A spatial analysis of land use change and water quality in Lake Biwa, Japan

Katsuya Tanaka
Research Center for Sustainability and Environment
Shiga University
1-1-1 Bamba, Hikone, Shiga 522-8522 Japan
Phone/Fax: +81 (749) 27-1154
Email: tanakak@biwako.shiga-u.ac.jp

JunJie Wu
Department of Agricultural and Resource Economics
Oregon State University
200A Ballard Extension Hall, Corvallis, OR 97331-3601
Phone: (541) 737-3060
Fax: (541) 737-2563
Email: junjie.wu@oregonstate.edu

Poster prepared for presentation at the Agricultural & Applied Economics Association 2010 AAEA,CAES, & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010

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Katsuya Tanaka, Shiga University
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Introduction

Lake Biwa (670.49 Km^2 in surface area) is the largest lake in Japan, formed about 400,000 years ago (Shiga Prefectural Government, 2008). Due to its long history, Lake Biwa is known as one of the oldest twenty lakes in the World. Lake Biwa has a high biodiversity, with approximately 600 animal species and 500 kinds of plants, including 58 endemic species such as *Biwa trout*.

This lake is also a valuable water source for 14 million people in Kinki region including three major cities: *Kyoto*, *Osaka*, and *Kobe*. However, due to intensive agriculture and rapid urban development around Lake Biwa, water quality indicators such as chemical oxygen demand (COD) and total organic carbon (TCC) in the lake has declined significantly over the last 30 years.

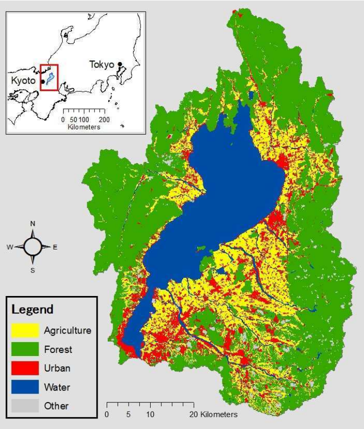

Figure 1. Lake Biwa and drainage basin. Land uses are based on observations in 2006

Objective

In this paper, we conduct an empirical analysis to evaluate the interaction between land use around Lake Biwa and lake water quality. Our empirical specification is based on Wu and Irwin (2008), who developed a spatially explicit theoretical model to analyze the dynamic interactions between land development and water quality.

Methods and data

We divide a drainage basin of the Lake into 20 subbasins based on hydrological boundaries and physical features such as elevation and slope. Each subbasin is then divided into 10 buffers based on the distance from lake shore (figure 2). Using this data, we specify the empirical water quality models as a special lag model:

$$Q_{st} = a_0 + \rho \sum_{k \neq s} w_k Q_{kt} + \beta x_{st} + \varepsilon_{st}$$

where s = 1, 2, …, 20; t = 1976, 1987, 1991, 1997, and 2006 (the total sample size is 20 x 5 = 100). Qst is the water quality in neighboring section s in year t; ρ is a spatial weight; x is a vector of variables representing urban land composition in different buffers of section s. A use of spatial weights allows us to take into account the effect of water quality in neighboring sections (i.e., transport between sections). Figure 2 shows 20 subbasins and 1 km buffer zones around Lake Biwa.

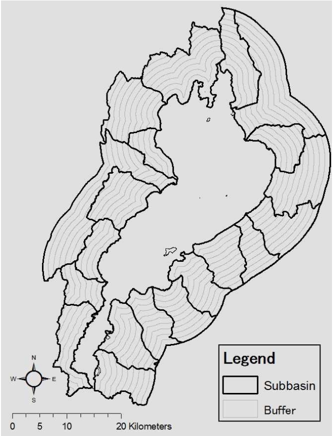

Figure 2. Subbasins, buffer zones, and water quality monitoring stations in Lake Biwa

Results

The model was estimated using the OLS and spatial lag models; we find that the spatial lag model outperforms the OLS under the presence of spatial autocorrelation. Based on the estimated parameters from the spatial lag model, the elasticity of COD pollution with respect to urbanization is calculated for different buffers in 20 subbasins (figure 3).

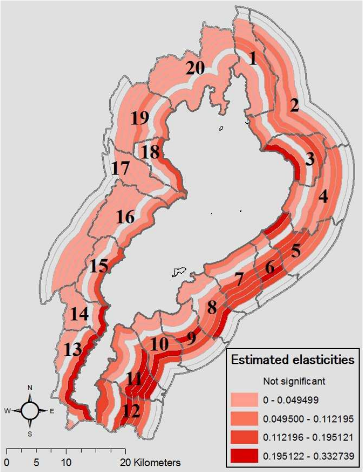

Figure 3. The estimated elasticities in different buffer zones and subbasins

Overall, the elasticities are relatively high in southern and eastern part of the lake. In south, buffers near the lake are shown to have higher elasticities. In east, COD pollution is relatively more elastic in 1st and 5th buffers. Overall, spatial patterns of the elasticities and urbanizations are highly correlated. This implies an importance of introducing land use regulations for already urbanized areas. In this region, such areas have been experiencing further urbanization due to rapid population growth. However, there is little regulation currently imposed from local government.

Conclusions

Contrary to previous literature, our results show that water quality in Lake Biwa is found to be highly influenced by urbanization in drainage basin. Contribution of pollution is highly dependent upon spatial pattern of urban development.

To date, there is only a limited land use regulation regarding urban development, and no regulation has been designed for lake water quality. Land use regulation should be much considered for managing urbanization and urban runoff toward sustainable lake basin management in Lake Biwa. Furthermore, such regulations need to be location-specific to take spatial patter of urbanization into account.

Literature cited

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Acknowledgments

We thank Elena Irwin for valuable comments on special modeling. We also thank Masashi Konoshima for suggestions regarding GIS operations. This project is financially supported from Japanese Ministry of the Environment.

For further information

Please contact Katsuya Tanaka at katsuyat@gmail.com or tanakak@biwako.shiga-u.ac.jp.