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Predicting land-use change for biodiversity conservation and climate-change mitigation and its effect on ecosystem services in a watershed in Japan

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ABSTRACT

Potential conflicts between biodiversity conservation and climate-change mitigation can result in trade-offs in multiple-use land management. This study aimed to detect possible changes in land-use patterns in response to biodiversity conservation and climate-change mitigation measures and the effects on ecosystem services across a watershed. We analyzed land-cover change based on past and future scenarios in the rural Kushiro watershed in northern Japan. The analysis showed that if no conservation measures were implemented and the timber and agricultural industry remained small until 2060, supporting and provisioning services would decline due to less land management. Although biodiversity conservation measures are predicted to improve three of the ecosystem services that we studied, carbon sequestration and timber production would be improved to a greater degree by climate-change mitigation measures. The greatest land-cover changes are likely to occur in the unprotected area around the middle reaches of the Kushiro River, and such changes could affect the provision of ecosystem services throughout the entire watershed. Thus, our findings indicate that landuse decisions for the middle reaches of the watershed are particularly important for managing the integrated ecosystem services of the entire watershed for the future.

1. Introduction

In response to the trade-offs necessary in multiple-use land management, the concept of ecosystem services has been introduced to find synergies between nature conservation and other aspects of human welfare improvements (Tallis et al., 2009). However, the concept has not yet been used to support decision-making processes. Thus, researchers must move from devising the conceptual framework to the practical integration of ecosystem services into real decision-making (Daily and Matson, 2008). Several studies have revealed existing spatial trade-offs of ecosystem services, which potentially arise in land management choices that influence the provision of ecosystem services within a landscape (Bennett and Balvanera, 2007; Bennett et al., 2009; Ruijs et al., 2013). Thus, predicting the effects of land-cover change on ecosystem services is crucial in planning (Geneletti, 2013).

The United Nations Framework Convention on Climate Change and the Convention on Biological Diversity are key agreements adopted in the early 1990s. Recent studies have clearly revealed a decline in biodiversity globally, and threats and pressures on biodiversity have been increasing, particularly over the past decade (TEEB, 2010). This decline in biodiversity could have a major impact on ecosystems and human society as well as climate change (Cardinale et al., 2012; Maestre Andres et al., 2012; Nagendra et al., 2013). Therefore, efforts to conserve biodiversity need to be strengthened by measures such as integrating biodiversity conservation into land management decision-making. Mitigating climate change is also a pressing concern for both ecosystem and biodiversity conservation. However, at the local scale, land-use changes for climate-change mitigation may pose threats to biodiversity. For instance, converting diverse natural vegetation to monoculture plantations to capture greenhouse gas emissions may adversely affect biodiversity (Secretariat of the Convention on Biological Diversity, 2009). Therefore, in practical terms, seeking synergy between biodiversity conservation and climate-change mitigation has become necessary. However, few practical strategies have been suggested in terms of applying these global needs to local situations because trade-offs among ecosystem services need to be clarified to support decision-making.

From the perspective of rural landscape management in Japan, the underuse of natural resources is a direct driving force of environmental degradation and biodiversity loss (JSSA, 2010).

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Depopulation and aging in rural areas have led to reductions in land management and increased land abandonment, both of which have resulted in the degradation of ecosystem services. Because the rural landscape is a key source of natural resources that benefit society, the Japanese government has strengthened measures to maintain natural resources across rural landscapes. However, it is not clear whether ecosystem service trade-offs are being recognized comprehensively in terms of ecosystem management. In this case, scenario analysis is a fundamental tool of environmental assessment to reduce future uncertainty when choosing among policy alternatives. Future scenarios are derived from different assumptions about the underlying driving forces, which are important factors that affect land management. Quantifying the impact of future land-use change on ecosystem services and human well-being at the local scale has been addressed in recent studies (Estoque and Murayama, 2012; Geneletti, 2013; Goldstein et al., 2012; Leh et al., 2013; Nelson et al., 2010).

Here, we present a case study that explores empirically how land-use policies for biodiversity conservation and climate-change mitigation will affect the future provision of ecosystem services within a rural landscape in Japan. The effects of the land-use change on selected ecosystem services are then quantified and compared using indicators. The aim of this study is to analyze the effects of some rural landscape conservation practices on the target area. Specific objectives are two-fold: (1) to detect land-use change patterns across a watershed based on past changes and future scenarios; and (2) to quantify changes in the provision of ecosystem services caused by predicted future land-use change and then identify areas susceptible to ecosystem degradation. We first constructed land-use scenarios associated with rural land management. Next, the effects of the land-use change on the provision of selected ecosystem services were evaluated using GIS-based models. Finally, the selected indicators were compared to assess spatial ecosystem service trade-offs in the target area. Our findings can be used to support spatial natural resource planning in this rural landscape.

2. Methods

2.1. Study area

The study area is the Kushiro watershed, which is located in Hokkaido Prefecture on Japan's northernmost island (Fig. 1). The total length of the Kushiro River is 154 km, and the total area of the watershed is 2510 km^2. The watershed includes a population of about 200,000, located in a city, three towns, and a village. By 2050, the population in the area is predicted to decline by 55% from that in 2005; in particular, the working-age population (age 15–64) is predicted to decline from 63% to 42% of the total and the aged population (age 64+) is predicted to increase from 23% to 51% (Fig. 2). Population decline and aging are the greatest impediments to the continuation of local communities and rural landscape management.

The area is considered to have a high degree of natural capital and includes two national parks, Akan Forest National Park in the upper reaches and Kushiro Wetland National Park from the middle to lower reaches, with the latter designated as a Ramsar Convention site in 1980. In the past few decades, however, most of the

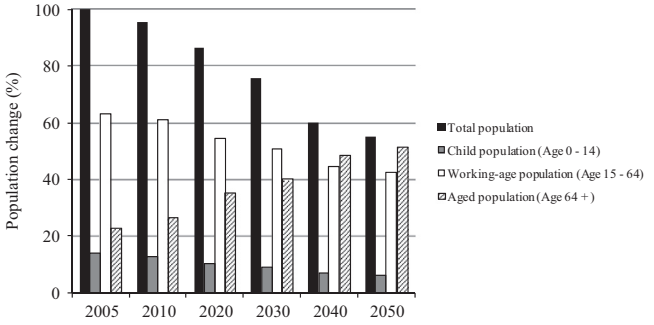

Fig. 2. Predicted population changes in the Kushiro watershed between 2005 and 2050 (data source: National Institute of Population and Social Security Research).

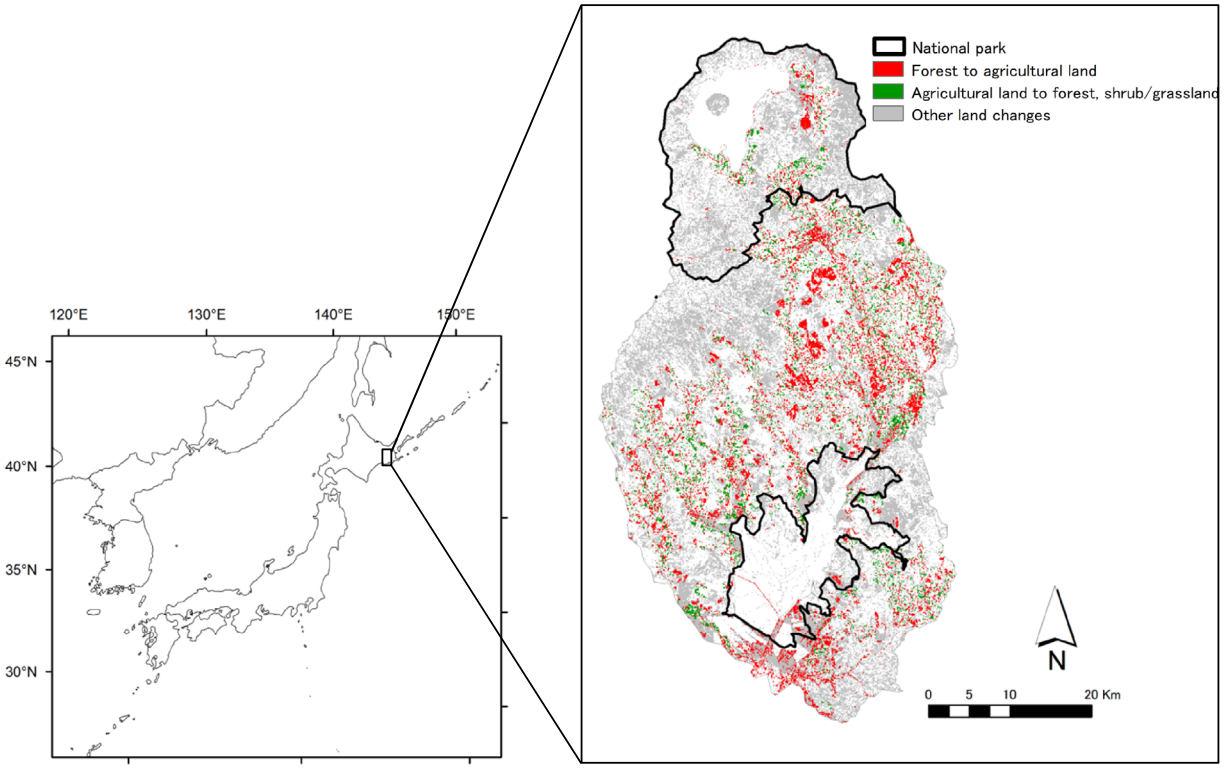

Fig. 1. Map of the Kushiro watershed showing land-use changes that occurred between 1977 and 2011.