

# CLIMATIC ADAPTATION OF COASTAL COMMUNITIES ON THE SOUTHWEST OF TAIWAN

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## ABSTRACT

Flooding is the most common and critical climatic disaster for coastal communities in Taiwan. This study applied an evaluation framework comprising five categories, namely “community competence,” “infrastructure stability,” “social-economic support,” “interior environmental capacity,” and “outdoor environment adaptability,” to six coastal communities of Tainan City, Taiwan, to evaluate their climatic adaptation. Having experienced multiple floods, all six communities performed relatively well in the infrastructure stability, but poorly in outdoor environment adaptability. In face-to-face interviews, interviewees reflected that the most vital sector affected by climate change is their fishing industry; however, the “industry” item was eliminated by experts during the implementation of the Fuzzy Delphi questionnaire. Therefore, beside the evaluation framework of community climatic adaptation, another contribution of this study is the execution of the interviews to reduce the inconsistency between real life situations and academic development.

## I. INTRODUCTION

The current awareness of climate change extended from a conference convened by the World Meteorological Society, United Nations Environment Program (UNEP), and International Council for Science (ICSU) in Villach, Austria, in 1985 (WMO/ICSU/UNEP, 1985). The conference reported on the build-up of carbon dioxide and other greenhouse gases in the atmosphere and predicted global warming. The Intergovernmental Panel on Climate Change (IPCC) has published several

research papers on, and assessments of, the impact of global climate change and the adaptation of communities to it. Its 2013 publication, the Fifth Assessment Report (IPCC, 2013), indicated the increasing frequency of extreme climatic events, such as floods, droughts, and heat waves, and the increasing differences between dry and rainy seasons and between arid and moist regions (IPCC, 2013). Some of these climatic effects are already familiar in Taiwan.

Taiwan is an island country located on the northwest Pacific Ocean. Records of the Central Weather Bureau indicate that in the past ten decades, the temperature in Taiwan has increased by 0.8°C (Central Weather Bureau, 2015). From 1995 to 2015, the temperature in the most pleasant month of the year, May, has risen by 1.32°C. The amount of rainfall has become greater and more concentrated from June to August. People in Taiwan experience from floods and drought that are caused by this increase in temperature. To elucidate the adaptation of Taiwan’s communities to climate change, the current study used the index framework from an earlier work, but focused on the climatic adaptation of coastal communities; this is because many studies and predictive models have revealed that climatic disasters, such as tropical cyclones, rainfall, and surge flooding, are particularly intense in coastal areas (Knutson et al., 2010; Nicholls and Cazenave, 2010; DasGupta and Rajib, 2015).

The coastline of Taiwan is approximately 1,200 km long. A total of 881000 people live in 442 communities in coastal areas (Ministry of the Interior, Department of Statistics, 2015). Nearly 4% of Taiwan’s population is exposed to dangerous environmental phenomena that are caused by climatic changes. As researchers such as Mimura (2007), McGranahan et al. (2007), and Nicholls et al. (2007) have stated, “communities in small islands and low-lying coastal areas are exposed to an unparalleled risk from rising sea levels, stronger storms and other sea-ward hazards.” The annual rise in sea level in the regional seas of Taiwan is approximately 2.51 mm, which is 1.4 times the global rise in sea level (Tseng et al., 2010).

In addition to the aforementioned extreme climatic events, if tropical cyclones or floods occur during rising tides, then salt water intrusion usually follows. Some coastal Folkcommunities make their living from marine aquaculture. Groundwater overdraft lowers the ground level of coastal areas below any other

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**Table 1. Index, category and weight of evaluating community adaptation.**

Category/Item	Definition	weighting
<b>1. Community competence</b>		<b>0.171</b>
Population density	The area with low population density is usually short of resources, transportation service and infrastructure, response and recovery capacity of the community is weak when disaster happened.	0.037
Ratio of senior and disability	Due to physical or mental conditions, this portion of population, unlike normal people, might have lower ability to flee from the disaster or withstand the pressure.	0.065
Large public indoor spaces	Large indoor space will become important shelter when the disaster occurred, can be regarded as one of the disaster adjustments.	0.069
<b>2. Infrastructure stability</b>		<b>0.314</b>
Independent power supply system	When a power outage occurs in the disaster, independent power supply system could quickly restore power supply as soon as possible to resume normal life.	0.101
Transportation network system	Integrity of the transportation system or networks, providing residents in the disaster a faster evacuation passageway, avoid the delays caused more damage.	0.064
Drainage and pumping system	Such systems can increase community capacity, reduce the loss of life and property.	0.149
<b>3. Social-economic support</b>		<b>0.167</b>
Medical care system	The higher level of the medical service, the more diverse care items provide.	0.025
Community organization system	The organization organized by the residents in the form of normality, is familiar with community environment and affairs, will contribute to the community to recover from the strain.	0.088
Disaster education	To hold the activities like teaching the basic knowledge of facing disaster, disaster prevention exercises, and refuge route planning, could improve disaster response ability.	0.053
<b>4. Interior environmental capacity</b>		<b>0.091</b>
Building orientation and allocation	The comfort of living conditions could be different because the appropriate orientation of building can reduce sunlight, improve natural ventilation.	0.020
Building sunshading, heat insulation and ventilation	Appropriate outdoor sun shading can increase indoor comfort.	0.028
Canopy/Flood reduced facility	Such facility can reduce direct damage caused by rainfall or flood to the building and community.	0.043
<b>5. Outdoor environment adaptability</b>		<b>0.258</b>
Outdoor ventilation efficiency	Good building allocation will retain the ground ventilation path, increase ground wind speed, smooth the heat discomfort and increase ventilation effectiveness in community activities area, attracting residents stepped and stayed outside.	0.029
Green covered ratio	Evaluate greening design of community environment to encourage greening diversity, reduce CO <sub>2</sub> concentration, improve air quality and reach the purpose of alleviating the phenomenon of urban high temperature, increase community climate adaptability.	0.102
Site water retention	The condition and distribution of bare land, permeable pavement in community can effectively conserve groundwater, and improve rainwater storage, retard the immediate flood damage.	0.127

Source: Ou (2015)

surrounding areas, increasing the severity of flooding.

Numerous recent studies have targeted the resilience and adaptation of coastal communities. Gibbon et al. (2002) claimed that community resilience is the ability of individuals and communities to change the conditions that influence them. Community resilience can be improved by learning from natural disasters and increasing one's ability to resist harmful change (Folke et al., 2003). Moreover, such resilience can be improved by reducing the dependency of communities on fossil fuels, maintaining forestland and agriculture, developing local food supplies, and engaging in other climate-friendly activities that enhance the ability to manage climate change (Walker and Salt, 2006).

Adaptation has become a key policy because future hazards

will be associated with increasing challenges. Adaptation at the coast is critical to help communities to avoid the effects of climate change and withstand impacts that cannot be avoided (Button and Harvey, 2015). In Australia, most main cities lie on its coast, and approximately 86% of its population lives in the coastal zone (Harvey et al., 2008; Button and Harvey, 2015); an estimated 30% live within 2.0 km of the shoreline. Hence, the Local Adaptation Pathways Program has sought to improve the capacity of local government to identify and treat climate change-related risks in coastal communities (Department of Environment, 2014). Overall climatic adaptation has been considered the capacity to adjust oneself to dynamic environmental conditions. Specific adaptation may include modifying the sensitivity of a

system to perturbations to improve its resilience (IPCC, 2013).

To summarize previous studies and developments related to the topic of climate adaptation, the current study suggests the following points:

1. Most of the published studies have focused on developing evaluation structures of climate resilience, evaluating the types of disaster caused by climate change, and promoting the concepts of disaster insurance.
2. The study areas of the mentioned studies are in dry and cold weather regions of the Frigid Zones. No domestic evaluation mechanism is available for the wet and humid weather in the subtropical area of Taiwan.
3. Instead of conducting analyses on a microscale or community scale, studies on climate risk assessment in Taiwan were basically based on the data on a national or regional scale, and such studies have analyzed only information that the government has opened for public use.

The mentioned points provided the motivational basis for the current study to choose communities as the research object and to design indices of community adaptation to climate change, particularly coastal communities.

This research extended a previous study entitled, “Establishment and application of indices of community adaptability to respond to floods and high temperatures,” and applied only the effective and quantified indices of the adaptability of Taiwan’s communities proposed in that study to evaluate the coastal communities in Taiwan.

## METHODS

The framework of the evaluation indices is based on several variables identified in relevant references, considering social and geographical differences among communities, living patterns in communities, and local infrastructure. Fuzzy Delphi questionnaires involving 15 indices in 5 categories were developed, and an AHP expert questionnaire was used to assign a weight to each index and category; the questionnaire results were transformed using the software package Expert Choice. Table 1 describes in detail all categories and indices. Additional details concerning questionnaire survey, database, Fuzzy Delphi and AHP method are available in the aforementioned study and Ou (2015).

An investigation that was based on these indices was performed in Tainan, which is located on the southwest coast of Taiwan. Communities that have experienced flooding and salt-water intrusion in the past few years were identified, and six communities were chosen randomly as samples.

Fig. 1 displays the locations of the six communities in Tainan. The yellow area in the figure represents Taiwan; the irregular segments represent the administrative boundaries of 20 counties; and the orange area along the coastline represents the coastal area considered in this study, and the six coastal communities,

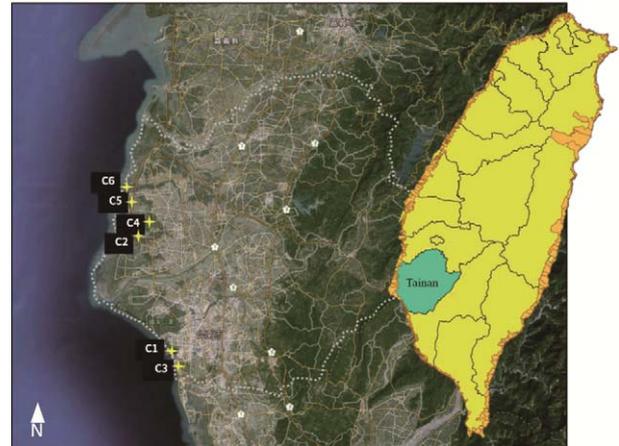
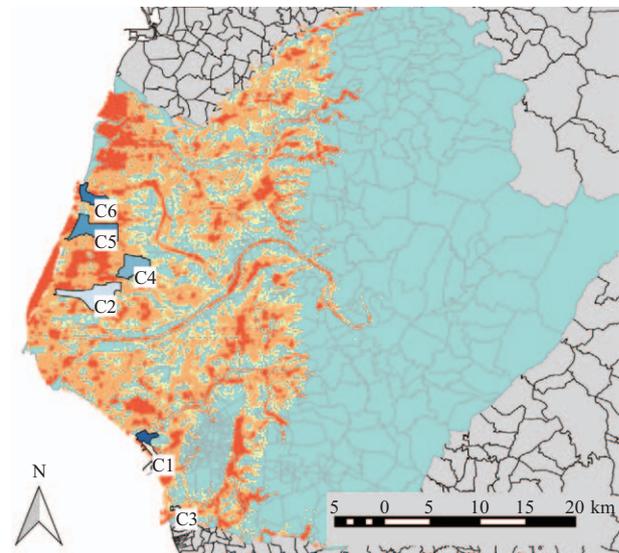


Fig. 1. Locations of the six coastal communities.



Source: Water Resource Agency, 2012

Fig. 2. Flood potential map of a scenario involving continuous 3-day cumulative rainfall of more than 1200 mm (regions with a higher red intensity represent more severe flooding).

namely C1-C6 (indicated by the plus signs), were selected from this area.

Fig. 2 illustrates a flood map of a potential scenario involving a continuous 3-day cumulative rainfall of more than 1200 mm in Taiwan (Water Resource Agency, 2012). The six sample communities are located in areas with potential flooding. Specifically, almost Taiwan’s entire coastline is located in the warning area. Additionally, the combination of low ground level and high tide occurring twice every month contributes to potentially disastrous flooding.

After the investigation, this study conducted face-to-face interviews with the residents of the six coastal communities to elucidate their practical experiences. An analysis framework, called DPSIR, was employed in this study. This framework is used to describe the interactions between a community and the en-

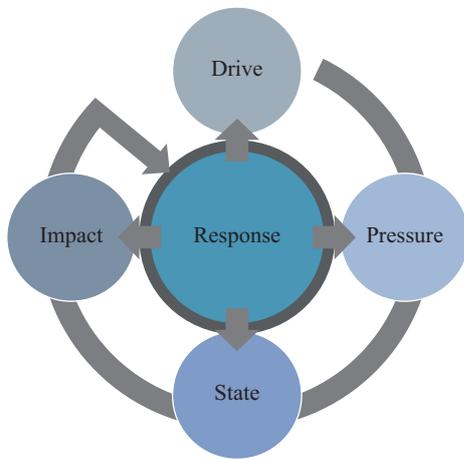
**Table 2. Select comparative statistics of six communities.**

Community	Land area (ha)	No. of Households	Population <sup>1</sup>	Population Density (people per ha)	Population Growth <sup>2</sup>
C1	1816.88	675	2185	1.20	-1.97%
C2	9632.43	659	1971	0.20	-1.26%
C3	354.24	215	523	1.48	-0.75%
C4	5675.87	326	971	0.17	-0.70%
C5	7871.00	761	2163	0.27	-0.77%
C6	4169.01	493	1610	0.39	-1.75%

Note:

<sup>1</sup> The population is in June, 2015.

<sup>2</sup> The population growth ratio calculates from 2011-2015.



**Fig. 3. Concept of DPSIR.**

environment and to record the reactions, actions, and perspectives of residents in relation to the threats posed by climate change. In addition, the framework is an extension of the pressure-state-response model developed by the Organization for Economic Co-operation and Development (EEA, 2015). Fig. 3 displays the concept and mutual relationship among the elements of DPSIR. Interviewees were asked the following questions:

1. “How does climate change influence the community?”
2. “What is the influence?”
3. “What have you done to reduce this impact of climate change on your community?”

Possible connections among these different elements were posited after the interviews. A cross analysis of the DPSIR framework reveals the real and complex impacts of events of interest; such an analysis also facilitates comparing interviewees’ real thoughts and the components of an index for evaluations.

#### IV. RESULTS

Every index in Table 1 was investigated in the six coastal communities. These communities shared the following attributes: The population growth rates in the communities were rela-

tively low; and all communities had a negative population growth, which is a general phenomenon of coastal communities in Taiwan, because of poor work opportunities, the inconvenience of everyday life, and a lack of public facilities. Table 2 presents basic statistical information concerning the communities.

On the basis of the evaluation framework presented in Table 1, the communities were arranged in descending order according to their total scores as follows: C3, C6, C5, C2, C1, and C4. Fig. 4 presents the weighted index scores of these communities, converted to 100 points for the five categories. The five angles of the radar charts represent the five categories of the evaluation framework. These charts not only enabled clearly determining how each community performed in each aspect, but also facilitated conveniently comparing every aspect among the different communities. Category 1 comprised three items, namely “population density” (the higher the better), “ratio of senior and disability” (the lower the better), and “large public indoor spaces.” Compared with the other communities, C2 had a higher population density and C1 had larger public indoor spaces; the conditions of the remaining communities were almost opposite to the evaluation requirements.

All six communities have drainage and pumping systems that are independent of the public sewerage system, and this was reflected in the score of category 2, “infrastructure stability.” Category 3 contained three items, namely “medical care system,” “community organization system,” and “disaster education.” Compared with the other communities, C2 and C3 had a more complete community organization; moreover, C3 carried out routine disaster education advocacy. Category 4, “interior environmental capacity,” also comprised three items: “building orientation and allocation”; “building sunshading, heat insulation, and ventilation”; and “canopy/flood reduced facility.” This study observed poor performance for C4 in terms of the first and third items of this category. Category 5 involved three items, namely “outdoor ventilation efficiency,” “green covered ratio,” and “site water retention.” Among the six communities, C6 and C3 ranked first and second, respectively, regarding green covered ratio, and C4, C5, and C6 exhibited more favorable site water retention.

The face-to-face interviews were one of the vital components of this study. These interviews facilitated further determining

Category 1: Community competence; Category 2: Infrastructure stability;  
 Category 3: Society-economic support; Category 4: Interior environment capacity;  
 Category 5: Outdoor environment adaptability

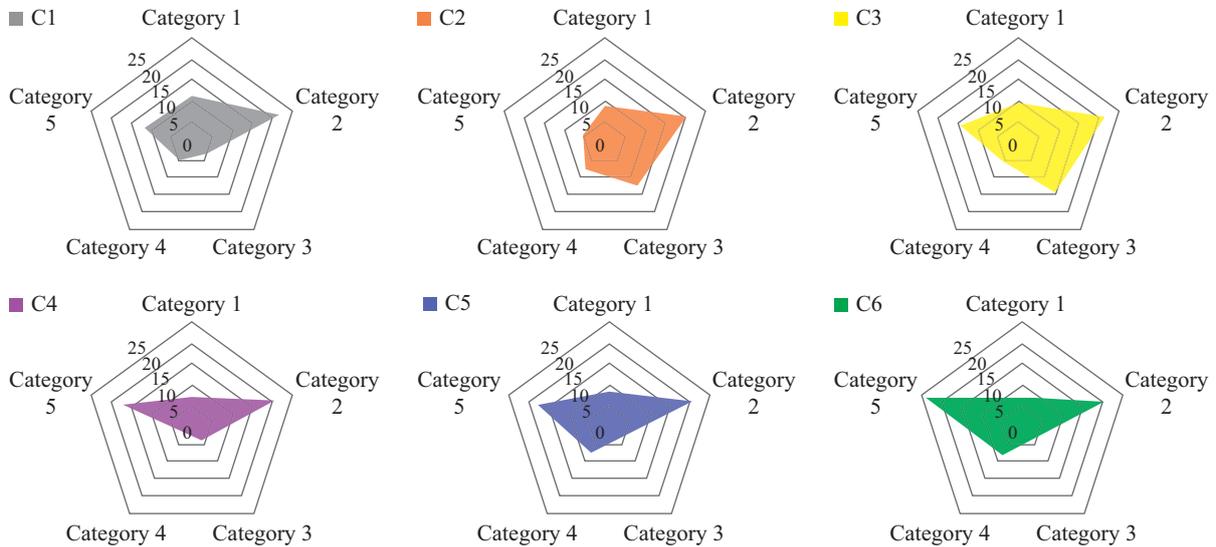


Fig. 4. The scores of the six communities calculated weighted and converted to 100 points.

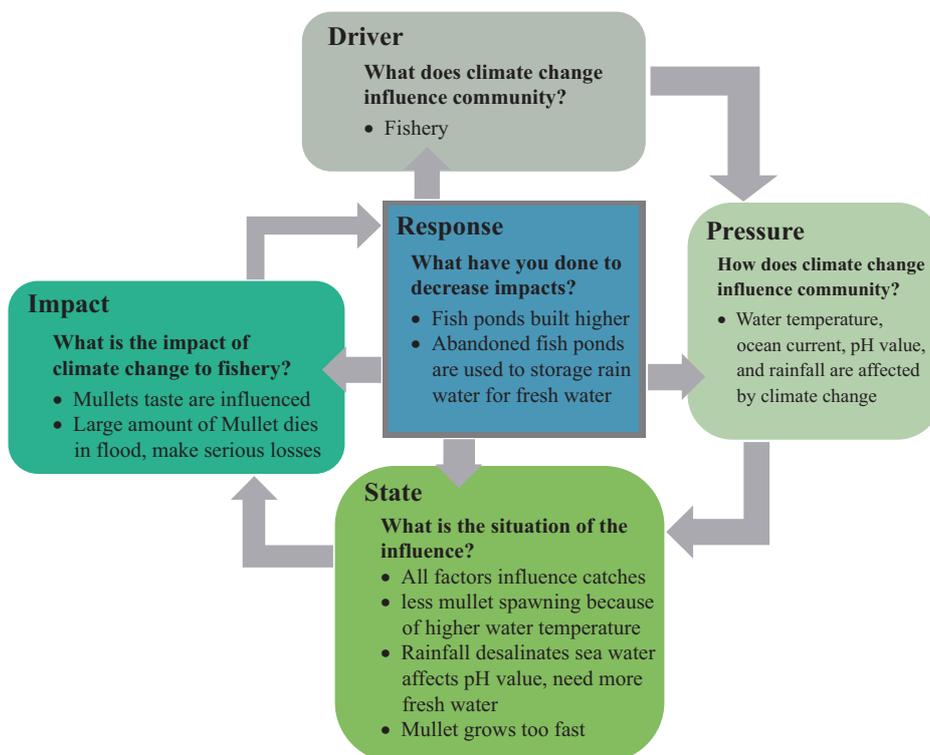


Fig. 5. Analysis of the interviews according to the concept of DPSIR.

the situation of the local residents' concerns about climate change. The contents of the interviews were organized according to the concept of DPSIR and are shown in Fig. 5. More than 80% of the interviewees reflected that rainfall, floods, and high tem-

perature caused by climate change influenced the quantity and quality of their fish catch. To adapt to the changes, they progressively raised the banks of fish ponds, in addition to using abandoned ponds to store fresh water for reducing the concen-

tration and temperature of the sea water.

**DISCUSSION**

In this study, infrastructure stability was the most highly weighted category, and the drainage and pumping system was the most vital item in this category, reflecting the fact that all six coastal communities considered herein have well-based pumping systems, which were developed either by the local government or the residents. Climate change is engendering more intensive rainfall in Taiwan. In the past, 100-year flood prevention has been the basic standard for urban design, but recent heavy rainfall events have invariably exceeded this design threshold easily. Every heavy rainfall event tests the infrastructure of a community.

Most coastal communities are away from regional medical facilities. In the past, every township had a public health center; however, because of the cost of personnel, some of the public health centers had been either closed or merged with other health centers. Clearly, timely and comprehensive care is not provided in some remote coastal communities. As indicated by the results of this study, most of the six coastal communities lacked disaster education, except for C3. C3 carries out climate disaster education advocacy and drills, and these routine practices can convert to higher resilience when this community faces the challenges of climate change. Some concepts concerning the prevention of natural disasters must be taught. Therefore, community associations are entrusted with various relevant responsibilities such as scheduling educational programs on climate change, as well as familiarizing the residents with evacuation routes; these preparations enable the residents to practice skills useful in responding to disasters.

This study quantified the adaptation of a community in terms of its area, population, and potential exposure to flooding to determine whether such a community possesses high or low adaptive capability to climate change hazards. For example, a community facing high hazards and exhibiting high adaptability to climate change is plotted in Quadrant I; moreover, a community facing medium hazards and having medium adaptability to climate change is plotted in Quadrant IV. Fig. 6 presents the distribution of all six sample communities.

As indicated in Fig. 6, although C6 was highly adapted to climate change, it was also associated with a high hazard of exposure to climate change because of its large area. By contrast, C3 was highly adapted to climate change, and it was associated with a lower hazard because of its smaller area and low population distribution. C1 had a medium hazard of suffering from climate change, but its poor community adaptation reflects its residents' closeness to threats posed by flooding.

Fig. 6 indicates that communities incur only medium hazards when climate change occurs; however, C3 had a moderately high adaptation to climate change. Moreover, C4 was at a high risk of climate change, and it possessed the least adaptation to climate change. This study determined a noteworthy phenomenon, according to the described investigation: C3 and C4 both

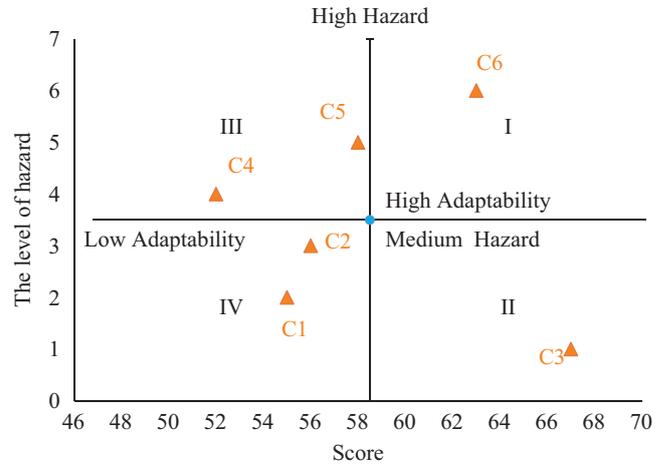


Fig. 6. Hazard and adaptability to climate change of the six communities.

demonstrated higher performance in the same categories, but had highly different environmental adaptability levels. C3 and C4 exhibited the highest and lowest adaptation levels, respectively. C3 is a small fishing village, and its residents currently make a living from selling handicrafts. The artificial wetland of this village helps to collect wastewater and to relieve flooding.

This study conducted face-to-face interviews, and the results reveal that the fishing industry is the most vital sector affected by climate change. Most of the interviewees were only concerned about their community industry, on which they depend for a living.

The main industry of the interviewed communities is specifically mullet aquaculture, which depends on the appropriate temperature and pH value of water after fresh water is added to the local sea water. Climate change increases the temperature of sea water, reducing the appetite of mullets and their reproduction. In addition, climate change intensifies rainfall and causes frequent flooding, inducing the water in fish ponds to overflow and consequently killing mullets by rushing them to the ground. The interviewees explained that they had begun to raise the banks of fish ponds to adapt to or resist these natural hazards. However, the ponds are now approximately 2 to 3 m high, and this is because deeper ponds are prone to the collection of excessive dirt at the bottom, which engenders another aquaculture problem. Because of a shortage of fresh water, residents use abandoned ponds to collect rain water that they add to salt water to eliminate the necessity of drawing ground water.

Although the residents had considered the possibility of transforming their facilities into leisure farms, doing so would require creating activities for the farms and integrating with combining with nearby scenic areas or tourism resources as attractions. Success would depend on the collaboration of the government and related industries, and this would require long-term planning. Furthermore, transitioning from primary industrial sectors to tertiary industrial sectors is difficult for the residents. In that they must learn about packing and marketing new products, interacting with consumers, and behaving like businessmen.

The “industry” item was eliminated by the experts during the first round of the Fuzzy Delphi questionnaires. This is a limitation of academic research, thus indicating the importance of combining academic studies and interviews, as conducted in the current study. Academic research must take more real life accounts to ensure that sustainable living is promoted. The industry item fell under the category of “social-economic support,” but the experts considered industry to be relatively irrelevant to a community’s adaptation to climate change. However, for local residents, the most direct impact of climate change is the impact on their local economy. Incorporating residents’ opinions into questionnaires may be a valuable strategy in future research.

### CONCLUSION

This study provides a means of diagnostically evaluating the adaptation of Taiwan’s coastal communities to climate change. Quantitative data on the conditions affecting the recovery of a community from disasters engendered by climate change in the shortest possible time clearly reveal the strengths and weaknesses of that community against climate change.

The accomplishments of this study are outlined as follows:

This study applied the adaptation to climate change as a framework of risk assessment. The study not only used a quantitative assessment structure, but also coordinated on-site interviews in accordance with local characteristics to determine potential problems that cannot be otherwise determined the quantitative method alone.

This study is the first in Taiwan to focus on evaluating the adaptation of coastal communities to climate change. The evaluation items were derived by referring to previous heat and moisture environment studies in Taiwan and a localized evaluation framework proposed by experts and scholars.

Only a few of statistical data from the government are supplied in a neighborhood unit. Most data required in the evaluation items of this study were not disclosed by the government. Nevertheless, this study investigated numerous first-hand information and analyzed the information in a quantitative combination.

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