Sustaining Agriculture in Disaster Prone Coastal Lands through Subsurface Land Drainage Technology (SLDT)

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ABSTRACT

The vast arable land adjacent to Indian coastline perpetually faces the problems of waterlogging and salinity. The occurrences of sea related disaster is common almost every alternate year in one or more of the coastal states. The events like cyclone, super cyclone, hurricane and tsunami further add to the problems of soil salinity. The salinity-induced land degradation causes very low crop yield, even after adopting high yielding varieties and applying other inputs. And this environmental condition worsens the agriculture dependent economy of the rural coastal people further. In this article, the authors endeavour to draw the attention of the nation builders and policy makers towards the worldwide proven subsurface land drainage technology (SLDT) that had been in vogue in developed world extensively for the remediation of coastal land in an accelerated manner. The authors propose creation of a large-scale subsurface land drainage infrastructure (SLDI) and its integration into the network of canal irrigation system in coastal irrigated plains to achieve manifold increase in agricultural production and upkeep of sustained soil health.

Keywords: coastal agriculture, land remediation, SLDT, SLDI, sustainable development

Introduction

India has about 7000 km long coastline encompassing eight states. The vast arable land adjacent to this coastline perpetually faces the problems of waterlogging and salinity. The occurrences of moderate to heavy cyclones are common almost every alternate year in the coastal states. Such cyclones cause seawater inundation of agricultural land adding further salts to the already saline land. As a result, the agricultural productivity of the arable coastal lands has been generally low, causing

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the agriculture-dependent community to slide below the poverty line. The frequency of occurrences of cyclones, high tides and other disastrous events do not allow the coastal population to grow above the base of the poverty line.

The super cyclone that struck coastal Orissa in 1999 had made huge tracts of agricultural land unfit for cultivation. According to the Orissa state department of agriculture, the anticipated loss of 1.8 lakh ton of paddy crop in lowlands amounting to Rs. 95.4 crore; was mainly ascribed to the salinity factor (The Hindustan Times, December 18, 2000). Most of the affected lands could not even support growing paddy nursery for transplanting. In areas where seedlings could be raised, stunted plant growth was reported due to high soil salinity.

Recent tsunami waves of December 26, 2004 have destroyed thousands of hectare arable land in two districts namely; Cuddalore and Nagapattinam of Tamil Nadu. The soil survey reports suggest that seawater has infiltrated to a depth of 60 – 90 cm from soil surface and totally affected the crop root zone. With such an instantaneous event, a lot of arable lands have been salinized overnight and with the resulting soil salinity no paddy crops could be cultivated unless the entire soil is leached by fresh water. Land reclamation might take 3 to 4 years if the poor farmers depend upon leaching of salts by natural rainfall.

The situation is identical in coastal Andhra Pradesh and coastal Kerala where salinity-induced land degradation permits only very low rice yield, even after adopting high yielding rice varieties and applying other inputs.

The question is how to improve the soil expeditiously and maintain its normal health in coastal arable lands against the threat of frequently occurring natural calamities by way of seawater intrusion due to excessive tidal inflow perpetrated by hurricane, cyclone and tsunami-like causes.

This paper endeavours to draw the attention of the nation builders and policy makers towards the worldwide proven subsurface land drainage technology (SLDT) that has been one of the most effective measures for land reclamation in an accelerated manner and in maintaining the soil health on a sustainable basis. The authors propose creation of a large-scale subsurface land drainage infrastructure and its integration into the network of canal irrigation system in coastal irrigated plains to achieve manifold increase in agricultural production and upkeep of the soil health on a long-term basis.

Concept of Sustainable Development

Sustainable development is the practice of simultaneous exploitation, management and conservation of the natural resource base through appropriate technological interventions that ensures fulfillment and continued satisfaction of human needs -

food, water, shelter, clothing and fuel for the present and the future generations. Sustainable development, naturally therefore, has to be environment-friendly, technically appropriate, economically viable, and socially acceptable.

Sustainable development meets the needs of the present population without compromising the needs of future generations. This conceptual approach is accepted worldwide and fully applies to the use of land and water resources in agriculture. Land resources are limited for a country and particularly in the coastal region, as there is no scope for expansion into the sea. Land resources in irrigated inland regions also suffer from poor water management, flood hazards, salinization and drainage problems. These lands have the potential for increasing food production if suitably treated. But the coastal ecosystem is more fragile and requires a greater and sustained effort to maintain the ecological balance and increasing agricultural productivity without disturbing the balance.

Irrigation has been crucial in increasing crop production by eliminating plant water stress. Irrigation development, while contributing to the economic well being of the farmers of India, also has given certain adverse side effects *viz.* waterlogging and soil salinity. Interest in sustainable development has arisen as a result of regional, national and subsequently, global concern about the environment. The concept of sustainability is not new but has recently received considerable attentions, especially while comparing the irrigated agricultural practices between the developed and the developing countries of the world. In the context of agriculture, the essence of the concept of sustainability is the legacy in the form of natural resource assets that the present generation should leave for the use of the future generations.

Cause and Effect

An example is considered here to highlight the problems of coastal agriculture. In the last 30 to 35 years the soil properties in Krishna district, the granary of Andhra Pradesh, has undergone a sea change because of the indiscriminate use of fertilizers and pesticides, affecting the overall soil health and the total agricultural production (Deccan Chronicle, February 2, 2001). The determinants of agricultural production such as the soil physical and chemical properties, rainfall, crop varieties, the cultural practices, the causes and the severity of drainage problem, vary widely from place to place in the large coastal region of the country. Depletion of micronutrients has been reported from several coastal districts of West Bengal, Orissa, Andhra Pradesh and Tamil Nadu. In Andhra Pradesh, laboratory tests on 1000 soil samples drawn from 50 *Mandals* with 20 samples from each *Mandal,* which are in close proximity of the Bay of Bengal, suggest that the level of soluble salts in soil has increased manifolds (Deccan Chronical, February 2, 2001). At the same time, the soil pH is also reported to be in the range of

6.8 to 9.1 in coastal villages of Madalapattu, Gunduuppalavadi, Subbauppalavadi and Nananedu of Tamil Nadu, after Tsunami catastrophe. At some pockets, the soils there have become unfit for cultivation. The low organic carbon content in the soil adds another dimension to the problem. These above mentioned factors caused improper soil drainage and reduced microbial activity resulting into deterioration of soil health to a great extent. A hard pan is reported at many places at a depth of 1.0 to 1.5 m from the soil surface. This has developed due to excessive accumulation of calcium and other salts present in artificial nutrients. This hard pan prevents the penetration of the root system and restricts natural deep drainage, which damage the garden lands (Deccan Chronicle, February 2, 2001). As, fertilizer and chemical inputs are far more under irrigated agriculture than in rain-fed agriculture; the above are some of the direct consequences of intensive irrigated agriculture (I I A) in the coastal region.

The land drainage problem in most of the cases are caused by restricted natural outflow due to the combined effects of flat topography and heavy downpour in the catchment areas, silted natural or man-made drains, higher downstream water level and sea water back flow during high tides, cyclones and tsunami waves. The elevation of the coastal agricultural lands is close to the sea level (or even below sea level as in the case of *Kuttanad* in Kerala). Not only the overland flow is slow, even the drains carry discharge very slowly towards the sea. When these areas suddenly receive large quantity of water, which may be due to high rainfall associated with cyclones or hurricane, water release from upstream reservoirs or accumulation of runoff from the higher reaches, all of which are uncontrollable to a great extent, the water naturally stagnates over the cultivated lands for a long duration and damages the standing crop.

Quite often, the largest depth of land submergence may go up to 2 m which declines slowly, keeping the paddy plants submerged for long enough duration to destroy them completely. *Kharif* cultivation, therefore, in these areas becomes risky and can succeed only in some years when the magnitude of the incoming water from different sources are small. Seawater back flow during high tides brings in considerable amount of dissolved salts, which contaminates the local water bodies and may also inundate the land. This is a recurring phenomenon and increases the soil salinity. Therefore, waterlogging and salinity are two major problems faced by the farmers of the coastal region. Waterlogging problem is dominant during the monsoon season as compared to salinity, as there is a dilution effect of the large volume of incoming water on the salt concentration. Salinity problem is dominant in the dry season due to high evapotranspiration, contaminated waters in the local water bodies and lack of adequate fresh surface or ground water for irrigation application and salt leaching.

The rice productivity under the above conditions is usually less than 1 t ha-1. When adequately drained, all kinds of coastal soils offer good prospects for agricultural production (Devadattam and Ramesh Chandra, 1995; Rycroft and Amer, 1995; Bhattacharya, 1996). Subsurface drainage is an appropriate and proven solution to the predominant problem of salinity and waterlogging in the coastal tracts.

What is Subsurface Land Drainage Technology ?

Conventionally, subsurface drainage is the removal of excess water and dissolved salts from below the soil surface as groundwater flow towards a network of buried drains. This technology ensures a conducive crop root zone environment and is adopted when the natural subsurface flow is inadequate to control waterlogging and soil salinity in the crop root zone. The process by which the applied water washes the salts out of the root zone is called leaching. Thus, in saline but non-waterlogged lands also subsurface drainage is useful provided there is enough fresh water available to apply over the land for dissolving the accumulated salts in the crop root zone and leach them down, to be carried away by the buried pipe drainage network. Thus, subsurface drainage technology is adopted for either or both water table control and leaching out salts from the soil profile. The process of removal of excess subsurface water and salt solutions through the soil pores is slow and, therefore, subsurface drainage is not the answer to evacuate vast amounts of surface accumulated water during the monsoon season. For this, surface drainage is the solution.

Keeping in view the soil salinity as a major constraint in coastal agriculture, leaching out of excess salts and other harmful chemicals from the soil surface and from the crop root zone would prove to be useful to the farmers. A combination of surface salt washing through limited surface drainage in the *rabi* season and subsurface drainage to leach out the profile salts from the root zone are likely to remove most of the constraints to agriculture in the coastal regions. The surface salt washing alone, without any subsurface drainage may improve the chemical composition of the surface soil, which should help in proper establishment of transplanted rice or in the germination of broadcast paddy seeds. With the support of irrigation by fresh water or even with saline water of permissible salt concentration, reasonable paddy yields are assured. Following the adoption of subsurface drainage for leaching out of excess salts, growing crops other than rice may also become possible, which in turn may increase the agricultural production at least 5 times (Singh *et al.*, 2001) and may provide more crop cultivation options.

Impact of SLDT on Nitrate Load in Ground Water

The spatial and temporal variation of nitrate load in ground water in subsurface drained fields were studied for three years and the results suggested that only the most stable form of nitrogen i.e. nitrate, was found in all the ground water samples (Singh *et al.*, 2002). The cumulative accumulation of nitrate in ground water, after long-term usage of land, water and fertilizer, was found to be lower than the threshold value. The reasons for very low concentration of nitrate in ground water were two. The first was a shallow water table situation and the second was effective interception of the nitrate load by the subsurface drainage system. This finding suggested that the subsurface drainage system prevented ground water from nitrate contamination, besides reclaiming the land by salt leaching. Thus, adopting the subsurface drainage technology can reduce the risk of nitrate pollution in ground water on a long-term basis.

Effect of Drainage on Nitrogen Uptake and Crop Yield

The nitrogen uptake by rice plants was observed highest for those plants, which grew in the least saline environment i.e. in the subsurface drained fields. This was the direct consequence of the reclamation by subsurface drainage. Also, it was found that the mean nitrogen uptake by the rice hills planted in the non-reclaimed area was just half of what was observed in the area reclaimed by the subsurface drainage. As a result of poor nitrogen uptake in non-reclaimed area, the rice grain yield was 25 to 30% of the potential yield observed in reclaimed area (Singh *et al.*, 2001).

Salt Accumulation in Root Zone Soil Layer in Absence of Drainage

Coastal clay soils are prone to quick secondary salinization if the root zone soil layer is not continuously leached by sub surface drainage. A study conducted in the subsurface drained and undrained rice fields at Machilipatnam, Andhra Pradesh showed that the soil salinity in 0-15 and 15-30 cm layers, in a span of 3 years, had increased approximately 8 and 5 folds, respectively in the absence of leaching by subsurface drainage. The salinity in 15-30 cm layer in which maximum root activity of the rice crop takes place, increased to over 8 dS m-l in one year and exceeded the critical value of salinity for the rice cultivation when the subsurface drainage did not operate. It was further found that 25.2 Mg ha-l yr-1 salt was added in the root zone with an average moisture depletion of 2 mm d-l in 2 to 3 months of dry season. In the process of salinization an annual increase of 38% in Exchangeable sodium percentage (ESP) of root zone layer was estimated.

The Cost of the SLDT

At the current price level, the approximate one-time investment required is Rs. 50,000/- per hectare for a subsurface drainage system with a drain spacing of about 50 m and average drain depth of 1 m. This includes the cost of related structures e.g. laterals, collectors, inspection chambers and sump etc. The operational cost of subsurface drainage system will be additional if gravity outfall is not available and the leachate is to be pumped out.

Future Prospects

Considering the causative factors of waterlogging and salinity mentioned above, theoretically all, except the mean sea level (m.s.l.), the cyclone and tsunami waves, but their ill effects could be controlled by adopting subsurface drainage technology. Leaching of salt solutions through a subsurface drainage system can reduce salinity. Even seawater inflow can be controlled by sluicing and, in fact, so is being done in Kerala over a few natural drains joining the Arabian Sea. The important questions are, at what cost and for who all these activities are? These are essentially for natural calamity prone poor coastal farmers. Thus, the financial and infrastructures requirements to accomplish control over the causative factors (high tides, cyclones and tsunami) and also the overall economics of such an endeavour are the important issues for consideration.

To enable formulation of a comprehensive and sustainable development plan or blueprint for coastal plains (approx. 3 to 4 million hectare), an exhaustive assessment of the aerial extent of the affected lands, tangible and intangible losses and /or gains have to be compared with the public funds released from time to time for short-term relief to the affected coastal community. Experiences with SLDT in Canada, France, Germany, The Netherlands, USA and All India Coordinated Research Project on Drainage in several states suggest that it would be worthwhile to go for it for a long-term remediation of coastal lands that are subjected to frequent build up of soil salinity and waterlogged conditions due to various factors. The long-term trade-off may go in favour of creation of large-scale subsurface land drainage infrastructure (SLDI) for the lasting solution of the problems of coastal agriculture.

In order to attempt for such a solution, databases may be created through the remote sensing agency for aerial extent and the depth of inundation at macro level. Other minute details of ground truth may be established locally and organized in GIS environment. These modern tools and know how are very efficient in organizing and managing the databases which may be utilized in planning and feasibility studies. Initially, it may be necessary to adopt drainage and related interventions on a pilot basis at multi locations based on the prioritization of the affected areas into smaller regions (Drainage Blocks) for evaluation of the economics and the sustainability of the adopted interventions.

The SLDI proposed in this paper will not wish away the causes of natural disasters. They would visit and revisit governed by the complex natural phenomena. But if SLDI is in place, the ill-effects of the natural disasters could be mitigated within a year, as against the three to four years needed for reclamation of the land by the slow natural processes.

Conclusion

At the present stage, most of the possible solutions to the problems of the coastal regions in vogue are highly location specific, primitive and of short-term or ad-hoc in nature. Their economic viability on adoption over a large area has not been worked out. There is an urgent need of inclusion of the network of drainage (both surface and subsurface) system by making investments in creation of agricultural land drainage infrastructure in the already existing net works of canal irrigation system in coastal plains. It would be worthwhile to consider a permanent/long-term solution to the drainage related problems of natural calamity prone areas by investing towards agricultural land drainage infrastructure, should the benefit cost analysis permit. Technical experts strongly feel that Water management programme coupled with large scale SLDI may contribute to establishing a more diversified, competitive and sustainable irrigated agriculture in coastal region, and surely contribute to rural development, rural well being, employment generation and poverty alleviation in coastal areas. It is argued that there is ample scope of increasing the productivity of the coastal lands by installing large-scale subsurface land drainage systems network on the coastal regions.

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