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Criteria of selecting satellite data for studying land resources

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Abstract

In recent years, acquiring information of remote sensing data, especially satellite data has excessively increased and several methods are presented in order to improve the quality of remote sensing studies in earth sciences. It is possible to manage many projects and provide different types of thematic maps in a short period of time, and a low cost by utilizing satellite data and GIS method. Recent researches show that utilizing satellite data in studying natural phenomena can effectively help to reduce the time and cost at the same time maximize the precision. But, many users of these data face confusion at choosing suitable image for their subject and lack a special criterion for that end, Or else they merely take one or two criteria in to account and lack a comprehensive view in choosing the best image. Therefore, defining and analyzing criteria for correct and precise selection of satellite data, in accordance with case-study, is crucial. So, in this article, we investigate the image selection criteria, especially their role in minimizing time, cost and extracting useful data. On the basis of the results, prior to doing of the project, users of these data need to study selection criteria properly. After that, on the basis of these criteria and phenomena under study they should set out to choose sensor type, date of image acquisition, image type, and methods of information extraction. Therefore in research, different practical aspects of satellite images as well as criteria for selecting suitable images are investigated and subsequently information and suitable solutions are provided for users.

Keywords: Criteria; Image selection; Land resources; Satellite; Remote sensing & GIS

1. Introduction

Remote sensing is defined as the science and technology of detection and measurement of spectral properties of objects and phenomena related to earth, atmosphere, and sea from a far distant and analyzing the collected data. This technology is useful in investigation and recognition of features and natural recourses. Scanning large area with repetition cycle, providing up-to-date thematic maps, knowing environment and the factors affecting it are among the factors which are useful in reaching sustainable development. Therefore, utilizing remote sensing technology is one of effective tools in environmental and geosciences studies. Knowing many of natural resources such as soil, water, mine, vegetation and monitoring devastating events such as floods, desertification, water and wind erosion, sand dunes, water and soil salinity and finally, degradation of forests and

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rangelands are essential in order to reach sustainable development. To this end, using remote sensing technology and utilizing satellite data lead to decreasing the costs, economizing on time and increasing precision and speed, so this technology is gaining more importance in sustainable development day by day. Remote sensing technology is among the modern tools provides the access to basic information for land-resources management. Utilizing remote sensing it becomes possible to spend less cost and time but cover a wide range of projects in different global, national, regional, and local levels (Alavi-Panah, 2003).

Since a general knowledge of different types of remote sensing is necessary in the study of criteria, at first we take a brief look at different types of remote sensing. In relation to spectral intervals and wavelength, remote sensing is divided into three types:

1. Reflective remote sensing (visible, near and middle infrared) (from 0.4 to 3 μm)
2. Thermal infrared remote sensing (3-15 μm)
3. Microwave remote sensing (1 mm to 1 m).

While the main source of energy in visible remote sensing, near and middle infrared remote sensing is the sun, in Thermal remote sensing the heat stored in the earth is the main source of energy which is provided by the sun. This kind of sensing is also called passive remote sensing. But the source of energy in microwave remote sensing can be both from sensor and the energy stored in the earth that are called active and passive remote sensing respectively. Therefore microwave remote sensing is independent from solar radiation and at night and bad weather condition is also able to gather information from phenomena.

Information and data gathering from land phenomenon such as urban, rural, mines, forests, soil and vegetation from far distance by using remote sensing technology in time intervals of few hours to some days during a month or a year which happens repeatedly, provides users of different domains of geosciences with a considerable amount of information. Therefore, if various information in different data layers which are gathered in this way don't get processed and extracted this would be a kind of wasting resources and data. But, if these information get analyzed and processed precisely using tools and suitable methods, they would be so efficient in the detection and analysis of various terrestrial and atmospheric phenomena (Jensen, 2002).

In order to monitor and gathering the information from the earth surface a number of different sensors from European countries, US and Japan in 1 to 176 day periods, gather a entire image of the earth surface in visible to infrared bands and send to ground stations. These sensors have different spatial, radiometric and spectral resolutions that provide the users with choice proportionate to their case study. Among these sensors, NOAA provides an entire image of the earth every 12 hours and simultaneous imaging of four sensors of such type, would provide an entire cover of earth every 3 hours. So such kind of information is so efficient in the examination of atmospheric phenomenon, process of plant growth, showing fire progress especially in forests, monitoring floods, and predicting its trend of spread. On the other hand IKONOS or Quick bird sensors with spatial resolution of 1 meter or less provide the possibility of detecting single trees and vehicles in cities. Therefore the gathered data by space sensors have different spatial, spectral, temporal and radiometric resolutions. That's why to select best sensor or sensors, users need criteria to extract more comprehensive data by spending less cost and time.

In this paper we try to introduce criteria of selecting remote sensing data for quick and precise access of users to these data and economizing their time and cost.

2. Criteria of image selection

To order and request satellite images different factors should be taken into account. These factors include:

1) Imaging purposes, 2) Image characteristics, 3) Region size, 4) Needed details and project purposes, 5) Image costs. It is required of every project to determine the goal of image usage prior to any other task. After that the important factors in image selection should be considered. The most important criteria to be taken into account at the time of image request are:

2.1. Costs

Satellite data and images distinguishes from other types of data sources base on their high coverage and little cost - considering both time and money - at the time of gathering spatial and geographical data. For example nowadays there are different kinds of techniques and methods for survey and updating geographical information.

But the main point is that which techniques, while having the high efficiency, are less costly. Map scale is one of the factors affecting the cost of providing thematic maps directly. So that the less the scale gets, the less would be the costs and vice versa. So users should know what scale efficiently suits with their needs and is less costly. Table 1 show the scale factor's role in production costs of the map by images or photo in large to small scales.

Table 1. Comparison of production costs(dollar) of residential area mapping per km^2 in different scales

Operation type	Scale 1:6500	Scale 1:13000	Scale 1:40000
Aerial photography	8000	5000	4110
Scanning	6000	1500	165
Aerial triangulation	10000	2500	275
Generation of a digital elevation	48000	12000	1320
Digital orthophoto generation	12000	3000	330
Mosaicing of digital orthophoto	8000	2000	220
Total orthophoto cost	92000	26000	6420
Line mapping 1:1000	800000	200000	22000
Total line mapping cost	892000	226000	2842

In order to settlement mapping with an area of 259 km^2, considering 60% longitudinal and 40% lateral overlap of aerial photos, 400 photographs are needed in scale of 1:6500 with an area of 1.5×1.5 km, 10 photographs in scale of 1:13000 with an area of 3×3 km, and 100 photographs in scale of 1:40000 with an area of 9.2×9.2 km. By reducing the scale, costs are reduced strongly, so that the production cost of mapping per km^2 at scales of 1:6500, 1:13000, 1:40000 equals 892000, 226000, 2842 USD, respectively.

Investigations show that using satellite data and GIS techniques for providing thematic maps leads to economizing the cost at about 40-60% at mapping time compared to current methods. So combination of above mentioned items can increase the precision of results and improve the quality of produced maps. Moreover there is the possibility of economizing on time and cost and updating the data.

To compare costs and time needed, surveyors of British Columbia University surveyed an area of 800 square miles once by means of aerial photos and other time by using Landsat satellite imagery. The level of correspondence between provided maps and ground truth maps for aerial photos were 60% and for satellite imagery, the amount was 50%. Results show that using aerial photos cost 442000 USD and need 54 months (map at the scale of 1:1000000), while using aerial photos cost 2000 USD and need 6 months (map at the scale of 1:500000). So it is obvious that large scale maps which provide ground features twice as much spatial accuracy as smaller ones cost less considerably at both money and time in proportion to traditional methods. Summary of the results are shown in Table 2 (Jensen, 1996).

Table 2. Comparison time and costs of traditional and digital methods mapping

	Operation type	Costs (dollars)	Activity	Time
Photogrammetric technique	Purchase of 2250 photos	12000	photograph	36 months
	Fly cost	300000	Survey using 1125 photos	14 month/person
	Camera cost	130000	Control, production and print the photo	9 months
	Total costs	442000	total	59 months
Remote sensing (satellite) technique	imaging	1600	imaging	1 month
	Mosaicing of images	400	Survey using of 45 images	1.2 month/person
			Control, production and print of maps	4 months
	Total costs	2000	total	6.2 months

As can be seen the time spent for map production using satellite images (digital method), is 12.5% of time needed in traditional method and the costs are also cut to 0.5 percent. If the large amount of information that can be extracted from satellite data spending less time be taken into account, efficiency and usefulness of satellite data would be clearer.

On the other hand, remote sensing data are one of sources of high quality for providing digital elevation model (DEM), slope and aspect map, which is less expensive compared to other methods, have effective role in improving the quality of produced maps. The digital elevation model is so useful in finding the relationship among extracted phenomena from remote sensing images in nature. As an example in order to understand the relationship between soil and environment some extra data such as digital elevation model, aspect and slope map are needed. In Table 3, different techniques of producing digital elevation model as well as their cost is given. For every technique a suitable application is suggested that can be considered as basis of users' decision-making.

Table 3. A comparison method of DEM production regarding cost, precision and its main applications

Techniques of DEM production	Elevation accuracy (m)	Cost by dollar per km^2	Application
Satellite data	±12	2	Topography
Aerial photo at scale of 1:40000	±0.6	25	Topography & modeling of urban
Aerial photo at scale of 1:30000	±0.2	100	Non-forested areas
Aerial photo at scale of 1:6500	±0.1	350	Non-forested areas
Ground survey	±0.1	1000	Forest areas

2.2. Study type and atmospheric windows

Considering the role of H_2O, CO_2 and O_3 in absorption of spectral energies, atmospheric windows should be taken in to account at choosing the images.

As it can be seen in figure 1 the white spots are atmospheric windows that show the percentage of spectral energy transmission of atmosphere. As the level of it increases the amount of sensor energy absorption increases. On the other hand black zones show the regions where atmosphere absorbs the highest amount of energy. So considering atmospheric windows can be useful in cases it is needed of the sensor to absorb the highest amount of energy of the earth surface to be utilized in special purposes.

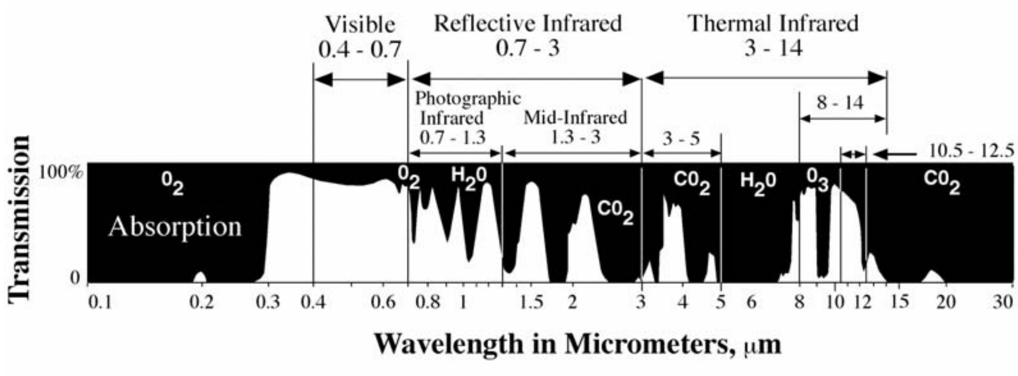

Fig. 1. Atmospheric windows in the electromagnetic spectrum

2.3. Proper time and season for study and imaging

Various phenomena of the earth surface can be investigated by means of satellite images. But studying each phenomenon has a special time. So in choosing satellite images it should be taken into account and for that end, the proper image regarding time and season should be chosen. In what follows proper time and season of different studies are presented.

2.3.1. The study of soil and geological formations

Due to harvesting agricultural crops and drying rangelands as well as livestock grazing in late summer and early fall, the earth surface has the least vegetation and the spectral reflectance of green vegetation is the least. This period thus provides the best time for recognition of geological formations and soils, since vegetation causes less confusion in recognition and separation of phenomena. One more advantage of imaging during this time is that due to no precipitation, soil contains the least amount of moisture. Moreover during summer, sun angle is close to vertical and shadow effect is the least. Naseri and Khodayi (2002) used TM data at summer in order to separation of geological formation in the west of Orumieh Lake, because the sun angle was close to vertical and shadow effect was the least (figure 2).Post et al. (1994) used Landsat-MSS data collected on June, to investigate the relationship between soils color and MSS spectral data in Arizona semi dry region. In hard formations and karstic areas, the existence of groundwater is a function of secondary porosity. Increase of secondary porosity happens along lineaments, joints, faults and bedding planes. In order to find zones with increased secondary porosity, a number of landforms such as lineaments, rock type, pattern of channels and green vegetation in dry season in dry and semi dry areas are used which are called groundwater indices. Recognition and extraction of these data can be carried out in summer more accurately. Naseri and Khodayi (2002) has extracted groundwater indices from satellite digital data in summer in south western part of Orumieh Lake (Oshnavieh region) and used them to identify the susceptible areas in hard formation to own groundwater. The results show that the before mentioned susceptible areas have a significant correspondence with green vegetation in dry season and geological lineaments (Fig. 3).

Fig. 2. Geological unit's separation, using Landsat-TM data in summer season - south western region of Orumieh lake

Spectral behavior of saline soils in dry and moist situations has special characteristics. In moist condition, by absorbing water molecules, salt crystals have the ability of absorbing electromagnetic waves, so they look darker in the image and spectrally look like non-saline soils. But in dry condition, salt crystals lose their water they reflect more of electromagnetic waves. That’s why they look brighter in image and can be clearly distinguished from other lands (Matinfar, 2006). Images taken from Playa region in Kashan on Mehr, clearly distinguish saline from non-saline lands. In Figure 4, regions A and C are saline soils, and dark areas are non-saline soils.

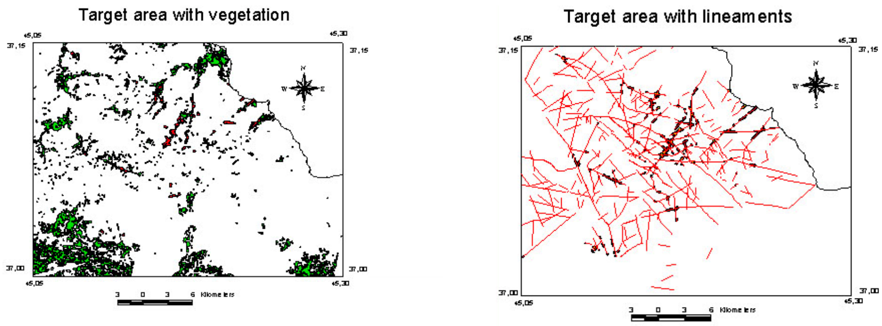

Fig. 3. Correspondence degree of lineaments & green vegetation in dry season with the selected susceptible areas to own groundwater – south western region of Orumieh Lake

2.3.2. Study of vegetation

When growing cycle of plants or estimation of vegetation indices is being considered, synchronization of imaging with the stage of vegetation growth is crucial. Figure 5 shows changes in chlorophyll concentration of leaves of some plant in different months and increase of concentration difference in third to sixth month from the beginning of growing period. Therefore, the difference in chlorophyll concentration causes the difference in plant combinations which leads to difference in their reflections. So this period can be useful to distinguish the plants.

Moreover, Figure 6 shows spectral reflectance curves of vegetation in different dates. As can be seen, in August 16th when the leaf area index reaches its highest value during growth period (LAI=4.4), amount of spectral reflectance in NIR region is maximum and in June 23rd when value of leaf area index is low (LAI=1.6), spectral reflectance in NIR region is a little above the bare soil curve. So acquaintance with different stages of plant growth and choosing the images when plant shows highest value of its growth period, can lead to the increase of accuracy in studying of vegetation properties.

To study type of forest trees, the suitable season should be taken into account. Also to investigate the vegetation moisture stress, imaging in two periods of plant blooming and fading should be carried out repeatedly to achieve a clear pattern of these two opposite situations in images. So the repetition of images is required for vegetation studies.

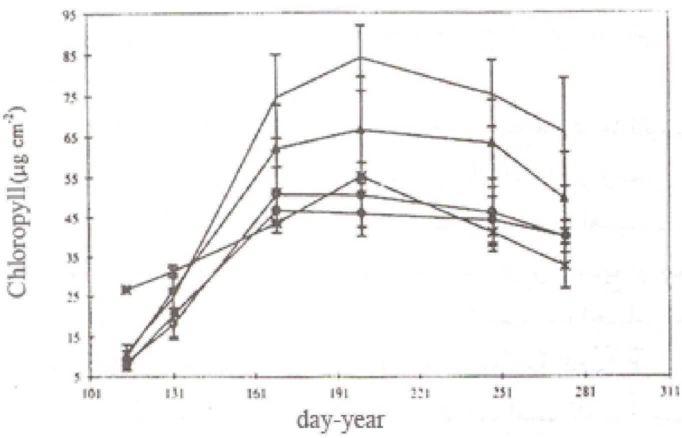

Fig. 5. *Chlorophyll concentration measured in leaves of some plants between April and September: sun-exposed leaves of oak(-), shaded leaves of oak(-Δ-), sun-exposed leaves of beech (-o-), shaded leaves of beech (-□-)*

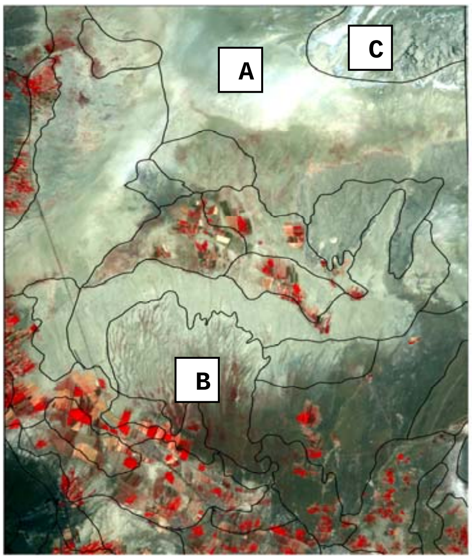

Fig. 4. *Soil map on false color composite, ETM+ 4, 3, 2 - Kashan*

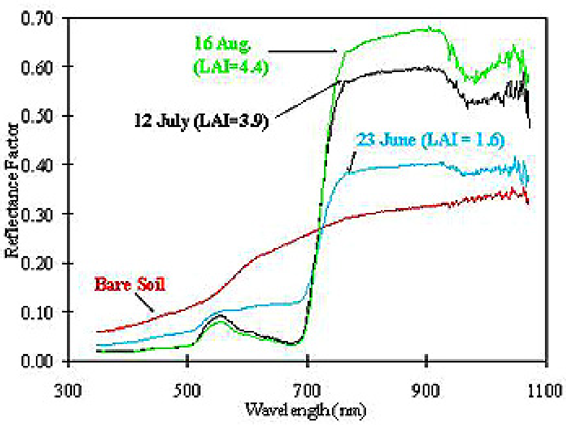

Fig. 6. *Spectral reflectance curves of plant in different dates*

2.3.3. Study of surface water resources

The characteristics of energy reflectance of water are a function of water and its contained material (both organic and inorganic materials). The existence of suspended materials, moss, algae in water, water fluctuation, and thermal variation during the day affect the value of energy reflection of water. Application of remote sensing in monitoring of water resources can be divided in to quantitative and qualitative assessments. Among quantitative assessment of water sources are depth variation assessment or bathymetry of water resources. Qualitative assessment includes measuring chemical, physical, and biological parameters such as water salinity, sediment and suspended materials, color of water, phytoplankton and algae, chlorophyll etc. The main point is the time of satellite imaging which is determined regarding the aim of studying resources of surface water. Alavipanah and Khodayi (1383) used satellite data to investigate the qualitative parameters of Orumieh Lake water and the effect of the lake's causeway on the quality of water in two sides of the causeway. To this end, and in order to show the way in which water exchanges in two sides of the causeway, they chose a time after a heavy rain when Talkhe-Rood river which enters the lake passing the causeway from southern part, was full of suspended material. Since Orumieh Lake water has a high density due to high salinity, suspended material can not be deposited swiftly. This issue provides the possibility of investigation and tracking water exchange in both sides of the causeway and variations of qualitative parameters using satellite data.

2.4. Synchronizes of satellite passage and field study time

One of important and considerable points in remote sensing studies is the simultaneity of imaging and gathering field data. In all of remote sensing studies, field data are needed since modeling and results are based on them. So they are significant. In addition to precision of measurements and field observations, simultaneity of gathering these data with imaging of the region is very important. To this end after choosing the proper image for study, imaging time should also be taken into account for studying and field operation to be carried out.

5.2. Imaging swath width

One of the advantages of satellite data is their wide and integrated coverage as well as presenting the information related to climatic, spatial, and temporal conditions. For instance GOES and NOAA meteorological satellites with the swath width of 2700 km or Landsat ETM^+ and TM with swath width of 185 km, HCMM satellite with a coverage of 700×700 km which equals 16 Landsat TM scan, and finally TERRA satellite which covers the earth every two days And its swath width is 2330 km, can be mentioned. The user chooses data according to his/ her need and the region under study. Therefore on the basis of local, regional, national or international level of the project the proper image should be selected.

2.6. Resolution

Each remote sensing system is related to four important resolutions. In order to provide the suitable satellite images, a clear understanding of resolution is necessary. Resolution as criterion of ability an optical system is used to distinguish the signs which are spatially close or spectrally similar.

2.6.1. Spectral resolution

Spectral resolution is defined as the number and dimensions of specific spectral range in electromagnetic spectrum to which sensor system is sensitive. In other words, spectral resolution represents the ability of a sensor to distinguish the spectral ranges (Campbell, 1996).

Remote sensing systems are divided in to three types according to their spectral resolution:

- Panchromatic sensors which are sensitive to only one part of electromagnetic spectrum such as black and white cameras and panchromatic band of ETM, IRS, and SPOT sensors.
- Multispectral sensors which record data in several bands of electromagnetic spectrum such as ETM^+, TM, MODIS sensors.
- Hyperspectral sensors which collect data in many spectral bands. Such as AVRIS which acts in 224 bands in the region of 0.4µm to 2.5 µm with 10 µm intervals separately. Hyperspectral sensors are means for scanning the numerous narrow contiguous bands of spectrum. These images are taken at visible, infrared and thermal infrared parts of electromagnetic spectrum. These systems gather data in 200 bands or more (400

bands). A hyperspectral sensor can provide images with spectral width of 0.01 μm, that way it also provides the possibility of direct detection of the material (Lillesand, Keifer, 2004).

The diagram of soil and calcareous gravels spectral reflectance, in multispectral and hyperspectral systems clearly shows the differences of these two sensing. The result of multispectral sensing is a diagram like a broken line with turning points in spectral range of each band, while the result of hyperspectral sensing is a diagram with a higher fluctuation which represents a more realistic picture of these phenomena's spectral behavior. For instance, soil and gravel material, these diagrams display more details (Fig. 7-a and 7-b). A comparison of the two diagrams shows the higher capability of hyperspectral sensors compared to sensors with broad bands and low spectral resolution. Considering low and numerous bands in different visible, infrared and thermal spectrums, investigating precise characteristics and nature of some minerals, soils and rocks becomes possible, and their distribution map also can be provide.

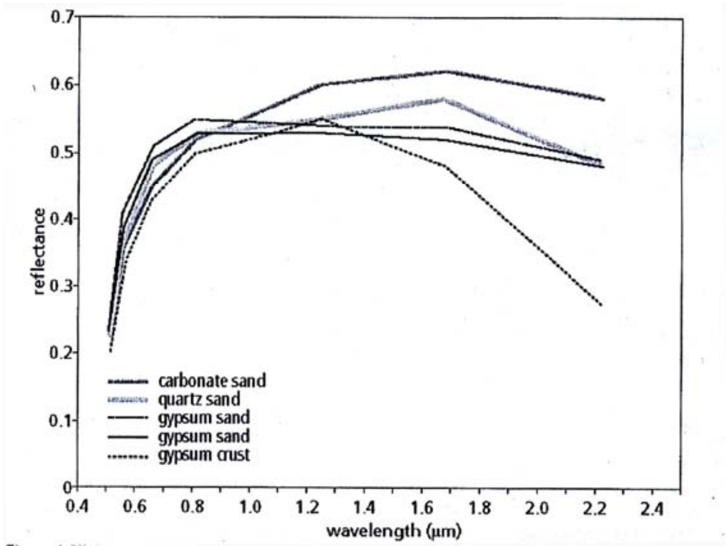

Fig. 7-a. Multispectral Spectral curve with low resolution carbonate sand, quartz sand, gypsum sand and gypsum crust

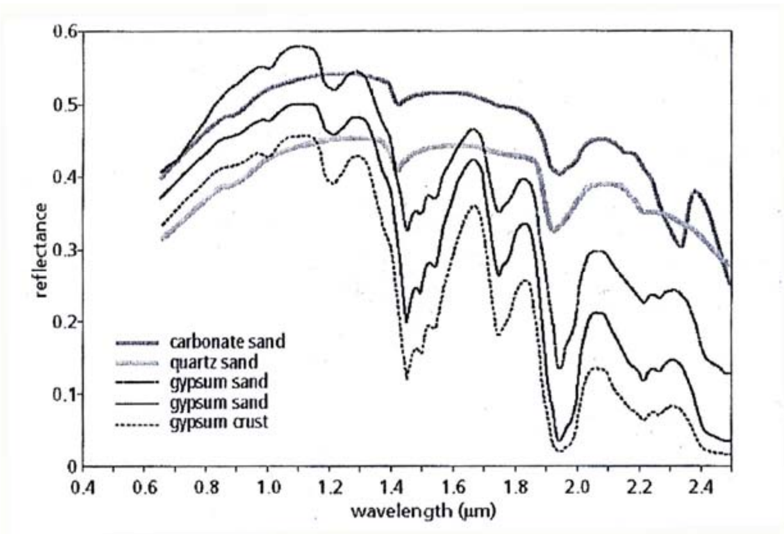

Fig. 7-b. Hypespectral Spectral curve with high resolution for carbonate sand, quartz sand, gypsum sand and gypsum crust

Using remote sensing, it is possible to measure depth variation in shallow water such as lakes, pools, and sea coast. In lower depths of water, visible wavelengths can penetrate into the water, reach its bottom and reflect. For example, blue wavelength (0.4-0.5 µm) in depths lower than 30 meters reaches the bottom of water and reflects a little. As depth decrease, the reflection increases.

In waters with 2 or 3 meters depth or less, red light (0.6-0.7um) reaches the bottom as well, and the reflection increases. Bathymetry can be carried out using digital false color composite image and interpreting them or else by making light transmission model in water using reflectance values from seabed. Spectral properties of water vary according to the material suspending in it. Evaluation and assessment of suspending material in water is one of the parameters which should be taken into account for examining the water quality. The existence of suspending material in water increases the reflection in visible range of spectrum. Figure 8 shows increasing reflectance energy of water containing of sediment compared to reflectance energy of clear water. As can be seen in the figure, by in crease of sediment density, the curve peak tends towards higher wavelengths.

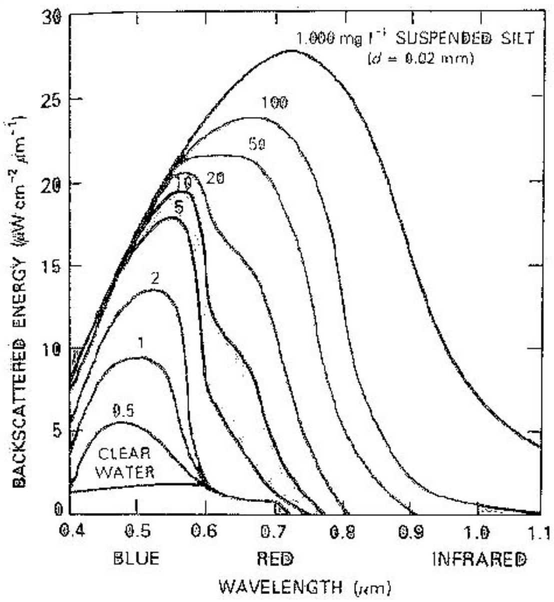

Fig. 8. The influence of sediment in water reflectance energy

Part of electromagnetic spectrum containing visible and infrared wavelengths is useful to enhancing the water quality indicators. TIR can be also used to measure the water quality. Thermal remote sensing in range of 8-14 µm of the spectrum is used to this end. This is dependent on the direct measurement of the energy emitted by the water surface. Therefore, based on the aim of studies, suitable spectral range is chosen and used in selecting satellite data.

Khorram and Cheshire (1985) used Landsat MSS data to examine the water quality and presented an evaluation model for water quality parameters. To this end, they sampled 50 areas in San Francisco. Gulf and then developed a regression model between water quality parameters and average of radiance values of different bands of Landsat and presented a model for salinity, turbidity, suspending material, and chlorophyll parameters. After that, they used these models to predict and provide the map of water quality parameters. They stated that there is a high correlation between salinity and turbidity of water, so saline water has more turbidity compared to fresh water. they also suggested spectral ratio to evaluate chlorophyll and providing it's thematic map, so that they suggested reflectance ratio between blue/red band (450-520mm) and NIR band (910-1050mm) for low concentration of chlorophyll and reflectance ratio between red band (630-690mm) and NIR band (690-750mm) for high concentration of chlorophyll. Bhargava and Mariam (1992) examined the simultaneous effect of salinity and suspended solids on value of the spectral reflectance of water in laboratory and concluded that the value of the spectral reflectance of water is in direct relation with the concentration of suspending materials and in reverse relation with the salinity level, i.e. as salinity increases and suspending materials decrease, spectral reflectance decreases and vice versa.

Serwan and Baban (1993) studied quality parameters of water such as suspending solids, salinity, total phosphorus, and temperature using Landsat TM data. After that, they modeled the relationship between Landsat TM bands and water quality parameters using field data. Ultimately, they used these models to predict and provide the maps of water quality parameters.

2.6.2. Spatial resolution

Spatial resolution is defined as the minimum area of land which can be detected by sensors. Therefore, based on the sensor ability, ground dimensions of features are defined which can be detected by sensor. For example, the ground resolution of visible bands of Landsat7 is 30×30m. If there is less ground resolution, the resolution of features would increase and the wider the area, the higher the spatial resolution would be suitable. For example, data with the ground resolution of 80×80m is not suitable for studying most of urban uses. A sensor's ground resolution should be less than half of considered feature in its smallest dimension to be able to detecting the object. For example, if we want to locate an elm tree in a park, the minimum ground resolution should be about half of the smallest diameter of elm tree canopy. It should be kept in mind that if all these criteria are met, there is no guarantee to be able to detecting the tree unless there would be a difference between spectral reflectance of these trees and the grass or soil around. Figure 9 shows difference of the spatial resolution of two sensors of MSS and ETM+ for case study of Arak and and it's surrounding areas.

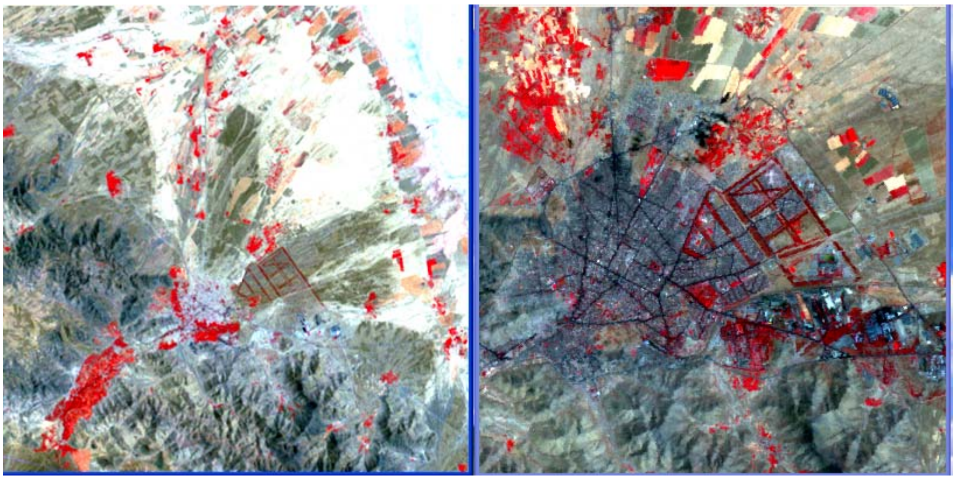

Fig. 9. MSS & ETM$^+$ images of Arak city

One of the other factors for selecting and using remote sensing data is the harmony among spatial, temporal and spectral resolution and usage type. Fig. 10 shows the relations among spatial and spectral resolutions and usage types. For every kind of usage, one can choose a suitable technique by taking into account factors such as accuracy, rightness and economy. For instance, for urban uses, the best method is spatial resolution of 0.1 to 0.01 meter and panchromatic spectral resolution.

2.6.3. Radiometric resolution

Radiometric resolution or spectrometry sensitivity refers to the steps, or digital levels which are used to present gathered data from sensors. Generally speaking, the higher number of steps indicates the higher level of detailed information. Steps or levels are usually shown by binary digits (bits) which are necessary for saving the amount and value of the maximum step. For step 2, the number of bits is 1, while for steps 16, 64 and 256 the number of bits needed are 4, 6, and 8 respectively. The number of levels for separable signs has a great effect on our ability in evaluating and assessing objects characteristics. For example, Landsat1 MSS data are coded by values in a range of 0-63 (6bits=64=2^6) and Landsat5 or Landsat6 TM data are coded by values in a range of 0-256 (8bit=256=2^8). Therefore, TM sensor has higher radiometric resolution compared to MSS sensor. There are several other sensors with a 12-bit coding scale (0-4095).

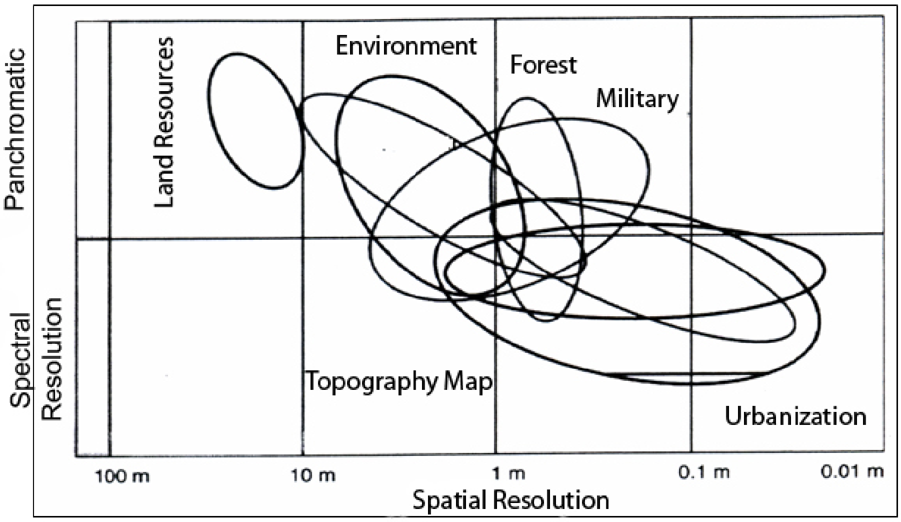

Fig. 10. Relationship between Spectral, spatial Resolutions and usage type

2.6.4. Temporal resolution

Temporal resolution is one of the sensor characteristics which determines the next imaging time of a spot. Imaging repeatability provides the ability to investigate the changes in a time interval, since the study on many features should be carried out on the images related to these two times. So, image selection is important considering the suitable repetition period.

Naturally, sensors look at earth surface vertically (Nadir). The time of imagining repetition in this case is the time needed for the satellite to stand exactly at the same spot of earth surface, and start imaging. This time duration varies indifferent satellites.

Different parameters can affect in this time duration. Here, three parameters of swath-width, spatial resolution and time interval are related to each other. What's clear is that as satellite images wider swath-width in each track, repetition cycle decrease. For instance, NOAA sensor of AVHRR satellite has the swath-width of 2700 km, and is able to have revisit periods of 1 or 2 days. But TM sensor of Landsat satellite has swath-width of 185km and its revisit period is 16 days.

Therefore, satellites which image a wider swath-width have shorter repetition cycle. But, because of the limitation in the volume of saved information, the more gets the swath-width, pixels should have less information or in other words, the captured details are less. In this way, spatial resolution decrease. For instance, although sensor has a high swath-width and therefore, has a less repetition cycle, its spatial resolution is 1100 meter. It means the least dimension which is recognizable in this image is about 1 km. This spatial resolution overshadows many satellite image capabilities in relation to data extraction. While TM sensor, which has repetition cycle of 16 days, has spatial resolution of 30 meter. So, it can be seen that the decrease of repetition cycle leads to the decrease of image spatial resolution. Considering all these, achieving a high spatial resolution, leads to lengthening repetition cycle.

New generation of satellites are so designed to have an oblique view and the ability to provide oblique view up to several degrees. Oblique view of a sensor helps to decrease the revisit period. So that, the sensor when it is in the several strips adjacent to the zone strip, by tilting the sensor, scans that strip. For instance, If IKONOS sensor with a spatial resolution of 80cm, only gets to image Nadir point (the point under sensor), repetition cycle of imaging is 144 days, while because of the possibility of tilting up to 26°, the time decreases to 3-5 days, or using QuickBird sensor with a spatial resolution of 60cm and 45° tilting capability, this time is 1-3 days.

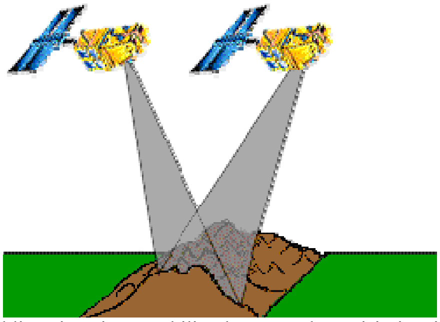

Fig. 11. Oblique imaging capability decreases the revisit time in a region

It should be noted that latitude has also influence over revisit period. So that, revisit period decreases in higher latitude. In the time being, the highest quality of spatial resolution belongs to QuickBird which is able to decrease the revisit period to at least 1 day. Table 4 shows variation of the revisit time by different tilt angles in QuickBird satellite.

Table 4. Variation of the revisit time (days) in QuickBird by different tilt angles

Latitude	Revisit time (days) by 15° tilt angle	Revisit time (days) by 30° tilt angle	Revisit time (days) by 45° tilt angle
0	11	6	3
10	11	6	3
20	9	5	3
30	9	5	2
40	8	5	2
50	7	4	2
60	7	4	1
70	5	3	1
80	3	2	1

Although imagining with high tilt angle can improve and decrease revisit time, it can create distortions and errors and decrease image resolution. In this case, the features in image show themselves in unreal dimensions, especially in regions with high-altitude variations, these errors increase noticeably. Table 5 shows spatial resolution variations by different tilt angles.

Table 5. Effect of tilt angle on spatial resolution in QuickBird

Spatial Resolution (cm)	tilt angle of sensor (degree)
60	0
62	5
63	10
65	15
68	20
72	25
78	30
86	35
97	40
114	45

2.7. Image overlapping to make 3D vision

Maybe one of the problems with satellite data before launching sensors with an oblique view capability where incapacity of the data in providing overlap as well as lack of ability to 3D stereoscopic of images. For instance, Landsat or NOAA sensors are of this type, while aerial photos generally have stereoscopic ability and are capable of providing topographic maps and digital elevation model (DEM). By launching satellites with sensors which are capable to imagine with oblique-view, they enjoy more capabilities. Therefore to provide maps which need overlapping (e.g. DEM mapping), it is necessary to use images of sensors with overlapping ability, like SPOT or ASTER images. Axis of SPOT or HRV sensors have the ability of oblique view, therefore it becomes possible to image repeatedly in short temporal intervals, and provide stereo-pair images. SPOT or ASTLER stereo-pair images cause their advantage over images of other sensors such as TM or ETM$^+$.

2.8. Wind *and* cloud cover effects

2.8.1. Cloud cover

Cloud is considered as one of the imitations for optical satellite images. Frequently, due to cloud cover, using satellite data (e.g. NOAA & AVHRR data) for wide regions face limitation. In small areas, it is possible to acquire images without clouds, but in wider regions it is almost impossible. For instance, in satellite images of whole Europe, it isn't possible to have images without clouds (Addink & Stein,1999). Statistical studies show that in the north-western part of Europe in months with the least cloud cover, still there is problems with a 40% cloud cover (Leemans & Cramel, 1991). These types of problems cause no limitation for dry and semi-dry regions of Iran (especially the Central Iranian Plateau) in late spring, whole summer and early fall. The sunny hours are so that there is no serious problem for imaging. As an example, in Kashan in statistical period from 1967 to 2002, there were averagely 84 cloudy days and 281 sunny days. So as can be seen the probability of clear sky is there three times more than cloudy sky.

Usually clouds show up like spots in images. As Figure 12 shows the dark part is cold and the light part is warm. Scattered showers cause parallel vein pattern with scan lines on the images. Due to energy reflectance between features and cloud layer, dark cloudy layer decrease thermal contrast between land features. Although images can be acquired through flight under the cloud layer, thermal contrast would be low. If clouds cause critical problems, Radar images can be used.

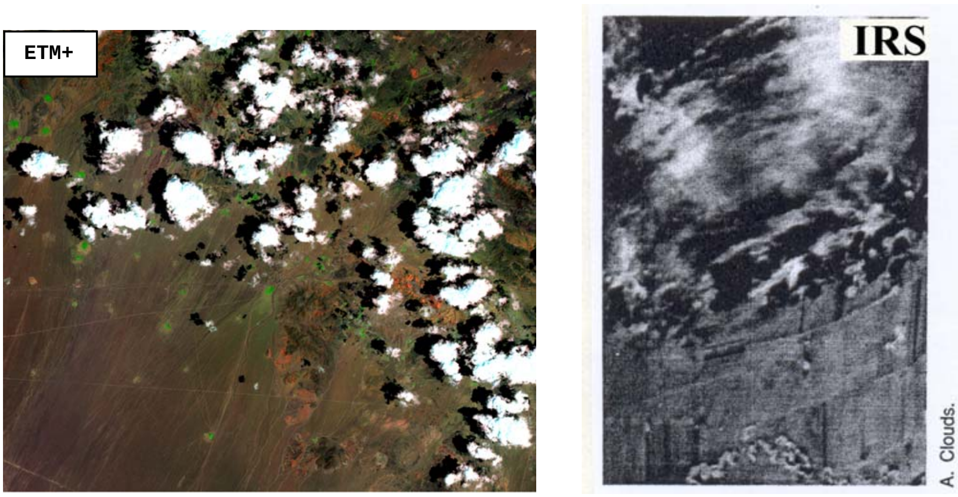

Fig. 12. Cloud cover effects over IRS & ETM+ images

2.8.2. Wind

Wind causes a certain patterns like spot or vein on images. Such spots are like parallel curved lines which are dark and light alternatively and cover the entire image (Fig. 13-a). Veins are made in wind-ward side and are generally similar to light and warm patterns (Fig. 13-b). By passing the barriers, wind speed in wind-ward side decreases which leads to decreasing the cold effect. Therefore, the features inside shelter are warmer than those open to wind. Wind spots and veins can be removed by imaging in still and calm nights. Analyst should be careful not to mistake wind signs for land features. Also, Figure 14 shows 120 days winds of Sistan which led to sand storm.

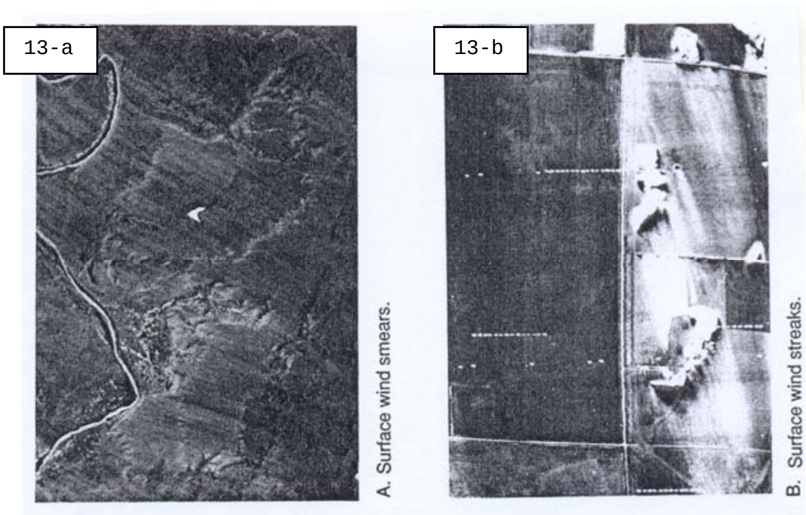

Fig. 13. IRS images affected by wind

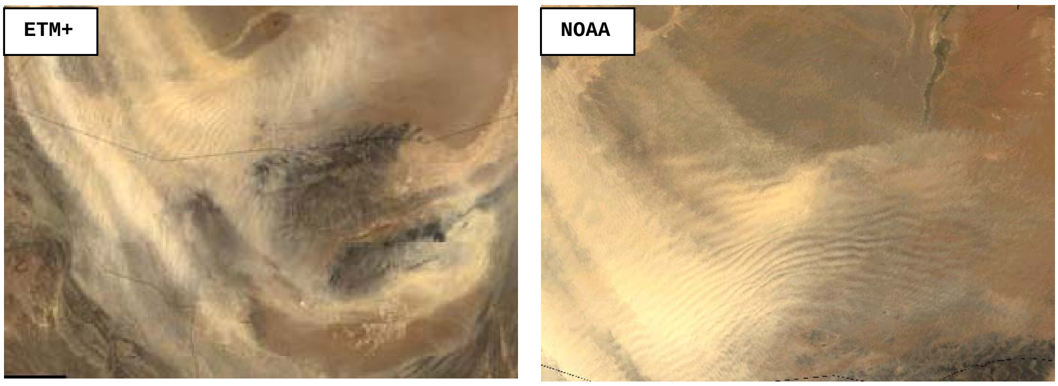

Fig. 14. Wind effect on formation of sand storms in Sistan region (AVHRR & ETM+ images)

2.9. Fog and Dust

As moisture get higher, amount of scatter of light goes higher. So, higher wavelengths pass moisture better than shorter wavelengths. Tiny particles of dust in dry and desert regions have a great effect on ecosystem. Therefore, many of researchers that deal with dust directly or indirectly face problems. The physical behavior of dust is different during night and day. In other words, the concentration of dust is a function of atmosphere stability (Goroch et al., 1980). In most dry regions, the earth's atmosphere is more stable at nights and less stable during the day. Atmospheric instability is more in summer days than in winter, but at night and in winter stability is higher (Zangavil et al., 1991). Dust also cause to increase atmospheric scattering of electromagnetic waves.

2.10. Imaging at night

Reflections of visible spectrum can be scanned merely during the day, but thermal data can be captured both at night and during the day. In some cases, thermal data of both day and night time are needed. For instance, one of the main usages of joint day and night thermal data is the study of urban regions temperature. Lo et al. (1997) using infrared thermal images with high spatial resolution assessed the temperature of several cities. They found out that during the day commercial part and after that transportation areas have the highest temperature. The lowest temperature belongs to regions with water, vegetation and farmlands (see Fig. 15). With these kinds of images, it is possible to recommend planting trees and increasing the vegetation of the cities in those special parts to decrease their temperature.

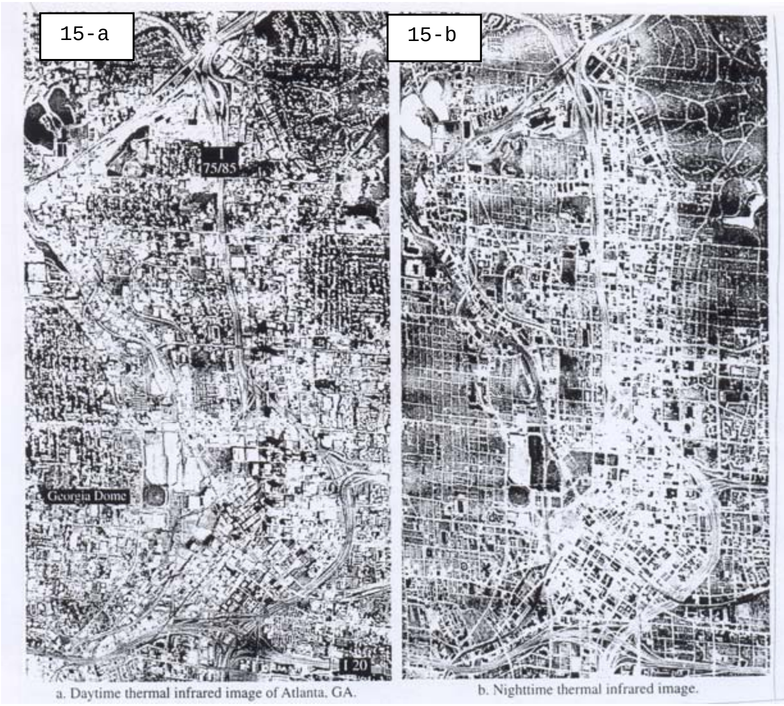

Fig. 15. Thermal IR (band 13, 9.6-10.2 μm), Atlanta city: (a) Day Thermal IR, (b) Night Thermal IR (Jensen, 2000)

By using Radar remote sensing, imaging is possible at night. Generally speaking, Radar is an active remote sensing system and in all weather conditions, during night and day and in cloudy and foggy weather can be used easily.

2.11. Examination of image repetition in proper times

Many studies are possible through compassion of the results of images in different times. Therefore, selecting suitable image or repetitive images at suitable time and season is very important. For instance, to investigate moisture stress in plants, they should be imaged at two states of blooming and fading, so that a clear pattern of these contrasting states be obtained. Therefore, repetition of images is crucial in this kind of studies. As another example, soil identification can be mentioned. To this end the best time for investigation is the time in which soils own the least vegetation and surface moisture. Because, these two factors are considered as the main intervening factors in spectral identification of soil. To identify the soils of dry regions of Kashan, ASTER, MSS, IRS, TM and ETM+ images were investigated. The results showed that the best time for soil identification is the dry season, i.e. from late Ordibehesht to late Mehr. Since in this period of time, green Vegetation and moisture which act as trouble factors are the least or non existent.

2.12. Topography

One of the factors that can affect the amount of correlation between bands is the local and positional topography which is mainly due to shadow effect. The shadow region has less radiance both in visible and thermal bands. In the early hours of the day the correlation between thermal and reflective bands is usually positive, not negative. Since, at this time variance in thermal and reflective images is related to shadow.

As shadow decreases, correlation tends toward negative (Ben Dor, 2004). Correlation coefficient between reflective and thermal images of a slope & shaded surface is assessed and shown in figure 16. Correlation coefficient increases immediately after sunrise and decreases quietly as it gets close to noon. Then Correlation increases in sunset. According to the results, topography plays an important role in correlation between reflective and thermal images.

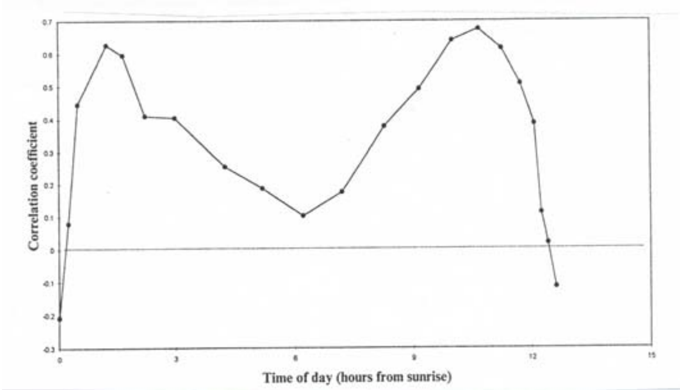

Fig. 16. Correlation between reflective & thermal images on desert surface

In some phenomena such as soil, topography is considered to be an important factor in formation and evolution of them. Therefore, by generating digital elevation map, it can be used as a helping layer to identify the phenomena under study which own a similar reflectance in different states.

2.13. Film or Digital formats

By considering the aims of project, image type (digital or film) should be designated. Some sensors such as Russian satellites of KATE & MKF record images on film. In these kinds of satellites having imaged, the film out of the satellite and gets analyzed on the earth. Now days the majority of satellites do imaging digitally, in spite of this for special thematic regions using analogue images printed on paper can be suitable.

2.13. Satellite data errors

Satellite raw data have numerous errors that should be investigated and disambiguated before usage. These data errors are (1) errors cause by platform, (2) errors caused by sensor and (3) errors caused by earth's rotation.

2.13.1 Technical fault of sensor

In selecting satellite data, operation of sensors and probably their technical fault should be taken into account. For instance, sometimes sensors detector get technical fault and as a result, there would be some lines among scanned lines with a brightness degree of zero, because the detector has not scanned it. Fig. 17 shows SWIR band of IRS sensor in Kashan with some out of order detector.

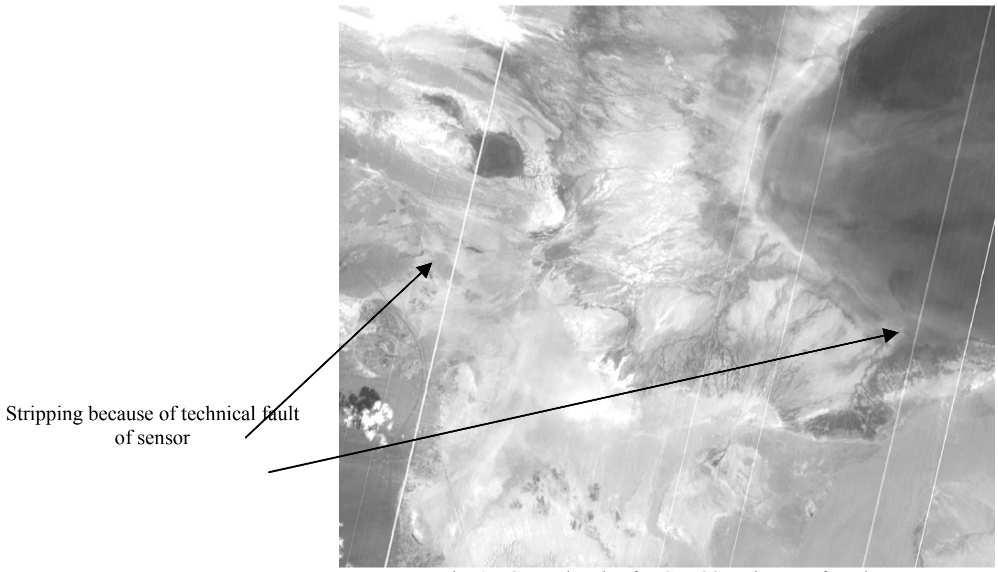

Fig. 17. SWIR bands of IRS LISS III image of Kashan

2.13.2. Unwanted Signs

Another problem about satellite data is accidental unwanted signs that are seen as unsystematic variances. Figure 18 shows the problem of accidental unwanted signs for 16 pixels in TM3 band of Ardakan region in Yazd province. To identify these unwanted signs, first all the pixels of TM3 & TM4 bands of Ardakan region were plotted. Then, they were identified on 2D axis and their brightness degree on bands 3 & 4 were determined. Having done all these, by using mask, their positions were located. Because of inefficiency of the landsat7 scan-line-corrector (SLC), then are some lacks of data in some parts of image.

In May 31 2002, landsat7 SLC was broke and stopped working. Stoppage of the system caused single scan lines alternatively overlapped and made a big gap in margins of the image. This fault and lost data reduce the level of Landsat efficiency and usefulness.

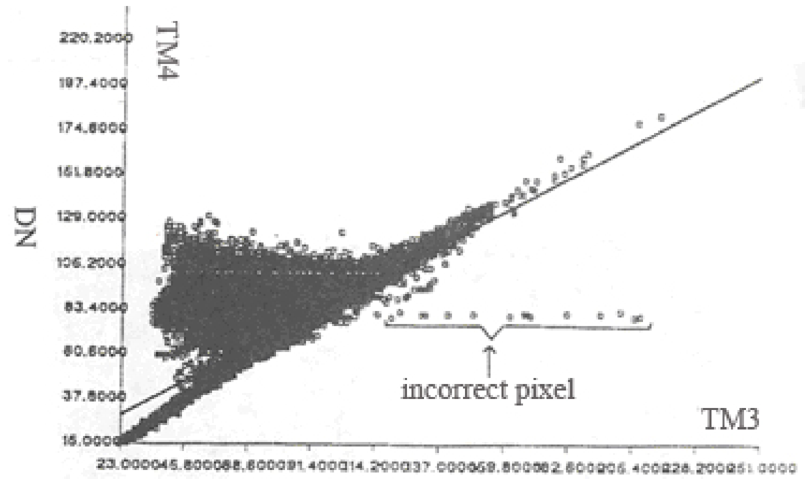

Fig. 18. 2D-graph of TM3 & TM4 data that determines unwanted signs

2.14. Temperature effect on thermal remote sensing studies

Numerous factors are involved in selecting an appropriate time or the time of acquiring thermal data. Knowing of Effect of periodic temperature variations is useful in interpretation of thermal images. This sort of data can be considered as a criterion for selecting thermal sensor and interpretation. Figure 19 shows the variations in periods of emitted heat of soil, rock, water, temperature scope and the speed of heating. Temperature variations usually present important information about type and the conditions of different phenomena. Twice a day, some materials such as soil, rock and water have similar emissive temperature. So it seems that the best time to capture the thermal infrared data is middle of the day, since at this time phenomena have the highest difference in radiation temperature. Therefore, in choosing the sensor type for acquiring the data, it should be kept in mind that at some hours e.g. 2 pm, it is also possible to distinguish the levels of some materials in the region. In other words, this can be a criterion for data selection at the satellite passage time.

The other capability of thermal remote sensing is the identification of buried traditional objects. Thermal multiband scanners can be caused to gain information about low depths. Windes (1991) used such scanners to identify the prehistoric road in New Mexico. In archeological studies, a combination of thermal and reflective hyper-spectral scanners is widely used (Bendor, 2001). Bianchi et al (1997) used MIVIS sensor with 102 band in VNIR-SWIR and 10 band in TIR region to generate traditional Sicily city map in 1500m altitude.

Therefore, for effective usage of thermal characteristics to identify expected phenomena, the following factors should be taken into account:
(1) Imaging time (diurnally & annually)
(2) Object depth
(3) Soil thermal characteristics and environmental conditions
(4) The relationship between soil and vegetation.

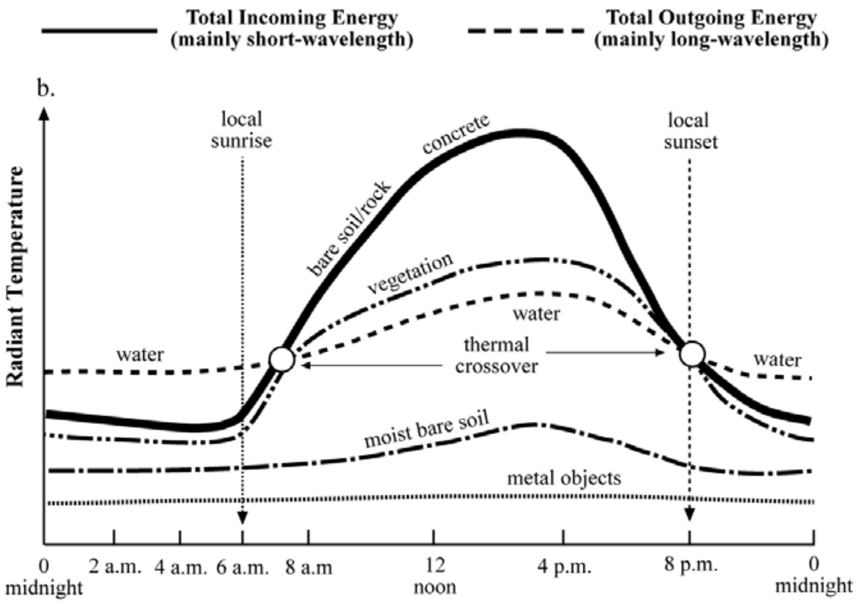

Fig. 19. Periodic Variations of emissive heat from different phenomena

2.15. The speed of access to satellite image

To study the phenomena which show a quick change, speed in acquiring the repeating images is important. So, acquaintances with different centers and websites in and out of the country and knowledge of data type and format they provide are crucial. In what follows a short list of some centers and sites is given. Images of some sensors can be acquired free in less than 1 hour[1] :

1) **NOAA**
http://www.noaa.gov/
http://www.saa.noaa.gov/

2) **SPOT**
http://www.spotimage.com/home/

3) **TERA**
http://eospso:gsfc.nasa.gov/
http://edcimswww.cr.usgs.gov/pub/imswelcome/

4) **LANDSAT MSS & TM**
http://geo.arc.nasa.gov/sge/landsat/landsat.html
http://edcsns17.cr.usgs.gov/EarthExplorer/

5) **LANDSAT7 ETM+**
http://www.landsat.org/

6) **IRS**
http:/www.nrsa.gov.in/

7) **GOES**
http://www.oso.noaa.gov/goes
http://www.goes.noaa.gov/

8) **IKONOS**
http://www.spaceimaging.com/products/ikonos/index_2.htm
http://www.spaceimaging.com/

3. Conclusion

The results of present study show that precision in applying image selection criteria has some advantages besides economizing on time and costs of land studies as for example:
1) Making maps in short time and economizing on time.
2) Making maps with better quality and less cost.
3) Making thematic maps needed by special users.
4) Facilitating the map making process and updating them.
5) Minimizing the use of printed maps and archive and maintenance costs.

Therefore, considering the increasing development of this technology and need of different sector's executives e.g. urban planners, of knowing population distribution, service centers, residential lands, and also natural

1 The time is taken to download an image from a site depends on the user computer's capabilities.

resources planners to know about distribution of forests, grasslands, mines, cultivable lands as well as plant spices, saline lands and desert areas, precision in choosing data regarding various capabilities and application of remote sensing technology for aforementioned executives become clear.

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http://www.digitalglob.com