Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

MULTI-CRITERIA DECISION ANALYSIS INTEGRATED WITH GIS FOR RADIO ASTRONOMICAL OBSERVATORY SITE SELECTION IN PENINSULAR OF MALAYSIA

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Published online: 17 October 2017

ABSTRACT

The purpose of this article is to choose the best possible places for radio astronomical observations sites using Multi-Criteria Decision Analysis (MCDA) coordinatedusing Geographical Information Systems (GIS). The study was carried out in the Peninsular of Malaysia, which is favourable for astronomical site observatory facilities with its appropriate climate properties and weather environments. Eleven factors were resolved, divided into two categories; geographical and anthropogenic. This parameter was estimated using Analytical Hierarchy Process technique and the weights of criteria layers were determined. Therefore, the most suitable areas were located widely in eastern and southern part of Peninsular Malaysia. This finding offers a sturdy, accurate, cost and time effective procedure for preliminary site selection for radio astronomical observatory.

Keywords: site selection; radio astronomical observatory; multi-criteria decision analysis; geographical information system; Peninsular of Malaysia.

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doi: http://dx.doi.org/10.4314/jfas.v9i5s.27

1. INTRODUCTION

Radio astronomical observation is affected by sources of Radio Frequency Interference (RFI) [1]. Technology application for human purpose is one of the noise of RFI [2]. Human RFI is still the one of the main threats in selection anappropriate sites for the installation of a new radio telescope. For example, mobile phone and TV transmitters and population density as well need to be addressed in this case. Some minor influence of the noise level also produced from sensitivity of equipment and add-on ground based noise [3]. For solar monitoring in radio region, most of the time, RFI is located at highly populated urban areas and lead to main issues in monitoring process [4]. The selecting of location for a radio observation is very crucial in order to find a low level site in RFI value. Increasing polluted of RFI is a core challenge for site finding [5].

The objective of this stage is to develop the predicted atlas illustrating the profile of RFI in peninsular Malaysia by using GIS mapping. GIS are computer-based schemes that assist users to collect, store, process, analyse and present spatial data [6]. GIS is a system organized as a combination of software and hardware which is displaying data retrieved by capturing and recording information, storing and checking, manipulating and analyzing that information and are spatially referenced to the Earth [7]. This gives benefit for the choosing of the best possible candidate for radio astronomical observation sites. The study was carried out in the Peninsular of Malaysia that is favourable for astronomical site observatory facilities with its appropriate climate properties and weather conditions.

Eleven factors were determined, splitting into two categories: geographical factor and anthropogenic factor. The geographical factors which have been investigated are slope of the hill, rainfall and river. The anthropogenic factors which also means the artificial RFI that made by human is the biggest contributor of interference sources. They consist of population of density, road network, land used (e.g: commercial, plantation, industry etc.), second-generation of mobile communication, third-generation of mobile communication, amplitude modulation, frequency modulation and television transmitters.

All of these factors are essential to create the RFI profile in peninsular Malaysia. They are defined based on the study done by [11] in which they conducted the astronomical observatory site selection in Antalya province, Turkey [8]. They used MCDA method coordinated with GIS and remote sensing technologies. However, they have classified the factors determined into 3 categories which are meteorological, geographical and anthropogenic criteria. The factors they have reviewed are cloud cover, precipitable water, earthquake areas, geology, landslide, active fault lines, DEM Model, lights of city, mining and settlement areas.

2. RESULTS AND DISCUSSION

Each data for each parameter was combined to form a layer using GIS technique and produce a map of each. The weight coefficients were calculated to classify the region in all around the peninsular Malaysia based on the degree of criteria influence, accordingly. All layers of map for each criterion are shown in Fig. 1.

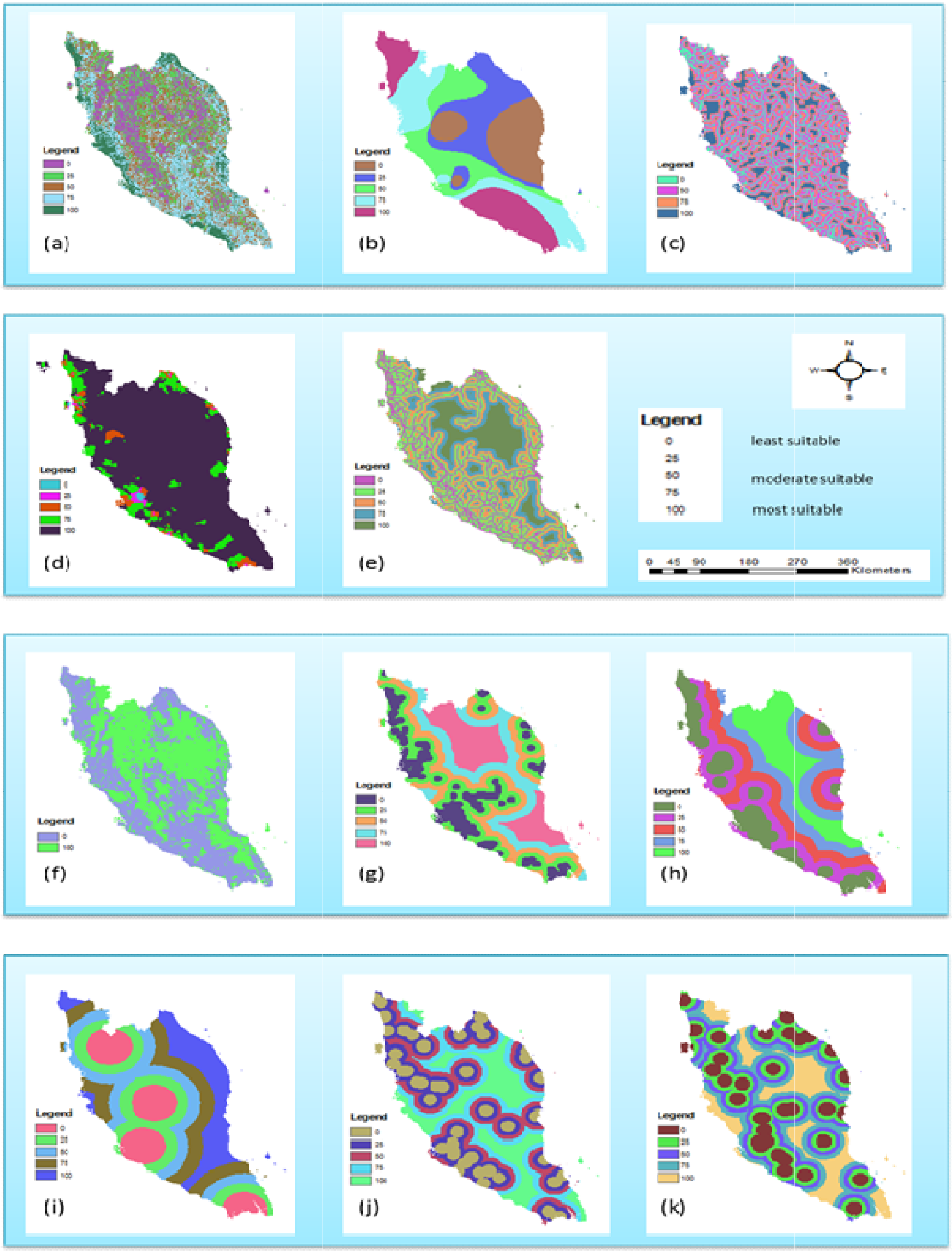

Fig.1. Used data sets; geographic population density (a), road network (b), elevation (c), rainfall (d), land used (e), river (f) and anthropogenic data sets, 2G (g), 3G (h), AM (i), FM (j), and TV (k)

Fig. 1 illustrated suitable areas for geographical and anthropogenic conditions for eleven parameters. Scale of 100 shows the best suitable sites which are less in RFI. Previous study by Umar et al shows only four parameters and being divided by meteorological, geographical and anthropogenic conditions [9-10].

Finally, each layer is combined to produce the RFI profile map of peninsular Malaysia as can be seen in Fig. 2. After implementing the dense computation for obtaining weightage of corresponding criteria and multiplying each criterion with these weights by AHP and GIS, the subsequent atlas that designates candidate sites was developed [11]. Fig. 2 showed the top possible sites that were obtained by applying a threshold value when selecting the areas which had the highest scores. As we can see that, the fit areas in terms of geographical and anthropogenic conditions which were widely located in western and eastern area of the study area are shown in Fig. 2.

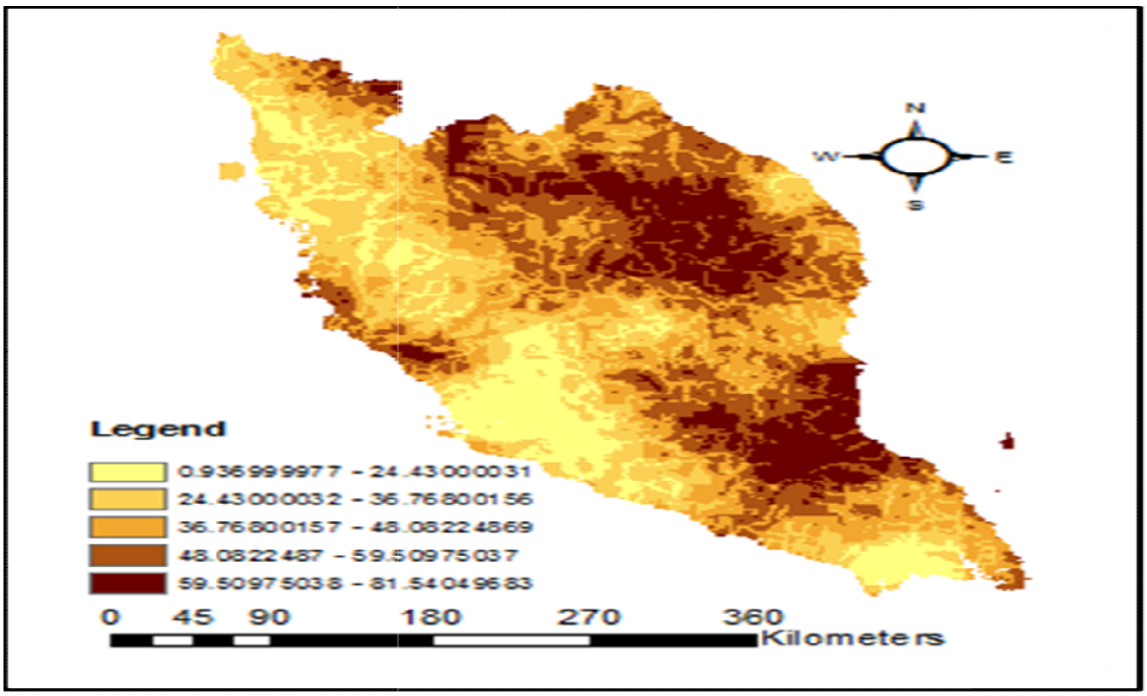

Fig.2. Final mapping for best site selection (after consideration of eleven parameters)

3. EXPERIMENTAL

To construct the radio astronomy observatory such as SKA project, main importance is governed by the following key factors, the cost of building telescopes (dish) and identification location of RFI free site.

In this study, the multi-criteria decision analysis (MCDA) method is the perfect, well known structured methodology to be practiced. This technique is suited to support decision makers facing problem while deciding the best influence factor. Hence, the entire region in around peninsular Malaysia will be categorized out from the lowest RFI (the best site) to the highest RFI (the most unsuitable place to consider for observation).

Three major steps are involved: estimate the threshold value for each of the parameters, combine the data to produce a map for each parameter and conduct an Analytical Hierarchy Process (AHP) method.

The threshold value is determined based on random assumptions, so the map of RFI can be predicted. In this case, spatial analyses were implemented using GIS. The eleven criteria are stored as a layer each into a GIS. The layers are then evaluated using AHP method to determine the weightage for each factor. Thus, the layers are combined and RFI map is produced to be utilized as a reference map for further study.

The AHP method is a well-known and the best practice in multi-criteria analysis approaches which has been developed by [12]. It allows the weightage to be assessed relative to the given criteria. This method proposes such pairwise comparisons based on the importance of one criterion to another (eg: A is more important than B but less than C). The degree of importance is expressed into in a set of numbers ranging from 1-9 representing the relative priority of each of the criteria. The basic scale of pairwise comparison is shown in Table 1.

Table 1. Basic scale of pairwise comparison [11]

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and evaluation slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favor one activity over another
6	Strong plus	
7	Very strong or demostrated importance	An activity is favored very strongly over another ; its dominance demostrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

3.1. Source of Data

The data were personally collected from different agencies such as Malaysia Geo-spatial Data Infrastructure (MyGDI), Department of Statistic Malaysia, Department of Meteorological Malaysia, Malaysia Communication and Multimedia Commission (MCMC) and Department of Maps and Surveying of Malaysia Data include spatial and attribute data. Spatial data are maps of Peninsular Malaysia which we receive from Department of Maps and Measurement of Malaysia. Other sources of spatial data include topology maps for high places in Malaysia and GIS maps acquired from anearlier study which is from Faculty SainsSosial and Sastera (FSSS), University of Malaya.

3.2. Best Site Selection

In order to construct a matrix for AHP evaluation based on pairwise comparison technique, the matrix element determination is the first step we need to consider [11]. The equation is

$$c_{ij}=(1/c_{ji}) \qquad (1)$$

Thediagonalvaluesofthismatrixareequaltoone(c_{ii} =1, c_{jj}=1, c_{nn}=1 etc.) asthecolumnandrow datalayersareequavalenttoeachother.

$$AW = \begin{bmatrix} c_{11} & \cdots & c_{1n} \\ \vdots & \ddots & \vdots \\ c_{n1} & \cdots & c_{nn} \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ \\ w_i \end{bmatrix} \quad (2)$$

where A is a pairwise comparison matrix while W and wi (i = 1, 2, ..., n) stands for corresponding eigenvector and the value of weightage, respectively. n defines the number of criteria or parameter involves which is in this study, the value is n = 11.

The AHP matrixwhich has grade of importance between pair of criteria need to be constructed. The decision maker has to rate the criteria priority compared to other assigned criteria. Table 2 shows comparison of variable in matrix.

Table 2. Comparison of variable in matrix

Variable	**A Road Network**	**B Slope**	**C Elevation**	**D Rainfall**	**E Land Use**	**F River**	**G 2G**	**H 3G**	**I AM**	**J FM**	**K TV**
Road Network	1	1	1	1	1	1/9	1/7	1/9	1/7	1/3	1/9
Slope	1	1	1	1	1	1/9	1/7	1/9	1/7	1/3	1/9
Elevation	1	1	1	1	1	1/9	1/7	1/9	1/5	1/3	1/9
Rainfall	1	1	1	1	1	1/9	1/7	1/9	1/5	1/3	1/9
Land use	1	1	1	1	1	1/9	1/7	1/3	1/5	1/3	1/9
River	9	9	9	9	9	1	1	1	1/3	1	1
2G	7	7	7	7	7	1	1	1/3	1	1/3	1/7
3G	9	9	9	9	9	1	3	1	1/4	1	1
AM	7	7	5	5	5	3	1	4	1	1	1/7
FM	3	3	3	3	3	1	3	1	1	1	1/9
TV	9	9	9	9	9	1	7	1	7	9	1

Variable scale was changed into decimal places before calculation of weightage. These variable scale for each column were calculated by a formula of:

$\Sigma AC = C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11$

= 1 + 1 + 1 + 1 + 1 + 9 + 7 + 9 + 3 + 7 + 9

= 49

Table 3. Variable comparison in decimal places

Variable	A Road Network	B Slope	C Elevation	D Rainfall	E Land Use	F River	G 2G	H 3G	I AM	J FM	K TV
Road Network	1	1	1	1	1	0.11	0.14	0.11	0.14	0.33	0.11
Slope	1	1	1	1	1	0.11	0.14	0.11	0.14	0.33	0.11
Elevation	1	1	1	1	1	0.11	0.14	0.11	0.20	0.33	0.11
Rainfall	1	1	1	1	1	0.11	0.14	0.11	0.20	0.33	0.11
Land use	1	1	1	1	1	0.11	0.14	0.33	0.20	0.33	0.11
River	9	9	9	9	9	1	1	1	0.33	1	1
2G	7	7	7	7	7	1	1	0.33	1	0.33	0.14
3G	9	9	9	9	9	1	3	1	0.25	1	1
AM	7	7	5	5	5	3	1	4	1	1	0.14
FM	3	3	3	3	3	1	3	1	1	1	0.11
TV	9	9	9	9	9	1	7	1	7	9	1

Table 3 shows ratio of importance for each variable. Each ratio was gained by dividing each ratio with summation of ratio in each column. The formula is as following:

$$R = \frac{c11}{\sum c}$$

$$= \frac{1}{49}$$

= 0.2

Table 4. Ratio of importance for variable

Variable	**A Road Network**	**B Slope**	**C Elevation**	**D Rainfall**	**E Land Use**	**F River**	**G 2G**	**H 3G**	**I AM**	**J FM**	**K TV**
Road Network	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.03
Slope	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.03
Elevation	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.03
Rainfall	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.03
Land use	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.04	0.02	0.02	0.03
River	0.18	0.18	0.19	0.19	0.19	0.12	0.06	0.11	0.03	0.07	0.25
2G	0.14	0.14	0.15	0.15	0.15	0.12	0.06	0.04	0.09	0.02	0.04
3G	0.18	0.18	0.19	0.19	0.19	0.12	0.18	0.11	0.02	0.07	0.25
AM	0.14	0.14	0.11	0.11	0.11	0.35	0.06	0.44	0.09	0.07	0.04
FM	0.06	0.06	0.06	0.06	0.06	0.12	0.18	0.11	0.09	0.07	0.03
TV	0.18	0.18	0.19	0.19	0.19	0.12	0.42	0.11	0.61	0.60	0.25
$\sum =$	1	1	1	1	1	1	1	1	1	1	1

Summation of each row was calculated and being divided by count of N of variable in order to calculate its weightage:

$$W = \frac{\sum c}{N}$$

$= C_{11} + C_{12} + C_{13} + C_{14} + C_{15} + C_{16} + C_{17} + C_{18} + C_{19} + C_{110} + C_{111}$

$= 0.02 + 0.02 + 0.02 + 0.02 + 0.02 + 0.01 + 0.01 + 0.04 + 0.02 + 0.02 + 0.03$

$= 0.20$

In the process of RFI prediction map construction, the pairwise comparison matrix was built based on the effect to a radio signal. The average weight for each criterion is then determined by normalizing the weighing and averaged them. Table 4 shows reading of weightage for each variable and its importance of criteria. Anthropogenic factors lead the percentage in term of importance of criteria. In the final stage, each data for each parameter was combined to form a layer using GIS technique and produce a map of each. The weight coefficients were calculated to classify the region in all around the peninsular Malaysia based on the degree of criteria influence accordingly.

In Table 5, anthropogenic factor had the highest weightage which are TV (28 %), 3G and AM (15%) followed with river (14%). These are factors that contribute towards less effective radio observational site.

Table 5. Weightage of variable for radio observational site at peninsular of Malaysia

Variable	Weightage	Important of Criteria	Important of Criteria (%)
Road Network	0.20	0.02	2
Slope	0.20	0.02	2
Elevation	0.21	0.02	2
Rainfall	0.21	0.02	2
Land Use	0.23	0.02	2
River	1.58	0.14	14
2G	1.09	0.10	10
3G	1.69	0.15	15
AM	1.64	0.15	15
FM	0.90	0.08	8
TV	0.28	0.28	28
$\sum$ =	11	1	100

4. CONCLUSION

Main factor for a good final mapping is the arrangement of pairwise comparison for AHP. The values of each matrix have to be given from a professional in observatory of astronomy. Effect and importance for each criterion is known by the expertise. The final map will show incorrect place if the value of the matrix is not reliable because the weightage failed to compute correctly. AHP evaluation has also shown results that the variables anthropogenic are key elements that affect the suitability of radio observatories in Peninsular compared to geographical variables.

5. ACKNOWLEDGEMENTS

This study was supported by University Malaya's grants which is IPPP (PV025-2011A) and Research Acculturation Collaborative Effort (RACE) UM(CR008-2015), UNISZA (RACE/F1/ST1//UNISZA/15-RR118)and Special thanks are also dedicated to the other researchers in the EMRG Group for their assistance for this work.

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How to cite this article:
Umar R, Abidin Z Z, Ibrahim Z A, Kamarudin M K A, Hazmin S N, Endut A, Juahir H. Multi-criteria decision analysis integrated with gis for radio astronomical observatory site selection in peninsular of malaysia. J. Fundam. Appl. Sci., 2017, *9(5S), 381-393.*