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Emerald Book Chapter: Chapter 16 The experiences of DRR through CCA in Taiwan

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CHAPTER 16

THE EXPERIENCES OF DRR THROUGH CCA IN TAIWAN

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INTRODUCTION

Taiwan is located between the world's largest landmass, the continent of Asia, and its largest ocean, the Pacific Ocean. The Tropic of Cancer passes through the island of Taiwan, giving it a subtropical and tropical oceanic climate. High temperatures and rainfall and strong winds characterize the climate. Because of Taiwan's position in the Asian monsoon region, its climate is greatly influenced by monsoons as well as by its own complicated topography. The annual mean temperatures in the lowlands are 22–25°C, and the monthly mean temperature exceeds 20°C for eight months starting with April each year. The period from June to August is the hottest season with mean temperatures of 27–29°C. Temperatures are cooler between November and March; in most places, the coldest monthly mean temperature is above 15°C. The climate is mild rather than cold and temperatures only fall dramatically when a cold front affects the region. Average annual rainfall in the lowlands of Taiwan is in the range of 1,600–2,500 mm. Due to the influences of topography and the monsoon climate, the rainfall differs greatly with different areas and seasons. In mountainous areas, average rainfall may exceed 4,000 mm/yr. Rainfall is generally higher in mountainous areas than in lowland areas, higher in the east than in the

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west, and higher on windward slopes than on the leeward side. The northeast monsoon prevails during the winter; this is the rainy season in the north though rainfall is not intense. But the same winter period is the dry season in the south. During the summer, the southwest monsoon prevails, often giving rise to convective thunderstorms and bringing intense and copious rainfall. With added downpours brought by typhoons, this season often accounts for over 50% of annual rainfall in the south so that central and southern regions often suffer greatly. Relative humidity on the island of Taiwan, surrounded by ocean, is high, usually measuring in the range of 78–85%. In the north, relative humidity is higher during winter than during summer. The situation in the south is the opposite. Over the past 100 years, the rainfall in the north has increased, while the rainfall in the south has decreased. The trend is not as consistent as that of the temperature change (Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan), 2002).

Because of the characteristics of the location, climate, and geology of Taiwan, there are seven kinds of disasters that have frequently occurred in the past. These are land erosion, earthquakes, scarcity of water resources, environmental change, landslides, land subsidence, and floods. Most of these have annually caused the loss of human life and cost the nation great expense. These disasters then affect the advancement of society by requiring restructure of governmental policies and efforts in Taiwan. These natural disasters are a constant threat to Taiwan.

IMPACTS OF CLIMATE CHANGE ON TAIWAN

People's activities have enlarged the emission of greenhouse gases since the Industrial Revolution, and in turn, the greenhouse effect has resulted into global climate change. According to the Intergovernmental Panel on Climate Change (IPCC), the concentration level of CO_2 in the atmosphere would at least double since the Industrial Revolution (280 ppm). The global average temperature from 1990 to 2100 may rise from 1.4 to 5.8°C, while the average temperature of the last 100 years has risen to 1.1°C in Taiwan (Hsu & Chen, 2002).

Climate change directly affects hydrology, water resources, agricultural production and agricultural water demands, ecosystems, and so on. With the natural environment of a subtropical island, Taiwan is very vulnerable to the impacts of climate change including sea level rise, damages of primary industries, public health, among others. The direct impacts of sea level rise cause the flooding of coastal lands, coastal erosion, and coastline recession. Coastal communities face the possible problems of relocation and subsequent social adaptation. The impacts on water resources include probable increase in frequency and intensity of droughts, lack of water resources, and impact on people's livelihood and industrial development. On the other hand, the increase in CO_2 concentration would enhance photosynthesis of plants and promote forest and agricultural growth. However, it would also promote the growth of pests and propagate diseases. Concerning the impact on the ecoenvironment, the long-term trend shows that some negative impacts would occur like reduction of inhabited areas of biological species and reduction or vanishment of biological groups (Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan), 2002).

Based on the studies of the Global Change Research Center at the National Taiwan University, in the last 100 years (1900–2000), the temperature of Taiwan increased 1.6°C/yr, which is about double of that of the northern hemisphere, and the sea level rising rate of the last 50 years is about 2.51 cm/yr, which is about 1.4 times of the global average rising rate. According to IPCC, the sea level will rise 1 m by the end of this century; at that time, 10% coastal or low-lying areas of Taiwan will be flooded.

Based on the studies of the Research Center of Environmental Change in Academia Sinica, winter and spring are the dry seasons and summer is the rainy season in Taiwan. Such weather pattern influences agricultural development and results in the lack of food and the insufficiency of storage water and, moreover, enlarges the frequencies of floods and droughts. In the most recent years, the intensity of abnormal climate has increased and the frequency is higher. According to the Institute of Earth Science in Academia Sinica, there were three typhoons with extreme rainfalls in Taiwan in August 1994, ten in October 1998, and one in September 2001. The interval during this period is about three to four years. But there were three typhoons in August 2007, two in September 2008, and even Typhoon Morakot, an extremely strong typhoon, appeared in August 2009. The interval currently has shortened to one to two years. Such situation shows that the interval of extreme weather has shortened, but the intensity has become stronger. If the temperature rises by 2°C by the end of this century, heavy rainfall in the top 10% scale will double. If energy conservation cannot be implemented, the temperature will rise by 4°C, and the heavy rainfall intensity ranked at the top 10% will increase 5.6 times. Typhoons will bring extreme rainfall that will cause debris flows; therefore, the environmental risks in mountain and coastal areas will eliminate available space to live and threatened people's livelihood and safety. The impacts of climate change in different sectors of

Table 1. The Impacts of Climate Change in Different Sectors of Taiwan.

Sectors	The Impacts of Climate Change
Sea level rise	Sea level rise may seriously influence the use of coastal lands. The major economic impacts resulting from damages regarding social cost includes some direct damages involving land and capital loss, cost of mitigation measures to reduce damages, and loss of structure and development opportunities near the coastline.
Water resources	The uneven rainfall of rainy and dry seasons may increase the extent of floods and droughts and increase the difficulties of disaster prevention. Related problems that may occur during drought is difficulties of allocating water resources and during the rainy season is insufficient capacity of storage structures to store excess rainfall, thus creating insufficient water supply during droughts.
Industries	The climate conditions of rising temperature and uneven rainfall may reduce crop production. The El Niño–Southern Oscillation affects the growth and decline of the Kuroshio main current and its branching process and reduces fishery production. The change of water temperature also changes the geological distribution of fish. The rise of temperature may also influence livestock and poultry propagation and growth.
Public health	The rapid temperature increase may result in an increasing death rate and in propagating the disease vector more easily, thus inducing infectious diseases. Dengue fever in Taiwan has spread to northern areas and the propagation of rats, the host of hantavirus, has also rapidly increased.
Ecological systems	Climate change may lower the production ability of aquatic life forms, reduce biodiversity, and influence oceanic temperature and current flow to affect the ecology of fish and other organisms.

Source: Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) (2002).

Taiwan can be simplified in Table 1. The sectors that are discussed include sea level rise, water resources, industries, public health, and ecological systems.

International studies have indicated that climate change might change the available water demand and rising temperature might result in the increase of evapotranspiration (Tung & Haith, 1995), while domestic studies have indicated that climate change causes an extreme difference between rainy and dry seasons (Tung & Li, 2001). Therefore in order to understand the impacts of climate change on hydrology and the climate of Taiwan, this chapter analyzes some possible factors from climate change impacts and provides domestic researches in recent years that support the analysis of such factors.

Sea Level

Based on the long-term sea level variation data of 14 domestic tidal monitoring stations, the sea levels of Keelung and Kaohsiung have a rising trend in the most recent 90 years at the rising rate of 0.035 cm/yr in Keelung and 0.061 cm/yr in Kaohsiung, respectively. However, Taichung Port has the descending rate of 0.364 cm/yr. Overall, data from the tidal stations indicate that sea levels in parts of the northeast, northwest, and south have an increasing trend; sea levels in central Taiwan have a decreasing trend (Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan), 2002).

An analysis of long-term changes at the coastal lines of Taiwan shows that coastal lines in the north currently remains stable overall, but erosion is more serious in some parts. In the past 20 years, coastlines in the southeast have retreated by 20–50 m. Furthermore, coasts in central and southern Taiwan show signs of erosion in recent years and a decrease in the shorelines (Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan), 2002).

Rainfall

Based on the climate data of the last few years, the average annual rainfall in Taiwan is 2,500 mm, which is about 2.6 times of the world average value. However, 78% of the rainfall occurred during the rainy season (from May to October), and most of the rainfalls are from typhoons; on the other hand, only a small amount of rainfall occurred during the dry season (from November to April). Therefore, the hydrology and water resources conditions are full of much uncertainty. The average annual rainfall has changed little, but the number of rainfall days is continuously decreasing and the rainfall intensity is persistently increasing. According to rainfall data, the rainfall intensity of central, southern, and eastern Taiwan has an increasing trend, and it shows that the opportunity for heavy rainfall has apparently increased also (Lee, 2009).

The study of the Research Center of Environmental Change in Academia Sinica discusses the impact of climate change on the rainfall characteristics of Taiwan. The research divides Taiwan into northern, southwestern, and southeastern parts and has calculated the rainfall from 1941 to 2005. It indicates that the rainfall intensity, the ratio of annual rainfall amounts to the number of rainfall days, is 16.2 mm/day in Taiwan. Statistically, the individual regions indicate 16.4 mm/day in northern Taiwan, while southwestern Taiwan has the largest value of 17.7 mm/day, and southeastern Taiwan has the smallest value of 13.1 mm/day. These districts all have an increasing rainfall intensity trend. The study shows that the changes of rainfall patterns are different for northern and southern Taiwan. In recent years, northern Taiwan received more rainfall in fewer days, and this phenomenon may result in creating less reliable surface water resources due to the limited capacity of storage facilities. The trends of rainfall amount and the number of rainfall days are decreasing in southwestern Taiwan, but rainfall intensity has slightly increased. According to the rainfall data, southern Taiwan receives less rainfall amounts with comparatively more uneven seasonal distribution than northern Taiwan, and this is unfavorable for water resources (Hsu, Wang, Chen, Chen, & Ma, 2007).

Flow Rate

Based on past data, the river annual average runoff did not have any apparent increasing or decreasing trend in Taiwan. In northern Taiwan, when the northeastern monsoon prevails, approximately from October to January, the river runoff had a decreasing trend. But the river runoff increased at the onset period of the plum rainy season, from April to May, especially in central Taiwan (Juang & Chen, 1994). There were nine rivers impacted due to climate change, and the flow rates had an apparent decreasing trend in winter and spring and had an increasing trend in summer, but not so apparent in fall (National Science Council, 2005a).

There are researches that have simulated the impacts of climate change on the watershed flow rates in Taiwan. One research indicates the watershed flow rates will decrease as time increases, and the decreasing range is more apparent in northern Taiwan. Overall, the watershed flow rates will have a decreasing trend (National Science Council, 2008). Another research indicates that in the future Taiwan will be affected by climate change so much so that the flow rate will increase in the rainy season and will decrease in the dry season. This result means that the frequencies of floods and droughts may increase (National Science Council, 2005b).

POSSIBLE DISASTERS AS A RESULT OF CLIMATE CHANGE

Global warming will increase the number and severity of extreme events such as storms, floods, droughts, typhoons and related landslides, fires, and so on. In the last 100 years, Taiwan, in different locations and seasons, has had different warming trend variations and different abnormal climate conditions like storms, typhoons, droughts, and sandstorms. The occurrence frequencies and times of these conditions in Taiwan also have changed. More than 70% of the land in Taiwan is mountains with an average elevation of 600 m, so that the rivers in Taiwan have characteristics of steep slopes and rapid flows. As large-scale land development and urbanization have begun in recent years, the ability to contain water has worsened. Therefore the abnormal climate changes like storms and typhoons also have weakened the resistance of mountain soil and have caused severe damages due to debris flows and landslides. Besides the damages of basic livelihood structures and threats of the people's safety and property, abnormal climate changes would therefore result in subsequent effects on the ecosystem and environmental health (National Science Council, 2005b).

The annual rainfall amounts differ greatly during rainy seasons and dry seasons; therefore, abnormal rainfall in rainy seasons usually brings flood disasters. The floods and droughts that have occurred from 2003 to 2008 have indicated that the water resources supply and demand are very unstable in Taiwan due to climate change, such as Typhoon Nari in 2001 and the severe drought in 2002 (National Science Council, 2005a).

The surface water resource use in Taiwan is inefficient because precipitation differs considerably during rainy and dry seasons and rivers in Taiwan are steep and short in length. The lack of surface water resource is more significant because there are not enough water storage structures such as reservoirs in southwestern Taiwan. In addition, agriculture and fishery are the major economic productions that consume great quantities of water. If surface water supply is insufficient, groundwater will become the primary water resource and the overpumping of groundwater will cause serious land subsidence. Because of the low elevation in coastal areas, flood control and drainage systems lose their preventable potency in land subsidence regions. For this reason, serious flooding occurs during typhoons or torrential rains. Furthermore, when the Chi-Chi earthquake shook the entire island of Taiwan, it also loosened soil and rock on the hillsides in 1999. After that, the colluviums piled up in most valleys and have resulted in serious debris flows or landslides during heavy rains.

As a result of climate change, the intensity of typhoons has increased. The common typhoon paths in Taiwan are shown in Fig. 1. From 1897 to 2003, the paths statistically experienced came from nine different directions with the fifth and sixth directions being the predominant pattern with the fifth path going northwest off of the southern coast of Taiwan and the sixth

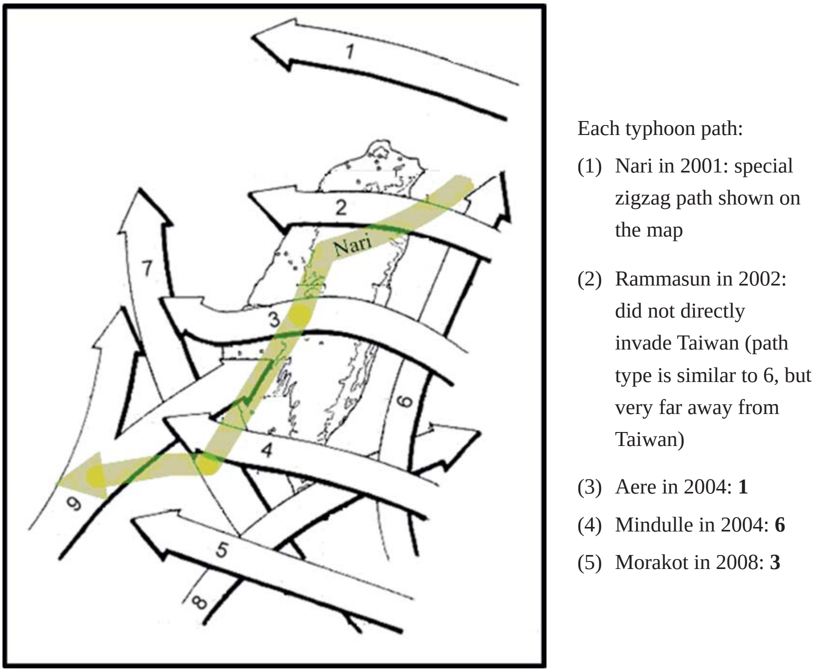

Fig. 1. Common Typhoon Paths in Taiwan (100 Questions about Typhoons, Central Weather Bureau, 2004, Modified).

path going northeast off the eastern coast of Taiwan. Paths of several specific typhoons mentioned in this chapter are also illustrated in this figure.

The following listed items are disasters highly relative to Taiwan as a result of climate change with supportive data.

Coastal Disasters

Damages from sea water level rise affect people's livelihood and coastal ecosystems; such disasters include sea water intrusion, tidal surges, coastal area floods, and so on. More specifically, there are some townships in Taiwan classified as severe land subsidence areas, and the effect of the rise of sea water level has greatly impacted these areas due to land subsidence. The primary damage is caused by tidal surges that are distributed mainly in low-lying lands of southwestern Taiwan. In recent years, flooding has occurred in these areas due to typhoons or heavy rainfalls. Furthermore, these areas have severe land subsidence, and the intensity of flooding may become even more severe because of the combined effects of seawater rise and land subsidence.

In recent years in Yunlin County, for example, the range of coastal areas being flooded due to heavy rainfalls or typhoons correlate with the land subsidence areas (Fig. 2). It presumes that land subsidence may be one of the factors contributing to disasters, such as the heavy rainfalls that occurred from 2004 to 2007. On July 2, 2004 heavy rainfall resulting from typhoon Mindulle (Fig. 1) flooded the western coastal areas of Yunlin County in Kouhu, Tuku, Taisi, Dabi, Yuanchang, Douliou, Shuelin, and so on. The following year on June 12, 2005, heavy rainfall with a daily precipitation amount of more than 350 mm occurred in southern Taiwan, which resulted from the plum rainy front and southwestern airflow. This rainfall caused flooding in these areas and threatened people's safety and damaged property. Then on June 9, 2006, the Central Weather Bureau continually announced torrential rainfall warnings posed by a stationary front. In Yunlin County, the persistent rainfall also resulted in severe flooding in low-lying areas of Taisi, Kouhu, and Sihhu. Severe flooding took place again on August 19, 2007 when Yunlin County received large amounts of rainfall that severely flooded the coastal areas of Lunbei, Mailiao, Taisi, Sihhu, Kouhu, and Sheilin, among others. In these areas, some classes were suspended due to flooding. According to the rainfall statistics of the Central Weather Bureau, the rainfall amounts were between 160 and 300 mm in Sihhu, Mailiao, Baojhong, Beigang, Gukeng, and Douliou.

Flood Disasters and Droughts

According to some researches (National Science Council, 2005b), the rainfall intensity in recent years (1941–2005) has an increasing trend in Taiwan. Therefore flood disasters will increasingly cause more disasters. In addition, the water resource supply in Taiwan mainly comes from stationary rainfalls (plum rains) from May to June and tropical cyclones (typhoons) from July to October, while the rainfall amounts during the other months amount to only 20–30% of the annual rainfall. Therefore, if plum rains and typhoons bring very little rainfall amounts, drought may occur in Taiwan. Based on the data of the monthly and annual average rainfall from 1953 to 1990, the annual rainfall in northern and eastern Taiwan had increasing

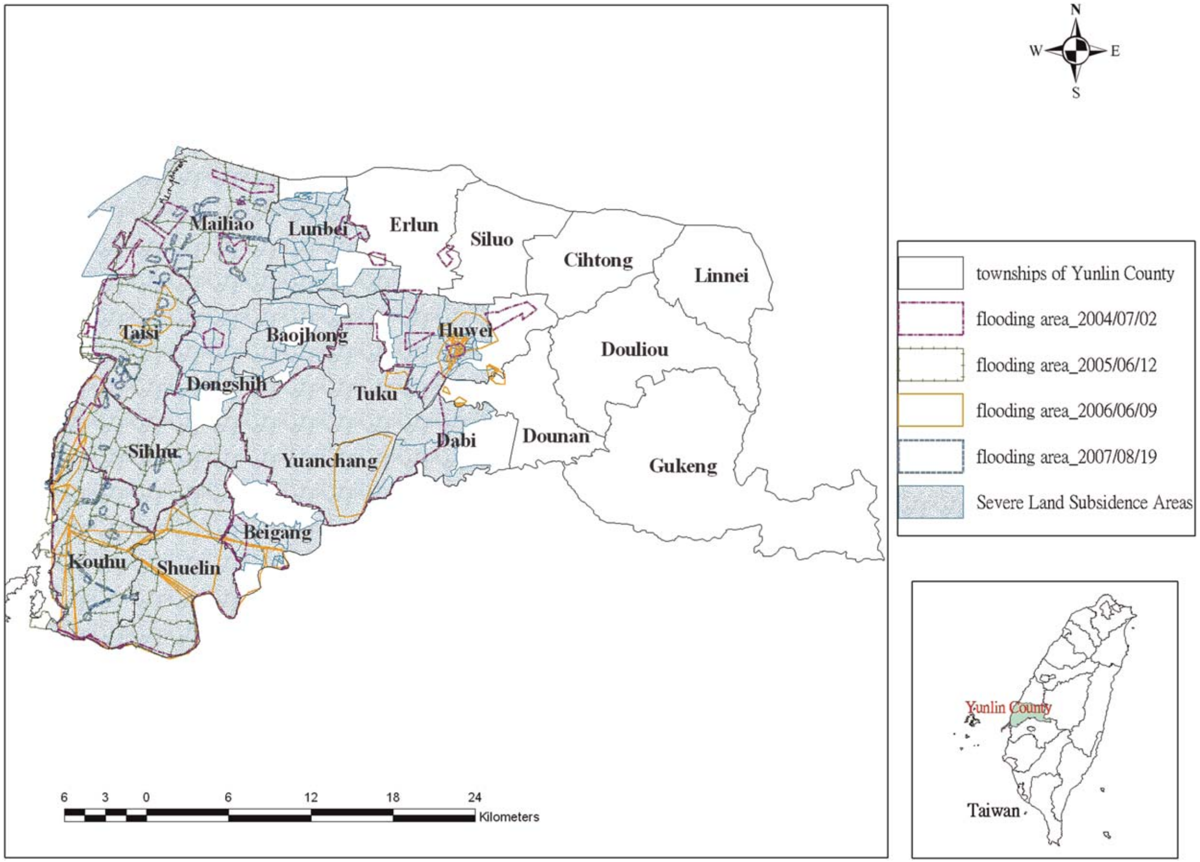

Fig. 2. Correlation of Previous Flood Ranges of Yunlin County with Severe Land Subsidence Areas.

trends, but central and southern Taiwan had decreasing trends. In addition, days lacking rainfall in southern Taiwan had increased.

The Shihmen reservoir water supply system, for example, had observed changes from floods and droughts that occurred in Taiwan during the years 2002 and 2004 (National Science Council, 2005b). The drought, which occurred in northern Taiwan in 2002, had an accumulated rainfall amount of only 216.66 mm in the Shihmen Reservoir Watershed from November 2001 to April 2002, which was the most minimal amount during the last 35 years. Due to insufficient amount of rainfall in the Shihmen Reservoir Watershed, a water shortage warning was announced, and the related governmental organizations had meetings to review the irrigation water for the fist crops and to discuss the related responses needed to face water shortages. By March 2002, the water level of the Shihmen Reservoir descended to a serious limited drawdown of the rule curve (water level was 220 m). And in April 2002, the very small rainfall amounts were, in general, everywhere in Taiwan; meanwhile, water shortage warnings were announced, respectively, in Miaoli, Taichung, Matsu, and so on. The following year in May 2002, the water level of Shihmen Reservoir went down to 204 m, which was less than the serious limited drawdown. During the periods from May to June, the government carried out stricter water limitation measurements according to the water shortage situation. In addition, they dug wells and did pumping tests in response to the situation after the reservoir dried up from the overpumping of groundwater. Finally in July 2002, relief came when the medium-size typhoon Rammasun distantly passed in a northwesterly direction along eastern Taiwan and brought abundant rainfall. The drought in northern Taiwan finally came to an end.

Another water shortage occurred in Taoyuan in 2004 when the water treatment plants were shut down as a result of typhoon Aere (Fig. 1), which attacked northern Taiwan from August 23 to 26 in 2004 and brought abundant rainfall that averaged 973 mm, which was about 50% of the annual rainfall. The storm occurred mainly on August 24–25 with the rainfall intensity of 88 mm/h, peak flow of 86,000 cm, and a total flow of 700 million tons, which was about three times of the reservoir effective storage capacity. Such heavy rainfall that precipitated into the watershed caused soil erosion and landslides of 295 ha. In addition, because of the erosion of the river bank of Tahan Creek, about 20 million cubic meters of sand deposition were estimated, which is about 14 times of the reservoir annual deposition (1.4 million cubic meters) flowing into the reservoir. Therefore turbidity of the water in the reservoir quickly increased from 70,000 to 1.2 million NTUs, which was far from the treatable value (5,000 NTUs) set by the

Taiwan Water Corporation. As a result, the Taiwan Water Corporation had to shut down all water treatment plants that supplied water to Taoyuan on August 26 and stopped water supply from August 26 until September 8. This measure affected about 1.45 million families in Taoyuan and Taipei. A comprehensive water supply started up after September 8.

Rainfall-Induced (or Climate-Induced) Disasters

These kinds of disaster include debris flows, landslides, land subsidence, active faults, and so on, and the debris flow is the most frequent disaster resulting from typhoons or heavy rainfalls. According to the data of the Soil and Water Conservation Bureau, there are 1,503 potential streams of debris flows in Taiwan, and Taipei County and Nantou County possess the largest quantities. The heavy rainfall brought by typhoons is the major inducing factor causing debris flows. Based on the last rainfall characteristics of debris flows, most of them resulted from typhoons; except in some regions, the debris flows were caused by normal rainfall. The statistical data indicated that there were six typhoons on average that attacked Taiwan from 1991 to 2008. But the annual number of typhoons was greater than this value during 2003 and 2004 as a result of nine typhoons occurring for each year of 2003 and 2004, respectively. The number of typhoons that would result in a debris flow is 2.5; that is, about 40% of typhoons may induce debris flows annually.

More recently, typhoon Morakot (Fig. 1) attacked Taiwan on August 7, 2009 and brought severe damages to Taiwan, especially in southern and southeastern Taiwan with landslides and debris flows (Figs. 3 and 4). The Central Weather Bureau predicted rainfall amounts were about 2,500 mm in Pingtung, which were equal to the annual rainfall normally precipitated in three days. Such huge amounts of rainfall caused the roads and buildings to be destroyed in great numbers in the townships. Regarding the populace, death, and injuries were most severe in the mountainous villages of Kaohsiung. In addition, Tainan and Nantou received severe damages as well. The images of house destructions and traffic disruptions caused by landslides and debris flows were displayed through the media and became a high point of focus. But before typhoon Morakot attacked Taiwan, the government was contemplating on how to solve the problem of drought. No one imagined that the rainfall brought by Morakot would not only resolve the drought but also turn into a flood. Such extreme change warns the people about the power of nature. With climate change,

Fig. 3. Landslide Occurred in Chayi County During Typhoon Morakot (Photograph Taken by Tsai Mu-Fan).

we predict that the number of strong typhoons may increase in the future, and we have to take adequate disaster response measures to protect people's lives and property to prevent such regrets from occurring again.

ADAPTATION STRATEGIES AND DISASTER PREVENTION INITIATIVES

In order to protect the global environment and to avoid adverse impacts from international politics and trade, the Republic of China (Taiwan), though not a member of the United Nations, has always complied with international environmental treaties and acted as a responsible member of the global world. In May 1992, the Executive Yuan established the ministerial-level interdepartmental agency the Global Change Working Group to coordinate activities related to the United Nations Framework Convention on Climate Change (UNFCCC) and other global

Fig. 4. Debris Flow Occurred in Chayi County During Typhoon Morakot (Photograph Taken by Tsai Mu-Fan).

environmental issues. In August 1994, the working group was further reorganized and elevated as the Committee on Global Change Policy (CGCP), under which the UNFCCC Working Group was established. Due to the growing importance of sustainable development in the countries around the world, the government decided to integrate all domestic matters related to sustainable development. In August 1997, CGCP was expanded to form the National Council for Sustainable Development (hereinafter referred to as the "Council"), while the Atmospheric Protection and Energy Working Group under the Council was responsible for affairs related to the Montreal Protocol and the UNFCCC. In 1999, the Council was further elevated and chaired by the Vice Premier, thus showing our commitment in response to the UNFCCC (Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan), 2002).

To address the impacts of climate changes on Taiwan, in addition to related studies on greenhouse gases, adaptation strategies are being considered to lessen the levels of impact from climate change. Considering the results of related studies and policies, the relevant government agencies have devised five adaptation strategies in regard to sea level rise, water resources, industries, public health, and ecological systems. Two of those, sea level rise and water resources, include disaster prevention strategies. The essentials of these two strategies are as follows (Council for Economic Planning and Development, 2007; Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan), 2002).

Sea Level Rise

Like other islands, Taiwan will increasingly face serious coastal erosion. As precautionary measures, the following adaptation strategies will be taken:

(1) Complete an impact assessment of sea level rise of the entire Taiwan region: Delimit potentially flooded areas, affected population, and socioeconomic impacts according to the local terrain, nearby industries, population, and culture as useful references for preparing appropriate strategies and prevention measures.
(2) Protect coastal zone and establish a new tidal wave prevention and drainage system: Establish and draw up new design standards for coastal embankment, tide, and flood prevention as well as drainage systems; draft new prevention methods and carry out flood modeling analysis in order to respond to the future conditions of protecting life and property in the coastal regions.
(3) Reduce impacts from sea level rise: Establish land use restriction in coastal areas; control building in low-lying areas; establish industry transformation assistance, wetland protection, flood protection, and sand dune protection.
(4) Preserve coastal wetlands and ecosystems: Using transplantation, cofferdams, or other artificial means to protect rare coastal ecosystems.
(5) Control large-scale coastal developments: Reevaluate plans for coastal industrial parks and integrate sea level rise as an element of environmental assessment of large coastal projects.
(6) Obtain experiences from international cooperation: Actively participate in international cooperation projects.
(7) Establish transitional assistance and planning for nonrecoverable industries: For flooded areas not able to be recovered by preventive strategies, assist the residents in relocation and job changes in order to minimize socioeconomic impacts.

(8) Define flood plain areas and implement flood insurance systems: Establish different levels of flood areas, prevent reckless development, and implement a flood insurance system.
(9) Establish monitoring systems: Including a sea level monitoring system, a coast and coastal structure monitoring system, expand on the subsidence monitoring system, and enhance the establishment of the coastal database.

Water Resources

In order to reduce the level of impacts of climate change on water resources in Taiwan, suitable adaptation strategies are needed in three major areas: water resource conservation, development, use, and management; strengthening flood control and rescue; and drought prevention and emergency response. Below are listed the strategies for each.

(1) Water resources conservation, development, use, and management
  (a) Develop surface water as the primary objective by giving consideration to the base flow of the river ecology, and development of groundwater as a supplementary source with increased development of other water resources.
  (b) Actively develop and allocate water resources.
  (c) Establish management of water rights and collect water right tariffs, and develop a standard function for water measurement equipment in order to put into practice the user pays principle.
  (d) Strengthen water utilization management, raise water utilization efficiency, and allocate waster resources.
  (e) Reinforce the management and conservation of watersheds, conserve water sources, and maintain the natural ecological function of water systems.
  (f) Promote modernization of hydrological monitoring, develop a groundwater observation network, and establish the principles for groundwater use and protection.
  (g) Promote research and development of water resource technologies in order to meet the technological needs for water supply, water conservation, diversion dams, flood control, coastal protection, groundwater conservation, and subsidence prevention.
(2) Strengthen flood prevention and rescue
  (a) Construct flood prevention structures: Construct river and sea embankment and regional drainage projects.

(b) Strengthen maintenance management: Reinforce river management plans, establish a safety inspection system for water structures, and integrate protection plans for small and medium dams.
(c) Establish a disaster prevention and response mechanism.
(d) Perform research in disaster prevention technology: Focus research on flood prevention and rescue databases, typhoon disaster potential analysis, and a flood forecast network.
(e) Establish nonengineering flood control measures: Strengthen the review of land use planning for flood plains, promote a flood insurance system, and establish a flood warning system.
(f) Integrate flood control measures for reservoirs: Strengthen water conservation, increase surface permeation, decrease flood peak flow, and take into consideration ecological protection and the environmental landscape.

(3) Drought prevention and emergency response
(a) Establish drought prevention and response systems.
(b) Promote related work on prevention and response: Enhance reservoir protection and groundwater control and monitoring, research water conservation technologies for industries, develop alternative water resource technologies, develop new water resources, protect water quality, regularly publish water supply and demand conditions, and promote education on water resource protection and conservation. Special emergency response measures for droughts include: regularly publish drought information, stop fallow irrigation, and make artificial rain.
(c) Devise future development goals and response measures: Establish a central to local drought prevention and relief system, strengthen research on the drought warning system, promote education on water resources and watershed protection, and review coordination problems among the existing policies and regulations.

Nevertheless, disaster prevention adaptation strategies devised by the Taiwan government do address the impact from climate change and do focus on sea level rise and water resources. The conservation of watersheds included in the water resource strategy closely interrelates with debris flow prevention in Taiwan. Therefore, the adaptation strategies include all kinds of disaster issues. Recently, many works that follow adaptation strategies are still in the research stage. These two more efficient works are the main establishment of the disaster prevention mechanism and the Flood-Prone Area Management Plan (FPAMP) (National Fire Agency, Ministry of the Interior, 2008).

The capacity of the disaster prevention and response system in Taiwan met an unprecedented challenge when the Chi-Chi earthquake occurred in 1999. The central government (Executive Yuan) instructed the National Science Council (NSC) to assist the National Fire Agency (NFA) in drafting the Disaster Prevention and Protection Act (DPPA). This chapter is consistent with the conditions of real disasters and similar bills of the United States and Japan. The draft of DPPA was adopted by the Executive Yuan on December 25, 1999. And then the draft was considered by the Legislative Yuan and put into practice on July 19, 2000. DPPA is the first law dealing with the disaster prevention and response issues. It includes eight chapters entitled General Principles, Disaster Organization, Plan of Disaster Prevention and Protection, Disaster Prevention, Disaster Response Countermeasures, Recovery and Reconstruction after Disaster, Penal Provisions, and Supplementary Provisions, respectively. DPPA explicitly defines the responsibility of the government, the populace, the community, the civil defense, and the army when disaster occurs. DPPA is the superior law regarding all disaster prevention issues in Taiwan. In recent years, the regional plans of disaster prevention and protection for each county in Taiwan have been subsequently devised. The mechanism of disaster prevention and response is currently more intact (National Fire Agency, Ministry of the Interior, 2008). Fig. 5 shows the framework of the current disaster management.

In order to effectively resolve inundation problems in land subsidence areas, low-lying terrain, and urban planning areas, the central government announced the “Special Act for Flood Management (SAFM)” on January 27, 2006. SAFM is the superior law pertaining to flood prevention action. It explicitly indicates the participatory organizations, needed budget, and necessary measures to prevent flood disasters. According to the purpose of SAFM, the Ministry of Economy Affairs (MOEA) proposed the FPAMP, which was adopted by the Executive Yuan on March 3, 2006. FPAMP has an NT$116 billion budget to be dispensed over a period of eight years. The budget aims to systematically harness 35 county and city rivers, 238 regional drainage systems, 4 enterprise-related sea dikes, and 350,000 ha of hillsides. Almost 500 km^2 of flood-prone areas will be improved. FPAMP is the largest flood protection action plan. The main four objectives of FPAMP are to decrease the 12 billion NT dollars financially lost by floods every year, to protect 250 million people by avoiding floods every year, to reduce the influence of floods on 500 km^2 of flood-prone areas, and to raise the complete ratio of the flood protection structure from 30% to 60% (Ministry of Economic Affairs, 2006).

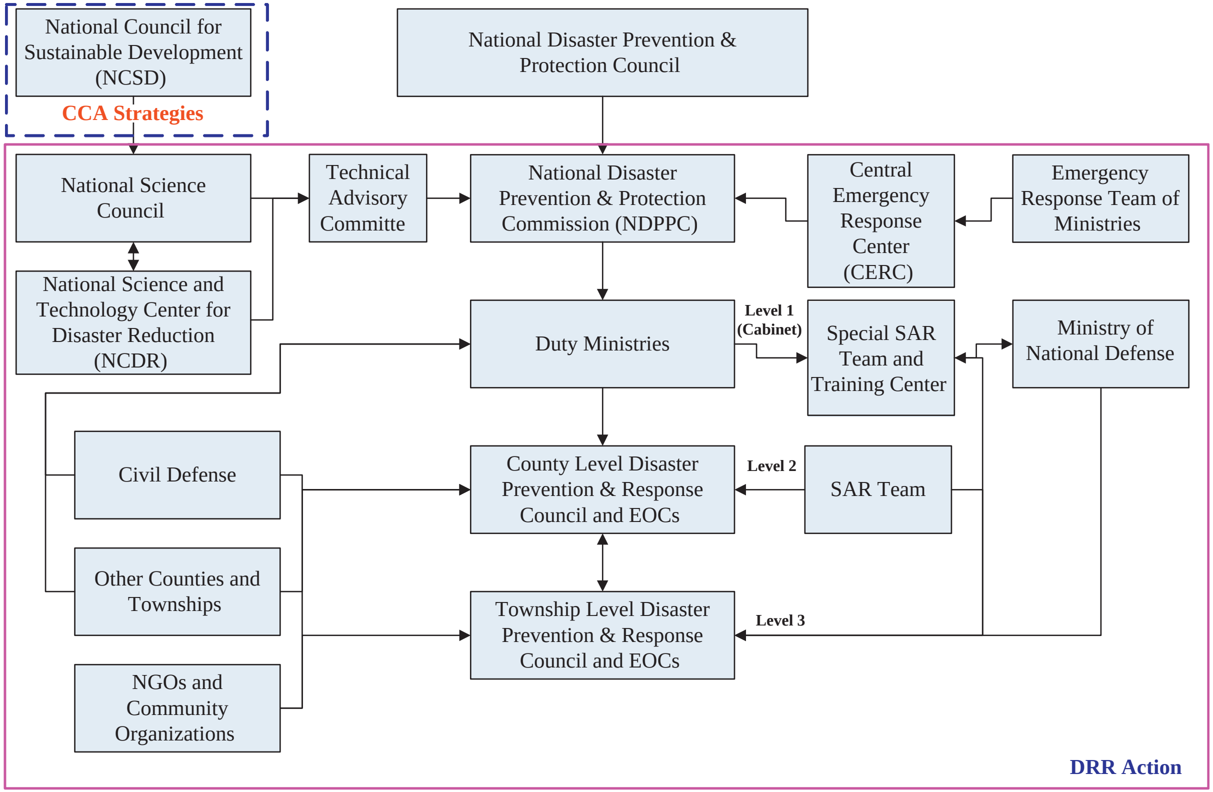

Fig. 5. Framework of Current Disaster Management Organizations in Taiwan (Diagram Linking CCA and DRR).

Recently, all works of the first stage of FPAMP are completed. The government finished 634 dredge channel works with a total length of 1868 km, 724 emergency works, and 123 comprehensive water control plans. Furthermore, in order to delay the flood arrival time and increase the mobility of drainage, the Water Resources Agency (WRA) purchased 150 mobile pumps. Today, there are 642 mobile pumps that can be dispatched immediately to drainage areas. According to the drainage of narrow areas where mobile pumps cannot be used, WRA purchased 661 small pumps that would protect almost 100,000 people, 258 villages, and 30 schools by avoiding water disasters (Lee, 2009; Water Resources Agency, Ministry of Economic Affairs, 2008).

Even though the foregoing two laws (DPPA and SAFM) have been announced, there still is no adaptation operation for the impact of climate change. Recently, many subjects related to the adaption of climate change have been studied. The uncertainty of the impact of climate change still cannot be quantified. Hence, the adaption of climate change is not joined with the two foregoing laws. Nevertheless, the achievement of reducing disasters through disaster prevention efforts may still be possible at the current extent until a climate change adaptation strategy is proposed.

REFERENCES

Central Weather Bureau. (2004). *100 Questions about typhoons* (in Chinese). (p. 33). Taipei: Central Weather Bureau.

Council for Economic Planning and Development. (2007). *Study on the adaptation strategies for global warming in Taiwan* (in Chinese). Taipei: Council for Economic Planning and Development.

Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan). (2002). UNFCCC national communication of the Republic of China (Taiwan) (in Chinese), July 2002, Web 21, September 2009. Available at http://epa.gov.tw/FileLink/FileHandler.ashx?file = 12434

Hsu, H. H., & Chen, C. T. (2002). Observed and projected climate change in Taiwan. *Meteorology and Atmospheric Physics*, *79*, 87–104.

Hsu, K. C., Wang, C. H., Chen, K. C., Chen, C. T., & Ma, K. W. (2007). Climate-induced hydrological impacts on the groundwater system of the Pingtung Plain, Taiwan. *Hydrogeology Journal*, *15*(5), 903–913. DOI 10.1007/s10040-006-0137-x.

Juang, B. J., & Chen, S. H. (1994). Reflection of the drought in 1993-counterattack of nature. *Water resources conference* (in Chinese).

Lee, Y. P. (2009). A review of the flood-prone area management plan (FPAMP). *International conference on the disaster prevention technology mitigation education*, Yunlin, Republic of China (Taiwan).

National Fire Agency, Ministry of the Interior. (2008). *Disaster prevention and protection act, 2008* (in Chinese). Taipei, Republic of China (Taiwan): National Disaster Prevention and Protection Commission, R.O.C.

National Science Council. (2005a). *The impact evaluation and response measures of climate change on hydrological environment and water resources management* (in Chinese). Taipei: National Science Council.

National Science Council. (2005b). *The impacts and adaptations of climate change on Taiwan-about public health, ecology, water resources, and disaster prevention* (in Chinese). Taipei: National Science Council.

National Science Council. (2008). *Sub-project 4: Hydrological environment research in Taiwan (β). Research of hydrological cycle and hydrological environment in Taiwan* (in Chinese). Taipei: National Science Council.

Ministry of Economic Affairs. (2006). *Special act for flood management*. Laws and Regulations database of the Republic of China, 2006. Available at http://law.moj.gov.tw/eng/LawClass/LawContent.aspx?PCODE = J0110072

Tung, C. B., & Li, T. Y. (2001). The impact evaluation of climate change on Chi-Jia-Wan Creek. *Journal of Chinese Agricultural Engineering*, *47*(1), 65–74. (in Chinese).

Tung, C. P., & Haith, D. A. (1995). Global warming effects on New York streamflows. *Journal of Water Resources Planning and Management*, *121*(2), 216–225.

Water Resources Agency, Ministry of Economic Affairs. (2008). *Regulation projection of flood-prone areas*. Update: November 6, 2008. Available at http://fcp.wra.gov.tw/. Accessed on September 21, 2009.