ENGINEER- Vol. XXXXI, No. 05, pp. 51-58, 2008

Application of GIS to Identify Infrastructure Needs for Land Suitability

A Case Study of Thoppigala area in the Eastern Province

H.W.W. Ranasinghe and N.T.S. Wijesekera

Abstract: Eastern province of Sri Lanka had been liberated by the Sri Lankan Government forces and after a democratic process the public representatives for the region have been appointed. As at present, a major concern of the decision makers would be to identify land areas according to their suitability and then to ascertain resource mobilization requirements to improve the suitability ranking of identified land extents. Ranking land suitability depends on many factors.

In the present work, a study area covering seven Divisional Secretariat Divisions in the Eastern province was selected to identify land suitability for housing. The natural environment, visibility, closeness to water bodies, green wild territory, and proximity to sea coast were considered as parameters of common preferences.

The multilayer GIS model divided the parameters in to three as natural, positive human influence and negative human influence. The modelling effort and its results indicate the strength of GIS and associated methodology for a resource manager to utilize similar systems for rational decision making. The paper also discusses the issues and improvements that could be effected when carrying out GIS modelling to analyze and evaluate geographical data.

Key words: GIS, Land Suitability

1.0 Introduction

Geographic Information Systems (GIS) are map based information systems which enable the planning and management of spatially distributed resources. While enabling the incorporation of spatial variability of various characteristics and parameters corresponding to several map layers, a GIS is capable of providing fast alternative solutions with relative ease.

GIS not only enables a decision-maker to analyze a given situation but also provides opportunity to generate scenario pertaining to resource mobilizations of various management options. GIS is a common tool for land assessment, land use or land suitability assessment using several data layers such as land cover, topography, roads, weather, satellite imagery, soil, population etc.[1, 2, 3, 4]. Eastern Province of Sri Lanka had been liberated by the Sri Lankan Government forces and after a democratic process, public representatives for the region have been appointed. His Excellency the president and the government of Sri Lanka have clearly indicated commitment of the government to develop the Eastern Province through the Nagenahira Navodaya (Eastern Reawaking) Programme [5, 6, 7]. As at present a major concern of the decision makers is to identify land areas according to their suitability to assess options for resource mobilization. Resource mobilization requires prioritization and hence land suitability pertaining to any objective would require ranking of land according an order of preference. In this aspect, identification of land suitability for housing is considered as important information for resource mobilization. Having considered the importance of assessing, the land suitability for housing, a spatial extent commonly known as Thoppigala area falling within seven Divisional Secretariat Divisions (DSD) in the Eastern Province was selected as the study area. The present work describes a methodology of using GIS for land suitability assessment, through a

*H.W.W. **Ranasinghe**, Research Analysist, Geographic Information for Strategic Defence Applications, Centre for Research & Development, Ministry of Public Administration, Defence, Law and Order, Army Cantonment, Panagoda, Homagama, Sri Lanka*

***Eng. (Prof.) N.T. Sohan Wijesekera** B.Sc.Eng. Hons.(Sri Lanka), PG.Dip (Moratuwa), M.Eng.(Tokyo),D.Eng. (Tokyo), MICE(UK), FIE(SL), Chartered Civil Engineer, Department of Civil Engineering, University of Moratuwa, Katubedda, Moratuwa, Sri Lanka.*

case study. This work also would enable a decision maker to assess and improve land suitability for a similar objective by incorporating appropriate changes to the spatial database.

2.0 Objective

The objective of this study is to demonstrate the potential of GIS to assess and manage the land suitability of Thoppigala area in the Eastern Province, through a case study of land suitability for housing.

3.0 The Study Area

The study location of approximately 201500 Ha commonly known as Thoppigala area falls within seven Divisional Secretary

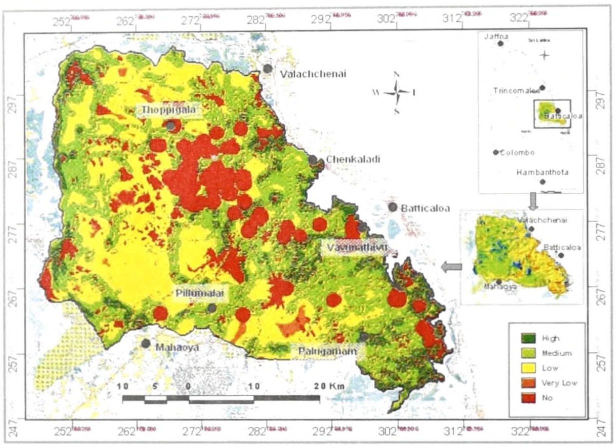

Figure 1: Map of Study Area

Table 1. Distribution of land cover in the study area

	Description	Area Ha	%
1	Built-up Area	143	0.1
2	Water Bodies	13521	6.6
3	Scrub	77360	38.4
4	Chena	3440	1.7
5	Rock	7363	3.6
6	Forest	24506	12.3
7	Garden	8950	4.5
8	Roads	4394	2.2
9	Other Plantation	6999	3.5
10	Paddy	54739	27.1
	Total	201415	100

administrative units (DSD) called Eravur Pattu, Koralai Pattu West, Koralai Pattu, Maha Oya, Manmunai Southwest, Manmunai West and Porativu Pattu. The area is bounded by 7^0 25' 47" and 7^0 56' 53" North latitudes and 81^0 11' 47" and 81^0 48' 5" East longitudes. Thoppigala area is approximately 180 Km to the East of Colombo and 90 Km to the South of Trincomalee. (Figure1). The Land use distribution of the area shows that most of the land is scrub jungle (38%) and another 27% consists of either abandoned or practising paddy lands. (Table 1). Study area has 113 Grama Niladhari Divisions (GND) and the population in the entire area is 161525 according to respective DS Division reports in year 2004 [8]. Average population density of the area is approximately 1 person per Ha. Distribution of roads in the study area is shown in Table 2.

On average the eastern sea cost located radially

Table 2. Distribution of roads in the study area

Name of Divisional Secretary Division	Road Length (Km)					Road Coverage (Km/ Ha)				
	Main Road-A	Main Road Under Construction	Minor Road	Jeep or Cart Track	Total	Main Road-A	Main Road Under Construction	Minor Road	Jeep or Cart Track	Total (Km/ Ha)
1 Eravur Pattu	41.5	-	20.5	279.0	341.0	0.07	-	0.04	0.49	0.60
2 Koralai Pattu West	-	-	-	67.0	67.0	-	-	-	0.57	0.57
3 Koralai Pattu Valachchenai	-	-	7.5	233.0	240.5	-	-	0.02	0.57	0.59
4 Maha Oya	6.0	21.0	7.0	72.5	106.5	0.02	0.05	0.02	0.19	0.28
5 Manmunai Southwest	10.5	-	30.5	113.0	154.0	0.07	-	0.22	0.80	1.09
6 Manmunai West	-	-	34.0	257.0	291.0	-	-	0.12	0.88	1.00
7 Porativu Pattu	-	-	23.5	188.0	211.5	-	-	0.19	1.48	1.67
Total	58	21	123	1209.5	1411.5	0.16	0.05	0.61	4.98	5.80

5 km from the study area has an approximately distance of 8 km along the roads.

4.0 Methodology

Study framework indicates the rational flow of activities carried out for the development of GIS model for land suitability assessment. (Figure 2). Conceptualization of land suitability identified that the land suitability for housing is directly influenced by factors such as availability of water, status of surrounding green environment, ease of accessibility, form of terrain, spread of population, fertility of soil, secure living conditions, etc. The identification of parameters influencing the objective function was initially done with literature reviews and discussions with experts. Various influencing data layers [1, 4], identification of generic targets

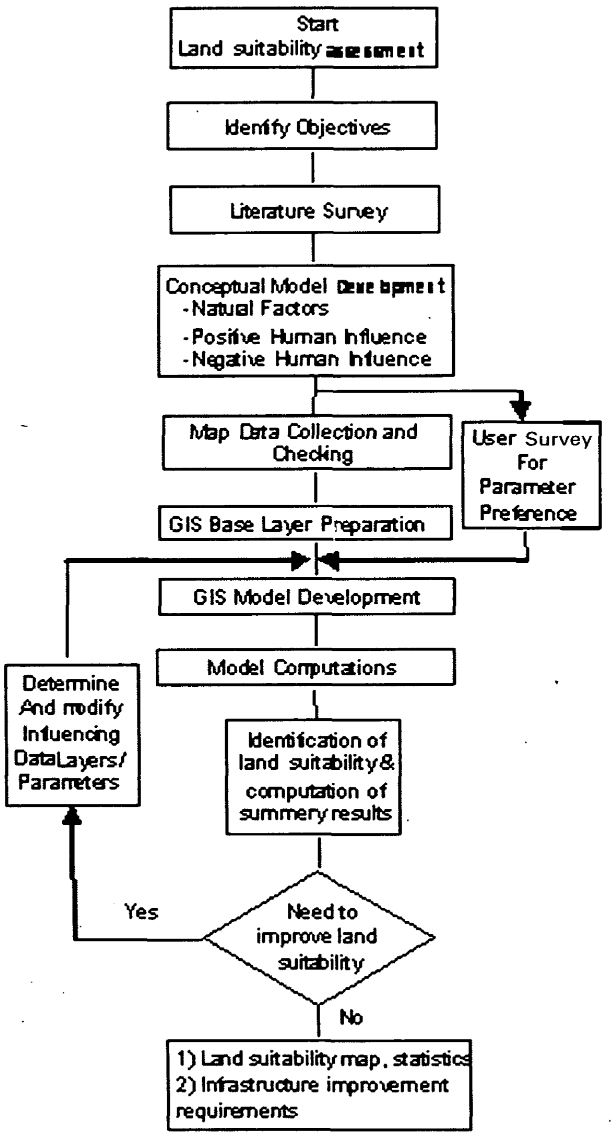

Figure 2 : Methodology Flow Chart

[9], influencing indicators [10] were carried out in the perspective of study objectives. (Table 3) Selected influencing parameters were, Land cover distribution, Distance to water bodies, Roads coverage, Population distribution, Topography and distribution of Terrorist influence area.(Table4)

The objective function used for the GIS overlay is as shown below. (Notations used are explained in Table 6)

A questionnaire survey was used to identify the

$$\text{Overall Land Suitability Ranking} = \text{Weighted Ranking of } (WB+LU+PD+R+T+LM+T)$$

preference and order of preference for each parameter. Survey questionnaire which used a random sample of 38 persons indicated their ranking as shown in Table 5.

Numerical values were assigned as in Table 6 for each qualitative index of the base data layers and numerical values of overall land suitability index was reclassified based on equal interval identified using the frequency curve[10].

Ratio Estimation Procedure [11] was used to compute preferential weights for each parameter. The survey had identified seven parameters. Ranking for the ith parameter (Ri) was given a weight (Wi) of (n + 1 - i) to compute the ratio scale which was then converted to the normalized weight. Survey questionnaire also identified the preferred land uses, preferable distances from each feature in a parameter layer. This identification methodology was treated as the best option as there were no well established threshold values. Based on the identified proximities and grouping, Each layer was classified in to qualitative spatial zones as indicated in Table 6.

In the qualitative spatial aggregation to assess the land suitability, arithmetic addition of parameters was used.[12] Overlay operations and weights application were carried out on Arc GIS platform. In order to support the formulation of easy management alternatives with respect to spatial resources mobilization, the parameters were grouped in to three sets of influence. Accordingly the GIS framework classified the layers into three groups as Natural factors, Positive Human Influence and Negative

Table 3 : Influence Parameter and Data Selection

Major Concerns	Influencing Parameters	Selection reasoning
1 Availability of water	Location of water bodies	Water bodies layer - Land cover maps
	Water supply lines	No spatial coverage data, Reflected in present population maps
	Ground water level	No spatial coverage data, Reflected in water bodies, terrain & land cover
	Water quality	No spatial coverage data, No known significant spatial variation
2 Surrounding Green Environment	Land cover distribution	Land cover / use map
	National parks	No spatial coverage data, Reflected in land cover/ use
	Wildlife sanctuaries	No spatial coverage data, Reflected in land cover/ use
	Air Quality	No spatial coverage data, No known significant spatial variation
	Noise levels	No spatial coverage data, Presently no known significant in land selection, partial reflection in population
3 Accessibility	Road network	Roads map
	Ports, Airports	Located at a significant distance, No spatial significance
	Telecommunication	No spatial coverage data, Generally uniform in the study area
	Radio, Television	No spatial coverage data, Generally uniform in the study area
4 Form of terrain	Topography	Contour maps, Land cover/ use maps
	Geography	Contour maps, Land cover/ use maps
	Land cover/ use	Land cover/ use maps
5 Soil fertility	Soil types	No spatial coverage data, Reflected in land cover/ use
	Land cover	Land cover/ use maps
	Topography	No spatial coverage data, Reflected in contour maps
6 Weather	Rainfall	No spatial coverage data, No known significant spatial variation
	Temperature	No spatial coverage data, No known significant spatial variation
	Humidity	No spatial coverage data, No known significant spatial variation
	Sunshine hours	No spatial coverage data, No known significant spatial variation
	Sea coast influence	Located at a significant distance, No spatial variation
7 Security	Military presence	No data availability
	Police presence	No data availability
	Private security services	No data availability
	Terrorist threats	Former LTTE camp sites/ mined area- Former LTTE camp map, Proximity to active terrorist area, Map of active terrorist area.

Table 4 : Data layers used for the study

Data Layer	Description	Layer type	Spatial zoning
1 Land cover	1 : 50,000 reclassified to groups according to study objectives	Polygon	Land use type
2 Water bodies	1 : 50,000 Land use	Polygon	Buffering of water bodies
3 Roads	Main road, Minor road, Jeep or cart track, 1 : 50,000	Poly line	Buffering of roads
4 Topography	1 : 50,000 Contours,	Poly line	Classification according to elevation clusters
5 DSD	Total population as attributes, 1: 50,000	Polygon	Population density
6 Land mine area	1 : 50,000, Land mine area	Polygon	Buffering of land mine areas
7 LTTE influence	1 : 50,000, LTTE influence area	Poly line	Buffering of LTTE influence areas

Table 5: Weight allocation

Parameter	Preference Level						Ratio scale (w_iR_i)	Original weight	Normalized weight
	1	2	3	4	5	6			
1 Land cover	6	3	14	9	4	2	144	2.12	0.17
2 Water bodies	11	13	6	6	2	0	177	2.60	0.20
3 Roads	15	15	5	2	1	0	193	2.84	0.22
4 Minefields	2	1	3	1	6	24	68	1	0.08
5 Terrorist influence	2	1	3	1	6	24	68	1	0.08
6 Population	2	4	8	14	5	5	121	1.78	0.14
7 Topography	2	2	2	6	19	7	93	1.37	0.11
Total							864	12.71	1

Table 6. Classification of Land Suitability preference

Layer Description	Notation	Qualitative Classification High 7	Medium 5	Low 3	Very low1	No 0
1 Land Use	LU	√	√	√	-	√
2 Topography	T	√	√	√	-	-
3 Population	PD	√	√	√	-	-
4 Water Bodies	WB	√	√	√	√	√
5 Roads	R	√	√	√	√	√
6 Land Mine Area	LM	√	√	√	√	√
7 Terrorist Influence	TI	√	√	√	√	-

Human Influence. This was done in order to facilitate a resource manager to identify options to improve the ranking of a spatial extent. A manager would be able to assign resources to negate the negative or enhance the positive human influence factor to arrive at a better land preference indicator. The influence type for each input data was assigned as shown in Table 7. This categorization methodology which permits a clear separation of zoning characteristics, enables the differentiation of zero buildable land suitability of water bodies, from zero land suitability which has been assigned to lands that are known land mine fields. GIS model in each zone clearly identified the zero suitability zones. In case of natural factors, the data availability captured rivers, lakes, water bodies, roads and rock as the set of zero suitability land uses. In the survey for parameter identification, the respondents identified a zone of 3 Km from the mined area as zero suitability, displaying the feelings of respondents with respect to a known danger. The survey data were reviewed and a distance of 1 Km from land mine area was taken as zero suitability. Spatial zoning for each layer was based on the user survey responses. Rank Reciprocal prioritization was adopted to classify

Table 7 : Parameter Grouping for Influence

	Influence Type: Environmental	Positive Human Influence	Negative Human Influence
Layer/ Parameter Description	• Land cover • Water Bodies • Topography • Population	• Roads	• Land Mine area • Terrorist Influence

Table 8 : Spatial Zone Classification

Layer		Zone identification	User rank and Zone classification
1	Land Cover	1 Built up area 2 Garden 3 Grassland	1 High 2 3
		4 Chena 5 Paddy	4 Medium 5
		6 Scrub 7 Forest 8 Sand or beach	6 Low 7 8
2	Water bodies	1 0 - 500 m 2 500-1000m 3 1000-2000m 4 > 2000m	High Medium Low Very low
3	Roads	1 0-500m 2 500-800m 3 800-1000m 4 > 1000m	High Medium Low Very low
4	Population	1 5 person per Ha 2 3 person per Ha 3 1 person per Ha	High Medium Low
5	Topography	1 Elevation 20 - 40m 2 Elevation 40 - 100m 3 Elevation > 100m	High Medium Low
6	Mine Fields	1 0 - 1 km 2 1 - 5 km 3 5 - 10 km 4 10 - 15 km 5 > 15 km	No Very low Low Medium High
7	Terrorist influence	1 0 - 5 km 2 5 - 10 km 3 10 - 15 km 4 > 15 km	Very low Low Medium High

the land use. The values thus obtained are shown in the Table 8.

In case of spatial zoning of water bodies, roads, land mined area, population and topography layers, the questionnaire captured the minimum, maximum and average distance a person would prefer for housing. Frequency distributions of the responses and careful reviews were used to classify the spatial zoning limits. Model incorporated a qualitative classification for each data layer to identify the overall index of land accessibility.

5.0 Results

Overall land suitability index with the terrorist influence and land mine areas are shown in Figure 3 and without such influences are shown in Figure 4. Table 9 and Figure 5 indicate the area distribution pertaining to each spatial zone.

The Figure 5 shows that a spatial resource manager could mobilize resources to remove the land mines and achieve a 252 % increase in the high land suitability area. The Figure 6 shows the land suitability index of negative human influence plotted against the weighted averaged overall land suitability index for each GND. Road network density (km/Ha) were computed for each GND and was plotted against the overall land suitability (Figure 7). Land suitability index due to Environmental Influence factors plotted with the road network is in Figure 8. Figure 9 shows the relationship between land suitability indices with and without negative human influence.

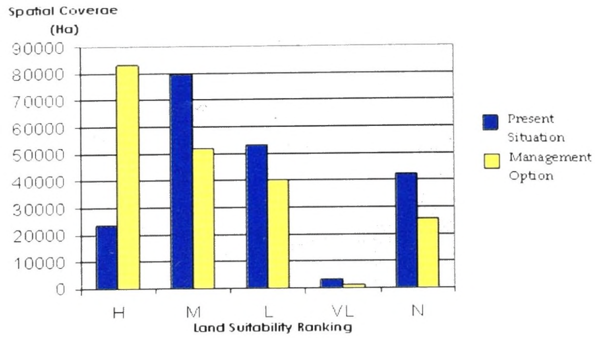

Figure 5 : Comparison of Land Suitability with and without a management option

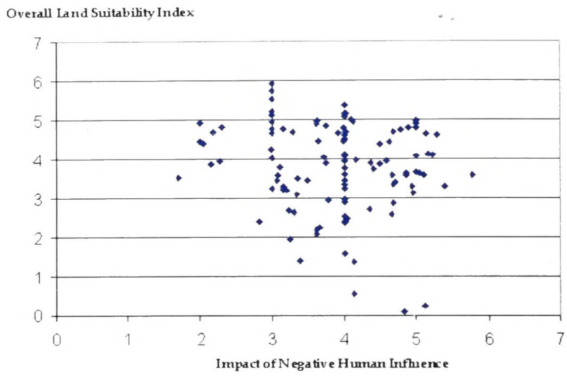

Figure 6 : Comparison of Overall and Negative Human Influence Indices for Land Suitability

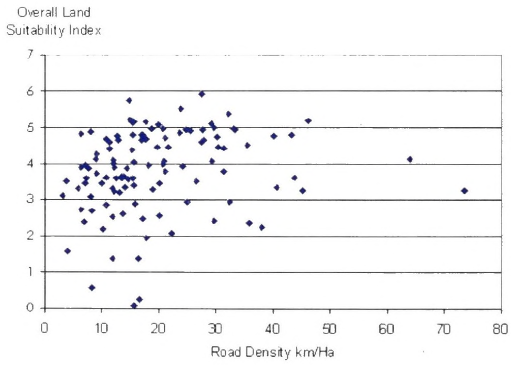

Figure 7 : Impact of Roads for the Land Suitability

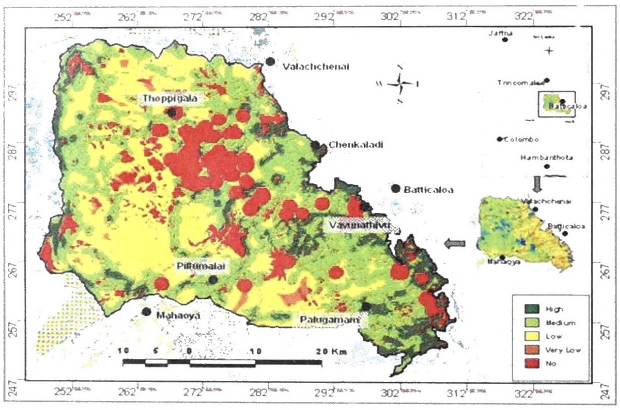

Figure 3 : Overall Land Suitability Index

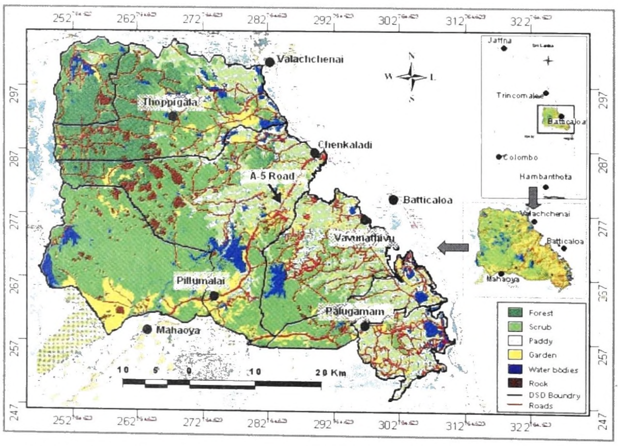

Figure 4 : Land Suitability Index without Terrorist Influence

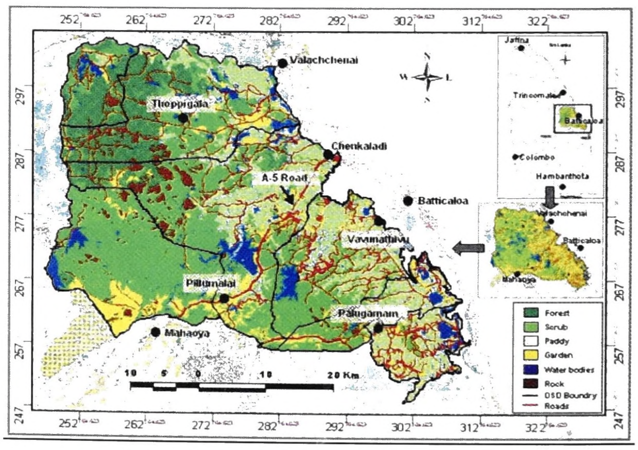

Figure 8 : Land Suitability index of Environmental Factors

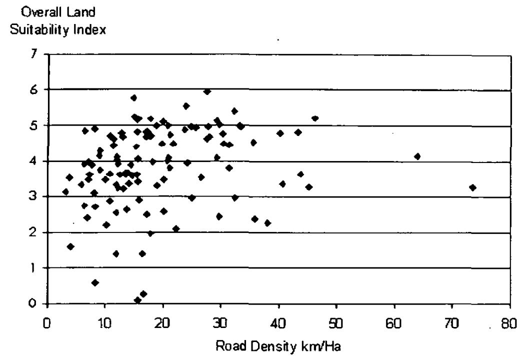

Figure 9 : Comparison of Land Suitability Index with and without Negative Human Influence

Table 9. Comparison of Land Suitability with and without a management option

Land Use Ranking	Spatial Coverage (Ha)			
	With Mines	%	Without Mines	%
High	23530	11.6	82921	41.2
Medium	79440	39.4	52083	25.9
Low	53107	26.3	40034	19.9
Very Low	3160	1.7	1103	0.5
No	42178	21	25274	12.5
Total	201415	100	201415	100

6.0 Discussion

The patterns of land suitability condition were obtained from the chosen set of parameters combining layers according to the user identified weights applied to the accumulative objective function. The main influencing parameters of land suitability were identified as Land use, Water bodies, Topography, Population, Roads, Mine and Terrorist influence areas, which could be classified as three major impact groups.

The study showed that a simple conceptual model with limited parameters could provide an overall picture of the entire spatial extent of Thoppigala enabling national or regional resource managers to plan or manage resource mobilization. The increase of high land suitability with the removal of negative influence through management options provides an encouragement to land development personnel enabling the spatial prioritization to reap maximum benefits. The comparison of suitability indices pertaining to negative human influences and the overall value for each GND indicates the spatial locations which could enable the highest benefit by mobilizing resources to remove the negative influence. The regression line would enable to easily identify the respective GND that need to be attended early.

Similarly the comparison of road density shows that there are many areas with low to moderate overall suitability index and at the same time having a low road density. Also the data shows that Moderate suitability indices are not supported with high road densities. Overall Land Suitability Index and Negative Human Index relationship shows that the GN averaged values of indices do not show a clear trend. Though the values may be used to identify each GN with particular level of suitability, a general relationship can not be concluded. This effect could be due to the fact that the weighted effect of a mine field or a terrorist activity getting thinned out once averaged in a GN Division. However, these summary comparisons are very helpful for resource planning and management for the development of Thoppigala area.

The present study shows the potential of the use of GIS for land suitability assessment and identifying rational management options. The stakeholder surveys done for the study with a limited user community could be improved by reasonably sized samples and this would lead to better results. The present work indicated a systematic scientific procedure for carrying out similar assessments to suit the stakeholder aspirations.

According to the GIS model estimates, the area consists of approximately 23530 Ha of lands with high land suitability.

Study of the influence zoning would enable a land use planner to carry out suitable environmental changes to enhance land suitability, a resource manager to provide roads and other service facilities, along with suitable arrangements for the removal or reduction of negative human influences.

7.0 Conclusions

1.0 The study showed the potential of GIS to incorporate multiple data layer operations to identify land suitability index for the Thoppigala area.

2.0 A simple GIS model with the systematic selection of parameters could produce very satisfactory and useful results for a resource manager targeting the development of an area in a spatially distributed manner.

3.0 Spatial analysis through the GIS, clearly indicated the capability to identify spatial patterns pertaining to parameter behaviour and the capability to carryout spatially averaged parameter aggregation to administrative units.

4.0 Spatial statistics can be effectively used with conventional plots for the identification of parameter behaviour which provides great strengths for rational decision making.

5.0 Thoppigala area can be developed and its land suitability index can be enhanced significantly by the successful removal of landmines in the area.

8.0 Acknowledgement

The authors wish to extend sincere appreciation of the encouragement given by the management and the staff of Ministry of Defence, and the Centre for Research and Development to publish this work. Support of the ICGAT of University of Moratuwa and its staff is gratefully acknowledged.

9.0 References

1.0 Yong Liu, Xiaosheng Qin, Huaicheng Guo, Yajuan Yu, Jinfeng Wang, Guozhu Mao, "An intergrated GIS-based analysis system for land-use management of lake areas in urban fringe", Landscape and Urban Planning 82 (2007)233-246, http://www.elsevier.com/locate/landurbplan.

2.0 Fabiola Saroinsong, Koji Harashina, Hadi Arifin, Komarsa Gandasasmita, Keiji Sakamoto, "Practical application of a land resources information system for agricultural landscape planning", Landscape and Urban Planning, (2006), http://www.elsevier.com/locate/landurbplan.

3.0 Dao Huy Giap, Yang Yi, Amararatne yakupitiyage, "GIS for land evaluation for shrimp farming in Haiphong of Vietnam", Ocean & Coastal Management 48 (2005) 51-63, http://www.elsevier.com/locate/ocecoaman

4.0 Eddie W.L. Cheng, Heng Li, Ling Yu, "A GIS approach to shopping mall location selection" http://www.elsevier.com/locate/buildenv.

5.0 Sri Lanka President's address at the Nagenahira Navodaya celebration at Independence Square, Thursday, July19, 2007, 14:04GMT, http://www.colombopage.com/archive_07/July1940432Jv.html, Visited, 19th July 2008.

6.0 A new dawn for the east, http://www.neweast,lk, Visited, 19th July 2008.

7.0 Nagenahira Navodaya Progrramme, http://www.mahaweli.gov.lk/other%pages/Nagenahira%Navodaya.html, Visited, 19th July 2008.

8.0 Population data of GND, DS office Batticaloa, personal communication. 2004.

9.0 J. Tixier, A. Dandrieux, G. Dusserre, R. Bubbico, B. Mazzarotta, B. Silvetti, E. Hubert, N. Rodrigues, O. Salvi, "Environmental vulnerability assessment in the vicinity of an industrial site in the frame of ARAMIS European project" Journal of Hazardous Materials 130(2006) 251-264, www.elsevier.com/locate/jhazmat.

10.0 Joe Walker, Trevor Dowling, Simon Veitch, "An assessment of catchment condition in Australia" Ecological Indicators 6(2006)205-214, www.elsevier.com/locate/ecolind

11.0 GIS and Multicriteria Decision Analysis; Criterian weighting; Jacek Malczewski 1999 John Wiley and sons inc, UK.

12.0 Introduction to the use of GIS Information Systems for Practical Hydrology; Data Analysis and Modelling, AMJ Meijeriuk, HAM de Brouwer, C.M. Mannaerts, C Valenzula, ITC, The Netherlands 1994.