Annals of Arid Zone 42(1): 1-11, 2003

Water Resources Accounting in Arid Zone of Northwest China: A Case Study of Integrated Environmental and Economic Accounting

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Abstract: Water resources play an important role in production, survival, and maintenance of environmental functions. Water resources accounting is an important part of integrated environmental and economic accounting. Based on the introduction of the System of Integrated Environmental and Economic Accounting (SEEA), we take Zhangye Prefecture, which lies in the arid zone of Northwest China, as a case to illustrate the process of water resources accounting. Water resources accounts include a physical account, monetary account and allocation of water depletion cost account. The results show that the depletion cost of excessive water use was equivalent to 197.93 million RMB in Zhangye Prefecture for the year 2000, and the net domestic product (NDP), deducting water depletion cost (EDP), was 3.56% less than the NDP. Water depletion cost accounted for 9.39% of the traditional net capital formation.

Key words: Depletion cost of excessive water use, EDP, integrated environmental and economic accounting, service value of water resources, water resources accounting.

The earth's ecosystem provides a number of vital functions and services that include acting as a source of resources and providing sink and recycling services to mankind and other living beings. The traditional System of National Accounting (SNA) has failed to incorporate the value of natural resources and the cost of environmental degradation (Holub *et al.*, 1999). This provides inaccurate signals for policy makers to exploit and even deplete natural resource base to achieve rapid economic growth. Such behavior may result in short-term illusory gains in income, but in the long run it may lead to permanent losses in wealth at both national and regional levels.

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In order to correct the shortcomings of traditional accounting, many efforts have been made in the area of resources and environment accounting since the 1970's (e.g., Denison, 1979; Repetto *et al.*, 1989; UNSD, 1993; Keuning, 1995; Uno and Bartelmus, 1995; Uno, 1995; UNSD, 1997). The most widely accepted approach to this has been the System of Integrated Environmental and Economic Accounting (SEEA) developed by United Nations (UNSD, 1993). The framework of SEEA has been applied and adapted in many developed and developing countries such as Japan, India, Indonesia, Mexico, New Zealand, Papua New Guinea, Sweden, China, etc. (Bartelmus, 1999; Haripriya, 2001; Kusmadi and La, 2000; Markandya

and Milborrow, 1999; Ming, 1999; UNEP, 1998; Xuelin, 1998). In these countries, cases involved several natural resources (e.g., subsoil, forestry and land) and environmental degradation (Bartelmus, 1999; Markandya and Milborrow, 1999; Ming, 1999; UNEP, 1998), while others investigated only one type of natural resource (e.g., forestry, fishery) (Harirpriya, 2001; Kusmadi and La, 2000; Xuelin, 1998). Results of such studies show that environmentally adjusted net domestic product (EDP) and capital accumulation tend to be less than net domestic product (NDP) and capital formation drawn from traditional economic accounting, respectively. At times the environmentally adjusted net capital accumulation will be negative, which indicates that the studied economic body failed to pass the test of weak sustainability (Neumayer, 2000).

There are few experiments in the area of water resources accounting in the listed studies. In arid zones, water resources are probably the most important natural resource. Thus, construction of water resources accounts should be an important step in the integrated environmental and economic accounting of such regions. In this paper, we take Zhangye Prefecture, which lies along the second longest inland river in Northwest China, Heihe river, as a case to illustrate the compilation process of water resources accounting.

The Framework of SEEA

The framework of SEEA is shown in Table 1. The shaded area identifies supplemental elements that are needed for the incorporation of environmental assets into the SNA framework. There are two additional groups of elements. The first

Table 1. Framework of SEEA

	Economic activities					Non-produced natural assets (6)
	Production (1)	Rest of world (2)	Final consumption (3)	Produced assets (4)	Non-produced assets (5)	
Opening stock of assets (i)				Kop.cc	Konp.ec	
Supply (ii)	P	M				
Economic use (iii)	C_i	X	C	Ig		
Consumption of fixed capital (iv)	CFC			-CFC		
Net domestic product (v)	NDP	X-M	C	I		
Use of non-produced assets (vi)	**Use_{np}**				**$-Use_{np.ec}$**	**$-Use_{np.en}$**
Accumulation of non-produced assets (vii)					**$I_{np.ec}$**	**$-I_{np.en}$**
Environmentally adjusted aggregates (viii)	**EDP**	**X-M**	**C**	**$A_{p.cc}$**	**$A_{np.ec}$**	**$-A_{np.en}$**
Revaluation (ix)				$Rev_{p.cc}$	$Rev_{np.ec}$	
Other changes in volume of assets (x)				$Vol_{p.cc}$	$Vol_{np.ec}$	
Closing stock of assets (xi)				$Kl_{p.cc}$	$Kl_{np.ec}$	

Source: UNSD, 1999.

group in column 6 records the effect of economic activities on non-produced natural and environmental assets such as water resources, air and virgin forests. The second group of elements in the rows (vi), (vii), and (viii) represent the use of non-produced natural assets, other accumulation of non-produced natural assets and environmentally adjusted aggregates, respectively. The elements recorded in column 6 and rows (vi) and (vii) can be interpreted in physical as well as monetary terms. Row (viii), which is relevant only in the case of monetary environmental accounting, is included to derive the environmentally adjusted net domestic product (EDP) and other environmentally adjusted aggregates. Use_{np} (column 1, row vi) reflects the use of non-produced (natural) economic assets ($-Use_{np.ec}$) and the degradation of environmental assets ($-Use_{np.en}$). $-Use_{np.ec}$ reflects the consumption of mineral resources, the economic disafforestation and the influence of soil erosion and acid rain on the productivity of forest and agricultural land, etc. $-Use_{np.en}$ includes excessive catch from sea and rivers, logging and over-hunting, the influence of waste emission on the quality of water, air, fish and virgin forest and the influence of other economic activities (e.g., outdoor recreation activities, agricultural production and transportation) on ecosystem and human living environment, etc. Row (vii) and column 5 represent the transfer of natural assets to economic uses (such as transfer of land to economic uses, conversion of forests, etc.) as a change in the stock of non-produced (natural) economic assets ($I_{np.ec}$) in physical/monetary terms. The counterpart to this increase in economic assets is the reduction of natural assets, other than the economic assets ($-I_{np.en}$). Besides the EDP term, net capita accumulation, including the accumulation of produced assets ($A_{p.cc}$), non-produced economic assets ($A_{np.ec}$) and non-produced environmental assets ($-A_{np.en}$), is listed in row (viii). From Table 1 some identities can be shown as follows:

$A_{p.cc}$ = In = Ig-CFC for produced assets,

$A_{np.ec}$ = $I_{np.ec}$-$U_{senp.ec}$ for non-produced economic assets,

$A_{np.en}$ = $I_{np.en}$-$U_{esnp.en}$ for non-produced natural assets,

EDP = P-C_i-CFC-Use_{np} from income side, and

EDP = C+ (X-M) + ($A_{p.cc}$+$A_{np.ec}$)-$A_{np.en}$ from expenditure side,

where,

In = net capital formation; Ig = total capital formation; CFC = consumption of fixed capital; P = the gross supply of product; Ci = immediate consumption; C = final consumption; X-M = net export. Other variables have been defined in the paragraph.

The SEEA was developed as a satellite system for the SNA. It complements the current SNA in two important ways, which include additional information on: (i) depletion of natural resources in both production and final demands, and (ii) changes in environmental quality. The SEEA contains both physical accounts and monetary accounts. Asset boundaries in the physical accounts are very general and include, in principle, all assets (UNSD and UNEP, 2000). The SEEA was developed in response to a demand for an analysis of the interaction between the economy and the environment in a common framework (UNSD, 2001). The integrated accounting process provides a host of

information that can be used to facilitate the formulation and evaluation of economic and environmental policies aiming at sustainable development. The generated information can be used to assess economic performance, reform economic policies and assess the effectiveness of current policies. It can also help in identifying environmental problems and priorities, trace environmental pressure points, design environmental policies, determine international arrangements to control transboundary pollution, and evaluate the effects of environmental policies (Uno, 1995; UNSD and UNEP, 2000). All these characteristics of SEEA put it at the frontier of research in ecological economics.

Compilation of Water Resources Accounts of Zhangye Prefecture

Study region

Zhangye Prefecture is located in the middle reaches of the second longest inland river, the Heihe river, in the arid zone of northwest China. Its average annual rainfall is between 60 and 500 mm, while the annual potential evaporation is between 2048 and 2341 mm. The Prefecture has a population of 1.25 million, which is little over 2.0 times the 1949's figure of 0.55 million. Oasis environment accounts for 5650 km^2 (13.48%) of its territory (41924 km^2), the rest being desert, Gobi and mountainous regions. The Prefecture now has 0.187 million hectare arable land, much of which is being used for irrigated farming. Planting is the most important economic activity, in which wheat and corn are two important crops. The main source of water supply is the Heihe river. With the development of economy and an increase in population, the water demands are steadily increasing in the prefecture, which has caused environmental degradation such as soil erosion, vegetation degradation and soil salinization. A major effect of the growing water demand is the decreased amount of water flowing down to the Erjina oasis, located in the lower reaches of the Heihe river. The oasis is now facing a collapse of its ecosystem and economic system due to reduced water inflow from Zhangye Prefecture. Erjina oasis is the major habitation within Erjina Banner, Inner Mongolia Autonomous Region, China. Since water discharge from Zhangye Prefecture has dwindled, the oasis is getting affected by desertification, and becoming a main source of sandstorm. In order to achieve sustainable development in the whole catchment, compilation of water resources account of Zhangye Prefecture may offer helpful information for water management and lead to adjustment of industrial structure in the catchment.

Data sources

The water use information was obtained from the Official gazette of water resources in Gansu Province, China, published by Water Resources Bureau of Gansu Province, China (1999-2000). The supplementary data on water resources were derived from the Annual accounting of farmland irrigation in Zhangye Prefecture in 2000 and annual accounting of environmental protection Zhangye Prefecture in 2000, published by the Government of Zhangye Prefecture, Gansu Province, China. The information on economic activities was collected from the input-output table by us.

Steps in the compilation of water resources accounts

In order to integrate the information of water use in Zhangye Prefecture into a national account in monetary form, four steps were designed. The first step consisted of constructing a physical account of water resources that contained information on the sustainable development and depletion volume of water resources. The second step involved establishing monetary account of water resources, in which its valuation was a matter of importance. In the third step, allocation depletion cost of excessive water use to economic sectors and final consumption were entered into another account to investigate the contribution of economic activities to water resources depletion. The final step involved integrating the accounts, including water resources, and adjusting it to some traditional economic aggregates.

Compilation of physical account

Meaning of each item: Physical account records the opening stock, closing stock and volume change of surface water and groundwater in Zhangye Prefecture for the year 2000. There are six designed items. 'Opening stock' and 'Closing stock' represent stock volume of surface water and groundwater resources present at the beginning and the end of the accounting period, respectively. 'Sustainable development' records the development volume of water resources within the replenishment capability of them. 'Depletion' items show the number of water resources used excessively beyond their regeneration capability. 'Other accumulation' refers to the supply of water resources in the accounting period. 'Other change in volume' is comprised of water resources flowing out of Zhangye Prefecture and the over-calculation between surface water and groundwater resources

Compiling accounts: Water is a cyclic natural resource that moves rapidly, escaping from human control and ownership (Mϕllgaard, 1997). Thus, measuring the long-term availability of water under current economic and technical conditions for assessing the (non-) sustainability of water use is one of the most difficult tasks in natural resources accounting. However, because of the important role of water resources in arid zone, such as in the northwest of China, water resource accounting should not be neglected.

Table 2 shows that total economic use of water resources in Zhangye Prefecture was 2.152 billion m^3 in 2000, of which 1.852 billion m^3 consisted of surface water, which accounted for 86.1% of the total economic use of water resources in that year. The largest amount of water use was for planting that accounted for approximately 85.7% of the total economic use of water resources. The economic use of water in agriculture (including planting, forestry, stock breeding and other agricultural activities that include fishing and hunting) was about 95.7% of the total water use. Water use in non- agricultural activities (91.91 million m^3) was much smaller than that in agricultural activities, reflecting that agriculture imposes the greatest demands on water resources in the Prefecture.

During compilation of groundwater accounts in 2000, the residual total net

Table 4. Monetary accounting of water resources of Zhangye Prefecture in 2000 (10^6 RMB)

	Opening stock	Sustainable development	Depletion	Other accumulation	Other change in volume	Revaluation	Closing stock
Groundwater	21.97	-108.68	0.00	768.53	-674.41	0.55	7.69
Surface water	188.05	-406.74	-197.93	900.52	-239.25	-65.63	179.01

Notes: Figures in 'depletion' are the product of indirect services value and excessive use of water resources. Other figures are products of unit service value (including direct and indirect) of water and corresponding volume of water use in physical account (Table 3). 'Revaluation' is a residual item, which includes holding gain and loss of water resources, to make balance of the account during accounting period. The values have been rounded.

valuation method (Westman, 1977) was applied to assess the value of water resources in the Prefecture according to the non-perfect water market and to highlight significant functions of water resources to arid zone environments.

Water resources offer not only ecological products (e.g., irrigation, drinking water), but also ecological services (e.g., preventing desertification, protection of vegetation, and providing recreation areas) to humans. According to Constanza *et al.* (1997), surface water accounts for 200 million ha of terrestrial surface and the service value of terrestrial water is equivalent to US$ 8,498 $(ha \bullet a)^{-1}$. The total runoff value for the world is 38,830 km^3 (World Resources Institute *et al.*, 1999). The unit value of water resources services (0.362RMB $(m^3 \bullet a)^{-1}$) was calculated from the above data (the ratio was 8.27RMB $US\$^{-1}$ in 2000), of which the service value of water products (here called direct service value) was 0.090 RMB $(m^3 \bullet a)^{-1}$ and value of ecological functions (here called indirectly services value) is 0.272RMB $(m^3 \bullet a)^{-1}$. As to groundwater, its service value was taken as equal to the service value of surface water due to the absence of a study evaluating its value.

Monetary account

Every figure in the monetary account (Table 4) is the product of a unit service value of water resources and a corresponding figure of the physical account (Table 3). It was revealed that the total value of water resources (186.7 million RMB) towards the end of accounting period was less than that (210.0 million RMB) in the opening accounting period. Both 'other change in volume' and 'other accumulation' of water resource values during the accounting period was the largest. The depletion cost of surface water was 197.93 million RMB, which was larger than the total service value of surface water in the opening accounting period.

Allocation account of depletion cost

Based on the analysis of the stock and flow of water in the accounting period, it is possible to allocate depletion cost to flow account. The allocation method is designed as follows: taking the ratio of water use of each sector (including final consumption) to total water use (coming

Table 5. Allocation of depleted cost of water resource in Zhangye Prefecture in 2000 (10^6 RMB)

	Planting	Forestry	Stock-breeding	Other agriculture	Mining	Manufacturing	Electricity	Construction	Services	Final consumption	Total
Surface water	169.82	17.84	2.25	3.07	0.005	1.79	0.24	0.004	0.184	2.726	197.93
Ground water	0	0	0	0	0	0	0	0	0	0	0
Total	169.82	17.84	2.25	3.07	0.005	1.79	0.24	0.004	0.184	2.726	197.93

from Table 2) as the ratio of excessive water use of each sector to total excessive water use, allocation of depletion cost to activities (Table 5) is made. This is done by multiplying the 'depletion figures with the ratios'.

Table 5 shows that the depletion cost of excessive water use in agricultural sector (192.98 million RMB) accounted for 97.50% of the total loss of water resources service value (197.93 million RMB), within which planting (169.82 million RMB) accounted for 85.80% of the total loss. The results suggest that planting was mainly responsible for environmental degradation. It is necessary to resolve unsustainable use of water in agriculture, especially for planting. This will help to provide benefits for sustainable development of water resources and for sustainable development of the ecological economic system in the whole catchment area.

Conclusions

The following conclusions can be derived from the study:

- Compilation of water resources accounts according to SEEA framework can provide helpful information for the enforcement of water resource management in effective water development. Results indicate that depletion cost associated with excessive water use, based on service value of water in the Zhangye Prefecture, was 197.93 million RMB. This accounted for 3.56% of NDP and 9.39% of traditional net capital formation in the year 2000. Planting activity contributed the most to loss of water resource services, accounting for 85.8% of the total loss. From these results one can infer that in order to reduce water resource service losses, careful attention is needed to save water within agricultural sector, especially in planting practices.
- The water resources accounts for Zhangye Prefecture have a concise format and the results are preliminary. Based on the guidelines offered by SEEA, only quantities of water resources were taken into account. However, quality of water resources should also be an important accounting item in the future.
- Compilation of water resources accounts in a certain year is not the final goal. Offering original parameters for modeling the development trends in ecological economic system under a given policy related to water use should be the goal.
- Calculating water price from the view of ecosystem services is at a trial stage.

Whether it is accepted or not needs to be examined.

- Due to inadequate data, the present study has made several assumptions concerning the allocation of water use, depletion cost to economic sectors and its value to groundwater resource. However, the water resource accounting suggests that water depletion cost in Zhangye Prefecture has a very meager impact on its NDP.

Acknowledgements

The research was financially supported by National Natural Science Key Foundation of China (No. 40235053) and Talent Cultivation Foundation (No. 990015). We wish to thank the anonymous referee for his valuable suggestions.

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