RELOCATION SITE IDENTIFICATION OF DAVAO CITY USING GIS AND AHP

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ABSTRACT: Davao City is in need of larger relocation sites for the informal settlers currently living in flood-prone areas and in the road right of ways due to the development of roads to solve the worsening traffic problem. This study identified relocation sites of Davao City, Philippines using Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) tool. The criteria used for relocation site identification are safety, geographical features, zoning, and accessibility. Slope map, which was generated from Light Detection and Ranging Digital Elevation Model (LiDAR DEM), was used as the geographical criterion. These data were collected from designated agencies. By the use of GIS software, these data were weighted using analytical hierarchy process and were processed to generate map of suitable relocation sites. The map showed suitable relocation areas categorized from highly suitable, moderately suitable, poorly suitable, and unsuitable for housing. This study can provide information to the City Planning and Development Office (CPDO) to aid the search for additional relocation sites within the city.

INTRODUCTION

Relocation site identification is a land suitability process which determines the fitness of a given tract of land for a defined use (Steiner et al, 2000). It is a spatial decision problem that involves many considerations or criteria (Rikalovic et al, 2014). In order to determine the most desirable relocation areas, the criteria are set and weighted using Analytic Hierarchy Process (AHP). The main objective of the study is to produce a map showing viable relocation sites in Davao City categorized from highly suitable, suitable, moderately suitable, poorly suitable, and unsuitable. Specific objectives include: (a) to determine the criteria to be used for relocation map generation and collect those datasets, (b) to generate weight of each criterion using AHP, and (c) to generate relocation map.

The output of the study can be useful to land developers, planners, and decision makers in considering factors and constraints in other ways and also to the City Planning and Development Office (CPDO) in providing information in search of additional relocation sites.

Study Area

Davao City is located in southern part of the Philippines. From the City Information Office of Davao City, the city has a total land area of 2,444 square kilometers which makes the largest city in the country. It is divided into 3 congressional districts which are divided into 11 administrative districts. Poblacion and Talomo Districts were clustered as District I; Agdao, Buhangin, Bunawan and Paquibato were District II; and District III consists of Toril, Tugbok, Calinan, Baguio and Marilog. It has a total population of 1,632,991 people as of 2015 census. Agricultural production is the main economic activity of the city, however, the city is also the main industrial, commercial and trading hub in the island of Mindanao. Due to persistent economic development of the city, the government is keen on searching for relocation areas for the residents who will be hit by the road widening to ease the traffic flow of vehicles. On the other hand, the city is also apprehensive of transferring amilies living in the identified flood prone areas.

METHODOLOGY

According to Malczewski, et al (2015), the concept of integrating GIS and multi-criteria evaluation (AHP) is a suitable method for resolving and linking geographic data and preferences to represent information for decision making. Excellent relocation site must satisfy safety, geographic attributes (slope), zoning and accessibility criteria (Bunruamkaew et al, 2011) and also must have basic services such as water and electricity (Lopez, 2012). The

workflow of the study has four stages as shown in Figure 1. The criteria that were identified and used for the relocation site identification are safety, geographical features, accessibility, basic services, and zoning. Each criterion has sub-criteria: for the safety, the sub-criteria are flood hazard and geo-hazard maps; for the geographical features is the slope map that was generated using LiDAR DEM; for the accessibility are road networks, schools, hospitals and markets' proximity map; for the basic services are electrical and water connection map; and lastly for the zoning is the land use map. These datasets were gathered from the City Planning and Development Office of Davao City.

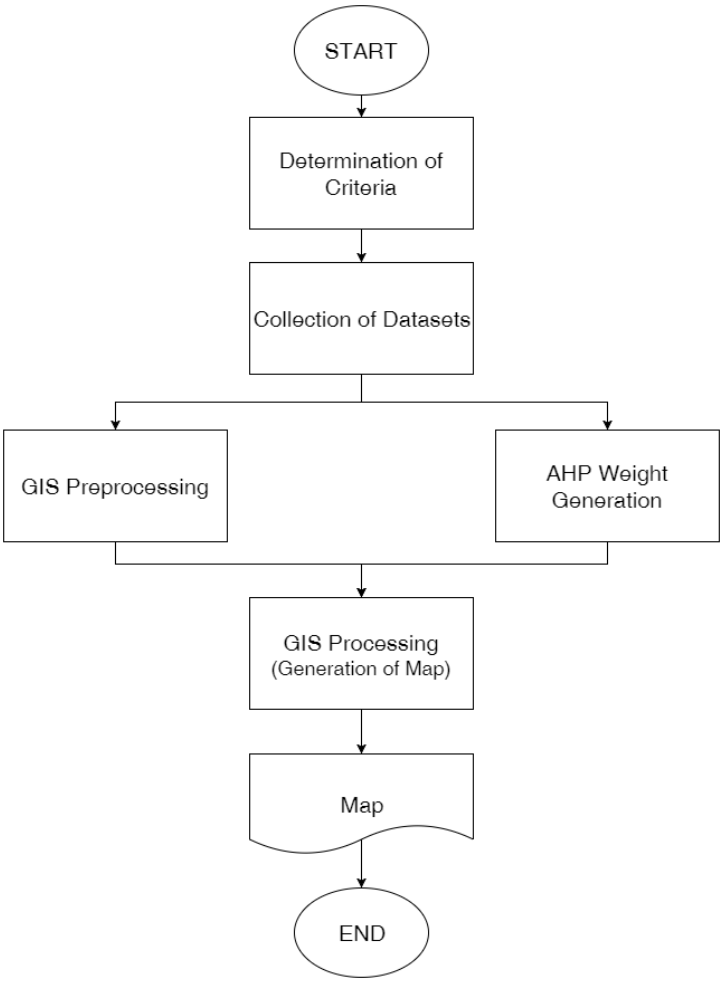

Figure 1. Process flow of the relocation site identification of Davao City using GIS and AHP

GIS Preprocessing

GIS is a wide variety of logical and mathematical analyses that displays results in a map or tabular form Eastman, et al (1998). ArcMap software was used to process maps from raw data to reclassified raster images and to perform the generation of relocation sites. The maps of each sub-criterion were georeferenced, digitized, rasterized and reclassified based on suitability rating. According to Alparslan, et al. (2008), the suitability rating of the map is 20 if it is highly suitable, 15 if it is suitable, 10 if it is moderately suitable, 5 if it is poorly suitable, and 0 if it is unsuitable. Figures 2-11 show the reclassified maps of each criterion with defined values.

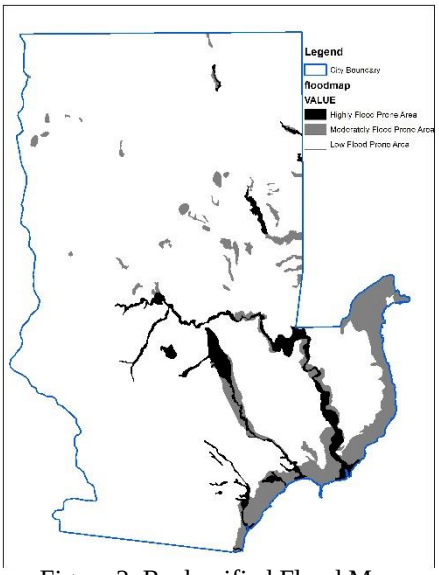

Figure 2. Reclassified Flood Map

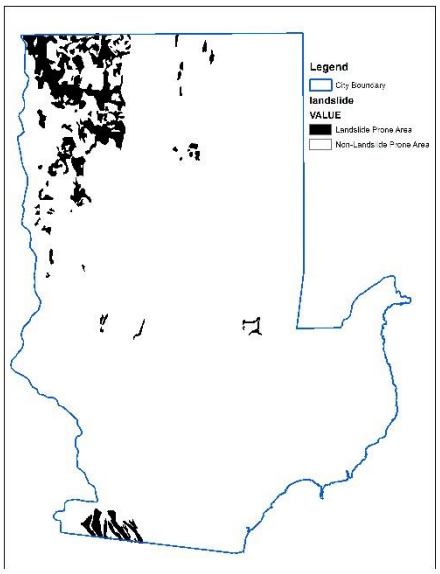

Figure 3. Reclassified Landslide map

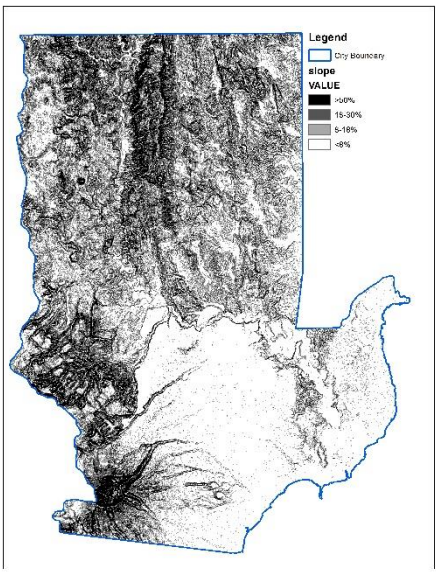

Figure 4. Reclassified Slope Map

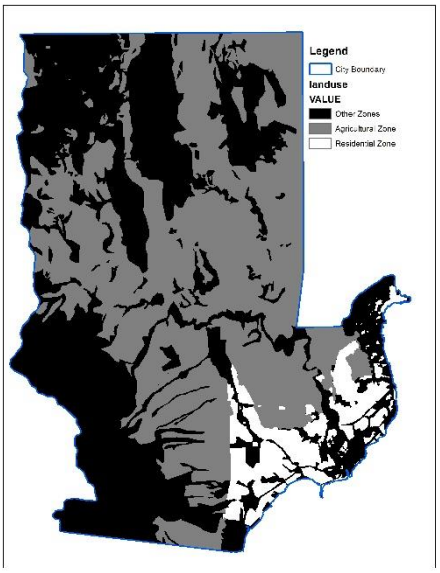

Figure 5. Reclassified Land Use map

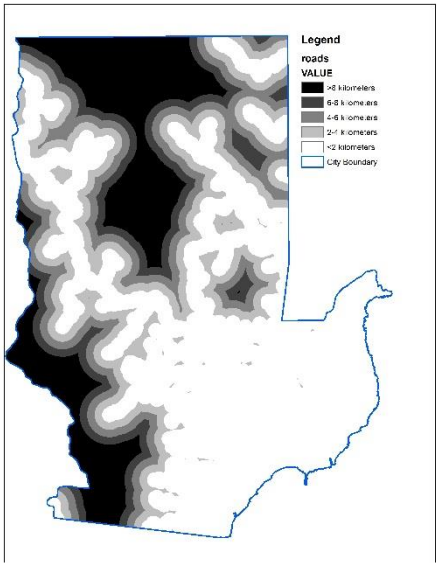

Figure 6. Reclassified Road Map

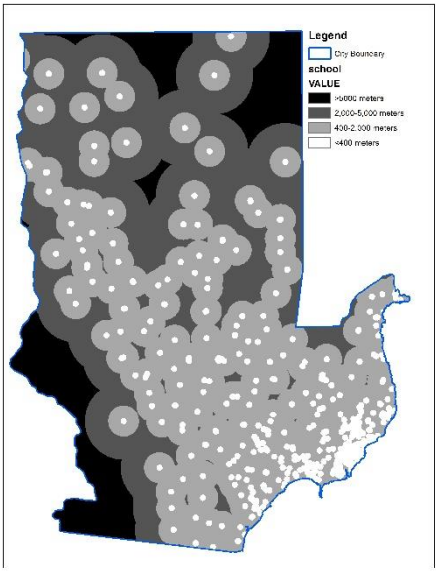

Figure 7. Reclassified School Map

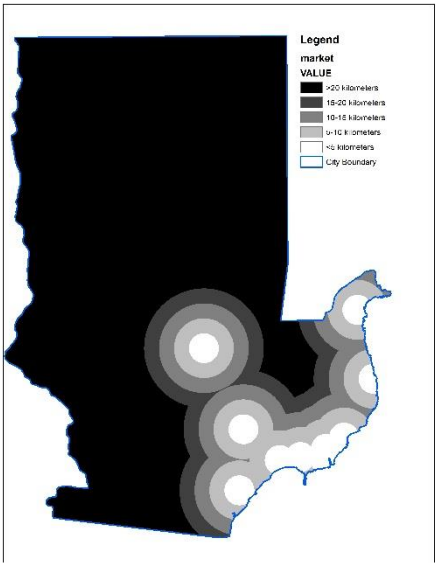

Figure 8. Reclassified Market Map

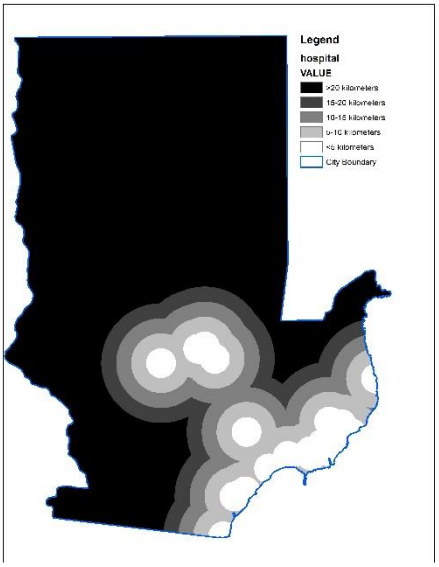

Figure 9. Reclassified Hospital Map

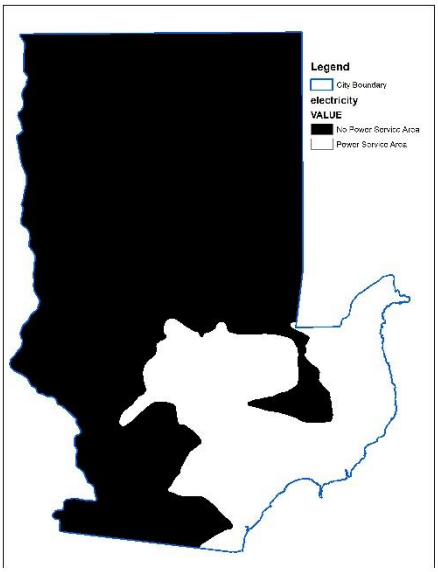

Figure 10. Reclassified Electrical Service Map

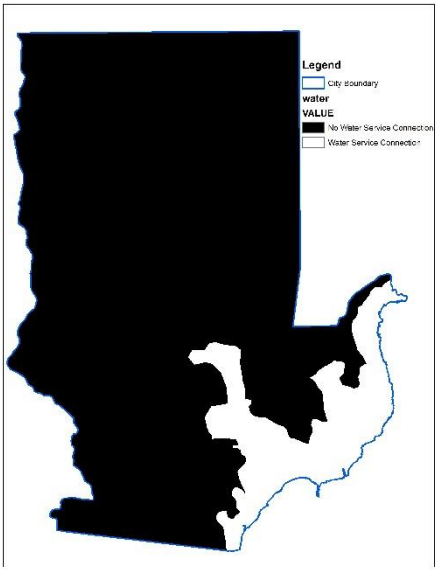

Figure 11. Reclassified Water Service Map

AHP Weight Generation

The Analytical Hierarchy Process (AHP) is the most widely used among Multi Criteria Decision Making (MCDC) methods. This method is an organized way to make decisions and collect relevant information by taking into consideration all the important factors, to derive priority scales, and use it to make a pairwise comparison between two alternatives (Saaty, 2008). Table 1 shows the pairwise comparison matrix for the criteria where a_{11} to a_{55} represent preferences between each criterion. Each column is summed up and normalized the decision matrix by dividing each element of the matrix by the column sum as show in Table 2. The row averages represent as the weight of each criterion which the sum is 1.000.

Table 1. The pairwise comparison matrix for the criteria.

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5
Criterion 1	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
Criterion 2	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}
Criterion 3	a_{31}	a_{32}	a_{33}	a_{34}	a_{35}
Criterion 4	a_{41}	a_{42}	a_{43}	a_{44}	a_{45}
Criterion 5	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}
Column totals	$S_1 = \sum_{i=1}^{5} a_{i1}$	$S_2 = \sum_{i=1}^{5} a_{i2}$	$S_3 = \sum_{i=1}^{5} a_{i3}$	$S_4 = \sum_{i=1}^{5} a_{i4}$	$S_5 = \sum_{i=1}^{5} a_{i5}$

Table 2. The adjusted pairwise comparison matrix for the criteria.

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Row Average
Criterion 1	$L_1 = \frac{a_{11}}{S_1}$	$L_2 = \frac{a_{12}}{S_2}$	$L_3 = \frac{a_{13}}{S_3}$	$L_4 = \frac{a_{14}}{S_4}$	$L_5 = \frac{a_{15}}{S_5}$	$\frac{\sum_{i=1}^{5} L_i}{5}$
Criterion 2	$M_1 = \frac{a_{21}}{S_1}$	$M_2 = \frac{a_{22}}{S_2}$	$M_3 = \frac{a_{23}}{S_3}$	$M_4 = \frac{a_{24}}{S_4}$	$M_5 = \frac{a_{25}}{S_5}$	$\frac{\sum_{i=1}^{5} M_i}{5}$
Criterion 3	$N_1 = \frac{a_{31}}{S_1}$	$N_2 = \frac{a_{32}}{S_2}$	$N_3 = \frac{a_{33}}{S_3}$	$N_4 = \frac{a_{34}}{S_4}$	$N_5 = \frac{a_{35}}{S_5}$	$\frac{\sum_{i=1}^{5} N_i}{5}$
Criterion 4	$O_1 = \frac{a_{41}}{S_1}$	$O_2 = \frac{a_{42}}{S_2}$	$O_3 = \frac{a_{43}}{S_3}$	$O_4 = \frac{a_{44}}{S_4}$	$O_5 = \frac{a_{45}}{S_5}$	$\frac{\sum_{i=1}^{5} O_i}{5}$
Criterion 5	$P_1 = \frac{a_{51}}{S_1}$	$P_2 = \frac{a_{52}}{S_2}$	$P_3 = \frac{a_{53}}{S_3}$	$P_4 = \frac{a_{54}}{S_4}$	$P_5 = \frac{a_{55}}{S_5}$	$\frac{\sum_{i=1}^{5} P_i}{5}$

It was rated using Saaty scale of 1 to 9 that defines from equal importance to extreme importance between the two comparatives, normalized the decision matrix, calculated the weights, and computed the consistency ratio. Consistency ratio defines the acceptable inconsistency when the value is less than 10% or 0.1.

GIS Map Generation

As shown in the figure below, all the reclassified raster maps were overlaid and multiplied with the equivalent weights generated from AHP and were processed using ArcMap to generate the relocation map.

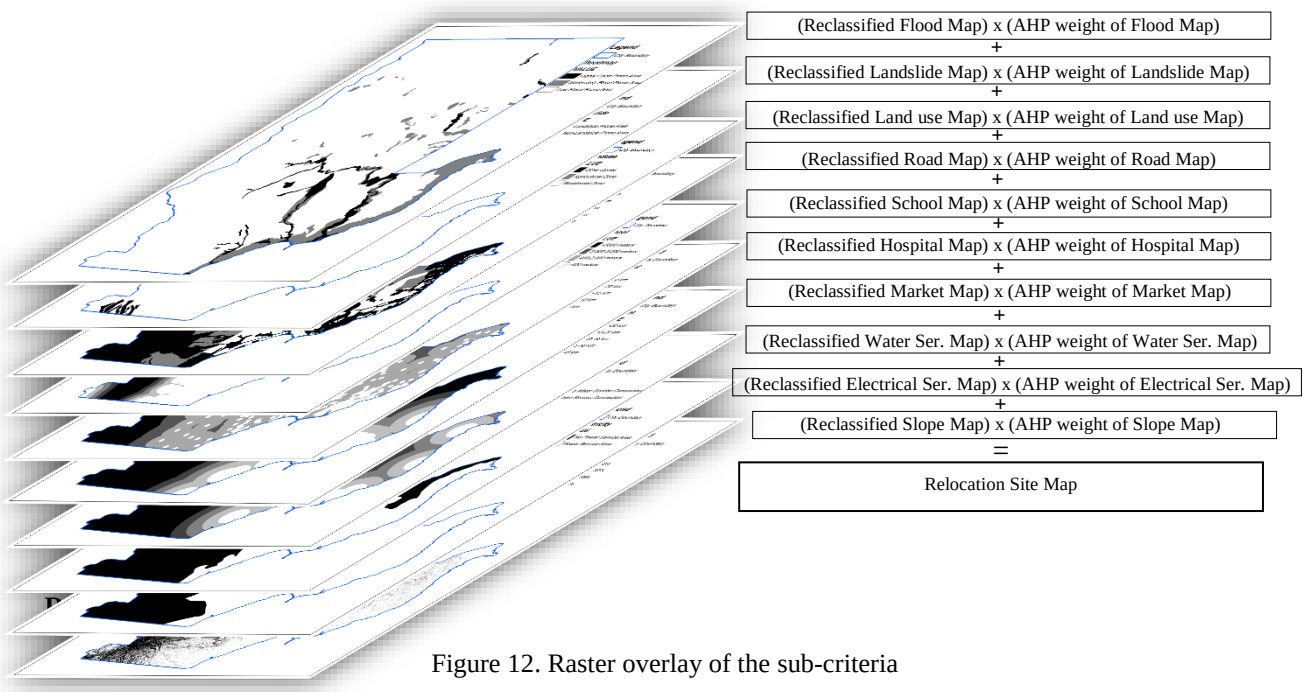

Figure 12. Raster overlay of the sub-criteria

RESULTS AND DISCUSSIONS

AHP Weight Generation

Table 3 shows the generated weights of the criteria. Safety criterion has the highest weight of 36.57 % which is considered the most important of the criteria based on them. The weight averages for sub-criteria under safety criterion is summarized in Table 4. It shows that flood and landslide hazards are equally important. Second in the rank is zoning which has a weight of 25.80%, followed by accessibility which has a weight of 15.53%. Table 5 shows the weight averages for the sub-criteria under accessibility criterion. The accessibility to road networks was considered most important, followed by schools, markets and hospitals. Further, services criterion has a weight of 13.41%, with sub-

criteria weight averages of equal values as shown in Table 6. Lastly, the geographical features which has a weight of 8.69%. The consistency ratio is at most 2.6% which is less than 10%, this means that all ratings have an acceptable inconsistency according to Saaty (2008).

Table 3. The criteria weight averages.

Criteria	Average	Final Weights (%)	Consistency Ratio
Safety	0.3657	36.57 %	2.5 %
Zoning	0.2580	25.80 %	
Geographical	0.0869	08.69 %	
Accessibility	0.1553	15.53 %	
Services	0.1341	13.41 %	

Table 4. The safety sub-criteria weight averages.

Sub-Criteria	Average	Relative Weights (%)	Final Weights (%)	Consistency Ratio (%)
Flood	0.5000	50.00	18.29	0.1 %
Landslide	0.5000	50.00	18.29	

Table 5. The accessibility sub-criteria weight averages.

Sub-Criteria	Average	Relative Weights (%)	Final Weights (%)	Consistency Ratio (%)
Roads	0.4476	44.76	06.95	2.6 %
School	0.2829	28.29	04.39	
Market	0.1636	16.36	02.54	
Hospital	0.1059	10.59	01.65	

Table 6. The services sub-criteria weight averages.

Sub-Criteria	Average	Relative Weights (%)	Final Weights (%)	Consistency Ratio (%)
Water	0.5000	50.00	06.71	0.1 %
Electricity	0.5000	50.00	06.71	

Relocation Map

Figure 13 shows the viable relocation sites of Davao City which are categorized from highly suitable, suitable, moderately suitable, poorly suitable, and unsuitable for housing. The result shows that there is 17.98% of the total land area of Davao City that is identified as highly suitable for relocation sites, this comprises 436.77 square kilometers of the city. The largest area, that is 47.54% of the total land area of the city, is identified as suitable for relocation sites which covers 1,154.67 square kilometers. Moderately suitable relocation sites encompasses 32.54% of the total land area and is equivalent to 790.31 square kilometers. The remaining 1.94% of the total land area which is equivalent to 47.04 square kilometers is identified as poorly suitable. The map shows only the areas suitable and unsuitable for housing. However, only the City Planning and Development Office of Davao City has the updated copy of built-up structures to be overlaid in the map to eliminate areas that has already occupied by the structures and able to show the available suitable areas for housing. Table 7 shows the summary of area covered by suitability rating category for each administrative district.

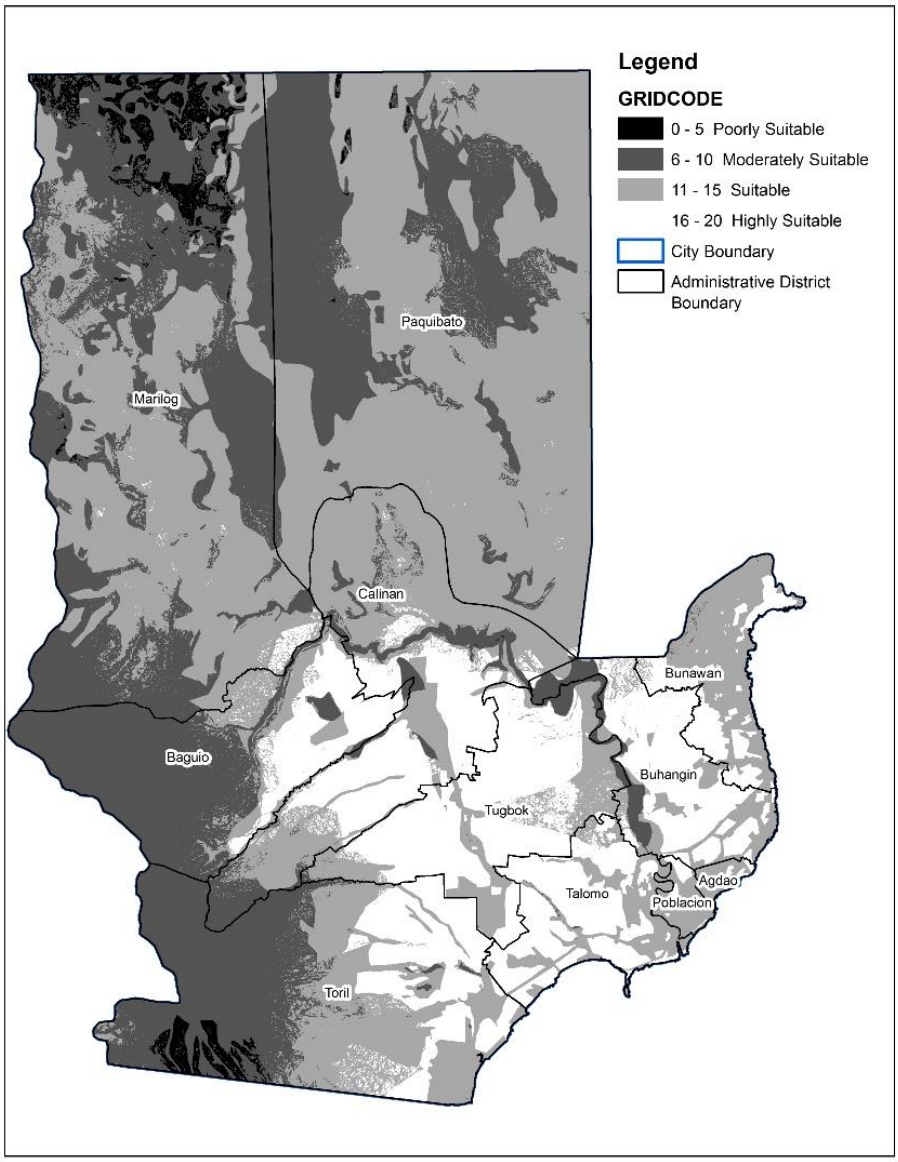

Figure 13. Map of Identified Relocation Site of Davao City

Table 7. Summary of area (in square kilometers) covered by suitability rating category for each administrative district.

District	Highly Suitable	Suitable	Moderately Suitable	Poorly Suitable	Total Area
Agdao	1.78	4.88	0.00	0.00	6.66
Baguio	41.19	32.42	114.19	0.00	187.80
Buhangin	61.13	23.55	10.66	0.00	95.33
Bunawan	23.99	45.41	0.38	0.00	69.79
Calinan	73.41	126.12	32.11	0.06	231.69
Marilog	4.36	293.22	299.20	34.43	631.21
Paquibato	0.47	447.32	207.76	1.18	656.74
Poblacion	2.36	9.40	0.02	0.00	11.77
Talomo	60.60	28.80	0.38	0.00	89.78
Toril	66.80	100.89	119.56	11.37	298.63
Tugbok	100.67	42.67	6.04	0.00	149.38

CONCLUSION

Land suitability identification of sites in Davao City using GIS and AHP produced a map that shows the possible areas for relocation of those who are residing in flood-prone areas and those who are affected with the road-widening projects. The relocation suitability map considered safety as the top priority, followed by zoning, accessibility, services, and geographical features. In addition it shows that 17.98% of the total land area of Davao City are highly suitable for relocation, 47.54% are suitable, 32.54% are moderately suitable, and 1.94% are unsuitable based from the criteria that were rated. With this, decision makers and planners will now have a concrete reference in determining land suitability by the use of GIS and AHP. Lastly, the map can help the City Planning and Development office of Davao City to aid the search for additional relocation site in the city.

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