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Water resources management in the urban agglomeration of the Lake Biwa region, Japan: An ecosystem services-based sustainability assessment

Xiaochen Chen^{a,b}, Yuqing Chen^a, Toshiyuki Shimizu^b, Jia Niu^{c,d,*}, Ken'ichi Nakagami^{e,f}, Xuepeng Qian^g, Baoju Jia^b, Jun Nakajima^h, Ji Hanⁱ, Jianhua Li^j

^a College of Environment and Resources, Fuzhou University, No. 2 Xueyuan Road, Fuzhou, Fujian 350116, China

^b Ritsumeikan-Global Innovation Research Organization, Ritsumeikan University, 1-1-1 Noji-higashi, Kusatsu, Shiga 525-8577, Japan

^c College of Ecological Environment and Urban Construction, Fujian University of Technology, No. 3 Xueyuan Road, Fuzhou, Fujian 350118, China

^d Ritsumeikan Research Center for Sustainability Science, Ritsumeikan University, 2-150 Iwakura-cho, Ibaraki, Osaka 567-8570, Japan

^e College of Policy Science, Ritsumeikan University, 2-150 Iwakura-cho, Ibaraki, Osaka 567-8570, Japan

^f Integrated Research System for Sustainability Science, Todai Institutes for Advanced Study, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8654, Japan

^g College of Asia Pacific Studies, Ritsumeikan Asia Pacific University, 1-1 Jumonjibaru, Beppu, Oita 874-8577, Japan

^h College of Science and Engineering, Ritsumeikan University, 1-1-1 Noji-higashi, Kusatsu, Shiga 525-8577, Japan

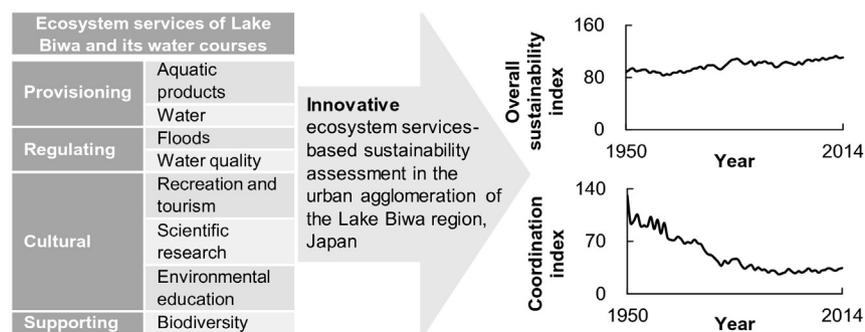
ⁱ School of Ecological and Environmental Sciences, East China Normal University, 500 Dongchuan Road, Shanghai 200241, China

^j College of Environmental Science and Engineering, Tongji University, Shanghai 200092, China

HIGHLIGHTS

- An innovative ecosystem services-based sustainability assessment was conducted.
- Changes in ecosystem services of Lake Biwa, and experience and lessons, were shown.
- Sustainability of the urban agglomeration nearby Lake Biwa was assessed.
- Economic rejuvenation could be achieved by improving water resources management.
- The study is educational and inspirational for other places facing similar issues.

GRAPHICAL ABSTRACT



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ABSTRACT

An innovative ecosystem services-based sustainability assessment was conducted in the important urban agglomeration of the Lake Biwa region, Japan, covering the time period from 1950 to 2014. A 22-indicator system was established that was based on the major ecosystem services of Lake Biwa and its water courses, i.e., provisioning services regarding aquatic products and water; regulating services regarding floods and water quality; cultural services regarding recreation and tourism, scientific research, and environmental education; and supporting services regarding biodiversity. First, changes in the eight ecosystem services were discussed together with the considerable experience and difficult lessons that can be drawn from the development trajectory. Next, with the indicators rearranged according to sustainability principles, the regional sustainability over the past six-plus decades was assessed. In general, this urban agglomeration has been progressing in terms of its sustainability, although economic and social development was achieved at the cost of environmental degradation in the

* Corresponding author at: College of Ecological Environment and Urban Construction, Fujian University of Technology, No. 3 Xueyuan Road, Fuzhou, Fujian 350118, China.
E-mail address: niuujia_2010@163.com (J. Niu).

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past, and the current economic downturn is hurting the balanced development and integrated benefits. The results lead directly to recommendations for regional development, especially in terms of economic rejuvenation, from the perspective of improving management of Lake Biwa's water resources. Moreover, the relevant knowledge is educational and inspirational for other places in the world that are facing similar development issues. For example, the effective and even pioneering countermeasures that have been taken against environmental degradation, as well as the participation and collaboration of multiple stakeholders, could be useful as a model. Moreover, the study invites increased understanding of ecosystem vulnerability to anthropogenic devastation and emphasizes the priority of precautionary measures over countermeasures in the context of holistic urban planning and sustainable urban development.

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1. Introduction

Having an age of four million years, Lake Biwa (Biwako in Japanese) in Japan is the 3rd oldest ancient lake on earth. With an area of 674 km² and a perimeter of 235 km, it is the country's largest freshwater lake, supporting the lives of more than 10% of the country's population. In 1993, Lake Biwa was designated a wetland of international importance, in accordance with the Ramsar Convention (The Ramsar Convention Secretariat, 2014). Geographically, Lake Biwa is located in Shiga Prefecture, one of the leading manufacturing prefectures in Japan. Because of a long history of interactions with Lake Biwa, Shiga Prefecture is also known as the "Lake Country". In addition, many important cities of Japan are located downstream of Lake Biwa, especially the cities of Kyoto, Osaka and Kobe, which are collectively termed the Keihanshin metropolitan region. It is the 2nd most densely populated urban region nationwide. This region is also capable of ranking among the top twenty largest economic entities worldwide, in regard to its gross domestic product (GDP). The important urban agglomeration encompassing Shiga Prefecture, the Keihanshin metropolitan region, and the nearby areas at large relies almost exclusively on Lake Biwa and its water courses for agricultural, industrial and municipal water utilization and other accompanying benefits.

Almost three decades have passed since the classic definition of "sustainable development" was published (WCED, 1987). Currently, however, the world is still seeking for a sound development approach through which economic and social advancement can be achieved without the costs associated with causing harm to our living environment. Sustainability assessment offers a comprehensive and quantitative evaluation of the development performance of a specific region and leads to feasible management recommendations and development strategies. Thus, it has been broadly practiced (Singh et al., 2012; Huang et al., 2016). To our knowledge, no sustainability assessment has ever been conducted for the important urban agglomeration of the Lake Biwa region, which has a long history of interactions between human beings and nature. As a result, the experience obtained and lessons learned from this management history could not be systemically studied and thoroughly summarized. Moreover, the majority of the relevant data and materials are recorded in Japanese, which further impedes the dissemination of this valuable knowledge. These factors became our primary motivation for carrying out this study.

Another motivation was to explore better methodologies for sustainability assessment so that it could be more closely linked with the management of key regional natural resources such as Lake Biwa and its water courses. In this study, the indicator-based method was adopted. Because indicators can simplify, quantify, analyze and communicate sophisticated information, the indicator-based method is arguably the most feasible tool for evaluating regional sustainability (typically based on sustainability principles, i.e., factors contributing to environmental, economic and social sustainabilities) and for making management recommendations (Dewan, 2006; Bell and Morse, 2008; Singh et al., 2012). However, to date the selection of indicators and the establishment of indicator systems have mainly been performed by referring to existing sets of indicators in the relevant literature. In

certain cases, this may lead to the inclusion of irrelevant and even misleading information in the assessment and recommendation processes. For example, in a similar study on the sustainability of a coastal zone, Shi et al. (2004) introduced indicators such as the "natural birth rate" and the "telephone occupation per thousand people" into the indicator list. These indicators, in a sense, did reflect social sustainability. Nevertheless, they per se had a closer relation to the specific region or city that owned the coastal zone, rather than reflecting essential attributes of the coastal zone itself. Changes in the values of these indicators do not necessarily mean a change in state of the coastal zone, and the results obtained by analyzing these indicators might not lead to pertinent suggestions for improving the management of the coastal zone and its natural resources. Inspired by ecosystem services science, a new theory of indicator system design is proposed in this study. Whether the area studied is a lake region or a coastal zone, an ecosystem has goods and services that benefit humankind (Granek et al., 2010). Ecosystem services science differs from conventional sustainability assessment, which mainly focuses on "conservation" (i.e., the environment should not be negatively influenced by human activities), in that it emphasizes the human needs met by ecosystems, and advocates a balance between "utilization" and "conservation" (i.e., the environment and resources need to be rationally exploited) (Gómez-Baggethun et al., 2010). From this point of view, indicators directly related to the ecosystem services of Lake Biwa and its water courses should be determined first, followed by rearrangement into three categories of environmental, economic and social sustainabilities. The procedure ensured that no unnecessary information interfered with the assessment process, and all selected indicators were useful for evaluating regional sustainability and further for making pertinent recommendations for management of the key water resources.

In this study, an innovative ecosystem services-based sustainability assessment was carried out in the important urban agglomeration of the Lake Biwa region, Japan. Through an in-depth analysis of the development trajectory over the past six-plus decades, both the considerable experience and difficult lessons derived from this case were thoroughly examined. The results are informative for holistic and integrated management of Lake Biwa and the entire urban agglomeration with an eye toward sustainable development. The relevant knowledge is also educational and inspirational for many other places in the world that face similar development issues.

2. Study area and methodology

2.1. Study area

Fig. 1 shows the Lake Biwa and Yodo River Basin in detail. Situated within the boundary of Shiga Prefecture, Lake Biwa has more than four hundred tributaries, while there are only two outflowing water courses. One is a natural water course called the Seta River (also called the Uji River within Kyoto Prefecture), which later converges with the Kizu River and the Katsura River to form the Yodo River, and then stretches through Osaka Prefecture toward Osaka Bay and eventually the Pacific Ocean. In addition, the neighboring city of Kobe in Hyogo

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