# The Use of Remote Sensing and GIS to Detect Salt Crust in the Iranian Deserts

**S.K.Alavi Panah ***

* Iran Desert Research Center, University of Tehran, Iran
Salavipa @ chamran. ac. ut. ir

## Introduction

The presence of surface crust is an obvious phenomenon seems indicative of soil degradation ( Stoops, 1984 ). The desert crusts in Iran are mainly situated in the salt lakes of the playas. Goudharzi ( 1970 ) showed that playa are the site of chloride, sulfate, nitrate and borate. Some studies showed the predominance of salt crust and salt flat zone in the Iranian playas. All the Iranian playas with different surface characteristics exist in areas where the annual evaporation is considerably greater than annual precipitation. With evaporation of water from the flooded playa, salt concentration increases until crystals of salts begin to be precipitated at its saturation point. The following types of crusts have been recognized in the Iranian deserts:

a) desert crust or soil crust with a bright surfaces that are usually up to 3 to 5 mm thick,

b) Salt crust is as a result of evaporation from shallow water table.

Alavi panah S.K. et al, 1999 reported that the desert crusts are characterized by a very high reflection and the more the desert crust is destroyed, the more the reflection of the original material will dominate the overall reflection and mainly this correspond with a lower reflection. The salt lakes as a source of non- metallic materials have not received much attention. The main reason may be attributed to the limitations of trafficability and harsh climate. The current study is concerned with salt crust types and the capability of remotely sensed data ( Landsat TM data ) for delineating of salt crust from desert crust. Because the capability of Landsat TM data for detection of the salt crust diversity and purity is not well known, we attempted to use the remotely sensed data from Landsat TM on Qom and Ardakan salt zones .

## Materials and Methods :

Landsat satellite images and other ancillary data are used for the study of salt crust in the Ardakan and Qom salt lakes. The 7 TM bands dated from September 1991, have been used for this study. To study the information content of TM band on the two studied areas, the following attempts were made ( Figure 1 ) :

1- Any unwanted disturbance in image data that is due to limitation in sensing, signal digitization, or data missing were studied and noisy pixels were masked for further analysis,

2- The initial statistics and histograms were extracted for evaluation of information content of TM bands finding pixels with particular Digital Numbers (DN) assessing the radiometric quality of the images and also peaks and valleys correspond with types of crusts. In this study, the Principal Component Analysis ( PCA ) is performed based on correlation matrix,

3- The TM FCC,S and Photomorphic Unit Analysis ( PMUA ) and ancillary data were used to improve the image interpretation in a visual way. The collection of field data and use of accurate field observations were assisted in validity of the image analysis and selection of training areas,

4- The validity of the training data is evaluated both from visual examination and from quantitative characterization. Therefore, in this study, the spectral signatures for salt crust types were evaluated by two dimensional feature space ( FS ) and statistics. The spectral signatures of the training samples was evaluated by using 7 TM bands.

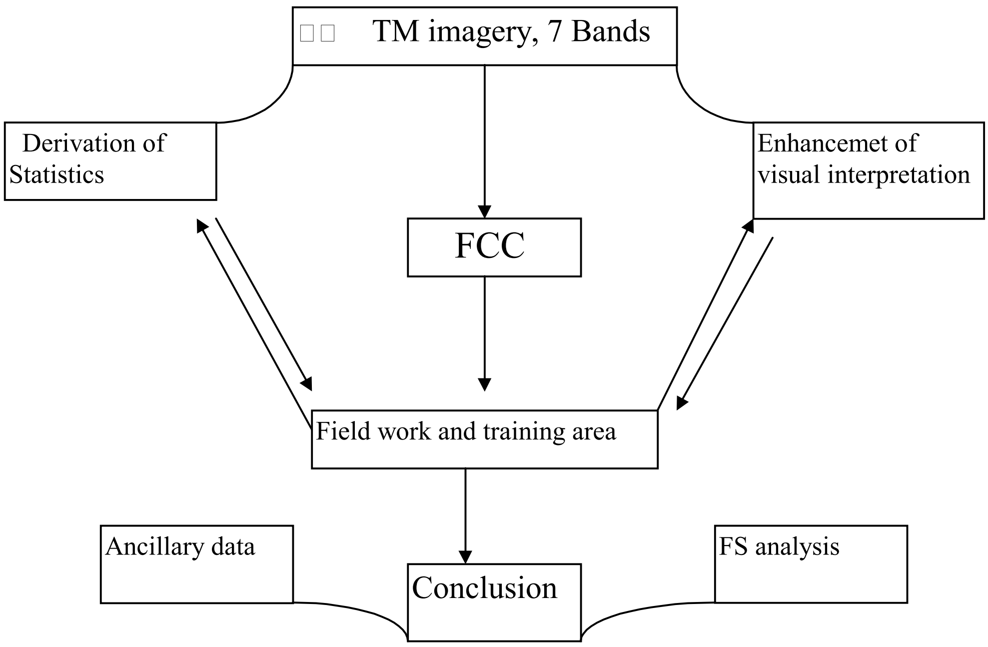


Figure 1, Flowchart indicates the mothodoloy of the research

## Result and discussions

The result of tabulating frequencies of brightness values ( DN ) within the TM band 1 shows that values of 255 correspond with salt crusts, eroded soil and desert crusts. The Desert crust areas are mainly non saline soil with bare soil surface conditions with a few millimeters thick and usually a bright surface. These areas located almost near the Qom and Ardakan playas. Table 1 indicates the histogram of the crusted surface including salt crust and desert crust. This table reveals that TM band 1 with DN values of 255 correspond with a relatively wide range of other TM bands. For example, TM band 5 exhibits the minimum of 26 and maximum of 248 and TM band 7 with minimum of 9 and maximum of 157. Table 2 shows the histogram of the salt crust area in the Qom playa. Comparison between the range of DN values of TM bands, 2,3,4,5,6,7 in table 1 and 2 indicates that a narrow range of DN for the area including salt crust. Due to the fact that color and thickness of the desert crusts vary from area to area, therefore the range of DN values for desert crust is relatively wide. Table 2 shows the histograms of seven TM bands of the Qom playa.

Table 1. Histograms of seven TM bands of the Qom playa.

| TM1 | | TM2 | | TM3 | | TM4 | | TM5 | | TM6 | | TM7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DN | % | DN | % | DN | % | DN | % | DN | % | DN | % | DN | % |
| 255 | 0.0 | 104 | 0.0 | 151 | 0.0 | 120 | 0.0 | 26 | 0.0 | 143 | 0.0 | 9 | 0.0 |
| 255 | 1.0 | 127 | 0.1 | 158 | 1.0 | 127 | 1.0 | 28 | 1.0 | 143 | 1.0 | 12 | 1.0 |
| 255 | 0.5 | 130 | 0.5 | 163 | 0.5 | 130 | 0.5 | 31 | 0.5 | 144 | 0.5 | 13 | 0.5 |
| 255 | 1 | 132 | 1 | 166 | 1 | 133 | 1 | 32 | 1 | 144 | 1 | 14 | 1 |
| 255 | 2 | 135 | 2 | 170 | 2 | 135 | 2 | 34 | 2 | 144 | 2 | 15 | 2 |
| 255 | 5 | 143 | 5 | 179 | 5 | 141 | 5 | 38 | 5 | 152 | 5 | 32 | 5 |
| 255 | 95 | 188 | 95 | 237 | 95 | 191 | 95 | 96 | 95 | 153 | 95 | 34 | 95 |
| 255 | 98 | 191 | 98 | 240 | 98 | 192 | 98 | 99 | 98 | 155 | 98 | 35 | 98 |
| 255 | 99.5 | 193 | 99 | 242 | 99 | 193 | 99 | 100 | 99 | 156 | 99 | 36 | 99 |
| 255 | 99.5 | 196 | 99.5 | 246 | 99.5 | 194 | 99.5 | 103 | 99.5 | 157 | 99.5 | 42 | 99.5 |
| 255 | 99.9 | 202 | 99.9 | 252 | 99.9 | 196 | 99.9 | 119 | 99.9 | 159 | 99.9 | 156 | 99.9 |
| 255 | 100 | 209 | 100 | 255 | 100 | 203 | 100 | 248 | 100 | 173 | 100 | 157 | 100 |

Table 2. Histograms of seven TM bands of the Qom salt crust.

| TM1 | | TM2 | | TM3 | | TM4 | | TM5 | | TM6 | | TM7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DN | % | DN | % | DN | % | DN | % | DN | % | DN | % | DN | % |
| 80 | 0.0 | 31 | 0.0 | 28 | 0.0 | 21 | 0.0 | 26 | 0.0 | 76 | 0.0 | 9 | 0.0 |
| 94 | 1.0 | 43 | 0.1 | 46 | 1.0 | 44 | 1.0 | 33 | 1.0 | 133 | 1.0 | 14 | 1.0 |
| 103 | 0.5 | 47 | 0.5 | 57 | 0.5 | 49 | 0.5 | 42 | 0.5 | 139 | 0.5 | 16 | 0.5 |
| 106 | 1 | 49 | 1 | 61 | 1 | 51 | 1 | 49 | 1 | 143 | 1 | 18 | 1 |
| 109 | 2 | 51 | 2 | 64 | 2 | 53 | 2 | 59 | 2 | 145 | 2 | 20 | 2 |
| 113 | 5 | 53 | 5 | 68 | 5 | 57 | 5 | 75 | 5 | 147 | 5 | 30 | 5 |
| 254 | 95 | 162 | 95 | 204 | 95 | 163 | 95 | 209 | 95 | 184 | 95 | 120 | 95 |
| 254 | 98 | 172 | 98 | 227 | 98 | 179 | 98 | 234 | 98 | 186 | 98 | 145 | 98 |
| 254 | 99.5 | 184 | 99 | 233 | 99 | 187 | 99 | 248 | 99 | 187 | 99 | 156 | 99 |
| 254 | 99.5 | 187 | 99.5 | 236 | 99.5 | 190 | 99.5 | 253 | 99.5 | 188 | 99.5 | 166 | 99.5 |
| 254 | 99.9 | 192 | 99.9 | 241 | 99.9 | 194 | 99.9 | 254 | 99.9 | 191 | 99.9 | 182 | 99.9 |
| 255 | 100 | 209 | 100 | 255 | 100 | 213 | 100 | 255 | 100 | 194 | 100 | 206 | 100 |

Crust with a thickness of about 2-3 mm appears in dull colour ( 7.5 YR 6/4 ) in one of the training areas in the Ardakan area, due to the great extend of desert crust in the study area, and their effect on increasing the surface reflection, more attention is necessary to be paid on this matter. Table 3 shows the correlation matrix of TM bands on the Qom salt crust with whitish salt crust. Table 3 shows the zero correlation for TM band 1 with other TM bands that is due to the only DN values of 255 in TM band 1. The highest correlation coefficients are obvious between the TM bands 2,3,4 and 6 and the lowest correlation coefficients were obtained for TM bands 5 and 7. Among the seven bands, TM band 5 and 7 with the lowest correlation reveals that these two bands contains much information on salt crusted surface that could not be found in other TM bands. Table 4 points out the correlation matrix of TM bands on the crusted surface area in the Qom playa which includes salt crust and desert crust.

Table 3. Correlation matrix of TM bands of the Qom salt crust.

| | TM-1 | TM-2 | TM-3 | TM-4 | TM-5 | TM-6 | TM-7 |
|---|---|---|---|---|---|---|---|
| TM-1 | 0 | | | | | | |
| TM-2 | 0 | 1 | | | | | |
| TM-3 | 0 | 0.986 | 1 | | | | |
| TM-4 | 0 | 0.948 | 0.943 | 1 | | | |
| TM-5 | 0 | 0.266 | 0.215 | 0.489 | 1 | | |
| TM-6 | 0 | -0.847 | -0.868 | -0.782 | 0.06 | 1 | |
| TM-7 | 0 | 0.244 | 0.195 | 0.440 | 0.958 | -0.04 | 1 |

Table 4. Correlation matrix of TM bands of the Qom crusted surface ( salt crust and desert crust ) .

| | TM-1 | TM-2 | TM-3 | TM-4 | TM-5 | TM-6 | TM-7 |
|---|---|---|---|---|---|---|---|
| TM-1 | 0.0 | | | | | | |
| TM-2 | 0.0 | 1 | | | | | |
| TM-3 | 0.0 | 0.982 | 1 | | | | |
| TM-4 | 0.0 | 0.952 | 0.954 | 1 | | | |
| TM-5 | 0.0 | -0.459 | 0.482 | -0.272 | 1 | | |
| TM-6 | 0.0 | -0.595 | -0.583 | -0.638 | -0.178 | 1 | |
| TM-7 | 0.0 | -0.444 | -0.465 | -0.276 | 0.986 | -0.227 | 1 |
| Minimum | 255 | 104 | 151 | 120 | 26 | 143 | 9 |
| Maximum | 255 | 209 | 255 | 203 | 248 | 173 | 157 |

Comparison between the correlation coefficients in salt crust area and crusted surface reveals that when the desert crust areas are ignored from the analysis, the correlation coefficients between TM bands 5 and 7 decreases. It means that TM bands 5 and 7 are highly decorrelated in salt crust area. The result of FS analysis also showed that dominant types of following salt crust can be recognized :

a- efflorescent, very fragile crystalline which appears to be snow covered ,

b- a salt - silt- clay crust is massive, relatively hard, whitish gray and usually has a rough surface,

c- non- saline soil with a surface crust of a few millimeters thick and bright surface.

The results of PCA transformation on the crusted surface and salt crust are shown in table 5 and 6 respectively. The eigenvectors computed for the correlation matrix on the crusted surface indicates that TM visible bands 2,3,4 and TM band 7 have the most contribution to the PC1 and TM bands 5 and 7 have the highest relationship with PC2. No contribution of TM band 1 was found to the PC,S, that is due to the constant DN values of 255 in the TM band 1 on the study area. The highest contribution to PC3 is related to TM thermal band for both areas of salt crust ( table 6 ) and crusted surface (table 5). Based on the obtained results, we may generally label PC1 as surface appearance component, PC2 as moisture component. Table 5 shows that PC1 accounts for 62.74% of the total variance and PC2 accounts for 31.94% of the variance.

Table 5. Eigenvectors of the seven components of the Qom crusted surface.

| | TM-1 | TM-2 | TM-3 | TM-4 | TM-5 | TM-6 | TM-7 | Variance% |
|---|---|---|---|---|---|---|---|---|
| PC1 | 0.0 | 0.504 | 0.507 | 0.473 | -0.039 | -0.276 | 0.240 | 62.74 |
| PC2 | 0.0 | 0.10 | 0.086 | 0.221 | 0.564 | -0.529 | 0.576 | 31.94 |
| PC3 | 0.0 | 0.178 | 0.175 | 0.419 | 0.316 | 0.790 | 0.195 | 4.56 |
| PC4 | -0.0 | -0.517 | -0.319 | 0.068 | 0.148 | -0.235 | -0.381 | 0.51 |

Table 6. Eigenvectors of the seven components of the Qom salt crust.

| | TM-1 | TM-2 | TM-3 | TM-4 | TM-5 | TM-6 | TM-7 | Variance% |
|---|---|---|---|---|---|---|---|---|
| PC1 | 0.0 | 0.483 | 0.476 | 0.496 | 0.246 | -0.421 | 0.232 | 65.68 |
| PC2 | 0.0 | -0.167 | -0.206 | 0.005 | 0.641 | 0.312 | 0.649 | 30.09 |
| PC3 | 0.0 | 0.323 | 0.271 | 0.260 | -0.089 | 0.850 | -0.154 | 2.93 |
| PC4 | 0.0 | -0.246 | 0.193 | -0.428 | -0.545 | 0.036 | 0.648 | 0.86 |

The PCA transformation model for the three most informative components can be written as following:

PC1= 0.487 TM2 + 0.480 TM3 + 0.503 TM4 + 0.265 TM5 - 0.381 TM6 + 0.252 TM7
PC2= -0.185 TM2 - 0.225 TM3 - 0.013 TM4 + 0.632 TM5 + 0.328 TM6 + 0.640 TM7
PC3= 0.284 TM2 + 0.268 TM3 + 0.258 TM4 + 0.117 TM5 + 0.864 TM6 - ).145 TM7

Two dimensional FS analysis of the Ardakan area shows that the dark color salt crust can be separated by TM6. It means they have a large temperature rise of the dark crust class may be due its location in a depression. This depression may capture more radiation and retaining more temperature. In other words, the layout of buildings and pavement within an urban landscape can also affect the appearance of the urban heat island ( Goward, 1981 ). Nichol ( 1994 ) has successfully utilized Landsat TM thermal infrared data to derive surface temperature data for some housing estates in Singapore.

## Conclusion :

The TM satellite images is offering a valuable contribution to fulfilling the information need in detecting salt crust from the other crusted surface. Based on the obtained results we may generally conclude that TM visible bonds and TM infrared bands may have some valuable information on salt crust that are usually complementary to each other. we also may conclude that TM thermal band can be effectively used for separating urban and salt crust with dark to brownish color. We may also conclude that a better understanding of some characteristics of crusted surface developed in desert areas are necessary to improve image interpretation .

## References :

1- Alavi panah, S.K. and R. Goossens, 1999. The role of TM thermal band in describing the state/stress of vegetation in the Iranian Deserts. Proceedings of RS in the 21 century: Economic and Environmental applications. 19 the EARSel Symposium, University of vallodolid, Spain, 31 May-2June, 1999, 31-37.

2- Goossens, R. and E. Van Ranst, 1996. The use of RS and GIS to detect gypsiferous soils in the Ismailia province ( Egypt ), proceedings of the International Symposium on Soil with Gypsum. Lieida, 15-21 September, 1996. Catalonia, Spain.

3- Goudharzi, G.H. 1970, Non-metalic mineral resources : Saline deposits, Silica sand, sulfur and trona. USGS professional paper- 660.

4- Goward, S.N., 1981. Thermal behavior of urban landscapes and the urban heat island. physical geography, 2: 19-33.

5- Nichol, J.E, 1994. A GIS - based approach to micro climate monitoring in Singapore's high rise housing estates. Photogrametric Engineering and remote sensing, 60: 1225-1232.

6.Stoops, W, A., 1984. Soil formation processes in the west Africa Savanna landscape; implications for soil fertility and agronomic research aimed at different topsequence land types. ISNAR drattreport, July, 1984.