

# Sustainable Urban Forestry Potential Based Quantitative And Qualitative Measurement Using Geospatial Technique

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**Abstract.** In order to maintain the stability of natural ecosystems around urban areas, urban forestry will be the best initiative to maintain and control green space in our country. Integration between remote sensing (RS) and geospatial information system (GIS) serves as an effective tool for monitoring environmental changes and planning, managing and developing a sustainable urbanization. This paper aims to assess capability of the integration of RS and GIS to provide information for urban forest potential sites based on qualitative and quantitative by using priority parameter ranking in the new township of Nusajaya. SPOT image was used to provide high spatial accuracy while map of topography, landuse, soils group, hydrology, Digital Elevation Model (DEM) and soil series data were applied to enhance the satellite image in detecting and locating present attributes and features on the ground. Multi-Criteria Decision Making (MCDM) technique provides structural and pair wise quantification and comparison elements and criteria for priority ranking for urban forestry purpose. Slope, soil texture, drainage, spatial area, availability of natural resource, and vicinity of urban area are criteria considered in this study. This study highlighted the priority ranking MCDM is cost effective tool for decision-making in urban forestry planning and landscaping.

## 1. Introduction

Ward and Johnson, 2007 stated that urban forest as a variety and mixture of woody and other vegetation that cover the urban area [1]. Urban forest is a forest or a group of plants that grow in the city, town or in locations that are being developed [2]. It can also be presented as any type of wooden crop plants that grow around human exploration. It is importance to increase the urban green spaces with quality urban environment which is globally indirectly related to the partial urbanization [3]. In order to attain the stability of natural ecosystem in the urban, the restoration of urban forestry is a must. Challenge on conservation and sustainable development for protected area is widely discussed due to high demand in natural resource and land use changes with rapidly population growing [4].

Enormous use of remote sensing data would replace traditional visual forest inventory so as to reduce the operation cost [5]. The advancement of satellite optical image provides high spatial and spectral accuracy for land use classification and application of GIS in urban forestry shows great potential in data collection process to achieve better accessibility [6]. Many studies [7] have proved that the integration of remote sensing and GIS can be reliable and fast information with affordable cost and workforce for decision-making in forest resource planning and landscaping. Multi-criteria Decision Making (MCDM) is enabling to overcome the limitation on conflicting criteria especially in forest management planning [8]. Generally, MCDM is divided into two broad classes which are multi attribute decision making and multi objective decision making. Both decision making commonly used for determine the score of sets of attribute and to select the best alternative based on objectives

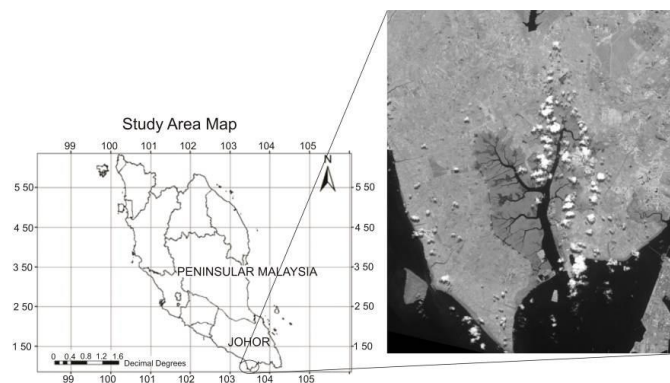
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respectively [9]. The integration of MCDM with GIS for urban planning has been revised since 1990's because of their ability to solve planning problem related to spatial entities.

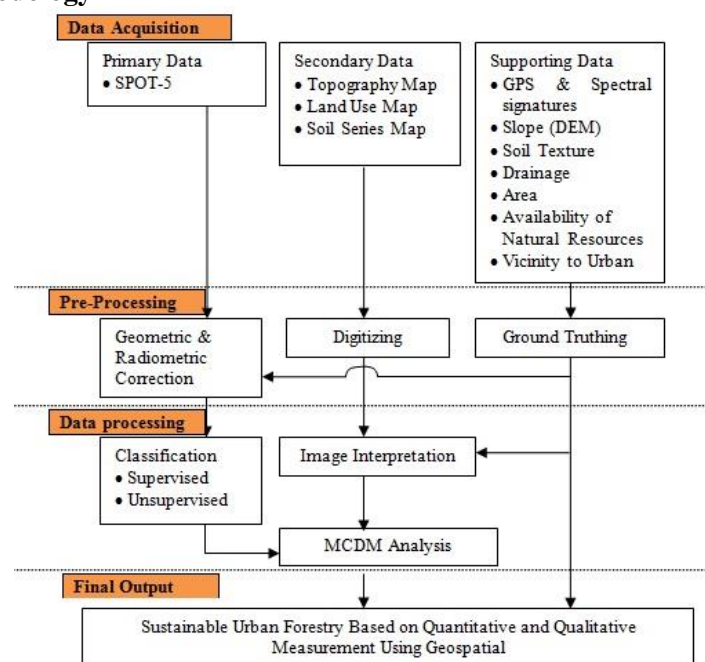
The qualitative and quantitative criteria [10] are taking into account for MCDM where qualitative measurement used land use and soil map to characterize the land potential area while the buffering zone for urban is developed for quantify the urban forest impact. However, these criteria introduced to less precision of accuracy and other constraint due to uncertain environment [11]. As a result, quantitative criteria also applied for MCDM such as weight determination. The confusion matrix of classification result is used to measure the accuracy hence applied in MCDM. This matrix is used to provide a site specific assessment between the satellite imagery and ground observation [12]. For this study, high accuracy of classification is needed to provide best MCDM result. The objective of this study is to measure the sustainability of urban forestry based on qualitative and quantitative using geospatial technique.

The study area is located in the southern of Johor, Malaysia (figure 1) within the latitude of 1°33'26.54" N to 1°15'59.25" N and the longitude of 103°24'21.11" E to 103°39'13.93" E. Temperature in Johor ranges from 21°C to 32°C with an average of humidity more than 82%.



**Figure 1.** Map of peninsular Malaysia showing the geographical location of the study area in box and the respective satellite image of southern Johor.

## 2. Research Methodology



**Figure 2.** Flow chart of the methodology of this study.

### 2.1. Planning and Preparation

Various data were acquired from different sources and classified in three classes – primary, secondary and supporting data. Table 1 gives the list of data and description for each one in details.

**Table 1.** List of data and its description used in MCDM technique.

Data	Description
Satellite Image SPOT-5 2010	Acquisition Date: 15 April 2010, Spatial Resolution: 10 meters, Spectral Resolution: Multispectral 4 bands.
DEM (Aster)	Acquisition Date: 10 Aug. 2010, Spatial Resolution 30 meters
Soil Series Map	Acquisition Date: 2006, Scale: 1:250 000
Soils Group & Hydrological Map	Acquisition Date: 2006, Scale: 1:250 000
Topography : Slope, DEM, and Contour	Acquisition Date: 1988, Scale: 1:50 000

### 2.2 Data Collection

The primary data is the multi-spectral SPOT-5 as in table 1 for updating land use information through feature extraction and image classification. The auxiliary data consists of topographic map, land use map and soil series map (table 1). To support both data, ground truth was undertaken to collect ground control points, spectral signatures of different ground features and environmental parameters which are important for determining the sustainable land potential in MCDM technique.

### 2.3 Data Processing

Data processing focuses on six environmental parameters; slope, soil texture, drainage, area, availability of natural resources, and vicinity to urban. In data processing, the classification of land use types from SPOT-5, digital secondary data and in-situ parameters were used in MCDM. Both supervised and unsupervised classifications were carried out, however, only classified image with high overall accuracy is used which is in this case the one produced from supervised classification. The MCDM was performed by using GIS platform and the map of sustainable land potential area for urban forest landscaping was produced.

### 2.4 Multi-Criteria Decision Making (MCDM) techniques

The analysis of multi-criteria parameter is carried out to determine the potential of urban forest area. Therefore, before performing the analysis, the weight of each parameter is assigned based on their priorities. This study applies a function developed by Stillwell et al. (1981) to compute the weight for each environmental parameter as below;

$$w_j = \frac{n-r_j+1}{\sum(n-r_k+1)} \quad (1)$$

where  $w_j$  is the weight value for each parameter  $j$ ,  $n$  is the parameter value,  $r_j$  is priority ranking for each parameter  $j$ , and  $r_k$  is the parameter number [13]. Eq.(1) assigns weights,  $w_j$  to  $n$  criteria with ranks  $r = 1, \dots, n$ , which have been suggested by Saaty T. L., 1990 [14]. Weight from evaluation using algorithm has been used to acquire final estimation value and mapped. Results of MCDM used to determine the weight of each environmental parameter. The site potential and final score mark are summarized in table 2.

### 2.5 Suitability Accuracy Assessment

Qualitative analysis was used to visualize the result while quantitative analysis presented by confusion matrix as shown in table 3. Congalton and Green, 1999 stated that accuracy assessments determine the quality of the information derived from remotely sensed data [15]. Based on the confusion matrix evaluation, the percentage (table 3) represents the accuracy of 8 land cover types classification. The overall accuracy of 69.29% and kappa statistic of 0.6117 is obtained. Based on this error matrix, the urban and vegetated areas are considered over estimated while the other features are underestimated. Overestimations of both features are reasonable due to mix pixels between the urban and the cloud reflectance in visible wavelength.

**Table 2.** Final score mark and suitable site potential analysis based for each parameter.

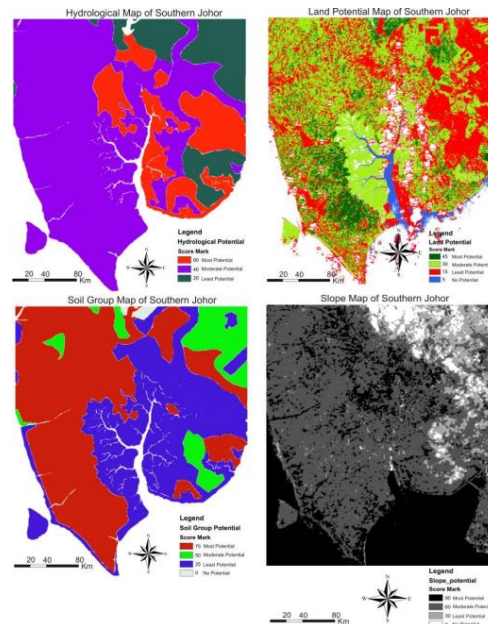
Data/ Map	Parameter	Description	Units	Suitable Score	Weight Value	Score Mark
<b>Slope Map</b> (ASTER DEM)	<b>Slope</b>	a) 0%-10%	Percentages [%]	3	30	90
		b) 11%-20%		2		60
		c) 21%-35%		1		30
		d) >35%		0		0
<b>Soil Group Map</b>	<b>Soil Texture</b>	a) Fine loamy, clay loam, deeply developed soil with detectable accumulation of organic material	Unit less [.]	3	25	75
		b) Sandy, silty and clayey alluvial soil		2		50
		c) Sandy soil, silty, clayey alluvial and 202ravelled alluvial deposits		1		25
		d) Very pebbly soil		0		0
<b>Soil Hydrology Map</b>	<b>Drainage</b>	a) Good drainage, good aquifer, surface water and infiltration zone	Unit less [.]	3	20	60
		b) Moderate drainage, inter floor water and spring zone		2		40
		c) Excessively drained, high runoff		1		20
		d) Bad drainage and not suitable for urban forestry location		0		0
<b>Land Potential Map</b> (SPOT Satellite Image)	<b>Availability of Natural Resources</b>	a) Dense forest, pond lake, and river, vegetation and plantation area	Unit less [.]	3	15	45
		b) Secondary forest, stream, vegetation and plantation area		2		30
		c) Open area, bare land and swampy		1		15
	<b>Vicinity to Urban Area</b>	a) <3km	Distances [km]	3	5	15
		b) 3km – 5km		2		10
		c) 5km – 10km		1		5
		d) >10km		0		0
	<b>Reservation Area</b>	a) Reserved Forest	Unit less [.]	3	5	15
		b) Historical Park		2		10
		c) Watershed area for urbanization water supply		1		5

**Table 3.** Confusion Matrix Analysis Assessment.

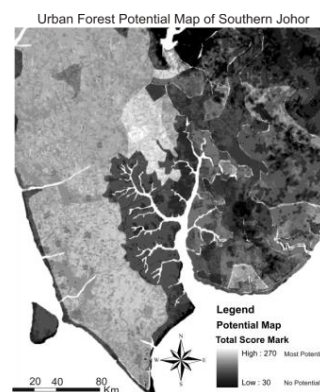
	Urban	Forest	Pond/lake	Open area	Vegetation	Sea	River	Mangrove	Total pixel	Accuracy (%)
<b>Urban</b>	<b>243</b>	48	1	5	77	7	6	33	424	57.31
<b>Forest</b>	12	<b>145</b>	-	-	84	-	1	13	255	56.86
<b>Pond/lake</b>	-	-	<b>3</b>	-	-	-	2	2	7	42.86
<b>Open area</b>	7	1		<b>11</b>	8	-	1	-	28	39.29
<b>Vegetation</b>	84	122	3	12	<b>469</b>	3	6	23	722	64.96
<b>Sea</b>	2	-	-	-	-	<b>346</b>	2	16	366	94.54
<b>River</b>	3	-	-	-	-	9	<b>44</b>	6	60	73.33
<b>Mangrove</b>	1	-	1	-	2	1	24	<b>156</b>	183	85.25
<b>TOTAL</b>	<b>352</b>	<b>316</b>	<b>8</b>	<b>28</b>	<b>640</b>	<b>366</b>	<b>86</b>	<b>249</b>	<b>2045</b>	

### 3. Result and Analysis

The potential area based on qualitative for urban forestry landscaping site was produced after the classification, digitizing and overlaying the auxiliary information. Sites indicating most potential, moderate potential, least moderate potential and no potential were finally mapped as illustrated in figure 4. From the quantitative analysis in table 2 and qualitative visualization in figure 4, final map is produced. Figure 5 shows the most potential area for urban forest landscaping, which was indicated in brighter white has the higher score marks and darker black has the lower score marks as shows in table 4.



**Figure 4.** Analysis of GIS produce the Urban forest Potential Map of southern Johor, Malaysia.



**Figure 5.** Urban forest Potential Map of southern Johor, Malaysia.

**Table 4.** Potential area based on score mark range as per final map

	Potential Score Mark Range	Description	Potential Location as per final map
Most Potential	180 ~ 270	Fine loamy to moderate soil, various natural resources as forest, plantation and vegetation.	Pontian Surrounding area
Moderate Potential	110 ~ 179	Moderate soil and Vegetation area	Gelang Patah
Least Potential	80 ~ 109	River, Mangroves and Steep slope	Gunung Pulai
No Potential	30 ~ 79	Sea, Steep slope and Reservation area	Gunung Pulai

#### 4. Discussion and Conclusion

As conclusion, the sustainable urban forestry can be measure by using geospatial technique with the integration between RS and GIS. The measurement involves both quantitative and qualitative evaluation with combination result from accuracy assessment and MCDM technique. MCDM generated based affordable cost and workforce for decision-making in urban forestry planning and landscaping. Thus, stabilize ecosystems in urban areas from the climate change such as extreme weather or flash floods. Integration of remote sensing and GIS results a powerful tool for generating map and identifying the potential area for landscape. Supporting information such as soil series, land use, soils group and hydrology map, topographical map and also digital elevation model from ASTER

with 30m resolution are very useful for identification and allocation of potential site in urban forest landscaping.

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