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Assessment of land cover relocation incorporating the effects of human activity in typical urban and rural catchments for the design of management policies

Goro Mouri *

Earth Observation Data Integration & Fusion Research Initiative (EDITORIA), The University of Tokyo, Be505, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan

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ABSTRACT

Densification due to the extreme increase in the population of urban and rural regions following rapid economic growth has occurred in many areas of the world. The pollution load in catchments affected by this increased population density far exceeds the self-purifying ability of the catchments. Land use changes in such river basins have affected the hydrological environment, as seen in diminished water quality not only in rivers but also in groundwater and springs, resulting in a decline in the available water resources. In particular, river water, which has different characteristics in urban and rural regions, must be considered, as the increased environmental impacts of changes in land use and human activities can create problems for society. Thus, following the adoption of a land use regulation system based on land use planning, the balance between the importance of conservation and the impact of human activities such as industrial production, agricultural production, and human waste is an important issue. In this study, using a catchment simulator model, we assessed the effectiveness of environmental management practices that incorporated the effects of alterations in land use, which were determined quantitatively from a catchment management perspective to solve environmental improvement problems based on land use and human activities in Tokyo (urban) and Hokkaido (rural). The results of this study are of use to stakeholders with an interest in the maintenance of social capital with an advanced urban function in the development of rural areas.

1. Introduction

Rapid urbanisation is occurring in many areas of the world and is a major item on the international political agenda (United Nations, 2002; Han et al., 2014; Long et al., 2014; Shen and Zhou, 2014). This rapid urbanisation has been described mainly from a scientific and socioeconomic perspective (McGee, 1991, 1995; Gabriel and Rosenthal, 2013; Elgin and Oyvat, 2013; Mouri et al., 2013a; Davis et al., 2014; Sadorsky, 2014), whereas the catchment management perspective has not been considered sufficiently. Of particular importance is the fact that the shift in land use processes and patterns from previous agricultural and industrial landscapes that

* Tel.: +81 3 5452 6382.
E-mail address: mouri@rainbow.iis.u-tokyo.ac.jp.
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incorporate the effects of human activity to current urban land uses are not yet understood fully, and consideration of the natural condition of land undergoing urbanisation has also not been sufficiently investigated. Cultivated environments have changed rapidly, not only because of the natural nutrient supply process but also as a result of human activity (Galloway et al., 2003; Albiac, 2009; Carpenter et al., 2009; Grimm et al., 2009; Butchart et al., 2010; Ojala and Louekari, 2002; Mouri et al., 2011a; Lewin et al., 2014; Qianyi et al., 2014). Historically, human settlements were located only on relatively high-level micro-landforms suitable for industrial and wastewater treatment plants (WWTPs), and most of the back marshes were treated as wasteland. Forest regions previously considered to be wasteland have been developed into productive farms. As agricultural practices have developed, the increasing population has become concentrated largely in cities and mega-cities during the last three decades (Lu and Campbell, 2009; Lo and Yeung, 1996; Mouri and Oki, 2010; Mouri et al., 2013b; Nastar, 2014; Rouillard et al., 2014; Sankaran et al., 2014). The shift from rice fields to urban land-uses requires landform transformation using landfill to protect against floods. The transition from rice fields to urban land-uses has resulted in a loss of floodwater retention areas, which often results in the creation of flood hazards (Haruyama, 1990; El-Fadel et al., 2001; Oguchi et al., 2001; Wu et al., 2001; Clarke, 2002; Chereni, 2007; Macleod et al., 2007; Bardsley and Sweeney, 2010; Godfray et al., 2010; Mouri et al., 2011b; Wang et al., 2014a,b). Therefore, detailed investigations of land-use changes with a quantitative estimation of the loss of inundation capacity due to a decline in the amount of forest and paddy fields are important for regional planning when considering flood hazards. Additionally, water quality is affected by a combination of natural and anthropogenic factors, the relative influences of which change at temporal and spatial scales. Meybeck et al. (1989) provided a detailed review. Most of these factors can be, and have been, affected by humans; consider, for example, changes in river discharges due to abstraction, urbanisation, or impounding, and discharges from industry, agriculture, or sewerage. Many of these anthropogenic influences are part of the larger process of catchment land use or land cover change that can affect water quality in rivers and lakes, as well as in downstream estuarine and coastal waters. Investigation of the relationship between land cover and water quality is particularly useful when considering diffuse source pollution. Diffuse sources of suspended sediments, pathogens, and nutrients from agricultural land, and nutrients and oxygen demanders in urban areas, are often difficult to measure. One aim of elucidating the relationships between land use and water quality is to use the information to assess and understand the water quality of rivers suffering from diffuse pollution, and improve the science and policy of land use management (Abler et al., 2002; Mouri et al., 2011a). Most existing studies have considered only horizontal land-use change on a macro-scale (Sui and Zeng, 2001; Mouri et al., 2010a, 2012; Kukkonen and Käyhkö, 2014; Munteanu et al., 2014; Zakkak et al., 2014), whereas little attention has been given to the details of land use change.

Several international projects have been established to restore degraded forest systems, and they have set goals, such as restoring 15% of the degraded ecosystems before 2020 (CBD, 2010; Stanturf et al., 2014). Restoration is driven by societal values that are often in conflict, and it is motivated by vague goals that generally fall within the concept of sustainability (Lackey, 2001; Clewell and Aronson, 2006; Baral et al., 2013; Mouri et al., 2013b; Mouri, 2014). These goals include repairing ecosystem functions or other desired attributes and enhancing or enlarging specific ecosystems (especially forest) and habitats for species of concern (Soranno et al., 1996; Mouri et al., 2011c; Seabrook et al., 2011; Thorpe and Stanley, 2011; Ciccarese et al., 2012). The human component, including attempts to formulate a universal definition of restoration or its various aspects, continues to generate discussion and elude consensus (Stanturf, 2005; Hobbs et al., 2011; Mu et al., 2013; Palmer et al., 2014). The process of setting restoration objectives, conditioned by the scale, environmental context, and level of restoration desired, translates vague goals into feasible, measurable targets and ultimately actions on the ground. Given these changes, a focus on historic compositions and structures becomes less achievable, because the characteristics deemed desirable now may become unsustainable in the not too distant future. A focus on restoring function avoids this pitfall and is still directly related to achieving stakeholder goals for the coexistence of environment, economic efficiency, and social wellbeing, as derived from functioning landscapes (Sarkis et al., 2012; Mouri, 2014; Stanturf et al., 2014; Wang et al., 2014a,b; Lucia, 2015). About 30% of the population of Japan is concentrated in the metropolitan Tokyo region (Mouri, 2014); a similar tendency has been found around the world (SWP, 2011). The present density of the human population is a pressing and important challenge to the design of management policies by stakeholders. At the same time, population centralisation has arisen in rural regions that have very small populations. Thus, catchment-level management of land cover relocation that incorporates the effects of human activity is a subject of great international interest. Furthermore, a new approaches to nitrogen policies and environmental policies such as land use management have become urgent issues in Europe due to new farm policies that must soon be implemented regarding the standard of living of farmers in the EU (Sonneveld and Bouma, 2003; Schulte et al., 2014). In this manner, land cover relocation that incorporates the effects of human activity in the design of management policies has become an urgent and common task of the global community.

We examined detailed land use changes incorporating the effects of human activity in the Asakawa catchment of Tokyo and the Shubuto catchment in the Hokkaido region. We examined the spatial distribution of land use changes incorporating changes from agricultural and industrial land to the current form and examined changes associated with the distribution of the new land use types. This information is very important for maintaining stocks of fish species in these environments. The results of this study contribute to our understanding of urban–rural land use management in the different environmental contexts of urban and rural regions.

In this study, we used multivariate analysis to examine how the total nitrogen (TN) outflow in river water is related to