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Eco-Environmental benefit assessment of the western route in China’s South-North Water Transfer Project

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Key words: Benefit assessment, China, eco-environment, water transfer; South-North Water Transfer, Western Route Project

SUMMARY

Assessing the benefits of China’s South-North Water Transfer project (SNWT) requires successful integration of an analysis of economic and eco-environmental benefits (EEB). To attain such integration, it is necessary to assess the EEB in detail, after the economic benefits have also been thoroughly assessed. The shadow engineering and market value methods are the major EEB assessment methods used in this study. We have assessed the EEB of the forest and grassland ecosystems in the recipient regions of the Western Route Project (WRP) for 2020, 2030 and 2050. Finally, some proposals are also made for efficient and sustainable management of the WRP.

INTRODUCTION

Water is one of the most important natural resources for the survival and development of humanity, integral to all environmental and social processes. Freshwater is scarce in China and the world in general (Björklund and Kuylenstierna 1998; Arnell 1999; Varis and Vakkilainen 2001). Socio-economic development and rapid population growth have made the situation worse, especially in northwest China (Feng and Cheng 1998). It is necessary to explore alternatives to alleviate this rapidly deteriorating and critical situation. One possibility is to transfer water over long distances from surplus to deficit areas. Already, many projects exist that divert water from one region to another (Golubev and Biswas 1979; Biswas *et al.* 1983; Snaddon *et al.* 1998; Feldman 2001). China’s

South-North Water Transfer (SNWT) is among the largest water transfer projects in the world. There are three planned routes in SNWT – the eastern, middle and western routes (Yao and Chen 1983). The western route project (WRP) is the focus of this paper. The necessity and feasibility of the WRP in terms of engineering and economics has already been discussed (Li *et al.* 2000; Jia 2001). However, other aspects should be considered, especially the social and environmental aspects (Biswas *et al.* 1983; Bruk 2001). The influence of the WRP on the eco-environment has also been considered (Song 1995; Qu 2001; Shang *et al.* 2001; Liu 2002; Wang 2002). The benefits to agricultural irrigation, domestic consumption and waterpower have been analyzed (Han *et al.* 1998). However, little attention

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has been paid to the eco-environmental benefits. Our objective is to assess the eco-environmental benefits (EEB) of the recipient regions in the WRP.

General layout of the WRP

To assess the EEB in recipient regions, it is necessary to review the basic status of the WRP and its recipient regions. The WRP will perform two important functions: (1) to supply water directly to users (agricultural, industrial, domestic), and (2) to add water to the mainstream of the Yellow River. The WRP will be completed in three stages:

- 1. The Da-Jia Line. This will lead from branches of the Da-Qu and Ni-Qu Rivers on the Ya-Long River to a branch of the Jia-Qu River, part of the Yellow River, via branches of the Du-Ke, Ma-Er-Qu and A-Ke Rivers on the Da-Du River. The amount of transferred water will be about four thousand million m³ by the year 2020.
- 2. The A-Jia Line. This will lead from A-Da on the Ya-Long River to a Yellow River tributary, the Jia-Qu River. The amount of transferred water will be about five thousand million m³. So, by 2030, the total amount of transferred water will be about nine thousand million m³.

- 3. The Ce-Jia Line. This will lead from Ce-Fang on the Tong-Tian River to a Yellow River tributary, the Jia-Qu River. The amount of transferred water will be about eight thousand million m³.

Consequently, by 2050, the total amount of transferred water will be about seventeen thousand million m³ (Figure 1, Table 1) (Hu *et al.* 2001; Zhang *et al.* 2001). The main goal of the WRP is to resolve the problem of water deficiency in northwest China and to meet basic water use demands (especially the eco-environmental water demand) within the next 50 years in six provinces (Qinghai, Gansu, Ningxia, Shannxi, Shanxi and Inner Mongolia) of the upper and middle reaches of the Yellow River and its

Table 1 The water amount for different stages of the WRP (unit: hundred million m³)

	For industry and living	For eco-environment	For agricultural irrigation
First stage (in 2020)	23	17	–
Second stage (in 2030)	45	38	7
Third stage (in 2050)	107	53	10

Figure 1 Sketch map of the Western Route project of the South-North Water Transfer project

adjacent regions (Hexi corridor) (Zhang *et al.* 2001). Besides the agricultural ecosystem, forest and grassland are the main ecosystem types prevalent in the region. In this paper, the water amount for the eco-environment will be assigned to the forest and grassland ecosystems. The benefits to the forest and grassland ecosystems will be assessed individually. The benefits to industry, livelihoods and agricultural irrigation are not discussed here (Han *et al.* 1998).

Recipient regions in the WRP

The major recipient regions in the WRP (Figure 2) are located in the upper and middle reaches of the Yellow River, and constitute ecotones in China (Chang *et al.* 1999; Zhang *et al.* 2001). Their eco-environment has been seriously damaged. The

situation is likely to become worse because of water deficit, rapid population growth and even more rapid economic development (Zhang and Xie 1999; He *et al.* 2000). The main eco-environmental problems are:

1. Desertification. China is one of the most severely desertified countries in the world. Approximately 400 million people and 3.3 million km² of land have been affected (Chen *et al.* 1996; Zha and Gao 1997), and desertified areas expanded at an annual rate of 2103 km² in the 1980s (Shou *et al.* 1992). The recipient regions for the water are among the most seriously desertified regions in China. Desertification has caused serious environmental problems, such as reduced soil fertility, damaged soil structure and reduced vegetation

Figure 2 The recipient regions in the first and the third stages of the WRP

- quality and substantial economic losses (Zhu and Cui 1996).
2. Soil and water loss. The Chinese loess plateau is the most extreme soil and water loss area in the world. The area of loss is about 60% of the total land area, and the annual average soil loss is 2000–2500 t km⁻² (Shi and Shao 2000). The majority of recipient regions for the water are located in the loess plateau. Soil and water loss has seriously destroyed land resources and degraded the eco-environment.
 3. Grassland degradation. In areas of northern China, such as Shanxi, degrading grassland represents about 95% of the total grassland area (Zhang 2001). The situation of grassland degradation is likely to become more serious, with problems of secondary salinization (Zhang and Li 2002), environmental pollution (Zhang and Li 2002) and decreased runoff (Tong *et al.* 2002).
 4. Other eco-environmental problems experienced in Yellow River include drying up of the Yellow River (Song 1995; Cai and Yang 2002), waterway stagnation (Yin 2001), carbon loss (Lal 2003), decreasing vegetation cover (Piao and Fang 2001) and eco-environmental calamities (Wu *et al.* 2000).

These eco-environmental problems result from both natural (harsh natural conditions) and man-made causes (population overload, over-grazing and reclamation of waste land and deforestation). To resolve these problems, it is necessary to restore the vegetation. Water is the pivotal factor for vegetation restoration in northwest China (Zhang and Li 2002). However, the degree of water deficit is serious (Zhang and Xie 1999; He *et al.* 2000; Qu 2001; Zhang *et al.* 2001), hence, the WRP provides a means of resolving these problems.

METHODOLOGY

The EEB of different ecosystems were assessed according to their service functions and with two different methods, market value and shadow engineering methods (Huan 2001). The main service functions of forest and grassland ecosystems include the ability to: (1) conserve water, (2) preserve the soil, (3) fix sand, (4) mitigate wind, (5) fix CO₂ and release O₂, (6) purify the atmosphere, (7)

decrease the loss of nutrient elements and organic materials (OM), and (8) remediate other ecosystem service functions (Ou Yang *et al.* 1999). There are many methods of assessing ecosystem service functions.

RESULTS

To assess the EEB of the WRP, it is helpful to take the WRP as a whole, and to measure the average of the transferred water's allocation. The EEB will be assessed according to the different ecosystems, different service functions, different assessment methods and different parameters for 2020, 2030, and 2050.

Eco-environmental benefits resulting from water conservation

Forest has an important water conservation function (Deng *et al.* 2002). To assess the EEB resulting from water conservation, the shadow engineering method was used. The major coefficients are the volume of increased water storage capacity, which is equal to the water conservation and engineering investment required per m³ of increased storage capacity. We assume that the water requirement of the forest (WRF) in northwest China is 11880 m³ ha⁻¹ year⁻¹. The water capacity (WC) of mature forest in northwest China is 1209.37 m³ ha⁻¹ year⁻¹ (Jiang 2002; Xu *et al.* 2003). The engineering investment (EI) required per m³ of storage capacity is 0.67 yuan (RMB) × m⁻³ (Ou Yang *et al.* 1999).

EEB1 = TWF × WRF⁻¹ × WC × EI (1)

where EEB1 represents the EEB resulting from water conservation in the forest ecosystem. Table 2 can then be generated using equation (1). Grassland also has an important water conservation

Table 2 Eco-environmental benefits from water conservation

Year	Transferred water for forest (10 ⁸ m ³)	Irrigation area of forest (10 ⁴ ha)	Amount of water held (10 ⁷ m ³)	Benefit (10 ⁸ yuan)
2020	7	5.89	7.12	0.48
2030	15	12.63	15.27	1.02
2050	23	19.36	23.41	1.57

function. However, the EEB from water conservation for grassland has not been assessed because of a lack of data. The assessment of EEB1 for 2020, 2030, and 2050 produces results of 0.48×10^8 , 1.02×10^8 and 1.57×10^8 yuan (RMB), respectively.

Eco-environmental benefits from fixing CO₂ and releasing O₂

Forest and grassland fix CO₂ and release O₂. The methods of calculation used are the market value and shadow engineering methods (Guan *et al.* 2002). The major coefficients are the amount of fixed CO₂ (AFC), the amount of released O₂ (ARO), the silvicultural cost (SC) for fixing CO₂, and the cost of producing O₂ (CPO). The productivity of the forest (PF) is 1.132×10^4 kg ha⁻¹ year⁻¹ (Ou Yang *et al.* 1999). The transfer coefficient (TC) from biomass to carbon is 0.45 in the northwest of China (Hakkila 1989). The SC is 2.733×10^{-1} yuan (RMB) kg⁻¹. The cost of producing O₂ (CPO) is equal to 4×10^{-1} yuan (RMB) kg⁻¹ (Ou Yang *et al.* 1999). Grassland water requirement (GWR) is 5625 m³ (Du 1991). The yield of hay (YH) is 1465 kg ha⁻¹ (Liao and Jia 1996). The ratio of stem/root of grass (RSR) is 0.24 (Fang *et al.* 1996).

EEB2 = TWF × WRF⁻¹ × PF × TC × (44/12) × SC (2)

EEB3 = TWF × WRF⁻¹ × PF × TC × (32/12) × CPO (3)

EEB4 = TWG × GWR⁻¹ × YH × (1 + RSR⁻¹) × TC(44/12) × SC (4)

EEB5 = TWG × GWR⁻¹ × YH × (1 + RSR⁻¹) × TC × (32/12) × CPO (5)

EEB2 and EEB3 represent the benefits for the forest from absorbing CO₂ and releasing O₂, respectively. EEB4 and EEB5 represent the benefits for

the grassland from absorbing CO₂ and releasing O₂, respectively. The benefits resulting from fixing CO₂ for the increased forest area can be assessed at 3.01×10^8 yuan (RMB) in 2020, 6.45×10^8 yuan (RMB) in 2030 and 9.88×10^8 yuan (RMB) in 2050. The corresponding values for releasing O₂ for the increased forest area amount to 3.20×10^8 , 6.86×10^8 and 10.52×10^8 yuan (RMB) in 2020, 2030 and 2050, respectively. For grassland, the corresponding benefits for fixing CO₂ are 6.07×10^8 , 13.96×10^8 and 18.20×10^8 yuan (RMB) in 2020, 2030 and 2050, respectively; for releasing O₂, 6.46×10^8 , 14.86×10^8 and 19.38×10^8 yuan (RMB) in 2020, 2030 and 2050, respectively (Table 3).

Eco-environmental benefits from retaining soil

Forest and grassland can decrease the loss of soil, organic material (OM) and nutrients in the soil, and they can decrease the stagnation of waterways, reservoirs and lakes. The methods of calculation used are the shadow engineering and market value methods (Hou *et al.* 1998). The amount of soil loss in wasteland (SLW) in northwest China is about 4.267×10^4 kg ha⁻² (Lu and Zhang 1995), and the ratio of forest soil loss to wasteland soil loss (RFW) is 5% (Wu *et al.* 2002). We assume the ratio of grassland soil loss to wasteland soil loss (RGW) is equal to the RFW. Loess soil is the main soil type in northwest China and its soil bulk density (SBD) is 1.190×10^3 kg × m⁻³ (Gansu Soil Survey Office 1993). The cost of building a reservoir (CBR) is 0.67 yuan (RMB) × m⁻³ (Ou Yang *et al.* 1999). The content of OM (COM) in the surface loess soil is 0.984%. The content of N (CN) and of P (CP) are 0.068% and 0.064%, respectively (Gansu Soil Survey Office 1993). The price of OM (POM) is 1.00×10^{-2} yuan (RMB) × kg⁻¹. The price of N (PN) is 1.304 yuan (RMB) × kg⁻¹. The price of P

Table 3 Eco-environmental benefits from fixing CO₂ and releasing O₂

Year	Ecosystem	Transferred water (10 ⁸ m ³)	Amount of CO ₂ fixed (10 ⁹ kg)	Benefit of CO ₂ fixed (10 ⁸ yuan)	Amount of O ₂ released (10 ⁸ kg)	Benefit of O ₂ released (10 ⁸ yuan)
2020	forest	7	1.10	3.01	8.00	3.20
	grassland	10	2.22	6.07	16.15	6.46
2030	forest	15	2.36	6.45	17.15	6.86
	grassland	23	5.11	13.96	37.14	14.86
2050	forest	23	3.62	9.88	26.30	10.52
	grassland	30	6.66	18.20	48.44	19.38

(PP) is 8.00×10^{-1} yuan (RMB) $\times \text{kg}^{-1}$ (Hou *et al.* 1998).

$$\text{EEB6} = \text{TWF} \times \text{WRF}^{-1} \times \text{SLW} \times (1 - \text{RFW}) \times \text{CN} \times \text{PN} \quad (6)$$

$$\text{EEB7} = \text{TWF} \times \text{WRF}^{-1} \times \text{SLW} \times (1 - \text{RFW}) \times \text{CP} \times \text{PP} \quad (7)$$

$$\text{EEB8} = \text{TWG} \times \text{GWR}^{-1} \times \text{SLW} \times (1 - \text{RGW}) \times \text{CN} \times \text{PN} \quad (8)$$

$$\text{EEB9} = \text{TWG} \times \text{GWR}^{-1} \times \text{SLW} \times (1 - \text{RGW}) \times \text{CP} \times \text{PP} \quad (9)$$

EEB6 and EEB7 represent the benefits resulting from decreasing the N and P loss, respectively, for the increased forest area as a result of water transfer. EEB8 and EEB9 represent the benefits resulting from decreasing the N and P loss, respectively, for the increased grassland as a result of water transfer. The benefits resulting from decreasing the N loss as a result of the increased forest area are 2.12×10^8 yuan (RMB) in 2020, 4.54×10^8 yuan (RMB) in 2030 and 6.96×10^8 yuan (RMB) in 2050. The benefits from decreasing the P loss as a result of the increased forest are 1.22×10^8 yuan (RMB) in 2020, 2.62×10^8 yuan (RMB) in 2030 and 4.02×10^8 yuan (RMB) in 2050. For grassland, the corresponding benefits are 6.39×10^8 yuan (RMB) in 2020, 14.70×10^8 yuan (RMB) in 2030 and 19.17×10^8 yuan (RMB) in 2050 for decreasing

N loss; 3.69×10^8 yuan (RMB) in 2020, 8.49×10^8 yuan (RMB) in 2030 and 11.07×10^8 yuan (RMB) in 2050 for decreasing P loss (Table 4).

The percentage of stagnation/soil loss is about 24% (Ou Yang *et al.* 1999). The EEB resulting from decreasing the stagnation can be calculated as follows:

$$\text{EEB10} = \text{TWF} \times \text{WRF}^{-1} \times \text{SLW} \times (1 - \text{RFW}) \times \text{SBD}^{-1} \times \text{CBR} \times 24\% \quad (10)$$

$$\text{EEB11} = \text{TWG} \times \text{GWR}^{-1} \times \text{SLW} \times (1 - \text{RGW}) \times \text{SBD}^{-1} \times \text{CBR} \times 24\% \quad (11)$$

EEB10 and EEB11 represent the benefits resulting from decreasing stagnation for the increased forest and grassland areas, respectively, as a result of water transfer. The benefits from decreasing stagnation for the increased forest area are 0.32×10^8 yuan (RMB) in 2020, 0.69×10^8 yuan (RMB) in 2030 and 1.06×10^8 yuan (RMB) in 2050. For grassland, the corresponding benefits are 0.98×10^8 yuan (RMB) in 2020, 2.24×10^8 yuan (RMB) in 2030 and 2.92×10^8 yuan (RMB) in 2050 for decreasing stagnation (Table 5).

EEB resulting from decreasing the loss of OM are calculated as follow:

$$\text{EEB12} = \text{TWF} \times \text{WRF}^{-1} \times \text{SLW} \times (1 - \text{RGW}) \times \text{COM} \times \text{POM} \quad (12)$$

Table 4 Eco-environmental benefits from reducing loss of nutrient elements

Year	Ecosystem	Transferred water for forest (10^8 m^3)	Amount of soil held (10^{11} kg)	Amount of N held (10^8 kg)	Benefit of N held (10^8 yuan)	Amount of P held (10^8 kg)	Benefit of P held (10^8 yuan)
2020	forest	7	2.39	1.62	2.12	1.53	1.22
	grassland	10	7.21	4.9	6.39	4.61	3.69
2030	forest	15	5.12	3.48	4.54	3.28	2.62
	grassland	23	16.57	11.27	14.7	10.61	8.49
2050	forest	23	7.85	5.34	6.96	5.02	4.02
	grassland	30	21.62	14.7	19.17	13.84	11.07

Table 5 Eco-environmental benefits from decreasing water stagnation

Year	Ecosystem	Transferred water (10^8 m^3)	Amount of soil held (10^{11} kg)	Volume of stagnation decreased (10^8 m^3)	Benefit of stagnation decrease (10^8 yuan)
2020	forest	7	2.39	0.48	0.32
	grassland	10	7.21	1.46	0.98
2030	forest	15	5.12	1.03	0.69
	grassland	23	16.57	3.34	2.24
2050	forest	23	7.85	1.58	1.06
	grassland	30	21.62	4.35	2.92

$$EEB13 = TWG \times GWR^{-1} \times SLW \times (1 - RGW) \times COM \times POM \quad (13)$$

EEB12 and EEB13 represent the benefits resulting from decreasing OM loss for the increased forest and grassland areas, respectively, as a result of water transfer. The benefits from decreasing OM loss for increased forest are 0.24×10^8 yuan (RMB) in 2020, 0.50×10^8 yuan (RMB) in 2030 and 0.77×10^8 yuan (RMB) in 2050. For grassland, the corresponding benefits are 0.71×10^8 yuan (RMB) in 2020, 1.63×10^8 yuan (RMB) in 2030 and 2.13×10^8 yuan (RMB) in 2050 for decreasing OM loss (Table 6).

Eco-environmental benefits from purifying the atmosphere

The forest ecosystem has the ability to absorb SO_2 and to remove dust from the atmosphere (Guan *et al.* 2002). The amount of SO_2 absorbed (ASA) by deciduous broadleaved and coniferous mixed forest is $152 \text{ kg ha}^{-1} \text{ year}^{-1}$. The amount of dust removed (ADR) by deciduous broadleaved and coniferous mixed forest is $2.17 \times 10^4 \text{ kg ha}^{-1} \text{ year}^{-1}$ (Ou Yang *et al.* 1999). The cost of decreasing SO_2 (CDS) is 10 yuan (RMB) kg^{-1} . The cost of decreasing dust (CDD) is 0.3315 yuan (RMB) kg^{-1} (Kang and Tian 2002).

$$EEB14 = TWF \times WRF^{-1} \times ASA \times CDS \quad (14)$$

Table 6 Eco-environmental benefits from reducing OM (organic material) loss of OM

Year	Ecosystem	Transferred water for forest (10^8 m^3)	Amount of OM held (10^9 kg)	Benefit of OM held (10^8 yuan)
2020	forest	7	2.35	0.24
	grassland	10	7.09	0.71
2030	forest	15	5.04	0.50
	grassland	23	16.31	1.63
2050	forest	23	7.72	0.77
	grassland	30	21.27	2.13

Table 7 Eco-environmental benefits from absorbing SO_2 and removing dust

Year	Transferred water for forest (10^8 m^3)	Amount of SO_2 absorbed (10^6 kg)	Benefit of SO_2 absorbed (10^8 yuan)	Amount of dust removed (10^9 kg)	Benefit of dust removed (10^8 yuan)
2020	7	8.96	0.90	1.28	4.24
2030	15	19.19	1.92	2.74	9.08
2050	23	29.43	2.94	4.2	13.93

$$EEB15 = TWF \times WRF^{-1} \times ADR \times CDD \quad (15)$$

EEB14 and EEB15 represent the benefits resulting from absorbing SO_2 and removing dust, respectively, for the increased forest area because of water transfer. The benefits from absorbing SO_2 because of the increased forest area are 0.90×10^8 yuan (RMB) in 2020, 1.92×10^8 yuan (RMB) in 2030 and 2.94×10^8 yuan (RMB) in 2050. The benefits from decreasing dust because of the increased forest area are 4.24×10^8 yuan (RMB) in 2020, 9.08×10^8 yuan (RMB) in 2030 and 13.93×10^8 yuan (RMB) in 2050 (Table 7). The benefits resulting from absorbing SO_2 and removing dust in the increased grassland area have not been assessed because of a lack of data.

Sum of eco-environmental benefits

Many other service functions have not yet been assessed, such as education, tourism, etc. Table 8 can be generated using the results from the above equations. The EEB are 15.73×10^8 yuan (RMB) in 2020, 33.68×10^8 yuan (RMB) in 2030 and 51.65×10^8 yuan (RMB) in 2050 for the increased forest area as a result of water transfer. The corresponding benefits are 24.30×10^8 yuan (RMB) in 2020, 55.88×10^8 yuan (RMB) in 2030 and 72.87×10^8 yuan (RMB) in 2050 for the increased grassland area as a result of water transfer.

DISCUSSION

Water, a limited and fragile resource, is different from other resources such as soil and vegetation (Savenije 2002). Water can be transferred over great distances. Opportunities to alter the distribution of water are immense (Biswas *et al.* 1983) and the WRP is one such opportunity. The WRP will bring about gigantic economic benefits. The direct economic benefit is about $213\text{--}809 \times 10^8$ yuan (RMB) for the recipient regions (Han *et al.* 1998). According to this study, the EEB are

Table 8 Sum of eco-environmental benefits over time (units: 10⁸ yuan)

Year	2020	2030	2050
Forest	15.73	33.68	51.65
Grassland	24.30	55.88	72.87
Total	40.02	89.57	124.52

40.02 × 10⁸ yuan (RMB) in 2020, 89.57 × 10⁸ yuan (RMB) in 2030 and 124.52 × 10⁸ yuan (RMB) in 2050. The eco-environmental benefit value is on the low side because of the lack of assessment of some system service functions and the lack of consideration of the long-term impact of the eco-environment. Natural resources are ample in northwest China and this preponderance in natural resources will convert into economic predominance after the WRP is carried out (Liu *et al.* 2001). The eco-environment functions will become more important following the forthcoming economic development and improvements in the living standards.

Using transferred water in the WRP continuously and effectively to resolve the water deficit in northwest China is propitious for many reasons: for socio-economic development and improvement in the standard of living, for construction of an ecological environment in the ecotone in northwest China, and for resolving the drying up of the Yellow River and stagnation of the riverbed. However, there is more work to do, of which water saving is the most important aspect. After the WRP is completed, the Yellow River and the recipient regions of the WRP will still have insufficient water (Zhang and Xie 1999; He *et al.* 2000). To encourage water saving, raising the price of water is a useful tool (Liu *et al.* 2003). However, water is not an ordinary economic resource (Savenije 2002) and institutional reform and more comprehensive other reforms are also necessary (Summerton 1998; Chaturvedi 2001;

Feldman 2001; Jin and Young 2001; Yang *et al.* 2003).

The benefit resulting from agricultural irrigation is about 1.5 yuan (RMB) m⁻³, the benefit from industry and lifestyle is about 5.5 yuan (RMB) m⁻³, and the benefit resulting from waterpower is about 0.9 yuan (RMB) m⁻³. The direct economic benefit in the recipient regions in the WRP is about 4.73–4.15 yuan (RMB) m⁻³ (Han *et al.* 1998). According to this study, the benefit of the WRP resulting from the eco-environment is about 1.0 yuan m⁻³. In fact, the ecological implications of water transfer have been and continue to be inadequately addressed (Snaddon *et al.* 1998) because of the externality and concealment of ecological benefits. Water management in integrated environmental management should, therefore, consider the EEB more, and the ecological water requirement should be met.

The WRP will help to alleviate water scarcity in northwest China and is necessary for improvements in the eco-environment and for economic development. Saving water and integrated water management are also very important. Detailed ecological studies of the effects of water transfer have, so far, fallen on deaf ears in administrative, engineering and political circles (Snaddon *et al.* 1998). More attention should be paid to the ecological aspects of the WRP and more studies should now be done.

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