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TECHNOLOGY AND POLICY PATHWAYS FOR RECLAMATION OF SALT AFFECTED LANDS IN INDO-GANGETIC PLAIN

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Abstract: Salinization of irrigated lands is a major issue in India having serious implications on food security and environment. Appropriate technology packages-one for reclaiming water logged saline soils underlain by brackish water aquifers; and the other for sodic soils, mostly underlain by good quality groundwater, have been evolved. The evolution and out-scaling of these agro-technologies with supporting policies and institutions, is presented. The restoration of sodic lands was achieved through integrated management of rainwater (in farm pond and rice paddies), chemical amendment for neutralization of alkalinity, shallow tube wells for irrigation and drainage and land surface modifications to improve salt leaching and irrigation efficiency. The technology for reclamation of saline soils, evolved from multi-location field experimentation, with focus on shallow horizontal subsurface drainage system for monsoonal climate. The system required minimal pumping, and offered opportunity for practicing controlled drainage to reduce irrigation requirements in post reclamation years. The monitored data indicated favourable changes in hydrology, subsoil water quality (in case of saline water logged lands), land productivity, farm income and employment. The assessment of out-scaled land restoration programme revealed that, public policies in respect of energy for energizing tube wells, subsidy on chemical amendments and farm credit, accelerated the pace of technology adoption. The institutional arrangements – research institutions, land reclamation corporations and international organizations with strong linkages at country level; and the users' associations, self-help groups and cooperatives at village level, very effectively supported the land reclamation, leading to transformative socio-economic changes.
Keywords: salinization, reclamation, drainage, technology, policies

1. INTRODUCTION

Soil salinity in irrigated lands, which is of common occurrence in India, has two main manifestations-saline soils with high concentration of soluble salts within the root zone due to occurrence of high water table in areas underlain by brackish water; and the alkali soils having high concentration of sodium and magnesium in exchangeable form. According to recent estimates salt affected soil are spread over 6.73 Mha, with serious implications on Indian economy (CSSRI, 2010, Joshi and Jha, 1992).Salinity and water logging which reduces land productivity and make land uncultivable, in case of high salt concentration, can be reclaimed for crop production mainly through improved drainage. Globally, horizontal subsurface drainage (HSSD) has been found to be quite effective and eco-friendly technology in areas with poor quality groundwater. In India, experimentation with HSSD began in 1873, when stone and tile drains were laid out to reclaim the lands in the Northwest. In the first quarter of 20th century, four major studies - one at Manjri (Maharashtra), Baramati (Maharashtra) Chalkanwali (now in Pakistan), Nissang (Haryana), were conducted (INDP, 2002). The significant observation from these studies was that though the installed system failed to keep water table below the desired levels during critical periods, yet it provided significant benefits in terms of increased crop yield over the un-drained cropland. The technology development for reclamation of waterlogged saline lands, which can be named as shallow horizontal subsurface drainage (SHSSD) described in subsequent sections has drawn support from these seminal studies.

2. MATERIAL AND METHOD

Like saline soils, alkali soils also have been a major concern as reflected in Reh Committee Report of 1879 and the scheme for experimentation recommended by this committee, as reported in Tyagi and Minhas (1998), were documented by Leather (1906,1911). Leather, on the basis of experimentation on alkali soils in United Province and Punjab, reported that "The only methods feasible are good cultivation practices-- and application of gypsum". Unfamiliarity with the cation exchange phenomena and lack of government support for chemical amendment, reclamation of alkali soils did not make much headway. But researches initiated by Leather and subsequently by Indian researchers as reported in Tyagi and Minhas (1998) provided basis for currently evolved reclamation technologies. Alkali land reclamation technology has been out-scaled in large area covering more than a million ha of degraded land.

Experience with technology adoption in the past had shown that capital intensive natural resources management technologies do not go very far without supportive policy environment by way of mainstreaming them in development programmes. Faced with the challenge of ensuring food security with declining land resources and growing population, institutional restructuring and policy initiatives were undertaken to promote salty land reclamation (INDP, 2002; Tyagi and Singh, 2009, Joshi and Jha, 1994). This paper aims at presenting the current status of technology which has been developed and refined though multi-location field experimentation and its out scaling with supportive policies, public sector institutions and grass root organizations.

3. RESULTS

≡ Technology for reclamation of alkali land

Major advancements in salinity research are due to US Salinity Research Laboratory, Riverside California; Institute of Soils, Hungary, and Central Soil Salinity Research Institute (CSSRI), Karnal, India (Szabolcs, 1977; Tyagi and Minhas, 1998; Wallender and Tanji, 2011). The researches at CSSRI and at several state agricultural universities in India have led to problem specific technology development in the last 40 years (Agarwal et al, 1982; Abrol et al, 1988; Tyagi and Minhas, 1998; and CSSRI, 2004). The solution of alkalinity/sodicity revolves mainly around application of chemical amendments along with use of appropriate crops and varieties and good agronomic practices. The current emphasis for reclaiming salt-affected soils is on harnessing the synergy of built-in plant salt tolerance and the chemical amendments (Singh et al, 2004)

≡ Innovations in sodic land reclamation technology and constraints

It is true that application of chemical amendments, which was mostly gypsum or in some cases pyrites, but Indian researches on alkali land reclamation made a number of innovations leading to reduction in cost and improvement in efficiency of water use.

≡ Reduced requirement of chemical amendments

A major advancement in technology of alkali land reclamation was the field tested recommendation on the reduction in doses of chemical amendment- a major item in reclamation cost. But field experiments conclusively established that gypsum requirement could be reduced by 50 percent of what was required for complete neutralization of exchangeable sodium, without any appreciable loss of crop productivity over a time span of 3-5 years (Abrol et al, 1988). Once initiated, the reclamation goes in auto mode taking advantage of calcium carbonate present in calcareous soils occurring in northern India. Advantage of salt tolerant crop varieties to reduce the requirements of chemical amendments was successfully tested and out-scaled (Singh et al, 2004, Tyagi and Singh, 2009).

≡ Land shaping and irrigation application system design

Standards for land leveling, grading and design of surface irrigation application methods for rice-wheat, which is the most prevalent cropping pattern, were evolved and propagated (Tyagi, 2007). It was established that light and frequent application of irrigation water was possible, if the leveling index (departure from the required surface elevation across the irrigation unit) was within limits (Tyagi, 1884). A major issue in design of surface water application was the conflicting water management demands of rice, which required uniform water depth of standing water across the rice paddies, as against the requirement of zero submergence in case of wheat to avoid aeration stress. The problem was resolved by adopting mildly sloping border check basins for wheat, which were compartmentalized into 2-3 check basins along the length, and were equipped with an overflow device on the earthen bunds across the width at desired elevation (Pandey et al, 1977).

≡ Farm drainage system

A three tier system of drainage, for taking care of surface water stagnation ;involving storage of rainwater within rice paddies ,storing part of the surplus rainfall in on-farm reservoirs ,which also served as source of irrigation water, and channelizing the remaining runoff into regional drains, was conceived and implemented. The permeability of alkali soils being extremely low, provision of horizontal sub surface drainage (HSSD) system for lowering the sub soil water level was not a very cost effective option. An innovative solution of this problem was found in shallow tube wells for every 2-3 hectare land, which served the dual purpose of providing vertical drainage, and of serving as dependable source of irrigation water. Recently another innovation has been introduced in the form of dugout ponds in water logged alkali lands, which collects subsoil water from the surrounding area resulting in lowering of water table, which in turn serves as source of irrigation water (CSSRI, 2010). Earth from dugout ponds is put on embankments, which are used for raising commercial crops and this has raised the benefit cost ratio of the reclamation technology.

≡ Technology for reclamation of waterlogged saline land

In India the need for provision of drainage and development of appropriate technology for reclamation of waterlogged saline lands in irrigated areas, has been emphasized as early as 1928 (Royal Commission, 1928) and has been subsequently emphasized by several other commissions (Irrigation Commission, 1972; National Commission on Agriculture, 1976), the real attempts to had to wait till 1982. These efforts initiated by Central Soil Salinity Research Institute (Rao et al, 1986), got further strength from Dutch collaboration in the form of Indo-Dutch project Pilot Area Drainage Research (INDP, 2002), Haryana Operational Pilot Project (HOPP, 2001), Rajasthan Agricultural Drainage Project (RAJAD, 1995)

Intensive monitoring of soil salinity, water table, sedimentation in drains, effluent quality and its reuse, and crop yields was undertaken for periods ranging from 3 to 12 years. These efforts, which are documented in several technical bulletins and research publications cited in Ambast et al (2004) and Gupta (2014), led to evolution of appropriate technology for reclamation of irrigated water logged saline lands in arid regions. The emphasis in these efforts was to keep focus on economic and environmental aspects, unlike the drainage in humid regions, where technical design criteria was given importance. The philosophy and innovations are briefly discussed.

≡ Technology innovations and constraints

The technology innovations for reclamation of waterlogged lands are based on the premise that in arid regions which are water scarce, and where water logging is the result of water percolating into the sub soil over the years, the aim of drainage should not be removal of large quantities of water of water in short time. The reduced drainage will lead to reduced irrigation requirements due to increased use of sub-soil water.

≡ HSSD with shallow depth and wider spacing

The drainage system for large scale implementation should aim at minimization of cost rather than maximizing crop yield with faster water table drawdown. Experience with operation of drainage system over a period of 12 years at Sampla in Haryana has shown that under the agro-climatic conditions prevailing in Northern India, close to 70 % of the root salt was leached after 5 years resulting in insignificant difference in yield of wheat crop in plots with drain spacing ranging from 25m to 75m after 5 years (Figure 1). Further, for field crops like wheat, maize, cotton etc., it did not make much sense to install HSSD at deeper depths, as this would increase cost without any commensurate gains in salinity profile of the crop root zone or crop yields. Therefore, for light textured soils of arid regions of Rajasthan, from economic and environmental considerations, the recommended depth and spacing of HSSD system were placed at 1.1 m, and 100-150 m. The corresponding values of these parameters for medium textured soils of semi-arid regions of Haryana were 50-100 m (INDP, 2002).

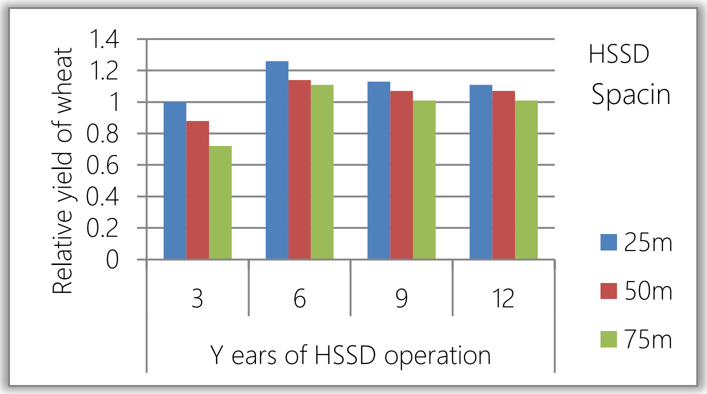

Figure 1. Change in relative yield of wheat under different drain spacing in post installation years (Data: INDP, 2002)

≡ Salinization and desalinization in monsoonal climate and greater reuse of drainage effluents

The salinity of drainage effluents from horizontal subsurface drained lands decreased with time and this increased the crop productivity and reduced the need for disposal of effluents. Monsoonal rains play a crucial

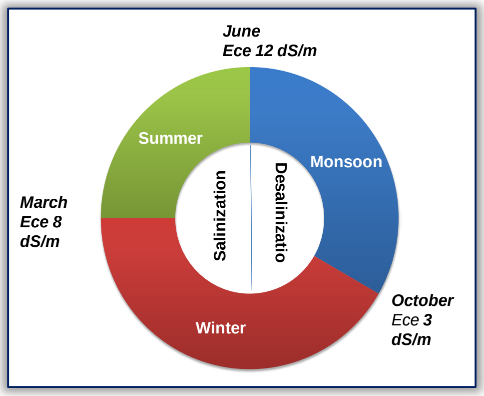

Figure 2. Soil salinization and desalinization cycle in monsoon climate

role in desalinization cycle and in regulation of seasonal salt balance in the root zone. The opportunity of continuous leaching and prevalence of higher moisture regime in the crop root zone in HSSD drained land resulted in higher crop productivity (Tyagi, 2011). Of course, distribution of monsoon rainfall, seasonal root zone salinity variation and long term aquifer salinity balance remain important considerations.

≡ **Disposal of saline effluents during monsoon season**

Salt laden drainage effluents often create environmental issues in disposal sites. This problem was effectively solved by organizing pumping for water table control mostly during rainy season (June-September) when rivers are in high flows. For example, the flow in River Yamuna, which drains a large part of the waterlogged in Haryana, the flow varies from June-September which effects huge dilution, with practically no adverse environmental effects. On the other hand, flow during winter months (December–March), when river flow is only the disposal of effluents is only through reuse in irrigation, which is favored by the desalinized post monsoon soil profile and the low evaporative demands during the winter season.

≡ **Socio-economic impacts of land reclamation**

One of the major benefits of land reclamation has been the generation of additional income and employment. Intensification and expansion of cultivated land were the major routes through which income of the order of US $ 297/ha/yr (Tyagi and Singh,2009) and additional employment of about 165 man-days ha^{-1} in the first year of alkali land reclamation (Joshi,1994). The incidence of poverty saw a sharp decline of the order of 40 percent. The transfer of land ownership right to the cultivators; and its consolidation encouraged farmers to make investment in land improvement; and in the long run it saw several fold increase in land value. The increased participation of women through self-help groups improved their self-confidence and made them the agents of change.

≡ **Evolution of institutions and policies for out-scaling technologies**

The technologies need the wings of appropriate policies, institutions and the long term funding to travel from labs to land at faster speed; and the case of land reclamation technologies was no different. The major components of alkali land technology were established in 1960s, but application had to wait, till the evolution of public policies, institutions and funding support. The major institutions and policy initiatives are briefly discussed.

≡ **Establishment of land reclamation corporations**

Institutionalized arrangement for implementation of reclamation programme was a significant departure from the past. The adoption of land reclamation technologies by the farmers began with demonstrations on farmers' fields and their success persuaded the state governments to establish land reclamation corporations with the mandate to establish infrastructure for soil testing, land leveling, and supply of inputs at government controlled prices. Establishment of command area development authority (CADAS) as early as 1974 with the mandate to improve irrigation water utilization through micro level infrastructure development and efficient farm water management played an important role. For example, the reclamation of water logged saline lands in the state of Rajasthan in black soils region of Kota was undertaken by Chambal Command Area Authority with Canadian International Development Agency (CIDA) (RAJAD,1995).

≡ **Community based organizations**

In the state of Uttar Pradesh, the sodic soil reclamation projects were implemented in a participatory mode based on the principles of: transparency, equity, accountability, decentralized decision making, and human and institutional building (World Bank, 2008). A management structure among the farmers was created to promote participation and share responsibilities. Water Users Groups, Land Drainage Associations, Self Help Groups, which were established in different projects played very crucial role (Tyagi and Singh, 2009). The nongovernmental organizations (NGOs) also assisted in spread of technology by increasing the awareness amongst the farming community.

≡ **Subsidy and credit policies**

Land reclamation is a capital intensive activity, which small and marginal farmers could not have taken without government support. The subsidy on chemical amendments, land shaping and, electricity etc.; and the credit for installation of tube wells were the major policy instruments which supported land reclamation. The policy of extending credit for agricultural inputs at nominal interest rates proved very helpful (Tripathi et al, 2004). The rural electrification programme that facilitated development of farmers' owned shallow tube wells for irrigation, took care of high water table. As a flagship programme of the salinity affected states, the land reclamation was mainstreamed into development programmes of the governments for large scale implementation. The impact of credit, subsidy and extension had very significant effect on technology adoption (Sharma,1997)

≡ **Public investment in land reclamation**

The government of India launched a number of special schemes for reclamation of salt affected land under which budget provisions for technology adoptions were made. To support these programmes National Bank for Agriculture and Rural Development (NABARD) provided refinance assistance for reclamation of saline soils, under land development activity. A very crucial role was played by international lending agency like the World Bank and bilateral project assistance by the European Commission for up-scaling land reclamation in sizeable proportion (Tyagi and Singh, 2009).

≡ **Research and development organization**

A number of public funded research organizations, such ICAR Salinity Research Institute at Karnal, and Agricultural Universities in the states, which were responsible for technology development also assisted in human capacity development and technical backstopping. The capacity building exercise covered village and district panchyats (local self-government organization), non-government organizations (NGOs), line departments and support agencies etc. Several international organizations including, World Bank, FAO-UNDP, and ILRI-ALTERA of Netherlands were partners in refinement and up-scaling of the reclamation technology.

4. CONCLUSIONS

The sustained research efforts over several decades have led to development of appropriate technologies for rehabilitation of salt affected waterlogged lands in the Indo-Gangetic Plain. The technologies are technically robust, economically viable and environment friendly. Large scale technology adoption has led to change from subsistence type of farming to more profitable agriculture. The favorable policy and institution regimes that were put in place have enabled the technology to make remarkably favorable impacts on capital formation, factor productivity, and crop yield. These changes ultimately led to positive socio-economic transformation in the society. The immense environmental benefits in the form of reduced floods in alkali watershed, removal of water logging and improved sub soil water quality in saline land, have made the development and implementation of land reclamation technology a win-win proposition.

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