PROSPECTIVE ZONE AREA FOR AGRICULTURE AND RESIDENTIAL BASED ON GEOLOGICAL DISASTER POTENTIALS IN SOUTH BANDUNG REGION

Nana Sulaksana[1*], Teuku Y.W.M.Iskandarsyah[1], Achmad Rifai[1], Pradnya P. Raditya Rendra[1], Murni Sulastri[1]
[1] Faculty of Geological Engineering, Padjadjaran University, Jalan Raya Bandung – Sumedang Km.21, Bandung, Postal Code 45363, Indonesia

*Corresponding Author: n.sulaksana@unpad.ac.id

ABSTRACT

The number of residents in Bandung continues to increase every year, especially in the southern part of Bandung. The development of residential areas needs to get attention from the local government and people in Bandung, especially to evaluate various geological hazards such as floods, landslide, earthquake, and other. Research methodolgy is qualitative method by interviewing local community and analyzing landsat image using Google Earth and Digital Earth Model (DEM) image to know land use in the research area. In addition, quantitative methods are also used with superimposed manual statistical analysis and weighting methods using Microsoft Excel, Global Mapper, and Mapinfo software. The result of research shows that South Bandung area has Land Suitability Score > 130 (Residential Area) and Land Suitability Score > 135 (Agriculture Area) which are categorized as very good settlement and education area; Land Suitability Score 116-130 (Residential Area) and Land Suitability Score 92-135 (Agriculture Area) are categorized as an obstacle area with various constraints such as water supply, disaster, and others but can still be overcome by artificial engineering. Land Suitability Score <116 (Residential Areas) and Land Suitability Score <92 (Agricultural Area) are limitation area that are not feasible to be used as residential and educational areas, a variety of constraint reduction efforts can be done but require very high cost. Therefore it is suggested to convert the area into conservation. It is concluded that the best areas to be used as residential and agricultural areas are located in the Banjaran District such as Banjaran, Kamasan, Sindangpanon, and Tarajusari Village.

Keyword: Disaster, Landsat Image, Environment, Weighting Method, South Bandung

INTRODUCTION

Rapid population growth requires the development of residential and agriculture areas. The research area is located in South Bandung, where most are changed into residential and industrial areas. Tarigan et al. (2016) indicates that Bandung is one of the areas in Indonesia experiencing a very rapid growth. The rapid development caused the emergence of environmental issues such as garbage disposal problem, water supply and flood. Bandung area is also prone to geological hazards such as landslide, earthquake, and many others. Geolgogical hazards affected residential and agriculture area, and caused destruction of public facilities and infrastructure, loss of life, disease, and the degraded human quality due to the disturbed education. Land use change factor contributes to the high flood potentials in a watershed (Tarigan, 2016).

Direct interview to the local community as the victims of landslides can also be done as one of the effective method to know quickly the history of the earlier landslide in particular area (Samodra et al., 2015). According to data from Bandung Government, floods in research area have frequently occurred in the past until now. In 2017 floods occurred in some areas in Bandung, especially in Dayeuhkolot. Land slide in January to March 2014 took place seven times in the southern part of Bandung caused by heavy rainfall. A landslide often occur in hilly or mountainous areas during heavy rainfall and even after the rains stop which destruct buildings, degraded environment, and loss of life (Dai and Lee, 2002).

Land use for urban areas is determined by the condition of land suitability, but it will be by influenced by various constraints such as geological disasters, rare groundwater, steep slopes, and low foundation strength (Sulaksana et al., 2017). The present study was conducted to mitigate the frequent problems occur in urban areas indocated by the previous research in the development of urban areas which includes residential areas, industry, agriculture and education in South Bandung (Rifai, 2017).

The ability of land could be revealed by a study designed to estimate the shape and the usefulness of the land to athe void environmental degradation (Marsh, 1983 from Yacobus, 2009). Land suitability for

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particular uses is usually evaluated based on the characteristics or the quality of the area and the complete information of the characteristics which include the influencing factors such as bulk rain and soil type to calculate and estimate. The quality of land influenced by the soil is more complex, because it includes the suitability of soil moisture, humidity against erosion and resilience of flood (FAO, 1976). Research area is located between 107° 34 '48.35 " E and 107° 41' 13:53" E and between 6° 58 '31.58 " S to 7° 7 '8.10" S or adminstratively in Baleendah Subdistrict, Arjasari, Banjaran, Ciparay, Cimaung and Pacet, Bandung, West Java (Figure 1).

RESEARCH METHOD

The research activitity was conducted by making digital map through digitized map, collecting regional geology map, land movement, earthquake, ground water potential, and rainfall data. The method is qualitative by wauy of collecting and producing descriptive data in the form of direct interviews with the local community. Quantitative methods are carried out by weighting techniques. Remote sensing data obtained through analysis with arcgis software, global mapper, mapinfo, and google earth. Field observations carried out to determine the characteristics of the rocks, the landscape, and the history of hazards in the research area.

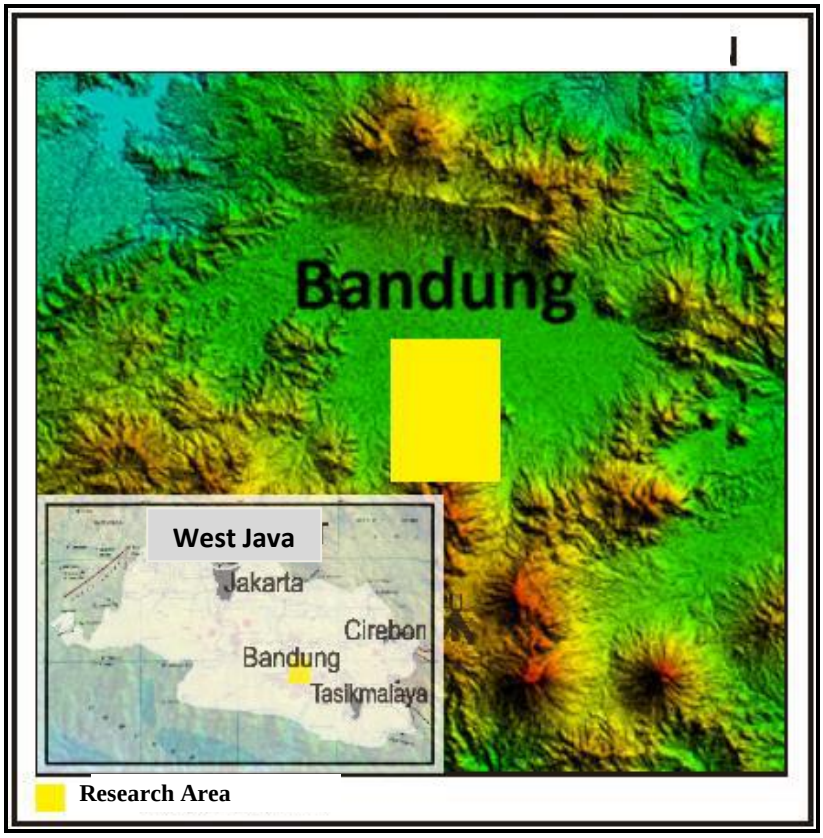

Figure 1. Index map of research area

Regional suitability classification is done by using a statistical method, namely the determination of the total score, the average score of the overall ability of the data, and the standard deviation to determine the range of land suitability classification.

1. Total score (Σx) was calculated from sum of overall total score. The calculation of all aspects of the department's ability maps prodeced Σx Score = 117 730
2. The total score average ($\bar{x}$), is calculated from the overall total score and divided by the number of scores, applying the following formula:

$$\bar{x} = \frac{\sum x}{n} = \frac{112115}{910} = 123{,}2. \quad (1)$$

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3. Standard Deviation can be seen in Figure 2.
4. The classification used in this study is Rifai Residential Area capability can be seen in Table 1.

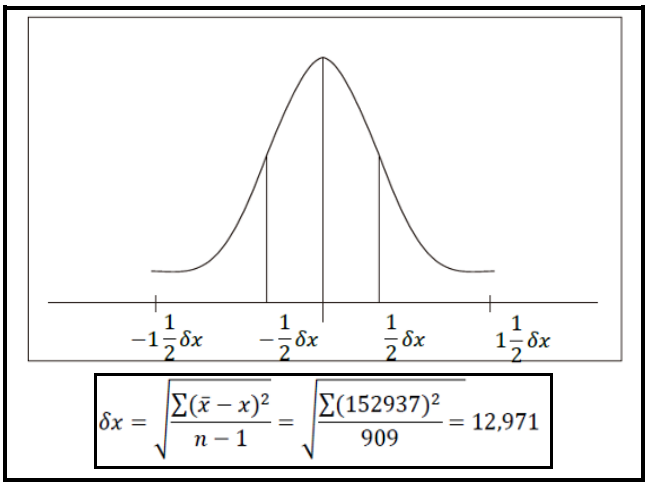

Figure 2. Standard Deviation (Howard and Remson, 1978 after Rifai, 2017)

Table 1. Rifai Residential Area Capability Classification (Howard and Remson, 1978 after Rifai, 2017)

Class of Area Capability	Criteria	Total Score Range
Very High	$>\bar{x} + 1\frac{1}{2}\delta x$	>144
High	$\bar{x} + \frac{1}{2}\delta x$ - $\bar{x} + 1\frac{1}{2}$	133-144
Intermediate	$\bar{x} - \frac{1}{2}\delta x$ - $\bar{x} + \frac{1}{2}\delta x$	116-130
Low	$\bar{x} - 1\frac{1}{2}\delta x$ - $\bar{x} - \frac{1}{2}\delta x$	102-116
Very Low	$< \bar{x} - 1\frac{1}{2}\delta x$	<102

The objects of research is measurement of slopes, rivers, and lithology using spatial analysis (Muzaki, 2008 after Ramadhan et al., 2016). Mapinfo software is used for spatial analysis on the slope and regional geology maps, and drainage pattern map to calculate the morphometry of the sub watershed, branching from river order and river branch ratio and river density. All the data were weighted to determine the zoning of the feasibility level of the regional development area.

RESULT AND DISCUSSION

Characteristics of Rocks

Characteristics of bedrock affect the carrying capacity of the infrastructure development and regional development, especially Residential and Agriculture area. Research area has 6 factors of physical characteristics of rocks and Alluvial deposit (DAT) dominated by fine-grained materials of clay silt sizes.

Bandung Basin is located in the northern area of research area, with the characteristics of the constituent material consisting of clay to silt soze and loose material (Figure 3). Based on the development aspects of the settlement the rock has the very bad ability to pass water, and caused pond of water in some places and the area can be flooded throughout the year. This area covers particularly the banks of the Citarum River with a very low Score based on the aspects of development of Agriculture. This area has the ability to save

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surface water which can be used during the dry season (Sugandi, 2007).

Figure 3. Deposition unit area of Dayeuhkolot

1. Tuff unit

This unit is dominated by tuff material, but in some places in the river lava and breccias were found. A fault occurs in this area, in the unit boundary of Puntang Mountain Unit, which will affect the movement of the area. It is difficult to find outcrop because the land use has change into agriculture and residential area (Figure 4). Based on the geomorphology map of the Old Malabar Volcanic, sheet of Banjaran 4521-IV, this unit consists of Delta Mount Tilu and Mount Malabar (DAG) to the west of the research area, and Volcano Puntang Unit (P2) in the form of volcanic Puntang body, resulting from the eruption of Mount Malabar Young, consisting of breccias and tuff.

Figure 4. Tuff in the Agricultural Area in the Ciparay region of Bandung

Volcano Malabar (M2) unit is part of the body Mount Malabar dominated by tuff, and breccias in the valley with the direction spreading to the north (M3) which is part of the body of Mount Malabar dominated by tuff, with breccias in the valley with the direction of eruption to the northeast. This unit was produced by the eruption of Young Mount Malabar after the eruption of Old Mount Malabar.

- Based on the aspect of development of residential area having soft character, and not well compacted (release material) it has the ability to pass water with good medium Score.
- Based on the aspect of the development of agricultural area tuff material has soil type andosol which is Malabar volcanic product with high fertility level to be used as media of plant growth (Bandung Central Bureau of Statistics) has high Score.

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2. Andesite unit

Andesite unit is dominated by andesite rocks, tuff, and breccias. This unit consists of the Malabar Units (M1) which is part of the Mount Malabar Cones dominated by lava, breccia, and grey lava flows. Phenocryst consists of plagioclase and fine-grained pyroxene (<1 mm). It has a bad water passing properties, but in the field found a fracture so it can still pass water down the surface, and has very hard physical properties (Figure 5). Mount Puntang unit (P1) in the form of Cone Peak Volcanic Lava Puntang dominated by the direction of flow towards the north. Andesite Basal mountainside Puntang is a lump of lava colored dark gray, finely textured. Phenocryst consists of plagioclase and pyroxene (1-2 mm), which is embedded in the base period afanitic. Then the unit of Mount Haruan in the form of the Great Peak which is located in the south - southwest which is the Old Malabar. Volcanic material making up this unit together with the Young Mount Malabar Unit in the form of lava and breccias.

- Based on the Residential Area development aspect, andesite rocks have high physical properties of hardness and poor water passing properties, but in the field there is a fracture so that it can still pass water down the surface (Bronto, 2006) has a very good Score.
- Based on the agricultural development aspect, andesite rocks have a high hardness so that it resistance to weathering, and in the top soil (top surface) does not have a high thickness so that the plant will be difficult to be developed has a very low Score.

Figure 5. Andesite outcrop in the Baleendah, Bandung

3. Intercalated andesite breccia unit

Intercalated Andesite Breccia Unit is the oldest unit in the research areas. It is compiled by intercalated andesite pyroclastic breccia (Figure 6) (Miocene). Andesite has particular permeability so the water can pass well, but in the field we found the fracture so that they can still be passed down to the sub surface, and it has very hard physical properties. At the research area, some andesite mines were found.

- Based on the Residential Area development aspect, breccia has hard and interlocking grains natural properties. So, it is very good to be a foundation in the development of both residential and educational areas. In some areas, it is found with a matrix such as tuff and andesite, but there is a fracture as a pathway for the passage of water. There is an active normal faults old quarter, which affect the movement of soil (Bronto, 2006).
- Based on the regional development aspects of agriculture, this unit has the physical properties of hard rock so it is resistant to weathering. That will produce a layer of top soil (medium to grow crops) which is not thick.

E-ISSN : 2579 – 3136

Figure 6. Breccia outcrop in the Baleendah, Bandung

Score of Weighting Analysis Results in South Bandung Area

1. Foundation supporting capacity analysis for habitation in south Bandung area.

Foundation carrying capacity is foundation strength (land) to hold the load in limited coverage area. This aspect is very important for the development of Settlement Region. In the research area there are 3 factors of land foundation carrying capacity :

1. Low; Foundation carrying capacity <3.6 ton/m^2, soil (surface material) arrange by organic clay, silt, and sand which is alluvium. (Score 3)
2. Medium; Foundation carrying capacity from 3.6 to 7.2 ton / m^2, soil (surface material) arranged by silt, clay to sandy silt. Quarter volcanic bedrock form of tuff, lava and breccias. (Score 4)
3. Good; Foundation carrying capacity from 7.2 to 21.6 ton / m^2, soil (surface material) arranged by silt sand. Bedrock forms of breccias, tuffs and lavas. (Score 5)

2. Land capability analysis for potential landslide

Landslide will affect the damages of both settlements, facilities public, etc. Potential ground movement is influenced by aspects of slope which is relatively steep to steep, rock constituent composition that easily eroded, and control structures which can be determined through analysis of the citra DEM (Figure 7).

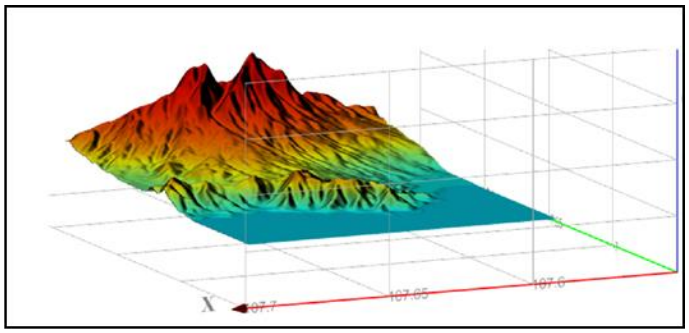

Figure 7. Digital Elevation Model of research area

1. *Very Low:* Areas that have a very low level of vulnerability to be affected by land movement. In this zone, the active soil movement, both old and new soil movement are rarely or almost never happen. This zone is located in the northern part of the research area. (Score 5)
2. *Low:* Areas that have a low level of vulnerability of soil movement. Generally in this zone is rare ground movement, and if there is a long slope ground movement will stabilize yourself back. The small dimension of ground movement may occur especially at the cliff and the river valley on the slopes rather steep cliffs. (Score 4)

E-ISSN : 2579 – 3136

3. *Medium:* Areas that have medium vulnerability level to ground motion. In this zone can occur land movements, especially in areas adjacent to river valleys, escarpments, road cliffs or if the slope is impaired. Old soil movements can reactivate due to high rainfall and strong erosion. Slope ranges from slightly steep to steep depending on the physical condition and engineering of rocks and soil forming slope, but generally the composers of this region are relatively homogeneous and harsh. (Score 3)
4. *High:* Areas that have high levels of vulnerability are exposed to ground motion. In this zone there is often a movement of land, while the movement of old and new soil is still actively moving due to high rainfall and strong erosion. The slope ranges from slightly steep to almost erect. (Score 2)
5. *Very High:* Areas that have a very high level of vulnerability of soil movement. This zone is located at the end of the transport of material erosion region that could be affected by a high pile of landslide material. And this region is around the zone of geologic structures (faults), then it has a very small chance to build infrastructure, because it is very susceptible to damage occurred. So, it is not possible to be a residential area and education. (Score 1)

3. Land capability analysis for earthquake

Earthquake is one aspect of regional capability that is important in the development of Settlement Area and Agricultural area. In the research area there are 2 factors of earthquake scale, namely:

1. *Medium Scale:* This area has potential to shake due to earthquake with scale VI MMI. Potential occurrence of land cracks, liquefaction, landslide on the topography of the hills and the occurrence of land shifts in small dimensions. The speed of the earthquake is in the range of 0.20 - 0.25 G. Generally composed of tertiary rocks, and some of the quarterly sediments commonly traversed by structures and depths of medium earthquake sources (35 - 90 km). (Score 3)
2. *High Scale:* This area could potentially occur with scale earthquake shaking intensity VII-VIII MMI. It has potential to crack the ground, liquefaction, and avalanches on steep topography. Acceleration of earthquake can occur between 0.25 to 0.30 G. This zone is close to the source of the earthquake on the ground with a shallow depth. This zone is composed by Quaternary rocks in the form of alluvium and volcanic rubuhan. (Score 2).

4. Residential area capability

Based on the statistical analysis of regional capabilities (Table 1 and Table 2) in the development of residential areas and educations, the research area was divided into five regions with the region's ability scores as follows:

1. Total score > 144, categorized as a region with very high level of capability region.
2. The total score in the range of 130 - 144, categorized as areas with high area capability levels.
3. The Total score in the range of 116 - 130, categorized as region with medium area capability level.
4. The total score in the range of 102-116 categorized as a region with a low level of regional capabilities.
5. The Total score < 102, categorized as region with very low area capability level.

Table 2. Weighted Land Capability

Land Capability	Characteristics	Weight	Score	Total
1. Physical Characteristics of Rocks				
Intercalated Andesite Breccia Unit	Composed by andesitic lava flow coating with intercalated pyroclastic breccia	5	5	25

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Andesite Unit	It is dominated by andesite and there are tuff, breccias, and pumice stone in some places		4	30
Tuff Unit	Dominated by tuff material, but in some streams found lava and breccias		3	15
Alluvial Deposition Unit	In the form of fine material dominance of clay - silt, soft, loose material, impermeable		1	5
2. Potential Ground Water				
A wide-ranging aquifer	Ground Water Level (GWL) at 2 - 5 meter below ground water, the aquifer through inter grain space	5	5	25
Productive aquifers are broad	Ground Water Level (GWL) at 4 - 9 meter below ground water, the aquifer through the inter-grain space spaces		4	20
Productive aquifers are local	Ground Water Level (GWL) at 2 - 5 meter below ground water, the aquifer through inter grain space		3	15
Local productive aquifers	Ground Water Level (GWL) at 4 - 9 meter below ground water, the aquifer through the inter-grain space spaces		2	10
Groundwater areas are scarce	Groundwater face, aperture aquifers and rare groundwater		0	0
3. Bearing Capacity of Soil Foundations				
High	Bearing capacity of foundation 7.2 - 22 tons / m^2, soil: silt sand and sand pebbles	5	5	25
Medium	The carrying capacity of the foundation is 3.6 - 7.2 tons / m^2, soil: silt, clay to silt sandstone		4	20
Low	The carrying capacity of foundation <3.6 tons / m^2, Soil: organic clay, silt, and sand		3	15
4. Potential of Mass Movement				
Very low	Land activation movement (old) and (new) did not happen	5	5	25
Low	Ground movements (new) occur on small-scale valley cliffs		4	20
Medium	New soil movement occurs, the movement of land (old) active again		3	15
High	Ground movements (old) and (new) are actively moving		2	10

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Very High	There are structural controls, and frequent landslides		1	5
5. Earthquake				
Medium scale	*Liquefaction*, 0,20-0,25 G, a medium depth source	5	3	15
High Scale	*Liquefaction*, 0,25-0,30 G, the source of shallow depth		2	10
6. Volcano				
Safe zone	Not affected by volcano eruption, Far from the source of volcano	5	5	25
Danger Zone	High potential volcano eruption, close to the source of volcanoes		0	5

5. Zone of compliance of residential area

Based on the statistical analysis of the ability of the region in the development of residential areas, it can be classified more specifically with the level of land suitability (Figure 8). The research area is divided into three regions with the regional suitability score as follows:

1. *Possible Areas:* This area has score > 130, scattered in the middle (East and West) area of research, with the ability of high to very high possibility to be developed into a residential area. It is against aspects of the potential for natural disasters which is very low, the potential existence of good ground water and good soil bearing capacity.
2. *Area Constraints:* This region has score of 116-130, scattered in the north, central, and southeast, with the ability for the area being developed into residential areas. It is based on a variety of obstacles that may occur, but these obstacles are tackled by engineering techniques to minimize or prevent such problems occur. These constraints include poor drainage, rare ground water, steep slope, and potential flood can be treated with drainage channel improvement.
3. *Areas of limitation:* This region has score of <116, dominated in the south and central area of research area. It has the ability to become very bad area to be developed into a residential area. It is based on various constraints that might occur, with engineering capabilities are still limited as an example of the flood that in the northern area of research has occurred in the Dutch colonial period, so that this region needs to be transformed to enable the reserve. South region can be utilized as a protected forest area. The obstacles that can occur in the forms of floods, steep slopes, volcanic eruptions, landslides, rare groundwater conditions, and so on.

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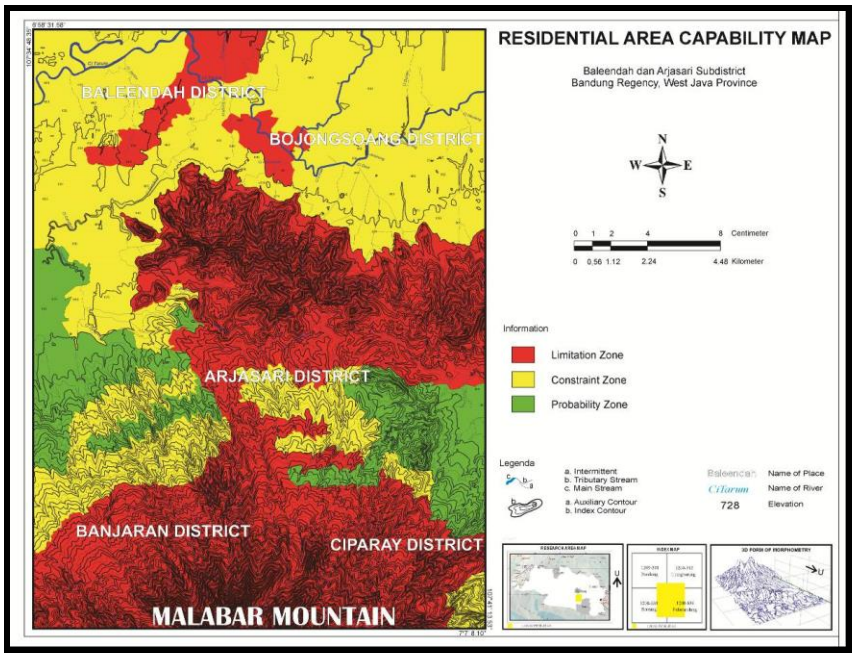

Figure 8. Residential Area Capability Map

6. **Zone of conformity of agricultural area**

Based on calculations using statistical analysis, the ability of the land, then it can be classified more specifically to the level of land suitability (Figure 9) The research area is divided into three regions with the regional suitability score as follows:

1. *Possible Areas:*This area has score > 114, scattered in the northern and eastern parts of the research area, with the ability of high to very high possibility for developed into agricultural research campus of the Padjadjaran University. It is against aspect of the potential for natural disasters which is very low, the type of soil that supports for mediated plant, and the potential of good groundwater presence.
2. *Area Constraints:* This area has score 92 - 114, scattered in the northern and central areas of research, with the ability of the area being developed into the area of Agricultural Research Center. This is based on various constraints that may occur, but the constraints can still be overcome by engineering and cost is not too high., These constraints include poor drainage, rare groundwater, slope and potential flood disasters that can be overcome by improving drainage channels.
3. *Areas of Limitation:* This region has score < 92 dominated in the southern and central part of the research area, with bad to very poorly regional capability to be developed into Agricultural Research Center. This is based on various obstacles that may occur, with engineering capabilities such as in the Southern Region with slightly steep slope to steep can be utilized as a protected forest area. Constraints that can occur are in the form of floods, steep slopes, volcanic eruptions, landslides, rare ground water conditions, etc.

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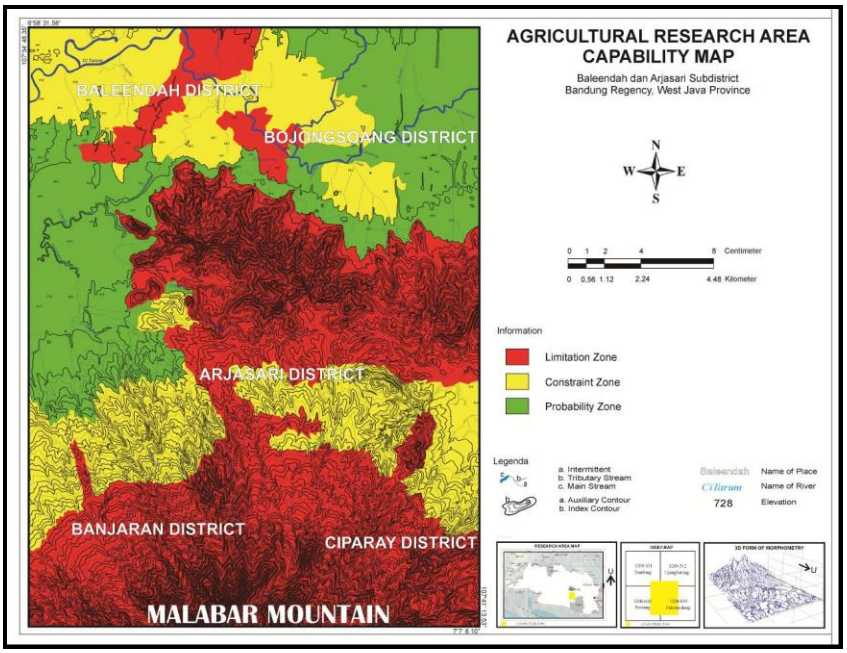

Figure 9. Agricultural Research Area Capablity Map

CONCLUSIONS

Based on the results of geological analysis, satellite imagery analysis, and calculation by using scoring analysis on the ability of the area in the development of residential and educational areas, the research area is divided into five areas of regional capability with the following scores:

A. Total scores > 144 for Residential Areas and total score > 135 for Central Agricultural Center, categorized as areas with very high regional capability.

B. Total score in the range of 130 - 144 for Residential Areas and the score of 14 - 135 for the Agricultural Research Area, categorized as areas with high area capability levels.

C. Total score in range of 116 - 130 for residential areas and the score of 92 - 114 for the Central Agricultural Research Institute, categorized as areas with medium area capability.

D. Total score in the range of 102 - 116 for residential areas and the score of 71 - 92 for the Central Research Institute of Agriculture, which is categorized as areas with low area capability levels.

E. Total score < 102 for the Residential Area and the score < 71 for the Agricultural Research Area, categorized as areas with very low regional capability.

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