Assessment Social Impact of debris flow disaster by Social Vulnerability Index

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Abstract
In Taiwan, disaster assessment has been an important topics for over 10 years. Assessment method was used as delineation method in the beginning. Then assessment is improved to cover financial loss in a disaster. However, recently, researchers realized that to assess a hazard is not just delineating, the possible loss from a hazard also depends on the social vulnerability (SV) of the local area. Therefore, this paper introduces an assessment method using the SV evaluation system. SV evaluation system is a data base system containing results of social impact and people awareness investigation in Taiwan. The new method can give a very different assessment in loss for debris flow hazard. This paper also uses a typical town in Kaoshiung, southwest Taiwan, as an example. The assessment with or without SV index results in an order of magnitude difference in financial estimation.
Keywords. debris flow assessment, Debris-2D, Social vulnerability

1. Introduction

As the assessment technology improves, the human based concept becomes more important. It was also discovered that the same scale of hazard can induce completely different disaster in neighboring locations. Therefore, it is believed that an assessment must contain human factors in order to reflect the real situations or to estimate the possible loss. The focus gradually shifted to social vulnerability.
However, to have a realistic assessment with social vulnerability (SV for abbreviation) concept, basic information on the area and the degree of possible damage from the disaster must be evaluated first. Therefore, a combination of a detailed delineating method must be used together with social vulnerability assessment. For the present paper, we combine debris flow simulation model Debris-2D to complete the on-site survey results, and SV index to assess social impact from a debris flow disaster. A real case in Xinfa Village, southwest Taiwan, is assessed for a demonstration. In what follows we shall briefly introduce the researches about SV.

During early periods, the concept of vulnerability was based on biophysical vulnerability, which included three dimensions: hazard, exposure and sensitivity (Adger et al., 2004). However, in recent years discussions have gradually turned towards the state of the subject (the human social system) before a disaster and how such a state affects its vulnerability, which is SV. In other words, SV is independent from the forces of a natural disaster, and originates from the characteristics inherent in a social system. Cutter (1996) summarized research between 1980 and 1995, but it still shows diversified opinions. If it comes to slopeland hazard, there is hardly any research. According to previous literatures, major slopeland vulnerability factors can be categorized into five dimensions, including vulnerable population, engineering project and geographical environment, disaster management and community disaster prevention, individual risk perception and adaptability and social support, as listed in Tab. 1.

2.Society Vulnerability Index for slope land disaster

Based on past researches, Li (2012) defines Social vulnerability as the degree of damage and resistance of a community against slope-land hazard event. As for the determination of SV inference factors, Li invited experts from many different disciplines such as experts of social system, transportation, urban design, environment to have a formal discussion. The final result for Social Vulnerability Influencing Factors in Disaster-isolated Areas is summarized in Fig. 1.

Tab. 1 Summary of Social Vulnerability Influencing Factors in Disaster-isolated Areas

Influence Dimension	Influencing Factors
Vulnerable population	elderly living alone, mentally and physically disabled, household of medium and low income, children and teenagers; the elderly and the invalid; economic power, poorer individuals, etc.
Engineering construction and geographic environment	slopeland infrastructure construction, irrigation system and retaining walls, limitations on development in areas prone to disaster, and the development of early warning systems, effective slopeland management system, outgoing roads in slopeland area, etc.
Disaster management and community disaster prevention	regional economy, land use planning, risk assessment, the implementation of government disaster assistance policies and insurance, promotion and advocacy, planning of evacuation route, community disaster prevention topics and promotion, etc.
Individual risk perceptions and adaptability	risk perceptions, hazard perceptions, evacuation decision making capabilities, previous experience, living cost and environment, etc.
Social support	social network , official social support (medical system and social service institutions), non-official social support (family members, relatives, neighbors, colleagues) catering assistance, financial support, transportation assistance, etc.

The four most important factors are exposure to potential maximum loss, resistance ability, recovery ability and engineering protection. These four factors contain all vulnerable factors of slopeland disaster, as below:

[1] Maximum possible loss: This factor measures the possible maximum damage, and it can be divided into human causalities and property loss in the debris flow danger zone.

[2] Engineering construction and geographic environment: Any countermeasure can protect people to a certain degree, so it is still one of the important factors. This factor includes slopeland infrastructure, effective slopeland management system, early warning system, stability of outgoing road system in slopeland area, etc.

[3] Self-preservation ability: This factor measures the people’s ability of resisting disasters. Self-preservation ability is an individual ability to protect his/her own life and property. The less they are able to protect themselves, the less they are able to resist the impact from a disaster. Indexes of self-preservation ability include females, elders, the disabled, homeless, risk awareness and disaster preparations, disaster drills, community disaster education etc.

[4] Recovery and adaptive capacity: This measures resilience in the concept of social vulnerability. After sustaining damages from a disaster, households that are able to withstand the damage and recover rapidly are less vulnerable than those can not recover. Here, recovery means to return to their normal lives rapidly. Adaptation means to learn from the disaster experience, turn it into effective disaster prevention knowledge, and use the knowledge to prevent from damage when the disaster occurs again. Recovery and adaptive capacity can be evaluated by several variables, including disposable income, low income household, community participation (social network) and insurance.

[5] To calculate the value of SV indexes, most common aggregation average method (Clark et al., 1998) is adopted. First step is to normalize the obtained SV statistical data by Eq. (7), and then uses the aggregation average method to calculate the comprehensive indicator, i.e. Eq. (8). The formula for normalization is

$$Z_{ij} = \frac{X_{ij} - M_j}{SD_j}, \tag{1}$$

where Z_{ij} : normalized value of different social vulnerable factors(j) in certain assessed area(i),
X_{ij} : value of different social vulnerable factor(j) in certain assessed area(i),
M_j : average value of certain social vulnerable factor(j),
SD_j : standard deviation of ceratinsocial vulnerable factor(j),
i : different area of assessment,
j : different social vulnerable factors.

The formula of aggregation average method reads

$$SVI_i = \frac{1}{N}\sum_{j=1}^{n} Z_{ij} \,, \tag{2}$$

where SVI_i : Social Vulnerability Index of the assessed area,
N : number of social vulnerable factors.

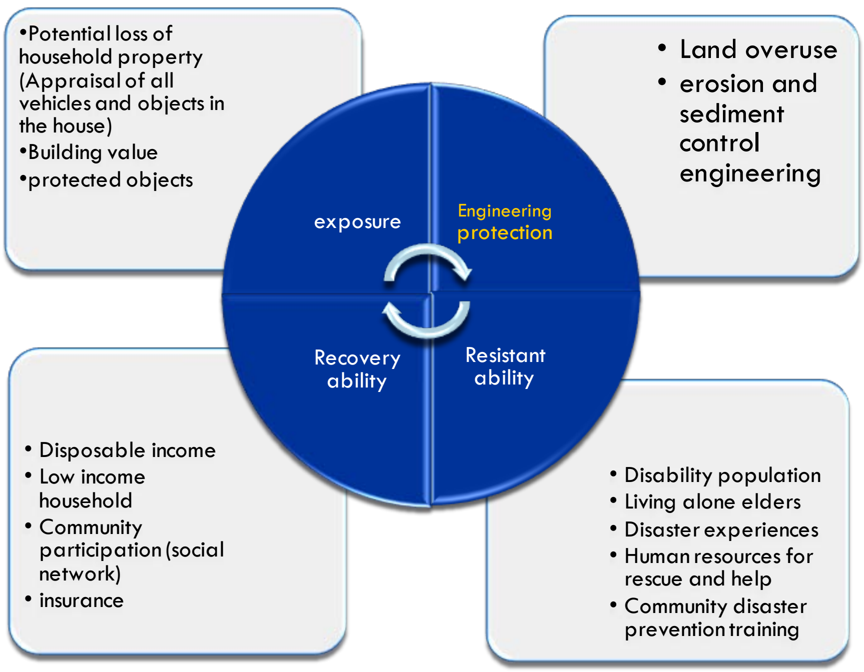

Fig. 1 Social vulnerability index of slopeland disaster

3. Case Study

3.1 Introduction of the field case - Xinfa Village

In order to perform assessment with Social vulnerability Index, a real case occurred during typhoon Morakot in Xinfa village, Liukuie downtown, Kaoshiung county, southern Taiwan (Fig. 2) is studied. Typhoon Morakot hit Taiwan on August 5-10, 2009 and brought world record heavy rainfall. There were severe floods, many landslides, and debris flow disasters associated with Typhoon Morakot. There were 673 deaths, 26 people missing, and about 70 million US dollars of agricultural and property loss induced by Typhoon Morakot and is the worst typhoon disaster in 20 years in Taiwan. Xinfa village landslide and debris flow is one of the disasters. At 6:00 AM on August 9, landslides in eastern part of Xinfa village occurred and induced debris flows. There were 5 people dead, 12 people injured, 6 houses buried, and about 15 Hectare destroyed agriculture area. The orthorectified aerial photo, which was taken six months after the disaster, of landslide and the final deposition area are shown in Fig. 2. From right to left in Fig. 2, the three landslide areas are 21183, 3562 and 285 m^2 respectively, as are circled by red lines. According to the field survey (Soil Water Conservation Bureau, 2010), the total volume of debris deposition is about 130,000 m^3, 30 household building were distoryed, From field examination by Debris-2D, the height of the trace indicated that debris flow passed that particular building at a height about 6 m, as is shown in Fig. 3, and the location of this house is marked A in Fig. 2.

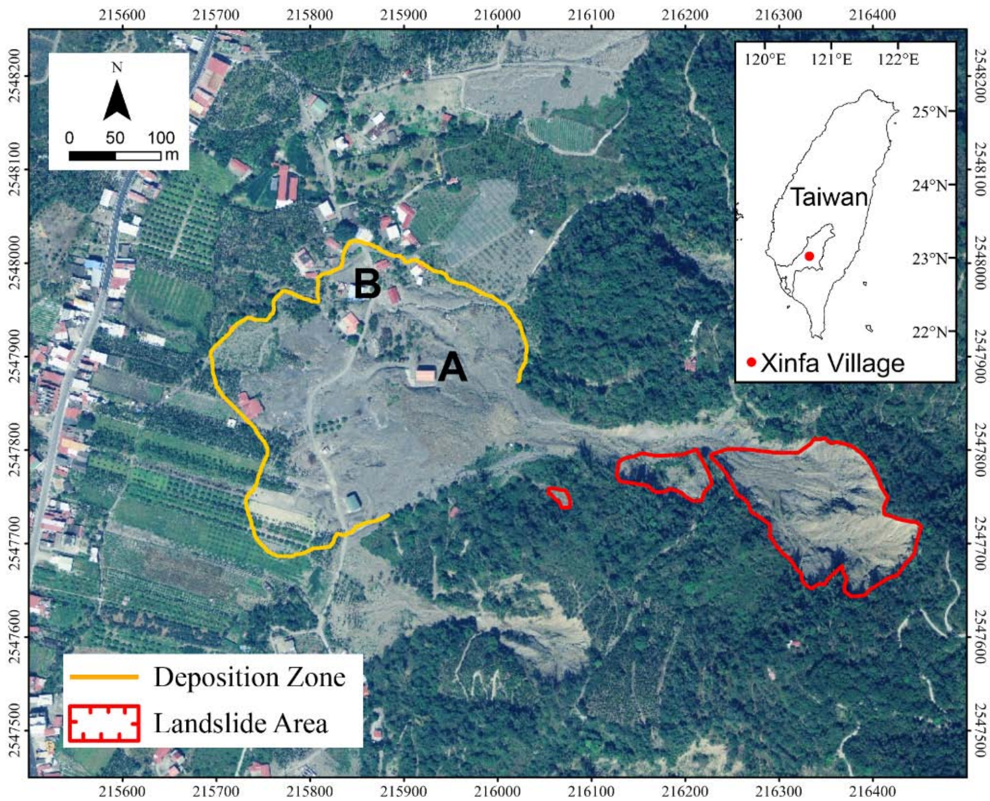

Fig. 2 Aerial photo of Xinfa Village (shooting time: 2010/3). The region circled by red line is landslide area, and orange lines indicates deposition zone. The marks A and B are buried houses, also see the zoom-in photo in Fig. 3.

3.2 Society Vulnerability of Xinfa Village

Before we start to estimate social impact form debeis flow disaster , we need to collect social vulnerability factors of Xinfa Village at first. According to the framework of Fig. 3 and factors collection situation , social vulnerability index of this paper lnclude: 1)Maximum possible loss: village population and building value; 2)Engineering construction：outgoing roads, building developed areas; 3) Resistant ability: elders, living alone elders, the disabled, manpower of rescue , disaster drills, disaster experiences etc.; 4) Recovery capacity: self-recovery ability(building value/disposable income per year), low income household. The detail data before and after debris flow disaster are listed in Tab. 2.

Tab. 2 is the social vulnerability factors of Xinfa village. We can learn that some SV factors were changed after disaster. According to the on-site survey and simulated results, Xinfa debris flow disaster totally destroy 30 buildings, therefore the SV factor of total building value and building developed area of Xinfa both reduced. And based on the lasted population bulletin of government, the population of Xinfa village is reducing form 1706 to 1420 after typhoon Morokat, thus the SV factor of village population also changed. In the part of resistant ability, the SV factors of manpower of resuce(%) increased for the village population decreasing. The SV factor of disaster drill was increased because of government started to hold the debris flow evacuation drill once a year. Also the disaster experience increased from 0 to 1 by this disaster event. Then, we use Eq. (7) to normalize all value of different social vulnerable factors. The SV calculated results of Xinfa village before and after disaster was showed as Fig.3.

Tab. 2 Social Vulnerability Factors of Xinfa Village

Dimension	SV Factors	Before disaster	After disaster
Maximum possible loss	Village population(P)	1706	1420
	Building value(NTD)	462723541	440003891
Engineering construction	Outgoing roads	2	2
	Building developed areas(Km^2)	311308	306604
Resistant ability	65 age elders	280	280
	Elders Living alone (%)	2.03	2.03
	The disabled (%)	3.82	3.82
	Manpower of rescue (%)	4.85	5.82
	Shelters	0	0
	Disaster drills	0	1
	Disaster experiences	2	3
Recovery capacity	Low income household	132	132
	Self-recovery ability (%)	0.96	0.96

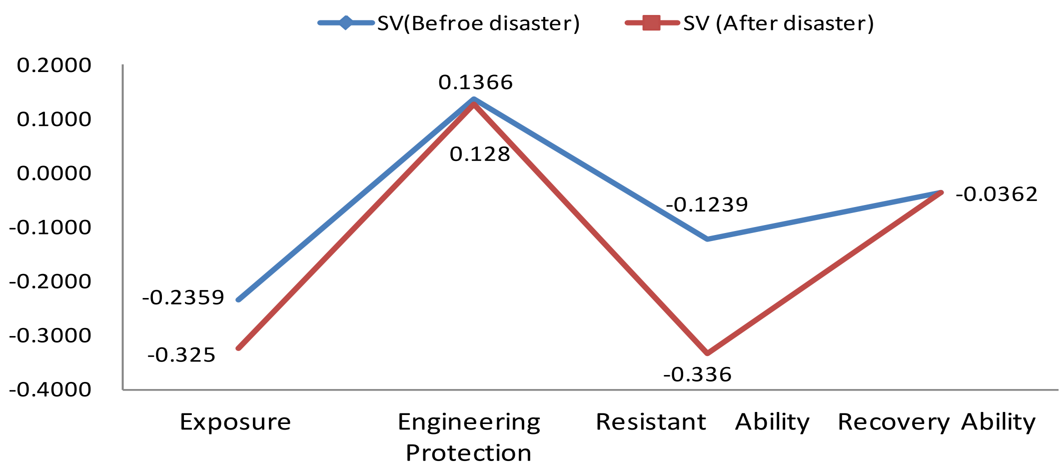

Fig. 3 Normalized SV Factor of Xinfa village in four dimensions

Fig. 3 means the four SV dimensions of Xinfa village. The blue line is original social vulnerability situation and the red line means the situation after disaster. That negative value means their original social vulnerability were less vulnerable than others, compare with whole Taiwan 2217 slopeland villages. Higher value means more vulnerable, otherwise means less vulnerable.

In Fig.3 we can figure out that the all SV dimensions were decreased except recovery. It means after disaster the social vulnerability wasn't as high as the situation before disaster. For further discussion and comparing the SVI of Xinfa with other villages, we collected all relative factors of Liukuie Town, the administrative region is showed as Fig.4.

Based on the methodology, and according to empirical data and government published information,. The social vulnerability index of Xinfa village can be calculated by Eq. (8). The final results of whole Liukuie downtown's SVI were showed in Tab.3 and Fig.5.

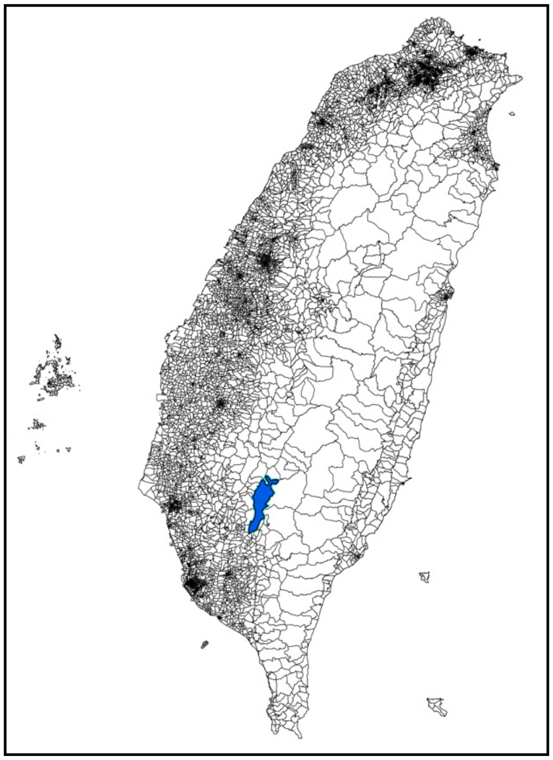

Fig. 4 The Administrative Region of LiuKuie Town

Tab.3 SVI Before and After Disaster Areas

Village	XinWay	XinXi	XinLau	XinFa	LauNo	LiuKuie	EiBau	XinLon	ChunXin	BauLai	WenWu	DaGin
SVI(Before disaster)	-0.17	-0.25	-0.14	-0.06	-0.22	-0.12	-0.01	-0.21	-0.13	-0.21	-0.09	-0.32
SVI(After disaster)	-0.17	-0.25	-0.14	-0.14	-0.22	-0.14	-0.01	-0.21	-0.15	-0.10	-0.09	-0.33

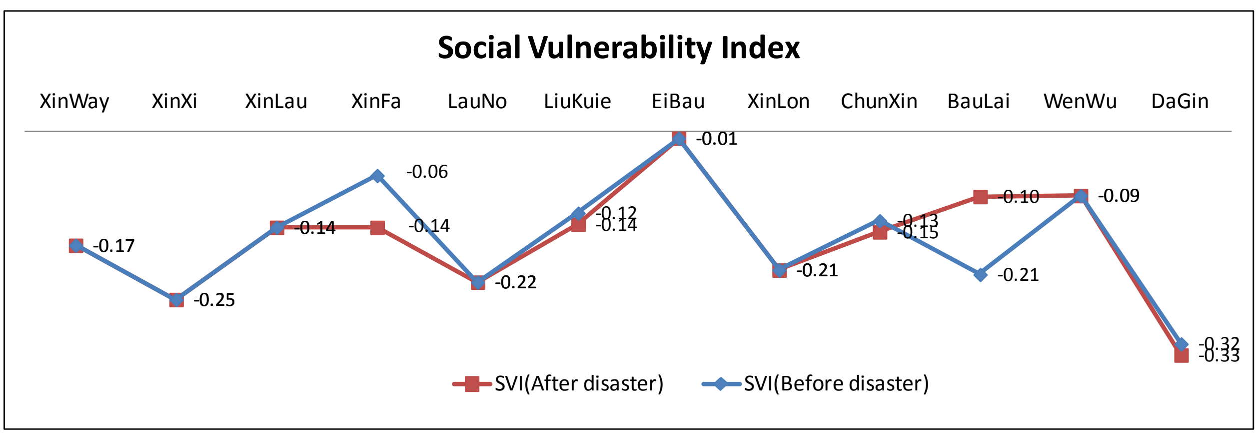

Fig. 5 Social vulnerability index of Xinfa village

In Fig. 5 we can obtain the SVI results before and after Typhoon Morakot. The blue line is original social vulnerability situation. We learn that the SVI of whole Liukuie downtown were from -0.33 to -0.01. That

negative value means their original social vulnerability were less vulnerable than others. But if we just compare the value within Liukuie downtown, the SVI of Xinfa village is -0.06, would the second highest of whole Liukuie village.
The red line is the social vulnerability situation after disaster, we found that the SVI of Xinfa Village was reduced from -0.06 to -0.14. It means that the social vulnerable situation of Xinfa village's become safer than before. The one main reason is that after disaster many people were move out this village, thus the exposure of this village was decreased. The other reasons are the disaster experience and government drill improves their self-preservation ability. According to the survey of the landslide protected households in Hualien County by Liu and Chen (2008), hazard perceptions will affect the people's willingness to evacuate. However, the disaster experience will affect the hazard perceptions of the residents. The other possible reasons is their recovery engineering also can strengthen their environment resist ability, but due to the recovery engineering is still ongoing, therefore, this paper did not discuss those factors, assume there are the same before or after disaster.
It needs to be emphasized that this result doesn't mean Xinfa village would not happened debris disaster again. SV analysis didn't include physical vulnerability, they are independent systems. Actually, according the past debris flow researches, Xinfa village has highly recurrence possibility of debris flow. But through the analysis of SVI, we can know that if Xinfa face the similar disaster, their loss would be reduced for their coping ability already be arisen.
Therefore, according to the SVI analysis of Xinfa village before and after disaster, we can learn that how to strengthen the disaster prevention education and pass on the previous disaster experience play important roles. Although we can not control natural disaster, we still can reduce the disaster impact by experience carried and well prevention education.

4. Conclusion

This paper used social vulnerability index to perform a disaster assessment. The SV assessment shows a different evaluation with different weight on all factors. Because SV factors considers the interaction between human and environment, the assessment can provide not only a moneytized assessment, it can also provide the direction for improved defense for disaster. Therefore, newly devoted budget in the area can be better used and is sure to have strong feedback from local people.

Acknowledgments

The authors deeply appreciated the financial support from National Science and Technology Center for Disaster Reduction of Taiwan.

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