

Evaluation of Ecosystem Services in Strategic Environmental Assessment for River Basin Planning

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ABSTRACT: Integrated plans for river basins (IPRB) serve as important and effective means of water resources governance, utilization and development in river basins. It remains a great challenge to scholars and practitioners of planning environmental impact assessment (PEIA) for river basins how to precisely assess the holistic, long-term and cumulative impacts of river-basin ecosystem services made by the implementation of IPRB. In fact, the scholars and practitioners of river-basins PEIA fail to provide a set of mature procedures and methods for impact assessments of ecosystem services. Therefore, this paper endeavors to define and categorize the ecosystem services of river basins, based on the pathways and features of impacts made by the implementation of IPRB on river-basin ecosystem services. On top of that, this paper establishes a set of procedures of assessing impacts of ecosystem services made by the implementation of IPRB, and provides the corresponding assessment methods, which tries to provide a demonstration of holistic and systematic assessments of impacts made by IPRB on ecosystem services, and to make contributions to the methods and theories of PEIA.

Keywords: *Integrated plans for river basins, Ecosystem Services, Strategic Environmental Impact Assessment, Water management*

1 INTRODUCTION

Integrated plans for river basins (IPRB) include strategic plans for flood mitigation, for comprehensive utilization of water resources, for protecting water resources and aquatic environment and for the integrated management of river basin. The implementation of IPRB helps to achieve optimal allocation and sustainable utilization of water resources, whereas, to some extent, it will make some impacts upon ecological environment as well as the economy and society in river-basin areas.

The assessments and predictions of holistic and long-term impacts as well as overall benefits need to be emphasized in the process of formulating plans, due to the particular impacts, with the features of relevance, continuity, superposition, latency and cumulation, generated by IPRB on environmental resources, ecological, social and economic environment. Inasmuch as ecosystem services serve as comprehensive indicators that measure the health of ecosystems, the quantitative assessments of ecosystem services will be of great help to determine the values and contributions of social and economic development made by the ecosystems, and will be of great importance to gauge reactions made by human interference as well. Some research shows that the integrated assessments of holistic impacts and overall benefits of ecosystems in the plans can be undertaken by the aid of assessments of ecosystem services. Some local Chinese scholars on EIA in the integrated land plans have already adopted the ecosystem services as the indicators of the holistic impacts made by the plan implementation on ecological environment (Tang et.al. 2007, Wu et.al. 2008, Wang et al. 2010, Li et al. 2011, Zhou et al. 2011). However, existing literature and practices merely focus on individual hydraulic construction projects, and their results and experiences can hardly be applied to the PEIA for river basins. As a matter of fact, the scholars and practitioners of PEIA for river basins have yet to provide a set of mature assessment procedures and methods for impact assessments of ecosystem services.

Therefore, this paper endeavors to define and categorize the ecosystem services of river basins, based on the pathways and features of the impacts made by IPRB on ecosystem services. On top of that, this pa-

per establishes a set of procedures of assessing impacts of ecosystem services made by the implementation of IPRB, and provides the corresponding assessment methods, aiming at providing a demonstration of holistic and systematic assessments of impacts made by IPRB on ecosystem services, and making contributions to the methods and theories of PEIA.

2 ECOSYSTEM SERVICES OF RIVER BASINS: DEFINITIONS AND CATEGORIES

The definitions and features of ecosystem services vary with scales. At present, different definitions and categories of ecosystem services have been made and related research is properly conducted according to divergent research needs and actual situations (Barbier et al. 1994, Costanza et al. 1997, Daily 1997, Millennium Ecosystem Assessment 2005, Ouyang et al. 1999, 2004, Zhao et al. 2003, Cai et al. 2003) Ecosystem services of river basins, linked with hydrologic cycle and ecological process, are regularly involved in providing water resources and hydrologic ecology. Their values embody the maintenance of social economic development, keeping the health of ecological system and safeguarding ecological securities, etc.

With the purpose of facilitating the work of PEIA for river basins, this paper categorizes four major services, namely provisioning services, regulating services, supporting services and cultural services that river-basin ecosystems provide, mainly based on the compositional and structural features of river-basin ecosystem, hydrologic cycle and ecological process as well as their utilities. (Table 1)

Table1. Categories of River-basin Ecosystem Services

Number	Categories	Main Services	Definitions
1	Provisioning Services	Water for Industry, Agriculture and Human Life	Water for human life, manufacture and agricultural irrigation, etc.
		Hydropower	Power derived from the energy of falling water and running water. Stream flows and reservoirs in river basins providing this service.
		Agricultural, forestry and fishery production	Providing agricultural, forestry and fishery products within the river-basin ecosystem
		Shipping	Providing conditions of shipping and downstream transportation in river basins.
2	Regulating services	Hydrological Regulation	Hydrological regulation of rivers, lakes and swamps, buffering for floods and reduction of economic loss.
		Accumulation and Regulation of Water Resource	Water resource accumulation of rivers, lakes, reservoirs and marshes which is closely connected with underground water; Greatly important to maintain river-basin ecosystem structures, functions and ecological processes
		Climate regulation	The mechanism of carbon fixation; Distinct effects of stabilizing regional climate and regulating climate by a broad expanse of water
		Water Purification	Provision and maintenance of good metabolic environment for pollutants in the river-basin areas; Improvement of purification capacity of the regional environment.
		River Transportation	Transportation, dispersal and cycling of sands and nutrients, siltation and epeirogeny
3	Supporting services	Provision of Various Habitat	Rivers and wetland provide habitats for a variety of aquatic organisms by high landscape heterogeneity
		Maintaining Biodiversity and Genetic Resources	Maintaining biodiversity of each species and providing services of sustainable development
4	Cultural services	Recreation spiritual and historical heritage	Nonmaterial benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences

3 ASSESSMENT PROCEDURES AND CONTENTS

According to the working procedures The Plan of Environment Impact Assessment Technical Guidelines Synopsis (HJ130-2014) and the features of EIA for ecosystem services, the procedures are divide into three stages, namely, preparation, formal session, and drafting assessment documents (Figure 1).

3.1 *The Analysis of Coordination for Planning On Ecosystem Services*

The analysis focuses on whether the plans meet relevant requirements regarding important ecosystems, biodiversity and civilizations, environment protection that do not violates the laws, regulations and policies in certain river basins. The analysis also includes whether the plans are in concert with national plans, special environmental planning, ecological functioning and zoning at all levels for ecosystem services, i.e. National Main Functional Areas Planning and Zoning, National Conservation Plan Outline of Fragile Ecosystem Areas, Plans of National Key Ecological Function Protected Areas, Ecosystem Protection and Restoration Plan for River-basin Areas, Special Planning for River Basins, etc. Moreover, the analysis should cover whether the implementation of plans will cause the compromises of interests that stakeholders originally receive from the ecosystem services, and whether the implementation will be of help to achieve the benefits of sharing.

3.2 *Investigations and Assessments of Ecosystem Services*

With the help of historical data and investigation of current status, the assessments of four major services, provisioning services, regulating services, supporting services and cultural services, will be made regarding their current status and evolutionary trends. Meanwhile, the investigation needs to pinpoint the current problems of ecosystem-service protection and find out the causes of those problems.

3.3 *Impact Identification of Ecosystem Services and Indicators Screening*

On the basis of the analysis of IPRB and the investigations of current status, the impact identification of ecosystem services is made by identifying the impacts of ecosystem services generated by the targets, layouts and scales of IPRB. Moreover, the changes in various ecosystem services, regardless of damages or losses, need to be identified by analyzing the implementation of IPRB. On top of that, based on the systematic, scientific, representative and operational principles, the impact indicators of river-basin ecosystem services are determined by analogy analysis and experts' consultations. This paper recommends a list of indicators that measures impact of river-basin ecosystem services (Table 2), and the selections and complements of indicators should be made based on the contents of IPRB and the features of river-basin areas.

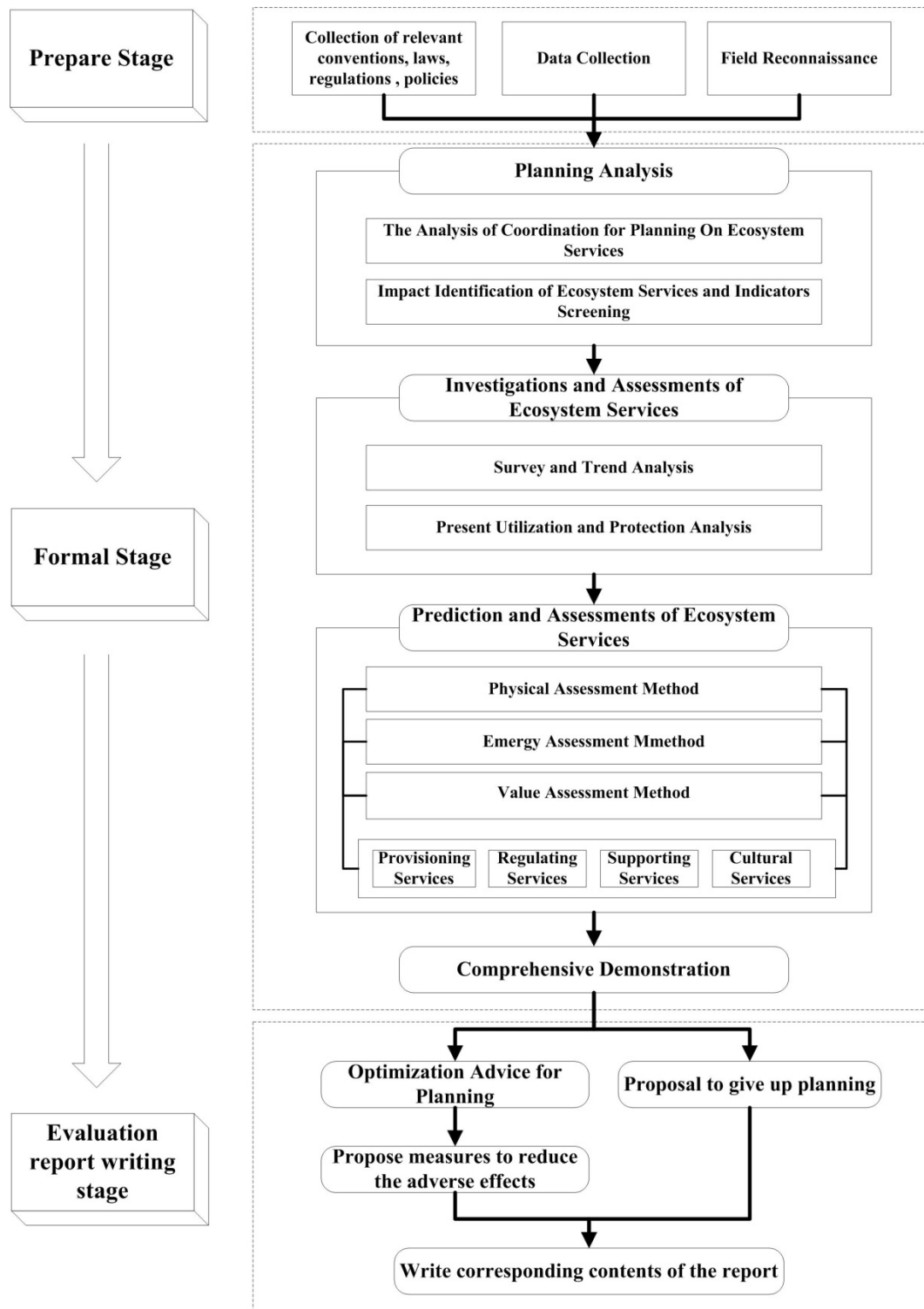


Figure 1. Evaluation Process of Ecosystem Services in Strategic Environmental Assessment for River Basin Planning

3.4 Prediction and Assessments of Ecosystem Services

Based on the survey result of watershed ecosystem services and the environmental impact of river basin plan, whether the plan will led to watershed ecosystem services occurred major changes should be analyzed. The way, range and degree of the effect on ecosystem services would be forecasted and evaluated. The impact assessment focuses on determining whether the plan implementation has a significant adverse change in or loss of the ecosystem major function.

Table 2. Categories of River-basin Ecosystem Services

Categories	Index Set	Unit	Index Nature
Provisioning Services	Water supply	t/a	required
	Area of irrigated fields	km ²	required
	Hydro power capacity	MW	required
	Shipping volume	t/a	optional
Regulating services	Stream discharge	m ³ /s	required
	Water area	km ²	required
	Water environmental capacity	t/a	Required
	silt content	kg/m ³	Required for sandy basins
Supporting services	Unique habitat, wintering grounds , spawning grounds and feeding grounds reserved	/	required
	Stream connectivity	/	required
	Biodiversity index	/	optional
Cultural services	Extent of damage to the cultural landscape and aesthetics	/	required
Features Index	To select according to the plan and the characteristics of river basin	/	optional

Current evaluation methods in ecosystem service functions are physical assessment method, value assessment method and emergy assessment method. The evaluation of single indicator can select one of the three methods according to the feature and data availability of the indicator. However, the evaluation results of single indicators do not reflect the overall impact of the planning on ecosystem service functions. The value assessment method can be used to evaluate integrate effects. By this method, the overall impact on ecological system service, caused by the plan implementation, could be calculated in monetary terms. This approach includes three technologies: directly market technology, and alternative market technology and simulation market technology.

3.5 Comprehensive Demonstration

Not only individual impact on the provisioning services, regulating services, supporting services and cultural services, but also the overall impact on river ecosystem service function should be evaluated. Whether the river ecosystem could maintain stability needs to be demonstrated when the planning promotes social development and economic growth.

3.6 Optimization Advice and Measures

According to the conservation goals and requirements of river ecosystem service function, the evaluation report should advance optimization advice on the planning from the angle of promoting ecosystem services protection and sustainability. The report could describe optimization recommendations in terms of goal, scale, structure and layout in a list. Table 3 is a reference table format.

When we implement measures to slowdown the impact on ecosystem service function, we need to follow the "prevention first" principle. The measures should be implemented in the order of avoidance, mitigation and restoration. If the planning affects some ecosystem service functions which are irreplaceable, vulnerable, or difficult to recover after destruction, the report should implement effective measures to avoid the impact. But if avoidance was impossible, and engineering and management measures could not mitigate the effects, the planners would put forward restoration and compensatory measures to protect the ecosystem services directly affected.

Table 3. Optimization Advice for the Planning Impact on Ecosystem Service Function

Planning Elements	Original Plan	Optimization Advice	Basis for Optimization	Effect of Optimization Advice
Goal				
Scale				
Structure				
Layout				
Measures				
.....				

4 CONCLUSIONS AND SUGGESTIONS

River-basin ecosystem has the features of complexity and diversity, and it can provide humans with a wide variety of ecosystem service function. The implementation of IPRB produces substantial and complex effects on ecosystem services. Combined with the characteristics of the environmental impact of IPRB, This study defined the connotation and classification of ecosystem service functions of river basins, and built a program to assess the impact on ecosystem service. This article defined the content and requirements of different steps, and it would offer guidance in evaluating the impact on ecosystem service of plan implementation.

Firstly, further study on the process and feature of the impact on ecosystem service functions of IPRB should be to promote, and it can help us build a more scientific and reasonable index system. Secondly, the evaluation methods in ecosystem service functions have their own advantages and limitations. A major disadvantage of value assessment method is that some impact on resources, environment and ecology is difficult to be measured by monetary value. Therefore, the evaluators need to select the appropriate method based on characteristics of river basins and the planning.

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