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Satellite data based spectral indices for estimating surface salinity in Pakistan

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Abstract: Pakistan is facing problems of salinity, which adversely affects growth and yield of agricultural crop. Since the economic development of the country is strongly linked to agriculture, reclamation of saline areas is always on high priority. Mapping of soil salinity is one of prime requirement for reclamation of saline areas to increase agricultural productivity of the country. To accurately delineate and map saline areas throughout the country, both qualitatively and quantitatively monitoring at temporal scale is a challenging job. Satellite Remote Sensing technology provides flexible and accurate method to monitor map and manage the resources in time and a cost effective manner. The aim of this study was to monitor and map saline area in selected portion of Larkana District, Pakistan. The remote sensing approach was applied by using multi spectral and multi temporal SPOT images. The image band ratios (salinity index, brightness index, and principal component analysis) were applied based on different spectral characteristics for varying kinds of surfaces. It was observed that the proposed indices provided more prominent view to the saline area, particularly between salt and salt free land by comparing the original images and indices applied images.

Key words: Brightness index, principal component analysis, salinity index, soil salinity, SPOT data.

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1. Introduction

Soil salinity is a critical environmental problem in many countries around the world. This problem has deleterious impact on soil fertility which in turns reduces the soil productivity (Farifteh *et. al.,* 2006). Pakistan, basically is an agricultural country and is blesses with has large-scale plain land, chain of rivers and canals. In Pakistan, about 6.30 million hectares of land is salt-affected (NARC, 2001). The irrigation water is mainly supplied through the canal system controlled through dams and barrages (WAPDA, 1999).

Intensive and continuous use of surface irrigation has altered the hydrological balance of the irrigated areas, especially Indus basin. The substantial rise in the water table has caused salinity and water logging in large areas of Sind, Punjab, KPK and Baluchistan. The magnitude of the problem can be gauged from the fact that the area of productive land was being damaged by salinity at a rate of about 40000 hectares annually (Aslam *et. al.,* 1997).

In irrigated fields, water pushes dissolved salts into the soil, after evaporation of water salts accumulate in the subsoil or spread to on the land surface. Soil salinization is becoming an increasing problem, especially in arid regions and wherever irrigation is practiced. In Pakistan, seepage through irrigation system gives rise to water table gradually and substantially flares up the twin menace waterlogging and salinity.

Resource planners are always eager to explore efficient and economical methods to reclaim more saline area so that it can be used for cultivation. The problem of detection, monitoring and mapping of salt-affected soils is known to be a difficult matter due to involvement of dynamic processes. Recent advances in the field of remote sensing (RS) technology for mapping and monitoring of land degradation particularly in salt-affected areas, with cost effective method, great accuracy and feasibility of application in wide range of environmental conditions. The approach to the problem of mapping saline soil using RS data has been proved in many research studies to be most efficient (Roa *et. al.,* 1991; Dwivedi *et. al.,* 1996). Recent advancement in RS methods has extended its application for soil studies and also in mapping soil salinity. Tagizadeh *et. al.,* (2008) used band 3 of Landsat TM to map soil salinity in Ardakane Yazd region, Iran. While different image enhancement techniques such as image proportional and principal component analysis were utilized by Dwivedi (1996) and Darvishsefat *et. al.,* (2000) to classify soil salinity based on ETM images for Hoze Soltan Ghom area. Saha *et. al.,* (1999) also found that bands 3, 4, 5 and 7 of the Landsat TM images were useful to classify the lands with salted areas in India. The contribution of false color composites and visual interpretations for monitoring salinity was accomplished and is widely available in literature (Kauth and Thomas, 1976; Hardisky *et. al.*, 1983; Steven *et. al.*, 1992; Vincent *et. al.*, 1996). Brightness index is meant to detect high levels of brightness appearing at enhanced levels of salinity.

In Pakistan, limited attempts have been made to apply RS for the detection of soil salinity. This study is an attempt to develop mathematical indices based on SPOT 2 multi-spectral and multi-temporal images for monitoring and mapping of soil salinity in a selected area of Larkana district in Sindh province

2. Material and Methods

2.1 Study Area

Figure 1 shows the location of study area. The study area covers a portion of Larkana district in province of Sindh. It is located within 27^{o} 37\` to $27^{o}$ 45\`North latitude and 68^{o} 05\` to $68^{o}$ 10\` East longitude and covers an area of about 5248 hectares (Figure 2 a & b).

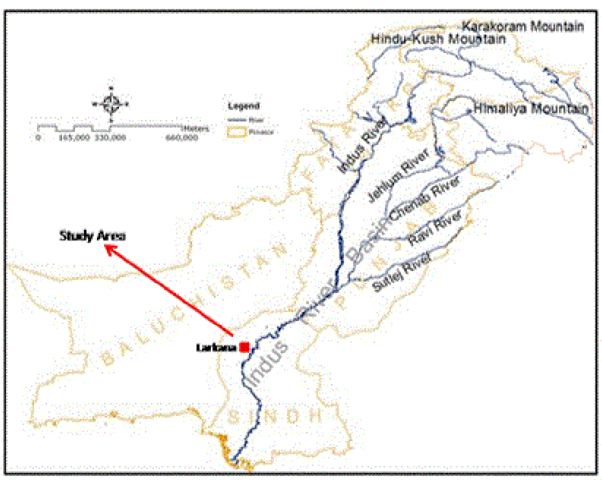

Figure 1: Map of Pakistan; with a small rectangle (red color) on the right lower side indicating the location of study area

The climate of the area is arid but the network of canals and presence of lakes adds sufficient moisture to the atmosphere particularly in the summer season. The average summer and winter temperatures are about 42^{o} C and 20^{o} C respectively. January is coldest and June is the hottest month. Mean annual rainfall ranges from 75mm to 200 mm. Major part of the district is irrigated by an extensive canal system fed from the River Indus. Larkana district is a major rice growing area. With the sufficient soil and availability of canal system make the area highly favorable for cultivation of paddy crop.

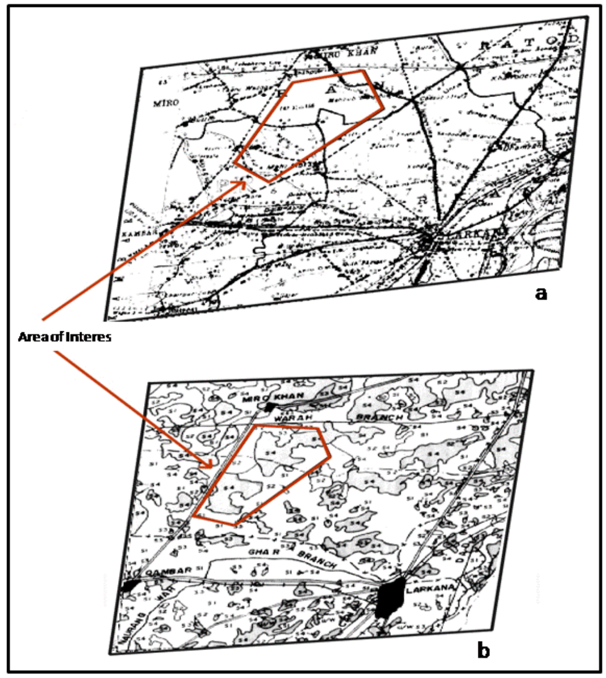

Figure 2: Study area; a) from topographic map (source: Survey of Pakistan) b) from Surface salinity map 1976-1977 (Source: WAPDA)

2.2 Data Used

Data recorded by multi spectral sensor of SPOT-2 satellite in three bands (B1: 0.5µm - 0.59 µ m, B2: 0.61µ m – 0.64 µm, B3: 0.79 µm – 0.89 µm) with 20 x 20 meter spatial resolution has been utilized in this study. Two SPOT XS images of two different years (i.e. January 2000 and January 2002 pertaining to Larkana district) were chosen to monitor the changes in salinity area during this period. Topographic map of Survey of Pakistan (SoP) at the scale of 1:50,000 (Figure 2a) was used as a main supporting data to register both images. For accurate assessment of results and comparison, spatial data-surface salinity map of WAPDA, 1976-1977 (Figure 2b) was used.

2.3 Methodology

An integrated approach was adopted using satellite RS data, mathematical models and image enhancement techniques for the assessment of soil salinity. Figure 3 shows the graphical presentation of the methodology applied in this study. The study area pertains to a small portion of Larkana covering about 5248 hectares was extracted from two SPOT XS images, January 2000 (Fig. 4a) and January 2002 (Fig. 5a) to monitor changes in saline area extended over a period of two years. The images of both times were imported in ERDAS imagine (an image processing software) and then rectified with SoP topographic sheets.

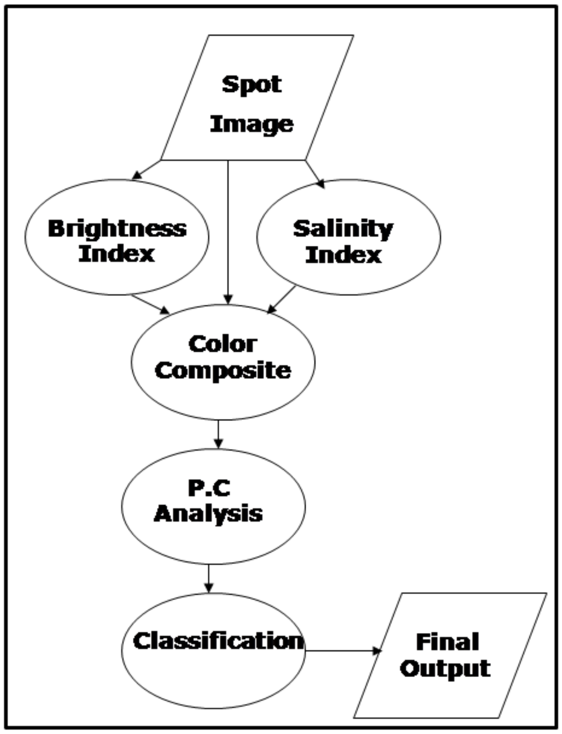

Figure 3: Graphical presentation of methodology

In order to detect the saline area from other features of in the study area, following two indices, namely Salinity Index (SI) and Brightness Index (BI) were applied, to achieve maximum differentiation between various surface features:

Salinity Index (SI) = SQRT (Band2 x Band3) (I)

Brightness Index (BI) = SQRT ($Band2^2 + Band3^2$) (II)

A Color Composite image was produced by integrating Salinity Index, Brightness Index and Band2. Principal Component Analysis techniques were then applied to the color composites of the images taken each year separately in order to minimize the inter-band correlation in images, which generally increase the computational efficiency for classification. The two images were then classified using supervised classification techniques. The results obtained from statistics of the classification techniques after the PCA.

3. Results and discussion

For precise signature selection of saline and non-saline area, it was necessary to have clear color differentiation between the two types of lands.

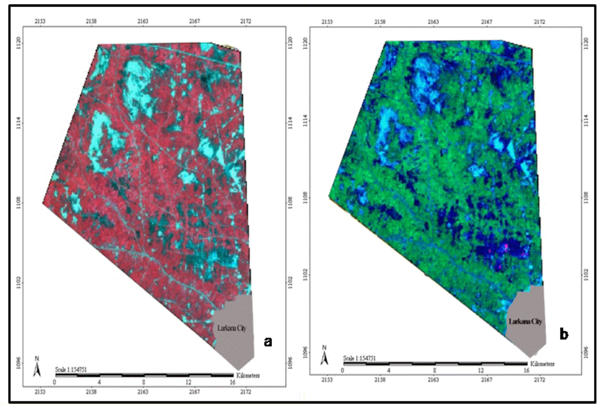

Figure 4: a) Study area from SPOT image'2000, b) Study area: color composite (Index 1, Index 2, Band 2)

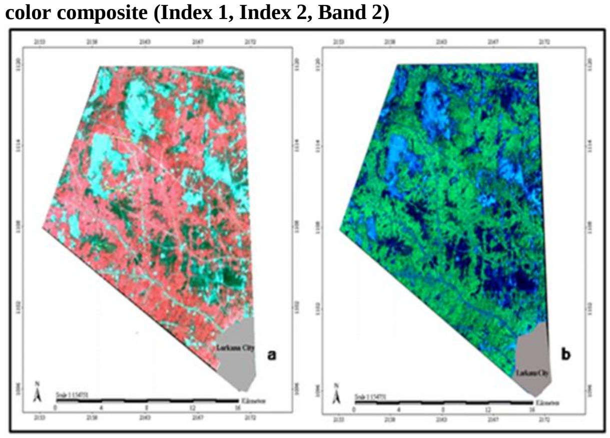

Figure 5: a) Study area from SPOT image'2002, b) Study area: color composite (Index 1, Index 2, Band 2).

The color composite shown in figure 4b & 5b, saline areas are shown in light bluish tone in the image. The principal component analysis (PCA) provides least variance among the bands, which are more interpretable, the results shown in figure, 6a & 7a, salt affected areas are shown in dark pink color. It was observed that use of PCA provide more prominent view to the saline area.

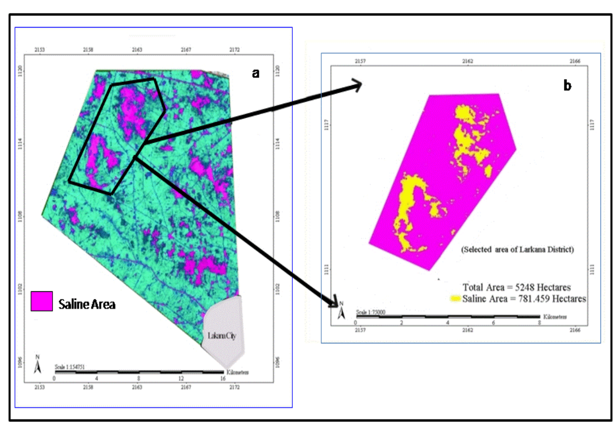

Figure 6: PCA of figure 4 (b), b) Classified Image of study area (2000)

A clear differentiation among the various surface features particularly between salt and salt free land has also been observed between the original images and PCA applied images. The supervised classification was based on the values which distinguished between saline and non-saline area, as found from the output of principal component analysis. For this purpose it was initially adequate to have just two classes- 'saline area' and 'non-saline area' (Figure 6b & 7b). Finally both classified image were overlaid to create change detection.

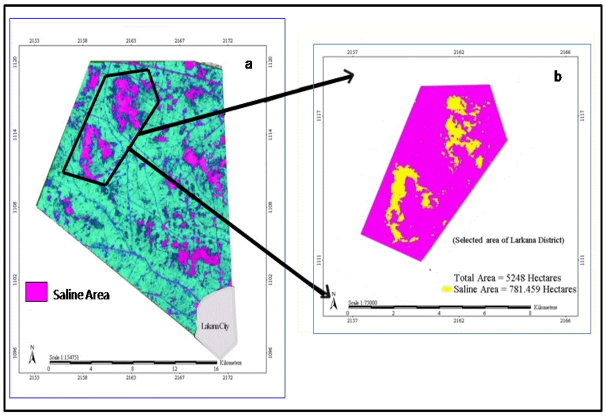

Figure 7: PCA of figure 5 (b), b) Classified Image of study area (2002).

Figure 8 reveals the changes in salinity extent from 2000 to 20002.

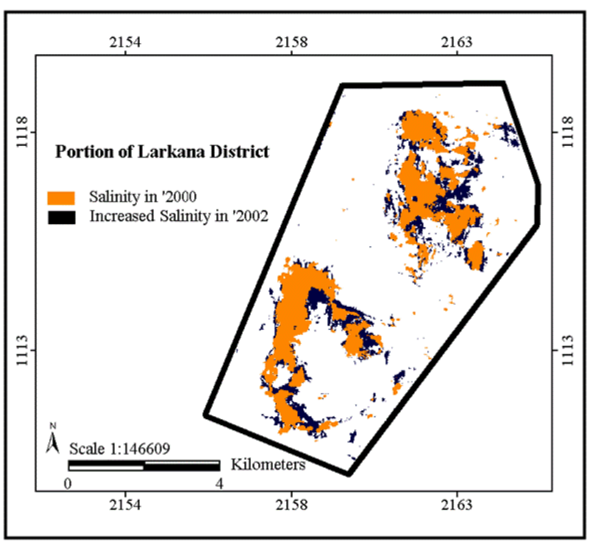

Figure 8: Changes in area under salinity from 2000 to 2002.

Table 1, reveals that ~ 781.459 hectares out of 5248 hectares was classified as saline in the year 2000 whereas ~ 926.914 hectares out of 5248 hectares was classified as saline in the year 2002. Approximately 0.03% increase in saline area has been observed in two years.

Table 1: Changes in saline area: during the year '2000 to '2002

	Area (hectares)	Area (%)
Total Selected Area	5248.00	100.00%
Salinity in 2000	781.459	14.89%
Soil Salinity in '2002	926.914	17.66%
Change in two years	+145.455	+2.77%

4. Conclusion

It is concluded that this simple approach based on specialized indices has shown promising potential in monitoring and mapping of saline areas using SPOT-2 satellite data. Although there is no doubt that RS and SPOT images are good tools for soil salinity monitoring and mapping, but the accuracy of the results needs verification through extensive ground truth survey of the area. The use of high spectral/spatial resolution satellite data gives precise input for saline area as well as salinity classes.

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Competing Interests

Authors declare that they have no competing interests and commercial names and equipments are for the guidelines only.

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