Resilience Assessment of Mountain Settlements Isolation Effects in Extreme Climate Change

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1 ABSTRACT

It's been a while since people have awareness of the environmental impact of climate change, especially in mountain settelements of Taiwan. Extreme heavy precipitation event was very rare in the past, we rarely saw a disaster occurrence that affect the daily life of human beings. However, due to the impact of climate change, the occurs of extremely heavy precipitation events in Taiwan are more and more frequent in the past 20 years. From once every few years to nearly a dozen times a year, including heavy rain and typhoon every summer and autumn. Taiwan has special geographical factors: narrow land, densely populated, and a high density of streams. If the slope is greater than 5 degrees or the elevation is greater than 100m, the region is regarded as a mountain area. Such an area occupies about 70% lands of Taiwan, and there are many old settlements and aboriginal tribes living here. The best-known disaster event was the typhoon Morakot in 2009, it caused serious flooding, mountain crashing, and landslides in many areas of Taiwan. These disasters in mountain settlements are the most serious, including road blockage, house inundation, water and food shortages, etc. After the typhoon Morakot, People refer to "the situation in which mountain settlements are blocked due to climate phenomena" as an "isolation effect" due to plenty of news reports. Mountain settlements that have an isolation effect are like inhabitants of isolated islands on the sea. It's difficult for local residents to save themselves, and it is hard to obtain external rescue resources. Because of the natural landform and special socio-economic environment of mountain settlements, we need to pay attention to such problems occur.

The collection of "isolation effect" data is from domestic news reports, from 2000 to October 2021. A total of 326 disasters had occurred in 151 villages(The level is larger than that of the settlement because the news media mostly reported the disaster situation in the village as a unit). The severity of the disaster ranges from mild to severe, there were also many villages where the isolation effect had repeatedly occurred in different years.

This study attempts to integrate and analyze the weights of the isolation effect from past studies, at this stage, the historic isolation effect villages have been split into 270 historic isolation effect settlements. The indicators include general isolation effect, hazard, exposure, and vulnerability. Then, the weight of the analyzed indicators is used to determine the other 360 mountain settlements in Taiwan. Looking forward to clarifying the potential degree of isolation effect that may occur in the future, and providing it to the public. It is hoped that such a demonstration will allow the government to carry out more disaster reduction measures for mountain settlements, and local residents can also have considerable disaster awareness in their homes. In the future, climate change will be more abrupt, but mountain settlement residents can also live and work in peace.

Keywords: climate change, disasters, resilience, isolation effects, mountain settlements

2 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) revealed in its sixth report on climate change that it compared with pre-industrial standards. The global surface temperature from 2011-2020 has risen by 1.07 degrees, including more severe polar ice melt, extreme rainfall, and marine heat waves, which can be described as an "era of climate emergency." (Portner, Roberts, Trisos, & Simpson, 2022) For every 1°C increase in global warming, the global extreme daily rainfall event is estimated to increase by about 7%. The global proportion of severe tropical cyclones and the maximum wind speeds of the strongest tropical cyclones are projected to increase. Heavy rainfall and associated flooding events are expected to become more intense and frequent across the Pacific Islands and many parts of North America and Europe. (TCCIP, 2021) Disaster events derived from extreme climates, especially heavy rains, have a severe impact on mountain settlements. However, due to the limitation of various factors, the benefits brought by disaster management strategies in mountain settlements are often challenging to quantify, resulting in ineffective

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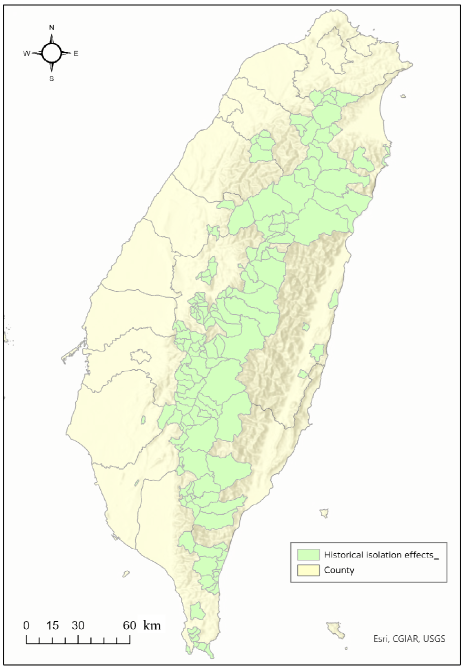
implementation.(Vorhies, 2016) The typhoon Morakot in 2009 caused many mountain settlements to collapse, the roads were interrupted, and the settlements needed to evacuate immediately.

The term "isolation effect" is precise because, after the 2009 Morakot typhoon, many news media used the term "isolated island" to describe the isolated and helpless mountain settlements in Taiwan. Even after the 2015 typhoon Soudelor hit the mountain settlements in Taiwan hard again, research and discussions on Taiwan have launched one after another: disaster identification and countermeasures and strategies in isolation effect areas. There is no complete definition of "isolation effects" in academics. For example, Pan (2016) defines it as an "isolation effect" when the external roads and bridges in a specific area are interrupted or closed and cannot pass through; Ting (2012) proposed that this area has an isolation effect where communications are interrupted, roads are damaged, and broken bridges; Lee (2012) pointed out that when a settlement is in a disaster, roads, bridges, or communications with the outside world cannot be used or interrupted, making it impossible for the settlement to communicate with the outside world. Based on the above description, the "isolation effect" is the occurrence of six situations: circuit breakage, water cutoff, power cutoff, signal cutoff, credit cutoff, and out of food.

Furthermore, in addition to discussing the identification of isolation, there should also be differences in the investment sequence between "isolation effects" and "disaster isolation effects." Mountain settlements, isolated and helpless due to road interruptions, unable to receive immediate assistance or lack temporary self-rescue ability, that is, the "disaster isolation effect." The isolation effect event refers to the identification mentioned above, which belongs to the "external intermedium damage" other than the settlement itself. In contrast, the disaster isolation effects refer to the disaster and damage to the settlement itself and the damage to the external intermedium. The urgency of investment in "disaster isolation effects" is more significant than "isolation effects" because the situation of further one is prone to direct damage such as industrial impact and residents' safety concerns due to their social and economic vulnerability and the relative disadvantage of the natural environments. Therefore, under the identification of these two types of isolation, their respective isolation effects indicators and corresponding climate change strategies are also different.

Under the threat of extreme weather, there are three areas in Taiwan that are likely to face higher disaster risks, including: urban communities with high population density and rapid development, coastal vulnerable and severely subsided rural communities, and highly vulnerable and sensitive mountain settlements. (Technology, 2014) Mountainous settlements are located in the border areas of human life circles. In addition to high environmental disaster exposure, they also have relatively fragile social and economic resilience and are more affected by climate change than other regions. Therefore, how to adjust measures to local conditions for highly vulnerable and sensitive situations such as mountain settlements is a topic that should be discussed and acted upon urgently in Taiwan in the near future.



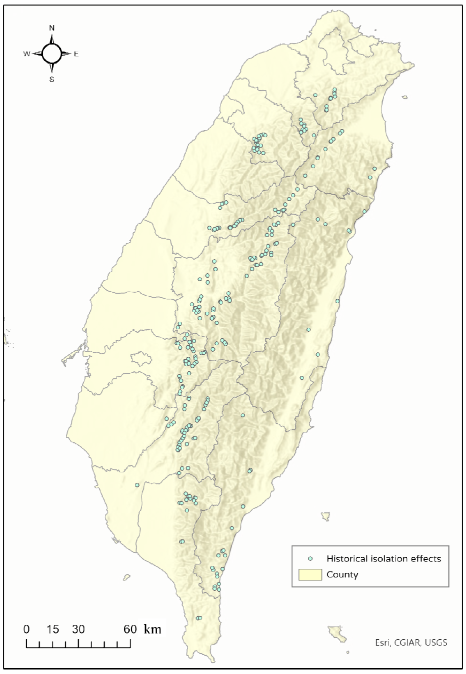


Fig. 1: Historical isolation effects (151 villages). Fig. 2: Spatial distribution of historical isolation effects (270 settlements).

3 HISTORICAL ISOLATION EFFECTS AND EVALUATION METRICS

This study collects past research (Pan, 2016)and online news about the isolation effect incidents in Taiwan from January 2001 to October 2021. Further, analyze the causes of disasters in historical isolation effects events and the socio-economic and natural conditionsbo of the neighborhood to which the isolation effect belongs. There were 326 spots that happened isolation effects and distributed in 151 villages. Overview them, With an overview, we found that from 2001 to 2007, there were three isolation effect incidents each in Lishan village and Boai village in the Heping District of Taichung; 2008 to 2014, there were five isolation effects incidents each in Shenmu village in the Xinyi District of Nantou and Fuxing village, Qinhe village, Tangaanua village of Kaohsiung; 2015 to 2021, there were seven isolation effects incidents each in Fuxing village, Lavulan village, and Meishan village of Kaohsiung.

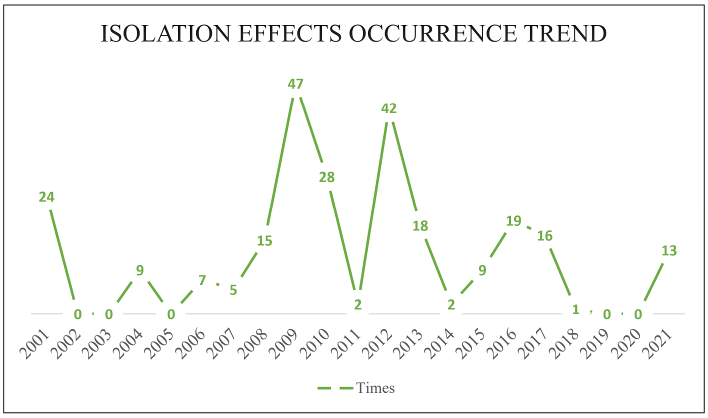


Fig. 3: Isolation effects occurrence trend for years.

Lishan village and Boai village in Taichung City were respectively affected by Typhoon Mindulle, Typhoon Krosa, and one torrential rain. They caused isolation effects. The disasters are mainly in the form of debris flow and landslides, causing broken bridges, roadbeds hollowing out, and falling rocks.Shenmu village of Nantou and Fuxing village, Qinhe village, and Tangaanua village of Kaohsiung were affected by Typhoon Morakot, Typhoon Parma, Typhoon Soulik, Typhoon Usagi, Typhoon Saola, and some torrential rains. The disasters were dominated by landslides, floods, and the destruction of access roads, bridges, houses, roads, etc. occurred one after another.Fuxing village, Lavulan village, and Meishan village of Kaohsiung were affected by Typhoon Nepartak, Typhoon Chanthu, and numerous torrential rains. The forms of disaster include floods, debris flows, and skyrocketing streams, including the continuous washing out of important connecting bridges, hollowing of roadbeds, falling rocks, and resource interruptions.

This study collects past research on isolation effects or mountain disasters, including National Fire Agency (2021), (Wu & Huang, 2018), Tsai (2016), Chen (2017), Pan (2016), (Chang & Wang, 2015), Huang (2014), Lin (2008), and Yang et al. (2010). Roughly, the island index can be divided into six dimensions, slope and elevation, disaster, road and bridge, critical infrastructure, social economy, and others. Since the spatial scale unit of this study is set as "settlement", considering the limitation of data acquisition, this study selects five dimensions to evaluate the potential location of isolation effects, as well as the disaster isolation effects that comprehensively accommodate the risk drivers of hazard, exposure, and vulnerability.

4 RESEARCH DESIGN

4.1 Research Conception

First of all, it summarizes the "isolation effect" evaluation indicators based on historical isolation effect events and brings risk dimensions to construct disaster isolation effect assessment indicators. Then, set high, medium, and low potential standards based on historical isolation effect events, based on the entire mountain settlements in Taiwan, overlap the disaster isolation effect index, and find out where will become disaster isolation effect settlements. The purpose of this research is to interpret high-potential disaster isolation effect mountain settlements based on historical isolation effect event as a reference for future disaster management, mitigation, and adaptation key areas.

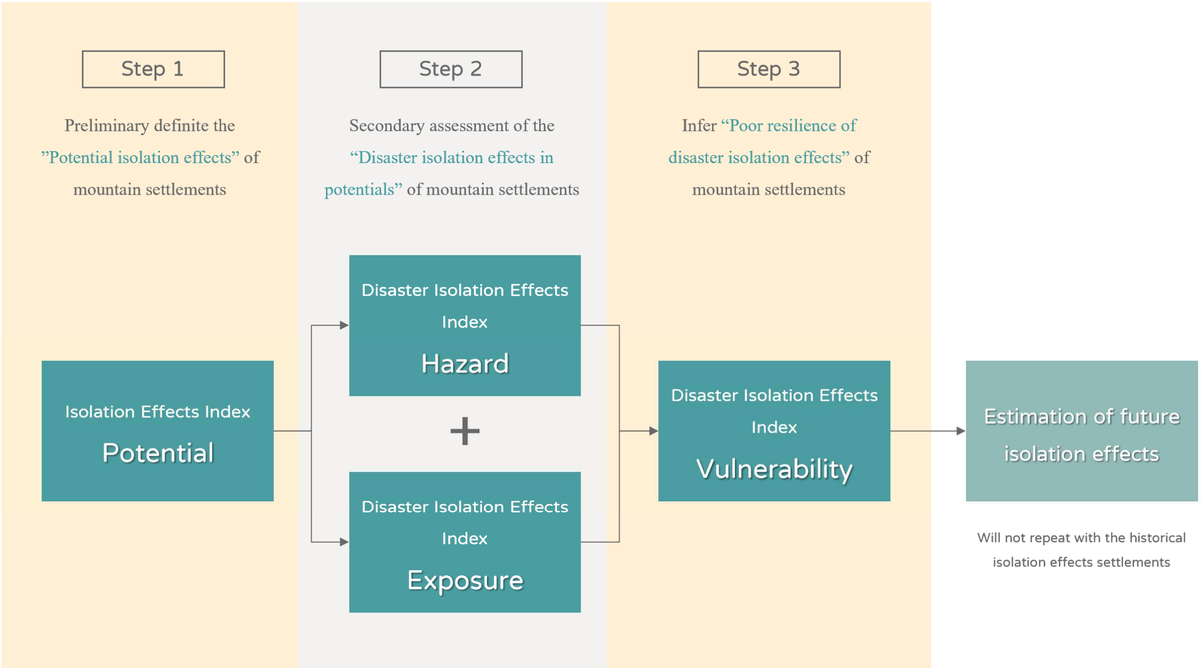


Fig. 4: Research process.

4.2 Study Area- Mountain Settlements

Taiwan is located at the intersection of Northeast Asia and Southeast Asia. Due to the mutual extrusion of the Eurasian plate and the Philippine Sea plate, orogeny has developed. The area of the mountains is larger than that of the plains, and its area ratio is about 7:3. Although the plains are suitable for human habitation and development, there are still many residents and aboriginals living in mountainous settlements for many years. (Tsai, 2016) According to article 3 of the "Slope Land Conservation Regulations", a hillside land is an area with an elevation of more than 100 meters or an area with an elevation of fewer than 100m and an average gradient of more than 5%. „Settlement“ generally refers to the aggregate of many residential houses in the hillside area or the distribution area where the population lives in a concentrated manner, which includes infrastructure, and life-sustaining pipelines, and is sufficient to provide the living resources of the residents in the settlement. (Chang & Wang, 2015)

Consequently, This research refers to the principles mentioned earlier of mountain settlements: areas with an elevation above 100m or an elevation less than 100m and an average slope of more than 5%; an aggregate composed of many residential houses in a hillside area, or population agglomeration areas.

4.3 Index of Isolation Effects

Internationally, disaster risk is defined as the possibility that a hazardous event will cause negative impact or to a place or a system. The size of disaster risk depends on factors such as hazard, exposure, vulnerability and adaptation capacity, while the probability and possibility of occurrence are implicit in the three factors above. That is to say, a place, system, or object must be expose to a hazard event, it has the characteristics of being vulnerable to adverse effects, and incapable of responding to this hazard event. All the three conditions must be met to cause a disaster to occur.

Based on historical isolation effect events and isolation effect indicators proposed by previous researches, this study aggregates and constructs "general isolated island index" and "disaster isolated island index", and further subdivides the disaster isolated island index into three major categories: hazard, exposure, and vulnerability according to the risk structure. Types to evaluate key indicators of island incidents.

Potential isolation effects index	Evaluation standards	Based on	Selection
Average slope	>5 degrees	Slopeland conservation and utilization act	Definite” Mountain settlements”
Mean elevation	>100m		
The number of the access roads	=1	K-means 1 of historical isolation effects	Definite the” Potential isolation effects” of mountain settlements
The number of streams pavement&bridges	≧2	K-means 1 of historical isolation effects	

Table 1: Potential isolation effects index.

Hazard index	Evaluation standards	Based on	Selection
The ratio of slope disaster potentials to the settlement area	High potential: >0.1083606080% Low potential: >0.0132916953%	K-means of historical isolation effects	Standard of low potential hazard isolation effects: conform any one of the low potential assessment criteria Standard of high potential hazard isolation effects: conform any one of the high potential assessment criteria If none of settlement meet any one of criteria, it is "nonpotential"
The ratio of geologically sensitive areas to the settlement area	High potential: >0.7223782528% Low potential: >0.0754282799%	K-means of historical isolation effects	
The ratio of flood potential areas to the settlement area	High potential: >0.0022938737% Low potential: >0.0000022209%	K-means of historical isolation effects	
The ratio of potential debris flow torrents to the settlement area	High potential: >0.0555677995% Low potential: >0.0287269599%	K-means of historical isolation effects	

Table 2: Disaster isolation effects index (Hazard).

Exposure index	Evaluation standards	Based on	Selection
The number of slope disasters	>2	Average of historical isolation effects	Standard of low potential exposure isolation effects: conform any one of the low potential assessment criteria Standard of high potential exposure isolation effects: conform any two of the high potential assessment criterias If none of settlement meet any one of criteria, it is "nonpotential"
The number of protected residents	>14	Average of historical isolation effects	
The number of access road points exposed to landslide risks	>5	Mode of historical isolation effects	

Table 3: Disaster isolation effects index (Exposure).

Vulnerability index	Evaluation standards	Based on	Selection
Old age dependency ratio(Village)	>23.07611111%	Average of historical isolation effects	Standard of low potential vulnerability isolation effects: conform any three of the criterias If none of settlement meet any three of criteria, it is "nonpotential"
Household income per year(Village)	<682.5087778	Average of historical isolation effects	
Shelters(700m)	=0	K-means of historical isolation effects	
Shelters suitable for weakness	=0	K-means of historical isolation effects	

Table 4: Disaster isolation effects index (Vulnerability).

5 RESULTS

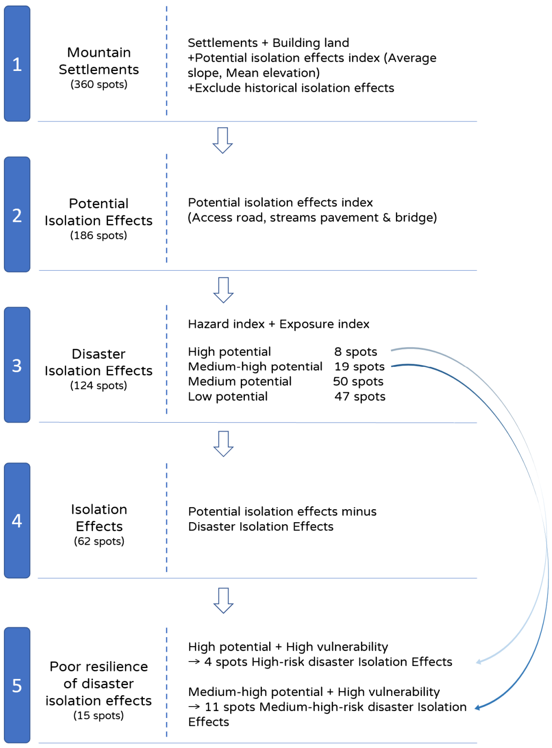


Fig. 5: Evaluation process of isolation effects.

This study uses the average slope and mean elevation to determine whether a settlement belongs to the mountain settlement identified by this research. The preliminary result is that there are 360 mountain settlements in non-historic isolation effects in Taiwan. Further based on the screening indicators of isolation effects: the number of the access roads and the number of streams pavements and bridges. Finally, a total of 186 potential isolated islands are obtained.

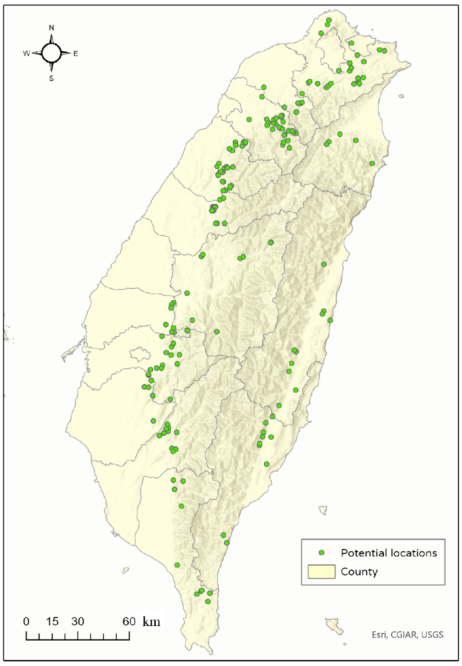
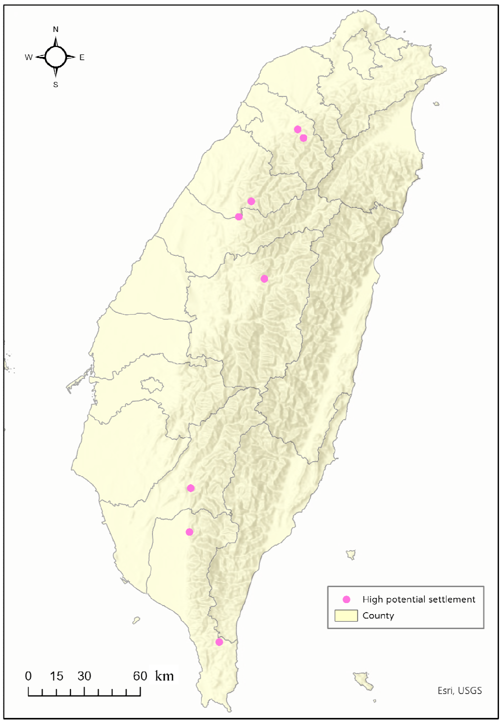


Fig. 6: Potential locations of isolation effects.

The study found that there are 8 settlements with high potential disasters, most of which are located in mountainous areas such as Hsinchu County, Miaoli County, and Pingtung County; 19 settlements with medium-high potential disasters, mainly in Jianshi Township, Hsinchu County, and Tai'an Township, Miaoli County. In addition, there is also Datong Township in Yilan County.

Last, 47 settlements with low potential disasters are mostly distributed in the mountainous areas of New Taipei City. There are also distributed in Fuxing District, Taoyuan City, Jianshi Township, Hsinchu County, and Dongshi District, Taichung City. Settlements that are not mentioned in the preceding paragraph are general isolation effect spots, with a total of 62 settlements.



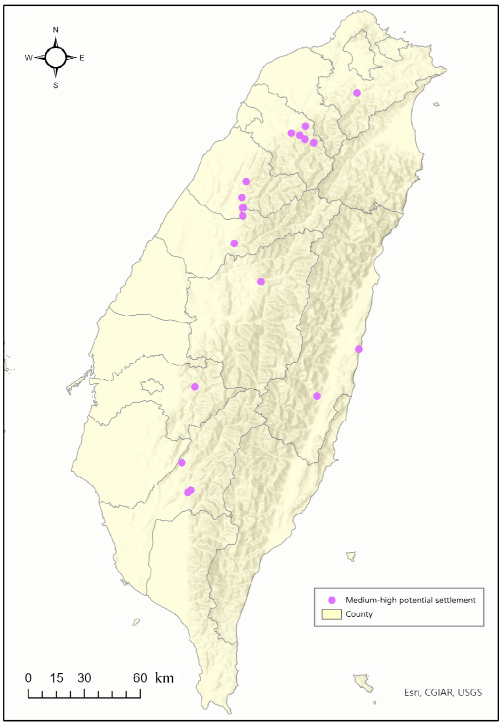
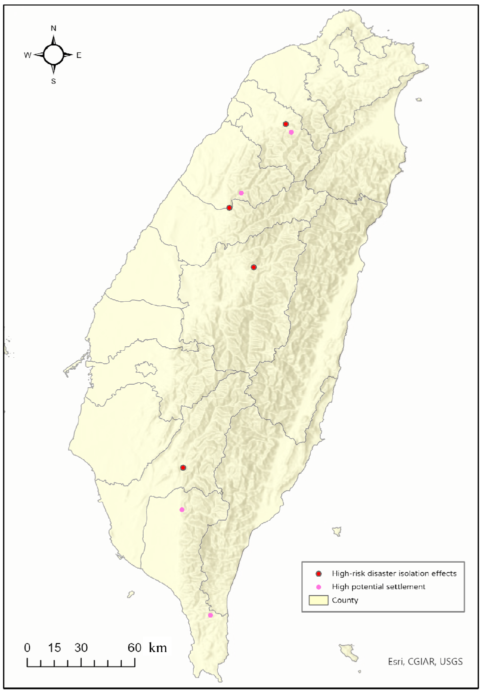


Fig. 7: High potential disaster isolation effects. Fig. 8: Medium-high potential disaster isolation effects.



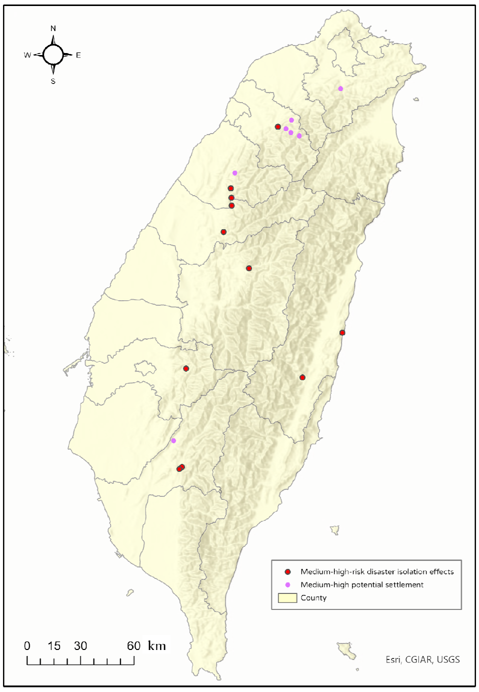


Fig. 9: High-risk disaster isolation effects. Fig. 10: Medium-high-risk disaster isolation effects.

At the end of this study, "vulnerability" was used to analyze the resilience of isolated islands. The results showed that 4 isolated islands with high potential disasters and 11 isolated islands with medium and high potential disasters had low resilience. A total of 15 settlements need to be given an overall review immediately within a certain period of time. What kind of response mechanism does it have to deal with the threats brought by climate change disasters? For example, have they signed an opening contract for road maintenance? The residents of the settlement have Have they all received education and training related to disaster prevention and relief? What are the residents' awareness and attitudes towards climate change disasters? Does the settlement have appropriate airdrop points and helicopter landing sites? Does the settlement have food and drinking water reserves, etc?

6 CONCLUSION

This study attempts to use the potential isolation effects index, hazard index, exposure index, and vulnerability index to evaluate mountain settlements. The research shows that there are 8 high potential disaster isolation effects areas, most located in the mountains of Hsinchu, Miaoli, and Pingtung County; medium-high potential disaster isolation effects areas are about 19 settlements, mainly distributed in Jianshi Township, Hsinchu County, and Tai'an Township, Miaoli County. Comprehensively analyzing the "Vulnerability" of isolation effects shows that 4 settlements with high-risk disaster isolation effects and 11 settlements with medium-high-risk disaster isolation effects have low resilience. Therefore, it is necessary to conduct a comprehensive review of these 15 mountain settlements in order to mitigate the impact of extreme disasters caused by climate change on mountain settlements.

The scale of the study area is mainly based on settlements to explore a more realistic aspect angle on isolation effects in this study. However, it is difficult to collect data at the settlement level at the present stage, especially the vulnerability index; data is relatively limited.

Once the isolation effect occurs in mountain settlements, it will significantly impact the local area due to its high disaster exposure and relatively fragile social economy. Thence, applying "Co-benefit" can help to enhance the additional benefits of Disaster Risk Management (DRM), such as the natural environment, human settlement environment, and economy.

7 REFERENCES

Chang, C.-H., & Wang, Y.-T. (2015). Establishing Hill Tribe Disaster Environmental Indicators and Application Security Assessment. [Establishing Hill Tribe Disaster Environmental Indicators and Application Security Assessment]. Journal of Chinese Soil and Water Conservation, 46(2), 123-132. doi:10.29417/JCSWC.201506_46(2).0007

Chen, Y.-H. (2017). An Evaluation of the Isolation Effects in Mountain Community. (master), National Taipei University of Education, Taipei City, Taiwan. Retrieved from https://hdl.handle.net/11296/x7gxb6

Huang, C.-H. (2014). A Study of Isolated Area Identification Model for Natural Disaster Prevention based on Prim Algorithm. (master), National Taitung University, Taitung County, Taiwan. Retrieved from https://hdl.handle.net/11296/5ce9d8

Lee, C.-C. (2012). Community independent discussion on disaster-preparedness promotion –Mau forest Wanshan tribes of the city as an example. (master), National Kaohsiung University of Applied Sciences, Kaohsiung City, Taiwan. Retrieved from https://hdl.handle.net/11296/34x2kx

Lin, H.-L. (2008). Establishing the Mechanism and Guidelines for Safe Construction of Land in Disaster-prone Areas (Phase 1). Taipei City, Taiwan: Urban and Rural Development Branch, Construction and Planning Agency

National Fire Agency, M. o. t. I. (2021, 05/30). Disaster Prevention and Relief in Isolation Effects Areas in 2021. Retrieved from https://www.nfa.gov.tw/cht/index.php?code=list&flag=detail&ids=1524&article_id=10375

Pan, Y.-X. (2016). Discussion of the Rural Settlements Isolation Effects Occurs. (master), National Taipei University of Education, Taipei City, Taiwan. Retrieved from https://hdl.handle.net/11296/jwa9bj

Portner, H.-O., Roberts, D., Trisos, C., & Simpson, N. (2022). Summary for Policymakers: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. doi:10.1017/9781009325844.001

TCCIP. (2021, 09/22). IPCC Sixth Assessment Report--Basics of Physical Science Summary for Policymakers Translation. Retrieved from https://tccip.ncdr.nat.gov.tw/km_abstract_one.aspx?kid=20210922175643

Technology, M. o. S. a. (2014). Disaster Sector Action Programme 2013-2017. Taipei City, Taiwan: Ministry of Science and Technology

Ting, S.-F. (2012). Study the concept of disaster risk and vulnerability analysis at Taitung County hillside fields. (master), National Dong Hwa University, Hualien County, Taiwan. Retrieved from https://hdl.handle.net/11296/92nqu7

Tsai, Y.-F. (2016). Sediment Disaster Risk Evaluation and Adaptation Study in Isolated Community(I). Retrieved from Taipei City, Taiwan:

Vorhies, F. (2016). Co-Benefits of Disaster Risk Management. World Bank Working Paper. doi:10.1596/1813-9450-7633

Wu, F.-J., & Huang, C.-N. (2018). Study on the Impact of Critical Infrastructure of Rural Settlements Island-A Case Study of Pingtung County, New Taipei City, Taiwan.

Yang, S.-R., Shih, Z.-Y., Huang, C.-M., Jheng, J.-T., Huang, W.-J., & Chen, J.-Y. (2010). Isolated Effect Induced by Typhoon Morakot in Laonong River Basin. Paper presented at the Taiwan Rock Engineering Symposium, Kaohsiung City, Taiwan.