Flood Susceptibility in The Border Area of Banyuasin Regency, South Sumatra Province, Indonesia

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Abstracts. Flooding is one of the most common problems that occur as a result of urban sprawl. The development of suburban areas (urban sprawl) is one of the factors that lead to increased intensity of flooding in Tanah Mas, Sukajadi and Sukomoro villages. This study aims to determine the flood vulnerability index in the urban area of Talang Kelapa, Banyuasin regency. The research method used was qualitative approach and spatial analysis using GIS (Geographical Information System) and SMCA (Spatial Multi Criteria Analysis) using limited rational model based on soil type, landform, rainfall, river elevation, land use, geology and slope class. The results show that most of the urban area of Talang Kelapa, Banyuasin regency, falls in the medium category, 61.5% of the area. Slope class and land cover are the most influential indicators of flood hazard, followed by soil type and rainfall indicators. The areas classified as very flood prone are mainly located in Sukajadi and Tanah Mas villages.

Keyword: Flood Susceptibility, The Border Area, Banyuasin Regency

1. Introduction

The continuous population growth affects the increasing population activity and the increasing demand for urban space [1]. The tendency of the population to move from the urban core to the suburbs. The value of ecosystem services has declined rapidly in recent decades due to the changes in land use/land cover caused by urbanization [2]. Population growth is related to land use change [3]. Urban suburbs are characterized by a diverse landscape that includes fenced residential areas, scattered rural homes, and industrial areas whose activities border commercial activities and residential areas border agricultural lands [4]. The suburban space is still developing and has the potential of an urban space that has not been optimally used in consideration of ecological balance and sustainability [5].

The development of suburban space as a form of urban sprawl has implications for changing land use from agricultural land to built-up land [1]. Settlement growth affects environmental conditions, which also change with the conversion of agricultural land to residential land [6]. The increasing demand for residential land and the limited availability of

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residential land require special attention in providing land for settlements [7]. Land capacity reflects the physical capacity of the environment, which is reflected in the topography, soil, hydrology, and climatic conditions, as well as in the dynamics that occur, especially erosion, flooding, and others [8]. Changing land use affects the congestion, land degradation, threat, vulnerability, and even disaster risk, especially in flood disasters that lead to disruption of the physical and social structure of settlements in the area [9].

The population of Banyuasin regency has increased by one third, from 639 thousand people in 2000 to 854 thousand people in 2019. One of the most populous sub-districts is Talang Kelapa district with an estimated population increase of 181,050 people in 2032, i.e. the population growth in Talang Kelapa district, which is located on the border between Banyuasin regency and Palembang city, is classified as very high density. This high population growth impacts the projected housing demand in Talang Kelapa District, Banyuasin Regency, which is 31,488 units in 2021 and will continue to increase to 36,210 units by 2032 (Facts and Analysis of RTRW Banyuasin Regency, 2019).

The development of suburban areas (urban sprawl) affects the quality of the environment, both soil, air, and water [10]. The growth of urban sprawl has transformed the area that was originally mainly agricultural into an area where mainly non-agricultural activities are carried out, changing the structure of the area's function as a place for urban settlements, the concentration and distribution of government services, social services and economic activities [1] the environment and the environment. have direct and indirect effects on human life [9]. Changing land use, which does not provide green open spaces for rainwater infiltration, leads to repeated flooding, which is certain to increase every year. Soils saturated with water and waterways blocked by dense development cause a lot of stormwater to run off the surface, which in turn leads to flooding [9]. In addition to the changes in urban morphology, in the upstream area, there is a transformation of the protected area used as an enrichment area into a residential area and a commercial center, which is a factor that increases the risk of flooding. One of the negative impacts of urban sprawl is the increased flood intensity in the border areas, including at the eastern dam at kilometer 12, Orchid Housing, Mekar Sari Housing, and Citra Tanah Mas Housing, Tanah Mas Village. An increase in flood intensity is also observed in Sukajadi sub-district, including Sukajadi sub-district office and Sukajadi Health Center, and Orchid Housing in Sukomoro Village (Banyuasin Regency Regional Disaster Management Agency, 2021) [11].

The objective of this study is to determine the changes in land use in Talang Kelapa District, Banyuasin Regency, and the extent of their impact on increasing flood risk in urbanized areas.

2. Research methods

The survey was conducted in the district of Banyuasin, an area adjacent to the metropolitan city of Palembang in South Sumatra, Indonesia, and geographically located between 1° 37 32.12 and 3° 09 15.03 south latitude and 104° 02 21.79 and 105° 33 38.5 east longitude. Banyuasin Regency consists of 21 sub-districts and has an area of 11,832.99 km 2. The topography of Banyuasin Regency is dominated by relatively flat and hilly areas of 0-45 Mpdl distributed across the sub-districts. Judging from the slope, the mainland of Rambutan District, Banyuasin Regency, is in the range of 0-2% 2-15% and 15-25% slopes. This research uses a case study with a qualitative approach. The research site focuses on Talang Kelapa urban area which consists of Sukajadi, Tanah Mas, Sukomoro and Talang Buluh villages and is the border area between Banyuasin regency and Palembang city. The data used in this study are primary data and secondary data. Primary data in the form of field studies and secondary data from government agencies in the form of population data, administrative maps, and supporting maps in terms of topographic maps, morphological maps, slope maps, geological maps, rainfall maps, and land use maps [12], [13]. In the data analysis in this study, spatial analysis (overlay) is performed using geographic information system (GIS). Geographic information system techniques (GIS) have proven to be a helpful and successful tool for studying, mapping, processing, and displaying spatial data, and are also an effective tool for evaluating the physical capabilities and suitability of land [14], [15]. The integration of remote sensing data with digital soil maps using GIS leads to a well-defined elaboration of maps for land suitability classification [16]. To determine the flood risk, the method of spatial multicriteria analysis (SMCA) is applied, using a limited rational model based on the criteria of soil type, landform, precipitation, river elevation, land use, geology, and slope.

The delineation of flood-prone areas was determined using seven indicators, namely: slope, elevation, land use, precipitation, landform, soil type, and geology [17]. The results of multiplication between the weights and scores are obtained for each indicator. To determine the flood-prone areas based on the results of analysis, the highest total score of 440 and the lowest total score of 85, then with three class groups obtained an interval of 118 as shown in Table 1.

Table 1. Flood-prone interval class

Vulnerability Class	Interval Class	Vulnerability Index
Low Grade	85-203	Low Hazard Zone
Medium Class	204-321	Medium Hazard Zone
High grade	322-440	High Hazard Zone

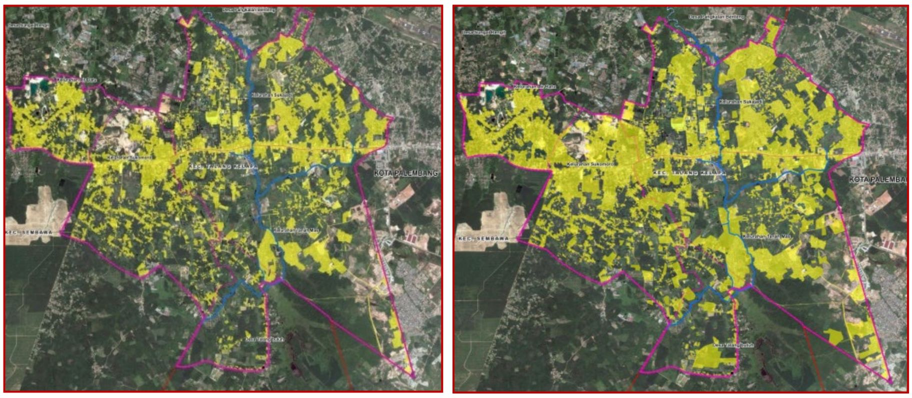
Source: Umar (2016)

3. Results and discussion

3.1 Talang Kelapa Urban Area

The urban area of Talang Kelapa is an area in the regency of Banyuasin in the form of plains and is directly adjacent to the district of Alang-alang Lebar, Palembang City. The urban area of Talang Kelapa has an area of 6,847.7 hectares and consists of three sub-districts and one village, namely Sukajadi Village, Tanah Mas Village, Sukomoro Village and Talang Buluh Village. The geographical location of Talang Kelapa urban area is an important factor affecting the development of this area. The development towards urban areas in this area from 2010 to 2020 shows an increase in changes from open land, i.e. land whose land use is permeable (water-permeable), to closed land in the form of built-up land whose land use is not water-permeable because it is in the form of cement/asphalt. usually a building, so this land is impermeable. The built-up area in 2010 was 902.94 ha or about 13.19% of the Talang Kelapa urban area and is expected to increase to 1339.93 ha or about 19.57% of the Talang Kelapa urban area by 2020, an increase of 48.4%. [Figure 1].

This also shows that uncontrolled urban development has occurred due to the dynamics of morphological changes of a city (urban sprawl). The changes that occur cannot be separated from the population growth in Talang Kelapa urban area, where the population in Talang Kelapa urban area increases from 59,393 people in 2014 to 72,242 people in 2020 or an increase of 12,489 people (21.63%).



2010 2017

Picture 1. Land cover change

Urban sprawl is a form of land consumption for housing, shopping centers, offices, and businesses. Originally, suburban development was a solution for people seeking an area protected from the hustle and bustle of a crowded and congested city. However, due to the increasing momentum of population growth and sprawling development, sprawl has a negative impact on a city's development, from economic and social development to the urban environment, which includes uncontrolled land use planning that makes the city vulnerable to flooding disasters.

Table 2. Total population of Talang Kelapa urban area in 2014 – 2020

No	Village/Village	Total Population 2014 (Soul)	Total Population 2020 (Soul)
1	Sukajadi Village	26,929	30,810
2	Tanah Mas Village	16,483	18,791
3	Sukomoro Village	13,732	19,383
4	Talang Buluh Village	2,249	3.258

Source: BPS Banyuasin, processed

Table 2 shows that the highest population growth in the last five years was in Talang Buluh village, with a growth rate of 44.86%, followed by Sukomoro village with 41.15%, Sukajadi with 14.41%, and Tanah Mas with 14.15%. The increasing population has caused the phenomenon of urbanisation to continue in the urban area of Talang Kelapa, resulting in land changes every year. The triggering factor for residential development in Talang Kelapa urban area is not only influenced by physical environmental factors and flat land areas, but also by easy accessibility and proximity to the workplace (Palembang).

High population growth in the Talang Kelapa urban area is leading to greater land use change from previously open to closed land. Changes in land use patterns in various forms and types have an impact on the environment [10]. Signs of a decrease in the carrying capacity of the environment in an area are various disasters such as floods, droughts, sedimentation, and abrasion. The occurrence of floods is mainly triggered by two things, the lack of land acting as a watershed and the occurrence of land subsidence due to groundwater exploitation and physical development that exceeds the carrying capacity. Therefore, the change of land use from undeveloped land to developed land will increase the amount of runoff [18].

3.2 Talang Kelapa Urban Area Flood Vulnerability Level

The level of flood vulnerability is determined based on the flood vulnerability index. The flood susceptibility index is an index formed based on several indicators, namely criteria for soil type, landform, precipitation, river elevation, land use, geology, and slope class [19].

The soil type criteria that must be considered include texture, structure, organic matter, density, permeability, and the soil's ability to hold water. This is because all of these are closely related to how quickly water disappears from the soil. The number that indicates how quickly water escapes from the soil surface is called permeability. It depends on this number whether a flood will form sooner or later and whether it will end [20]. Soil water permeability is highly dependent on soil texture and structure. Soil protection with cover crops maintains aggregate stability and porosity so that infiltration capacity and permeability are increased, and the gaps and holes caused by insects and other living organisms in the soil increase water absorption capacity [21]. Talang Kelapa urban area consists of three soil types, namely A. Andosol Brown and Latosol, A Glei Humus and Low GH, and A Glei Humus and Organosol. Based on this soil type, flood risk can be generally classified into two classes, namely low and medium.

Landform criteria are established based on topographic impressions, slopes, and lithological or geological conditions of the Talang Kelapa urban area. The land units from the formation map can be distinguished based on the information about the rock material found in the lithological conditions of the rock, including volcanic, fluvial and a small part of the structure with limestone and mudstone materials. Topographic impressions obtained from three-dimensional elevation models can be used for more detailed landform classification. Mapping results show that based on landform, Talang Kelapa urban area consists of two landforms, fluvial (55.6%) and denudasional (44.4%). Fluvial landforms are all landforms formed as a result of water flow processes, both concentrated in the form of rivers and unconcentrated due to surface runoff [22]. Denudational landforms are landforms that result from weathering processes, erosion, rock movement (mass drift), and depositional processes due to agradation or degradation. The degradation process tends to reduce the earth's surface area, while aggradation tends to increase the earth's surface area [23]. Flood-prone areas are generally located in the lowlands. Due to the relatively shallow slope of the hillside, water flows more slowly, so the potential for flooding is greater. The results of flood susceptibility analysis based on landform show that areas with high and very high susceptibility are found only in floodplains.

In general, rainfall in the Indonesian region is determined by the influence of several phenomena, including the Asian-Australian monsoon system, El Niño, the east-west circulation (Walker circulation), and the north-south circulation (Hadley circulation), as well as some circulations due to local influences [24]. The movement of the sun, which moves from 23.5^{o} north latitude to 23.5 south latitude during the year, leads to the onset of monsoon activity, which also plays a role in influencing climate change, including in the urban area of Talang Kelapa. Precipitation is a natural phenomenon that is the main component of the hydrological cycle. Attention to climate change has increased the need for accurate information on statistical variations in precipitation characteristics. Statistical tests confirm that a proposed model can be used to predict the amount of precipitation in an area. Mapping results show that the entire urban area of Talang Kelapa belongs to one class based on rainfall or has the same rainfall, ranging from 2500 mm/year to 3000 mm/year.

The Gasing River is the main river that divides the urban area of Talang Kelapa. Being a low-lying area, this marsh also acts as a floodplain when the Gasing River overflows its banks, as it cannot accommodate large amounts of runoff. The plan to convert the Sungai Gasing area into a residential area will obviously have a significant impact on the flood behavior in this area. Depending on the elevation, the river elevation in the Talang Kelapa urban area ranges from 1 to 5 meters.

In Talang Kelapa urban area, land cover conversion from permeable to impermeable cover occurs every year. Land cover conversion affects direct runoff, which increases, and reduces the amount of water that infiltrates. The magnitude of the effect of land use change on runoff is calculated using the formula of multiple linear regression equations and is obtained from the calculation of the coefficient of determination of 92.4% to 93.1%, which means that the flooding that occurred in the study area was mostly influenced by land cover and the rest was influenced by other factors [25]. The results of the analysis show that most of the land cover in Talang Kelapa urban area is dominated by settlements and other places of activity (30.39%) and plantations (30.38%). The rest consists of fields/crops (21.8%), shrubs (7.21%) and open land (4.82%).

Geomorphologically, the urban area of Talang Kelapa consists of fluvial landforms such as alluvium, swamps, and floodplains, so the flooding that occurs in this area is consistent with the origin of the formation process or morphogenesis of the landforms that make it up. Thus, the problem of flooding is an interesting phenomenon to study as it relates to urban growth and spatial planning. Geologically, the urban area of Talang Kelapa is composed of the Water Bendakat Formation (37.4%), the Gumai Formation (7.4%), the Kasai Formation (50.8%), and the Talangakar Formation (4.34%)

The slope of the land has a great influence on flooding. In areas with a higher slope, the water that flows through is also higher. Water that is on a property with a steep slope will be directed to a deeper location more quickly compared to a property with a low slope. Thus, the relationship between slope and flooding potential is inversely proportional. The higher the slope of a site, the lower the flood potential [26]. The mapping results show that based on slope, the urban area of Talang Kelapa is dominated by areas with flat slopes (59.79%), gentle slopes (26.38%), while the rest are areas with fairly steep slopes (10.6 %) and very steep (0.4 %).

3.3 Flood Hazard Index

Flooding is a common problem that occurs in some parts of Indonesia, especially in densely populated areas such as cities. The cause of flooding itself can be due to various causes, both natural and human. Floods can be caused by natural events such as rainfall over a long period of time and lack of water infiltration [27]. Flood vulnerability or susceptibility in an area indicates the intensity of occurrence of flood disasters in that area. The larger the flood-prone area in an area, the more likely it is that flood disasters will occur. The smaller the flood hazard area in an area, the lower the probability of a flood disaster and the lower the intensity of the disaster.

The extent of potential flood hazard in the Talang Kelapa urban area can be determined by analysing the flood hazard index. The flood hazard index for the Talang Kelapa urban area was constructed using indicators of soil type criteria, landform, precipitation, river elevation, land use, geology, and slope. The results of the analysis show that the flood hazard in Talang Kelapa urban area is mostly in the medium category (61.5%), the rest have high category (38.2%) and few have low classification (0.3%). This indicates that Talang Kelapa urban area is an area that is highly prone to flooding (Figure 2)

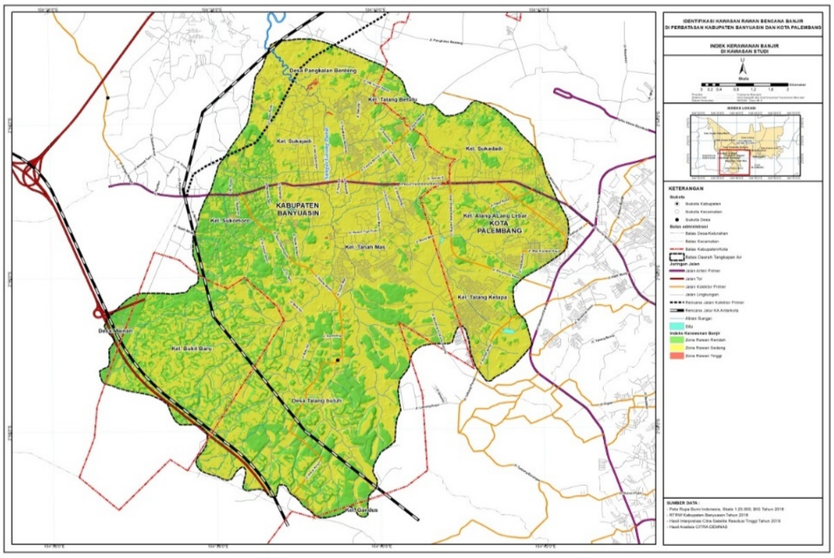


Figure 2. Flood susceptibility index

The results of the analysis (Figure 2) show that the urban area of Talang Kelapa is moderately prone to flooding, which accounts for 4208 ha or 61.5% of the total area of the urban area of Talang Kelapa (6,847.7 ha). The dominance of flood-prone areas is due to the parameters that determine the extent of flood vulnerability, most of which have very high values. Based on the slope in the urban area of Talang Kelapa, which is dominated by areas with shallow (59.79%) and gentle (26.38%) slope and thus has a great impact on flooding. Topographic conditions are one of the main factors for flooding disasters, as water inundates shallower areas. Most of the land use in Talang Kelapa urban area is dominated by settlements and other places of activity (30.39%) and plantations (30.38%) and in the form of fields (21.8%), the areas with moderate water supply from rivers, irrigated rice fields do not require a large amount of rainwater, so flooding occurs when it rains because there is very little land in the form of forest as a barrier to surface runoff in Talang Kelapa urban area.

In addition to the two factors of slope and land use, soil type and climateor rainfall also have a great influence on the value of flood susceptibility index. Soil type has a great influence on soil infiltration. The nature of soil texture in Talang Kelapa urban area has an effect of 51.28% on water infiltration rate, which is mainly dusty clay (55% dust and 25% clay) in the form of medium material. The number of rivers that often overflow due to the influence of rain, and land use that affects the level of vulnerability to flooding. The climate in the urban area of Talang Kelapa is type C or slightly humid, so it can be assumed that the average rainfall is moderate to high, considering that climatic conditions tend to be humid. The average rainfall in Talang Kelapa urban area is 2500 - 3000 mm/year, which corresponds to moderate to high rainfall intensity that causes flooding. There is a Gasing River that flows into the Banyuasin River. When the water volume increases during the rainy season due to high water discharges influenced by the upstream area, it may cause flooding or inundation. In addition, the conversion of undeveloped land to developed land also has a great influence on the occurrence of floods. The spatial distribution of medium and high vulnerability is found in almost all villages in Talang Kelapa urban area, but it is greatest in Tanah Mas village and Sukajadi village.

4. Conclusion

The built-up area in Talang Kelapa urban area has increased by 48.4% from 902.94 ha in 2010 to 1339.93 ha in 2020. The determination of the degree of flood vulnerability in Talang Kelapa urban area is influenced by the parameters of soil type, landform, rainfall, river elevation, land use, geology, and slope class. According to the degree of flood susceptibility, most of Talang Kelapa urban area falls in the medium category, 61.5% of the area. Slope class and land cover are the most influential indicators of flood susceptibility, followed by soil type and rainfall indicators. The areas classified as highly susceptible to flooding are mainly located in Sukajadi and Tanah Mas sub-districts, whose areas are located in the lowlands and whose land use is mainly residential/construction and open land, where flat and sloping land is predominant.

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