INTEGRATED REMOTE SENSING AND GIS APPROACH FOR DETERMINING SOIL SALINITY

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Abstract:

Salinity occurs through natural or human-induced processes that result in the accumulation of dissolved salts in the soil water to an extent that inhibits plant growth. Soil salinity is a severe environmental hazard that impacts the growth of many crops. Worldwide, salinization problems are spreading at a rate of up to 2 million hectares a year, which offsets a good portion of the increased productivity achieved by expanding irrigation. Remote sensed data has a great potential for monitoring dynamic processes, including salinization. Remote Sensing has been shown to be a particularly valuable tool for obtaining relevant data on soil salinity in the irrigated area. The presence of salts at the terrain surface can be detected from remotely sensed data either directly on bare soils, with salt efflorescence and crust, or indirectly through the biophysical characteristics of vegetation as these is affected by salinity. The ability to predict soil salinity accurately from remote sensing data is important because it saves labour, time, and effort when compared to field collection of soil salinity data. This paper evaluates the relationship between soil salinity and satellite imagery and also describes an approach to develop soil salinity maps using remotely sensed data.

Keywords: Remote Sensing, Soil Salinity, Water logging

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Introduction:

Soil salinity is a severe environmental hazard (Hillel 2000) that impacts the growth of many crops. Salinisation is the process that leads to an excessive increase of water-soluble salts in the soil. The accumulated salts include sodium, potassium, magnesium and calcium, chloride, sulphate, carbonate and bicarbonate. A distinction can be made between primary and secondary salinisation processes. Primary salinisation involves salt accumulation through natural processes due to a high salt content of the parent material or in groundwater. Secondary salinisation is caused by human interventions such as inappropriate irrigation practices e.g. with salt-rich irrigation water.

Remotely sensed data has a great potential for monitoring dynamic processes, including salinization. Remote sensing of surface features with aerial photography, videography, infrared thermometry, and multispectral scanners has been used intensively to identify and map salt-affected areas (Robbins and Wiegand 1990). The integration of remotely sensed data, Geographic Information Systems (GIS), and spatial statistics provides useful tools for modeling variability to predict the distribution, presence, and pattern of soil characteristics as well as for assessing the landscape scale structure of forest and rangelands (Kalkhan et al. 2000). The objective of this paper is to present a review on selected papers on application of RS and GIS for studying the waterlogged and salt-affected areas.

SALT AFFECTED SOIL:

Soil salinity, as a term, that refers to the state of accumulation of the soluble salts in the soil. Soil salinity can be determined by measuring the electrical conductivity of a solution extracted from a water-saturated soil paste. From the agricultural point of view, saline soils are those, which contain sufficient neutral soluble salts in the root zone to adversely affect the growth of most crops (Table 2.1). For the purpose of definition, saline soils have an electrical conductivity of saturation extracts of more than 4 $dS.m^{-1}$ at 25° C (Richards, 1954)

Table 1.1 General ranges for plant tolerance to soil salinity

Salinity (EC $dS.m^{-1}$)	Plant Response
0 to 2	Mostly negligible
2 to 4	Growth of sensitive plants may be restricted
4 to 8	Growth of many plants is restricted
8 to 16	Only tolerant plants grow satisfactorily
Above 16	Only a few, very tolerant plants grow satisfactorily

However, the determination of when, where and how salinity may occur is vital to determining the sustainability of any irrigated production system. Remedial actions require reliable information to help set priorities and to choose the type of action that is most appropriate in each case. Decision – makers are growers need confidence that all technical estimates and data provided to them are reliable and robust, as the economic and social effects of over – or underestimating the extent, magnitude, and spatial distribution of salinity can be disastrous (Metternicht and Zinck, 1996).

APPLICATION OF REMOTE SENSING FOR SALINITY:

The acquisition time of the RS data is important for the identification of soil salinity. Venkataratnam (1983) used temporal Landsat-MSS images of pre-monsoon, post-monsoon and harvest seasons to map soil salinity in the State of Punjab, India and concluded that the spectral curves of highly and moderately saline soils change considerably throughout the annual cycle, which significantly complicates the time composition procedure. Johnston and Barson (1990) reviewed RS applications in Australia and found that discrimination of saline areas was most successful during peak vegetation growth. In other periods the low fractional vegetation cover of salinized area could not be distinguished from areas that were bare due to overgrazing, erosion, or ploughing.

Metternicht and Zinck (1996) concluded, based upon their studies related with ground observation and radiometric measurement in the visible and near-infrared wavelengths, that the main factors affecting the reflectance are the quantity and mineralogy of salts together with soil moisture, soil colour and terrain roughness which in turn are controlled by different combination of salts and type of soil surface, texture and organic matter content. Salts influenced surface features includes the soil crusts with or only little evidence of the presence of the salts. The crusted soil surfaces are generally smoother than nonsaline surfaces and causes higher reflectance values in the visible and near infrared bands. TM bands 5 and 7 are frequently used to detect soil salinity or drainage anomalies (Moulders and Epema, 1986; Menenti et al., 1986; Zuluaga 1990; Vincent et al. 1996). Moulders (1987) remarked that in general, bands in the near and middle infrared region give reasonable information on soil moisture and salinity. Rao and Venkataratnam (1991) studied the spectral behaviour of salt-affected soils of Indo-Gangetic Alluvial Plain and concluded that salt-affected soils as compared to normal cultivated soils showed relatively higher spectral response in visible and near-infrared regions. Further, strongly saline-sodic soils were found to have higher spectral response as compared to moderately saline-sodic soils. The vegetation cover modifies the overall spectral response pattern of salt-affected soils especially in the green and red spectral bands. In addition, variation in the Sun elevation angle and moisture content were also found to modify the observed spectral response of salt-affected soils.

SOIL SALINITY MAPPING:

Remote sensing investigation on soil salinity can be divided into the delineation of salt-affected soils under (i) bare condition and (ii) cropped condition. Salinized and cropped areas can be identified with a salinity index based on greenness and brightness that describes leaf moisture as influenced by salinity, with classical false colour composites of separated bands, or with a computer assisted land surface classification (Kauth and Thomas, 1976; Hardisky et al., 1983; Vincent et al., 1996). Essentially, a brightness index is meant to detect high levels of brightness appearing at high levels of salinity. The contributive power of false colour composites and visual interpretations is demonstrated in most studies. The unique patterns of geomorphologic shapes are thought to be helpful in discriminating the salinization process from a physiographic perspective. Singh and Dwivedi (1989) used Landsat-MSS digital data over parts of Uttar Pradesh, India and delineated salt-affected soils on an interactive multi-spectral data analysis system (MDAS). Based on the spectral response of these soils and subsequent correlation in the field by studying terrain characteristics and soil profiles, besides salt-affected soils, other categories such as normal soils, forests, water bodies, river sand, gullies and ravines were also mapped. Dwivedi (1996) used principal components analysis for monitoring the salt-affected soils of the Indo-Gangetic alluvial plains. It was concluded that the principal components analysis of temporal Landsat-MSS data reveals an overall significant change in brightness and greenness of the terrain. However, these changes have not been found related with the spatial extent and distribution of salt-affected soils.

Singh and Srivastava (1990) used microwave radiometers for identifying the problems of waterlogging and salinity in coastal regions. Numerical calculations of brightness and temperature have been carried out over one and two layered models representative of waterlogged and salt affected areas. The results presented in their study showed the utility of microwave radiometers in mapping of waterlogged and salt-affected areas.

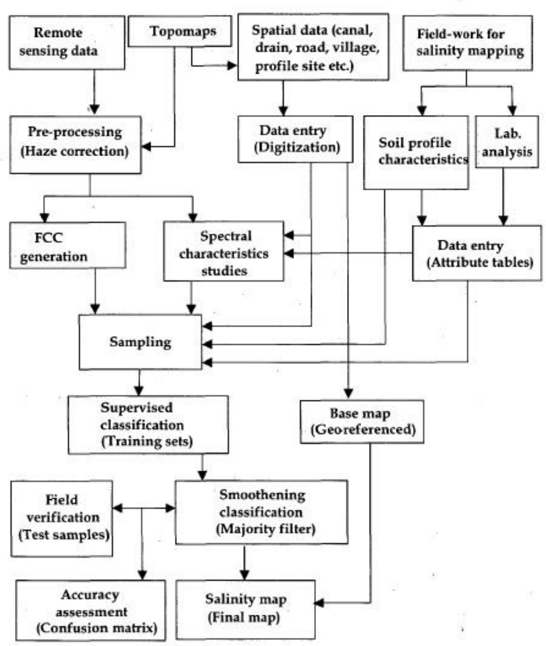

Figure 1 A Flow chart for salinity mapping using digital image analysis and GIS

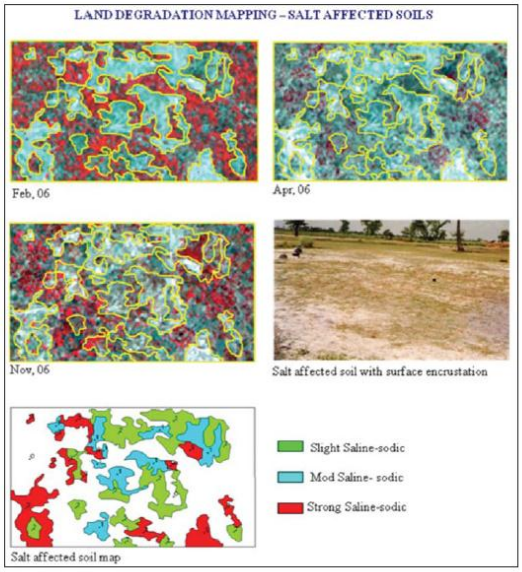

Figure 2: Soil – affected soil map prepared from multi-season temporal LISS – III satellite data.

MONITORING OF LAND DEGRADATION:

Repetitive nature of satellite data enables to monitor land degradation process over a period of time in any geographical location. NRSC had carried out monitoring of waterlogging and salinity in the major command areas in various states in India like Uttar Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Rajasthan and New Delhi. In this project using pre – monsoon and post – monsoon season satellite data salinity and waterlogging were identified with field investigations. Sample areas portraying significant changes in land degradation status has been appended as shown in figure 3.

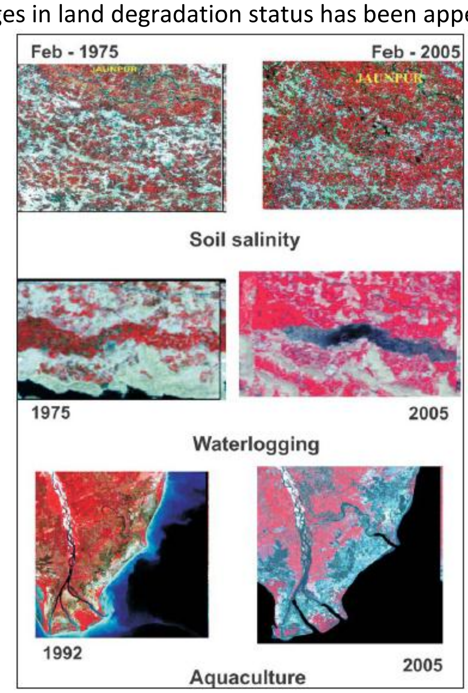

Figure 3: Monitoring Land degradation

Conclusion:

Satellite images can be used to get insight in the dynamics of the salinity and water logging in the area. However general conclusions, even on broad classes such as cropped area, saline areas etc., have to be drawn with great care. A good knowledge of cropping pattern, meteorological conditions at recording time of the image and agricultural practices are needed in order to correctly assess the classification results. The variation of reflectance properties of different land uses in an irrigation command affected with waterlogging and salinity problems makes it possible to diagnose the water logging and salinity affected area.

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