https://doi.org/10.56093/ijas.v90i1.98683

Indian Journal of Agricultural Sciences **90** (1): 212–9, January 2020/Article

Techno-economic evaluation of recharge structure as localized drainage option for sustainable crop production in sodic agro-ecosystems

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Received: 31 December 2019; Accepted: 7 January 2020

ABSTRACT

The low infiltration capacity of sodic soils and alkaline irrigation water are the main limiting factors in sustaining crop production under salt affected agro-ecosystems. The extreme rains aggravate the chances of crop failure further, due to water stagnation for prolonged period under sodic lands. Frequency of such extreme rainfall events is likely to increase in near future due to changing climatic scenario. ICAR-Central Soil Salinity Research Institute, Karnal, designed, developed and installed the cavity type individual farmer's based recharge structure at four locations in low lying areas of adopted villages (under Farmer FIRST Project) of Kaithal district for evaluating their effectiveness in facilitating the localized drainage option and sustainable crop production. The study results indicated that the installed structures were quite effective in saving the submerged crops particularly during the periods of intense rain in addition to augmenting groundwater and improving its quality. The groundwater table rose to an extent of 2-3 m beneath the structure during monsoon month (July 2017) compared to summer month of April 2017. The improvement in groundwater quality was also observed in surrounding areas as a consequence of reduction in RSC by 2-3 meq/l compared to the values at the time of installation of the structure. A heavy rainfall (~150 mm) resulted in 35-40% crop damage in open-fields which was reduced down to 5-15% due to provision of recharge structure, significantly decreasing the additional cost towards re-transplanting and compensated the yield loss. Benefit-cost ratio of 1.93 and internal rate of return of 145% indicated economic feasibility of the investment on recharge structure. The results revealed that installation of recharge structure was quite advantageous in providing the localized drainage option in low lying and land locked areas where runoff gets accumulated and adversely affected the crop production.

Key words: Economic feasibility, Sodic environment, Recharge structure, Rice-wheat system

Globally, about 1125 million hectare (M ha) of arid and semi-arid lands became salt-affected due to geological, hydrological, and pedological processes (Hossain 2019) with the estimated annual economic loss of US$ 27.5 billion (Qadir *et al.* 2014) and associated social consequences. In India, salt affected lands are spread over an area of 6.74 M ha (Mandal *et al.* 2009), losing 16.84 million tonnes of farm production valued at US$ 3.5 billion per annum (Sharma *et al.* 2015). Such economic losses are likely to attain epic proportions as this area would almost treble to 16.2 M ha by 2050 (Vision 2050, ICAR-CSSRI, https://www.cssri.res.in). The continuous irrigation with high alkalinity water containing dispersive sodium cations results in development of sodic soils. In general, pH of such soils remains 8.5 or more and in extreme cases may be above 10.5. Sodic soils tend to develop poor structure because adsorptions of sodium ions on clay complexes cause the soil particles to deflocculate or disperse (Choudhary *et al.* 2011, Minhas *et al.* 2019). Furthermore, the natural drainage courses are becoming disturbed over time due to unplanned developmental activities like construction of road, railway tracks etc. The uneven and erratic spatio-temporal distribution of monsoonal rains poses threat to sustainable crop production in sodic environments with poor drainage facility where water remained stagnant for longer time. Untimely occurrence of intense rainfall events within short time span is a very common phenomenon now a days and its frequency may certainly increase in the times to come due to climate change effects. Sathaye *et al.* (2006) have also predicted highly uncertain spatial and temporal distribution of precipitation and air temperature in India under changing climatic condition. These changes will have profound effects on agriculture-a source of livelihood for millions of people and water resources (Mall *et al.* 2006).

In recent times, it has been observed that the crop of low lying areas gets submerged whenever heavy monsoonal

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rains occur causing crop damage and realistic yield penalty. The magnitude of decrease in yields depends upon the degree of crop tolerance and the developmental stage (vegetative or reproductive) at which the rainfall event coincides. Also, the occurrence of untimely winter rains in the months of February-March due to western disturbances and even 2-3 days water stagnation may cause substantial yield loss in wheat. Therefore, an assured drainage facility is required to counter the localized water stagnation and harvest satisfactory yields in sodic areas. In the absence of proper surface drainage network and disturbance in natural drainage course, there is need to develop farm level location-specific drainage options in disposing off the accumulated rainwater from low lying areas because neighbouring farmers does not even allow diverting excess water through their fields. Under such situations, the only option left is to divert excess water directly to the aquifer through individual groundwater recharge structure (Kamra *et al.* 2010). Diverting rainwater to aquifer will not only save the submerged crop but the good quality harvested excess water will also help in diluting and improving the quality of poor quality underground water. A number of agencies in India including the Central Ground Water Board (CGWB), research institutes, state agricultural universities and non-governmental organizations (NGOs) have undertaken various studies on artificial groundwater recharge (Chadha 2002). But, these studies were targeted on the establishment of big structures installed at community level which may not be quite suitable and serve the purpose at farm level. Further, post-installation monitoring revealed that though big artificial groundwater recharge structures are quite effective, but their success is very limited due to poor post-installation maintenance. In view of such techno-economic limitations, ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal designed, developed and installed individual farmer's based recharge structures to evaluate their feasibility in providing location specific drainage option, its impact on poor quality groundwater of the surrounding area and support sustainable crop production in sodic environments.

MATERIALS AND METHODS

Brief description of study area

The study was undertaken in Farmer FIRST project adopted villages (Sampli Kheri and Kathwar) of Kaithal district in Haryana state representing salt affected agro-ecosystems of Ghaghar plains. The experimental location represents semi-arid monsoonal climate with three-fourth of total precipitation (~563 mm) received during July to mid-September. The soils of the study area are classified as acquic natrustalfs with soil pH_2 >9.0 in surface soil (0-15 cm) and >9.5 in sub-surface (>15 cm). The infiltration rate (2.4-4.1 cm/day) of soil was poor with bulk density of >1.4 g cm^{-3}. The groundwater of the study area is bicarbonate dominated and water table remains >15 m below ground level. Rice-wheat is the dominant cropping system in the area. The crop failure in lowland area caused by rainwater accumulation during intense rainfall is the major limitation affecting crop production to a greater extent. The recharge structures were installed at four locations in the study area to facilitate quick drainage and safeguard standing crop from submergence particularly in low lying areas during the periods of heavy and untimely rainfall events. The GPS location of installed structures is depicted in Fig 1.

Design, construction and technical evaluation of recharge structure

Based on formal group discussions, transect walks

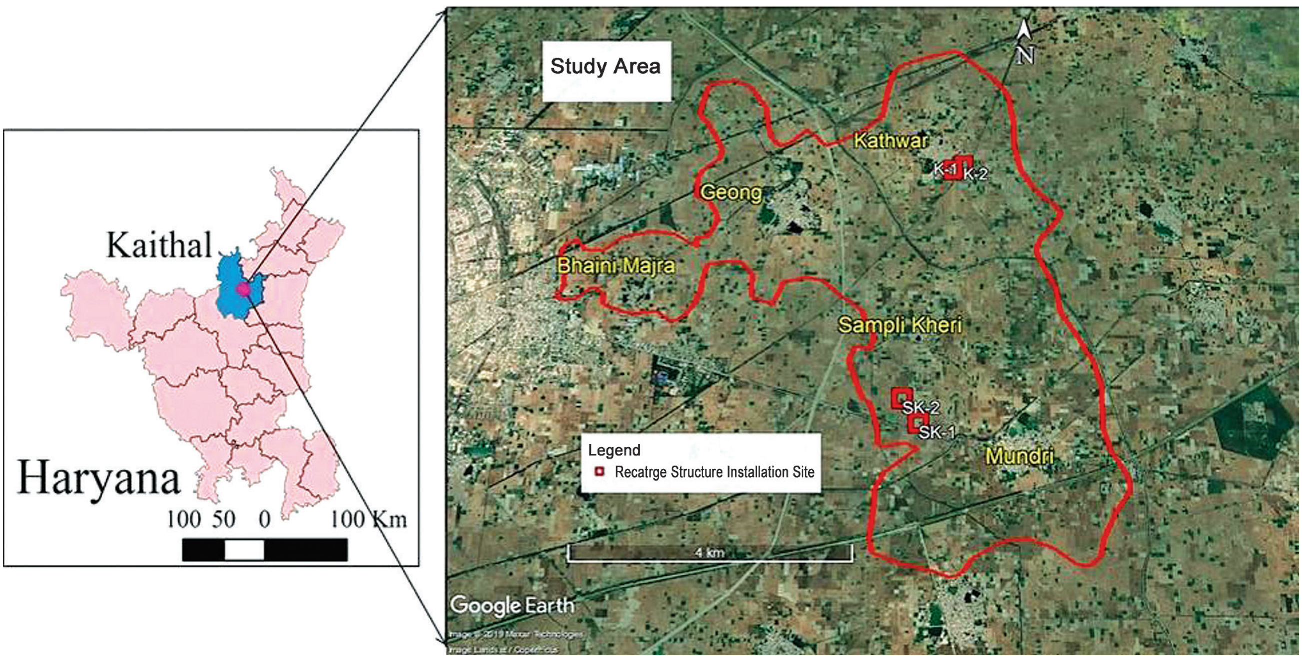


Fig 1 GPS location of installed recharge structures in the study area.

and farmers' feedback, the lowest points where rainwater gets accumulated during the periods of intense rains and damage the crops were selected for installation of recharge structures. The cavity type recharge structure was designed and installed at all the selected sites. The design feature of installed structure is shown in Figure 2. The recharge cavity was constructed by drilling a bore hole until a sandy layer (> 10 m) was found below a clay layer. A high pressure (10 kg cm^{-2}) PVC pipe of 22.5 cm diameter was inserted in 25 cm drilled bore hole. A PVC reducer of 22.5 cm × 15 cm size was fixed at the bottom of recharge pipe and rested whole length on hard pan (clay layer) with the help of this reducer. The PVC pipe pierced through a hard thick clay layer below. A semi-spherical cavity was formed in extensive sand zone by following the standard methodology of continuously pumping till sand free water is achieved. To retain physical impurities carried away with runoff water from entering into aquifer, a sand-cum-radial filtration unit was also constructed. Filtering unit consisted of 3 m × 3 m × 3 m size brick masonry chamber around recharge pipe. A 9 inch perforated pipe wrapped with synthetic filter (plastic net) was placed horizontally at the bottom of the brick chamber to receive water passing through sand filter and transfer to recharge pipe. The sand based vertical filter consisted of three layers of materials, viz. 40 cm thick boulders at the bottom, 40 cm thick layer of gravels in the middle and about 75 cm thick coarse sand layer on the top. Above sand layer, a 1.5 m long and 12 inch diameter pipe was fixed on 9 inch diameter recharge pipe. The 1.0 m portion of 12 inch φ pipe was perforated and covered with synthetic net (filter) to retain physical impurities entered into masonry chamber. The lower 0.5m pipe was not perforated so as to provide space for settlement of sediments moving with inflowing recharge water.

The technical evaluation of recharge structures was done in terms of recharge rate, groundwater level fluctuation and improvement in groundwater quality. Recharge rate was estimated as amount of water recharged in a unit time. The recharge structure had the capacity to drain out 8.64 ha-cm of water into aquifer within 24 hour. The water table depth and water quality parameters such as electrical conductivity (EC) and residual sodium carbonate (RSC) of water samples were monitored periodically at 15 days interval. Groundwater table was measured using water level recorder (OTT KL 010). The indigenous water sampler was used for collection of water samples from installed structure's pipe and installed observation wells. Electrical conductivity and pH of water samples was measured using EC meter (CON 700, EUTECH,) and pH meter (pH 700, EUTECH), respetively. RSC was analysed in laboratory using titration method. Observation wells were installed at varying distance (10, 30, 60 and 90 m from the main unit) to monitor the spatio-temporal changes in water table depth and water quality. Depth of each observation well was kept similar to the depth of recharge structure. Manual drilling of 62-75 mm diameter was done up to the desired depth and 50 mm diameter PVC pipe was inserted into bore hole. Perforated pipe wrapped with synthetic net was lowered against the saturated sandy layer while blind (no perforation) pipe was in the remaining portion. At the top of PVC pipe, one meter length of galvanized iron (GI) pipe of 50 mm diameter was fixed at about 30 cm below the ground surface. This joint was reinforced with the concrete base of size 30 cm × 30 cm × 30 cm. To safeguard against clogging, runoff water was first passed through a filtering unit consisting of layers of coarse sand, gravel and boulders and perforated pipe wrapped with synthetic filter in a small brick-masonry chamber (Kumar *et al.* 2012 and 2014).

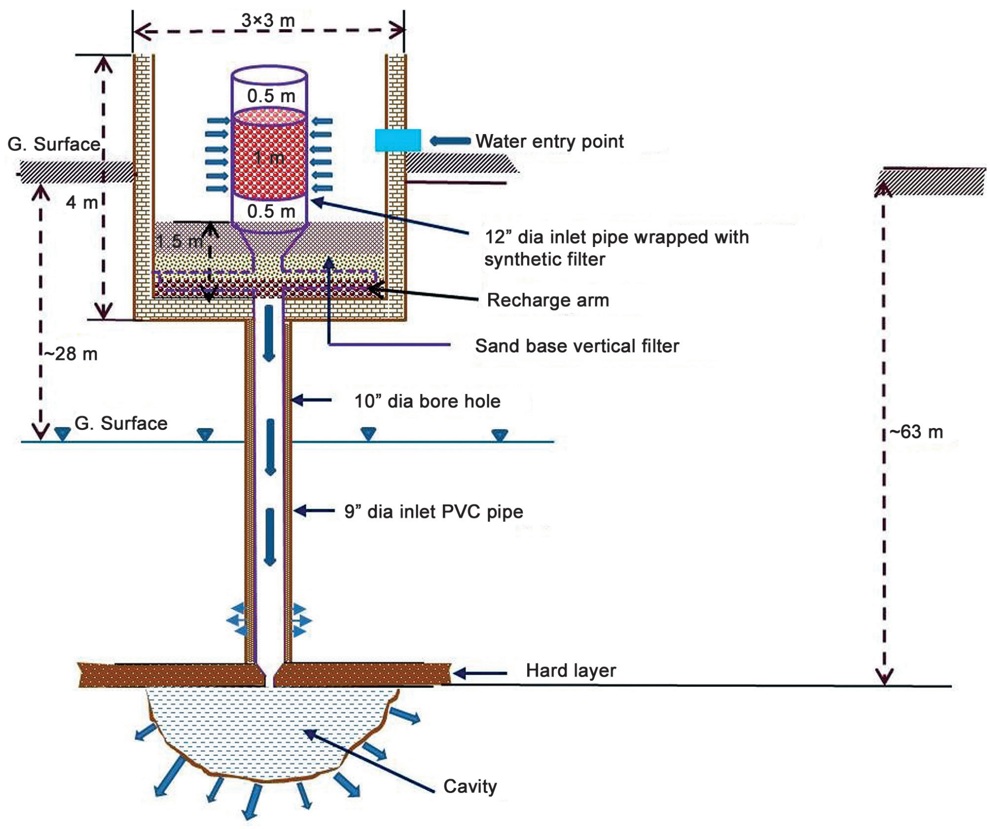


Fig 2 Design specification of a recharge structure installed at study sites.

Economic evaluation

The economic and financial viability of installed structure was studied by considering the capital requirement for installation of structure, its annual operational and maintenance cost and benefits generated by the system. The initial investment is made once for installation of the structure, whereas the returns obtained from the project is spread over life of the structure. The financial appraisal of project includes costs and benefit analysis by estimating economic parameters. Four criteria were used to assess the economic feasibility of investment (Gittinger 1976) on ground water recharge structure installed to protect the crop during extreme rainfall events. These were (i) Benefit-cost ratio (BCR); (ii) Net present value (NPV); (iii) Internal rate of return (IRR) and (iv) Payback period (PBP). The present analysis is based on the following two assumptions; *viz*. the market rate of interest was considered 10 per cent per annum and the life of the ground water recharge system was assumed 20 years.

Benefit Cost Ratio (BCR): The benefit-cost ratio is calculated by dividing the discounted present worth of benefits by discounted present worth of costs expected at different points of time using the following formula:

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}$$

where, ‘Bt’ is the benefit received in t^{th} year; ‘C_t’ is the cost incurred in t^{th} year; ‘t’ is the time in years; ‘n’ is the life of system; and ‘i’ is the rate of interest for discounting the cost or benefit.

Net Present Worth (NPW): The NPW is calculated by taking the difference between the discounted present worth of benefits and discounted present worth of costs. The positive values of NPW reflect economic viability of the project whereas negative NPW indicates economic loss in the project. The formula used for estimation of NPW is:

$$NPW = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}$$

Internal Rate of Return (IRR): The IRR is the marginal efficiency of capital or discounted cash flow of the investment on a project. IRR is the discount rate at which the NPW is equal to zero and the benefit-cost ratio is equal to one. In calculating the NPW, we independently chose a discount rate based on the opportunity cost of capital and then found the differences between discounted benefits and costs. The process of finding the IRR involves trial and error method. The IRR is compared with the opportunity cost of capital and if it is either higher than or equal to it, the technology is assessed to be desirable. The IRR can be expressed in algebric form as:

$$IRR = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} = 0$$

The easier and widely adopted method employed for estimation of true IRR is the interpolation formula as follows.

$$RR = \textit{Lower discount rate} + \textit{Difference between the two discount rates} \times \frac{\text{NPW at lower discount rate}}{\textit{Difference between NPW's at the two discount rates}}$$

Pay Back Period (PBP): The payback period measures the number of years a project will take to repay the investment. The following formula is used to calculate the payback period, if the cash flows are uniform.

$$PBP = I/E$$

Where, ‘PBP’ is the number of years required paying back the investment, ‘I’ is the initial capital investment; and ‘E’ is the annual net benefits. If the per year cash flows are not uniform, the payback period can be calculated as the cumulative proceeds in successive years until the total is equal to the original outlay.

RESULTS AND DISCUSSION

Technological evaluation

The design of all recharge structure installed at 4 selected sites in the study domain was similar in design except the depth from ground surface where cavity was formed. The recharge rate (disposal of excess water into aquifer) at one site, i.e. Kathwar (K-1) was determined and considered it as a representative value for the others. It was found that rate of recharge varies with operation time because of clogging of top sand layer of vertical filter. However, structure was remained under operation with radial filtering arrangement provided with vertical sand filter. This showed the benefit of integrated filtering unit as compared to vertical sand filter alone for recharge structure as drainage option in sodic environment. The recharge rate was determined as 14.5 liters per second (lps) in the beginning of recharge period when filtering unit was working at its full capacity, which had been reduced to 5.9 lps by the end of the period. The reduction in recharge rate with time was attributed to clogging of the filter with sediments carried away with runoff water. By considering the average recharge rate, it is estimated that about 4406 m^3 rain water was diverted to poor quality aquifer during one recharge event of 05 days. Few more recharge events also took place during the study period of 2017-19. The quick disposal of accumulated rain water at the lowest point into aquifer not only helped in saving transplanted rice seedlings and standing crop from submergence, but also improved the groundwater quality.

The impact of installed recharge structure on groundwater resources was also assessed in terms of fluctuation in water level and improvements in its quality. The reduction in residual sodium carbonate (RSC) was considered as one of the indices for calculating the water quality parameter. The groundwater fluctuation beneath the structure at four different sites is presented in Fig 2 (a-d). The data showed that groundwater table raised to an extent of 2-3 m beneath the structure at all the sites during monsoon month (July 2017) as compared to summer month (April 2017). This was due the fact that about 147 mm rainfall occurred by virtue of single rainfall event and a substantial volume of water recharged through installed recharge structure. Though, water level beneath the structure raised at all the sites, but magnitude of change was different at different sites depending on the quantity of excess rain water available for recharging. Temporal data on groundwater table depth also indicated that the water level below ground surface was lower in October, 2017 than the summer months which indicated that recharging took place only during the monsoon season (Fig 3a-d). However, in October, 2018, groundwater depth was higher at all locations in comparison to summer months, which confirmed that there was no recharge event during the monsoon season of 2018. The RSC of groundwater during the installation of structure was found in the range of 6-8 meq/l, which was reduced to 3-5 meq/l (Fig 3a-d). Hence, reduction in RSC was in the range of 2-4 meq/l at different locations. The significant reduction in RSC was mainly due to substantial recharging of rain water into aquifer which might have diluted the original RSC. These results confirmed the earlier findings of Narjary *et al.* (2014), reported as improvement in groundwater quality beneath the groundwater recharge structure. In subsequent time, RSC values slightly increased or remained almost similar at all the study sites confirming that either recharge event did not happen or there was scanty rain water which did not have much dilution effect on groundwater. In general, trend was more or less similar at all the sites but it varied slightly with the variation in the volume of rain water available for recharging at different sites.

In order to assess the impact of installed structure on ground water quality at spatial scale, ground water samples were collected from the distance of 10, 30, 60 and 90 m (through piezometers) from the actual recharging points for estimation of RSC. The RSC values of collected ground water samples are presented in Fig 4a for Sampli Kheri (SK-1) site and Fig 4b for Kathwar (K-1) site. The RSC of ground water at the time of installation (April 2017) was recorded as 6.3 meq/l and 5.95 meq/l at SK-1 and K-1 sites, respectively. The temporal data on groundwater quality showed that up to the distance of 10m from the actual

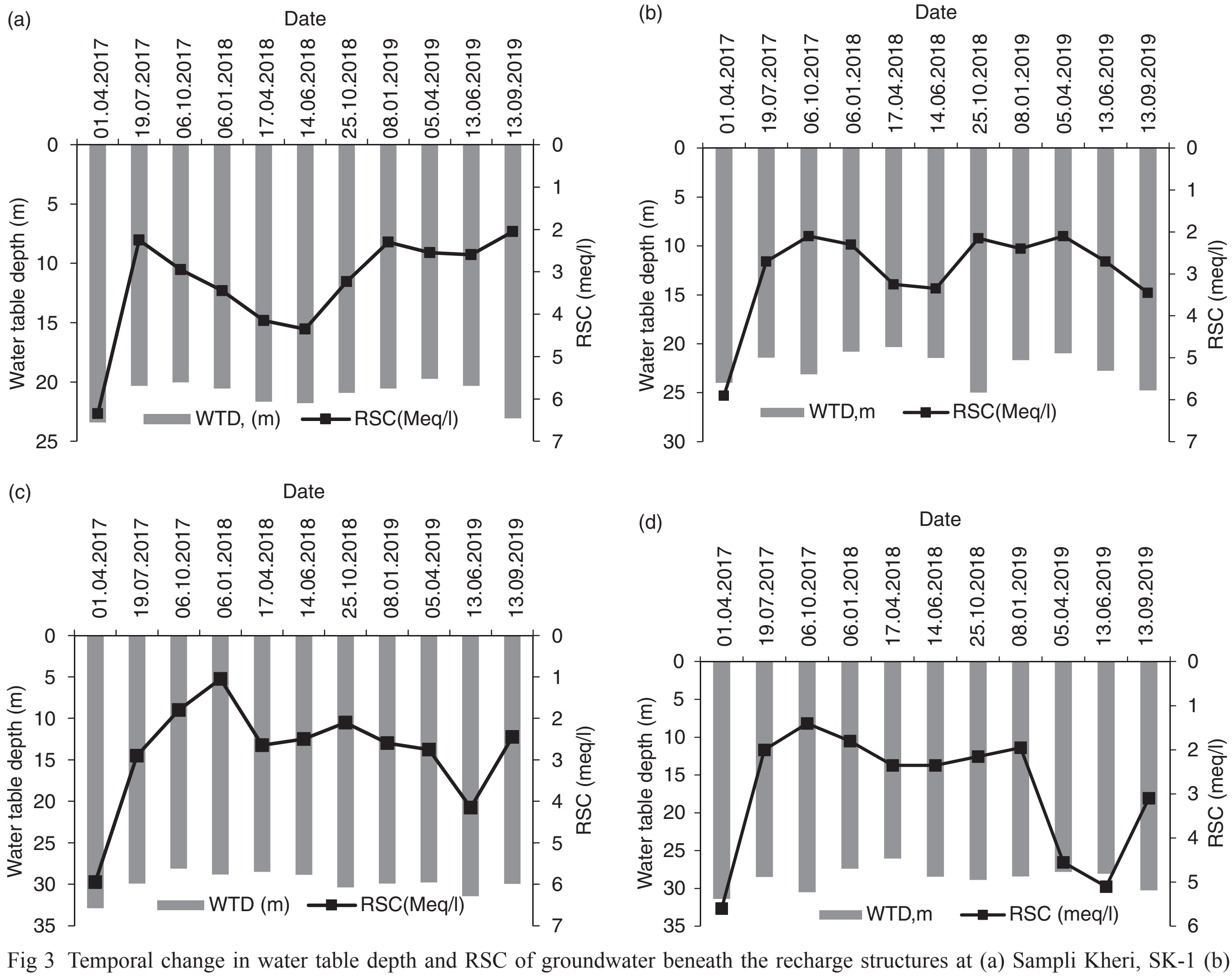


Fig 3 Temporal change in water table depth and RSC of groundwater beneath the recharge structures at (a) Sampli Kheri, SK-1 (b) Sampli Kheri, SK-2 (c) Kathwar, K-1 and (d) Kathwar, K-2.

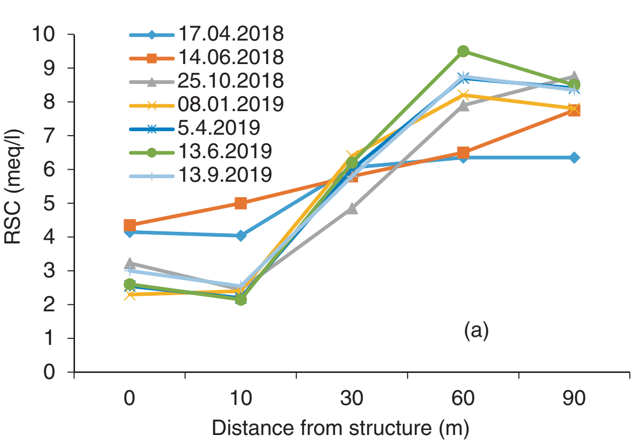
recharge structure, RSC value reamined <6 meq/l during the entire period of observation and it tended to reach 6 meq/l at the distance of 30 m from the recharging point at SK-1 (Fig 4a). At K-1 site, RSC value was <4 meq/l at all dates of observation points (Fig 4b). Hence, the reduction in RSC value beneath the recharge structure as compared to the RSC value recorded at the time of installation exhibited dilution of poor quality groundwater by mixing with good quality recharged rain water. A recharging event took place during early July, 2017 contributed significant contribution towards reduction in RSC value beneath and around (10m) the recharging point. But, RSC of the samples collected from 30 m distance showed slightly lesser or almost same RSC as compared to the respective RSC values before installation of respective structure, which revealed very less influence of installation of structure on groundwater quality. However, RSC value at 60m and 90m from the recharging point remained same or slightly higher clearly indicating that there was no impact of recharging event happening during April 2017-June 2019. Hence, it can be concluded that structure did not have any influence on groundwater quality beyond 30m from the actual recharging point. However, the effect of structure on groundwater resources is directly associated with number and amount of recharging event taking place during the monsoon months. If more rainwater is recharged, there is possibility that improvement in water quality will certainly be more profound and to larger extent covering more areas.

Economic analyses of groundwater recharge structure

The capital cost of recharge structure depends on the lithology of the area where the structure has been installed. In the present study, the capital cost was estimated to be ₹ 2.5 lakh considering ₹ 5000 towards annual operational and maintenance cost. For estimating the financial viability of the recharge structure, the project life is considered as 20 years with annual discount rate of 10%.

The economics of crop production was worked out with rice and wheat crops grown in annual rotation while considering the impact of individual farmer's based recharge structure installed at farmer's field. A heavy rainfall event (~150 mm) occurred immediately after rice transplantation in the last week of June. The recharge structure saved about 85-95% of the established paddy crop in vulnerable 5 ha area. In contrast, about 35-40% crop damage was noticed in the area without recharge structure. To compensate the crop loss, the farmers were forced to bear an additional cost of ₹ 5000 (with structure) and 7500 per ha (without structure) incurred towards the purchase of rice seedlings for re-transplanting the affected areas. The potential reduction in yield of vulnerable area was estimated by taking into account the severity of crop damage under both the situations. Overall the yield reduction due to delayed re-transplantation was estimated as 3.5 per cent (with structure) and 17.5 per cent (without structure) leading to estimated yield penalty of ~1.25 q/ha and ~6 q/ha, respectively, as against the average yield (30 q/ha) of cultivated rice cv. Pusa 1121 under the present scenario. The study revealed that the recharge structure is quite beneficial in reducing the crop loss owing to unexpected heavy rainfall events during *kharif* season. No such rainfall event occurred during *rabi* season, therefore, no detrimental effect on wheat crop was noticed. Though no such heavy rainfall event occurred during the winter *rabi* (wheat) season. However, if 10 cm rainwater would have stagnated for 4-5 days in vulnerable 5 ha area, then, the reduction in average wheat yield would have been up to the extent of ~50% in areas with recharge structure as compared to ~75% loss where no drainage option was provided.

The economic analysis revealed that the establishment of groundwater recharge structure has a potential risk reduction capacity by saving the crops during the periods of adverse rainfall situations. Though the initial capital investment cost was relatively high for installation of recharge structure, the present study revealed that the investment can be expected back within 2 years (payback period) of installation. Considering the life of recharge structure as 20 years and discount rate of 10% per annum, the net present value (NPV) was estimated to be ₹ 3357091 with a benefit cost ratio (BCR) of 1.93 and an internal rate



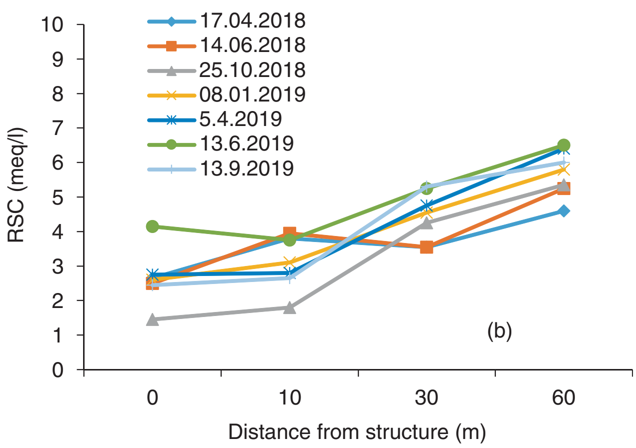


Fig 4 Spatio-temporal influence of structure on residual sodium carbonate (RSC) of groundwater at (a) Sampli Kheri–SK1 (b) Kathwar–K-1 sites.

Table 1 An account of economic analysis of groundwater recharge structure

Particulars	Unit	Without recharge structure	With recharge structure	Difference (%)
Capital cost of recharge structure (including installation cost)	₹	-	250000	-
Annual operational and maintenance cost	₹	-	5000	-
Life of recharge structure	Years	20*	20	-
Crop damage due to intense rainfall**	%	35-40	5-15	-
Yield reduction due to delayed re-transplantation in rice crop considering 5 ha vulnerable area	%	15-20	2-5	-
Harvested yield @ soil pH_2~9				-
Rice cv. Pusa 1121	q/ha	24.00	28.95	20.63
Wheat cv. KRL 210	q/ha	40.00	40.00	Nil
Market price @ 2017-18				-
Rice cv. Pusa 1121	₹/q	3250	3250	Nil
Wheat cv. KRL 210	₹/q	1735	1735	Nil
Discount rate	%	10	10	Nil
Cost of cultivation***	Rs/ha/annum	80250	78750	-1.87
Gross returns	Rs/ha/annum	149838	163488	9.11
Net returns	Rs/ha/annum	69588	84738	21.77
Discounted total cost	₹	3416067	3602216	5.45
Discounted total benefit	₹	6378256	6959306	9.11
Net present value (NPV)	₹	2962188	3357091	13.33
Benefit cost ratio (BCR)	-	1.87	1.93	3.21
Internal rate of return (IRR)	%	-	145	-
Pay back period (PBP)	Years	-	2	-

*considered only for estimation of cost and returns and not as project life, **paddy crop was re-transplanted later by spending an additional cost of Rs 5000 and Rs 7500 per ha in with and without recharge structure. ***only variable cost was taken into account.

of returns (IRR) of 145% (Table 1). On the other hand, the farmers achieved lesser net returns (₹ 69588 per ha) and benefit cost ratio (1.87) where no structure was installed. The significantly higher IRR, BCR, NPV and lesser payback period clearly indicated that the economic feasibility of investment on recharge structure for providing drainage option under sodic environments.

Conclusions

The poor infiltration capacity and alkaline irrigation water poses problems in sustainable crop production under sodic environments. The crops in low lying lands often face crop failures as a result of water stagnation for prolonged period. Therefore, a recharge structure was designed, developed and evaluated for its techno-economic feasibility in providing a localized drainage option while disposing off the excess water into aquifer so as to avoid water stagnation in low lying areas. The total cost of individual farmer's based recharge structure was estimated to be ₹ 2.5 lakh (₹ 1200/ ft approximately), depending upon lithology of the area. The present study puts insights into the rise in groundwater table to the extent of 2-3 m beneath the structure during the monsoon months as compared to pre-monsoon period. Compared to the observed RSC at the time of installation, an improvement in groundwater quality was also recorded as perceived by reduction in RSC value to the tune of 3-4 meq/l after recharge event. Economic analysis revealed the beneficial effect of installing recharge structure under sodic environments with higher BCR (1.93), IRR (145%), NPV (₹ 3357091) and lesser payback period (2 years). Therefore, the installation of recharge structure can be an effective strategy for sustainable crop production in low lying and land locked areas of sodic environments by facilitating point drainage option, diverting rain water to aquifer, diluting the high RSC groundwater.

REFERENCES

Chadha D K. 2002. State of art of artificial recharge applied on village level scheme in India. (*In*) *Proc.: Seminar on Management of Aquifer Recharge and Subsurface Storage: Making Better Use of Our Largest Reservoir*, Wageningen, The Netherlands, 18–19, 2002.

Choudhary O P, Ghuman B S, Singh B, Thuy N and Buresh R J. 2011. Effects of long-term use of sodic water irrigation, amendments and crop residues on soil properties and crop yields in rice–wheat cropping system in a calcareous soil. *Field Crops Research* **121**: 363–72.

Hossain M S. 2019. Present scenario of global salt affected soils, its management and importance of salinity research. *International Research Journal of Biological Sciences* **1**(1): 1–3.

Kumar S, Kamra S K, Yadav R K and Narjary B. 2014. Effectiveness of horizontal filter for artificial groundwater recharge structure. *Journal of Agricultural Engineering* **51**(3): 24–33.

Kumar S, Kamra S K, Yadav R K and Sharma J P. 2012. Evaluation of sand-based storm water filtration system for groundwater recharge wells. *Current Science* **103**(4): 395–404.

Mall R K, Gupta A, Singh R, Singh R S and Rathore L S R. 2006. Water resources and climate change. *Current Science* **90**(12): 1610–1626.

Mandal A K, Sharma R C and Singh G. 2009. Assessment of salt affected soils in India using GIS. *Geocarto International* **24**: 437–456.

Minhas P S, Qadir M and Yadav R K.2019.Groundwater irrigation induced soil sodification and response options. *Agricultural Water Management* **215**: 74–85.

Narjary B, Kumar S, Kamra S K, Bundela D S and Sharma D K. 2014. Impact of rainfall variability on groundwater resources and opportunities of artificial recharge structure to reduce its exploitation in fresh groundwater zones of Haryana. *Current Science* **107**(8): 1305–1312.

Qadir M. Quillerou E, Nangia V, Murtaza G, Singh M, Thomas R J, Drechseland P, Noble A D. 2014. Economics of salt-induced land degradation and restoration. *Natural Research Forum* **38**: 282–295.

Sathaye J, Shukla P R and Rabindranath N H. 2006. Climate change, sustainable development and India: Global and national concerns . *Current Science* **90**(3): 314–325

Sharma D K, Thimmappa K, Chinchmalatpure A R, Mandal, A K, Yadav, R K, Chaudhari, S K, Kumar S and Sikka A K. 2015. *Assessment of production and monetary losses from salt affected soils in India*. Technical Bulletin, ICAR-CSSRI, Karnal, India. pp. 1–99.

Vision 2050. https//www.cssri.res.in