Table 2 Guidelines for suitability of groundwater quality for irrigation

S No	Water quality	EC (dS m^{-1})	SAR (m-mol $l^{-1})^{1/2}$	RSC(me l^{-1})
1.	Good	<2	<10	<2.5
2.	Saline			
	Marginally saline	2–4	<10	<2.5
	Saline	>4	<10	<2.5
	High-SAR saline		>10	<2.5
3.	Alkali waters			
	Marginally alkali	<4	<10	2.5–4.0
	Alkali	<4	<10	>4.0
	Highly alkali	Variable	>10	>4.0

10 to 48 % of worldwide total irrigated area (FAO 1995). Groundwater quality contributing to soil salinisation is grouped into seven classes, viz. good, marginally saline, saline, high-SAR saline, marginally alkali, alkali and highly alkali waters (Table 2) based on EC, SAR and RSC (residual sodium carbonate) as criteria for suitability of irrigation (Minhas and Gupta 1992).

The different infestations of waterlogging are measured by the depth to water table. Initially, a 1.5 m deep water table was considered as the cut-off line for waterlogging in most alluvial soils and 3.0 m as cut-off line for vertisols. Three categories of waterlogging, viz. waterlogged area (<2 m), potential waterlogging area (2–3 m) and safe area from waterlogging (>3 m) are used as guidelines for management. Groundwater in areas dominated by saline soils has generally high EC and may have a potential salinity hazard, whereas groundwater in areas dominated by sodic soils has generally low to medium EC and may also have residual sodicity hazard.

Table 3 General ranges for plant tolerance to soil salinity

Salinity (ECe, dS m^{-1})	Plant response
0–2	Mostly negligible
2–4	Growth of sensitive plants is restricted
4–8	Growth of many plants grow satisfactorily
8–16	Only tolerant plants grow satisfactorily
Above 16	Only a few, very tolerant plants grow satisfactorily

Amacher et al. (2000)

Effect of Salinity on Plant Growth and Crop Productivity

Salt-affected soils including those waterlogged or irrigated with poor-quality waters have impaired seed germination and plant growth, leading to poor crop yield. Plants and crops' tolerance decreases beyond 2 dS m^{-1}, restricting plant growth in some crops, while in some plants many grow well even at an ECe of 8 dS m^{-1}. Beyond that only very few plants can survive depending on their tolerance. Crops suffer the effects of salinity because of toxic and osmotic reasons. Osmotic pressure increases with increasing salinity of the water and lessens the availability of water for the plant to grow. Plants might germinate and not survive or exhibit early signs of moisture stress which in turn would be an impediment to plant growth. Toxicity becomes a serious problem in plant growth due to a higher concentration of particular cations or anions, resulting in adverse conditions where plants do not survive or suffer other side effects as a result of excessive uptake of Na^+ and Cl^-. As salinity levels increase they can cause nutrient imbalances, which then result in the accumulation of elements toxic to plants, and reduce water infiltration if the level of one salt element (like sodium) is high (Table 3).

Remote and Proximal Sensing-Based Modern Tools for Diagnosis and Prognosis of Salt-Affected Soils and Water

Diagnosing and prognosing takes on importance where crop sustainability affects food production and thereby livelihood concerns of nations. Applying remote-sensing and contemporary technologies becomes vital. Conventional methods of soil and water sampling and laboratory analysis are the most accurate for salinity assessment and mapping, but these are expensive, time-consuming and labour intensive when applied to large-area mapping (Singh 2005). Mapping and monitoring of soil salinity using remotely sensed imagery is a requisite for establishing its areal extent and also to keep track of changes in salinity in order to formulate appropriate and timely reclamation and rehabilitation approaches. Remote-sensing data have been extensively used in soil salinity studies as they are not only quicker but are also useful for making realistic predictions. Proximal sensing-based tools are being increasingly applied to fill in the data gap between conventional method and remote-sensing method. Alongside geographic information system (GIS) tools facilitate the complex studies of soil and water hazards and are used to manage a great set of variables and a huge amount of spatial data. In addition, data on rainfall, topography, soil type and other spatial information which affect or lead to soil salinity can be analysed using proximal tools and GIS to determine spatial patterns of salinisation and to predict regions that may be at risk. All this information is being applied as input for spatial salinity modelling for rapid spatial diagnosis and prognosis of soil and water salinisation.

Remote sensing, GIS and GPS are the cost-effective and accurate methodologies for identifying, diagnosing and prognosing problems of land and water. An integrated approach using remote sensing offers, technologically, the appropriate method of analysing land and water resources and identifying constraints that include a lack of data and information preventing management strategies/indicators to be evolved both at the regional and farm level. A variety of remote-sensing data have been used for identifying, mapping and monitoring salt-affected areas, including aerial photographs, video images, infrared thermography and visible, infrared, multispectral and microwave images (Metternicht and Zinck 2003).

Multispectral and hyperspectral sensors with capabilities to map surface salinity features and crop growth, electromagnetic sensors with capabilities to penetrate into root-zone radar and resistivity sensors with capabilities to penetrate deeper subsoils and groundwater can be deployed with multi-scale approach in GIS. A variety of remote and proximal sensing sensors (satellite multispectral, hyperspectral and microwave; aerial photographs; airborne geophysics; electromagnetic induction metres; GPR, etc.) and combined approaches of data transformation, data fusion and data integration for improved feature recognition and mapping have been used for diagnosing and monitoring salt-affected areas and salinised groundwater. Therefore, an integrated methodology combining proximal and remote-sensing-based geophysical tools with spatial modelling of temporal and spatial changes of salinity can be applied to diagnose and provide a prognosis about the status of salinisation of soil and water. The comparison of different smart modern tools for diagnosis and monitoring of root-zone and deeper salinity and groundwater quality in terms of depth of resolution, application and scale is presented in Table 4.

Aerial Photography

Salt crusts on the surface can easily be detected directly or indirectly through plant/crop growth pattern on aerial photographs and satellite images. Aerial photography is the earliest method of remote sensing, and even in today's age of satellites and electronic scanners, it remains the most widely used remote-sensing method. Aerial photos are taken of the earth's surface through cameras fitted in an aeroplane or balloon. These photographs are normally used in