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GIS Based Analysis for Developing Residential Land Suitability

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ABSTRACT

The process of urbanization is a universal phenomenon taking place all over the world. All countries are prone to this phenomenon mainly determined by the increase in population growth, economy and infrastructure initiatives. Bangladesh is one of the world's most densely populated countries and it has faced rapid population growth throughout the last century. Unplanned urbanization leads to land-use change and creates not only noisy and unhealthy environment but also inadequate infrastructure facilities and poor living condition. This study is an attempt to work on residential land use suitability assessment through the application of Geographic Information System (GIS) and Multi-Criteria Decision Analysis. In the study, the development of the main criterion and sub-criterion factors selected for suitability analysis were used in the Saaty's pairwise comparison of Analytic Hierarchy Process technique (AHP) for getting the weight for each of the criteria. To reflect the preferences towards a certain factor, definite to very strong preferences was given to that factor in their pair wise comparison. The consistency was checked to verify the reliability of the results of the study. Each of the input themes was assigned a weight influence based on its importance, then multiplying the given weights by each of the factor maps in the form of a Weighting Overlay process. The system integrates two major tools (GIS and AHP) in a manner that reach the correct solution to assist the decision-makers in determining appropriate values for the suitability criteria. This method would help planners and policy-makers in formulating urban growth policies and strategies of the city.

1. INTRODUCTION

The world is undergoing the largest wave of urban growth in history. Especially developing countries are facing unprecedented expansion of urban areas and growth of urban population. In this context, it is expected that 60% of the world's population will be living in urban areas by 2030, and among them most of the urban growth will occur in less developed countries [1]. Currently, according to World Health Organization (2011), about half of all urban dwellers live in cities and less than 10% of urban residents live in megacities [2]. The process of urbanization is a universal phenomenon taking place all over the world. All countries are prone to this phenomenon mainly responsible due to the increase in population growth, economy and infrastructure initiative [3]. The extent of urbanization is one such phenomenon that drives the change in land use patterns [4]. Bangladesh is not an exception to this context. Bangladesh is one of the world's most densely populated countries and has also faced rapid population growth throughout the last century. The country is going to witness a rapid spread of urbanization over the next decade [5]. The country's population will be over around 190 million by 2030 [6]. This fast urbanization is putting pressure mainly on the city's limited land. An

unplanned urbanization leads to land use change and growing of industrial areas in the residential area, which is a common phenomenon today. This situation creates not only noisy environment but also inadequate infrastructure facilities, unhealthy environment and poor living condition. In most cases the City Authorities are facing challenges for the unplanned development.

Though the formal comprehensive policy on urbanization is in the process of formulation, the government has already undertaken some programs which either constitute part of a possible national policy or provide guidelines or indications for such a national policy. In Bangladesh, the first National Development Plan was elaborated in 1973 and had comprehensive coverage of the urban sector. The following plans and programs have been undertaken by the government wherein public and other stakeholders were consulted so as to ensure governance issues: preparation of *Detailed Area Plans* (DAPs), preparation of *Structure Plan,* and *the Master Plan*. These plans are elaborated by various planning organization of Bangladesh under the supervision Ministry of Housing and Public Works [7]. The existing planning rules are not properly exercised by relevant organizations (i.e. RAJUK for the capital city of Dhaka) to control and manage the development of the city. One of the main reasons behind this is the insufficient legal support. It happens that they move away from their master plan in many cases. People also violated the plans during the construction of buildings and structures because of lack of law enforcement and strong monitoring. On the other hand, RAJUK is not sufficiently equipped with institutional capacity to foresee the consequences of issuing randomly the plan-permissions of construction to individual/company owning the plot. As a result, cities are experiencing haphazard-unplanned urbanization with unmanageable population size and at the end of day a completely unmanageable city. Corruption and unethical practice in the plan permission starting from land use clearance to building permission is also a common phenomenon for Bangladesh, which is obstructing the planned development of the city [8].

Residential areas are the major part of urban land use in any city. Residential environment in a city gives the sense of belongingness among residents. As a planned residential neighborhood, it provides opportunity of more social interaction and increases social security or comfort, and city dwellers usually prefer to live in this area [9]. The tasks for designing a residential area includes formulating location requirements, mapping the suitability for development of a residential area, deriving space requirements, analyzing the holding capacity of suitable lands, adding local shopping and other population supporting uses and facilities, and finally, synthesizing all those considerations into a land use design [10]. For proper land use planning, suitability measures are important tools of planning. This study is an attempt to work on residential land use suitability assessment through the application of Geographic Information System (GIS) and Multi-criteria Decision Analysis.

The hypothesis of the study can be stated as follows - *It is expected to prepare reliable residential land suitability map and also to identify considerable number of potential area to support housing with mutual application of GIS technology and Pairwise comparison*. Land use suitability analysis considered various criteria in this study, such as natural capacity of land use, socio-economic and environmental variables. Geographic Information System (GIS) is an important tool to handle spatial data in land use analysis. However, GIS application is not enough to overcome the issue of inconsistency when judging and assigning relative importance to each of the many criteria considered in a suitability analysis. To address this inconsistency issue and for evaluating the various factors considered in residential land suitability, pairwise comparison of AHP techniques has been chosen [11].

2. RESEARCH PROBLEM

Population is growing fast and land is in shortage, as well. In response to the growing demand for housing, private land development companies play a dominating role on the land market. Even though there are sufficient policies for planned development of housing projects, due to high profit making approach of land developer companies, most of the large cities of Bangladesh are growing in an unplanned way. This is causing adverse effects on the environment and society. If people begin to reside in unplanned way, they will face problems due to lack of utilities and other community facilities [12]. So, suitability assessment is necessary for residential land use in the present context of Bangladesh. The current land suitability practice in Bangladesh is focused primarily on agricultural issues, such as crop zoning, crop suitability for specific land and also for aquaculture activities. There are also some research works on suitability of coastal zoning as Bangladesh is vulnerable to natural disasters. Till now there is no published work related to land suitability assessment for residential land use in Bangladesh. Land suitability assessment can help planners to select proper areas for planning development activities according to the different land use type. By taking the results of land suitability assessment into consideration properly, planners and decision-makers can plan the future land use planning properly and maximize benefits from the use of land resources.

Aims: The main aim of this study is to find a suitable land use location for residential use in the Rajshahi Development Authority Area. To attain the

aim the following research questions and objectives have been developed.

2.1. Research questions

a). What is the existing condition of land use in the study area and why is it necessary to define suitable location for residential use?

b). What are the available techniques for identifying suitable location of residential use?

c). How Multi-Criteria Decision Analysis will be helpful for developing suitability analysis?

d). What will be the role of GIS techniques in developing the residential land suitability?

2.2. Objectives

a). To develop a conceptual framework for understanding land use suitability techniques.

b). To design and develop a GIS-based land suitability for residential use.

3. LITERATURE REVIEW

Carver (1991) worked on for suitable sites for the disposal of radioactive waste in the UK using the Arc/Info GIS. He tried to discuss the integration of multi-criteria evaluation (MCE) techniques with GIS to evaluate various alternatives on the basis of multiple and conflicting criteria and objectives [13]. This paper gave an introduction to the basic principles of MCE and also made a discussion on how the two techniques may be combined.

In his paper, Mu (2006) tried to examine how land suitability assessment methods could be used in land planning processes in China to identify where future residential development should be located [14]. He examined Toronto Waterfront Plan and the more recent 2005 Ontario Greenbelt Plan to develop a framework for describing the potential for land suitability assessment in his study area.

Shalabi et al (2006) in their paper entitled *GIS Based Multi-criteria Approaches to Housing Site Suitability Assessment* developed a model to evaluate the possible location of building sites and the authors also tried to make a decision on the location of additional housing areas in Sana'a city [15]. For doing so they used several decision support tools such as high spatial resolution remotely sensed data, Geographical Information System (GIS) and Multi-Criteria Analysis (MCA) using analytical hierarchy process (AHP).

In their research, Sarmadian et al. (2010) tried to analyze the application of MCDM method in Fuzzy Modeling of Land Suitability Evaluation [16]. They used Pairwise Comparison Method in the form of Analytical Hierarchy Process (AHP) for weighting different assessment criteria for land suitability of an irrigated wheat field in Takestan.

Patil et al (2012) described the role of Analytical Hierarchy Approach for the land use suitability of residential land [17]. An attempt has been made by authors for residential land suitability analysis in the Analytical Hierarchical Process in combination with environmental factors using spatial technique for Pimpri – Chinchwad - Municipal Corporation (PCMC) area. In case of Bangladesh, GIS developed rapidly in the past twenty years.

The application of GIS in Bangladesh started in 1991 by ISPAN (Irrigation Support Project for Asia and the Near East) for the Flood Action Plan-19 Project [18]. Since the late 1990s, GIS have been applied to land suitability assessment for managing spatial data and presenting visual results in agricultural sector.

4. WORKING METHODOLOGY

Among the various methods, weighted suitability analysis has been chosen for defining the residential land use suitability. The reason for using weighted suitability analysis with raster data is to solve a multi-criteria problem quickly and easily.

ArcGIS and some of its extensions and tools such as model builder have been used for performing the whole work. The working steps are as follows:

Step 1. Data collection and processing.

Step 2. Criteria selection for achieving the aim.

Step 3. Weighting and scoring of selected criteria.

Step 4. Calculation of each criterion and inconsistency checking.

Step 5. Development of criteria map with reclassification.

Step 6. Preparation of the final suitability map.

These steps focused on establishing a set of criteria and sub-criteria. Then it assigned ranks to the criteria and alternatives. A pairwise comparison method /matrix was carried out to get relative weights. Then, gathered weights were computed manually by the author keeping view of consistency ratio (CR). If CR is satisfactory, the computed weights will be recorded for further processing. It should be noted that for preventing bias thought criteria weighting the consistency ratio (CR) was used.

The main techniques used for executing the weighted suitability analysis were direct ratio technique, geo-processing, development of Pairwise Comparison Matrix for Criteria Ranking, computation of the Criterion Weights, reclassification and weighted overlay, pass or fail screening for erasing the no go zone.

4.1. Data collection

To complete the study various types of data/information was necessary. The nature of the study is that it is mainly based upon GIS database and theories.

Data were collected both from primary and secondary sources. One of the key source was Expert's Opinion regarding criteria selection for suitability analysis.

The author conducted interviews with some experts whose field of expertise is on Housing & Planning development. Discussion with Urban Planner of Rajshahi Development Authority (RDA) regarding the existing condition and related problem of the study area were carried out. GIS database was also taken from RDA Urban Planner.

Interview with the ordinary people of the study area for taking the existing land values of the study area. Secondary data are quite important to back up the study. Secondary sources include different study reports, master degree dissertation, statistical books, international journal articles, relevant rules and regulation of Bangladesh etc.

4.2. Criteria selection

In general, the development of urban residential land use is influenced by numerous factors. These include physical, socio-economic and environmental quality and amenities [19]. Criteria were selected to get prospective housing sites, i.e. residential land use of the study area. The criteria were selected in accordance with the literature and planning guidelines (master plan, detail area plan, structure plan) of the study area. These factors are shown in Table 1.

Table 1. Criteria selection for suitability analysis.

Main criteria	Sub-criteria	Main criteria	Sub-criteria
Accessibility of service and facilities	Near to existing settlement	Socio-economic aspects	Population density
	Distance to market places		Land value
	School proximity	Environmental aspect & safety	Flood prone area
	Hospitals proximity		Airport area
	Distance of park and playground		Industry and brick burning kiln
Road accessibility	Road proximity of paved and semi-paved road	Topographical aspect	Slope
	Proximity of bus stops		
	Distance to major highways		

Source: elaborated by the author, 2014.

4.3. Weighting and scoring of selected criteria

For suitability analysis it is necessary to assign some score to each of the criteria as per their suitability for urban development. For this purpose the pairwise comparison matrix using Saaty's nine-point weighing scale was applied (Table 2).

These pairwise comparisons were taken as input and relative weights were produced as an output.

Table 2. Nine-point weighting scale for pairwise comparison.

Intensity of importance	Definition	Suitability class
1	Equal importance	Lowest suitability
2	Equal to moderate importance	Very low suitability
3	Moderate importance	Low suitability
4	Moderate to strong importance	Moderately low suitability
5	Strong importance	Moderate suitability
6	Strong to very strong importance	Moderate high suitability
7	Very strong importance	High suitability
8	Very to extremely strong importance	Very high suitability
9	Extremely importance	Highest suitability

Source: Extracted from Satty, (1980) & prepared by author, 2014.

4.4. Calculation of each criterion and inconsistency checking

After the formation of pairwise comparison matrix, computation of the criterion weights had been done. The computation involves the some operations like: a) finding the sum of the values in each column of the pairwise comparison matrix; b) division of each element in the matrix by its column total (the resulting matrix is referred to as normalized pairwise comparison matrix); and c) computation of average of elements in each row of the normalized matrix, i.e. dividing the sum of normalized scores of each row by the total no of criteria (Table 3 & 4).

Table 3. Pairwise comparison matrix.

Criteria	Pairwise comparison matrix				
	Accessibility of service & facilities	Road accessibility	Socio-economic aspects	Environmental aspect & safety	Topographical aspect
Accessibility of service & facilities	1.00	2.00	4.00	5.00	9.00
Road accessibility	0.50	1.00	2.00	4.00	5.00
Socio-economic aspects	0.25	0.50	1.00	2.00	4.00
Environmental aspect & safety	0.20	0.25	0.50	1.00	2.00
Topographical aspect	0.11	0.20	0.25	0.50	1.00
Total	2.06	3.95	7.75	12.5	21.00

Table 4. Normalized pairwise comparison matrix.

No. crt.	Accessibility of service & facilities (a)	Road accessibility (b)	Socio-economic aspects (c)	Environmental aspect & safety (d)	Topographical aspect (e)	Computation of weights (a+b+c+d+e)/5
1	0.49	0.51	0.52	0.4	0.43	0.47
2	0.24	0.25	0.26	0.32	0.24	0.26
3	0.12	0.13	0.13	0.16	0.19	0.15
4	0.10	0.06	0.06	0.08	0.09	0.08
5	0.05	0.05	0.03	0.04	0.05	0.04
Total	1.00	1.00	1.00	1.00	1.00	1.00

4.4.1. Estimation of the Consistency Ratio

After computing the weights for five criteria, a calculation was made to estimate the inconsistency by Consistency Ratio (CR) checking. CR is generally used to measure how reliable the decisions made relative to several criteria of purely random judgments. The AHP deals with consistency explicitly. During making paired comparisons between criteria, it is usual that people do not have the intrinsic logical ability to always be reliable [21]. For estimating consistency, the following process was followed:

a). The first step is computation of the weighted sum vector (Table 5). It was done by multiplying weight of matrix comparisons for each of the criteria by the vector of priorities to get a new column vector. Then, the first component of weighted sum vector was divided by the first component of priorities vector to get consistency vector. This way, all the component of weighted sum vector were divided by the component of priorities vector with the help of the previous Table 4. Finally, sum up these values over the rows.

b). After the calculation of consistency vector, another two terms i.e. lambda (l) and the consistency index (CI) calculations were required to check the inconsistency. The value for lambda computed as the average value of the consistency vector (Table 5).

Table 5. Computation of consistency vector.

Criteria	Weighted sum vector	Consistency vector
Accessibility of service & facilities	[(1*0.47)+(2*0.26)+(4*0.15)+(5*0.08) +(9*0.04)]= 2.35	2.35/0.47=5
Road accessibility	[(0.5*0.47)+(1*0.26)+(2*0.15)+(4*0.08)+(5*0.04)]= 1.315	1.315/0.26=5.06
Socio-economic aspects	[(0.25*0.47)+(0.5*0.26)+(1*0.15)+(2*0.08)+(4*0.04)]=0.72	0.72/0.15=4.8
Environmental aspect & safety	[(0.2*0.47)+(0.25*0.26)+(0.5*0.15)+(1*0.08)+(2*0.04)]=0.39	0.39/0.08=4.88
Topographical aspect	[(0.11*0.47)+(0.2*0.26)+(0.25*0.15)+(0.5*0.08)+(1*0.04)]=0.22	0.22/0.04=5.5
Lamda (λ) = Average of consistency vector (5+5.06+4.8+4.88+5.5)/5=5.05		

The calculation of CI is based on the observation that l is always greater than or equal to the number of criteria under consideration (n) for positive, if the pairwise comparison matrix is consistent matrix.

This measure was normalized with the following equation:

$$CI= (\lambda-n)/ (n-1)$$

as n=5 main criteria = (5.05-5)/ (5-1)= 0.0125

The term CI, is defined as consistency index. To determine the quality of C.I., AHP compares it by random index (R.I.) and the result is called consistency

ratio (C.R.), which can be defined as:

$$CR = CI/ RI$$

The random index is the consistency index of a randomly generated pairwise comparison matrix of order 1–10 obtained by approximating random indices using a sample size of 500 [25].

Table 6 shows the value of R.I. sorted by the order of matrix. The consistency ratio (CR) is designed in such a way that if CR<0.10, the ratio indicates a reasonable level of consistency in the pairwise comparisons; if, however, CR >0.10, then the ratio indicates of inconsistent results. In such cases one should review and go through again the original values in the pairwise comparison matrix.

Table 6. Average random consistency index (RI).

Order matrix	1	2	3	4	5	6	7	8	9	10
R. I.	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Extracted from [22], [23] & [24].

$$CR = CI/ RI= 010125/1.12 = 0.011$$

So, the ratio of 0.011 indicates a reasonable level of consistency in the pairwise comparisons. For the calculation of the sub-criteria the author took the help of Expert choice software. As there were 16 criteria that is why expert choice software was used. With the help of this software along with the calculation of criteria weight, consistency ratio was also checked. It should be noted that in that case the consistency ratio was also less than 0.10.

Another thing is as slope is only one sub-criteria under topography and it was already calculated in the previous section so this was not calculated again under the expert choice.

4.5. Development of criteria maps

Depending upon the reclassification, 16 criteria maps were prepared separately (Figure 1-16). For preparing the criteria map, buffer distances (in meters) from the criteria were carried out for defining the suitability level. The buffer distance for each criterion depends upon author's idea, databases of the study area, expert opinion, relevant rules and regulation especially [26].

The author used the Schedule-3 (Space Standards for Urban Community Facilities in acres by Population size) of this rule to find out the space standards.

These criteria maps showed the suitability level of different class i.e. the lowest suitable to the highest suitable. After reclassification and weighted overlay, these classified raster maps were converted again in polygon data and then the no go zone was erased from the weighed overlay result to get the final site suitability map.

After that some cases were also tested to get the best output.

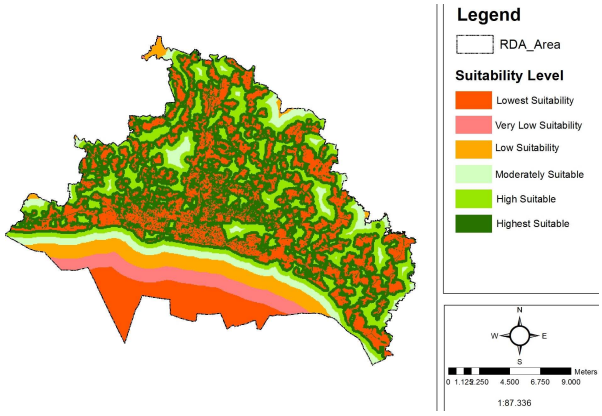

Fig. 1. Nearness to existing settlement suitability.

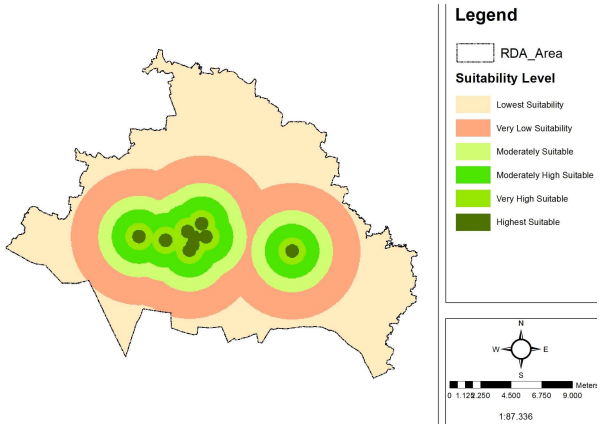

Fig. 2. Close to market/central place.

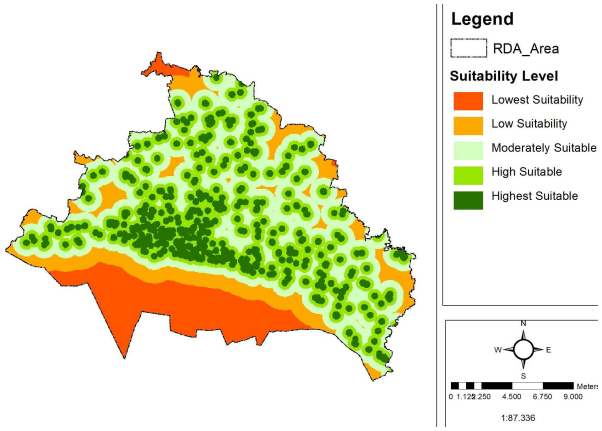

Fig. 3. School proximity.

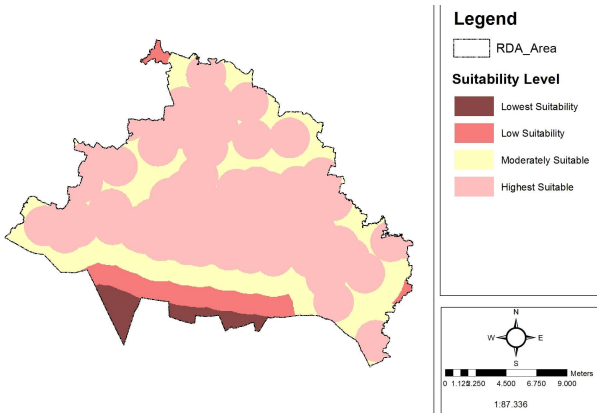

Fig. 4. Hospital proximity.

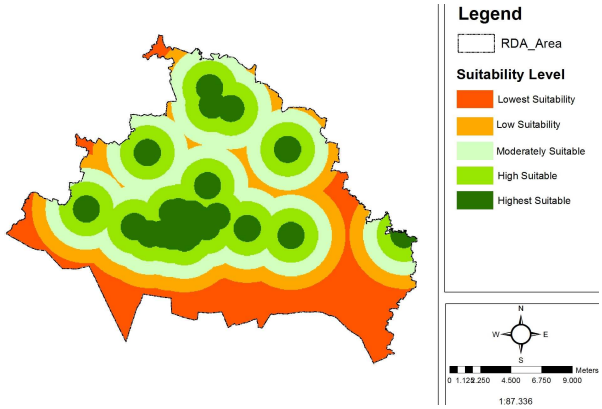

Fig. 5. Close to park and playground.

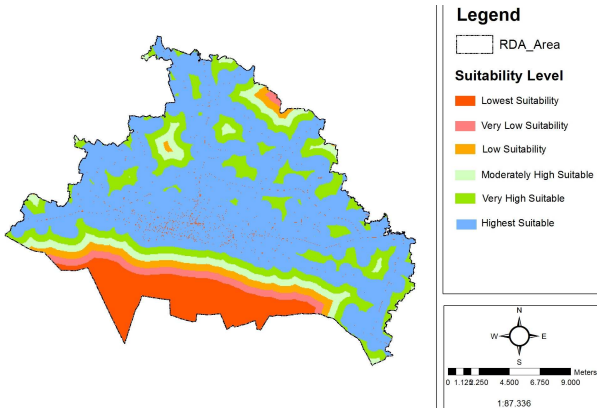

Fig. 6. Close to paved road.

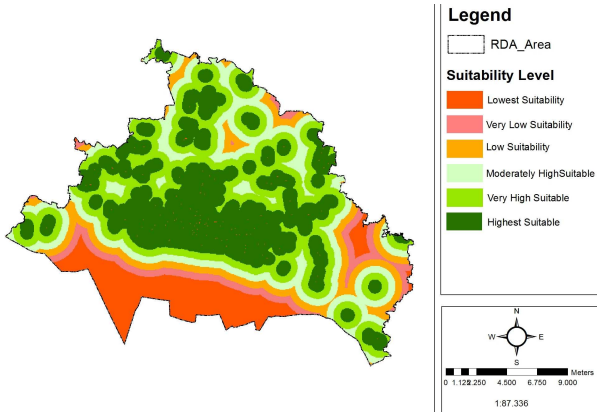

Fig. 7. Proximity to semi-paved road.

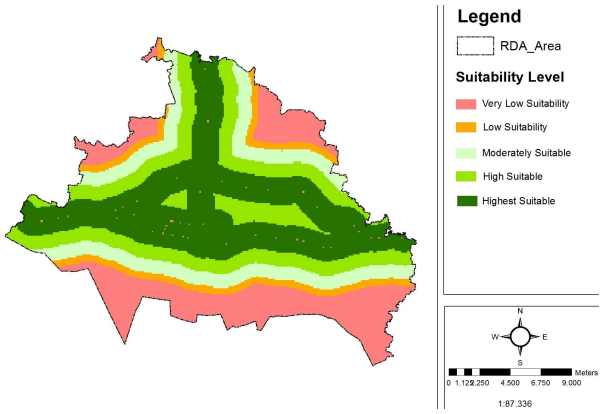

Fig. 8. Major highways and suitability.

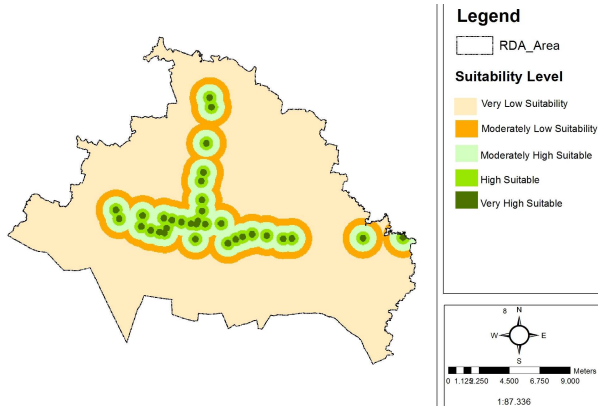

Fig. 9. Near to bus stops.

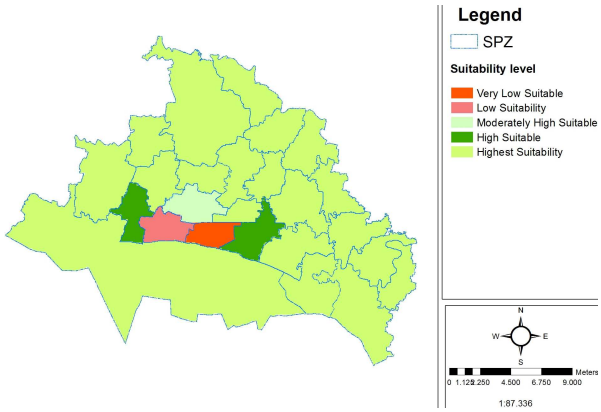

Fig. 10. Population density per km².

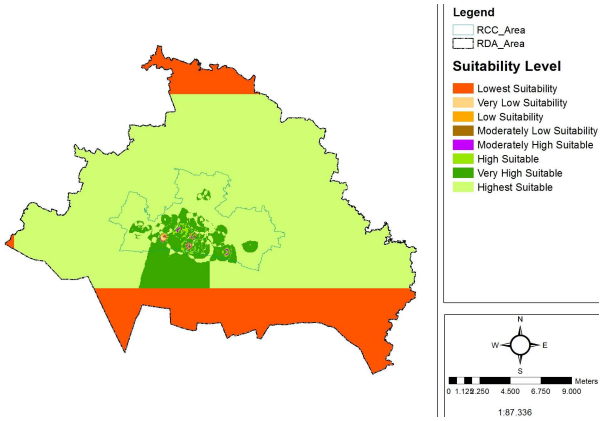

Fig. 11. Land price suitability.

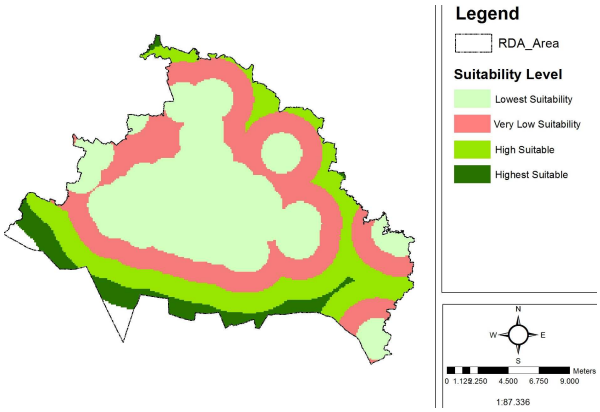

Fig. 12. Suitability in respect of industrial location.

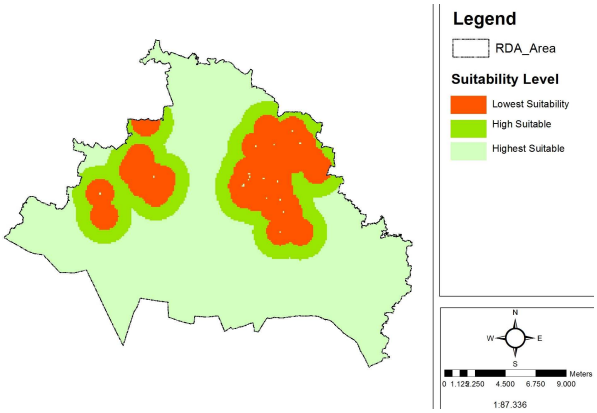

Fig. 13. Brick field location and residential suitability.

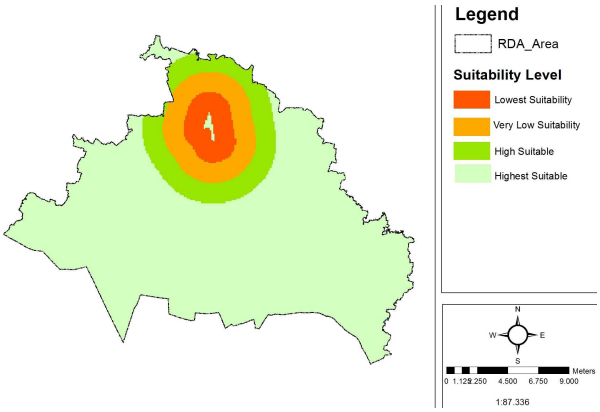

Fig. 14. Airport location and residential suitability.

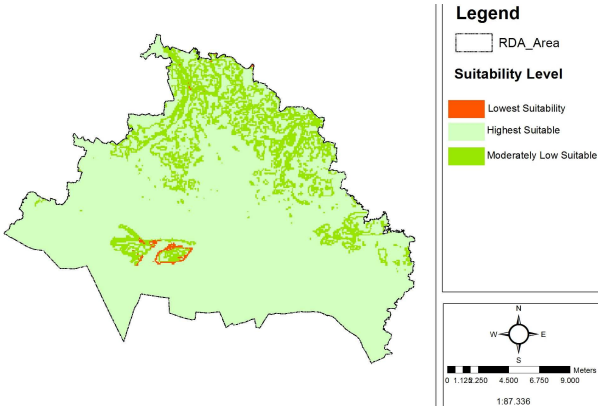

Fig. 15. Flood prone area and suitability.

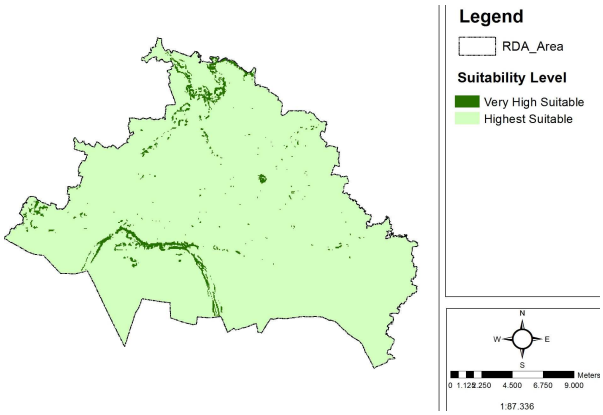

Fig. 16. Slope level and suitability.

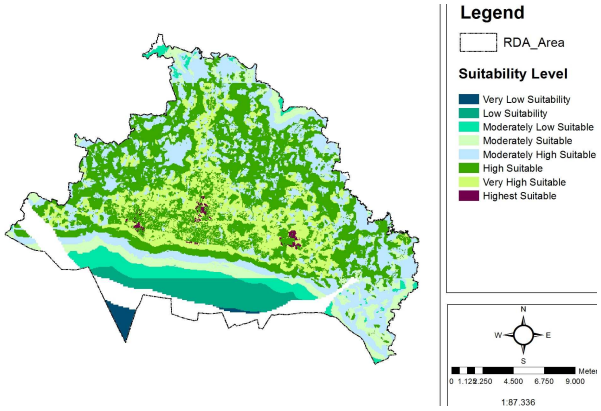

Fig. 17. Weighted overlay output of the study area.

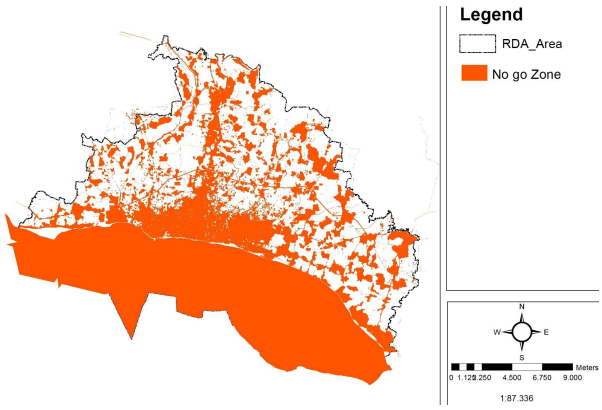

Fig. 18. No go zone of the study area *(source: [27] & Prepared by author, 2014).*

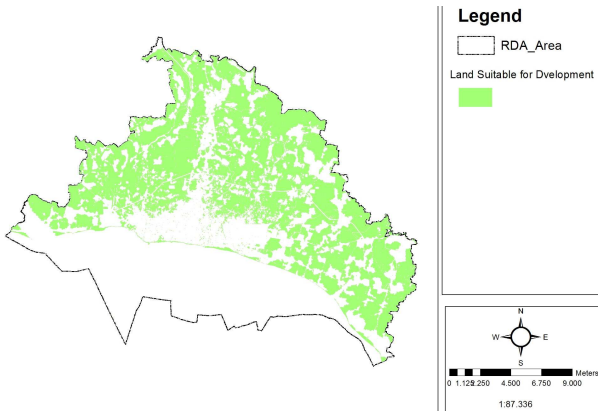

Fig. 19. All suitable places for development.

4.6. Weighted overlay and suitability map

According to the weight age for the criteria of suitability the following Figure 17 came out from the weighted overlay process. After getting the suitability map, the no go zone (Fig. 18) was erased from weighted overlay output to get the final suitability map where development can take place (Fig. 19).

Restrictions are translated here as *"no-go-zones"* for residential development. For the study area the following features were taken as no go zone. All built structures (Residential, Industrial, Commercial and Institutional building), Char Land, Conserved Area, Infrastructures (Embankment, Road, Railway, Airport, Water reservoir), Recreational Place, and River. In the dynamics of erosion and accretion in the rivers of Bangladesh, the sandbars emerging as islands within the river channel, or as attached land to the riverbanks, often create new opportunities to establish settlements and pursue agricultural activities on them. Once vegetated, such lands are commonly called chars in Bangladesh [28]. Wetland, water bodies (pond, small canal) fall under the head of the conserved area.

4.6.1. Reclassification of suitable site

After getting the final suitability class map, reclassification was made to get only the suitable place. For this reason, criteria was reclassified only for 6 to 9 class, because 6 denotes moderately high suitable and 9 denotes the highest suitable place for development.

The following Figure 21 shows the suitable places for housing development with three different colors. In the study area most of the residential project was carried out by Rajshahi Development Authority. The projects are: Padma Residential area, Chandrima residential area, Banolata residential area, etc. The project area varied due to plot size and plot number planned for that area. The recent project area ranges from 0.74 acre to 62 acre. For land suitability, in accordance with the table 7 average area size more than equal to 60 acre and 30 acre land size were selected as a filter to get the result. The reason behind taking 60 acre is recently RDA completed a successful housing project named Padma Residential Area. This project was a complete one with all the facilities and its land size was 61.44 acre. The reason behind 30 acre is that the average land size of some selected large housing projects is around 30 acre (Table 7). So if the authority wanted to take some projects for further residential project then they can found the potential site from the following Figures 20, 21 and 22.

Table 7. Comparison between two filters (>= 30 acre & 60 acre land size) of suitable site.

Features	More than equal to 60 acre (in numbers)	More than equal to 30 acre (in numbers)
Total plot number	159	318
Suitability class	From 6 to 8	From 6 to 9
% of total suitable plot	0.4	0.8
Moderately high suitable plot	37	58
High suitable plot	93	177
Very high suitable plot	29	82
Highest suitable plot	0	1

Source: RDA database and prepared by author, 2014.

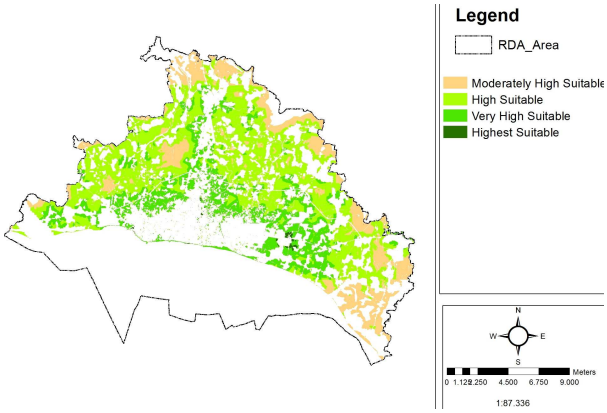

Fig. 20. Reclassified site suitability class from 6 to 9 (*source: RDA Database & prepared by Author, 2014).*

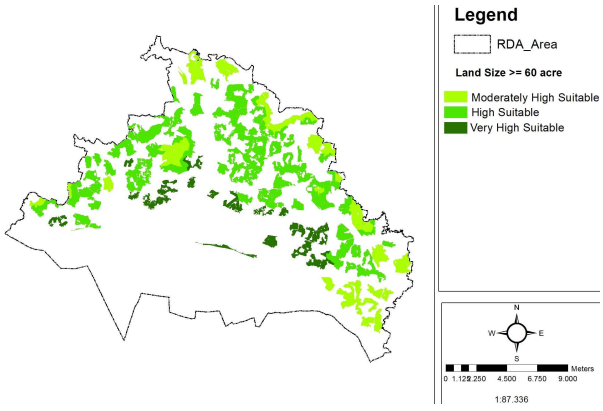

Fig. 21. Suitable land more than equal to 60 acre *(source: RDA Database & prepared by Author, 2014).*

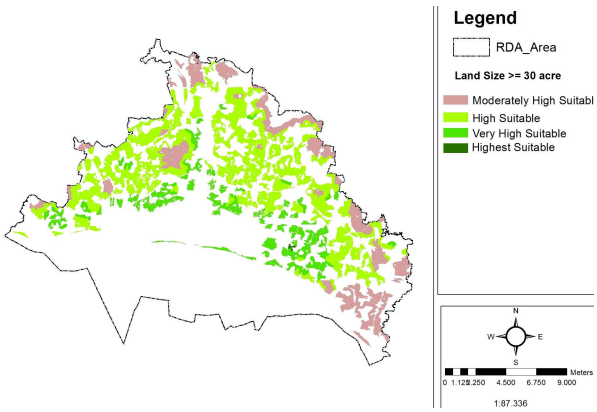

Fig. 22. Suitable land more than equal to 30 acre (*source: RDA Database & prepared by Author, 2014).*

5. RESULTS AND DISCUSSION

This assessment creates an index of the influencing factors for the residential land suitability based on the literature review. Overlay mapping is the basic method applied in GIS and helps the planners to obtain the final suitability map. The pairwise comparison method is one of the methods to combine attribute scores with a weight or preferences that should be used in the process of weight value calculating so that we can avoid some subjective ideas affecting the results and combine the quantitative and qualitative methods. Consequently, it can be concluded that the residential land suitability assessment of the RDA area provides a technical basis for sensible land use planning at the regional level. After completing the land suitability assessment process, some lands were found as suitable and unsuitable. The efforts will help the government to make the decisions on which area will be more suitable for the future urban developments by way of effectually use the limited land resource. After erasing the no go zone from the weighted overlay results, land suitability was found. In the suitability level, without considering the land size it was found that about 89.94% of the total suitable land ranges from moderately high suitability to highest suitability. Among the suitability class, 23% of land falls under moderately high suitable, 51% as high suitability, 25% as very high suitability and 1% as highest suitable. The recent housing project by RDA is Padma Residential Housing Project which is 61.44 acre in size. Only 0.4% of the suitable land came out when filtered land size was more than equal to 60 acre. RDA is also taking some future housing projects.

The average land size of those projects is around 30 acre. For example: Chandrima Residential Project. Only 0.8% of the suitable plot came out when filtered land size was more than equal to 30 acre.

Table 8. Comparison among scenarios.

Features	Final output	Road accessibility scenario	Environment scenario	Socio-economic scenario
Total plot (in numbers)	2654	67	408	187
Suitability class (6 to 9)	2387	25	61	56

Source: RDA database and prepared by author, 2014.

There is also need to check the result between the final output and the scenarios. The Table 7 & 8 gave a comparison between different features. From the table it could be said that among the scenarios most suitable land found from the final output.

6. CONCLUSION

There are some limitations in the research because of some data unavailability. First, the selection of criteria for the suitability analysis; in this case only those important criteria found in GIS database and other data format were selected. For example, this study has no data for soil fertility of the study area. About 43.39% of the total land use is agricultural land and it was not considered as no go zone in weighted overlay. In the final output of land suitability, there is also agricultural land. As there is no soil fertility class so there is a chance to destroy the more fertile land. Another data limitation was from environmental aspects. There was no data about environmental biotopes and about their protection. The limited database is still a challenge for future studies in Bangladesh. Second, there are limited literature reviews about the urban residential lands and no published research regarding residential land suitability. Some studies were carried out by researchers on the land suitability assessment for agricultural purpose. So, it was quite a challenge for the author to set the right criteria for suitability analysis

Some impersonal mathematic method could reduce the subjective feelings in the process of suitability assessment, such as certain influential factor chosen by some experts is a limitation in assessment. Incorporating other criteria would help to class the suitability class in the assessment based on the detailed data support [29], [30]. Environmental impact assessments can be also combined with the suitability assessment for appraising individual projects and inhibiting environmental conflicts. For land suitability to be more feasible in Bangladesh, land resources database should be established and implemented in most cities. If the public has an easy access to these databases, it will contribute to wider public participation into the urban planning process. The government should also ameliorate the land

compatibility database, for example, environmental sensitive area and specialty-fertile crop lands should not be transformed into other lands due to their special features. This method will help to improve the efficiency of using limited land resource.

The outcome of the present research will have a significant contribution in land suitability analysis considering accessibility to the residential development using the integrated GIS-based multi-criteria decision analysis method. GIS-based methods provide more feasible system and attainable objectives on a biased free basis for making decisions on site selection. The study concludes by contributing a body of scientific results and knowledge related to the land suitability analysis. In addition, the results have been obtained through the proposed systematic research design process and will be published accordingly. Site selection is a crucial, multifaceted process that could significantly impact the profit and loss of capital investments. The system integrates two major tools (GIS and AHP) in a manner that reach the correct solution to assist the decision-maker in determining the appropriate values for the suitability criteria. This process was successfully tested in determining the optimum land suitability for housing. This method would help planners and policy makers to monitor urban land development for formulating urban growth policies and strategies of the city. In summary, despite these limitations, this analysis provided new and valuable insights for a process that can be used in new housing planning. The methods used in this study present a flexible and comprehensive approach to land suitability assessment. It can be easily tailored to suit the needs of various stakeholders by altering criteria and their respective weights.

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