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Integrate Traditional Ecological Knowledge into Disaster Mitigation and Adaptation Strategies in High Risk Settlements – a Case Study of Taiwan

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1 ABSTRACT

The accelerated pace of climate change in today's global world has intensified the frequency and intensity of extreme weather events. Structural engineering measures are the common ways to cope with disasters. However, with the increasing frequency and intensity of extreme disaster events, the general engineering design standards could not stand with severe disasters. Non-structural engineering measures are the alternative including zoning and insurance. In fact, resettlement or relocation is the possible approach to relocate people from high risk areas to relative safer places. Nevertheless, such relocation might destroy the original living context and livelihood thoroughly. In the other hand, traditional ecology knowledge is the long lived knowledge inherited from ancestor. Traditional ecological knowledge could become a useful warning system to warn people when should retreat and when should be prepared. As a whole, the purpose is to collect possible traditional ecological knowledge in areas suffered from disasters and improve such knowledge to become a feasible disaster mitigation approach.

Keywords: non-structural engineering measures, traditional ecological knowledge, extreme weather events, mitigation, adaptation

2 INTRODUCTION

Global climate change has intensified the frequency and intensity of extreme disaster events suchs as torrential rain, snow storm, drought and so on. Acoording to the scientific reports, the extreme weather events caused by climatic variability have already occurred in the past decades and it is very likely to emerge in the future (Pareek & Trivedi, 2011). In order to respond the increasing disasters, a four-phase disaster management strategy has been applied in the worldwide including (mitigation, preparedness, response, and recovery to cope with climate variabilaity (O'Brien et al., 2006; Alexander, 2002). Structural and non-structural enignnering measures are the two common approaches. Structural enginnering measures such as dikes, pump stations, dams are based upon engineering technologies to mitigate potential impacts. In the other hand, non-structural enginnering measures such as land use plan and insurance to lead human settlements away from the disaster risks areaas. Due to the frequent and intensified extreme disasters, the design standard of traditional structural engineering measures might not enough to cope with such disasters. Therefore, more attentions have been put on non-structural enginnering measures.

Among a suite of strategies, retreat from hazard-prone locations seems to be a great solution to reduce the risk posed by climate change (King et al., 2014). In fact, whether temporary, permanent, internal or international migration is recognized as a viable and sustainable adaptation strategy to reduce disaster risk and adapt climate change (King et al., 2014; Marino, 2012; Gemenne, 2011; IOM, 2011; Mayer, 2011; Black et al., 2011; Warner, 2010; Morton et al., 2008). However, such relocation and climatic migration might further result in the break down of couumities or unanticipated social chnges (King et al., 2014; Lizarralde & Boucher, 2004; UNDRO, 1982). In addition, involuntary outmigration involves changes in family commitment, livelihood opportunities, financial constraints and emotional ties and maladjustment is likely to occur (King et al., 2014; Oliver-Smith, 1991). The impacts of the society which has settled for centuries may cause devastating consequences and threat to its existence (Oliver-Smith, 1991). A great amount of research has indicated that relocation may levies high social cost, including impoverishment, social disarticulation, and decrease in livelihood security, social capital and cultural ties (King et al., 2014; Marino, 2012; Scudder, 2012; Usamah & Haynes, 2012; De Wet, 2006; Oliver-Smith, 2006; Cernea, 1996, 1997, 2000; Oliver-Smith, 1991).

In traditional disaster management systems, the long-term accumulated local knowledge has been one of indispensable components and is a significant tool today (Mavhura et al., 2013; Pareek & Trivedi, 2011). In order to adapt severe damages from climate change, traditional ecological knowledge (TEK) has been gradually recognized of the feasibility on coping disasters (Berkes, 1993). TEK refers to people's knowledge

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of their local environments, and is derived from experience and traditions evolving by adaptive processes and has been passed down through generations by cultural transmission, about the relations of specific human societies to the local environments (Hernández-Morcillo et al., 2014; Leonard et al., 2013; Houde, 2007; Folke, 2004; Berkes et al., 2000; Berkes, 1999). TEK has enabled local communities to live in harmony with their environment for generations and included information necessary for survival (Folke, 2004; Mwaura, 2008; Pareek & Trivedi, 2011; Iloka, 2016). The long-term persistence of settlement can be seen as an evidence enough that the knowledge accumulated through trial and error over many years works (Folke, 2004; Freeman, 1992).

Past studies have showed that settlements located at hazard-prone areas might come up traditional ecological knowledge (TEK) including prevention and mitigation, early warning systems, preparedness and post-disaster recovery (Pareek & Trivedi, 2011). In fact, since the 1970s, a growing evidences show that TEK can improve disaster preparedness and practice (Hiwasaki, Luna & Shaw, 2014; Dekens, 2007). The inheritance of long live experiences and knowledge can be applied to possible disaster mitigation and adaptation in the future. Therefore, the knowledge acquired through perceiving disaster and respond to natural hazards can help understand environmental science and improve disaster mitigation and adaptation strategies (Dekens, 2007). Hence, this This study attempts to build up community resilience in hazard-prone area under traditional ecological knowledge. First of all, this study will review the nature, forms, and cases regarding traditional ecological knowledge. Afterwards, this study will apply GIS-based land suitability analysis methods to search for hazard-prone indigenous tribes in southern Taiwan. And then this study will apply a systematic literature review in indigenous tribes with hazard-prone area to collect traditional ecological knowledge. As a whole, the purpose is to integrate traditional ecological knowledge (TEK) into scientific knowledge and help human beings improve capacity to disaster adaptation and resilience strategies to adapt the changing environment.

3 LITERATURE REVIEW

3.1 Migration in high risk areas

Migration from high risk areas (post-disaster resettlement, post-disaster relocation, pre-disaster migration etc.) seems to be inevitable while it is much more complicated than expected. In fact, climatic migration might be related not only safety but also social and economic issues (King et al., 2014; Usamah & Haynes, 2012; Oliver-Smith, 1991). Although resettlement indeed could reduce direct exposures from disasters, individual vulnerability might be increased due to the process such as the loss of livelihood, loss of community context, loss of religious belief and so on (Usamah & Haynes, 2012; Gaillard, 2008; Cernea, 1997; Oliver-Smith, 1991; Quarantelli, 1984). An outmigration strategy in Mayon volcano in the Philippines shows that the area has successfully reduced risks from volcanic- and typhoon-related disasters. Instead, the community has lose the livelihood options. In order to make their livelihoods, people return to their old workplaces or commute great distances to maintain lifehood. The continuing mobility of resettles who travel for their livelihoods may cause the loss of community connections (Usamah & Haynes, 2012). The economic advantages which people have built in their original settlement are the main cause of failure. (Oliver-Smith, 1991). Thus, the consequences of migration can be more devastating than the disaster event (Usamah & Haynes, 2012; Oliver-Smith, 1991).

Formalizing outmigration into disaster policy may reduce resilience for those communities in the long term, thereby initiating unanticipated changes based on economic, political or sociocultural factor and expose people to greater risks (King et al., 2014; Hernández-Morcillo et al., 2014; Oliver-Smith, 1991). In most migration policies,in order to maximize efficiency, the location of migration are mainly determined by authorities. Land which government owned or controlled may be considered as a priority for migration. With the ignorance or lack of concern for social and economic, the resettlement in a top-down manner frequently cause the failure of migration (Oliver-Smith, 1991). In addition to socioeconomic issues caused by migration, people's attitude towards relocation is also a material concern. Evidence shows that people in hazard prone areas often show the reluctance to migrate. In the case of Antigua, suffered from severe earthquakes and a huge landslide, the city was relocated for the third time to safer terrain (Oliver-Smith, 1991). Although the citizenry refused to immigrate, a new capital, Guatemala City, was founded. However, people remained in the old city and repopulated it immediately. Today, the old city continues to exist and is

one of Guatemala's major tourist attractions (Oliver-Smith, 1991; Tobriner, 1980). Given such difficulties, it is suggested that migration should not be adopted as a strategy and efforts are make to rebuild original sites (Oliver-Smith, 1991; Aysan & Oliver, 1987).

3.2 Traditional Ecological Knowledge

Over the last two decades, traditional ecological knowledge (TEK) has increasingly recognized as a source of information for environmental science, policy, and management (Hernández-Morcillo et al., 2014). There is a growing awareness on TEK for to contemporary resource management problems in various parts of the world (Berkes, 1993; Freeman, 1992). For illustration, people in Uganda have forecasted seasonal weather in order to increase or stabilize crop yields (Okonya & Kroschel, 2013). It is quite common for people to use words such as "local," "indigenous," "folk," and "traditional" as synonyms to describe their local environments (Hernández-Morcillo et al., 2014; Mercer et al., 2010; Sillitoe, 1998).

TEK is holistic and dynamic in nature and is gathered over generations through accumulation of experiences, society-nature relationships, community practices and institutions, and observation in long term (Mercer et al., 2010; Berkes, Colding & Folke, 2000; Flavier et al., 1995). The knowledge based on tradition and non-industrial societies is ecology-oriented, it attempts to understand and explain the operation of ecosystems, containing many interacting species of animals and plants (Freeman, 1992). Evolved through trial and error, Traditional ecological knowledge has a unique living style to confront a variety of environments and transmitted to future generations by oral narrative and practical experiences (Berkes et al., 2000; Ohmagari & Berkes 1997). Therefore, TEK can be viewed as part of the adaptive strategies to dwell and survive (Hernández-Morcillo et al., 2014).

Since the 1970s, there is grown evidence that TEK can improve disaster preparedness and practice (Hiwasaki et al., 2014; Dekens, 2007). Those have settled in inhospitable environments may develop a capacity for the survival of whole groups and have collectively accumulated a vast number of knowledge on disaster prevention and mitigation, preparedness and response and post disaster recovery (King et al., 2014; Pareek & Trivedi, 2011; Freeman, 1992). The nature of the community affects the knowledge which those have acquired (Dekens, 2008). The region in Himalaya had often been suffered from landslides and flash floods. Through experience and accumulated knowledge of the generations, the people here develop the sensitivity to select habitation places that were relatively safe from these disasters.

Though people cultivate lands closed to areas affected by these disasters, they decided to settle down at the upslope locations where are less vulnerable to disaster (Rautela, 2005). During the December 26 tsunami which caused 163,795 death in Indonesia's northern Aceh province, the knowledge of the sea phenomenon and the behaviors of buffaloes helped people in the Simeulue community flee the shore for nearby hills (de León, Bogardi, Dannenmann & Basher, 2006). As mentioned previously, over the course of history and up to this day, it is demonstrated that traditional ecological knowledge is critical to save lives in the face of disasters (Pareek & Trivedi, 2011; McAdoo, Moore & Baumwoll, 2009). Traditional ecological knowledge gained from local experience and practices should be integrated into disaster mitigation and adaptation to further aim for sustainability.

4 RESEARCH DESIGN

4.1 Conceptual Model

The purpose of this study is to integrate traditional ecological knowledge (TEK) into scientific knowledge to improve disatser adpatation and resilient strategies under global climate change. Therefore, this study begins with the suitability analysis of overlaying disaster risk areas (such as flood-prone areas, soil liqifaction, Dip slope areas, landslide-prone areas, collapse-prone areas, fault zone areas, rockfall-prone areas and detritus sliding-prone area) and human settlements. Afterwards, the study conduct comparative analysis between disater risk and past disaster records to find out settlements located at hazard-prone areas and suffered with disasters. This study assumes that such hazard-prone settlements might have TEK to help them continue live in such high risk areas. Therefore, a systematic review will then be applied to collect possible TEK. Figure 1 is the conceptual model of this research.

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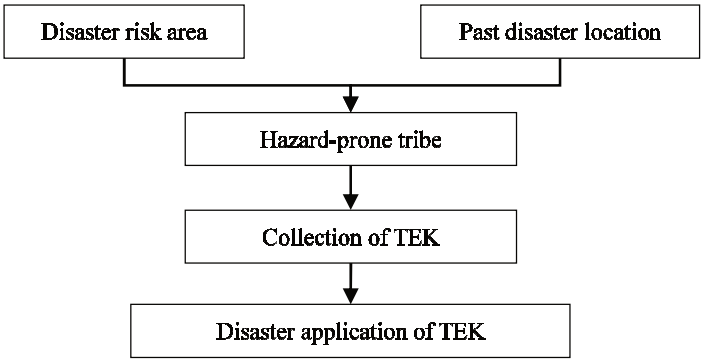

Fig. 1 Conceptual model

4.2 Suitability Analysis

This study applies geographic information system (GIS) as the main methodology to precede suitability analysis on hazard-prone settlements. GIS is a computer-based tool that analyses and visualizes geographic data on the map. There are various software could be used for analysing and visualizing geographic data such as MapInfo, ESRI ArcGIS, QGIS, GeoDa and so on. ArcGIS can visualize the features that can recognize the patterns and provide vital information to the users. It can demonstrate and convert numerous diverse data into a single visualization platform. In this study, we apply ESRI ArcGIS as the basic workstation to find out the spatial distribution of hazard-prone settlements.

4.3 Systematic review

Systematic literature review is one of the methods applied to summarize both present and past findings in specific topic. The main purpose is to integrate and categorise relevant research to collect information. It aims to assess the strengths and limitations of existing findings and integrate the fingings into conceptual framework (Uscher-Pines, 2009). In this study, systematic literature review enables us to understand how people in high risk area respond to disasters, and to reveal the application of traditional ecological knowledge related to disaster management.

5 HAZARD-PRONE SETTLEMENT

This study has applied suitability analysis via geograpgic information system to select settlements located at hazard-prone areas. Afterwards, the comparative analysis is conducted to further find out settlements which had disaster loss. Eventually, the results will be overlapped with historical disasters including flood, debris disaster and slope disaster. The purpose is to explore why people could continued live in such high risk areas and find out whether traditional ecological knowledge exists or not. After the screening process above, three settlements that located at landslide-prone areas and suffered from disasters are selected.

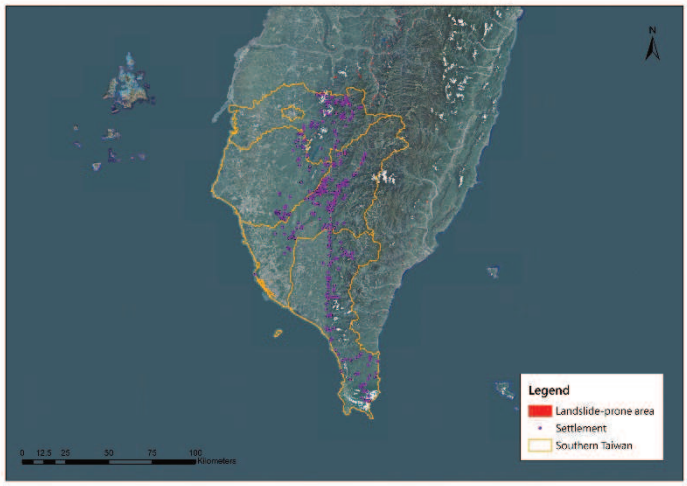

Fig. 2 Potential disaster risks. (A) Landslide-prone area

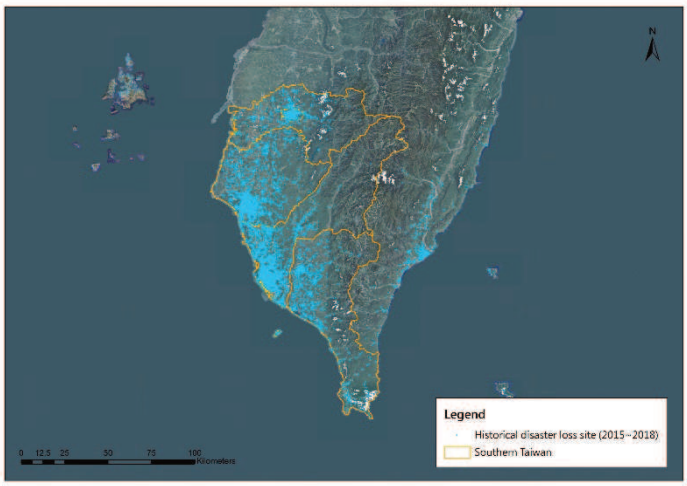

Fig. 3 Historical disaster loss site

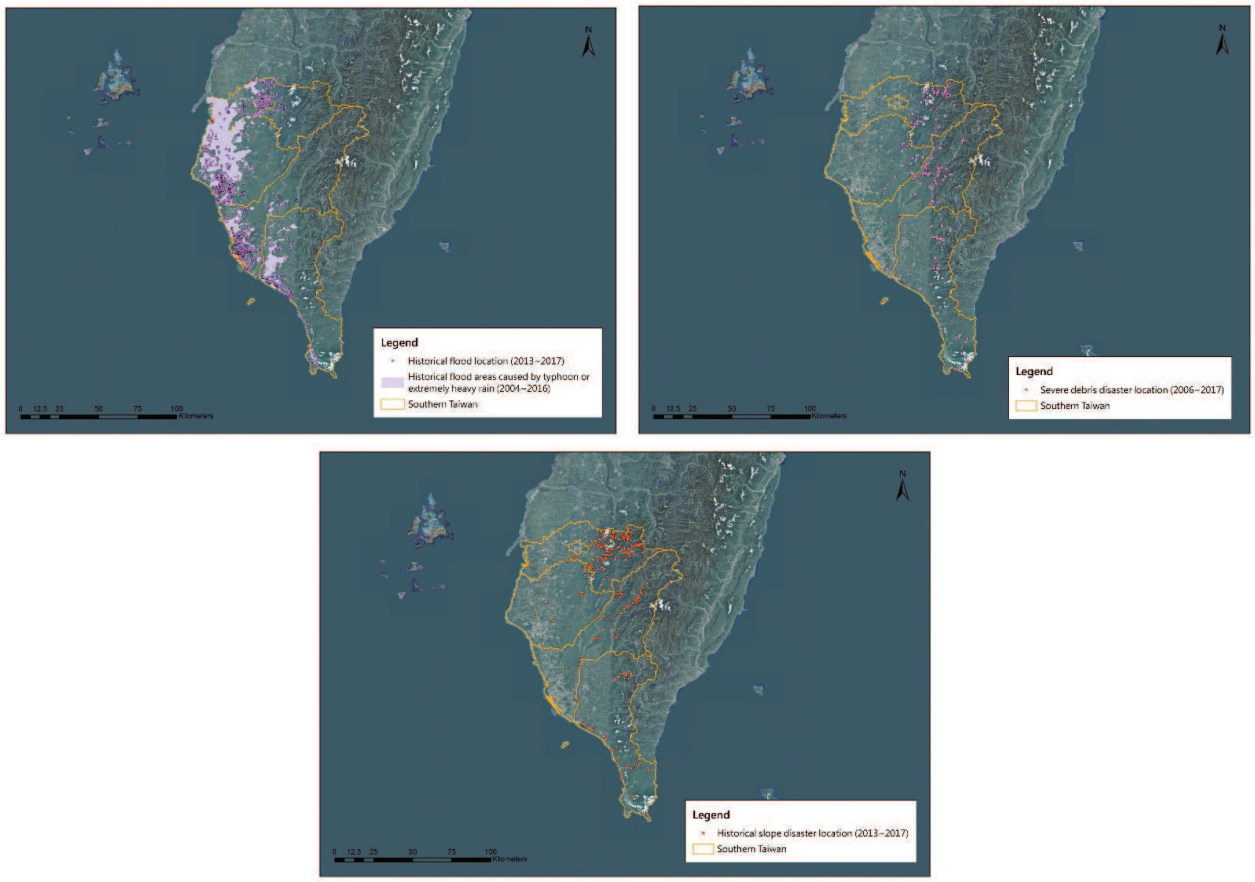

Fig. 4 Historical disaster records: (A) Historical flood disaster, (B) Severe debris disaster, (C) Historical slope disaster

According to the suitability analysis, three settlements of Paiwan peope have been selected including Yilin tribe is located in Laiyi Township, Siadanlu tribe and Chiaotung tribe had settled in Shizi Township. The historical disaster data shows that Yilin tribe was attacked by Typhoon Megi in 2016. In 2010, typhoon Fanapi brought extremely heavy rain and caused mudslide which buried roads and rivers and rushed into houses. Typhoon Trami in 2013 caused Siadanlu tribe suffering from slope disaster. Because of the debris accumulation affecting the waterway, the tribe was in urgent need of help from the government during typhoon Haitang and Nesat in 2017. During typhoon Nepartak in 2016, collapse of trees crushed high-voltage power lines and traffic was impacted in Chiaotung tribe because of the damage of electric pole. In addition, historical disaster records indicate that slope disaster occurred in neighboring area due to heavy rain in the winter of 2017. To sum up the above, disasters are very likely to occur repeatedly in the three settlements that located at hazard-prone area and made them suffered from disasters continuously. Therefore,

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the study attempts to explore if there is any TEK among Paiwan people to keep them staying such high risk areas.

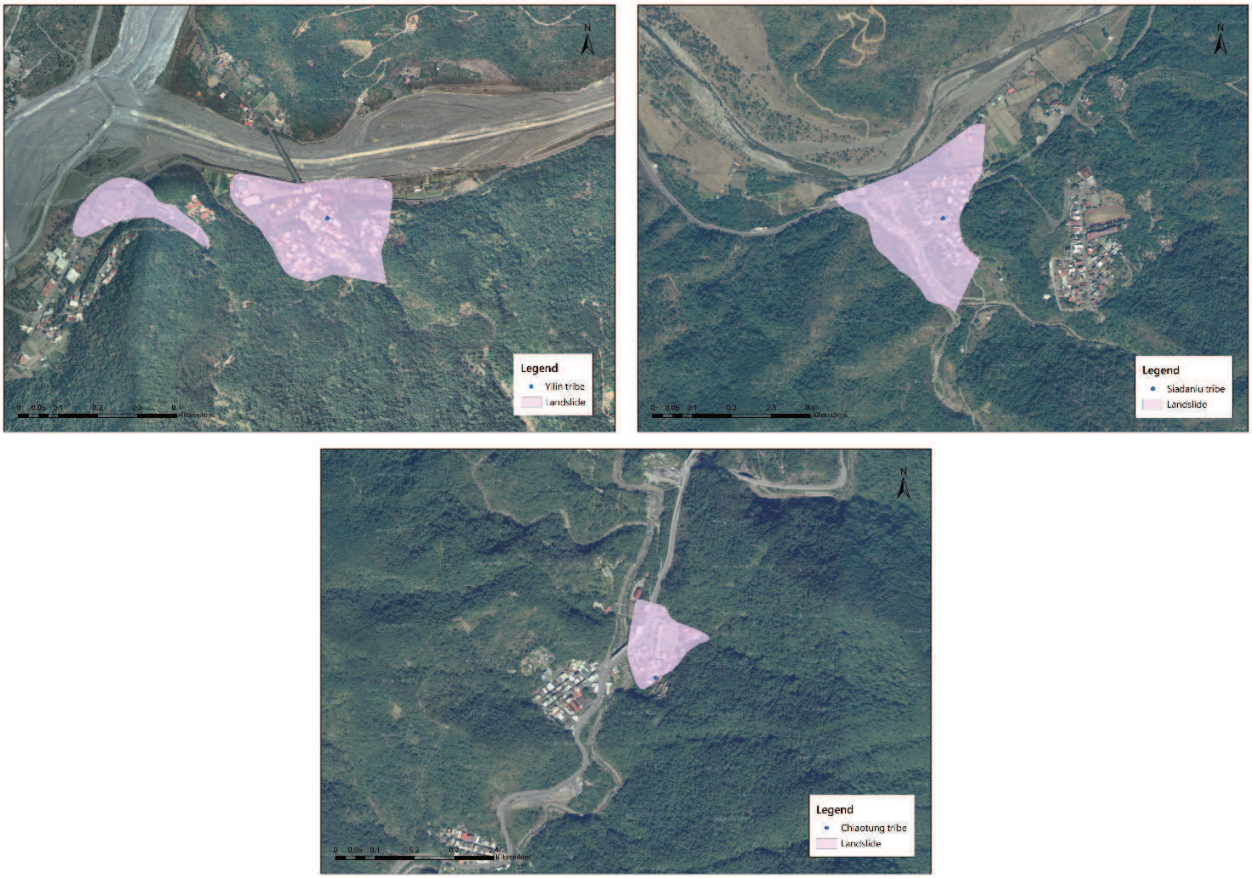

Fig. 5 Study area: (A) Yilin tribe, (B) Siadanlu tribe, (C) Chiaotung tribe

6 TRADITIONAL ECOLOGICAL KNOWLEDGE OF PAIWAN PEOPLE

Paiwan is one of the indigenious people in Taiwan. Paiwan people practice traditional social context and believe in Christianity, Catholicism and aboriginal traditional beliefs (Laiyi Township Office, 2020). The settlement pattern is collective village and mainly distributed in the southern part of Taiwan mountains in Pingdong and Taitung (the height is around 500 meters to 1,300 meters) and most of Paiwan people are located in Laiyi township, Pingtung county (Lin, 2010). Situated in the subtropical monsoon region, heavy rain and cyclones occur frequently in Taiwan. For Paiwan people, because of weather and geographical environment, is often affected by earth and rock disasters and floods. Hence, Paiwan people have extensive knowledge to cope with disasters.

Fig. 6 Landscape of Yilin tribe

Traditional ecological knowledge could be divided into various stages including days before disaster and during disaster. There are multriple signs could be applied to forecasting whether there is a storm coming or how bad will the storm is. In general, Paiwan people could predict a storm is coming by observing weather condition such as thunderstorm comes in summer afternoon and stops suddenly, feather shaped clouds or horsetail shaped clouds. or the color of the sky might be changed right before the storm. In addition to meteorological changes, unusual animal behavior can also be used to predict the onset of extremely heavy rain. Ant migration is believed to sense the nearness of heavy rains. There's a Paiwan nursery rhymes about it, "window in the sky, window in the sky, when does it rains, look at the ants climbing up (Guo & Chen, 2017)."

Fig. 7 Cloud signs

Landslide are predicted when it's raining. Paiwan people observe environmental conditions to judge whether landslide will happen. Depending on the environmental changes, Paiwan people will determine whether the disaster will happen and when to leave. It's mainly based on changes in rivers and indicators included the rising of water level and the rivers become turbid. It is noted that when the flow rate and velocity of rivers changes, accompanied by strong ground vibrations, and fog appears upstream, these signs represent the appearance of the landslide (Guo & Chen, 2017; Xiao, 2013).

7 CONCLUSION

Traditional ecological knowledge enables local people to adapt to their environmental problems for long periods of time. Although limited by the open data, only information in recent years has been collected. It is still revealed from the literature that indigenous tribes in high risk area have traditional ecological knowledge to cope with disasters. The study found that the application of traditional ecological knowledge in Paiwan is mostly used for disaster prediction or reducing disaster risk and less for disaster recovery. In this case, migration is not a necessary solution which may cause disruption of a society. In contrast, high risk areas without traditional ecological knowledge are more in need of migration strategies or require the traditional ecological knowledge from surrounding area. Traditional ecological knowledge should contribute to disaster application and help people in high risk improve their capacities to disaster adaptation and resilience strategies to adapt the changing environment. With the expansion of traditional ecological knowledge, it is highly possible to reduce the need for migration in high risk areas and the economic, political or sociocultural problems derived from migration.

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