Optimum Site Selection for Fire Brigade in Ella, Sri Lanka by Utilizing GIS

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Abstract: *As an island nation, Sri Lanka is facing different disasters while the forest fire disasters that are dominant in the highlands of the country are significant. In the Ella neighbourhood, forest fires occur every year near the end of the dry season. Further, the absence of other fire stations near the area is a considerable issue and under the investigation found a suitable location for the forest fire brigade and analysed the network connectivity to the selected location from any place of the Ella. To find the best placement for a fire station, a site selection analysis was performed in a GIS context via weighted overlay analysis. As the data sources of the study population, Land use land cover, elevation, water sources, road, building, pre-fired area, and pre-hazardous areas were utilized in the ArcMap 10.5 software platform through spatial analysis tools and network analysis tools. For the determination of weights for each factor, the Analytical Hierarchy Process was used as the main statistical technique of the study. Finally, the selected areas were examined via visual validation in Google Earth and selected the most suitable location for fire brigade establishment along with the network analysis. In addition, the establishment of the fire brigade is crucial in the central part of the country due to the magnitude and the frequency of the disaster. Further, the proposed study can be utilized as a comprehensive guideline for any organization before the establishment of the fire brigade.*

Keywords: *Analytical Hierarchy Process, Forest fire, Geographical Information Science*

1. Introduction

The Ella area of Sri Lanka is very popular not only for locals but also for foreign tourists and most people come to Ella every day, the fire brigade is not available near Ella city for their safety of them because this area is extremely vulnerable to occurring forest fires. It is difficult to mitigate if forest fire occurs in the Ella area because of the geographical situation like winds blowing fast as well as mountains with forest and the distance for the nearest fire brigade situated at Badulla is more than 23 Km. Therefore, the availability of a fire brigade is significant for the Ella area and searching for a suitable location in the Ella area to establish the fire brigade is currently an ongoing significant research area. The Geographic Information System (GIS) is a system of collection of modern software and computer technology for creating, managing, analysing, and mapping all types of data and it is vital for selecting a suitable location for the fire brigade with an optimum path to access location via network analysing (Nay *et al.*, 2019). Thus, the objective of the study is to find a suitable geographical location for the fire brigade in Ella, Sri Lanka, and find the optimal path for accessing the selected place from the pre-fire locations.

2. Methodology

Various environmental variables need to be considered when selecting a place for construction, especially in sensitive factors like constructing a fire station. A considerable extent of experimental design reports, documents, and case studies to

identify both critical success factors and failures and different hardware and software tools in data gathering, analysis, and conceptual design building were studied for that. In the study, the Ella city area was selected as the study area, and it is shown in Figure 1.

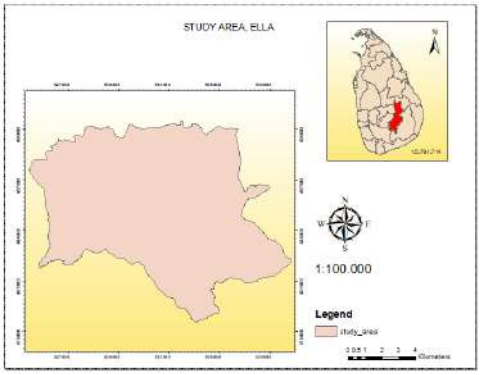


Figure 1: Study area

First, spatial data from the survey department and population data from the statical department website were gathered. In the study, eight data layers such as land use, road, water, population, building, pre-fired area, pre-hazardous areas, and slope are used for achieving the objective. During the analysis, pre-processing was conducted, and all required layers were converted into a raster format. My case analysis has two parts spatial analysis to find the best location for the fire brigade and network analysis to find the optimum path from the selected fire brigade to pre-fire locations.

The four scale values used in the land use layer were forest, cultivation, home gardens, and others. Among those scale values, priority was given to forest. The second place was given to cultivation and home gardens were given the third place. Others were given the least priority.

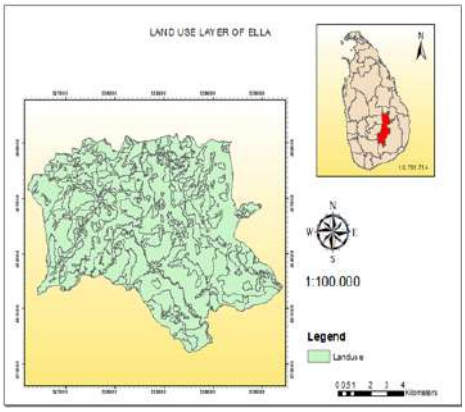


Figure 2: Land use layer of Ella

The road layer in the GIS model was divided into four parts 0-75, 75-150, 150-225, and 225 or more according to the distance from the road. In this layer, the Euclidean distance method was used according to the parameters.

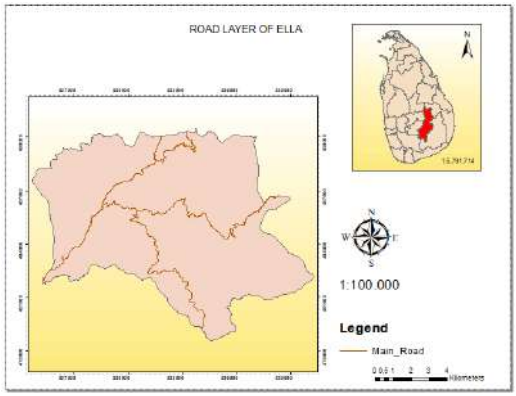


Figure 3: Road layer of Ella

The water layer also ranks according to the distance from the water feature as below 200m, 200-400m, 400-600m, and above 600m.

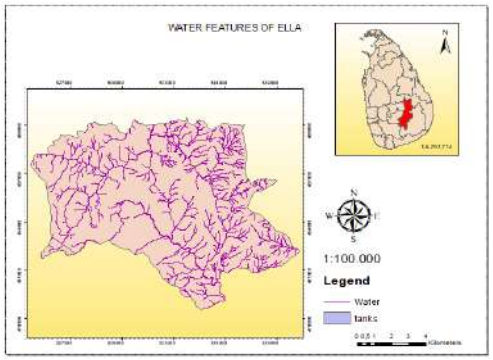


Figure 4: Water features layer of Ella

The population layer was divided into three layers less than 1000, 1000-2500, 2500, and more.

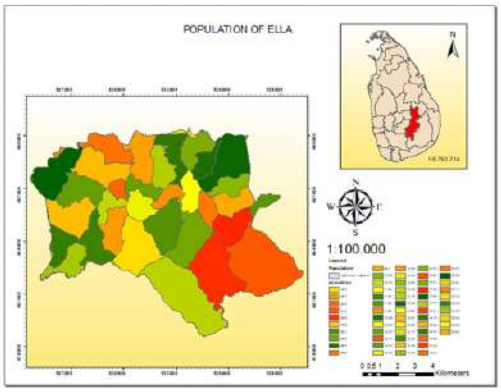


Figure 6: Population layer of Ella

Figure 5: Population statistics of Ella

The building layer was divided into four scale values 0-500m, 600-1000m, 1100-1500m, and 1600-2000m according to the Euclidean distance.

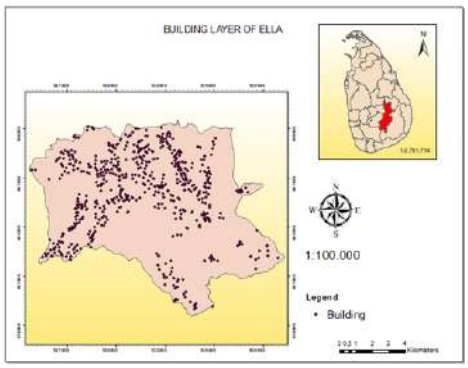


Figure 6: Building layer of Ella

When constructing a fire station, it is vital to locate it far from fired areas. By considering this, according to the distance from pre-fire locations, it was scaled as 250m, 500m, 1000m, and 1500m. Pre hazards also should be considered when constructing a new fire brigade and it was scaled as 100, 200, 400, and 600 m distances from hazard. And, the slope of the ground should be considered, and a flat area was considered the most suitable area to construct the building. It is also scaled by using slope values.

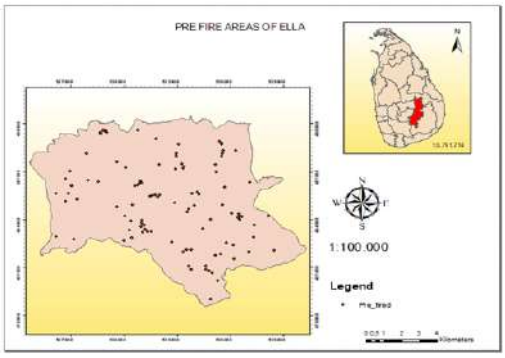
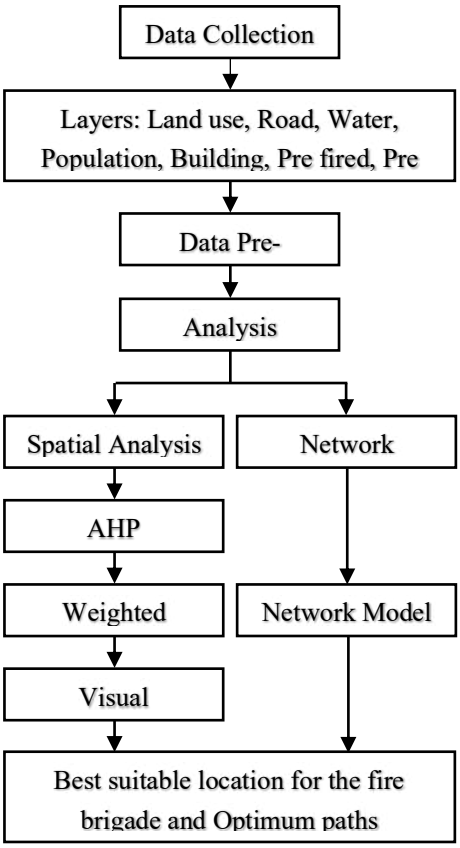


Figure 7: Pre-fire layer of Ella

Before doing the spatial analysis, it is needed to assign weights for each data layer. So, Analytical Hierarchical Process (AHP) was used to determine the weights of data layers. The AHP is a powerful simple method for making decisions and it is commonly used for project prioritization and selection as well as it is a method that is mostly used in past research and most findings when the final choice or selection is uncertain. (Green

et al., 2014). The procedure of using AHP is to define alternatives, define the problem and criteria, establish priority amongst criteria using pairwise comparison, check consistency and finally get the relative weights (Kaleji, 2019). Before-mentioned layers were reclassified into four classes and applied the weighted overlay, as well as

Figure 8: Methodology flow chart



again reclassification, was done for selecting suitable areas for the fire brigade. Finally found a suitable place by visual validation for the establishment of the new fire brigade with optimum access from pre fire locations with the help of network analysis. The above-mentioned methodology is shown in the Figure 8.

3. Results

As mentioned in the methodology, land use, road, water, population, building, pre-fired, pre-hazard, and slope layers were utilized for the study. GIS model had selected to complete the analysis which consists of eight layers. In the study, weights are assigned by using the AHP method and based on the calculated weights, a pairwise comparison matrix was prepared, and it is appearing in Table no 1.

After that above eight data layers were weighted overlayed by using the weighted overlay tool and obtained output is shown in Figure 09.

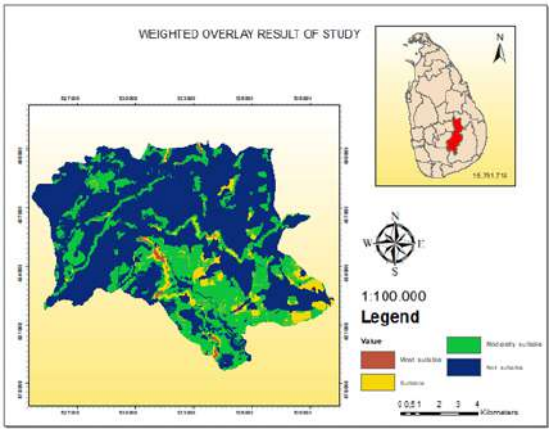


Figure 09: Output of weighted overlay

Based on a weighted overlay, several land lots were obtained to establish the new fire brigade and these suitable locations are shown in Figure 10.

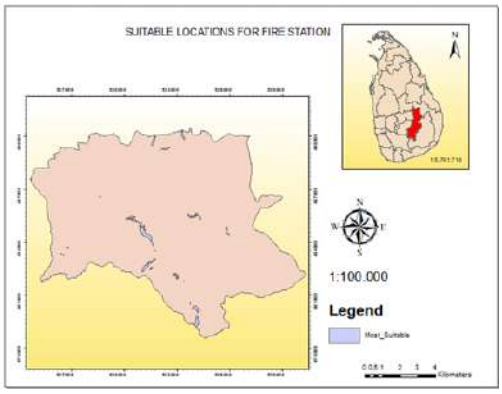


Figure 10: Suitable locations for the fire station

Table 1: Weighted overlay matrix

A. No	B. Layer	C. Influence	D. Field	E. Scale Value
F. G. 1	H. Land use	I. 28%	J. Forest	K. 9
			L. Cultivation	M. 3
			N. Home Garden	O. 2
			P. Others	Q. 1
R. 2	S. Road	T. 19%	U. 0-75m	V. 9
			W. 75-150	X. 4
			Y. 150-225	Z. 2
			AA. 225-300	BB. 1
CC. 3	DD. Water	EE. 15%	FF. <200m	GG. 9
			HH. 200-400	II. 6
			JJ. 400-600	KK. 2
			LL. 600-800	MM. 1
NN. 4	OO. Population	PP. 13%	QQ. Less than 1000	RR. 9
			SS. 1000-2500	TT. 5
			UU. 2500-5000	VV. 3
WW. 5	XX. Building	YY. 9%	ZZ. 0-500m	AAA. 9
			BBB. 600-1000m	CCC. 5
			DDD. 1100-1500m	EEE. 2
			FFF. 1600-2000m	GGG. 1
HHH. 6	III. Pre fire	JJJ. 6%	KKK. 1500-1001	LLL. 9
			MMM. 1000-510	NNN. 8
			OOO. 500-260	PPP. 3
			QQQ. less than250m	RRR. 2
SSS. 7	TTT. Pre hazard	UUU. 7%	VVV. 600-400	WWW. 9
			XXX. 400-200	YYY. 6
			ZZZ. 200-100	AAAA. 2
			BBBB. <100m	CCCC. 1
DDDD. EEEE. 8 FFFF.	GGGG. lope	HHHH. 3%	IIII. Flat<2	JJJJ. 9
			KKKK. Gently sloping2-3	LLLL. 4
			MMMM. sloping3-6	NNNN. 2
			OOOO. Steep>6	PPPP. 1

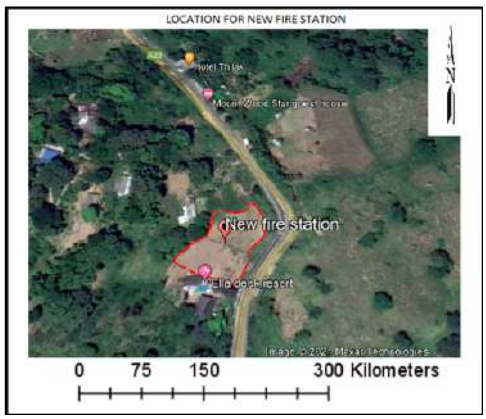


Figure 11: Location of the new fire station

With help of Google Earth, visual validation was done to find the most suitable location to establish the new fire brigade and the selected place is shown in Figure 11.

Lastly, network analysis was performed to find the optimum path from pre-fire locations to the location selected to be established for the new fire brigade.

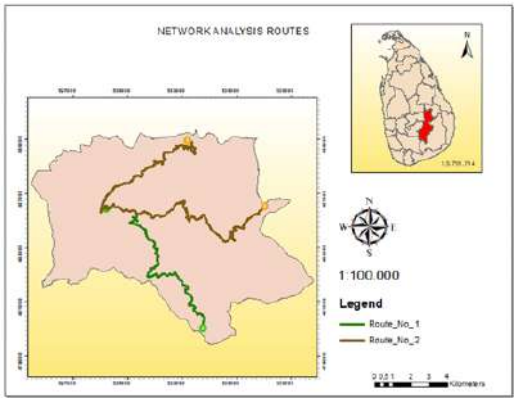


Figure 12: Output of Network analysis

4. Discussion and Conclusion

There are many subcategories under-identified factors and hard to identify and select the factors among all available factors. It is challenging to design experimental design as selecting a geographical location is different from others. According to the analysis, there are suitable areas that can be used to locate the fire bridge at Ella, Sri Lanka. Using GIS tools and technologies with ArcGIS software could map and display the geographical areas graphically to identify the suitable place with factors considered in the study. This research paper focused on finding a suitable geographical location for a fire bridge in Ella, Sri Lanka. According to the requirement of the factors used in the research, the ArcGIS tool was used to analyse the compatibility of factors and identify the most suitable places. Finally, the visual validation through Google Earth is incorporated for the selection of the best location. Further, the experimental workflow can be utilised as a guideline for future forest fire brigade site selection.

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