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Selecting Remotely Sensed Images Radiometric Calibration Site (Case Study: Tehran Province)

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Abstract

Radiometric errors are the most common errors of data acquired by remote sensing sensors. Correction of this type of error requires knowledge about the atmospheric conditions during imaging of the sensor. The aim of this study is to select an ideal location for the construction of a radiometric calibration site. Tehran province was selected as a case study to conduct research in a pilot environment. Based on the studies performed on the CEOS standards in site selection as well as the criteria observed in Cal Val sites, 14 parameters were selected as important and necessary parameters for calibration site selection. The data used in this research include two categories of satellite data and GIS layers. After applying the preprocessing on the data and obtaining the weight of each layers, suitable places were obtained for the construction of the calibration site between 2012 to 2019 years. Due to the importance of the consistency of the selected place during different years, the places that were always suitable between the evaluated years, were selected. The results of the research show an ideal location in the western region of Tehran for site construction, which has been selected very well suitable in terms of all criteria. In addition to developing the appropriate location for the calibration site uses, instruments such as san-photometer and goniometer were also developed to be installed on the site to provide services to multispectral and hyperspectral sensors.

***Keywords**:* Radiometric Calibration Site, Remote Sensing, Atmosphere, Tehran.

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1. Introduction

Remote sensed data have been used to extract relevant information on various natural resources and environments (Zeaiean Firrozabadi and Hasani Moghaddam, 2018). In real world applications with, various optical sensors are used for images acquisition, it is often difficult to obtain a good quality image without applying calibration procedure (Hasani Moghaddam et al, 2019). Calibration has to be applied in order to relate the digital counts given by the sensor to the incoming radiances, of the physical units of interest (Muller, 2014). The simple calibration of the sensor, in radiance or reflectance, does not provide information on surface that is directly accessible but a composite signal which depends on atmospheric conditions (gas absorption, molecules and aerosols scattering) during measurements. The need of radiometric correction is obvious. That is extracting, from the composite signal, information that depends only on the ground's surface being studied (Hadjit et al., 2013). The available applications that have been used for images calibration (Like ENVI), do not have many of user needed parameter for calibration. However, it is necessary to develop additional features to fit user's application purposes (Kim & Lee, 2020). Locating of calibration site is one of the first step to achieve trustworthy calibration data. Choosing best location for radiometric calibration of remotely sensed images, needs to provide a set of requirements in that environment (Thome, 2002). It is needed to be considered situation of very parameter where it wants to be selected like rain, Aerosol Optical Depth (AOD), soil wetness, NDVI, slope, cloud covering, land use/cover and many other parameter (Wang et al, 2015). The next step in order to obtain calibration-related information is to use precision instruments to obtain reflective and spectral information of the earth and attenuation information of atmosphere (Li et al., 2019).

Xinkai et al. (2020), selected three new radiometric calibration sites were selected in Dunhuang and Golmud. The radiometric stability of the sites is evaluated using the long-term sequence of Landsat8 image data from 2013 to 2019. The surface directional characteristics of the sites are evaluated by using MODIS images at different angles in sunny weather on adjacent dates. The results showed that the three new radiometric calibration sites have uniform and stable surface characteristics and atmospheric characteristics, and are suitable for on-orbit radiometric calibration of satellite sensor.

Wilson & Milton (2010), described a method to automatically select suitable Ground Calibration Test Site (GCTs), using a combination of remotely sensed multispectral and topographic data. Spatial statistics were used to assess local patterns of spatial uniformity, and endmember abundances (extracted using the SMACC algorithm) were used in a novel method to ensure a spread of calibration sites throughout the brightness range for each band. The results of this process showed a map of candidate GCTs, classified according to their suitability.

Kacker and Yoon (2015), provided guidelines for conducting radiometric calibrations of electro-optical (EO) sensors. Technical terms and definitions are introduced as needed throughout the document. Important terms, acronyms, and common references used in this text are summarized in the glossary at the end of the publication.

The aim of this study is to select the optimal location for the construction of remotely sensed image calibration site. First, the required criteria for selecting the calibration site based on the Committee on Earth Observation Satellite (CEOS) standards were studied. After selecting the criteria and data's, processing operations were performed on them and suitable locations were selected for the construction of the site. In comparison of similar studies that have only selected the appropriate site or only evaluated the suitability of site, in the present study, in addition to selecting the optimal site location based on CEOS standards, the instrument needed to operate this calibration site have also been developed.

2. Materials and Methods

2.1. Study area

Tehran province is one of the 32 provinces of Iran, with a total area of 12981 km². It is located to the north of the central plateau of Iran, spanning over 34º to 36º5´N and 50º to 53ºE. Figure (1), shows geographic location of study area.

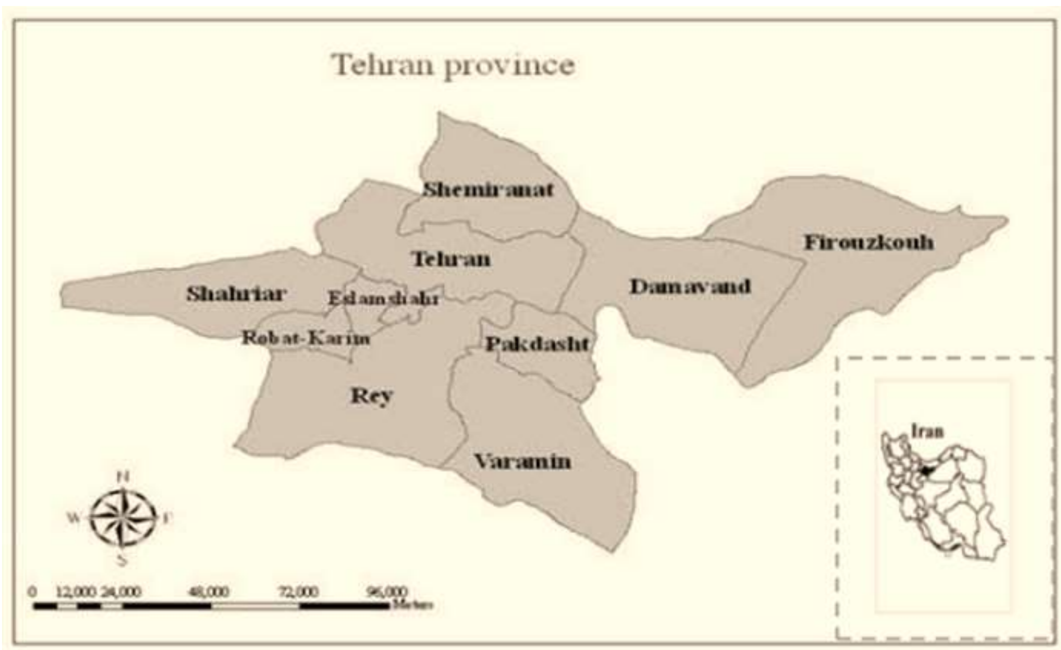


Figure 1. Geographic location of study area (Soltani et al., 2011)

2.2. Data and Layer

Based on CEOS calibration site selecting standards, CalVal sites, environmental, geomorphological and atmospheric condition of study area, 14 parameters were selected. These parameters categorized into satellite based and GIS based data and layers. Figure (2), shows the data and layer used for the selection of radiometric calibration site.

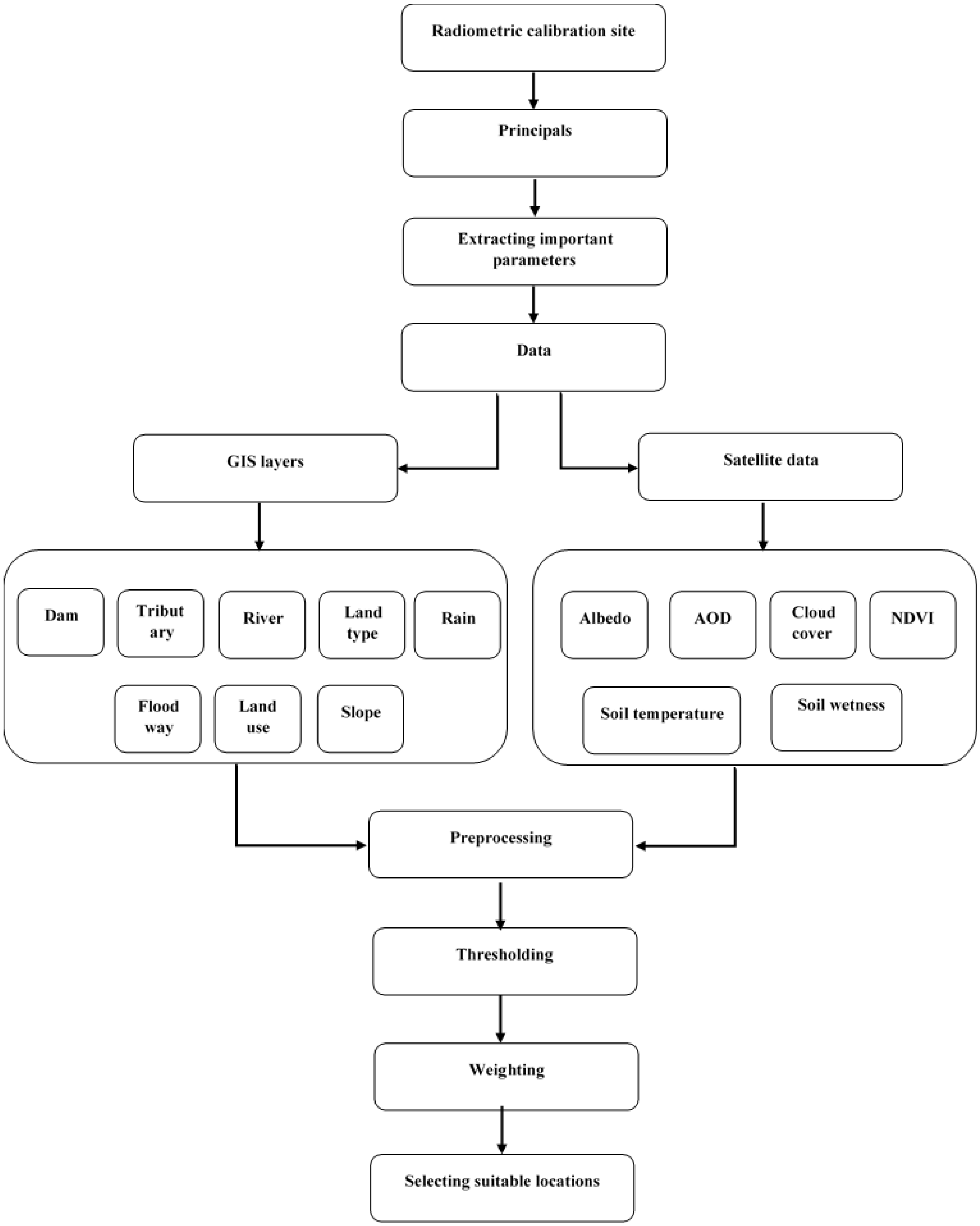


Figure 2. Block diagram of radiometric calibration site selecting

2.3. Analytic Hierarchy Process (AHP)

The multi-criteria programming made through the use of the analytic hierarchy process is a technique for decision making in complex environments in which many variables or criteria are considered in the prioritization and selection of alternatives or projects. AHP was developed in the 1970s by Thomas L. Saaty and has since been extensively studied, and is currently used in decision making for complex scenarios, where people work together to make decisions when human perceptions, judgments, and consequences have long-term repercussions. AHP transforms the comparisons, which are most often empirical, into numerical values that are further processed and compared. The weight of each factor allows the assessment of each one of the elements inside the defined hierarchy. This capability of converting empirical data into mathematical models is the main distinctive contribution of the AHP technique when contrasted with other comparing techniques. After all the comparisons have been made, and the relative weights between each of the criteria to be evaluated have been established, the numerical probability of each alternative is calculated. This probability determines the likelihood that the alternative has to fulfill the expected goal. The higher the probability, the better the chances the alternative has to satisfy the final goal of the portfolio. The mathematical calculation involved in the AHP process may at first seem simple, but when dealing with more complex cases, the analyses and calculations become deeper and more exhaustive (Vargas, 2010). The comparison between two elements is done in AHP as in Table 1 procedure.

Table 1. Scale of relative importance

Scale	Numerical Rating	Reciprocal
Extremely preferred	9	1.9
Very strong to extremely	8	1.8
Very strong preferred	7	1.7
Strongly to very strong	6	1.6
Strongly preferred	5	1.5
Moderately to strongly	4	1.4
Moderately preferred	3	1.3
Equally to moderately	2	1.2
Equally preferred	1	1

3. Results and Discussion

In order to perform the site selection process, the achieved layers and data were prepared in Arc GIS software. Data and layers were prepared using IDW, Euclidean distance, polygons coding and resampling methods. Figure (3), shows the implementation of preprocessing method on data and layers.

Based on the studies performed on the study area, and the observance of CEOS standards in selecting the calibration site, the allowable values of each layer were determined in order to be in the optimal state and obtaining the best situation of land and atmosphere condition. Table (2), shows the optimal value for each dataset.

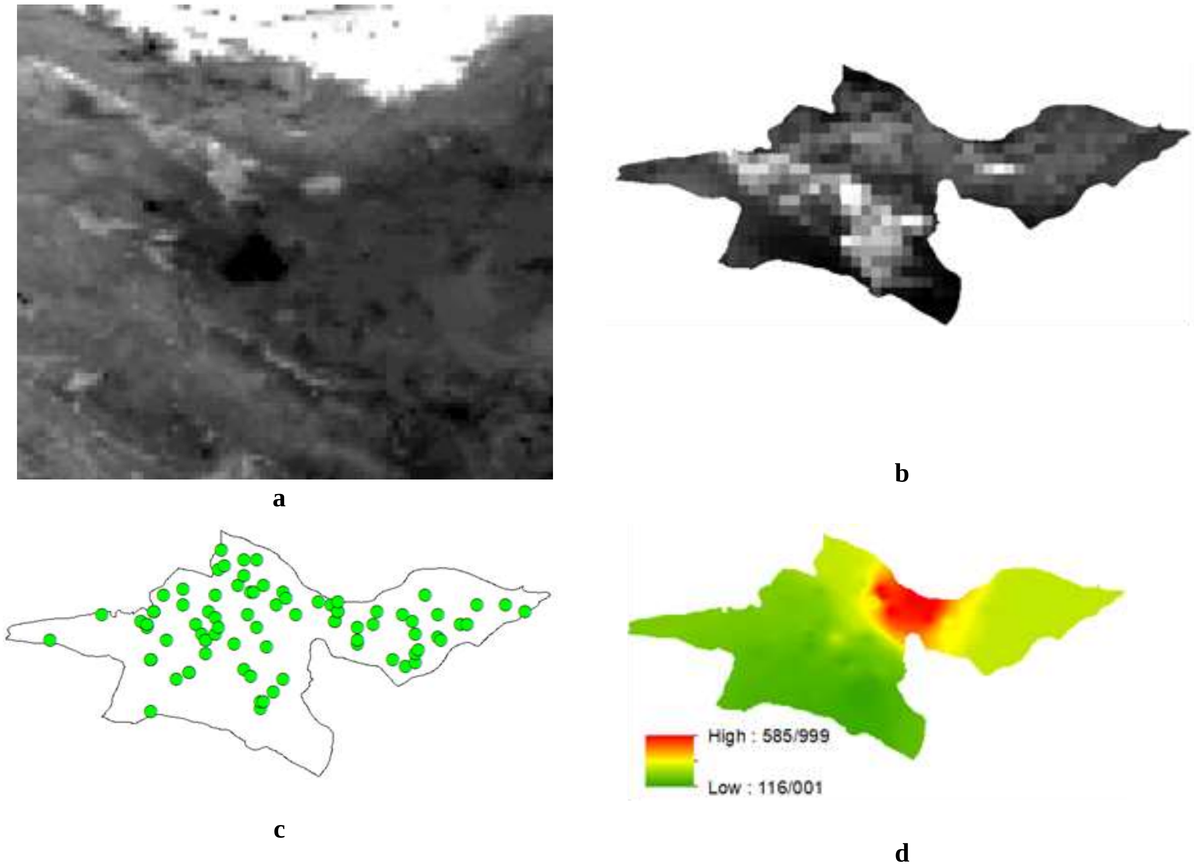


Figure 3. Example of data and layers preprocessing. a) NDVI data with 1km resolution, b) Resamples and region of interest mask of NDVI, c) Rain station data, d) Interpolation of rain station data by using IDW

Table 2. Optimal threshold of dataset

Num	Dataset	Sub data	Threshold
1	**Satellite data's**	Surface Albedo	> 0.2
2		AOD	< 0.5
3		Cloud Cover	< 0.4
4		NDVI	0.2 > NDVI >0
5		Soil Temperature	> 285 kelvin
6		Soil Wetness	< 0.53
7	**GIS layers**	Rain	< 300 mm
8		Land Type	Smooth terrain without roughness
9		River	> 1000 meter
10		Tributary	> 300 meters
11		Dam	> 3000 meters
12		Slope	< % 4
13		Land use	No agri, resident and …
14		Flood way	No flood damage

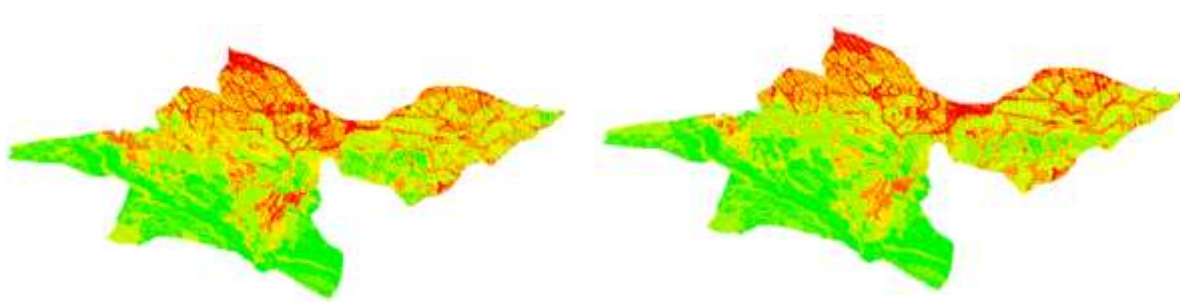
Using the AHP model, the data were compared in pairs and the importance and priority of each over the other was measured. The output of this model provided weights for layers and data, which are shown in Table 3.

Table 3. Calculated Weight of dataset

Dataset	Sub data	Weight	Sum
Satellite data	Surface Albedo	0.03	**0.30**
	AOD	0.04	
	Cloud Cover	0.03	
	NDVI	0.09	
	Soil Temperature	0.04	
	Soil Wetness	0.07	
GIS layers	Rain	0.06	**0.70**
	Land Type	0.08	
	River	0.08	
	Tributary	0.08	
	Dam	0.08	
	Slope	0.1	
	Land use	0.12	
	Flood way	0.1	

According to the above table, the role and impact of data types in site location are different from each other. As can be seen, satellite data take on less weight than GIS data. Considering that the radiometric calibration site consists of two parts: land surface and atmosphere, it can be said that the selected location, indicates the atmospheric condition of that area. The location of the calibration site is always constant, while atmospheric conditions can be changed over the times. Based on these cases, in the first step, for a calibration site, the suitability of the location is considered as the first priority and atmospheric conditions as the second priority, which does not mean ignoring any of these factors. Accordingly, finding a place that has a very good location, and also has a stable atmospheric condition, considered as a major component in the final decision to build a calibration site.

Selecting a suitable location for the construction of the calibration site was done using the prepared dataset and the extracted weights. In order to more accurately assess the site and identify a place with the least changes in different time periods, changes in the characteristics of Tehran province in an 8-year period were investigated. In this study, the changes that occurred between 2012 and 2019 were examined by averaging 2-year data. Figure (4), showed the suitable location for constructing radiometric calibration site in Tehran province based on time period analysis.



2012-2014 2014-2016

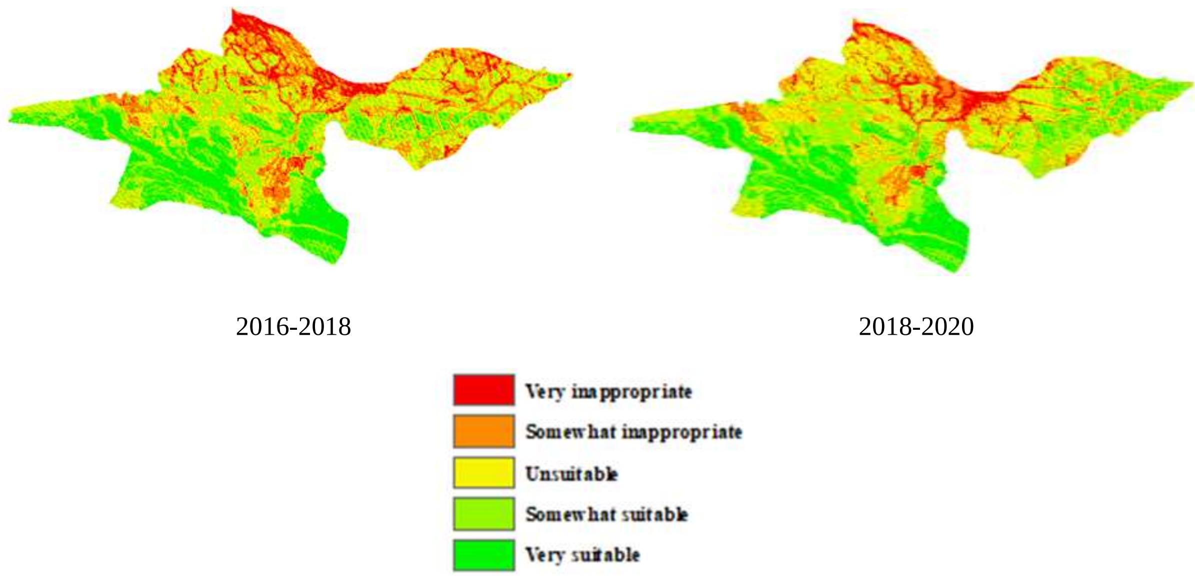


Figure 4. Suitable and unsuitable location for calibration site selecting based on 8 years' data analysis

Due to the fact that choosing the best place requires the study and use of time series data, in this study, places that have been selected as very suitable in all of this 8-year period were selected. Figure (5), shows the final locations selected for the construction of the radiometric calibration site.

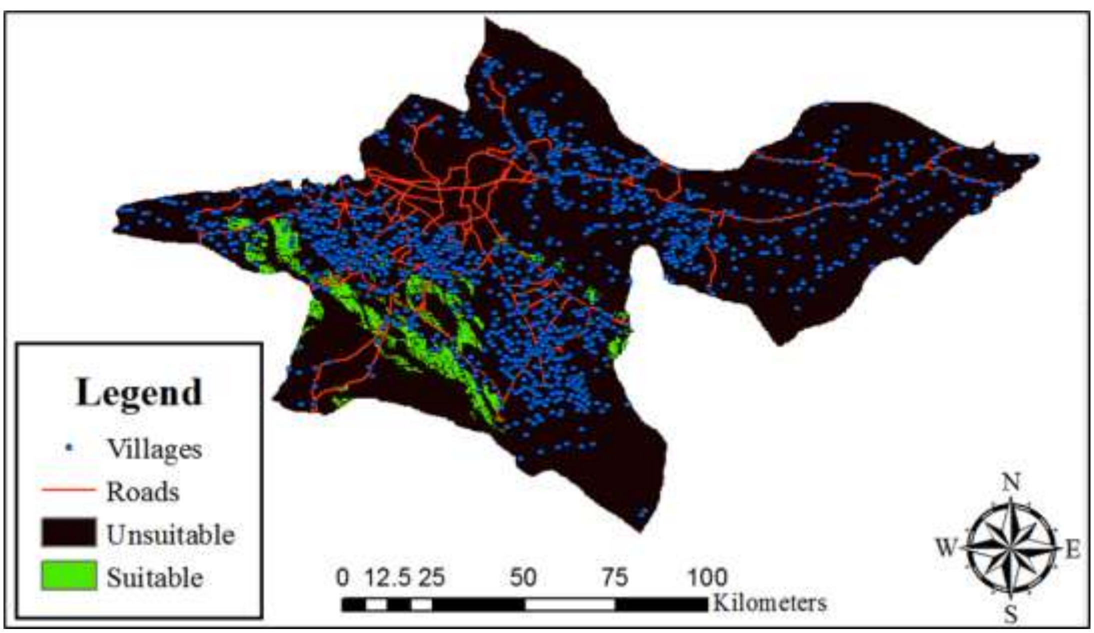


Figure 5. Selected location for calibration site

The basis of any scientific research is the evaluation of the accuracy of the results obtained. In this research, after identifying suitable places, by using field evaluations, we selected the places that were most relevant to the purpose of the research. From the selected locations, one point was selected as the ideal location for the construction of the radiometric calibration site. Figure (6), shows the final selected location.

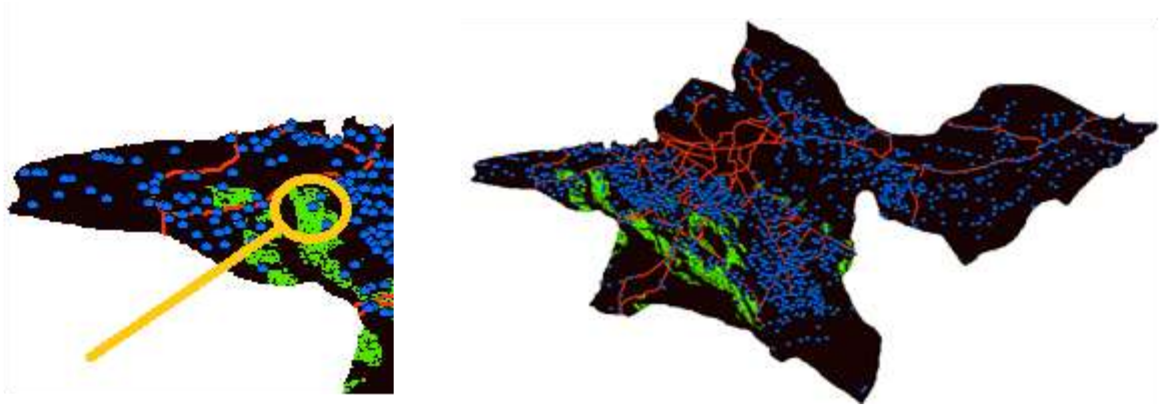


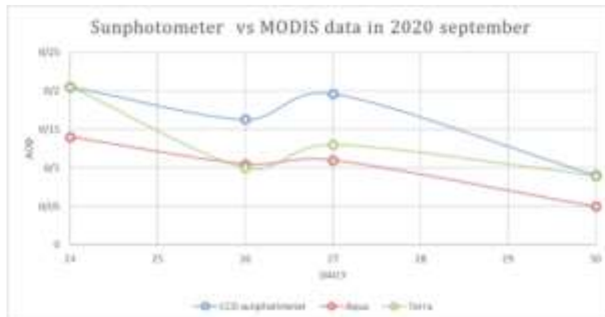
Figure 6. Final selected location (West of Tehran province in 35º32'23''N and 50º44'42''E)

The results of the field evaluation, surface coverage and sky clearing of the selected site are shown in Figure 7.

Figure 7. View of the selected site

In order to use a radiometric calibration site, it is necessary to provide standard instruments to obtain accurate measurements and data from the site. For this purpose, we designed and developed Sun-photometer and goniometer that have been necessary to place in calibration site. Figure (8), showed sun-photometer and its accuracy evaluation.

time	CCD Sun-photometer	Aqua	Terra
24	0.205	0.14	0.205
26	0.162522	0.105	0.1
27	0.196	0.11	0.13
30	0.09	0.05	0.09



a b

Figure 8. a) Designed sun-photometer, b) Sun-photometer output and MODIS data

Another device that has been developed for use in the calibration site, is the goniometer. This device is used to evaluate the reflection of the calibration site surface at different solar angles.

Figure 9. Developed goniometer

Compared to similar work done in the field of locating, the present study identifies for the first time in Iran the appropriate location for the construction of a remote sensing data calibration site. Given that there were no similar activities in the country and the relevant international research was related to the climate and geography of those areas, the present study evaluates for the first time a zone of Iran in relation to the appropriateness of the construction of the calibration site. However, despite all these reasons, this research can be compared with researches such as (Yang et al, 2020. Myers et al., 2017). Research on radiometric calibration sites has generally been conducted in countries that have previously had similar experience. In addition to the fact that the authors of the present article had to extract important parameters based on the geography of Iran, they were also able to design tools for the operation of this site. One of the strengths of the present study, which distinguishes it from other related researches, is the ability to use the selected site for radiometric correction of multispectral and hyperspectral sensors. Due to the environmental and atmospheric constraints of different regions, calibration sites are able to provide services to a certain number of sensors. We solve this problem by choosing an ideal location in terms of remote sensing parameters and developing a sun-photometer with different spectral bands data capturing capability.

4. Conclusion

Images acquired from remote sensing sensors have a number of errors because they are affected by atmospheric conditions. These atmospheric errors correcting, requires knowledge of atmospheric conditions and the Earth's surface reflectance. In order to optimally correct the remote sensing images, in this research, first a suitable position was selected for the construction of the radiometric calibration site. One of the main challenges in choosing a calibration site are identifying important parameters and using them in the process of identifying the suitable location. Investigation of atmospheric factors by influencing the remote sensing process and spectral validation of remote sensing data, identified 14 types of important parameters in the selection of the radiometric calibration site. The importance of each of these parameters is determined by the effected errors that they have on the images. Selecting the location of a radiometric calibration site is not limited to the software process and requires field surveys to determine the accuracy of the output data. In this research, quantitative and qualitative evaluations show the identification of a very suitable place in terms of all 14 used parameters. The selected site has firm and stable soil conditions and is very little affected by wind in terms of soil surface movements. Excessive movement of surface soil particles causes an error in measuring total surface reflectance and causes an error in the radiometric calibration operation. Using a designed goniometer, the surface reflectance status, which is one of the most important parameters in this research, was investigated and the appropriateness of the selected location was confirmed. According to the presented items, the selected site according to the spatial conditions, dimensions and devices developed, can be used for a variety of sensors from resolutions below meters to 500 meters. This variety of service to different sensors makes this it's, main site of satellite calibration for space organizations.

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