

Early Warning System through Sustainability Livelihoods Approach for Volcanic Disaster Management

Diah Setyawati Dewanti¹ Dusadee Ayuwat² Sekson Yongvanit³

1 Lecturer of Development Economics, Faculty of Economic and Business, Universitas Muhammadiyah Yogyakarta

2 Assoc. Professor, Department of Sociology, Faculty of Humanities and Social Science, Khon Kaen University

3 Professor, Department of Public Administration, Faculty of Humanities and Social Science, Khon Kaen University

E-mail: ddewanti@umy.ac.id

Abstract. The main objective of this study is to analyse the early warning system of volcanic disaster management through sustainable livelihoods approach. The early warning system is the most important phase on disaster management as to reduce the risk of hazard during the eruption appear. Active volcano in Indonesia has been spread since it is located in the ring of fire. This study uses sequential mixed methodology, start with qualitative-quantitative methodology. The study area are Mt. Slamet and Mt. Merapi where located in Java island. The first phase of the research uses exploratory qualitative methodology to identify the term of indicators for Sustainability Livelihoods Approach (SLA), hereafter quantitative is to calculate the path of each variable supported to volcanic disaster management. The qualitative approach took 31 key informants spread in two village surround Mt. Slamet and 19 key informants spread in two village surround Mt. Merapi. The sample of quantitative research on Mt. Slamet is 538 respondents and 137 respondents in Mt. Merapi. SLA is supported to the early warning system. Household networking for social capital directly effect to early warning phase both volcanoes. Nevertheless, human capital, natural capital, physical capital and financial capital is indirectly effect to early warning capacities through transformation of process and structure.

Keywords: Early Warning System, Volcanic Disaster Management, Sustainable Livelihoods

1. Introduction

Natural hazards have been part of Indonesia living condition since it's located in the ring of fire. Hereafter, Indonesia has many natural disasters appear as earthquake, volcano, tsunami, landslide, flood and drought. Therefore, the adoption living with disasters need to applied in many sectors, physical and non-physical preparation. The adoption could be measured on capability in coping with the temporary disruption with minimum damage. The level of mitigation and preparedness of community are the capacities required to owned by community who live in the disaster area (Lindell & Whitney, 2000).

According to Asian Disaster Preparedness Centre [ADPC] defines a disaster as "the serious disruption of the functioning of society, causing the widespread human, material or environmental losses, the which exceed the ability of the affected communities to cope using their own resources". Meanwhile, Indonesia Law Number 24 Year 2007 describe disaster as "an event or series of events that threaten and disrupt

the lives and livelihoods caused by natural factors and/or non-natural factors and human factors that lead to the emergence of human casualties, environmental damage, loss of property, and psychological impact". Many studies identify disaster management in four phases, which consist of mitigation, preparedness, response and recovery phase. Those define in to three stage, pre-disaster, during disaster and post disaster. All of the phase is important to carried out but Early Warning System (EWS) is important to reduce the risk and hazards as the impact of the disaster since it is the beginning of the chain (Konečný & Reinhardt, 2010). An EWS is an integrated system for several activities, which are monitoring, collecting the data, analysing, interpreting and communicate the data to sum up to the proper decision for protecting vulnerable and impacted people in disaster area(Quansah & Engel, 2010). In this study, EWS meaning is the process of reducing risk and hazards impact for volcanic disaster management which describe in the stage of mitigation and preparedness.

Mt. Slamet is the second highest mountain in Java island where located in the highest (3,428 meters) density population province in Indonesia. Mt. Merapi is the most active mountain in Java island and located in Yogyakarta province. Both of mountain has located in Java island and well-known the hazard impact from the eruption phase. The biggest eruption in Mt. Merapi on 2010 was affected in four districts which killed 386 people and damages on US\$ 403 million. One of the most destructive impact is in Cangkringan village (Brata, Rietveld, de Groot, Resosudarmo, & Zant, 2014; Ali, 2019). On 2014, Mt. Slamet had big eruption for several months and impacted to the several places. The society surround Mt. Slamet has strong belief and apply culture process known as *Ruwat Bumi* to avoid the hazard impact from eruption (Dewanti, Ayuwat, & Yongvanit, 2016). Both of mountain has their own spiritual leader named as *Juru Kunci* and play role as the person who responsible and taking care Mt. Merapi and Mt. Slamet. This strategy carried out based on tradition and cautions all villagers to prepare themselves for living in a worrying situation (Suwarno, 2014).

Early warning system is important to the citizens where settled in disaster prone area or red zone for disaster area. Each population could impede the early signal from volcanic disaster management based on the local wisdom and knowledge based on their experiences. Therefore, early warning system play role as critical factor to understand the system of disaster management (Cowan, O'Brien, & Rakotomalala-Rakotondrandria, 2014). Indonesia has National Disaster Management Agency (NDMA or *BNPB* in Indonesia) as the non-departmental government institution who carried out the disaster management activities. Since Indonesia has autonomy system, the implementation of disaster management is applied in each of Province and District level, called as Regional Disaster Management Agencies (RDMA or *BPBD* in Indonesian). RDMA has many working collaboration to the community to support volcanic disaster management (Mei, Estuning Tyas Wulan, 2010). However, hazards are impacted to the community, including their resilience capacities to cope hazard. Community is impacted to their living and livelihoods. To improve the cope capacity for the disaster response, need further research concerning EWS using sustainable livelihoods approach. Therefore, this research has an aim to analyse the early warning system of volcanic disaster management through sustainable livelihoods approach.

2. Literature Review

Early warning is the important and critical phase on disaster management. Volcanic disaster is natural hazard which could be manage to reduce the risk impact (Konečný & Reinhardt, 2010). Early warning system defines as the pre disaster which consist of mitigation and preparedness phase. Each of household has their own capacities to practice disaster management, however, the capacities level defines based on their characteristics. Household characteristics is the availability, capacity and capability of household based on their social, demographic and economics (Viegas, Vieira, Sousa, Melício, & Mendes, 2015) for coping the hazards.

H_1^1 : Based on the literature reviews and the development of study, the household characteristics supported directly and indirectly to EWS. The household characteristics consists of job characteristics (farming and non-farming), dependency ratio, labor force, health, migration, electricity, vehicle and size of land.

Sustainable Livelihoods Approach (SLA) is an approach explain the process of objective, scope and priorities for development activities. It is involving the way of thinking to improve the living of the poor

and vulnerable live and the importance of policies and institutions supporting this group. SLA consist of the interaction between capital assets and policies institutions to produce outcome. Capital assets consist of five capitals, which are human capital, natural capital, financial capital, social capital and physical capital (Serrat, 2017). Capital assets is the first identification of household's ability and competence to achieve outcome (Colombo, Romeo, Mattarolo, Barbieri, & Morazzo, 2018). In this study, capital assets of each household who live in disaster prone measured their capacity confront and applied EWS. Transformation on process and structure were describe as the policy and role of government and private institution (Colombo et al., 2018).

H₂¹: Through related concept and theories concerning SLA confronts directly and indirectly to EWS. The SLA consist of human capital, social capital, natural capital, physical capital and financial capital.

The conceptual framework is describe in figure 1.

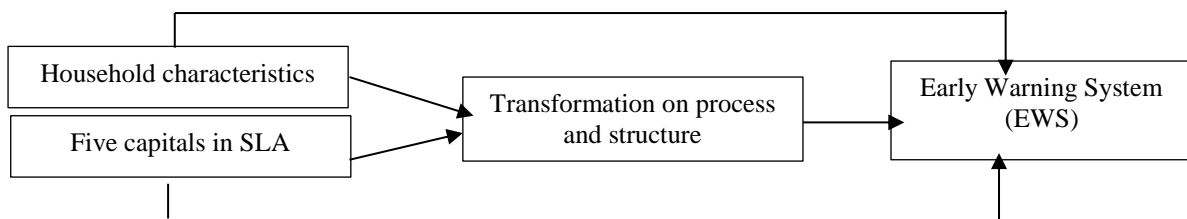


Figure 1. The conceptual framework of SLA to EWS for volcanic disaster management

3. Research Methodology

This research aims to analyse the early warning system of volcanic disaster management through Sustainable Livelihoods Approach (SLA). This study was carried out through sequential mixed methodology, which started with qualitative data design and analysis on a relatively unexplored topic. Hereafter, by the result from the qualitative data collection, the indicator was use to design a subsequent quantitative phase (Tashakkori & Teddlie, 2010). The unit of analysis of this study was households, include for both phase, Qualitative and Quantitative research methodology.

The first phase of the research design, it was discover comprehensive information concerning the study area of Mt.Slamet and Mt.Merapi. The qualitative research method aims to describe the context and components of sustainable livelihoods practicing volcanic disaster management. Two villages in each of the mountain were selected based on the geographical area of disaster prone II. Disaster prone II is the high impact from the volcanic hazards and permitted to be sheltered by human. Two village were chosen as the study area; Sawangan village, Guci village (Mt.Slamet), Girikerto village and Umbulharjo village (Mt.Merapi) (Figure 2). This study was conducted using in-depth interview to 31 key informants for Mt.Slamet and 19 key informants for Mt.Merapi. The technique for data collection employed participatory observation model and carried the verification of validity and reliability through methodological triangulation. It is the process of examining the result of data by checking validity and reliability from the information of the key information through in-depth interview and non-participant observation methods (Babbie, n.d.). The qualitative methodology use content analysis by the help of Atlas.ti software as the processing of data collection.

The quantitative research method was carried out based the result of qualitative methodology. The objective of second phase is to identify the factors supporting early warning system based on SLA. The number of sample for Mt.Slamet is 538 households and 137 households for Mt.Merapi. The quantitative method was carried out using interview with questionnaire as the tools of the research. Structural Equation Model using Path analysis was the data analysis to determine the non-experimental data which is fits well to the partial causal model (Ahn, 2002). To obtain the objective as to identify the factors supporting the early warning system based on SLA, this study use Path analysis. The identification of effect in each of variable were define using unstandardized coefficient (β).

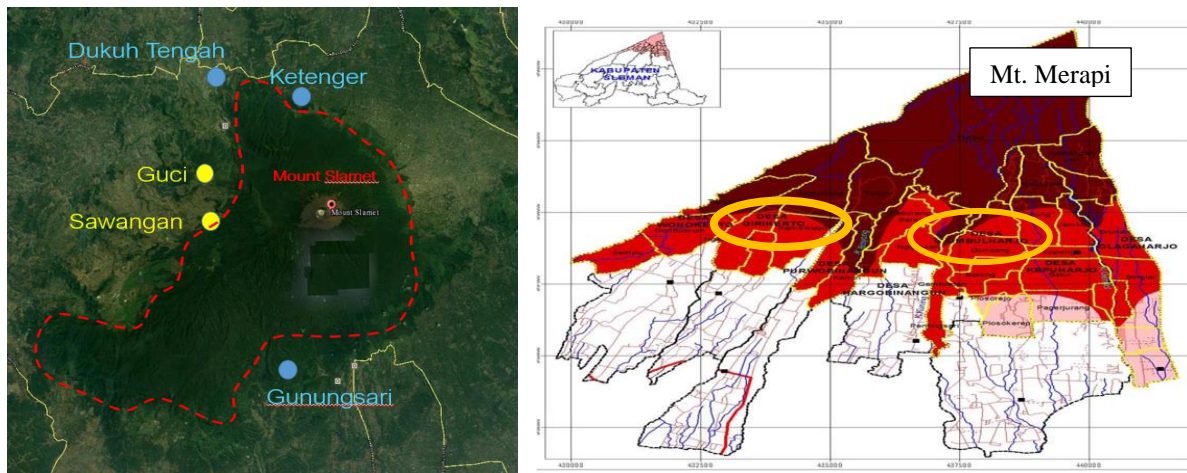


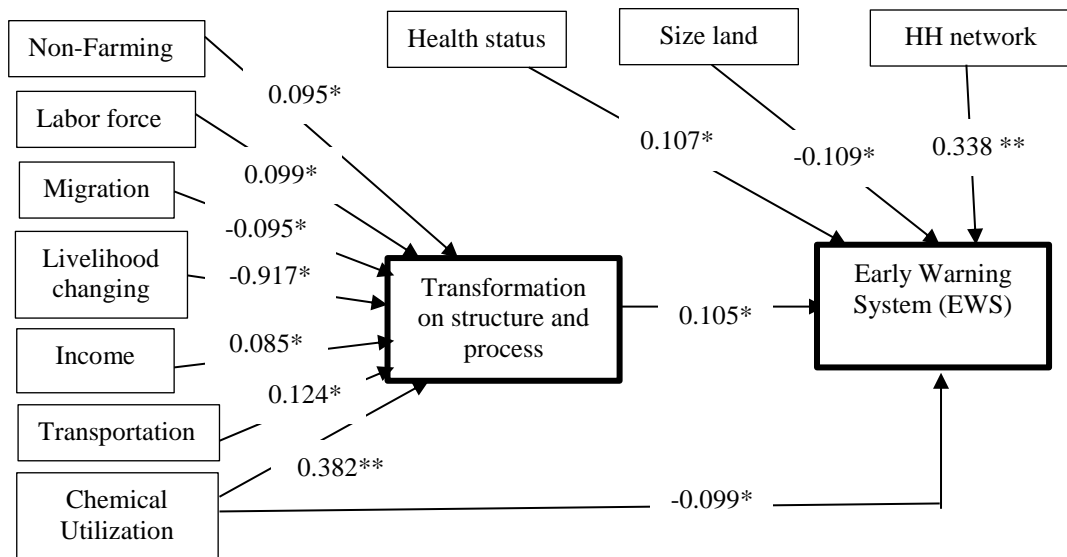
Figure 2. Study area of Mt. Slamet and Mt. Merapi
Source: BNPB Indonesia

The dependent variable for this study was early warning system which describe the mitigation and preparedness phases. The independent variables (IVs) were description of household characteristics, human capital, social capital, natural capital, physical capital, financial capital and transformation of structure and process. Human capital consists of the length of education, agricultural knowledge and livelihood changing. The social capital defines as support kinship, community relations, household networks and group membership. The natural capital are access of water and chemical fertilizer utilization. Physical capital consists of electricity, communication and transportation access. The financial capital measures the number of income and assets in each of households. Transformation of process and structure play role as the mediatory variable between independent variable to dependent variable. The sampling design was using two-stage stratified, which determined by area based on sub-district through village area.

To measure the goodness of fit of the data and model, content validity was performed by sending the questionnaire and the result of reliability through Cronbach's alpha is at 0.908. Content validity was performed by sending the questionnaire to an expert in environmental studies and disaster management to make improvement of the questionnaire. As this study employed path analysis, multicollinearity diagnostic was employed to examine the correlation between IVs. In this study use VIF measurement to 25 independent variables and found the VIF in between 1.09 and 2.15 which is less than 10. This study has ethical approval to conduct the study was obtained from Khon Kaen University with registration number HE 583022.

4. Result and Discussion

This study found, among Mt.Slamet and Mt.Merapi has differences variables effected to EWS. The result of path analysis for Mt.Slamet (Figure 3), there was direct effect between transformation on structure and process which describe as the policy and the role of government and private institution, with β as 0.105 (p-value less than 0.05). Through the variable of transformation on structure and process, there were seven (7) IVs indirectly effected to EWS. Non farming (0.095*); labor force (0.099*) and migration (-0.095*) as the household characteristics indirectly effected to EWS. Mt.Slamet is surround by farming land, however, many farmers hedge the EWS phase for the hazard. Migration has a negative impact to EWS when the male is migration to other places and only female left in the house (Siddiqui, Towheedul Islam, & Akhter, 2015). Livelihood changing (-0.917*), income (0.085*), transportation (0.124*) and chemical utilization (0.382**) as representative indicators of five capacities in SLA, were indirectly effect to EWS. The livelihood changing is the indicator to household who change their living job within one year. To household who mostly easier to change their working place, it impacted negatively to EWS level.



*p-value less than 0.05 ** p-value less than 0.01
 R² is equal to 0.42

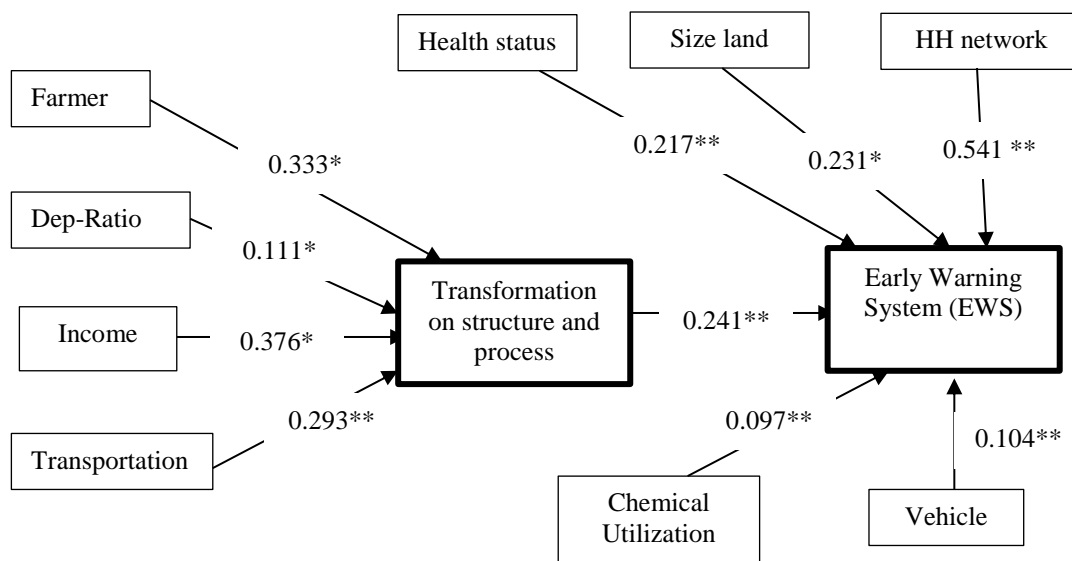
Figure 3. Path analysis for Mt. Slamet

The direct effects were found on health status (0.107*), size of farming land (-0.109*), household network (0.338**) and chemical fertilizer utilization (-0.099*). Household network has strong effect to EWS since several findings during qualitative methods were carried out. It was stated that the very important thing has to improve on mitigation phase is to enlarge the collaboration to other villages or sub-district which located in safer zone. Since the previous findings found non-farming job characteristics in household inclined to have EWS capacities, therefore, indicator of size of farming land and chemical fertilizer utilization were intent to have negative β .

“...it is important our head of village has collaboration to Bumiayu village. The collaboration is easy, just ask their help to accept us during Mt.Slamet is eruption. This is what happen in recently, when Mt.Slamet start to increase the activities, we got confuse to whom we could propose help during evacuation time.” (Male, 49 years old, farmer, Mt.Slamet)

Mt. Merapi has similar findings compare to Mt. Slamet, since the household characteristics were divided into two types of working, such as farmer and tourist-entrepreneur support (Figure 4). However, the household characteristics found that farmer (0.333**), dependency ratio (0.111*), income (0.376*) and transportation access (0.293**) were significantly indirect effected to EWS through variable of transformation on structure and process. The farmers of Mt. Merapi had significantly effects to EWS since they have their local belief. But non-farming household found non-significant effect to EWS. Variable of financial capacity through income is significant positive to EWS since the preparation phase need more fund to be applied by the household. Health status (0.217*); size of farming land (0.231*); household network (0.541**); chemical utilization (0.097**) and vehicle ownership (0.104**) have direct effect to EWS.

“what do we plan is the one we eat and sold, whole process is blessed from Allah mediatory by Mt. Merapi. So, we know when Mt. Merapi will eruption, it will give us the signs” (Male, 38 years old, farmer, Mt. Slamet)



*p-value less than 0.05 ** p-value less than 0.01
 R² is equal to 0.62

Figure 4. Path analysis for Mt. Merapi

As the qualitative methods after the quantitative phase has finish to carried out, the result of this findings was use as the instrument for collecting the qualitative data. The qualitative methods found in the nearest village to Mt. Slamet, named as Sawangan village, whole of the community practice EWS through community-based and less of government intervention. However, most of them were potato farmers and they are semi-isolated area to their local government of Tegal. The application of EWS were describe in less technology support. Sawangan do not have good signal for telecommunication facilities even though it located in the Red-zone as the highest risk for hazard impact.

“...Sawangan is a special village, we do not have much facilities on telecommunication, but we have social support each other. Networking between one to another could improve our preparation on evacuation or during eruption coming...” (Male, 34 years old, farmers, Mt.Slamet)

The EWS acts among whole households lived in surround Mt. Slamet and Mt. Merapi were applied in several steps: (1) community preparedness; (2) increase the knowledge the proper EWS from volcanic disaster management; (3) infrastructure preparedness, such as road condition and build up evacuation path. Community preparedness mostly use concept of EWS’ community-based disaster management. The main aim of the community-based disaster management is to improve the awareness of household to cope the disaster or any hazard (Ali, 2019). Moreover, community preparedness was also applied by delivering knowledge and awareness to the younger age. Communication between other household to gather more information and knowledge were part of community preparedness based on themselves (Nakamura, Umeki, & Kato, 2017).

“...We do gather the information between one and another. If we only rely on help, aid, organization or others, we could not survive. The best way is to improve our knowledge by meeting, gathering, discuss each other...” (Female, 55 years old, tourist guide, Mt. Merapi)

“...In the school, there is subject which studied by our children how to prepare ourselves for disaster. But, mostly of parents tell the story of 2010 eruption and give them advices...” (Male, 34 years old, administrative officer, Mt. Merapi)

Community preparedness have also carried out by practical issue, in example preparing all of the important papers in a rescue bag. So, during the eruption appear, they could take the rescue bag with them. The infrastructure preparedness mostly relied on government support. It is appears based on the findings of transformation on structure and process. Government policy need to support the disaster facilities, including the shelter. In Mt. Merapi, infrastructure preparedness was found on the establishment of “*huntap – hunian tetap*” (English: permanent shelter) for households who become the victim of 2010 eruption. The *huntap* need to improve based on the local households need, especially to breeder of cow and goat as their livelihoods.

“...this house (*huntap*) is gift by government to help us. However, in this house, we do not have much space to breed our cow, we need to sell them and buy others and also find other job...” (Male, 59 years old, breeder, Mt. Merapi)

As the final conclusion, EWS capacities have to be improved and need to integrated to the government program. Each of area has their own household characteristics and different capitals effected to the EWS. Sawangan area as the study area in Mt. Slamet has different capitals supported to EWS implementation. Then, it could be concluded that the Early Warning System in each of district and different disasters has their own guidelines based on local wisdom.

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