WATERLOGGING AND SALT AFFECTED AREA MAPPING USING REMOTE SENSING

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Waterlogging was never heard of before the introduction of irrigation. Salt affected areas existed but not of large extent prior to the irrigation. Salt affected areas were found to disappear after the irrigation is discontinued. Thus, there exists cause and affect relationship between the two. The productivity decline in these areas and slowly wasteland develop if not treated. Thus, the identification and amelioration of these problems is urgently required.

In India, irrigation existed since 2000 BC in the Indus valley civilization. In the early period, the irrigation is introduced in southern India and in Rajasthan through anicut and water tanks. King Feroz Shah Tughlak built many canals in Indus and Yamuna system including western Yamuna canal. Sher Shah Suri also built canals. In these periods, salt affected areas appeared at many places and these later disappeared when the canals turned in disuse. Large-scale irrigation projects have come up in British India times and after independence in the Republic of India (Table 1). These led to development of the waterlogging and salt salinity problem in the command areas where these problems were never heard of. The vast areas in Harayana, Punjab, Uttar Pradesh etc. were affected by these problems. Even during British rule the salt affected area developed e.g. in Meerut and Aligarh districts, Kali Nadi catchement etc. Thus, a close association between irrigation and waterlogging and salinity exists.

1.0 Effect

The salt affected soils cause hindrance in uptake of water by plants due to affected osmotic pressure regime at the root- soil interface, ionic poisoning in the root system especially due to the carbonates and bicarbonates. The waterlogging causes reduction of air supply to the root system thereby affecting the physiological function e.g. respiration etc. in the roots and resulting in their withering.

2.0 Genesis

All kind of soils can develop in to the Salt affected soils. Salts are formed due to the weathering of the minerals. The weathering occurs continuously within the soil profiles and thus salts are continually formed. Under normal soils, the salts are washed in to the lower soil horizons due to percolation of rainwater. When there is build up of water table within soil profiles, the removal of salts is hindered but supply continues, thereby causing build up of the salts in the soil profile. Thus, most likely places where these soils develop are low lying areas or profiles with clay/ hard pan. The soil develop in arid/ semi arid/ sub humid environments over coarse sandy, sandy loam, loam, black cotton soils, organic soils etc. There may be argillic, cambric, gypsic, calcic, petrocalcic etc. horizon in these soils.

Various salts found in soil profile are chlorides and sulphates of the sodium, magnesium and calcium, carbonates and bicarbonates of sodium. The carbonates and bicarbonates of calcium are also present on the salt affected soils.

3.0 Types

Salt affected soils are classified as saline, alkali and saline-alkali. Saline- alkali soils are less in extent in India as compared to other types. These soils are differentiated based on chemical characteristics, physical properties etc. These differences are given here.

Chemically, the salt affected soils are differentiated based on the pH, ESP and EC in the soil. The ranges of these for the salt affected soils are given by United States Soil Salinity Laboratory (USSL) in 1954 (Table 2). In India, based on experimental data, it is recommended that a lower value of soil pHs i.e. 8.2 should be taken instead of value of 8.5 for the alkali soils. In the alkali soils, the presence of carbonates and bicarbonates is more important chemical characteristics. The ECe may be some times more than 4. For heavy texture soils, the ESP in the alkaline soils can even be less than 15 say nearly 8. These soils are found in central and southern India. In saline soils and saline- alkali soils the dominant salts are chlorides and sulphates of sodium. Instead of pH from saturation paste the pH can also be determined from the 1:2 soil water suspension. The pH of the soil water suspension is 0.5 higher at lower pH e.g. at less than 8.0 and 1.0 more at higher pH e.g. at more than 8.0.

Table 1. Salt affected soils in India, Gupta and Gupta (1997)

Regions	Area m ha
Indo- Gangetic alluvial plain (Uttar Pradesh, Delhi, Punjab, Bihar, Haryana, Rajasthan)	4.0
Medium and deep black soil (Madhya Pradesh, Rajasthan, Gujrat, Maharastra, Karnataka, Andhra Pradesh, Tamil Nadu)	4.0
Coastal region (West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Maharastra, Gujarat)	3.1
Arid and semi arid region (Rajasthan, Gujrat)	1.0

Table 2. Chemical characteristics for the salt affected soils by USSL, 1954 (vide Mehta 1986)

Class	ECe	ESP	pHs
Alkali	<4	>15	>8.5
Saline	>4	<15	<8.5
Saline-alkali	>4	>15	Variable

Physically, the saline soils have white salt efflorescence, fluffy surface, water is not stagnated on the surface, the crust may or may not be present, but is thin and not very hard etc. In the alkali soils, ash colored or dark brown salt efflorescence, the rate of infiltration is very low which causes stagnation of water on the surface, presence of hard and thick crust in dry condition that turns soft in wet condition etc.

4.0 Mapping

To ameliorate the problem, first step is identification, mapping and characterization of the waterlogged and salt affected areas. In this remotely sensed data such as aerial photographs, satellite images etc. have proved to be very useful. These problem areas show typical signature on the data and thus their identification is easy on these. Limitation in use of this technique are that small areas as compared to the resolution of the remotely sensed data are not delineated, high water table without any significant expression on the surface are not detected and there may be confusion between ponds, flood irrigation and waterlogged areas; salt affected areas and rocky/ barren/ urban areas etc. Many small patches of the problem areas are left out in the mapping and these can only be identified in the field traversing. The traversing can be done in area with potential to develop in to this kind of degraded land e.g. areas near roads/ rail/ canals etc. Not withstanding these differences, the technique has proved to be very useful in identification and mapping of these areas.

5.0 Signature

On satellite data such as False Color Composite (FCC), aerial photographs, the waterlogged and salt affected areas have typical signature and it is possible to delineate these using visual interpretation or digital classification techniques. The waterlogged areas with standing water or moist soil can be delineated. The aquatic vegetation areas are also delineated. The areas with standing water are seen as blue or black in standard FCC. This signature is similar to that of water. The moist soil areas also possess dark signature. Water possess low digital number (DN) is visible and near infrared bands. The areas with aquatic vegetation show pink, grayish pink signature. The DN in green is little more than other bands. DN in infrared band is quite less than that for the vegetation class. There is possibility of misclassification for the waterlogged area with water, fallow and black cotton soil areas etc.

Salt affected areas are seen in white, dull white and cyan, brown colors etc. Brown color can be scrub vegetation supported by the soil. The patches are in general irregular interspersed with red patches of the cultivated areas. There is misclassification of this class with the barren/ rocky areas, especially for highly salt affected areas with white signatures. The moderately affected areas are confused with the fallow areas. The areas may occur in association with waterlogged areas and such areas, thus, are very well identified.

6.0 Characterization

This involves collection of groundwater table data, morphological and physical and chemical properties of the soils at various depth etc. The monitoring is done also during the treatment to monitor the effect of the treatment of the land. For the waterlogged areas soil texture, infiltration and hydraulic conductivity, presence of clay/ hard pan, water table depth information are useful. For salt affected areas information e.g. soil pH, EC and ESP are useful apart from above information. Using soil pH, EC and ESP, the soil is characterized as saline, saline- alkali and alkali and accordingly the treatment are prescribed.

7.0 Amelioration

The amelioration of the degradation involves various steps. These are described here. For the waterlogging, the steps involve, decreasing the water input to the system, increasing the drainage or water output from the system. These may involve structural and non-structural measures. Structural measures include canal lining, land leveling, field channel lining, laying surface, subsurface drainage, vertical drainage etc. If the clay/ hard pan is present, the step could be breaking this pan at regular grid points. Non structural measures could be changing the cropping patterns to less water intensive crop/ dry land system, tree farming/ horticulture etc. In the arid areas tree plantation could be used in bio drainage to fight the waterlogging problem, utilizing the large rate of evapotranspiration.

To ameliorate the problem of the salt affected soil, the drainage and leaching, applying salt amendments, tree farming, changing the cropping pattern to tolerant crops (Table 3- 4) etc. are few solutions. By laying the subsurface drainage the excess salt can be leached. However, the problem in this method is safe disposal of the salty water. Based on soil investigation, suitable amount of soil amendments are added to the soil e.g. gypsum,

Table 3. Relative alkali tolerance of crops Abrol et. al, 1973 (vide Bhargava 1989)

Tolerant	Semi- tolerant	Sensitive
Rice	Barley	Cotton (at germination)
Dhaincha	Shaftal	Maize
Sugar beat	Berseem	Groundnut
Spinach	Wheat	Peas
Turnip	Sugar cane	Cow peas
Paragrass	Raya	Mung
	Oats	Mash (Urad)
	Cotton	Lentils
	Senji	Sunflower
	Sudan grass	Safflower
	Napler hybrid	Guar
	Bajra	Gram
	Sorghum	
	Potato	
	Water- melon	

Table 4. Relative salinity tolerance of crops Abrol et. al, 1973 (vide Bhargava 1989)

Tolerant (ECe 8-16)	Semi- tolerant (ECe 4- 8)
Sugar beat	Jowar (Sorghum)
Barley	Rice
Turnip	Maize
Dhaincha	Oats
Tobaco	Wheat
Spinach	Senji
Date palm	Berseem
	Tomato
	Bajra
	Mango
	Guava
	Pomegranate

pyrites, sulfuric acids etc. These can rehabilitate the soils. Planting particular salt tolerant plants or grasses can also be beneficial as they improve soil physical and chemical properties. These can also provide fuel wood, forage and thus, revenue to the farmers.

8.0 Alkali soils

An amendment in the alkali soils, Gypsum acts on the sodium clay and makes sodium sulphate. Pyrites and sulfuric acids utilize insoluble calcium carbonates in the alkali soils to form calcium sulphate, which in turn acts on sodium in the soil to make sodium sulphate. The sodium sulphate thus formed in leached to deeper layers by irrigation application. For application of the amendments, the land is required to be leveled and bunded, gypsum is required in powder form (passed through 2 mm sieve), good quality of water is required for irrigation of the land etc. FYM increases the solubility of gypsum. Gypsum is more effective if spread on the surface rather than ploughed. Before the application of gypsum, it may be required to leach the soil, especially the high ESP, pH and EC soils. For low ESP and pH, soils leaching may be sufficient. Irrigation is required after the application of gypsum due to low solubility of it. The solubility is increased by adding rice husk, FYM etc. They also improve the physical condition of the soil. FYM adds zinc in the soils and requires less dose of external zinc. High water table may cause reappearance of the salts and thus will require laying of the sub surface drains, vertical drainage through shallow tubewells etc. Gypsum requirements for various soils are given in the Table 5.

Table 5. Gypsum requirement (t/ha) for alkali soils by Abrol et. al, 1973 (vide Mehta 1986)

pH (1:2)	Soil texture		
	Light	Medium	Heavy
9.2	1.7	2.5	3.4
9.4	3.4	5.0	6.8
9.6	5.0	7.5	10.0
9.8	7.5	10.0	12.5
10.0	8.5	12.5	15.0
10.2	10.0	15.0	15.0

Gypsum requirement is also dependent on the crop type. The semi- tolerant crops can withstand the pH up to 9.0. Rice can withstand the pH up to 9.5. Deep ploughing should be avoided since it brings saline soils from the deeper layer to the surface, causing problem to reappear.

The amendment application can be done in one year. In later years, the amendment is only required if there was no proper leveling done initially. This may also require if deeper ploughing is done bringing saline soil on the surface. The residue, FYM etc. cause formation of acid, which helps in offsetting the salinity problem further. For proper yield other agronomic practices are also required e.g. fertilizer application (N and zinc), no puddling, more plant density, crop rotation etc. The crop rotation of rice-wheat, rice-wheat-dhaincha and rice-barseem can be followed. Dhaincha is useful to reduce the N- application. Berseem is useful to control the weed problem, which starts after 2- 3 years of rice- wheat rotation. Sugarcane, Moong etc can be grown after 4- 5 years of cropping following the reclamation.

Other method used are applying farm yard manure (FYM), rice husk etc., plantation and grass growing. Application of FYM and rice husk etc. requires longer time for the reclamation. Trees and grasses are useful in undulating land, marginal land etc.; when not enough finance is available for the reclamation etc. The economic return from the grasses may be marginal, but these improve the soil condition for the cropping to be done after 3- 4 years. Trees may give good economic return. Trees also improve the soil condition. Various techniques are adopted for tree plantation e.g. pits method, auger method etc. Auger method is cheaper. The presence of hard pan can pose problem in the method. The hard pan must be broken for success in the plantation as in later years. Pan causes hindrance to the roots growth. The addition of gypsum, FYM and removal of gravel etc. to the soil in the pit/ auger hole improves the growth rate and survival in the plants. Transplanting of the six month plants gives good results. The fencing, irrigation, replacements of dead plants are also required. The suitable tree species are given in Table 6. For the Zizyphus Spp., the grafting of Umran variety can be done to get good results. In grasses, Rhode's grass (Chloris gayana), Bermuda grass (dab grass), Para grass (Brachiaria mutica), Karnal grass (Diplachne Fusca) perform well. The mixed grass can improve palatability of the grasses. The grasses are less palatable after one or two years of harvest. The grass may be feed after chaffing, mixing of wheat bhusa etc. For grasses the areas may be reclaimed with gypsum application. Leaching and irrigation application are also required.

9.0 Leaching

Saline and saline- alkali soils only require leaching whereas alkali soils requires use of amendments and leaching both. The reason for this that former soils contains only the water soluble salts whereas in latter soils the soluble salts are formed from the use of amendments which are leached. The leaching in latter case also helps in application of amendments to soil profile.

As a thumb rule, 1 cm water depth is required for each 1 cm soil depth treated. For medium and coarse texture soils; intermittent leaching etc., less quantity will be needed. In case of limited availability of fresh water, the saline ground water may be employed along with the fresh water. In successive leaching more quantity of fresh water is used. The saline water with EC up to 40 may be used when the surface soil EC is quite high. For leaching to be success, high permeability rate are needed. The rates may be increased by deep ploughing, inverting the soil profile (when the sub soil is less saline), adding green manure, FYM, adding coarse texture soils etc.

10.0 Sub-surface Drainage

Drainage is an important and essential structural hydrological means of the water logging and salinity control. The drains are laid at 8 to 30 m spacing depending up on the soil texture. The heavy texture soils requires more closure spacing. The depth of the drains is governed by the capillary rise in the soil effecting the soil condition in the root zone. For heavy texture soils, up to 2 m depth may be required. The optimum depth is also dependent on the crop type (Table 7), ground water salinity (Table 8), allowing movement of agriculture machinery etc. In general the depth may be 0.5 m to 2.0 m. The design is done not from leaching but the drainage point of view, since former is required only during reclamation. The increase in the size of the drain is not proportional to that of increase in the spacing. The sub surface drains are also used for leaching purpose. The drainage efficiency is maximum close to the drains. The efficiency is also increased by doing leaching operation during May- June when the water table is low. The leaching also can be undertaken when effective drainage has

Table 6. Suitable tree species by Mehta, 1986

Alkali severeness	pH (1:2)	Tree species
High	9.5- 10.0	Acacia nilotica (Babul), Prosopis Juliflora (Vilayati babul)
Medium	9.0- 9.5	Eucalyptus hybrid (Mysore Gum), Zizyphus spp. (Ber), Eucalyptus tereticornis
Low	8.5- 9.0	Albizzia lebbek (Siris), Terminalia arjuna (Arjun), Azadirachta indica (Neem), Mulberry

Table 7. Optimum depth of water table (good quality) for crops, Gupta and Gupta (1997)

Crop	Water table depth (M)
Pearl millet	1.25
Soybean	1.25
Cotton	1.22
Maize	1.2
Safflower	1
Barley	0.9
Gram	0.9
Cowpea	0.75
Pea	0.75
Setaria	0.75
Sugarcane	0.6
Wheat	0.6
Rice	0.3

Table 8. Depth of water table for saline ground water, Gupta and Gupta (1997)

Ground water EC	Ground water table depth (m)
<0.16	1.0
2.34	1.5
3.1- 4.7	2.5
4.7- 15.6	3.0
15.6- 31.2	3.5

been achieved in the area. The leaching can also be improved by proceeding in parts. The areas near the center of tile line may be leached first.

11.0 Other Drainage Methods

Other drainage methods are surface, vertical, bio drainage etc. The surface drainage is effective for draining the flood water, borrow pits etc. The vertical drainage has also been found to be effective. This may require installation of one tube well for every 20 ha. This also requires the water table to be connected with the aquifer being drained.

12.0 Conclusions

Remote sensing is very useful to locate the waterlogging and soil salinity areas with some limitations. When major symptoms are apparent on the surface and the problem area is large, the area is well detected on the data. Identification and mapping is a first step to wards amelioration of the problem. Further steps are followed as per the well developed science of the management of the degraded areas. The success often depends on the applying scientific principles, education and extension, resources management etc.

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