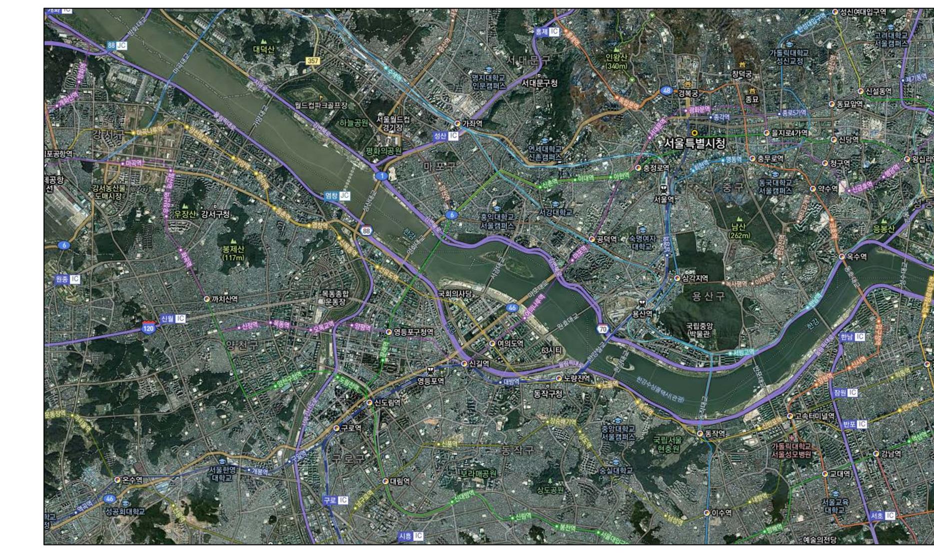
Viewing from the past: Development and flood in South Korea



Sunhak Bae[1] & Heejun Chang[2]

1. Department of Geography Education, Kangwon National University, Korea, 2. Department of Geography, Portland State University

Abstract

We investigated factors affecting flood damage in Seoul and Gyeonggi province in South Korea that experienced rapid economic growth and urbanization. Using spatial regression models, we examined how land cover change and demographic factors affect flood damage in the study area for each ten year period from 1986 to 2015. A unique aspect of this study is the use of an old map that was created more than 100 years ago. Our results show that high flood damage areas are spatially clustered in the north and eastern part of the study area. Population density was the common factor that best explained flood damage in all three periods. In the early stage of urban expansion, the higher the ratio of agricultural land that had been converted to urban land, the greater the flood damage. As urbanization continued and matured, the higher the ratio of forest areas that had been converted to urban areas, the greater the flood damage.

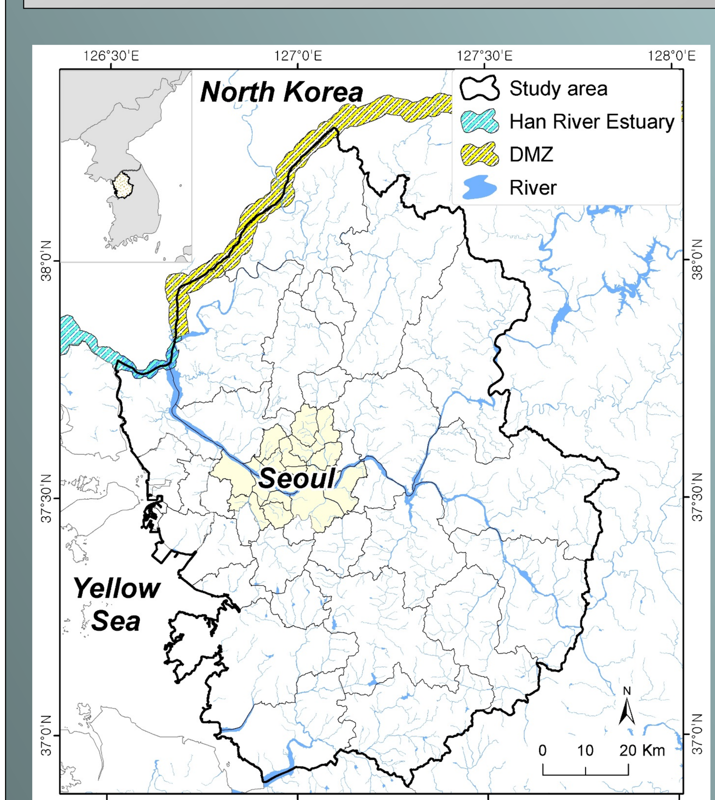


Figure 1: Study Area

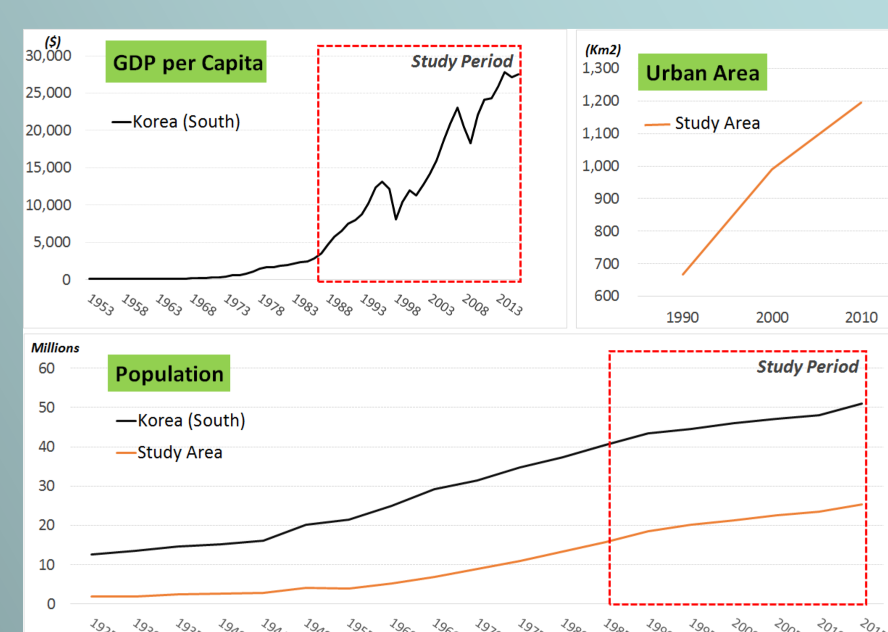


Figure 2: GDP, urban areas and population changes

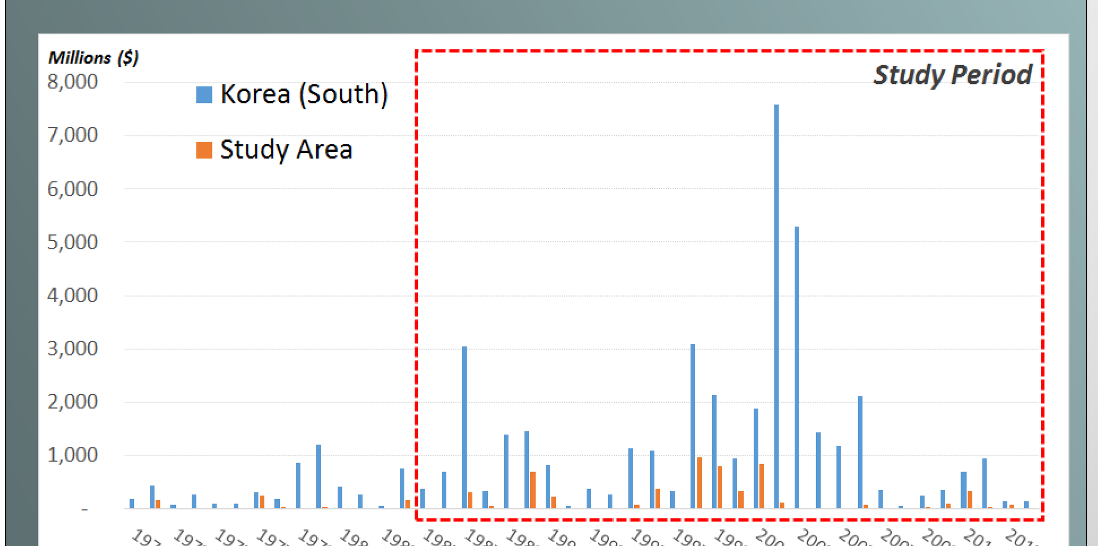


Figure 3: Annual flood damage (Monetary value in 2015)

Study Area

- Gyeonggi Province, South Korea
- Area: 11,070 km^2
- Sub-division district: *n=48*

Study Period

- Total: 1985 ~ 2014
- Period #1: 1985 ~ 1994
- Period #2: 1995 ~ 2004
- Period #3: 2005 ~ 2014

Research Questions

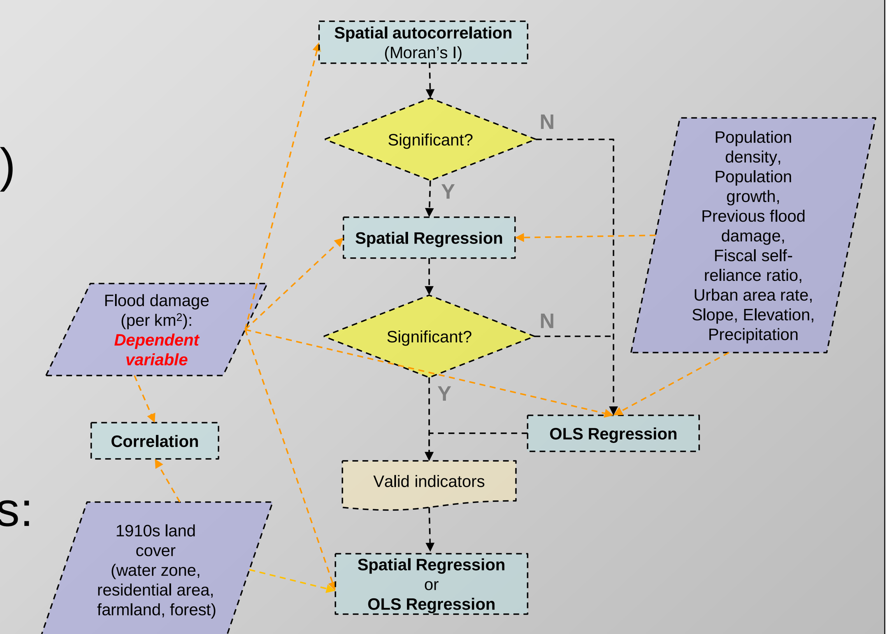
1. Where are the hotspots of flood-vulnerable areas in the study area?
2. As urbanization progresses, what biophysical characteristics of urban areas are associated with flood damage?
3. How has the conversion of natural areas to urban land covers been associated with flood damage?

Methods

a. Spatial autocorrelation
b. Spatial regression
c. OLS (Ordinary Least Squares) regression

Data

a. Flood damage: Dependent variable
  - Flood damage during 30 years: 1985 ~ 2014
  - Subdivided into 10 years: 1990s, 2000s, 2010s

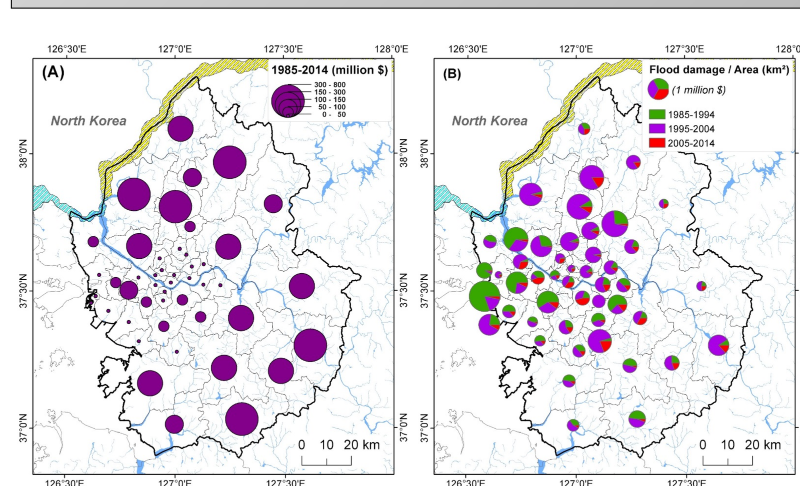


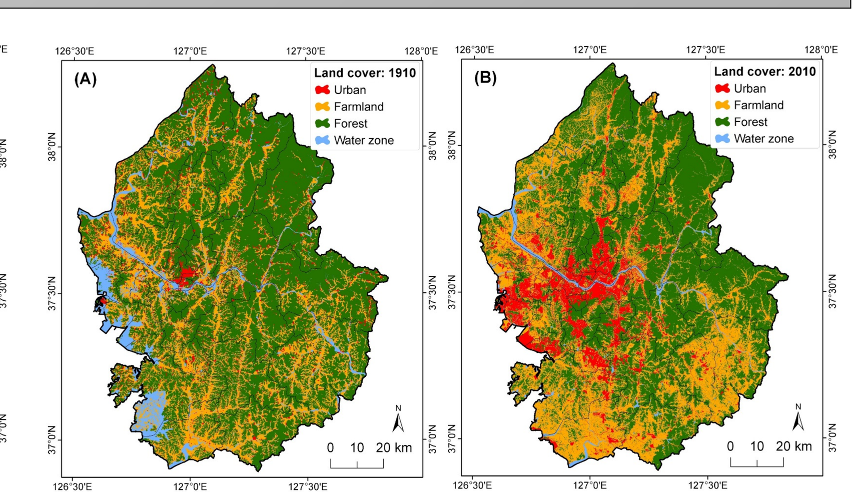
Figures 4: Research flow

b. Flood damage factors: biophysical and socioeconomic variables
  - Urban area, Precipitation, Elevation, Slope, Soil drainage, Population density, Population growth, Fiscal self-reliance

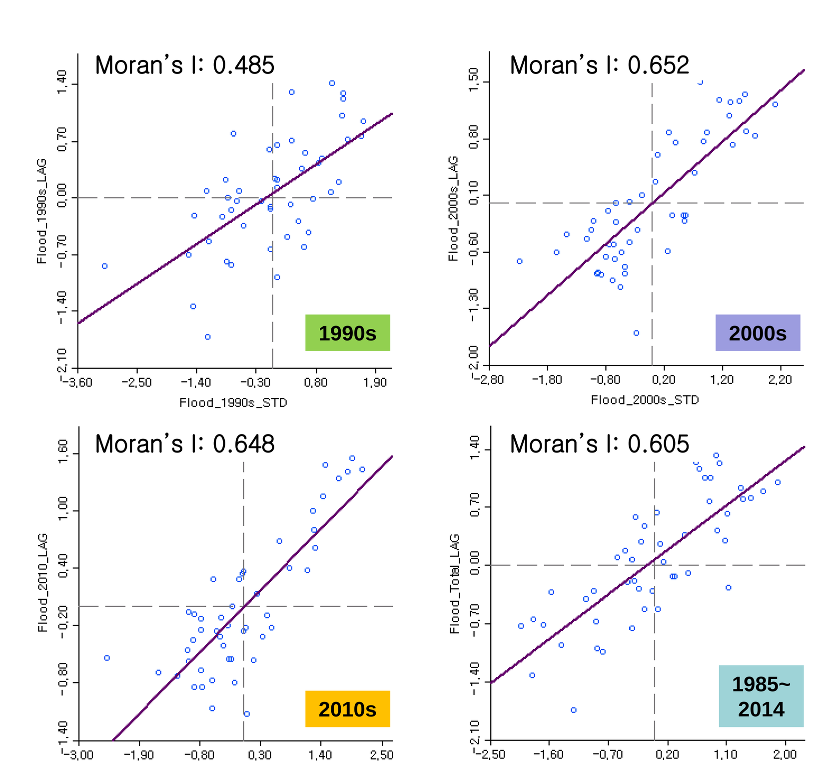
c. Pre-modern (100 years ago, 1910s) land cover: % land cover in the current urban areas
  - Residential area, Farmland, Forest, Water zone

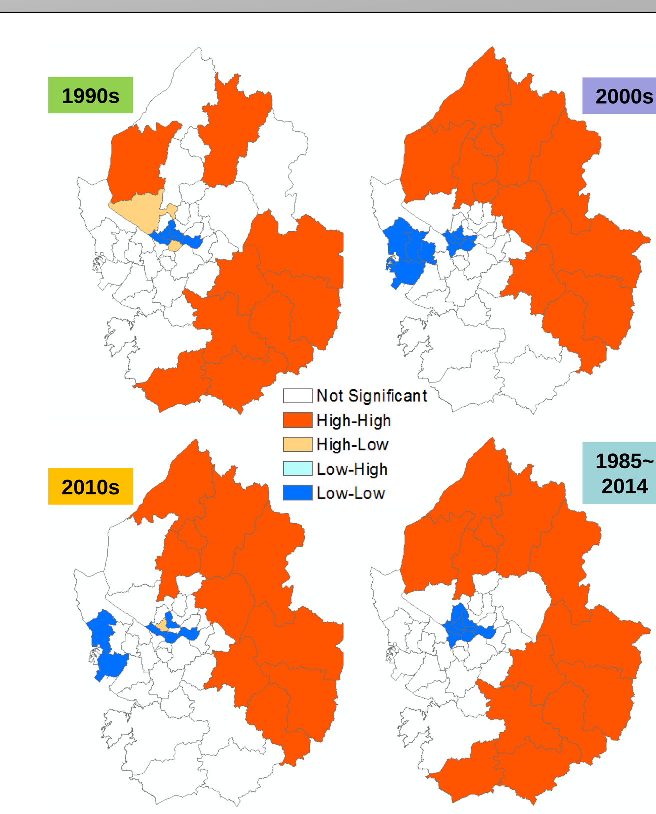
d. Data transformation and normalization
  - Log: Flood damage, Population density
  - (x – min)/(max – min): Precipitation, Elevation, Slope
  - Percentage: Urban area, Soil drainage, Population growth, Fiscal self-reliance





Spatial autocorrelation detection (Moran's I)





Regression: Spatial vs. OLS Regression

	1990s		2000s		2010s	
	Spatial Regr.	OLS Regression	Spatial Regr.	OLS Regression	Spatial Regr.	OLS Regression
Significant variables	**Pop_Density** (-0.800)	Pop_Density (-0.800)	**Pop_Density** (-0.422) Urban area rate (-0.012)	Pop_Density (-0.444), Urban area rate (-0.12)	**Pop_Density** (-0.378), Slope (0.796), Previous flood damage (0.270)	Pop_Density (-0.416), Slope (0.783), Previous flood damage (0.259)
LAMDA (probability)	0.23 (0.254)		0.36 (0.048*)		0.33 (0.076)	
R^2 (AjR^2)	**0.536**	**0.518 (0.508)**	**0.762**	**0.739 (0.727)**	**0.707**	**0.686 (0.664)**
AIC	96.6	97.9	44.5	47.6	50.5	52.6

*N=48, *P < 0.05*

- Dependent variable: *Log Flood damage of Urban area (per km^2) for each decade*
- Independent variable: *Urban area rate, Precipitation, Elevation, Slope, Previous flood damage, Population density, Population growth rate, Fiscal self-reliance ratio*
- Population density is consistently negatively associated with flood damage in all periods.
- More explanatory variables were included for explain flood damage in later periods

Regression: Flood damage with 1910s Land cover

	1990s		2000s		2010s	
	Spatial Regr.	OLS Regression	Spatial Regr.	OLS Regression	Spatial Regr.	OLS Regression
Significant variables	Pop_Density (-0.696), **Farmland** (0.013)	Pop_Density (-0.692), Farmland (0.014)	Pop_Density (-0.696), **Farmland** (0.011)	Pop_Density (-0.702), Farmland (0.012)	Pop_Density (-0.597), **Forest** (0.016), **Farmland** (0.008)	Pop_Density (-0.611), Forest (0.017), Farmland (0.008)
R^2	0.54	0.52	0.75	0.69	0.64	0.60
R^2 (include 1910s land)	**0.58**	**0.57**	**0.78**	**0.76**	**0.72**	**0.71**
AIC	93.8	94.6	40.8	42.6	57.6	49.3
LAMDA (Probability)	0.14 (0.494)		0.25 (0.217)		0.28 (0.145)	
Log Flood damage of urban area (per km^2)	**7.612 + (-0.692*Pop_Density) + (0.014*Farmland)**		**8.106 + (-0.702*Pop_Density) + (0.012*Farmland)**		**6.732 + (-0.611*Pop_Density) + (0.017*Forest) + (0.008*Farmland)**	

- Spatial Regression models show moderate improvement over OLS (higher R^2 and lower AIC)
- Farmland is the significant variable for explaining the variability of flood damage in 1990s and 2000s.
- Forest and farmland are the significant variables for explaining variability of flood damage in the 2010s.
- Including 1910s Land cover variables consistently improved the explanatory power of the model.

Main Findings

1. Hotspots of flood damage shifted to north, suggesting that food damage increased with urbanization.
2. Population density was consistently the common factor affecting flood damage in all periods, other variables became significant later periods.
3. Percent farmland in 1910 was the common variable affecting flood damage in 1990s and 2000s, while % forest in 1910 was significant for 2010s.

Way Forward

1. Applying the same method to different areas of South Korea.
2. Analysis of the relationship between urban shape and flood damage.
3. Future projection of flooded areas considering climate change.

KNU KANGWON NATIONAL UNIVERSITY

Portland State UNIVERSITY