Ecosystem services analysis as disaster prevention and protection functions in Bogor Regency, West Java

S L Munajati1,3, H Kartodihardjo2, M B Saleh2 and Nurwadjedi3

1 The Study Program of Natural Resources and Environmental Management, Graduate School of IPB University Campus IPB Baranangsiang, Bogor 16144, West Java Indonesia
2 Department of Forest Management, Faculty of Forestry, IPB University Jl. Lingkar Akademik Campus IPB, Dramaga Bogor, West Java Indonesia
3 Geospatial Information Agency of the Republic of Indonesia, Jl. Raya Bogor KM 46 Cibinong Bogor West Java Indonesia

E-mail: lestari_2015@apps.ipb.ac.id

Abstract. Bogor Regency is vulnerable to multi-disaster-threats areas such as flood, erosion, and landslide. The purpose of this study was to analyze the ecosystem services in Bogor Regency. The aspect of ecosystem services is the function of prevention and protection from natural disasters. Land-use change and land facet maps are primary data used in determining the ecosystem services index of disaster prevention and protection. The SPOT 4, 6, and 7 were interpreted to determine changes in land use from 2010 to 2017. The land facet data was sourced from the Geospatial Information Agency (BIG). The analysis in this study was carried out by Analytical Hierarchy Process (AHP) sourced from 35 contributors. The results showed that 8.94% of the total area of Bogor Regency had undergone land-use changes from 2010-2017. The most extensive land-use changes were plantation (2.65%) and farming fields (2.47%). The most vulnerable area to the threat of a multi-disaster is the eastern part of Bogor Regency. This area is already congested with settlements, so that the vulnerability and element at risk are fairly high. Meanwhile, results gained from the AHP show that forests play an important role in disasters prevention and protection in Bogor Regency.

1. Introduction

Indonesia is one of the countries with the highest disaster threat in the world. Physiographic and climatic factors make Indonesia vulnerable to various types of natural disasters such as volcanic eruptions, landslides, floods, droughts, forest fires, erosion, earthquakes, and tsunamis [1]. Bogor Regency is one of the areas in Indonesia that has high-risk multiple disasters [2]. The existence of volcanic landforms in the south, which is associated with structural hills in the middle, makes Bogor Regency vulnerable to the threat of erosion and landslides [3, 4, 5, 6]. The existence of four principal rivers such as Ciliwung, Cibeet, Cileungsi, and Cidurian, also can cause flooding and sedimentation. The risk has been exacerbated by the local rainfall rate, which tends to be higher than other areas on the island of Java.

The natural factors of Bogor Regency, which tend to be complex, must be managed and planned properly. The problem is when Bogor Regency becomes a satellite city of Jakarta and impacts on massive land-use changes to support economic activities. The forest area in Bogor Regency in the last
17 years tends to decrease [7]. The decline in forest area is quite unfortunate considering that Bogor Regency also functions as a catchment area for downstream areas such as Depok and Jakarta. Runoff from the Bogor area and its surroundings to the Jakarta area in 2002-2007 caused losses of up to IDR 12 trillion [8]. A formula is needed to carry out integrated and holistic planning in terms of the physical aspects of Bogor Regency, which is quite complex so that people can live side by side with nature.

Analysis of ecosystem services is a parameter to assess the benefits that nature can provide to humans. The disaster prevention component is one of the aspects offered in the analyzing ecosystem services to determine how well the ecosystem's ability to deal with disasters is. Disaster risk reduction studies with an ecosystem services approach are proven to minimize the impact of natural disasters in the long term [9, 10, 11, 12, 13].

Several studies related to disaster risk have been carried out in Bogor Regency [1, 2, 3, 4, 5, 6, 14]. However, the aspect of the ecosystem's ability to cope with disasters has not been investigated. This study aimed to identify the ability of ecosystem services to prevent disaster in Bogor Regency in the 2010-2017 period. The result of this study is a map of the disaster prevention ecosystem service index. The map can be used as the basis for managing and mitigating multi-disaster threats.

2. Methodology
The researchers conducted the study in Bogor Regency West Java, Indonesia. This administrative area was chosen as the research location because land-use changes occur rapidly and are prone to various natural disasters such as floods, landslides, and environmental pollution [1, 2, 3, 4, 5, 6]. Bogor Regency has various reliefs, from flat to mountainous areas, that make the area vulnerable to multi-disaster threats. Furthermore, the daily rainfall in Bogor Regency is relatively high and can reach 80 mm-192.88 mm [14]. The combination of various slope factors and high rainfall rates can trigger disasters, such as erosion, flooding, and landslides.

Land-use change analysis is carried out through visual detection and digital interpretation to obtain good map accuracy. The materials used are SPOT 4/6/7 images in 2009, 2010, 2011, and 2017. According to the criteria for topographical mapping of scale 1:25,000, the land use classifications in this study are grouped into nine classes. Checking Fieldwork is carried out in areas where the interpretation results are still in doubt by considering the aspect of affordability. Land facet data was re-delineated using SPOT 6/7 2017 interpretation combined with National Digital Elevation Model (NDEM). Land facet data and NDEM data were sourced from the Indonesian Geospatial Information Agency (BIG). The first step is to identify the morphology using 3D data from NDEM. Detailed morphological interpretation results to obtain morpho-genesis, morpho-arrangement, and morphology chronology by considering identified geomorphological processes based on 3D data and 6/7 SPOT Imagery. If errors are found in the interpretation, ground checks were conducted. Then the land facet unit boundaries were re-interpreted.

Analysis of disaster prevention ecosystem services is carried out by overlapping temporal land-use maps with land facet maps. The weights of land-use parameters and land facets were analyzed using the Analytical Hierarchy Process (AHP) approach [15, 16]. The weighted value was obtained from 35 experts. The values are then included in the spatial data attributes so that the data can be superimposed. The formula for calculating the Ecosystem Services Index [17, 18] is:

\[
ESI = \frac{ESI_{fac} \times ESI_{lc}}{\text{max}(ESI_{fac} \times ESI_{lc})} \tag{1}
\]

where:

- ESI : Ecosystem services index
- \( ESI_{fac} \) : Ecosystem services index based on land facet
- \( ESI_{lc} \) : Ecosystem services index based on land use
- \( \text{Max} \) : Maximum value of the index synthesis result
3. Results and Discussion

3.1 Bogor Regency Land Use Change in 2010-2017

Identification of trends in land-use change is one of the keys to maintaining natural ecosystems in an area. Bogor Regency has unique trends of land-use change because its location is close to the capital city and has two national parks. The national parks are protected and regulated by the national government. In 2010, forests dominated as land coverage in the southern and western regions of Bogor Regency. These areas can potentially function as a catchment area because their location is upstream of four principal rivers that flow in Bogor Regency.

The plantation area is the most dominant land use after the forest. The area distributes in the western and eastern parts of Bogor Regency. The site has a typology of undulating to choppy land, so it is suitable for development as a plantation area as long as it pays attention to good conservation rules. The interviews with key informants resulted in the conversion of moors/fields into plantations in recent years under a lease system by the company to the community.

Paddy fields also became a relatively dominant type of land use in 2010. Paddy fields are spreading evenly in all areas of Bogor Regency. The potential of fertile soil and abundant water resources in Bogor Regency provides opportunities for the community to utilize the land optimally while still paying attention to the sustainability aspects of the regional ecosystem. The condition of land use in Bogor Regency in 2010 is presented in Figure 1.

An exciting fact occurred in 2017, where the plantation area decreased significantly. The decline in plantation area is quite significant for seven years, which is almost close to 8,000 ha. Many plantations were converted into paddy fields and settlements in Cisarua, Ciawi, and Megamendung subdistricts. Some of the factors identified as the reason for the conversion of plantations to paddy fields are the economic value generated from land production. What's more, the economical turnover of paddy fields tends to be faster because in one year, it can be harvested up to three times. One thing to watch out for is the conversion of plantation land into settlements. The subdistricts of Cisarua, Ciawi, and Megamendung are Foot Slopes and Toe Slopes. Those subdistricts should be used as buffer areas and watershed catchments.

The dry area also experienced an increase in the 2010-2017 period. The increase in the number of fields in the 2010-2017 period occurred in the eastern part of Bogor, especially at Klapanunggal and Citeureup subdistricts. The bare land was converted by the community into a field planted with secondary crops. In 2010-2017, forest area was converted into settlements, fields, and plantations. Interestingly, there is a reasonably large area in the eastern parts of Bogor Regency converted to forest. Based on interviews with key informants, the forest was originally a plantation. The operation of the plantation was complained about by the community because of detriment to the environment. As the result, the area was reforested. The 2017 land use map is presented in Figure 2.
The eastern part of Bogor Regency became an area that experienced many changes in land use in the 2010-2017 period, which included Citeureup, Megamendung, and Cisarua subdistricts. The three subdistricts experienced a difference of more than 40%. Citeureup subdistrict experienced the most significant change in this period, namely changes in land use reaching 3,349.54 ha or 48.65% of the total area of the subdistrict. Conversion of the farming fields into bare land and vice versa is a common phenomenon. The field survey shows that the farming field converted into bare land. The bare land usually was prepared for other uses, such as housing and industries. Citeureup subdistrict, which is close to the center of the Bogor Regency government offices, is one of the choices for the community and developers to use as a residence.

The growth of paddy fields in southern, especially at Megamendung and Cisarua subdistricts in 2010-2017, was exceptionally high. Like to other areas in Bogor Regency, the tendency of the community to switch from plantation activities to land use in the form of paddy fields is motivated by the factor of economic certainty. Clear and regular yields are more promising for the community. The potential of local natural resources in the form of fertile land and abundant water is also a driving force for developing paddy fields. The limiting factor in relief in this area can still be appropriately managed by the community.

The addition of settlements and activity areas in Megamendung and Cisarua subdistricts needs special attention. The increase in settlements and activity areas in Megamendung subdistrict reached 126.40 ha, while in the Cisarua subdistrict, it reached 253.93 ha. The number of settlement growth is relatively high, compared to the development in the Citeureup subdistrict, which is closer to the center of local government office areas. The attractiveness of the land in the form of beautiful scenery and the economic potential of the tourism sector makes investors interested in developing these two subdistricts as settlements and activity areas. In recent years, the growth of settlements and activity areas has accelerated rapidly and the increasing public interest in tourism. The growth of settlements and activity areas in the upstream (southern part) will affect the function of the downstream ecosystem (northern part). Details of the area of land-use change in Bogor Regency in 2010-2017 are presented in Table 1.

**Table 1. The extent and percentage of land-use change in Bogor Regency 2010-2017**

| No | Land-Use                        | Area (ha)     | Gap        | Percentage | Status   |
|----|---------------------------------|---------------|------------|------------|----------|
| 1  | Forest                          | 82,482.63     | 77,014.15  | 5,468.48   | 1.82     | Decreased|
| 2  | Plantation                      | 71,521.27     | 63,573.74  | 7,947.53   | 2.65     | Decreased|
| 3  | Settlement and Activity Areas   | 51,357.47     | 53,610.3   | 2,252.83   | 0.75     | Increased|
| 4  | Paddy field                     | 64,762.8      | 65,138.1   | 375.3      | 0.13     | Increased|
3.2 Bogor Regency Land Facet

Bogor Regency comprises of four main geneses, namely volcanic, structural, fluvial, and karst [7]. Volcanic genesis dominates the total area of Bogor Regency, which is spreading from southern to western parts. The existence of volcanic genesis is influenced by the Gede-Pangrango and Salak volcanoes in the south. The volcanic genesis is very profitable when viewed from agriculture and plantations, because it has fertile soil. Judging from the disaster aspect, this volcano is a low hazard because it has not erupted for a long time. However, this area has a vulnerability to flash floods and landslides due to the slope aspect. Structural landforms exist in the east and northwest. The eastern structural site also has the threat of landslides and flash floods due to steep slopes (>45%). Structural regions in the northwest have a low disaster risk because they have weak undulating land characteristics [7]. The fluvial area dominates the northern region and has a disaster threat in the form of inundation floods. Nevertheless, inundation events in Bogor Regency only occur briefly and on a small scale because it has many lakes and large rivers that can drain runoff due to rain. The distribution of land facets in Bogor Regency is presented in Figure 3.

![Land Facet Map of Bogor Regency](image)

### Table 2. The extent and percentage of land facets in Bogor Regency

| No | Land Facet Classification | Area (ha) | Gap | Percentage | Status |
|----|---------------------------|-----------|-----|------------|--------|
| 5  | Shrubs                    | 6,736.29  | 9,003.09 | 2,266.8    | 0.76   | Increased |
| 6  | Bare Land                 | 2,551.45  | 3,143.88 | 592.43     | 0.20   | Increased |
| 7  | Farming field             | 17,245.39 | 24,661.04 | 7,415.65   | 2.47   | Increased |
| 8  | Water Body                | 2,424.77  | 2,418.43 | 6.34       | 0.00   | Decreased  |
| 9  | Other Non-Cultivated Vegetation | 1,138.03 | 1,657.44 | 519.41     | 0.17   | Increased |
|    | Total area                | 300,220.2 | 300,220.2 | 26,844.77 | 8.94   | -        |
3.3 Changes in Bogor Regency Disaster Prevention ESI 2010-2017

Land-use is a controlling factor for ecosystem services which has a dynamic nature. Changes in land use can take place massively in a short time. The weighting results using AHP show that the types of land use that have the most influence on ecosystem services for disaster prevention are forests, plantations, and water bodies. The physiography of Bogor Regency and the existing water potential was assessed by these experts. Forests and plantations can hold and store water when conditions are good. The existence of more than 100 lakes can also be a control for flooding, which has never happened on a large scale in Bogor Regency. Details of the weighted values of land use on disaster prevention ecosystem services in Bogor Regency based on AHP was shown in Table 3.

Table 3. The weighted values of land use on disaster prevention ecosystem services

| No | Land-Use                      | Weighted |
|----|-------------------------------|----------|
| 1  | Forest                        | 0.1343   |
| 2  | Plantation                    | 0.1343   |
| 3  | Settlement and Activity Areas | 0.1045   |
| 4  | Paddy field                   | 0.0896   |
| 5  | Shrubs                        | 0.0896   |
| 6  | Bare Land                     | 0.0746   |
| 7  | Farming field                 | 0.1194   |
| 8  | Water Body                    | 0.1343   |
| 9  | Other Non-Cultivated Vegetation | 0.1194 |

The land facet in this study only uses one year of data because the change in the land facet takes a long time. The assessment of experts indicates the three most dominant land facets, namely weak wavy volcanic plains, low hilly tuffaceous sedimentary plains, and lightly incised volcanic alluvial fans. The weight of these three land facets is 0.049451 (Table 4). Areas with volcanic genesis and flat slopes tend to have a high significant in disaster prevention ESI assessments. The structural and volcanic regions with steep slopes tend to have low consequences because they have a high vulnerability to multi-disaster threats.

Disaster management and prevention must be carried out in a systemic and integrated manner to avoid the domino effect of disasters. Like other areas on the island of Java, Bogor Regency also has multiple threats of disasters, especially natural disasters. According to the physiographical aspect, Bogor Regency has a flat to very steep relief with a very complex landform origin process. This fact indicates that the geomorphic processes that occur are also very varied, so that they require serious attention, especially if they have the potential to interfere with human activities.
Table 4. Land facet weighted values on ecosystem services for disaster prevention

| No | Land Facet Classes                                           | Weighted |
|----|-------------------------------------------------------------|----------|
| 1  | Intermediate lava flow to the moderately incised base       | 0.043956 |
| 2  | Steep hill in marl                                          | 0.032967 |
| 3  | Hills with steep slopes on-base volcanoes                   | 0.043956 |
| 4  | Weak wavy volcanic plain                                    | 0.049451 |
| 5  | Minor river floodplain between hills                        | 0.038462 |
| 6  | Low-lying plains in mixed sedimentary rocks                 | 0.038462 |
| 7  | Low-lying plains on acid volcanic tuff                      | 0.038462 |
| 8  | Combined plains of estuaries/riders in dry areas            | 0.038462 |
| 9  | Mixed sedimentary plains with weak to the wavy solid surface| 0.049451 |
| 10 | Low hilly tuffaceous sedimentary plains                     | 0.032967 |
| 11 | Tuffaceous sedimentary plains with soft to the wavy solid surface | 0.043956 |
| 12 | Corrugated acid volcanic tuff plain                         | 0.043956 |
| 13 | Incised volcanoes on intermediate basalt rock               | 0.027473 |
| 14 | Parallel ridges on acid volcanic tuff                       | 0.032967 |
| 15 | Oriented mountain ridges with extra steep slopes on mixed metamorphic rocks | 0.032967 |
| 16 | Irregular mountain ridges on intermediate/basaltic volcanoes| 0.027473 |
| 17 | Extended mountain ridges on marl with rock outcrops         | 0.027473 |
| 18 | Very steep ridges on-base volcanoes                         | 0.027473 |
| 19 | Very steep ridges on tuffaceous sediments                   | 0.027473 |
| 20 | Very steep ridges on limestone                              | 0.032967 |
| 21 | Intermediate volcanic cone to inscribed base                 | 0.027473 |
| 22 | Lightly incised volcanic alluvial fan                       | 0.049451 |
| 23 | Sloping lava with rounded basalt hills                      | 0.032967 |
| 24 | Incised lava with moderate slope                            | 0.021978 |
| 25 | Low karst hills on limestone and marl                        | 0.032967 |
| 26 | Low hills rounded on marl and claystone                     | 0.038462 |
| 27 | Plateau with sloping layers deeply incised on tuffaceous sediments | 0.032967 |
| 28 | Asymmetric widened ridges on sandstone and mudstone         | 0.032967 |

Historical data shows that Bogor Regency often experiences landslides. This phenomenon usually occurs in the southern and eastern parts of Bogor Regency [19, 20]. Rows of volcanoes to the southern part and hills to the eastern part have become driving factors to the occurrence of landslides. The high intensity of rain accompanied by a thick layer of surface soil makes this area more vulnerable to the threat of multiple disasters, especially landslides. The existence of several large rivers and valleys in the southern part also has the potential for disaster threats, especially flash floods. Changes in land use at several points that are not well planned can make the surface runoff larger. Control of waterways, especially in the V-shaped valley, must be carried out so that no bottleneck can be a trigger factor for flash floods.

The results of the calculation of ESI for disaster prevention in 2010 show that moderate ESI dominated Bogor Regency. The low and very low classes distribute in the central to southern parts of Bogor Regency. This area has undulating to mountainous slopes, so it is vulnerable to the threat of landslides. Areas with high vulnerability usually have land cover in the form of bushland and bare land because the weight of the land cover is relatively low. Areas dominated by low ESI for disaster prevention exist in the Leuwiliang subdistrict extending eastward to the Ciawi subdistrict. The Eastern part of Bogor Regency, which has a relatively low ESI for disaster prevention, is spread across the Sukamakmur subdistrict extending to Cariu Subdistrict.

Areas in the northern part tend to have low ESI disaster prevention because they have flat relief and good drainage. Those areas include Tajur Halang subdistrict extending to Gunung Putri subdistrict. The fact that the ESI value for disaster prevention in the northern part is high is an opportunity because the area in the northern part is the center of economic activity in Bogor Regency. In this area, proper land management is important because settlements growth has taken place rapidly in recent years. This condition can cause the northern to be at risk of floods. Details of ESI disaster prevention in 2010 can
be seen in Figure 4, while the ESI value for disaster prevention in Bogor Regency in 2017 was shown in Figure 5.

![Figure 4. ESI Map of Bogor Regency Disaster Prevention in 2010](image1)

![Figure 5. ESI Map of Bogor Regency Disaster Prevention in 2017](image2)

The ESI value in Bogor Regency has changed in the 2010-2017 period with a declining trend (Figure 6). The value of the decline is quite broad considering that the phenomenon of decline exists in the eastern part of Bogor Regency. The decline occurred massively in the subdistricts of Ciawi, Megamendung, Cisarua, Citeureup, and Gunung Putri. This decline is an important aspect taking into account that the districts are mostly hilly, so they may have a relatively high threat of landslides. The conversion of forests and plantations to other uses triggered the decline. If it is not properly planned, it can cause land quality degradation. To increase the capacity of the community in dealing with multi-disaster threats, the community needs to be educated.

The disaster aspect in Bogor Regency needs to get serious attention from both the community and the government. This attention needs to be done because it is motivated by the declining trend of ESI disaster prevention in the last seven years. The actual ESI value in 2017 was more than 20%, which indicates that more than one-fifth of Bogor Regency has a high disaster threat (Table 5). Currently, there is still no major disaster in Bogor Regency that has caused significant loss of life and property, but that does not mean that the community and the government can ignore it. The smallest changes in land use and weather anomalies may trigger unexpected disasters, so the community and the government must always be prepared.
Figure 6. ESI Changes Map of Bogor Regency Disaster Prevention from 2010 to 2017

Table 5. Changes in the index of disaster prevention ecosystem service in Bogor Regency from 2010 to 2017

| No | Category     | Area (ha) 2010 | Area (ha) 2017 | Gap         | Percentage | Status       |
|----|--------------|----------------|----------------|-------------|------------|--------------|
| 1  | Very Low     | 3,592.82       | 10,814.98      | 7,222.16    | 2.41       | Increased    |
| 2  | Low          | 5,7577.4       | 70,009.87      | 12,432.47   | 4.14       | Increased    |
| 3  | Moderate     | 14,2472.44     | 136,676.04     | 5,796.4     | 1.93       | Decreased    |
| 4  | High         | 77,544.47      | 71,038.83      | 6,505.64    | 2.17       | Decreased    |
| 5  | Very High    | 19,033.05      | 11,680.46      | 7,352.59    | 2.45       | Decreased    |
|    | Total area   | 300,220.20     | 300,220.20     | 39,309.26   | 13.09      | -            |

4. Conclusion
In the 2010-2017 period Ecosystem Services Index (ESI) disaster prevention in Bogor Regency experienced a decrease. The conversion of forest land and plantations to other uses triggered the decline in ESI. This phenomenon often occurs in the eastern part of Bogor Regency. Economic is factors that lead to forest and plantation land conversion. The integrated disaster aspects into all components of ecosystem services are important in the preparation of the Detailed Spatial Planning (RDTR) to improve the quality of local ecosystem services. Enhancing ecosystem services, especially in disaster prevention, can provide additional benefits for other sectors such as biodiversity, carbon sequestration, food provision, and many more. Further research on a larger scale is important to enhance the quality of the resulting maps.

Acknowledgments
We would like to thank the Indonesian Geospatial Information Agency (BIG) for providing data and other support for this research. We also thank our colleagues from the Center for Research, Promotion, and Cooperation of BIG for their valuable support and input for this research.

References
[1] Subagyo Y V and Kuningsih T W 2019 Analisis stabilitas lereng di Desa Sukamulih Kecamatan Sukajaya Kabupaten Bogor Jurnal Kajian Teknik Sipil 04 (2) 128-135
[2] Raharja, R, Wibowo F G, Ningsih R V, Machdum S V 2016 Peran Kearifan Lokal dalam Mitigasi Bencana: Studi Masyarakat dalam Menghadapi Bencana Longsor di Desa Bojongkoneng, Kabupaten Bogor Jurnal Dialog Penanggulangan Bencana 07 (2) 111-119
[3] Rahayu A M U, Ardiansyah A N, Nuraeni NS 2019 Wilayah Kerawanan Longsor Kecamatan Pamijahan Kabupaten Bogor Jurnal Geografi Gea 19 1-8
[4] Naryanto H S, Prawiradisastra F, Ardiyanto R, Hidayat W 2020 Analisis Pasca Bencana Tanah Longsor 1 Januari 2020 dan Evaluasi Penataan Kawasan di Kecamatan Sukajaya Kabupaten Bogor Jurnal Geografi Gea 20 197-213

[5] Fitri R 2018 Prediksi Erosi pada Lahan Petani Agroforestri di DAS Ciliwung Hulu Provinsi Jawa Barat Jurnal Agrosains dan Teknologi 3 13-18

[6] Hariyanto R D, Harsono T N, Fadiarman 2019 Prediksi Laju Erosi Menggunakan Metode USLE (Universal Soil Loss Equation) di Desa Karang Tengah Kecamatan Babakan Madang Kabupaten Bogor Jurnal Geografi, Edukasi dan Lingkungan 3 92-99

[7] Munajati S L, Kartodihardjo H, Saleh M B, Nurwadjedi 2019 Sensitivity analysis of ecosystem services especially food provisioning due to the dynamics of land use change in Bogor Regency, West Java, Indonesia IOP Conf. Series: Earth and Environmental Science 399 (2019) 012024

[8] Martdianto R, Kadri T 2012 Prioritas Penentuan Lokasi Waduk pada DAS Ciliwung untuk Pengendalian Banjir Jakarta J@TI Undip 7 (2) 123-130

[9] Reyers B, Nel J L, O’Farrell P J, Sitas N and Nel D C 2015 Navigating complexity through knowledge coproduction: Mainstreaming ecosystem services into disaster risk reduction PNAS 112 (24) 7362-7368

[10] Orimoloye I R, Zhou L and Kalumba A M 2021 Drought Disaster Risk Adaptation through Ecosystem Services-Based Solutions: Way Forward for South Africa Sustainability 13 1-15

[11] McVittie A, Wreford A, Sgobbi A and Yordi B 2017 Ecosystem-based solutions for disaster risk reduction: lessons from European applications of ecosystem-based adaptation measures International Journal of Disaster Risk Reduction 32 42-54

[12] Kaiser G, Burkhard B, Römer H, Sangkaew S, Graterol R, Haitook T, Sterr H and Sakuna S D 2013 Mapping tsunami impacts on land cover and related ecosystem service supply in Phang Nga, Thailand Nat. Hazards Earth Syst. Sci. 13, 3095–3111

[13] Zang Z, Zou X, Zou P, Song Q, Wang C and Wang J 2017 Impact of landscape patterns on ecological vulnerability and ecosystem service values: An empirical analysis of Yancheng Nature Reserve in China Ecological Indicators 72 142–152

[14] Bahunata L, Waspodo R S B 2019 The Design of Infiltration Wells to Reduce Runoff in Babakan Village, Cibinong, Bogor Regency Jurnal Teknik Sipil dan Lingkungan 04 37-48

[15] Enrique M, Milagros P R 2017 Practical Decision Making: An Introduction to the Analytic Hierarchy Process (AHP) Using Super Decisions Springer Briefs in Operations Research, Springer International Publishing

[16] Pawestri D 2013 Perbandingan Penggunaan Metode AHP dan Metode SAW Surakarta.

[17] Riqqi A, Hendaryanto, Safitri S, Mashiha N, Sulistyawati E, Norvyani D A, Afriyanie D 2018 Pemetaan Jasa Ekosistem Seminar Nasional Geomatika 2018

[18] Pusat Pengendalian Pembangunan Ekoregion Sulawesi dan Maluku 2015 Studi Awal Inventarisasi Daya Dukung Daya Tampung Lingkungan Hidup Berbasis Jasa Ekosistem Makassar: PPPESUMA, KLHK.

[19] Gojali M R, Tjahjono B, Rustiadi E 2020 Pemodelan Spasial Bahaya Longsor di DAS Ciliwung Hulu, Kabupaten Bogor Komputasi 17 311-318

[20] Ramdani D, Kresna wati D K, Apriyanti D 2020 Analysis and Map of the Potential Longsor Area at Bogor in 2019 using Weighting Methods on Geographic Information System Jurnal Teknik 21 (2) 1-12