Available online at www.sciencedirect.com
ScienceDirect
Journal of Environmental Sciences 2011, 23(12) 2005–2012
JOURNAL OF ENVIRONMENTAL SCIENCES
ISSN 1001-0742
CN 11-2629/X
www.jesc.ac.cn

Computing payment for ecosystem services in watersheds: An analysis of the Middle Route Project of South-to-North Water Diversion in China

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Received 08 December 2010; revised 03 March 2011; accepted 12 April 2011

Abstract

Payment for ecosystem services (PES) has attracted considerable attention as an economic incentive for promoting natural resource management recently. As emphasis has been placed on using the incentive-based mechanism by the central government, rapid progress on PES research and practice has been achieved. However PES still faces many difficulties. A key issue is the lack of a fully-fledged theory and method to clearly define the design scope, accounting and feasibility of PES criteria. An improved watershed criteria model was developed in light of research on PES practices in China, investigations on the water source area for the Middle Route Project of South-to-North Water Diversion and ecosystem services outflows theory. The basic principle of assessment is the direct and opportunity cost for ecological conservation and environmental protection in the water source area deduct nationally-financed PES and internal effect. Then the scope and the criteria methods were determined, and internal effect was put forward to define benefits brought from water source area. Finally, Shiyan City, which is the main water source area for the Project of Water Diversion, was analyzed by this model and its payment was calculated. The results showed that: (1) during 2003–2050, the total direct cost and opportunity cost would reach up to 262.70 billion and 256.33 billion Chinese Yuan (CNY, 2000 constant prices), i.e., 50.61% and 49.38% of total cost, respectively; (2) Shiyan City would gain 0.23, 0.06 and 0.03 CNY/m^3 in 2014–2020, 2021–2030, and 2031–2050, respectively.

Key words: watershed; payment for ecosystem services; ecosystem services; cost-benefit analysis; Middle Route Project of South-to-North Water Diversion

DOI: 10.1016/S1001-0742(10)60663-8

Citation: Dong Z J, Yan Y, Duan J, Fu X, Zhou Q R, Huang X et al., 2011. Computing payment for ecosystem services in watersheds: an analysis of the Middle Route Project of South-to-North Water Diversion in China. Journal of Environmental Sciences, 23(12): 2005–2012

Introduction

Payment for ecosystem services (PES) is generating a great deal of world-wide attention, as it could translate external, non-market environmental values into real financial incentives for local stakeholders to sustain the provision of environmental services based on voluntary, and therefore play an important role in achieving conservation goals and sustaining ecosystem health (Turpie et al., 2008; Pagiola and Platais, 2002, 2007; Wunder, 2005). Many discussions consider PES to be an important supply-side innovation of direct "buying conservation" (Wunder et al., 2008).

To relieve devastating environmental crises, China has been trying to implement PES projects at different scales. Some laws were revised to promote these projects, including the Forest Laws of the People's Republic of China and the Laws of People's Republic of China on Prevention and Control of Water Pollution. In addition some new government policies, such as Regulations on Grain to Green, and Regulation on Collection, Usage and Management of Sewage Charges were enacted. Moreover, the State Environmental Protection Administration issued the Guideline about Developing PES Pilot Program. At the same time, the government has supported the development of a PES market and is supporting its practice at a massive scale. Until now, more than 700 billion CNY have been invested in PES programs (Daily et al., 2009), of which the Natural Forest Conservation Program (NFCP) and the Grain to Green Program (GTGP) are the most well known. These two programs have encompassed 97% of China's

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counties and are the largest PES programs in both China and the world in terms of scale, payment, and duration (Liu et al., 2008; Li and Zhai, 2002; Ferraro and Kiss, 2002) .

Despite considerable achievements in the PES program, there are some deficiencies in PES design and implementation, of which criteria is the key issue. Internationally, the payment criteria are defined as "they exceed the additional benefit that would be received from the alternative land use, but are less than the value of the benefit to ecosystem services (ES) users" (Engel et al., 2008). In China, the main calculation methods for criteria of environmental service values or ecological conservation costs include the present value approach (PVA), renovation cost approach (RCA), opportunity cost approach (OCA), and Pareto optimization approach (Li et al., 2006; Yu and Ren, 2008; Liu and Yu, 2007; Liu and Hu, 2009; Cai et al., 2008).

At present, the difficulties are in determining compensation scope and establishing accounting methods, to choosing strong calculation indexes and related methods. Ecological production functions could translate the structure and function of ecosystems into the provision of important services (Heal, 2000; National Research Council, 2004). ES outflows are produced by ecological construction and conservation and flowed into the benefiting areas from supply areas. Based on this principle, the total incremental ES which could be produced by the cost in the supply areas can be confirmed. Recently, water-related PES has already been the subject of numerous reviews, lessons and guidelines related to PES development and implementation (de Groot and Hermans, 2009). Thus it provides foundation for computation criteria.

Criteria are the most important part of PES. Not only are they the basis of PES theory, but also the reference for government and negotiation implementation in market transactions. Among many criteria, watershed criteria are easier to be constructed than forest criteria, grassland criteria and others because ES providers, ES users and bearer of compensation (water) are clearly to be defined. At the same time, watershed criteria could provide reference for constructions of other criteria.

In this article, we tend to develop a watershed criteria model by setting up the accounting framework and methodology in light of ES outflows and cost-effectiveness analysis. The Middle Route Project of South-to-North Water Diversion to alleviate water shortage in Northern China is the largest water transfer project in the world, and has huge potential influences on socioeconomic development and the ecological environment (Li and Xu, 2004). This project has a capacity of transferring a total of 13 billion tons of water annually from Danjiangkou Reservoir (32°14′N–33°48′N; 109°25′E–111°52′E) on the Hanjiang River, a tributary of the Yangtze River, to North China, including Henan, Hebei, Tianjin and Beijing, for irrigation, industrial and domestic usage (Li et al., 2009). Shiyan City is main water source area for the Middle Route. The data from Shiyan City were used to develop a model for computing PES payment amount in the Water Transfer Project.

1 Construction project impact on the ecosystem and economy of Shiyan City

Water source area for the Middle Route Project of South-to-North Water Diversion includes the Danjiangkou Reservoir and upper reaches of Hanjiang River, and ranges over Shaanxi, Henan, Gansu, Sichuan, Hubei and Chongqing Provinces and Autonomous Regions.

Shiyan City is an important part of the water source protected region for the Middle Route and is located near Danjiangkou Reservoir. It has become the most sensitive region for maintaining water security because it has the largest volume of water inflow and the longest shoreline (Fig. 1).

Shiyan City includes Danjiangkou Town, Yun County, Yunxi County, Fang County, Zhu County and Zhuxi County. It has an administrative area of 2,368,000 ha and a

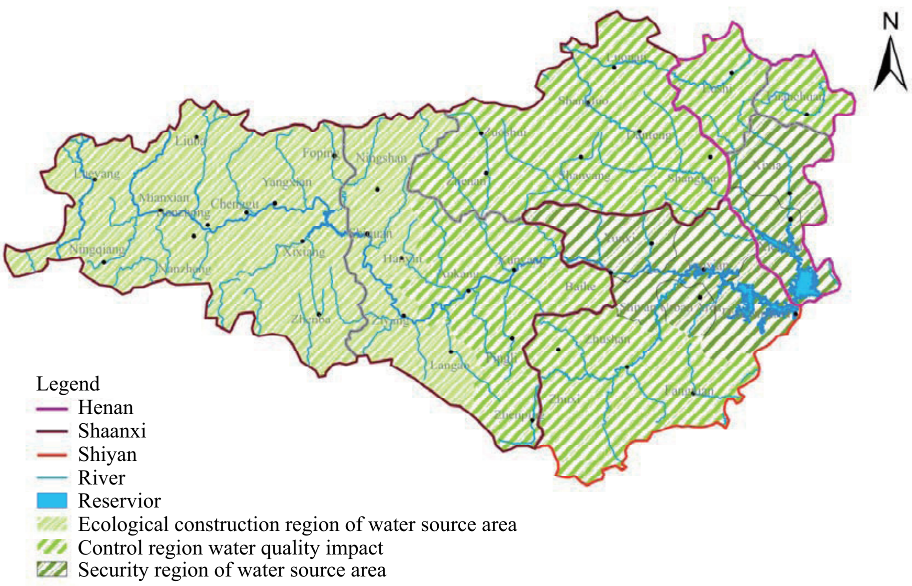

Fig. 1 Geographical location of water source area for the Middle Route Project of South-to-North Water Diversion and Shiyan City.

human population of 3.47 million.

Shiyan City is largely hilly and mountainous land (Shiyan City Bureau of Statistics, 1998–2007), and the population is concentrated in districts surrounding the Danjiangkou Reservoir and Hanjiang River Basin. Its economic development is mainly dependent on natural resource exploitation including traditional agricultural production, as well as some high-energy, high-pollution industries such as mining and papermaking (Zhang and Li, 2004). The sewage discharge of Shiyan City seriously impacts water quality in the reservoir, and in 2006, 9.2% of the total reaches in Shiyan City exceeded the governmental standard (over Class III) (SBWCHP, 2007).

Due to the construction of the Middle Route Project of South-to-North Water Diversion, 15,870 ha land will be flooded and 116,000 people will have to emigrate from their hometown in Shiyan City (CPDSRI, 2005). In order to protect water quantity and quality in Danjiangkou Reservoir, much labor and financial resources have been invested in ecological construction projects. From 2003 to 2008, GTGP converted almost 18,175 ha of cropland into forest/grassland and afforested 74,992 ha of barren land, increasing Shiyan City forest cover by 11.4% (SIDRI, 2003; WPCSWCP, 2005). Land use changes after project implementation are summarized in Table 1.

In order to protect water quality, Shiyan City has shut down a large number of polluting enterprises including 3622 paper mills (Shiyan City Bureau of Statistics, 1998–2007). At the same time, many sewage and waste treatment facilities have been constructed, and eco-energy development measures have been carried out in rural areas. Our field investigation in Wulongchi Village of Danjiangkou Town suggested that 30%–40% of households have built methane-generation facilities with local government compensation that included 2 tons of cement and a subsidy of 1000 CNY.

While these measures are effective for natural environment improvements, they have a significant influence on economic development (Xia and Chang, 2007). Shiyan City has spent 5.34 billion CNY on local ecological construction and environmental protection, and its financial revenue has reduced by 0.65 billion CNY due to the closure and removal of pollution-cause enterprises. Moreover, restrictions on the type of investment projects have led to lay-off of opportunities for 12,000 people, with potential influences on local socioeconomic development.

2 Methodology

In our criteria model, the net direct-opportunity cost that ES provider pays was set as the PES lower bound, and the net benefits that ES users accept was set as the upper bound. This article focuses on developing the model of the lower bound. The criteria for PES can be calculated as: the direct opportunity cost for ecological construction and environmental protection in the water source area, minus the nationally-financed PES and internal effect:

$$A_{\text{PES}} = C_{\text{D}} + C_{\text{O}} - I_{\text{N}} - E_{\text{E}} \quad (1)$$

where, A_{PES} (CNY), C_{D} (CNY) and C_{O} (CNY) represent the amount of PES, direct cost and opportunity cost, respectively; I_{N} (CNY) measures nationally-financed PES; E_{E} (CNY) represents internal effect.

2.1 Direct cost

Direct cost includes the funds that are invested in ecological construction and environmental protection in the water source area. Based on a large amount of data obtained by survey, collection, screening and prediction, factor inputs and capital inputs can be determined. C_{D} is mainly constituted by the ecological construction and conservation cost (C_{ED}, CNY), the water environmental protection and control cost (C_{PD}, CNY) and other cost (C_{AD}, CNY):

$$C_{\text{D}} = C_{\text{ED}} + C_{\text{PD}} + C_{\text{AD}} \quad (2)$$

The classification and calculation indexes of direct cost are summarized in Table 2.

2.2 Opportunity cost

Opportunity cost is the economic loss and development rights lost by stakeholders due to environmental protection and ecological construction in the water source area. In our survey region, the measures for environmental improvement have a huge influence on the development of primary and secondary industry, while having less influence on tertiary industry. Thus, C_{O} is mainly constituted by industrial opportunity cost (C_{IO}, CNY) and agricultural opportunity cost (C_{AO}, CNY).

(1) Industrial opportunity cost (C_{IO})

Selecting a region which is similar to the survey region in natural conditions, we calculate industrial opportunity cost by comparing differences in per capita GDP from secondary industry between the two regions (Mao and Liu, 2005). Accordingly, C_{IO} can be measured as:

$$C_{\text{IO}} = \text{GDP}_{nc} \times N_n \times m_n \; (n = 1, 2, 3 \cdots) \quad (3)$$

where, GDP_{nc} (CNY) measures the loss of per capita GDP of secondary industry at nth year; N_n (pcs) measures the population of survey region at nth year; m_n measures the ratio of state revenue to GDP at nth year.

Based on calculation method of Green GDP, GDP_{nc} can be measured by per capita GDP from secondary industry

Table 1 Land use change after project enforcement in Shiyan City (unit: ha)

Area	Cropland	Forest	Grassland	Water body
Inundated area	–6428.9	–5469.7	–739.9	17000
Ecological protection area	–26723.0	496019.7	3447.3	0
Total area	–33151.9	490550.0	2707.4	17000

Table 2 Classification and calculation indexes of direct cost

Scope	Type	Formula	Index
Ecological construction and conservation	Forest construction cost (C_f)	$C_f = \sum_i \left(\sum_t A_{fi} \times c_{it} + \sum_m c_{im} \right)$	A_{fi} (ha): annual forest construction area of type i; c_{it} (CNY): annual construction investment of item t in type i; c_{im} (CNY): annual management investment of item m in type i measure.
	Water and soil conservation cost (C_s)	$C_s = \sum_i \left(\sum_t A_{si} \times c_{it} + \sum_m c_{im} \right) + C'_p$	A_{si} (ha): annual water and soil conservation area where type i measure for water and soil conservation is implemented; c_{it} (CNY): annual construction investment of item t in type i measure; C_p' (CNY): annual monitoring investment.
	Ecological immigration cost (C_m)	$C_m = \sum_i P \times c_i$	P (pcs): amount of annual ecological immigration; c_i (CNY): annual compensation payments of type i measure for ecological immigration.
	Development cost of nature reserve (C_n)	$C_n = \sum_i c_{ni} + c_{im}$	c_{ni} (CNY): annual construction investment for nature reserves of type i.
Water environmental protection and control cost (C_{PD})	Monitoring cost of water quality and quantity (C_q)	$C_q = \sum_i \left(\sum_t c_{it} + \sum_m c_{im} \right)$	i (pcs): types of facilities in water quality and quantity monitoring; c_{it}: annual construction investment of item t measure in facility of type i; c_{im} (CNY): annual operation and management investment of item m measure in facility of type i.
	Control cost of point source pollution (C_p)	$C_p = \sum_p \left(\sum_t c_{pt} + \sum_m c_{pm} \right)$	p (pcs): measures of point source pollution control; c_{pt} (CNY): annual construction investment of item t in measure of type p; c_{pm} (CNY): annual operation and management investment of item m in measure of type p.
	Control cost of non-point source pollution (C_{np})	$C_{np} = \sum_n \left(\sum_t c_{nt} + \sum_m c_{nm} \right)$	n (pcs): measures of non-point source pollution control; c_{nt} (CNY): annual construction investment of item t in measure of type n; c_{nm} (CNY): annual operation and management investment of item m in measure of type n.
Other cost (C_{PD})	Water conservation cost (C_w)	$C_w = \sum_w \sum_t c_{wt}$	w (pcs): measures of water conservation; c_{wt} (CNY): annual construction investment of item t in measure of type w.
	Cost related to direct agricultural loss (C_{sa})	$C_{sa} = \sum_s \sum_t A_s \times c_{st}$	A_s (ha): annual ecological construction area caused by s type ecological construction measures which could lead to economic loss; c_{st} (CNY): annual agricultural cost of item t in measure of type s.
	Cost related to science and technology (C_t)	$C_t = \sum_t c_t$	c_t: (CNY) annual cost related to science and technology in type t measure.

at the year before protection (GDP_0, CNY), per capita GDP from secondary industry at nth year after protection (GDP_n, CNY), added value growth from secondary industry (a_t) and industry opportunity cost parameter (i).

$$GDP_{nc} = GDP_0 \times \prod_{t=1}^{n} (a_t + i) - GDP_n \ (n = 1, 2, 3 \cdots) \quad (4)$$

i can be measured as:

$$i = \left|(a' - b') - (a - b)\right| \quad (5)$$

where, a measures average annual growth ratio of per capita GDP from secondary industry before protection; a' measures average annual growth ratio of per capita GDP from secondary industry after protection; b measures average annual growth ratio of per capita GDP from secondary industry before protection in the reference region; b' measures average annual growth ratio of per capita GDP from secondary industry after protection in the reference region.

(2) Agricultural opportunity cost (C_{AO})

Landowners have more detailed information than researchers about the opportunity cost of supplying ES (Ferraro, 2008). Thus we conducted a survey and collected data during interviews with 20 local residents in Danjiangkou Country, Yun Country and Yunxi Country. We determine the agricultural opportunity cost as landowners' agricultural income if their forest is converted to cultivated land or other types of land, measured as:

$$C_{AO} = \sum_i \sum_t A_{it} \times c_t \quad (6)$$

where, A_{it} (ha) measures the annual area of agricultural land for GTGP of type i for breeding crops of term

t; c_t (CNY) measures annual benefit which stems from breeding crops of term t in type i per year.

2.3 Nation-financed subsidies

Recently China has launched a large number of national policies for PES. In some cases, such as NFCP and GTGP, the government operates PES programs by providing special financial support to ES providers. In other cases, the government operates programs by participating in investments to improve the environment in water source areas. We, therefore, deduct these investments that are not made by Shiyan City.

2.4 Internal effect

Although measures for environmental protection and ecological construction have some negative effects on local economic development in the short term, they will produce benefits to the water source area due to environmental improvements in the long term, and this phenomenon is defined as "internal effect" in this article. The internal effect contains cleaner air for local people's health, better landscape for tourism, less natural disaster and more chances for attracting high-technology, low-polluting industries because of better environment. However, this effect cannot be calculated with PVA, RCA or OCA directly because it involves a large number of related factors and complex relationships with regard with nature, economy, society and culture. Therefore, we set α as a ratio factor of cost-effectiveness to exclude internal effect in the water source area.

By comparing the data of water source area before project, reference region up to now with data of water source area after project, α can be determined by the proportion of ecological improvement cost which should be expended and will be expended; the proportion of increased ecological benefits between the water source area and receiving areas; and the proportion of investments for environmental improvement between the water source area and receiving areas. According to direct-opportunity cost, we divided α into α_D and α_O, allowing E_E to be measured as:

$$E_E = (C_D - I_{ND})\,\alpha_D + (C_O - I_{NO})\,\alpha_O \quad (7)$$

where, I_{ND} (CNY) represents nation-financed subsidizes for direct cost; I_{NO} (CNY) represents nation-financed subsidizes for opportunity cost; α_D represents ratio factor of direct cost-effectiveness; α_O represents ratio factor of opportunity cost-effectiveness.

3 Results

The construction of inter-basin transfer project started in 2003, and will begin to supply water in 2014. According to Water Pollution Control & Soil and Water Conservation Program of Danjiangkou Reservoir and Upstream, Shiyan City will have to invest huge amounts of money for conservation before 2020. As the industrial structure adjusts, the influences caused by this transition project will almost disappear by 2050. Therefore, the accounting period in this study is determined from 2003 to 2050. Since the receiving area does not yet give compensation to Shiyan City, the compensation is set to begin in 2014 and end in 2050.

3.1 Total cost

Combining the outcomes of the population growth model developed by Song and Yu (1985), the future GDP growth rate predicted by the Development Research Center of the State Council (2005) and He (2001) with Shiyan City socioeconomic data, we forecast the future total population, urban population and GDP in Shiyan City.

Then we choose a nearby region, Xiangfan City, with similar natural, social and economic situations to Shiyan City. Located in the southwest of Shiyan City and downstream of Danjiangkou Reservoir, Xiangfan City is also largely hilly and mountainous land. Its economic development is also mainly dependent on natural resource exploitation. In this article, we use Xiangfan City as a control. According to data collected from government projects, yearbooks and plans (Shiyan City Bureau of Statistics, 1998–2007; CPDSRI, 2005; SIDRI, 2003; WPCSWCP, 2005; GB18918–2002, 2002; Xiangfan City Bureau of Statistics, 2008, 2007; Hubei Bureau of Statistics, 2008), we chose the data which was closely interacted with the transferred project and calculated the direct and opportunity costs of environmental protection and ecological construction in the water source area in Shiyan City (Table 3).

3.2 Nation-financed subsidies

According to data from the 10-year Program of Soil and Water Conservation in Water Source Area of Middle Route Project of South-to-North Water Diversion and Water Pollution Control & Soil and Water Conservation Program of Danjiangkou Reservoir and Upstream (WPCSWCP, 2005), we calculated government investments for Shiyan City during 2003–2030 (Table 4).

Table 3 Direct and opportunity costs of environmental protection and ecological construction in Shiyan City (1000 CNY, 2000 constant prices)

Scope		Type	2003–2010	2011–2020	2021–2030	2031–2040	2041–2050
C_D	C_{ED}	C_f	158266	171729	181399	212654	243909
		C_s	1920238	1508738	1925390	1116005	512850
		C_m	1411410	1220393	1220393	–	–
	C_{PD}	C_q	1331292	900664	750214	817946	816723
		C_p	504133	760835	1194684	1,705898	2314917
		C_{np}	799226	843195	1082139	1042809	743453
	C_{AD}	C_{sa}	77030	21893	–	–	–
C_O	C_{IO}	GTGP cost	473122	785574	831,185	827073	827073
	C_{AO}		2580000	19920000	–	–	–

Table 4 National investment for environmental improvement in Shiyan City

Scope		Type	2003–2010	2011–2020	2021–2030
C_D	C_{ED}	C_s	496081	227924	–
		C_m	561232	485276	485276
	C_{PD}	C_q	508582	427923	–
		C_p	81572	15023	–
		C_{np}	95760	81795	–
C_O	C_{IO}	GTGP cost	264118	138032	16970

3.3 Internal effect

Comparing investments for ecological construction and environmental protection between Shiyan City and Xiangfan City, the investment which should be borne by Shiyan City was determined. In addition, ecological and socioeconomic benefits brought by ecological improvement were evaluated. Finally, the proportion of internal effect in the general benefit was determined and the amount of internal effect was calculated (Table 5).

3.4 PES criteria

From the outcomes of the results above, we can determine the annual compensation amount during 2003–2050. Since we set the start year for payments to be 2014, the compensation for the period 2003–2013 should be converted and added to payments during 2014–2020, with an annual return of 3%. The final compensation (C_P) can be measured as:

$$C_P = \frac{i_s (1 + i_s)^{T_0}}{(1 + i_s)^{T_0} - 1} \sum_{t=1}^{T} C_t (1 + i_s)^{T-t+1} \quad (8)$$

where, C_t (CNY) measures construction cost at tth year; T measures the number of years of investment; i_s measures rate of capital gains; T_0 measures the PES compensation period.

Accordingly, annual PES of Shiyan City would be 2175.79 million, 532.58 million, 439.62 million, and 407.42 million CNY in 2014–2020, 2021–2030, 2031–2040, 2041–2050, respectively.

Based on the annual volume of water which transferred from the water source area (between 2014 and 2030: 9.5 billion m^3; after 2030: 13 billion m^3), the compensation amount could be completed through adding water price. This corresponds to 0.23, 0.06 and 0.03 CNY/m^3 in 2014–2020, 2021–2030 and 2031–2050.

Compared with disposable income and industrial output, water prices of receiving regions if adding PES charge are in the affordable range of residents and industrial enterprises. Therefore, the increment in water prices is reasonable.

4 Discussion

(1) Although the criteria lower bound and upper bound are set in this study, the model is mainly established based on the lower bound, due to the following considerations:

First, the annual increment amount of ES value could reach up to 4.55 billion CNY per year (calculated with ES methods), and therefore the ecological value of ES outflows supplied to benefiting area is reach up to 0.78 billion CNY per year. Although the production of ES would increase, these ES values are difficult to account for a value reference in real market transactions (Wunder, 2007).

Second, the net benefits that ES beneficiaries accept are hard to definitely evaluate, due to the complicated relationship with the region's natural and socioeconomic conditions, different consumption purposes of water in the receiving regions, and ecological, economic and social changes brought by transferred water. More importantly, the receiving regions would not agree to pay the total net benefits to the water source area (Engel et al., 2008).

Finally, people have been used to taking free advantage of ES for a long time, and it will take time to change people's attitudes to accept PES. At present, if the payment criteria are too high, people may directly refuse to pay it. Meanwhile, if the criteria less than the lower bound, PES could not achieve the purpose to encourage the action of ecological conservation and environmental protection (Duan et al., 2010). Therefore, based on the demands of government references and market transactions, it may be more acceptable for beneficiaries to use net direct-opportunity cost as the criteria.

(2) Ecological construction and conservation bring benefits not only for the receiving water area, but also for the water source area. This is described by internal effect, defined as the cost-effectiveness ratio factor (α) determined by the proportion of ecological improvement cost which should be burden by the water source area, the proportion of increased ecological benefits, the proportion of investments for environmental improvement, and so on. For example, when we count the proportion of internal effect in agricultural opportunity cost, the change in the water and soil conservation area before and after construction is compared. Then the natural and socioeconomic development conditions are compared with a reference region. According to these results, we conclude that Shiyan City should only burden 10% of the current water and soil conservation area. Because of agricultural structural adjustment, ecological agriculture and distinctive agriculture with high added-value should be gradually developed to make up the input of agricultural opportunity cost caused

Table 5 Internal effect of source water area protection in Shiyan City (1000 CNY, 2000 constant prices)

Scope	Type	2003–2010	2011–2020	2021–2030	2031–2040	2041–2050
C_D	C_{ED}	364890	328149	426286	199299	113514
	C_{PD}	389747	395991	605407	713330	775019
	C_{AD}	46218	13136	–	–	–
C_O	C_{IO}	41801	194263	325686	413536	496244
	C_{AO}	1548000	15936000	–	–	–

by land use change. Thus the proportion of agricultural opportunity cost in 2003–2010, 2011–2020, 2021–2030, 2031–2040 and 2041–2050 should be 20%, 30%, 40%, 50% and 60%, respectively.

(3) There are few studies on the degree to which environmental conservation relative to a baseline or the effect of program participation on farmer livelihoods (Cole, 2010). Therefore, we used a field investigation to gain more information about the research region. Semi-structured questionnaires were administered to ES providers and in-depth interviews were conducted with stakeholders and representatives from government organizations. We also collected secondary information on the legal, institutional and socioeconomic contexts. Thus if people need to use this criteria model, some field investigations will be necessary.

(4) The annual PES in Shiyan City during 2014–2050 tends to decrease. The decline rate is fast in 2014–2030 and then slows down in 2031–2050. The reasons for this result are: (I) the amount of annual PES in 2014–2020 is relatively large, because it includes the PES both for 2003–2010 and for 2011–2020; (II) Shiyan City has to invest a great deal of manpower and financial resources to improve the ecological environment before 2020 (SIDRI, 2003; WPCSWCP, 2005). After 2020, large-scale programs will mostly end, and financial resources will then mainly be invested in operation and management. Moreover, with the development of new industries, the limitation factors of local economy caused by conservation will almost have disappeared by 2050; (III) the data used in this article were mainly collected from local and national construction plans with a duration mainly from 2004–2020. After 2020, the data are mainly from our predictions, therefore Shiyan City's investment costs may be incomplete.

5 Conclusions

In this article, criteria accounting approaches for watershed PES are improved by setting up an accounting framework and methodology. The direct and opportunity costs for ecological protection in the water source area, minus the nationally-financed PES and internal effect, are defined as the criteria. The cost-effectiveness ratio factor (α) is put forward to account for internal effect in the water source area. Using this model, the payment amount for Shiyan City in PES for the Middle Route Project of South-North Water Diversion was calculated.

Acknowledgments

This study was supported by the National Natural Science Foundation of China (No. 70703034), State Key Laboratory of Urban and Regional Ecology (No. SKLURE 2008-1-02) and the National Major Program on Pollution Control and Management of Water Body (No. 2009ZX07318–006). We greatly appreciate the support and help provided by Senior Engineer Guojun, Hubei North-to-South Water Diversion Project Leading Group Office, Senior Engineer Zhang Yuhua, Soil and Water Conservation Monitoring Centre of Changjiang Water Resources Commission, Engineer Zhang Yushui, Immigration Office of Shiyan City and Engineer Wang Zhian, Shiyan City North-to-South Water Diversion Project Office.

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