

Secondary salinity and waterlogging

in the IGNP command area: A threat to agricultural sustainability

P C Moharana¹, R S Singh², R K Jena³, B L Tailor⁴ and S K Singh⁵

National Bureau of Soil Survey and Land Use Planning, Regional Centre, Udaipur 313 001

Development of salinity and waterlogging in Indira Gandhi Nahar Pariyojana (IGNP) command area is a serious problem. High temperature, presence of excessive water soluble salts in soils and high rate of evapotranspiration have caused the twin problem i.e. secondary salinization and accumulation of salts on top soils or in sub-soil horizons. The presence of impervious layers accompanied by absence of surface drainage outlet is a major factor in rise of the water table and subsequent waterlogging. Sustainability of irrigated agriculture in the IGNP command area is potentially threatened by progressively increasing soil salinity. In eventual course, the affected land has become absolutely unfit for agriculture. Cost-effective long-term mitigation measures and strategies are urgently encouraged to sustain a reasonable soil productivity and quality in irrigated arid region.

Key words: Arid ecosystem, Indira Gandhi Nahar Pariyojana, Irrigation, Soil salinization

SOIL degradation resulting from salinity and sodicity is a major environmental constraint with severe adverse impacts on soil productivity, agricultural sustainability, and food security; particularly in arid regions of the world.

In India, 8.4 Mha (million ha) is affected by soil salinity and alkalinity,

of which about 5.5 Mha are waterlogged. Problems of waterlogging and soil salinization are known to have developed in irrigated agriculture since the first human civilization in Mesopotamia. The fall of this ancient civilization is attributed to both waterlogging and soil salinity. The salinity hazard posed

by irrigation development in the arid zone is not limited to the well-known land degradation due to secondary salinization (generally referred to as waterlogging and salinity). Irrigation-induced salinization and mobilization of primary salts are at least of equal concern in the Indira Gandhi canal command area.



Development of waterlogging and secondary soil salinity in the irrigated area of IGNP command area

Indira Gandhi Nahar Pariyojana

The Indira Gandhi Nahar Pariyojana (IGNP) is one of the most ambitious surface irrigation projects which occupy the north-western and far western parts of the Thar Desert of Rajasthan, India. It is one of the biggest projects of its kind in the world aiming at transforming desert wasteland into agriculturally productive area with the objectives of drought proofing, providing drinking water, improvement of environment, development and protection of animal wealth and increasing agricultural production. Since its commencement in 1963, the IGNP has been the principal source of the irrigation in the areas it covers. The project was undertaken to provide irrigation facility to 1.79 million ha area in the districts of Ganganagar, Hanumangarh, Bikaner, Jaisalmer, Jodhpur, Barmer and Churu in Rajasthan. During last 60 years the irrigation network has transformed the barren deserts into rich and lush fields. Soils of arid regions under intensive cultivation have changed with respect to their various properties. Development of salinity and water logging in IGNP area is a serious problem.

How a rising watertable affects salinity

The watertable will rise when the influx of water to the soil profile exceeds outflux of water. When the watertable is about 2 m from the soil surface, groundwater can be brought to the surface by capillary rise. Water is then evaporated from the soil surface, leaving dissolved salts behind in the root zone. If the watertable is beyond 2 m, however, capillary rise does not reach the root zone of most agricultural plants.

Therefore, one aim of irrigation, drainage and land management should be to keep the watertable well below 2 m depth from the surface and so keep salty groundwater well away from plant roots. In IGNP command area, the current estimates indicated that about 0.208 million ha land is already affected by waterlogging and associated salinity (Table 1).

The salt affected and water logged soils in this command are mainly located in Anupgarh Branch,

Table 1. Waterlogged area (ha) in IGNP commands of Rajasthan

Category	Years						
	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
<i>Stage I</i>							
Waterlogged area	10,098	5,755	2,531	2,968	3,125	6,875	1,875
Critical area	11,355	8,750	9,259	10,625	11,250	16,875	12,500
Potentially sensitive area	179,170	164,375	195,000	168,750	196,875	20,2150	181,250
<i>Stage II</i>							
Waterlogged area	78	16	4	4	484	805	320
Critical area	1,261	453	317	476	1,129	2,576	1,120
Potentially sensitive area	18,304	24,572	13,481	16,018	18,548	15,906	11,840

Waterlogged area (watertable within 0 to 1 m), critical area (watertable within 1 to 2 m), potentially sensitive area (watertable within 2 to 6 m) (Source: CAD, IGNP, Bikaner)

Suratgarh Branch and Charanwala branch. In the IGNP area, the natural groundwater balance has been disturbed, and waterlogging has arisen due to several causes. These are discussed here.

Seepage from various sources: According to Central Water and Power Research Centre's report on IGNP, there are two main reasons of seepage from the main canal. The sidewalls of the main canal have been constructed using 25-50% of silt and 50-75% of fine to medium sand with a high range of water permeability. Another possible cause is the injured lining of the main canal.

Absence of natural drainage system: One of the most important factors that cause waterlogging in the IGNP area is absence of any natural drainage system. There is virtually no effective river in the area hence no surface drainage is possible. Many researchers have indicated that a river system existed in this area in the past geological ages.

Presence of hard pan: Presently, the aquifer system in the IGNP area is made up of a complex arrangement of layers of sand and clays. It has frequent lenses of silt, clay and kankar and occasional gravel horizons. This hard pan, a hydrological barrier, does not allow the percolated water to infiltrate deeper. The presence of impervious layers accompanied by absence of surface drainage outlet is a major factor in rise of the watertable and subsequent waterlogging also.

Soil related causes: The soils of the IGNP area form a part of vast former flood-plains mixed with sandy aeolian deposits of Ghaggar, Saraswati,

Chautang, Sutlej and eastern branches of Indus. The flood plain soils are highly stratified, deep, calcareous and generally associated with the problems of salinity and alkalinity. Aeolian soils are overlying the flood plains and other extensive areas of medium to high dunes. In the interdunal planes, occasional kankar or gypsiferous soils are present in the sub-soil within 1.5 m of the soil surface at places.

High water allowance: Excess application of water particularly during the initial years when the command area was not fully developed and constant excessive intense irrigation are two of the important causes of waterlogging. It is clearly evident now that in early years, availability of water was much higher than the actual requirements.

Gradient flow of water from the upper irrigated areas to low lying areas: The IGNP was designed after considering the topography that it flows down from higher altitude areas to lower altitude areas. The entire main canal and the feeder have no lift systems. This design has prompted all the surface water to flow downwards. It is assumable that if the higher altitude areas get waterlogged due to hydraulic pressure of water, the infiltrated sub-surface water might flow downwards as well. Gradient flow of infiltrated water has occurred from the upper Suratgarh and Hanumangarh to low lying area.

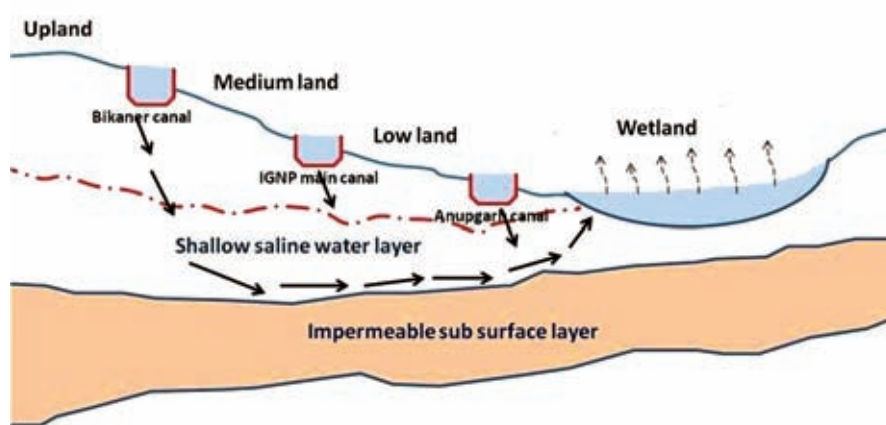
Development of secondary soil salinity: Secondary soil salinity is, in general, a process associated with irrigated areas that have poor water quality and improper soil and water

management. Inappropriate irrigation methods, poor water quality, insufficient or lack of drainage, and poor land and crop management are examples of anthropogenic factors inducing severe changes in soil salinity. However, the hydrologic processes causing the salt mobilization in primary as well as secondary forms of salinity are similar and the main difference between the two lies in the management options available to address the salinity risk.

The weathering of parent material of soil is the primary source of salts in irrigation water. In arid regions, owing to high evaporative conditions, salt concentration has gradually increased in the water sources and soil profile. It shows that soil salinization responds strongly to the effects of local meteorological factors. When evaporation intensity exceeds water infiltration, salts will eventually accumulate in the surface layer due to the uplifting effect of plant transpiration and evaporation on the salts dissolved in the phreatic aquifer. Consequently, intense evaporation becomes the main factor in relation to the dynamic status of the arid region.

Salt mobilization: Large scale irrigation development in the arid zone almost inevitably leads to the mobilization of part of the large primary salt storages in the surrounding land and/or in the underlying deeper strata. Some typical examples of the principal mobilizing mechanisms are depicted in figure.

Salt mobilization by leakage and seepage is very common from upland to low lying area. Salt mobilization to



Salt mobilization in the different landscape of IGNP command area

the soil surface is mainly attributed to convection due to upward water movement in response to evapotranspiration and diffusion due to a salinity gradient with depth. Both the soil texture and the layering of differently textured soils affect salt migration. The presence of impervious layers accompanied by absence of surface drainage outlet is a major factor in rise of the water table and subsequent waterlogging in lowland and wetland.

Reclamation of saline waterlogged soils

Surface and subsurface drains: The first requisite in the prevention or elimination of waterlogging and salinity problems is an adequate drainage system. Very often, the natural drainage in an area along with good water management is sufficient to eliminate excess water and to preclude the need for expensive subsurface drainage systems. However, almost every farmer who

applies water by surface irrigation should have adequate surface drainage facilities to remove excess water. Subsurface drainage may be accomplished either through the construction of open trenches or through buried clay or concrete tiles or perforated pipe. The design of subsurface drains is generally more complex than for surface drains and requires significant knowledge of groundwater hydrology.

Agroforestry: Several grass species have mechanism to tolerate high salt concentration in the root zone soil. Some of these highly tolerant grasses exclude the absorption of salts from the soil as well as deposit the translocated salts at points within the plant system which do not allow them to interfere in metabolic processes. *Bricharia mutica* is another salt tolerant grass, which can be grown even under prolonged waterlogged and salty conditions. The performance of these grasses in association with salt tolerant trees like

Alleviation of drought stress and saving of irrigation water

Evaluation of five endophyte bacteria (*Bacillus firmus* J22, *Bacillus subtilis* REN51, *Pseudomonas pseudoalcaligenes* SEN29, *Acinetobacter junii* J20 and *Pseudoxanthomonas mexicana* R47) with five levels of irrigation water (one, two, three, four, and 10 flood irrigations at field capacity after emergence) with cultivar TG 37A revealed that application of endophytes and four irrigations can provide as much pod yield (average 1,873 kg/ha) as that obtained with 10 supplementary irrigations after emergence (1,766 kg/ha) in summer 2017. Inoculation of endophytes improved the pod and haulm yield of groundnut at all level of irrigations. Maximum benefit was received by *Acinetobacter junii* J20 and *Bacillus subtilis* REN51, followed by *Pseudomonas pseudoalcaligenes* SEN29 with application of four irrigations. However, during summer, 2018, maximum benefit was accrued with application of *Bacillus firmus* J22 followed by *Pseudomonas pseudoalcaligenes* SEN29 with four supplementary irrigations. Thus, it would be feasible to reduce quantity (at least 30–50%) and frequency of irrigations (3–4) substantially for raising summer groundnut with endophytes and there is possibility of horizontal spread in areas with the application of endophytes with the available quantity of irrigation water.

Prosopis juliflora and *Acacia nilotica* in a unified agroforestry system, were studied. *Leptochloa* grass has a special characteristic that it starts disappearing when sodicity level in the soil decreases.

Biodrainage: It refers to a technique of lowering groundwater in waterlogged areas by raising tree plantations. This technique removes excess soil water through the process of transpiration by trees using solar radiation energy. It is a kind of preventive technique to avoid the development of salinity and waterlogging problems in canal command areas. The technique is highly useful when the soils are still in the process of salinization due to rise in groundwater level. However, if the soils are already salinized it has limited scope. The most promising species identified for biodrainage include *Eucalyptus*, *Populus*, *Casuarina* and *Bambusa*. Several programmes are in progress throughout the country to reclaim waterlogged areas in canal commands through biodrainage.

Soil amendments and water treatments: Soil amendments and water treatments often offer a practical and economical means for managing many problems common to saline and sodic soils. Since evaporation from the watertable deposits salt on the soil surface, breaking the hydraulic connectivity of

capillary up-flow by cultivating abandoned soil prior to and in between monsoon rains would lead to the reclamation of saline soil. In this strategy, monsoon rains provide leaching, while cultivation breaks up the hydraulic connectivity. In general, water applications are intended to alter the chemistry of irrigation water such that no further degradation in soil quality will occur. Soil applications of amendments are used for initial reclamation and long-term maintenance of soil quality. Gypsum and elemental S are used for reclamation of sodic soils.

Fertilizer management: Many fertilizers contain soluble salts in high concentrations. Therefore, the nutrient source, rate, timing and placement are important considerations in the production of crops. Salt indices for most commercial fertilizer products have been reported. For example, KCl has a salt index 205 times that of K_2SO_4 . Generally, band application of fertilizers with high salt indices near seedlings should be avoided. The salt content of other things added to the soil, such as gypsum and manures, also should be considered. Applying gypsum is a useful management practice for precluding sodium accumulation on the soil's exchange complex, maintaining soil structure and improving water infiltration. For salt-sensitive crops such as lettuce,

apply gypsum well before sowing so that soluble salts released during dissolution do not negatively affect production.

SUMMARY

Sustainability of irrigated agriculture in the IGNP command area is potentially threatened by progressively increasing soil salinity. Waterlogging and surface ponding has destroyed the natural environment of the wetland and has caused formation of saline soils. In eventual course, the affected land has become absolutely unfit for agriculture. The progressive increase in soil salinity in the lowland of IGNP area is attributed to unsustainable agricultural practices and inputs, quality of irrigation water, lack of advanced irrigation technologies and efficient drainage systems, and improper land management. Fertilization and irrigation practices should be based upon sound recommendations that consider the pedoclimatic conditions and crop demands. Cost-effective long-term mitigation measures and strategies are urgently encouraged in order to sustain a reasonable soil productivity and quality in irrigated arid region.

¹Scientist, ²Head, ⁴Technical officer, NBSS and LUP, Udaipur; ³Scientist, NBSS and LUP, Jorhat; ⁵Director, NBSS and LUP, Nagpur; Corresponding authors' e-mail: pravashiari@gmail.com

A Success Story

Improving resilience in flood prone area through submergence tolerant varieties

Dhubri district in Asom experiences a warm humid climate. Monsoon usually starts from June and continues up to early September. The district also experiences substantial amount of pre-monsoon rain starting from April. The average annual rainfall is about 2,233 mm. Flood is the major constraint affecting productivity of rice in the village Udmari. During 2017, the village experienced flood conditions during July and August.

Rice is the most important crop of Udmari village under Bilasipara sub-division of Dhubri district, Asom. Floods affect *kharif* rice during July–August and sometimes do not allow farmers to transplant rice seedlings in time resulting in very low yields. Flood tolerant varieties were demonstrated in the farmers' fields to popularize these situation specific rice varieties. The main characteristics of these varieties are: (i) Submergence tolerant varieties Jalashree and Jalkuwari can tolerate 12 to 15 days water submergence once seedlings are established; (ii) staggered planting variety Gitesh can be transplanted with 30 to 60 days-old seedlings; (iii) short duration varieties Luit and Kolong (105 days) can be transplanted up to last part of August and are also suitable for direct seeding with sprouted seeds if there is no time for nursery raising. These varieties are suitable for post-flood as well as pre-flood situations.

Adoption of these varieties resulted in about 50 to 60% higher grain yield than the existing varieties.