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ARCHAEOLOGICAL SURVEY OF THE WESTERN BOUNDARY STRIP OF IRAN THROUGH USING REMOTE SENSING TECHNIQUES

1. Introduction

Remote sensing has a long history in archaeology (Luo *et al.* 2019; Davis, Douglass 2020). In the last 20 years, along with big data and information and communication technologies, remote sensing has radically changed the current cultural heritage perspectives and future prospects (Lasaponara, Masini 2020). Remote sensing offers an effective mean to increase survey areas and discovery of new cultural deposits (Davis *et al.* 2019; Trier *et al.* 2019). Many studies (Davis, Douglass 2020) illustrate the great potential of this approach to expand our understanding of the archaeological record at the landscape scale and, consequently, the different social, economic and political processes.

Paying less attention to make use of aerial and spaceborne technologies makes it more likely that Iran's archaeological sites and cultural landscapes will be soon permanently lost. With today's impending critical threatening crisis, it is imperative to learn all that we can from these sites before they disappeare.

The widespread use of such methods would allow Iranian archaeologists to investigate settlement distributional patterns and landscape use in multiple temporal contexts at extraordinary speeds. Remote sensing instruments provide the ability to survey large geographic areas much faster than traditional approaches, as has been demonstrated by many studies throughout the world (see e.g. Zanni, Rosa 2019).

We argue that these latest trends in remote sensing can offer a cost-effective solution for addressing the issue of systematic broad scale survey in Iran by reducing the amount of time required to investigate landscapes, thereby improving our overall understanding of landscape level phenomena throughout the region's history.

The study area is located in the western border line of Iran on the Zagros Mountains which is one of the longest and widest mountain ranges in the country; the significant part of Iran's water is being supplied from the Zagros Area. By conducting the 360-kilometer construction project for water transfer as well as the creation of several dams, canals, gigantic tunnels for the irrigation of the central part of the Zagros Mountains, it was required a thorough archaeological study aiming to document and record the monuments along with locating the settlement sites on the way to the project path. The security condition of the area for the implementation of the project, war remains as well as minefields in the border area between Iran and Iraq resulted in a great deal of hard challenges in the process of comprehensive pedestrian surveys. Due to the difficulty in the project implementation conditions, it was necessary to apply remote sensing methods in the area. The main target of the satellite survey is to identify the settlement sites without a large presence of archaeologists in the area.

Analysis of satellite imagery, along with predictive modeling, appears a promising way to bypass these issues, further capturing sites that may have been otherwise difficult to detect (Klehm *et al.* 2019).

In this study, the detection of ancient sites is based on the identification of their internal and external characteristics. Some internal characteristics are site dependent and are directly linked to archaeological features. They include: the differences in soil moisture; soil color; the texture and density of ancient soil; regular geometric shapes; the difference of plants covers; soil chemistry; thermal anomalies of ancient soil; the differences in soil conductivity; composition; magnetic fields; organic materials; subsurface anomalies; shadow signs; stone signs; soil signs; topography; plowing signs; the difference in special plant species related to ancient sites; the density of some elements in ancient soils; signs of human and animal destruction of ancient sites' surface. Some others are site independent, namely, linked to environmental or social characteristics, and are termed here as external characteristics such as slope, direction of slope; distance from other sites; distance from ancient routes; relief; aspect; the geomorphology processes; soil type; altitude above sea level; vegetable coverage of the region; distance to water; proximity to food source; average of wind speed and so on. Knowledge of the environmental variables influencing activities of original inhabitants is used to produce GIS layers representing the spatial distribution of those variables. The GIS layers are then analyzed to identify locations where combinations of environmental variables match patterns observed at known sites.

The Central Zagros Archaeological Project (CZAP) was started to achieve a series of best practices to detect ancient sites without the physical presence of the archaeologists in the survey area and this approach has being completed in succeeding research steps. We look to contribute to a new methodological approach to this research paradigm, especially for recognition of small hinterland sites located in challenging environments, and to identify new questions that this approach helps to raise. As traditional pedestrian surveys favor sites with easy access, reduced vegetation cover and conspicuous aboveground features, archaeologists can use remote sensing methods to improve archaeological surveys. The focus of the present study is the observation of the earth through sensors installed on the satellites since many minefields are still existing in the area and make impossible the routine pedestrian surveying.

The identification of settlement sites through the predictive model as well as the observation and process of digital images have been conducted by using

ENVI GIS software. However, until now the visual interpretation is still the main technique in analyzing changes from these images (Kraub, Tian 2020).

2. The study area and the segmentation of archaeological landscape

The long history of Zagros region of western Iran, which is a key area in the human life development, has long been a focus in the archaeological research. It is of great importance for archaeologists, who since the beginning of the 19th century have been seeking to find the major development of human history from the beginning of plant and animal husbandry to the formation of early states which have been followed by the great political changes to evolve local powers (see Hole 1987 and references therein). In the Zagros region, even if a large number of archaeological researches especially in the course of site identification were carried out, the present research using remote sensing techniques represents the first challenge to deal with the site detection procedures.

The first aerial archaeological studies in Iran were conducted by Erich Schmidt in 1935, when aerial archaeology was not yet so widespread (Schmidt 1940). Schmidt's photos were extremely significant in the history of photography; moreover, his aerial and historical photography was a very important action to detect most of the unknown sites in Iran. The use of historical aerial photographs in recording archaeological sites worldwide has continued to the present day (Stott *et al.* 2018). Unfortunately, although aerial archaeology has a long history in Iran, it has not remarkably advanced recently due to lack of support of research plans and archaeologists' training in the fields of remote sensing and GIS, and aerial projects have not continued. Archaeological prospection through remote sensing offers a practical and economical mean to detect and characterize different types of archaeological sites, over traditional field walking survey methods (Thabeng *et al.* 2019). Concerning the history of archaeological field surveys of the Zagros Region, which goes back to the activities of Professor Robert John Braidwood (Braidwood 1960), the present study can be considered the first satellite remote sensing-based archaeological project of the region in dealing with detecting ancient sites.

The study area is located in the central part of the Zagros Mountain Range, within the boundary strip between Iran and Iraq with geographical longitude and latitude 34°49'55.36"N, 45°50'31.91"E (Fig. 1). The region receives precipitation from westerly disturbances and is mainly affected by the Mediterranean climate (Mostofi 1965). In the central Zagros, precipitation usually falls over a period of 8 months, from October to May, whereas there is no effective precipitation in other months. The tree stands are generally open with crown coverage of ca. 10 m, such that the possible effects of competition among trees are very low. The dominant species are oaks, intermixed

Fig. 1 – Map of Iran and location of the area under study.

with other species such as *Crataegus*, *Pistacia* and *Amygdalus* (Arsalani *et al.* 2014). Growing season begins in April and the late wood of the trees completes in September. Due to the Zagros geological formations, the soils of the region are generally shallow and very rocky (Moghimi 2010). Since there are different geological structures in mountainous areas, it is difficult to detect ancient sites thanks to aerial survey.

Analyzing is a hard task in mountainous areas due to the fact that the abundance of minerals causes satellite images to show different reflections of the electromagnetic spectrum.

There are also other problems in identifying the ancient sites in mountainous areas, including surface topography, erosion, fault, avalanche, and landslide, which can disrupt/disturb ancient sites. In addition to environmental problems in the area, the identification of ancient sites from the space completely depends on the understanding of processes that affected and changed the landscape characteristics to be differentiated from modern ones. The existence of trenches, canals, areas evacuated from mines, levees and desert garrisons has caused such disturbances during the war between Iran and Iraq and the distinction between ancient mountainous routes and communication networks in the time of war has been impossible. Moreover, agricultural exploitation in this area has spoiled most of ancient sites' characteristics.

Therefore, the identification of settlement sites in satellite survey depends on image type, size of buried remnants and conditions of ancient sites' surface, land characteristics, lighting conditions (Lasaponara, Masini 2012), as well as environmental and human conditions in the area.

3. Methods

The choice of the techniques to be used depends on the aims of the investigation and on what the archaeologist expects from remote sensing images (Masini, Lasaponara 2017). In this study, all characteristics of the ancient sites were investigated. Anomalies on the surface of settlement sites as the internal characteristics and their spatial (environmental and social) features as the external characteristics were also explored.

At the first stage of this project, as for regular aerial survey, a grid was superimposed on the survey path in the very high-resolution satellite image (Fig. 2).

Due to the different nature of ancient sites characteristics as well as the mountainous landscape of the area under study, in addition to the use of images with extremely high resolution, hyperspectral, thermal, infrared and radar images were required to be applied (Tab. 1). Also, ArcGIS and ENVI software were used to identify spectrally unique surface features that discriminate sites from surrounding areas (Klehm *et al.* 2019). The data of each satellite image were recorded in separate layers and images which contained information of internal characteristics overlapped, while locations which had at least three internal characteristics were selected.

In the second research stage, the predictive model (see below) was determined on effective parameters (environmental and cultural), and locations that had a strong possibility for the presence of ancient sites were selected (Masini, Lasaponara 2017). Finally, identified locations on the satellite images were integrated with identified locations in the predictive model. As a result, locations that had a series of internal and external characteristics were assumed to have been archaeological sites regardless of their chronologies. Finally, to assess the validity of the identified points in the aerial survey, the shortest distance was chosen to visit the points.

Spatial resolution is another key consideration in the detection of small buried structures. TerraSAR-X dependably acquires high-resolution and wide-area radar images, regardless of the climatic conditions. The satellite provides a unique geometric accuracy that is unmatched by any other spaceborne sensor

CHARACTERISTICS	SATELLITE	
(PAN+8MS+8SWIR.12 CAVIS Bands.0.31m)	WorldView-3	1
(3MS+6SWIR+5TIR.10m)	ASTER	2
(X-band wavelength 31 mm, frequency 9.6 GHz 0.25 m)	TERRASAR–X	3
(13MS+3SWIR.10m)	Sentinel-2A	4
(PAN+6MS+3SWIR.30m)	Hyperion/EO-1	5
(PAN+6MS+2SWIR+2TIR.15m)	LANDSAT 8	6
(PAN= 10m)	CORONA	7
(PAN+4MS+SWIR.1.5m)	Spot-6	8

Tab. 1 – Satellite images used in the project.

(X-band wavelength 31 mm, frequency 9.6 GHz 0.25 m). The subsurface imaging potential of SAR has been exploited for archaeological prospection in multiple desert environments in Africa, Asia, North and South America (Stewart *et al.* 2018). Given that there is a greater choice of VHR sensors operating at shorter wavelengths, some attempts have been made to use short wave (X-band) spaceborne SAR for archaeological prospection in mountainous regions. However, prospection was conducted less through surface penetration, and more through exploitation of the SAR sensitivity to subtle surface roughness variations caused by traces of archaeological structures.

The image of SAR was also used for detecting conductive differences as well as the magnetic field of ancient sites' soil. WorldView-3 is the first multi-payload, super-spectral, high-resolution commercial satellite sensor operating at an altitude of 617 km. WorldView-3 satellite provides 31 cm panchromatic resolution, 1.24 m multispectral resolution, 3.7 m short wave infrared resolution (SWIR) and 30 m CAVIS (Clouds, Aerosols, Vapors, Ice, and Snow) resolution. The satellite has an average revisit time of <1 day and is capable of covering up to 680,000 km^2 per day. The data of the WorldView images were considered as the basis for detecting most of subtle characteristics of ancient sites in this survey. SPOT-6 is an optical imaging satellite capable of imaging the Earth with a resolution of 1.5 m panchromatic and 6 m multispectral (blue, green, red, near-IR). The SPOT-6 images were used in the regions where it was not necessary to use the WorldView costly images.

The ASTER satellite images, which have high spectral power, are extensively used, especially in geology and in separating alterations which are considered as the most important characteristics of mineralization in different ways. Two visible bands, a near infrared band, six short infrared bands and five thermal bands of ASTER images provide the possibility of distinguishing epithermal clays, iron oxides, silica, carbonates, mafic rocks and prophylactic alterations in mountainous areas. The data of ASTER are effective for detecting thermal anomaly and identifying ancient soils. The Hyperion hyperspectral sensor collects 220 unique spectral channels ranging from 0.357 to 2.576 µm with a 10 nm bandwidth. The instrument operates in a push broom fashion, with a spatial resolution of 30 m for all bands. The significant advantage of this sensor over multispectral instruments is its narrow contiguous bands, which provide detailed spectra to distinguish different target materials and quantify their constituents (Khurshid *et al.* 2006).

For this purpose, data from this sensor have been applied in the areas of agriculture, archaeology, forestry, geology, and environmental monitoring to extract an enhanced level of information. Integrating the images of ASTER and Hyperion allows identifying difference in the color of ancient soils. With the significant improvement in spectral resolution comes the need to have accurate image processing.

4. Proxy indicators: generalities

4.1 *Internal characteristics of ancient sites*

The proxy indicators are the result of physical and chemical interaction between archaeological remains and their surroundings that can produce changes in moisture content, soil nutrients and vegetation growth visible from above (Masini, Lasaponara 2017), in such a way the soil over ancient sites results different from the surrounding soils in terms of various characteristics. The presence of structures, buried holes and ancient remnants disrupts the natural physical order of the soil and creates disassociations in sub-surface that affect the surface visible soils. The most important differences which we could observe and record (as shown in Figs. 2-4) match with those experienced by some scholars. For example, the differences in soil moisture (Kempf 2019), soil color (Masini, Lasaponara 2017), texture and density, soil chemistry (Tilton *et al.* 2013), and so on. In this study, to detect the archaeological sites of the Zagros Region, each of these characteristics was traced on the satellite images. To better understand the different nature of sites' internal anomalies, Figs. 2-4 show the recorded examples of sites internal characteristics of the Zagros Region in various kinds of satellite images.

4.2 *External characteristics of archaeological sites*

In addition to the internal characteristics mentioned above, there are important regulations and signs which can help to investigate ancient sites concerning their surrounding environment. Prediction models aim at identifying the presence of archaeological sites on the basis of observed patterns and on the assumptions about human behaviors that have functioned within the environmental and geographical contexts. These models assume that individuals settled areas with the best overall suitability (with regards to available resources) and that, as population density and resource consumption increase, settlements shift to areas with lower resource suitability (Davis, Douglass *et al.* 2020). Such modeling approaches have proven useful in exploring the rationale behind observed phenomena in anthropology, including archaeological evidence of behavior and choice (Robinson *et al.* 2019). In this section, spatial characteristics (environmental and cultural) of ancient sites were used as external characteristics influencing the location of the sites (Klehm *et al.* 2019) in the predictive model databases.

There is a handful of relevant literature that defines prerequisite conditions for human occupational locations. In the same way, the maps provided show manipulation standards for the preferences of places where the inhabitants set up their lives. Most of the ancient sites in the Zagros areas have been formed in close proximity to current settlements and are located in the closest distance

Fig. 2 – Difference in soil color. Image: 2019 Hyperion/ EO-SWIR 10m.

Fig. 3 – Difference in the texture and density of ancient soil Image: WorldView-3. SWIR.

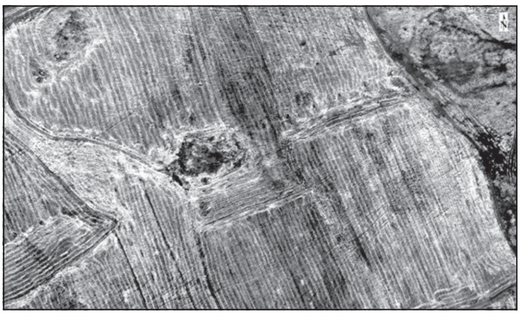

Fig. 4 – Difference in soil chemistry. Image: TERRA-SAR X, 0.25 m.

from communication routes. Human settlements are mostly located in slopes ranging from 5 to 10 percent. Most of the sites have a northern aspect to catch directly the sun light. Other maps also show the factors contributing to the human decisions for the selection of suitable locations, i.e. wind direction, land elevation, water sources, vegetal coverage of the area. There have been also variables that seem to affect human decisions in the selection of settlement locations, for instance vegetation diversity, index of productivity of agricultural lands, variation in climatic conditions, irrigation system and water canals environmental anomalies and many others (Brandon, Burgett 2005; Parcak 2009; Giardino 2012; Stewart *et al.* 2018).

All these variables were taken into account as factors affecting settlement selection processes which can be used in the development of prediction modeling.

5. Results and discussion

Challenges related to finding, access, or physical conditions of the environment often make extensive surveys impractical. Photography often allows buried archaeological remains to be detected through small changes in relief or discoloration of overlying soils or crops and allows large areas to be surveyed within short time scales (Luo *et al.* 2019). Reducing labor, time, and, ultimately, money spent on investigating a study area makes remote sensing a particularly attractive complement to traditional field work (Klehm *et al.* 2019). According to the results, all settlements have general internal and external characteristics acting as proxy indicators for the identification of archaeological sites in this study. The detection of a series of these characteristics within a designated area will lead to the discovery of settlement sites. Hence, three methods were applied to identify their location.

5.1 *Identification with satellite images*

Due to the different nature and features of settlement sites characteristics, the interpretation of distinct anomalies could be improved exploiting radiometric, spectral and temporal resolutions of images acquired from airborne and spaceborne platforms (Luo *et al.* 2019). Hyperspectral remote sensing could detect and identify weak spectrum differences of ground objects (Kelong *et al.* 2008; Yu *et al.* 2018; Kempf 2019). This research demonstrates that hyperspectral remote sensing is effective for archaeology even when no ground remnants or other traces are found. These differences influence light absorption and reflection as well as thermal shine and radiance and they can be detected in the satellite images, whereas archaeologists are visually unable to detect them on the earth (Gupta *et al.* 2019). This feature allows archaeologists to detect subtle environmental changes in such a way that they can even discover subsurface remnants (Osicki 2000).

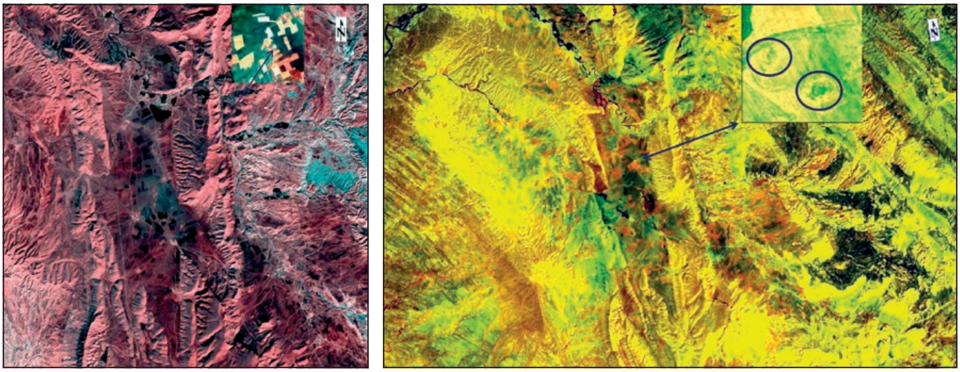

Fig. 5 – a) ASTER, Hyperion/EO-1; identification of points based on the differences in soil color in the integration of images; b) WorldView-3 SWIR, identification of positive and negative signs of vegetal coverage.

Overall, 773 locations were identified based on each one of the internal characteristics (Fig. 5). Despite the extensive application of remote sensing in archaeological research, there are still some issues limiting the more accurate and effective detection of archaeological targets (Yu *et al.* 2018). There were two main challenges in this satellite survey. First, weakness of satellite images data; therefore, in the ASTER image of the thermal band only larger settlement sites could be identified. Moreover, hyperspectral images with very high spatial resolution are required to identify the characteristics of ancient sites, but there is not such a possibility in the latest images WorldView-4.

The second challenge concerns the issue that ancient sites show different characteristics in satellite equal images. For example, in infrared WorldView-3 images, some sites show differences in vegetal growth. Moreover, there is a similarity between environmental features and ancient characteristics; for example, it is very difficult to distinguish between the color of ancient soil and mineral soils. In addition, when the physical interaction between anthropic transformations of cultural interest (buried walls, ditches, pits, etc.) is not evident through vegetation and moisture content changes, one cannot rely only on optical remote sensing for detecting archaeological features. In such cases, passive data should be integrated with other kinds of earth observation technologies including the active ones, such as LiDAR and SAR, especially where the microtopography is a valuable archaeological proxy indicator. Further opportunities to improve the knowledge could be provided by integrating remote sensing with geophysics (Masini, Lasaponara 2017).

Therefore, in the satellite survey, it is not possible to trust one feature of satellite images (such as very high resolution, hyperspectral, or thermal)

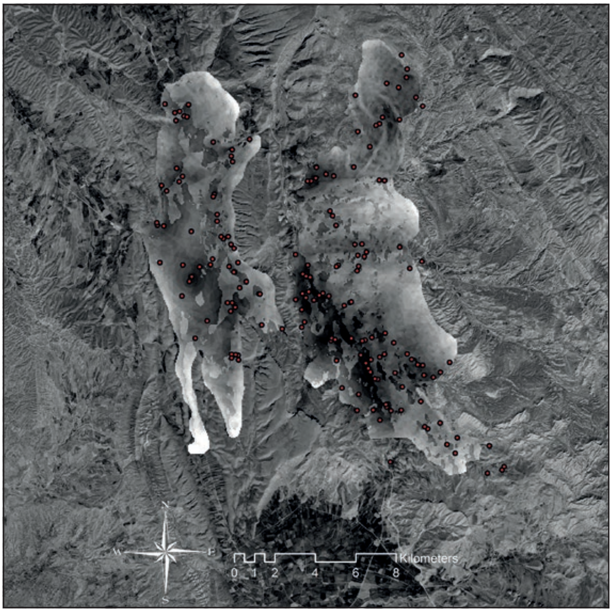

Fig. 6 – Overlapping at least three internal signs and selecting 159 locations seeming to be archaeological sites.

or a particular characteristic of the archaeological site (such as soil signs, vegetation, or soil color).

Data fusion can further enhance the weak marks linked to archaeological deposits. As a result, the data of each satellite image, overlapped to increase the possibility of settlement site presence and locations, which incorporated at least three internal characteristics were selected. Therefore, from among 773 identified locations, 159 points with three internal signs remained (Fig. 6).

5.2 *Identification with the predictive model*

Spatial approaches have a deep history in archaeology where researchers have long been concerned with the location and measurement of artifacts, sites, and cultural and natural features, as well as the relations between them (Klehm, Gokee 2020). We presented a methodology to create an Archaeological Predictive Model that can indicate areas with high potential for hosting archaeological sites. In this study, the Archaeological Predictive Model was used to predict archaeological site locations, based on the observed patterns and assumptions about the human behavior and it was constructed through the combination of GIS tools, remote sensing data, and archaeological data (Nsanziyera *et al.* 2018). The selection of parameters depends on many

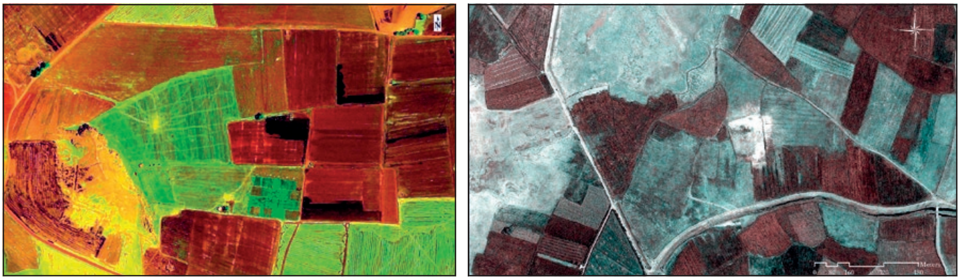

Fig. 7 – a) CORONA, WorldView-3 + 2019; NIR images, the routes for commuting the ancient site; b) CORONA, WorldView-3 + 2019; SWIR images of the ancient river route.

factors; of course, different cultures, locations, and historical periods require different approaches. Studies of settlement sites' location have mostly investigated environmental factors in locating ancient sites, but most of them emphasized the importance of cultural landscape.

Most modeling studies have examined environmental patterning exhibited by archaeological site locations (Brandt *et al.* 1992), but many have also emphasized the importance of a cultural landscape (Tilton *et al.* 2013). It is a crucial question for anthropologists and archaeologists how humans interacted with the landscape around them in the past. To answer this question, the satellites provide a very different landscape of such interactions (Parcak 2009).

Today, predictive models are generally regarded as useful tools for archaeological research. They can constitute an important decision support system providing useful information for defining survey priority and facilitating new site discovery, saving time and money, especially in the large areas (Masini, Lasaponara 2017).

Archaeological predictive modeling is a remote sensing analytical technique in which the locations of archaeological sites are predicted either through observed or deduced patterns (Klehm *et al.* 2019, 69). The premise behind modeling is that prehistoric and historic peoples were closely tied to their natural and cultural environment and that these environments were a significant determinant in their choice of site location (Nsanziyera *et al.* 2018). Our survey showed that the points incorporating settlement sites exhibited non-random trends, in such a way that there were similar trends and patterns between the location of ancient sites and external characteristics. External characteristics of settlements were entered in the GIS program as base information for the predictive modelling. A problem in the location of ancient sites is that not all data of external characteristics of an ancient site are available. For example, some of the characteristics (rivers and routes of ancient travels have disappeared

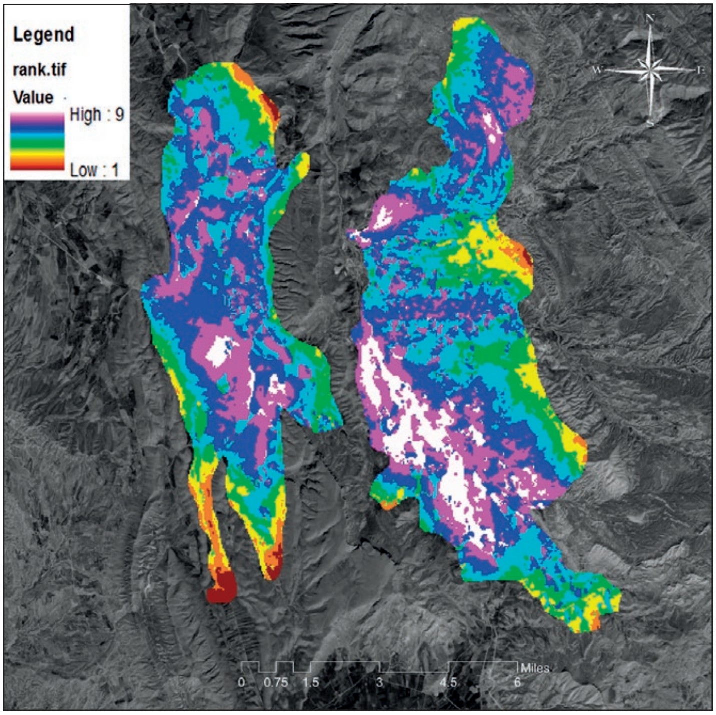

Fig. 8 – Ranking of external characteristics overlapping and identification of 186 points with the possibility of settlement site presence.

due to climatic changes and human modern activities. Accordingly, it is not possible to use all of the external data in the predictive model; therefore, the results of the predictive model may not be accurate.

The time series analysis of multi temporal aerial and satellite images has been shown to be useful and valuable in detecting changes in archaeological sites and discovering previously unknown archaeological features (Yu *et al.* 2018).

Some characteristics of the archaeological sites could not be tracked in the new satellite images. Therefore, in this investigation, the time series analysis of the old images was performed, they were overlapped with the new ones, and a portion of the archaeological walking routes and rivers of the region was identified (Fig. 7).

Therefore, the relationship of these kinds of characteristics with the identified points was visually investigated with the satellite images. Based on the analysis of external characteristics of ancient sites, 186 locations with the most possibility of sites presence were predicted (Fig. 8).

5.3 *Integration of satellite images data with the predictive model*

In the identification of ancient sites' location, there are extra patterns which cannot be observed on the satellite images. Only the combined use of remote sensing techniques and GIS provides the possibility of full and effective utilization of data related to an ancient site.

159 points regarding their internal characteristic were identified as the archaeological sites in the satellite images, while on the basis of the external characteristic 186 points were identified by the prediction model applied. Points from both approaches were then overlapped in the GIS environment. As a result, 67 points that presented a series of internal and external characteristics were chosen to be the most likely archaeological sites. In order to validate the accuracy of the technique applied, a field walking project was made to see how and where physically the sites were exactly located. Through this project we found about 57 points on the ground matching with those identified before by satellite survey (Tab. 2). The 10 remaining sites may have been demolished after they were abandoned.

Name	Longitude	Latitude	Name	Longitude	Latitude
1	45.828275	34.69479722	31	45.83262689	34.68353825
2	45.72798333	34.74116111	32	45.81655833	34.75489167
3	45.84515	34.82901389	33	45.74435556	34.75883889
4	45.72038611	34.81074167	34	45.7403	34.77671944
5	45.72480556	34.8127	35	45.74232222	34.76868889
6	45.79173611	34.78325833	36	45.749175	34.72566944
7	45.842575	34.839075	37	45.74951389	34.70483333
8	45.75300556	34.70591944	38	45.75322778	34.70391944
9	45.75008705	34.72933402	39	45.79320833	34.78333889
10	45.78837222	34.74201389	40	45.8329	34.78328889
11	45.74553784	34.75791152	41	45.78798056	34.73322778
12	45.76013056	34.80217778	42	45.83076209	34.70563371
13	45.85375556	34.81625278	43	45.72374308	34.78580171
14	45.89605833	34.65538333	44	45.7408	34.77767222
15	45.70969167	34.76526667	45	45.78748056	34.71821389
16	45.74819167	34.75884444	46	45.89493333	34.65390833
17	45.72353611	34.74631944	47	45.88712548	34.65077521
18	45.73963889	34.74893056	48	45.83475833	34.65789444
19	45.83089578	34.75039576	49	45.85271944	34.74708611
20	45.76487222	34.733025	50	45.75181111	34.76230833
21	45.82976389	34.80949167	51	45.74966389	34.75530556
22	45.8033	34.76988611	52	45.75132778	34.75359167
23	45.80365556	34.71323333	53	45.71121667	34.74748333
24	45.80545002	34.7125893	54	45.75335278	34.74721111
25	45.79229506	34.74054671	55	45.72291111	34.73252778
26	45.72185407	34.7835022	56	45.76586389	34.71934444
27	45.78995556	34.73148333	57	45.87088333	34.66847778
30	45.74958889	34.70636944			

Tab. 2 – Identification of 57 archaeological site locations found by field walking project.

The result of this study shows that the integration of satellite images data kinds with the predictive model is effective on the identification of settlement sites which have no remnants and/or visible surface impacts. A challenge in the integration of satellite images data with the predictive model is that some identified points on the satellite images of an ancient site may not be identified in the predictive model. In contrast, there are some identified locations in the predictive model of ancient sites which were not shown in the satellite images. In further projects, we will try to find techniques of remote sensing so that in addition to the compensation of budget and time limitation of field surveys, archaeologists can accurately explore settlement sites without regional and border restrictions in a wide cultural environment.

6. Conclusions

In this work we present a methodology to detect sites susceptible of containing buried archaeological remains using remote sensing data. Three methods used in this study – comprising (1) identification of ancient site's location using satellite images; (2) identification of ancient site's location using predictive model and (3) integrating satellite images data with the prediction model – were successfully applied to identify ancient sites in the Zagros Mountain Range. By combining all methods of remote sensing (satellite, aerial, airborne geophysics), it is expected that ancient sites would be accurately detected, surveyed and protected without the presence of archaeologists in the field. These techniques offer great potential to increase our knowledge of the human past and help to record and protect cultural heritage that is at risk from anthropogenic and natural forces.

In most countries of the Middle East, looting and site destruction are evident. In Iran alone, if looting or other destructive processes will continue at the current rate, by 2040 many of the archaeological and historic sites will be affected. Other countries likely have similar challenges. It is interesting to note that projected 2040 forecast matches the known "tipping point" for global environmental destruction as well. Archaeologists have a primary responsibility to protect and preserve our shared heritage for future generations, but they cannot do it without using state-of-the-art technologies in an equally responsible way. With hundreds of thousands, if not millions, of undocumented archaeological sites across the globe, archaeologists now have sufficient tools and technologies available to detect and protect these sites, but not enough is being done. While the Iranian archaeology has a long history using aerial surveys, the most recent advances in aerial and spaceborne technology have been slow to break into research practices in the country. It is therefore necessary to increase the rate at which researchers document the archaeological record as many archaeological deposits in Iran are rapidly disappearing.

Archaeologists need to adopt remote sensing methods that can quickly and accurately record the increasingly threatened archaeological heritage in different parts of the country. The speed and accuracy attainable through remote sensing survey methods are essential for future archaeological research, as datasets continue to expand. However, it is also essential that training in remote sensing techniques become a featured component of archaeology programs throughout Iran and Iranian departments more broadly. Rigorous training is especially critical for the use of techniques involving machine learning and automated analysis. By incorporating remote sensing datasets into future studies, Iranians contributions will be enhanced with more complete datasets and greater geographic coverage of the diversity of Iran's human past. What we hope to achieve via remote sensing archaeology will be influenced by both the possibility of new technologies and the threats to archaeological sites.

The hope is that we can work fast enough to map and protect our ancient heritage and treasures before they disappear. Such an approach in archaeology can be considered as a revolution in current archaeological surveys. In the future, more specialized technologies will be applied in remote sensing; therefore, in addition to the identification and protection of ancient sites, the oldness of a site will be detected from the space.

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ABSTRACT

A huge irrigation project is being conducted in the Iranian western border and satellite investigation of the area was initially performed in order to identify archaeological settlement sites before they were threatened by the so-called Garmsiri water project. Because of the diverse geography and the inherited critical war conditions such as mined lands, the investigation of ancient sites in this region is not easy; therefore, satellite-based methods can play an important role in the detection and documentation of archaeological sites. The main hypothesis of this study is that all settlements have internal and external characteristics allowing to detect the presence of archaeological sites. The identification of a series of these characteristics in a spatial area will lead to the discovery of archaeological sites. Three general methods which this study utilizes to identify the location of the site include: 1) Identification using satellite images; 2) Identification using the predictive model based on GIS; 3) Integration of satellite images data applying the prediction model. Thereby, those points having a series of internal and external characteristics related to settlement sites were introduced as potential ancient sites. In the field survey, 57 points were confirmed as settlement sites. The perspective of this study helps archaeologists to explore the surface and subsurface remnants of ancient sites without conventional field-walking survey.