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Changes in peak flow with decreased forestry practices: Analysis using watershed runoff data

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ABSTRACT

The prevalence of forestry practices such as thinning and pruning have gradually decreased since the 1980s. Researchers have noted an increased flood risk with decreased forestry practices for coniferous plantations in Japan on the basis of infiltration and overland flow measurements at a plot scale (typically several square meters). However, no studies have examined changes in peak flow with decreased forestry practices at a watershed scale (typically several tens or hundreds of square kilometers) even though flood disasters generally occur at this scale in Japan. We examined changes in frequency distributions of daily precipitation (*P*) and runoff (*Q*) during the period 1979–2007 at the Terauchi watershed, where forestry practices are known to have decreased. For this purpose, we divided *P* and *Q* data into 14 and 15 classes according to the magnitude, respectively, and examined changes in the frequency for each class during the period. We observed no significant increasing trend for any *P* or *Q* class. Even when taking into account the effect of interannual variations in precipitation on the frequency for each *Q* class, there was no significant increasing trend in the frequencies except for two *Q* classes with moderate *Q* values. These results suggest that the increase in flood risk due to decreased forestry practices might be less than expected.

1. Introduction

Watershed runoff is influenced by many factors, such as climate, geology, topography, and vegetation (Ward and Robinson, 2000; Komatsu et al., 2008a; Shinohara et al., 2009). Human activities that influence vegetation cover could affect the runoff regime (e.g., Yue and Hashino, 2005; Komatsu et al., 2008b, 2009b; Yao et al., 2009), which in turn could alter flood and drought risks.

Forestry clear-felling (or conversion from forests to pasture) and development of forest cover following clear-felling (or conversion from pasture to forests) are the most significant examples of vegetation change. Many studies (e.g., Bosch and Hewlett, 1982; Brown et al., 2005; Farley et al., 2005; Grant et al., 2008) have examined the effect of clear-felling or development of forest cover on the runoff regime.

Changes in the runoff regime with clear-felling and development of forest cover are not critical issues in Japan, because such land-use changes have recently been uncommon, and therefore, the percentage of forested area has been nearly constant over the past 40 years (National Astronomical Observatory, 2009). Instead, forestry practices and their effect on runoff have recently been raising as a concern in Japan (e.g., Kuraji and Hoyano, 2004; Calder, 2005; Komatsu et al., 2007b,c, 2009a; Onda, 2008; Onda et al., 2010).

Japan developed large areas of coniferous plantations for timber production from the 1950s to 1970s, mainly by converting natural broadleaved forests (Fujimori, 2000). Coniferous plantations occupy approximately 40% of forested areas and approximately 25% of Japan's land surface (National Astronomical Observatory, 2009). To develop these plantations, seedlings are planted typically at approximately 3000 stems ha^{-1}. Trees are thinned and pruned several times in the decades after planting and are harvested at an age of 40–50 years (e.g., Kikuzawa, 1999). By this stage, the stem density is typically 500 stems ha^{-1}. Forestry practices such as thinning and pruning were conducted in these plantations during the 1950–1980 period. However, the prevalence of these practices has gradually decreased since the 1980s, because of low timber prices and increased labor costs (Fujimori, 2000; Japan Forestry Agency, 2007; Onda, 2008). Thus, many plantations in Japan have become unmanaged.

Researchers (Kuraji and Hoyano, 2004; Kuraji, 2007; Onda, 2008; Onda et al., 2010) have noted increased flood risk with

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decreased forestry practices in coniferous plantations in Japan. The leaf area index (LAI) of unmanaged coniferous plantations is high owing to the absence of forestry practices such as thinning and pruning, which results in the sparse distribution of understory vegetation (Kiyono, 1988; Fukada et al., 2005, 2006; Japan Forestry Agency, 2007). When understory vegetation is sparse, throughfall strikes the ground surface directly, resulting in compaction of the ground surface and therefore lower rates of infiltration of the soil surface and greater overland flow (e.g., Yukawa and Onda, 1995; Onda and Yukawa, 1995; Gomi et al., 2008a; Kato et al., 2008; Hirano et al., 2009; Hiraoka et al., 2010). The infiltration rate for unmanaged coniferous plantations has been found to be lower than that for bare soil in some cases (Onda, 2008). This contrasts to having dense understory vegetation, in which case the infiltration rates for the ground surface are relatively high. In addition, the presence of understory vegetation reduces the persistence of overland flow even when flow does occur, owing to the roughness that the vegetation provides (Gomi et al., 2008a,b, 2010a; Wakiyama et al., 2010). Researchers (Kuraji and Hoyano, 2004; Kuraji, 2007; Onda, 2008; Onda et al., 2010) speculated that these results imply increased flood risk in watersheds where coniferous plantations are unmanaged. On the basis of this speculation, many local governments in Japan have introduced local taxes to stimulate forestry practices (Imawaka and Sato, 2008).

However, the increase in flood risk might be less than expected for two reasons. First, the speculation is mainly based on plot-scale measurements (typically within several square meters) of infiltration and overland flow (e.g., Hattori et al., 1992; Tsujimura et al.,

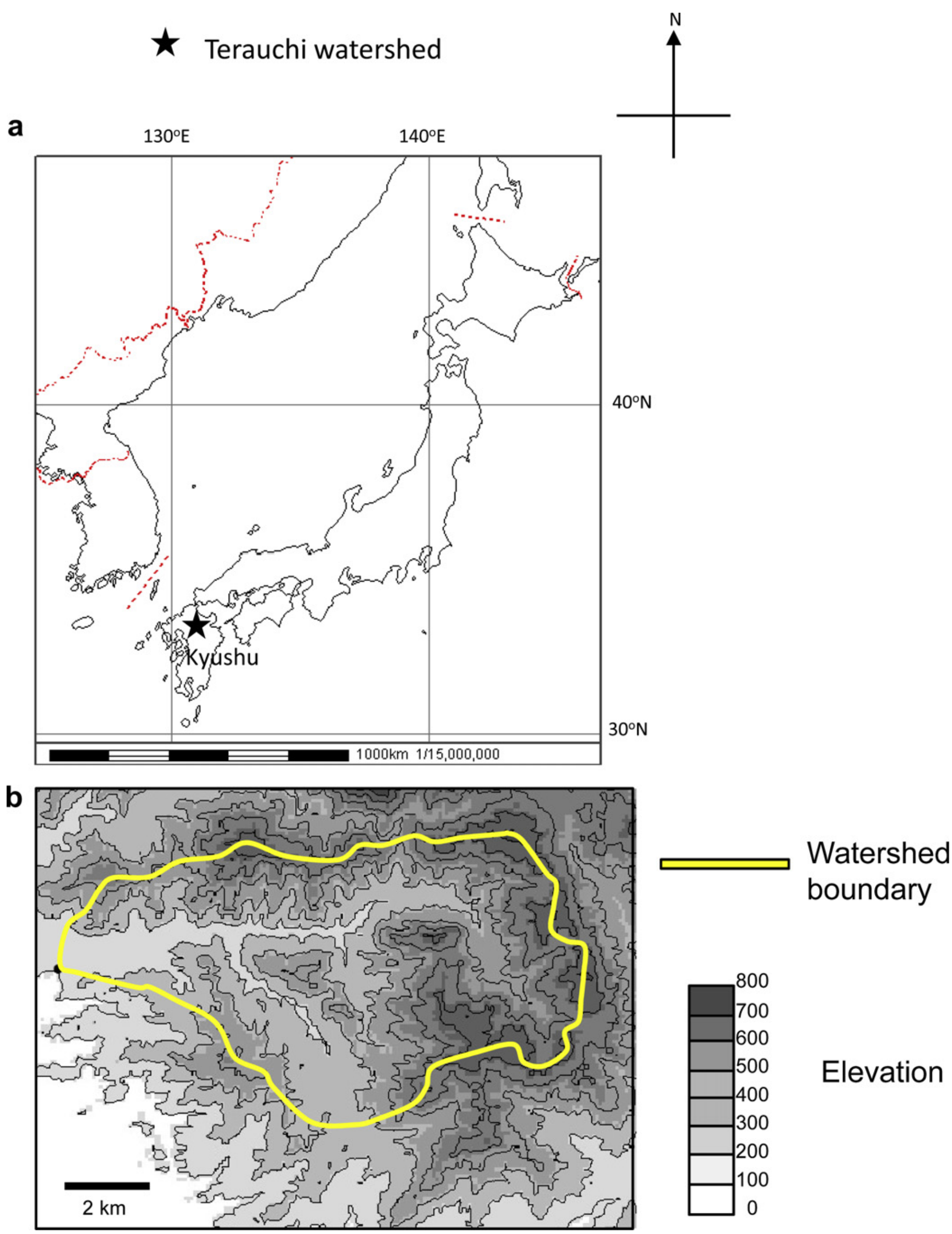

Fig. 1. (a) Location of the study area and (b) topographical map of the area.