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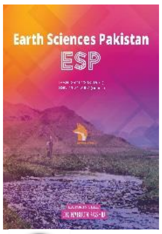

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RESEARCH ARTICLE

SOIL SALINITY MAPPING USING SATELLITE REMOTE SENSING: A CASE STUDY OF LOWER CHENAB CANAL SYSTEM, PUNJAB

Muhammad Mohsin Waqas[a*], Yasir Niaz[a], Sikandar Ali[b], Ishfaq Ahmad[c], Muhammad Fahad[d], Haroon Rashid[e], Usman Khalid Awan[f]

[a] *Department of Agricultural Engineering, Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan*
[b] *Department of Irrigation and Drainage, University of Agriculture, Faisalabad*
[c] *Centre for Climate Research and Development, COMSAT, Islamabad*
[d] *PMAS-Arid Agriculture University, Rawalpindi*
[e] *Department of Structures & Environmental Engineering, University of Agriculture Faisalabad.*
[f] *International Centre of Agriculture Research in Dryland Areas, Islamabad*
**Corresponding author email: mohsin.waqas@kfueit.edu.pk*

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ABSTRACT

Salinity is the most important factor of consideration for the water management policies. The water availability from the rootzone reduced with the increase in the soil salinity due to the increase in the osmatic pressure. In Pakistan, salinity is the major threat to the agriculture land due to the tradition practices of irrigation and extensive utilization of the groundwater to meet the cope the irrigation water requirement of high intensity cropping system. The salinity impact is spatially variable on the canal commands area of the irrigation system. There is dire need to map the spatially distributed soil salinity with the high resolution. Landsat satellite imagery provides an opportunity to have 30m pixel information in seven spectral wavelength ranges. In this study, the soil salinity mapping was performed using pixel information on visible and infrared bands for 2015. These bands were also used to infer Normalized Difference Vegetation Index (NDVI). The raw digital numbers were converted into soil salinity information. The accuracy assessment was carried out using ground trothing information obtained using the error matrix method. Four major classes of non-saline, marginal saline, moderate saline and strongly, saline area was mapped. The overall accuracy of the classified map was found 83%. These maps can be helpful to delineate hot spots with severe problem of soil salinity in order to prepare reciprocate measures for improvement.

KEYWORDS

Landsat, NDVI, Soil Salinity, LCC System.

1. INTRODUCTION

Salinity and water logging are considered as severe environmental hazard to the irrigated agriculture especially in arid and semiarid regions. The salinity has the inverse relation with the water availability to plants, the increase in the salinity reduced the ability of the plants to extract water (Al-Khaier, 2003). FAO reported that about half of the world irrigated land is affected by the secondary salinity and water logging (FAO, 1988). (Dudal and Purnell 1986) reported that about 7% of the global land is affected by salinity. A study reported about 77 million ha is salinized and about 56% is from irrigated land (Dregne, 1991).

The condition in Pakistan is alarming due to the traditional practice of the irrigation and excessive use of groundwater. Total irrigated area of Pakistan is estimated at 16.2 mha that lies in Indus Basin Irrigation System. A group researchers estimated that about 6.3 mha area of this areais facing the problem of salinity and water logging (Qureshi et al., 2008). The degradation of about 40% of irrigated land means a direct threat to economic and food security as land productivity may decrease in saline soils.

The situation is becoming even worse as more and more groundwater is being abstracted to supplement limited surface supplies. Now the groundwater has to be pumped from deep aquifer, that comprises of saline water layers that is causing secondary salinization in the country. There is no up to date spatial map of soil salinity available that can provide gridded information at the canal command area in the Indus basin at the high resolution.

The spatial mapping of the soil salinity at high resolution requires the very high-resolution data that requires very heavy coast and intensive labour work requirement. Remote sensing makes it possible to map the land use land cover, predication of crops yield, groundwater resources and actual evapotranspiration with the high resolution (Waqas et al., 2019; Fahad et al., 2019; Cheema et al., 2014; Awan et al., 2016; Awan et al., 2017; Liaqat et al., 2015). A study reported the use of the remote sensing for the mapping of the soil salinity (Abbas et al., 2013; Al-Khaier, 2003; Eldeiry and García n.d.; Gutierrez and Johnson, 2010). There is no significant spatial work available in the irrigated area of Indus Basin with the field level resolution. The International Water Logging and Salinity Research Institute (IWASRI) in 2003 maps the Indus basin for mapping the soil salinity using the conventional interpolation technique.

In this study a novel approach is proposed to spatially map soil salinity using the Landsat imagery and ground data. It will provide a knowledge base on spatially distributed soil salinity at a pixel that represents local

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land holding within the irrigated area of the Indus Basin. The maps thus produce will provide hot spots where soil salinity is more than permissible limits.

2. Materials and Methods

2.1 Study Area

The study area comprises of canal command areas (CCA) of Lower Chenab Canal (LCC) System (Figure 1). The LCC is oldest irrigation scheme of the Indus basin lies in the Rechna doab. The climate of the irrigation scheme is in the category of the semiarid region. The summer is very hot in the peak days and the winter nights get freezing temperature at the mid nights. The LCC is considered as one of the most fertile area of the Indus Basin. The Major crops of the LCC includes the wheat, rice, maize, cotton and sugarcane.

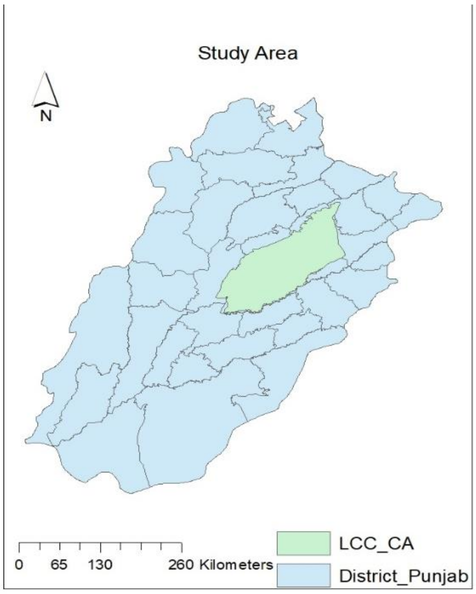

Figure 1: Study Area

2.2 Data Collection

2.2.1 Satellite Data

Landsat was launched 1972 for the acquisition of the satellite derived earth imagery. The upgraded version of the Landsat is Landsat 8 that was launched in 2013. The major function of the satellite imagery is spati-temporal mapping of the agriculture, forestry, urban development, geology and education. In this study, Landsat 8 product was acquired for the soatial mapping of the soil salinity. Landsat 8 gives information in visible (red, Green, Blue) and infrared range (Near, Thermal and mid infrared) from band 1 to 7 with spatial resolution of 30 meter and temporal resolution of 16 days. Landsat 8 has one additional panchromatic band at 15-meter resolution. The various bands of Landsat satellite were used to estimate soil salinity. The information on Red (R) and Infrared (IR) bands as well as Normalized Difference Vegetation Index (NDVI) were used to determine soil salinity at 30 m pixel resolution. The images from Landsat satellite series for selected year were downloaded from the USGS database website (www.glovis.usgs.gov).

2.2.2 Field data

In-situ information on soil quality was collected through field survey of canal command areas. Lower Chenab canal (LCC) was selected for conducting detailed field survey. The soil samples were collected from various locations in the CCAs along with their GPS locations. Soil sampling was carried out using augur hole at different depth and composite samples were used in this study. Soil Survey Manual Agriculture Hand book No. 18 (Soil Survey Division Staff,1993) were followed to categorized the soil salinity thresholds i.e. Non-saline (0-4 dSm^{-1}), Marginal Saline (4-8 dSm^{-1}), Moderate Saline (8-15 dSm^{-1}) and Strongly Saline (>15 dSm^{-1}).

2.3 Methodology

Soil salinity was computed at 30 m pixel resolution using satellite imagery obtained from Landsat 8. ERDAS Imagine 2014 was used for the processing of the Landsat Image. The images were processed using the model maker in the ERDAS Imagine. Final reclassification of the processed image was performed in the GIS. Pixel information of Red, Near Infrared and Infrared bands were then extracted to parameterize Spatial Auto Regressive model as suggested (Elhaddad and Garcia, 2003). Pixel based salinity was mapped using Spatial Auto Regressive model. To fetch the improvement in the accuracy of the model, the model was applied on two different ground condition i.e., bare and soils having vegetation. The NDVI was used to incorporate effect of vegetation in the model. The mathematical representation of the model used to extract the soil salinity is given as:

$$\text{Soil Salinity} = 9.6914 - (0.0047 \times \text{IR}) - \text{R} - (8.3907 \times \text{NDVI}) + \left(0.8743 \times {}^{\text{IR}}\!/_{\text{R}}\right)$$

The accuracy of the soil salinity maps generated using GIS were validated using the error matrix method based on the ground truthing data collected through the field survey.

3. Results and Discussion

3.1 Image Processing

The derived spectral response of these classes shows that saline soils have more reflectance and non-saline and saline soils reflect changed performance in electromagnetic spectrum. Accumulated salt over saline soil reflect more incident radiation as compared to non saline soil. This makes it easy for extrication of salt affected soil from ordinary soil. Sal affected soils have more reflectance in visible part of electromagnetic spectrum predominantly in blue band (band 1). While, low reflectance in near infrared (band4) region verifies low reflectance and higher NDVI as an indicator of decent crop growth.

Soil salinity and Normalized vegetation Index (NDVI) are inversely proportional to each other. NDVI shows the vegetation density on the soil surface. Salinized area limits the crop growth and eventually affects the NDVI of the area. The verification was also conducted using the average NDVI of study area with the assumptions of higher NDVI expresses more decent crop growth and low salinity. The comparison of the NDVI shows the highest NDVI value of about of 0.53 for the non-saline soil and the lowest of about 0.30 for the strongly saline soil.

3.2 Accuracy Assessment

An Error Matrix described was developed for accuracy Assessment of classified map as given in Table 1 (Campbell, 2002).

Table 1: Accuracy Assessment

Classes	Non-Saline	Marginal	Moderate	Strongly Saline	Total	PA %
Non-Saline	73	6	4	2	85	86
Marginal Saline	1	24	2	3	30	80
Moderate	1	0	26	3	30	87
Strongly Saline	2	1	3	16	22	72
Total	77	31	35	24	167	OA= 83%
UA %	94	77	74	67		

PA= Producer Accuracy UA= User Accuracy OA= Overall Accuracy

A total of 167 samples were collected from LCC and after analyzing them they were classified into i.e Non saline, Moderate and strongly saline and confusion matrix was developed to see classified map accuracy with ground sampling points results. The overall accuracy of 83% and accuracy of all classes are quite promising and reasonable.

3.3 Soil Salinity Mapping

Spatial soil salinity is important to identify the areas with saline or non saline soils. The soil salinity maps were prepared using Landsat Red and Infrared wavelength bands and NDVI. The models were developed in ERDAS Imagine software and were re-sampled to 60m. These spatial maps help to validate our hypothesis on high water allowances and were used to develop relationship with groundwater quality. The hot spot of the strongly saline area was found in the middle of the irrigation scheme. A significant area of the largest irrigation scheme is under the marginal to moderate saline. The maps thus produced are shown in Figure 2.

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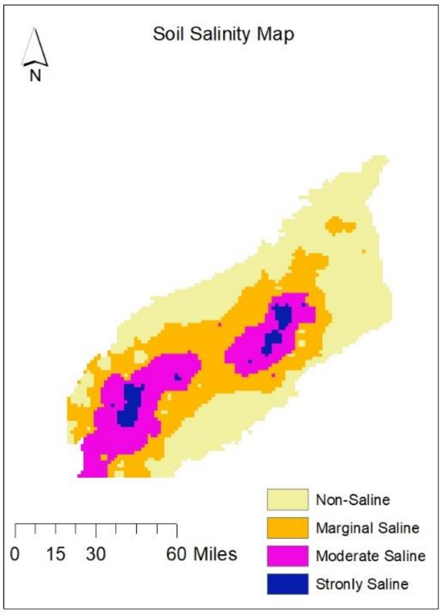

Figure 2: Spatial map of soil salinity

The field survey carried out in canal command provided in-situ information on soil salinity. This in-situ data were used to check the accuracy of the salinity maps by comparing with pixel-based estimates. The saline soils are expanding with time due to lack of attention on reclamation side. The researchers found 6.3 mha land saline in the Indus basin 6.0 mha area saline in the Indus basin (Qureshi et al., 2007; Mahmood et al., 2009).

4. Conclusions

Land degradation due to secondary salinization is a big threat to ensure the food security and poverty evaluation in the agricultural economy-based country. The excessive use of the groundwater is the major contributor for the increase in the soil salinity in the irrigated areas of the Indus basin. Remote sensing using Landsat provides the high-resolution information for mapping the soil salinity with the ground truthing data.

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