Land use sustainability to mitigate potential land slide in Ciletuh watershed, Sukabumi, Indonesia

A N Wahidah¹, D N Martono¹, Supriatna²

¹ School of Environmental Science, Universitas Indonesia, Jakarta, Indonesia
² Departement of Geography, Faculty of Mathematics and Natural Science, Universitas Indonesia, Depok, Indonesia

Email: w.andhika.nurul@gmail.com

Abstract. The widespread use of agricultural land and the built-up areas will decrease the land carrying capacity, which means that the area will be more vulnerable to natural disasters. Furthermore, the local community has used the Ciletuh area for agriculture, plantations, and forestry to fulfil the food needs in southern Sukabumi then developing some tourism areas. This study aims to analyse the effects of land management on the ecosystem and develop strategies of land management based on the ecosystem for communities affected by disasters. The analysis was conducted by interviewing community representatives in the upstream, middle, or downstream of the watershed, then elaborated by expert judgment through the Analysis Hierarchy Process method on seven expert respondents. The result shows that potential landslides in December and January due to the highest precipitation occur in both months. Most deforestation occurs in the long term due to the cultivation need for food crops, and increasing more landslide potential. It concludes that both communities and experts consider the community social capacity for spatial arrangement and land use, especially the intensification of land use, could be an alternative to land use sustainability to mitigate potential landslides in the Ciletuh watershed.

1. Introduction

Land-use change is one factor that affects the dynamics of biodiversity, aquatic ecosystems, and Hydrological Response Units in water catchments of a watershed [1][2], either for settlements, plantations, or agricultural. Agricultural mismanagement can also lead to groundwater salination, soil degradation, and erosion [3]. Soil degradation by erosion, overgrazing, and recovery organic matter trouble threatens most of the world's agricultural land productivity [4] [5]. It also occurs in tourist areas that have shifted forests into buildings or infrastructures so that land fragmentation is not suitable for construction and active geomorphological processes [6]. The environmental, social, economic, and political capacities change as regional resources, increasing the uncertainty of natural disaster threats that might hit Indonesian tourist destinations [7].

Southern Sukabumi has prone-disaster areas caused by agricultural activities and land conversion into built-up areas [8]. The Ciletuh watershed protects water catchment areas and springs as the Sukabumi Regency regional spatial plan 2012-2032 regulate. The development of Ciletuh geological sites in South Sukabumi, which has an amphitheatre-like landscape, and Jampang plateau began around 2002 until experiencing its peak since the Ciletuh-Palabuhanratu Geopark has inaugurated as a UNESCO Global Geopark in April 2018 [9]. Although currently become a geopark that protected areas,
several problems occur in conservation areas, waste management, water pollution, or land degradation due to illegal mining activities [10].

The socio-cultural changes pervade the community livelihoods in geopark and its geotourism development so that farmers, ranchers, and fishers turn into tourism actors [9]. It also grows the local organizations for tourism management, revitalizes local traditional arts as a tourist commodity, and creates new social interaction patterns between local communities and tourists [9]. In addition, Geopark has shifted people's perspective in the South Sukabumi tourist area to improve and maintain the aesthetics of the significant increase in tourists visiting [11].

This study analyses the effect of land management on the ecosystem and formulates ecosystem-based land management strategies by disaster-affected communities in the Ciletuh watershed. The analysis can be helpful for land use in the Ciletuh watershed with landslide disaster management that stakeholders, communities, and regional manager to determine which priority of the strategy for landslide risk mitigation can be practice. The analysis result gives an alternative to adjusting the community's land use with the ecosystem's capability and regional vulnerability level, thus would create more sustainable and long-lasting utilization for the long-term environmental changes in the future [12]. Although similar research has been conducted in Indonesia [13] [14] [15], it could provide constructive ecosystem-based natural disaster mitigation management strategies for the local community level.

2. Methods
This study was conducted in the Ciletuh watershed covering a 195 hectares area and is located in the southern part of Sukabumi Regency, West Java which is included in three sub-districts, Ciemas, Simpenan, and Waluran. This analysis was conducted by interviewing the community in the Ciletuh watershed then elaborated by the expert judgment through the Analysis Hierarchy Process method on seven expert respondents. The sample is determined by the purposive sampling method [16] to evaluate sustainable land management for the community for nine informant representatives in the upstream, middle, or downstream of the watershed. In this case, the distribution of the watershed ecosystem is divided into the upstream, middle, and downstream based on the typology of the watershed area and community characteristics. Informants are village apparatus or community organizations, village elders, and local communities who used land in the Ciletuh watershed area before 2000 and are willing to be asked for information. The distribution of informants was chosen to represent each area that has experienced land change since 2000, has landslide potential in the upstream-middle-downstream watershed, and represents each land use. Sample determination also considers the head of the family role because land ownership is represented by every head of the family [17].

The analysis was then elaborated to recommend the landslide risk mitigation strategies with an expert judgment through the Analysis Hierarchy Process method on seven expert respondents from practitioners and academics in land management, disaster management, earth sciences, and environmental sciences. The recommendation hierarchy compares the criteria on landslide risk mitigation capacity with the land use sustainability strategy based on similar research on land use sustainability [14] and disaster risk mitigation [18]. The criteria for expert respondents refer to specific background or knowledge according to the required data [19] and understand the problem posed, feel the consequences of a problem, or be interested in the problem [20]. It is recommended that 7-8 experts provide assessments in the AHP method to obtain unbiased results and ease researchers to identify and correct the inconsistent weighting of respondents [21].

3. Result and Discussion
3.1. Community's Land Use Sustainability Knowledge to Landslide Risk
This evaluation interviewed nine informants who live in the upstream, middle, or downstream watershed and are disposed to be asked for information. The informants are the member of Paguyuban Lahan Parahyangan (Palapah) organization in Waluran Village, an elder of Kertajaya Village, an adlay entrepreneur in Waluran Mandiri Village, head of Paguyuban Alam Pakidulan Sukabumi (PAPSI)
organization in Tamanjaya Village, plantation worker in Mekarjaya Village, tourism actors in Ciwaru Village, rangers in Cikepuh wildlife reserve, Principal of Elementary School in Ciwaru Village, and daily officer of public Works Department in Tamanjaya Village.

There are eight information points regarding the landslide occurrence and ten information points for landslide response and mitigation. However, the actual comparison between all responses and the information points obtained does not reinforce individual informants who discussed more than eight information points about landslides in the Ciletuh watershed, resulting in none of the informants having deep knowledge of landslides and their mitigation. Informants mentioned that landslides were caused by high rainfall. Some were caused by soil type or occurred when land use changes due to forest vegetation loss upstream or on the hill. Landslides occur if there is rain for three days in December until the Chinese New Year (beginning of the year). Three informants explained that this incident could hinder access. Unfortunately, the road repairment by the relevant agencies only occurred on provincial roads. This limitation makes the village level road repairments need to use the village disaster management budget. These are just done a month after the incident through the community's mutual cooperation.

In addition to unwanted landslides, there are also intentional landslides by communities on the upstream and downstream watersheds. Some people intentionally did it to clearing forest land until they could dig up the sand material. Some people intentionally carry out landslides in the upper watershed to dig for gold mining materials.

The land use change in the upstream watershed is massive deforestation and turning them into dry fields or plantations. There is some deforestation near settlements upstream, which changed for paddy and dry fields distributed almost equally. Since 2000 downstream, many settlements have started to develop. From 2010 to 2020, several areas in the middle of the watershed have transformed into palm oil plantations. Settlements will continue to grow, especially construction for homestays, both in the middle and downstream parts of the watershed, made by reclamation to pile up the swamps. The PAPSI community organization suggests encouraging land ownership, preferably as cooperation between investors and residents, to empower the local communities and improve eco-social quality.

Most of the built area expands from land that previously functioned as cultivated land, which impacts the dynamics of the potential for landslides. Mostly built-up expand from converting paddy fields and mixed agriculture. Those urbanizations and industrializations that remove agricultural land and woods could affect the watershed hydrological response balance [22]. It will cause land degradation and increases sedimentation risk and soil erosion.

In terms of land use, cultivated land is managed intensively by using unused land owned by residents or land under government management rights planted with a periodic system for uninterrupted productivity. It is in line with the concept of intensification [15]. Aside from the concept, diversification has also applied for generations by intercropping on palawija (third harvest) and talun (plantations), which is primely for soil grip [23] [24]. Some lands are still poorly managed, one of which has occurred upstream since deforestation start and changing it into dry fields and rice fields, eventually this causing a water crisis for some communities.

Environmental impacts are the most effective tool to evaluate the disaster damage intensity rather than effects on humans and artificial structures [25]. However, it is still necessary to know the optimum land use sustainability strategy for mitigating landslide risk to predict future socio-economic dynamics. It is very advised to do mutual cooperation as the structural mitigation for landslide risk from the local government or village government [26]. Social capital in spatial and land use comprehension on cultivated land is also vital to reduce landslide potential and financial-physical losses. It has to be under the tolerant and mutual cooperation perspective [27].

3.2. Land Use Sustainability Strategy for Landslide Risk Mitigation

The land use sustainability strategy for landslide risk mitigation determines by the AHP method through seven expert respondents. The seven experts selected in formulating the strategy affiliated different institutions, both from the central government, local governments, and academics. Four respondents are
practitioners in disaster early warning, land resources and disaster mitigation, environmental geology, and research and development evaluation. The other three experts are earth sciences academics. Two of them participate in the Ciletuh-Palabuhanratu UNESCO Global Geopark planning, and the other one is an engineering geologist.

On the objective opinion of the seven experts, there are differences in determining which mitigation capacity is the most important and which sub-criteria should be a priority. Therefore, the authors combine all AHP results using the geometric mean [28] with the result combined weighting is shown in Figure 1. It recommends having higher priority on the social aspect [15] and other capacities then followed by the institutional aspect (0,251), economy (0,237), and physical (0,166), with spatial and land use sub-criteria as the essential option (0,684), then formal institutions as a priority that follows (0,671). Figure 1 shows the determination of alternative options by synthesizing the goal based on the seven experts' input. It generates intensification-extensification as a priority strategy for land use sustainability which reach a 0,445 score, followed by managing with diversification (0,352) and migration (0,202).

![Figure 1. AHP model result.](image)

Predict possible future land use and its strategy need elaborating on landslide-prone areas. Completing the environmentally-oriented spatial pattern policy by undertaking forest restoration efforts in protected areas for forest and non-forest protected areas might reduce land use mismatches and fulfil a minimum of 30% forest cover regulations in each watershed. In traditional Sundanese, land use is categorized to its ecosystem function, such as forest upstream (*gunung kayuan*), growing bamboo clumps on steep slopes (*lamping gawit awian*), agroforestry practice for plantations (*kebun talun*), paddy fields on flatland (*datar sawahan*), and fish ponds on basins (*legok balongan*) [29]. This zoning affects local people's behaviour manage their natural resources with sustainable habits seeing that everything is entrusted to the present generation solely for future generations [30] [31]. From the ecological
perspective, it shall have a positive impact on the environment and disasters. Therefore, a beneficial strategy both ecologically and economically is necessary.

As the recommendation besides planting wood upstream, planting bamboo on steep slopes would greatly support environmental and economic recovery. Bamboo, which functions as a barrier to water flow, water absorption, and reforestation, provides economic value as a construction material and food resource. In the middle part of the watershed cultivated as a plantation, including on the regional spatial plan, possibly apply the *talun* system or agroforestry and mixed plantations as suggested by other studies in southern West Java [29] [32]. For settlement areas (home yards) and many paddy fields downstream are recommended to arrange with mixed gardens, *karangkitri* (edible garden), barrier plants, and medicinal plants.

4. Conclusion
Both communities and experts consider intensification-extensification treatment for land use sustainability rather than diversification and migration, in line with expert recommendations to prioritize spatial and land use sub-criteria as the essential option and socio-cultural interest in landslide prevention community to physical, economic, and institutional interests. The land use sustainability knowledge possessed by the community to practice intensification-extensification and diversification of cultivated land reduces landslide potential. The strategy that prioritizes the community social capacity for spatial arrangement and land use, especially the intensification of land use, could be an alternative to land use sustainability to mitigate potential landslides in the Ciletuh watershed. The intensification also becomes the essential recommendation for built-up and reforestation areas.

The government needs to elaborate on their spatial planning between disaster potential, landscape patterns, and landscape processes on a detailed scale, including government-owned land, which is the responsibility of local government-owned enterprises at the district level. In addition to public facilities and access to priority areas, disaster risk management also needs to be monitored in plantation areas or production forests that have been missed from supervision so far. Ciletuh watershed residents also need detailed spatial planning of their land by paying attention to crucial economic (financial), social (mutual cooperation), and natural resources. Self-regulating community-own land is related to land management and landscaping (plains, basins, and slopes) for their future.

Acknowledgement
The authors would like to thank Katon Sena Adjie Nugraha, Irpan Alamsyah, Tasya Taranusyura, Nadhira R. Yusuf, Adjie, Mega F. Rosana, Iwan G. Tejakusuma, Dian Andry P. S., Rinaldi Ikram, Yudi Indriawan, Oki Oktariadi, Endang Sutisna, Uteng, Arif Rusnandi, Dadah Suhanda, Dede Rusman, Asep Hidayat Mustofa, Haji Toni, Oke Roban, Asep Mulyadi, PAPSI, and Palapah members, who helps retrieve data.

References
[1] Butt A Shabbir R Ahmad S S and Aziz N, 2015 Land use change mapping and analysis using Remote Sensing and GIS : A case study of Simly watershed , Islamabad , Pakistan Egypt. J. Remote Sens. Sp. Sci. 18, 2 p. 251–259.
[2] Ramadhan K and Supriatna S, 2019 Erosion rate prediction model ssing SWAT and CA-Markov methods ( case study: Upper Ci Cath catchment Area ) Erosion rate prediction model ssing SWAT and CA-Markov methods ( case study: Upper Ci Cath catchment Area ) Padjadjaran Earth Dialogues, Int. Symp. Geophys. Issues 311, 012072.
[3] Costello A et al., 2009 Managing the health effects of climate change. Lancet and University College London Institute for Global Health Commission Lancet 373, 9676 p. 1693–1733.
[4] Verheye W H, 2009 Land Use, Land Cover and Soil Sciences - Volume IV EOLSS Publ. IV.
[5] Magdoff F and Foster J B, 2010 What every environmentalist needs to know about capitalism Mon. Rev. 61, 10 p. 1–30.
[6] Kullenberg G, 2010 Human empowerment: Opportunities from ocean governance *Ocean Coast. Manag.* **53**, 8 p. 405–420.

[7] Kurniasari N, 2017 Strategi Penanganan Krisis Kepariwisataan dalam Kebijakan Badan Nasional Penanggulangan Bencana (BNPB) *Mediat. J. Komun.* **10**, 2 p. 177–189.

[8] Akbar F and Supriatna, 2019 Land cover modelling of Pelabuhanratu City in 2032 using cellullar automata-markov chain model *IOP Conf. Ser. Earth Environ. Sci.* **311**, 1.

[9] Wendita S A T, 2019 Pengembangan Geowisata dan Perubahan Sosial-Budaya Masyarakat di Area Geopark Ciletuh-Palabuhanratu *Indones. J. Anthrop.* **4**, 1 p. 31–43.

[10] Hadian M S D H Yuliwati A K and Pribadi K N, 2016 Increasing community environmental awareness through geodiversity conservation activities at Ciletuh, Sukabumi, West Java *J. Environ. Manag. Tour.* **VII**, 2.

[11] Savity R and Herdiana A, 2018 Arah Pengembangan Objek Pariwisata Geopark Ciletuh di Kecamatan Ciemas Kabupaten Sukabumi *J. Ilm. Plano Krisna* **12**, 2 p. 12–31.

[12] Miller G T and Spoolman S E, 2016 *Environmental Science* Fifteenth Boston: Cengage Learning.

[13] Supriatna S Sobirin S and Pratiwi A N, 2018 Spatial model of vulnerability towards tsunami in Bayah coastal area, Banten, Indonesia *AIP Conf. Proc.* **2023**, October.

[14] Wijayanti R, 2011 Studi Identifikasi Pengelolaan Lahan Berdasar Tingkat Bahaya Erosi (TBE) (Studi Kasus di Sub Das Sani, Das Juwana, Jawa Tengah) *J. Ilmu Lingkung.* **9**, 2 p. 57–61.

[15] Wijayanti R Baiquni M and Harini R, 2016 Strategi Penghidupan Berkelanjutan Masyarakat di Sub DAS Pusur, DAS Bengawan Solo *J. Wil. DAN Lingkung.* **4** p. 133–152.

[16] Sugiyono, 2016 *Metode Penelitian Kuantitatif, Kualitatif, dan R&D* Bandung: Alfabeta.

[17] Priambudi; B N and Pigawati B, 2014 Faktor-Faktor yang Mempengaruhi Perubahan Pemanfaatan Lahan dan Sosial Ekonomi di Sekitar Apartemen Mutiara Garden *J. Tek. PWK* **3**, 4 p. 576–584.

[18] Zalukhu R S, 2019, Klasifikasi Tanah di Indonesia, Universitas Andalas, Padang.

[19] Suganda K U, 2009, The Ciptagelar Kasepuhan Indigenous Community, West Java: Developing a bargaining position over customary forest, in *Forests for the Future - Indigenous Forest Management in a Changing World*, E. O. Kleden, L. Chidley, and Y. Indradi, Eds. (Jakarta:
Indigenous Peoples Alliance of the Archipelago and Down to Earth), p. 27–61.

[30] Brundtland G H Khalid M Agnelli S Al-Athel S and Chidzero B J N Y, 1987, Report of the World Commission on Environment and Development: Our common future, Oslo.

[31] Blewitt J, 2015 Understanding Sustainable Development New York: Routledge.

[32] Ramdhani D Utomo S W Thayib H and Wardhana Y, 2019 Model of sustainable land management (study at Bukit Sepuluh Ribu area of Bungursari Sub-District, Tasikmalaya City, West Java) J. Pengelolaan Lingkung. Berkelanjutan (Journal Environ. Sustain. Manag. 3, 2 p. 346–353.