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Studies on Potential Water Resources Crisis Based on STIRPAT Model: A Case from Zhejiang in China

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ABSTRACT

Zhejiang province in China is confronting with pressing problems for how to rationally develop and sustainably use water resources. Due to the large population base, water resource per capita in Zhejiang is not plentiful, although it is a place abundant in water. As in the 2011, water resource per capita in Zhejiang province is 1,362 m^3. In view of this, Zhejiang province should be regarded as an area of moderate water shortage. The paper introduces the STIRPAT model to describe and further explore linkages between water consumption and population as well as other socio-economic factors to select out major ones affecting water resources consumption for 11 prefecture-level cities in Zhejiang province. Based on the empirical results, paper tries to propose suggestions for long-term water management in Zhejiang province.

INTRODUCTION

In many places, freshwater has become a scarce and overexploited natural resource (UNESCO-WWAP 2003, Bradley & Stephan 2010) leading to a wide range of social and environmental concerns (Falkenmark 2008, Bradley & Stephan 2010). Demand for freshwater is rising, but a variety of factors including population growth, water pollution, economic progress, land-use change and climate change render its availability into the future uncertain (Evan & Slobodan 2011). So, the shortage of water resources which is threatening the survival of humanity, and restricting economy and society to develop sustainably, and even lead to regional conflicts has been of concern in recent years (Chen et al. 2003). In the future, water resource may become the cause of international disputes.

In line with internationally recognized standards, per capita water resources less than 3,000 m^3 is for mild water shortage; less than 2,000 m^3 is for moderate water shortage; per capita water resources less than 1,000 m^3 is serious lack of water; water resources per capita less than 500 m^3 is for extreme water shortage. China is a mild water-scarce country, whose total water resource ranked 6th in the world, but the per capita share of river runoff is only 2,300 m^3 (estimated as the year has a population of 1.2 billion), which is one-fourth of world water resource per capita, and ranked 88th in the world (Han & Zhang,1998). According to the statistics of the Chinese Ministry of Water Resources, 110 cities in China have problems as serious water shortage, approximately 30% of which listed as water resource high pressure zone, more than 60% cities' per capita discharging wastewater exceed the national average, and some big cities like Shanghai, Beijing and Tianjin are treating with more prominent contradictions between use of water resources and economic growth (Lu & Zhou, 2010). Moreover, safe drinking water in rural areas has become an important part of people's livelihood in China, is the core of solving "three rural issues" that means the issues of rural areas, agriculture and farmers (Liu 2012).

According to "Master Plan of Water Resource Protection and its Development and Use in Zhejiang Province" published by Water Conservancy Bureau of Zhejiang Province, in past years of Zhejiang province, its average water resource is 95.5 billion m^3, and its average per area water resources is 920,000 m^3/km^3. If we take Zhejiang province's average per area water resources into consideration, it can be characterized by water resources abundant area. But, due to large population base, water resource per capita in Zhejiang is not plentiful. As in 2011, province's water resource per capita is 1,362 m^3. In view of this, Zhejiang province should be regarded as an area of moderate water shortage. Zhejiang province is confronting with following three main water resources problems:

The distribution of water resources is uneven both in time and space; moreover, both population distribution and economic layout do not match water conditions.

The paper adopts the concept of ecological security Gini coefficient to measure the rationality and efficiency of water resources distribution in Zhejiang province. Table 1 lists GDP, population, water resources amount and GDP per capita for 11 cities in Zhejiang province, all of which are sorted from low to high according to water resources amount.

Based on Table 1, we calculate cumulative percentage for each indicator, which is shown in Table 2. In this paper, we calculate ecological security Gini coefficient with method of trapezoid area, the formula is shown as follows:

$$GINI = 1 - \sum_{n=1}^{i} (X_i - X_{i-1})(Y_i + Y_{i-1})$$

Here, X_i indicates cumulative percentage of population, GDP and GDP per capita; Y_i indicates cumulative percentage of water resources; When i= 1, (X_{i-1}, Y_{i-1}) refers to (0, 0).

It is internationally accepted that Gini coefficient below 0.2 indicates the distribution of social income is equal in highest degree or says absolute equal; between 0.2 and 0.3, income distribution is relative equal; between 0.3 and 0.4 represents it is relatively reasonable; from 0.4 to 0.5 says the income gap is too large; higher than 0.5 for highly unequal. 0.4 is the internationally recognized warning line. According to estimated results, we found ecological security Gini coefficient calculated based on water resources and population is 0.2, the same as which based on water resources and GDP, but when we consider the one based on water resources and GDP per capita, we found the value raises to 0.4, which has reached the warning line. So, in some degree, we can think that there is still a room for Zhejiang province to improve water resources distribution.

The use pattern of water resources, in general, is still extensive. In Fig. 1, lose rate indicates water lose amount per consumption amount, use rate indicates amount of water consumed in total water resources amount. We can find, in past seven years, average water resources use rate is 23%, and lose rate did not change a lot whose average rate is 53%, so there's large potential room for water conservation.

Water bodies are increasingly polluted by human activities along with the rapid development of industry and agriculture, and the improvement of human living. Wastewater discharge increasing substantially has resulted in incalculable damage to the social and economic development. Fig. 2 shows us wastewater discharge status in Zhejiang province, in which we can find there is an increasing trend in total wastewater discharged as well as in wastewater discharged from living or industry.

In view of above, how to rationally develop and sustainably use water resources have become pressing problems for Zhejiang province. Hereinafter, the paper introduces the STIRPAT model to describe and further explore linkages between water consumption and population as well as other socio-economic factors in Zhejiang province to find major ones affecting water resources consumption for 11 prefecture-level cities in Zhejiang province.

MATERIALS AND METHODS

Model specification and variable selection: The IPAT model is the earliest one of the formulas used to describe the determinants of environmental degradation - the contributions of size of the population (P), affluence level (A) and technical level (T) - to the environmental impact (I)) (Ehrlich & Ehrlich,1970, Commoner & Barry 1972). Environmental impact (I) can be viewed as resource depletion or waste accumulation (Commoner & Barry 1972), water resources belong to the scope the model tries to explain. Meanwhile, our study aims to solve question as "Why city by the Yangtze River still faces water resource shortage", and tries to explore the economics meanings behind the shortage of water resources mainly from the population perspective, there-

Table 1: Values for GDP, population, water resources amount and GDP per capita in 2011.

City	Water resources amount (100 million m^3)	Population (10 thousand)	GDP (100 million Yuan)	GDP per capita (100 million Yuan/10 thousand persons)
ZS	4.26	96.99	772.75	7.97
JX	15.01	343.05	2677.09	7.80
HUZ	34.72	261.05	1520.06	5.82
SX	58.58	440.01	3332.00	7.57
NB	61.23	576.4	6059.24	10.51
TZ	63.94	586.79	2794.91	4.76
JH	80.19	469.07	2458.07	5.24
QZ	81.96	252.55	919.62	3.64
WZ	88.76	798.36	3418.53	4.28
LS	118.86	251.33	798.22	3.18
HZ	136.7	695.71	7019.06	10.09

Note: Characters marked as HZ, NB, JX, HUZ, SX, ZS, WZ, JH, QZ, TZ and LS in Table 1 respectively represent 11 prefecture-level cities in Zhejiang province, i.e., Hangzhou city, Ningbo city, Jiaxing city, Huzhou city, Shaoxing city, Zhoushan city, Wenzhou city, Taizhou city, Lishui city, Jinhua city and Quzhou city. These symbols have been applied throughout the following text. Statistics in the table are collected from Zhejiang Statistical Yearbook 2012.

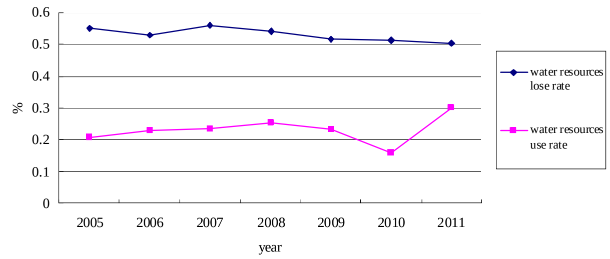

Fig. 1: Water resources lose rate and use rate for Zhejiang province.
Note: Statistics are collected from reports published by Water Conservancy Bureau of Zhejiang province.

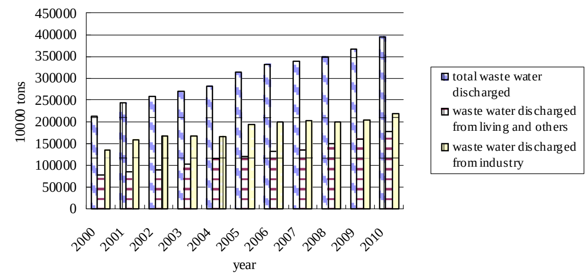

Fig. 2: Discharging of wastewater in Zhejiang province.
Note: Statistics are collected from Zhejiang Statistical Yearbook 2001-2011.

fore, it is reasonable for us to apply this model to the study on the supply and demand of water resources in Zhejiang province.

Since the IPAT model being introduced, many new forms have been developed, like the ImPACT (Waggoner & Ausubel 2002), ImPACTS (Xu et al. 2005), IPBAT (Schulze 2002), but most articles both domestic and foreign use IPTA model of random form which is established by Dietz and Rose (Rosa et al. 2004). It can be called STIRPAT mode, and written as $I = aP^{b}A^{c}T^{d}e$. One advantage of this model is that you can use linear regression to estimate the model through logarithm processing. Moreover, its interpretation of the coefficient of elasticity can help to describe the impact of various drive factors on environmental impact during empirical analysis. STIRPAT model we built decomposes demographic factors for two indicators - population and level of urbanization (the proportion of urban population in total population of an area) - which are used to analyze the impact of population change, urban development and urbanization on regional water use. Model form is shown as below:

$$I_{it} = f(P_{it}, A_{it}, C_{it}, T_{it}) = aP_{it}^{\alpha_1}A_{it}^{\alpha_2}C_{it}^{\alpha_3}T_{it}^{\alpha_4}e_{it}$$

From logarithmic processing of above equation, we can achieve a new one:

$$\ln(I_{it}) = \ln(a_{it}) + \alpha_1\ln(P_{it}) + \alpha_2\ln(A_{it}) + \alpha_3\ln(C_{it}) + \alpha_4\ln(T_{it}) + \ln(e_{it}),$$

In this paper, *i* ranges from 1 to 11 which stands for cross-section of prefecture-level city in Zhejiang province; *t* refers to time span which range from 2001 to 2011; I_{it}, P_{it}, A_{it}, C_{it}, T_{it} represent the water resources-environmental impact, population size, degree of affluence, urbanization level and water-resources-use-technical level respectively; $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are the coefficients of elasticity of each drive factor; e_{it} stands for residuals.

Data description: The paper collected data of city$_i$'s water supply in year *t* (Unit: 100 million cubic meters) together with population size to make water supply per capita, which can be used to represent water resources supply pressure and indicate water resources-environmental impact (I_{it}); city$_i$'s total population at the end of the t year stands for population size (P_{it}), Unit: million; Urbanization level is calculated as $C_{it} = C_{it}^{0}/C_{it}^{1}$, within which C_{it}^{0} refers to non-agricultural population of cityi in the end of year *t* (Unit: million), and C_{it}^{1} refers to total population of city$_i$ in the end of year *t* (Unit: million); technology level of water-resources-use is calculated as $WT_{it} = I_{it}/GDP_{it}$, but here we take its reciprocal value which can be written as $T_{it} = 1/WT_{it} = GDP_{it}/I_{it}$. It will enable the indicators to be more consistent with our representation of water-resources-use-technical progress, that is, the less water use amount per GDP, the greater water-resources-use-technical level. GDP$_{it}$ indicates output value of city$_i$ in the end of year *t* (Unit: 100 million Yuan). All relevant data are collected from Zhejiang Province Statistical Yearbook from 2001 to 2012, as well as Statistical Yearbooks of 11 prefecture-level cities in Zhejiang province from 2001 to 2012.

The test on form of the model: The empirical analysis part of the paper is based on statistical software Eviews 7.2. While determining the form of the model, we generally use F-test to judge we should establish a variable coefficient model, variable intercept model or constant intercept constant coefficient model, and use Hausman test to determine should the model be built with fixed-effect or random-effects. F-test statistics we obtained based on the model data are F1 = 4.863780277601379 and F2 = 1.540539962. Two statistics are both larger than the corresponding threshold value F1~F0.05(40,66) = 1.57633722, F2~F0.05(50,66) = 1.540539962. According to the basic principle of the F-test, it supports to establish a variable coefficients model of fixed-effect. The null hypothesis of Hausman test is the individual impact is unrelated to the explanatory variables, that is to say there are random effects. According to the test results shown in Table 3, we find Hausman test rejected the null hypothesis at the 0.01 level of significance, so we establish a model of fixed effect.

Table 2: Cumulative percentage for GDP, population, water resources amount and GDP per capita.

City	Cumulative percentage for water resources (%)	Cumulative percentage for population (%)	Cumulative percentage for GDP (%)	Cumulative percentage for GDP per capita (%)
ZS	0.57	2.03	2.43	11.24
JX	2.59	9.22	10.86	22.25
HUZ	7.25	14.69	15.64	30.47
SX	15.13	23.92	26.13	41.15
NB	23.35	36.00	45.20	55.99
TZ	31.95	48.29	54.00	62.71
JH	42.72	58.13	61.74	70.10
QZ	53.73	63.42	64.63	75.24
WZ	65.66	80.15	75.39	81.28
LS	81.63	85.42	77.91	85.76
HZ	100.00	100.00	100.00	100.00

Table 3: Hausman test.

Test Summary	Chi-Sq. Statistic	Prob.
Cross-section random	50.060680	0.0000

Table 4: Fitting status of panel model regression.

Fit index	Value	Fit index	Value
R-squared	0.999574	Adjusted R-squared	0.999226
F-statistic	2870.811	S.D. dependent var.	6.187301
Prob. (F-statistic)	0.000000	Durbin-Watson stat	2.254386

Panel data regression estimates and the results: According to the F-test and Hausman test results, in this paper, we use the cross-section weighted ordinary least squares estimation to establish fixed effects varying coefficient model, along with "cross-section weights (PCSE)" to eliminate individual heteroscedasticity, thereby enhancing the soundness of the standard deviation estimates of the coefficients. Table 4 shows fitting status of panel model regression, in which all fit index values are within proper scope. Table 5 shows estimated results of panel model regression, and estimates of the coefficients are sound and meet our expectation**.**

RESULTS

Population size: According to model estimation results in Table 5, the population factor for HZ, NB, JX, HUZ, SX, ZS, WZ, JH, QZ, TZ and LS significantly affect water resources environmental impact in the 1% significant level. By an increase of 1% in population for JX, HUZ and SX, it will have a negative impact on water resources environment, and water-resources-environmental impact will respectively drop by 10.12507%, 6.054022% and 18.30498%. By every increase of 1% in population for HZ, NB, ZS, WZ, JH, QZ, TZ and LS, water-resources-environmental impact will respectively increase by 3.745666%, 9.624761%, 3.786676%, 5.5420301%, 9.71519%, 3.958617%, 1.033084% and 0.223269%.

Urbanization level: In addition to TZ, urbanization level of HZ, NB, JX, HUZ, SX, ZS, WZ, JH, QZ and LS respectively has a significantly positive or negative impact on water resources environment. By increase of 1% in urbanization level for HUZ, SX, QZ, water-resources-environmental impact will respectively decline by 0.103176%, 0.224278% and 0.154377%. By an increase of 1% in urbanizetion level for HZ, NB, JX, ZS, WZ, JH and LS, water-resources-environmental impact will respectively increase by 1.515501%, 0.200320%, 1.081233%, 0.216744%, 1.269302% and 1.241157%.

Affluence degree: The average regional affluence degree for HZ, NB, JX, HUZ, SX, ZS, WZ, JH, QZ, TZ and LS has close relationship with water-resources-environmental impact. For JH, if its average regional affluence degree increases 1%, water-resources-environmental impact will drop by 0.211307%. But other cities will perform in opposite way, and water-resources-environmental impact for these cities will respectively increase by 0.044335%, 0.064405%, 0.167915%, 0.540429%, 1.0693-37%, 0.561062%, 0.271799%, 0.481971% by every 1% increase in the average regional affluence degree for HZ, NB, JX , HUZ , SX, ZS, WZ , QZ , TZ and LS.

Water-resources-use-technical level: By each 1% increase in water-resources-use-technical level for HZ, NB, JX , HUZ , SX, ZS, WZ, JH, QZ, TZ and LS, water-resources-environmental impact respectively decreases by 0.551601%, 0.395568%, 0.461736%, 0.456219%, 0.719356%, 0.587142%, 0.735164%, 0.702723%, 0.580321%, 0.990171% and 0.606089%.

DISCUSSION

According to the model results, except for some cities whose population size and urbanization level demonstrate a water-saving expansion, most other cities in Zhejiang province as

Table 5: Estimated results of panel model regression.

Intercept	Value	*t*-Statistic	Prob.
C	-6.399192	-27.09156	0.0000

Fixed Effects (Cross)

Intercept	value	Intercept	Value	Intercept	value	Intercept	value
_HZ-C	-11.02048	_JX-C	69.69123	_SX-C	112.2799	_WZ-C	-24.79843
_NB-C	-50.01882	_HUZ-C	38.94042	_ZS-C	-13.00649	_JH-C	-104.4250
_QZ-C	-15.74758	_TZ-C	-2.965680	_LS-C	1.070979		

Variable	Coefficient	*t*-Statistic	Prob.	Variable	Coefficient	*t*-Statistic	Prob.
Ln(A_HZ)	0.044335	12.98792	0.0000	Ln (T_HZ)	-0.551601	-129.6543	0.0000
Ln (A_NB)	0.064405	51.39343	0.0000	Ln (T_NB)	-0.395568	-181.3005	0.0000
Ln (A_JX)	0.167915	39.46903	0.0000	Ln (T_JX)	-0.461736	-177.5782	0.0000
Ln (A_HUZ)	0.540429	88.32441	0.0000	Ln (T_HUZ)	-0.456219	-112.2847	0.0000
Ln (A_SX)	1.069337	181.4834	0.0000	Ln (T_SX)	-0.719356	-144.4974	0.0000
Ln (A_ZS)	0.561062	168.4254	0.0000	Ln (T_ZS)	-0.587142	-196.7602	0.0000
Ln (A_WZ)	0.271799	37.65395	0.0000	Ln (T_WZ)	-0.735164	-270.0988	0.0000
Ln (A_JH)	-0.211307	-51.72849	0.0000	Ln (T_JH)	-0.702723	-471.6059	0.0000
Ln (A_QZ)	0.481971	182.6991	0.0000	Ln (T_QZ)	-0.580321	-179.1042	0.0000
Ln (A_TZ)	0.988678	1549.137	0.0000	Ln (T_TZ)	-0.990171	-1511.121	0.0000
Ln (A_LS)	0.716162	222.9065	0.0000	Ln (T_LS)	-0.606089	-200.6677	0.0000
Ln (P_HZ)	3.745666	26.17398	0.0000	Ln (C_HZ)	1.515501	53.24603	0.0000
Ln (P_NB)	9.624761	217.8360	0.0000	Ln (C_NB)	0.200320	42.56364	0.0000
Ln (P_JX)	-10.12507	-71.66089	0.0000	Ln (C_JX)	1.081233	128.2952	0.0000
Ln (P_HUZ)	-6.054022	-48.46743	0.0000	Ln (C_HUZ)	-0.103176	-4.820596	0.0000
Ln (P_SX)	-18.30498	-52.73687	0.0000	Ln (C_SX)	-0.224278	-40.66078	0.0000
Ln (P_ZS)	3.786676	42.81966	0.0000	Ln (C_ZS)	0.216744	22.64972	0.0000
Ln (P_WZ)	5.542030	112.1424	0.0000	Ln (C_WZ)	1.269302	94.42122	0.0000
Ln (P_JH)	19.71519	283.2840	0.0000	Ln (C_JH)	1.241157	155.9877	0.0000
Ln (P_QZ)	3.958617	46.58954	0.0000	Ln (C_QZ)	-0.154377	-35.23815	0.0000
Ln (P_TZ)	1.033084	134.5670	0.0000	Ln (C_TZ)	-0.008046	-0.777271	0.4398
Ln (P_LS)	0.223269	8.009754	0.0000	Ln (C_LS)	-0.918253	-56.06739	0.0000

Note: In Table 5, HZ and NB, JX, HUZ, SX, ZS, WZ, JH, QZ, TZ and LS indicate 11 prefecture-level cities; T_, P_, C_, A_ respectively represent water-resources-use-technical level, population size, urbanization level, affluence level of each city, for example, A_HZ on behalf of the affluence level of Hangzhou; -C on behalf of the fixed effects intercept of the cross-section of prefectural-level city , for example, _HZ-C on behalf of fixed effects intercept of Hangzhou corresponding equation .

a whole still support that population growth induces greater amount of water resource usage. The results are consistent with our expectation for the effect of demographic factors. With the expansion of the population, if the government does not take any measures, total amount of social water consumption would increase. It is not difficult to imagine, if social progress and improved quality of life are taken into consideration, the society's total water consumption will be higher. Take propulsion of urbanization for example, in the process of urbanization, domestic water and industrial water demand will increase, as well as the city public water and service water demand will surge.

According to relationship between the amount of water use and affluence degree, we can find, as a whole, improvement of the household wealth level will stimulate social water consumption a significant increase. As income level increases, the share expenditure on water declines. In the case of water price keeping stable, in order to achieve consumer utility maximization in current income level, social water is bound to increase. Meanwhile, the increase of income will cause the relative cost of water declines, so that social price of water will be lower than the actual price. According to the principle of supply and demand, when supply and demand reaches equilibrium, the amount of social water consumption under social price will be far greater than the amount of water consumption under actual price. In addition, the improvement of the affluence degree will also promote consumption, and increase the total society demand, and aggregate demand driven industrial expansion which is partly stimulated by the input of water resources.

For water-resources-use-technical level, if estimate result is negative, it indicates that advances in water-resources-use technology contribute to balance out water consumption increase. It means that, in the last ten years, the application of water saving technology in Zhejiang province is obviously effective. Conversely, we say it is less effective. Parameter estimates of water-resources-use-technical level show that there is significant negative correlation between water consumption and water-resources-use-technical level for eleven cities. So we can conclude that, in past ten years, water-saving engineering in Zhejiang province is determinant to social water consumption, and plays decisive role in promoting the social water-saving.

CONCLUSION

Zhejiang province is confronting with water resources shortage crisis caused by three main reasons. Empirical results have confirmed the importance of demographic factors on the water resource shortage in Zhejiang province. But, for government it is not easy to shrink population size in a short period of time, and it is more likely to be controlled within long period of time. Comparatively speaking, in a short period of time, controls on people's behavior are what can play an immediate effect on solving the problem. It means that, except for improving people's awareness of the water crisis by intensifying media publicity and education, the government should implement appropriate effluent control approaches to guide businesses and residents to rationally use water and choose proper way of drainage. In addition, due to the positive role of technical factors in water conservation work, the government also should invest, subsidize or take other measures to ensure water-saving technologies work well, and introduce new water-saving technologies.

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REFERENCES

Bradley. G., Ridoutt and Stephan Pfister 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Global Environmental Change, 20: 113-120.

Chen, Kun, Zhong-jie Yao and Guang Yao 2003. Implementation approach for water recycling economy mode in China. China Population, Resources and Environment, 13(5): 120-121.

Commoner, Barry 1972. The Environmental Cost of Economic Growth in Population, Resources and the Environment. Government Printing Office, Washington, DC.

Ehrlich, P.R. and Ehrlich, A.H. 1970. Population, Resources, Environment: Issues in Human Ecology. Freeman, San Francisco.

Evan, G.R. Davies and Slobodan, P. Simonovic 2011. Global water resources modeling with an integrated model of the social-economic-environmental system. Advances in Water Resources, 34: 684-700.

Falkenmark, M. 2008. Water and sustainability: A reappraisal. Environment, 50(2): 4-16.

Han, Qin-hai and Zhang, Yao-hui 1998. Water resources use and sustainable economy development in China. Territory & Natural Resources Stuty, 1: 35-38.

Liu, Zhen-hua 2012. Systematic analysis of rural safe drinking water based on PSR model in China. JCIT: Journal of Convergence Information Technology, 7(15): 169-175.

Lu, Ning and Zhou, Hai-guang 2010. Study on the relationship between water-use-press and economic growth of cities in China. China Population, Resources and Environment, 20(5): 48-50.

Rosa, E. A., York, R. and Dietz, T. 2004. Tracking the anthropogenic drivers of ecological impacts. Ambio, 33(8): 509-512.

Schulze, P.C. 2002. I=PBAT. Ecological Economics, 40: 149-150.

UNESCO-WWAP 2006. Water: A Shared Responsibility: The United Nations World Water Development Report 2. United Nations Educational Scientific and Cultural Organization-World Water Assessment Programme. www.unesco.org/water/wwap/wwdr/wwdr2/

Waggoner, P.E. and Ausubel, J.H. 2002. A framework for sustainability science: A renovated IPTA identity. Proceeding of the National Academy of Sciences, 99(12): 7860-7865.

Xu, Zhong-min, Guo-dong Cheng and Yu-guo Qiu 2005. ImPACTS identity of sustainability assessment. Acta Geographica Sinica, 60(2): 198-218.