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Examining the impact of land use on flood losses in Seoul, Korea

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ABSTRACT

Floods have been the costliest and most disruptive of all natural hazards worldwide. In particular, urban flooding continues to be a concern for both developed and developing countries. Increasing physical risk associated with environmental changes combined with rapid land use change and development make many urban areas more vulnerable to floods. Floods are not solely based on hydro-meteorological conditions, but also result from human activities such as unplanned land use or haphazard development.

While there is a growing body of research focused on understanding the impacts of land use on flood impacts in the United States, little empirical research has been conducted outside of the country although many other nations experience flooding. In particular, many countries in south and east Asia have undergone rapid urbanization concurrent with industrialization and population growth, resulting in worsening flood problems over time.

To address this knowledge gap, this study examines the factors contributing to flood loss in Seoul, Korea, with a particular focus on land use status and change. Panel regression models are analyzed using actual flood loss data for Seoul from 2003 to 2012.

Results indicate that urban built-up land with higher impervious surfaces and agricultural land may cause more flood damage than other land uses analyzed in the study. However, a high density development of compact design can decrease flood loss. These results indicate the importance of resilient land use planning in urban areas. Overall, this study provides insights to planners and decision makers about how they can effectively reduce flood risk and associated adverse impacts.

1. Introduction

Floods have been the most frequent, disruptive, and costly of all natural hazards worldwide. In particular, urban flooding and associated damages continue to be a concern for both developed and developing countries (Jha et al., 2012). The damage caused by floods in urban areas have increased across the world due to high population concentrations and greater asset values. As of 2008, half of humanity lived in cities and 70% of the world's population is expected to reside in urban areas by 2050 (Habitat, 2008). This trend makes urban flooding more of a challenge due to the fact that high population density, critical infrastructure, and expensive commercial and residential structures are considered more vulnerable to hazards (Klein et al., 2003). In particular, many countries with warm humid climates have experienced intensive floods throughout their history. Since some countries have a long history of rice paddy agriculture that depends on this type of climate, communities have tended to develop in flood-prone areas (Kundzewicz and Takeuchi, 1999). As these localities underwent rapid urbanization concurrent with industrialization and population growth, the flood problem worsened over time.

Floods are not solely based on hydro-meteorological conditions, but can also result from human activities such as unplanned land use or haphazard development (Brody et al., 2011a, 2011b; Matthai, 1990; Mileti and Gailus, 2005). Urban areas are characterized by a high proportion of paved streets and development within these areas usually involves alteration of the natural landscape into impermeable surfaces, which lead to increased overland flow and discharge. Therefore, improper land use planning and development can make many urban areas more vulnerable to floods when combined with the increased physical risk associated with environmental change.

While there is a growing body of research examining the impacts of land use and land use change on floods in the United States, very little

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empirical research has been conducted elsewhere despite the fact that many other countries experience urban flooding. Recent attention has been given to flood impacts in several Asian megacities (Klein et al., 2003), but few studies have been done in these areas that look at the role of human systems in urban flooding.

To address this knowledge gap, this study investigates the factors contributing to flood loss in Seoul, Korea, with a particular focus on land use status and change. Seoul is the capital and largest metropolitan area in South Korea with a population of 10 million. This megacity has experienced urban flooding at its center since 2010 due to unusual localized heavy rains. The busiest section in the city was crippled by the most severe floods ever recorded in both 2010 and 2011. The total economic losses in the ten years from 2002 to 2011, including property damage from floods, was approximately $65 million with more than $50 million lost in 2010 and 2011 alone. In 2011, a flood caused 24 causalities and inundated 21,832 buildings (Kang and Lee, 2012; Kim et al., 2012a,b).

A major issue is that localized flooding has become chronic and repetitive. Regular floods in the same areas of Seoul suggest that these events may not only be driven by biophysical factors, but also by human activities (Mileti and Gailus, 2005). In response to this problem, decision makers must fully understand the impacts of land use and changes that can cause flooding and exacerbate the associated damage in order to incorporate the concept of flood risk into the implementation of plans and policies.

The following section addresses the context of Korea to present a background of the study area, and reviews existing research on factors contributing to floods and flood losses with particular attention paid to land use and development patterns. Next, the research methods are described, including sample selection, concept measurement, and data analysis. The results of both descriptive statistics and panel regression models are reported and the implications of these results for policy decisions are discussed. Finally, the conclusion of the article includes a summary of the findings and suggestions for future research.

2. Context and literature

2.1. Floods in a korean context

Seoul, a megacity with over 10 million people, contains more than 20% of the nation's population. It was not until the late 1960s that Seoul recovered from the effects of the Korean War (1950–1953). After the war, the Korean government made a considerable effort to improve the country's economics and Seoul began to experience rapid industrialization and urbanization. As a result, Korea's economy grew so rapidly it was named one of the "Asian tigers" (Kim et al., 2012a,b). As the Korean economy grew, the population of Seoul increased from 1.6 million to 10.4 million between the years of 1955 and 2012 (Korea Statistics, 2013) and the proportion of developed area increased from 29% to 65% between 1973 and 2001 (Kim, 2008).

Seoul consists of 25 districts managed by the Seoul Metropolitan Government (SMG). The SMG is an upper level (provincial or regional) local government, and the districts are the lower level (municipal) local governments. Korea, as a centralized unitary state, has a rigidly hierarchical system. The local governments are considered sub-national governments, and the central government can control local decisions through various means. Local governments also rely heavily on financial contributions from upper level governments through intergovernmental transfers such as subsidies and grants. In this sense, local governments in Korea have limited autonomy in every aspect compared to those in the United States. In the United States, it is argued that strong leadership from the state and federal government is necessary to build and implement effective flood mitigation strategies (Mileti, 1999). However, in Korea it is asserted that the functionally and financially limited autonomy of the centralized local governments are responsible for the lack of proper flood mitigation measures at the local level (Cho, 2000).

Regarding the socio-economic context, Seoul is different from cities in the United States in that it is racially homogeneous. Despite this homogeneity, there have been social polarization and segregation problems due to income inequality and expensive housing prices in Seoul (Kim et al., 2012a,b). These worsened as Korea went through the Asian Economic Crisis from 1997 to 1998, which substantially reduced the number of people in the middle class. Although the SMG has been trying to resolve this problem and promote social cohesion, it was found that the gap between wealthy and poor districts is not decreasing (Kim et al., 2012a,b; Maeng, 2009, 2010).

It is important to note that Seoul has its own social, cultural, historical, political, and economic contexts which distinguishes it from study areas in the United States. Therefore, applying the methods from the studies conducted in the United States to Seoul is meaningful in that it has never been done before.

2.2. Land use and development patterns influencing flood loss

Better understanding of the impacts of land use and development triggering flooding and associated damage can help local governments build a resilient land use plan that reduces flood risk over the long term. Land use and development activities reflect human behavior, and are considered "powerful levers" on the problems of flooding (Brody et al., 2011a,b). Land use status and development involves imperviousness, which is a quantifiable and accurate predictor of urbanization with unfavorable impacts on hydrological cycles (Arnold and Gibbons, 1996). It has been reported that an increase in impervious surfaces cause higher runoff peaks and volume with a shortened lag time (Shuster et al., 2005). Rose and Peters (2001) reported that peak discharge increased by 80% in urban catchments with an impervous area of 50% and that peak flow is 30–100% higher than in rural areas. In addition, other studies found that when impervious surface cover exceeds 10% of the watershed, runoff increases by 200–500% (Arnold and Gibbons, 1996; Paul and Meyer, 2001). Many other studies have noted the association between an increase in impervious surfaces and flood magnitudes (Dietz and Clausen, 2008; White and Greer, 2006; Williams and Wise, 2006).

While impervious surfaces pertain to development intensity and location issues, development density is about the pattern (Brody et al., 2011a,b). Since it is frequently assumed that development patterns in urban and suburban areas impact the environmental, social, and economic conditions of local communities, studies focusing on the influence of development patterns on flood damage have recently increased. The flood problems caused by development density are mainly associated with sprawl due to rapid popluation growth which is accompanied by haphazard outwardly expanding developments resulting in land conversion. Also, land conversion becomes an issue when land surface changes from pervious to impervious. Sprawl is characterized by low density residential unit development and an over-consumption of land which used to be open space, wetlands, or agricultural (Brody et al., 2011a,b). Sprawl has also been a problem in Korea, particularly in the outskirts of Seoul. Because of this, the Korean government created a Green Belt around the city of Seoul in the 1970s.[1] Although sprawl is not as much of a problem as it was in the 1970s to the 1980s, a substantial amount of land in Seoul was made impervious.

This conversion from pervious land to impervious surfaces made these areas vulnerable to floods. Furthermore, the long distance between each area, caused by low density residential unit development, makes it difficult to establish effective flood resilient communities since it forces residents to rely on automobiles and increases the need for

[1] As a growth management strategy, any kind of development was strictly prohibited within this area. Since 1999, this regulation has been gradually relaxed.