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Reconstruction assessment of historical land use: A case study in the Kamo River basin, Kyoto, Japan

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ABSTRACT

Reconstruction assessment of historical land use can be useful for understanding historical conditions and the impact of long-term land-use change. This study establishes a new method to estimate historical land use based on a set of basic rules generated from the comparison of present land-use and historical documents. This method has been formalized in the paleo-land-use reconstruction (PLUR) program, allowing users to quickly reconstruct historical land use using historical information. The 1843, 1902 and 1927 historical land use conditions were generated using the PLUR model for the Kamo River basin (KRB). Our results show that between 1902 and 1976, three golf courses (Ohara Public course, Kamigamo course and Funayama course) replaced forest land in the KRB. As a result of agricultural development, the area occupied by paddy fields in 1843 was 2.48 km^2 less than that in 1902. Urban areas increased from 1843 to 1976, mainly reflecting declining coverage of paddy fields after 1902. The approach presented in this study can be used to support land-use change analyses and reconstruction of paleo-hydrology. This study also provides a discussion of the major drivers of land use change.

1. Introduction

Rapid urbanization has driven significant changes in environmental conditions and land-use between the late Modern era and the present. Land-use change and environmental degradation have affected flood frequency, water quality, as well as ecosystem health in general. Reconstruction of historical land use is an essential exercise for evaluating the effect of land-use change on hydrology, particularly for periods that predate modern hydrologic monitoring systems.

Recent studies have focused on the impact of land-use change on catchment hydrology (Siriwardena et al., 2006; Mao and Cherkauer, 2009) and the quantification of the influence of land-use and water management on streamflow (Romanowicz and Osuch, 2011). An assessment of the long-term effect of land-use change on hydrology and solute budgets was conducted on small catchments in Amazonia (Germer et al., 2009). A series of four studies focused on assessing the impact of land-use change on hydrology by ensemble modeling (LUCHEM). The first is a model intercomparison using current land-use (Breuer et al., 2009). The second presents ensemble combinations by simple averaging and a comparison of predictions using single-models (involves the use of a number of realizations of a single deterministic model) and multi-model ensembles (involves several different deterministic models) (Viney et al., 2009). The third and fourth present land-use change scenario analysis (Huisman et al., 2009) and the effect of spatial resolution and distribution of model input data on the results of regional-scale land-use scenarios (Bormann et al., 2009). Wijesekara et al. (2011) developed a method for extending assessments of land-use change impacts on hydrologic processes into past and future periods. However, most assessments of land-use change impacts consider only the past several decades. A land-use change impact assessment on hydrology and sediment (Ward et al., 2008) included a simple introduction to the reconstruction of historical land use, underscoring the importance of historical land use reconstruction for land-use change impact assessments and simulations of paleo-hydrology.

The reconstruction of historical land use and environmental conditions includes the reconstruction of paleo-channels, paleo-land-use/landscape and the paleo-environment. Schumm (1968) investigated paleo-channels of riverine plains of the Murrumbidgee River, Australia and reconstructed the shape of the cross-section and the slope of the paleochannel using alluvial sediment cores in the river valley. A newly-discovered spatial correlation between paleo-channels and nearshore morphology provided

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graphical correlation and statistical cross-correlation analyses for the reconstruction of paleo-channels (Browder and McNinch, 2006). Ward et al. (2008) described a way to generate paleo-land-use based on CORINE data (Land Cover 2000 (CLC2000) EEA, 2001), census data, historical records, and pollen analyses. Several studies focus on the use of historical census information in Belgium (WL, 1994), the Netherlands (Knol et al., 2004) and France (Dutoo, 1994). Pollen analysis was mainly used for simulating the period from 4000 to 3000 BP (Bunnik, 1995; Gotj´e et al., 1990; Henrard, 2003). Kuzyakov et al. (2006) investigated paleo-environmental reconstructions using isotopic exchange of carbonate re-crystallization in soil. Field observation approaches can be used as a foundation for paleo-environmental reconstruction (Saengsrichan et al., 2011). Multiple techniques including sediment size distribution, stable carbon isotopes, pollen, and phytolith analyses can also be used for paleo-environmental reconstruction (Bement et al., 2007). However, the above methods are expensive, time consuming, and difficult. At present, there is no simple, detailed method for reconstructing historical land use based on historical information and paper maps.

The Kamo River Basin (KRB) is located in Kyoto, the former capital of Japan (794AD to 1868AD). Due to Kyoto's long history, there are many historical documents related to the Kyoto landscape. In recent years, the Virtual Kyoto project, part of a 21st Century Center of Excellence (COE) project called "Kyoto Art Entertainment Innovation Research" in Ritsumeikan University was funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) (Nakaya et al., 2010). The "Virtual Kyoto" research integrates Geographical Information System (GIS) and virtual reality (VR) technologies to develop a 4 Dimension (4D)-Geographic Information System (GIS) model of Kyoto in order to view the city's modern landscape (17th–20th centuries) and hindcast the landscape to the Heian period (8th–12th centuries) (Yano et al., 2008). Isoda et al. (2009) used historical documents from Edo era Kyoto to create large-scale urban 3D models in which the landscape of the entire Edo era city is reconstructed. This study describes the urbanization driven changes in socio-economic factors and urban structures observed in the Meiji, Taisho and Showa periods in Kyoto. Previous reconstructions of the Kyoto historical environment focused on urban areas. Reconstruction of historical land use at the river basin scale on the basis of historical documents has not yet been done. Compared with previous methods employed in the KRB, our approach is simple and integrates methods for addressing historical information including socio-economic indicators, paper maps and present land use.

The main objective of this study is to develop a method for reconstruction of historical land use. Using historical information (historical social structure, historical environment, old books, drawings and historical documents) and present digital land-use data, we have developed basic rules that together are incorporated in the paleo-land-use reconstruction (PLUR) program. We present the results of an application of PLUR for reconstructions at the KRB for the years 1843, 1902 and 1927. The methods and results of this study may be useful for reconstruction of paleo-hydrology and land-use change impact assessments. The primary drivers of land-use change are also discussed.

2. Study site

The KRB is used as a case study site for the reconstruction of historical land use. The KRB is a sub-basin of the Katsura River basin (Fig. 1). The Kamo River passes through Kyoto, the capital of

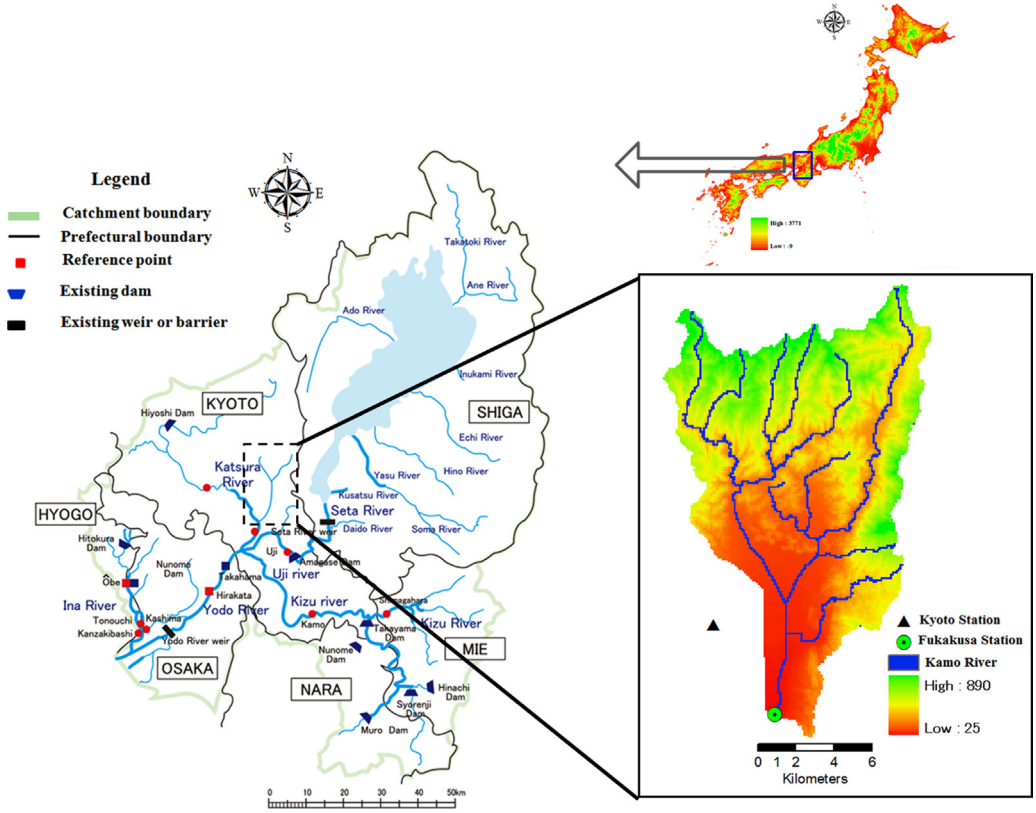

Fig. 1. Location and Digital Elevation Map (DEM) (original source from MLIT) of the KRB (Luo et al., 2013).