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Ecohydrologic modelling of water resources and land use for watershed conservation

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ABSTRACT

Land use land cover is an important determinant of ecohydrologic processes in watershed systems. Continued urbanization changes the very nature of ecohydrological regimes of watersheds and increases their vulnerability to flooding, soil loss, and water pollution. To integrate hydrologic risk and suitability analysis into land use decisions, we used an ecohydrologic risk criteria for land use impacts on water quality and quantity in the Riva Creek watershed located to the east of Istanbul, Turkey. Hydrological risks are modeled for each sub-watershed using a spatial analysis. A spatial quantitative assessment is used to rank sub-factors for evaluating suitability for agricultural, residential and forest operations. An expert focus group is used to quantify weights. The results revealed that about 58% of the watershed is prone to hydrologic risk in medium to severe levels. We concluded that ecohydrological evaluations should form the background of landscape assessments in watersheds. An integrated approach and spatial results can provide the basis for long-term planning.

1. Introduction

Land use land cover (LULC) continues to be a primary determinant of ecohydrologic processes in watershed systems (Camorani et al., 2005; Fohrer et al., 2001; Li et al., 2009; Mao and Cherkauer, 2009; Moglen et al., 2004; Nosetto et al., 2012; Öztürk et al., 2013; Thanapakpawin et al., 2007). LULC directly impacts hydrologic processes that may result in floods, soil and water pollution, erosion (Alkharabsheh et al., 2013; Du et al., 2012; Huisman et al., 2009; Tripathi et al., 2014; Wheater and Evans, 2009; Yan et al., 2013) and many other deleterious effects on land and water resources (Alam, 2014; Molina-Navarro et al., 2014). Urban, agricultural, and forest areas are forms of LULC that can strongly affect ecohydrological regimes of watersheds and make them vulnerable to floods, soil loss, and eutrophication. There is a need for comprehensive assessment of watershed hydrologic risk at site-specific scale using both water quantity and quality attributes. This study develops an integrated spatial assessment for prioritizing conservation areas for reducing flood and nonpoint source pollution risk in Riva Creek watershed in Turkey.

Hydrologic responses can be different among land uses (Lin et al., 2009) and their implications for water resources can also vary. Kalantari et al. (2014) use road and catchment characteristics (topography, soil type, and land use) to predict critical areas prone to flood risks in Sweden. Bu et al. (2014) observe that vegetated areas contribute positively to river water quality in contrast to agricultural and impervious areas. Alkharabsheh et al. (2013) show that land cover changes significantly affect the soil erosion rate. Lin et al. (2007) analyze impacts of different future land uses based on scenarios of different land use patterns and observed that hydrological components are cumulatively influenced by land use change. Conway and Lathrop (2005) study impacts of residential areas on water demand, urban non-point source pollution, terrestrial habitat fragmentation, flood hazards, and soil loss. Marshall and Randhir (2008) use a Markov Chain analysis and Cellular Automation process to model land cover change and observe a significant impact on the water quality and quantity, both spatially and temporally. These examples show that land cover change is significant for watersheds. The negative impacts of increasing urban sprawl (Ekness and Randhir, 2015), together with the loss of agricultural and forest areas highlight the need for ecohydrological approaches to watershed management.

For a better landscape planning and to better understand its roles, these land use forms need to be assessed based on ecohydrological assessments. Ecohydrological assessments lead to us to determine hydrologic risks on land uses. These risks are the result of variations in geomorphic and land use conditions that increase their vulnerability

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by disrupting integrity (Alkharabsheh et al., 2013; Bu et al., 2014; Camarasa-Belmonte and Soriano-García, 2012; Deasy et al., 2014; Jordan et al., 2014; Shrestha et al., 2013). For example, impervious cover in urban areas increases runoff (Du et al., 2012; Scalenghe and Marsan, 2009; Verbeiren et al., 2013), decreases the time of concentration and has deleterious effects on stream water quality (Randhir, 2002). Agricultural implementations in farmlands increase pollution and soil loss. Steep slopes increase erosion risk and sediment movement where there is no vegetation cover (Sun et al., 2014). While forests ecosystems decrease water yield (Wang et al., 2011a,b), they improve water quality, attenuate small-scale floods, and regulate hydrologic regime. Thus, hydrologic risk assessment based on ecohydrological approaches play an important role in reducing these risks on land uses.

A typical watershed is variable in natural, cultural, and socioeconomic characteristics and requires site-specific assessment of land suitability in order to minimize hydrologic risk. Therefore, an integrated approach to determine suitable land use and to minimize hydrologic impacts is needed. The conceptual framework of the suggested is supported by the fact that risks in a watershed are influenced by a set of natural and human-induced variables. Therefore, an integrated risk evaluation procedure can be applied to identify hydrologic risks.

The general objective of our study is to prioritize land uses based on land suitability and hydrologic risks using an ecohydrological assessment at a watershed scale. Therefore, hydrologic risks are quantified and land suitability is evaluated to specify optimal land uses. We evaluate optimal agricultural, forest and residential areas under specific objectives: (I) to evaluate hydrologic risks at a spatially explicit scale within the watershed; (II) to assess land suitability using spatial assessment; and (III) to study land use and hydrologic risks through ecohydrological analysis at watershed scale. Specific hypotheses that are tested are: (i) H_0 (Null): Hydrologic risks are constant in geographic spread within a watershed; H_A (Alternate): Hydrologic risks are variable in geographic spread depending on topographic factors and hydrologic characters of the watershed; (ii) H_0: Land suitability does not vary in watersheds; H_A: Land suitability is variable in geographic space; (iii) H_0: Potentially suitable land uses do not coincide with hydrologic risks of the watershed; H_A: Hydrologic risks can be improved by selecting optimal land uses.

2. Methods

2.1. Study site

The study area covers Riva Creek watershed (246.37 km^2) to the east of Istanbul in the Anatolian part of Turkey, between 41°14′ and 41°02′ North latitude and 29°08′ and 29°22′ East longitude (Fig. 1). The south part of the boundary is uplands and the river meets the Black sea at the north. The main stream length is about 32 km. between the Black Sea and Ömerli Dam. Riva Creek riparian zone has a beautiful scenery and natural wildlife and provides bird watching, nature photography, hiking, and water sports opportunities. That is why this zone is valued by many communities.

The watershed is composed of an alluvial floodplain and hill slopes that surround it. The elevation of the study area varies from 0 to 442 m, with slopes ranging from 12 to 20% having the largest share (27%) of the area (Fig. 2). Brown forest soils (without lime) are widespread in the study area and have larger coverage (90%) than alluvial soils. Class VI type based on Land Capability Classification System (LCCS) (Klingebiel and Montgomery, 1961) occupies the largest area (20.78 ha – 84%). LCCS is a US origin classification of land under 8 land use classes based on several attributes of land that enable or disable agricultural use. The landscape around the river is slowly urbanizing as the city of Istanbul sprawls into neighboring regions, even main land use is the forest (78%) (Fig. 3). The weather station of Şile, the closest station to study site at the Black Sea Coast, shows an annual average temperature of 13.4 °C annual average precipitation of 72.5 cm, and annual average humidity is about 79.3%.

2.2. Hydrologic risk assessment

We use an ecohydrologic assessment to integrate hydrological risks and land use suitability for prioritizing to landscape planning. We

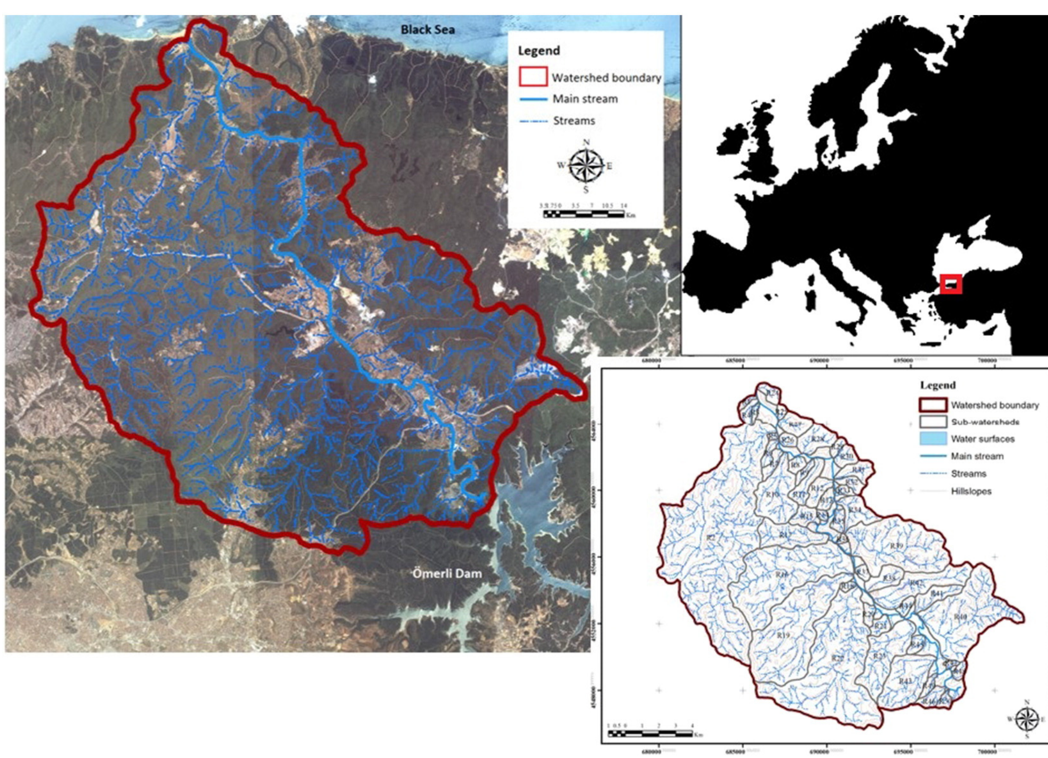

Fig. 1. The study watershed.