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Impact of Subsurface Drainage System on Soil Physico-Chemical Properties - A Review

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ABSTRACT: Subsurface drainage has been used for more than a century to keep water table at a desired level of salinity and water logging control. This paper has been focused on the impact assessment of pilot studies in India from 1991 to 2018. This review article may prove quite useful in deciding the extent of reduction in salt content in soil after installation of subsurface drainage system. A number of pilot studies have been taken up in past to solve the problems of soil salinity and water logging in India. The general guidelines that arise on the behalf of this review paper are, leaching through subsurface drainage increased soil porosity, infiltration rate, organic carbon, available water, and decreased bulk density. The analysis of pre and post subsurface drainage soil samples revealed that the treatment is effective for saline soil reclamation by reducing in pH and EC of post subsurface drainage soil samples and ECe, Ca^{2+}, Mg^{2+} and Na^{+} content was found to be reduced significantly as compared to pre- subsurface drainage soil samples. Thus, SSD system is one of the best tools for permanent reclamation of water logged and saline soils in command areas.

Keywords: Subsurface drainage, salinity and water logging.

INTRODUCTION

The introduction of irrigation in agriculture under arid and semi-arid regions of India has resulted in the development of the twin problems of water logging and soil salinization. Considerable areas have already gone out of production or are being experiencing reduced yields, with the misconception that, more they irrigate, more the yield they will get. The introduction of canal irrigation not only supplies the water but also imports considerable amounts of salts. Due to excess application of water to the field, leads to soil salinity, water logging and abandoning productive agricultural land in the long run. In the short and medium terms, they adversely affect the crop productivity. These problems mostly occur in arid and semi-arid irrigated areas, when percolation losses from the applied irrigation water disturb the natural equilibrium between groundwater recharge and discharge causing a rise in the groundwater level, which also brings soluble salts towards the surface (Srikanth *et al*., 2004). Subsurface drainage has been found to be the only solution for providing land reclamation on a long-term basis when salts are present in the soil and groundwater. Subsurface drainage has been provided in 75–80 % of irrigated area in Egypt and 25–30 % irrigated area in western USA Goel and Tiwari (2013). Agricultural subsurface drainage is a process of removal of excess groundwater from the crop root zone system which promotes safe environment for efficient crop growth and for better health in rural and urban areas. Subsurface drainage lowers the high water tables, and the main causes of the rise in water table are precipitation, excess irrigation, leaching water, seeps from higher land or irrigation canal and ditches and groundwater under artesian pressure. This technique has gained international acceptance. Subsurface agricultural drainage provides agronomical and environmental benefits in terms of leach out of soluble salts more effectively in soil depths, improvement in soil physico-chemical properties and thus improvement in crop performance (Kornecki *et al.,* 2001).

Impact of SSD on soil physical properties

Physical properties play an important role in determining soil's suitability for agricultural, environmental and engineering uses. The supporting capability; movement, retention and availability of water and nutrients to plants; ease in penetration of roots, and flow of heat and air are directly associated with physical properties of the soil. Physical properties also influence the chemical and biological properties.

Sharma and Singh (1998) conducted an experiment in waterlogged sandy loam saline field and observed that the bulk densities were 1.68, 1.54, 1.55 and 1.58 Mg m^{-3} for the undrained, 25, 50 and 75 m drained plots respectively. Decrease in bulk densities in the drained treatments was due to increase in porosity under the drained conditions, which were evidently the results of higher proposition of both large and medium sized pores.

Bharambe *et al.,* (2001) observed that the bulk density of the salt affected plot was 1.29 Mg m^{-3}, while it was reduced to 1.26, 1.25 and 1.25 Mg m^{-3} in 25, 50 and 75 m drain spacings respectively.

Shrimanth *et al.* (2017) carried out an experiment on physical properties of waterlogged vertisols under subsurface drainage system with different drain spacings and depths in farmers' field at Mouje Digraj village, Sangli district (Maharashtra), India, during *Adsali* sugarcane season (16-18 months crop duration) of 2012-13 to 2013-14. The bulk density, particle density, total porosity and basic infiltration rate of soil were determined at initial and 18 months after drainage with respect to twelve treatment combinations consisting of four drain spacing (10, 20, 30 and 40 m) and three drain depths (0.75, 1.0 and 1.25 m). It was found that the subsurface drainage system with drain spacing of 10 m and drain depth of 1.25 m recorded highest per cent improvements in bulk density (20.99 %), particle density (6.10 %), total porosity (13.74 %) and basic infiltration rate of soil (13.75 %) following 18 months of drainage.

Impact of SSD on soil chemical characteristics

Soil pH. Soil pH is one of the most important determinants of soil fertility through its influence on the solubility of metal ions, such as Al, Mn, Fe, Cu, Zn and Mo, its effect on the supply of nutrient cations and anions, and its influence on microbes present in soil and their activity.

Soil pH is one of the most informative properties of the soil. It is a measure of the hydro-gen ion concentration in soil and also determines the solubility and availability of most nutrients in soil (Hue 1992; Hue and Licudine 1999). Extremes of soil pH are not onlydetrimental to crops but also imply the toxicity or deficiency of some soil nutrients.

Firake and Pampattiwar (1991) observed that subsurface drainage and gypsum application to sodic soil considerably reduced the soil pH at various depths. The pH of the soil the before the installation of SSD was 8.90, 8.97, and 9.28 for 0-30, 30-60 and 90-120 cm depth respectively. The pH decreased to 8.50, 8.71 and 8.79 respectively two years after installation of SSD. The reduction in pH was further complimented by application of 100 per cent gypsum requirement. The pH decreased to 8.39, 8.68 and 8.73 for 0-30, 30-60 and 60-90 cm depth respectively.

Doddamani *et al.,* (1995) conducted an experiment to study the effect of SSD and gypsum application on physico-chemical condition of a sodic vertisol. It was observed that the pH of soil in control was 9.3 where as it was reduced to 9.1, 8.8 and 8.4 for the tile placed at 0.9, 1.2 and 1.5 m soil depth respectively.

Sharma and Singh (1998) reported that leaching through SSD in water logged sandy loam saline field, increased the pH of soil profile. The increase in pH in drained soil is mainly attributed to better aeration, leaching of neutral salts and hydrolysis of bicarbonates. The average pH values of different depths for undrained, 25, 50 and 75 m spaced drained plots were 7.40, 7.95, 7.87 and 7.92 respectively.

Supekar *et al.* (2000) conducted an experiment to know the response of salt affected soil for drainage system and gypsum application, and observed that the pH of the soil decreased from 8.90 to 8.10 in the treatment which had subsurface drains installed at 15 m apart with gypsum application.

Bharambe *et al.* (2001) observed that the pH of the salt affected soil was 8.26 which reduced to 8.22, 8.23 and 8.24 for the 25, 50 and 75 m drain spaced SSD system respectively.

Rao *et al.,* (2001) conducted a study at the Konanki subsurface drainage pilot area (in Andhra Pradesh, India) and observed that after one crop season, pH was reduced by 7 per cent.

Hebsur *et al.* (2006) undertook an experiment to study the effect of poor quality groundwater on the yield of maize and soil chemical properties at Nandagaon village of Mudhol taluk in Bagalkot district, Karnataka during *kharif* 2003-04 and 2004-05 with subsurface drainage as main plots and amendments as sub plots. The soil reaction (pH) after harvest of the maize crop was lower in subsurface drainage (8.23) compared to no drainage plots (8.39).

Padalkar *et al.,* (2012) conducted experiment on use of subsurface drainage treatment for reclamation of saline soil. In this experiment analysis of irrigation water and soil were carried out before and after the subsurface drainage treatment in the field. The reduction in pH was observed from 8.7 to 7.27 after subsurface drainage treatment.

Soil salinity. Soil electrical conductivity (EC) is a measure of the amount of salts in soil (salinity of soil). It is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms which influence key soil processes including the emission of greenhouse gases such as nitrogen oxides, methane, and carbon dioxide. Excess salts hinder plant growth by affecting the soil –water balance. Soils containing excess salts occur naturally in arid and semiarid climates. Salt levels can increase as a result of improper cropping, irrigation, and land management.

Soil salinity is a measure of the concentration of all the soluble salts in soil water, and is usually expressed as electrical conductivity (EC). The major soluble mineral salts are the cations: sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and the anions:

chloride (Cl^-), sulfate (SO_4^{2-}), bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), and nitrate (NO_3^-). Hyper-saline soil water may also contain boron (B), selenium (Se), strontium (Sr), lithium (Li), silica (Si), rubidium (Rb), fluorine (F), molybdenum (Mo), manganese (Mn), barium (Ba), and aluminum (Al), some of which can be toxic to plants and animals (Tanji 1990).

Singh (1982) used the salt and water balance technique to evaluate the effectiveness of SSD practice for the reclamation of saline soil. The observation revealed that provision of SSD improved the yield by creating favourable environment for crop production. There was an increase in the salt within the soil profile due to use of rain water during monsoon season. The accumulation of salts as results of soil water evaporation was higher in case of undrained plot as compared to drained plot.

The studies carried out on hydrological considerations for the reclamation of saline soils, indicated that field bunding results in significant decrease in soil salinity, which was further reduced by providing SSD system (Singh, 1985).

Data on influence of SSD and phosphorus application on soil salinity and uptake of phosphorus by wheat in a saline soil revealed that installation of SSD system helps in appreciable reduction in soil salinity of the soil profile after three monsoon leaching and cropping. Average EC values was less than 4 ds m^{-1} up to the depth of 60 cm in 25 m drain spacing after installation of SSD, whereas EC values before the installation of SSD were 42.5, 30.3 and 23.4 ds m^{-1} for 0-15, 15-30 and 30-60 cm soil depth respectively (Singh *et al.*, 1990).

Basker *et al.*, (1990) studied the SSD system for saline soil reclamation. The vertisol in the command area of India's Parambikulum-Aliyar project suffer from inherent soluble salts below the root zone. When subjected to excessive irrigation for a period of 4-5 months followed by subsequent dry spell, salts rose by capillarity and accumulated in the surface making the soil saline and unproductive. SSD system was provided to the soils by open ditches and SSD pipes. They opined that, though open drainage can remove large amount of water they would require maintenance. Hence, they proposed SSD system with clay pipes (75 mm diameter) or high density polythene pipes at 25 m spacing have been identified as an optimum means of removing salts and increasing crop production.

Firake and Pamapattiwar (1991) studied the effect of SSD and gypsum application on leaching of salts in sodic soil. The ECe values in 1985, before the installation of SSD were 2.23, 1.99 and 0.59 ds m^{-1} for the 0-30, 30-60 and 60-90 cm soil depth respectively. Over a period for two years after the installation of SSD, the soil salinity increased by 36 per cent at depth below 60 cm. They were concluded that application of gypsum complimented the reduction in soil salinity, along with SSD leaching. Further the effects were more pronounced in top layers of the soil.

Buckland and Hendry (1992) compared the effects of SSD and irrigation, alone and in combination on a severe saline soil in Alberta, (Canada). The treatment were irrigated with non-drain, irrigated drained, non-irrigated drained and control. After three years average profile (0-12 m) ECe values for the above treatments were 67, 60, 104 and 99 per cent of initial levels respectively. Minor desalinization also occurred in some years and this was attributed to high rainfall. All treatments resalinized during the non-irrigated season in one or more years, but the relative degree of resalinization was greater in the irrigated non-drained treatments.

Rao *et al.* (1994) conducted an experiment at the fodder farm of the Central Institute for Research on Buffaloes in Rohatak district, Haryana state on 40 ha area laid with subsurface drains at 75 and 100 m spacings at a depth of 1.75 m on silty loam soil. The salinity in 30 cm surface layer reduced from 84.15 to 7 dS m^{-1} in two years time. The improvement with 100 m spacing plots was lesser than that of 75 m spacing.

Singh *et al.* (1994) carried out studies on drainage characteristics and performance of subsurface drainage system for Dabhou and Moraj valley sites in Gujarat. Their results indicated that root zone salinity of 14.8 dS m^{-1} in April, 1987 was reduced to 7.25 dS m^{-1} at the end of September, 1987. And drain water salinity also reduced and the highest yield of 4 t ha^{-1} was achieved.

Subsurface drainage with monsoon drains and continuous cropping resulted in appreciable reduction of salts in the soil profile (Anand, 1995).

Doddamani *et al.*, (1995) in their studies on effect of SSD and gypsum application on physico-chemical conditions of a sodic vertisol observed that the ECe values of the soil in control plot was 1.40 ds m^{-1} while it was reduced to 1.10, 0.90 and 0.85 ds m^{-1} in the tile depth of 0.90, 1.20 and 1.50 m.

Aheer (1995) observed that the SSD effectively reduced the soil salinity and sodicity in Chambal command area of Rajasthan. Depending on the soil type of the experimental sites 30 m or 40-60 m drain spacing were recommended.

Sharma and Singh (1998) in their studies on effect of SSD in a water logged sandy loam saline soil noticed that SSD (1.75 m depth) after 8 years of operation has resulted in appreciable reduction in soluble salts due to monsoon leaching and continuous cropping. Prior to installation of SSD system, the soil was too saline to grow any crop. The ECe value was 58.90 ds m^{-1}.The average ECe values were reduced to 1.18, 3.83 and 4.27 ds m^{-1} respectively in the 25, 50 and 75 m drain spacings.

Studies on response of salt affected soil for SSD system and gypsum application by Superkar *et al.* (2000) revealed that initial ECe values of the soil was 2.26 ds m^{-1}. It was reduced to 1.68 ds m^{-1} in the treatment that received only SSD. It was further reduced to 1.64 ds m^{-1} in the treatment that received SSD system and 50 per cent gypsum application of gypsum requirement. Similarly initial salt status of the soil was 3760.64 kg ha^{-1} in the control plot while, it was reduced to 2795.52 and 2728.96 kg ha^{-1} in SSD and SSD with 50 per cent gypsum application treatments respectively.

There was a decrease in salinity in the 35 and 65 m drain spacings with 1.2 m depth. The salt leached through SSD was 8 times higher than the salt removed by surface runoff (Rana *et al.*, 2000).

Sharma *et al.,* (2000) in their studies on rehabilitation of waterlogged saline soil by SSD concluded that by installing the SSD system in monsoon climate, waterlogged saline soils can be reclaimed by leaching of salts that can take place from rainfall.

Bharambe *et al.,* (2001) observed that the control plot had ECe value of 3.06 ds m^{-1} while it was reduced to 2.03, 2.13 and 2.15 in the 25, 50 and 75 m subsurface drain spacings respectively.

Mathew *et al.* (2001) studied the influence of SSD on crop production and soil quality in low-lying acid sulphate soil. They concluded that the soil salinity could be controlled considerably by SSD. The iron transformations were not serious enough to cause concern for rice cultivation when SSD was adopted. Accumulation of sulphates in insoluble form occurred during drainage due to the oxidation of pyrites. SSD was also very efficient in leaching of sodium, calcium and magnesium and chloride present in soil.

Rajkumar *et al.* (2001) monitored the subsurface drains on farmers' fields at four different locations (Vaddarahatti, Gundur, Siddapur and Gangavati) in Tungabadra project command area, Karnataka during 1996 to 1998. The lateral drains of the subsurface drainage were installed at a uniform spacing of 27 m at a depth of 0.90 m, while the collector drain was placed at 1.05 m depth. The results indicated that the subsurface drainage system had positive effect on soil physico-chemical properties, hydrological parameters and crop yield. A considerable reduction in soil salinity resulted in improvements of crop yield suggesting the need of subsurface drainage for reclaiming saline vertisols.

Ali *et al.,* (2001) reported that soon after the completion of the high Aswan dam in 1970, one of the largest drainage programmes was started in Egypt. The effects of subsurface drainage on groundwater table and soil salinity were assessed and the impacts on yield and farm income were determined. The results showed that the drainage programme was an effective measure in controlling groundwater table and soil salinity and a highly profitable investment for both the national economy and farmers.

Rao *et al.*, (2001) conducted a study at the Konanki subsurface drainage pilot area (in Andhra Pradesh, India) and observed that ECe has been reduced by 10 per cent. The EC, SAR (sodium adsorption ratio) and RSC (residue sodium carbonate) values also were reduced.

Shrivastava and Patel (2001) assessed the impact of subsurface drainage on the removal of salts from their study area of 188 ha block in Segwa drainage pilot area, Gujarat. Pre-drainage estimations were done to quantify the total salts deposited during 1996-1997. Later post-drainage estimation of salts left out during the year 1999-2000 was done based on field measurements. Equations on salt and water balance were formulated separately for pre and post-drainage situations depending upon the available data. From the study, it was observed that during pre-drainage period 7 t ha^{-1} of salts remained as balance, whereas during post-drainage period 4.7 t ha^{-1} of salts remained as balance.

Manjunatha *et al.* (2004) reported that with the introduction of irrigation in areas with rolling topography, low-lying areas are prone to water logging and soil salinization. Subsurface drainage was applied to reclaim the water logged saline land at Virupapur village, Karnataka, India. The monitoring and evaluation of the system revealed that the electrical conductivity (EC) of the soil decreased and crop yield and cropping intensity increased in the drained area.

Srikanth *et al.*. (2004) observed the effect of the subsurface drainage in reclaiming the water logged and saline black soils in the UKP command area of Karnataka using salt and water balance approach. The study revealed that the amounts of salt removed from the study area were 0.98 and 1.09 t in *kharif* and *rabi* seasons respectively.

Pradeep *et al.* (2005) carried out experiment on subsurface drainage and no drainage in Mudhol taluk of Bagalkot district. They reported that physical properties like per cent aggregate stability indices, infiltration rate, and porosity were higher and chemical properties such as pH, EC and ESP values in soil after harvest of maize were lower in subsurface drainage plot when compared to control.

Srinivasulsu *et al.* (2006) conducted an experiment by installing SSD in farmers' fields at Uppurgunduru in Krishna Western Delta (KWD) in South India to combat the problems of water logging (depth of water table, 0 to 2.04 m) and salinity (ECe, 1.0 to 52.7 dS m^{-1}, pH, 6.5 to 8.8). A total of 567.21 and 197.92 tons of salts were disposed from 81.03 and 39.58 ha during the three years from 1999-2000 to 2001-02 through pipe and open drainage systems, respectively.

Tahir and Nasir (2008) conducted a field study at Shahbaz Ghari pilot project area of Swabi SCARP project, Pakistan to evaluate the effect of enhanced water allowance on the performance of tile drainage system from August to December, 2002. According to the farmers, salinity and water logging problems significantly declined after the increase in water allowance. It was concluded from the results that after increase in water allowance, the singular tile drainage system of Shahbaz Ghari pilot project area was found working well.

Azhar and Latif (2011) conducted experiment on impact of subsurface drainage on soil salinity in Pakistan and concluded that, the net decrease in surface & profile salinities were 20 per cent and 14 per cent respectively with respect to the pre-project *i.e.*, year 1984; thus showing decrease in the salinity extent of the study area.

Kale (2012) carried out an experiment on to determine the comparison of salt accumulation in soil profile and crop yields under drained and un-drained conditions. Results revealed that percentage of salt decreased in soil profile occurred by 24.1, 37.9 and 14.4 for wheat, bean and fallow location respectively with adequate drainage conditions.

Padalkar *et al.,* (2012) conducted experiment on use of subsurface drainage treatment for reclamation of saline soil. In this experiment analysis of irrigation water and soil were carried out before and after the subsurface drainage treatment in the field. It was found that the treatment was effective for saline soil reclamation by reducing the EC from 4.5 dS m^{-1} to 2.81 dS m^{-1} after subsurface drainage treatment.

Srinuivasulu *et al.,* (2014) conducted experiment on performance of subsurface drainage system installed at Appikatla region of Andhra Pradesh and the results reveal that, the ECe was reduced in the range of 5 to 64.2 per cent due to installation of SSD system. It was estimated that a total of 59.79 tonnes of salts were leached out through the drainage system.

Patil *et al.* (2016) conducted experiment to check the impact of subsurface drainage system on salt affected soils in the Upper Krishna Command Karnataka, and based on the observation and analysis of the soils samples collected before sowing and after harvesting of the crop, it was observed that the ECe of soil reduced from 12.09 to 7.25 ds m^{-1} in 0-30 cm soil layer.

Chinchmalatpure *et al.* (2016) revealed that the SSD helped in desalination of soil profile as aoil EC was reduced to a range of 0.42 to 3.90 ds m^{-1} from its initial range of 1.2 to 7.3 ds m^{-1}.

Exchangeable sodium percentage, sodium adsorption ratio and other soil nutrients

Exchangeable Sodium Percentage (ESP) is the relative amount of the sodium ion present on the soil surface, expressed as a percentage of the total Cation Exchange Capacity (CEC).

Sodium adsorption ratio is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity (Ksat) and aeration, and a general degradation of soil structure.

Firake and Pampattiwar (1991) in their studies on effect of SSD and gypsum application on leaching of salts in a sodic soil observed that after two years of installation of SSD with 100 per cent gypsum requirement, the ESP reduced to 21.59 from the initial values of 29.06 in 0.90 m soil depth.

Doddamani *et al.,* (1995) conducted a field experiment to study the effect of tile drains and gypsum amendment on a sodic vertisol. It was observed that there was decrease in soluble cations and anions concentration in the drained and gypsum treated plots in the surface soils. The extent of decrease was found to be increased with increase in depth of placement of tile drains. Exchangeable Ca + Mg increased from 49.5 in control plot to 50.43 (cmol (p+) kg^{-1}) where tile drains were placed at a depth of 1.5 m, whereas, exchangeable sodium and ESP decreased in all the depth of tile placed treatments. The extent of decrease in exchangeable sodium was from 13.92 (cmol (p+) kg^{-1}) in control to 8.2 in tile placed at 1.5 m depth. There was also decrease in ESP when compare to control plots.

Sharma and Singh (1998) studied the long-term effect of SSD system on some physico-chemical properties in a waterlogged saline soil. SAR value of soil sample before the installation of SSD was 12.19 (m $mol^{-1})^{1/2}$. After 8 years of installation of SSD the SAR values were 2.19, 4.26 and 5.58 (m $mol^{-1})^{1/2}$ in the 25, 50 and 75 m tile drain spaced plots respectively.

Supekar *et al.* (2000) in their studies on response of salt affected soil for drainage system and gypsum application observed that the initial ESP value was 15.19 per cent in August 1996, while it was reduced to 13.35 and 13.68 per cent in SSD with application of 50 per cent gypsum requirement and SSD alone in February 1997. Thus the subsurface drains installed at 15 m apart with gypsum application about one half of the gypsum requirements of soil has been found to be most effective treatment for reclamation of salt affected soil.

Bharambe *et al.* (2001) in their studies on management of salt affected vertisol with SSD observed that after 3 years of installation of SSD, the ESP values were reduced to 10.2, 9.8 and 9.9 per cent respectively for the 25, 50 and 75 m drain spacings, from the initial ESP of 14.7 per cent.

Pradeep *et al.,* (2005a) conducted a field experiment using poor quality ground water at Nandagaon village of Mudhol taluk in Bagalkot district during *kharif* 2003 to study the effect of subsurface drainage and amendments on osmotic potential and uptake nutrients by maize. Osmotic potential in maize leaves was lower in subsurface drainage plots than in no drainage plots. The uptake of nutrients such as N, P, K, Ca and Mg was significantly higher in subsurface drainage plots than no drainage plots.

Hebsur *et al.,* (2006) undertook an experiment to study the effect of poor quality groundwater on the yield of maize and soil chemical properties at Nandagaon village of Mudhol taluk in Bagalkot district, Karnataka during *kharif* 2003-04 and 2004-05 with subsurface drainage as main plots and amendments as sub plots. The water soluble Na^{+}, Ca^{++} and Mg^{++} and sodium adsorption ratio were reduced in subsurface drainage plots than in no drainage plots.

Kamble *et al.,* (2006) assessed the subsurface drainage system installed on-farm with corrugated perforated PVC pipes in 8.81 ha of salt-affected soils at Agricultural Research Station, Digraj, Sangli district, Maharashtra during December, 2002 to study its effect. The results revealed that the pH, ECe, SAR and ESP of soil in SSD with synthetic envelope, coarse sand filter and synthetic envelope plus coarse sand filter were decreased in monsoon and winter seasons but slightly increased during the summer season. This indicated that the improvement in salt-affected soils was due to subsurface drainage and gypsum application within a period of one year.

Jadhao *et al.,* (2009) carried out an experiment on subsurface drainage of salt-affected area over 8.1 ha during 2001-02 in Mahatma Phule *Krishi Vidhyapeeth,* Rahuri, Maharastra. They collected soil samples and analysed for different soil salinity parameters *viz*., pHs, ECe, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, CO_3^{-2}, HCO_3^{-} and SO_4^{-2} with respect to drain spacing and depth. By these they concluded that the 15 m drain spacing with 120 cm drain depth was found better in improving the soil properties.

Padalkar *et al.,* (2012) conducted experiment on use of subsurface drainage treatment for reclamation of saline soil. In this experiment analysis of irrigation water and soil were carried out before and after the subsurface drainage treatment in the field. There is a noticeable increase in organic carbon and nitrogen content of soil after inception of subsurface drainage. There is not much difference observed in other major and minor nutrients like phosphorus, potassium, calcium and magnesium.

Patil *et al.,* (2016) conducted experiment to check the impact of subsurface drainage system on salt affected soils in the Upper Krishna Command Karnataka, and based on the observation and analysis of the soils samples collected before sowing and after harvesting of the crop, it was observed that the Ca^{2+}, Mg^{2+}, Na^{+} and ESP content of soil was found to be reduced significantly as compared to pre-sowing conditions owing to removal of excess soluble salts through leaching.

Raju *et al.,* (2016) carried out an economic impact analysis on saline soil reclamation through subsurface drainage in Ugar Budruk village, Athani taluk of Belgaum district, Karnataka, by installing subsurface drainage in 925 ha of saline soil, study revealed that due to the intervention of subsurface drainage technology the land productivity has increased significantly. The mean soil salinity was reduced from 6.6 to 2.52 dS m^{-1} during post-SSD showing 163 per cent reduction in soil salinity.

Pradeep *et al.,* (2018) conducted the experiment on performance evaluation of subsurface drainage system on drain discharge, leachate quality, salt load and crop yield improvement in water logged saline areas in UKP command area, Karnataka, during 2014-15 by comparing the post-drainage scenario with the pre-drainage conditions. During the study period the total amount of salt removed was observed to be 109.75 t from the entire study area.

Mallika *et al.,* (2018) carried out the experiment on effect of sub-surface drainage system on soil chemical properties and yield of rice crop at head region of Tungabhadra command area results revealed that, EC of post sub-surface drainage soil samples and EC, Ca^{2+}, Mg^{2+}, Na^{+} and ESP content of soil was found to be reduced significantly as compared to pre-subsurface drainage soil samples.

CONCLUSION

The research studies revealed that subsurface drains were adopted to lower the water table and leach away the excess salts from the crop root zone. These drains were useful in reclamation of waterlogged saline lands, by improvement in soil hydrologic, physico-chemical parameters of aggregate stability indices, porosity, hydraulic conductivity and infiltration and reduction in pH, EC, ESP, water soluble Na^{+}, Ca^{++} and Mg^{++} and sodium adsorption ratio. However, the negative aspect of subsurface drainage was considerable loss of irrigation water particularly in rice fields, plant nutrients in the form of organic matter, available P and K through drain discharge/leachate water and therefore they were needed to be applied regularly and poor quality leachate causing environmental problems to downstream area fauna and people. Further, the contiguous nature, magnitude and vastness of the problems of water logging and salinity in irrigation command areas considering the socio-economic dimensions mainly associated with majority of small and marginal farmers, demand the State and Central Governments come forward and jointly take up the land reclamation work on large scale and community basis.

FUTURE SCOPE

As subsurface drainage system leaches out excess water soluble salts from the soil, there is also apprehension about the significant loss of nutrients if we keep the SSD in operation for a long time. Therefore, future research should focus on:

1. Long term impact of SSD on nutrient losses from soils.
2. Feasibility study of controlled SSD system to sustain the efficient management of salt affected soils over a period of time.

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REFERENCES

Aheer (1995). Performance of drainage system in controlling salinity and waterlogging in Chambal command, Rajastan: Reclamation and management of waterlogged saline soils. *National seminar proceedings, 5*(8): 85-106.

Anand, S. (1995). Phosphorus and potassium fertilization of pearlmillet and wheat on a reclaimed saline soil. *Journal of Potassium Research, 11*(2): 185-192.

Azhar, A. H. and Latif, M. (2011). Subsurface drainage impact assessment on crop yield. *Journal of Animal and Plant Sciences, 21*(2): 215-219.

Basker, A., Selvaseelan, D. A., Ramanathan, G. and Kandaswamy, P. (1990). Subsurface drainage system for saline soil reclamation, a case study. Proceeding of 14th international congress on irrigation and drainage, Rio-de-Janerio, Brazil, No. 1-B, 577-584.

Bharambe, P. R., Shelke, D. K., Jadhava, G. S., Vaishnava, V. G. and Oza, S. R. (2001). Management of salt-affected vertisols with subsurface drainage and crop residue in corporation under soyabean-wheat cropping system. *Journal of Indian Society Soil Sci*ences, *46*(1): 24-29.

Buckland, G. D. and Hendry, M. J. (1992). Ground water response and salt removal in a saline-seep soil in

Southern Alberta. Canadian Agricultural Engineering, *34*(2): 125-134.

Chinchmalatatupure, A. R., Sagar, D. V., Kaledhonkar, M. J., Sanjay, V. K., Sharan, K., David, C., Indivar, P., Kamra, S. K. and Sharma, P. C. (2020) Perpormance evaluation of subsurface drainage under waterlogged salinw vertisol for sugarcane crop in Ukali Kakarpar Canal Command Gujarath. *Journal of* Agricultural Engineering, *57* (3): 248-258.

Doddamani, V. S., Kumte, S. S. and Hebsur, N. S. (1995). Efects of subsurface drainage and gypsum application on physico-chemical condition of a sodic vertisol. *Journal of Maharashtra Agricultural Uni*versity, *20*(20): 281-282.

Firake, N. N. and Pampattiwar, P. S. (1991), Note on the effect of subsurface drainage and gypsum on leaching of salts in sodic soil. *Current Agriculture*, *15*: 71-73.

Goel, A. and Tiwari, P. (2013). Review of computer based software tools for salinity management in agricultural lands. *Journal of Indian Water Resources Society, 33*(4): 25–32.

Hebsur, N. S., Tamgale, S. D. and Renuka, P. M. (2006). Effect of poor quality groundwater on dry matter production and yield of maize and chemical properties of soil in Ghataprabha command area. *Karnataka Journal of Agricultural Sciences, 19*(4): 816-820.

Hue, N. V. (1992). Correcting soil acidity of a highly weathered *Ultisol* with chicken manure and sewage sludge. *Communications in Soil Science and Plant Analysis*, *23*: 241–264.

Hue, N. V. and Licudine, D. L. (1999). Amelioration of subsoil acidity through surface application of organic manures. *Journal of Environmental Quality, 28*: 623–632.

Jadhao, S. M., Konde, N. M., Patil, A. S. and Nillam, M. K. (2009). Impact of assessment of sub-surface drainage with saline-sodic swell shrink soils. *Indian Journal of Agricultural Research, 43*(2): 113-118.

Kale, S. (2012). Impact of drained and un-drained soil conditions on water table depths, soil salinity and crop yields. *African Journal of Agricultural Research, 7*(19): 2935-2945.

Kamble, B. M., Chougule, B. A., Rathod, S. D. and Rathod, P. K. (2006). Improvement of salt affected-water logged soils in western Maharashtra through subsurface drainage (SSDs) system. *Asian Journal of Biological Sciences, 1*(2): 64-67.

Kornecki, T. S., Fouss, J. L., Grigg, B. C. and Southwick, L. M. (2001). Drainage research to improve runoff water quality and soil trafficability. *Land Water Management, 45*(3): 10–13.

Mallika, K., Ayyanagowdar, M. S., Polisgowdar, B. S. and Kumar, U. S. (2018). Effect of sub-surface drainage system on soil chemical properties and yield of rice crop at head region of tungabhadra command area. *International Journal of Current Microbiology and Applied Sciences*, *7*(10), pp.1212-1220.

Manjunatha, M. V., Oosterbaan, R. J., Gupta, S. K., Rajkumar, H. and Jansen, H. (2004). Performance of subsurface drains for reclaiming waterlogged saline lands under rolling topography in Tungabhadra irrigation project in India. *Agricultural Water Management, 69*(1): 69-82.

Padalkar, R. C., Jadhav, P. L., Jadhav, A. S. and Raut, P. D. (2012). Use of sub-surface drainage treatment for reclamation of saline soil: A case study of Kasabe Digraj village, District: Sangali, State: Maharashtra. *Proceedings of International Conference, SWRDM*, pp. 269-280.

Patil, R., Balakrishnan, P., Satish, K. U., Srinivasa, R. G. V., Channabasavanna, A. S. and Rajkumar, H. (2016). Impact of subsurface drainage system on soil chemical properties and crop yield in Upper Krishna Command. *International Journal of Agricultural Sciences, 8*(51): 2202-2205.

Pradeep, C. M., Balakrishnan, P., Satishkumar, U., Dandekar. A. T., Lokesh, H. and Bellakki. M. A. (2018). Performance evaluation of subsurface drainage system on drain discharge, leachate quality, salt load and crop yield improvement in waterlogged saline areas in UKP command area, Karnataka. *Journal of Pharmacognosy and Phytochemistry, 7*(1): 109-114.

Pradeep, H. M., Hebsur, N. S., Gali, S. K. and Koti, R. V. (2005). Effect of subsurface drainage and amendments on soil physical and chemical properties of black soils of Ghataprabha command area. *Karnataka Journal of Agricultural Sciences, 18*(3): 953-958.

Pradeep, H. M., Hebsur, N. S., Gali, S. K. and Koti, R. V. (2005a). Effect of subsurface drainage and amendments on osmotic potential and uptake of nutrients by maize in Ghataprabha command Area. *Karnataka Journal of Agricultural Sciences, 18*(4): 946-952.

Raju, R., Thimmappa, K., Praveen, K., Satyendra, K. and Tripathi, R. S. (2016). Reclamation of saline soil through subsurface drainage technology in Haryana. *Journal of Soil Salinity and Water Quality, 8*(1): 194-201.

Rana, J. S., Sewa, R., Rao, K. V. G. K. and Rama, S. (2000). Effect of subsurface drainage on soil salinity and crop yields in vertisols of Chambal command, Rajastan. Role of drainage and chanlleges in 21th century, vol. 1, *Proceeding of the eighth ICID international drainage workshop*, New Delhi, India, 31th January-4th February, 2000, pp. 356-357.

Rao, K. V., Kamra, S. K. and Kumbhare, P. S. (1994). Drainage requirements of alluvial soil of Harayana. *Nation. Sem. Proc. Reclamation and Manage. Waterlogged Saline Soils*, CSSRI, Karnal (Haryana) April, 5-8, pp. 36-49.

Rao, S., Lakshmi, G. V., Sujanirao, C. and Satyanarayana, T. V. (2001). Control of soil salinity through subsurface drainage - A case study of Konanki Experiment, 1st Asian Regional Conference of ICID, Seoul, Korea Republic, 16-21 September 2001.

Sharma, D. P. and Singh, K. (1998). Effect of subsurface drainage system on some physico-chemical properties and wheat yield in waterlogged saline soil. *Journal of Indian Society of Soil Sci*ence, *46*(2): 284-288.

Shrimanth, D. R., Sudhir, D. D., Sunil, D. G., Bhimrao, M. K. and Mukund, G. S. (2017). Physical properties of waterlogged vertisol under subsurface drainage system with different drain spacing and depths. *International Journal of Agricultural Engineering, 10*(1): 22-30.

Shrivastava, P. K. and Patel, B. R. (2001). Study on salt and water balances at Segwa drainage pilot area. *Journal of Agricultural Engineering, 38*(4): 39-46.

Singh, K. N., Anand, S., Sharma, D. P. and Rao, K. V. G. K. (1990). Influence of subsurface drainage and phosphorus application on soil salinity and uptake of phosphorus by wheat in a saline soil. *Journal of Indian Society of Soil Sci*ence, *38*: 511-515.

Singh, O. P. (1982). Salt and water balance for evaluating the effectiveness of drainage in saline soils. *Current Agric*ultural, *6*(1-2): 9-16.

Singh, O. P. (1985). Hydrological considerations for the reclamation of saline soils. *Journal of Indian Society of Soil Sci*ence, *33*: 118-127.

Singh, O. P., Zama, M. S. and Kumbhare, P. S. (1994). Performance of drainage system in controlling salinity in Gujarat. *National Seminar Proceeding on Reclamation and Manage*. *Waterlogged Saline Soils*, CSSRI, Karnal (Haryana), April, 5-8, pp. 63-84.

Srikanth, Shirahatti, M. S. and Balakrishnan, P. (2004). Salt and water balance studies in waterlogged and saline soils of Upper Krishna command of Karnataka. *Journal of* Agricultural Engineering, *41*(2): 49-54.

Srinivasulu, A., Satyanarayana, T. V., Raghu Babu, M. and Hema, H. V. (2006). Performance evaluation of drainage systems in water logged coastal sandy clay loam soil at a pilot area in Krishna Western delta. *Journal of* Agricultural Engineering, *43*(1): 8-12.

Srinuvasulu, M., Ramarao, A., Raghubabu, M., Ravibabu, G. and Hemakumar, H. V. (2014). Performance of subsurface drainage system installed at Appikatla region of Andra Pradesh. *Journal of* Agricultural Engineering , *7*(1): 180-185.

Sumner, M. E. (1993). Sodic soils: New perspectives. *Australian Journal of Soil Research*, *31*, 683–750.

Supekar, S. J., Jadhav, S. N. and Pendke, M. S. (2000). Resopnse of salt affected soil for drainage system and gypsum. *Karnataka Journal of Agricultural Sciences*, *13(*3): 735-736.

Tahir, S. and Nasir, M. (2008). Effect of enhanced water allowance on the performance of tile drainage system at Shahbaz Ghari pilot project area of swabi scarp. *Sarhad Journal of Agricultural, 24*(1): 59-68.

Tanji, K. K. (1990). Nature and extent of agricultural salinity. Agricultural salinity assessment and management, ASCE manuals and reports on engineering practice No 71. ASCE, New York, USA, pp 1–17.

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