Research article

Geomorphological Mapping for Land Suitability Evaluation

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Abstract.
Geomorphology affects the potential of land. The geomorphological condition of an area has implications for physical characteristics, including: 1) type; 2) material; and 3) processes formed upon it. Understanding land capability allows for the evaluation of land suitability. Classification of land suitability is carried out by combining the results of land capability identification with requirements for plant growth or existing land use. Evaluation of land suitability can be done using the survey method. This study aimed to assess the suitability of land in Sumbersuko Village in Wagir District, Malang Regency. Land suitability was evaluated by matching the characteristics of the land with the land suitability class. This study used primary data taken from the regional morphology survey. Secondary data included: 1) digital elevation model data; 2) geological maps; 3) maps of soil types; and 4) Sentinel-2A images. The data from the field survey were then compiled using a geographic information system into maps using 2D and 3D modeling. The results of GIS analysis showed that Sumbersuko Village has six landform units, namely M1V1, M1V2, H2V2, U2V2, P2V2, and M3V3. Analysis of land capability and suitability of the six land units in a row gave the following results: 1) forest (highly suitable/S1); 2) forest and industry (suitable/S2); 3) plantation/agrotourism (moderately suitable /S3); 4) agriculture (not suitable/N); 5) residential area (less suitable/S3) S4); and 6) forest (highly suitable/S1).

Keywords: scientific, approach, methodological, techniques, geography

1. Introduction

The suitability of land use can be assessed based on geomorphological aspects. The main aspects of geomorphology are morphology (morphography and morphometry), morphogenesis (passive morphostructure, active morphostructure, and morphodynamics), morphochronology, and morphoarrangement [1]. The earth's surface can develop and change over time as a result of geomorphic processes and as a result of human actions. Changes occur in physical landforms and changes in land use types [2]; [3]. Therefore, land evaluation based on geomorphological conditions in an area can be carried out.

Land suitability is a land evaluation activity based on a comparison between land quality and land use requirements. Land suitability can be identified and evaluated from the land capability of an area [4]; [5]. The principle of land suitability classification is carried out by combining the results of the identification of land capabilities with requirements for plant growth or existing land use. Therefore, this classification is often called species matching [6]; [7]; [8].

Geomorphological mapping is carried out to study landforms and other interrelated phenomena [9]; [10]. Inventory of geomorphological data in the field was carried out using terrestrial survey techniques [11]; [12]. Terrestrial survey is a branch of mapping science that focuses on modeling the earth's surface [13]. This observation consists of several stages, namely before mapping which includes processing survey points and making checklists, field (data collection), and data processing after the field.

Geomorphological mapping is done by reviewing aspects of morphology, morpho-genesis, morphochronology, and morphoarrangement [1]. Aspects of morphometry and morphography are included in the morphological aspects. Morphometry is the size and shape of the constituent elements of landforms, while morphography is the arrangement of all objects on the earth's surface. The morphogenesis aspect is the story of the origin and development of landform formation.

Morphochronology is a sequence of landform formation processes. Meanwhile, the morpho-arrangement aspect is the spatial arrangement and the relationship between a landform and other landforms in a related process. This research focuses more on morphological aspects, especially morphometry. The morphometric condition of the area was measured by direct measurement method in the field.

Geomorphological conditions are one of the initial parameters that can be used to carry out land suitability analysis [14]; [15]; [16]. This is because the aspects contained in geomorphology can affect slope conditions, processes, types and properties of materials on the earth's surface, as well as the availability of water [17]. Based on this, it is possible to know the land capability in an area based on the physical properties of the soil and groundwater conditions which can be interpreted from the geomorphological conditions of the area. Then, the ability of the land can be compared with the existing land use to identify the suitability of the land. Based on this analysis, it can be seen whether the land currently used is in accordance with the land capability based on the geomorphological conditions of the area.

Sumbersuko Village is one of the areas with geomorphological conditions that have not been mapped optimally. There have not been many specific studies regarding the

relationship between geomorphological conditions and land use in this area. Geomorphologically, land use in the middle slope area should still be used as a forest area or an unmanaged area. However, the existing land use in this area consists of natural tourism areas, agriculture, and production forests. Based on this, this study aims to: 1) understand the general geomorphological conditions in the research area, 2) identify the suitability of land use based on the geomorphological conditions of the area, and 3) evaluate the existing land use based on the results of the identification of land use suitability.

2. Method

This research is a qualitative descriptive study conducted in Sumbersuko Village, Wagir District, Malang Regency, East Java Province, Indonesia. This village is located at 112°28'48"–112°33'40" East Longitude and 7°58'41"–8°1'19" South Latitude. Based on the location of latitude and longitude, Sumbersuko Village is included in a tropical climate (moderate to cold in the Junghuhn climate classification). Sumbersuko village has an area of 10.89 km2. Sumbersuko village is located in the highlands. Physiographically, Sumbersuko Village is in volcanic morphogenesis (V). The morphology of this area is found in the upper slope to the foot slope of Kawi Volcano. The administrative map of Sumbersuko Village can be seen in Figure 1.
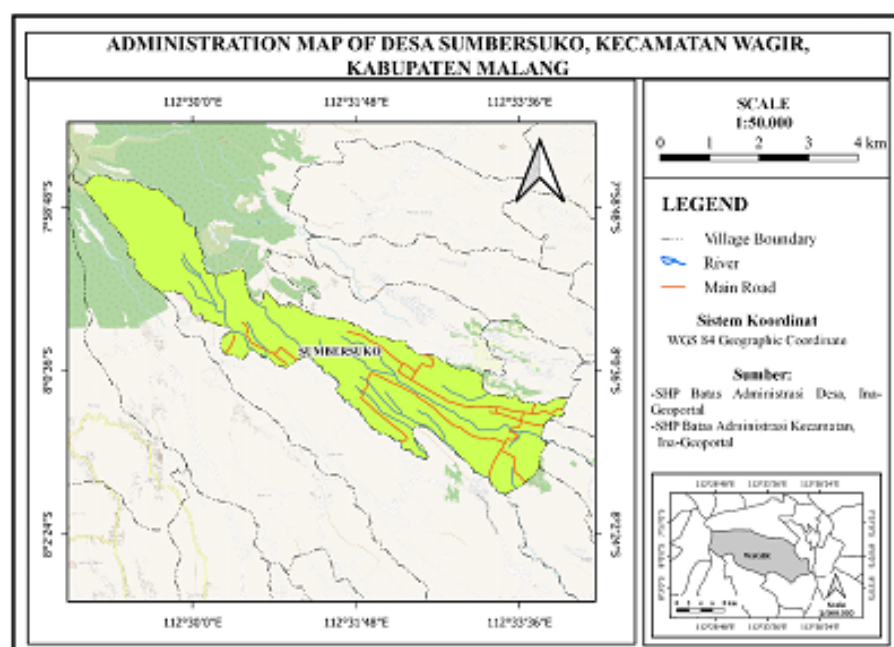

Figure 1: Administrative Map of Sumbersuko Village, Wagir District, Malang Regency.

This study examines the suitability of land use from a geomorphological point of view. Studies Land suitability based on the geomorphological conditions of an area can be identified using a geographic information system (GIS) [18]; [19]. However, primary data is still needed to support mapping data. Primary data is data obtained by researchers directly in the field, without going through intermediaries or second hands [20]; [21]; [22]. Secondary data is data that is already available or has been processed by primary parties who come from outside the research team [23];.

The primary data in this study were taken from observations and morphological surveys of the area, while the secondary data used were DEM (digital elevation model) data, geological maps, soil type maps, and Sentinel-2A images. Secondary data is processed and visualized into a geomorphological map of the area. Then, the ideal land use analysis is carried out from the geomorphological conditions of the area. After that, observations were made to determine the suitability of land use from the mapping results with existing land uses. Morphological surveys are used to determine the slope conditions of the area in more detail—especially in the middle slope area which has variations in land use. Thus, land use comparisons can be analyzed and presented descriptively. Systematically, the research method can be seen in Figure 2.

3. Result and Discussion

3.1. Sumbersuko Village Topographic Condition

Sumbersuko Village is located on the upper and middle slopes of Kawi Volcano. The middle slope is generally classified as a flat to slightly steep slope class. The slope of the slope increases as it approaches the upper slope, this can be seen from the increasingly dense contours. In addition, the slope map shows that the upper slope has a moderately steep (15-30%) and steep (30-100%) slope class. There is also a steep slope in the dike area which is located south of Sumbersuko Village. The slope gradient of Sumbersuko Village can be seen in the transverse profile image on the geomorphological map. Topographic maps and slope maps of Sumbersuko Village can be seen in Figure 3 and Figure 4.

3.2. Geomorphological Condition of Sumbersuko Village

Regional geomorphological maps were analyzed from the results of overlays between topographic maps, slope maps, geological maps, and soil type maps. The data is then
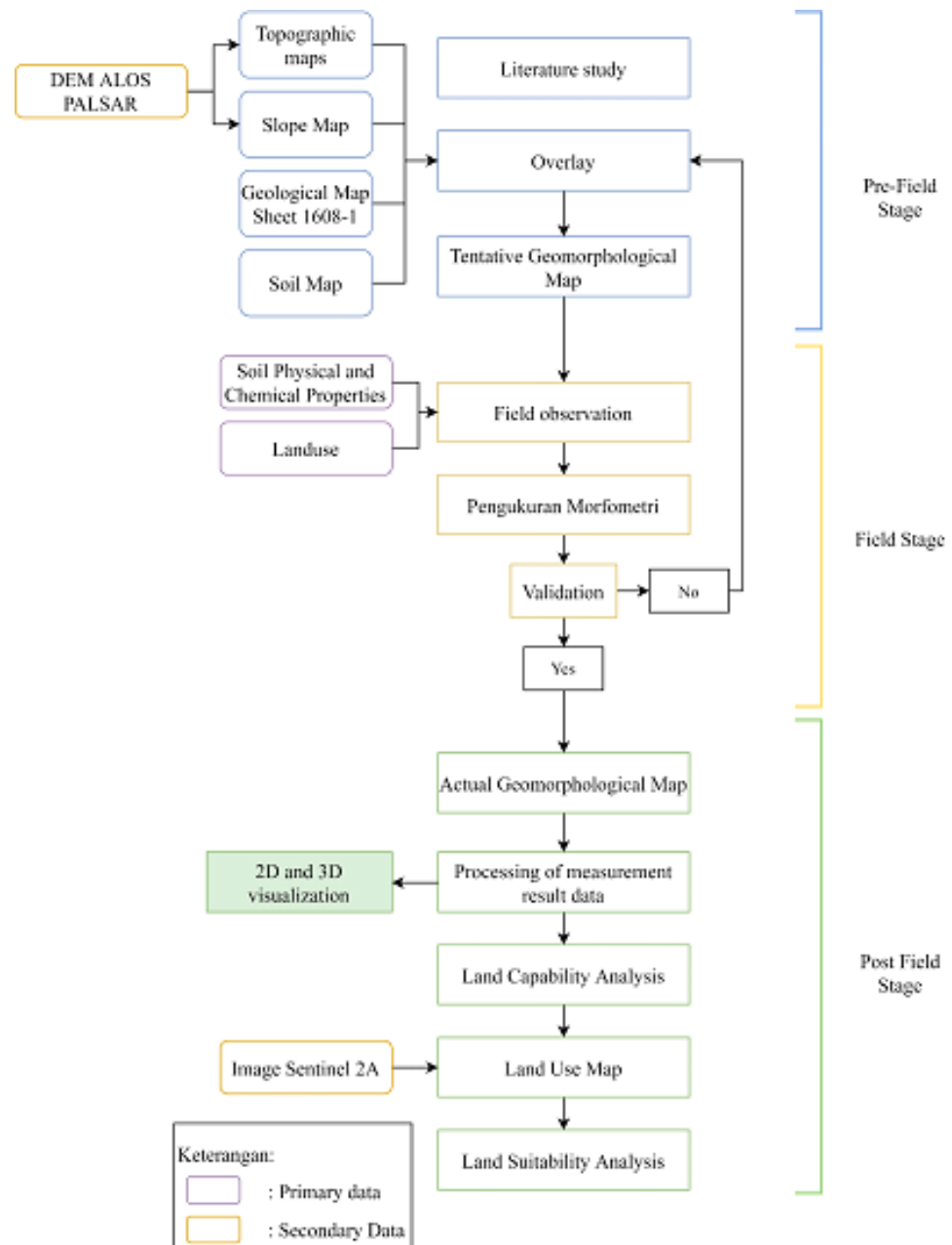
Figure 2: Research Workflow.

compiled and visualized into a geomorphological map. Based on the analysis, it can be seen that Sumbersuko Village is divided into six land units, namely: 1) M1V1, 2) MIV2, 3) H2V2, 4) U2VA, 5) P2V2, 6) M3V3. The geomorphological map of Sumbersuko Village can be seen in Figure 5 as follows.

The boundary of the middle slope with the upper slope of Sumbersuko has a different height. This region has a negative formation. The basin has a steep slope and was formed due to erosion. The soil in the area is eroded and sedimented at the bottom
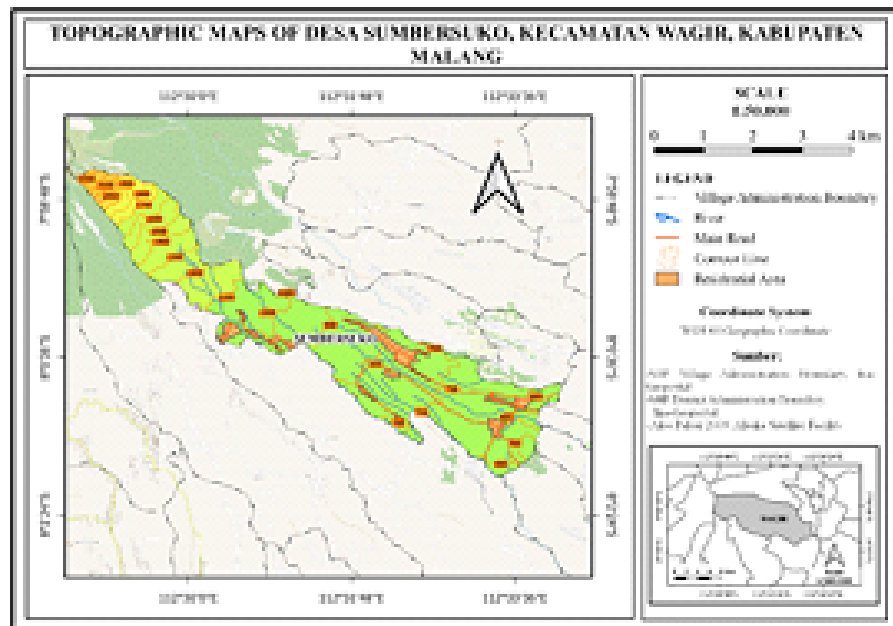
Figure 3: Topographic Map of Sumbersuko, Wagir, Malang, East Java, Indonesia.
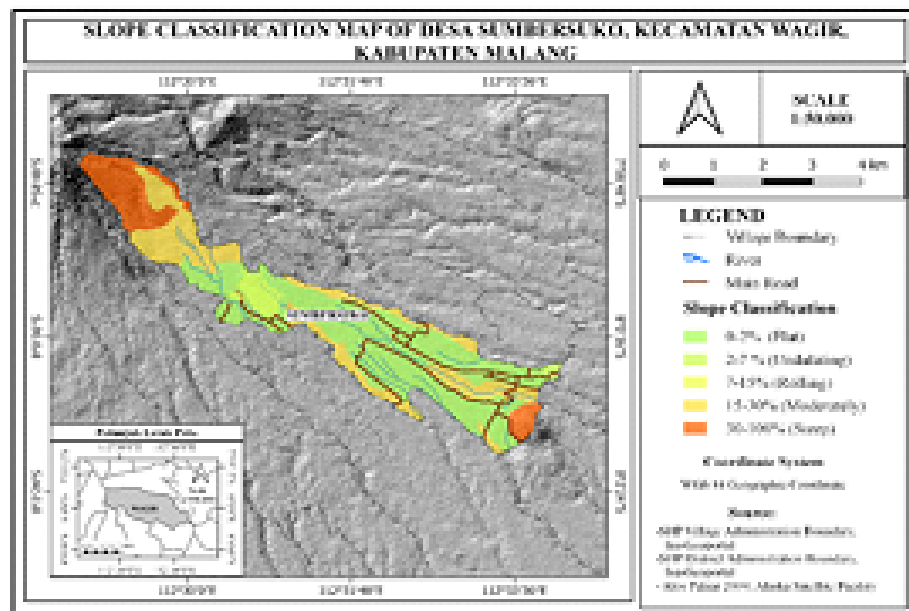

Figure 4: Slope Classification Map of Sumbersuko, Wagir, Malang, East Java, Indonesia.

of the slope. The negative formation can be seen from the 3-dimensional modeling as shown in Figure 6 as follows.

Identification of land units can be done through several analyzes including: 1) landform, 2) parent material, 3) depth, 4) drainage, 5) texture, 6) Ph, 7) CEC. The entire area of Sumbersuko Village based on geological maps is known to have Andesite and Basalt rock types. Andesite rock is an intermediate rock formed by cooling magma on
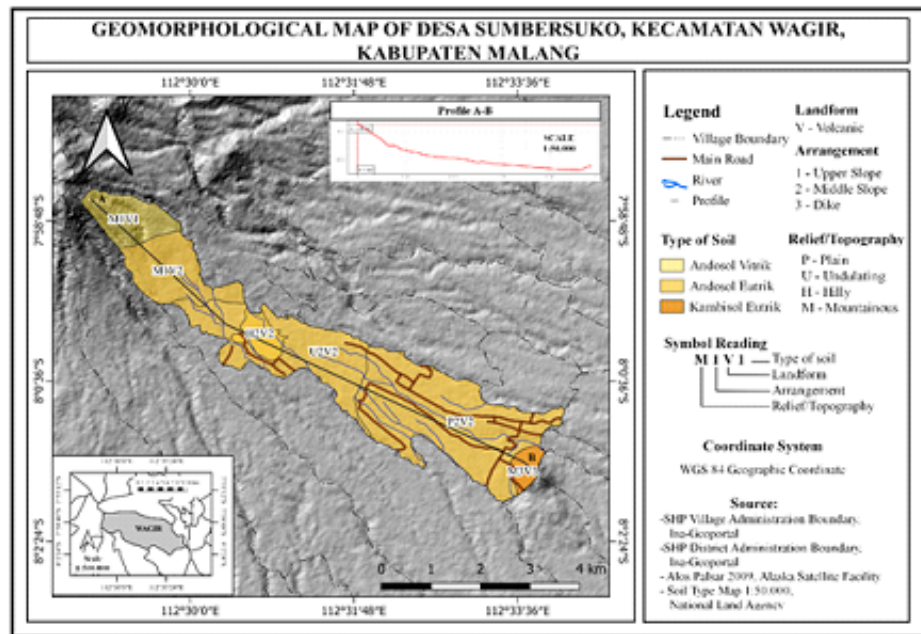
Figure 5: Geomorphological Map of Sumbersuko, Wagir, Malang, East Java, Indonesia.

(a)   (b)
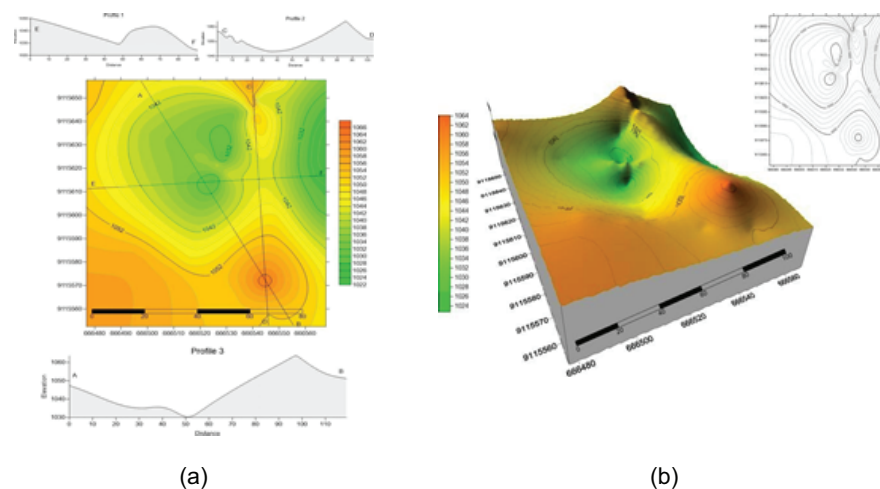
Figure 6: (a) Contour dan (b) 3D Surface.

the earth's surface [24]. Basalt rock is an igneous rock formed as a result of the rapid cooling of basaltic lava exposed at or very close to the earth's surface. These rocks can be easily found in the Kawi Volcano area and are scattered in Sumbersuko Village, especially around the river.

In addition to geological materials, soil types can also be used as a basis for making geomorphological maps. There are three types of soil in Sumbersuko Village, namely: 1) Vitric Andosol, 2) Eutric Andosol, and 3) Eutric Cambisol. In more detail the identification of soil types based on land units in Sumbersuko Village can be seen in Table 1.

TABLE 1: Identification of soil types in each land unit in Sumbersuko Village.

Land Unit	Landforms	Parent Material	USDA	Depth	Drainage	Texture	PH	CEC
M3V3	*dyke*	Andesit basalt	Andic Eutrudepts	Deep	Good	Slightly Smooth	7	Moderate
M1V1	Upper Volcanic Slope	Andesit basalt	Typic Hapludands	Moderate	Good	Moderate	5	Low
M1V2	Upper Volcanic Slope	Andesit basalt	Vitric Hapludands	Deep	Good	Moderate	5	Low
U2V2	Middle Volcanic Slope	Andesit basalt	Typic Hapludands	Very deep	Good	Moderate	7	Moderate
P2V2	Middle Volcanic Slope	Andesit basalt	Typic Hapludands	Very deep	Good	Moderate	5	Very High

Andosol soil has a dark color and is porous. Soil is the development of volcanic parent materials such as volcanic ash, tuff, and pumice. Andosol has a high aluminum content. In addition, this soil also reacts to inorganic phosphate. This causes the basic phosphate is not easily dissolved even though the soil has good water holding capacity. This condition makes it difficult for plants to absorb phosphate, so farming without fertilization will cause problems.

Andosol Vitrik is located at the peak of Volcanic Kawi. This soil has good drainage with medium texture. Andosol Vitrik in Sumbersuko Village has an acidity level of 5 (slightly acidic) with a low Cation Exchange Ability (CEC). Meanwhile, the Andosol Eutric soil type is spread on some of the upper slopes to the middle slopes. The upper slope has two different soil types, namely Andosol Vitric and Andosol Eutric. Eutric Andosols are found on the upper slope border with the middle slope. The Eutric Andosol found on the upper slope is different from the Eutric Andosol found on the middle slope. The difference lies in the physical and chemical properties of the soil. Andosol Eutric on the upper slope has a medium texture, with an acidity level of 5 (slightly acidic). This soil also has a low Cation Exchange Capacity. In contrast to Andosol Eutric on the middle slope which has a medium texture with a neutral to slightly acidic acidity level (5-7). This soil also has a medium to very high Cation Exchange Capacity (CEC). Meanwhile, Eutric Cambisol soil is found in dykes. This soil has a slightly fine texture with a neutral pH (7). This soil also has a moderate Cation Exchange Capacity.

3.3. Land Capability

Land use must be adapted to the physical conditions of the area (soil conditions and water availability). The goal is to maintain a balance of functions in the environment.

Thus, disaster risk can be minimized. Land is a system composed of various components. Land components are categorized into two, namely structural components which are commonly called land characteristics and functional components which are referred to as land quality [25]. Land quality is a collection of land elements that determine the level of capability and suitability of land use.

Land use must be in accordance with the ability of the land so as not to cause land damage and reduce land productivity. Land use that is not in accordance with the potential of the land can provide a risk of failure and can trigger environmental degradation. The damage that occurs is due to land use errors that result in the expansion of critical land, thereby reducing the land's ability to store water which has an impact on increasing the frequency of floods, erosion, and the spread of landslides in the rainy season and drought in the dry season.

Land capability analysis based on geomorphological conditions can be identified using a geographic information system (GIS). GIS has advantages in the effectiveness and efficiency of research time. To determine the land capability class in the research area, it is done by making a map of the land unit. Stated that the land unit map was obtained from several maps, namely soil type maps, slope maps, and land use maps [26]; [27]; [28]. The three maps are superimposed so that they can produce a map of land units.

Based on the research results, Sumbersuko Village has six land units. These six land units can be seen in Table 2. From these land units, M1V1, M1V2, and M3V3 land units can be used as forest areas. The area of the H2V2 land unit can be used as land for plantations and agro-tourism locations. In the area of the U2V2 land unit, the land has the potential to be planted with secondary crops, vegetables, and horticulture. Meanwhile, P2V2 land units can be used as residential areas.

TABLE 2: Land Units in Sumbersuko, Wagir, Malang.

No	Land Units	Information
1	M1V1	Mountainous, upper slope, volcanic, andosol vitic
2	M1V2	Mountainous, upper slope, volcanic, andosol eutric
3	H2V2	Hilly, middle slope, volcanic, andosol eutric
4	U2V2	Undulating, middle slope, volcanic, andosol eutric
5	P2V2	Plain, middle slope, volcanic, andosol eutric
6	M3V3	Mountainous, dyke, volcanic, kambisol eutric

Based on the geomorphological conditions, land units M1V1, M1V2, and M3V3 can be used as forest areas. Forests are an effective form of land cover naturally to reduce erosion. This relates to the ability of vegetation to absorb water into the soil. The

process of water absorption into the soil is influenced by the physical properties of the soil related to the ability to pass and store water.

The availability of litter, soil organic matter, plant root systems, and fauna has a role in the magnitude of the capacity of water recharge into the soil. Cracks and holes that exist as a result of plant roots and the activity of soil organisms will increase soil porosity and reduce soil density. Forests located on hilltops and steep mountains can reduce fluctuations in water flow between the rainy and dry seasons. The presence of forests on the top of the mountain will maximize the hydrological function of the area as a water storage area.

The area of the H2V2 land unit can be used as land for plantation crops and agro-tourism locations that can attract tourists so as to provide additional income to the people living around the location. The P2V2 land unit can be used as a residential area because it is located in an area with a sloping morphology. So that it is easier for this area to build a local community service center. Geomorphologically, the U2V2 land unit is a good area if it is planted with secondary crops, vegetables, and horticulture. This is supported by the type of soil and elevation found in this land unit. In addition, this area also has a topography that is not too steep (wavy) so that agriculture can still play a role in maintaining the ecological function of the soil and water availability while maintaining the economic function of the area.

3.4. Land Use

The land use in Sumbersuko Village in 2020 can be divided into 5 land uses, namely: 1) forest, 2) agriculture, 3) agriculture, 4) industry, and 5) settlements. This land use is dominated by plantations and forests. It is known that the use of garden land reaches 492 ha or reaches 32.69% of the total land use. The high use of land for plantations is caused by the needs of the livestock industry in Sumbersuko Village. Most of the land use on the middle slopes is used as mixed plantations. The slopes are planted with elephant grass to meet livestock feed. Land use in the form of forest dominates the upper slope of Kawi Volcano. Overall forest use occupies the second largest position after Agrikebunan with a forest area of 456 ha or reaching 30.3%. The land use of Sumbersuko Village can be seen in Table 3 and Figure 7.

TABLE 3: Land Use in Sumbersuko, Wagir, Malang.

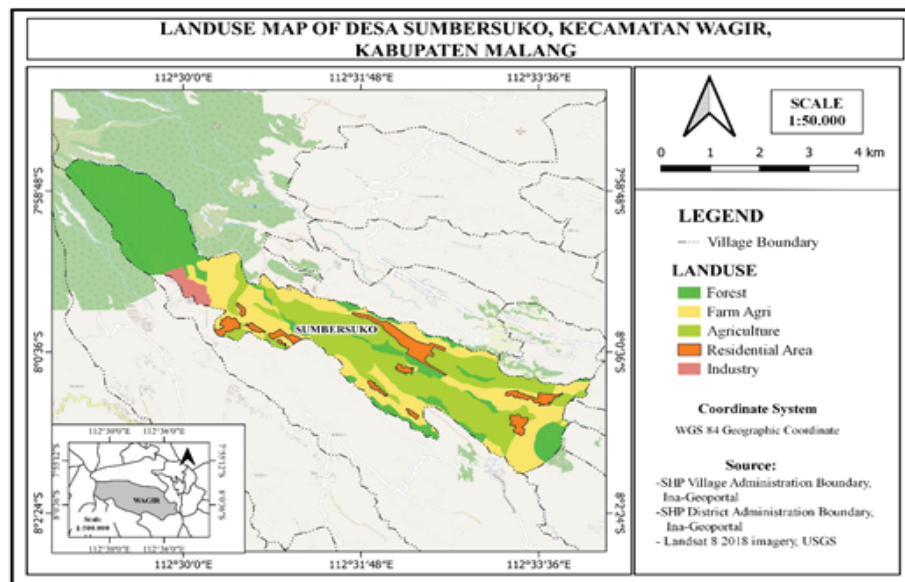| No	Land Use	Surface Area (ha)	Percentage (%)
1	Forest	456	30,3
2	Farm Agri	492	32,69
3	Agriculture	441	29,3
4	Indusrty	28	1,86
5	Residental Area	88	5,85
	Total	1.505	100

Figure 7: Landuse Map of Sumbersuko, Wagir, Malang, East Java, Indonesia.

3.5. Land Suitability

Land suitability analysis is carried out by comparing the results of the land capability analysis with the existing land use map. The matrix of land unit, geomorphological conditions, land capability, and land suitability can be seen in Table 3. The suitability class is divided into five, namely 1) Very suitable/S1, 2) Appropriate/S2, 3) Quite suitable/S3, 4) Not suitable/ S4, and 5) Not Appropriate/N. The assessment is carried out by looking at the percentage of the existing land use area to the land use area based on its ability. Broadly speaking, land use based on the regional profile of Sumbersuko Village can be seen in Figure 8.

Based on the results of the analysis, the existing land use in the M1V1 and M3V3 land units is in accordance with the land capability, namely forest. This area is a protected forest designated as a conservation area. Land use in these two land units has a very important role for environmental sustainability and sustainability, both in this area and its

TABLE 4: Matrix of Land Units, Geomorphological Conditions, Land Capability, and Land Suitability of Sumbersuko, Wagir, Malang.

No	Land Unit	Topography	Morpho-arrangement	Land form	Type of soil	Land Capability	Existing Land Use	Land Suitability
1	M1V1	Mountainous	Upper Slope	Volcanic	Andosol Virtric	Forest	Forest	HighlySuitable (S1)
2	M1V2	Mountainous	Upper Slope	Volcanic	Andosol Eutric	Forest	Forest and Industry	Suitable (S2)
3	H2V2	Hilly	Middle slope	Volcanic	Andosol Eutric	Farm/ agrotourism	Plantations and Fields	Moderate Suitable (S3)
4	U2V2	Undulating	Middle slope	Volcanic	Andosol Eutric	Agriculture	Farm, Forest, Plantation Industry	Not Suitable (S3)
5	P2V2	Plain	Middle slope	Volcanic	Andosol Eutric	Residential	Field, Residential	Less Suitable (S4)
6	M3V3	Mountainous	Dike	Volcanic	Cambisol Eutric	Forest	Forest	Highly Suitable (S1)

Figure 8: Cross-sectional profile and land use in Sumbersuko, Wagir, Malang.

surroundings. The suitability of land use can also be triggered by the natural conditions of this area which is topographically located in a mountainous area with a fairly high contour density. As a result, it is relatively difficult for residents to access, carry out activities, and/or build settlements in this area. The M1V2 land unit is included in the S2 land suitability class, which is appropriate. When viewed qualitatively, the land use in this area is dominated by forest. However, suitability is reduced due to the presence of industrial land uses. The industry in this area is the dairy farming industry for dairy products. Possibly, one of the reasons this area was chosen was due to the optimal temperature and the abundant availability of food. On the other hand, this area should be used as a forest area when viewed from the geomorphological condition of the area. This refers to the morpho-arrangement of the area on the upper slopes of Kawi Volcano so that the presence of industry in this area is likely to disrupt soil stability and the hydrological cycle in the long term.

The suitability of H2V2 and P2V2 land units is quite suitable and less suitable, respectively. Broadly speaking, these three areas have more diverse land uses so that their suitability is seen from the most dominant land use in the area. The H2V2 land unit has plantation and field land use, while the land capability is more optimal in plantations or can even be used as an agro-tourism area. Thus, the suitability class is only included in the moderately appropriate class. The existing land uses in the P2V2

land unit are plantations, fields, and settlements, while the land capability can be used as a residential area. Unlike the M1V2 land unit, the discrepancy in this land unit is more positive. This means that areas that can be used as settlements, green open spaces are still maintained in the form of plantations and fields.

The U2V2 land unit has the highest diversity, with four land uses in the region. Based on the results of geomorphological analysis, this land unit has the ability if it is used as an agricultural area. Meanwhile, the existing land use is more diverse—which is dominated by plantations, followed by fields, forests, and a small part of which is also the livestock industry. Thus, the discrepancy is more directed at the percentage of land use for the entire area.

4. Conclusion

Sumbersuko Village has six landform units, namely M1V1, M1V2, H2V2, U2V2, P2V2, and M3V3. The landform unit has the following land capabilities: 1) M1V1 in the form of forest, 2) M1V2 is forest, 3) H2V2 is plantation and/or agro-tourism area, 4) U2V2 is horticultural agriculture, 5) P2V2 is settlement, and 6) M3V3 is forest. After comparison with the existing land use, the land units M1V1 and M3V3 have a very suitable land suitability class (S1). The M1V2 land unit is included in the S2 land suitability class, which is appropriate. Although qualitatively the land use in the M1V2 area is dominated by forest, suitability is reduced due to the presence of land use in the form of livestock industry. The suitability of H2V2 and P2V2 land units is quite suitable (S3) and less suitable (S4), respectively. The U2V2 land unit has the highest diversity than other areas so that the inappropriate land suitability class (N) is more directed at the percentage of land use for the entire area.

5. Acknowledgments

References

[1] Zuidam RAV. Guide to geomorphologic aerial photographic interpretation and mapping. International Institute for Geo-Information Science and Earth Observation, Enschede; 1983.

[2] Raharjo PD, Haryono E. Sintesa geomorfologi atroposen kawasan cagar alam geologi karangsambung bagian selatan. Jurnal Geografi Gea. 2020; 20:141-150. https://doi.org/10.17509/gea.v20i2.27727.g13242

[3] Sutikno S, Dibyosaputro S, Haryono E. Geomorfologi dasar. Yogyakarta: Fakultas Geografi, Universitas Gadjah Mada; 2020.

[4] Jayanti DS, Goenadi S, Hadi P. Evaluasi kesesuaian lahan dan optimasi penggunaan lahan untuk pengembangan tanaman kakao (*Theobroma cacao* L.) (Studi kasus di kecamatan batee dan kecamatan padang tiji kabupaten pidie propinsi Aceh). Agritech : Jurnal Fakultas Teknologi Pertanian Universitas Gadjah Mada. 2013;33(2):208-218. 10.22146/agritech.9808

[5] Anwar GM, Wahyuni M. Kajian metode evaluasi kesesuaian lahan untuk kakao di kabupaten bantaeng. Agrotechnology Research Journal. 2019;3(2):85-92. https://doi.org/10.20961/agrotechresj.v3i2.33174

[6] Arsyad S. Konservasi tanah dan air (Edisi kedua). Bogor: Institut Pertanian Bogor Press; 2009.

[7] Susetyo B, Widiatmaka W, Arifin HS, Machfud M, Arifin NHS. Analisis spasial kemampuan dan kesesuaian lahan untuk mendukung model perumusan kebijakan manajemen landskap di sempadan ciliwung, kota Bogor. Majalah Ilmiah Globe. 2014;16(1):51-58.

[8] Harahap FS, Rauf A, Rahmawaty R, Sidabukke SH. Evaluasi kesesuaian lahan pada areal penggunaan lain di Kecamatan Sitellu Tali Urang Julu Kabupaten Pakpak Bharat untuk pengembangan tanaman cabai merah (*Capsicum annuum* L.). Jurnal Tanah dan Sumberdaya Lahan. 2018;5(2):829-839.

[9] Husein S, Srijono S. Peta geomorfologi daerah istimewa. Paper presented at: Simposium Geologi Yogyakarta; 2010 Mar 23; Yogyakarta, Indonesia.

[10] Gracia-Ruiz JM. Why geomorphology is a global science. Cuadernos de Investigacion Geografica. 2015;41(1):87-105. https://doi.org/10.18172/cig.2652

[11] Kennedy DM. Topographic field surveying in geomorphology. Treatise on Geomorphology. 2013;14:110-118. https://doi.org/10.1016/B978-0-12-374739-6.00377-8

[12] Malik RF, Sartohadi J. Pemetaan geomorfologi detail menggunakan teknik step-wise-grid di daerah aliran sungai (DAS) bompon kabupaten magelang, jawa tengah. Jurnal Bumi Indonesia. 2017;6(2):1-15.

[13] Susetyo DB, Yuniar HT, Saputra LR. Standarisasi aplikasi survey pemetaan terestris dalam bidang kosntruksi struktur bawah bangunan. Paper presented at: Forum Ilmiah

Tahunan Ikatan Surveyor Indonesia, Sekolah Tinggi Pertahanan Nasional; 2013 Okt 31; Yogyakarta, Indonesia.

[14] Adhitya L. Identifikasi kesesuaian lahan untuk tanaman jati di kecamatan padas kabupaten ngawi. Skripsi tidak diterbitkan. Surakarta: Universitas Muhammadiyah Surakarta; 2008.

[15] El Gammal ES, Salem SM, Greiling RO. Applications of geomorphology, tectonics, geology and geophysical interpretation of East Kom Ombo Depression, Egypt, using landsat images. The Egyptian Journal of Remote Sensing and Space Sciences. 2013;16:171-187.

[16] Rusdi M, Roosli R, Ahamad MSS. Land evaluation suitability for settlement based on soil permeability, topography and geology ten years after tsunami in Banda Aceh, Indonesia. The Egyptian Journal of Remote Sensing and Space Science. 2015;18(2):207-215. https://doi.org/10.1016/j.ejrs.2015.04.002

[17] Ayuningtyas EA, Mardiatno D. Kesesuaian lahan untuk tempat tinggal di das secang, kabupaten kulonprogo, daerah istimewa Yogyakarta. Jurnal Bumi. 2012;1(2):67-74.

[18] Youseff AM, Pradhan B, Sefry SA, Abdullah MMA. Use of geological and geomorphological parameters in potential suitability assessment for urban planning development at Wadi Al-Asla Basin, Jeddah, Kingdom of Saudi Arabia. Arabian Journal of Geosciences. 2014;8:5617-5630. https://doi.org/10.1007/s12517-014-1663-9

[19] Benardi AI. Analisis kesesuaian permukiman terhadap bahaya longsoran dengan menggunakan teknologi sistem informasi geografi di kecamatan tembalang kota Semarang. Jurnal Geografi. 2015;12(2):174-182.

[20] Sanusi A. Teknik pengumpulan data dan instrumen penelitian. Metodologi Penelitian. 2014;104-105.

[21] Jatmiko W, Gernowo R. Analisis korelasi citra data primer dengan data sekunder menggunakan citra grid analysis and display system (GrADS). Youngster Physics Journal. 2014;3(1):63–70.

[22] Khairunisa NS, Safitri DR. Integrasi data sampah sebagai upaya mewujudkan zero waste management: Studi kasus di kota Bandung. Jurnal Analisa Sosiologi. 2020;9:108-123. https://doi.org/10.20961/jas.v9i0.39829

[23] Sugiyono S. Memahami penelitian kualitatif. Bandung: ALFABETA; 2012.

[24] Tamanak T, Melkianus A, Berhitu T, Ode DG, Cahyono YDG. Pengaruh pelapukan terhadap kekuatan batuan andesit. Jurnal Sumberdaya Bumi Berkelanjutan (SEMITAN). 2020;2(1):599-604.

[25] Putera P, Satria RB. Strategi perencanaan pembangunan dalam pemanfaatan lahan sumberdaya air pada sungai kalimalang di kota bekasi

Jawa Barat. Universitas Islam Malang, Malang; 2020. Available from: http://repository.unisma.ac.id/handle/123456789/224

[26] Hidayat M. Inequality across districts and cities in the Riau. Economic Journal of Emerging Markets. 2014;6(2):106-108.

[27] Budiarta IG. Analisis kemampuan lahan untuk arahan penggunaan lahan pada lereng timur laut gunung agung kabupaten Karangasem-Bali. Media Komunikasi Geografi. 2014;15(1):19-32.

[28] Jawang UP, Simajuntak BH, Prihtanti TM. Evaluasi kesesuaian lahan komoditas unggulan perkebunan kecamatan katiku tana selatan kabupaten sumba tengah. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan. 2018;8(3):396-405. https://doi.org/10.29244/jpsl.8.3. 396-405