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Impact Of Seawater Intrusion Bund On Soil & Water Conservation Along The Coastal Line Of Poonakary, Sri Lanka

Sanjeepan S[1], Weerasinghe T.K[2]. and Satheeswaran S[3]

[1]Sri Lanka School of Agriculture, Vavuniya, Department of Agriculture, Sri Lanka

[2]Department of Botany, Open University of Sri Lanka

[3]Seed & planting Material Development Centre, Paranthan, Sri Lanka

Abstract – Saltwater intrusion into coastal aquifers is reported at coastal region of Poonakary, Kilinochchi district. A sea water intrusion bund was constructed by United Nations Development Programme in 2015 to reduce the issues with seawater intrusion. This study aimed to measure the variations of soil salinity and pH before (2015), just after (2016) and three years after (2018) the construction of bund and to identify the impacts of seawater intrusion bund on soil, water quality and crop improvement in the area. The study was conducted in three selected Grama Niladari Divisions of Poonakary, during July to September period in 2018. Soil samples were collected from 30 locations at different sampling depths and the locations were recorded by using GPS and fifteen water samples were collected to measure the water quality parameters and the values compared with WHO standards. A questionnaire survey was conducted to assess the crop improvement in the selected locations. When comparing the soil pH in 2016 and 2018, at all depths except 60cm, changes were highly significant and at 60 cm, it was significant. The Soil EC during 2016 and 2018 revealed that, at 15cm, 30cm and 60cm the changes were significantly different and at 45cm it was not significantly differ due to hardpan formation. A considerable improvement in the water quality and yield improvement of paddy were observed. The study reveals that, the seawater intrusion bund can be considered as a potential permanent solution for seawater intrusion at Poonakary.

Keywords – Aquifers; Hardpan; Recharge potential; Seawater intrusion; Water quality.

I. Background

Seawater intrusion is the movement of saltwater into freshwater aquifers due to natural processes or human activities that occurs in virtually all coastal aquifers. Seawater intrusion is caused by the decrease in groundwater levels or by the rise in seawater levels [10]. It occurs naturally to some degree in most coastal aquifers, owing to the hydraulic connection between groundwater and seawater. Saline water has a higher mineral content than fresh water, it is denser and has a higher water pressure. As a result, saltwater can push inland beneath the freshwater. Groundwater pumping from coastal freshwater wells has increased saltwater intrusion in many coastal areas. Other contributors to saltwater intrusion include navigation channels or agricultural and drainage channels, which provide conduits for saltwater to move inland and it can also make sea level rise. Saltwater intrusion can also be worsened by extreme weather events like hurricane storm surges [8].

According to the Ghyben-Herzberg Principle, the saltwater rises 40 times for every time of freshwater depression and forms a cone of ascension. Intrusion can affect the quality of water not only at the pumping well sites, but also at other well sites, and undeveloped portions of the aquifer. Saltwater intrusion prevention may be a continuous requirement, or it may be an intermittent need [10].

Further, Saltwater intrusion is a serious issue in the coastal zone wells of Jaffna resulting low quality groundwater which is unsuitable for drinking and agricultural purposes [15]. This eventually left hundreds of acres of arable lands abandoned and caused hundreds of wells with brackish water in the coastal zone [9] , [18].

In northern part of China, the area around the Bohai Sea was reported as seawater-intruded land due to excessive groundwater utilization and the area was estimated to be approximately 2,457 km^2 in 2003. Great efforts have been made to mitigate the extent of seawater intrusion and to secure more freshwater resources, including building monitoring networks, subsurface barrier and groundwater reservoirs, and artificial infiltration facilities [17]. In Qatar, it has been noted that the seawater interface in the north eastern zone of the peninsula is advancing inland at an average rate of approximately one km / year. Rainfall is believed to be the sole natural water resource available to recharge the groundwater in the Qatar peninsula. Natural recharge could be enhanced by the construction of recharge wells, bunds and deliberate loosening of the bedrock on the edge of the Rodats depressions [6]. In United Arabic Emirates, a rock fill dam was constructed at Wadi Bih to retain the floods and to recharge the groundwater aquifers. Another dam was constructed at wad Hamm, northwest of the city of Fujaairah, with recharge facilities consisting of trenches perpendicular to the flow direction [6]. In Chennai, India, the seawater intrusion has been identified along the coastal aquifers. The improvement of groundwater potential by a check dam over the Arani River, Tamil Nadu, India shows that the check dam has considerable effect on increasing the quality of groundwater [14].

In Sri Lanka, Jaffna, barrages across the three main sea mouths of Thondamanaru, Ariyalai and Arali of Jaffna lagoon stop seawater intrusion towards the peninsula [18].

It was pointed out by Central Ground Water Board, Ministry of Water Resources, India (2007), the regions experiencing high (1000 to 2000 mm/year) to very high (>2000 mm/year) rainfall, a major part of the water received during the rainy season goes as surface runoff. Only 5 to 10 percent of the total precipitation may infiltrate into the ground and reach the water table, which may be enough for adequate recharge, whereas in the alluvial areas that figure is about 15 to 20 % of the rainfall [2]. It was estimated that the annual groundwater recharge as 10 million-acre feet or about 12,375 million cubic meters (MCM) by taking as 10% of rainfall as average recharge in Sri Lanka [12]. However, this does not represent the total water stored in the ground since it can only be determined by estimating aquifer volumes and properties.

In India, the effect of water harvesting structures on groundwater recharge and water quality was evaluated in a watershed situated in a semi-arid region in Andhra Pradesh, India. Two percolation tanks and two check dams with a total storage capacity of 4.209 ha/m were selected to assess their effects on groundwater recharge and water quality within the influence zone of the water harvesting structures. Daily rainfall, evaporation and storage depth in structures were measured to quantify percolation. Using rainfall–run-off relationship with antecedent precipitation index as a factor, complete water budgeting was carried out. Results show that the threshold value of rainfall for ensuring 1 mm potential recharge is 61 mm. Potential recharge is only 3% of annual rainfall received. Water quality analysis revealed that except pH, all other water quality parameters like electrical conductivity, sodium adsorption ratio, residual sodium carbonate, total hardness, nitrate and fluoride content reached desirable limits in close vicinity (< 100 m) to the water harvesting structures. Increased availability of groundwater led to subsequent over-exploitation in below normal rainfall years and the number of bore wells increased by three times [1].

The importance of the seawater intrusion bund is, to prevent the entry of seawater, improve the ground water recuperation and quality, extend the cultivable land extent and improve the productivity of existing cultivable land.

The main objectives of this study are to:

- assess soil salinity status and pH before and just after and three years after the construction of bund
- identify the contribution of seawater intrusion bund on water quality improvement
- identify the crops and their varieties cultivated in the area before and after the construction of bund

II. MATERIALS AND METHODS:

The study area is situated in Kilinochchi District, Northern dry zone of Sri Lanka. It is bounded in the North by Uppuaru lagoon, where saline intrusion in the freshwater base is reported, especially during dry period and water scarcity is a main constraint for many inhabitants of the Division, even for drinking and domestic usage [4].

United Nations Development Programme (UNDP) has erected a seven-kilo meter bund in 2015. The seawater intrusion bund (Fig.I) prevents saltwater intrusion towards Kiranchi, Pallavarayankattu and Kariyalainagapaduvan Grama Niladari divisions of Poonakary. The three Grama Niladari divisions were seriously affected by seawater encroachment before the construction of bund [19]. As a result, people faced problem in getting good quality water in their wells and cultivable lands.

Figure I: Location map of seawater intrusion bund and sampling locations of Poonakary division

The soil and water quality data for the year 2018 were collected from July to September 2018. A questionnaire survey was carried out to gather information regarding the type of crops and the varieties cultivated before and after the construction of bund. A direct field observation during the period of questionnaire survey was performed as required to validate the information gathered and to obtain additional information. Target group interviews were conducted with provincial Irrigation Department officials, Community Based Organizations (CBOs) & communities in the area of influence, to discuss seawater intrusion bund related aspects, water quality improvement and soil salinity improvement. The secondary data were gathered from the Department of Irrigation and UNDP before and after construction of seawater intrusion bund in 2015 and 2016 respectively and the rainfall data from 2012 to 2016 were obtained from the Department of Meteorology.

2.1 Soil Quality Parameters:

There were 30 farmers' fields selected from the selected Grama Niladari divisions and 10 soil samples were collected from each site for soil salinity and pH analysis. The soil samples were collected at different soil depths, 15cm, 30cm, 45cm & 60cm. A similar method was practiced by the UNDP in 2015 and 2016. While collecting the samples, the locations were recorded by using Global Positioning System (GPS). The EC of soil and soil pH were measured by using EC meter and pH meter respectively.

2.2 Water quality parameters:

The water samples were collected randomly from selected Grama Niladari divisions of the study area, domestic wells, agro wells, tube wells and some ponds were used for this purpose. Totally 15 samples were collected (5 samples / each location) and packed in Polyethylene containers. The samples were brought to the laboratory within 24 hours for analysis. The water quality parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Hardness were measured.

The following classification systems were used to categorise the soil based on EC and pH values. Based on EC values, the land was categorized as non-saline, slightly saline, moderately saline, severely saline and very severely saline (Table I).

Table I: Categories of land based on EC values

Rank	EC range(ds/m)	Land category
1	0 – 2	Non – saline
2	2 – 4	Slightly saline
3	4 – 8	Moderately saline
4	8 – 16	Severely saline
5	>16	Very severely saline

Source: Handbook for saline soil management – FAO, 2018

Based on the pH, the land was categorised as very strong base, strong base, moderately base, slightly base, neutral, slightly acidic, moderately acidic, strongly acidic, and very strongly acidic (Table II)

Table II: Categories of land based on pH values

Rank	pH range	Land category
1	3 – 4	Very strong acid
2	4 – 5	Strong acid
3	5 – 6	Moderately acid
4	6 – 7	Slightly acid
5	7	Neutral
6	7 – 8	Slightly alkaline
7	8 – 9	Moderately alkaline
8	9 – 10	Strongly alkaline
9	10 - 11	Very strong alkaline

Source: Handbook for saline soil management – FAO, 2018

2.3 Groundwater recharge potential:

Monthly rainfall data for last five years were collected from the meteorological department, Kilinochchi to calculate groundwater recharge.

2.4 Statistical Analysis:

The data were statistically analysed by Paired "T" test using Minitab Version 10. The water quality parameters of domestic well, agro well, tube wells and seasonal ponds were compared with WHO standards and assessed the improvement of water quality parameters after the construction of bund. Rainfall distribution pattern was analysed on monthly and yearly basis to find out groundwater recharge rate by using runoff co- efficient. The present crop cultivation pattern and the yield were compared with the previous reports.

III. RESULTS & DISCUSSION:

3.1 Soil pH:

In 2015 and 2016 at 15cm depth, 36.6% of the samples were within the pH range of 7 – 9, moderately alkaline to very strongly alkline. But in 2018, 33.3% of the samples were recorded under the limit. Just afetr the construction of the bund (in 2016), there was no marked change observed. It may due to the prolonged drought prevailed in 2016. At 30cm depth, in 2015, there were 56.6% of the samples within the pH range of 7 – 9 and in 2016 it was 43.3% and in 2018 it was 40%. At 45cm depth, in 2015, there were 66.6% of the samples showed moderately alkaline to very strongly alkaline and in 2016 there were only 43.3% of samples and in 2018, 40% of the samples were under the above range. At 60cm depth, in 2015, 70% of the samples were moderately alkaline to very strongly alkline and in 2016 and 2018, 46.6%, 36.6% of the samples respectively under the above range.

The above result revealed that from top to bottom the soil pH increased due to washed out ions from the top soil layers accumulate at the bottom layers due to the formattion of hardpan.

In salinity intruded soils, the electrical resistance increases from the surface to a depth of 2–4 feet (60–120 cm) and conductivity values increase correspondingly (mostly double)(Paul & Rashid , 2017). According to Weaver and Crist (1922), hardpan layer of soil underlies much of these areas of low rainfall, at depths varying from 15 inches to 3 feet. It varies from 8 inches to over 1.5 feet in thickness.

Table III shows the result of "Paired T test" for the effectiveness of bund on soil pH in 2016 & 2018, revealed that soil pH at 15cm, 30cm and 45cm are highly significantly different ($P < 0.01$) just after and three years after the construction of bund. At the depth of 60 cm, there is significant change ($P < 0.05$) observed. When comparing the mean values of pH in 2015 at different depths, it was revealed that, in 2016 and 2018 the soil pH was closer to neutral.

Table III: Result of "Paired T test" for the effectiveness of bund on soil pH during 2016 & 2018

Area	Detail	15cm	30 cm	45 cm	60 cm
Kiranchi	2015 Mean	6.214	6.420	6.450	6.012
Pallavarayanattu		8.012	8.321	8.299	8.451
Kariyalanagapaduvan		8.015	7.896	7.914	8.102
Kiranchi	Mean / SD 2016	6.444 ± 0.985	6.561 ± 1.324	6.508 ± 1.451	6.262 ± 1.718
	Mean / SD 2018	7.350 ± 0.923	7.800 ± 0.811	7.800 ± 0.822	7.850 ± 0.875
	Probability	0.003	0.003	0.008	0.016
Pallavarayanattu	Mean / SD	7.938 ± 1.039	8.201 ± 0.883	8.294 ± 0.760	8.339 ± 0.812

	2016				
	Mean / SD 2018	7.070 ± 1.197	6.890 ± 1.016	6.890 ± 0.961	6.890 ± 0.985
	Probability	0.014	0.000	0.000	0.000
Kariyalanagapaduvan	Mean / SD 2016	7.912 ± 1.547	7.875 ± 1.371	7.881 ± 1.248	7.926 ± 1.343
	Mean / SD 2018	7.810 ± 1.268	7.800 ± 1.129	7.770 ± 1.196	7.210 ± 0.998
	Probability	0.056	0.047	0.048	0.042

* P < 0.05, ** P < 0.01, NS, P > 0.05

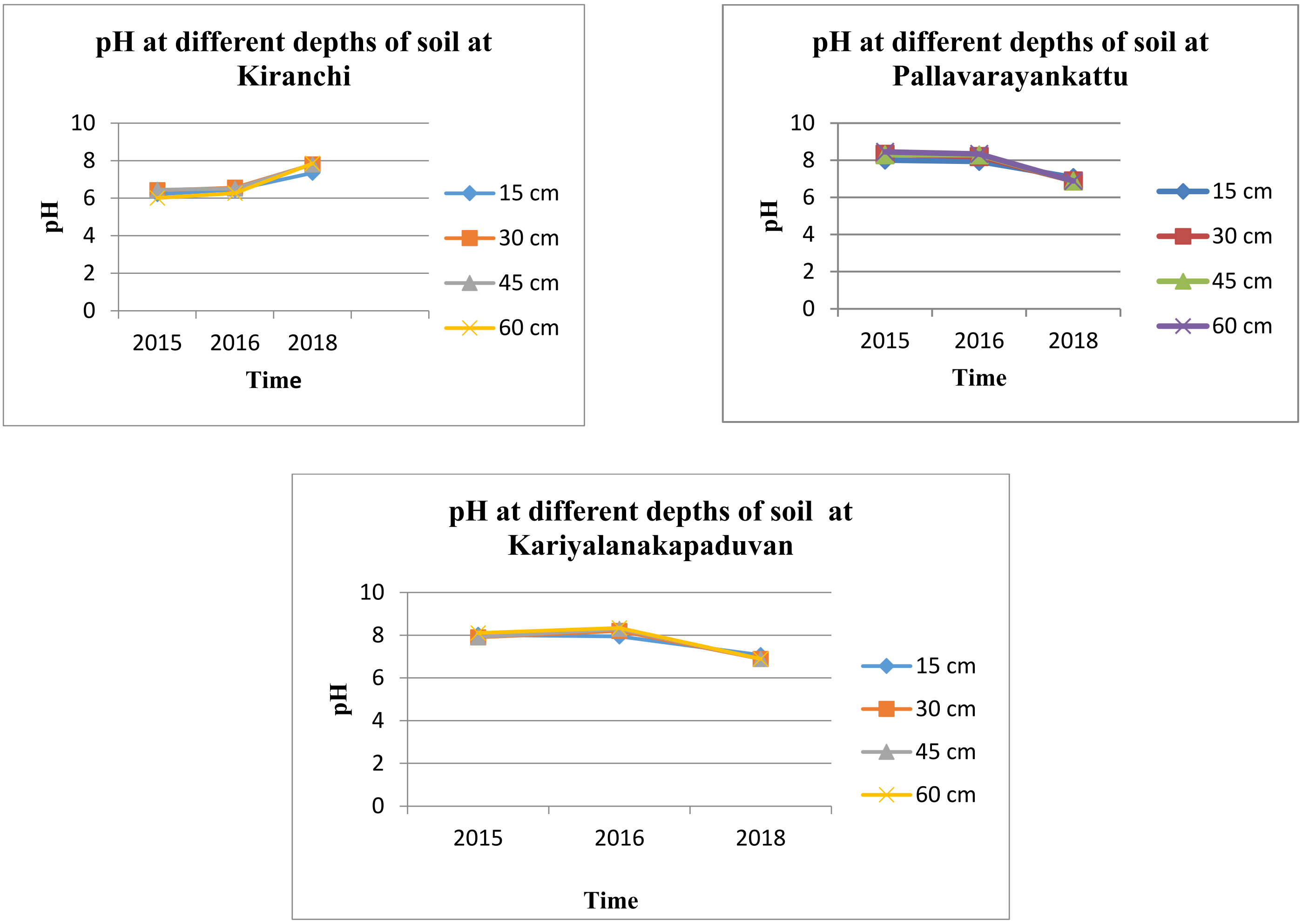


Figure II: Changes of soil pH with different soil depths at three selected locations

The Fig. II shows the changes of soil pH mean value with different soil depths in 2015, 2016 and 2018 at selected locations. When comparing the pH mean values of all three locations in 2016 & 2018, in 2018, at 15cm depth the mean pH value ranged from 7.07

– 7.81 and at 30cm depth it varied from 6.89 – 7.8 and at 45cm depth it was 6.89 – 7.8 and at 60cm depth it was 6.89 – 7.85. The result revealed that the pH values were closer to neutral pH. When compared to other two locations at Kiranchi, the pH values were slightly acidic in 2015 & 2016. Because of its lower elevation (approximately 0 - closer to sea), soil erosion was high. Due to soil erosion slightly acidic soil pH was observed. The bund constructed stoped the velocity of surface run off water and improved deep percolation. So that gradual improvement of soil pH was observed from 2015 to 2018. According to Osman Ardahanlioglu *et.al*, (2002), in Turkey, the variation of salt affected soil study revealed that the soil pH at 0- 30cm depth was 8.1 ± 0.8 and at 30-60cm it was 8.2 ± 0.7. But in this study the obtained values in the year 2018 were lesser than the referred values. Therefore, it is clearly obvious that there is an improvement in soil pH in 2018 due to the bund.

3.2 Soil EC:

It was noted that 40% of the samples collected in 2015 and 43.3 % of the samples collected in 2016 were fallen under Non saline category; but in 2018 it was 56.6%. In 2015, there were 23% of the samples under slightly saline category, in 2016 it was 16.6 % and in 2018 it was 23.33%. Moderately saline condion was observed in 2015, 2016 and 2018 with the percentage of 17%, 30% and 16.67% respectively. Severely saline condition gradually reduced from 2015 to 2018. (17% to 3.3%). Very severely saline soil was 3% in 2015. But in 2016 & 2018, very severely saline condition was not observed. At the depth of 30cm, from 2015 to 2018 the percentage of non saline soil increased from 53% to70% and slightly saline condition and moderately saline condion were reduced from 2015 to 2018. At 45cm depth, non saline condition in 2015 was 60%, in 2016 it was 70%, but in 2018 it was 66.6%. Compared to 2015, there was an improvement in soil salinity in 2016 & 2018. At 60cm depth, the percentage of non saline soil samples were increased from 67% to 83.33%, from 2015 to 2018. The percentage of slightly saline soil samples were reduced from 33% to 16.67% from 2015 to 2018. When compared with 2015, after the construction of the bund, there was a considerable improvement observed in the soil EC. However, the top layer salinity will come down drastically when these areas receive showers during Maha season followed by excess run off to the seaside. Not only the top layers but the bottom layers also will be influenced and there will be drastic reduction in long term when the recommendations are implemented in future.

The findings of "Paired T test" for the effectiveness of bund on soil EC at Kiranchi, Pallavarayankattu and Kariyalainagapaduvan in 2016 & 2018 revealed that at the depth of 15cm and 30cm, the effect of bund on soil EC improvement is significant ($P < 0.05$) and at 45cm it is not significant ($P > 0.05$) due to hardpan formation, which restricts the leaching out of salts from soil. At the depth of 60cm it is highly significant ($P < 0.01$).

Table IV: Results of "Paired T test" for the effectiveness of bund on soil EC during 2016 & 2018

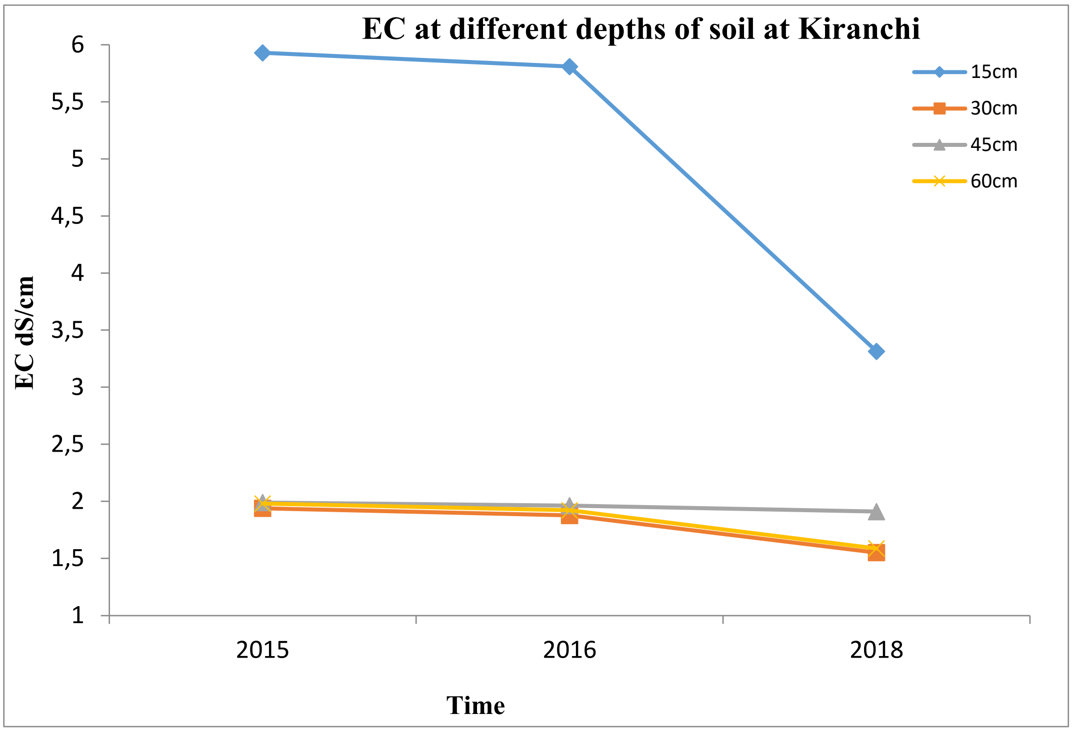
Area	Detail	15cm	30 cm	45 cm	60 cm
Kiranchi	2015 Mean(dS/m)	5.930	1.940	1.990	1.981
Pallavarayanattu		2.711	1.321	1.192	1.024
Kariyalanagapaduvan		2.661	1.704	1.192	1.114
Kiranchi	Mean / SD (dS/m) 2016	5.810 ± 4.808	1.877 ± 1.316	1.962 ± 1.335	1.922 ± 1.292
	Mean / SD (dS/m) 2018	3.315 ± 2.404	1.552 ±1.084	1.911 ± 1.307	1.588 ± 1.109
	Probability	0.012	0.011	0.686	0.000
Pallavarayanattu	Mean / SD (dS/m) 2016	2.654 ±3.200	1.296 ±1.197	1.112 ±0.899	0.957 ±0.612

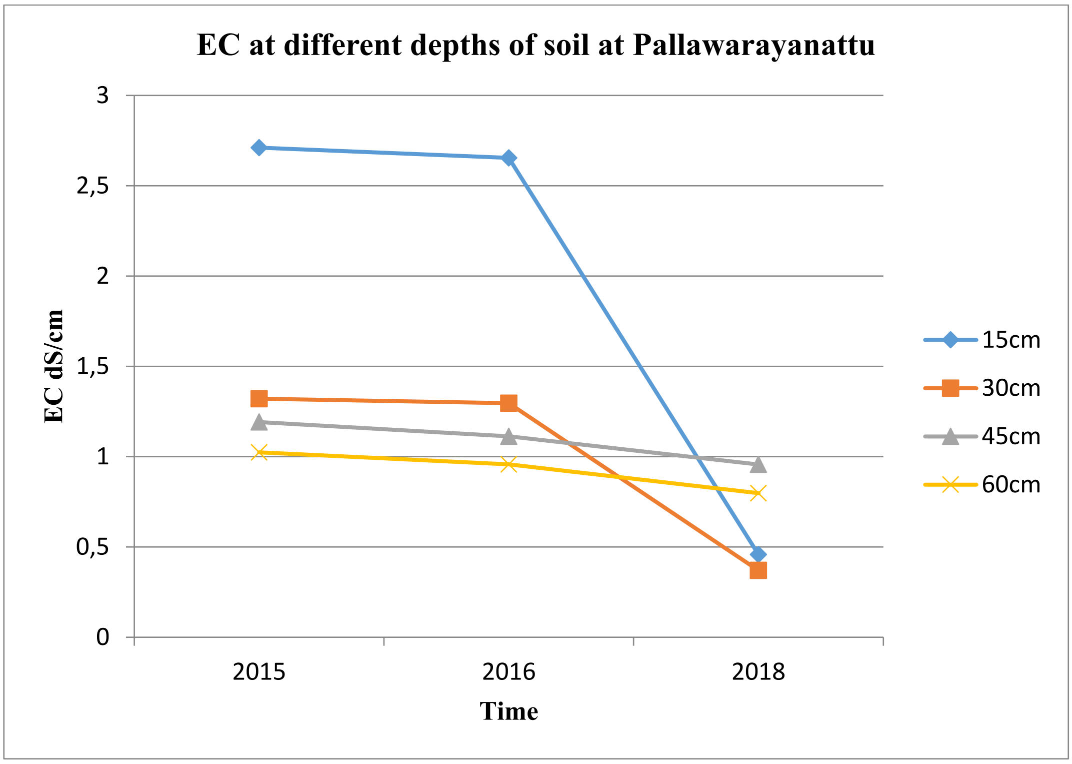
	Mean / SD (dS/m) 2018	0.458 ± 0.462	0.370 ±0.334	0.957 ±0.610	0.798 ± 0.510
	Probability	0.033	0.008	0.162	0.001
Kariyalanagapaduvan	Mean / SD (dS/m) 2016	2.567 ±2.406	1.652 ±1.622	1.181 ±1.044	1.013 ±0.843
	Mean / SD (dS/m) 2018	2.034 ± 1.029	1.504 ± 1.009	1.013 ± 0.843	0.844 ± 0.702
	Probability	0.041	0.046	0.064	0.004

* P < 0.05, ** P < 0.01, NS - P > 0.05

According to Paul & Rashid, (2017) and Weaver and Crist (1922), in salinity intruded soils, the electrical resistance increases from the surface to a depth of 2–4 feet (60–120 cm). The hardpan layer underlies much of this area of low rainfall at depths varying from 15 inches to 3 feet. When compairing the mean values of EC in 2015 at different depths revealed that, in 2016 and 2018, the soil EC indicated non saline condition at three selected locations.

The above results of statistical analysis revealed that the bund could cause the reduction of salinity and once it is maintained properly for at least 3-5 years period which could facilitate the complete stoppage of the seawater intrusion.





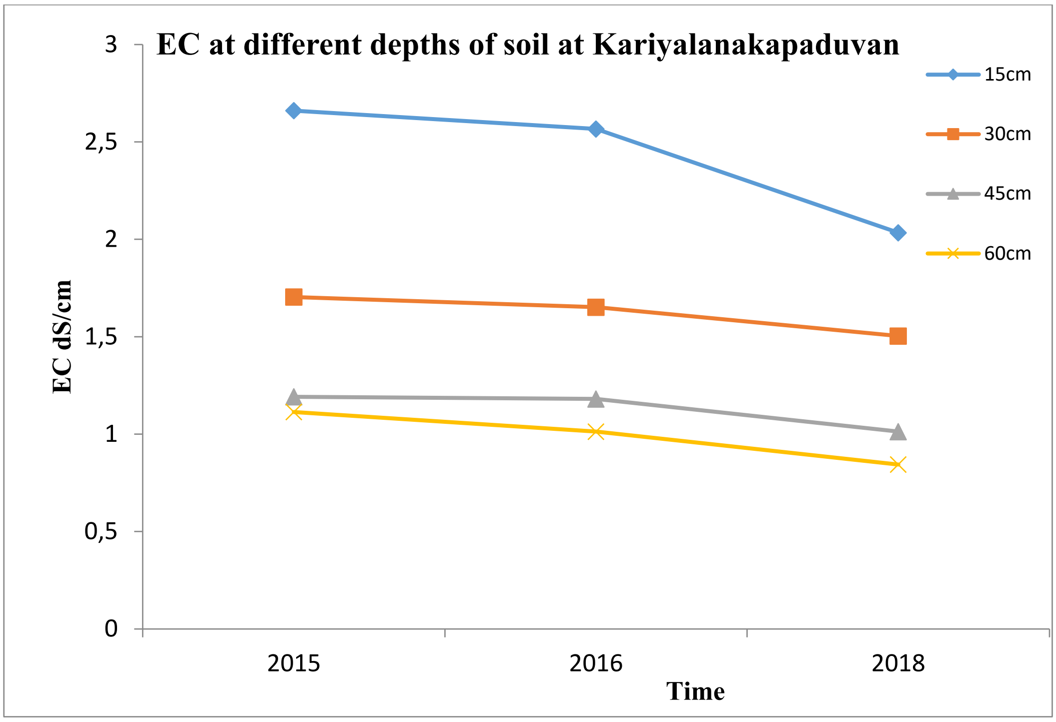


Figure III: Changes of soil EC with different soil depths at three selected locations

The above Figure (Fig. III) shows the variation of EC with different depths of soil in 2015, 2016 and 2018 of the selected locations. In 2016, a small reduction in the EC mean value observed, when compared to 2015. In 2018, a considerable reduction in the EC value was observed. In 2018, at 15cm dept, the EC value ranged from 0.458 – 3.315 and at 30cm depth, it varied from 0.37 – 1.552 and 45cm depth it was 0.957 – 1.911 and at 60cm depth it was 0.798 – 1.588. The improvement of EC was clearly indicated in 2018, due to the effect of bund. Shamsun Naher et.al, 2017, stated that in Bangaladesh, the electrical conductivity values of salinity affected soils varied from 1.50 to 35.90 dS/cm. Osman Ardahanlioglu et.al, 2002, pointed out that in Turey, the mean value of EC of salt affected soil at 0 – 30cm depth was 39.30 ± 20.3 dS/cm, at 30 – 60cm depth it was 37.80 ± 18.6 dS/cm. Therefore, the observed result was lesser than the referred values in 2018. The reduction of EC mean values can be due to the effect of sea water intrusion bund.

3.3 Water quality parameters (WQP)

The Table V shows the water quality parameters (pH, Electric Conductivity – EC, Total Dissolved Solids – TDS and Hardness – HD) of different available water resources (pond, open dug well and tube well) of Kiranchi, Pallawarayankattu and Kariyalainagapaduvan Grama Niladari Divisions.

Table V: The water quality parameters of selected water bodies in 2018

Pond water

WQP	Unit	Desirable limit (WHO)	Permissible limit (WHO)	Pond I	Pond II	Pond III
pH		7.0-8.5	6.5-9.0	8.30	8.50	8.20
EC	µS/cm	750	3500	3,170.00	747.00	735.00
TDS	mg/l	500	2000	1,491.00	333.00	302.00
HD	mg/l	200	600	500.00	185.50	172.00

Open dug well

WQP	Unit	Desirable limit (WHO)	Permissible limit (WHO)	ODW I	ODW II	ODW III
pH		7.0-8.5	6.5-9.0	8.28	7.43	8.65
EC	µS/cm	750	3500	1,673.20	1,392.50	2,619.50
TDS	mg/l	500	2000	766.40	624.00	1,691.00
HD	mg/l	200	600	322.20	390.25	542.00

Tube well

WQP	Unit	Desirable limit (WHO)	Permissible limit (WHO)	TW I	TW II	TW III
pH		7.0-8.5	6.5-9.0	7.76	7.37	7.50
EC	µS/cm	750	3500	5,528.00	1,289.33	3,065.00
TDS	mg/l	500	2000	2,673.60	583.67	1,457.00
HD	mg/l	200	600	645.60	290.00	497.00

According to Table V, the pH of all the available water resources at three locations were recorded under permissible limit of WHO standard, (6.5 – 9.0). The obtained EC, TDS and HD values of ponds, open dug wells and tube wells II & III had permissible limit of WHO standards, except tube well I, which showed extreme values of EC (5528 µS/cm) , TDS (2673.60 mg /l) and HD (645.60 mg/l) due to seawater intrusion. Lenntech water treatment & air purification, 1998 pointed out that seawater intrusion can affect the quality of water not only at the pumping well sites, but also at other well sites and according to Ghyben-Herzberg Principle, tube wells have high risk of seawater intrusion. The above result clearly pointed out the improvement of water quality parameters by effectively controlling seawater intrusion.

3.4 Groundwater recharge potential

Groundwater recharge is one of the most important parameters required to support sustainable management of groundwater resources. It is one of the most difficult parameters to evaluate accurately, due to the numerous factors involved in recharge processes.

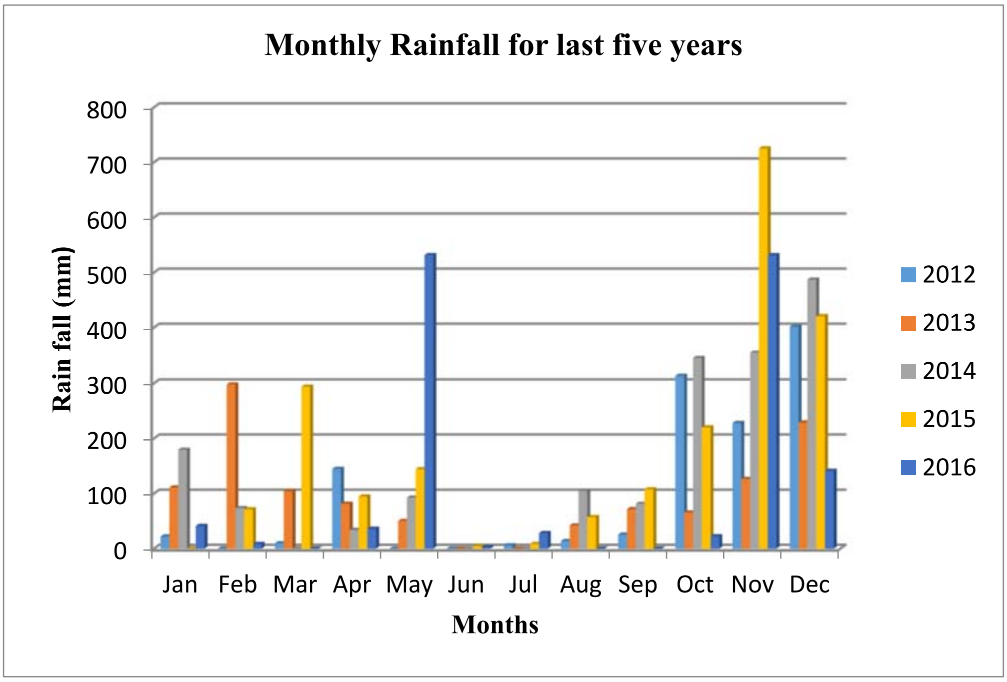


Figure IV: Monthly rainfall pattern of Kilinochchi district for last 5 years

Source: Department of Meteorology, Kilinochchi

The Figure IV shows the monthly rain fall pattern of Kilinochchi district for last 5 years. Peak rain fall was observed in November. During June & July months very few or no rainfall was reported. Spatial variation is observed in the rainfall. When compare to other two stations, Kariyalainagapaduvan area receives less peak rainfall, due to its location. The average annual rainfall of the district was 1,352mm.

The available ground water recharge of Kilinochchi district can be calculated

- Catchment Area = 1,200 km^2
- Average Rainfall = 1,352 mm
- Effective Infiltration = 80%
- Yield from catchments = $(0.8 \times (1200 \times 10^6) \times 1352 \times 10^{-3})$
  = 1,297,920,000 m^3 / year
- Losses (Evaporation,
  transpiration & etc.) around 65% = 842,648,000 m^3 / year

Ground Water Recharge Potential = 455, 272,000 m^3 / Year

- For domestic Uses = $(113{,}000 \times 120 \times 10^{-3}) \times 365$
  (120 l / day) = 4,949,400 m^3

- For Agriculture purpose = 91,800,000 m^3

  (Source dept. of Agriculture - verbal info)

- For Industrial use & others = 990,000 m^3

  (20% of domestic use) (Source: Water Supply & Drainage Board –verbal info)

  Annual total Requirement = 97,739,400 m^3

  Possible Ground water Recharge Potential = 357,532,600 m^3

  (Source: Water Supply & Drainage Board, Sri Lanka, - verbal info)

According to Water Board, Sri Lanka, the groundwater recharge calculation for Kilinochchi district showed that the annual possible ground water recharge potential was 21.5% of annual rainfall. It is actually not happened due to surface runoff and seepage losses. The actual recharge will be 5 – 10% of the total precipitation. According to Central Ground Water Board, Ministry of Water Resources, India (2007), only 5 to 10 percent of the total precipitation may infiltrate into the ground and reach the water table, which may be sufficient for adequate recharge, whereas in the alluvial areas that figure is about 15 to 20 % of the rainfall (Athavale et al., 1992). Panabokke and Perera (2005) estimated that 10% of rainfall as average recharge in Sri Lanka. The recharge potential of the study area can be achieved through construction of bunds such as sea water intrusion bund, which can effectively prevent the surface runoff and seepage losses.

3.5 Crop improvement

The statistical data collected from Divisional Secretariat, Poonakary revealed that, there were 6000 acres of land at Poonakary extended for cultivation and expanded for livelihood opportunities of local farmers due to the construction of seawater intrusion bund. 90% of the people in the selected locations are involved in farming. The predominant crop of the area was paddy. Only rain fed paddy cultivation in Maha season was observed. 98% of the farmers had soil salinity problems in their fields for more than ten years. They pointed out that majority of the farmers in the selected location have given up farming due to soil salinity.

The main source of water for the cultivation and domestic usage was open dug wells and tube wells. In some parts of Pallavarayankattu, seasonal ponds were utilized as water sources. Electric motor and water pumps were used to lift the water from wells. At Kiranchi, most of the farmers had more than 3 acreage of cultivable land. Before the construction of the bund, 25% of the cultivation was ruined due to the salinity of the soil. The most popular rice varieties used by the farmers were at 362, Aattakari, Bg 359 before and after the construction of bund. But it was pointed out that the farmers were able to achieve 80 % of the expected harvest (32 – 35 Bushels / Acreage) and they were really very happy of the construction of bund. Coconut cultivation was very common, and the soil was very much suitable for coconut cultivation.

The most popular rice varieties were At 308, Bg 360, At 362 and Aattakari before and after the construction of bund. But farmers pointed out that about 50% of yield increment observed in their harvest. Ground nut cultivation was also popular (average ½ Acreage per farmer) under irrigation. Saline tolerant rice varieties (Most popular variety Bg 369) recommended by Department of Agriculture, have been cultivating in the selected locations.

Vegetable cultivation was carried out at home garden level, long bean, brinjal, okra and chilli were common. There was no large extended cultivation of vegetables, because the sandy saline coastal soil is not suitable for vegetable cultivation. It was noted that in crop cultivation especially in paddy there was not much change in the varietal selection before and after the construction of bund, but considerable yield improvement was observed in the selected locations with the existing varieties.

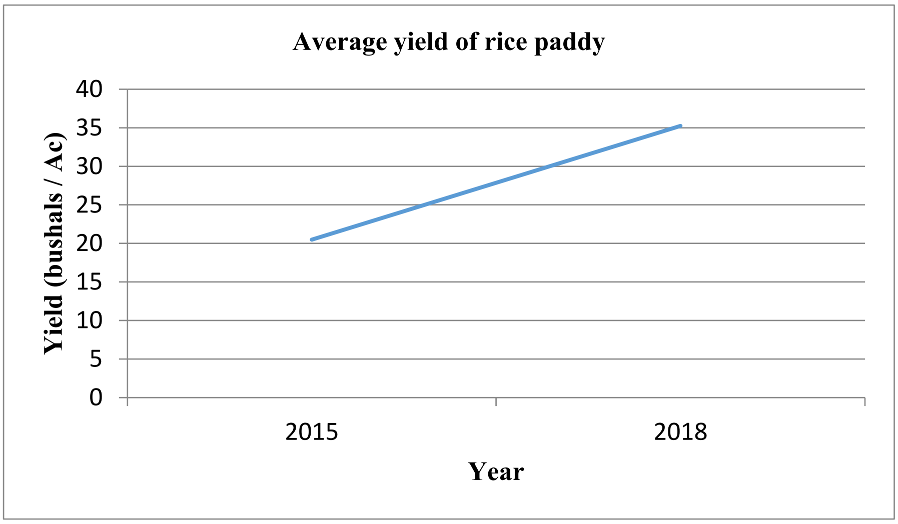


Figure V: Average yield of rice paddy at selected locations of Poonakary in 2015 & 2018

The Figure V shows the average yield of paddy in the selected locations during 2015 & 2018. When compared with 2015, there was a considerable yield improvement observed in 2018 due to soil salinity reduction.

IV. Conclusions & Recommendations:

Findings of this research showed that the soil pH and EC values were almost reached the normal soil pH and EC values due to the construction of the bund. The values of water quality parameters also approached the values close to drinking water. The bund not only stops the seawater intrusion but also enhances deep percolation of rainwater and considerable groundwater recharge. Owing to the soil reclamation with the seawater intrusion bund, crop cultivation especially paddy cultivation was restored.

It is recommended that:

- Limited groundwater withdrawal is important to prevent intrusion of the seawater into the main land areas of aquifer even with the bund.
- Repeated impact assessments in this area should be carried out in five to ten years' time to have some idea of reclamation of soil and water salinity problems, mainly for paddy cultivation.
- The farmers of this area are to be educated about the importance of the bund and its maintenance.
- A soil survey should be conducted at least once a year to monitor the improvement of the soil salinity status due to the bund construction.

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Conflict of Interest

The authors declare that there is no potential conflict of interest regarding the publication of this manuscript. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

Author Contribution

S.Sanjeepan performed the literature review, experimental and statistical analyses and interpreting the data and prepared the manuscript text. T.K.Weerasinghe assisted in structuring the objectives, designing the experimental protocols and correcting the format of interpreted data. S.Satheeswaran helped in sample collection and laboratory experiments.

ABBREVIATIONS

At - Ambalantota

Bg - Bathalagoda

CBO - Community Based Organization

EC - Electric Conductivity

HD - Hardness

ODW - Open Dug Well

TDS - Total Dissolved Solids

TW - Tube Well

WHO - World Health Organization

WQP - Water Quality Parameters