The Use of Digital Elevation Model in A GIS For Flood Vulnerability: Case Study of Sitiarjo Village Malang District East Java Indonesia

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Abstract. The purpose of this research is the use of a Digital Elevation Model (DEM) was used in conjunction with a Geographic Information System to compute morphometric factors influencing flooding vulnerability. These causal factors were subjected to a weighted overlay analysis in order to categorize areas based on their flooding vulnerability. The research location is in Sitiarjo Village Malang District East Java Indonesia. The flood disaster that most harmed the community in Sitiarjo village occurred in 1983, 2003, 2007, 2010, 2013 and 2017. Sitiarjo village is crossed by two major rivers, namely the Panguluran river and the Mbambang river which meet at the river in the southern part of the village. The results showed that the flood vulnerability of sitiarjo village has a high level in the center of the village (flood plain and fluvial landforms). The greatest flood hazard is at the bottom of the confluence of the Pangluran and Mambang rivers in Rowo Terate Sub Village.

1. Introduction
The flood disaster that most harmed the community in Sitiarjo Village occurred in 1983, 2003, 2007, 2010, 2013, and 2017. Floods hit Sitiarjo Village, Sumbermanjing Wetan District, Malang Regency in October 2017 and were caused by the overflow of the Panguluran river. The Panguluran River flood repeated the floods in 2016 and 2013. Flooding from the overflow of the Panguluran river indicates an accumulation of runoff originating from the upstream area of the Panguluran watershed. This flood disaster caused several access roads to be damaged, and dozens of houses were flooded. Floods hit Sitiarjo Village, Sumbermanjing Wetan District, Malang Regency in October 2017 and were caused by the overflow of the Panguluran river. The Panguluran River flood repeated the floods in 2016 and 2013. Flooding from the overflow of the Panguluran river indicates an accumulation of runoff originating from the upstream area of the Panguluran watershed. This flood disaster caused several access roads to be damaged, and dozens of houses were flooded.

Geographically, the location of Sitiarjo village is in Sumbermanjing Wetan District, Malang Regency. Sidodadi borders the western part, the northern part is Sumber Agung Village, Tambakrejo Village, and Kedungbanteng Village borders the eastern part, and the south side is directly adjacent to the Indian Ocean. Sitiarjo Village is located in the Penguluran River Basin. The hydrological characteristics of the watershed with a rounded shape are one of them when it is flooded. Reaching the peak discharge only takes a relatively short time, and it takes a long time to return to the initial position. The condition of the branching flow pattern in the upstream and out in one flow outlet at the downstream, causing the accumulation of high flow rates quickly. The condition of land use in the Penguluran watershed is still dominated by natural land use, which is dominated by plantations by 55%. Settlements are spread from upstream to downstream. Sitiarjo village is located in the valley, and there are rice fields farming activities.

Floods are high flows that cause problems for humans. Floods are the most significant natural hazard and cause loss of life and economy. The cause of the flooding is generally high rainfall with a poor
infiltration system, lower ground elevation, non-smooth river flow, and low vegetation in the upper reaches [1]. Flood events in some areas can be affected by changes in land use or population increases in an area [2]. Flood characteristics can be influenced by water depth, flood duration, flood velocity, sediment produced, level of water level rise, and frequency of events [3]. Floods are relatively high flows and cause problems for humans [4]. Floods can also be defined as the worst and most expensive natural hazard that causes economic losses and casualties [5]. Flooding consists of two events, namely inundation in an area that has never been flooded and caused by water runoff from rivers where the water discharge cannot be flowed by river water [6]. Flood events can be overcome through risk reduction. Flood risk reduction uses several measures such as dams, non-technical engineering, floodplain building codes, and flood insurance programs [5].

2. Material and Method

Land and water are the main components of natural resources, and they work together in one integrated watershed system. Humans live to adapt to an area by utilizing natural resources to sustain their life. The form of utilization by human activities follows the characteristics of the land and the working hydrological processes. The potential of natural resources does not only work locally but works interrelated in one watershed system. The watershed system works hierarchically from upstream to downstream but is interconnected. This natural process has become an element that provides natural resources for human life. However, often this natural process works to have a destructive impact on human life. Not the slightest result of human activities that impact changes in the response of natural systems.

The flood that hit Sitiarjo Village (Figure 1) is one example of a natural process that disturbs human life. This research was conducted to evaluate the problem of inundation from a geodetic point of view with consideration of physical characteristics. This study consists of data on geomorphological conditions and soil physical properties. The research mainly investigated the spatial distribution of flood susceptibility and the factors that cause flooding based on landform conditions with a digital elevation model. For this purpose, conducted field surveys.

Sitiarjo village has a unique and interesting geomorphological condition. The landscape consists of structural, karst, fluvial and marine. Structural hilly landforms are dominated by the northern region. Karst landscapes occur in the east and west. The shape of the geomorphology can be seen in Figure 2. Structural landforms are formations with geomorphic characteristics due to geological influences [7] with the distribution of rocks that have a certain resistance to erosion [8].
There are at least four landscapes. The landscape in Sitiarjo Village includes structural, karst, fluvial, and marine landscapes. The structural landscape dominates the northern part of the village in slopes above structural hills, down slopes of structural hills, fault escarpments, and Colluvial plain. Karst landscapes are found in the east and west, flanking Sitiarjo Village. The existing landforms include karst hills, uplands, karst plains, and Dolina. Structural landforms can be derived from processes originating from endogenous forces. The endogenous force can be uplifted, fractured or folds from the earth.

The existing lithology has different lithologies: lithology of swamp and river deposits, the Wonosari formation, and the Wuni formation. Based on the location traversed by the profiling path, the structural landform has the Wonosari formation and the lithology of swamp and river deposits. Judging from the surface relief in the figure, the condition of the structural landform generally has rock layer deformation, which has rock layer stratification. The landscape of the origin of the structural process in Sitiarjo Village and its surroundings is divided into several landforms. The landforms include structural hilltop slopes, swamp slopes, fault escarpments, and colluvial plains.

3. Result and discussion

Sitiarjo Village is primarily located in a valley flanked by steep structural hills and karst hills. Sitiarjo Desa Village included in the Stretching watershed system. This watershed is unique because, in addition to its rounded shape, there is a basin in the form of a plain alluvial in the middle-downstream with flat relief, making it prone to flooding inundation. Geomorphologically, the Penggulungan watershed is composed of several units of landform. In the upper part, there are structural hill units of volcanic deposits. The Mandalika Formation and the Tuff Members of the Mandalika Formation are Tertiary in age. On depicting topographic profiles from upstream to downstream, it is seen that the slope gradient is very steep in the upstream and sloping in the downstream with moderate changes firm. Visually, the topographical configuration shows that this alluvial plain is a naturally occurring basin that becomes a place of accumulation of river water flow from upstream. In other words, data indicates that the area is prone to flooding by overflowing river
water. The inundation flood susceptibility map shows the most prone areas are the banks of river flows, especially on the Alluvial Plain. Based on the results of field observations, many found former flood inundation on the walls of houses in the most flood-prone zones. While areas far from the river, there are no signs of former flooding, but that doesn't mean it's not prone to flooding. The extent of the flood inundation varied according to the height and extended inundation. The stretching river that crosses Sitiarjo Village has undergone a meandering process. The degree of meandering of this river decreases when it crosses the confluence of the karst hills. At this point, the stretching river meets the mambangan river. In the suppression area, there is a settlement called the Rowotrate village. According to reports from residents, these settlements are most prone to flooding that reaches as high as the house's roof. This high inundation can occur because steep structural hills geomorphologically flank the area. The river that crosses the area is a single flow outlet in the Stretching Watershed. If the flow rate exceeds the cross-sectional capacity of the river so that it overflows, the inundation is blocked by steep hills so that the distribution of the inundation does not expand. As a result, the tremor was only concentrated in the valley from the highlands until the recharge discharge from the upstream began to decrease.

According to Susilo and Pratomo, 2006 [9], the rounded shape of the watershed tends to produce a higher surface flow rate than the elongated watershed. The concentration-time required to drain water from the farthest point in the flow area to the dating outlet downstream. This condition is found in the Pengulan watershed. The Pengulan watershed has a rounded shape, a dendritic flow pattern upstream, and a parallel pattern downstream. The amount of runoff resulting from the dendritic flow pattern to the parallel flow pattern is considerable and gradually increases in a short time. The watershed system will be vulnerable to inundation. The amount of high surface runoff can cause high sediment loads. These differences can be seen in several areas around the river body Changes in river morphology are visible from 1994 to 2020. In the meander of the river, high sedimentation causes the formation of horseshoe lakes and the narrowing of the pond area.

Solutional landscapes are landscapes controlled by the dissolving process [10]. Solutional landforms are between karst hills, karst plains, and karst plains. Solutional landforms are landforms that originate from the dissolving process. The dissolving process is a rock dissolution process that occurs in carbonate rocky areas. The result of this dissolution forms a karst area characterized by characteristics such as easily soluble rock, thick texture, and the presence of fractures in the rock. Based on the field's existing conditions, the karst area with lithological solutional landforms from the solutional landforms in the study area is the Wono Sari formation, which refers to the 1970 Java geological map. The soil in the karst area. However, from the various types of solutional landforms that exist, solutional landforms are passed during profiling. Based on the conditions in the field wherein this karst area, there is vegetation. In addition, based on the type of landform, which is a solution, the rock type in the area is carbonate rock in addition, where the karst area is a rocky area with high topography so that when it rains, the karst area is not an area that is prone to flooding. Based on the vulnerability map, the solutional landform area is of moderate vulnerability due to the existing rock types. The solutional landform area or karst area is not high flood susceptibility.

The fluvial landforms found in this area are rivers, river valleys, alluvial plains, flood plains, back swamps, and horseshoe. The boundary between Sitiarjo village is in the west and Sidodadi Village. A large river that passes through this village is the Penguluran River and River. A watershed with a gentle slope with a smooth flow pattern is more accessible to channel water to the outlet than a sloping watershed with a rare flow density. As a result, a watershed with characteristics like this will produce more runoff with a long time. This condition is found in the Stretching Watershed. It can be seen that the Stretching Watershed has a rounded shape, has a dendritic flow pattern in the upstream, and changes to a parallel pattern in the downstream; the amount of runoff resulting from the dendritic flow pattern to the parallel flow pattern is enormous and gradually increases in a short time. The watershed system with these characteristics to be vulnerable to inundation. The amount of high surface runoff can cause high sediment loads. Changes in river morphology are visible from 1994 to 2020. In the meander section of the River, high sedimentation causes the
formation of horseshoe lakes and the narrowing of the pond area. In the meander of the River, high sedimentation causes the formation of horseshoe lakes and the narrowing of the pond area. As a result of a dead river. The mainstream from the River is formed. Based on the characteristics of the fluvial landform, it is found in the study location, namely the Penguluran Watershed. A sampling is located upstream of the Penguluran watershed. The horseshoe in the Fegularan watershed is precisely at the back. A sedimentation process occurs while the horseshoe is determined based on the erosion process and forms a slow river flow. The analogy to the horseshoe is in the lithology of the laughter and river deposits. The existing Kaula poultice in the study area also follows the characteristics that are located and formed due to the meandering part of the River. Therefore, based on the typical series, the horseshoe is in the appropriate characteristics and characteristics.

3.1 Digital Elevation Model

When viewed in the watershed system, the upper slope of the structural hills when viewed in the watershed system is the upstream area of the Panguluran watershed (Figure 3). This area has a firm morphological impression due to the geological structure at work. The division of the upper slope is adjusted to the elevation and surface conditions in satellite imagery and field observations. A different process is on the downslope of the structural hill. In these areas the process of erosion and erosion occurs more intensively. The morphological area to tend to be smooth.

![Figure 3. Digital Elevation Model of Study Area](image)

Based on the geological map, by region genesis. The slopes of these structural hills are composed of volcanic materials that include the composition of the mandalika formation, the tuff members of the mandalika formation, and the wuni formation. Mandalika formation material comprises andesite lava rock, basaltic, and prophesized andesite breccia. Meanwhile, the tuff members of the mandala formation are composed of andesite-rhyolite-dacite tuff material and pumice tuff breccia. Then, andesite-basalt lava material, tuff breccias, as well as lava breccias and sandy tuffs can be found in the wuni formation. Structural hillside downslope landforms with sedimentary lithology swamps and rivers. The lower slopes of the structural hills have land uses which include mixed gardens. Types of rock on the lower slope structural hills in the form of rhyolite, a type of acid igneous rock with a smooth texture. The slope of this landform is 20. The lower slope of this structural hill has a convex slope. The types of vegetation around are teak and sengon. The lower slope of the structural hills is based on the existing soil conditions, one of which is permeability. Permeability on the downslope of structural hills shows the classification of the ability of the soil to
flow water both vertically and horizontally. Classification of soil capability on structural hill slopes indicates a moderate classification. The ability soil to drain water with moderate capacity so that the ability of this land if categorized into moderate flood susceptibility. According to the existing flood susceptibility map, this is where This form of land is prone to flooding, namely moderate flood vulnerability. The form of the land from which the structural process originates is in the form of a hillside downslope. The structural structure is located at the transition between colluvial plains with formation lithology Wonosari and swamp and river deposits. This location has land use which is a plantation. Types of rock at the transition of the lower slopes of the structure of the hills with colluvial plains in the form of andesite rocks. Existing andesite rocks with a smooth texture and dark and light minerals. The slope of the slope at the location of this landform is 29.5°. This landform has a slope shape convex. The types of vegetation around are cassava, bamboo and bananas. The slope of structural hills with colluvial plains based on the existing soil conditions are permeability and soil drainage. The existing soil drainage conditions are classified as good. The soil has a good water flow. Soil Permeability on Slope Transition under structural hills with Coluvial plains show the ability of the soil to drain water very slowly. Even though the soil permeability is relatively slow-very slow, but with good soil drainage conditions based on the conditions on the flood susceptibility map at the location of the slope transition landform under structural hills with colluvial plains classified into vulnerability The low one.

Another landform that can be identified is the presence of a fault escarpment. Gawir A fault is an inclined plane which is a steep tab due to the presence of a fault. In general, the fault escarpment can be in the form of an arc with displacement material dominant in the middle [8]. Morphologically, this region has a very steep slope with the potential for mass transfer large when triggered by an earthquake. Forming process The local paleoseismology influences this landform at work. At the study site, the fault escarpment has a weak notch indicated by the appearance of not so intense erosion. Coluvial plain landforms generally have associations with the presence of depositional material and weathering material from the above slope.

At the study site in Sitiarjo Village, colluvial plains are found at the bottom of the fault escarpment and in several locations close to the lower slopes of the hills. Structural. Colluvial plains are aggradation of material displacement having a wavy morphology. Colluvial plains have land use in the form of mixed gardens. Type the vegetation in the colluvial plains is banana and teak. The type of rock in this colluvial plain is a fine-grained carbonate rock. The slope of the existing slope at the location is 12.5°. Slope shape on the shape of this land is convex. Seeing based on the existing soil conditions, namely soil drainage and permeability, will be associated with flooding. Soil drainage in both horizons 1 and 2 is at a moderate level. This matter indicates the ability of the soil to drain moderate water. While the permeability soil shows slow classification. Based on the level of the existing condition flood susceptibility at the location of this landform shows a low level, but based on the existing vulnerability map, this location, even with the level of low vulnerability but also close to high flood susceptibility.

The inundation flood susceptibility map (figure 4) shows the most vulnerable area is the river bank (alluvial plain). Based on the field survey, it was found that there were former flood inundations on the walls of residents’ houses in the most flood-prone zones. Meanwhile, in areas far from the river, there were no traces of flood inundation. The extent of the flood inundation varies according to the height and duration of the inundation. This is influenced by concentration time. Concentration time is the time required to drain water from the farthest point in the downstream single outlet area. As a result there is a faster concentration of water in the final channel which affects the rate and volume of surface runoff relatively quickly.
4. Conclusion
Landscape morpho-arrangements in Sitiarjo Village in the middle is a stretching river and Mbambangan with a boundary to the west of the clan east flanked by karst landscape. The northern part of the village is the lower and middle slopeskarst hills and the southern part of the marine landscape. Flood awareness in Sitiarjo Village has a high level of the center of the village on a floodplain landform and fluvial. The greatest flood vulnerability is at the bottom of the meeting Stretching River and Mbambangan in Rowotrate Hamlet. the flood there is a flood inundation so that the shape of the land and morpho-arrangement is the main determining factor for flood events.

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