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Clustering Coping Capacity using HCSS (Hard Clustering based on Soft Set)

***Abstract*—Coping capacity, or the capability of individuals, communities, and society to successfully respond to and recover from bad events, is a critical component of disaster risk reduction. Formulating successful preparedness, response, and recovery plans for disasters requires an understanding of coping capacity. Building resilient communities that can face landslide difficulties and lowering susceptibility need assessing and improving landslide coping capacity. In order to identify separate groups of communities with comparable coping ability features and to enable focused used interventions and resource allocation, the Clustering based on soft set method is used in this study. The experiment provide 3 clusters based on the Dun Index value. This can be used by investigator or government to provide recommendations to determine different treatments and the creation of sensible regulations that will promote catastrophe risk reduction and neighborhood safety in the area.**

Keywords—Coping Capacity; Landslide; Clustering; Soft set.

I. Introduction

Coping capacity is the ability of individuals, groups, and society to effectively respond to and recover from unpleasant events, shocks, or disasters. It is a multidimensional notion that incorporates many factors, resources, and capacities that enable individuals and communities to withstand, adapt to, and recover from the effects of catastrophes or crises. [1].

Physical infrastructure, social networks, economic resources, knowledge, skills, and governance systems are all components of coping capability. These characteristics jointly affect a community's ability to foresee, absorb, and recover from the effects of a disaster, thereby lowering vulnerability and increasing resilience [2].

Understanding coping capability is critical for developing successful preparedness, response, and recovery strategies in the context of catastrophe risk reduction and management. Communities with greater coping capacity are better prepared to handle and mitigate the negative effects of disasters, resulting in less loss of life, property, and livelihoods. [3].

The ability of a community or region to effectively respond to and recover from landslide disasters is referred to as landslide coping capacity. It includes a variety of elements and resources that help to mitigate the impact of landslides and facilitate a quick and efficient recovery. [4].

It is critical for disaster risk reduction initiatives to assess and improve landslide coping capacity. Policymakers and disaster management organizations may conduct targeted interventions, distribute resources more efficiently, and build more resilient communities capable of dealing with the problems posed by landslides by identifying the strengths and weaknesses of a community's coping capacity [5].

One of the challenges that may have various coping capability profiles due to varying socioeconomic, geographical, and cultural contexts is heterogeneity among communities or different communities. Clustering enables us to identify discrete groupings of communities with comparable coping capacity features, allowing us to take a more customized approach to disaster risk reduction. [6], [7].

Clustering algorithms are unsupervised learning methods used in data analysis and machine learning to group comparable data points together based on similarities or characteristics. These techniques seek to uncover underlying patterns and structures in datasets and organize data into clusters, with data points within one cluster being more similar to those in other clusters. Pattern recognition, picture segmentation, data mining, and customer segmentation are all examples of where clustering is applied [8].

Numerous clustering approaches have been proposed. Xu et al. et al. [10] proposed fuzzy k-modes. It is based on the matching dissimilarity metric. Due to the potential for artifacts associated with the usage of hard centroids, Kim et al. [11] increased the performance of fuzzy k-modes by replacing fuzzy centroids (FC) with hard centroids. It is a non-parametric technique based on the principle of minimizing the sum of squared errors within clusters. Miin-Shen et al. [12] introduced the Fuzzy k-partitioning (FkP) algorithm, a parametric approach based on the likelihood function of multivariate multinomial distributions.

Furthermore, the FkP approach for categorical data can be thought of as a fuzzy-based clustering algorithm. On the other hand, practically all of the previously discussed fuzzy categorical data clustering approaches express data sets as binary values. Categorical data, on the other hand, have multi-valued attributes that can be represented as a multi-soft [13]. The use of a multi-soft set for multi-valued attributes provides advantages in displaying categorical data without the need to convert it to binary values. Based on these advantages, Yanto et al. presented HCSS, a clustering technique for categorical data via multinomial distribution based on soft set theory [9]. Thus, this paper undertake an experiment to determine the feasibility of grouping the Coping capacity dataset using HCSS.

II. Literature Review

A. Coping capacity

The ability of a community or region to effectively respond to and recover from landslide disasters is referred to as landslide coping capacity. [14]. Coping capacity is a multifaceted concept that considers a variety of characteristics and resources that might assist communities in mitigating the impact of landslides and recovering more quickly and efficiently when such occurrences occur. [15].

A community's coping capacity in the face of landslides may include the following factors.:

1. Early Warning Systems: Effective early warning systems can offer communities and authorities with timely warnings about potential landslide dangers, allowing for evacuation and preparedness steps.
2. Retaining walls, slope stabilization techniques, and drainage systems, among other things, can lessen a community's vulnerability to landslides.
3. Emergency Response and Preparedness: Having well-prepared emergency response plans and trained personnel can help to ensure efficient and coordinated activities during and after a landslide.
4. Social Networks and Communication: During a landslide, strong social networks and community engagement can aid in the spread of information and resources.
5. Financial Resources: Access to financial resources and insurance can help communities rebuild and restore their livelihoods following a landslide..
6. Land Use Planning: Proper land use planning can assist building and development avoid high-risk landslide zones, decreasing exposure to potential dangers.
7. Knowledge and Awareness: Individuals and communities can be empowered to take proactive efforts to reduce risks by increasing their awareness and knowledge about landslides, including their causes and preventive methods.

B. *Hard Clustering Based on Soft Set* (HCSS)

The data is analysed using the clustering technique based on soft set. The technique using multinomial distribution function to find the highest probability and multi soft set based for decompose the data into several set with similar values [9].

Let $S = (U, A, V, f)$ be a categorical-valued information system , where $U = \{u_1, u_2, \dots, U_n\}$ is finite set of instance, $A = \{a_1, a_2, \dots a_m\}$ is finite set of attribute, V is values set of each attribute A, f is maping function

$f: (U, A) \to V$ and $S = (U, a_i, V_{a_i}, f), i = 1,2, \cdots, |A|$ Boolean-valued information system, it can be decomposed to be multi-boolean information system as

$$S = (U, A, V, f) = \begin{cases} S^1 = (U, a_1, V_{\{0,1\}}, f) \Leftrightarrow (F, a_1) \\ S^2 = (U, a_2, V_{\{0,1\}}, f) \Leftrightarrow (F, a_2) \\ \vdots \\ S^{|A|} = (U, a_{|A|}, V_{\{0,1\}}, f) \Leftrightarrow (F, a_{|A|}) \end{cases} = \left((F, a_1), (F, a_2), \cdots, (F, a_{|A|})\right)$$

Then, $(F, E) = \left((F, a_1), (F, a_2), \cdots, (F, a_{|A|})\right)$ can be defined as a multi soft set over universe U representing a categorical-valued information system $S = (U, A, V, f)$.

The multivariate multinomial distribution of multi soft set can be defined as is defined as :

$$Maximize\ L_{CML}(z, \lambda) = \sum_{i=1}^{|U|} \sum_{k=1}^{K} z_{ik} \sum_{j=1}^{|A|} \sum_{l=1}^{|a_j|} \ln\left(\lambda_{kjl}^{u_i}\right)^{|F, a_{jl}|}$$

Subject to

$$\sum_{k=1}^{K} z_{ik} = 1, for\ i = 1,2, \dots, |U|.$$

$$\sum_{l=1}^{|a_j|} \lambda_{kjl} = 1.$$

The maximization of the objective function $L_{CML}(z, \lambda)$ can be obtained by updating the equation as follows:

$$\lambda_{kjl} = \frac{\sum_{u_i \in (F, a_{jl})} z_{ik}(u_i)}{|U|}$$

$$z_{ik} = \begin{cases} 1 & if \ \sum_{j=1}^{|A|} \ln \lambda_{kjl}^{u_i} = \max_{1 \le k' \le K} \sum_{j=1}^{|A|} \ln \lambda_{k'jl}^{u_i} \\ 0 & otherwise \end{cases}$$

where $U = \{u_1, u_2, \dots, U_n\}$ is finite set of instance, $A = \{a_1, a_2, \dots a_m\}$ is finite set of attribute. $(F, E) = \left((F, a_1), (F, a_2), \cdots, (F, a_{|A|})\right)$ can be defined as a multi soft set over universe U as in [16], where $(F, a_1), \cdots, (F, a_{|A|}) \subseteq (F, A)$ and $\left(F, a_{j_1}\right), \cdots, \left(F, a_{j_{|a_j|}}\right) \subseteq (F, a_j)$.

The HCSS algorithm is shown in algorithm 1.

Step 1. Fix $2 \le K \le |U|$ and fix $\varepsilon > 0$ and Max iter.
Give initials $z_{ik}^{(0)}$ and let $t = 1$.
Step 2. Compute $\lambda_{kjl}^{(t)}$ with $z_{ik}^{(t-1)}$
Step 3. Update $z_{ik}^{(t)}$ with $\lambda_{kjl}^{(t)}$
Step 4. Compare $z_{ik}^{(t)}$ to $z_{ik}^{(t-1)}$ in a convenient norm
IF $||z_{ik}^{(t)} - z_{ik}^{(t-1)}|| < \varepsilon$ or $t =$ Max iter, THEN Stop
ELSE t=t+1 and return to Step 2.

Algorithm 1. The HCSS algorithm

III. RESULTS AND DISCISSION

A. *Analysis and Data description*

The research was conducted on communities adjacent to the landslide points. Then analyzed based on data that has been collected by distributing questionnaires, to as many as 40 respondents as a research sample. There are 14 landslide points in Sidoharjo Village as shown in Figure 1.

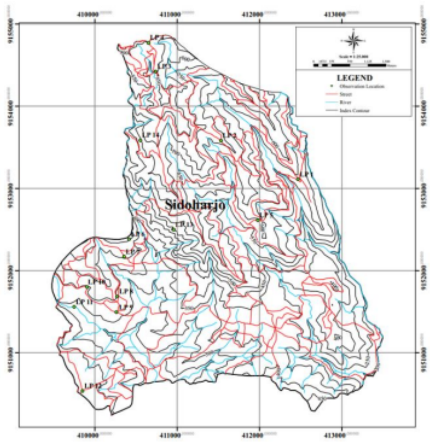

Fig 1. Distribution Map of Landslide Point

The variable of the coping capacity consist of the mitigation knowledge and disaster risk knowledge. The mitigation knowledge involve knowledge level, Action plan and Local culture. Meanwhile, the disaster risk knowledge involve Landslide Risk Reduction and Rescue from Disaster. The description of variable is shown in Table 2.

TABLE I. DATA DESCRIPTION

No	Category	Landslide Risk Reduction		Rescue from Disaster	
		Frequency	Percentage	Frequency	Percentage
1.	Very Dissatisfied	4	10.0 %	6	15%
2.	Not satisfied	20	50.0 %	15	37.5 %
3.	Enough	12	30.0 %	15	37.5 %
4.	Satisfied	4	10.0 %	4	10.0 %
5.	Very satisfied	0	0.0%	0	0.0%
	Total	40	100%	40	100%

Based on Table 2, the general knowledge of landslide risk reduction is mostly in the dissatisfied category as many as 20 people (50.0%) and a few respondents who stated that they were satisfied with their knowledge about landslide risk reduction as many as 4 people (10.0%). Most of the community's knowledge about disaster relief was in the quite satisfied and dissatisfied categories, 15 people (37.5%) respectively. At least in the satisfied category, namely 4 people (10.0%).

Based on Table 2 the capacity of the community with parameters of the level of knowledge about landslides is mostly in the sufficient category of 20 people (50.0%), in the good category 12 people (30.0%) and knowledge in the less category is 4 people (10%) . The capacity of the community with the parameters of the action plan is most in the sufficient category as many as 28 people (70.0%), in the less category as many as 7 people (17.5%) and in the good category as many as 5 people (12.5%). The capacity of the community with local culture parameters is mostly in the good category, namely 34 people (85.0%), in the sufficient category 4 people (10.0%) and in the less category 2 people (5.0%).

TABLE 2
Predictor Variable Statistics

No	Category	Knowledge level		Action plan		Local culture	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
1.	Not enough	4	10.0%	7	17.5%	2	5.0%
2.	Enough	20	50.0%	28	70.0%	4	10.0%
3.	Well	12	30.0%	5	12.5%	34	85.0%
	Total	40	100%	40	100%	40	100%

B. Cluster Analysis

The cluster result is analyzed using Dunn Index resepect to the number of cluster to determine the desirable number of cluster. In the clustering phase, The Dunn index is calculated with the variation number of clusters are 2 until 10. The Dunn index coefficients is summarized Figure 2. From Figure 2, It can be seen that the best number of clusters is 9 on the first level and 3-8 on second level, because it has higher Dunn index. For this case, the data is clustered into 3 clusters using the proposed technique.

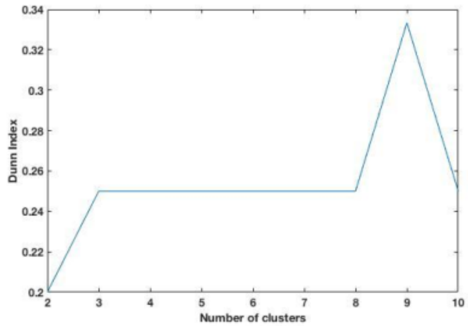

Table 3. Cluster results

Cluster		C1	C2	C3
Area	Wonogiri	0	2	1
	Nglambor	1	2	5
	Keweron	1	2	3
	Blender	0	4	3
	madugondo	1	2	1
	nyemani	0	2	1
	sulur	2	0	5
	serbo	1	1	0
	sum	6	15	19
disaster risk knowledge	average	3	3	1,67
	Level	High	High	Low
mitigation knowledge	average	1.67	3	2
	Level	Low	High	Low

Based on the Table 3. The data has been grouped into three distinct clusters (C1, C2, and C3). Each cluster represents a group of areas with similar characteristics in terms of disaster risk knowledge and mitigation knowledge.

Cluster C1 includes the areas of Wonogiri, Blender, Nyemani, and Serbo. In this cluster, the average disaster risk knowledge is 3, indicating that these areas possess a relatively high level of knowledge about disaster risks. However, the average mitigation knowledge is lower, with a score of 1.67. This suggests that while the residents in these areas are aware of potential risks, they may need more education and support in terms of implementing effective mitigation measures to reduce the impact of disasters.

Cluster C2 comprises the areas of Nglambor, Keweron, and Madugondo. This cluster demonstrates high levels of both disaster risk knowledge and mitigation knowledge, with an average score of 3 for both variables. The residents in these areas are well-informed about disaster risks and have a good understanding of effective measures to mitigate potential hazards. They are better equipped to respond to disasters and reduce their vulnerabilities, making them relatively resilient communities.

Cluster C3 includes the area of Sulur, and it stands out as the cluster with the lowest scores in both disaster risk knowledge and mitigation knowledge. The average disaster risk knowledge is 1.67, indicating a lower level of awareness and understanding of potential risks. Additionally, the average mitigation knowledge is 2, suggesting that residents in this area may have some basic knowledge about mitigation strategies, but there is room for improvement in this aspect. For this cluster, there is a need for targeted educational initiatives and capacity-building programs to enhance disaster preparedness and risk reduction efforts.

IV. CONCLUSION

The clustering analysis provides valuable insights into the distribution of disaster risk knowledge and mitigation knowledge across different areas in Wonogiri. It highlights the varying levels of awareness and preparedness among the surveyed communities. By understanding the specific strengths and weaknesses of each cluster, local authorities and disaster management teams can develop tailored interventions and educational campaigns. These efforts can empower communities to become more proactive in disaster preparedness, enhance their resilience, and reduce the potential impacts of future disasters. The findings from this analysis serve as a valuable foundation for future research and the development of effective policies aimed at fostering disaster risk reduction and community safety in the region

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