

STORM SURGE VULNERABILITY ANALYSIS BASED ON SEA LEVEL RISE OF LOW ELEVATION COASTAL ZONE

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INTRODUCTION

The reason of recent Sea Level Rise:

- ◆ Due to the large demand of fuel burning increasing quantities of greenhouse gases including carbon dioxide (CO_2), methane (CH_4) and nitrogen dioxide (N_2O) are emitted into the Earth's atmosphere. The process causes Land ice melting (0.2 – 0.4 mm/a)
- ◆ The increasing ocean temperatures result in thermal expansion of the oceans. And thermal expansion of the oceans is the biggest contribution (0.7mm/a) to the sea level rise.

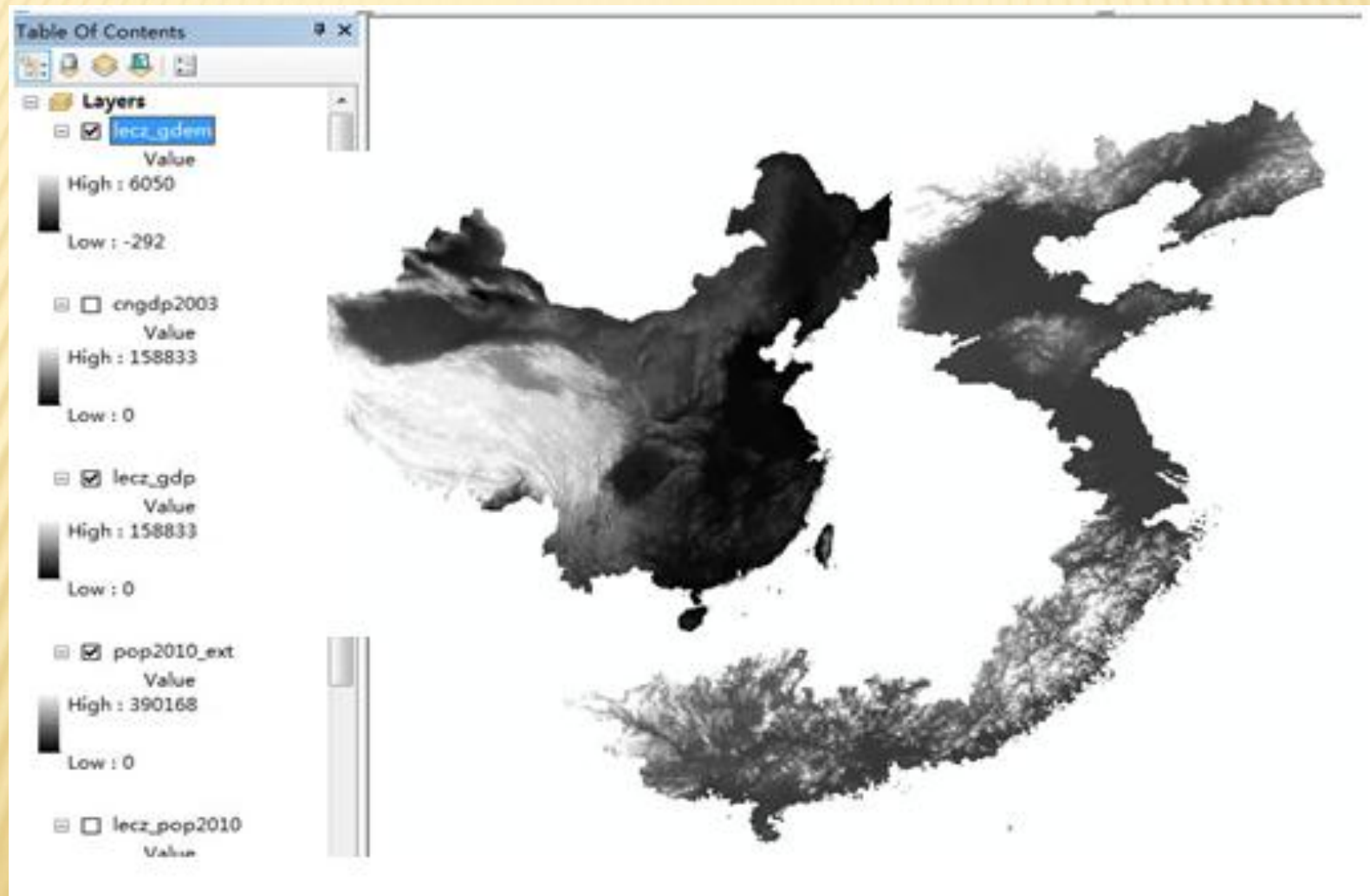
LOW ELEVATION COASTAL ZONE IN EAST CHINA

- ◆ Low elevation coastal zone (LECZ) or coastal low-lying area, is defined as the contiguous area along the coast which is normally less than 10 metres above sea level.
- ◆ Low elevation coastal zone is a place where natural disasters and environmental hot spots are located disproportionately
- ◆ Storm surge is one of the main disasters impact on east China coastal zone every year, because that storm surge can be strengthened by tropical cyclone and lunar high tide in summer time.

PURPOSE

- ◆ Low elevation coastal zone extraction (Elevation<10m)
- ◆ Exposure analysis of population and GDP in LECZ area
- ◆ Estimation of tide height in LECZ area, and inundation based on scenario
- ◆ Return period calculation of storm surge area, and new RP based on scenario
- ◆ Adaptation assessment and model
- ◆ Vulnerability of population and GDP in LECZ area

RESEARCH AREA



DATA RESOURCE

- ◆ DEM data use Advanced Spaceborne Thermal Emission and Reflection radiometer Global Digital Elevation Model (ASTER GDEM), the horizontal resolution is 1 arc second (30m), output format is GeoTIFF, signed 16 bits. Data downloaded from <http://reverb.echo.nasa.gov/reverb/>.
- ◆ Population data download from <http://sedac.ciesin.columbia.edu/gpw/>, called Gridded Population of the World, version 3. Data format choose grid, resolution choose 2.5' and the year 2010.
- ◆ GDP File from <http://www.resdc.cn/newold/060106.asp>. The data is 1km Chinese national GDP grid file and the each grid stands for 1km/10000RMB.

DATA RESOURCE

- ◆ High tide data from <http://surge.srcc.lsu.edu/>, and the data conclude all over the world high tide records from 1886 until now. The data have longitude and latitude, time, tide height, county name and rank. Chinese have 62 tide records.
- ◆ Administrative division data is in a scale of 1:1 million (ESRI Shape file format). The data includes the province-level divisions such as provinces, municipalities, autonomous regions and special administrative regions, etc., as well as the county –level divisions.

DATA PRE-PROCESS

Pre-processing the download data and gets the research area

- ◆ 1. Matching each download patches together (ArcToolbox: mosaic to new raster).
- ◆ 2. Unify different layers projection (WGS_1984) to a standard geographic coordinate system and projection coordinate system in ArcMAP.

coordinates system use Krasovsky_1940_Albers

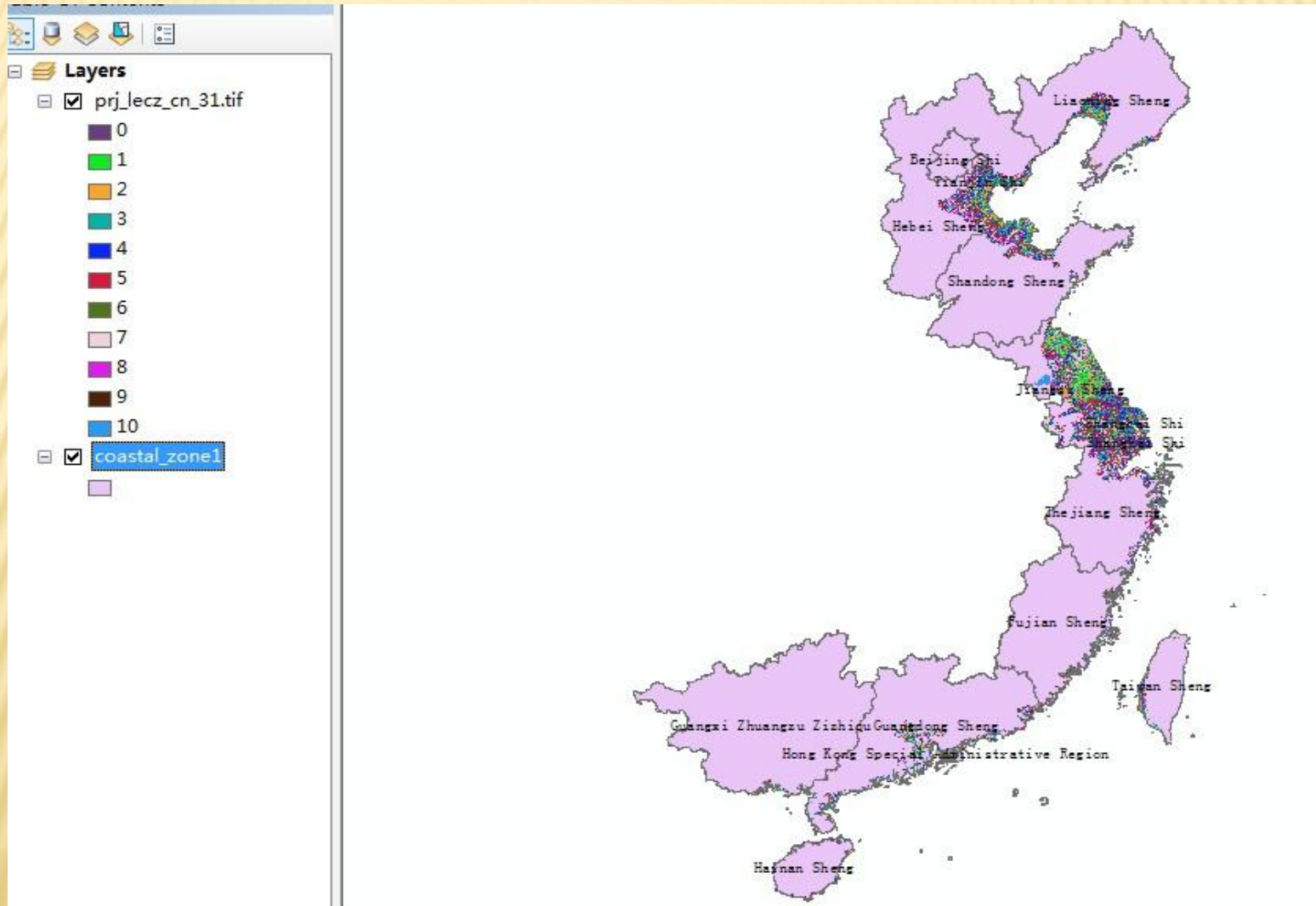
datum use D_Krasovsky_1940.

The converted data including DEM and Population, (Using Arctoolbox method Raster: Define Project).

DATA PRE-PROCESS

- ◆ 3. Clip population data, GDP, population and DEM data to research area: LECZ in east China (Using Arctoolbox method Extract by Mask.).
- ◆ 4. Data resample: population data and need to be resample to 1km resolution since the original resolution is 2.5×2.5 arc minutes, which is too coarse to apply to the smaller patches in this study.
- ◆ 5. Using con function to extract research area: LECZ (elevation<10m). (Arctoolbox: Conditional: Con. The sentences is Con ("demvalue" <= 10 ,"demvalue") .

RESEARCH AREA MAP



METHODOLOGY

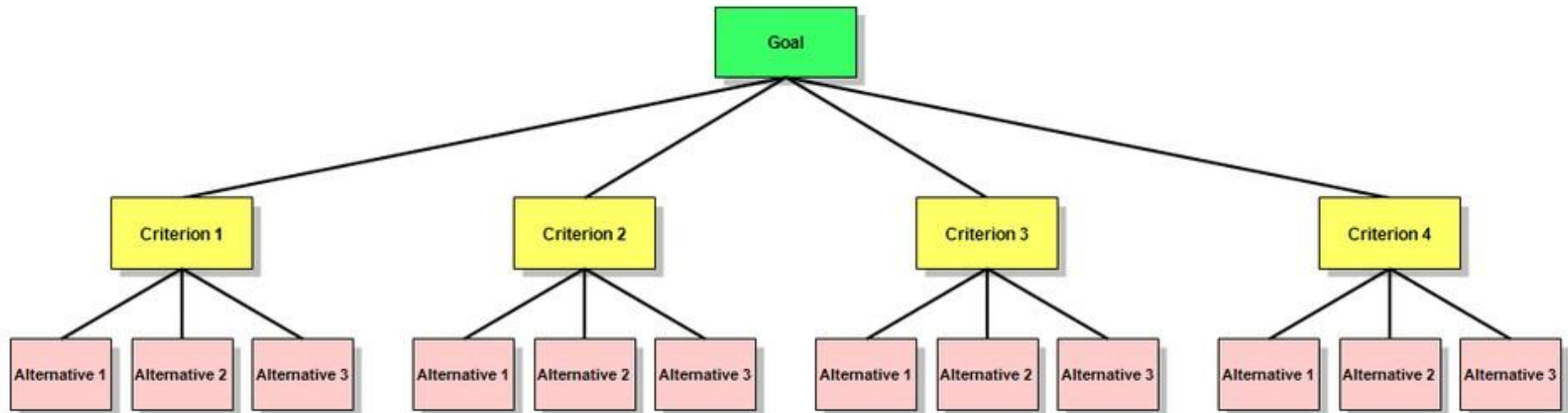
- ◆ 1. Create tide height shape file by importing the .xls form to Arcmap, adding XY data, and then exporting shape file layer.
- ◆ 2. Using Zonal Statistics function to calculate and analyze population distribution and GDP distribution of LECZ area.
- ◆ 3. Classify the tide height data, order the tide frequency and calculate the return period of the storm surge. ($p = m / (n + 1) \times 100\%$, p is return period, m is the rank of total number, n is total number).

METHODOLOGY

- ◆ 4. Animate the inundated area of 0.25m, 0.5m, 1m sea-level rise: using conditional function: $\text{Con} ("demvalue", "demvalue" + \text{high tide} - \text{surface subsidence})$ to animate the inundated area. And recalculate new return period by 25cm, 50cm, and 100cm sea level rising.
- ◆ 5. Choose reasonable indices (population age, gender, production of agriculture, etc.) to quantify the vulnerability of population and GDP. Analyze the vulnerability when facing all kind of scenarios based on storm surge return period.
- ◆ 6. Find out factors of each adaptation strategies, then weighted those factors by reliable information.

METHODOLOGY

- ◆ 7. Using **Analytic Hierarchy Process** and **Expert Decision** to weighted each of the factors.



A simple AHP hierarchy. There are three Alternatives for reaching the Goal, and four Criteria to be used in deciding among them.



METHODOLOGY

- ◆ 8. Evaluate all the factors by integrating them together. The conceptual method could be: **Vulnerability = Vul – Adaptation_Strategy** (Vul is the vulnerability without considering adaptation and the value varies from (0- 1), adaptation strategy have 2 option (the value of each one is from 0 to 1)). Then map out the vulnerability distribution based on different strategies and sea level rise scenarios.
- ◆ **Vul** can be calculated by the equation:
Pi stand for the value of indices i
Wi stand for the weight of indices i

$$V = \sum_{i=1}^n P_i \cdot W_i$$

HOW TO WEIGHT

- ◆ 1. Use AHP to decide a conceptual hierarchy

| First Hierarchy | Weight | Second Hierarchy | Weight |
|-----------------|--------|---------------------------|--------|
| Population (A) | 0.5 | Doctor Number Per 100 POP | A1 |
| | | Percentage of Age<10 | A2 |
| | | Percentage of Age>60 | A3 |
| | | Percentage of Gender | A4 |
| GDP (B) | 0.5 | GDP Per Capita | B1 |
| | | GDP Density | B2 |
| | | Percentage of Agriculture | B3 |
| | | Percentage of Industry | B4 |

- ◆ 2. Create a judge matrix

| A_k | B_1 | B_2 | B_3 | | B_N |
|-------|----------|----------|----------|-------|----------|
| B_1 | b_{11} | b_{12} | b_{13} | | b_{1n} |
| B_2 | b_{21} | b_{22} | b_{23} | | b_{2n} |
| B_3 | b_{31} | b_{32} | b_{33} | | b_{3n} |
| | | | | | |
| B_N | b_{n1} | b_{n2} | b_{n3} | | b_{nn} |

HOW TO WEIGHT

- ◆ 3. Calculate low- hierarchy weight (w is feature vector)

$$AW = \lambda \max W_i$$

- ◆ 4. Calculate Total – hierarchy weight

$$W_{xi} = W_x \times W_{x-xi};$$

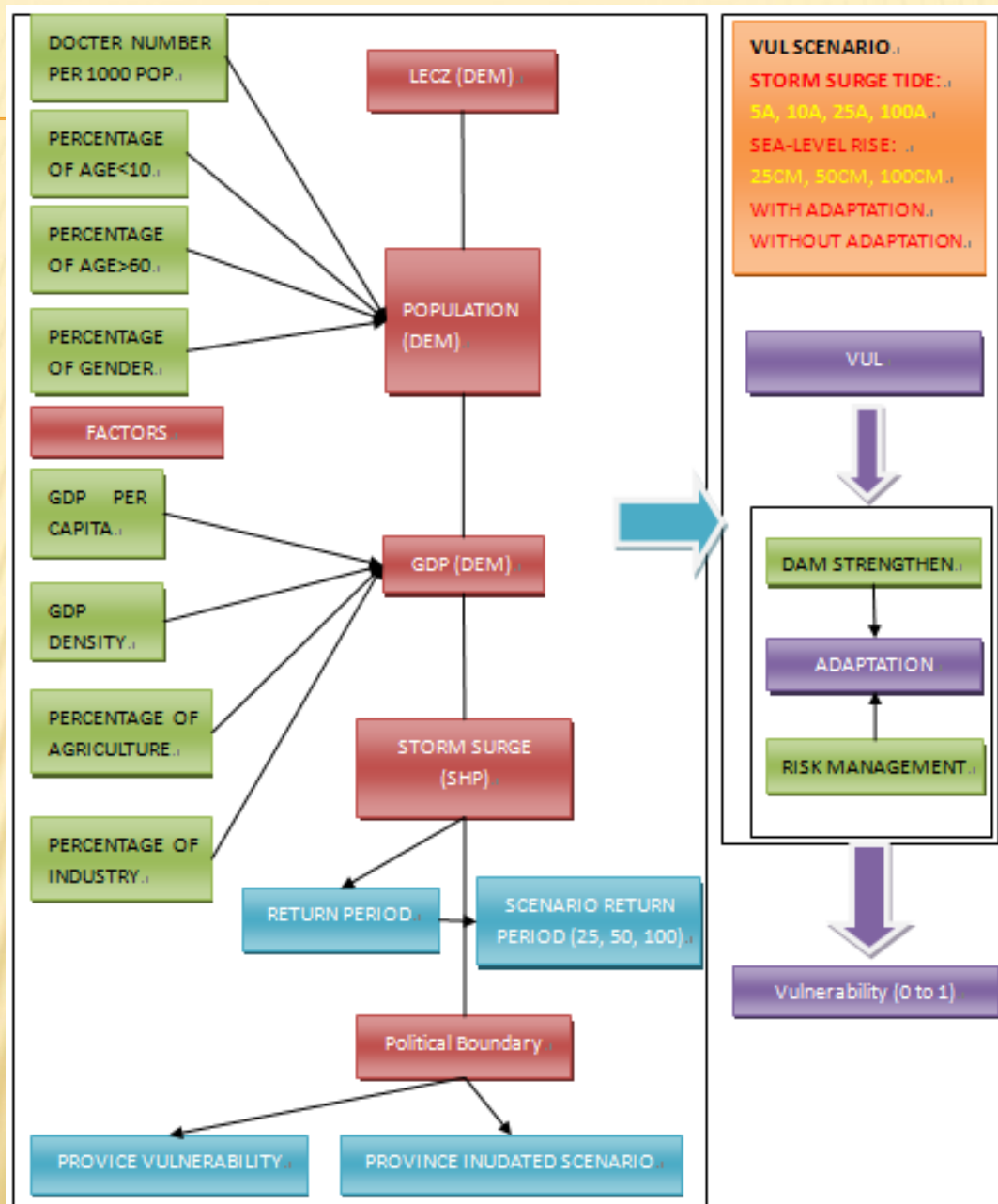
- ◆ 5. Consistency test

$$CI = \frac{\sum_{j=1}^m W_{aj} CI_j}{\sum_{j=1}^m W_{aj} RI_j}$$

$$RI = \frac{\sum_{j=1}^m W_{aj} RI_j}{\sum_{j=1}^m W_{aj} RI_j}$$

$$CR = \frac{CI}{RI}$$

$$CR = \frac{CI}{RI} < 0.1$$



RESULT

- ◆ 1. The study map out the research area of LECZ in east China already.
- ◆ 2. The study can analyze the distribution of GDP and Population.
- ◆ 3. The study would calculate the storm surge return period and recalculate them based on sea level rise 25cm, 50cm, 100cm.
- ◆ 4. The study would map out the inundated area based on 3 sea level rise scenarios.
- ◆ 5. The study would calculate the vulnerability of population and GDP facing storm surge of each counties and cities with different strategies in the research area based on 3 sea-level rise scenarios.

THANK YOU