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Mapping environmental land use conflict potentials and ecosystem services in agricultural watersheds

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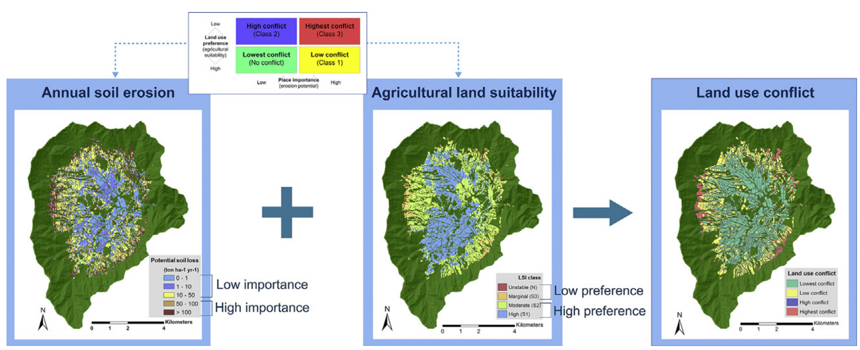
HIGHLIGHTS

- Land use conflicts are classified by provisioning versus regulating ecosystem services.
- The highest land use conflicts occur in steeply-sloped, marginal agricultural areas.
- Conservation program capture synergies or trade-offs between ecosystem services.

GRAPHICAL ABSTRACT



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ABSTRACT

In mountainous watersheds, agricultural land use cause changes in ecosystem services, with trade-offs between crop production and erosion regulation. Management of these watersheds can generate environmental land use conflicts among regional stakeholders with different interests. Although several researches have made a start in mapping land use conflicts between human activities and conservation, spatial assessment of land use conflicts on environmental issues and ecosystem service trade-offs within agricultural areas has not been fully considered. In this study, we went further to map land use conflicts between agricultural preferences for crop production and environmental emphasis on erosion regulation. We applied an agricultural land suitability index, based on multi-criteria analysis, to estimate the spatial preference of agricultural activities, while applying the Revised Universal Soil Loss Equation (RUSLE) to reflect the environmental importance of soil erosion. Then, we classified the agricultural catchment into four levels of land use conflicts (lowest, low, high and highest) according to preference and importance of farmland areas, and we compared the classes by crop type. Soil loss in agricultural areas was estimated as 45.1 t ha yr, and agricultural suitability as 0.873; this indicated that land use conflicts in the catchment could arise between severe soil erosion (environmental importance) and agricultural suitability (land preferences). Dry-field farms are mainly located in areas of low land use conflict level, where land preference outweighs environmental importance. When we applied farmland management scenarios with consideration of services, conversion to highest-conflict areas (Scenario 1) as 7.5% of the total area could reduce soil loss by 24.6%, while fallow land management (Scenario 2) could decrease soil loss 19.4% more than the current scenario (Business as usual). The result could maximize land management plans by extracting issues of spatial priority and use-versus-conservation conflicts as ecosystem service trade-offs from arguments over land use policy.
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1. Introduction

Land use and cover changes by human activities cause changes in ecosystems and their functions (Foley et al., 2005; Turner et al., 2007). Many ecosystem functions are beneficial to human societies, supporting the delivery of ecosystem services (Daily, 1997; de Groot et al., 2002). In mountainous landscapes, agricultural practices of land management plans can affect the capacity to deliver ESs such as provision of crops and regulation of soil loss and water quality (Power, 2010). Intensive agriculture in these ecosystems reduce the ability to reduce soil loss as a trade-off with food production and this worsens water quality in downstream areas (Foley et al., 2005; Montgomery, 2007; Maes et al., 2012; Valle Junior et al., 2014a; Pacheco and Sanches Fernandes, 2016). Therefore, it is necessary to use land resources effectively under land management plans, which is a region specific policy to reduce trade-offs between ecosystem services.

Land use and cover changes by land management plans can generate land use conflicts among stakeholders who have different interests related to specific land uses and concerns about negative impacts on their interests (Von der Dunk et al., 2011; Brown and Raymond, 2014). In particular, conservation and management in mountainous ecosystems are among the most common areas of contention in land use conflicts because of trade-offs among ecosystem services (Bengston et al., 2004). Because these land use conflicts also accompany spatial disagreements among stakeholders as to use of land resources, land management plans should consider the different interests of stakeholders and their potential conflicts (Brown and Raymond, 2014). Land use conflicts occur when ecologically vulnerable lands are used by human activities, thus causing conflicts between two different stakeholders: those favoring conservation and those favoring use of land (Von der Dunk et al., 2011). Agricultural activities in marginal forests, which can generate severe soil erosion, can cause land use conflicts between regional farmers and local government, where the former use lands to cultivate crops and the latter strives to conserve lands. These different purposes of land use are directly related to the trade-off between food provision and regulation of soil erosion. In the Haean catchment of South Korea, expansion of intensive agriculture for annual crops has caused severe soil erosion (Park et al., 2010; Arnhold et al., 2014), and thus, the national government has tried various policy programs such as reforestation to reduce soil erosion. Currently, land use conflicts occur primarily between agricultural production and natural conservation in marginal farmlands where soil erosion is a serious problem. Therefore, it is necessary to consider both land use conflicts and impacts on ecosystem services that arise from agricultural land use changes.

Development of studies on land use conflicts has focused on solutions of the conflicts rather than on the analysis of their characteristics (Torre et al., 2014; Hersperger et al., 2015). Although land use conflicts are related to spatial characteristics of land, few studies have conducted methodological approaches to map conflict potentials (Brown and Raymond, 2014; Hersperger et al., 2015). Several studies developed spatial decision support systems for land use conflicts, combining multi-criteria analysis (MCA) and geographic information system (GIS), such as for oil and gas production (Brody et al., 2004, 2006) and urban expansion (Iojă et al., 2014). Other studies focused on mapping land use conflict potential using GIS based on development preference, which identified spatial preference conflict areas (Brown, 2006) as well as exurban development (Nielsen-Pincus et al., 2010; Goldberg et al., 2011). Although these studies conducted surveys on spatial preference or participatory GIS to map land use conflicts, existing approaches are still limited to mapping land use conflicts to reflect different objectives such as natural conservation or economic use of land resources. Few studies have investigated land use conflicts between human activities (agriculture, urban development) and natural conservation as trade-offs (Henle et al., 2008; Willemen et al., 2010; Goldberg et al., 2011; Bourgoin et al., 2012). Goldberg et al. (2011), for instance, spatially estimated land use conflicts between urban development and habitats for species; and Bourgoin et al. (2012) focused on spatial assessments of land use conflicts on environmental issues and their trade-offs between economic and environmental returns. On this topic, Pacheco et al. (2014) quantified the consequences of the amplification of soil losses as environmental land use conflicts in a vineyard-dominated mountainous catchment; furthermore, Valle Junior et al. (2014a) recognized it as a threat that worsened soil vulnerability. Subsequently, several studies have been recently conducted to map environmental land use conflicts between land use and environmental degradation on surface water (Pacheco and Sanches Fernandes, 2016), underground water (Valle Junior et al., 2014b), and soil quality (Valera et al., 2016). These studies applied concepts of land preference and capacity based on spatial data and actual land use maps, which were combined with environmental indicators such as soil degradation and water quality to map environmental land use conflicts and classify areas with regard to conflict levels based on land use types. However, these researches did not treat land use conflicts within agricultural areas where both agricultural activities and natural conservation are considered. Moreover, the concept of ecosystem services and their trade-offs has not been considered in these studies, which could cause conflicts owing to different purposes in land use decisions.

The aim of this study was to map land use conflicts with indicators to quantify values for both conservation and development of agricultural lands. We applied the agricultural land suitability index (LSI) and soil loss potentials to estimate and classify land capacity within agricultural areas in order to locate land use conflicts between agricultural land use and natural conservation. In addition, we assessed two land management scenarios (i.e., reforestation and cultivation of perennial crops) to identify trade-offs between ecosystem services and to identify the suitability of policy options for reduction of land use conflicts in a mountainous agricultural catchment.

2. Materials and methods

2.1. Study area

This study was conducted in the Haean catchment, located at northern border of South Korea (Fig. 1). The catchment is a branch of the watershed of the Soyang River, which is a major water source for downstream metropolitan areas (Ruidisch et al., 2013). The catchment is a bowl-shaped basin surrounded by mountainous forests and covered by agricultural areas in the center. Agriculture covers 30% of the land area, comprising 8% rice paddies and 22% dry fields where highland commercial crops are widely cultivated (Jun and Kang, 2010; Kim et al., 2014). The main field crops are annual (radish, Chinese cabbage, and potato) and perennial (ginseng and orchard fruits). Agricultural areas are spatially distributed by type of crop: rice paddies are centered in flat areas, while dry-field crops are cultivated on steeper slopes (Poppenborg and Koellner, 2013) (Table 1). Although the area is only 64 km^2, the Haean catchment is regarded as a hotspot of agricultural production for highland annual field crops (Kim et al., 2017). Because the elevation ranges from 340 to 1320 m, it is regarded as an optimal area for highland cash-crop agriculture.

However, annual crops are normally cultivated on steep slopes, causing severe soil erosion and, thus, water pollution problems in the downstream reservoir (Park et al., 2010). In particular, water pollution by soil erosion is worsened during the summer monsoon period, and this has become a significant environmental issue (Lee, 2008). To solve this problem, the South Korean government promotes various management plans in highland agricultural areas of the catchment such as erosion prevention facilities, farmland conversions, and crop diversification (Lee, 2008). In recent years, fruit orchards and ginseng farms have increased while radish farms have decreased because of climate changes and subsidies from conservation policies (Jun and Kang, 2010). However, the application of those policies was accompanied by some problems in terms of local policy responses to crop conversion

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