DETECTION AND DOCUMENTATION OF THE RED SNAKE BY MEANS OF REMOTE SENSING TECHNIQUES

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Abstract: The present research is related to the documentation of the great historical monument, Gorgan Wall, and its magnificent surroundings that is considered as the greatest historical Wall after the Great Wall of China in the world, using modern techniques of remote sensing. In this line, both spectral and structural capacities and fusing data in a two-level strategy have been used to make high spatial and spectral resolving power simultaneously and for fusing data in decision making level to accomplish desired goals. Moreover, some structural and descriptive layers were made and then, for the maximum simulation to the reality and taking into account the vagueness and inexactness of layers, Fuzzy ANP (Analytical Network Process) method for weighing the layers and Fuzzy WLC (weighted linear combination) technique, were used for standardizing and combining the layers. The achieved results of the detected monuments coincide completely with the existing realities on the ground.

Keywords: Heritage Documentation, Remote sensing, Image Processing, Gorgan Great Wall (the Red Snake).

1 Introduction

The natural and cultural heritage are of among the expensive gifts and capitals of each country, and the management approach of governments, must be based on giving priority to maintenance and reviving the natural and cultural heritage and paying attention to it and making it known. The importance and unique role of natural and cultural heritage in extending and developing the economic, industrial and social situation of the countries, requires that every activity about the betterment of maintenance and providing better facilities to study the natural and cultural heritage be done. Documentation, maintenance, restoration and reconstruction of monuments belonging to the natural and cultural heritage and also, their surrounding area, are of important duties of people and governments. For this reason, having spatial information and exact maps, will be the base of changes detection operation, maintenance, research, reconstruction and providing the national heritage archive (NHA). According to international treaties, the real shape of historical monuments, should be documented based on sufficient and different documentary indices and this, must include all encountered damages to the monument and its arena. Performing any fundamental operation for reconstruction, repairing, reviving, research and analysis of historical monuments and natural and cultural heritage, is just possible in case of complete measurement and documentation. Every kind of distortion and change in natural and historical monuments before scientific documentation the monument and complete knowledge about it must be forbidden and in case of occurrence, must be stopped immediately. By having correct spatial information, it is possible to guarantee the intelligent maintenance and knowledge-based management of natural and cultural heritage efficiently. A reliable archive of these monuments, makes it possible to prepare different maps, fast, easily and on time, and also, to exploit every information related to the natural or cultural monuments and doing research about them unlimitedly, even if it is severely damaged or completely destroyed. Heritage documentation is in fact used for the delivery of repairing design, environmental and archaeological projects, pathology and maintenance and reviving the natural and cultural heritage monuments. No activity can be correctly done in this scope, including research, holding and reconstruction, unless the monument and its surrounding area is correctly documented and recorded. Having such a database in Iran, is necessary, respect to there being numerous precious monuments that are unique in the world. Obeying the exploited laws and regulations from documentation, is obligatory for project executors, civil engineers and regional managers. Today, by the fast growth of citizenship and the extension of modern technologies, the necessity for more attention to health and stability of natural and cultural heritage and its arena and outlook, has increased. In case of lack of attention to this topic, human society will face non-compensable harms. The natural and cultural heritage is under two harming factors:

The first group of the harming factors includes the natural phenomena that entail cases like flood, earth-quake, volcano activity, erosion and the effect of plants and animals and so on. The second group of the harming factors that are the main and concerning factor, and has found an unprecedented speed and severity in last decades, is derived from humans unset meddling in nature and destroying the natural and cultural environment of the earth. Polluting water and soil, destroying jungles, making cities and also building industrial equipment in unauthorized places, destroying cultural and historical textures and destroying natural landscapes and many other anomalies can be mentioned among these factors. For this reason, it deserves that any effort be done in order to obtain practical ways and suitable guidelines for better understanding of the situation and maintaining the heritage and its arena. One of the important aspects of cultural heritage is its surrounding area that must be under attention and it is necessary that all developmental activities and also, aversion to arena and landscapes of historical monuments, be avoided. For this reason, according to the aforementioned treaty and also, determination and measurement of the extent of the harm to the arena, documentation by remote sensing can play an affective role in order for documentation and maintenance and also, for helping the responsible people in structure-making and setting their programs in damage prevention and crisis management. Now, in most countries, recognition and managing monuments and historical sites, is done in order to register and document the cultural heritage based on field works. These methods, in addition to low precision and non-completion in giving results, are very difficult and expensive. On one hand, respect to the high vastness of Iran and there being so much unknown historical monuments, knowledge-based guidelines are required that facilitate the recognition and management of country cultural heritage. So, using new technologies of remote sensing and geospatial information system are considered in different parts of the world and become known useful for this reason. Remote sensing in archaeology, tries to recognize the monuments and patterns remained from the humans past activities on the earth. Many researches have been done around the world about the function of remote sensing in archaeology that unfortunately, the contribution of Iran in it, is very low. In fact, remote sensing with vast and global visibility is able to act as a fast and exact tool for discovering the archaeological monuments information on or under the surface of the earth. By the development of this science in the recent years, the satellite and aerial images with high spatial and spectral resolving power are used for more exact discoveries of historical monuments on and under the surface of the earth. As far as the archaeological research are related to other sciences like botanical studies and other sciences and also, based on the principles of remote sensing, the spectrum of sunlight reflected from the earth surface, includes some information of the combination of the earth surface, thus, collecting these information in image and studying them by remote sensing, reveals clues from the past activities of human about agriculture, monuments and ways and the botanical coverage of that time and different kinds of stones and materials based on this assumption that each of them have different spectral specifications. Therefore, the remote sensing as a useful way for collecting information came into the competition stage and took step in line with completing and interpreting the archaeological studies and decreasing costs and times for detection and identification of ancient sites and monuments. Also, the changing factors on data and the harming factors on the arena, must be recognized and based on the correct recognition of the monument and its harming factors, the fundamental affairs must be conducted for solving these harming factors as well as for reviving the monument and its peripheral environment and improving level of intelligent management of natural and cultural heritage. In the present research, the efficiency of modern ways of remote sensing, for cartography, and documentation of parts of Gorgan Great Wall, that is the second great Wall in the world, after the Great Wall of China, is studied. For this purpose, some images with proper spatial and spectral resolution were prepared and were processed from spatial and spectral point of view, so that the promising signs in soil and plants anomalies and the geometry of the region under study can be detected. Then, for management and making an exact map, and considering all layers made based on an ANP Fuzzy technique, were integrated with each other till, the most exact possible output, that is, the promising regions map that includes the probable ancient points and the extent of probability, will be produced about Gorgan Great Wall and any historical and cultural monuments related to that.

1.1 The research background

Respect that the proper and high quality satellite images related to archaeological research, have been recently available, there are little research done about using remote sensing in revealing the cultural heritage and it is a very modern topic. Among the research works done in this subject, the following examples can be pointed out:

olsen (2004), showed in his study that many materials like phosphate and heavy metals, are in human ancient inhabits and proved that these materials can be detected by remote sensing methods (olsen, 2004). Grøn and Loska (2002), conducted a research about little anomalies in color and botanic coverage of places that have been the humans living places in the past. He showed that proper spectral indices, are designable and implementable to reveal such variations(Grøn and Loska ,2002). Barlindhaug (2007), used remote sensing to detect the changes of regions that had been settlement places in the past being used as agricultural fields(Barlindhaug ,2007). Egitto (2014), considered the systematic height disorders in regions that had cultural structures in the past(Egitto ,2014).

2 Gorgan Great Wall (the Red Snake)

The Gorgan Great Wall that has been called the red snake in the old texts is a historical Wall that starts from the Caspian seaside in Gomishan region and is continued till Golidagh Mountains in north east of Kelaleh. Figure 1 show the occasion of this Wall. Now, almost all parts of this wall have been destroyed and just, small parts of it that are under soil, is remained. The Gorgan historical Wall is the largest defensive Wall in the world, after the Great Wall of China. The first archaeological research performed on this Wall, was done by French scientist Zhak Demorgan. After him, another French archaeologist, called, Oren recognized and introduced parts of Gorgan Wall in a traversing form in 1933. In 1933, Erik Schmitt, flew over the region and observed a red color line on the ground. Mohammad Yousef Kiani, in 1971, flew over the Wall again and took some interesting images of the Wall and recognized the length of the Wall about 175 kilometers with 22 related parts (T. J. W. and J. N. Eberhard W.sauer,2015). An aerial view of the Wall is shown in figure 2. This Wall is longer than Hadrian Wall that was established by Hadrian Emperor in England and Scotland borders and is more than 1000 years older than many parts of the China Wall. This is also assumed that this Wall, is the world third historical wall and the world biggest brick wall (T. J. W. and J. N. Eberhard W.sauer,2015).

Figure1-USA military map of the USSR-Iran border compiled in 1951 illustrating the route of the great Wall of Gorgan

This historical wall, with moats, brick-making pits, dams and water-sending canals, castles connected to the Wall and the castles of big and small peripheral cities, is the longest architectural and military monument and also, is the biggest defensive structure of Persia. This ancient monument is also called "Sekandar (Alexander) dam", "Anoushiravan (Khosrow) dam", "Firouz dam", "Ghezel olang" and the defensive Wall. So far, the remainder of 30 castles and military colonies, have been recognized throughout this historical and old Wall in Golestan province and most of these castles, are built on its southern furrow, and still, some of these castles exist in some parts of the region such as BiBi Shiravan castle, Topragh castle and Dashte Halgheh. In figure 3, a sample image of the landscape of Gorgan Great Wall is shown.

Figure 2- Oblique aerial photo of the Gorgan Great Wall

The brick-kilns, were discovered and realized in line with this Wall, and also, it can be found red and grey crockery monuments aligned with the Gorgan historical due to the colonies and monuments that contain food dishes and different statues. The Wall is about 10 meters high and there are castles around the Wall that their nearest one is 50 meters and their farthest one is 100 kilometers and the castles are square-shaped or rectangular and their size is different. Their smallest size is 120 in 120 meters and their biggest one is 280 in 200 meters.

Figure 3- Excavation workshop before recovery operation of Gorgan Great Wall

According to the archaeological investigations, 30 castles are recognized and it seems that totally 40 castles exist. There is a moat in the northern part of the Wall that is mostly seen in its middle section. A sample view of exploration operation related to brick-kiln is shown in figure 4.

Figure 4-Archaeological excavation in a part of Gorgan historical wall

Now, in "pishkamar", north east of Kalaleh, a part of Wall, still, exists, and the best place that the remainders of the Wall can be observed, is the north of Gonbad, towards Kalaleh and Maraveh Tappeh and the best place among these regions, is also, "Namar Ghareh Ghouzi" village. That part of the Wall which is shown in figure 5 and on the Ikonos image of Gonbade Kavous city was considered as the case study in the current research.

Figure 5- The study region on the Ikonos satellite image of Gonbade Kavous

3 Methodology

After preliminary study on the subject, appropriate data were collected and a pre-processing procedure was applied. Then, required information layers from both structural and descriptive aspects were produced in order to get optimum results about track able ancient signals. These layers are then normalized and input the weighting and decision making process. The flowchart of the employed method is presented in figure 6.

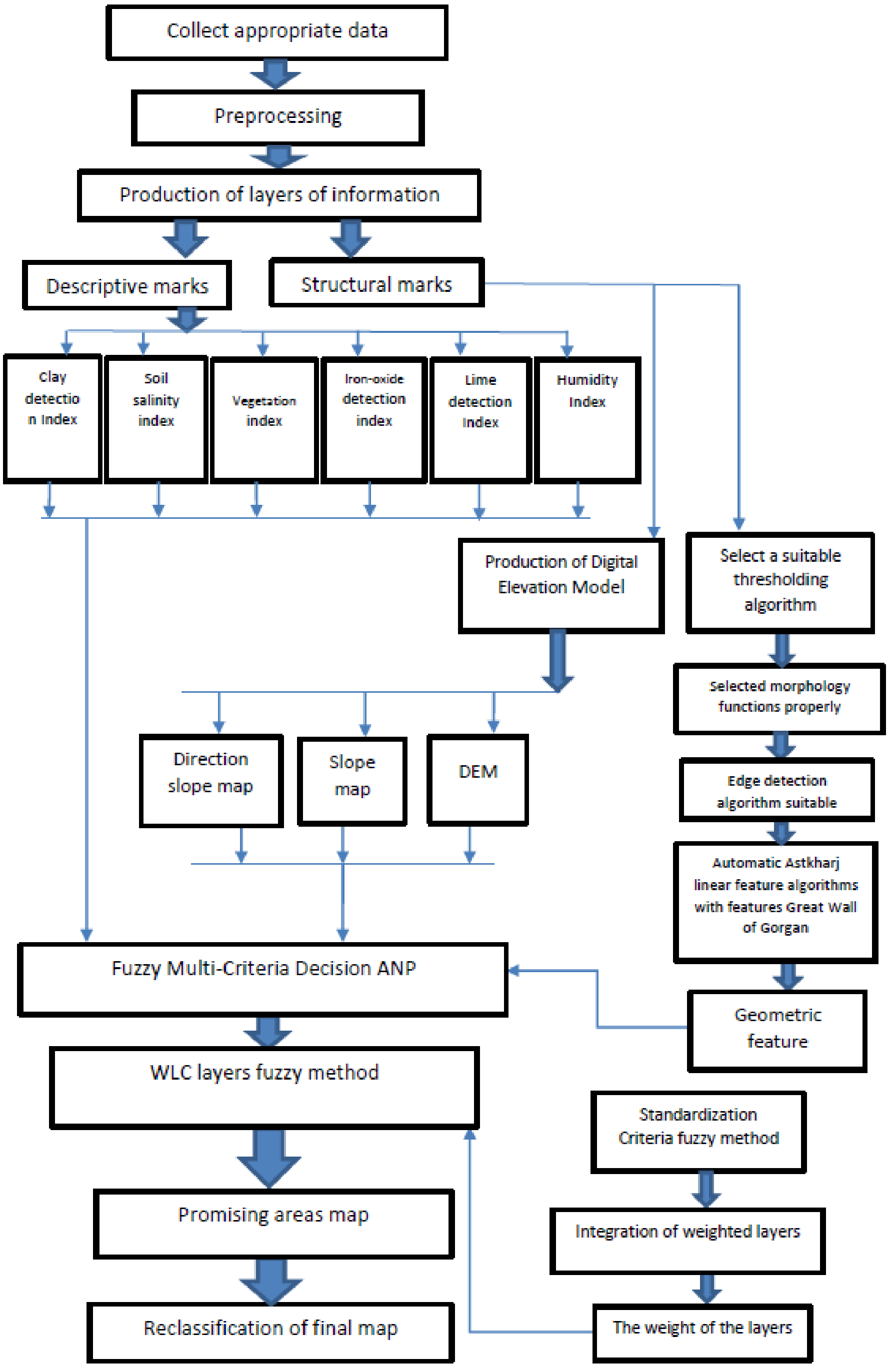


Figure 6-Flowchart of the conducted research work

3.1 Used data

The data accessible and used in this research are categorized in two parts: high resolution data and multispectral data that were used in combination with each other so as to get the best answer to the problem of detection and documentation of the Red Snake. The data used in this research are listed in table (1).

Table 1- Data used in the research

Data	Date
Multispectral image Landsat 8	2016
Panchromatic and multispectral Ikonose image	2000
Aerial Photos	1979
1:2000 Topographic map	2001

3.2 Pre-Processing

The acquired data must be pre-processed to be corrected for essential radiometric and geometric errors and preparing images for mosaic making and fusion. The conducted phases are explained in the following section.

3.3 Geometrical and radiometric correction

After acquiring proper data, the satellite images were considered from radiometric error point of view of and in this step, only the image of Landsat 8, needed correction and according to the dark object subtraction technique, the image was enhanced. Then, the images were corrected for geometric errors. To do this, precise 1:2000 topographic maps were used for extracting appropriate ground control points (GCP) that were used together with polynomials and nearest neighbor interpolation method to conduct the geo-referencing process. This operation was performed with accuracy better than 0.5 meter.

3.4 Making image mosaic

For making a suitable set of images, adjustment of their histograms was made so that an integrated image was made. In figure 7, the pictorial mosaic is shown that is cut by the size of studied region.

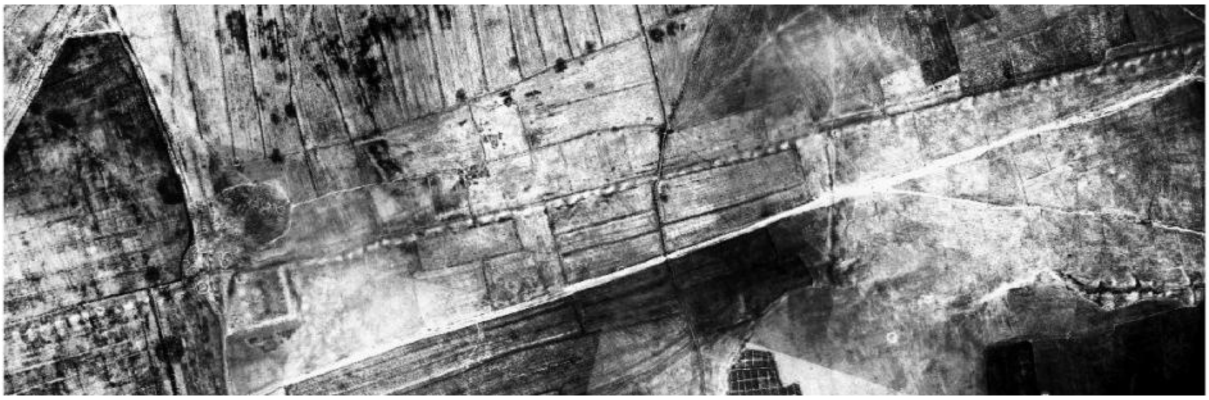
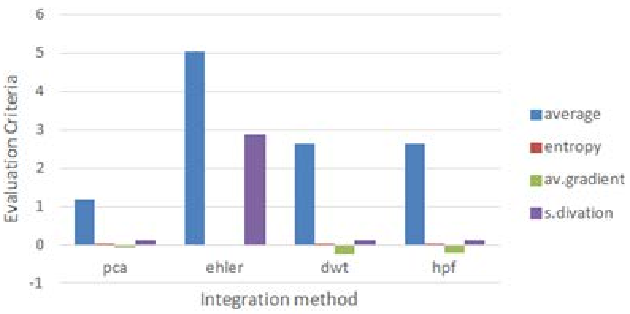


Figure 7- The cropped and the histogram-equalized image of the photo mosaic

3.5 Fusion of satellite and aerial images

Because of limitations of remote sensing technology, one sensor cannot make a high spatial and spectral resolving power simultaneously. Archaeological inspections require both aspects of acquired images. So, the OLI image data of Landsat 8 satellite was fused with Ikonos and photo-mosaic by means of Ehler, principal component analysis (PCA), Intensity-Hue-Saturation (IHS) transformation and discrete wavelet transform (DWT) and the results were assessed by criteria that were entropy, average, standard deviation and gradient average. The more these criteria are, the higher the information content becomes. This means more distribution of the grey levels and, hence better contrast of the fused image. So, it is concluded that the fusion algorithm used has operated better. The results of comparing band to band of fusion output have shown that the satellite images of Ikonos and photo-mosaic of the first group, has better results in all 4 criteria.



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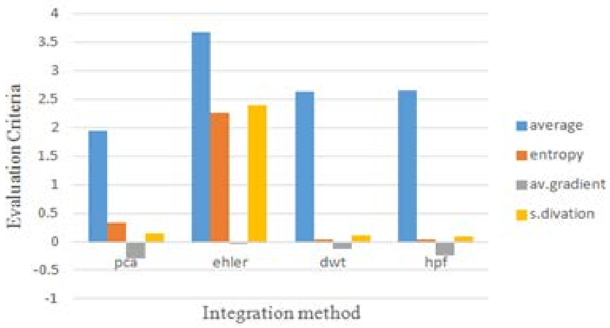

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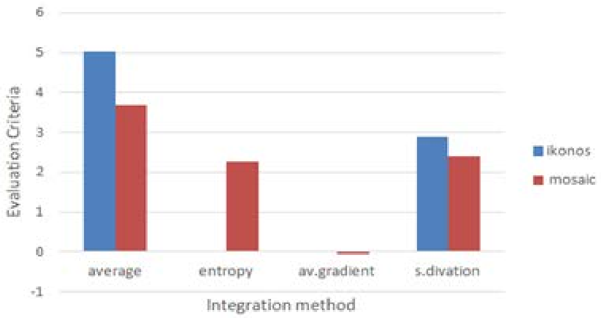

c

Figure 8- Comparison of different methods of image fusion. a) For each band, in Landsat- Ikonos image fusion, four methods were compared with each other. b) For each band, in Landsat-photo mosaic image fusion, four fusion methods, were compared with each other. c) Comparing the results of phase (a) and (b) with Ehler method.

In figure 8, three comparison charts are shown for the third band. In these charts, at first, 4 fusion methods were compared with each other, for each band, that is for the two groups of images, the first group; fusion of the Landsat image with Ikonos image and the second group; fusion of the Landsat image with photo-mosaic and then, the proper fusion technique was selected and the two groups, were compared with each other.

3.6 Detection the descriptive and spectral signs related to the existence of Gorgan Great Wall

As it was mentioned in the introduction, the registered light has some information from the surface and under the surface of the earth and also, the remaining tracks of humans, has some undeniable effects on the soil (olsen, 2004), (Grøn O. and Loska A,2002) and in real, there being a kind of moisture under the earth, affects the health, growth, kind and type of botanic coverage (Barlindhaug,2007). The capability of remote sensing for detecting such signals has been proved. So, it is worth pursuing a method for identification of promising areas that contain ancient sites based on remote sensing data analysis.

3.7 The trackable spectral features of Gorgan Great Wall

Based on what was told about the discovered parts of Gorgan Great Wall, and paying attention to what is available about this huge monument and of the red brick that is a combination of red soil, lime and special metallic components, good results can be got. In addition to this, tracking the moisture of the moats belonging to the Wall can be one of the promising signs for detection of this great monument and its belongings. The effect of the Wall and its belongings that are under the surface, are completely visible and these effects, are sometimes negative and sometimes positive. For example, the effect on the top of moats is positive (Science,2014). In this research, three spectral indices were used that are respectively, normal difference vegetation index (NDVI), Normal difference salinity index (NDSI), and normal difference water index (NDWI). Moreover, three band ratios were employed including Iron-Oxide index, clay-minerals index, and lime combinations index, respectively (Saturno,2006). For finding the promising descriptive signs, the images made by fusion of OLI image and Ikonos image, fused by Ehler method were used. The resulted images made of each of these indices are shown in figure 9.

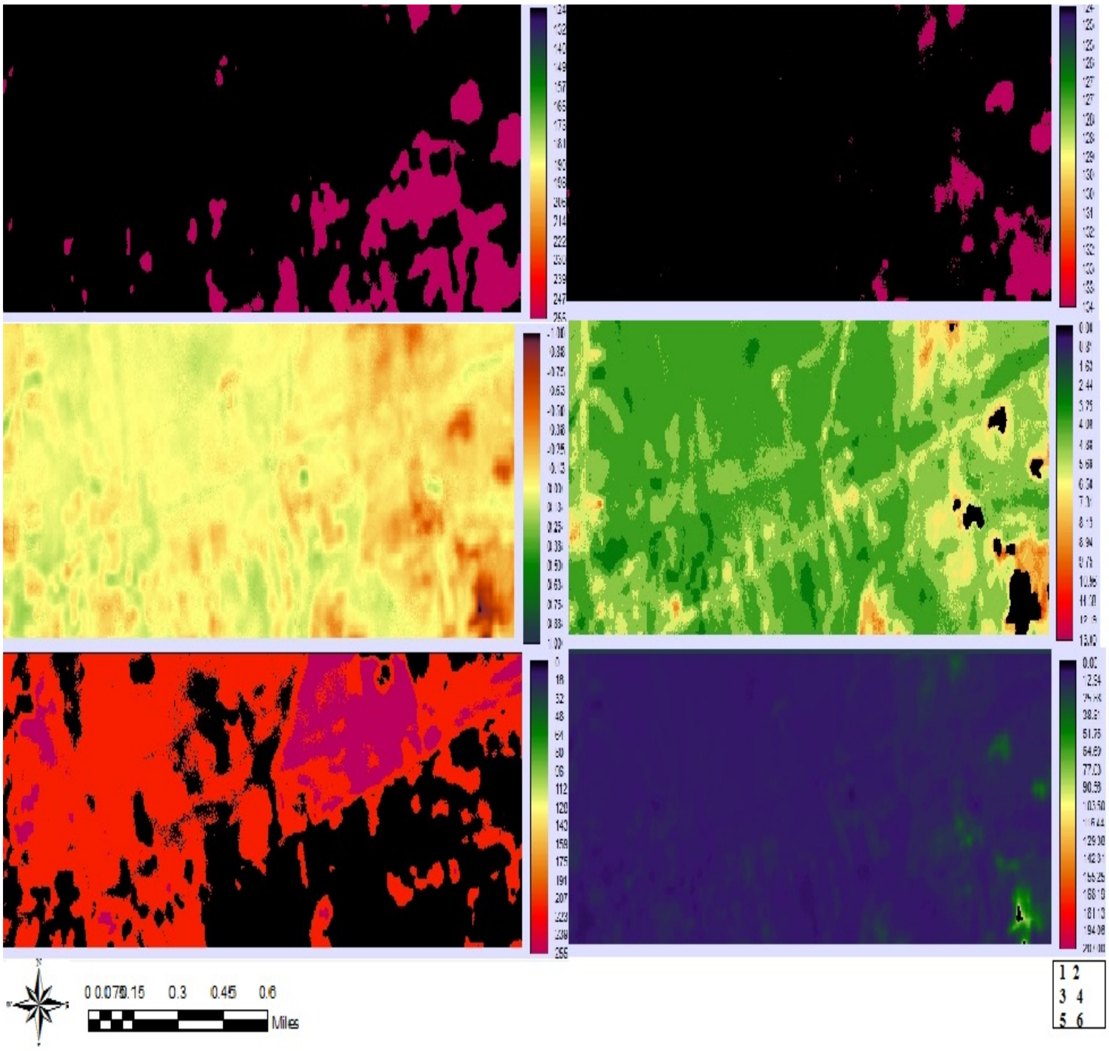

Figure 9-the spectral index maps produced. 1) Lime detection band ratio, 2) Iron-oxide detection band ratio, 3) NDVI, 4) NDSI, 5) Clay detection band ratio, 6) NDWI

3.8 The trackable geometric features of Gorgan Great Wall

The geometric phenomena made by human, has a main difference with natural phenomena and that is special order and particular shape. Using these characteristics, artificial phenomena can be discriminated from the natural phenomena. Remote sensing with its extensive and global coverage is a valuable tool for this job. So, in this project, both spectral and geometrical features discriminating man-made objects from natural phenomena, is used in order to track the Wall and the ancient monuments related to it.

3.9 Making digital elevation model (DEM), slope map and aspect map

Man-made objects make sudden changes in elevation and topography of the place even if the monuments are abandoned and under the surface of the earth. Sudden and limited changes in slope and elevation in a region can be considered as a probable candidate site for archaeological excavation and searching for human settlement residuals. Using topographic maps and satellite images, makes it possible to make digital elevation models of the terrain and to produce slope and aspect maps. Based on these data, change map can be made so as to focus on the desired phenomena. In many cases, there being of hills and abnormal outstanding on the surface of a region, implies existence of destructions and ancient monuments (Egitto,2013). Moreover, because of the inappropriate land use of the region, complete destruction of the Wall in most parts has occurred and only a few parts of the Wall are remained. Thus, having high elevation precision to be able to track the slight anomalies that may be related to the purpose of the study is necessary. The digital elevation model of this region is based on the precise 1:2000 topographic map and was made by inverse distance weighting (IDW) interpolation technique with a pixel size of 0.5 meter. The three-dimensional presentation of this layer is realized by applying an elevation magnification that reveals hidden structures (Figure 10). Since the slope of moats beside the Wall reduces from east to west, the slope layer of region together with the elevation layer, are considered as promising signs of the ancient site or historical monuments.

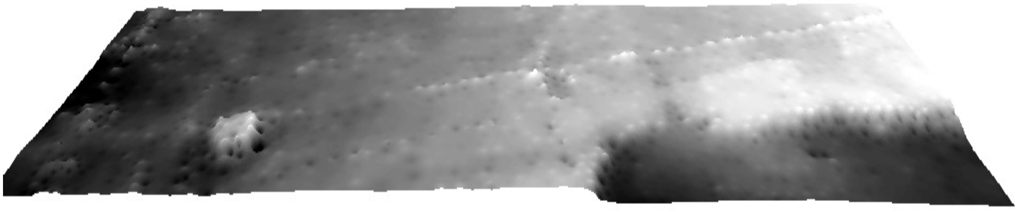

Figure10- The three-dimensional digital model of the study area

Because of serious impact of aspect layer on shadow, wind direction, and wall erosion rate, this important factor, as a tracking sign, was created from DEM of the region (Figure 11).

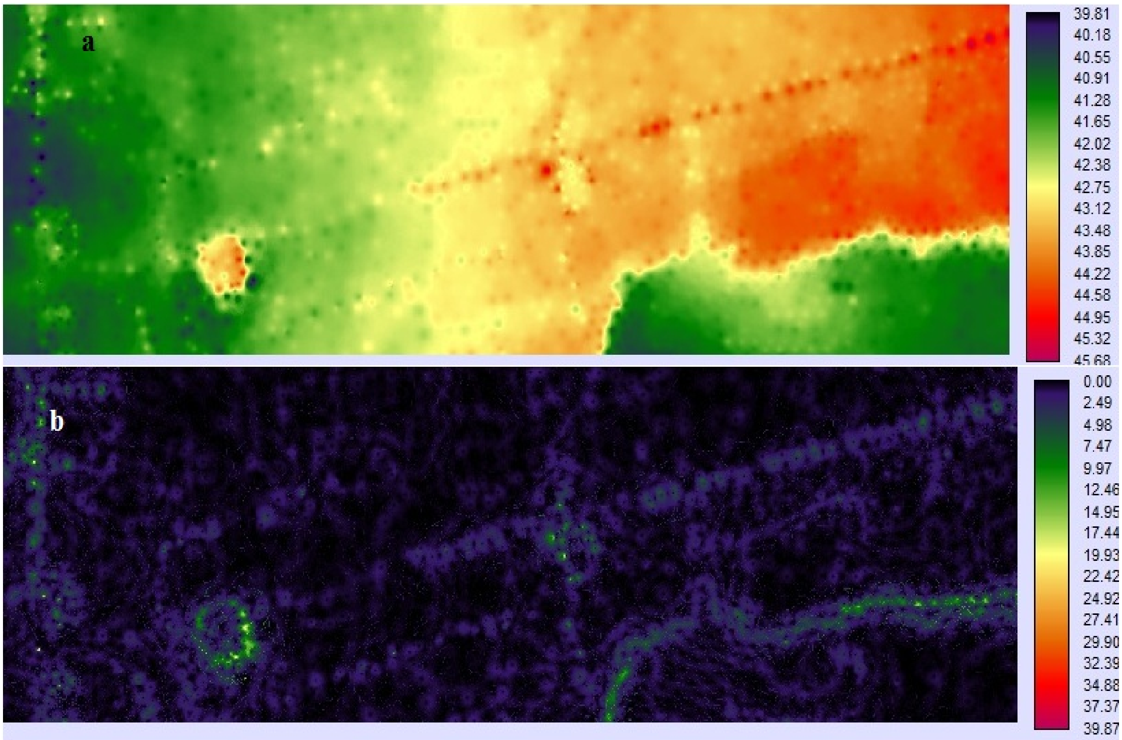

Figure 11- a) Slope map, b) Aspect map

3.10 Linear feature extraction and the main skeleton of the Gorgan Great Wall

Based on what has been recorded in old maps and what we can understand by putting these observable parts together with each other, it is obvious that, there is a geometric linear shape belonging to the Wall. Although, some points that are in one direction or some pixels that are related to one line can be identified by visual inspection, but, a more robust method based on automatic detection and intelligent identification is required for complete and precise documentation of this monument.

The algorithm proposed for this purpose in the current research consists of proper thresholding, applying suitable morphological operations, edge detection and linear feature extraction using Hough transform. According to field exploration results, if the direction of detection operation coincides with the Wall orientation and the less the distance to the Great Wall is, the more the probability of finding historical monuments will be. The aforementioned steps are described in the following sections.

3.11 Thresholding

As the oldest pictorial data related to the Great Wall of Gorgan is the aerial photo in which more parts of the monument are visible, and also considering the excellent spatial resolution of these photos that makes them suitable for tracking and identifying ancient residuals, the complied photomosaic of the region was used for extraction of main skeleton of the Wall. In order to perform this task, it was necessary to first make a binary image from the grey-scale photo. This requires a precise threshold for density slicing that preserves the pixel values of the Wall. Since the light condition varies from image to image, an adaptive thresholding method based on Wellner technique was developed. The results obtained from this threshold was compared to that of the Otsu and C-Means clustering methods by means of two quantitative and one qualitative criteria; structural similarity measure (SSIM), signal to noise ratio (PSNR) and visual assessment. Figures 12 and 13 show the corresponding results.

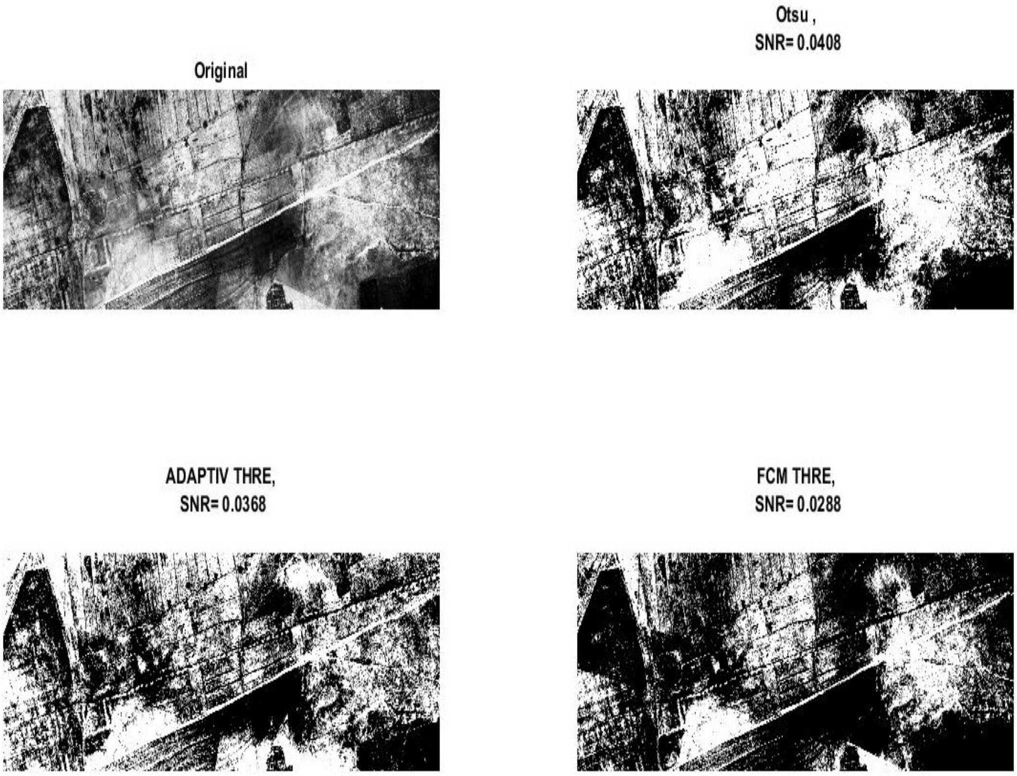

Figure 12- Image resulted from Otsu algorithm has the highest S/N

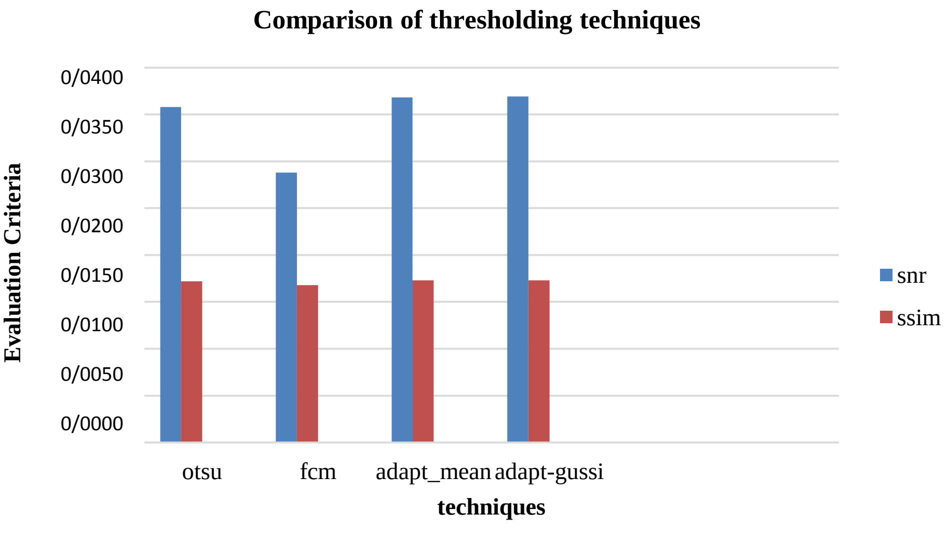

Figure 13- Comparison of thresholding techniques

3.12 Morphological operation and edge detection

The produced binary image in the previous phase includes both desired and undesired information. So, in order to merge discrete parts of the Wall image and also to remove undesired image artifacts, closing and erosion morphological operations with linear structuring element in different sizes were applied on the output of Sobel edge detecting algorithm so that required edge segments were implemented for assessment and extraction of linear layers.

3.13 Extraction of linear feature from photo-mosaic

Hough transform was considered as the linear feature extraction tool. By applying this transform, Cartesian coordinates are converted to polar coordinates and image lines are detected. Line direction and its offset are outputs of Hough transformation. According to this algorithm, each line in Cartesian space is represented as a point with (ρ , ɵ) coordinates in the output space. As seen in figure 14, this algorithm was successfully implemented.

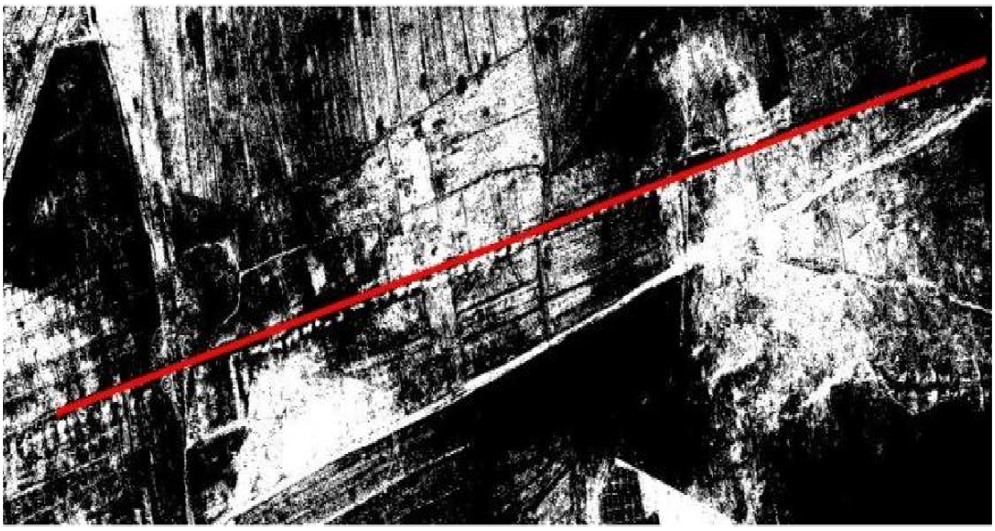

Figure 14- the output of linear feature extraction algorithm with desired characteristics

3.14 Fuzzy ANP multi-criteria decision-making

Having prepared all necessary informational layers, they must be entered into a decision-making process in order for the final decision-making. The developed Analytical Network Process (ANP) decision-making strategy is a hierarchical decision-making method (AHP) and its basis is on comparing the related criteria, but, the problem of this method is that it does not consider the relations and internal dependence of criteria. So, the ANP model that is the developed version of AHP model makes the decision-making process more exact and more reliable. The Fuzzy logic model is based on the analysis of the reality. In fact, the Fuzzy theory, is able to mathematize many concepts, variables and non-exact and vague systems and provide the field of implication, induction, control and decision-making in the conditions of lack of confidence (Ribeiro,1996), (Zadeh,1983). So, in decision-making and weighing processes considering the internal relations among criteria and the type of goal and the criteria related to this research, an ANP Fuzzy algorithm was used that works based on change development paradigm. The weights of the criteria were determined using two questionnaires about the importance of the criteria and the internal relations of criteria in a five-stage fuzzy technique by several professionals of remote sensing, architecture and the archaeology. The final weight and criteria, are shown in table 2, also, the role of each criterion in assigning weights is shown in figure 15.

Table2- weights obtained by ANP fuzzy criteria

Vegetation	Amount of humidity	The iron oxide	The clay compounds	Salinity and electrical conductivity	Lime compounds	Geometrical structure	Elevation	Slope	Aspect
0.0835	0.0552	0.0745	0.1275	0.0497	0.0662	0.2392	0.1771	0.0467	0.0803

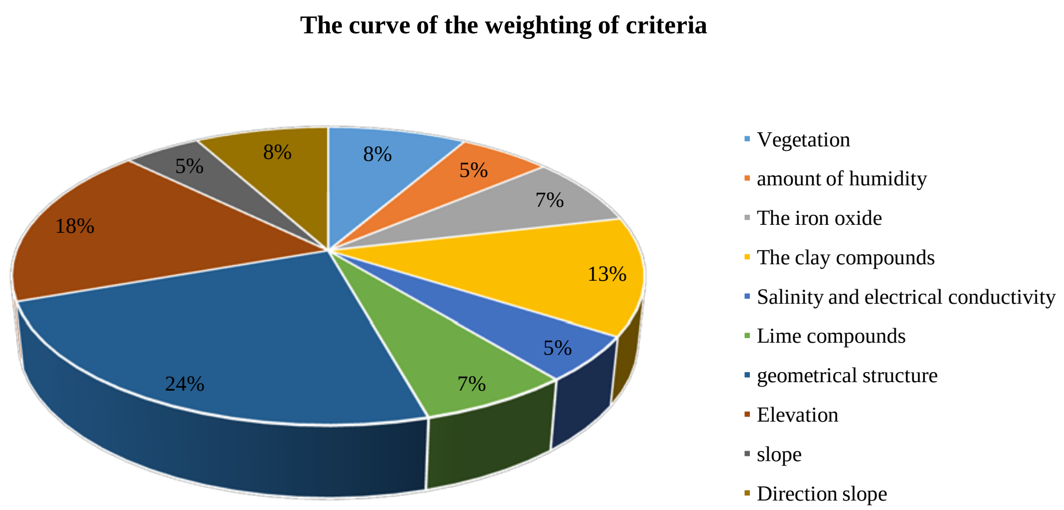

Figure 15- Contribution of criterion in the final decision according to the assigned weights

3.15 Standardizing the criteria maps

Most of the criteria used in decision-making models, are of different scales and are mostly opposing each other. Some criteria are positive and some others are negative. So, for making the different scales comparable, they must become normal and in this way, the different criteria, become dimensionless and are classified somehow that they could be compared. For this reason, fuzzification of the criteria maps was used. In addition to selecting scales for preparing Fuzzy maps, the Fuzzy function must be considered and the proper function must be chosen for desired criteria. In the current research, sigmoidal and linear functions were used. Besides the precision of fuzzifying function in fuzzification process of maps, threshold problem should be solved as well. This is related to control point concept. These points and the type of function or exact analysis of each criterion map are determined and are separately and exactly transferred to a Fuzzy map with 0 to 255 scaling. In figure 16 one of the criterion maps after and before fuzzification is presented.

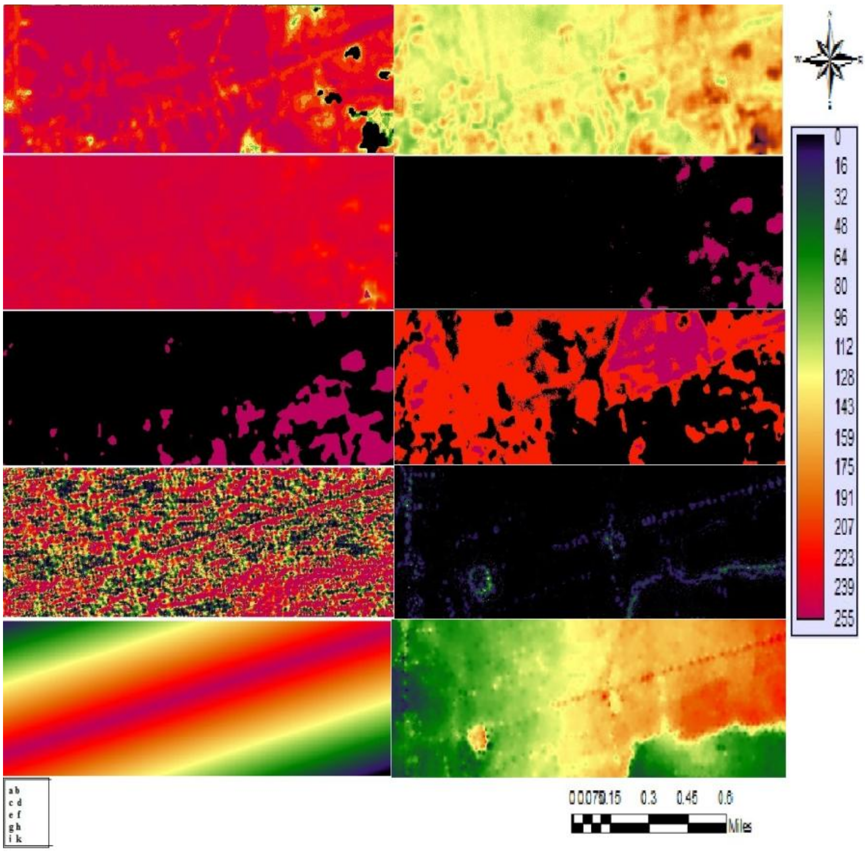

Figure 16- Fuzzified produced layers. a) NDSI, b) NDVI, c) NDWI, d) Lime detection band ratio, e) Clay detection band ratio, f) Iron-oxide detection band ratio g) Aspect, h) slope, i) Distance from extracted wall texture, k) DEM

4 Conclusion and Results

The weighted linear combination (WLC) is one of the successful and robust techniques for integrating maps in decision-making level based on using the mathematical and logic functions. In this technique, after normalization of criteria maps and determining the weight of each layer, standardized weighted map layers are produced by overlaying of layers and applying union operation so that total value for each choice is determined. The results are then re-classified. In this way, the obtained map, have values between 0 and 255 in which 255 shows the complete desirability. All layer fuzzification operations and integrating layers was implemented in IDRISI software. The final map, after the WLC process and after re-classification, is shown in figure 17. What is concluded from the comparison of the resulted map with ground truth, is that, using remote sensing method with promising signs in the detection identification process, is surely an efficient technique for exact documenting and precise monitoring of cultural heritage and its maintenance (Eastman, 2003). After map compiling in decision making (weighting) phase and fusion of data, a reclassification operation was carried out in each of the six classes for normalizing the results for comparison. These classes are very high chance: 225-226, high chance: 197-226, medium chance: 153-197, rather low chance: 117-153, low chance: 87-117, very low chance: 0-87. The final map produced after applying WLC is shown in figure 17 and the resulted map after reclassification is presented in figures 18 and 19.

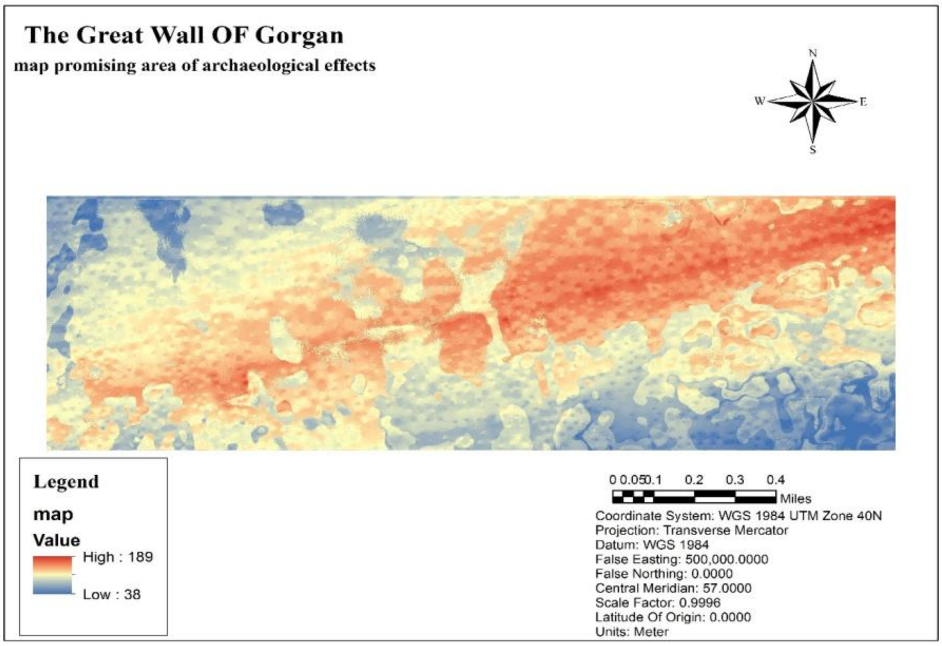

Figure 17- Final map of promising areas concerning archaeological features of Gorgan Great Wall and its related historical monuments

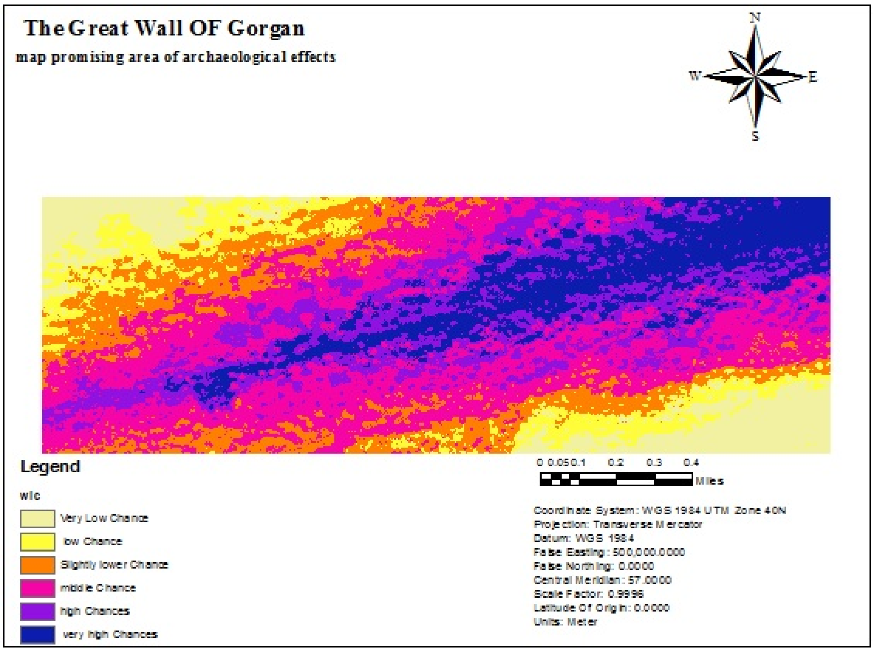

Figure 18- Resulted map after reclassification into six classes according to the probability of existence of ancient features

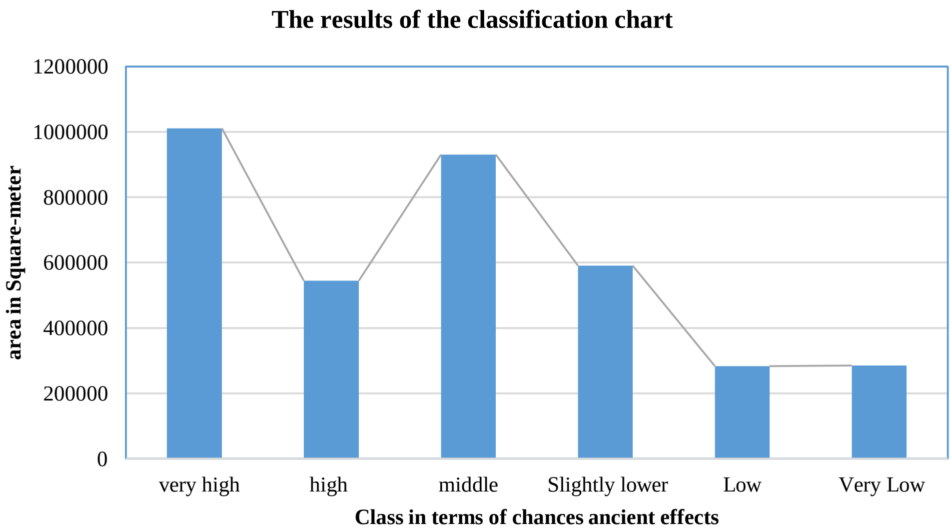

Figure 19- Area of each class after reclassification

It is evident from comparing the resulted maps with ground truth that remote sensing is capable in detection promising signs and identification of historical sites for the purpose of documentation and precise monitoring of the cultural heritage.

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