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The Development Of A Site Suitability Map For RBF Location Using Remote Sensing and GIS Techniques

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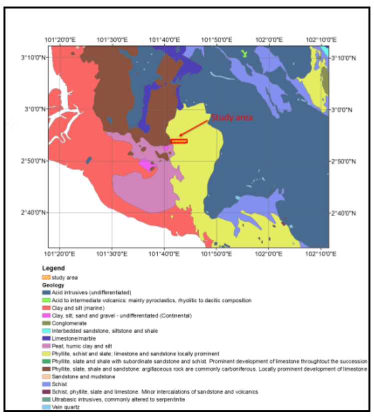
Graphical abstract



Abstract

Remote sensing and Geographic Information System (GIS) techniques was used in this study to develop the site suitability map for river bank filtration (RBF) locations based on a case study in Jenderam Hilir, Dengkil. A high resolution 2012 GeoEye-1 satellite image was classified into six classes using the supervised maximum likelihood classification process. The classified image was further analyzed using GIS techniques such as overlaying, buffering and Boolean analysis, to identify the suitability of a RBF location area based on location, distance from the river and distant from built up area. Geology and hydrogeological map were extracted from published maps, which are then converted and integrated into the GIS spatial database. The classified GeoEye-1 results show that the overall accuracy is 89% with kappa statistic of 0.864. The developed site suitability map for RBF locations also in good agreement with the existing borehole location of the study area.

Keywords: GIS, RBF, remote sensing, site suitability map

Abstrak

Untuk membangunkan peta kesesuaian tapak untuk lokasi penapisan tebing sungai (RBF), teknik penderiaan jauh dan sistem maklumat geografi (GIS) telah digunakan untuk kawasan kajian Jenderam Hilir, Dengkil. Imej satelit GeoEye-1 yang beresolusi tinggi telah dikelaskan dengan menggunakan proses pengelasan kebolehjadian maksimum terselia kepada enam kelas. Imej yang telah dikelaskan ini seterusnya dianalisis menggunakan teknik GIS seperti tindanan, penimbal dan analisa untuk mengenalpasti kesesuaian lokasi RBF berdasarkan pada lokasi tempat, jarak dari sungai dan jarak dari kawasan pembinaan. Maklumat geologi dan hidrogeologi kawasan telah diperoleh daripada peta terbitan dan kemudiannya telah ditukarkan dan disepadukan ke dalam pangkalan data spatial GIS. Hasil keputusan pengkelasan imej GeoEye-1 menunjukkan bahawa ketepatan keseluruhan adalah 89% dengan nilai statistik kappa 0.864. Peta kesesuaian tapak untuk lokasi RBF telah dihasilkan dimana bertepatan dengan lokasi borehole yang sedia ada di kawasan kajian.

Kata kunci: GIS, kawalan penderiaan jauh, peta kesesuaian tapak, RBF

1.0 INTRODUCTION

Riverbank Filtration (RBF) is defined as the influx of river water to the aquifer induced by a hydraulic gradient [1]. It offers low-cost and efficient natural alternative technology for water supply application where surface water contaminants are removed or degraded as the infiltrating water moves from the river/lake to the pumping wells [2]. The technology can be applied directly to existing surface water reservoirs, streams, lakes and rivers[3]. It is now used as a guiding factor in hydrogeological investigation of new supply source[4].

Surface characterization is important to determine suitable areas for RBF sites where characteristic in terms of environment, utilities, geography, geology, hydrological and buffer zone area have to be complied[5]. However, selecting the suitable area for a RBF location using conventional methods are costly, time consuming and restricted to a small area. Nowadays, many engineering techniques have been developed to facilitate the site selection process in order to minimize the risks. Spatial analysis such as remote sensing and GIS analysis technique can be used to facilitate the task especially for spatial data [6].

Remote sensing can be used to derive information for the top layer of the soil,[7] location of fracture, [8] recharge and discharge areas [9] Recent land use and land cover information can be extracted efficiently from satellite images with a minimal cost and wide range of landscape biophysical properties in a short time compared to in-situ monitoring systems [10, 11]. In this study, remote sensing was used to extract surface information, derive and infer soil properties, and integrate the satellite data into the GIS framework [12].

Integration of remote sensing and GIS technologies provide an efficient method for the analysis of land cover issues and tools for land cover planning and modelling. It is able to plan and manage the land use suitability mapping for various uses of natural resources and conservation with the availability of land use and land cover surface terrain by using remote sensing data together with GIS analysis by modern GIS tools [13, 14, 15]. Therefore, the main objective of the study is to develop a RBF site suitability map using remote sensing and GIS techniques. The study would be conducted in an area in Jenderam Hilir, Dengkil to validate the method used.

2.0 STUDY AREA

The study area is located in Jenderam Hilir, Dengkil, Selangor as shown in Figure 1 with latitudes of 2°52’55’’ to 2°53’40’’ North and longitudes of 101°40’20’’ to 101°43’40’’ East. The study area is situated in the Langat basin that has a total area of 2,100 km^2. The area comprises of 1,155 km^2 hilly mountain terrain and 945 km^2 of coastal terrain. The nearest town, Dengkil is located at the southern part of Putrajaya.

The main river that flows through the study area is the Langat River measured at 78 km long and has a catchment area of 2,100 km^2. The river originates from Titiwangsa Range at Gunung Nuang and drains westward from northeast to Straits of Malacca. The main tributary of the Langat River consist of Semenyih River and Labu River. There are eight water treatment plants along the Langat River but several water intakes and treatment plants were shut down due to serious river pollution that affect the water supply services and economic activities of the industries since the last 20 years [16].

The site was chosen where an existing borehole that was used as an experimental study area by the National Hydraulic Research Institute of Malaysia (NAHRIM) located at coordinates of latitude 2.891222° North and longitude 101.701528° East. The availability of the borehole data can be used to validate the results of this study.

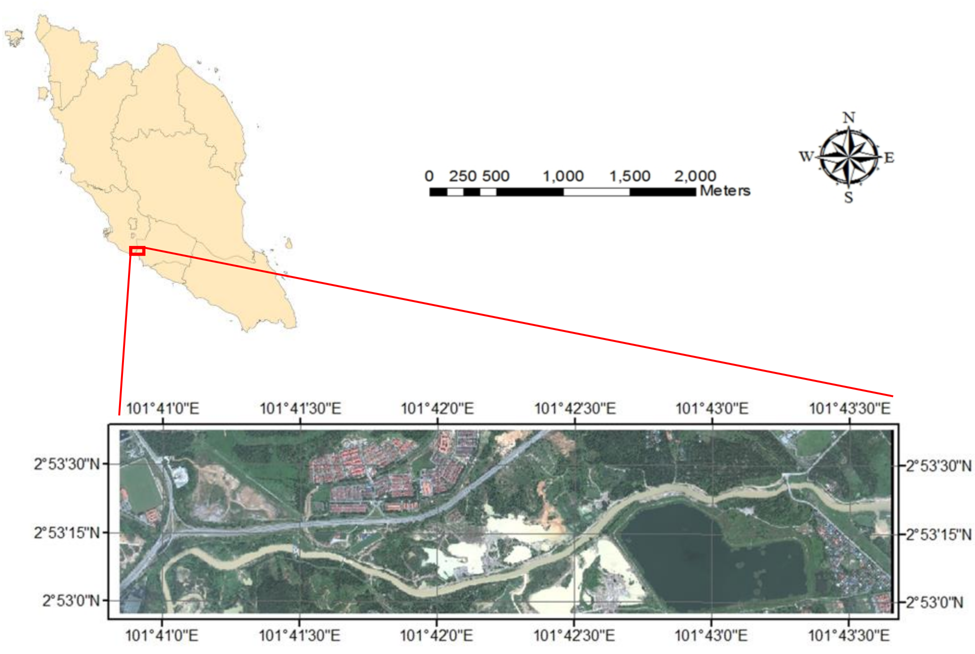


Figure 1 Location of the study area in Jenderam Hilir, Dengkil, Selangor, Malaysia

3.0 DATA SOURCES

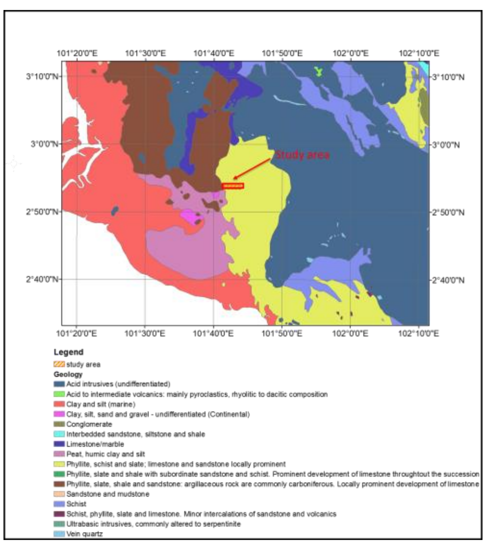
The data sources comprised of remote sensing satellite imagery and ancillary data. GeoEye-1 Satellite data was acquired in December 2012 with 0.6m resolution from Geo Spatial Solutions Sdn Bhd. Malaysia. The image was acquired during the hot and humid weather in December. Ancillary data includes Topographic, Land Use, Geological and Hydrogeological maps (Figure 2), obtained from the Department of Agriculture (DOA), Department of Survey and Mapping Malaysia (JUPEM), and Minerals and Geoscience Department Malaysia (JMG). The GeoEye-1 image and all the maps were rectified using geometric correction and projected onto Oblique Mercator Kertau RSO Malaya projection.

4.0 METHODOLOGY

4.1 Satellite Imagery Classification

The aim of image classification is to categorize all pixels in an image into land cover classes automatically. The classification scheme adopted shows in Table 1 is based on the classification scheme source from U.S Geological Survey Land Use/Cover System by Anderson *et al.* (1976) with slight modifications to meet the native land cover of the study area. Land covers were classified into six classes namely agricultural, rangeland, river, shallow water, built up and barren land (see Tab. 1).

The GeoEye-1 image was classified using the supervised maximum likelihood techniques using the ERDAS Imagine version 9.1 software. Initially, the spectral signature class of land cover types for the study area was extracted from the original satellite image. During the process, ancillary data such as topographic map, land use map and field knowledge were used to assist the visual interpretation process. A total of 42 spectral signature classes were collected by categorizing according to the classes given in Tab. 1. The separability analysis of the spectral signature class was conducted and then the final six sets of class signatures were produced by merging and recoding the initial classes. Next, the maximum likelihood classification techniques were applied to produce the land cover classification map. The post-classification processing method with majority filtering iteration is then applied to reduce the scattering results appearance error onto the classified images. In the final classification process, the accuracy of the classified image was evaluated by selecting more than 150 with a minimum of 15 sample points by using stratified random sampling. The sample points generated were validated through reference data by visual interpretation. The accuracy report which described the overall accuracy, user's accuracy, producer accuracy and kappa statistic value was subsequently computed.



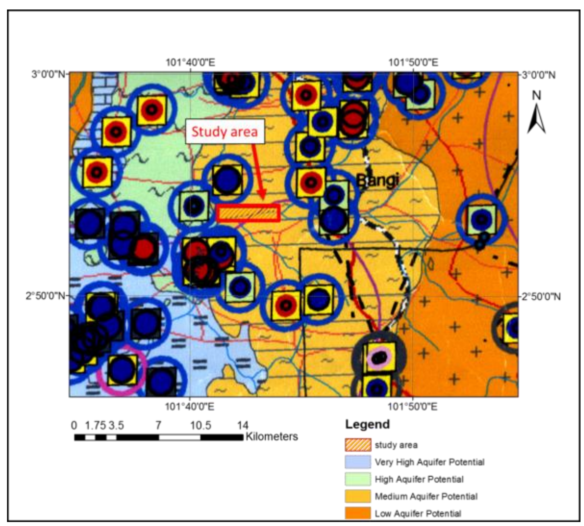


Figure 2 External data source used for the study area (a) Geological map and (b) Hydrogeological map of Peninsular Malaysia, scale of 1:500,000

Table 1 Description of Land Cover class in the study area (Source; Anderson *et al.,* 1976).[17]

Name of Class	Description
Agricultural	Mixed agriculture land
Range-land	Shrub, brush and grassland
River	River classes cover streams, canals, bays and estuaries
Shallow water	Lakes classes cover a pond, and former mine to differentiate with the river
Built-up	The area covered by residential, commercial and services, industrial and road
Barren-land	Open area covered by bare, expose rock, soil and mining activities

4.2 GIS Analysis

The first step in delineating a suitable area for RBF area is to identify the relevant surface land area component variables. Several variables that are relevant for suitable locations of RBF extraction areas are: (1) range-land and barren-land/open areas, [1] (2) distance from the river should be within the range of 10% to 20% of river width,[18] and (3) the RBF well location should be 15m far from the built-up area.[19] Boolean techniques were then applied to create the RBF suitability map for RBF location areas using these variables as the criteria.

Next, four classes that consist of range-land, barren-land, river and built-up were separated into a new layer as shown in Figure 3. A buffer zone of 4m to 8m which is about 10%-20% of the river width was determined. The built-up class was buffered with a radius of 15m to indicate the unsuitable area. Subsequently, Boolean 'AND' logic were applied to all layers (range-land layer, barren-land layer, river buffer layer and built-up buffer layer) in order to create an overlapping area thereby producing an overlay layer of site suitability area for RBF locations. These GIS analysis was conducted by using the ArcGIS V10 software.

5.0 RESULTS AND DISCUSSION

5.1 Classification Analysis

A final land cover classification map and a summary of land cover classification area statistics are shown in Figure 3 and Table 2. The highest percentage area is the agricultural class that consist of 31.2%, followed by 29.9%, 13.6%, 11.7%, and 7.7% for range land, barren-land, shallow water, and built-up respectively. The lowest class area is river that takes up about 5.9% of the total area and is mainly contributed by the Langat river that flow from east to west of the study area. The built-up class, especially urban area is mainly located at the north-western and some region at the east part of the study area.

The accuracy measures such as producer's accuracy, user's accuracy, overall accuracy and the kappa statistic of classified images using the supervised maximum likelihood technique are summarized in Table 3. The supervised classification technique produces the overall accuracy and kappa statistic of 89% and 0.864 respectively. This accuracy result is within the 75% to 95% satisfactory level for land cover classification map using high resolution imagery. [20, 21, 22, 23].

Table 2 Distribution of land cover class area for classified image

Class Name	Area	
	Ha	%
Agricultural	202.3	31.2
Range-land	193.8	29.9
River	38.1	5.9
Shallow water	75.8	11.7
Built-up	49.9	7.7
Barren-land	88.5	13.6
Total	648.4	100.0

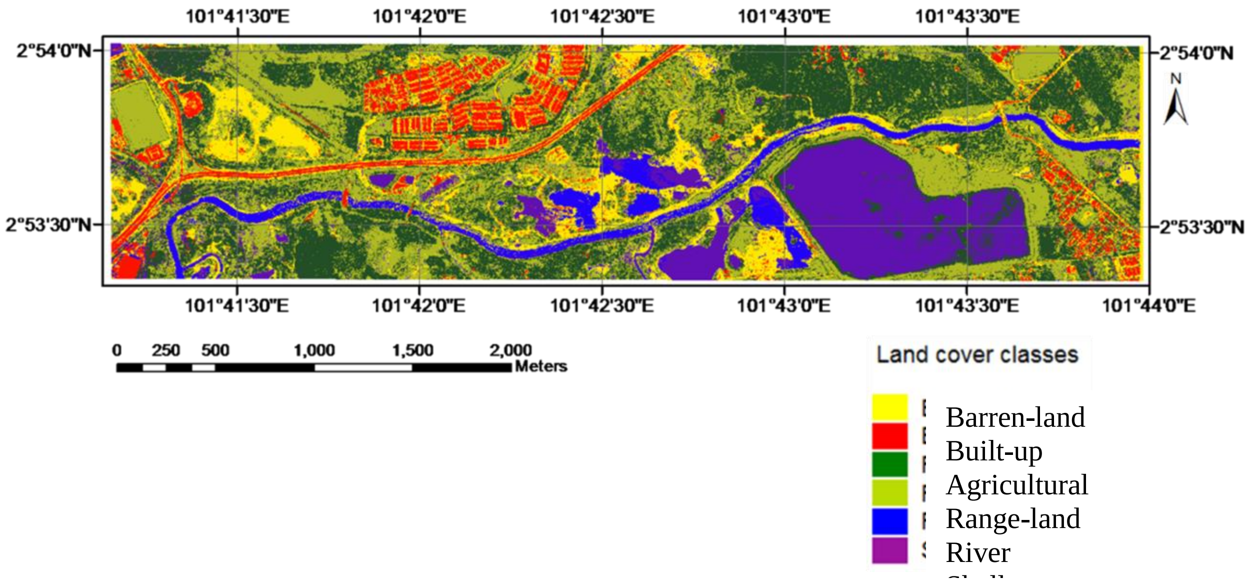


Figure 3 Classification image using the supervised maximum likelihood classification technique

Table 3 Error matrix of classified image

Class Name	Supervised Maximum Likelihood	
	Producer's Accuracy	User's Accuracy
Agricultural	100.00%	88.24%
Range-land	81.97%	100.00%
River	94.12%	80.00%
Shallow water	85.71%	88.89%
Built-up	80.00%	90.91%
Barren-land	95.83%	76.67%
Overall accuracy		:89.00%
Kappa statistic		: 0.864

5.2 RBF Suitability Analysis

The site suitability map for RBF location in the study area is developed as shown on Figure 4. The light blue colour on the map (Figure 4) indicates the suitable location for RBF area that is mostly concentrated at open areas (range-land and barren-land) near (4 to 8 meters) to the Langat river. The results also indicates that the total suitable RBF area is approximately 27,081.75m^2 which is around 0.42 percent of the total study area.

The presence of an aquifer layer is a very important factor in determining the availability of water for RBF. Ground resistivity survey conducted at the study area shows that the aquifer thickness of the alluvium in the study area ranges from 5 to 20m [24]. From the lithology logging, the subsurface is covered by alluvial deposits, consisting of sand, silt and gravel, which forms the shallow aquifer [25] The site is situated at the medium aquifer potential type which gives the moderate potential of transmissivity and storability characteristic based on the hydrogeological map (Figure 2b). This shows that the site area is suitable as a site for RBF. Furthermore, an existing borehole at the study area coincides with the results of RBF area, and further supports the location suitable for RBF water extraction.

6.0 CONCLUSSION

This study has successfully developed the site suitability map for RBF locations in Jenderam Hilir, Dengkil using remote sensing and GIS techniques. The accuracy result of the classification map produced by using supervised maximum likelihood is above 80% and is acceptable for high resolution satellite imagery. The total suitable area for RBF is found to be 0.42% (27,081.75m^2) of the total study area and has been validated through the site of an existing borehole. The final suitability map produced can be readily used to provide the information for suitable application of RBF location area that can be used by water supply management for extraction purposes.

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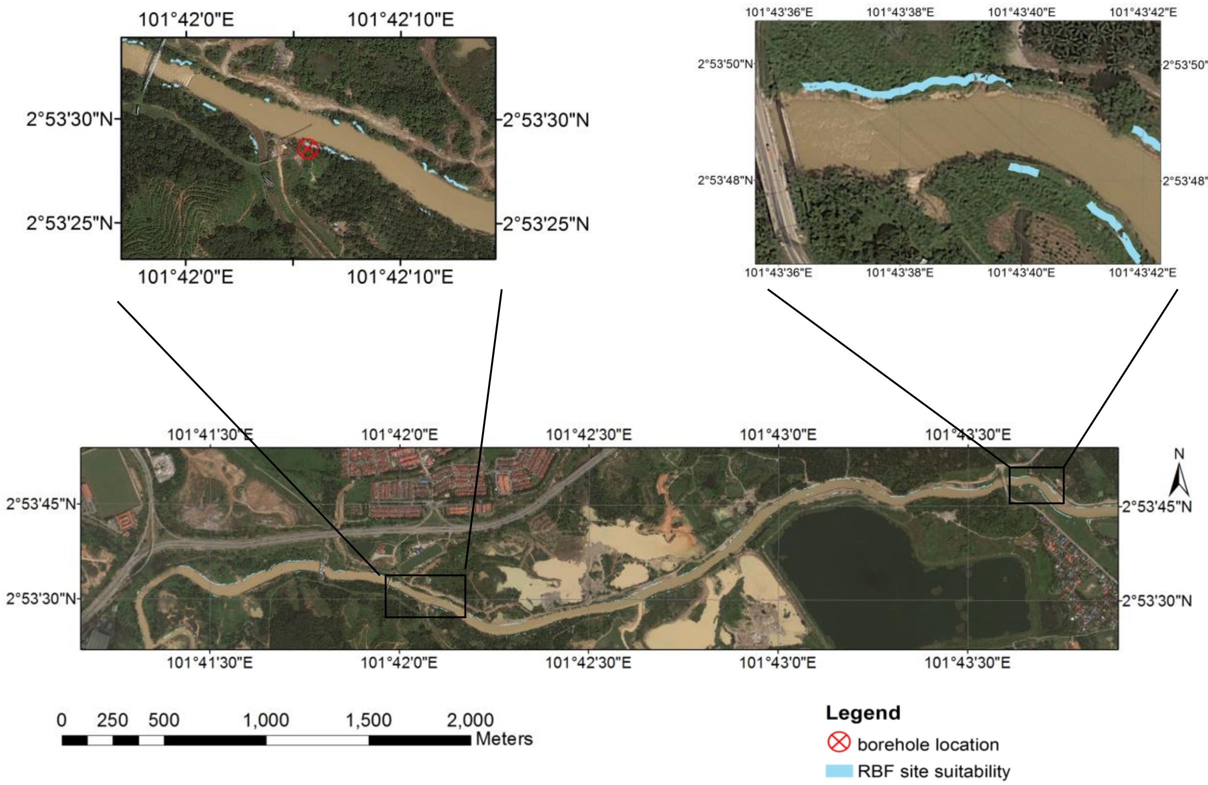

Figure 4 Site suitability map for RBF location area at Jenderam Hilir, Dengkil

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