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Soil Erosion Assessment Based on Remote Sensing and GIS in the East Bandung Basin, Indonesia

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Abstract. The research area is located in the East Bandung Basin, West Java, Indonesia. This research aims to assess the soil erosion rates in East Bandung Basin using remote sensing and Geographic Information System method. It was calculated using the Universal Soil Loss Equation, involves rain erosivity, soil erodibility, slope length and steepness, and land use indices. Rain erosivity and soil erodibility indices were determined from secondary data analysis whereas slope length and steepness, and land use indices were determined from the image analysis. The soil erosion rates in the research area can be classified into 5 classes, namely very low which is mapped across the foot slope to toe slope in the Rancaekek and Majalaya (7,055.22 ha), low in the shoulder to back slope (7,325.71 ha), moderate mostly from the summit to toe slope in half of the research area (17,151.91 ha), severe (3,223.97 ha) and very severe (2,891.49 ha) across the shoulder to back slope in parts of the Tanjungsari, Cileunyi, Jatinangor, Cimanggung, Cicalengka, Cikancung and Paseh areas. The results are expected to be important contribution to the government and local communities in order to minimize the impact of land use changes that can increase the risk of erosion.

1 Introduction

Each part of the Bandung Basin Area has distinctive characteristics [1-3]. For example, the eastern part of the Bandung Basin, where parts of the area are composed of volcanic rocks [4]. These volcanic rocks in several places have not been fully lithified which can result in weathering and erosion.

Mass movement can occur suddenly or gradually, initiated by an intensive and continuous process of soil erosion. Soil erosion is directly related to erodibility and erosivity [5]. If erodibility is related to soil then erosivity is related to rainfall. These two things cannot be separated from soil erosion. Since the 1920s, soil erosion has become a topic that continues

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to be researched because it has impact on the livelihoods of many people and natural resources [6, 7].

Every year the number of people living in the Bandung area is increasing [8], including in the eastern part of Bandung. This has an impact on changes in land use. Changes in the earth's surface that involve continuous exogenous processes can have an impact on the emergence of potential disasters such as landslides that usually preceded or occur simultaneously with soil erosion. The potential for these disasters can be observed through remote sensing approaches [9, 10].

Remote sensing can be used to support the analysis of physical conditions in an area about disasters such as landslides, soil erosion, etc [11-15]. Satellite image media can be used in the remote sensing analysis. Visual identification using Landsat satellite image through supervised classification in practice can help identify areas that have the potential for geological disasters such as landslides and soil erosion [16, 17]. This research aims to assess the soil erosion rates in East Bandung Basin using remote sensing and Geographic Information System (GIS) method.

The interaction of various factors that cause the phenomenon of geological disasters is very important to study. Soil erosion study with remote sensing approaches and Geographic Information Systems (GIS) is expected to be a solution in providing disaster information as well as disaster mitigation efforts that can be carried out.

2 Methodology

The research area is located in the East Bandung Basin, West Java, Indonesia which is administratively included in the districts of Bandung, Sumedang, and Garut. It is located at the coordinates 107°41'25.06" E - 107°57'43.56" E and 6°48' 7.6" S - 7°8'37.8" S (Fig. 1). This research was carried out through a studio analysis, using remote sensing and Geographic Information System (GIS) method which can be used in various fields [18-20]. The supporting data used includes stream network, monthly rainfall, geology, slope and elevation, and land use data.

2.1 Soil erosion analysis

Calculation of annual erosion predictions in a particular area can use the USLE formula. Several revisions to the calculations have also been carried out by several previous researchers. The amount of annual soil loss due to erosion (A) can be obtained by multiplying several parameters including the rainfall-runoff erosivity factor (R), soil erodibility factor (K), slope length and steepness factor (LS), cover management factor (C), and supporting practices factor (P).

$$A = R.\ K.\ L.\ S.\ C.\ P \qquad (1)$$

The rain erosivity index can be obtained by calculating the kinetic energy generated by maximum rainfall for 30 minutes (El_{30}). The rain erosivity index equation is:

$$El_{30} = R = 0.41\ H^{1.09} \qquad (2)$$

where El_{30} = rainfall-runoff erosivity factor and H = annual rainfall intensity (mm) [21-23].

The soil erodibility index (K) for calculating erosion using the USLE formula is obtained from the criteria shown in Table 1. The slope length and steepness index (LS) for calculating erosion using the USLE formula is obtained from the criteria shown in Table 2. The cover management and supporting practices index (CP) for calculating erosion using the USLE formula is obtained from the criteria shown in the Table 3. The soil erosion rate calculations are classified based on Table 4.

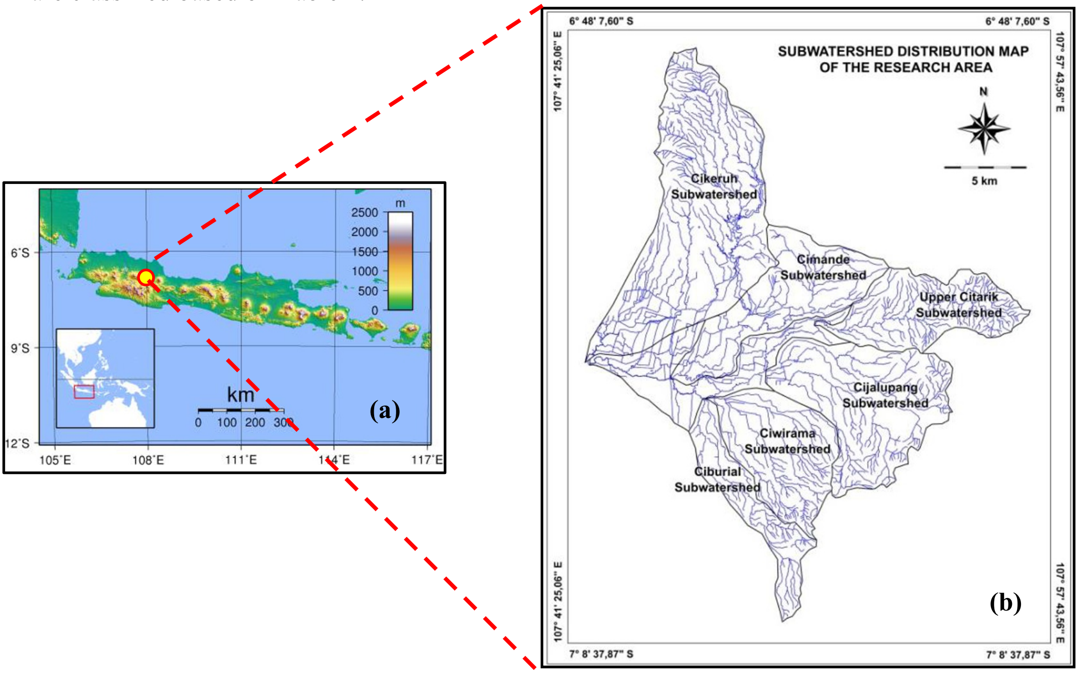

Fig. 1. (a) Java Island; (b) Research area in the East Bandung Basin.

Table 1. Soil erodibility index (K) [24].

No	Soil type	K
1	Alluvial	0.29
2	Andosol	0.28
3	Brown Forest	0.28
4	Gle	0.29
5	Grumosol	0.16
6	Latosol	0.26
7	Litosol	0.13
8	Mediteran	0.16
9	Organosol	0.29
10	Red Podzol	0.20
11	Regosol	0.31

Table 2. Slope length and steepness index (LS) [25].

No.	Slope (%)	LS
1	0 – 8	0.40
2	8 – 15	1.40
3	15 – 25	3.10
4	25 – 40	6.80
5	> 40	9.5

Table 3. Cover management and supporting practices index (CP) [26].

No.	Cover management / Land use	CP
1	Residential area	0.60

2	Mixed garden/shrubs area	0.30
3	Paddy-field/wetland	0.05
4	Moorland	0.75
5	Plantation area	0.40
6	Forest area	0.03

Table 4. Classification of soil erosion rates [27].

No.	Soil Erosion (ton/ha/year)	Soil Erosion Class	Soil Erosion Index
1	< 15	I	Very low
2	15 – 60	II	Low
3	60 – 180	III	Moderate
4	180 – 480	IV	Severe
5	> 480	V	Very Severe

2.2 Image processing analysis

Supporting data such as monthly rainfall and rock formation obtained through a literature review can be processed and analyzed spatially to obtain a rainfall map and soil map of the research area. Rain erosivity index for the rainfall map of the research area is classified based on rain erosivity index [21-23] whereas the soil map of the research area is classified based on soil erodibility index [24].

Satellite image data processing is carried out in the studio to obtain land use units (land use map of the research area) and slope percentage (slope map of the research area). It consists of image cropping, image sharpening, image identification and analysis based on supervised classification, and image interpretation. The land use units that have been obtained are then classified based on cover management and supporting practices index [26]. Image processing and analysis through GIS will show a range of slope degree. The range of slope degree is classified into a slope classification [25].

3 Result and discussion

3.1 Rain erosivity index (R)

The research area consists of several sub-districts which are included in Bandung and Sumedang districts. The rainfall intensity is obtained from rainfall data published by the Central Bureau of Statistics sourced from the Meteorological, Climatological, and Geophysical Agency [28-37]. The rainfall data is obtained from 2017 - 2022. The calculation of the rain erosivity index is supported by Microsoft Excel software. The calculation results of rain erosivity index are shown in the Table 5 and rainfall map of the research area in the Fig. 2.

Table 5. Rain erosivity index of the research area.

Sub-district	R (mean)
Cimanggung	2235.83
Jatinangor	1812.40
Tanjungsari	1741.85
Cileunyi	1653.34
Cicalengka	1770.03

Sub-district	R (mean)
Rancaekek	1653.17
Cikancung	1769.32
Majalaya	1769.32
Paseh	1719.18

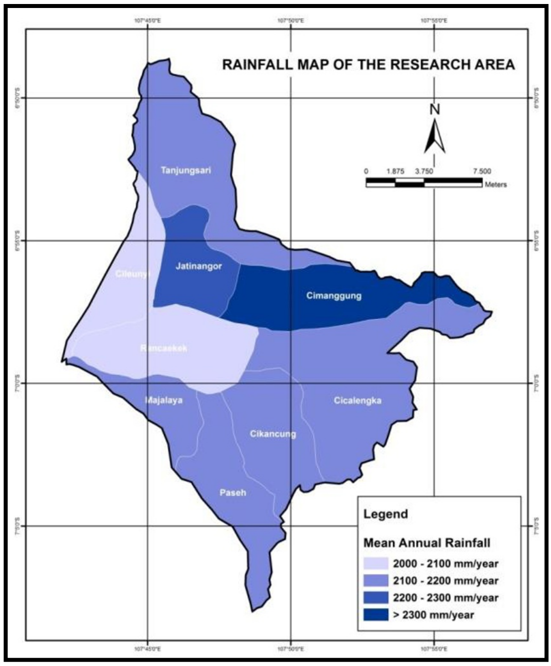

Fig. 2. Rainfall map of the research area.

3.2 Soil erodibility index (K)

Based on the results of literature review [38, 39], it is known that the research area is composed of a dominance of volcanic rocks in the north, east, and south, also lake deposits in the center. The result of the weathering process of volcanic rocks is identified as andosol soil whereas the alluvium is identified as alluvial soil (Fig. 3).

The soil erodibility index was obtained from criteria are shown in Table 1 [24]. The soil erodibility index also depends on the type of volcanic rock from which it originates. Therefore, the K value for lake deposit or alluvial soil is 0.29 while for the other or andosol soil is 0.28.

3.3 Slope length and steepness index (LS)

The slope length and steepness index were obtained from the criteria shown in Table 2. The main consideration is the percentage of slope of the research area. Based on the results of spatial analysis, the results obtained show that the research area has a slope from 0% to more than 40% (Fig. 4), so that the LS value ranges from 0.40 – 9.50.

3.4 Cover management and supporting practices index (CP)

The land cover types obtained from the results of satellite image processing are revised and reclassified to obtain land use of the research area. In addition, cover management and supporting practices index was obtained from the criteria shown in Table 3. This index depends on aspects of land use in the research area. Based on the results of the revision and reclassification of land cover, it was found that the research area has 5 land use units, namely residential area, mixed garden/shrubs area, paddy-field/wetland, plantation area, and forest area (Fig. 5).

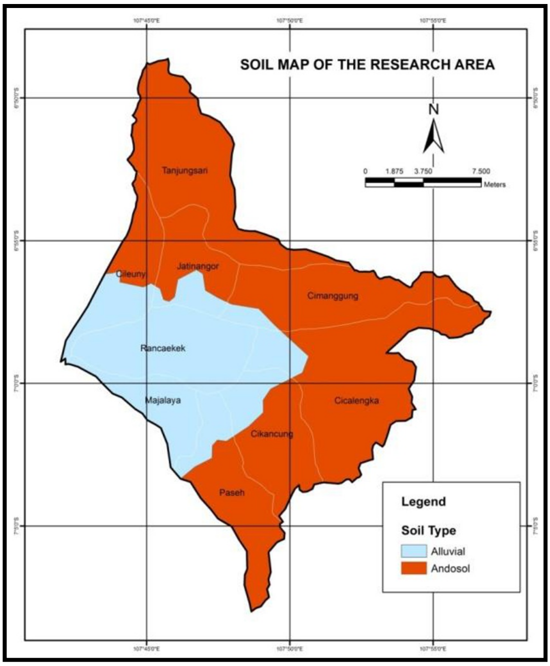

Fig. 3. Soil map of the research area.

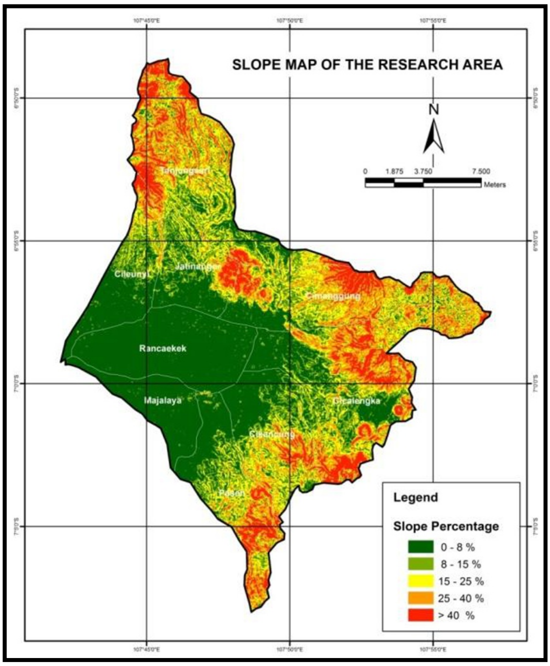

Fig. 4. Slope map of the research area.

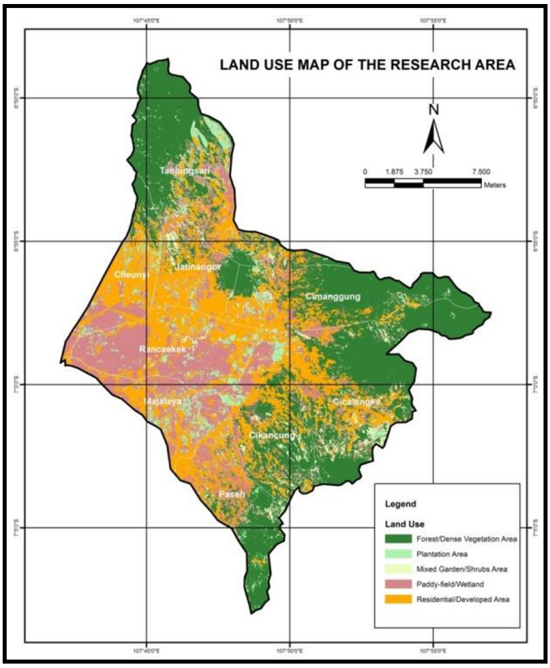

Fig. 5. Land use map of the research area.

3.5 Soil erosion calculation

The results of calculating the erosion value can be seen on the soil erosion map (Fig. 6). The soil erosion rates in the East Bandung Basin can be classified into 5 classes, namely very low (< 15 ton/ha/year) which is mapped across the foot slope to toe slope in the Rancaekek and Majalaya areas (7,055.22 ha), low (15 - 60 ton/ha/year) in the shoulder to back slope areas (7,325.71 ha), moderate (60 - 180 ton/ha/year) mostly from the summit to toe slope in almost half of the research area (17,151.91 ha), severe (180 - 480 ton/ha/year) with total areas 3,223.97 ha and very severe (>480 ton/ha/year) with total areas 2,891.49 ha across the shoulder to back slope in parts of the Tanjungsari, Cileunyi, Jatinangor, Cimanggung, Cicalengka, Cikancung and Paseh areas.

4 Conclusion

Soil erosion impacts the livelihoods of many people and natural resources in the East Bandung Basin. Soil erosion can occur simultaneously with mass movements, landslides, or other natural disasters on the earth's surface that involve exogenous processes. The soil erosion rates in the East Bandung Basin can be classified into 5 classes, namely very low (< 15 ton/ha/year) which is mapped across the foot slope to toe slope in the Rancaekek and Majalaya areas (7,055.22 ha), low (15 - 60 ton/ha/year) in the shoulder to back slope areas (7,325.71 ha), moderate (60 - 180 ton/ha/year) mostly from the summit to toe slope in almost half of the research area (17,151.91 ha), severe (180 - 480 ton/ha/year) with total areas 3,223.97 ha and very severe (>480 ton/ha/year) with total areas 2,891.49 ha across the shoulder to back slope in parts of the Tanjungsari, Cileunyi, Jatinangor, Cimanggung, Cicalengka, Cikancung and Paseh areas. The results are expected to be an important contribution to the government and local communities in order to minimize the impact of changes in land use that can increase the risk of erosion.

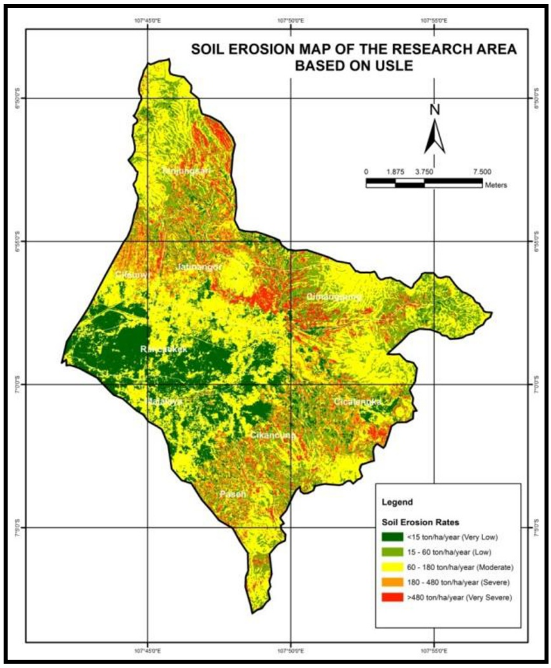

Fig. 6. Soil erosion map of the research area.

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References

1. S. Bronto, U. Hartono, Potensi sumber daya geologi di daerah Cekungan Bandung dan sekitarnya. J. Geol. Indones. **1**, 9-18 (2006)
2. E. T. Haryanto, E. Sukiyah, P. P. R. Rendra, Hendarmawan, Suratman, Implication of catchment morphometric on small river discharge of upper Citarik River West Java. Indones. J. Geogr. **51**, 224-230 (2019)
3. P. P. R. Rendra, E. Sukiyah, M. S. D. Hadian, S. B. Daliman, N. Sulaksana, The quantitative geomorphology of upper Citarik Watershed and its implication to the flash flood potential. BIO Web Conf. **73**, 04010 (2023)
4. E. Sukiyah, S. Mawardi, P. P. R. Rendra, E. Tresnasari, E. Nurfadli, H. Setiawan, The active fault detection base on morphotectonic characteristic of Cikeruh Watershed West Java. J. Eng. Sci. Technol. **18**, 34-41 (2023)
5. R. U. Ayadiuno, D. C. Ndulue, Analysis of soil erosion causative factors and susceptibility in Anambra State, Southeastern, Nigeria. Biosci. Biotechnol. Res. Commun. **14**, 212-218 (2021)
6. J. M. Laflen, W. C. Moldenhauer, Pioneering soil erosion prediction: the USLE story. Soil Water. **1** (2003)
7. N. Sulaksana, A. Sjafrudin, E. Sukiyah, P. P. Raditya, F. Abdulah, P. Setiyanto, Peran tata guna lahan terhadap distribusi tingkat kerawanan erosi di kawasan Ciletuh Jawa

Barat. Bull. Sci. Contrib. **13**, 159-167 (2015)

8. A. Rifai, N. Sulaksana, T. Y. W. M. Iskandarsyah, M. Sulastri, P. P. Raditya, S. Mulyani, Development of urban areas in potential areas of natural disasters in South Bandung, Indonesia. IOP Conf. Ser.: Earth Environ. Sci. **145**, 012116 (2018)
9. T. Widodo, Y. Hepta, H. Fairuz, Aplikasi sistem informasi geografis dan penginderaan jauh untuk zonasi kerawanan bencana gempa bumi Sesar Lembang. J. Dialog Penang. Benc. **8**, 54-68 (2017)
10. Yunarto, Teknik penginderaan jauh dan sistem informasi geografis untuk pemetaan zona kerentanan gerakan tanah dengan metode tidak langsung di Kabupaten Kuningan. Bul. Geol. Tata Lingkung. **22** (2012)
11. R. Septianugraha, R. Harryanto, D. S. Sara, Remote sensing and GIS method for assess erosion with satellite imagery at Citarik Sub-Watershed. IOP Conf. Ser.: Earth Environ. Sci. **393**, 012064 (2019)
12. H. Xu, X. Hu, H. Guan, B. Zhang, M. Wang, S. Chen, M. Chen, A remote sensing based method to detect soil erosion in forests. Remote Sens. **11**, 513 (2019)
13. P. P. R. Rendra, E. Sukiyah, Morphometric characteristics of Cipeles Watershed to identify flood prone area. Int. J. Adv. Sci. Eng. Inf. Technol. **11**, 889-897 (2021)
14. P. P. R. Rendra, E. Sukiyah, N. Sulaksana, Karakteristik morfometri DAS cipeles menggunakan pendekatan sistem informasi geografis. Bull. Sci. Contrib. Geol. **18**, 81-98 (2020)
15. P. P. R. Rendra, E. Sukiyah, M. S. D. Hadian, S. B. Daliman, N. Sulaksana, Quantitative geomorphology of Cipancar Watershed and the implication for flood risk. Int. J. GEOMATE. **25** 16-23 (2023)
16. P. P. R. Rendra, N. Sulaksana, B. Y. C. S. S. Alam, Peran citra satelit landsat 8 dalam identifikasi tata guna lahan di wilayah Kabupaten Sumedang. Bull. Sci. Contrib. Geol. **17**, 101-108 (2019)
17. E. Sukiyah, A. Sudradjat, R. F. Hirnawan, D. Muslim, M. F. Rosana, The simple grid method in GIS application for delineation of erosion and flood zones: case study at Bandung Basin, in Proceedings of the SKIM-X, Malaysia, May 29-31 (2007)
18. J. James, S. Daliman, P. P. R. Rendra, E. Sukiyah, M. S. D. Hadian, N. Sulaksana, Integrating remote sensing and GIS techniques for accurate mapping and analysis of oil palm plantation distribution in Kelantan: a case study. BIO Web Conf. **73**, 05009 (2023)
19. N. A. Mohd Aris, S. Daliman, P. P. R. Rendra, E. Sukiyah, M. S. D. Hadian, N. Sulaksana, Integrating remote sensing and GIS techniques for accurate mapping and analysis of paddy field distribution in Kelantan: a case study. BIO Web Conf. **73**, 05010 (2023)
20. N. Sulaksana, D. Gentana, P. P. Raditya, R. A. Sentosa, The determination of geothermal potential area based on remote sensing, Micromine software, and land surface temperature calculation. IOP Conf. Ser. Mater. Sci. Eng. **550**, 012005 (2019)
21. S. Ambar, Aspek vegetasi dan tata guna lahan dalam proses erosi di daerah tampung Waduk Jatiluhur Jawa Barat, Doctoral thesis, Universitas Padjadjaran (1986)
22. E. Sukiyah, Model erosi bentang alam vulkanik kuarter di Cekungan Bandung bagian selatan, Doctoral thesis, Universitas Padjadjaran (2009)
23. O. Soemarwoto, Analisis mengenai dampak lingkungan (UGM Press, Yogyakarta, 2007)
24. Bappenas, Analisa perubahan penggunaan lahan di ekosistem DAS dalam menunjang ketahanan air dan ketahanan pangan. Inf. Kaj. Bappenas. **10** (2013)
25. I. W. Sutapa, Analisis potensi erosi pada daerah aliran sungai di Sulawesi Tengah.

SMARTek. **8** (2010)
26. Departemen Kehutanan, Petunjuk memperkirakan besarnya erosi pada suatu lahan dengan menggunakan rumus USLE. (Direktorat Jendral Reboisasi dan Rehabilitasi Lahan, Jakarta, 1985)
27. Kementerian Kehutanan, Peraturan menteri kehutanan No: P.32/MENHUT-II/2009 tentang tata cara penyusunan rencana teknik rehabilitasi hutan dan lahan daerah aliran sungai (Jakarta, 2009)
28. BPS Kabupaten Sumedang, Kabupaten Sumedang Dalam Angka (Sumedang, 2023)
29. BPS Kabupaten Sumedang, Kabupaten Sumedang dalam Angka (Sumedang, 2022)
30. BPS Kabupaten Sumedang, Kabupaten Sumedang dalam Angka (Sumedang, 2021)
31. BPS Kabupaten Sumedang, Kabupaten Sumedang dalam Angka (Sumedang, 2019)
32. BPS Kabupaten Sumedang, Kabupaten Sumedang dalam Angka (Sumedang, 2018)
33. BPS Kabupaten Bandung, Kabupaten Bandung dalam Angka (Bandung, 2023)
34. BPS Kabupaten Bandung, Kabupaten Bandung dalam Angka (Bandung,2022)
35. BPS Kabupaten Bandung, Kabupaten Bandung dalam Angka (Bandung,2020)
36. BPS Kabupaten Bandung, Kabupaten Bandung dalam Angka (Bandung,2019)
37. BPS Kabupaten Bandung, Kabupaten Bandung dalam Angka (Bandung,2018)
38. P. H. Silitonga, Geological map of the Bandung quadrangle, Java (Geological Research and Development Centre, Bandung, 2003)
39. M. Alzwar, N. Akbar, S. Bachri, Geological map of the Garut and Pamengpeuk quadrangle, Java (Geological Research and Development Centre, Bandung, 1992)