Classifying 226 local entities in Korea: climate change vulnerability analysis

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AIM
ASIA-PACIFIC INTEGRATED MODEL

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I. Introduction

Purpose of study

- To assess regional vulnerability to climate change in 226 local entities in Korea
- To enable local entities to get ready for locally adjusted adaptation strategies
- To identify and prioritize medium and long-term adaptation policies that maximize benefits
- To help local entities establish ‘Detailed implementation plan for local(lower level) climate change’ every 5 years

Contribution of study

- A very few studies on cross-sectoral climate change vulnerability indicators (First study on 226 low-level local entities)
- Only one data standardization method has been adopted (Comparison between Z-score and Rescaling methods to check data robustness)
- Principal Component Analysis: statistically robust methodology to draw weight for index composition (Conventional method: AHP)

II. Theoretical Background

- **Vulnerability**
- The degree to which geographical, biological and socio-economic systems are susceptible to, and unable to cope with adverse impacts of climate change (IPCC, 2007)
- The concept of vulnerability evolved to include non-climatic determinants to climate change, including adaptive capacity, and the shift from estimating expected damages to attempting to reduce them (Fussel & Klein, 2006)

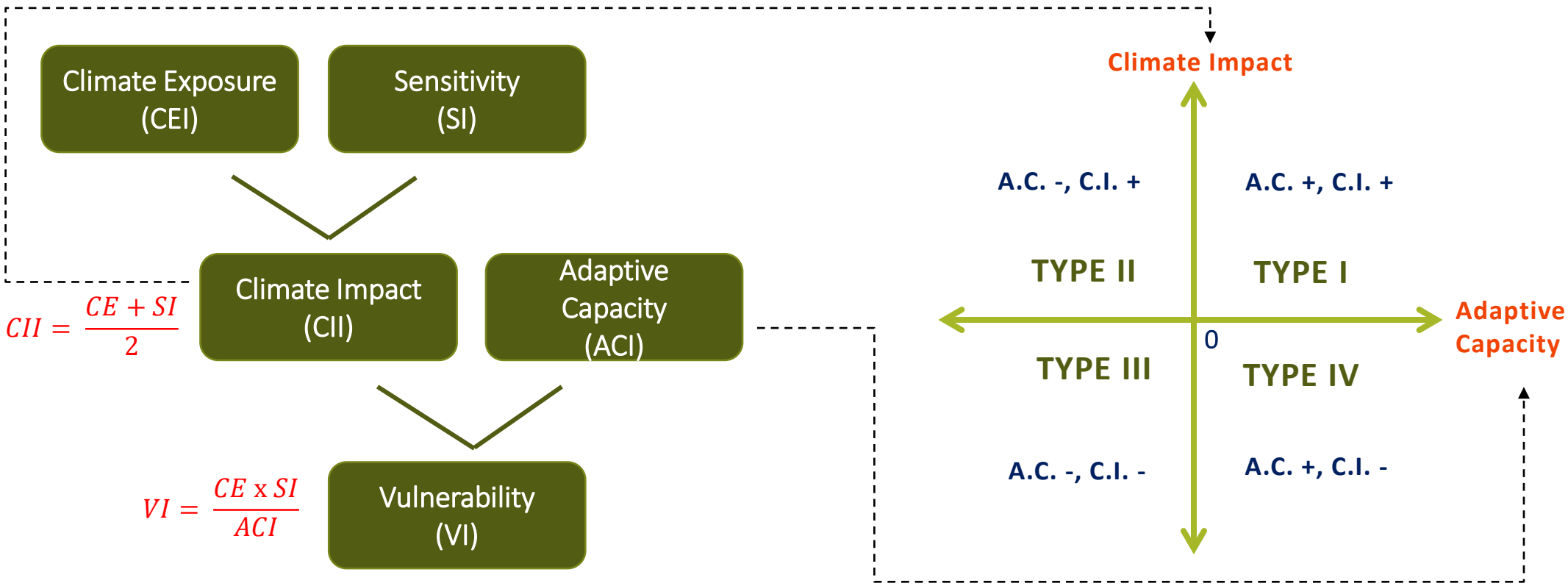
- **Exposure**
- Degree to which a system is exposed to climate related stimulus (Fussel et al., 2006)
- Temperature, humidity, ozone, wind speed, fine dust etc.

- **Sensitivity**
- Degree to which a system will respond to a change in climatic conditions (Fussel et al., 2006)
- Demographics, infrastructure & industry, geographic characteristics, land use etc.

- **Adaptive capacity**
- Degree to which adjustments are possible in practices, processes or structures of systems to projected or actual changes of climate as response to, or anticipatory of change (Fussel et al., 2006)
- Human capital, physical capital, social capital, financial capital (Ellis, 2000; Jacobs et al., 2014)

II. Theoretical Background

- Conceptual Framework



III. Indicators

- **Data Collection**

- 2013-19 most recent available data
- Climate data: RCP 8.5, 2021-2030 projection at VESTAP
- Socio-economic variables collected from various sources
- No interpolation done, fill the missing values from several data source

III. Indicators

Y-axis

Exposure
Relative humidity per day
Discomfort index (temperature humidity index)
The number of days that the minimum temperature -12 degrees or less in winter lasted more than 2 days
Number of days when ozone concentration per hour is more than 100ppb
Number of days under EDDI -1 for 6 months per year
Maximum number of consecutive precipitation-free days
Number of days with a thermal index of 32 or higher
Number of days with a temperature and humidity index of 72 or more
Number of days when the minimum temperature per day is 25℃ or higher
Number of days with more than 150mm of daily precipitation
Number of days when the maximum daily wind speed is 14m/s or more
Snowfall (kg/m2)
Number of days with more than 20cm of snowfall
Heat wave persistence index (HWDI)
Time The number of days when the fine dust concentration is more than 100ug/m3
Annual average fine dust concentration (㎍/㎥)

Sensitivity	
Demographic characteristics	Population density
	Population growth rate
	Percentage of population under 5 years old
	Percentage of population over 65
	Percentage of elderly living alone (65 years and older) among the total population
	Percentage of population of recipients of basic living
	Non-treatment rate for necessary medical services
	Annual number of malaria cases per 100,000 population
	Annual number of cases of Tsutsugamushi per 100,000 population
	Percentage of outdoor workers (agriculture, forestry and fisheries population)
Infrastructure & Industry	Gas supply facility area
	Road area ratio by area of administrative district
	The number of businesses in the 1st and 2nd industry (%)
	Share of number of workers in the 1st and 2nd industries (%)
	1st and 2nd industry sales share (%)
Geographic characteristics and Land use	Orchard
	Rice field
	Marsh
	Forest
	Field
	River
	Groundwater use per population
	Area of damage to forest pathogens in administrative districts
	Ratio of fertilizer used area per cultivated land
	Altitude by administrative district
	Managed land rate
	Average slope of river basin
	Forest area ratio by area of administrative district
	Ratio of agricultural land area by administrative district area
	Lowland household below 10m
	Regional average slope
	A dry area within 1km of the coast

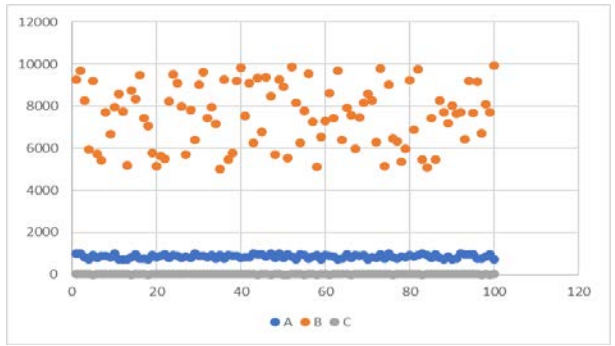
X-axis

Adaptive Capacity	
Human Capital	Number of students per faculty
	Number of childcare facilities per 1,000 infants
	Number of doctors in medical institutions per 1,000 population
	Number of hospital beds per 1,000 population
	Influenza vaccination rate
	Number of residents in charge per firefighting officer
	Number of public officer related to disaster prevention
Physical Capital	Sewer system supply rate
	Water supply rate
	Ratio of water supply facility area to administrative district area
Social Capital	Ratio of visiting medical care centers
	Ratio of visiting bathing centers
	Ratio of visiting nursing centers
	Percentage of health & social welfare companies
	Ratio of health and social welfare workers
	Number of cultural infrastructure facilities per 100,000 population
	Participation rate in 19th presidential election
Financial Capital	Share of health expenditure in general accounts
	Share of environmental protection expenditure in general accounts
	Share of social welfare budget in general accounts
	Proportion of public administration budget among general accounts
	Gross Regional Domestic Product (GRDP)
	Financial Independence

IV. Analysis & Empirical Findings

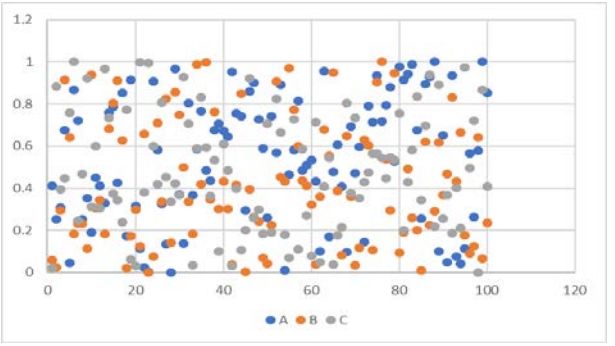
- **Standardization (z-score):** $x_{new} = \frac{x - \mu}{\sigma}$
- Transform the distribution of data to the standard normal distribution (mean:0, standard deviation:1)
- How many times S.D. is separated from the mean of distribution as z

- **Normalization (min-max scaling):** $x_{new} = \frac{x - x_{min}}{x_{max} - x_{min}}$
- Adjusting values measured on different scales to a notionally common scale(between 0 and 1)
- Extreme values could become unreliable outliers, may have a distorted effect



[Raw Data]

[Standardization]



[Normalization]

IV. Analysis & Empirical Findings

Principal Component Analysis

- Given data matrix $X \in \mathbb{R}^{nxk}$ (n samples, k variables), the goal is to find orthogonal projections in the lower-dimensional space with the highest variance
- The first principal component: unit vector $v_1 \in \mathbb{R}^k$:

$$v_1 = \arg\max_{\|v\|=1} (Xv)^T (Xv)$$

- Then, repeat this process to find *p*th principal components

$$v_p = \arg\max_{\|v\|=1, v^T v_j = 0, j=1,\ldots,p-1} (Xv)^T (Xv)$$

- The highest component loadings for each indicator variable were squared, and the value of the squared component loadings becomes the weight for the indicator. By applying factor analysis, the weights of each sub-indicators were found and index is constructed

IV. Analysis & Empirical Findings

Equations for index composition

- $\boldsymbol{Climate\ impact\ index\ (CEI)} =$

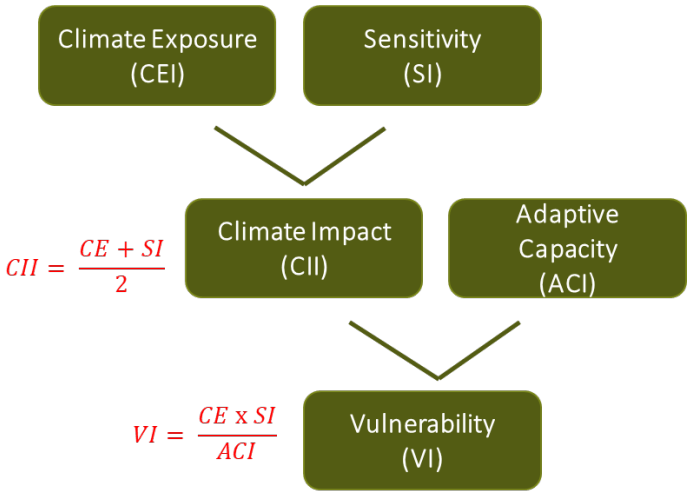
$$\frac{1}{2}\left(\sum_{i=1}^{k} Climate\ exposure(a_i W_i) + \underbrace{\sum_{i=1}^{l} Demographic(b_i X_i) + \sum_{i=1}^{m} Infra(c_i Y_i) + \sum_{i=1}^{n} Geographic(d_i Z_i)}_{Sensitivity}\right)$$

- $\boldsymbol{Adaptive\ capacity\ index\ (ACI)} = \sum_{i=1}^{o} Human(e_i V_i) +$

$$\sum_{i=1}^{p} Physical(f_i Q_i) + \sum_{i=1}^{q} Social(g_i R_i) + \sum_{i=1}^{r} Financial(h_i S_i)$$

Two-stage of PCA

- Stage I: PCA by Category
- Stage II: PCA by result value from Stage I



IV. Analysis & Empirical Findings

Standardization (z-score)

Normalization (rescaling)

	Type I	Type II	Type III	Type IV
Type I	**54**	4	4	17
Type II	2	**23**	14	0
Type III	2	8	**41**	1
Type IV	5	0	6	**45**

Same type: 72.12% of 226 local entities

▪ Findings

1. Type I
- High in climate impact (PM, heatwave)
- High in adaptive capacity (human capital, financial capital, physical capital)
- Seoul, Gyeonggi and Gwangju

2. Type II
- High in climate impact (humidity, demographic sensitivity)
- Low in adaptive capacity
- Jeonnam, Chungnam, Gyeongbuk, Gyeongnam

3. Type III
- Low in climate impact(humidity, heat, PM, ozone)
- Low in adaptive capacity
- Gangwon, Chungbuk, Gyeongbuk, Incheon(Ongjin, Ganghwa: high in ozone, lack of medical services)

4. Type IV
- Low in climate impact
- High in adaptive capacity
- Metropolitan area: Seoul, Gyeonggi, Incheon, Daejon

IV. Analysis & Empirical Findings

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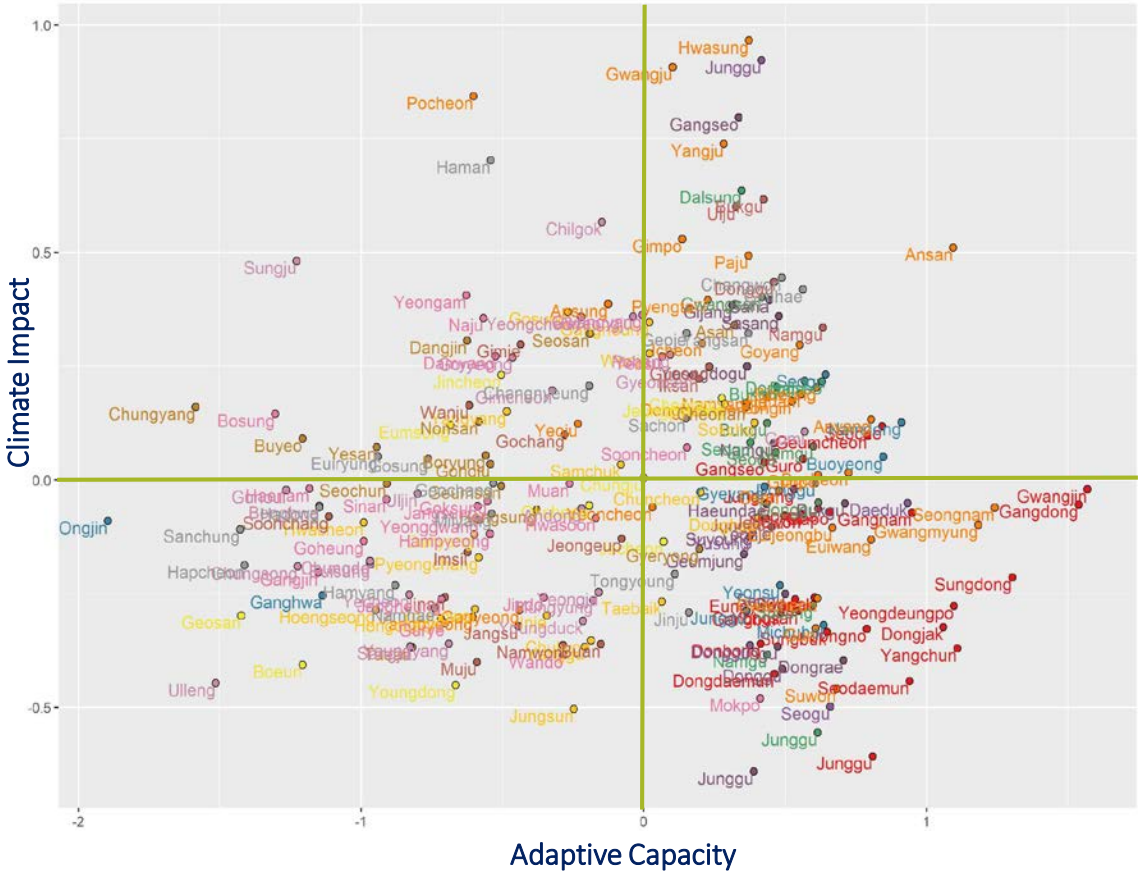
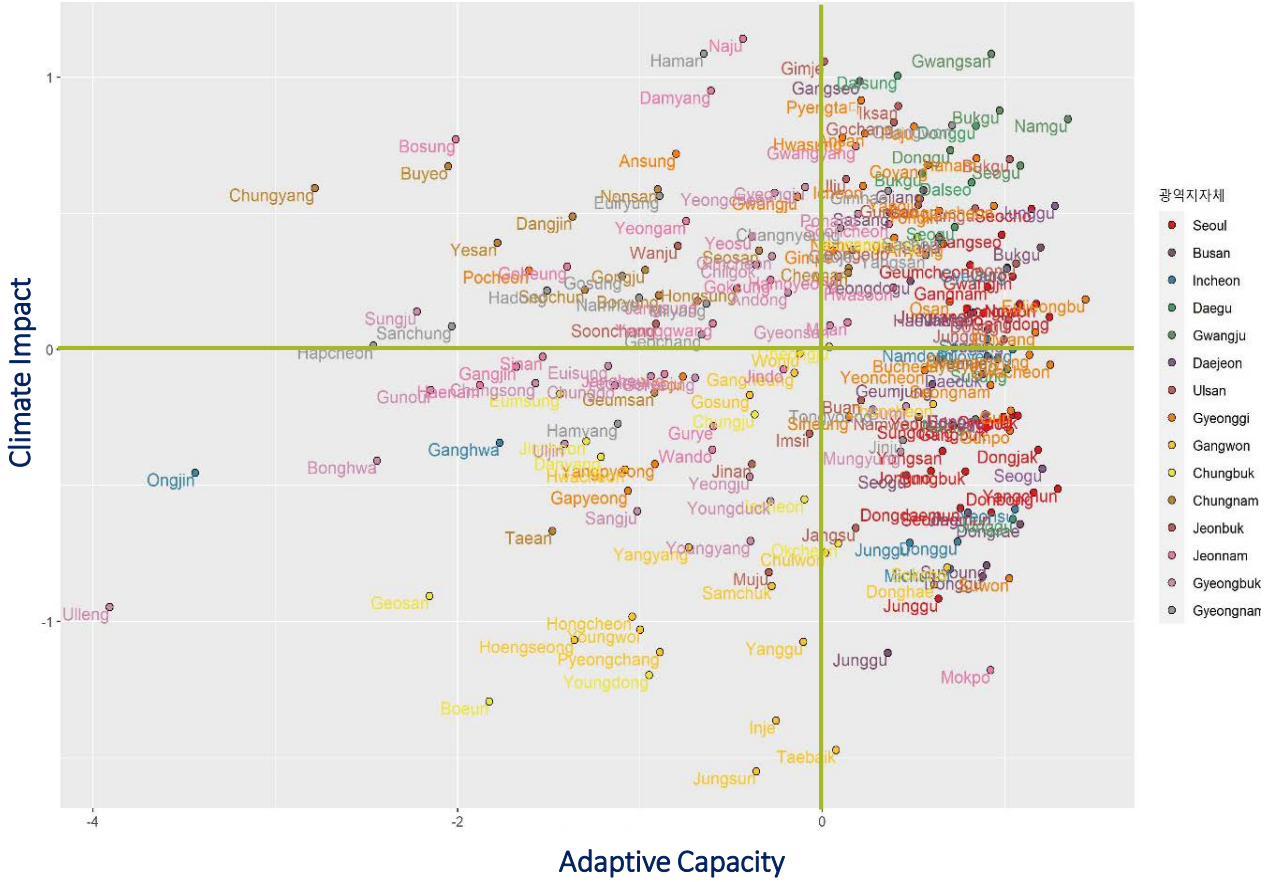
Standardization (z-score)



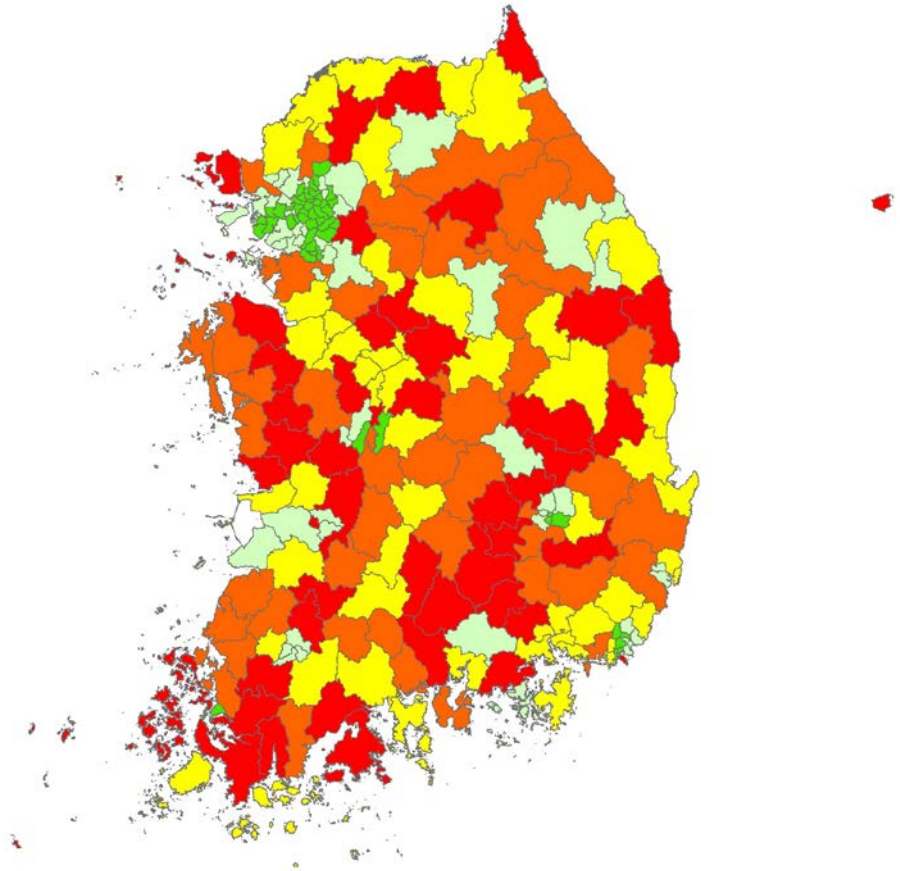
Normalization (rescaling)



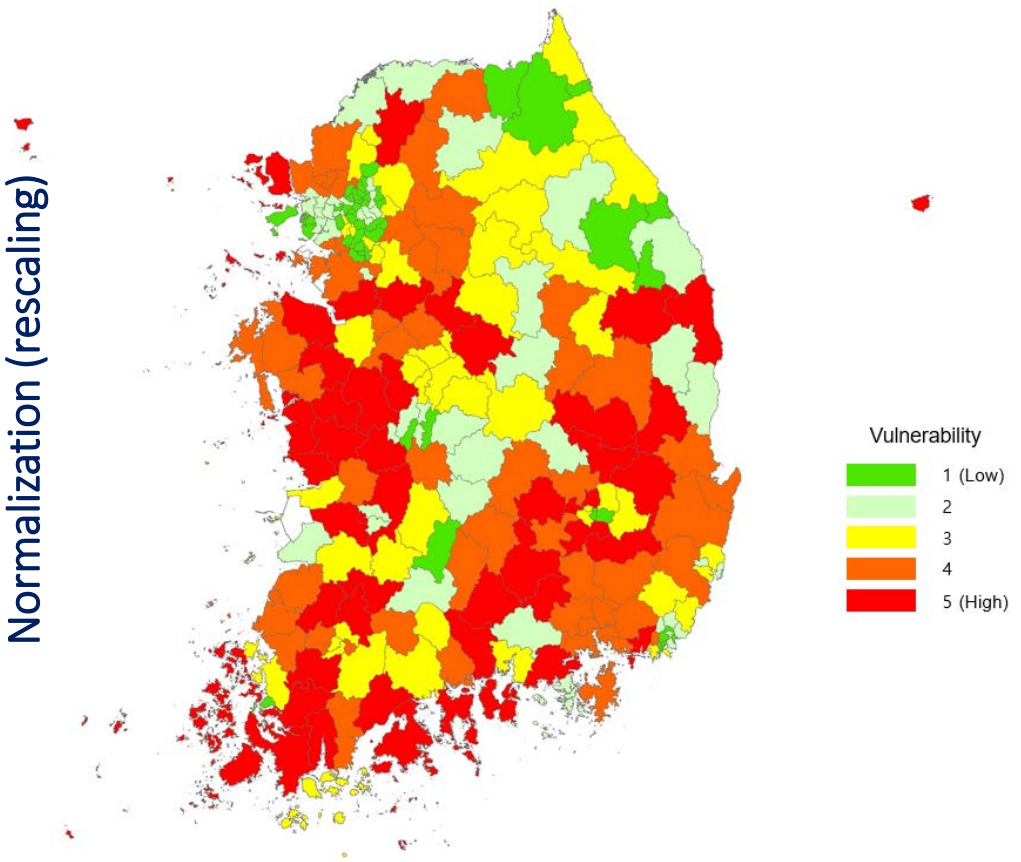
IV. Analysis & Empirical Findings

- Vulnerability Index for 226 local entities: $Vulnerability\ Index = \frac{Climate\ Impact\ -\ Adaptive\ Capacity}{2}$

Standardization (z-score)



Normalization (rescaling)



V. Conclusion

- **Findings and Policy Implications**

- **Type I**: cities at municipality level are less vulnerable to climate change (i.e. Seoul, Busan, Incheon, Daegu, Daejon, Gwangju, Ulsan) due to high adaptive capacity, yet **need to be prepared for city specific climate impact such as air pollution and heatwave**
- **Type II**: most vulnerable, thus difficult to implement adaptation policy. Rural area with system sensitive demographic condition, as well as low adaptive capacity (i.e. Jeonnam, Chungnam, Gyeongbuk, Gyeongnam). **Financial support from the central government required**
- **Type III**: low climate impact as well as low adaptive capacity, thus less attention about climate change adaptation. Nevertheless, high vulnerability due to low adaptive capacity. **Citizen education and promotion required. Customized strategy even within the same municipality (i.e. Ongjin, Gwanghwa)**
- **Type IV**: lowest in vulnerability. Metropolitan area(Seoul, Gyeonggi, Incheon, Daejon) with high population and infrastructure. **Need to be prepared for future uncertainty to prevent massive damage by climate change**

- **Further Studies**

- 5 sectoral classification (health, disaster, agro-livestock/fisheries, forest/ecosystem, water)
- Expert verification on the analysis results
- Model elaboration to find outliers and to provide concise policy recommendations to those who near the border line

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Thank you for listening!

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