

Fostering ecosystem resilience through targeted communication : a cluster analysis of Ijen Geopark Communities

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Abstract. As global environmental challenges like climate change and biodiversity loss grow, achieving ecosystem resilience and sustainability is increasingly vital. Geoparks, which integrate geological heritage conservation and community-based sustainable tourism, provide innovative solutions. Ijen Geopark in East Java, Indonesia, exemplifies this by combining environmental conservation with socio-economic development. However, active community participation is crucial, and effective environmental communication is key in fostering engagement. This study focused on four villages, Tamansari and Kemiren in Banyuwangi and Sumberwringin and Kalianyar in Bondowoso to identify community clusters based on their interactions with conservation and tourism activities. A survey of 245 respondents was conducted, and Cluster Analysis categorized them into three groups "young professionals with moderate knowledge," "senior citizens with minimal interaction," and "middle-aged moderates." These findings highlight the importance of tailored communication strategies to enhance community involvement. By incorporating indigenous knowledge and participatory approaches, Ijen Geopark can strengthen ecosystem resilience while promoting local development. Traditional knowledge, particularly in conserving plant species like food crops, is crucial in supporting biodiversity and human survival. These insights can guide strategies to balance environmental sustainability with community well-being.

1. Introduction

The intersection of geological conservation and community-based tourism has emerged as a pivotal strategy for enhancing ecosystem resilience, particularly in geoparks. Ecosystem

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resilience, defined as the capacity of ecosystems to recover from disturbances while maintaining their essential functions, is increasingly recognized as a critical factor in addressing global environmental challenges such as climate change and biodiversity loss. The resilience of ecosystems is not merely about returning to a previous state ; it encompasses the ability to maintain functionality and structure amidst changing conditions and pressures [1,2]. Geoparks, as designated areas promoting the conservation of geological heritage, play a crucial role by integrating geodiversity, biodiversity, and cultural diversity into their frameworks. This integration preserves natural resources and supports sustainable socio-economic development through community-based tourism.

Geoparks are recognized for their potential to foster sustainable tourism that generates economic benefits for local communities and encourages the conservation of natural resources. The UNESCO Global Geoparks Network emphasizes the role of geotourism as a strategic sector that can lead to new employment opportunities and economic activities, particularly in rural regions [3]. This economic empowerment is vital for enhancing community engagement in conservation efforts, as local populations become stakeholders in the sustainable management of their natural heritage. By promoting local products and handicrafts, geoparks can further stimulate economic growth while ensuring that tourism activities are aligned with conservation goals [4]. Thus, sustainable geotourism serves as a means of economic development and a mechanism to bolster ecosystem resilience by integrating conservation efforts into the livelihoods of local communities.

Environmental communication plays a fundamental role in the success of geoparks by facilitating a comprehensive understanding of geodiversity and its relationship with biodiversity and cultural heritage. As a component of the environmental communication approach, educational initiatives within geoparks enhance awareness of geological heritage and its significance in the broader context of environmental sustainability [5]. Engaging individuals of all ages in educational activities helps communities recognize the value of their natural resources and motivates them to participate in conservation efforts. This educational approach is crucial for fostering long-term conservation and promoting a culture of stewardship among local populations. Furthermore, community involvement in the planning and management of geoparks has been demonstrated to enhance the effectiveness of conservation strategies, as incorporating local insights allows for more contextually relevant and sustainable practices [6]. The bottom-up participatory model that many geoparks adopt empowers communities to take ownership of their natural resources, leading to more resilient ecosystems that can better withstand and recover from environmental disturbances [7].

Geoparks also serve as platforms for promoting ecosystem services and the benefits humans derive from nature, such as clean water, air purification, and climate regulation. By fostering a holistic understanding of the interconnections between geodiversity and biodiversity, geoparks enhance the capacity of ecosystems to provide these services [8]. This integrated approach contributes to the overall resilience of ecosystems and local communities in global environmental challenges.

Effective communication strategies are essential for engaging local communities and visitors in geoparks, ensuring the sustainable management of these protected areas. Previous research has emphasized the role of communication in promoting environmental awareness [9,10] fostering community involvement [11,12] and enhancing tourism experiences in geoparks [13,14]. Several studies have explored using various communication tools, such as social media, public relations campaigns, and educational programs, to promote the natural and cultural heritage of geoparks [15,16].

Targeted communication is pivotal in fostering awareness, understanding, and actions that support ecosystem resilience, particularly within the Ijen Geopark. Communication strategies can only be effective when tailored to the intended audience's specific needs, behaviours, and characteristics rather than being generic. A key approach in developing such

strategies is audience analysis, which involves segmentation or targeting to identify distinct audience groups. This process enables the classification of communities based on behaviour, knowledge levels, values, and socio-cultural needs, thereby, enhancing the adaptability and responsiveness of communication efforts to diverse audience segments [17]. Consequently, targeted communication strategies become more relevant and impactful, ensuring that messages resonate with different groups [18–20]. Furthermore, audience segmentation contributes to the efficient utilization of resources, optimizing both the reach and effectiveness of communication interventions [21,22].

However, despite these efforts, there exists a significant gap in the research regarding communication strategies specifically tailored to engage local communities in supporting the long-term sustainability and management of geoparks. While considerable attention has been given to visitor engagement, few studies have investigated how communication can be adapted to address the unique needs and characteristics of different community groups within geoparks.

Addressing this gap is crucial for enhancing community involvement in geopark management and maintaining the balance between conservation and local development. By understanding how tailored communication strategies can better engage specific community clusters, geoparks can foster a greater sense of ownership and active participation among residents, contributing to both the geopark's sustainability and the community's well-being. Ijen Geopark was selected as the research subject due to its significant biological, geological, and cultural value, as well as the complex challenges it faces in sustainable management, particularly those related to the diverse backgrounds of its communities. This study aims to develop targeted communication strategies that enhance ecosystem resilience and foster active community participation. Moreover, as Ijen Geopark was designated a UNESCO Global Geopark in 2023, the findings of this research are expected to provide strategic recommendations that will be valuable for its revalidation process in 2026. This study aims to address this gap by identifying distinct community clusters within Ijen Geopark and examining how tailored communication strategies can enhance community involvement in supporting the geopark's functions.

2. Materials and method

2.1 Study design

This research employed a survey methodology to explore the perceptions and interactions of local communities surrounding the Ijen Geopark area. The study focused on 245 respondents from four distinct villages : Tamansari and Kemiren in Banyuwangi, and Sumberwringin and Kalianyar in Bondowoso. These villages were purposively selected to represent the key components of the Ijen Geopark, namely the geosite, biosite, and culture site, ensuring that the study captured the diversity of the geopark's landscape and cultural richness. The selection of these sites was based on their geographic and sociocultural relevance to the geopark, providing a balanced representation of the different ecological and cultural aspects of the area.

2.2 Sampling technique

A purposive sampling method was utilized to identify the four villages within the Ijen Geopark area. This non-probability sampling technique was chosen to ensure that the selected villages would provide comprehensive insights into the various interactions between local

communities and the geopark's environmental, cultural, and economic functions. The four villages—Tamansari, Kemiren, Sumberwringin, and Kalianyar—were strategically chosen based on their proximity to geosites, biosites, and cultural heritage areas, reflecting the multidimensional aspects of the geopark's influence on local livelihoods.

The sample of 245 respondents was distributed across these villages, with each village contributing a proportionate number of participants relative to its population size and significance within the geopark's framework. Specifically, the sample consisted of 61 respondents from Tamansari village, 60 from Kemiren village, 64 from Kalianyar village, and 60 from Sumberwringin village. The purposive approach ensured that the sample represented individuals who directly interacted with or were impacted by the geopark through tourism, conservation activities, or local economic practices.

Household units represent the sample respondents in this study with several inclusion criteria that must be met. First, respondents must be at least 18 years old to ensure they can provide valid and relevant responses. Second, respondents must be permanent residents of one of the four selected villages for at least two years, ensuring a deep understanding of the impact of Ijen Geopark on their community's life. Third, respondents must have direct or indirect interaction with Ijen Geopark through employment, tourism-related activities, conservation programs, or cultural practices associated with the geopark. These criteria ensure that the sample provides comprehensive insights into the community's involvement with Ijen Geopark.

2.3 Data collection

Data was collected using structured questionnaires to capture respondents' demographic characteristics, interactions with the Geopark, knowledge levels, and occupational ties to Geopark-related activities. The questionnaire included closed-ended and open-ended questions, enabling quantitative data collection (e.g., age, education, occupation) and qualitative insights. In addition to general respondent information, the study gathered qualitative data on the characteristics of key individuals in each cluster and local environmental knowledge, providing a deeper understanding of Geopark's role in daily life and community development.

The research variables used in the questionnaire included several key areas. First, demographic factors such as age, gender, education level, and occupation were assessed to understand the respondents' background. Second, the questionnaire explored respondents' involvement with the Ijen Geopark, including whether family members were employed in the Ijen Geopark area or the tourism sector, to enhance understanding of the geopark's Geo/Bio/Culture components. Third, public awareness regarding the Ijen Geopark components was examined, focusing on knowledge of geosites, biosites, and cultural sites. Lastly, the study also assessed public awareness of the objectives of the Ijen Geopark, specifically about conservation efforts, educational initiatives, and local economic development. These variables collectively provided a comprehensive view of the respondents' perceptions and interactions with the geopark.

To ensure clarity and relevance, the questionnaire was pilot-tested in a selected village before full-scale data collection. This process allowed for adjustments to question phrasing and structure to enhance the reliability of responses. Data collection teams were trained to administer the survey and assist respondents as needed, ensuring that language barriers or literacy levels did not impact the quality of the data collected.

2.4 Data analysis

The data were analyzed using the K-Means Clustering method to explore relationships among respondents based on the measured variables, with SPSS 22 software employed for this purpose. Cluster analysis is a robust tool for identifying audience-specific patterns, thereby enhancing the refinement of communication strategies. For example, the K-Means Clustering method was employed to categorize international students based on their COVID-19 risk perceptions to improve tourism marketing [23]. It was also used to compare the communication strategies of Chinese and American corporations on YouTube to increase audience engagement [24]. Additionally, this method was applied to examine disaster communication strategies across South America, highlighting differences in approaches during pre-and post-disaster phases [25,26]. These studies collectively demonstrate the effectiveness of cluster analysis in enhancing communication and decision-making strategies across diverse contexts. This research applies cluster analysis to identify specific group behaviours and characteristic patterns, focusing on knowledge. The insights gained will facilitate the identification of distinct community clusters within Ijen Geopark, guiding the development of targeted communication strategies to improve community participation and support the geopark's initiatives. Moreover, cluster analysis enables the categorization of respondents into meaningful groups that can be further interpreted based on their proximity to geosites, biosites, and cultural sites, as well as their level of engagement with geopark-driven activities.

Table 1. Distances between final cluster centers

Cluster	Cluster 1	Cluster 2	Cluster 3
Cluster 1	0.000	33.130	15.304
Cluster 2	33.130	0.000	17.828
Cluster 3	15.304	17.828	0.000

Table 1 presents the distances between the final cluster centres, which are crucial for understanding the relationships and distinctions among the identified clusters. A distance of 0.000, observed along the diagonal, indicates that the comparison is within the same cluster, reflecting identical centres with no variation. In contrast, non-zero distances represent the degree of dissimilarity between different clusters, with larger values indicating more significant heterogeneity and separation. In comparison, smaller values suggest a higher degree of similarity.

The distance between Cluster 1 and Cluster 2 is 33.130, representing the most significant separation, suggesting substantial differences in respondents' characteristics, particularly regarding age, gender, and education. In comparison, the distance between Cluster 1 and Cluster 3 is 15.304, indicating a closer relationship with more shared similarities, especially in gender and education. The distance between Cluster 2 and Cluster 3 is 17.828, reflecting moderate differentiation, primarily influenced by variations in age and occupation.

These distances provide insights into the distinctiveness of each cluster. More considerable distances imply clear groupings with minimal overlap in characteristics, while smaller distances may indicate potential similarities, warranting further evaluation or even the possibility of merging clusters. Understanding these patterns is essential for interpreting clustering results and guiding subsequent analyses. In the context of this study, the cluster analysis aims to identify behavioural and demographic patterns that can inform targeted community engagement strategies to enhance participation in geopark-related activities, particularly in tourism, conservation, and cultural preservation.

2.5 Ethical considerations

Ethical approval for the study was obtained from the relevant academic and local authorities before data collection. Respondents were informed about the purpose of the research and assured that their participation was voluntary. Informed consent was obtained from all participants, and confidentiality was maintained by anonymizing the data.

3. Results and discussion

The data collected for this research were analyzed using SPSS Statistics and subjected to K-means cluster analysis to identify distinct community groups within Ijen Geopark. After evaluating multiple clustering options, a three-cluster solution was chosen to fulfil the study's objectives. The clusters were formed by maximizing the differences in demographic characteristics and levels of community engagement. ANOVA testing was applied further to assess the significance of these differences (Table 2). As shown in Table 1, the results indicated statistically significant differences among the clusters. However, these differences do not necessarily correspond with theoretical expectations, primarily because clusters are created to emphasize the maximum variance between groups. This method inherently results in significant differences between the vectors, making it difficult to test hypotheses based on ANOVA averages, as the clustering process prioritizes statistical divergence over theoretical consistency.

Table 2. The analysis of variance (ANOVA) analysis

Variables	Mean Square (Cluster)	Mean Square (Error)	F	Sig.
Age	19874.44	30.402	653.7	0
Gender	0.424	0.249	1.707	0.184
Education	27.101	1.002	27.04	0
Occupation	1.639	12.611	0.13	0.878
Interaction with the Geopark	1.3	0.86	1.512	0.222
Knowledge Score	1.272	0.414	3.073	0.048

In the cluster analysis, several variables emerged as significant in distinguishing the identified groups, with age being the most prominent factor. It exhibited an exceptionally high F-value of 653.727 and a significance level of .000, indicating its critical role in differentiating the clusters. This result aligns with the substantial age differences observed between the groups, suggesting that age-related factors strongly influence cluster formation. Similarly, education showed significant differentiation, with an F-value of 27.035 and a significance level of .000, underscoring its importance in shaping the distinct characteristics of each cluster. Additionally, the knowledge score was significant at the .048 level, reflecting slight but notable variations in knowledge levels across clusters. This finding is consistent with previous research [25] which emphasizes the pivotal role of knowledge in fostering community engagement.

The influence of age and education extends beyond cluster differentiation, as these variables also shape media consumption patterns, which are crucial for developing effective communication strategies. Different age groups and educational backgrounds tend to prefer distinct communication channels. For instance, a study identified significant associations between education and radio use for accessing environmental information and between age, education, and television usage [27]. These findings suggest that tailoring communication strategies to align with the preferred media platforms of various demographic groups can enhance the reach and effectiveness of environmental messages.

Moreover, education is fundamental in shaping environmental attitudes and behaviours, influencing individuals' engagement with sustainability initiatives. A study on significant life experiences highlighted the impact of educational institutions in fostering environmental stewardship among adults [28]. These findings underscore the importance of considering individuals' educational backgrounds when designing environmental communication strategies, as educational experiences can significantly influence their commitment to environmental causes.

Maximizing the effectiveness of environmental communication requires tailoring strategies to different age groups. Research on environmental communication training programs for young adults (aged 18–29) has demonstrated the necessity of age-specific approaches to enhance environmental communication skills [29]. These findings indicate that customizing messages based on age-related preferences and learning styles can improve audience engagement, promote behavioural change, and contribute to more effective environmental stewardship. Understanding the role of demographic variables such as age, education, and knowledge can significantly enhance the design and implementation of targeted communication strategies, particularly in environmental sustainability.

On the other hand, some variables were not significant in distinguishing the clusters. Gender, occupation, and interaction with the geopark did not show significant differences across the clusters, suggesting they do not strongly contribute to the forming distinct groups in this analysis. Table 3 provides a detailed description of each cluster.

Table 3. Demographic, occupational, and knowledge characteristics of community clusters related to Geopark Ijen

Variable	Cluster 1	Cluster 2	Cluster 3
Age	27	60	43
Gender	Male	Female	Female
Education	High School	Elementary School	Junior High School
Occupation	Private Sector Worker	Farm Laborer	Private Sector Worker
Job Interaction with Geopark	Family member's job related to Geopark Ijen	Family member's job and head of household not related to Geopark Ijen	Family member's job associated with Geopark Ijen
Knowledge Score	2.47	2.21	2.40

The following paragraphs provide a detailed description of the groups, highlighting their key characteristics. Based on these attributes, we propose a communication strategy specifically tailored to each group.

3.1 Cluster 1: Young professionals with moderate knowledge

Cluster 1 consists of younger individuals, with an average age of 27, predominantly male, and with higher levels of education. Many in this group interact moderately with Geopark Ijen, either through their work or through family members whose jobs are related to the Geopark. This cluster represents a significant potential for involvement in the Geopark's conservation efforts. Cluster 1 predominantly comprises young individuals actively engaged in the Ijen Geopark's development initiatives. This includes key stakeholders such as the head of the Tourism Awareness Group, the leader of the Village-Owned Enterprise, and café owners. Moreover, the occupations of cluster 1 members are primarily concentrated in tour guiding and various forms of self-employment or entrepreneurship, demonstrating engagement in sectors directly associated with Geopark tourism. The prevalence of these

professions is notable, with 14 individuals employed as tour guides and 18 individuals involved in trade, self-employment, or entrepreneurial ventures. This distribution underscores the significant role cluster 1 plays in tourism-related activities.

The Tourism Awareness Group and the Village-Owned Enterprise are crucial in leading sustainable tourism initiatives. Their involvement in community development and self-help programs significantly enhances local participation, which is vital for the long-term success of tourism projects [30]. Collaborative efforts between Village-Owned Enterprise and local tourism stakeholders are key to establishing an ecosystem that promotes economic growth and environmental sustainability [31]. The synergy between these groups fosters a comprehensive approach to sustainable tourism development. Furthermore, as highlighted by Khanifah et al., the collaborative governance model underscores the importance of partnerships among local governments, community organizations, and private sector actors to maximize the impact of tourism initiatives [32].

Regarding their characteristics, their higher education levels and moderate knowledge of conservation indicate that these young professionals are well-suited to participate in environmental conservation activities. They could serve as volunteers in initiatives aimed at preserving the Geopark. Their awareness and interest in these activities, coupled with their educational background, suggest a strong capacity for further involvement in conservation. Young professionals with a moderate understanding of local history and cultural wisdom can effectively communicate these narratives to diverse audiences. Their ability to convey local wisdom enriches educational experiences, creating a more profound connection between individuals and environmental conservation efforts, as Asrial et al. (2021) noted, who emphasize the positive impact of local wisdom in environmental education [33].

Cluster 1 stands out compared to other clusters due to its higher potential for contributing to digital advocacy and awareness-raising campaigns. Their moderate interaction with the Geopark and their professional status and digital literacy enable them to support conservation efforts. They could leverage their networks to promote sustainable practices and engage with a broader audience through digital platforms. Given their digital literacy and professional connections, this cluster could be key in promoting Geopark through social media or as influencers.

Their professional standing also allows them to connect with business or governmental sectors that can support Geopark's development, making them valuable contributors to both environmental advocacy and community outreach efforts. Moreover, effective management requires equal participation from all stakeholders, essential for successfully integrating the various elements involved [34]. In line with this, research further emphasizes the importance of a collaborative governance model, showing that sustainable geotourism management depends on cooperation between stakeholders and the community [35]. Such collaboration is particularly relevant in the Rinjani-Lombok Geopark, where stakeholder cooperation, framed within the concept of social capital, underscores the critical role of community engagement in achieving sustainable outcomes [36]. Looking ahead, Cluster 1 can be positioned as young advocates and ambassadors for the Ijen Geopark. Their ability to drive conservation initiatives and promote educational outreach through digital platforms and professional networks can significantly enhance the visibility and sustainability of Geopark's conservation programs.

3.2 Cluster 2: Senior citizens with minimal interaction

Cluster 2 paints a picture of older individuals, predominantly 60 years of age, predominantly female with lower levels of education. This group has minimal interaction with Geopark Ijen, which shapes their current role within the broader conservation efforts. Their limited connection to the Geopark may imply that they are not actively participating in conservation

activities. However, their value lies elsewhere—within their deep-rooted connection to local traditions and knowledge. Cluster 2 represents a wealth of cultural history and environmental practices that could be woven into the narrative of Ijen Geopark, preserving traditional conservation methods and integrating them into modern sustainability strategies. Regarding education, this group is not looking for complex discussions or detailed ecological data. Instead, they would benefit from simplified, easy-to-understand campaigns highlighting practical, daily ways to support Geopark's goals. Focusing on how small actions, like conserving water or reducing waste, can contribute to a more significant environmental cause could resonate with them.

The Osing community in Kemiren Village, Banyuwangi, exemplifies the dynamic interplay between cultural preservation and adaptation in the face of tourism development. While embracing the economic opportunities tourism presents, the community remains deeply rooted in its local wisdom and traditions, which play a significant role in environmental conservation. Central to their cultural practices are sacred sites such as Buyut Cili, which hold spiritual significance and contribute to protecting natural resources, including water sources and agricultural lands. The community's reverence for these sacred sites fosters a sense of environmental stewardship, ensuring the sustainable management of their natural surroundings. Similar conservation patterns rooted in traditional beliefs can be observed in various parts of the world. In Yucatán, Mexico, the cenotes—natural sinkholes considered sacred by the indigenous Maya people—have been historically protected due to their cultural and spiritual importance. Traditional practices have preserved these water resources, although modern challenges such as pollution threaten their ecological integrity [37]. Likewise, sacred lakes and rivers in Kenya are conserved due to their association with supernatural powers, with local communities implementing traditional practices to protect these vital water bodies [38].

Sacred natural sites are not limited to water bodies; sacred mountains also play a crucial role in biodiversity conservation. Depending on their geographical context, these sites often encompass diverse ecosystems, ranging from forests and plains to underwater systems. The spiritual reverence for sacred mountains inspires conservation efforts that extend beyond the immediate sacred area, promoting the protection of broader ecological landscapes [39]. Collectively, these examples highlight the significant role that cultural and spiritual beliefs play in fostering environmental stewardship, demonstrating how traditional knowledge systems can complement modern conservation strategies.

Community engagement is key here. While this group might not actively pursue involvement with the Geopark, they can be encouraged to participate through familiar, locally-based initiatives. Events like community festivals, heritage celebrations, or simple workshops allow them to engage in a more informal, approachable setting. Festivals and heritage celebrations serve as platforms for knowledge exchange and community engagement, fostering a sense of ownership and responsibility among residents.

This collaborative spirit is essential for effectively managing geoparks, as it aligns with the three pillars of geopark management: geological, biological, and cultural heritage [40]. As discussed by Pijet-Migoñ and Migoñ, the holistic approach to heritage management emphasizes the interconnectedness of geological and cultural heritage [41]. Festivals celebrating both aspects can provide educational opportunities for visitors, enhancing their understanding of the area's unique features and the importance of conservation efforts. This educational component is vital for fostering a culture of sustainability and stewardship among visitors and residents alike. This passive involvement can gradually build their awareness and connection to Geopark's efforts. Cluster 2 may not be the most engaged or active demographic, but they hold untapped potential. Focusing on local traditions,

intergenerational knowledge transfer, and low-barrier ways to get involved, this group could become quiet yet valuable supporters of Geopark's long-term conservation goals.

3.3. Cluster 3: Middle-aged moderates

Cluster 3: Middle-aged moderates consist of individuals with an average age of 43, mostly female, and possessing a moderate level of education. Their connection to Geopark Ijen is solid, with active, but not extensive, participation in geopark-related activities. Cluster 3 is characterized by working-age individuals who exhibit moderate engagement in geopark development initiatives. The occupations of cluster 3 members are distributed equally between tourism-related and non-tourism fields. However, the primary distinction from Cluster 1 is that within Cluster 3, those employed in the tourism sector are predominantly over 35 years of age.

When it comes to conservation, Cluster 3 holds a strategic role. They are already somewhat engaged, but there is room to expand their involvement. They could be key players in family-oriented environmental programs, taking on leadership roles within the community to further conservation education. Local leaders can facilitate dialogues and partnerships between community members, educational institutions, and conservation organizations, ensuring conservation education is a shared responsibility. This collaborative approach is essential for creating a cohesive strategy that aligns with the goals of the geopark. In addition to facilitating educational programs, local leaders can promote community-based initiatives emphasizing the importance of living heritage conservation. Aziz et al. argue that community participation is critical for the success of heritage site conservation, as it fosters awareness and appreciation of heritage values among residents [42].

In terms of education, Cluster 3 is well-positioned to benefit from both theoretical and practical knowledge. With their moderate education and existing awareness of the geopark, hands-on learning experiences, like workshops or guided eco-tours, would resonate well with them. Furthermore, they have the potential to become community educators, bridging the knowledge gap between younger and older generations and sharing their understanding of environmental issues.

Community involvement is likely a significant factor for this cluster. Their sense of responsibility and commitment to local activities positions them as ideal organizers and participants in geopark events. Whether it is eco-tourism initiatives, community fairs, or environmental education programs, Cluster 3 could drive increased community participation in Geopark Ijen's conservation efforts. Cluster 3 is ripe for development as a foundation of the Geopark's sustainable tourism and conservation efforts. With their moderate knowledge and active involvement, they can take on leadership roles, becoming local champions of education and environmental preservation, helping to weave Geopark Ijen deeper into the fabric of the community.

4. Conclusion

The results of this study reveal three distinct community clusters within the Ijen Geopark, each with varying degrees of interaction and engagement with geopark-related activities. Cluster 1, consisting of young professionals with moderate knowledge, shows the most potential for active conservation and digital advocacy involvement. Their professional standing and digital literacy are key players in promoting environmental sustainability through modern communication platforms. Cluster 2, characterized by senior citizens with minimal interaction, holds valuable traditional knowledge and cultural history. Although their direct participation in geopark activities is limited, they possess untapped potential for passive engagement through locally-based initiatives and cultural events. Cluster 3,

comprising middle-aged moderates, already displays moderate engagement with geopark initiatives, but there is room for them to take on leadership roles in community-driven conservation and education efforts. Their ability to bridge the gap between younger and older generations positions them as vital contributors to education and environmental stewardship within the geopark.

Effective conservation engagement requires tailored communication methods for each cluster. Cluster 1 could benefit from using digital platforms to advocate for conservation and raise awareness among a broader audience. For Cluster 2, simple and practical messages delivered during cultural gatherings can resonate deeply. In contrast, Cluster 3 may be best engaged through immersive learning experiences, such as eco-tours and interactive educational programs that foster a hands-on understanding of conservation practices.

Incorporating traditional ecological knowledge from Cluster 2 into Geopark's conservation strategies is crucial for preserving intergenerational wisdom. Organizing heritage festivals that celebrate and share these practices can strengthen community ties to sustainable habits and encourage environmental care as a collective value.

To foster local conservation leadership, Cluster 3 members should be equipped with resources and training to serve as community leaders and educators in environmental stewardship. Empowering these individuals can help establish a network of local advocates, enhancing the community's capacity to advance conservation efforts.

Finally, sustainable outcomes depend on active collaboration between clusters, local government, and stakeholders. This integrated approach supports conservation objectives while fostering socio-economic development, creating a balanced framework that promotes ecological health and community prosperity..

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