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Subsurface drainage to combat waterlogging and salinity in irrigated lands in India: Lessons learned in farmers' fields

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ABSTRACT

The introduction of irrigated agriculture in the arid and semi-arid regions of India has resulted in the development of the twin problem of waterlogging and soil salinization. It is estimated that nearly 8.4 million ha is affected by soil salinity and alkalinity, of which about 5.5 million ha is also waterlogged. Subsurface drainage is an effective tool to combat this twin problem of waterlogging and salinity and thus to protect capital investment in irrigated agriculture and increase its sustainability. In India, however, subsurface drainage has not been implemented on a large scale, in spite of numerous research activities that proved its potential. To develop strategies to implement subsurface drainage, applied research studies were set-up in five different agro-climatic sub-regions of India. Subsurface drainage systems, consisting of open and pipe drains with drain spacing varying between 45 and 150 m and drain depth between 0.90 and 1.20 m, were installed in farmers' fields. The agro-climatic and soil conditions determine the most appropriate combination of drain depth and spacing, but the drain depths are considerably shallower than the 1.75 m traditionally recommended for the prevailing conditions in India. Crop yields in the drained fields increased significantly, e.g. rice with 69%, cotton with 64%, sugarcane with 54% and wheat with 136%. These increases were obtained because water table and soil salinity levels were, respectively, 25% and 50% lower than in the non-drained fields. An economic analysis shows that the subsurface drainage systems are highly cost-effective: cost–benefit ratios range from 1.2 to 3.2, internal rates of return from 20 to 58%, and the pay-back periods from 3 to 9 years. Despite these positive results, major challenges remain to introduce subsurface drainage at a larger scale. First of all, farmers, although they clearly see the benefits of drainage, are too poor to pay the full cost of drainage. Next, water users' organisations, not only for drainage but also for irrigation, are not well established. Subsurface drainage in irrigated areas is a collective activity, thus appropriate institutional arrangements for farmers' participation and organisation are needed. Thus, to assure that drainage gets the attention it deserves, policies have to be reformulated.

1. Introduction

Although India, in recent years, is emerging as an industrial nation, agriculture remains a key sector in India's economy, contributing about 35% of the gross domestic product and employing 72% of its adult population (ICID, 2003). Annual agricultural growth has been modest at 2.6% per annum over the last 25 years (IDNP, 2002a). The average Indian farmer is a

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Table 1 – Recommended drain depth-spacing combinations for various agro-climatic regions in India

Agro-climatic region	Drain depth (m)	Drain spacing (m)	References
Semi-arid coastal plains of Andhra Pradesh	1.4	10–15	Rao (1994)
Semi-arid Trans-Gangetic plains of Haryana	1.4–1.75	60–100	Rao et al. (1995) and Achthoven et al. (2000)
Humid coastal plains of Kerala	1.0	30	Mathew et al. (2003)
Semi-arid plains of Gujarat	1.0	20–40	Parikh et al. (1999)
Arid lands of Rajasthan	1.0–1.5	30–60	Aheer et al. (1997) and RAJAD (1996)
Sub-humid regions of the lower Gangetic plains in West Bengal	1.75	15–45	Rao (1994)

smallholder owing less than 1 ha of cultivable land, harvesting one crop a year and striving to harvest a second crop (Pangare et al., 2006). Development plans of the Government of India and State Governments give priority to alleviate poverty and to create employment, particularly in rural areas. Agriculture depends largely on the monsoon; rains, however, are unevenly distributed in time and space. To sustain agricultural production against these vagaries of rainfall, irrigation has been created in about 57 million ha, covering about 34% of the total arable land (ICID, 2003). The introduction of irrigated agriculture, however, has resulted in the development of the twin problem of waterlogging and soil salinization. Considerable areas have either gone out of production or are experiencing reduced yield. With the misconception, that the more they irrigate, the more yield they will get, farmers apply huge quantities of canal water, e.g. in Segwa, one of the study areas, the actual supply of 2924 mm/year by far exceed the crop water requirements of 1912 mm/year, based on a 65% application efficiency (Ritzema et al., 2003). Furthermore, the introduction of canal irrigation not only brings the much-needed water, but also imports salts as irrigation water contains considerable amounts of salt. In Segwa, the canal water has a salinity of 0.3 dS m^{-1}, thus an irrigation gift of 1912 mm/year will add 3.7 t ha^{-1} of salts to the soil profile. It is estimated that nearly 8.4 million ha of the irrigated lands are affected by soil salinity and alkalinity, of which about 5.5 million ha is also waterlogged (IDNP, 2002a).

Drainage, as a tool to combat waterlogging and salinity, has not been given importance as much as irrigation by the individual farmers as well as the governmental agencies. In only about 2.5 million ha of the affected lands some sort of drainage system has been installed (ICID, 2003). Subsurface drainage was introduced only recently. Most systems are less than 15 years old and widespread adoption did not take place (Gupta, 2002). So far subsurface drainage systems have been installed in about 18 000 ha (Nijland et al., 2005). For the prevailing conditions in India, subsurface drainage systems with rather deep drains, i.e. drain depth >1.75 m, are recommended (Gupta, 2002). This recommendation is based on the critical depth concept, i.e. to avoid secondary salinization caused by the upward flux of water once the water table rises to 2–3 m below the soil surface (Gupta and Gupta, 1997). These deep drains have their drawbacks. Firstly, the deeper the drain, the higher the installation cost. Secondly, deep drains can only economically be installed by mechanical construction practices, ignoring the huge employment needs of the rural poor. Thirdly, deep drains lower the water table during the irrigation season. These lower water tables reduce the rate of capillary rise and thus increase the burden on the already poorly performing irrigation systems. Research in countries with similar conditions, i.e. Egypt and Pakistan, indicates that shallower drains can maintain salinity levels within safe limits for crop production (Abdel-Dayem and Ritzema, 1990 and Ritzema et al., 2007). Research conducted in various agro-climatic regions in India also suggested that the drain depth can be reduced, although the recommended drain depth/spacing combinations vary considerably between the various agro-climatic regions (Table 1). Although sound theories now form the basis of modern drainage systems, there will always remain an element of art in land drainage. It is not possible to give beforehand a clear-cut theoretical solution for each and every drainage problem: sound engineering judgement on the spot is still needed, and will remain so (Bos and Boers, 2007). To develop location-specific guidelines for subsurface drainage, the Governments of India and The Netherlands jointly initiated the Indo-Dutch ''*Network Operational Research Project on Drainage and Water Management for Control of Salinity and Waterlogging in Canal Commands*'' (IDNP, 2002a). The recommendations and strategies developed by this project are presented in this paper.

2. Materials and methods

Six pilot areas in farmers' fields, one experimental plot and one large-scale monitoring site were established in those agro-climate regions where canal irrigation is most important (IDNP, 2002a).

Islampur in the Southern Plateau and Hills of Karnataka (Fig. 1). Islampur/Devapur pilot area is located in the Upper Krishna Project (16°08′N and 75°37′E). The climate is semi-arid tropical monsoon with a mean annual rainfall of 768 mm and potential evaporation of 2176 mm. The area is irrigated with good quality canal water and the main crops are rice, cotton, chillies, wheat during *Kharif* (monsoon season from July to October) and sorghum during *Rabi* (post-monsoon or winter season from October to March). During the *Zaid* or summer season (March to June) fields are prepared for the *Kharif* crops. Most farmers are illiterate and poor (Table 2), 23% of the farmers have land holdings smaller than 1 ha. Although the quality of the irrigation water is good ($EC_i = 0.6$ dS m^{-1}), waterlogging and salinity problems occur. The causes are the poorly drainable black soils, seepage from the canal network, lack of land development, inefficient irrigation practices and inadequate drainage.