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Impact of Saline Soil Reclamation on Enhancing Farm Productivity and Farmers Income in Karnataka – An Economic Analysis

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Abstract: *In India 2.95 m ha. area is affected by soil salinity spread in 13 states, out of which Karnataka has 1893 ha. In Karnataka about 925 ha saline land has been reclaimed through installation of subsurface drainage technology which costs about Rs. 52000 per ha of land reclamation. The post reclamation study revealed that land has become almost normal within 2 to 3 years and the land value has been increased upto 500 per cent. The yield of sugarcane has been increased from 42 t/ha to 119 t/ha after reclamation. Overall, the crop yield has been increased upto 200 per cent. The farmers obtained per hectare net income of Rs. 1.02 lakh after reclamation compare to a loss of Rs. 53,000 per hectare before reclamation. Though the saline soil reclamation technology is capital-intensive, farmers in Karnataka are coming forward to install the subsurface drainage technology on their own cost due to its effectiveness.*

Keywords: *Saline Soil, Subsurface drainage, Productivity, Income, Karnataka.*

INTRODUCTION

Soil salinity is one of the major land degradation problem in Indian agriculture which adversely affects the productivity of agricultural land. In India saline soils occur in 2.95 mha area spread in 13 states including Andaman and Nicobar, constitutes 44 per cent of the total salt-affected soils in the country. Karnataka has 1893 ha of saline soils constituting 0.06 per cent of the country's total saline soils (Sharma *et al*., 2015). No crop can be grown on severely salt affected soils without proper treatment (Tripathi, 2011). Several studies by Joshi *et al.* (1987), Datta and Joshi (1993), Datta *et al.* (2004), Mathew (2004), Shekhawat (2007), Ritzema and Schultz (2010) indicated that the subsurface drainage (SSD) technology for saline land reclamation is technically viable, economically feasible and socially acceptable by all the categories of farmers (Chinnappa and Nagraj, 2007 and Tripathi, 2011). Subsurface drainage removes excess salts and water from the root zone through leaching to create favourable conditions for crop production (Gajja *et al*., 2002). In Karnataka about 925 ha saline land has been reclaimed through installation of subsurface drainage technology. The present study has estimated the economic impact due to reclamation of saline soil and feasibility of technological intervention on increasing productivity of land and enhancing farm income in Karnataka.

STUDY AREA AND THE DRAINAGE FEATURES

The study was carried out at subsurface drainage project area of the village Ugar Budruk located in Athani Taluk of Belgaum District in Karnataka state. The study area is situated at about 74^0 47′ East longitudes and 16^0 40′ North latitude. It is about 110 km away in the North from district headquarter Belgaum. Athani taluk has a tropical climate and receives normal rainfall of 541 mm from both the northeast and the southwest monsoons and the wettest months are June to September (Anonymous, 2012-13). The coldest month is December with an average low temperature of 25.3 °C and the hottest

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month is May with an average high temperature of 40 °C. The driest month is January, with 10 mm of rainfall. The total cultivable area of the village is 2510 ha. Out of this, 1750 ha is affected due to salinity and waterlogging, which constitutes 70 per cent of the cultivable area. The farmers of the project area reported that since 25 to 30 years, the affected land of the village was either partially cultivated or it was left barren depending on the degree of salinity affected.

The subsurface drainage system was installed between 2009-10 to 2011-12 in the salinity affected area of village Ugar Budruk. The total area covered was 925 ha and 644 farmers were associated with the land reclamation process. The drainage system was designed with a discharge rate of 1.5 mm/day, depth of drain as 1.0-2.0 m and spacing of lateral pipe as 30 m. The size of laterals and collector pipe were of 80 mm and 250-315 mm, respectively.

The drainage area was divided into 25 outlets (blocks) including 3 closed drains and 35 manholes. The outlets (to remove drain water from field) were connected to 5.6 km long open drain which is connected to the river Krishna. The approximate per hectare cost of saline land reclamation through installation of subsurface drainage was estimated at Rs. 52,000.

DATA AND METHODOLOGY

The study was based on primary as well as secondary data collected from different sources. The primary data were collected from 120 sample farmers from subsurface drainage project area using area random sampling. The primary information was collected through personal interview with the respondents on socio-economic status, use of farm inputs, crop yields and farm returns obtained during pre and post-SSD installation. The costs and returns were estimated and compared for pre and post-SSD installation by considering the actual quantity of inputs used by the farmers and quantity of output harvested by them during respective years were multiplied with the prices of input and output prevailing during 2014-15. The costs of all inputs and output parameters pertaining to sugarcane, wheat, chick pea, soybean and jowar production were based on average values of the sampled farms. The cost concepts, viz. cost A_1, A_2, B_1, B_2, C_1 and C_2, were considered for the estimation (CSO, 2008). The cost C_1 was considered to estimate net income and benefit-cost ratio (Tripathi, *et al.,* 2005, Tripathi *et al.,* 2013 and Raju *et al.,* 2015). The cost C_1 included all direct expenses made in cash and kind for crop production such as hired human labour, machine labour, seeds, fertilizers, irrigation, plant protection measures, imputed value of family labour, interest on working capital and depreciation on fixed assets

The secondary data included cropping pattern, soil and water parameters, technology related aspects were collected wherever necessary. The analysis was carried out to study the economic impact due to technological intervention in the project area. The benefit-cost ratio was estimated to know returns obtained from the investment on subsurface drainage technology. The average values of input and output were compared with the situation before (2008-09) and after (average value of 3 years data of 2012-13, 2013-14 and 2014-15) the installation of subsurface drainage.

Simultaneously, in the project area water table depth was measured, representative soil samples were collected from different drainage blocks and the drain water samples were collected from the outlets and sumps. To study the ground water level, water table depth was recorded. Similarly to study the status of soil as well as drain water salinity in the project area, the samples were analysed and their electrical conductivity (EC in dS/m) and pH were recorded (Raju *et al.,* 2015). The salinity and pH of soil and drain water samples collected from the study area were also compared in a similar fashion.

RESULTS AND DISCUSSION

Socio-economic Features

The socio-economic features of the sample farmers revealed that the average family size was of 8 persons and literacy rate was around 73 per cent. Agriculture was the main occupation and about 91 per cent households were engaged in activities such as crop production and working in agro-based industries located in and around their habitations. The majority of farmers were smallholders with average farm size of 1.44 ha, out of which approximately 70 per cent land was problematic, being affected by waterlogging and or soil salinity.

The project area farmers obtaining 80 per cent of their annual family income from agriculture and allied activities followed by 15 per cent earnings from working in the sugar factories which were based on production of sugarcane in the area. Altogether 95 per cent of the farmer's depends on agriculture as their source of income. The major irrigation source was lift irrigation. The study area has about 90 lift irrigation schemes connected from the river Krishna. Among farm machineries owned by farmers, 15 per cent had tractors and trucks. The study revealed that about 60 per cent farmers avail agriculture loan from commercial banks and cooperatives.

Impact on Cropping Pattern and Cropping Intensity

The cropping pattern in the study area during pre and post-SSD period reflects that the major crop grown in the project area was sugarcane followed by oilseeds and cereals (Table 1). The horticulture, vegetables and pulse crops has occupied smaller area during both pre and post-SSD installation periods.

Table 1
Cropping pattern and cropping intensity of study area during pre and post-SSD installation

Crops	*Pre-SSD*		*Post-SSD*		*Per cent change*	
	Area (ha)	*Area (%)*	*Area (ha)*	*Area (%)*	*Area (ha)*	*Area (%)*
Sugarcane	776.83	30.95	1745.87	69.55	969.04	124.74
Cereals	228.02	9.08	13.41	0.53	-214.61	-94.12
Pulses	46.00	1.83	0.00	0.00	-46.00	-100.00
Vegetables	12.72	0.51	17.53	0.70	4.81	37.81
Oil seeds	427.64	17.04	155.57	6.20	-272.07	-63.62
Horticulture	42.51	1.69	15.92	0.63	-26.59	-62.55
Uncultivated Land	937.73	37.36	561.81	22.38	-375.92	-40.09
Total cultivable land	2510.00	100.00	2510.00	100.00	-	-
Cropping intensity		62.64		77.62		23.91

During both pre and post-SSD installation in the project area sugarcane was the major crop which occupied 30.95 per cent in pre-SSD and 69.55 per cent in post-SSD leading to 124.74 per cent increase in post-SSD installation (Table 1). During pre-SSD period, oilseeds and cereals occupied a major portion of the cultivable area as the land was affected by waterlogging and soil salinity, hence not suitable for sugarcane production. During post-SSD due to reclamation process, the crop scenario in the project area was significantly changed and about 969.04 ha additional area was brought under sugarcane production. The improved condition of the land allowed farmers to grow sugarcane as a cash crop and hence the maximum area under sugarcane lead to decrease in area under other crops. The area under other crops was reduced by 100.00, 94.12, 63.62 and 62.55 per cent respectively, for pulses, cereals, oilseeds and horticulture crops. The area under vegetables has showed an increase of 4.81 ha in post-SSD installation. Though this increase is phenomenal, the suitability of land after reclamation and increase in prices of vegetables influenced the project area farmers to grow vegetables in their field. Overall, during post-SSD, the uncultivated area has been reduced by 40 per cent and it was observed that the reclamation process brought an additional 375.92 ha area under cultivation. This indicates that after installation of subsurface drainage in the project area land use was intensified, cropping pattern changed in favour of more remunerative crops and crop yields increased (Datta *et al.*, 2000 and Raju *et al.*, 2015).

The cropping intensity of the drainage area has been increased significantly during post-SSD installation (Table 1). Cropping intensity during pre-SSD it was 62.64 per cent and it has been increased to 77.62 per cent during post-SSD period. The overall cropping intensity increased by 23.91 per cent due to installation of subsurface drainage in the region. The increase in cropping intensity shows a positive impact of drainage technology on reclamation of saline soils.

Impact on Soil Salinity

To assess the impact of subsurface drainage on improvement in land productivity, soil samples were collected after the harvest of sugarcane crop. It was observed that soil salinity in the study area varied between the locations and slope of the land. This variation was probably caused by the amount of irrigation and its distribution. The mean soil salinity of the project area was 6.63 during pre-SSD was reduced to 1.80 dS/m in post-SSD installation, indicating 72.85 per cent reduction in soil salinity during post-SSD (Table 2). The study reveals that there is a significant reduction in the maximum and minimum salinity, representing 37 per cent and 96 per cent, respectively. The improvement in soil salinity indicate that subsurface drainage system is a viable management option for saline soils (Datta *et al.*, 2004). The higher coefficient of variation during post-SSD period may be attributed to the maximum reduction in salinity in the project area as compare to salinity during pre-SSD.

Table 2
Soil salinity (dS/m) during pre and post-SSD installation

Particulars	*Pre-SSD*	*Post-SSD*	*Per cent Change*
Mean	6.63	1.80	-72.85
Minimum	4.80	0.16	-96.60
Maximum	10.60	6.68	-37.00
Standard Deviation	2.67	1.91	-28.68
Coefficient of Variation (%)	40.36	106.01	162.65

Impact on Water Table Depth and Drain Water Salinity

To study groundwater fluctuation in the project area, the water table depth was measured on regular intervals from the sumps located in all the drainage blocks. Simultaneously, the drain water was collected from the outlets to measure its salinity level. The data revealed that the mean water table depth in the drainage area was 0.32 m and 1.66 m, respectively, during pre-SSD and post-SSD installation indicating 427.78 per cent reduction in post-SSD installation (Table 3). The minimum and maximum depth of water table was 0.13 and 1.52 m respectively, during pre and post-SSD installation, showed a significant reduction in the water table depth. The depth to ground water table in drained area remained below 1.0 m during the crop growing season (Datta *et al.*, 2004). The least variation in the minimum and maximum depth was observed in post-SSD compare to pre-SSD. In the project area, drain water from the higher end moves towards the lower end of the drain where outlets were connected to main to drain. Due to which, the farmers in the upper side, or who are away from the sump were significantly benefitted in comparison to those whose land were towards lower side or near the outlet. However, the natural slope of the land makes the difference (Raju *et al.*, 2015).

Unfortunately, data on drain water salinity before installation of subsurface drainage system

Table 3
Water table depth and drain water salinity during pre and post-SSD installation

Particulars	*Water table depth*			*Post-SSD*	
	Pre-SSD	*Post-SSD*	*Per cent Change*	*Salinity (dS/m)*	*pH*
Mean	0.32	1.66	427.78	4.60	7.79
Minimum	0.13	1.52	1069.23	1.53	7.51
Maximum	0.52	1.73	232.69	10.50	8.35
Standard Deviation	0.19	0.10	-48.58	2.33	0.23
Coefficient of Variation (%)	60.15	5.86	-90.26	50.58	2.91

was not available. The salinity of drain water in post-SSD installation was ranges between 1.53 to 10.50 and the mean salinity was recorded as 4.60 dS/m. The drain water salinity of the project area has shown 50.58 per cent variation (Table 3), indicating a wide gap in salinity of drain water after the installation of subsurface drainage. However, this gap reduces over a period of time. The higher lying areas relatively remain in production if sufficient water is available for irrigation and leaching takes place. The water table is maintained by gravity flow over the years (Datta and Jong, 2002).

Impact on Crop Yield

The major crop grown in the region was sugarcane as it was a cash crop and the area is known for it. About 90-95 per cent farmers harvests two crops from sugarcane planting i.e., one planted crop and one ratoon crop. After the harvest of a ratoon crop and before planting of sugarcane in the next season, there will be a gap of 3-4 months. During this gap farmers grow some short duration crops like chick pea, wheat, jowar, soybean, etc. The crops grown in the region and their yield performance during pre and post-SSD installation were presented in Table 4. The mean yield of all the crops grown in the drainage area has significantly increased after the installation of subsurface drainage.

Table 4
Yield of major crops during pre and post-SSD installation (q/ha)

Crop	*Pre-SSD*	*Post-SSD*	*Per cent Change*
Sugarcane*			
Planted	42.0	119.0	183.33
Ratoon-I	26.0	82.0	215.38
Ratoon-II	-	57.0	-
Wheat	8.0	26.0	225.00
Chick Pea	4.5	12.2	171.11
Soybean	7.3	16.8	130.14
Jowar	5.2	15.4	196.15

*yield in t/ha

The yield of planted sugarcane crop during pre and post-SSD installation was 42 t/ha and 119 t/ha respectively and yield of sugarcane ratoon-I crop was 26 t/ha and 82 t/ha respectively during pre and post-SSD installation. The per cent increase in yield due to reclamation was 183.33 and 215.38 respectively, for planted and ratoon-I sugarcane crops. Similarly, in post-SSD the increase in yield of wheat, chick pea, soybean and jowar crops were 225, 171, 130 and 196 per cent, respectively (Table 4). It was observed that after installation of subsurface drainage, approximately 5-10 per cent sugarcane growers' harvest third crop from the planting i.e. ratoon-II crop and obtained the average yield of 57 t/ha which was more than the yield obtained from planted crop during pre-SSD.

Before installation of subsurface drainage in the region, the loss in yield of major crops due to waterlogging and soil salinity was up to 30 per cent in the upland and the loss was more than 50 per cent in the low land areas (as recorded by the watershed development department of Belgaum in their preliminary survey conducted before subsurface drainage installation in the year 2006). After the installation of subsurface drainage, the situation was significantly changed and farmers were getting relatively better yields. Overall, the net impact of yield increase due to drainage was about 186 per cent.

Economics of Major Crops

The cost of production and net returns were estimated for sugarcane (Table 5) and selected off-season crops viz., wheat, chick pea, soybean and jowar (Table 6) during pre and post-SSD installation in the project area.

The study reveals that the cost of cultivation was increased during post-SSD installation by 9.08 and 14.06 per cent respectively, for cultivation of sugarcane planted and ratoon-I crops (Table 5). Similarly, the cost of cultivation of off-season crops was increased during post-SSD installation by 19.08, 15.52, 14.86 and 13.92 per cent respectively, for cultivation of chick pea, jowar, wheat and soybean crops in that order (Table 6). This increase in cost may be attributed to better performance of crops after reclamation demands more use of inputs viz. fertilizer, pesticides, irrigation management and labour for operation and maintenance.

Table 5
Economics of Sugarcane cultivation during pre and post-SSD installation

Particulars	*Pre-SSD*		*Post-SSD*		*Per cent change*	
	Planted	*Ratoon*	*Planted*	*Ratoon*	*Planted*	*Ratoon*
Cost of cultivation (Rs./ha)	145566	100785	158786	114955	9.08	14.06
Net income (Rs./ha)	-53188	-43728	102046	64367	-291.86	-247.20
Cost of Sugarcane production (Rs/t)	3467	3886	1339	1410	-61.37	-63.71
Benefit-Cost Ratio	0.63	0.57	1.64	1.56	158.84	175.55

The significant increase in farmers net income from sugarcane cultivation was observed in the study area. The per hectare net income was Rs. -53188 and Rs. -43728 for planted and ratoon-I sugarcane crop during pre-SSD was increased to Rs. 102046 and Rs. 64367 respectively, for sugarcane planted and ratoon-I crop during post-SSD installation. The increase in net income was largely related to the increase in crop yield due to intervention of subsurface drainage technology. During pre-SSD, benefit-cost ratio was less than one depicting 0.63 and 0.57 respectively, for planted and ratoon-I crops has been increased to 1.64 and 1.56 constituting 159 and 175 per cent increase in these ratio in post-SSD installation. The per tone cost of sugarcane production was reduced from Rs. 3467 and Rs. 3886 to Rs. 1339 and Rs. 1410 showing a reduction of 61.37 and 63.71 per cent respectively, for planted and sugarcane crops during post-SSD. The increase in yield due to land reclamation lead to reduction in the cost of production. It indicates the worthiness of the subsurface drainage technology for reclaiming waterlogged saline soil in the study area (Datta *et al.*, 2004).

The significant increase in net income from cultivation of off-season crops was observed in the project area. The per hectare net income obtained during post-SSD was higher from wheat (Rs. 16705) followed by soybean (Rs. 13890), chickpea (Rs. 12989) and jowar (Rs. 6551), indicating a per centage increase of 350.15, 463.80, 280.64 and 200.38 respectively, in that order (Table 6). During pre-SSD, benefit-cost ratio was less than one for all the crops and it has been increased to more than one during post-SSD installation.

The per cent increase of these ratios were 182.94, 127.68, 102.01 and 156.37 respectively for wheat, chickpea, soybean and jowar. The increase in benefit-cost ratio of chickpea and soybean were in line with the findings of Tirlapur and Mundinamani (2014). The increase in yield due to land reclamation lead to decrease in per quintal production cost of all the crops showing a reduction of 50.50 to 64.66 per cent during post-SSD installation. This indicates the worthiness of the subsurface drainage technology for reclaiming waterlogged saline soil in the project area.

Table 6
Economics of cultivation of off-season crops during pre and post-SSD installation

Crops	*Pre-SSD*	*Post-SSD*	*Per cent change*
Cost of cultivation (Rs./ha)			
Wheat	18278	20995	14.86
Chick pea	21366	25441	19.08
Soybean	19513	22230	13.92
Jowar	14326	16549	15.52
Net income (Rs./ha)			
Wheat	-6678	16705	-350.15
Chick pea	-7191	12989	-280.64
Soybean	-3816	13890	-463.80
Jowar	-6526	6551	-200.38
Benefit-Cost Ratio			
Wheat	0.63	1.80	182.94
Chick pea	0.66	1.51	127.68
Soybean	0.80	1.62	102.01
Jowar	0.54	1.40	156.37
Cost of production (Rs/q)			
Wheat	2285	808	-64.66
Chick pea	4748	2085	-56.08
Soybean	2676	1323	-50.50
Jowar	2755	1077	-60.99

IMPACT ON LAND VALUES

The value of land, besides giving a prestige in society to the owner, decides credit worthiness of the farmer and plays an important role in many decision making processes on the farm (Tripathi, 2011). The value of the land used for agricultural purpose primarily depends on its productivity. The data on land values for pre and post-SSD installation was obtained from the project area farmers. Based on their observation and perception, land types were classified according to the severity of land affected by salinity and waterlogging in the project area. The study reveals that per acre value of the land has been increased from 1.6 lakhs to 8.6 lakhs indicating 437.5 per cent increase in post-SSD installation (Table 7). The land reclamation programme has proved a boon both to the farmers as well as to the country (Tripathi, 2011).

Table 7
Land values during pre and post-SSD installation (Rs./acre)

Land Type	*Pre-SSD*	*Post-SSD*	*Per cent change*
Severely affected	0.5	3.0	500.0
Moderately affected	1.0	5.0	400.0
Medium land	1.5	8.0	433.3
Good	2.0	12.0	500.0
Very Good	3.0	15.0	400.0
Mean	1.6	8.6	437.5

DISCUSSION

The soil salinization is a dynamic process and its influence changes over time. The project area farmers reported that salinity and waterlogging problems started during 1980s. As per farmers' experience, before the introduction of canal irrigation, their lands were productive and providing normal yield. But, after the introduction of canal, salinity problem started slowly in the initial years and became problematic during late 1980s. Over a period of time the land became less productive or barren since 25 to 30 years. This was mainly due to seepage as their land located along the banks of irrigation canals. To overcome the problem of waterlogging and soil salinity, installation of subsurface drainage technology was very much required.

The effects of subsurface drainage were a considerable increase in cropping intensity, a shift in the cropping pattern towards more remunerative crops, a remarkable increase in crop yields, and an increase in the productivity of fertilizers. The combined result of these changes was a substantial increase in farm incomes. In the arid and semi-arid regions, irrigation systems require a drainage system and without proper management of drainage system, irrigation systems will not sustain in the long run (Datta *et al.*, 2000). In India, both gravity and pumped systems were used, mostly draining back to the major rivers (Nijland *et al.*, 2005). The reason behind the success of subsurface drainage technology in Karnataka was gravity flow, due to which the drain water automatically removes without pumping. Although farmers clearly see the benefits of subsurface drainage, the support provided by the Government is insufficient to introduce the technology at large scale (Ritzema *et al.*, 2008a).

CONCLUSIONS

The post reclamation study revealed that land has become almost normal within 2 to 3 years after installation of subsurface drainage. The cropping pattern was changed towards remunerative and high value crops and cropping intensity was increased. The average soil salinity decreased by 72.85 per cent and the groundwater table was deeper by 427.78 per cent, especially during the monsoon period.

The yield of major crops has been increased upto 200 per cent. The farmers obtained per hectare net income of Rs. 1.02 lakh after reclamation compare to a loss of Rs. 53,000 per hectare before reclamation. The land value has been increased upto 500 per cent. The higher benefit-cost ratios indicate the economic viability of drainage technology. The subsurface drainage technology being capital-intensive, farmers in Karnataka were coming forward to install it on their own cost due to its effectiveness. But more support need to be provided by the Government to install subsurface drainage technology at large scale.

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