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Using Remote Sensing Coupled with Analytic Hierarchy Process Approach for Evaluating Water Harvesting in Baglia Site

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Abstract

This research involves the application of spectral indices and GIS techniques coupled with the Analytic Hierarchy Process, to assess Baglia site, eastern Missan, as a water harvesting potential site. The AHP and pairwise comparison have been used through select four criteria including TWI, TRI, MNDWI, and NDSI, which were deemed as impact factors for this study. All these criteria have been weighted according to their significance in the water harvesting system. The findings of the AHP analysis method explained that the WH potential zones in Baglia site were divided into three zones, namely, high, medium, and low suitability. The findings demonstrate that Bglia site, where the highly appropriate zone is located in the deep valley area, is the ideal location for setting up water harvesting operations. The low suitability zone, in contrast, is located in a higher terrain when there is a steep slope area.

Keywords: TRI, TWI, MNDWI, AHP, Baglia, water harvesting project

استخدام التحسس النائي مقترناً بنهج عملية التسلسل الهرمي التحليلي لتقييم حصاد المياه في موقع البجلية

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الخلاصة

تضمن البحث تطبيق المؤشرات الطيفية وتقنيات نظم المعلومات الجغرافية إلى جانب عملية التسلسل الهرمي التحليلي ، لتقييم موقع البجلية ، شرق ميسان ، كموقع محتمل لحصاد المياه. تم استخدام AHP والمقارنة الزوجية من خلال أربعة معايير مختارة بما في ذلك TWI و TRI و MNDWI و NDSI ، والتي تم اعتبارها عوامل مؤثره بالنسبة لهذه الدراسة .تم تقييم كل هذه المعايير وفقًا لأهميتها في نظام حصاد المياه. أوضحت نتائج طريقة تحليل AHP أن المناطق المحتملة كمناطق حصاد مياه ضمن موقع البجلية تم تقسيمها إلى ثلاث مناطق: وهي مناطق ملائمة بصوره عالية ومتوسطة ومنخفضة. تظهر نتيجة الدراسة أن موقع البجلية

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هو موقع مثالي لإنشاء مشاريع حصاد المياه ، حيث تقع المنطقة المناسبة بصوره جيدة في منطقة الوادي العميق.في المقابل, تقع منطقة الملاءمة المنخفضة في مناطق المتضرسة عندما تكون منطقة الانحدار عالية.

1. Introduction

Water is an essential element for life on the planet. Water scarcity was one of the major crucial problems that the world suffered from in recent decades. About 33% of developing countries have suffered from water scarcity for decades [1]. Iraq was an example for these countries, especially in the arid and semi-arid areas. By the influence of unplanned agriculture, industry, and human activities water resource are continuing to decline and deteriorate in quality. Therefore, a strategy for the sustainable management of water resources must be developed. In the eastern part of Missan water is always hampered due to the limited availability during the drought period (dry season), while flood frequently and intensely occurs in the wet season. In the same way, population growth is associated with water scarcity which may be increasing by global warming[2]. To overcome the problem by collecting water for completing the need and use of water inefficient ways, thus minimize the pressure on our limited water resource.

Water harvesting techniques are the chosen promoted strategy to be introduced to the community for handling water scarcity and disaster due to floods [3]. This term has a lot of definitions and classifications to summarize, it accumulates, stores and manages rainwater also flooding to be used for domestic and agricultural affairs. In addition to recharge groundwater [4]. In this paper, Baglia site, eastern Missam, Iraq, has been evaluated as a suitable site for water harvesting projects. Remote sensing data (Sentinal2 and SRTM DEM) and GIS were coupled with the Analytic Hierarchy Process.

The analytic hierarchy process (AHP) /is a multi-criteria analytical method has been evolved by Thomas L. Saaty in the 1970s [5]. Which is used to simplify and organize the difficult and complex results, depending on mathematics and psychology foundation [6],[7]. AHP is a delicate procedure to compute the weights of used criteria. During the evaluation the relative magnitude of the criteria of pairwise [8]. The analytic process hierarchy approach is widely used around the world in various fields like business, healthcare, and education [9]. The AHP method has been applied by many researchers in Iraq to assign water harvesting suitable sites.

In this study, four spectral parameters have been achieved using GIS and remote sensing strategies, previous studies, and study area conditions. All these parameters have been weighted according to their significance in the water harvesting system. The selected criteria are terrain roughness, terrain ruggedness, modified normalized difference water, normalized difference, and normalized difference sand index.

1. Topographic wetness index (TWI) / Topography is the major factor controlling the hydrologic process. The topographic wetness index (TWI) can be defined as a topographic index that is evaluated potential sites of water accumulation. The high rate of TWI reflects a low slope area and vice versa. TWI was created by Beven and Kirkby based on TOPMODEL [10]. TWI is a unitless index that is expressed as [11]:

$$TWI = \text{In}\,(a / \tan b) \quad (1)$$

Where: *a* is a local upslope of a certain area, and *b* represents a local slope.

In current study, DEM at 12.5 m is used to calculate the slope, flow direction, flow accumulation, tan of slope, and eventually TWI by equation no.1

2. Topographic Ruggedness Index (TRI) / An important variable which is used to analyze the landscape and reflect the hydrological process in a certain area [12]. In 1999 TRI had been improved by Riley and others to explain the variation in elevations between surrounding cells in the digital elevation model. In other words, TRI detects the topographic heterogeneity values (topographic roughness) for the center pixel and eight pixels surrounding it and calculates it in meters. This index plays a significant role in hydrologic, engineering, and geomorphologic applications. TRI can be calculated by this mathematical equation [13].

$$TRI = [\sum (x\alpha - x00)2]1/2 \qquad (2)$$

Where, $x00$ is elevation of each neighbour cell to cell (0, 0), and Y is a column in the model grid to the cell.

3. Modified Normalized Difference Water Index (MNDWI) / The MDWI is one of two significant spectral indices that are used to monitor surface water. MNDWI had been derived from NDWI, which is used near-infrared and short-wave infrared to detect water bodies. NDWI is highly affected by the reflectance of build-up land and vegetation. So, it has to minimize the exaggeration in water-reflected data [10]. Clearwater cannot reflect the electromagnetic of near-infra-red and short-wave-infra-red. In 2006 NDWI is corrected and modified by Hanqiu Xu by utilizing green and shortwave infra-red, as expressed [14]:

MNDWI = (Green – SWIR) / (Green + SWIR) …………..……………... (3)

4. Normalized Difference Sand Index (NDSI) / Known as a sand presence spectral index. In Landsat 8, the reflected bands recorded by OLI are ranging from (0.43 -2.29 µm). Sand reflectance values start from minimum wavelength (0.64–0.67 µm) and reach (0.43–0.45 µm) In other words differences between band1 and band4 help to explore sand reflectance in spectral recorder data. The NDSI can expressed mathematically as [13]:

NDSI = UTRABLUE - RED / UTRABLUE + RED ……………………… (4)

2. Study Area

This study was carried out in eastern Missan near the Iranian border. The study area is covering an area of 121km and lies between longitude 718788.53 m E, 739066.22 m E, and latitude 3583731.16 m E, 3566934.05 m N [15] (Figures 1, and 2). The study area is situated in the Foothill zone specifically in Makhul –Hamrin subzone [16]. The average elevation of Baglia site about (31 to 163) based on SRTM DEM with 12.5m Figure 2.

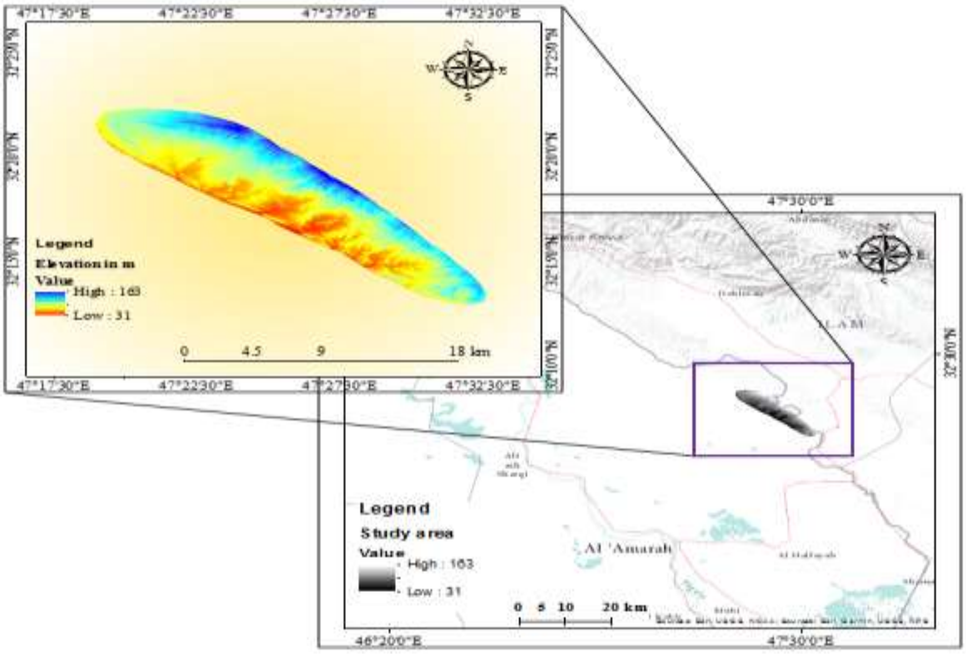


Figure 1: Location of study area

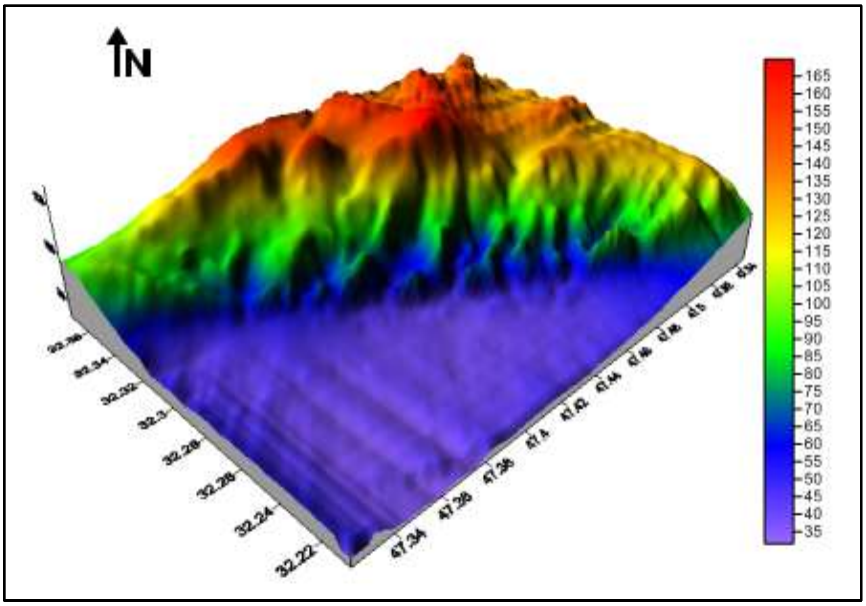


Figure 2: Topography of Baglia site

3. Methodology

in this research, GIS techniques and spectral were utilized indices to evaluate the Baglia site as a water harvesting suitable site. Remote sensing data (Sentinel2 imagery and SRTM DEM) and GIS coupled with the AHP approach in assessing the study area. These data were downloaded freely from USGS website [17]. Erdas imagine 14 software was used for enhancing the satellite imagery through radiometric and geometrical. Procedure of the study can be categorized into:

3.1 Application of AHP in the study

Set up an n*n matrix, the matrix of pairwise comparison pairs of factors that are compared with each other to determine the most important factor (Table1 and Figure 3). Making a pairwise comparison of each criterion according to their rank [18]:

Table 1: The Standardized pairwise comparison matrix and the weight of criterion adopted in the study

Criteria	**TWI**	**TRI**	**MNDWI**	**NDSI**	**Weight**
TWI	1	2	4	5	0.48
TRI	0.50	1	3	4	0.30
MNDWI	0.25	0.33	2	2	0.12
NDSI	0.20	0.25	1	1	0.07

3.2 Creating thematic layer of each parameter

Initially, the layers (chosen criteria) and determining the rank of each subdivision was achieved, according to the following steps:

- Topographic wetness index (TWI)

DEM was utilized to create TWI in ArcGIS by raster calculator in spatial analyst tool (Arc toolbox) through this equation [18]:

TWI = In (fa – scaled) / (tan slope).. (5)

Where: (fa – scaled) is flow accumulation raster +1 * cell size of raster, and (tan slope) equals (con (slope more than 0, tan (slope), 0.001). Equation 7 is applied to create TWI for the study area Figure 4.

- Topographic Ruggedness Index (TRI)

The topographic Ruggedness Index (TRI) is produced using focal statistics of digital elevation model by this formula [18]:

TRI = (Smooth area – Min R) / (Max R– Min R)... (6)

Where: Smooth area is focal statistic mean value, while Min R and Max R are minimum and maximum focal statistics respectively Figure 5.

- Modified Normalize Difference Water Index (MNDWI)

The MNDWI layer is created based on sentinal2 imagery, according to equation no.4 which utilized band3 and band12 [14] Figure 6.

- Normalized Difference Sand Index (NDSI)

Both band1 and band4 have been applied in equation no.6 to create NDSI thematic layer [13] Figure 7.The preparation of thematic layers of adopted criteria in the study was explained in detail in Figure 4.

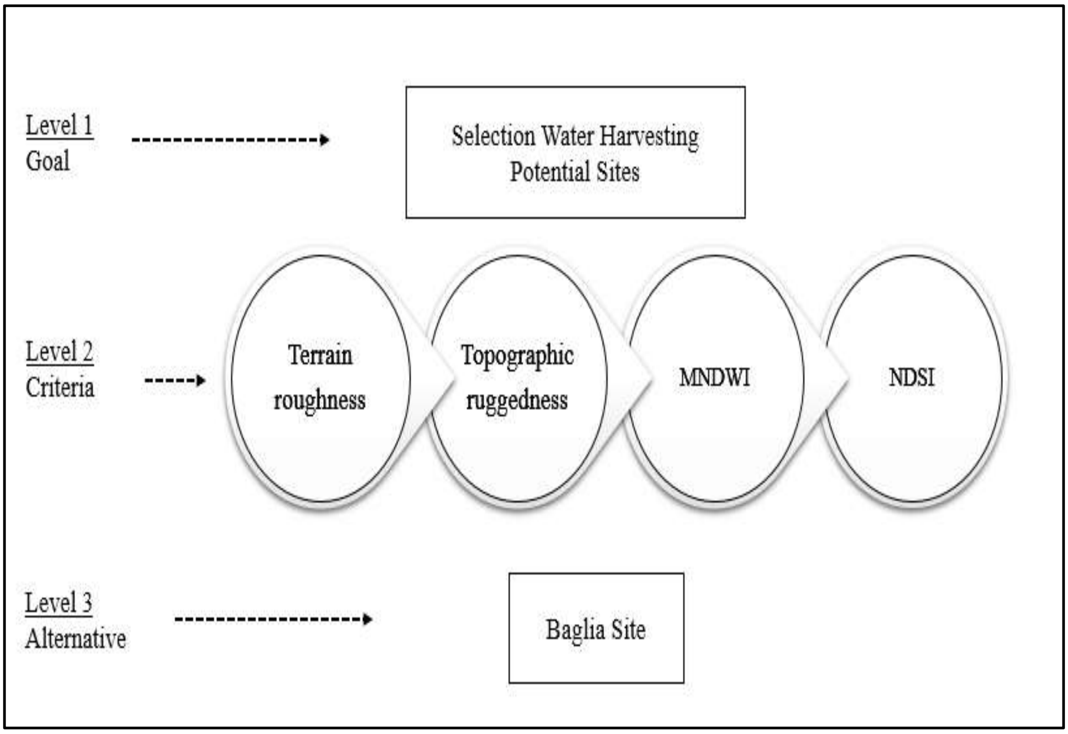


Figure 3: The analytical herrarchy process by Saaty Thomas,1980

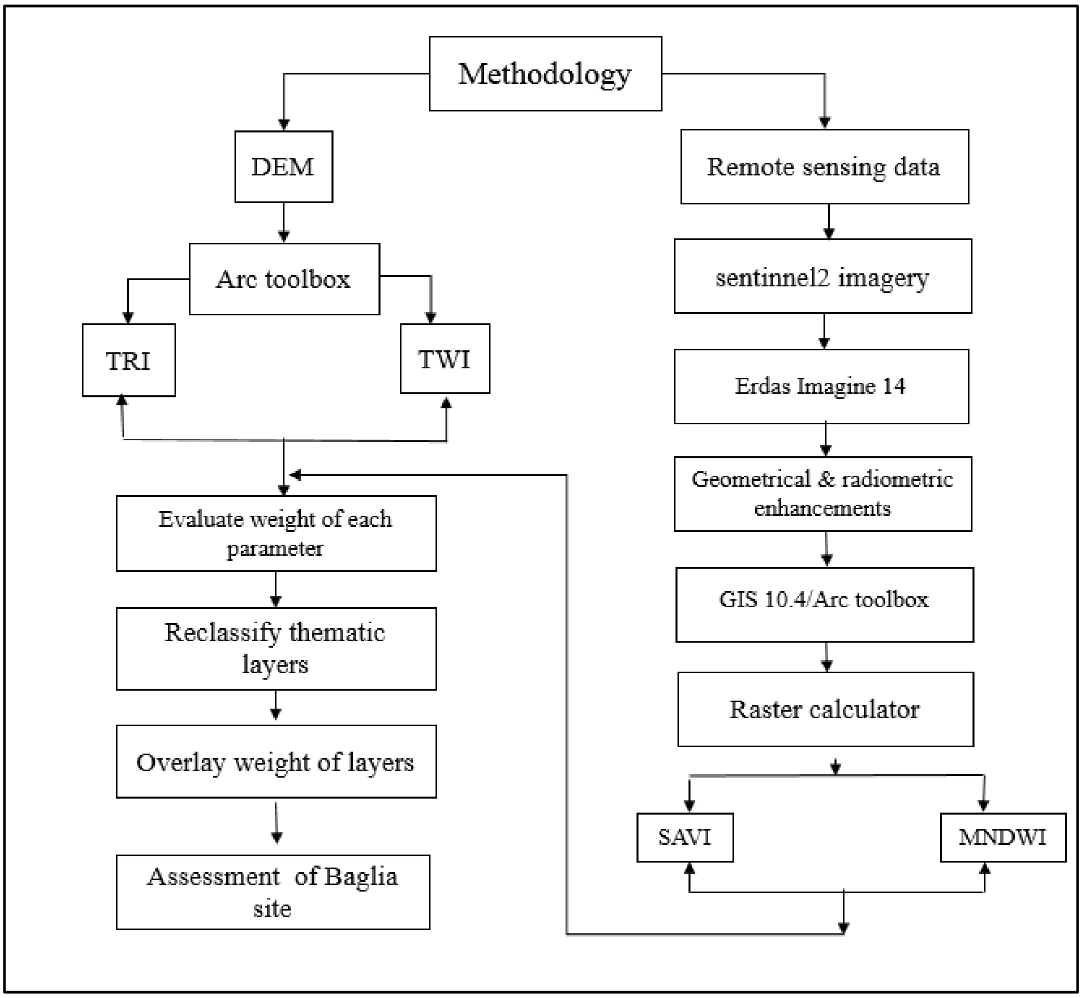
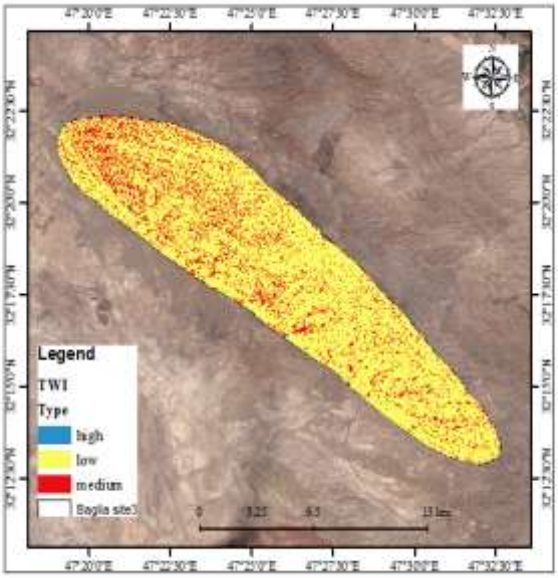


Figure 4: Creating thematic layer of each parameter

4. Results and Discussion

Figure 9 shows the final WH map, which was derived by an overlay layers TWI, TRI, MNDWI, and NDSI. This map reclassifies Baglia site into three subdivisions: High class/ the maximum value and high suitability area as a water harvesting site, medium class/ is the medium value of overlay and low value which is described as a low possibility to apply water harvesting projects.



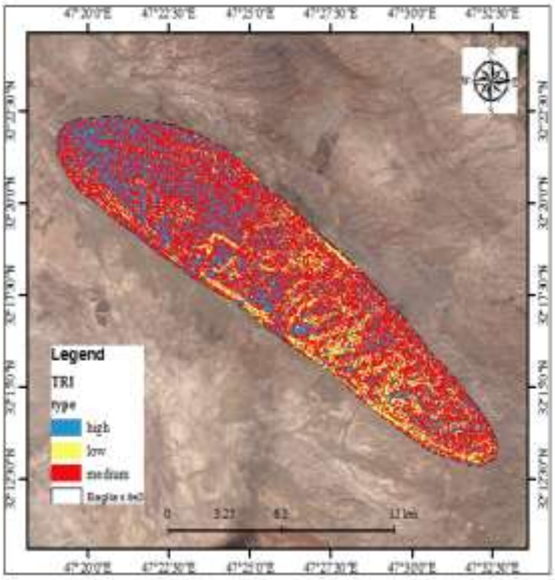
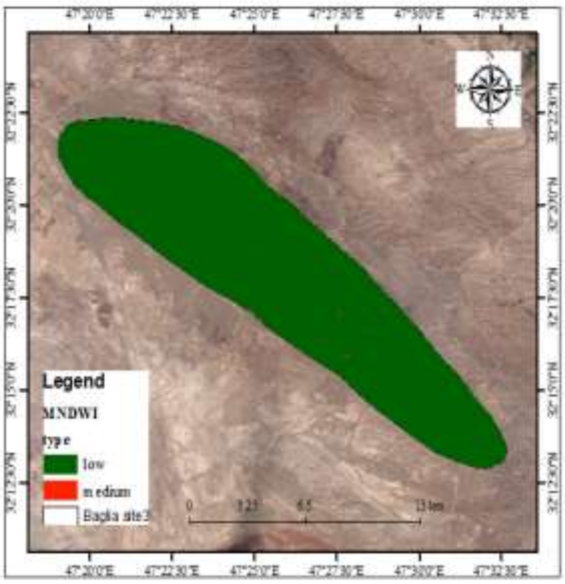


Figure 5: Topographic wetness index (TWI) **Figure 6**: Topographic Ruggedness Index (TRI)



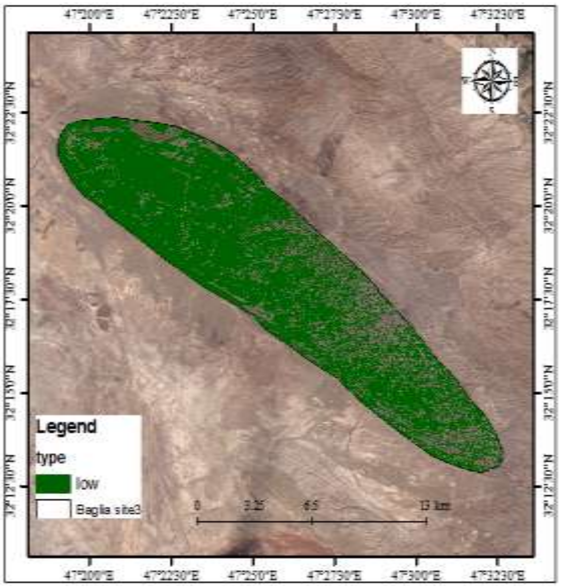


Figure 7: Application of MNDWI **Figure 8:** Application of NDSI

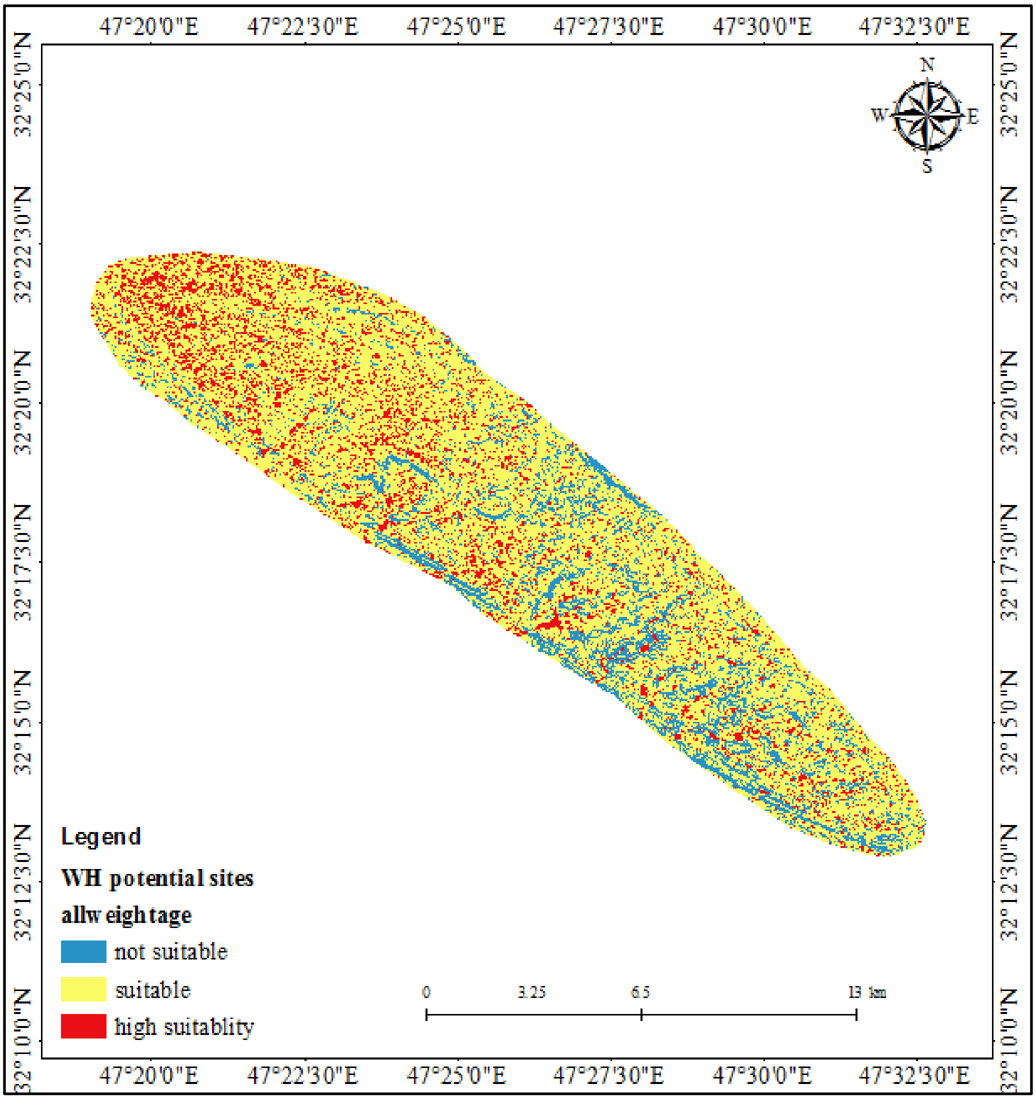


Figure 9: Map of water harvesting suitable site in Baglia site

5. Conclusions

The analytical hierarchy process (AHP) and remote sensing applications (spectral indices) have been used to evaluate the Baglia site as a potential site for a water harvesting project. The study has been achieved by several steps: create layers, then evaluating of weight, the relative weightage of each class of the four criteria has been discovered helpful in creating water harvesting mapping, finally overlay analysis of thematic layers. The WH potential zones in Baglia were divided into three zones, namely, high , medium, and low suitability. The result of the study shows that the Bglia site is a perfect site for establishing water harvesting projects, where the highly suitable zone is situated in the deep valley area. In contrast, The low suitability zone lies in a higher terrain when high slope. final water harvesting map derived from the integrated operation of several parameters: TWI, TRI, MNDWI, and NDSI. The research results show that the application of AHP and RS is powerful to delineate water harvesting zones in the three sites, In addition, this study can be adopted as a guide, for the exploitation of rainwater and torrential water through establishing surface and subsurface dams in Baglia site.

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