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Progress in Environmental Flows Research and Applications in China

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Introduction

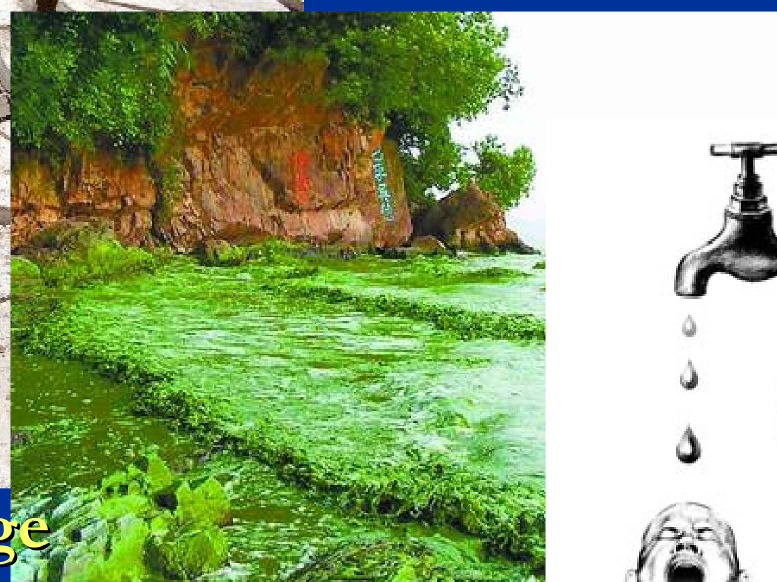
- Averagely, 2,800 billion water resources, the sixth of the world;
- Water resources per capita is only about 2,220 m^3 per annum now, 3 times less than the world's average level (Qian and Zhang, 2001);
- The spatial and temporal distribution of water resources is very uneven, 80 percent distributed in southern China.

Introduction

China has the most severe problems relating to the management and utilization of water resources.

Water shortage, water pollution, water waste are very severe in China.

water shortage



water pollution

water waste

Issues related to water

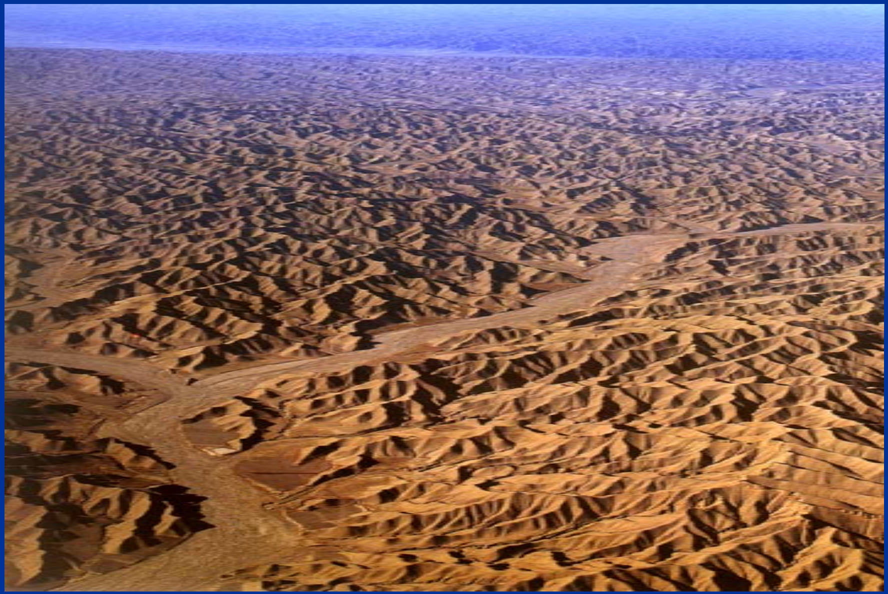
natural vegetation degradation

biodiversity reduction

river drying up

wetlands shrink

soil erosion



desertification

Concepts of EFs

There is no clear definition of EFs that is accepted globally.

In China, EFs is named "ecological water requirements/demand", "environmental water requirements/demand", ab. EWR/EWD.

Google Search

- 199 million “Environmental Flows”
- 253 thousand “Ecological Water Requirements”
- 566 thousand “Environmental Water Requirements”

Concepts of EFs

- Compared with its scope in foreign countries, the connotation and applications of EFs in China are much wider than elsewhere.
- In China, there is many types of EFs, such as EFs of rivers, vegetation, lakes and wetlands, cities and groundwater, and so on.

Concepts of EFs

Generally in China, the concept can be expressed as follows (Jia et al., 2002; Jia and Xie, 2004) :

EFs include water use not only for riverine ecosystems but also terrestrial ecosystems, such as vegetation, lakes and wetlands;

EFs may encompass water use for both native and artificial ecosystems.

In 1989, Tang (1995) first proposed the concept of EFs in his study of water resources and oasis construction in Tarim River Basin.

Concepts of EFs

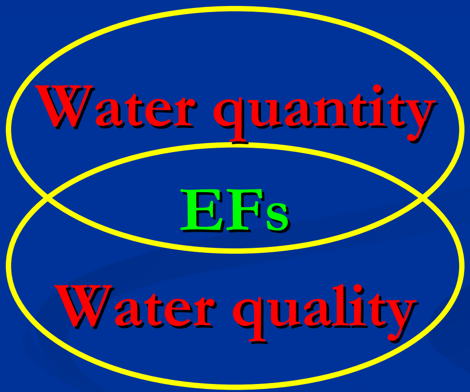
From Strategic Research on Sustainable Development of Water Resource in the 21st Century in China, Qian and Zhang (2001) defined EFs as follows:

- in a broad sense, water use in the global geosphere and biosphere to maintain the balance between water and energy, water and sand, water and salt;
- in a narrow sense, the total amount of water consumption to prevent the eco-environment from deterioration and to enhance eco-environment quality.

This concept has been widely accepted in China.

Characteristics of EFs

1. EFs is a part of the water resources required for plant and animal's survival as well as maintenance of favorable habitats;



2. Both desired water quantity and water quality are required for EFs to maintain and improve eco-environmental quality;

Characteristics of EFs

3. EFs is a compound spatial-temporal variable, which is strongly influenced by the geographical environment.

EFs in one region greatly differs from that in another, and it varies with time.

For example, in the lower reaches of the Yellow River, sediment transport mainly occurs in the flood season, while in the non-flood season, it is the base flow that should be first met via an EFs.

Characteristics of EFs

4. The actual amount of water left in an ecosystem should be within a range.

EFs can be categorized into three types:

- **Maximal EFs**, the highest threshold of water quantity that an ecosystem can tolerate;
- **Optimal EFs**, the amount of water which is can maintain eco-environmental quality most efficiently and effectively in a natural ecosystem;
- **Minimal EFs**, the least amount of water which can be expected to maintain the ecosystem's integrity and prevent eco-environmental quality from further declining.

Characteristics of EFs

5. To a certain extent, various types of EFs of an ecosystem are compatible and interactive.

Therefore, if they were merely added up, the sum could exceed the actual water demand for this ecosystem.

Total EFs for an ecosystem need further analysis by the couple of various types of EFs.

Progresses of EFs in China

- In China, EFs studies were first conducted shortly after their first appearance in literature from abroad.
- Most of the studies carried out to date have mainly concentrated on defining the concept from different points of view, or have qualitatively discussed it rather than quantitatively calculating the water requirements of ecosystems.
- There is still a lack of theoretical models and quantitative methodologies for the calculation of EFs.

Progress : EFs of rivers

- It was the least water flow of specific water quality which could perform the specific ecological functions of the riverine ecosystem.
- In China, early studies on EFs of rivers can be retrospected to the end of 1970s or the early 1980s.
- Many Chinese researchers have carried out many studies on EFs of rivers since the term of EFs was put forward by Tang (1995).
- EFs of rivers include basic flow, water demand for sediment transport, pollution purification, prevention from seawater intrusion, water evaporation and leakage.

Methods of EFs of rivers in China

- **Mean of annual minimum monthly flow method:** calculate basic flow (Li et al., 2001);
- **The monthly (annual) guaranteed frequency method**: calculate basic flow (Wang et al., 2001);
- **Hydraulic radius method** : calculate ecological water required of river channel (Men, 2006);
- **The average discharge of the lowest water month of per ten years:** calculate basic flow (Ni et al., 2002).

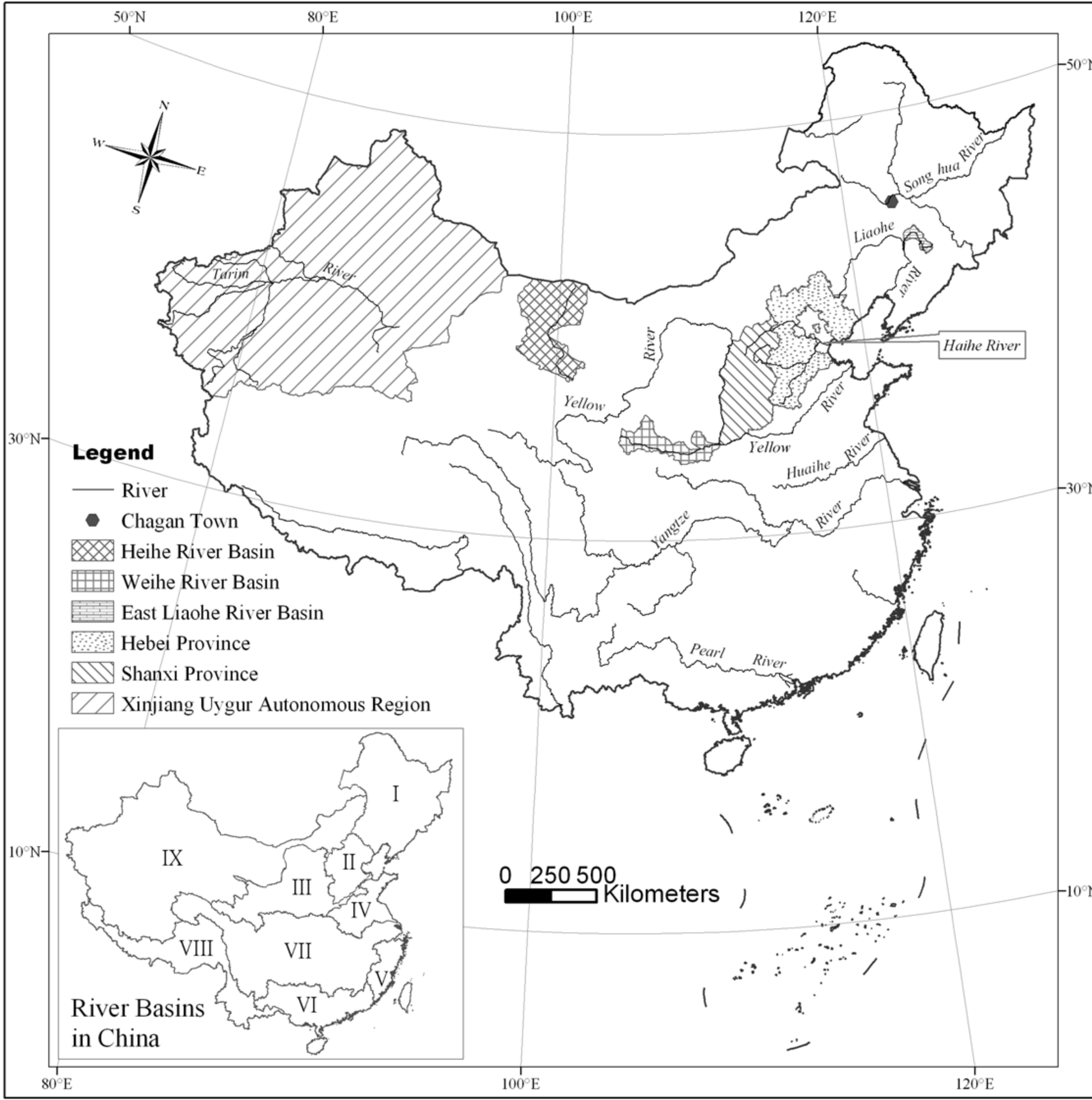
Progress : EFs of rivers (I)

Author	*Achievement*	*Methodology (Study Object)*
Li and Zheng, 2000	defined EFs of rivers and calculated it at about 12.4 billion m^3 in the Haihe and Luanhe River Basin	**mean of annual minimum monthly flow method** (*basic flow*); **sediment balance equation** (*water demand for sediment transport and salt drainage*); **Water Budget Method** (*water requirements of lakes*)
Wang et al. 2001a, 2001b	calculated the least annual EFs of rivers at 2 billion m^3 in Weihe River	**Upper-Reach Controlling Method**
Shi and Wang, 2002	Annual water demand for sediment transport was 8~12 billion m^3 and annual base flow were 5~6 billion m^3.	**sediment balance equation considering the bank-full discharge** (*water demand for sediment transport*); **mean of annual minimum monthly flow method** (*base flow*)

Progress : EFs of rivers (II)

Author	*Achievement*	*Methodology(Study Object)*
Ni et al. 2002	put forward eight principles for determining EFs of rivers including determination of EFs of rivers by functions, consideration of the seasonal or periodic changes, variation among different reaches, priority to the main function, maximization of the efficiency, minimization of harmful aftereffects, harmonization of multiple functions, and optimization for an entire river.	
Zhang et al., 2003	calculated EFs of rivers in Shanxi province at 2.3 billion m^3.	**mean of annual minimum monthly flow** (*basic flow*); **sediment balance equation** (*water demand for sediment transport*)

Vital rivers, river basins and regions mentioned in this report



Progress : EWR of vegetation

- Since the end of the 1980s, EWR of vegetation has been studied mostly in the northwestern arid regions of China;
- The rainfall could not meet the water demand of plant growth and thus, the surface runoff and underground water should be supplied as additional water resources to sustain vegetation.

Progress : EWR of vegetation (I)

Author	*Achievement*	*Methodology (Study Object)*
Wang, 2000	analyzed water-consuming characteristics for different types of vegetation and estimated them respectively.	**Water Budget Method**
Liang, 2000	divided EWR of vegetation into controllable part and uncontrollable part, and quantitatively estimated them in the northwestern regions.	**estimation method** in which land use maps, study results concerning water resources, and classical theories of phytoecology were sufficiently applied
Pan et al., 2001	EWR of various types of vegetation in Heihe River Basin was calculated by three methods.	**Observed Transpiration Method; Ayayangnov Equation; Potential Transpiration Method**

Progress : EWR of vegetation (II)

Author	*Achievement*	*Methodology (Study Object)*
Zuo, 2002	addressed direct and indirect methods for calculating EWR of vegetation.	**direct and indirect methods** for calculating EWR of vegetation
Zhang et al., 2003	calculated EWR of forest vegetation in Shanxi province at 11.97 billion m^3.	**Penman-Monteith Method** (evapotranspiration for forest vegetation)
Ye et al., 2007	calculated the least EWR of natural vegetation in the lower reaches of the Tarim River at 0.32 billion m^3.	**Ayayangnov Equation**

Progress : EWR of lakes and wetlands

- Lakes and wetlands in China are confronted with many severe crises, such as shrinkage, aridity, pollution and ecological deterioration.
- In order to restore and improve lakes ecosystems, a specified amount of water should be reserved to maintain reasonable water levels and the self-purification capability of the ecosystem.
- Accordingly, it is urgently needed to establish the scientific basis and principles for determining the reasonable water level and EWR of lakes and wetlands.

Progress : EWR of lakes and wetlands (I)

Author	*Achievement*	*Methodology*
Li and Zheng, 2000	estimated EWR of lakes in Hai and Luan River Basin at about 0.4 billion m^3.	**Water Budget Method**
Liu and Yang, 2002; Cui et al., 2005	compared four methods of estimation and concluded that the function method was the most effective method to offer scientific decision-making for the management and restoration of lakes.	**Water Budget Method water cycle period method, lowest water level method, and function method**
Pei et al., 2002	Annual EWR of main wetlands in Hebei province was calculated at 0.5 billion m^3.	**lowest water level method**
Cui and Yang, 2002	analyzed the main characteristics, key indices and calculating methods for EWR of wetlands.	

Progress : EWR of lakes and wetlands (II)

Author	*Achievement*	*Methodology*
Tang et al, 2005	calculated EWR of wetlands in Xianghai Natural Reserve at 0.3 billion m^3.	**Water Budget Method**
Tian, 2007	calculated optimal EWR of wetlands in Hebei province at 0.4 billion m^3.	**Water Budget Method**
Liu et al., 2007	calculated optimal EWR of wetlands in Zhalong Swamp at 0.6 billion m^3.	**Evaprotranspiration method**
Sun et al., 2007	optimal EWR of wetlands in Momoge Swamp was 1.5~2.1 billion m^3.	**Evaprotranspiration method**

Progress : EWR of groundwater

- In recent years, groundwater exploitation has gradually increased in China.
- Subsequent problems have occurred and increasingly become sharper and sharper, such as the lowering of underground water tables, depression cone of groundwater, land subsidence, soil salinization, and littoral seawater intrusion.
- These problems have greatly challenged and imperiled the security of the regional eco-environment and society.

Progress : EWR of groundwater

Effective measures is urgently needed to prevent the groundwater table from further dropping and to gradually restore aquifers:

- Groundwater exploitation should be strictly controlled from now on;
- Additional water resources should be supplied to the groundwater, which can be regarded as EWR of groundwater.

Progress : EWR of groundwater

Author	*Achievement*	*Methodology*
Qian and Zhang, 2001	The annual EWR of groundwater was estimated at about 8 billion m^3, and about 5~8 billion m^3 of surface water resources should be used to replenish the groundwater in China.	
Zhang et al., 2002	Considering ecological water use, a three-dimensional simulation and optimized management model of groundwater was established	**three-dimensional simulation and optimized management model of groundwater**
Wang et al., 2006	perdicted EWR of groundwater at 0.34 billion m^3 in the Minqin Oasis in the lower reach of Shiyang river in 2019.	

Discussion and Perspectives

1. Studies on the basic concepts and theory of EFs should be strengthened.

- In order to establish a uniform and acceptable system of concepts and principles, the concept of EFs, including its connotation and extension to many types of ecosystem, should be further studied.
- The temporal and spatial scales of the study of EFs should be defined as clearly as possible, and the coupling between water quantity and quality, as well as the thresholds of EFs, need to be further studied.

Discussion and Perspectives

2. To establish a rational classification system, it is necessary to comprehensively study the regional differentiation of the eco-environment, and then analyze the water-consuming characteristics of various types of ecosystem.

Furthermore, studies on logical and accurate calculation methods for various types of EFs should be strengthened in order to establish systematic and scientific methodologies for calculating EFs.

Discussion and Perspectives

3. Presently, it is imperative to reinforce such aspects of the study of EFs as the internal and external influencing factors of EFs, the engineering approaches or measures to meet EFs, and the practical applications of EFs, and so forth;

4. To expand applied research on EFs and to make great efforts to realize the optimized allocation of water resources, it is urgent to break through traditional ideas of water resources allocation and to comprehensively take into account the relationships and ratios among different water users, including EFs;

Discussion and Perspectives

5. There are many great differences in the study of EFs between in China and internationally.

- More emphases of the study of EFs in China are placed on 'minimum water requirement', but many ecologists suggest that there is no 'minimum' only an appropriate flow regime with spatially and temporally variable components;
- More attentions should be paid to international developments in EFs in such fields as the 'natural flows paradigm', and then, progress and achievements in the study of EFs in China can be incorporated in the international fields to jointly promote the development in EFs globally.

Thanks for your Attention