AN IMPROVED WATERSHED MANAGEMENT AND FLOOD MITIGATION POLICY IN TAIWAN

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ABSTRACT

After the 921 Chi-Chi Earthquake of 7.3 magnitude in the Richter scale in 1999, the fragile soils, frequent floods, and debris flows made homeland resources even weaker in Taiwan. The dense population of Taiwan forced the inhabitants to use hilly and mountainous regions for agriculture and development in the past. 92-Flood in 2004, which entailed vast monetary losses and casualties, forced the government to rethink its land use strategy. In order to use land in a more efficient and eco-friendly manner, the Council for Economic Planning and Development (CEPD), Executive Yuan of Taiwanese government, proposed the "Land Recovery Strategy and Action Plan" in 2006. The core concept is: "To respect Nature and to adapt to Nature". To contribute to achieve this goal, an improved watershed management and flood mitigation policy in Taiwan is proposed in this paper. Safety, economy and ecology factors are included in the policy discussions and accompanied measures listed for reference.

Key Words: National policy, Flood mitigation, Watershed management, Disaster prevention, Ecological engineering, National spatial planning

INTRODUCTION

In 2005, Hurricane Katrina struck Louisiana and Mississippi. Birkland (2006) regarded it as a case of "unlearning". Before Hurricane Katrina, the Mississippi River broke out of its levee system in 1927, and the area was inundated up to a depth of 30 feet (10 m). Van Heerden and Bryan (2006) pointed out the failures of Katrina are not only a product of Federal Emergency Management Agency's move into Department of Homeland Security, but also of short-sighted political maneuvering at both state and federal levels. The Katrina event has aroused a lot of discussions of disaster managements in the United States (Congleton, 2006; Sobel and Leeson, 2006; van Heerden and Bryan, 2006; Gerber, 2007).

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The Netherlands, with two-thirds of its lands below the sea level, faces the rising sea level due to climate change and the melting snow induced floods in the upper watersheds of other countries. The Dutch government has recently adopted the National Spatial Strategy (Nota Ruimte) which is based on the Fifth National Policy Document on Spatial Planning and the Second National Structure Plan for Green Areas (MHSPE, 2006). As for water related issues, the Dutch government adopts a "go with the flow" policy and anticipates expected developments. In 1993 and 1995, there were two floods in the Netherlands originating from the mountainous heartland of Europe with no fatalities but enormous economic damages (RWS, 2006). To enhance the capacity against flooding, more space has been released for the major rivers and the coastal defense systems. The Dutch government has then regarded water as an important structuring principle for landscape design. This approach appears more sustainable because it addresses all aspects of the problem and involves all stakeholders of the river water resources.

After the 1959 flood that left 5,000 casualties, the Japanese government invested approximately 660 billion USD during 1959-2002 to enhance its flood defense systems. The 2000 Tokai flood had unexpected discharge far beyond the designed river protection standard and brought economic damages of estimated 7.6 billion USD. Since that flood, the Japanese government has shifted its management strategy from disaster prevention with a presumed zero risk to disaster reduction with an acceptable risk (Ikeda *et al.*, 2006).

The 1998 flood on the Yangtze River, the longest river in China, inundated total area of 21,200,000 ha. This flood was the worst flood in China since 1954, when the water inundated about double the total area of the 1998 event. The casualties of the 1998 event were only about 1/30 of 1954 event (1,320), the total direct economic loss of 1998 (24,345 million USD) is 16 times of that of 1954. These increases in water level and damages were a result of human activity over nearly fifty years since 1954 (Wisner *et al.*, 2004). The remedy is to shift from flood mitigation to flood disaster management. New thoughts such as "living with floods rather than fighting them" (Jiang *et al.*, 2005) and "sharing both risks and benefits of flooding" (Cheng, 2006) are proposed in China.

Tompkins *et al.* (2008) explored disaster management of floods of the Cayman Islands and droughts of Northern East Brazil, and found the four factors critical to reductions in risk: (1) flexible, learning-based, responsive governance; (2) a committed, reform-minded, and politically active actor; (3) a disaster risk reduction integrated into other social and economic policy processes; and (4) a long-term commitment to managing risk. At the end of every hurricane season the National Hurricane Committee of the Cayman Islands reviews what it has done effectively the year before and what has not worked. Learning from successes and failures of the past year has been an integral feature of the response strategy, and it has allowed the Cayman Islands' government to avoid the "blame culture".

Using factors proposed by Tompkins *et al.* (2008) to examine the policies of above-mentioned countries, we found that these governments have shifted toward sustainable disaster management and have integrated social involvement and policy decision making processes into risk management. Historical and recent disasters of above-mentioned countries (including Taiwan) triggered policy reforms are listed in Table 1. The Chinese, Japanese, and Dutch governments noted that engineering countermeasures do not guarantee the success of risk reduction, and sometimes make it worse. People used to think it was very safe to live behind the dikes, but when the dikes breach, it may lead to catastrophic damages. The concept of "living with the nature" has been well-recognized by these governments. They learn from the

past disasters and so does Taiwan. The watershed management and flood mitigation policy in Taiwan policy are proposed in this paper. The following section briefly describes the basic facts and origins of disasters in the hills of Taiwan.

Table 1 Historical trends of major disasters in five countries triggering policy reforms.

Country	Year	Disaster
United States	1927	Great Mississippi Flood
	2001	September 11th Attack
	2005	Hurricane Katrina
Japan	1959	Flood
	2000	Tokai Flood
The Netherlands	1954	North Sea Flood
	1993	European Flood
	1995	European Flood
China	1954	Flood on Yangtze River
	1998	Flood on Yangtze River
Taiwan	1959	87-Flood
	1963	Flood
	1999	921 Chi-Chi Earthquake
	2001	Typhoon Toraji
	2004	92-Flood

BASIC FACTS AND ORIGINS OF DISASTERS IN THE HILLS OF TAIWAN

To better understand the policy, the basic facts and causes of disasters in the hills and mountains of Taiwan are illustrated in this section.

Basic facts

According to a Soil and Water Conservation Bureau (SWCB) survey on the debris flow induced damages from 1982 to 2004, the major debris flows had resulted in cumulative 150 deaths, 136 missing persons, 19 injuries, and 53 damaged houses.

The total area of hill sides in Taiwan defined by elevation above 100 m (calculated from mean sea level in Keelung Harbor, Taiwan) or elevation below 100m but with an average slope above 5% is roughly 2.64 million ha. (about 73.3 % of Taiwan's total area). This area is strongly affected by the forces of nature such as rainfall and earthquakes. The mountains of Taiwan are high and rainfall is amassed mainly in the wet season (May-September). About 3.5 typhoons strike Taiwan annually which causes an annual economic loss of about 12.8 billion NTD (0.4 billion USD). In 2004, 9 typhoons struck Taiwan, and 92-Flood inundated the area of 659 km^2 is one of them. In addition, the 612 Torrential Rains in 2005 inundated the area of 500 km^2 in the southern Taiwan.

In Table 2, expenditure of measures of eight severe typhoons and one heavy rain from 2001 to 2007 are listed according to statistics of the Debris Flow Emergency Response System (SWCB, 2007). During this period, the total landslide earth removal sites numbered 282 and cost 0.42 billion NTD; the total hillside and flood mitigation recovery sites numbered 2,973 and cost 7.8 billion NTD; village recovery sites numbered 62 and cost 0.18 billion NTD; and other sites numbered 151 and cost 0.18 billion. The overall sites numbered 3,477, and the total cost was about 8.5 billion NTD (equivalent to 0.3 billion USD).

Table 2 Expenditure of measures of severe typhoons or heavy rain in Taiwan (2001-2007)

Typhoon/Heavy Rain	Date	Landslide earth removal	Hillside and flood mitigation recovery sites	Village recovery sites	Others	Subtotal
Typhoon Toraji	2001/07/30	57,565	1,259,135	31,200	7,000	1,354,900
Typhoon Nari	2001/09/22	59,126	1,579,206	5,266	200	1,643,798
Typhoon Haima	2004/09/10	-	140,965	1,000	-	141,965
Typhoon Aere	2004/08/23	536	546,170	23,142	5,388	575,236
Typhoon Mindulle	2004/06/29	203,193	2,919,851	58,514	113,606	3,295,163
Typhoon Matsa	2005/08/03	-	136,013	-	-	136,013
Typhoon Haitang	2005/07/16	4,600	578,266	-	3,500	586,366
0609 Heavy Rain	2006/06/09	96,960	497,116	-	32,594	626,670
Typhoon Krosa	2007/10/04	510	184,860	1,300	20,633	207,303
Total		422,490	7,841,582	120,422	182,921	8,567,414

a) Unit: 1,000NTD
b) Source：SWCB (2007)

Origins of disasters

Taiwan is situated off the southeast coast of the Asian continent and lies between Japan (to the north) and the Philippines (to the south). Taiwan is 394 kilometers long in length, and 144 km in width. The total area is 35,980 km^2 which is only slightly larger than the combined states of Massachusetts and Connecticut. The island is surrounded by seas and located at the interface between the Eurasian Plate and Philippines Plate (see Fig. 1). The plates' movements created the Central Range which divided Taiwan in the middle and induced many faults and accompanying earthquakes. There are 51 active fault belts in Taiwan. The origins of disasters related to hillsides can be categorized into 4 subcategories:

1. Population of Taiwan increased from 9.75 million in 1959 to 22.9 million in 2006 (2.34 times of 1959) (MOI, 2007). The increase of population forces the Taiwanese to develop the hillside for multi-purposes. The developed areas in the hill side usually slide during heavy rains if erosion controls and slope stability measures are not properly taken.
2. In the past, due to a deficiency of financial support, streams were not mitigated in an integrated way so that rivers were taken different measures in different phases. That made past projects focus more on the local view than on the whole view.
3. The 921 Chi-Chi Earthquake had a great impact on the stability of the hillsides of the Central Range. The heavy rain carried by typhoons induced debris flows and floods which caused huge damages to the lives and properties of the indigenous peoples after that earthquake. Based on the satellite images, 2,365 landslides were identified in Taiwan after the 921 Chi-Chi Earthquake (Shieh, 2000). The total area of landslides of general slope land is 2,539 ha., and the total area of landslides of national forests is 11,807 ha. The sediments of those landslides provide the materials for the debris flow.

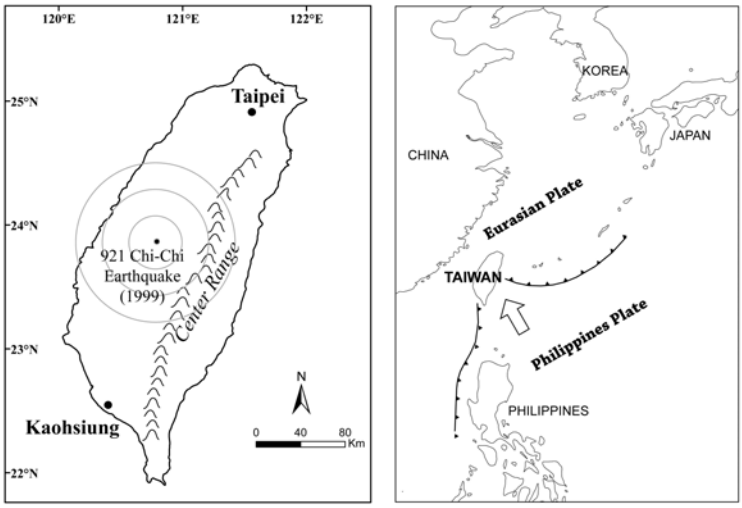

Fig. 1 Location of Taiwan

4. In the past 100 years, Taiwan experienced an island-wide warming trend (1.0-1.4 °C/100 years) based on IPCC (Intergovernmental Panel on Climate Change) climate models. Both the annual and daily temperature ranges have also increased (Hsu and Chen, 2002). The IPCC Working Group II Fourth Assessment Report (2007) has pointed out the frequency of heavy rain increases in the middle or low latitudes. Since Taiwan is in this zone, extreme hydrological events will be more frequent in Taiwan's future. Figure 2 shows the occurrences of top 10% typhoon precipitation indexes including the total cumulative precipitation, average precipitation, and maximum hourly precipitation of typhoons during 1970-2006. In this figure, the occurrences of the top 10% precipitation indexes are doubled for 2000-2006 than that of 1970-1979. The occurrences of serious typhoons have a tendency to increase in the future (NSTCDR, 2006). Figure 3 shows that the total number (moving average of 10 years) of typhoon struck Taiwan during 1958-2007 has a tendency of increasing from 1998. As breakdown to different strength of typhoons from small to medium to strong, the 10 year moving average number of the medium typhoons (maximum sustained wind speed = 32.7 m/s-50.9 m/s) increases from 1998 which shares the same trend as the total number of typhoons does during 1958-2007. Although the 10 year moving average number of strong typhoons (maximum sustained wind speed > 51.0 m/s) is decreasing from 1993 (see Fig. 3), the accompanying precipitations of 2000-2006 are more intense than before (see Fig. 2).

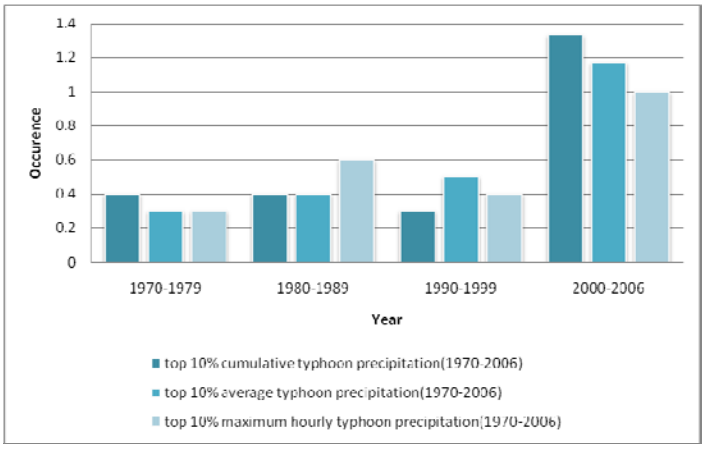

Fig. 2 The occurrence of top 10% cumulative typhoon precipitation, top 10 % average typhoon precipitation, and top 10% maximum hourly typhoon precipitation (1970-2006).
a) Source: NSTCDR (2006)

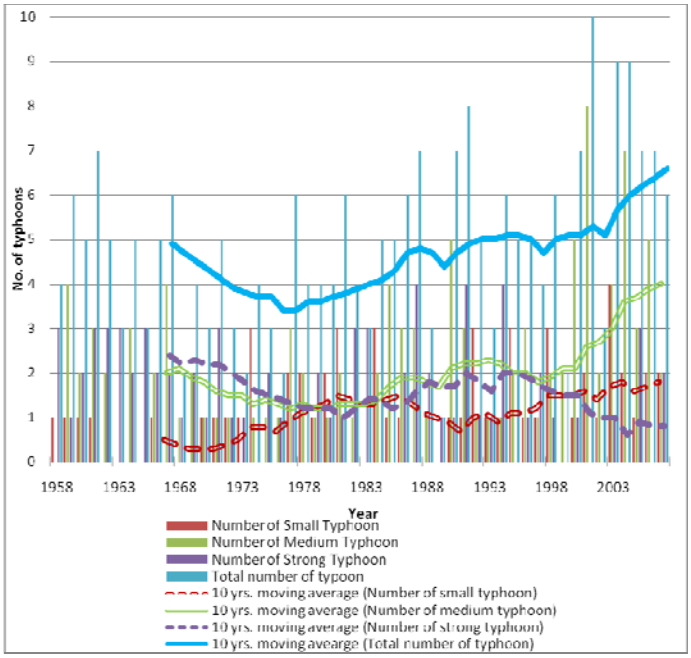

Fig. 3 Number of typhoons struck Taiwan (1958-2007). Small typhoon: maximum sustained wind speed = 17.2 m/s-32.6 m/s; medium typhoon: maximum sustained wind speed=32.7 m/s-50.9 m/s; strong typhoon: maximum sustained wind speed > 51.0 m/s.
a) Source: CWB TDB Database (http://rdc28.cwb.gov.tw/data.php)

The mountain side and near shore zone of Taiwan will be affected by the impact of global climate change. The authorities should aim at long-term preparedness for severe disasters. To overcome the impacts of those disasters, development of hillside watershed management and flood mitigation policy in Taiwan is necessary and urgent.

STRATEGIES AND MEASURES

Factors of flood mitigation

As for choosing the measures of flood mitigation, the three major factors are safety, economy, and ecology. Those factors are differentiated in time and space and affect each other to some degrees. We should choose the measures locally and flexibly. In Fig. 4 (modified from Lin, 2003), these factors locate in the three small circles outside the main measures triangle's three corners. How to choose proper measures to achieve an optimal balance among these three factors is an art. The three factors are outlined below:

- Safety: When measures are employed in areas of secure objects such as villages or private properties, the safeties of important life support systems (such as reservoir, agriculture, or special disaster hotspots) are of the first priority. The design of those sites should pass certain safety regulations and related tests.
- Economy: In the design process, economic issues are important, and a benefit analysis should be made. The homeland development and restoration strategy should be considered in the design phases. With practical financial support, the sustainable management of watersheds can be carried out.
- Ecology: When measures are applied in ecological protection areas, endemic species restoration area, or endangered species restoration areas, the adverse impacts of these

measures should be carefully evaluated. In the process of design, the measures taken should be of minimum disturbance of ecosystems. Necessary restoration and compensation should be made if the environment is degraded by the measures.

Fig. 4 The strategy and measures of the policy (Modified from Lin (2003))

To achieve the main goals of watershed management and flood mitigation, the 3R tactics are proposed here. They are the inverted triangle in the center of the main measures triangle (Fig. 4). The 3R tactics are named after the initials of the second word of the three tactics.

3R tactics

- Flood Relief: The consequences of flooding are reduced by launching the integrated watershed management, and associated flood mitigations are planned from point (local characteristics) to line (existing measures in the river) to face (national homeland spatial plan and environmental consideration). The flood relief tactic corresponds to the “Safety” factor.
- Production Renewal: A national spatial plan to change land use, to speed production renewals, and to help residents to adapt to global climate change impacts must be developed. Abandoning non-green productions which emit high CO_2 or other global warming gases are encouraged. The production renewal tactic corresponds to the “Economy” factor.
- Watershed Restoration: Conservation of water resources and natural resources are practiced by using natural materials instead of artificial ones. Eco-friendly materials such as porous media (increase the area of habitation) should be used for restoration. The watershed restoration tactic corresponds to the “Ecology” factor.

The three triangles outside the 3R inverted triangle (see Fig. 4) show measurers to be taken for different factors. These three triangles represent flood mitigation measures, ecological

measures, and national spatial planning. They are explained in the following three sub-sections.

Flood mitigation measures

There are two kinds of measures in the flood mitigation measures: the traditional structural measures and the nonstructural measures. As the structural measures concern more on the safety factor than on the ecology factor, they are placed near the safety factor. On the contrary, the nonstructural measures are placed nearer to the ecology factor.

1. Structural Measures

To cope with high hazard-potential hillside zones, five major structural measures are taken.

- Debris flow mitigation
- Stream mitigation
- Land slide mitigation
- Gully erosion control
- Slope land protection

2. Nonstructural measures

Nonstructural measures should follow the concepts of “Land Recovery Strategy and Action Plan of Taiwan” which emphasizes the adaption to and the respect of nature.

- Disaster monitoring and forecasting system
- Emergency evacuation plan
- Disaster prevention education and personnel training enhancements
- Endangered village settlements

Ecological measures

Ecological measures consist of ecological engineering and natural reserves. Ecological engineering can better take the ecological factor into account; therefore, it is put in the ecological measures instead of in the structural measures. Typically ecological engineering includes the following:

- Permeable Sabo dam
- River bank protection works
- Vegetation on the slope lands
- Fish ladders
- Ecological corridor

National spatial plan

To adapt to global climate change, the land use of Taiwan needs to renew. Measures of homeland spatial planning include the following: green production, integrated watershed management, and environmental impact assessment. Those measures are briefly highlighted below:

- Green Production
- Integrated watershed management

- Environmental impact assessment

Three-ion management

To manage the watershed more efficiently, three-ion management methods are used. (Three arc banner besides the main triangle in Fig. 4)

- Livelihoodization: Environmental education and disaster concepts should be rooted in everyone's daily lives. Then citizens can live ecologically and help to save the environment by themselves.
- Localization: Production renewal based on local characteristics in the hillside villages can be achieved by green production, and by this way sustainable developments can be achieved.
- Globalization: Globalization can be carried out by importing foreign advanced techniques and concepts, exchanging flood mitigation information, and sharing experiences with other countries whose geological conditions are similar to Taiwan.

CONCLUSIONS

To cope with disasters induced by typhoons, earthquakes, and impacts of global climate change, the old policy of flood mitigation of Taiwan should be modified. The balance of the mitigation among economy, ecology, and safety is suggested in this policy discussion. The accompanied measures, tatics are also listed for reference. The new policy of hillside watershed management and flood mitigation in Taiwan proposed in this paper can provide guideline for the future use. Humans have a responsibility to help the earth restore to a place where sustainable development for all living things are possible, and that can be done by sharing information, exchanging techniques, and cooperation among countries.

ACKNOWLEDGEMENTS

The material presented in this paper is partly adopted from a project granted by SWCB, Taiwan. The authors deeply appreciate SWCB Taiwan for the financial support and Feng-Chia University GIS Center of Taiwan for providing necessary data.

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