

## Relationship Between the Landsat TM, MSS DATA and Soil Salinity

S. K. Alavi Panah<sup>1</sup> and R. Goossens<sup>2</sup>

### ABSTRACT

To use remote sensing data effectively, one must understand the spectral characteristics of the particular features under investigations. To study the relationship between soil salinity and soil reflectance, four MultiSpectral Scanners (MSS) and seven Thematic Mappers (TM bands) over the Ardakan playa located on the Central Iranian Desert margins were selected. In this study soil map, soil salinity observations, an interpolated soil salinity map and 13 images in all, including 7 TM, 4 MSS and 2 Normalised Difference Vegetation Indices (NDVI) images were used. After smoothing the imagery using a  $3 \times 3$  kernel, and delineating the bare soil from vegetated areas, the correlation coefficients between soil salinity (Electrical Conductivity) and related Digital Number (DN) values from TM and MSS bands on different soil types, such as gypsiferous and saline soils, were calculated. The results obtained demonstrate the trend of the correlation coefficients between soil salinity and the related DN values of MSS and TM bands. Based on the results obtained, we may conclude that the presence of gypsum in soil plays a significant role in lowering the correlation coefficients between soil salinity and surface reflectance -further studies are required to draw more general conclusions. From the results obtained we may also conclude that the behavior of band 6 of TM on gypsiferous soil is completely different from that on saline soil and, therefore, we may generally conclude that Landsat TM imagery with six reflective bands, on the one hand, and the TM thermal band as complementary information to the TM reflective bands, on the other hand, contained some useful information that may play an important role in soil salinity studies and also the detection of gypsiferous soils in desert areas.

**Keywords:** Gypsiferous soil, MSS bands, Soil salinity, Soil reflectance, TM bands.

### INTRODUCTION

Some studies have described the relative contribution of soil parameters such as soil mineralogy, organic matter, soil moisture, particle size distribution, soil structure, iron oxide and parent materials to the reflectance of naturally occurring soils (Montgomery, 1976 and Stoner, 1979). Seghal *et al.* (1988) applied Landsat MSS data for mapping salt affected soils in the frame of the reconnaissance soil map of India. Dwivedi (1992) used Landsat MSS and TM data for more detailed mapping and monitoring of the salt-affected soils in the Indo-Gangetic alluvial

plain, India. Goossens and De Dapper (1993) indicated the development of GIS and remote sensing for monitoring and prediction of soil salinity in the Nile Delta, Egypt. Goossens and Van Ranst (1996) have shown the possibility of detecting different soil types, especially gypsiferous soils, by the choice of thermal band. The use of remote sensing for soil studies can be advanced by a better understanding of the relationship between the soil properties, surface characteristics and surface reflectance. The variability of the soil surface conditions and changes in bare soil surface conditions complicate the reflectance of the soil. Although spectral signatures play a central role in detecting,

<sup>1</sup> Iran Desert Research Center, University of Tehran, Islamic Republic of Iran. Fax: 0098-21 655287.

<sup>2</sup> Department of Regional Geography and Landscape Study, University of Gent, Belgium.



identifying and analysing earth surface materials, the spectral world is full of ambiguity. Radically different materials can have great spectral.

similarity making their differentiation difficult. Experience has shown that many earth surface features of interest can be identified, mapped and studied on the basis of their spectral characteristics although some features of interest may not be spectrally separable. To use remote sensing data effectively, one must know and understand the spectral characteristics of the particular features under investigation. A better understanding of the behavior of different wavelength regions on different soil materials and surface conditions may increase the efficiency of the study of soil salinity and gypsiferous soil on the basis of remote sensing. A number of mineralogically significant bands occur in the thermal infrared portion of the electromagnetic spectrum and they have been used in the laboratory to study silicates, carbonates, sulphates, phosphates, oxide and hydroxide-bearing materials in great detail (Hunt and Salisbury, 1976). Many physical and chemical characteristics of mineral rocks and soils influence their spectral emissions in the infrared region. These include mineralogy, particle size, packing, moisture and organic content. The infrared spectra of materials that scatter light are more difficult to interpret than those of non-scattering substances because they are dependent upon particle size and packing as well as the optical properties of the materials (Hapke, 1981). Of the imagery from satellite-borne sensors, Landsat TM data have proved useful for mapping depositional environments on playas in Tunisia (Millington *et al.* 1989). Crowley (1993) found that minerals that occurred in association with surface water on Death Valley, California expressed absorption over a similar wavelength range. Consequently, gypsum and halite were likely to be the only evaporite phases detected and mapped on the Chott el Dyerid using TM data. Salt affected soils in arid regions, especially when a salt crust (whitish color) is formed, show a high re-

flectance. The soil structure, which is the result of chemical and physical properties of the soil, may alter the reflectance. The water content of soil causes a decrease in the soil reflectance through the visible and near infrared spectrum. Structural conditions of the soil surface have an influence on its reflectance. Some other investigations also show that soil salinity status is a complex phenomenon and therefore the variation in the reflectance spectra may not be attributed only to the single soil salinity properties. In fact, the spectra of soil surface are full of ambiguity.

### Study Area

To study the contribution of soil salinity to the surface reflectance recorded by Landsat MSS and TM satellite onboard sensors, the Ardakan area covering 23790 ha. and located in the Central Iranian Desert was selected. The area investigated is located between latitudes, 32° 5' - 32° 34' N and longitudes, 53° 45' - 54° 14' E. This area is situated in the Ardakan-Yazd watershed to the north of the city of Yazd and to the south of the Ardakan playa (Fig. 1). The study area has an elevation varying from 965 m a.s.l in the Ardakan playa to 1939 m a.s.l in the Harish mountains to the north-east. In general, the Ardakan area may be characterised by a wide range of soil surface characteristics, such as gravelly surfaces, desert crust, and partly puffy surfaces which influence the spectral response. The rainfall in the study area with an annual average of about 70 mm is confined to the period of October to May. The mean annual pan evaporation (potential evaporation) of the Ardakan area is about 2660 mm (Yazd Soil and Water Institute, 1992). Alavi Panah (1997) estimated the soil surface temperature of the climatic station of the study area at the time of Landsat overpass to be about 33.9°C. In most parts of the study area, considerable soil moisture is not available at soil surface and no wind at the soil surface was reported at the time of the Landsat overpass, therefore it

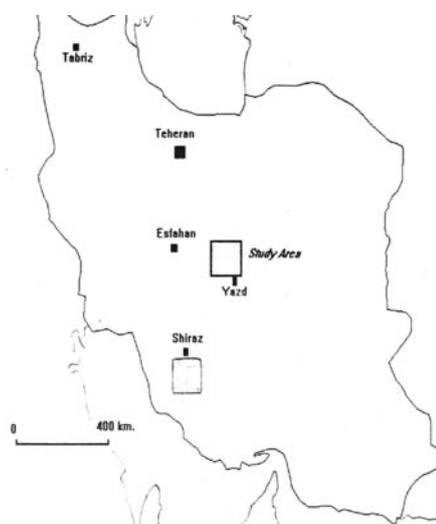


Figure 1: Location map of the study area.

seems that more of the radiation absorbed goes into heating the soil. The soil map of the Ardakan area shows the presence of the seven soil series (Yazd Soil and Water Institute, 1992). Based on the representative soil profiles, gypsiferous soils are mainly developed on the dissected plateau. They are very shallow with a light soil texture (sand), a platy surface structure and a massive subsoil structure. They usually contain more than 50% gypsum in the subsurface and sometimes the gypsum is on or very close to the surface. The gravel cover at the soil surface usually exceeds 35% (sometimes <15-35%) volume, and varies between 35-75% of the subsoil. The soils have a very low organic matter content (<0.1%). The purpose of this study has been to understand: a) the behavior of TM and MSS bands recorded by two different dates on the gypsiferous and non-gypsiferous soils, and b) the behavior of TM and MSS reflective bands on different soil surface conditions. Therefore, the relationship between DN values and soil salinity on different soil surface conditions was statistically examined through establishing the correlation coefficients between the DN values of the TM and MSS bands and soil salinity values.

## MATERIALS AND METHODS

Four MSS and seven TM bands, collected on 14/09/1975 and 11/09/1990 respectively, over the Ardakan area were selected for this study. These images were chosen, because late summer represents the most suitable time for direct soil investigation, especially soil salinity study, owing to maximum evaporation and enhancement of salinity problems, a clear sky and the absence of rainfall for a sufficient number of weeks before satellite overpass producing a dry enough soil surface. For this study, the available soil salinity data related to the non-cultivated area with almost stable surface conditions were used for further analysis. The soil salinity of the Ardakan area was measured in September 1983 by the Yazd Soil and Water Institute, which is in the middle time of the period between the two Landsat satellite MSS and TM overpasses dated September 1975 and September 1990 respectively. It means that the soil salinity is mapped with eight year intervals in the Landsat overpasses over the study area. To study the differences in the spectral behavior of the gypsiferous and saline soils, an attempt was made to calculate the correlation coefficients between the DN values of seven TM and four MSS bands as follows:

1) In order to discover the relationship between the soil salinity and DN values for the total pixels of the bare soil, an attempt was made to interpolate the soil salinity data. In order to interpolate the available soil salinity data, the 201 soil salinity observations (dS/m) at the topsoil (0-50 cm) derived from the soil salinity map were digitized and then rasterized. The rasterized map was then interpolated using the "From Isoline Option" in ILWIS software (version 1.4) which performs a linear interpolation based on the values of soil salinity at soil surface (Alavi Panah, 2000). In identifying the relationship between the interpolated soil salinity map and DN values all the interpolated pixels of the study area were used.



2) In total, 13 images including 7 TM, 4 MSS and 2 NDVI imagery were georeferenced toward the Universal Transverse Mercator (UTM) co-ordinate system. The TM and related NDVI were resampled to 30\*30 m pixel size and the MSS and related NDVI resampled to 80\*80 m pixel size. Resampling was performed using the nearest neighbor approach.

3) To reduce the effects of possible error in the geographic locations of the soil salinity sampling points, all the images were smoothed by a 3\*3 kernel.

4) The TM based NDVI was used as an indicator of vegetation cover to separate bare soil from vegetation cover in 1990 and the MSS based NDVI was taken to separate bare soil from vegetation cover in 1975.

5) Due to the influence of vegetation on the relationship between the soil salinity and reflectance, soil salinity observations located in the areas of vegetation cover were neglected

6) The digitised soil salinity points (observations) were overlaid with 13 TM and MSS

bands and then the DN values of the 13 smoothed images (3\*3 kernel) corresponding to the soil salinity observations were identified.

7) To study the differences in the spectral characteristics of saline soils and gypsiferous soils, the soil salinity observations were regrouped based on soil types (soil salinity and gypsiferous soil) which were delineated on soil and soil salinity maps as follows:

- 1- Gr: gypsiferous soil with a gravelly surface.
- 2- TA: total area including non saline, saline and gypsiferous soils.
- 3- TA-Gr non gypsiferous soil (saline and non saline soil).
- 4- TA-S0Gr: non gypsiferous soil with salinity condition.
- 5-Int: Interpolated soil salinity map.

8) In order to select more appropriate salinity observations, the bare soil and playa surface with stabilized conditions were carefully considered. Different maps and information for more local knowledge of the study area, such as a wind erosion sensitivity

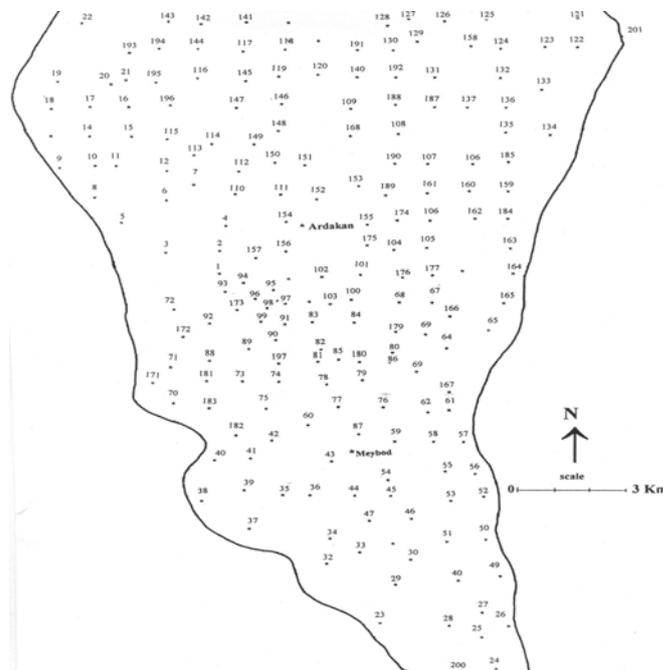


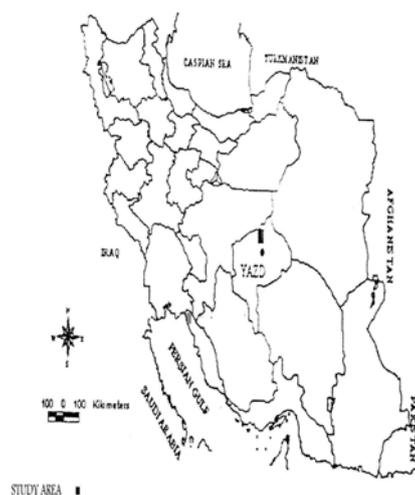
Figure 2. Soil salinity sampling sites.

map (1/250000), were therefore used. The 201 soil salinity observations (dS/m) (Fig. 2) show the mean of 18.97, a minimum of 0.21 dS/m and a maximum of 70.0 dS/m. The non saline soil class (S0) with 94 observations shows a mean of 7.72 and a very severe saline soil class (S4) with the mean of 35.13 that shows the range of EC from a minimum of 5 to a maximum of 70 dS/m. The numbers of salinity observations which fall in each of the four regrouped classes were identified and used for further analysis (Table 1);

9) Eventually, the correlation coefficients between the EC (dS/m) and DN values were calculated using the STATGRAPH program and the behavior of TM and MSS wavebands on different soil conditions were studied finally.

### RESULTS AND DISCUSSION

The results obtained showed that the thresholds of NDVI>93 and NDVI>60 from the TM-and MSS- based NDVIs are the lowest critical values for separating vegetation from bare soil. The lowest critical value was used, because even poor vegetation can influence the spectral response (Alavi Panah, 1997). Reclassification of TM- and MSS- based NDVIs showed that in 161 and 163 of the soil salinity observations the vegetation cover is absent. These observations were used for further analysis. Results



**Figure 3.** The scatter diagram for the TM3 DN whit a) the total soil salinity observation of bare land and b) the very severe saline soil observations.

of the correlation between the soil salinity data and the DN values of TM and MSS bands are shown in Table 1. In order to have a general understanding of the relationship between the Electrical Conductivity (EC) and DN values of TM warvebands, their scatterplots were evaluated (Fig. 3).

Figure 3 shows the scatter diagram of the EC over the DN of TM band 3 for 161 (TA) and 42 (TA-S0Gr) soil salinity observations respectively. Comparison between these two scatter plots indicates that when the

**Table 1.** Correlation coefficients between the soil salinity and DN values of the TM and MSS bands on different soil salinity groups in the Ardakan area.

| Soil Group | n1  | TM data |         |         |         |         |         |         | n2  | MSS data |         |         |         |
|------------|-----|---------|---------|---------|---------|---------|---------|---------|-----|----------|---------|---------|---------|
|            |     | Band 1  | Band 2  | Band 3  | Band 4  | Band 5  | Band 6  | Band 7  |     | Band 1   | Band 2  | Band 3  | Band 4  |
| Gr         | 43  | 0.014   | -0.031  | -0.045  | -0.155  | -0.047  | 0.387** | 0.014   | 39  | -0.110   | -0.119  | -0.099  | -0.104  |
| TA         | 161 | 0.367** | 0.275** | 0.230** | 0.102   | 0.203** | 0.148   | 0.176*  | 163 | 0.250**  | 0.131   | 0.062   | 0.000   |
| TA-Gr      | 118 | 0.400** | 0.342** | 0.325** | 0.306** | 0.284** | 0.009   | 0.340** | 124 | 0.440**  | 0.349** | 0.322** | 0.288** |
| TA-S0Gr    | 42  | 0.514** | 0.480** | 0.490** | 0.427** | 0.368*  | -0.039  | 0.466** | 55  | 0.539**  | 0.524** | 0.479** | 0.456** |
| Int.       | -   | 0.349   | 0.302   | 0.271   | 0.115   | 0.284   | 0.373   | 0.304   | -   | 0.265    | 0.186   | 0.098   | 0.023   |

\*\* = Significant at 1% level; \* = Significant at 5% level. n1 = Number of soil salinity observation in TM bands, n2 = Number of salinity observation in MSS bands, Int = Interpolated soil salinity map.

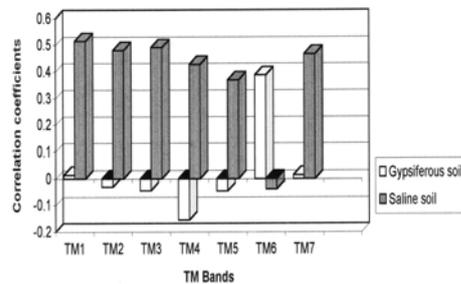


gypsiferous soils (Gr) and non saline soils (S0) are neglected, the relationship between EC and DN increased remarkably. The reason why points are not distributed regularly along the fitted line can be attributed to the fact that soil surface reflectance can not be attributed to a single soil property of salinity. Results of the correlation coefficients between the EC and DN values of TM and MSS bands can be summarised as follows:

#### Behavior of the TM Bands on Gypsiferous Soils

Table 1 shows that in the Gr class (gypsiferous soils where gypsums are mainly occurred on or close to the surface) no significant correlation between the soil salinity and DN values of the TM reflective bands was found, while a significant correlation coefficient ( $r = 0.387$ ) at 1% level with the TM thermal band was found. Figure 4 shows the variation of the correlation coefficients plotted over the TM wavebands. This figure shows the behavior of the TM thermal band on the gypsiferous soils which is completely different from the saline soils. It means that, as the correlation between soil salinity and TM reflective bands increases, the correlation between soil salinity and the TM thermal band decreases. For example, the highest significant correlation coefficients (0.514, 0.480, 0.490, 0.427, 0.368, 0.466) between the TM reflective bands and soil salinity were obtained for the TA-S0Gr, while no significant correlation (-0.039) between the TM thermal and soil salinity was obtained for gypsiferous soils. On the other hand, the highest significant correlation (0.387) was obtained for gypsiferous soils and no significant correlation coefficient (-0.014, -0.031, -0.045, -0.155, -0.047, 0.014) was found between soil salinity and DN values of the TM reflective bands.

A completely different behavior of the TM thermal band on gypsiferous soils from the behavior of TM reflective bands suggests that valuable information about gypsiferous soils could be found in the TM thermal band



**Figure 4.** Plot of the correlation coefficients between soil salinity and DN values over TM bands of the ardakan area.

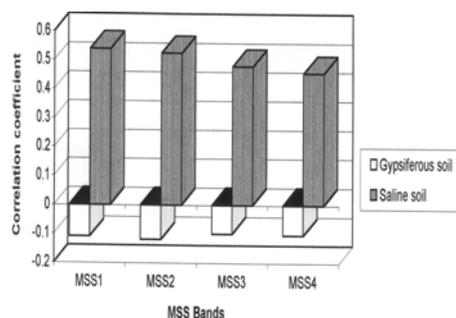
which could not be found in the TM reflective bands. It seems that more information about the occurrence of gypsum in the exact depth of soil may be useful for establishing a more meaningful relationship between EC and DN values. The results obtained from the different behaviors of the TM thermal and TM reflective bands on the saline and gypsiferous soils suggests that the information content of the two different TM thermal and TM reflective bands can be complementary to each other on saline and gypsiferous soils. This result also confirmed the result obtained by Goossens and Van Ranst (1996) and Goossens *et al.* (1999). They reported the key role of the TM thermal band in separating gypsiferous from saline soils. Based on the results obtained, we may conclude that the reflectance of the saline soil with gypsum not only depends on the type of the materials and surface conditions of the saline and gypsiferous soils, but also on the wavelength. The obtained results suggest that two types of saline soils (gypsiferous and non gypsiferous soil) may be distinguished by including the TM thermal band in addition to other six reflective bands.

#### Differences in the Behavior of the TM Reflective Bands on Saline Soils

The results obtained from the correlation coefficients between the soil salinity and DN values of the TM reflective bands in the four classes are shown in Table 1. It should be

noted that by using two different remotely sensed data, in this study some important problems, such as differences in spatial, spectral and radiometric resolutions must be taken into consideration. Result from the correlation coefficients between the soil salinity and DN values can be summarised as follows:

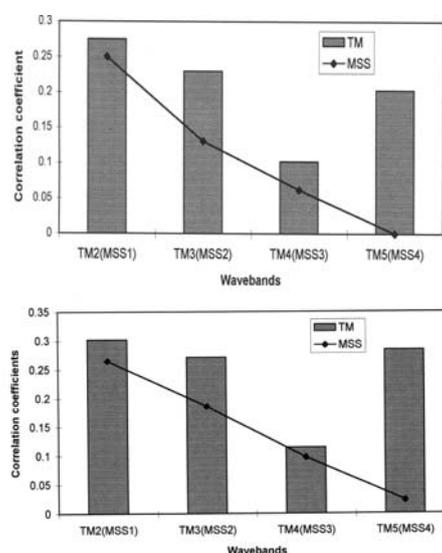
i) Table 1 shows a significant correlation between soil salinity observations and TM bands 1, 2, 3, 5 and 7 on the total area (TA) class while no significant correlation was found between soil salinity and TM bands 4 and 6. Interestingly, when the Gr class (gypsiferous soils) is neglected, not only a significant correlation between TM band 4 and soil salinity appears, but also the other corre-



**Figure 5.** Plot of the correlation coefficients between the soil salinity and DN values over MSS bands.

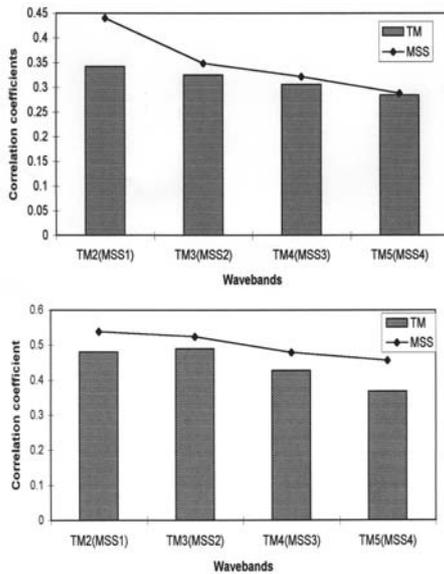
lation coefficients are also improved (Fig. 3). The results obtained from MSS data also show the same trend. It means that when gypsiferous soils are neglected, not only a significant correlation between MSS band 2, 3, and 4 is shown, but also the correlation of MSS band 1 and soil salinity is improved (Table 1). An inspection of Figures 4 and 5 reveals the trend of the correlation coefficients over the TM and MSS bands respectively.

Figure 6 shows the graph of correlation coefficients between the TM and MSS DN values with: a) soil salinity data (total area), and b) soil salinity interpolated map. Comparison between these two graphs indicates first that the behavior of soil salinity data



**Figure 6.** Graph of the correlation coefficients between the TM and MSS DN values with a) soil salinity data (total area) and b) soil salinity interpolated map.

and interpolated maps are the same and, second the trend of correlation coefficients from the green to near infrared band in the total area (TA) and Interpolated map (Int.) shows a decreasing rate and they are highly comparable. Figures 5a and b show that the trend of the correlation coefficients from the green to near infrared band in the non gypsiferous soil (TA-Gr) and non-gypsiferous saline soil (TA-GrSO) classes is also highly comparable. These results indicate the effect of gypsiferous soils on the surface reflectance. Non-significant correlations between the TM and MSS reflective bands and soil salinity on gypsiferous soils (Fig. 8) indicate the effect of gypsiferous soils on the surface reflectance scattering. Based on the result obtained (Table 1) a significant correlation was found in the relationship between soil salinity and TM thermal data ( $r = 0.387$ ). This effect can be attributed to surface temperature differences. We conclude that TM thermal band may have an important role to play in soil salinity studies of desert areas. The gypsiferous soils in the Ardakan area are usually covered by surface gravel and,



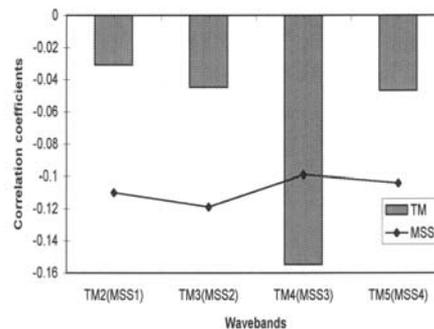
**Figure 7.** The graph of the correlation coefficients between the TM and MSS DN values with a) non-gypsiferous soil data (total area), and b) non-gypsiferous saline soil data.

on the other hand, the gypsum horizon occurs in the sub surface and/or very close to the surface. The curve AT-S0Gr shows that when non saline soil and gypsiferous soils are ignored, the correlation coefficients improved remarkably. The highest correlation between salinity and DN values in both MSS and TM bands was found for the TA-S0Gr class. It may be attributed to the effects of a) gypsiferous soil, and b) non saline soil conditions on lowering the correlation coefficients. The reason for improvement of the correlation coefficients may be summarised as a) the effect of the desert crust and eroded soil which mainly occurred in non-saline soils and decreased the correlation coefficients, and b) the effect of gravel and gypsum which effect the surface reflection and emission. The desert crust and eroded soils which mainly occurred in non-saline soil show very high reflection. The effect of gypsiferous soils on the correlation coefficients results may be attributed to the gypsum properties and/or gravelly surface which can hinder the soil reflectance.

ii) The highest correlation coefficients

were found between soil salinity data and visible bands (especially TM blue band) and the lowest correlation was found for the infrared band (Fig. 4). For example, TM bands 1 and 2 are correlated with soil salinity ( $r = 0.367$  and  $0.275$  respectively) at the 1% significant level, while a non significant correlation ( $r = 0.102$ ) was obtained for TM band 4. The trend of correlation coefficients for TM bands shows a decreasing rate from the visible to near infrared bands. Nevertheless, the TM blue band indicates a high peak which may be caused by the light scattering. The same trend was found for MSS data in non-gypsiferous soil (TA-Gr class). Figure 6 shows the graph of the correlation coefficients between the TM and MSS DN values with soil salinity data and an interpolated map that describes the decreasing rate of correlation from visible bands to the infrared band. This is not well known, but may be attributed to the effect of soil moisture on the reflectance. Because saline soils with a low moisture content have a high reflectance, values in visible bands (especially TM blue bands) and low reflectance occur in near infrared bands (Metternicht and Zinck, 1995). Metternicht and Zinck (1995) attributed the reason for high reflectance in the visible band (especially the blue band) and low reflectance in near infrared to the hygroscopic water in salt minerals or high moisture content.

iii) In general, a low or sometimes non significant correlation between saline soil,



**Figure 8.** Graph showing the correlation coefficients between the TM and MSS DN values with gypsiferous saline soil data.

TM and MSS reflectance may be due to the following different reasons.

a) salinity status is a complex phenomenon, therefore variation in the reflectance spectra of soils can not be attributed to a single soil property such as soil salinity. Key soil properties, such as pH, salt content and ESP, determine the salinity status of soils, and this is reflected in the spectra of surface samples interacting with organic matter content, clay content etc. The study area comprises mineral soils with a wide range of surface characteristics.

In this way, soil reflectance is affected by a complex combination of mineral, organic matter, particle size distribution, parent materials etc. Although there are numerous remote sensing studies concerned with salt affected soils (Szilágyi and Baumgardner, 1991), there have not been any that introduced narrow absorption bands linked to salinity status.

b) Some changes in soil salinity values in the period 1975-1990. Soil salinity is a phenomenon which may vary in time, especially in areas affected by erosion, irrigation, drainage status and human impact.

c) Variation in soil salinity distribution within the top layer (0-50 cm). The available soil salinity data are based on the weight average of 0-50 cm, while the soluble salts are usually accumulated in the uppermost horizon (usually less than 20 cm). Therefore a soil salinity of 0-50 cm, especially at slight and or moderate salinity levels, may not be a good indicator for the top surface. In other words, the soil salinity profile can not be evaluated on remotely sensed imagery but, as Agbu *et al.* (1990) state although satellite sensors observe only the ground surface both surface and subsurface conditions are affected conceptually by common genetic factors.

### CONCLUSION

Based on the low correlation obtained between the soil salinity and the TM and MSS DN values, we may generally conclude that surface reflectance is full of ambiguity, and

some soil surface conditions such as gravelly and crusted surfaces may hinder the reflectance of soils. Although the spatial, spectral and radiometric resolution of the two Landsat satellite MSS and TM onboard sensors are different, this study revealed that the behavior of the MSS and TM wavebands on surface soil salinity conditions are almost the same. We may also conclude that, in spite of great differences between MSS and TM imagery in terms of spectral and spatial resolution, both might be useful for detection of soil salinity change. Since the trend in the relationship between TM and MSS DN values with soil salinity on different soil groups are much comparable. Based on the correlation obtained between the soil salinity and TM and MSS DN values, we may generally conclude that thermal band of Landsat TM imagery provided some useful information that may have an important role in soil salinity studies and also in detecting gypsumiferous soils in desert areas. This effect can be attributed to surface temperature differences.

### ACKNOWLEDGMENTS

The author thanks the Vice Chancellor for Research, University of Tehran. Since this research was supported in part by a grant from the University of Tehran.

### REFERENCES

1. Agbu, P.A., Fehrenbacher, D.J., and Jensen. I.J. 1990. Soil Property Relationships with Spot Satellite Digital Data in East Central Illinois. *Soil Sci. Soc. Amer. J.*, **54**: 807-812.
2. Alavi Panah, S.K. 1997. Study of Soil Salinity in the Ardakan Area (Iran) Based Upon Field Observations, Remote Sensing and a GIS. p. 292. Gent: University of Gent (Ph. D. thesis).
3. Alavi Panah, S.K. 2000. Study and Evaluation of Soil Salinity Surveying Map. *Journal of BIABAN.*, **5(1)**: 1-14
4. Crowley, J.K. 1993. Mapping Playa Evaporite Minerals with AVIRIS Data: A



- First Report from Death Valley, California. *Remote Sen. Environ.*, **44**: 337-356.
5. Dwivedi, R. S. 1992. Monitoring and the Study of the Effect of Image Scale on Delineation of Salt Affected Soils in the Indo-Gangetic Plains. *Int. Remote Sen.*, **13**: 1527-1536.
  6. Goossens, R., and Van Ranst, E. 1996. The Use of Remote Sensing and GIS to Detect Gypsiferous Soils in the Ismailia Province (Egypt), *Proceeding of the International Symposium on Soils with Gypsum*. Lleida, 15-21, September, 1996. Catalonia, Spain.
  7. Goossens, R., Alavi Panah, S.K., De Dapper, M., and Ouns Kissyar. [initials] 1999 The Use of Thermal Band of Landsat TM for the Study of Soil Salinity Applied in Iran (Ardakan area) and Egypt (Ismailia Province). *Proceedings of International Symposium on Geoinformatics for Natural Resources Assessment, Monitoring and Management* (In press).
  8. Hapke, B. 1981. Bidirectional Reflectance Spectroscopy, 1, Theory, *J. Geophys. Res.*, **86**: 3039-3054.
  9. Hunt, G.R., and Salisbury, J.W. 1976. Mid-infrared Spectral Behavior of Metamorphic Rocks. *Environmental Research Paper* 543-AFCRL-TR 76-0003, Hanscom Air Force Base, Air Force Cambridge Research Laboratories, U.S.A.
  10. Lillesand, T.M., and Kiefer, R. W. 1994. *Remote Sensing and Image Interpretation*, (4th edition), New York, John Wiley and Sons.
  11. Metternicht, G., and Zinck, J.A. 1995. Spatial Discrimination of Salt and Sodium Affected Soil Surfaces. *Proceeding of the 2nd Annual Conference of the Remote Sensing Society*, 11-14 September, 1995. University of Southampton, USA, 1041-1049.
  12. Montgomery, O. L. 1976. An Investigation of the Relationship Between the Spectral Reflectance and the Chemical, Physical and Genetic Characteristics of Soil, Ph.D. Dissertation, Purdue Univ., West Lafayette, IN. Univ. Microfilm. Ann Arbor, MI (*Diss. Abster.* 37/08/-8: 3707).
  13. Millington, A.C. et al. 1989. Monitoring Salt Playa Dynamics Using Thematic Mapper Data. *I.E.E.E. Trans. Geosci. Remote Sens.*, **27**: 745-761.
  14. Seghal, J.L., Saxena, R.K., and Verma, K.S. 1988. Soil Resource Inventory of India Using Image Interpretation Techniques, Remote Sensing Is a Tool for Soil Scientists, *Proceeding of the 5th Symposium of the Working Group Remote Sensing ISSS*, Budapest, Hungary, 17-31.
  15. Stoner, E.R. 1979. Atlas of Soil Reflectance Properties. *Agric. Exp. Stn. Res. Bull.*, **962**. Purdue Univ., West Lafayette, IN.
  16. Szilágyi, A., and Baumgardner, M.F., 1991. Salinity and Spectral Reflectance of Soil, In *Proc. Am. Soc. Photogram. Remote Sens. Symposium*, Baltimore, 25-29 March 1991, ASPRS, Baltimore.
  17. Verma, K. S., and et al. 1994. Remote Sensing Technique for Mapping Salt Affected Soils. *Int. J. Remote Sens.*, **15(9)**: 1901-1914.
  18. Yazd Soil and Water Institute. 1983. Soil and Salinity Map and Data, Yazd, Iran.

### رابطه داده‌های سنجنده‌های لندست TM و MSS و شوری خاک

س. ک. علوی پناه و ر. گوسنز

#### چکیده

به منظور استفاده موثر از داده‌های سنجنش از دور (در مطالعات شوری خاک) لازم است که مشخصات طیفی انواع خاکها مورد مطالعه به خوبی درک شود. جهت تعیین رابطه بین شوری خاک و بازتابهای سطحی به ترتیب ۴ و ۷ باند ماهواره لندست MSS و TM منطقه اردکان یزد واقع در بخش مرکزی

کویرهای ایران انتخاب گردید. در این تحقیق از نقشه خاک، مشاهدات شوری خاک، نقشه شوری درون‌یابی شده و مجموعاً ۱۳ تصویر شامل ۷ باند TM، ۴ باند MSS و ۲ باند NDVI استفاده گردید. بعد از اجرای فیلترهای پایین‌گذر در اندازه ۳×۳ جداسازی خاکهای لخت از پوشش گیاهی، رابطه شوری خاک (هدایت الکتریکی)، DN های TM و MSS خاکهای مختلف مانند خاکهای شور و همچنین خاکهای گچی محاسبه گردید. نتایج حاصل از این تحقیق روند تغییرات ضرایب همبستگی بین شوری خاک و DN باندهای MSS و TM را نشان داد و همچنین نتایج حاصل نشان داد که خاکهای گچی نقش خاصی در پایین آوردن همبستگی بین DN و EC دارند که برای نیل نتیجه جامع مطالعات بیشتری نیاز می‌باشد. براساس نتایج بدست آمده نقش باند ۶ سنجنده TM در خاکهای گچی کاملاً متفاوت از خاکهای شوری می‌باشد. بر همین اساس می‌توان چنین نتیجه‌گیری نمود که تصاویر TM با ۶ باند انعکاسی از یکطرف و باندهای حرارتی از طرف دیگر بعنوان مکمل همدیگر دارای اطلاعات مفیدی هستند که می‌تواند نقش مهمی در مطالعات خاکهای شور و تشخیص خاکهای گچی از خاکهای شور در مناطق بیابانی داشته باشد.