Capital Investment**	**Project Sales Revenues**	**Non-capital Costs**	**Total Economic Benefits**	**Net Annual Value**
2019	(38,797)	0	(2,417)	0	(41,214)
2020	(4,731)	0	(2,375)	0	(7,106)
2021	(155,933)	0	(2,370)	0	(158,303)
2022	(290,896)	0	(2,370)	7,773	(285,492)
2023	(117,987)	0	(15,739)	16,166	(117,559)
2024	(23,370)	0	(15,890)	16,166	(23,094)
2025	(916)	0	(16,307)	100,731	83,508
2026	(568)	0	(16,307)	111,442	94,567
2027	0	0	(16,307)	113,167	96,860
2028	0	0	(16,307)	114,927	98,620
2029	0	0	(16,307)	116,722	100,414
2030	0	0	(16,307)	118,552	102,245
2031	0	0	(16,307)	120,420	104,113
2032	0	0	(16,307)	122,324	106,017
2033	0	0	(16,307)	124,267	107,960
2034	0	0	(16,307)	126,249	109,942
2035	0	0	(16,307)	128,270	111,963
2036	0	0	(16,307)	130,332	114,024
2037	0	0	(16,307)	132,435	116,127
2038	0	0	(16,307)	134,580	118,272
2039	0	0	(16,307)	136,767	120,460
2040	0	0	(16,307)	138,999	122,692
2041	0	0	(16,307)	141,275	124,968
2042	0	0	(16,307)	143,597	127,290
2043	0	0	(16,307)	145,965	129,658
2044	0	0	(16,307)	148,381	132,074
2045	0	0	(16,307)	150,845	134,538
Residual	633,197				633,197

( ) = negative amount or value, CNY = Chinese yuan, EIRR = economic internal rate of return, NPV = net present value.
Source: Asian Development Bank estimates.

Table A2-2: Output 2—Water Pollution Prevention and Control
(CNY '000)

				Project EIRR	**8.14%**
				NPV	**161,415**
Year	**Capital Investment**	**Project Sales Revenues**	**Total non-capital costs**	**Total eco benefits**	**Net Annual Value**
2019	(206,001)	0	(1,355)	0	(207,357)
2020	(5,450)	0	(1,332)	0	(6,782)
2021	(49,248)	0	(1,329)	0	(50,577)
2022	(77,569)	0	(1,329)	0	(78,898)
2023	(94,123)	0	(1,329)	0	(95,452)
2024	(130,889)	0	(1,329)	0	(132,218)
2025	(2,735)	0	(1,329)	0	(4,064)
2026	(401)	0	(1,329)	59,941	58,211
2027	0	0	(1,329)	61,139	59,810
2028	0	0	(1,329)	62,362	61,033
2029	0	0	(1,329)	63,609	62,280
2030	0	0	(1,329)	64,882	63,553
2031	0	0	(1,329)	66,179	64,850
2032	0	0	(1,329)	67,503	66,174
2033	0	0	(1,329)	68,853	67,524
2034	0	0	(1,329)	70,230	68,901
2035	0	0	(1,329)	71,634	70,306
2036	0	0	(1,329)	73,067	71,738
2037	0	0	(1,329)	74,528	73,200
2038	0	0	(1,329)	76,019	74,690
2039	0	0	(1,329)	77,539	76,211
2040	0	0	(1,329)	79,090	77,761
2041	0	0	(1,329)	80,672	79,343
2042	0	0	(1,329)	82,285	80,957
2043	0	0	(1,329)	83,931	82,602
2044	0	0	(1,329)	85,610	84,281
2045	0	0	(1,329)	87,322	85,993
Residual	566,415				566,415

( ) = negative value, CNY = Chinese yuan, EIRR = economic internal rate of return, NPV = net present value.
Source: Asian Development Bank estimates.

Table A2-3: Overall Project
(CNY '000)

				Project EIRR	10.24%
				NPV	669,475
Year	Capital Investment	Project Sales Revenues	Non-Capital Costs	Total Economic Benefits	Net Annual Value
2019	(244,798)	0	(3,773)	0	(248,571)
2020	(10,182)	0	(3,706)	0	(13,888)
2021	(205,181)	0	(3,699)	0	(208,880)
2022	(368,464)	0	(3,699)	7,773	(364,390)
2023	(212,110)	0	(17,068)	16,166	(213,011)
2024	(154,259)	0	(17,219)	16,166	(155,312)
2025	(3,650)	0	(17,636)	100,731	79,444
2026	(968)	0	(17,636)	171,383	152,778
2027	0	0	(17,636)	174,307	156,670
2028	0	0	(17,636)	177,289	159,653
2029	0	0	(17,636)	180,331	162,695
2030	0	0	(17,636)	183,434	165,798
2031	0	0	(17,636)	186,599	168,963
2032	0	0	(17,636)	189,827	172,191
2033	0	0	(17,636)	193,120	175,484
2034	0	0	(17,636)	196,479	178,843
2035	0	0	(17,636)	199,904	182,268
2036	0	0	(17,636)	203,399	185,763
2037	0	0	(17,636)	206,963	189,327
2038	0	0	(17,636)	210,599	192,963
2039	0	0	(17,636)	214,307	196,671
2040	0	0	(17,636)	218,089	200,453
2041	0	0	(17,636)	221,947	204,311
2042	0	0	(17,636)	225,883	208,246
2043	0	0	(17,636)	229,896	212,260
2044	0	0	(17,636)	233,991	216,355
2045	0	0	(17,636)	238,167	220,531
Residual	1,199,612	0	0	0	1,199,612

( ) = negative value, CNY = Chinese yuan, EIRR = economic internal rate of return, NPV = net present value.
Source: Asian Development Bank estimates.

ECONOMIC BENEFITS

A. Introduction

1. This appendix documents are on benefits of the Yunnan Sayu River Basin Rural Water Pollution Management and Eco-Compensation Demonstration Project. Benefits of the project outputs were estimated.

2. This appendix documents deal with household willingness-to-pay (WTP) for benefits of wastewater management improvements and flood damage reduction.

B. Willing to Pay for Wastewater Management Improvements

1. Approach

3. A stated preference approach was used to determine the value of wastewater management improvements. Contingent value (CV) questions were added to a household survey conducted for social impact analysis (SIA).

4. The selected CV question format was a multiple bounded discrete choice question. This question format resembles a payment card question; but unlike the payment card question which allows a yes or no response to each offer, it allows a polychotomous choice response to each offer ranging from "Definitely No" to "Definitely Yes."[1] To establish the context for the CV question, a wastewater tariff was used as the payment vehicle. A follow-up question was used to identify factors such as affordability and trust in government which could influence stated WTP amounts.

5. The response format and a typical set of interviewee responses for the WTP questions is as follows.

Table A3-1: Response Format and Typical Set of Interviewee Responses for WTP Questions

	1. Definitely YES	2. Probably YES	3. Probably NO	4. Definitely NO
Stay without wastewater tariff even if this means the project cannot be built	✓			
Set tariff to CNY1.0/ton or about CNY10.0/month	✓			
Set tariff to CNY1.5/ton or about CNY15.0/month		✓		
Set tariff to CNY2.0/ton or about CNY20.0/month		✓		
Set tariff to CNY3.0/ton or about CNY30.0/month			✓	
Set tariff to CNY4.0/ton or about				✓

[1] Hua Wang, Jie He, Yoonhee Kim, Takuya Kamata. 2013. Willingness-to-Pay for Water Quality Improvements in Chinese Rivers: An Empirical Test on the Ordering Effects of Multiple-Bounded Discrete. *Journal of Environmental Management*. 131 (2013) P. 256-269 (http://www.sciencedirect.com/science/article/pii/S0301479713005963).

	1. Definitely YES	2. Probably YES	3. Probably NO	4. Definitely NO
CNY40.0/month				
Set tariff to CNY5/ton or about CNY50.0/month				
Set tariff to CNY6/ton or about CNY60.0/month				

CNY = Chinese yuan.
Source: Asian Development Bank.

6. Original responses to the CV questions were coded as a series of scalar values indicating the degree of acceptance or rejection of successive offers on the scale: 1. “Definitely YES”, 2. “Probably”, 3. “Definitely NO”. Coding is bounded by the highest “Definitely YES” offer and the lowest “Definitely NO” value. In the above example, coding for the respondent is therefore as follows:

Table A3-2: Coding for Respondent

CNY0.0 No tariff	CNY1.0/ ton	CNY1.5/ ton	CNY2.0/ ton	CNY3.0/ ton	CNY4.0/ ton	CNY5.0/ ton	CNY6.0/ ton
-	1	2	2	3	4	-	-

CNY = Chinese yuan.
Source: Asian Development Bank.

7. Each respondent’s WTP is assumed to be a normally distributed continuous variable, and the objective of the survey is to identify each respondent’s mean WTP. This is done by assigning a probability of exceedance to each of the four possible responses and using a maximum likelihood approach to then estimate the mean WTP for each respondent. Estimated WTP values are then examined using regression analysis to identify the determinants of the WTP. The estimated WTP variable is continuous so that the ordinary least squares (OLS) regression can be used as the estimator.

8. The main benefit of the regression analysis is that it allows an analysis of potential bias in responses to the WTP questions arising from poor interviewer technique or respondent attitudes that distort responses to the CV question. Results of the regression analysis also allow correction for sampling bias which is a common problem with the SIA surveys that intentionally target low-income households.

2. Social Impact Analysis Household Survey

9. The WTP questions were added to a household survey conducted for poverty and social analysis. Survey instrument and questions related to the valuation of benefits were conformed to the selected CV question format. The CV questions were developed based on project data that was available in 2018.

10. A stratified random sampling protocol was developed by the SIA team to adequately cover project sites and beneficiaries.

11. Surveys were completed with 500 households in 16 administrative villages and natural villages in project areas. After screening, 200 valid survey forms remained (40%). With the stratified approach to sampling, the resulting survey data was not representative of the rural population.

3. Regression Analysis

12. The variables used in the regression analysis are shown in Table A3-3. This table does not describe all 64 variables which were tested.

Table A3-3: Continuous and Categorical Variables

CONTINUOUS							
			SUMMARY STATISTICS[a]				
VARIABLE	DESCRIPTION	No.	Mean	Standard Deviation	Maximum	Median	Minimum
WTP	WTP for wastewater management CNY/cubic meter	497	1.11	0.61	0.50	0.98	5.50
INC[b]	Estimated household income before tax	320	15,656	16,015	2,500	12,500	90,000
DYS_SICK	Total sick days for all household members	500	4.51	4.64	0.00	5.00	55.00
HHSIZE	No. persons in household	500	4.00	1.59	1.00	4.00	8.00
NO_CHIL	No. children in household	500	0.64	0.95	0.00	0.00	5.00
NO_RMS	No. rooms in house	485	2.98	2.36	1.00	2.00	30.00

Categorical Variables[c]	
VARIABLE	DESCRIPTION
PB_ALL	Aggregate score for respondent's ranking of problems to be addressed: 1. "Immediate", 2. "Can wait", 3. "Not important" for the following problems: 1. Collect and treat household wastewater 2. Collect and treat livestock waste 3. Increase wastewater treatment fee 4. Enhance management and inspection 5. Enhance public awareness of water environment protection
OTHSERV	Response to question "I want to see the government money spent on other services" on a scale from 1. "Strongly agree" to 5. "Strongly disagree".
POV_HH	Value of 1.0 indicates respondent self-classification as a poverty household, including having an income below the following limits: Urban minimum living guarantee line = CNY557/month/person; rural minimum living guarantee line = CNY292/month; rural poverty line = CNY3,500/year/person. Value of 0.0 is not a poverty household.
RESP_M	Respondent is male: 1.0; female: 0.0
ETH_HAN	Respondent is Han: 1.0; others: 0.0
WW_TOWN	1.0 = Respondents' wastewater is collected by community and/or village pipes; 0.0 = managed in another manner (flow into rivers, ditches, or ponds by private pipes, home collection in a septic tank, soak into the ground but no septic tank, flow overland, no treatment)

Table A3-3: Continuous and Categorical Variables

WW_n	Level of agreement with statement "n": 1 = Major problem, 2 = Minor problem, 3 = Not a problem. For "n" as follows: WW_OVFL - Overflow from sewers on the streets WW_OPDR - Wastewater in open drains or channels
NEG_ALL	Query level of negative impacts: "Do you think what will affect your life or negative impacts on your life during the project construction and operation?" based on the following ranking: 1. Very, 2. Some, 3. No impact. This variable aggregates across the following 10 factors: 1. Noise caused by construction 2. Solid waste produced by construction 3. Bad traffic due to construction 4. Noise cause by garbage facility operation 5. Bad odor near garbage collection station 6. Garbage liquid let out during transport 7. Farmland acquisition 8. Reduced agricultural output or income due to control chemicals and pesticides 9. Increased labor inputs due to change planting structures 10. Increased time inputs due to change planting structures
Attitude questions	Level of agreement with statement 'n': 1 = Strongly agree, 2 = Agree, 3 = Neither, 4 = Disagree, 5 = Strongly disagree. For 'n' as follows: GOVRESP - Solid waste and wastewater are government's responsibility; and so, I should not (need to) pay. AFFORD - I cannot afford even the present monthly bill for wastewater. NOPBLM - Wastewater and solid waste problems are not serious here. NOTEFFV - I do not think the new project will be effective. TRUST - I do not trust the government to use the money properly. RECYCLE - My household tries to reduce solid waste by recycling.
Issues	Ranking of issue 'n' in respondent's village/community as: 1. Very important, 2. Important, 3. Neutral, 4. Less important, 5. Not important, for the following issues: ISS_RD - Local road improvement and Improve public transport ISS_WW - More wastewater collection facilities, Control soil erosion ISS_SW - More garbage collection facilities, Improve garbage transport facilities, Control garbage dumpling into rivers ISS_RIVE - River dike consolidation, Dredging river ISS_HEA - Improve health care
Health impairment	Respondent ranking of causes of family members' sickness as: 1. Very Relevant, 2. Somewhat Relevant, 3. Not relevant, for the following factors: HEA_WW - Local wastewater HEA_ENV – combined influence of environmental factors (Garbage Management, Livestock and/or poultry Waste Treatment, Water Environment, Local wastewater, Air Quality)
EDU_LOW	1.0 = Respondent's education is junior high school or less, 0.0 otherwise

CNY = Chinese yuan, No. = number, WTP = willingness-to-pay.
[a] These are simple statistics that are not weighted to correct for income bias in the sampling.
[b] Survey question asked respondent to identify income range. Incomes were estimated as range mid-points. An alternative estimate of income based on reported expenditures was tested but proved not better than income.
[c] All normalized to a (0.1) scale.
Source: Asian Development Bank.

13. Initial regressions indicated a better performance for income and the WTP variables using their logarithms. The final model is shown in Table A3-4 below along with an initial regression.

Table A3-4: Water Supply Willingness-to-Pay Regression Results

FINAL: Regression model – OLS, Dependent variable = Ln (WTP) N = 298, R-bar squared = 0.19368, F [5,422] = 15.26827 P (F) > F* = 0.00000				
Regressor	**Coefficient**	**Standard Error**	**t**	**Prob │t│>T***
Constant	(2.09132)***	0.31348	(6.67)	0.0000
PB_ALL	0.44756***	0.13381	3.34	0.0009
ETH_HAN	(0.20734)**	0.09467	(2.19)	0.0293
Regressor	**Coefficient**	**Standard Error**	**t**	**Prob │t│>T***
WW_TOWN	0.19134**	0.07557	2.53	0.0119
NO_RMS	0.02565**	0.01191	2.15	0.0321
LN_INC	0.19555***	0.02982	6.56	0.0000
PRELIMINARY: Regression model – OLS, Dependent variable = Ln (WTP) N = 102, R-bar squared = 0. 23289, F [25, 361] = 2.05732, P (F) > F* = 0. 00712				
Regressor	**Coefficient**	**Standard Error**	**t**	**Prob │t│>T***
Constant	(1.49243)	0.97736	(1.53)	0.1311
PB_ALL	0.61511*	0.32192	1.91	0.0600
OTHSERV	1.12356**	0.48306	2.33	0.0228
POV_HH	0.02605	0.16344	0.16	0.8738
RESP_M	0.27913**	0.11975	2.33	0.0226
LN_INC	0.15522*	0.07857	1.98	0.0520
ETH_HAN	(0.32197)*	0.16902	(1.90)	0.0608
WW_TOWN	0.28983	0.17709	1.64	0.1061
WW_OVFL	(0.66309)*	0.35424	(1.87)	0.0653
WW_OPDR	0.29867	0.39754	0.75	0.4549
NEG_ALL	0.26867	0.24168	1.11	0.2700
GOVRESP	0.37534	0.36770	1.02	0.3108
AFFORD	(0.80121)**	0.40169	(1.99)	0.0499
NOPBLM	0.12823	0.33103	0.39	0.6996
NOTEFFV	0.49040	0.49635	0.99	0.3265
TRUST	(0.55833)	0.41494	(1.35)	0.1827
RECYCLE	0.19024	0.29258	0.65	0.5176
ISS_RD	(0.27833)	0.42441	(0.66)	0.5140
ISS_WW	0.38383	0.62126	0.62	0.5386
ISS_SW	(0.44186)	0.66392	(0.67)	0.5078
ISS_RIVE	0.72482*	0.40726	1.78	0.0793
ISS_HEA	(0.90747)**	0.42811	(2.12)	0.0375
DYS_SICK	0.01075	0.01366	0.79	0.4340

HEA_WW	(0.08169)	0.39528	(0.21)	0.8369
HEA_ENV	0.04009	0.49082	0.08	0.9351
HEA_SA	(0.14429)	0.12568	(1.15)	0.2548
HHSIZE	0.00154	0.04756	0.03	0.9743
NO_CHIL	0.11931	0.07496	1.59	0.1159
EDU_LOW	0.01245	0.24959	0.05	0.9603
NO_RMS	(0.05078)	0.03608	(1.41)	0.1636

( ) = negative value, OLS = ordinary least square, WTP = willingness-to-pay.
Note: ***, **, * → Significance at 1%, 5%, 10% levels.
Source: Asian Development Bank estimates.

4. Estimation of Willingness-to-Pay

14. The stratified sampling scheme employed in the household survey was designed to capture several lower-income and vulnerable households. The survey sample is therefore not representative of the rural population (Figure A3-1).

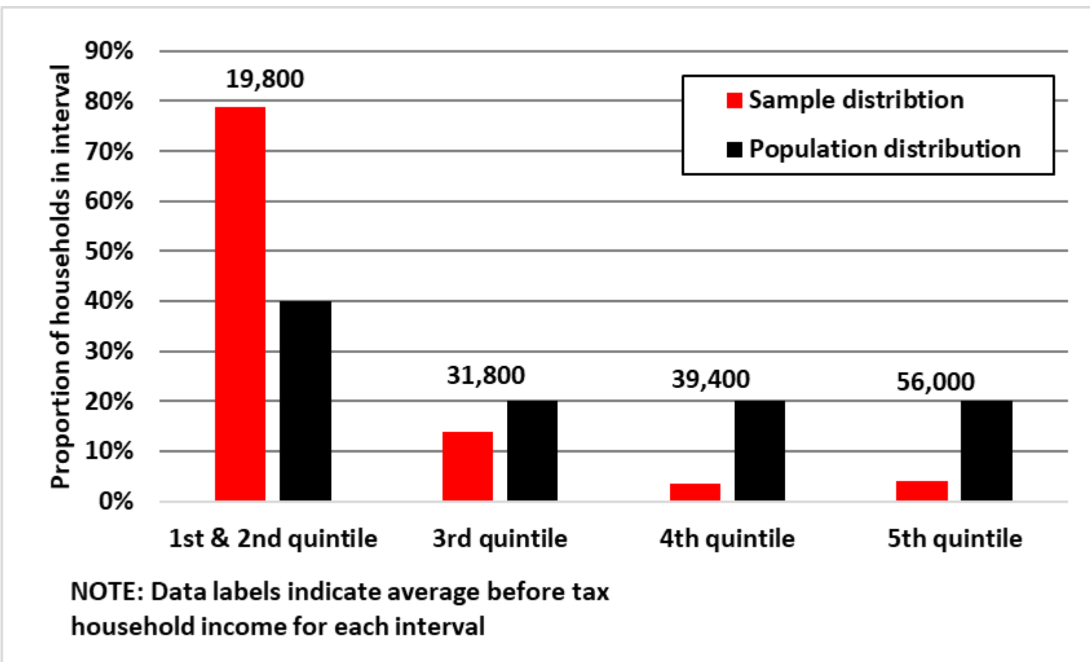

Figure A3-1: Sampling Distribution

15. For this reason, the final analysis of the WTP weights estimates of the WTP for respondents in the household survey to correct for the income bias. Weights are the ratios of the population and sample distribution in each income category.[2]

[2] Income distribution data were not available in the Zhaotong City or the Yunnan provincial statistical year books. Only averages of household income and size are available in the statistical year books. An

16. The WTP of each respondent was estimated based on coefficients for the final regression in the above table. The weighted average WTP for respondents was the Chinese yuan (CNY) 1.22 per ton. Since respondents are not currently serviced, this value measures the net WTP for improvements and represents net benefit or consumer surplus. The analysis assumes introduction of a wastewater tariff paid by newly serviced customers. Total benefits of wastewater management equal new tariff revenues plus the difference between the WTP and the tariff payment.

C. Willingness-to-Pay for Village Solid Waste Management Improvements

1. Approach–Benefits Transfer

17. Only one useful CV study dealing with solid waste in the People's Republic of China was located (described below). The results of this study were used to derive an estimate of household WTP for solid waste collection of CNY201 per year. This estimate of the WTP is based on income and household statistics for the project site and is updated to 2019 price levels. Detailed calculations are shown below.

Hua Wang, Jie He, Yoonhee Kim, Takuya Kamata, 2011. Municipal Solid Waste Management in Small Towns, An Economic Analysis Conducted in Yunnan, China. *Policy Research Working Paper*. 5767. The World Bank Development Research Group, Environment and Energy Team.

ABSTRACT (from original): Municipal solid waste management continues to be a major challenge for local governments in both urban and rural areas across the world, and one of the key issues is their financial constraints. Recently, an economic analysis was conducted in Eryuan, a poor county located in the Yunnan Province of the People's Republic of China, where the willingness-to-pay (WTP) for an improved solid waste collection and treatment service was estimated and compared with the project cost. This study finds that the mean WTP is about 1% of household income and the total WTP can basically cover the total cost of the project. The analysis also shows that the poorest households in Eryuan are not only willing to pay more than the rich households in terms of income percentage in general, but also are willing to pay not less than the rich in absolute terms where solid waste services are not available. The poorest households have stronger demand for public solid waste management

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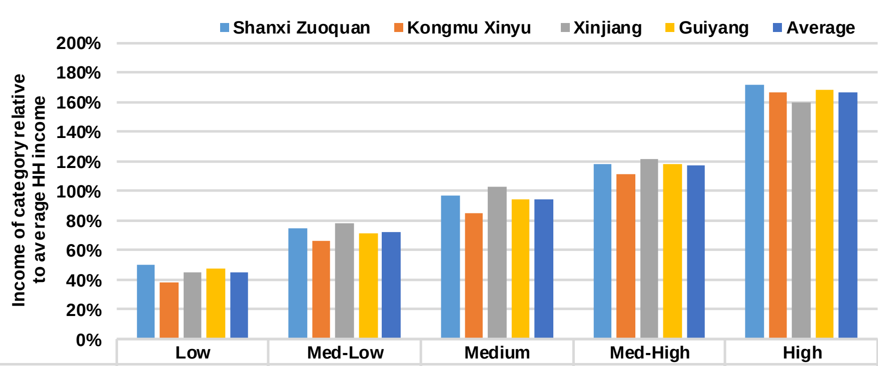
estimate of the distribution parameters was therefore made using the average of income distribution data from previous studies, as shown in the following figure:



	Low	Med-Low	Medium	Med-High	High
Shanxi Zuoquan	50%	75%	97%	118%	172%
Kongmu Xinyu	38%	66%	85%	111%	166%
Xinjiang	45%	78%	103%	122%	160%
Guiyang	48%	72%	94%	118%	168%
Average	45%	73%	95%	117%	167%

HH Income Category

HH = household.

services, while the rich have the capability to take private measures when public services are not available.
STUDY AREA: Yunnan Province, People's Republic of China
PERIOD OF ANALYSIS: 2007
SAMPLE SIZE: 221 households, 110 with a solid waste service, 113 in areas to receive a service. 218 valid responses.
MODEL AND ESTIMATOR: multiple bounded discrete choice question, Logit regression to determine each respondent's most probable bid followed by ordinary least squares regression to explore the resulting bid database. With multiple bounded discrete choice questions, response options to each offer are "Definitely No", "Probably No", "Not Sure", "Probably Yes", and "Definitely Yes". Thus, each respondent assigns an implicit probability to every offer. Offers range from CNY3/month to CNY500/month and are not varied across respondents.
COMMENT: Excellent study with a good review of past work in the area. Sample size seems small. Regression results probably could be used in a benefits transfer exercise.

18. The benefits transfer calculation is shown in Table A3-5. Variable statistics for the research site are shown along with assumed values for the policy site. The household WTP for solid waste management is CNY18.67 per month at 2006 price levels or CNY26.50 per month (CNY318 per year) at 2019 price levels.

Table A3-5: Variables Used in Soli Waste Management WTP Analyses

Variable	Mean	Standard Deviation	Minimum	Max	Policy Site[a]	Model Coefficient[b]	t-Scores[c]
Education University diploma, yes = 1, no = 0	0.16	0.37	0.00	1	0.16	0.063	(0.35)
Male Sex: male = 1 female =0	0.60	0.49	0.00	1	0.50	0.112	(0.95)
Age (years)	37.57	11.39	17.00	78	37.57	-0.002	(0.41)
Farmer Household head's profession: farmer = 1, other = 0	0.44	0.50	0.00	1	0.44	-0.013	(0.11)
Married Marital situation (married = 1, other = 0)	0.88	0.32	0.00	1	0.88	-0.169	(0.85)
Household income Household income (CNY '000) in 2006	22.33	33.75	0.50	200	36.22	0.247	(8.97)***
Family size Family size (person)	4.59	1.74	1.00	15	3.87	-0.030	(1.02)
Income decrease Do you expect your household income to decrease in future 5 years? yes = 1, no = 0	0.09	0.29	0.00	1	0.09	-0.428	(2.34)**
Donation in the Donation for social charity before? (yes = 1, no = 0) past	0.77	0.42	0.00	1	0.77	0.254	(1.96)*
Important Solid waste considered as one of the three most important environmental problem: yes = 1, no = 0	0.85	0.36	0.00	1	0.85	0.373	(2.63)***
Government responsibility Do you think environmental problems should only be resolved by government? yes = 1, no = 0	0.13	0.33	0.00	1	0.13	-0.380	(3.04)***
Estimated household WTP/month, CNY 2006	16.88	20.60	1.49	200	18.67		

( ) = negative value, CNY = Chinese yuan, WTP = willingness-to-pay.
[a] Variables adjusted to reflect the policy site are italicized. Income data for 2018 adjusted back to 2006 price levels using consumer price index.
[b] R-squared = 0.92; F statistic = 213.65.
[c] *** denotes 1% significance level, ** refers 5% significance level, and * indicates 10% significance level.
Source: Asian Development Bank estimates.

D. Health Benefits

19. A health benefits analysis was completed to complement the WTP analysis for wastewater and solid waste managements. Considering the possibility of double counting if both approaches to benefits assessment are used, the rationale for this analysis is the likelihood that rural village residents are poorly informed about the health effects of poor sanitation and will underestimate their WTP accordingly.

20. The analysis is based on findings of the report "Economic Assessment of Sanitation Interventions in Yunnan Province, People's Republic of China: A six-country study conducted in Cambodia, People's Republic of China, Indonesia, Laos, Philippines and Vietnam under the Economics of Sanitation Initiative (ESI), (September 2012, World Bank Water and Sanitation

Program East Asia and the Pacific Regional Office).”

21. Results of the analysis are summarized in Table A3-6. Original values in the referenced report were converted to 2019 CNY values and total benefits were estimated using recent population data. The total per capita benefit, CNY200/year, implies a household benefit of CNY660/year.

Table A3-6: Health Benefits Analysis (CNY 2018)

Disease Class	Age Class			Weighted Average[b]
	0-4 years	5-14 years	15+ years	
Annual costs per person attributed to poor sanitation and hygiene				
Diarrheal disease, hepatitis A and E	194.4	139.3	82.8	97.1
Soil-transmitted helminths	49.6	59.5	38.4	41.8
Hygiene-related	216.6	107.2	70.7	84.6
Benefit[a]	60.8	43.5	25.9	30.3
Average Productivity Cost Per Person Per Year in Field Sites, By Disease, Age Group, and Rural and/or Urban Location				
Diarrheal disease, hepatitis A and E	110.5	69.6	82.0	82.2
Soil-transmitted helminths	31.1	37.3	48.0	45.6
Hygiene-related	125.8	67.6	92.1	91.1
Benefit[a]	34.5	21.8	25.6	25.7
Average Mortality Cost Per Person Per Year In Field Sites, By Disease, Age Group, and Rural and/or Urban Location				
Diarrheal disease, hepatitis A and E	547.6	656.6	423.1	460.8
Soil-transmitted helminths	109.1	109.1	109.1	109.1
Hygiene-related	511.5	349.2	240.1	271.3
Benefit[a]	171.1	205.2	132.2	144.0
Total Benefit	266.4	270.5	183.7	200.0

CNY = Chinese yuan.

[a] Based on estimates of relative risk reductions in disease incidence and prevalence as follows: improvement from “Unimproved pit latrines (excreta partially isolated) – without hygiene” to “Septic tanks with emptying and treatment or sewerage With full wastewater treatment – without hygiene.” Reduction of 31.3% for diarrheal disease, hepatitis A and E; 60.0% for soil-transmitted helminths; and 0.0% for hygiene-related diseases.

[b] Based on the 2015 population age distribution for Yunnan Province (China Statistical Yearbook, 2016 http://www.stats.gov.cn/tjsj/ndsj/2016/indexeh.htm, Table 2-12)

Source: Asian Development Bank estimates.

E. Water Quality Benefits

22. Pollution control measures for the Sayu River will benefit downstream urban residents who depend on the Yudong Reservoir for their water supply. Valuation for the Sayu project is based on research in the Huaping Co. in the Northern Yunnan summarized in Table A3-7. Values from this paper below were used for a benefits transfer calculation.

Table A3-7: Review of Wetland and Green Space Valuation Studies

Hua Wang, Jie He, Yoonhee Kim, Takuya Kamata, 2013. Willingness-to-pay for water quality improvements in Chinese rivers: An empirical test on the ordering effects of multiple-bounded discrete choices. *Journal of Environmental Management*. 131 (2013), 256-269. **ABSTRACT** (from original): This paper presents a study of the willingness-to-pay (WTP) for surface water quality improvement in the People's Republic of China. In the Huaping County of Yunnan Province, we found that people are willing to pay CNY74 (or $12.33 in 2012 prices) per household per month (or 5% of household income) continuously for 5 years to achieve an improvement of water quality in the two major local rivers from the current Grade IV to Grade III, which denotes a level suitable for swimming and fishing and matches the water quality level from 10 years ago. This WTP study is based on an actual investment project that was under serious consideration by the government; and is based on the multiple-bounded discrete choice (MBDC) approach, which explicitly recognizes the potential uncertainties involved in the study. The potential ordering effects associated with the MBDC approach are empirically tested; and the results indicate that although the presentation order of the polychotomous likelihood choices may not have a significant impact on the WTP estimation, the presentation order of bid levels may have a significant impact. **STUDY AREA:** Yunnan Province, People's Republic of China **PERIOD OF ANALYSIS:** 2007 **SAMPLE SIZE**: 460 **MODEL AND ESTIMATOR**: Multi-bounded discrete choice

23. Regression coefficients from the Yunnan study are provided in Table A3-8 and data averages for the research and policy site are provided in Table A3-9 along with estimates of household WTP. Estimated WTP for the policy site is CNY162/month for 5 years. At 2018 price levels, this amounts to CNY230/month. This estimate, once converted to an ongoing payment assuming a 6% discount rate, is CNY58/month.[18] On an annual basis, the WTP is CNY700/year; or 0.5% of household disposable income.

Table A3.8: Description and Statistics of Regression Model Variables for the Hua Wang et.al. Paper

Variable	Description	Coefficient	t-score
Sex	Male = 1; female = 0	0.588	0.08
Age	Years of age	(0.245)	(0.75)
Income	Household income in the year of 2006 (CNY '000)	1.383	3.98***
Education	Primary education and above = 1; other = 0	14.653	1.55
Married	Married = 1; otherwise = 0	(7.943)	(0.56)
Income growth	Did your income increase from 2005 to 2006? Yes = 1; otherwise = 0	12.515	1.68*
Irrigation	Did you use the water for irrigation in 2006? Yes = 1; otherwise = 0	10.444	1.54
Water quality	1 = consider water quality to be one of the three most urgent problems; 0 = otherwise	4.138	0.60
Environmental donation	Would you donate for environmental protection? Definitely/probably yes = 1; otherwise = 0	16.566	2.27**

[18] Calculated as the net present value of payments over 5 years amortized over 99 years all at 6%.

Variable	Description	Coefficient	t-score
Press	Did you hear press discussion about the water quality in 2006? Yes = 1; no or do not know = 0	17.41	2.94***
Heard	Did you hear about the project? Yes = 1; no = 0	9.276	1.42
Income increase with water improvement	Would your income increase with the water quality improvement? Yes = 1; no or do not know = 0	15.452	2.30**
Income reduced with project construction	Would the construction of sewers and the wastewater treatment plant decrease your household income? Yes = 1; no or do not know = 0	(19.040)	(1.85)*
Scope	Target of water quality improvement: Grade II = 1; Grade III = 0	5.432	0.84
High-to-low	Bid price order: 1 = high-to-low; 0 = low-to-high	16.443	(2.60)***
Yes-to-no	Likelihood order: 1 = yes-to-no; 0 = no-to-yes	4.155	0.62
One-to-one	1 = one-to-one interview; 0 = group but self-completion with instructions	(5.447)	(0.78)
Constant		(14.839)	(0.58)

( ) = negative value.
Note: R-squared = 0.18, *** denotes 1% significance level, ** refers 5% level, and * indicates 10% level.
Source: Asian Development Bank estimates.

Table A3.9: Data Averages and Estimated WTP

Variable	Research Site	Policy Site	Comment
Sex	0.71	0.50	Assumed
Age	41.50	41.50	Original used
Income	15.27	100.93	See note
Education	0.97	0.97	Original used
Married	0.94	0.94	Original used
Income growth	0.46	0.46	Original used
Irrigation	0.44	0.00	Assumed
Water quality	0.63	0.63	Original used
Environmental donation	0.88	0.50	Assumed
Press	0.57	0.50	Assumed
Heard	0.60	0.50	Assumed
Income increase with water improvement	0.40	0.00	Assumed
Income reduce with project construction	0.10	0.10	Original used
Scope	0.49	0.00	Assumed
High-to-low	0.50	0.50	Original used
Yes-to-no	0.50	0.50	Original used
One-to-one	0.61	1.00	Assumed

Table A3.9: Data Averages and Estimated WTP

Variable	Research Site	Policy Site	Comment
Estimated WTP, CNY/month for 5 years	60.21	162.10	

CNY = Chinese yuan, WTP = willingness-to-pay.
Note: Income estimated using 2018 per capita income for Yunnan adjusted to 2006 with consumer price index and converted to household income assuming 3.3 persons per household (China Statistical Yearbook, 2016 http://www.stats.gov.cn/tjsj/ndsj/2016/indexeh.htm).
Source: Asian Development Bank estimates.

F. Wetland Benefits

24. Benefits from the proposed wetlands associated with recreation, biodiversity, and cultural or aesthetic amenities were not addressed in the household survey. Several published valuation studies with an Asian focus were reviewed as a source of information to assign value to these benefits (Table A3-11). Values from the first paper reviewed below were used for evaluation here. They are summarized in Table A3-10. The total value of CNY25,837/hectare converts to CNY36,669 at 2019 price levels.

Table A3-10: Wetland Values, CNY 2006

2006 Prices	CNY/ hectare	Proportion of Total Benefit	Values Used for this Project	Comment
Material production	7,410	13%	7,410	included
Water supply	5,695	10%	0	Accounted for under water quality benefit
Environmental purification	23,800	43%	0	
Disturbance regulation	7,627	14%	7,627	included
Gas regulation	7,288	13%	7,288	included
Biodiversity support	3,512	6%	3,512	included
Total	**55,332**		**25,837**	

CNY = Chinese yuan.
Source: C. Tong, R.A. Feagin, J. Lu, X. Zhang, X. Zhu, W. Wang, W. He, 2007. Ecosystem Service Values and Restoration in the Urban Sanyang Wetland of Wenzhou, China. *Ecological Engineering*. 29 (2007). 249-258.

Table A3.11: Review of Wetland and Green Space Valuation Studies

C. Tong, R.A. Feagin, J. Lu, X. Zhang, X. Zhu, W. Wang, W. He, 2007. Ecosystem Service Values and Restoration in the Urban Sanyang Wetland of Wenzhou, China. *Ecological Engineering*. 29 (2007). 249-258. **ABSTRACT** (from original): Over the course of a year, we conducted a study on future restoration work in the Sanyang Wetland, a degraded permanent river wetland that is close to the center of Wenzhou City, People's Republic of China (PRC). Our main objective was to plan the restoration by using both structural indices and a valuation of the wetland's ecosystem services, thereby linking the science to human welfare. Based on field surveys and research into the history of the study area, we calculated both the potential and current values of the main ecosystem services. The results showed that the potential value at the Sanyang Wetland was Chinese yuan (CNY)55,332/hectare (ha)/year, while the current value was only CNY5,807/ha/year. In other words, 89.5% of the service value needs to be restored for the wetland to reach its potential value. We recommend that the service provided by the wetland's ability to purify the environment needs to be the top priority in restoration. In addition, water and sediment quality should also be greatly improved.

STUDY AREA: Wenzhou, PRC
PERIOD OF ANALYSIS: 2002
SAMPLE SIZE: not applicable (NA)
MODEL AND ESTIMATOR: benefits transfer
COMMENT: The subject wetland is a large (11.41 square kilometers) degraded natural wetland. Values for ecological services are derived from Costanza and other authors.

Wendy Y. Chen and C.Y. Jim, 2008. Cost–benefit analysis of the leisure value of urban greening in the new Chinese city of Zhuhai. *Cities*. 25: 298–309.
ABSTRACT (from original): Nature in cities is increasingly preserved or created to improve urban environmental quality. Green space provision is proceeding apace in many PRC cities. Cost–benefit analysis of such projects is needed to justify the level of investment and the use of public funds. This paper assessed the use pattern of urban green spaces in the new Zhuhai City in southern PRC and employed the contingent valuation method (CVM) to estimate the non-market leisure value of an ambitious new urban greening project. A questionnaire survey of 850 randomly chosen households was conducted. Some 65.7% of respondents used public green spaces for leisure frequently and young residents aged 20–30 were less frequent users. The new greening project was strongly supported for its leisure and ecological values. The logit regression model indicated that household income and bid amount would affect individual willingness-to-pay (WTP). The mean WTP was CNY161.84 per household per year, translated into an aggregate leisure value of CNY12.3 million per year. The net present value is projected to be CNY32.94 million and the discounted benefit–cost ratio is 0.88 when other benefits were not included. The findings confirmed community support and verified the application of cost–benefit analysis in projects related to non-market public goods, and the applicability of the CVM in the PRC context. The study could serve as the basis to launch other cost–benefits analysis of nature conservation projects which need urgent attention in view of the rapid pace of urbanization in the PRC to contribute to sustainable city goals.
STUDY AREA: Zhuhai, Guangdong Province, PRC
PERIOD OF ANALYSIS: 2006
SAMPLE SIZE: 850 (598 valid)
MODEL AND ESTIMATOR: double-bounded dichotomous, logistic regression
COMMENT: May be useful for urban greening. Income was the only variable in the WTP equation.

Wu Yang, Jie Chang, Bin Xub, Changhui Peng, Ying Ge, 2008. Ecosystem service value assessment for constructed wetlands: A case study in Hangzhou, China. *Ecological Economics*. 68(2008).116–125.
ABSTRACT (from original): Based on a comprehensive analysis of various classifications of natural resource values, we summarized an ecological economic value system of constructed wetland ecosystems for treating eutrophic water. Using the constructed wetlands located at the Hangzhou Botanical Garden as an example, the CVM and shadow project approach (SPA) were applied to estimate the economic values of constructed wetland system ecosystem services. The CVM estimated a value of CNY800,000 as the total economic value of the constructed wetlands in a twenty-year period. Meanwhile, the SPA calculated a value of CNY23.04 million as the total economic value of the constructed wetlands in a twenty-year period. It is determined that compared to the CVM, the SPA provides a more approximate value of the true monetary value of the Hangzhou Botanical Garden constructed wetlands. This study could fill the gap of knowledge and provide a benchmark when evaluating constructed ecosystem services and help policy makers to promote the development of constructed wetlands in the PRC.
STUDY AREA: Hangzhou Province, PRC
PERIOD OF ANALYSIS: 2007
SAMPLE SIZE: 300 (294 valid)
MODEL AND ESTIMATOR: payment card question, ordinary least squares estimation
COMMENT: Final equation includes only income as an independent variable. Study is not relevant due to the context: small (800square meter) constructed urban wetland used to treat fishpond wastewater, the WTP was only for the treatment function.

A. Ghermandi, J.C.J.M. van den Bergh, L.M. Brander, H.L.F. de Groot, P.A.L.D. Nunes, 2009. The Values of Natural and Constructed Wetlands: A Meta-Analysis. *Tinbergen Institute Discussion Paper*. TI 2009-080/3.
ABSTRACT (from original): The values of goods and services provided by natural and constructed

wetlands are examined through a meta-analysis of 418 observations of the economic value of 186 wetlands. Water quality improvement, non-consumptive recreation, and provision of natural habitat and biodiversity turn out to be highly valued services. Substitution effects are observed through the negative correlation between values and proximity to other wetlands. Values are found to increase with anthropogenic pressure. Constructed wetlands are highly valued for biodiversity enhancement, water quality improvement, and flood control. This study provides a substantially new contribution in relation to previous meta-analyses of the wetland valuation literature.

STUDY AREA: NA

PERIOD OF ANALYSIS: NA

SAMPLE SIZE: 418 primary valuation studies comprising 132 from North America, 106 from Asia, 93 from Europe, 53 from Africa, 22 from South America and 16 from Australasia.

MODEL AND ESTIMATOR: ordinary and weighted least squares

COMMENT: The current interest pertains to passive or recreation values. In this meta-analysis, identified estimates of these values ranged between $101 and $9,144/ha/year. Applying their basic model (model B in table 3) gives a wetland value for non-consumptive recreation of 2015 CNY128/ha (2003 $11.43/ha):

Independent Variable	Coefficient	Variable value	Comment
Year of publication	(0.0410)	21.7700	Regression data mean
Marginal	0.7130	0.1200	Regression data mean
Estuarine	0.2700	0.0000	Based on characteristics of the proposed project (setting Lacustrine value at 1 gives the same total value)
Marine	0.7540	0.0000	
Riverine	0.3800	1.0000	
Palustrine	(0.4800)	0.0000	
Lacustrine	0.3320	0.0000	
Constructed	1.0230	1.0000	
Independent Variable	**Coefficient**	**Variable value**	**Comment**
Wetland size	(0.2340)	(1.7148)	FSR 06.15 Feasibility study of Xinyu landscape part (A4) .docx-Figure 3.1-1 General plan of the landscape
Flood control, storm buffering	0.4320	0.0000	Evaluated separately
Surface and groundwater supply	(0.0990)	0.0000	NA
Water quality improvement	0.7270	0.0000	Evaluated separately
Commercial fishing and hunting	0.2660	0.0000	NA
Recreational hunting	(1.0070)	0.0000	NA
Recreational fishing	(0.0820)	0.0000	NA
Harvesting of natural materials	(0.2020)	0.0000	NA
Fuel wood	(0.9680)	0.0000	NA
Non-consumptive recreation	0.6700	1.0000	Intended use
Amenity and aesthetics	0.5290	0.0000	NA
Natural habitat, biodiversity	1.1430	0.0000	NA
Medium-low human pressure	0.5720	0.0000	Assumed
Medium-high human pressure	1.2430	0.0000	Assumed
High human pressure	1.9920	1.0000	Assumed
GDP per capita	0.3580	8.6700	Xinyu 2014 per capita GDP in CNY - Jiangxi 2015 yearbook table 1-6 Inflation and exchange rates from ADB's Key Indicators for Asia and the Pacific 2015. (log value)
Population in 50 km radius	0.3990	14.9600	Population of Xinyu Prefecture (log value)
Wetland area in 50 km radius	(0.0580)	7.1700	Interim report, page 56 (log value)
Constant	(0.6810)	1.0000	

( ) = negative value, ADB = Asian Development Bank, CNY = Chinese yuan, FSR = feasibility study report, GDP = gross domestic product, km = kilometer, NA = not applicable.

S. B. Lu, S. G. Xu, and F. Feng, 2012. Floodwater Utilisation Values of Wetland Services – A Case Study in Northeastern China. *Natural Hazards Earth System Science*. 12 (2). 341–349.

ABSTRACT (from original**):** Water plays a significant role in wetlands. Floodwater utilization in wetlands brings a wide range of wetland services from goods production and water regulation to animal protection

and aesthetics related to water supply in wetlands. In this study, the floodwater utilization values of wetland services were estimated within the Momoge Wetland and the Xianghai Wetland in the western Jilin Province of northeastern PRC. From 2003 to 2008, the floodwater diverted from the Nenjiang and Tao'er rivers is 381 million cubic meters, which translates into a monetary value of approximately CNY1.35 billion in 2008; and the ratio of economic value, eco-environmental value, and social value is 1:12:2. Besides the monetary value of the water itself, excessive floodwater utilization may bring losses to wetlands; and the threshold floodwater utilization volumes in wetlands are discussed. Floodwater utilization can alleviate water shortages in wetlands, and the evaluation of floodwater utilization in wetland services in monetary terms is a guide for the effective use of the floodwater resources and for the conservation of wetlands.
STUDY AREA: Western Jilin Province, PRC
PERIOD OF ANALYSIS: 2003 to 2008
SAMPLE SIZE: NA
MODEL AND ESTIMATOR: NA
COMMENT: Valuation of benefits by various means. Recreation benefits are estimated using a travel cost model, but no details are provided.

Zhang Yiran, Zhou Demin, Niu Zhenguo, Xu Fengjiao, 2014. Valuation of lake and marsh wetlands ecosystem services. *Chinese Geographical Science*. 24(3). 269–278.
ABSTRACT (from original): Wetlands are highly productive natural ecosystems, providing valuable goods and services. There is growing interest in transferring ecosystem service value from the existing wetlands studied to other wetlands ecosystems at a large geographic scale. The benefit transfer method uses the known values from wetlands to predict the value of other wetland sites. This methodology requires only limited time and resources. The present study calculated the value of the ecological services provided by lake and marsh wetlands in the PRC in terms of biodiversity indices, water quality indices, and economic indices. Basic data on wetlands were obtained through remote sensing images. The results are as follows: (i) The total ecosystem service value of the lake and marsh wetlands in 2008 was calculated to be \$8.1841 × 1,010, with the marsh and lake wetlands contributing \$5.6329 × 1,010 and \$2.5512 × 1,010, respectively. Values of marsh ecosystem service were concentrated in Heilongjiang Province (\$2.5516 × 1,010), Qinghai Province (\$1.2014 × 1,010), and Inner Mongolia Autonomous Region (\$1.1884 × 1,010). The values of the lakes were concentrated in the Tibet Autonomous Region (\$6.223 × 109), Heilongjiang Province (\$5.810 × 109), and Qinghai Province (\$5.500 × 109; (ii) Waste treatment and climate regulation services contributed to 26.29% and 24.74%, respectively, of the total ecosystem service value of the marsh wetlands. Hydrological regulation and waste treatment contributed to 41.39% and 32.75%, respectively, of the total ecosystem service value of the lake wetlands; (iii) The total ecological service value of the lake and marsh wetlands was 54.64% of the total service value of natural grassland ecosystems and 30.34% of the total service value of forests ecosystems in the PRC.
STUDY AREA: PRC
PERIOD OF ANALYSIS: Socioeconomic data from 2008
SAMPLE SIZE: NA
MODEL AND ESTIMATOR: NA
COMMENT: Could apply to wetland valuation but must screen benefit categories for relevance.

M. Chaikumbung, H. Doucouliagos and H. Scarborough, 2015. The economic value of wetlands in developing countries: A meta-regression analysis. *Ecological Economics*. Col. 124, April 2016, Pages 164-174.
ABSTRACT (from original): This paper presents the first comprehensive synthesis of economic valuations of wetlands in developing countries. Meta-regression analysis (MRA) is applied to 1,432 estimates of the economic value of 379 distinct wetlands. We find that wetland size has a negative effect on wetland values, marine wetlands are more valuable than estuarine wetlands, and per capita GDP has a positive effect on wetland values. Wetland services for water treatment and biodiversity are valued more highly than recreation. Wetland values estimated by stated preferences are lower than those estimated by market price methods. The MRA benefit transfer function has an average transfer error of 31%, with a median transfer error of 17%. Overall, the MRA appears to be useful for deriving the economic value of wetlands at policy sites in developing nations.
STUDY AREA: NA

PERIOD OF ANALYSIS: various
SAMPLE SIZE: 342 wetland sites from 50 developing countries in Asia, Africa, Latin America, and the Pacific Islands (37 from the PRC). 1,432 observations of values based on different methods.
MODEL AND ESTIMATOR: ordinary and weighted least squares, random effects, panel
COMMENT: Average wetland value is 2002 $1,998/ha/year. This value includes all benefits. Applying the coefficients of the general least squares model from Table 2 gives a wetland value for non-consumptive recreation of 2015 CNY134/ha (2002 $11.56/ha):

Independent Variable	Coefficient	Variable Value	Comment
Constant	5.018	1.000	
Size (ln area)	(0.374)	(1.710)	FSR 06.15 Feasibility study of Xinyu landscape part (A4) .docx-Figure 3.1-1 General plan of the landscape
Riverine	0.481	1.000	Based on characteristics of the proposed project (setting Lacustrine value at 1 gives the same total value)
Marine	1.137	0.000	
Constructed	(0.729)	1.000	
Lacustrine	(0.017)	0.000	
Palustrine	(1.471)	0.000	
Other	0.087	0.000	
Independent Variable	**Coefficient**	**Variable Value**	**Comment**
Storm or flood protection	0.465	0.000	Evaluated separately
Water regulation	1.944	0.000	NA
Water supply	(1.070)	0.000	NA
Nutrient	1.475	0.000	NA
Erosion	0.433	0.000	NA
Carbon	(1.148)	0.000	NA
Water treatment	0.723	0.000	Evaluated separately
Biodiversity-Habitat	1.474	0.000	NA
Food	(0.698)	0.000	NA
Raw materials	0.619	0.000	NA
Culture	(0.028)	0.000	NA (recreation is the baseline category and is not included here)
Replacement cost	0.786	0.000	Regression data mean
Contingent Value	(1.746)	1.000	Assumed
Choice Experiment	(1.182)	0.000	Assumed
Travel Cost method	0.178	0.000	Assumed
Net factor income and Production function	1.027	0.000	NA
Opportunity Cost	(1.476)	0.000	NA
Hedonic Pricing	(2.048)	0.000	NA
Avoided damage cost	0.739	0.000	NA
Impact factor	(0.057)	0.820	Regression data mean
Published paper	(0.781)	0.480	Regression data mean
Thesis	(0.714)	0.070	Regression data mean
Year of survey	(0.099)	2.500	Regression data mean
Protected area	1.023	0.000	Assumed
Ramsar	(0.7520	0.000	Assumed
Urban	1.672	1.000	Assumed
ln (GDP per capita)	0.694	8.670	Xinyu 2014 per capita GDP in CNY - Jiangxi 2015

			yearbook table 1-6 Inflation and exch. rates from ADB Key Indicators for Asia and the Pacific 2015. (log value)
Absolute latitude	0.043	27.000	
ln (population density)	(0.039)	5.890	Xinyu data from 2012 Jiangxi statistical yearbook, Table 2-4 Population Natural Change
Middle East and North Africa	(0.321)	0.000	Based on characteristics of the proposed project (east Asia is the baseline category)
South Asia	(0.232)	0.000	
Africa	1.341	0.000	
Latin America	0.819	0.000	
Eastern Europe	1.781	0.000	

( ) = negative value, ADB = Asian development Bank, CNY = Chinese yuan, FSR = feasibility study report, GDP = gross domestic product, NA = not applicable.

G. Afforestation Benefits

1. Approach

25. Benefits from the proposed forest areas are associated with carbon fixation, oxygen production, air quality impacts, soil formation, recreation, and biodiversity. Several published valuation studies from the PRC were reviewed as a source of information to assign value to these benefits (Table A3-12). The average value for the reviewed studies is CNY21,440/hectare while the value from the province nearest to Yunnan, which was Guizhou, is CNY31,650/hectare (CNY33,264 at 2019 price levels). The Guizhou value is applied in this analysis.

Table A3-12: Review of Forest Valuation Studies

Zhongwei G., Xiangming X., Yaling G., Yuejun Z., 2001. Ecosystem functions, services and their values a case study in Xingshan County of China. *Ecological Economics*. 38 (2001). 141–154. **ABSTRACT** (from original): Forest ecosystem services can provide both direct and indirect economic benefits. In this case study, at county-level, we estimated the annual economic value of some ecosystem services by forest ecosystems in the Xingshan County of Hubei Province of the People's Republic of China (PRC), using both simulation models and geographic information system that helps to analyze the effect of ecological factors (vegetation, soil and slope) on ecosystem functions. Xingshan County is rich in forest resources, covering 50.64% of total land area in the county. In this study, we referred to ecosystem goods and services together as ecosystem services. The ecosystem goods include timber, other forest products, and forest tour; and produce a direct economic value about Chinese yuan (CNY) 54.23 million in 1997. The ecosystem services assessed relate to three aspects: water conservation, soil conservation, and gas regulation. Water conservation includes hydrological flow regulation and water retention and storage. Soil conservation relates to the reduction of land disuse, prevention of silt accretion, decrease of soil deposit, and protection of soil fertility. Gas regulation is by both carbon fixation and oxygen supply. These services provide an indirect economic value of CNY528.73 million per year based on our estimation. Thus, the total economic value of forest ecosystem services in the Xingshan County is estimated to be CNY582.96 million per year, being a part of actual ecosystem services. In addition, we analyzed the spatial distribution of forest capital stock in the county based on the economic values of forest ecosystem service. Our work can contribute to the conservation of the forest ecosystems and effective use of the ecosystem services. **STUDY AREA:** Hubei Province, PRC **PERIOD OF ANALYSIS:** 1997 **SAMPLE SIZE**: not applicable (NA) **MODEL AND ESTIMATOR**: various methods, including process-based calculations for soil erosion, water storage, etc. **COMMENT**: Based on data provided, the total value of ecological goods and services is CNY5,450/hectare (ha) at 1997 prices or CNY8,033 at 2018 price levels.

Wu Guo-yong, 2009. Measurement on Monetary Value of Forestry Multi-function: A Case of Danzhai County, Guizhou Province, China. *Asian Agricultural Research*. 2009 1(9). 25-28
ABSTRACT (from original): Forestry functions of Danzhai County are introduced from the aspects of physical production value, social service value, and ecological service value. Quantitative research on monetary value of the functions is conducted by using the replacement cost method, classification valuation method, and travel coat method. Result shows that the value of forestry production is CNY19.713 million; and the value of flood control and water conservation is CNY111.000 million, which is 5.63 times of forestry production value. Besides, the value of soil conservation and yield increase is CNY160.102 million, which is 8.12 times of the value of forestry production; the value of carbon fixation and oxygen release and air purification is CNY1,126.624 million, 57.15 times of the value of forestry production; and the value of the employment and income increase, and the landscape and recreation is CNY5,380 million, which is 0.27 times of the value of forestry production. Due to the important external role of the forestry, government should take into account the multifunction of forestry when making policies to promote the effective development of forestry and the sustainable development of agriculture.
STUDY AREA: Guizhou Province, PRC
PERIOD OF ANALYSIS: 2008
SAMPLE SIZE: NA
MODEL AND ESTIMATOR: various methods
COMMENT: The total value for ecological goods and services provided by 54,677 ha is CNY1,422,818,000 or CNY26,022/ha at 2008 price levels. (CNY32,399 at 2018 prices).

Shixiong C., Junze Z., Wei S. 2019. Difference in the net value of ecological services between natural and artificial forests in China. *Conservation Biology*. Volume 00, No. 0, 1–8
ABSTRACT (from original): Land degradation is a global problem that seriously threatens human society. However, in the PRC and elsewhere, ecological restoration still largely relies on a traditional approach that focuses only on ecological factors and ignores socioeconomic factors. To improve the effectiveness of ecological restoration and maximize its economic and ecological benefits, a more efficient approach is needed that provides support for policy development and land management; and thereby promotes environmental conservation. We devised a framework for assessing the value of ecosystem services that remain after subtracting costs, such as the opportunity costs, costs of forest protection, and costs for the people who are affected by the program; that is, the net value of ecosystem services (NVES). To understand the difference between the value of a resource and the net value of the ecosystem service it provides, we used data on the NVES, timber sales, and afforestation costs from the PRC's massive national afforestation programs to calculate the net value of forest ecosystem services in the PRC. Accounting for the abovementioned costs revealed an NVES of ¥6.1 × 1012 for forests in 2014, which was 35.9% less than the value calculated without accounting for costs. As a result, the NVES associated with afforestation was 55.9% less than the NVES of natural forests. In some regions, the NVES was negative because of the huge costs of human-made plantations; high evapotranspiration rates (thus, high water opportunity costs); and low forest survival rates. To maximize the ecological benefits of conservation, it is necessary to account for as many costs as possible so that management decisions can be based on the NVES, thereby helping managers choose projects that maximize both economic and ecological benefits.
STUDY AREA: PRC
PERIOD OF ANALYSIS: 2014
SAMPLE SIZE: NA
MODEL AND ESTIMATOR: benefits transfer
COMMENT: The NCES was estimated to be CNY15,900/ha for planted forests, CNY36,000/ha for natural forests, and CNY29,500/ha for all forests (2014 prices). At current prices, the value of all forests is CNY31,652/ha.

MA S., WANG J., 2013. Empirical Analysis of Forest Landscape Value Assessment: Huangshui Forest Park in Xining, Qinghai Province. *Journal of Landscape Research*. 2013, 5(6). 27-28.
ABSTRACT (from original): Questionnaire survey and contingent valuation method were adopted to evaluate economic value of the Huangshui Forest Park in Xining, Qinghai. Value of its forest landscapes was assessed. Multiple linear regression was established to analyze correlation between factors related to willingness-to-pay.
STUDY AREA: Qinghai Province, PRC

PERIOD OF ANALYSIS:
SAMPLE SIZE: NA
MODEL AND ESTIMATOR: benefits transfer
COMMENT: Interesting because of the use of contingent valuation method with park visitors to value this 89-ha forested park. Total park value is CNY21.9 million or CNY245,700/ha. The annualized value at 2018 price levels is CNY19,519/ha (6% discount rate, 30 years).

Jing Li, Zhiyuan Ren, Zixiang Zhou, 2006. Ecosystem services and their values: a case study in the Qinba mountains of China. *Ecological Research*. (2006) 2. 597–604.
ABSTRACT (from original): Terrestrial ecosystem services can provide both direct and indirect economic benefits. In this case study, we estimated the annual economic value of some ecosystem services provided by terrestrial ecosystems in the Qinba mountains of Shaanxi Province in the PRC, using both simulation models and a geographic information system that helps to analyze the effect of ecological factors on ecosystem functions. With respect to differences in vegetation types and their coverage by combining the latest research and using theory and methods for the value of terrestrial ecosystem services, we not only calculated goods produced by different types of vegetation; but also estimated the value of various terrestrial ecosystem services. We also set up a database and an eco-account of a terrestrial ecosystem. The ecosystem services assessed relate to the following aspects: the vegetation's primary productivity, soil and fertility conservation, water conservation, carbon fixation, and oxygen supply. The total economic value of terrestrial ecosystem services in the Qinba mountains was estimated to be CNY968.33 billion per year and represents a part of the actual ecosystem services. In addition, we analyzed the spatial distribution of the vegetation based on the economic values of the terrestrial ecosystem services. Our findings can contribute to the conservation of these terrestrial ecosystems and the effective use of these ecosystem services.
STUDY AREA: Shaanxi Province, PRC
PERIOD OF ANALYSIS: 2005
SAMPLE SIZE: NA
MODEL AND ESTIMATOR: benefits transfer
COMMENT: Total value amounts to CNY11,119/ha (2005 prices) or CNY15,624 at 2018 prices. Non-commercial ecological services account for 80% of this value.