Adaptation capacity of coastal disasters due to climate change to strengthen northwest area of Taiwan

Tai-Wen Hsu

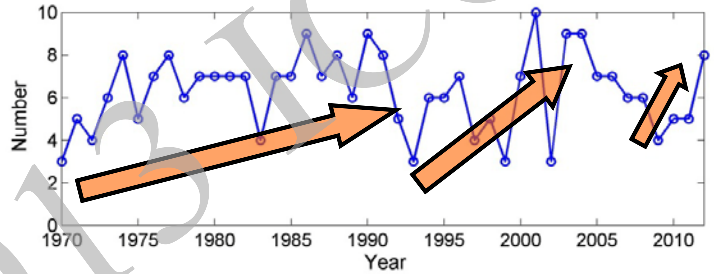
Distinguished Professor

Department of Harbor and River Engineering
National Taiwan Ocean University

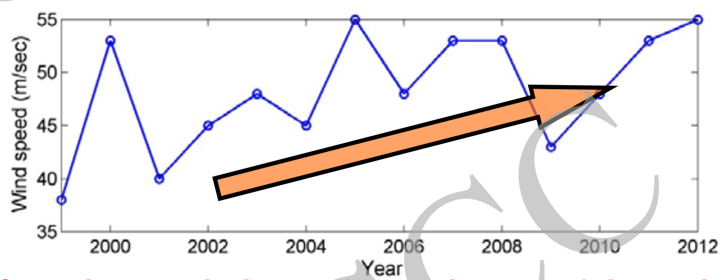
2013氣候變遷國際研討會暨成果發表會
2013 International Conference on Climate Change
Taipei, Taiwan, January 15-16, 2013

Introduction

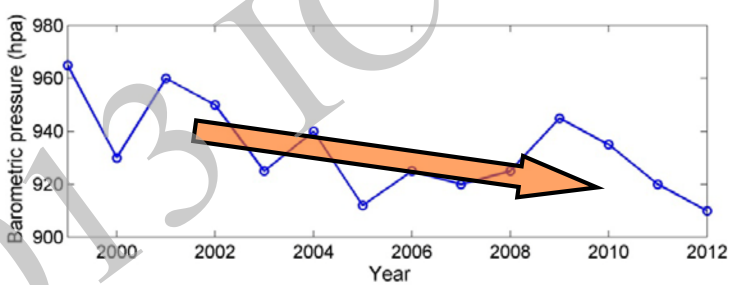
- **Changes of typhoon characteristics due to climate change**



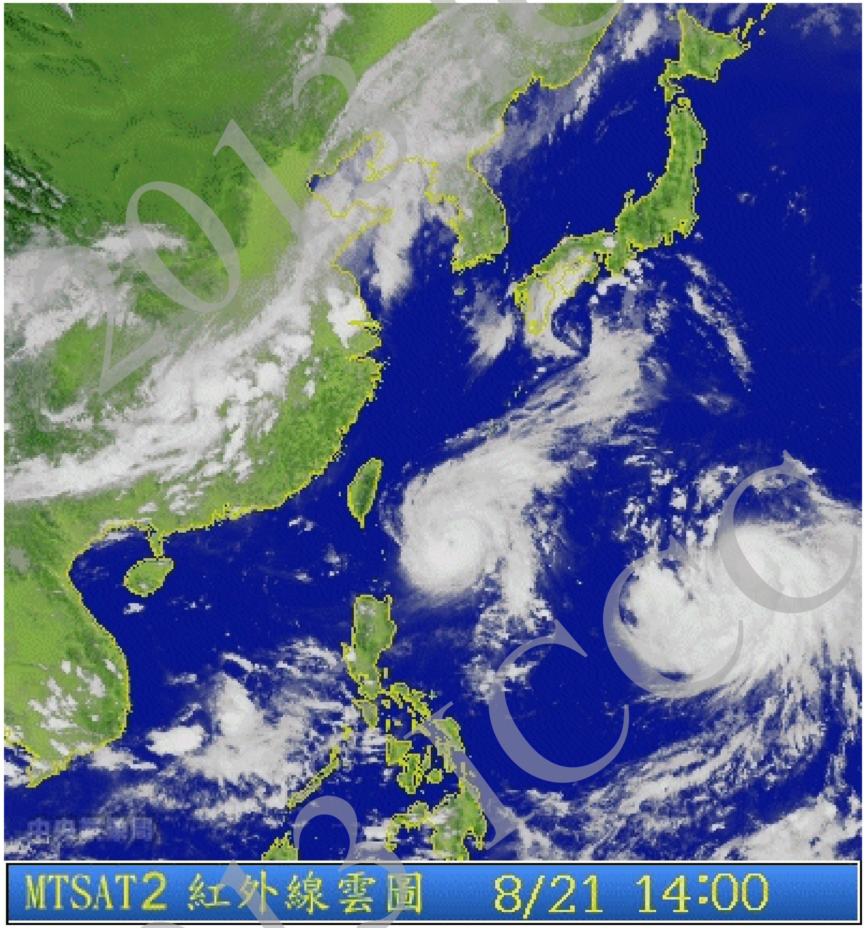
The frequency of typhoons hitting Taiwan over the past 43 years (1970 ~ 2012)



Annual maximum wind speed near the eye of the typhoon increases in the past 14 years (1999 ~ 2012)



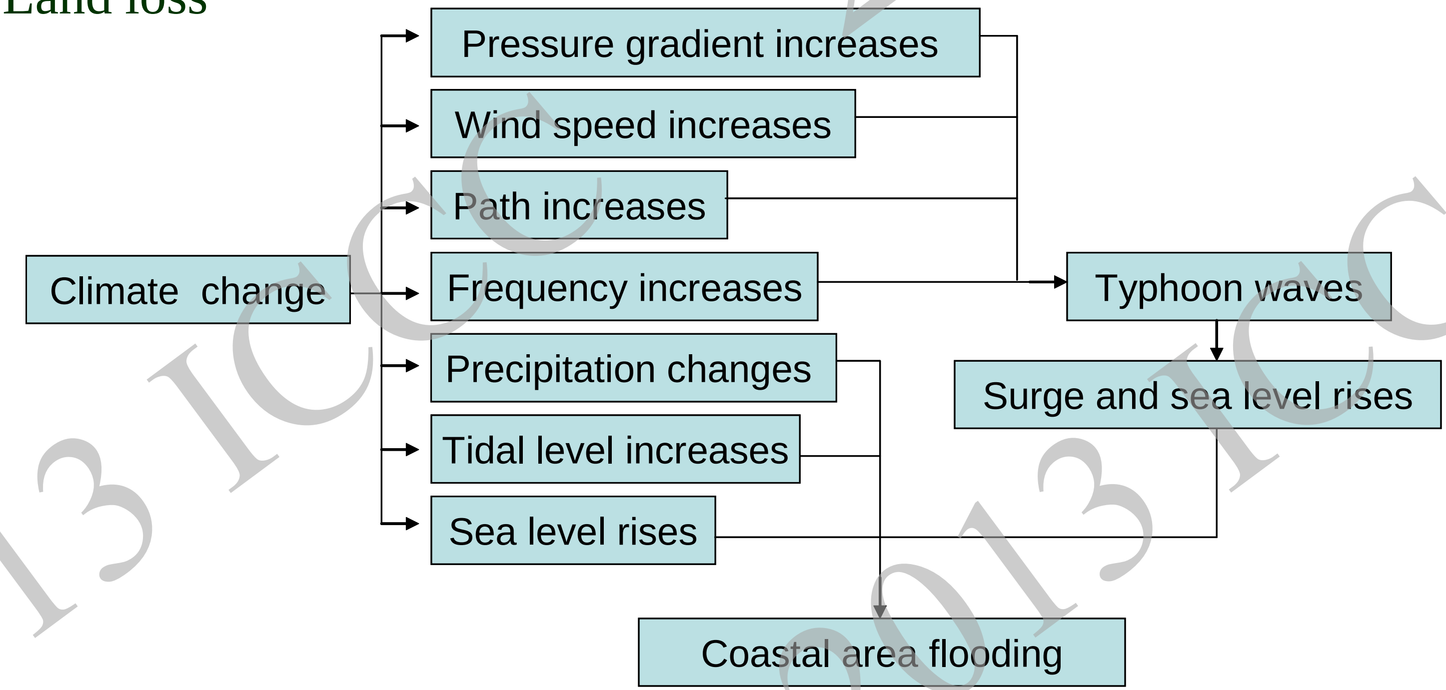
Annual minimum pressure of typhoon decreases in the past 14 years (1999 ~ 2012).



The typhoons of Tembin (the left side) and Bolaven (2012)

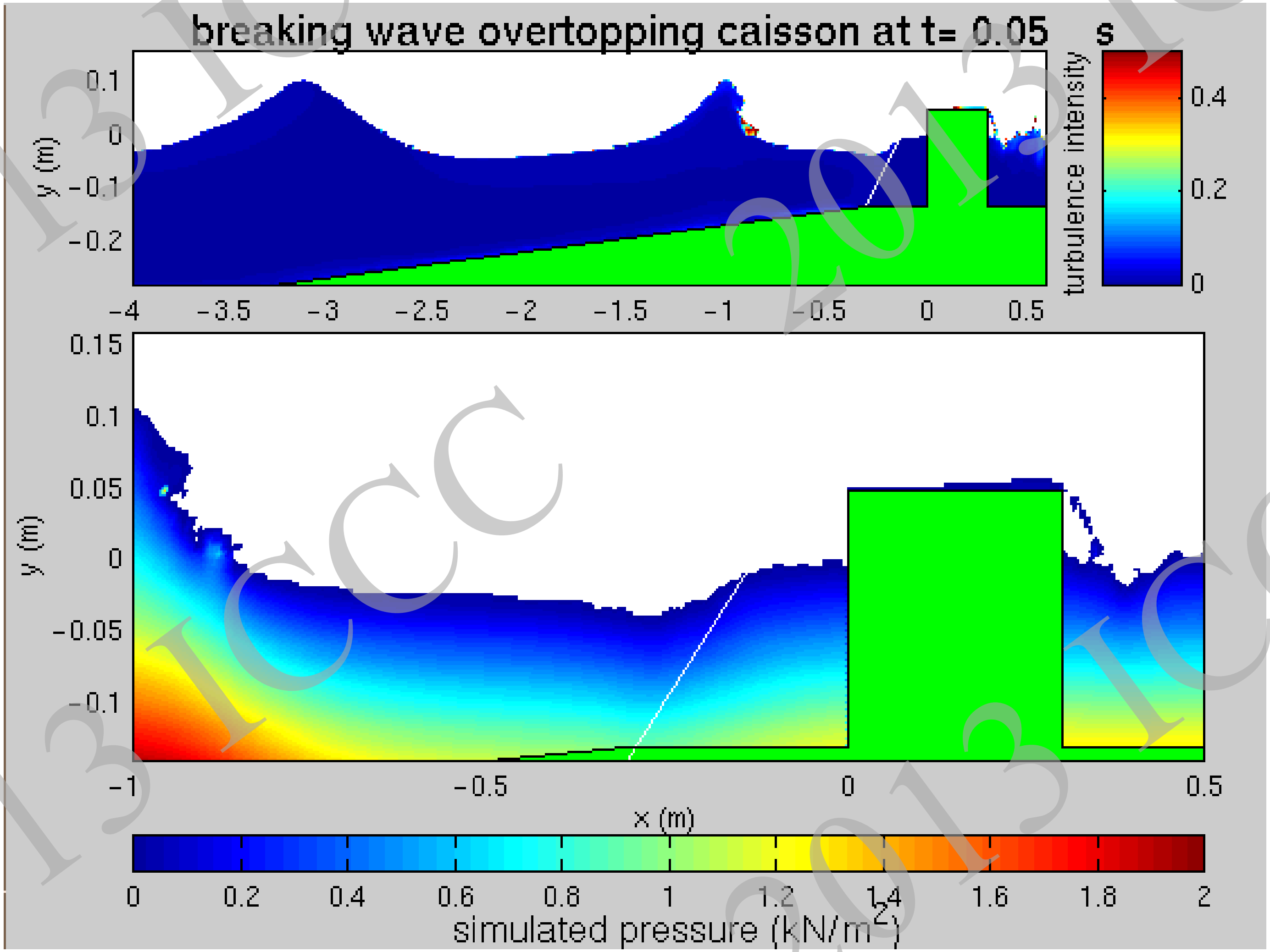
Introduction

- **The Impact of climate change on coastal areas**
  1. Wave breaking line migrates shoreward
  2. The increase of probability of wave overtopping
  3. Flooding area becomes larger
  4. Land loss



Introduction

➤ **Sea level rise – typical example of wave overtopping**

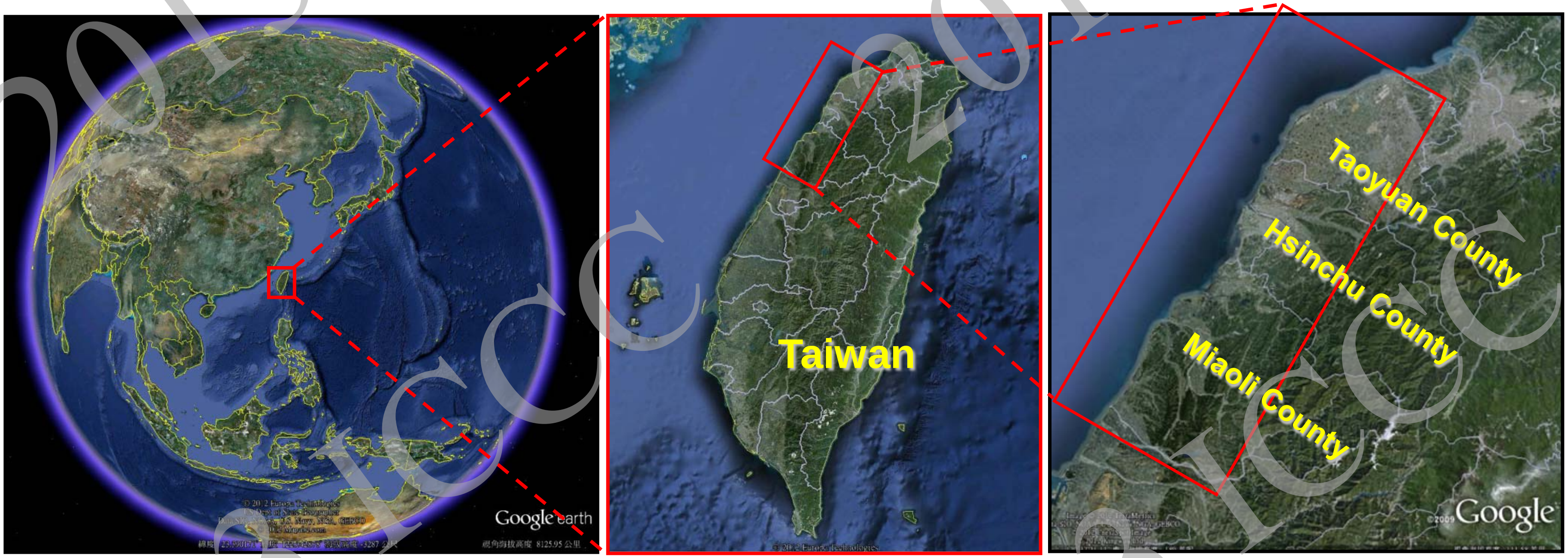


Purposes

1. Construction of the disaster warning system on Miaoli, Hsinchu and Taoyuan Coasts in Taiwan
2. Model development for scenario analysis of environmental factors
3. Impact assessment and indefinite analysis on disasters, and vulnerability and risk estimation on coastal disasters

Location

➢ **The location of the southwest area (Miaoli, Hsinchu and Taoyuan Coasts) in Taiwan**



Coastal Vulnerability and Risk Assessment

■ Definition of Vulnerability and Risk and Their Operating Model

◆ Vulnerability

- ►Consisting of exposure, sensitivity and adaptation

◆Level of risk

- ►Including vulnerability and hazard analysis
- ►In addition to the physical aspects of the problem, the economic, social and environmental problems are also considered
- ►*Risk* = *V* (*vulnerability*) × *H* (*hazard*)

Coastal Vulnerability Relative Research

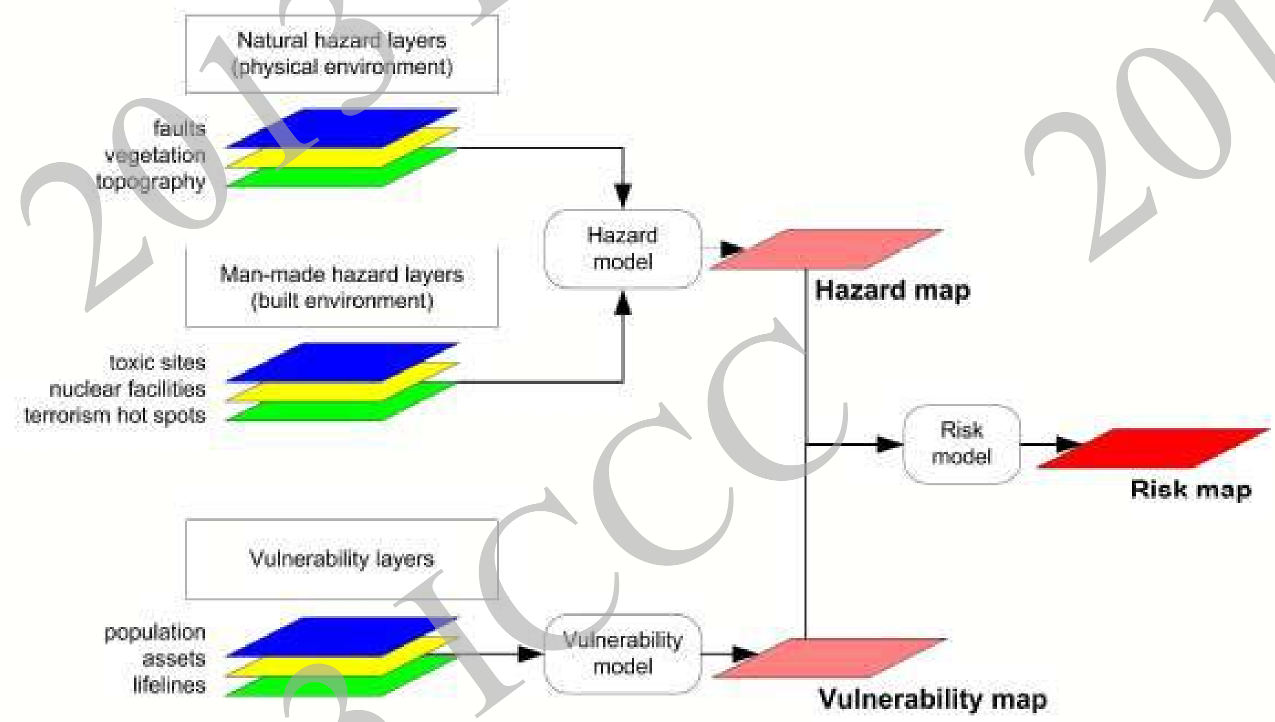
- United States Geological Survey（USGS）adopted coastal vulnerability assessment, which was proposed by Thieler and Hammar-Klose(1999), to analyze the influence of United States coastal line caused by sea level rises。
- There are six variables involved in the assessment : topography, shoreline change, coastal slope, relative sea level changes, significant wave height and tidal range.
- CVI's Formula：

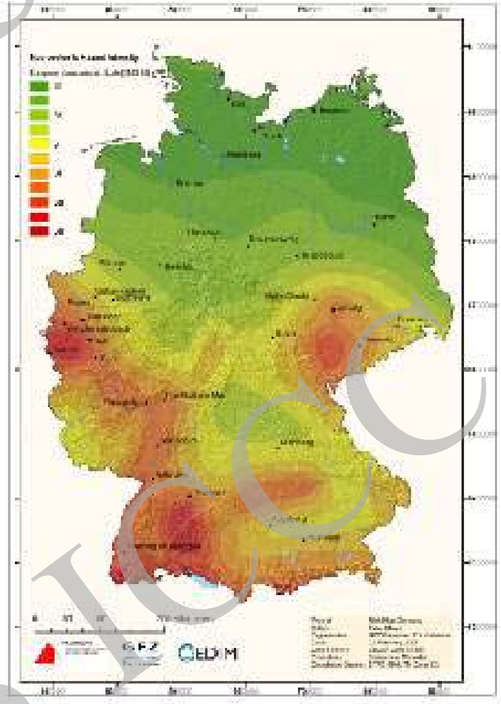
$$\text{CVI} = \sqrt{\frac{a \times b \times c \times d \times e \times f}{6}}$$

a= topography ，b= shoreline change ，c=coastal slope ，d=relative sea level changes ，e=mean significant wave height ，f=mean tidal range 。

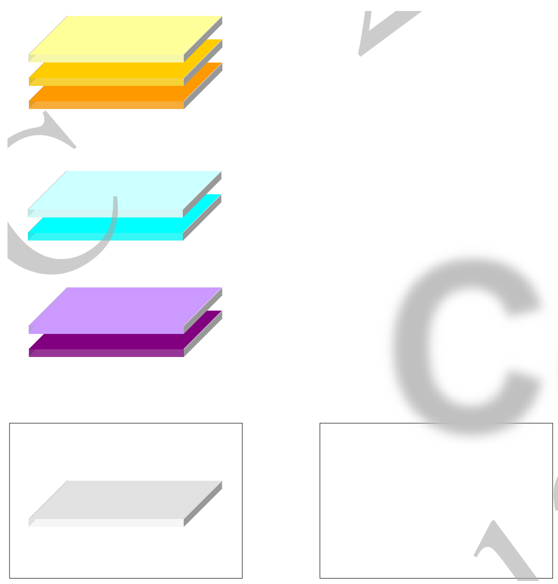
Coastal Vulnerability and Risk Assessment

➤ **Using CEDIM method to create vulnerability and risk maps**





CEDIM's risk map designation process (Muller et al., 2006)



Results

AHP Evaluation on the Index Weighting of Vulnerability Analysis In Northwest Coastal Area of Taiwan

Level	Domain	Weighting	Index	Weighting
Vulnerability	Artificial Facilities	0.328	Relative ratio of seawall length	0.257
			Relative ratio of seawall height	0.499
			Relative ratio of tidal gate	0.244
	Environmental Geography	0.548	Elevation	0.139
			Slope	0.098
			Tidal range	0.086
			Rate of land subsidence	0.226
			Rate of coastal erosion	0.359
			Land use	0.093
	Socioeconomic	0.125	Population density	0.415
			The relative value of education	0.223
			The rate for giving support to the elder	0.166
			Enterprise return	0.196

PS：Consistency Ratio (CR) = 0.02 < 0.1

Coastal Hazard Index

AHP Evaluation on the Index Weighting of Hazard Analysis In Northwest Coastal Area of Taiwan

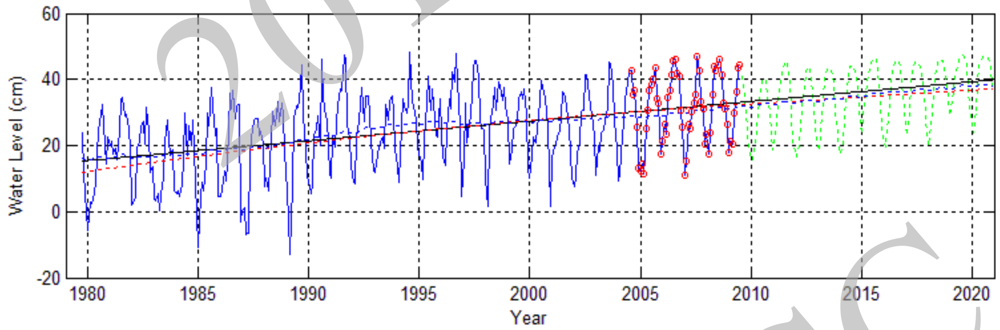
Level	Index	Weighting
Hazard Potential	Deluge flood area	0.384
	Deluge flood depth	0.271
	Surge flood area	0.159
	Surge flood depth	0.186

PS：Consistency Ratio (CR) = 0.02 < 0.1

Results - The estimation of sea level trends

◻ Methods of the estimate

1. **Regression analysis**
2. **Fourier series decomposition**
3. **EEMD method**
4. **Artificial Neural Network**
5. **Satellite data analysis**



The analysis of sea level in southwest coast of Taiwan

Results - The estimation of sea level trends

- **In 2039, the prediction of mean sea level rise in northwest coast of Taiwan**

Unit: cm

Tidal Station	Base Period	Regression	FFT	EEMD*	Average
*Jhuwei[1]	**1976-1991**	17.22	3.91	10.11	10.41
*Jhuwei[2]	**1992-2011**	21.81	6.31	17.97	15.36
*Hsinchu	**1992-2011**	11.23	4.76	11.31	9.10
Taichung Harbor	**1980-1999**	**11.82**	**4.02**	**6.76**	**7.53**
Taichung Harbor	**1972-2009**	**7.21**	**6.33**	**1.66**	**5.07**

* The data periods of Jhuwei and Hsinchu tidal stations do not match the base period (1980-1999).

* Jhuwei tidal station was replaced the location in 1992.

Results - The estimation of sea level trends

- In 2039, the prediction of mean sea level rise in northwest coast of Taiwan (by Satellite data)

Unit: cm

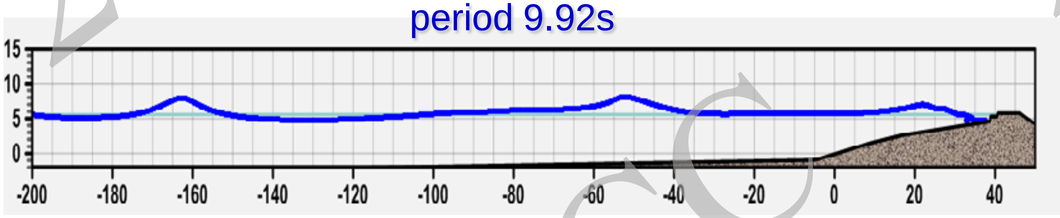
Area	Base Period	Longitude and Latitude	Regression	FFT	EEMD	Average
Miaoli, Hsinchu and Taoyuan	1992 | 2009	(121.25˚, 25.5˚)	6.01	4.17	6.51	5.56
		(121.25˚, 25.25˚)	5.98	3.95	4.83	4.92
		(121.00˚, 25.25˚)	5.89	4.25	5.15	5.10
		(120.75˚之, 25.00˚)	5.81	3.7	6.01	5.18
		Average	**5.92**	**4.02**	**5.62**	**5.19**

Results - The environmental factor of run-up and over-topping analysis in northwest coast

- **The wave run-up model simulates the wave form evolution with sea level rise from 2020 to 2039 when the 250-years return period typhoon wave attacks the northwest coast.**

Xiangshan Dist., Hsinchu City

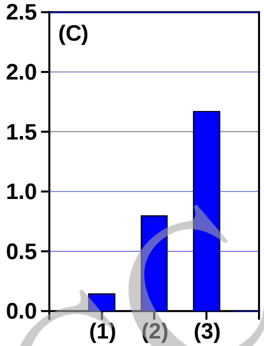
Scenario years (2020~2039): Sea level rise 7.53cm
250-yesrs return period: Tide level 4.02m,
Deep wave height 7.86m,
period 9.92s



Average quantity of overtopping (Q)

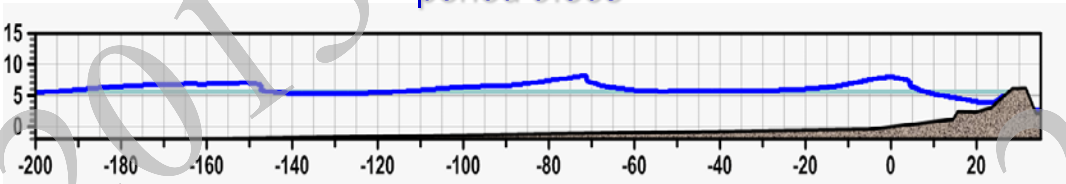
Scenario years (2020~2039)

(1) 50-yesrs return period
(2) 150-years return period
(3) 250-years return period



Dayuan Township, Taoyuan County

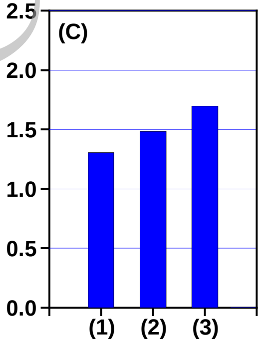
Scenario year (2020~2039): Sea level rise 7.53cm
250-yesrs return period: Tide level 4.21m,
Deep wave height 7.97m,
period 9.86s



Average quantity of overtopping (Q)

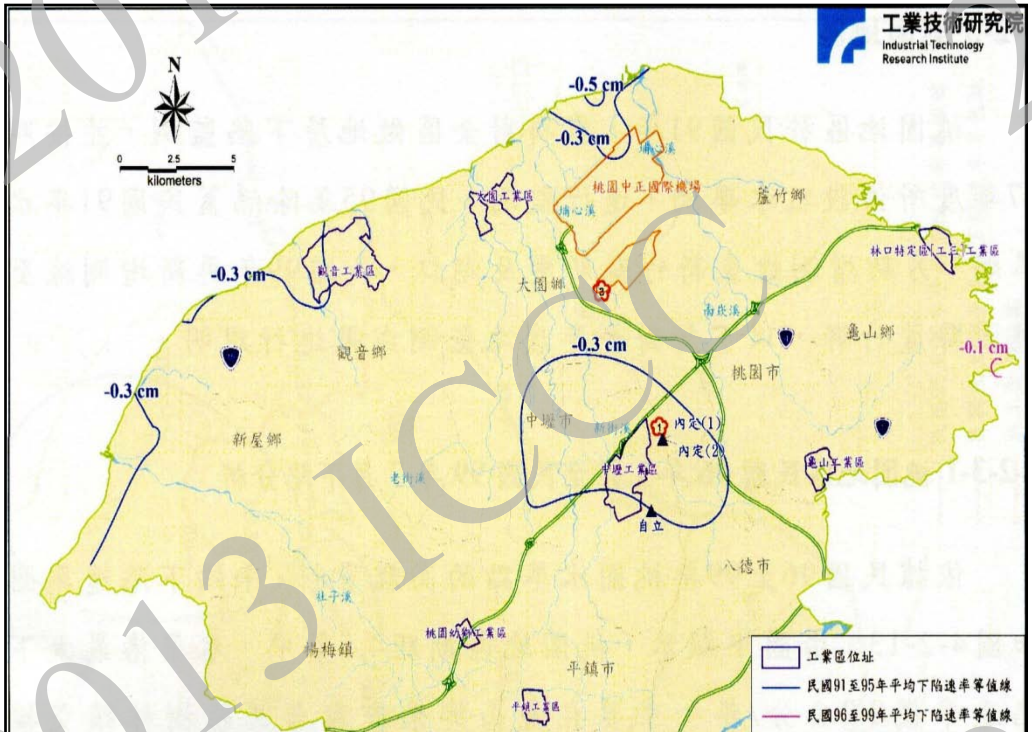
Scenario years (2020~2039)

(1) 50-yesrs return period
(2) 150-years return period
(3) 250-years return period

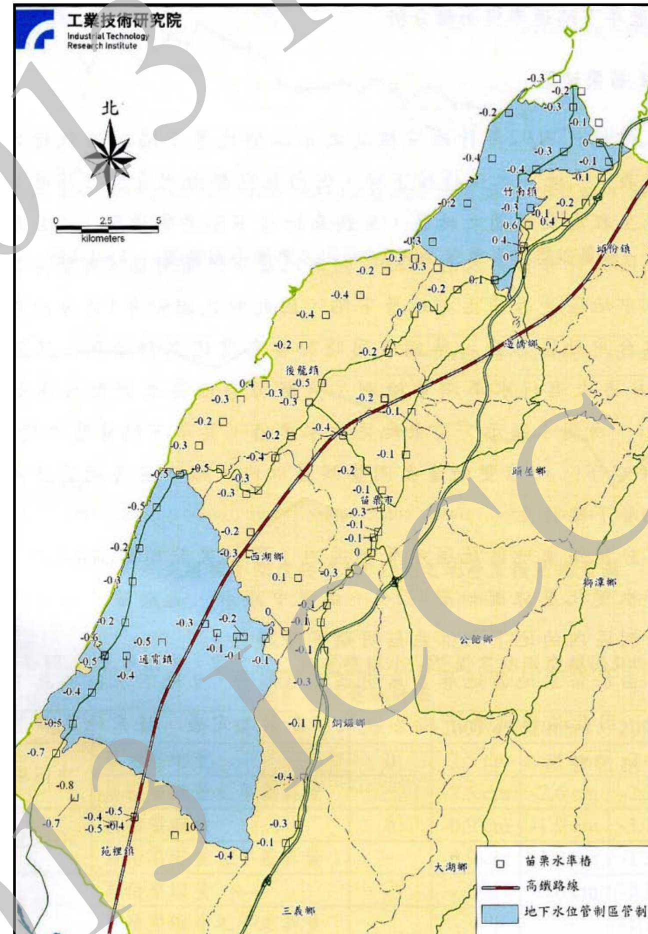


Results - Subsidence Area

- **Subsidence Area**
  - There are no severe subsidence area in Taoyuan, Hsinchu and Miaoli
  - In the subsidence areas of Taoyuan, the situation is stabilized



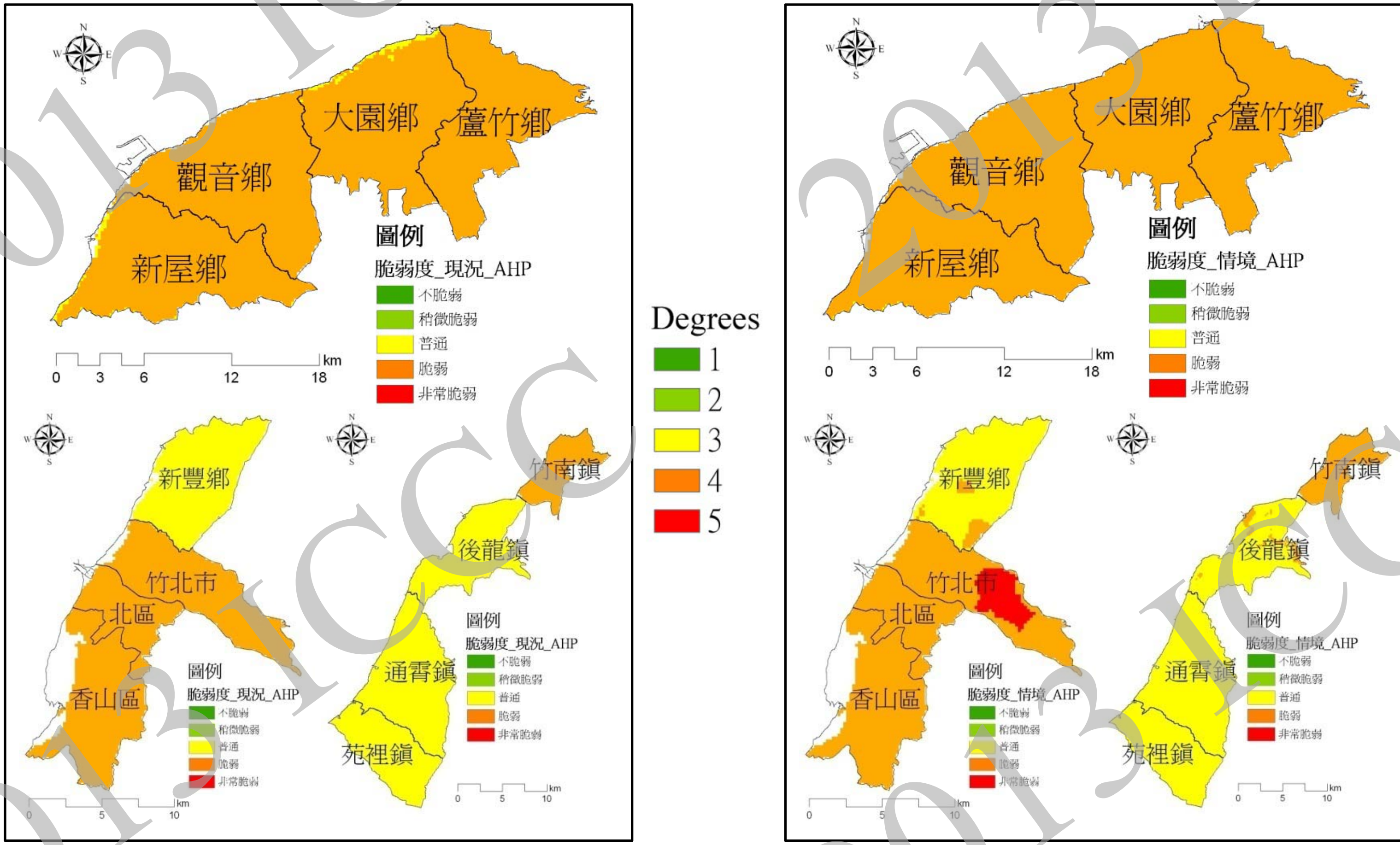
Taoyuan, form 2002 to 2006 and from 2007 to 2010



Miaoli, form 2007 to 2009

Results – Vulnerability Analysis

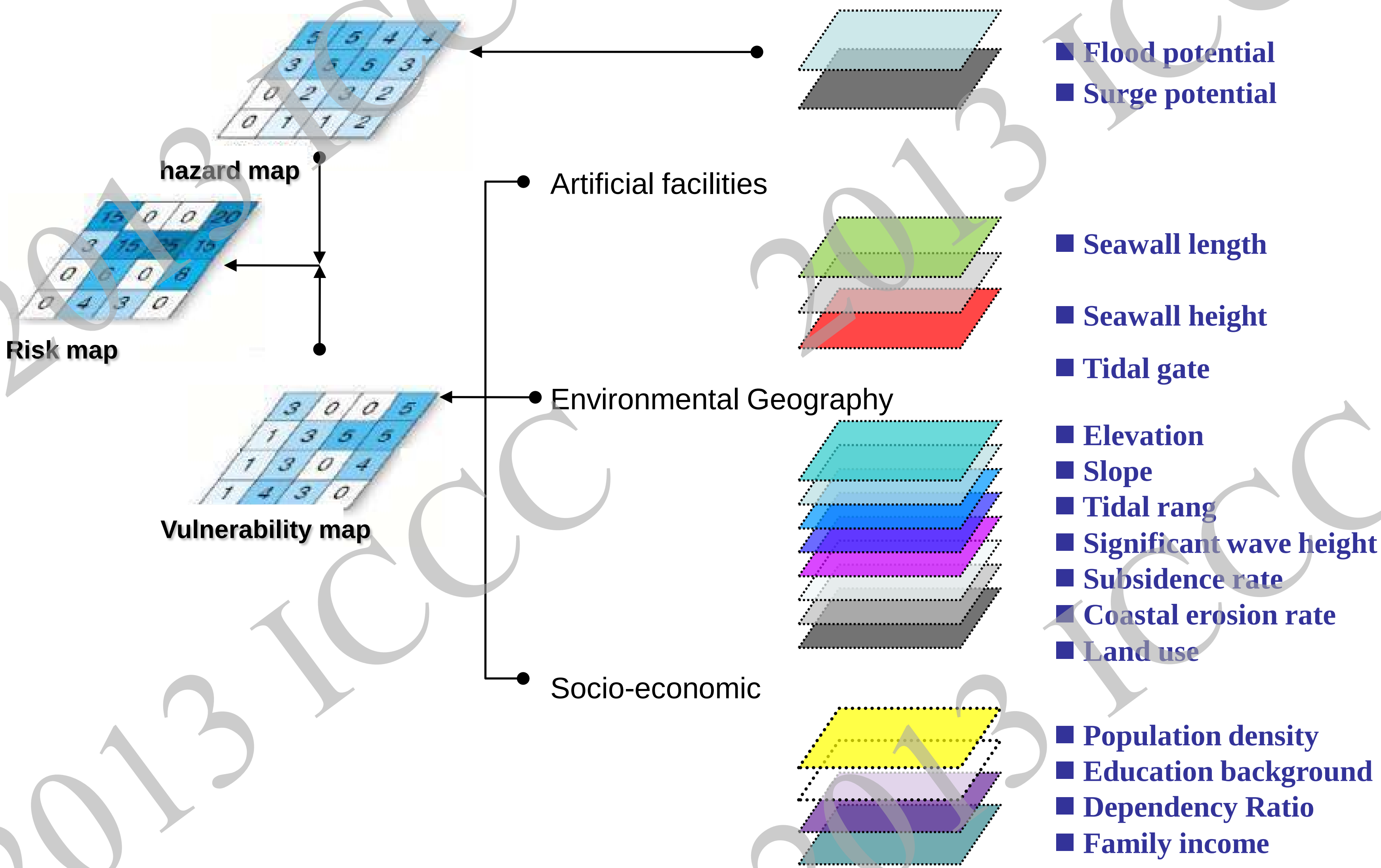
- **The result of vulnerability analysis of Miaoli, Hsinchu and Taoyuan coastal area - (AHP weighting)**



(a) Present & AHP weighting

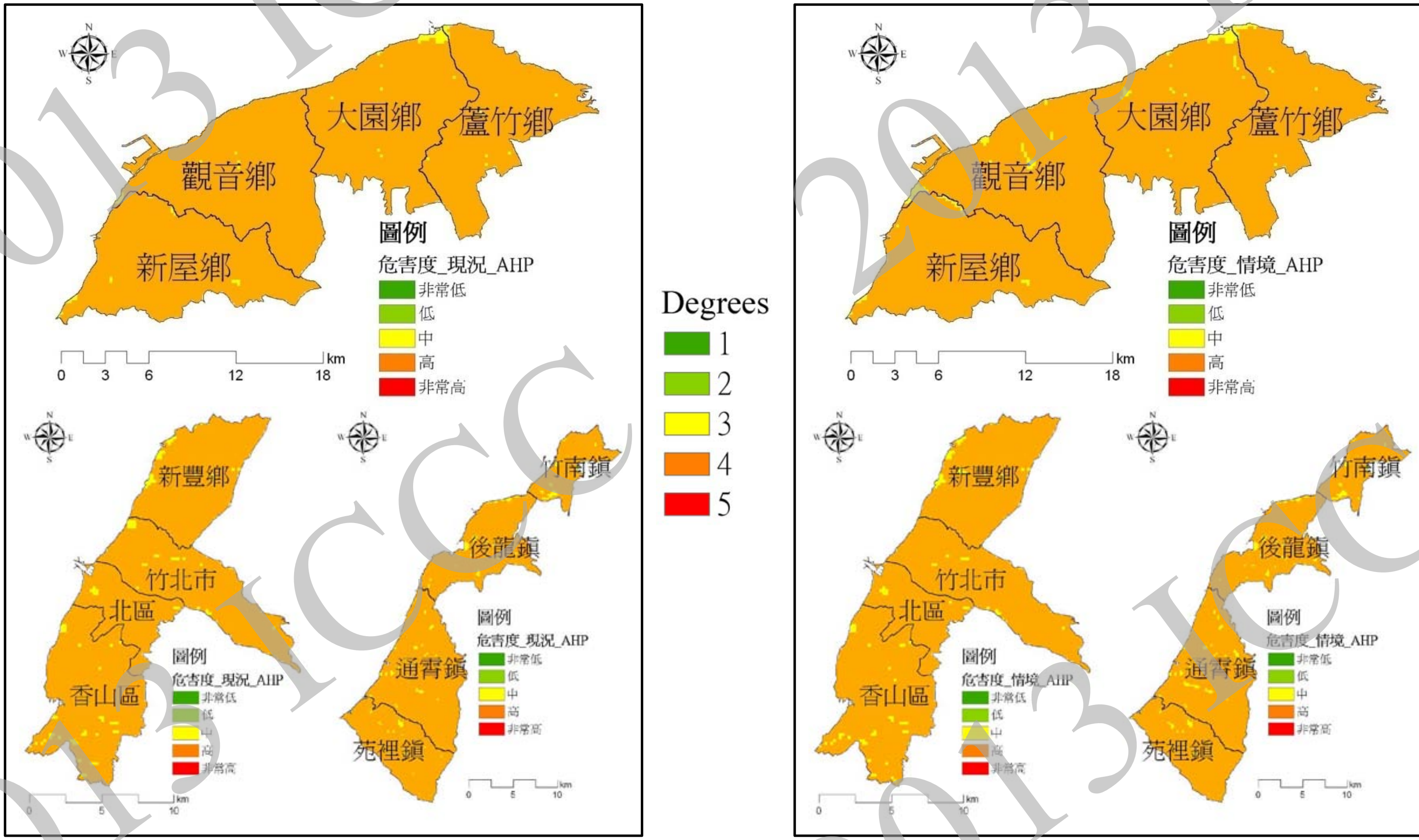
(b) Scenario & AHP weighting

Coast Disaster Risk Assessment



Results - The risk assessment of coastal disaster because of climate change

- Hazard factor - (AHP weighting)

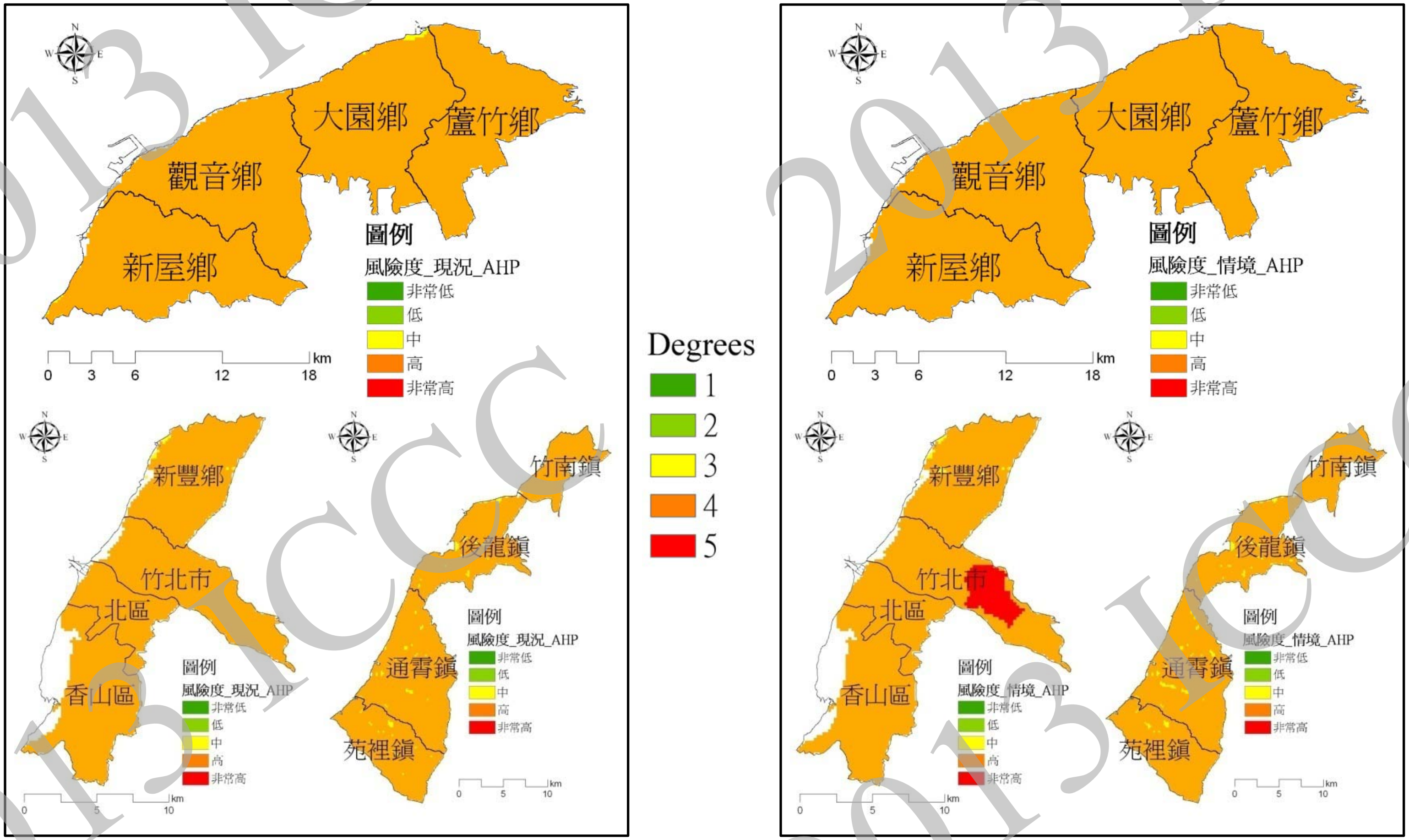


(a) Present & AHP weighting

(b) Scenario & AHP weighting

Results - The risk assessment of coastal disaster because of climate change

- The risk map of coastal disaster - (AHP weighting)



(a) Present & AHP weighting (b) Scenario & AHP weighting

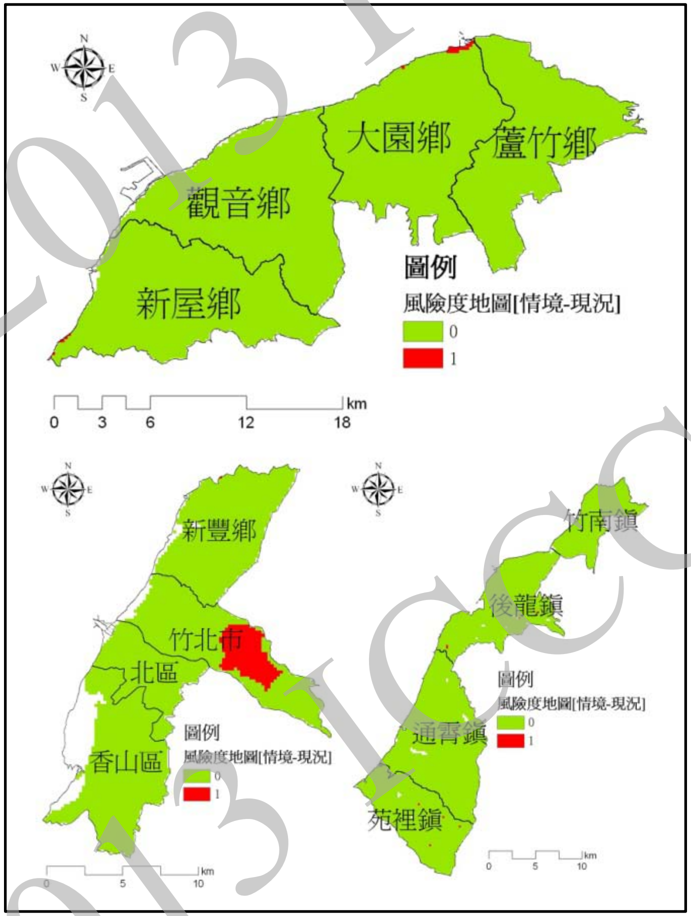
Results - The risk assessment of coastal disaster because of climate change

- The risk map of coastal disaster

Area difference analysis of present coastal disaster risk and scenario year (2039)

Degree	Area difference (scenario – present) (km^2)
1	0
2	0
3	0.52
4	-10.64
5	10.12

Risk Degree: 1 - very low, 2 – low, 3 - medium, 4 – high, 5 – very high.



The analysis result of difference between the present and the scenario

Results - The risk assessment of coastal disaster because of climate change

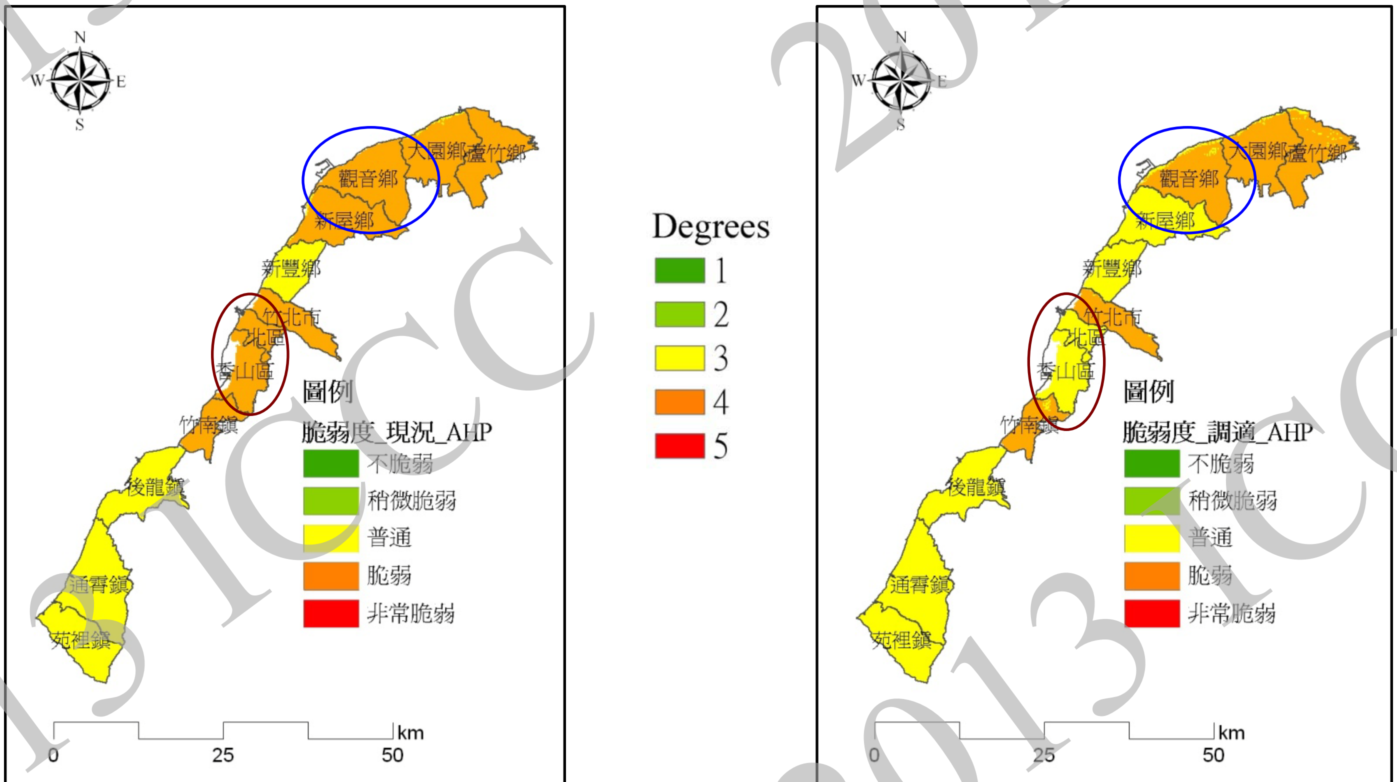
- Assessment of coastal vulnerability and disaster risk (scenario)

Region		Vulnerability	Hazard Factor	Disaster Risk
		Scenario (AHP)	Scenario (AHP)	Scenario (AHP)
Miaoli County	Yuanli Township	3	3, 4	3, 4
	Tongxiao Township	3	3, 4	3, 4
	Houlong Township	3, 4	3, 4	3, 4
	Zhunan Township	4	3, 4	4
Hsinchu City	Xiangshan Dist.	4	3, 4	4
	North Dist.	4	3, 4	4
Hsinchu County	Zhubei City	4, 5	3, 4	4, 5
	Xinfeng Township	3, 4	3, 4	3, 4
Taoyuan County	Xinwu Township	3, 4	3, 4	4
	Guanyin Township	4	3, 4	4
	Dayuan Township	4	3, 4	4
	Luzhu Township	4	3, 4	4

Degree: 1 - very low, 2 – low, 3 - medium, 4 – high, 5 – very high.

Results - Vulnerability Analysis - Consider adaptive strategies

- Adaptive strategies— Increase the seawall to 6 meters in height; reduce the erosion rate (60% reduction)
  - A decrease of one level: Xinwu Township in Taoyuan and North and Xiangshan Dist. in Hsinchu



Vulnerability (present & AHP weighting)

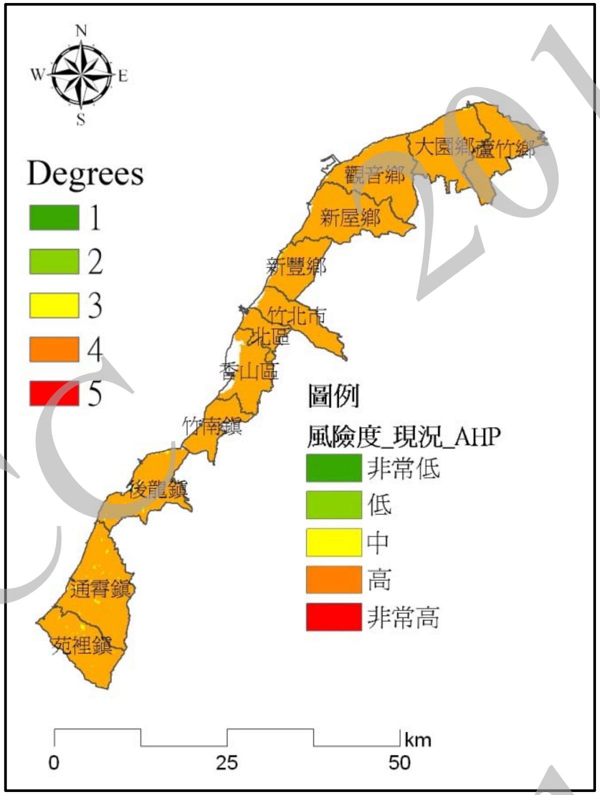
Vulnerability (adaptation & AHP weighting)

Results - Risk assessment - Consider adaptive strategies

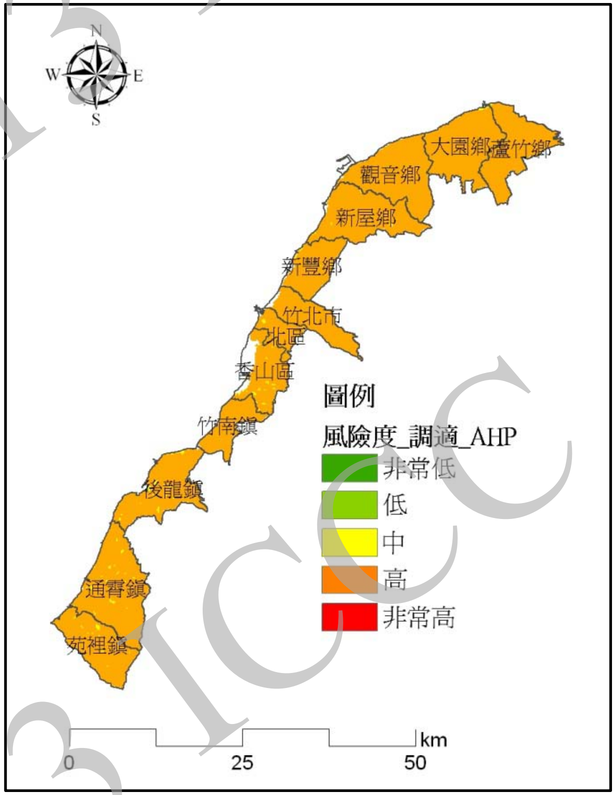
- The risk map of coastal disaster
  - — Consider Adaptive strategies

Area difference analysis of present coastal disaster risk with/without adaptive strategies

Degree	Area difference (adaptation / present) (km^2)
1	0
2	0
3	2.20
4	-2.20
5	0



Risk (present & AHP weighting)



Risk (adaptation & AHP weighting)

Risk Degree: 1 - very low, 2 – low, 3 - medium, 4 – high, 5 – very high.

Conclusions

1. In respect to the trend estimation of sea level rise, Three different numerical methods were used to analyze the change of sea level rise in northwest coastal area of Taiwan. The result shows that the sea level rises are in the range of 4.02 to 11.82 cm from 2020 to 2039.
2. For the vulnerability of coastal hazard under climate change and risk assessment, this project studies on the economic lost of coastal area hazard, land use and the socioeconomic environmental investigation.

Conclusions

3. **Based on the present coastal environment and protective facilities in southwest areas of Taiwan, this paper proposes different options to deal with the impacts of future climate change:**

   1) ***Impacts from sea level rise.*** **(a) Improve the monitoring techniques and data quality. (b) Enhance the protective facilities. (c) Assess the possibility of resident evacuation.**

   2) ***Impacts from sea dikes safety.*** **(a) Based on the sea states estimation under different return periods, the safety of some dikes should be inadequate in the future. To increase the height of dike or to enhance the rubble mound could be improve the situation. (b) Assess the possibility of the second sea dike.**

Conclusions

3) ***Impacts from coastal flooding*.** **(a) Carry out the performance of "Regulation Project of Flood-prone Areas". (b) Improve the drainage system in coastal low-lying zones. Carry out the river dredge. (c) Arrange the pumping stations for the potential areas.**

4) ***Impacts from vulnerability of coastal zones*.** **(a) Carry out the performance of "Regulation Project of Flood-prone Areas". (b) Review the design criteria of embankment. (c) Enhance the emergency operation system.**

Conclusions

4. This project is lack of the sea meteorology data (typhoon wind field, typhoon wave, surge, sea level rise etc.) from such as NCDR etc.. The breaking wave and the wave are estimated by the available data. If NCDR can provide the data, we suggest to estimate again for the consistence.