Applied Geography 87 (2017) 115–126

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Geologically constrained changes to landforms caused by human activities in the 20th century: A case study from Fukuoka Prefecture, Japan

Hiroaki Ikemi

Faculty of Engineering, Kyushu University, 744 Motooka, Nishiku, Fukuoka, 819-0395, Japan

A R T I C L E I N F O

Article history:
Received 18 January 2017
Received in revised form
30 July 2017
Accepted 1 August 2017
Available online 11 August 2017

Keywords:
Anthropogenic landform
Land use
Land cover
Regional geology
GIS

A B S T R A C T

Human activity has been recognized to be an important geomorphic agent, and the resulting changes to landforms and land cover are regarded as a global problem. Although there has been much research into the relationships between geomorphic processes and types of land use such as agriculture, mining, and urbanization, it is important to clarify spatiotemporal human impacts on topography on a regional scale when predicting future changes in land cover.

This study examined changes in land use to clarify the distribution and impact of anthropogenic changes to landforms, as well as the influence of geology on the extent of these changes. In a case study from Fukuoka Prefecture, Japan, changes in land use over the last century were analyzed using a geographic information system (GIS). The study area, which covers approximately 4930 km^2, has experienced urban development since 1950 and has a current population of over 5 million. Land use data were prepared using paper-based early editions of topographic maps. Subsequently, the distribution of anthropogenic landforms was evaluated by comparing landforms with regional geological data.

GIS analysis using our prepared land use data, landform data, and regional geological data has clarified the following characteristics of the study area. (1) Land uses prior to 1950 were constrained by topographic relief. After 1950, land use was characterized by urban sprawl. Urban areas expanded and contained both higher elevations and steeper slopes at their margins. The relationships between land uses and landforms during this urbanization are unclear. (2) The area of urban land increased in the geological regions with Paleogene sedimentary rocks (PSD) and Mesozoic granitic rocks (GR) during the 20th century. The largest coal mining area in Japan was located in the PSD geological regions, and ancient iron working was common in the GR geological regions, particularly during the 7th century. This result indicates that the land use distribution, especially urban areas in sloping terrain, is related to the regional geology. (3) Deforestation related to land use resulted in steeper terrain in forest land in the PSD and GR geological regions. These changes to landforms in forest areas occurred as a result of rapid urban sprawl and have created many new boundaries between forest areas with steeper slopes and urban areas with gentler slopes. This phenomenon may have caused an increase in the frequency of sediment-related disasters.

This case study indicates that predictions of anthropogenic changes to landform, which are important for the assessment of global climate change and natural hazards, must clarify the relationships between land uses, landforms, and regional geology.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

In recent history, human beings have been considered to be among the most significant geomorphic agents. The current worldwide rate of sediment discharge from rivers into oceans is calculated to be 12.6 Gt/yr (Syvitski, Vorosmarty, Kettner, & Green, 2005; Wilkinson & McElroy, 2007). This is higher than the average discharge rate of 5 Gt/yr calculated for the Phanerozoic eon (Wilkinson & McElroy, 2007). The current increase in sediment discharge is considered to be affected by changes in land use such as agriculture, mining, and deforestation (Ahn, Mizugaki,

E-mail address: ikemi@kyudai.jp.

http://dx.doi.org/10.1016/j.apgeog.2017.08.001
0143-6228/© 2017 Elsevier Ltd. All rights reserved.

Nakamura, & Nakamura, 2006; Hooke, 2000; Kasai, Brierley, Page, Marutani, & Trustrum, 2005; Price, Ford, Cooper, & Neal, 2011; Sandel & Svenning, 2013; Syvitski et al., 2005; Wilkinson & McElroy, 2007; Wilkinson, 2005). These human impacts have increased exponentially with population growth (Hooke, 2000; Wilkinson, 2005). They have become a more pronounced geological factor since the onset of the Industrial Revolution in the 18th century (Price et al., 2011), in particular from the mid-20th century as the impact of the Industrial Revolution became both global and near-synchronous (Zalasiewicz et al., 2015).

The human impact on geomorphic processes has been clearly related to each form of land use. Anthropogenic soil erosion started on Earth after agriculture appeared in the Middle East about 11,000 years ago (Cerdà, Flanagan, le Bissonnais, & Boardman, 2009; Dotterweich, 2013; Massa et al., 2012). Knox (2006) reported that the sedimentation rate in the Mississippi River flood plain increased by one order of magnitude after the introduction of agriculture. Montgomery (2007a, 2007b) mentioned that the erosion rates of agricultural land are one to two orders of magnitude higher than the rates of soil production and geological erosion on the basis of values reported by some researchers. Arnáez, Lana-Renault, Lasanta, Ruiz-Flaño, and Castroviejo (2015) pointed out that soil erosion will increase in abandoned terraced agricultural land on the Mediterranean coast. Terraced landscapes in the monsoon climate zone, such as in Japan, mainly comprise rice fields, and similar problems can be observed in abandoned agricultural land. There are also reports that vineyards in semi-arid areas are affected by extensive soil erosion (Martínez-Casasnovas & Sánchez-Bosch, 2000; Tetzlaff, Friedrich, Vorderbrügge, Vereecken, & Wendland, 2013).

Douglas and Lawson (2000) reported that approximately 57,000 Mt sediment per year is transported by mining worldwide, which is almost three times the amount of sediment transported annually from rivers to oceans. Sediment transport by soil erosion (Choi, Park, & Sunwoo, 2008; Meng, Feng, Wu, & Meng, 2012) has been pointed out at open mines.

Road construction also causes an increase in sediment production (Bochet, García-Fayos, & Tormo, 2010; Brown, Aust, & McGuire, 2013; Croke, Mockler, Fogarty, & Takken, 2005; Fransen, Phillips, & Fahey, 2001; Jungerius, Matundura, & van de Ancker, 2002; MacDonald, Sampson, & Anderson, 2001; Megahan, Wilson, & Monsen, 2001; Montgomery, 1994; Nyssen et al., 2002; Reid & Dunne, 1984; Sugden & Woods, 2007; Wemple, Swanson, & Jones, 2001; Ziegler & Giambelluca, 1997). On the basis of such reports, Foley et al. (2005) pointed out that land use is not a local environmental problem but a global problem.

Assessments of natural hazards require a spatial distribution analysis of anthropogenic changes to landforms. Fell et al. (2008) referred to the development of a landslide inventory and a quantitative evaluation of human impacts as a guideline on landslide susceptibility, hazard, and risk zoning. Although landslides are fundamentally a natural phenomenon, their hazard risk increases when human activities and naturally occurring processes overlap. Urban sprawl often increases the magnitude and frequency of floods and landslides (Glade, 2003). It is reported that flooding by mud due to soil erosion of agricultural land in Europe poses serious problems (Bielders, Ramelot, & Persoons, 2003; Boardman, Evans, & Ford, 2003; Evrard, Bielders, Vandaele, & van Wesemael, 2007). Baroni, Bruschi, and Ribolini (2000) mentioned that deposits of mining waste are a source of debris flow. Mining also causes slope instability (Cortopassi et al., 2008; Erginal, Turkes, Ertek, Baba, & Bayradkar, 2008) and ground subsidence (Bell, Stacey, & Genske, 2000; Dunrud, 1984; Esaki, Makino, Djamaruddin, & Ikemi, 2010; Jambrik, 1995; Wolkersdorfer & Thiem, 1999). Bentley and Siddle (1996) showed that landslide density has been highest in the South Wales coalfield over a period of 100 years. Mountain roads have often caused hill slope instability and disasters (Borga, Tonelli, & Selleroni, 2004; Fransen et al., 2001; Montgomery, 1994; Petley et al., 2007; Sidle & Ziegler, 2012; Swanson & Dyrness, 1975).

However, the spatial distribution of anthropogenic landforms on a regional scale is still unclear, because most studies of the human impact on landforms have so far been based on the amounts or ages of fluvial sediments. Tarolli and Sofia (2016) mentioned that the study of anthropogenic geomorphology is still in its early stages.

Recently, Jones, Baker, Miller, Jarnagin, and Hogan (2014) reported that urbanization changed terrain from smooth topography to terrain with discontinuities such as steep slopes. Tarolli and Sofia (2016) demonstrated that the slope distribution of the topography of terraced agricultural land became bimodal with another peak at low gradients. The probability distribution of natural terrain gradients tends to be normal with a peak around a gradient of 35°. Dietrich and Perron (2006) employed numerical modeling to search for a unique topographic signature of life. The topographies of other planets such as Mars and Mercury, on which no life has yet been detected, display elevation histograms with a unique Gaussian distribution (Smith et al., 1999; Zuber et al., 2012). Dietrich and Perron (2006) also predicted that the frequency distribution of some geomorphic quantities, such as topographic elevation and slope, will change as a result of the existence of life. As Hooke (1994) pointed out, there is no doubt that human activity leaves an imprint on land. Moreover, the Anthropocene has been proposed as a geological period defined by human activity (Jones, 2011; Monastersky, 2015; Walker, Gibbard, & Lowe, 2015; Zalasiewicz et al., 2015). Moreover, anthropogenic changes to tree cover can be amplified by global climate change via non-linear forest–atmosphere interactions (Bonan, 2008). Human activities such as open-cut mining are typically accompanied by deforestation with significant changes to landforms. Thus, it is important that predictions of global climate change should clarify the spatial distribution of human impacts on terrain. Furthermore, although Sandel and Svenning (2013) described human impacts that have resulted in a global tendency for tree cover to be confined to sloping terrain, human activities, such as mining and mountain road construction, are strongly related to regional geology as well as terrain. In order to predict the impact on climate due to anthropogenic changes to land cover, it is necessary to determine spatiotemporal changes in landforms on a regional scale in terms of various land uses.

In this study, we have clarified anthropogenic changes to landforms by a geographic information system (GIS) analysis of the correlation between changes in land use and the regional geology. For our case study, we employed land use data for Fukuoka Prefecture, Japan, for the 20th century. Public land use data have been collected in Japan since 1976. Information on land use prior to 1976 was collected by digitizing data from earlier editions of topographic maps on a scale of 1:50,000. Topographic maps showing boundaries between farmland and urban land have been published in Japan since 1900. Using these data from topographic maps and GIS, we developed a land use database for the last 100 years, which was then analyzed using data for the regional landforms and geology.

2. Regional setting of the study area

The study area, namely, Fukuoka Prefecture, is located in western Japan and has an area of about 4930 km^2 (Fig. 1). In this area, large cities such as Fukuoka and Kitakyushu have seen significant growth since the mid-20th century. Fig. 2A shows the official population figures for every five years from 1920 to 2010. The population in 1900 is officially estimated to have been about 1.5 million on the basis of the legally domiciled population. With the exception of the 1940s (at the time of the Second World War), the

Download English Version:

https://daneshyari.com/en/article/6458379

Download Persian Version:

https://daneshyari.com/article/6458379

Daneshyari.com