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Geomorphological Mapping of The Prambanan Hills Yogyakarta

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Abstract. Understanding geomorphological characteristics must provide morphographic, morphometric, morphogenetic, and morphochronological information. This study aims to identify geomorphological characteristics in the Prambanan hills area compiled in the form of a geomorphological map. The research is based on maps, previous research reports, and field observations in the form of field checks on the elements studied. The geomorphological mapping system used is the ITC system. The main analysis in this research is spatial analysis in the form of overlapping spatial data. The relationship between landform units, lithology, and slopes is information that is analyzed descriptively. The results showed that on a map with a scale of 1: 30,000, 9 geomorphological units could be identified. The 9 geomorphological units are a combination of morphometry, genetics, and lithology. The combination consists of 2 landforms, namely traditional and structural hills, and slopes; The lithology consists of 3 layers, namely the Lapili Formation of Semilir, Sand Formation of Kebo Butak, and Tuff Formation of Semilir. While the morphometry is in the form of slope units, namely 8-15%, 15-25%, 25-45%, and >45%. While the age based on lithology is Late Oligocene – Early Miocene in the Kebo Butak Formation and Early Miocene – Middle Miocene in the Semilir Formation.

Keywords. Geomorphological, Mapping, Prambanan, Hills

1 Introduction

Inventory of land resources and potential for disaster is the initial part of regional development. By knowing these characteristics, the development process for regional development is expected to be managed properly. Management following its carrying capacity is a process of sustainable regional development.

One area that is experiencing rapid development is the hills in Prambanan District, Sleman Regency, and its surroundings. The hilly topography and many historical relics have made this area designated as a protected forest area and cultural heritage in the provincial spatial pattern. On the other hand, in these hills, an alternative road connecting the districts will be built. With the diversity of tourism supported by good road infrastructure, this area has the potential to experience rapid development in the future.

The basic thing in the inventory of land resources and potential for disaster is geomorphological information. Geomorphology is the study of landforms that emphasizes natural properties, the origin of developmental processes, the composition of materials that influence their formation, the relationship between forms, and processes in spatial order [1][2][3][4]. The definition of geomorphology provides clarity that geomorphological studies are landforms. Landforms are features of the earth's surface that have different shapes and origins from one another, occur due to a certain genesis, giving rise to a distinctive shape characterized by the physical properties of the material due to dominant natural processes, and in its development, it can be associated with certain structures [5][6]. In summary, it can be emphasized that geomorphology is a study of landforms which includes elements of relief, processes, materials, structures, and geological time of the quarter as well as the time of the Anthropocene.

Geomorphological mapping is the basis for geomorphological research and practice [7]. A geomorphological map can be thought of as a graphical inventory of landscapes that depicts the surface landscape as well as the subsurface material [8]. Geomorphological mapping is a preliminary tool for land management and geomorphological risk management. It also provides baseline data for other sectors of environmental research such as landscape ecology, forestry, or soil science [1][9][10]. Geomorphological maps focus on selected landscape features, for example only describing morphology, active processes, or conveying a full view of landscape composition and evolution [11][12]. Basic geomorphological maps can be derived at a particular

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focus in the form of thematic maps in certain applications. One example of a derived map is a geomorphological hazard map that describes the phenomena causing the risk and the magnitude and frequency of disasters [9].

Geomorphological maps can be categorized as the basis for describing landscape features [7]. The fundamental thing in a geomorphological map is that it must provide information about the scale, distribution of the landscape, genetics, and age. The same opinion states that the general principle that must exist in geomorphological maps is the distribution of landscapes in certain sizes, genetics, and ages [13]. It was further explained that the most popular evolutionary results of geomorphological map legends were the principles of morphometry, genetics, and age. However, some legends in several countries such as Russia and France, also include rock or lithology elements [13].

In the 1970s, there was an attempt to set a general standard in geomorphological mapping which included information on morphogenesis, morphochronology, morphodynamics, morphometry, and lithology [12]. These principles have been accepted by all scientists in compiling geomorphological maps in various regions of the world [14][13]. The principle in geomorphological mapping is known as the ITC mapping system method, because it was developed by the Institute for Aerial Survey and Earth Sciences, Enschede, The Netherlands.

According to Sutikno [15], the development of geomorphology before 1970 was known as the Davis trilogy which emphasized structure, process, and stage. Meanwhile, geomorphology after 1970 was known as King's trilogy, which emphasized landforms, materials, and processes. The development of this thought is related to the effort to classify the shape of the earth's surface. The development of paradigms from the Davis trilogy to the King trilogy does not mean that one outperforms the other. On the contrary, both are complementary and relevant to be used in an integrated manner.

The protrusion of landforms in geomorphology is a significant advance because these landforms allow all areas on the earth's surface to be mapped with area symbols or closed polygons. This has an analogy with the concept of land use which can map the entire surface of the earth in the form of an area symbol. This area symbol can be used as a unit of analysis in the application of studies of various phenomena of the earth's surface. Landform areas based on their genetics can be grouped into ten main groups, namely volcanic, structural, denudation, fluvial, marine, solutional, eolin, organic, anthropogenic, and glacial [3].

The landform area unit on the earth's surface is a representation of the earth's surface space. Geomorphological mapping of the ITC system has an important role in geomorphological studies based on the earth's surface as the unit of analysis. Geographical geomorphology studies the functional relationship of landforms with physical and cultural phenomena [15]. This statement clarifies the position of geomorphology in the study of geography, namely the study of the dynamics of the landforms on which the phenomena of the earth's surface take place. This also shows that the arrangement of geomorphological area units is not only used in the procedure for naming geomorphological units [16]. A geomorphological area is a space with certain different characteristics. The difference in geomorphological space results in the diversity of resource potentials and potential disasters for human life.

The description above shows that understanding geomorphological characteristics must provide morphographic, morphometric, morphogenetic, and morphochronological information. The description of the information includes genetic elements, relief, structure, material, process, and time in landforms which are the object of geomorphological study. This information is the basis for making up the earth's surface space which is used as a basis for regional planning. The geomorphological principles that have been agreed upon by the geomorphologist should be contained in the geomorphological map as much as possible. Based on this, this study aims to identify geomorphological characteristics in the Prambanan hills area compiled in the form of a geomorphological map.

2 Research Methods

Administratively, the research location is Prambanan District, Sleman Regency, Yogyakarta Special Region. Morphologically, the study area is located in the hilly part of the Prambanan District. The elements studied in this study include rock conditions, slope conditions, genetics of landforms, and the main processes on the land surface. The study is based on maps, previous research reports, as well as field observations in the form of field checks on the elements studied. The materials used are SRTM imagery, Prambanan Earth Map, Geology Map, and Yogyakarta Engineering Geology Sheet. The survey tools used are GPS for field observations and computer equipment with ARCGIS software for map making and compilation. The research work steps are presented in Figure 1.

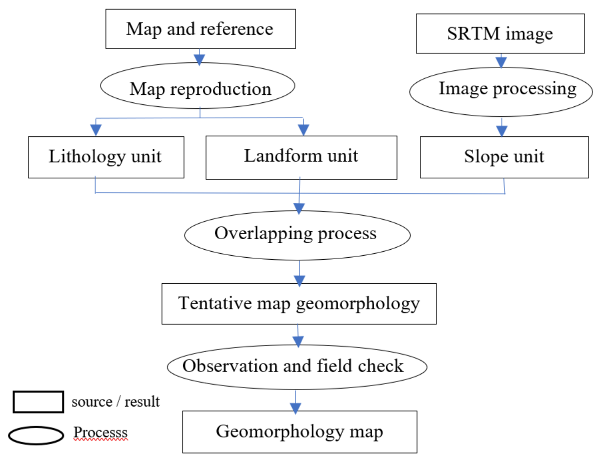

Fig. 1. Research Work Steps

The main analysis in this research is spatial analysis in the form of overlapping spatial data. The relationship between landform units, lithology, and slopes is information that is analyzed descriptively. The

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geomorphological units compiled are derived from the overlapping of lithology units, landform units, and slope class units. The lithology unit is sourced from the Geological Map. Landform units are sourced from the Landform Map. While the slope unit is sourced from the results of SRTM image processing. The results of the study are in the form of a Geomorphological map with a scale of 1: 30.000.

3 Results and Discussions

The Prambanan hills area covered in the Geomorphological Map of the Special Region of Yogyakarta at a scale of 1:50,000 shows the existence of two different landscape morphogenesis. The first landscape morphogenesis is structural with morphography in the form of a cake [17]. While the second is the morphogenesis of the volcanic landscape with the morphography in the form of volcanic remains [18]. The choice of the structural morphogenesis of the Cuesta is based on the relief. One side has a relatively sloping to a slightly steep slope, while the other side is steep to steep. While the choice of volcanic remnants of the volcano is based on rock material. Volcanic activity is estimated to occur during the late Oligocene to middle Miocene. For now, there is no more volcanic activity.

Geomorphological mapping of the area is based on morphogenetic and morphometric information. Morphogenetics provides information about the main processes that produced the current landform. Morphometrics provide information about the size of the relief characterized by the slope of the slope. In addition, it can also be seen the lithology of the area's material composition and the age of its formation.

For the 1:30,000 scale map of Prambanan hills, the morphogenetics are structural and traditional hills [19]. The traditional choice can be based on the basic concept of geomorphology that the surface topography that is older than the Tertiary epoch is less and mostly no more than the Pleistocene [20]. The situation on the ground also shows that the main dominant process at this time is erosional in the remaining volcanic material. The rate of erosion in this area is quite dependent on land use. In Sambirejo Village, the steep rainfed rice fields have an erosion of 6.96 tons/ha/year. Meanwhile, on very steep dry land units, the highest erosion estimation results are 5,210.45 tons/ha/year [21].

For the structural area, the emphasis is on the difference in hillsides where the slope is relatively gentle on one side and steep on the other. The Prambanan hills appear to be towering because they are surrounded by vast volcanic plains. The height of the hills is often associated with the boundary of the Opak fault. This is because it is easiest to see the morphology and topography that limits the height of Wonosari with Yogyakarta which is in a lowland area. In the Geological Map Sheet Yogyakarta, the Opak Fault is described as a normal fault [22]. However, the map does not clearly describe the location of the fault area, because it is thought to have been covered by the Merapi Muda deposits. It is estimated that the Opak - Prambanan River fault was originally a horizontal fault on the left, in subsequent developments it underwent rejuvenation so that there was a downward shift so that it became a descending fault [23]. Research by Urushibara (1995) cited by [24] shows that the average lifting speed of the Southern Mountains is 0.42 mm/yr.

The mention of the name of the traditional and traditional hills and structural escarpments is a combination of landform genetics and morphometry. The words hills and escarpments are qualitative words from quantitative morphometric measures. The term hills is a relief unit with a dominant slope of 14-20% and a dominant height difference of 50-200 m above sea level. Meanwhile, the escarpment is a term for steep terrain conditions with a slope of >140%. The escarpment is the part from the top to the bottom of the steep wall of the cake, as well as the steep hillside. Figure 2 presents a map of landforms based on the origin of the process which is currently still ongoing.

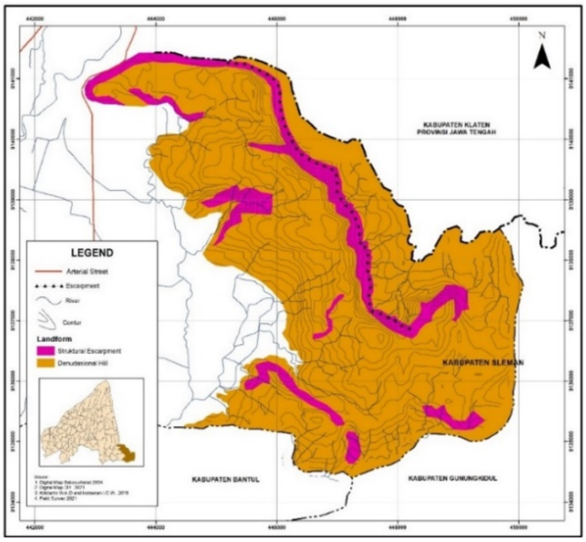

Fig. 2. Map of landforms based on the Morphogenetics of Prambanan Hills

For The results of the mapping of morphometric aspects in the form of slope aspects, the study area can be identified into five slope classes 0-7%, 8-15%, 16-25%, 26-45%, and >45%. The classification of slope classes is based on a modification of Van Zuidam and Hardjowegino [25][26]. The Van Zuidam slope class emphasizes the erosional aspect and the potential for a mass movement. Meanwhile, the Hardjowegino slope class used is related to the agreement forest. The use of this class is based on the condition of the study area on the planned spatial pattern of entry into the protected forest area. The slope class map is presented in Figure 3.

The results of the mapping of lithological aspects show that the research area has two formations, namely Semilir and Kebo Butak. The rocks that make up the Semilir Formation are tuff, lapilli tuff, lapilli, and bright white pumice breccia. The lithology of the Kebo Butak Formation at the bottom consists of layered sandstone, siltstone, claystone, shale, tuff, and agglomerates, while at the top consists of alternating sandstone and claystone with acid tuff insertions. The total thickness of this formation is more than 650 m [27]. The Semilir Formation in the study area is spread out on the west side of the study area. Meanwhile, the Kebo Butak Formation is spread on the east side of the structural slope. The Semilir Formation lies above the Kebo-Butak Formation [22]. The Semilir Formation does not contain carbohydrates and no fossils were found. The abundance of tuff and pumice in the Semilir Formation indicates that this formation is the product of a large volcanic eruption [28].

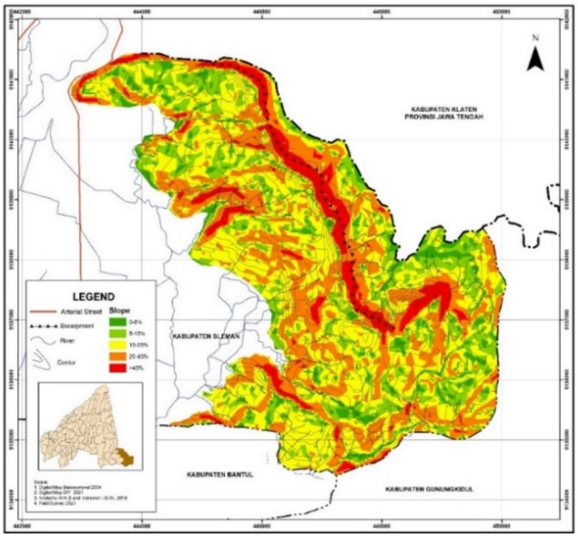

Fig. 3. Slope Class Map of Prambanan Hills

In the research area, the rock units that make up the Semilir and Kebo Butak Formation can be grouped into three. The three units include tuff units, lapilli units, and sandstone units. This grouping is based on the grain size of the relief constituents. Most of the rock surface has weathered into the soil with a dominant thickness of less than 1 m. Figure 4 presents the Geological Map.

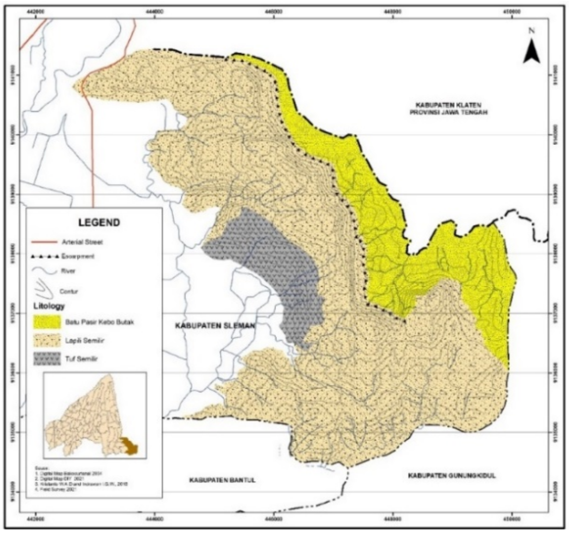

Fig. 4. Geological Map of Prambanan Hills

According to [19] the sandstone unit is dominated by sandstone, lapilli, tuff, and breccias are also found. The rock mass is generally moderate to high weathered, with generally weak to slightly strong hardness. Brownish gray with a diameter of about 2 mm. The lapilli unit consists of dominating lapilli, tuff, sandstone, and breccia. The rock mass of this formation is generally slightly to moderately weathered. Gray and brownish white with a diameter of less than 2 mm. It appears that there is a layered, massive structure, and it is difficult to excavate. While the tuff unit consists of tuff and a little lapilli and sandstone. Brownish white with a very fine diameter because it comes from the deposition of fine volcanic ash. It is found that there is a layered structure and the hardness is very weak so that it is easily weathered.

Based on the stacking of spatial information on landforms, slopes, and lithology, geomorphological units are arranged. The resulting map with a scale of 1: 30,000, for the unit was used to generalize the smallest area of 15 hectares. Based on this, 9 geomorphological units were produced. The Geomorphological Map is presented in Figure 5 while the Geomorphological Unit is presented in Table 1.

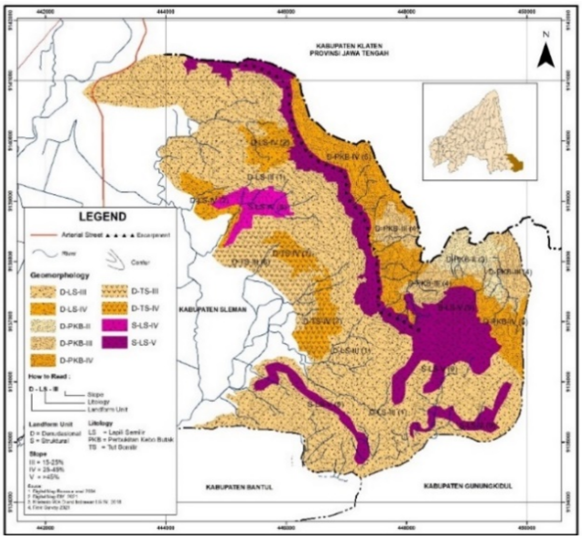

Fig. 5. Geomorphological Map of Prambanan Hills

Table 1. Setting Word's margins.

No.	Geomorphological Unit Symbol	Landform	Lithology	Slope
1	D-LS-III	Danudational Hills	Lapili Semilir Formation	16 - 25%
2	D-LS-IV	Danudational Hills	Lapili Semilir Formation	26 - 45%
3	D-PKB-II	Danudational Hills	Sand Kebo Butak Formation	8 - 15%
4	D-PKB-III	Danudational Hills	Sand Kebo Butak Formation	16 - 25%
5	D-PKB-IV	Danudational Hills	Sand Kebo Butak Formation	26 - 45%
6	D-TS-III	Danudational Hills	Tuff Semilir Formation	16 - 25%
7	D-TS-IV	Danudational Hills	Tuff Semilir Formation	26 - 45%
8	S-LS-IV	Structural escarpment	Lapili Semilir Formation	26 - 45%
9	S-LS-V	Structural escarpment	Lapili Semilir Formation	>45%

The geomorphological map produced in this study has incorporated the principles of morphometry, genetics, and lithology. Age can also be known from lithological information sourced from geological maps. The lithology of the Kebo Butak formation developed in the late Oligocene – early Miocene. Meanwhile, the Semilir formation lithology developed in the early Miocene – middle Miocene. Information on morphometric, genetic, lithological, and age in one geomorphological map provides convenience in understanding the characteristics of the earth's surface. A comprehensive understanding of the characteristics of the earth's surface will make it easier to plan its use and development in the future.

Geomorphological mapping research in tropical hills with studies on step-wise-grid techniques produces morphometric, genetic, lithological, and process information [29]. Geomorphological information in this study can be used as a comparison, that analytical geomorphological studies produce almost the same geomorphological information. Meanwhile, pragmatic geomorphological studies in non-tropical hills also use geomorphological information in the form of genetics, lithology, and processes, which are used for the evaluation of natural disasters [30]. The results of this study indicate that the variety of natural disaster susceptibility is determined by the characteristics of the existing geomorphological units. Another pragmatic geomorphological study is to support urban planning [31]. The geomorphological information used includes morphometry in the form of general relief conditions, detailed relief, genetics, lithology along with the degree of ease of destruction.

This research has several limitations. The first limitation is not using aerial photography as a source of landform information. Landforms are compiled based on landform information that has been studied by previous researchers. The second weakness is that the resulting geomorphological map does not provide an overview of the processes that occur on the surface. The process of surface erosion and the rest of the landslide that has occurred has not been presented in the map legend. The third weakness is that it still does not utilize raster-based remote sensing technology. It is necessary to understand that the current geomorphological mapping technology has followed the development of mapping information technology.

4 Conclusion

Geomorphological mapping of the ITC system has an important role in geomorphological studies based on the earth's surface as the unit of analysis. Geomorphological area is a space with morphographic, morphometric, morphogenetic, and morphochronological information characteristics. Geomorphological information becomes the basis for analyzing resource potential and disaster potential in regional development.

The results showed that on a map scale of 1: 30,000, 9 geomorphological units could be identified. The 9 geomorphological units are a combination of morphometry, genetics, and lithology. The combination consists of 2 landforms, namely hills and traditional and structural escarpments; The lithology consists of 3 layers, namely the Semilir Formation Lapilli, Kebo Butak Formation Sand, and Semilir Formation Tuff. Meanwhile, morphometry is in the form of slope units, namely 8-15%, 15-25%, 25-45%, and >45%. Meanwhile, the age based on lithology is Late Oligocene – Early Miocene in Kebo Butak formation and early Miocene – Middle Miocene in Semilir formation.

The limitation of this research is that it does not utilize remote sensing technology optimally. The map also does not include symbols for geomorphological processes. Further research needs to take advantage of rapidly developing earth mapping technology.

References

[1]. Cooke, R.U. and J.C. Dornkamp. Geomorphology in Environmental Management. A New Introduction, edisi kedua. Claredon Press, Oxford (1994)

[2]. Zuidam, V. *Aerial Photo-Interpretation in Terrain Analysis and Geomorphologic Mapping*. International Institute for Aerial Survai and Earth Sciences (ITC), Enschede (1983)

[3]. Verstappen, H. Th. *Applied Geomorphology*. Elsevier, Amsterdam (1983)

[4]. Haggett, R. J. *Fundamentals of Geomorphology*. Routledge, London (2003)

[5]. Hamblin, W.K. *Earth Dynamic System*. Mac Millan Publ.Co., New York (1992)

[6]. Sunarto. Perubahan Fenomena Geomorfik Daerah Kepesisiran di Sekeliling Gunungapi Muria Jawa Tengah (Kajian Paleogeomorfologi). *Disertasi (tidak dipublikasikan).* Program Pascasarjana Universitas Gadjah Mada, Yogyakarta (2004)

[7]. Otto, Jan-Christoph and Smith, Mike J. *Geomorphological mapping. Geomorphological Techniques*, Chap. 2, Sec. 6. ISSN 2047-0371. British Society for Geomorphology (2013)

[8]. Dykes A.P. Geomorphological maps of Irish peat landslides created using hand-held GPS. Journal of Maps 2008: 258-276 (2008)

[9]. Dramis F, Guida D, Cestari A. Nature and Aims of Geomorphological Mapping. In Geomorphological Mapping: methods and applications. Smith MJ, Paron P, Griffiths J (eds.). Elsevier: London, 39-74 (2011)

[10]. Paron P, Claessens L. Makers, and users of geomorphological maps. In Geomorphological Mapping: methods and applications. Smith MJ, Paron P, Griffiths J (eds.). Elsevier: London, 75-106 (2011)

[11]. Knight J, Mitchell W, Rose J. Geomorphological Field Mapping. In Geomorphological Mapping: methods and applications. Smith MJ, Paron P, Griffiths J (eds.). Elsevier: London, 151-188 (2011)

[12]. Verstappen, H. Th. Old and New Trends in Geomorphological and Landform Mapping. In

Geomorphological Mapping: methods and applications. Smith MJ, Paron P, Griffiths J (eds.). Elsevier: London, 13-38 (2011)

[13]. Radoane, M. and Cristea, A.I. Geomorphological Mapping. Evolution and Trends. *Review Of Geomorphologie*, Volume **13**, Editura University, din Bucuresti, pp.19-39 (2011)

[14]. Demek, J. (ed.). Manual of Detailed Geomorphological Mapping. Prague, Czechoslovakia: Academia (for the International Geographical Union, Commission on Geomorphological Survey and Mapping). (1972)

[15]. Sutikno. Geomorfologi dan Prospeknya di Indonesia. *Pidato Pengukuhan Jabatan Guru Besar pada Fakultas Geografi.* Universitas Gadjah Mada, Yogyakarta (1995)

[16]. Brahmantyo, B. dan Bandono. Klasifikasi Bentuk Muka Bumi (Landform) untuk Pemetaan Geomorfologi pada Skala 1:25.000 dan Aplikasinya untuk Penataan Ruang. *Jurnal Geoaplika*, Volume **1**, Nomor 2, hal. 071 – 078 (2006)

[17]. Srijono, Husein, S., Haryono, E., Yuwono, J.S.E., Samodra, H., Rachwibowo, P., Budiadi, E. Penerapan Pemetaan Geomorfologi Metode ITC dalam Menganalisis Geomorfologi Pegunungan Selatan Jawa Timur. *Prosiding.* Pertemuan Ilmiah Tahunan IAGI Ke-37, Bandung, 322-326 (2008)

[18]. Husein, S., Srijono. Peta Geomorfologi Daerah Istimewa Yogyakarta. https://www.researchgate.net/publication/308415694_Peta_Geomorfologi_Daerah_Istimewa_Yogyakarta. DOI: 10.13140/RG.2.2.10627.50726 (2010)

[19]. Kristanto, W. A. D., dan Indrawan, I. G. B. Karakteristik Geologi Teknik Daerah Prambanan Dan Sekitarnya, Kecamatan Prambanan, Kabupaten Sleman, Daerah Istimewa Yogyakarta. *Kurvatek* Vol. **3**. No. 2, pp. 21-29 (2018)

[20]. Thornbury. *Principle Of Geomorphology*. New York: John Willy & Sons Inc. (1954)

[21]. Malinda, R.N., Arbiwati, D., Wardoyo, S.,S. Pendugaan Erosi Dan Pemetaan Tingkat Bahaya Erosi Di Desa Sambirejo Kecamatan Prambanan Kabupaten Sleman D.I. Yogyakarta. *Jurnal Tanah dan Air (Soil and Water Journal)*, UPNV Yogyakarta, Volume **16** Nomor 1, pp. 43 – 54 (2019)

[22]. Rahardjo, W., Sukandarrumidi dan Rosidi, HMD. *Peta Geologi Lembar Yogyakarta skala 1 : 100.000*, Pusat Penelitian dan Pengembangan Geologi, Bandung. (1995)

[23]. C. Prasetyadi, Ign Sudarno, VB. Indranadi, Surono Surono. Pola Dan Genesa Struktur Geologi Pegunungan Selatan, Provinsi Daerah Istimewa Yogyakarta Dan Provinsi Jawa Tengah. *Jurnal Geologi dan Sumberdaya Mineral.* Volume **21** nomor 2. Pusat Survai Geologi, Badan Geologi, Kementerian Energi dan Sumberdaya Mineral, Republik Indonesia, Bandung, 91-107 (2011)

[24]. Haryono, E. Model Perkembangan Karst Berdasarkan Morfometri Jaringan Lembah Di Karangbolong, Gunungsewu, Blambangan, Dan Rengel. Disertasi (tidak dipublikasikan). *Fakultas Geografi.* Universitas Gadjah Mada, Yogyakarta (2008)

[25]. Zuidam, V. *Aerial Photo-Interpretation in Terrain Analysis and Geomorphologic Mapping*. International Institute for Aerial Survey and Earth Sciences (ITC), Enschede (1983)

[26]. Hardjowigeno, S., Widiatmaka. *Evaluasi Kesesuaian Lahan dan Perencanaan Tataguna Lahan.* Gadjah Mada University Press, Yogyakarta ((2007)

[27]. Surono, B. Toha dan I. Sudarno. *Peta Geologi lembar Surakarta – Giritontro, Jawa, skala 1 : 100.000*, Puslitbang Geologi, Bandung. (1992)

[28]. Cas, R.A.F. dan J.V. Wright. *Volcanic Successions. Modern and Ancient*, Allen & Unwin, London, **528**. (1987)

[29]. Malik R.F., Sartohadi. J. Pemetaan Geomorfologi Detail Menggunakan Teknik Step-Wisegrid Di Daerah Aliran Sungai (DAS) Bompon Kabupaten Magelang, Jawa Tengah. Skripsi. Fakultas Geografi Universitas Gadjah Mada, Yogyakarta. https://media.neliti.com/media/publications/228682-pemetaan-geomorfologi-detail-menggunakan-7bd7b675.pdf (2017)

[30]. A. C. Seijmonsbergen and L. W. S. de Graaff. Geomorphological mapping and geophysical profiling for the evaluation of natural hazards in an alpine catchment. *Nat. Hazards Earth System Science.* **6**. www.nat-hazards-earth-syst-sci.net/6/185/2006/ 185–193. (2006)

[31]. Daniel García - Soriano, Adolfo Quesada - Román, José Juan Zamorano - Orozco. Geomorphological hazards susceptibility in high-density urban areas: A case study of Mexico City. Journal of South American Earth Sciences**,** Volume 102. https://doi.org/10.1016/j.jsames.2020.102667 DOI link: https://doi.org/10.1016/J.JSAMES. 2020. 102667. (2020)

[32]. Cold storage. International Dairy Journal (17): 657–665.

[33]. Kai, Z. and Blanchard, Z. C. 2015. Resistant starch manipulated hyperglycemia / hyperlipidemia and related genes expression in diabetic rats. Int. J. of Biological Macromolecules **75**: 316-321.