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Hydro Chemical Assessment of Agro-well Water for Irrigation in *Thalawa* Block in *Mahaweli* System-H in Anuradhapura, Sri Lanka

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ABSTRACT

Purpose: *Large diameter agro-wells are the most valuable water resources for farmers in Mahaweli system H in Sri Lanka to sustain crop production during the dry spells. Deterioration of water quality is harmful to the crop growth. Present study evaluated the variation of irrigation water quality and water levels of agro-wells in Thalawa irrigation block of Mahaweli system H.*

Research Method: *Water samples from 10 agro-wells were collected during October 2016 to July 2017 once in a month and tested samples for irrigation water quality parameters using standard methods. Water levels were recorded for each sampling date.*

Findings: *Most of the water quality parameters tested in almost all wells are within the acceptable range for irrigation except for Residual Sodium Carbonate (RSC). 50 % of the wells are safe and rest 50 % of the wells are within marginal range in terms of RSC. Irrigation water quality index (IWQI) was assessed and it varied from 32.6 to 87.7. Considering the mean IWQI (48.2), water of Thalawa block can be characterized as good. The study also revealed that there was sufficient water in wells even during the dry spells and it varied with both the variation of rainfall and canal water availability.*

Research Limitations: *Sampling was limited to 10 agro-wells for a period of 10 months. This was avoided by selecting representative wells and months covering both dry and wet spells.*

Originality/ Value: *Overall, results envisaged that there is higher potential to use this water for any crop and soil without detrimental to crops grown.*

Keywords: *Agro-wells, Irrigation Water Quality, Mahaweli System, Water quality index*

INTRODUCTION

The agriculture sector is the largest global water user, and at present 70% of global freshwater withdrawals and 90% of global water consumption comprise with agricultural production (Hoekstra and Mekonnen, 2012). Similarly, in Sri Lanka, agriculture sector consumes 80% of water (Water sector Sri Lanka, 2014). In most tropical lands, groundwater is the important source of the freshwater for drinking and irrigation purposes. Similar to most other countries, groundwater in Sri Lanka in different climatic zones is under serious threat mainly due to pollution occurring through agricultural activities and over extraction that causes a decline of groundwater levels and which resulted in salt water intrusion in the coastal belt (Panabokke and Perera 2005; Chandrajith *et al*., 2014, Rubasinghe, 2015).

Traditionally, Sri Lanka has been divided into three zones, depending on rainfall: the wet zone in the south west where the annual rainfall is >2500 mm, the intermediate zone where the annual rainfall is between 1,500 and 2,500 mm, and the dry zone towards the east, north east and south eastern parts where the rainfall is

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below 1,500 mm (Dharmagunewardene, 2003). Water scarcity is experienced predominantly in the dry zone, due to a variety of reasons; unreliability of rainfall, high superficial runoff and evaporative losses, poor storage conditions in hard rock areas, both underground and in surface reservoirs, and increasing pressure of climate change (Ratnayake and Herath, 2005, Villholth and Rajasooriyar, 2010) and human activities. Groundwater is used extensively throughout Sri Lankan context. This is due to the recognition that groundwater provides a relatively stable source of water or acts as a reliable complimentary source to surface water, especially for irrigation, during the dry season or longer dry spells (Villholth and Rajasooriyar, 2010).

Although there was a transfer basin water diversion scheme from the wet zone to dry zone such as *Mahaweli* water diversion project, and small village reservoirs, the agricultural water demand of the dry zone could not be met. Therefore, an additional and a higher attention was given to explore the possibility of extracting groundwater for cropping during the 1980s and 1990s (Dharmasena, 1989). As a result, at present, large diameter agro-wells are the most valuable water resources for farmers in *Mahaweli* system H in Sri Lanka (Figure 01) to sustain crop production during the dry spells. In addition, informed exploration methods, improved drilling technology, cheaper pumps available today and government or NGO (Non-Governmental Organization) investment or subsidy schemes have made groundwater a relatively cheap alternative or supplement to surface water (Senarathna, 2002;IGES, 2007). In the central lowlands with shallow regolith aquifers, where significant groundwater extraction for irrigation takes place, the agro-wells are typically shallow (4.5–12 m deep) but of large diameter (4–6.5 m) in order to intercept and store sufficient groundwater (IGES, 2007).

Quality of groundwater is equally important as its quantity owing to the suitability of water for various purposes. Variation in groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities (Subramani *et al*., 2005; Schiavo *et al*., 2006). According to Babiker *et al*., (2007), the chemistry of groundwater is not only related to the lithology of the area and the residence time of water is in contact with rock material, but also reflects inputs from the atmosphere, from soil and weathering as well as from pollutant sources such as mining, land clearance, saline intrusion, industrial and domestic wastes.

Deterioration of well water quality has been reported in some areas of the dry zone in Sri Lanka (Rubasinghe *et al*., 2015; Harshan *et al*., 2016). Mahaweli system H is an area where water diverted from Mahaweli river reaches and this water is mainly allocated for paddy cultivation. Farmers in the area use large diameter agro-wells for the water needs of the other field crops. Thus, it is worth to evaluate the suitability of water of these agro-wells of Mahaweli system H, for irrigation.

MATERIALS AND METHODS

Study site and selection of Agro-wells

Agro-well water samples were collected from 10 representative agro-wells in *Thalawa* block in Mahaweli System H in Sri Lanka. *Mahaweli* System H is the first area settled under the Accelerated *Mahaweli* Development Program; the scheme started in 1975 with the settling of approximately 500 families in the area (Jayewardene and Kilkelly., 1983). System H of *Mahaweli* is located on the hard rock basement area and these irrigated command areas are serviced by a main, distributary and field canals which cover most of the landscape. However, Agro-well water for irrigation of agricultural crops during the much drier *Yala* cropping season (April to September) as well as during the water stress times of the *Maha* cropping season (October to March) is vital to *Mahaweli* system H (Jayakody, 2006). Figure 01 and 02 show the study site and the spatial distribution of selected Agro-wells for testing the water quality. These ten agro wells were selected from *Thalawa* block representing the canal systems and also spatial distribution of the agro-wells in the area.

Water sample collection and methods of analysis

This study tested the variation of irrigation water quality parameters and also the water levels of agro wells once in a month during October 2016 to July 2017.

Samples were collected in high density polyethylene bottles of 250 ml capacity. These bottles were pre-cleaned with 1:1 dilute hydrochloric acid and washed with distilled water. Two samples were taken per well for 250ml sample bottles after rinsing it thrice with the same water and covered with a lid. Water level, pH and Electrical conductivity (EC) in the agro wells were measured in situ at each sampling date.

Water temperature, pH and EC were measured immediately using the multi-parameter analyzer (HATCH, Sension 156) that was calibrated prior to analysis. Other parameters such as ammonium nitrogen ($NH4^+$ - N), nitrate nitrogen (NO_3^- - N), available P, total K, Na, Ca, Mg, Fe, Al, As, Cd and Pb were analyzed in the laboratory by using standard laboratory methods. Calibration of instruments was always carried out before measurements using standard methods. NH_4^+- N content of water samples was determined by UV – visible spectrophotometer with 4500 NH_3 F Phenate method (Solorzano, 1969). NO_3^- - N content of water samples was tested by UV– visible spectrophotometer with salicylic acid method (Cataldo *et al*., 1975). Available P content of water samples was determined by UV- visible spectrophotometer with ascorbic acid method (Olsen *et al*., 1954). Total K, Na, Ca, Mg, Fe, Al, As, Cd and Pb contents were measured by ICP-OES following the method Martin *et al*.,(1994).

Other than the above-mentioned parameters, Sodium Adsorption Ratio (SAR), Sodium Percentage (SP) and Residual Sodium Carbonate (RSC), Kelly's ratio (KR) and Magnesium hazard (MH) were calculated to test the suitability of water for irrigation.

SAR was calculated from the ratio of sodium to calcium and magnesium (Richards 1954).

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad (1)$$

All ionic concentrations are expressed in meq/l

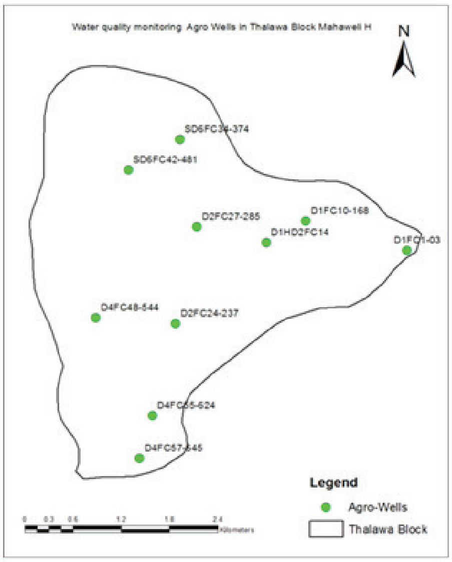


Figure 01: Location of selected Agro-wells in *Thalawa* block in Mahaweli System H in Sri Lanka

Sodium percentage (Na %) was calculated using the following formula,

$$Na\ (\%) = \left(\frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + K^{+}}\right) \times 100 \quad (2)$$

All ionic concentrations are expressed in meq/l

Residual Sodium Carbonate (RSC) index was calculated from the difference of total carbonate and bicarbonate with total calcium and magnesium (Ragunath 1987).

$$\text{RSC index} = [HCO_3^{-} + CO_3^{2-}] - [Ca^{2+} + MG^{2+}] \quad (3)$$

All ionic concentrations are expressed in meq/L

The Kelly's ratio was measured using the expression (Kelly, 1963),

$$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \quad (4)$$

All ionic concentrations are expressed in meq/L

The Magnesium hazard (MH) was calculated using the equation (Szabolcs and Darab 1964),

$$MH = \left(\frac{Mg^{+}}{Ca^{2+} + Mg^{2+}}\right) \times 100 \quad (5)$$

The impact of irrigation water quality on soil characteristics and crop yield is often a complex phenomenon that involves the combined effect of many parameters. A water quality index provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. Therefore, in this study we calculated Irrigation Water Quality Index (IWQI) using the following formula (Brindha and Kavitha, 2015; Houatmia *et al*., 2016) . Irrigation water quality index IWQI

$$IWQI = \Sigma\ (Wn \times Qn) \quad (6)$$

Wn = Unit weight of the nth parameter

Qn = Quality rating or sub index corresponding to the nth parameter

$$W_n = K / S_n \quad (7)$$

K = Proportionality constant which is computed by

$$K = 1 \Big/ \sum_{i=1}^{n} \frac{1}{S_n} \quad (8)$$

$$\sum_{i=1}^{n} \frac{1}{S_n} = \frac{1}{S_{pH}} + \frac{1}{S_{EC}} + \frac{1}{S_{Cl}} \ldots.. + \frac{1}{S_n} \quad (9)$$

Sn = Standard permissible limit in water for the nth parameter

$$Q_n = 100 \times [V_n - V_i] \big/ [S_n - V_i] \quad (10)$$

Where

Vn = measure value of the nth parameter in ground water at a sampling location

Vi = ideal value of the nth parameter in water (0 for all parameters).

RESULTS AND DISCUSSION

Groundwater needs to be recognized as a critical resource for the future development in agriculture especially under the changing seasonal rainfall pattern in dry zone Sri Lanka. The suitability of groundwater for irrigation depends on its chemical composition. Irrigation water quality is determined in several ways including the degree of acidity or alkalinity (pH), EC, SAR, RSC, Kelly ratio and Magnesium hazard etc. Table 01 shows the results of water quality parameters analyzed for 10 agro-well water averaged over the 10 times sampling and it further shows the mean, minimum, maximum and standard deviation for the block. In this study, we compared the results with FAO irrigation water quality guidelines and FAO irrigation water quality guidelines is shown in Table 02 (Ayers and Westcot, 1994).

Variation of pH

Acidity or basicity of a solution is determined by its pH. The average pH of the selected agro-wells varied from 6.82 to 7.23 and the average value for the block was 7.03. The optimum pH range for irrigation water is 6.5 to 8.4 (Table 02, Ayers and Westcot, 1994). Therefore, pH values are within the safe limit for irrigation. Rubasinghe *et al*., 2015 observed that the average pH of groundwater of dry zone of Sri Lanka is 7.22 and the minimum and maximum as 5.67 and 8.50 respectively. Lower mean value recorded in the present study may be attributed to the dilution effect of recharging of agro-well water with canal water characterized by surface water source.

Table 01 : Statistical summary of hydro-chemical parameters tested over agro-wells water

Well No.	EC (µs/cm)	pH	CO_3 (mg/l)	HCO_3 (mg/l)	NH_4-N(mg/l)	NO_3-N(mg/l)	P (mg/l)	Na^+ (mg/l)	Mg^{+2} (mg/l)	K^+ (mg/l)	Ca^{+2} (mg/l)	Cd(mg/l)	Pb (mg/l)	As (mg/l)	RSC	SAR	SP	KR	MH
D1FC1-03	400.7	6.82	6.96	248.94	0.49	0.51	0.15	19.67	10.59	1.42	57.25	0	1.33	0.83	1.54	0.64	21.46	0.28	27.16
D1FC10-168	240.4	6.88	5.84	144.22	0.58	3.69	0.1	11.04	4.88	0.88	36.18	0.04	0.82	0.73	1.01	0.47	21.71	0.3	25.05
D1HD2FC14	328.8	6.9	5.7	172.17	0.67	5.7	0.11	11.93	6.36	0.7	50.12	0	1.41	0.98	1.02	0.44	21.21	0.39	24.41
D6FC34-374	183.39	7.01	4.44	120.54	0.72	2.28	0.09	11.19	4.93	2.68	20.56	0	0.61	0.8	0.98	0.55	25.31	0.37	30.66
D6FC42-481	185.7	7.07	4.32	119.47	0.67	0.64	0.1	8.89	3.96	2.19	31.57	0	0.69	0.85	0.91	0.4	17.84	0.24	20.09
D4FC48-544	478	6.99	7	293.71	0.7	0.94	0.47	29.15	22.69	3.18	27.87	0	1.17	1	2.49	1.12	36.61	0.79	50.05
D4FC57-645	393.6	7.12	4.73	223.36	0.54	2.68	0.1	24.23	10.71	0.93	52.86	0	1.13	1.27	1.52	0.76	23.87	0.34	30.13
D4FC55-624	332.9	7.04	5.84	198.45	0.77	1.58	0.11	20.8	8.1	0.67	36.36	0.01	1.24	0.95	1.6	0.85	31.97	0.49	26.07
D2FC24-237	331.3	7.23	6.18	205.15	0.41	0.95	0.1	15.48	12.89	0.59	51.93	0.18	1.87	0.9	1.29	0.5	18.15	0.23	37.08
D2FC27-285	232.3	7.19	6.96	138.23	0.65	0.97	0.12	12.9	6.71	3.64	38.43	0.34	0.67	0.97	1.14	0.49	20.56	0.29	32.86
Min	183.39	6.82	4.32	119.47	0.41	0.51	0.09	8.89	3.96	0.59	20.56	0	0.61	0.73	0.91	0.4	17.84	0.23	20.09
Max	478	7.23	7	293.71	0.77	5.7	0.47	29.15	22.69	3.64	57.25	0.34	1.87	1.27	2.49	1.12	36.61	0.79	50.05
Mean	310.71	7.03	5.8	186.42	0.62	1.99	0.15	16.53	9.18	1.69	40.31	0.06	1.09	0.93	1.35	0.62	23.87	0.37	30.36
SD	93.34	0.13	0.97	55.14	0.11	1.57	0.11	6.32	5.29	1.08	11.55	0.11	0.38	0.14	0.45	0.22	5.72	0.16	7.98

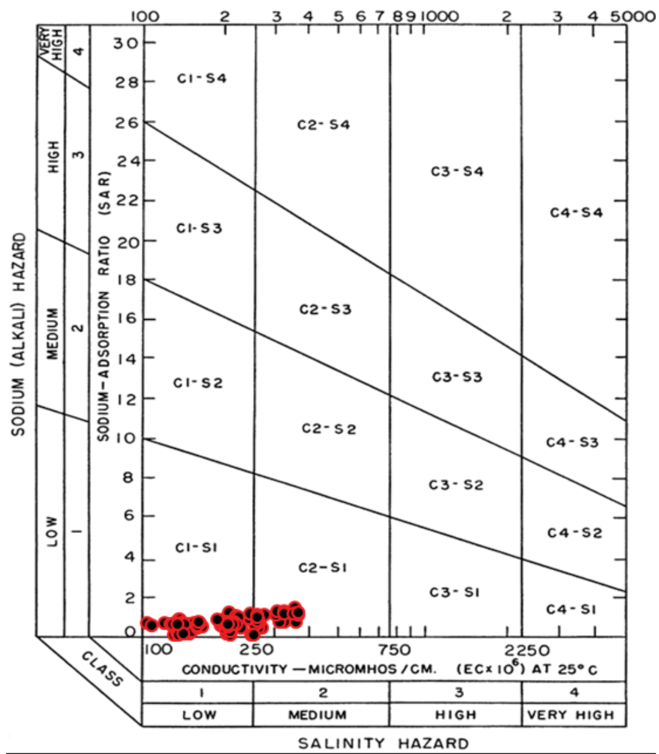
Table 02: Guideline for interpretation of water quality for irrigation adopted from FAO irrigation water quality guidelines

Potential irrigation problems		Degree of Restriction on Use			
		Units	None	Slight to moderate	Severe
Salinity (Affects crop water availability)					
EC_w		dS m^{-1}	<0.7	0.7-3.0	>3.0
Infiltration (Affects infiltration rate of water into the soil; evaluate using EC_w and SAR together)					
SAR 0-3	and EC_w		>0.7	0.7-0.2	<0.2
SAR 3-6	and Ec_w		>1.2	1.2-0.3	<0.3
SAR 6-12	and EC_w		>1.9	1.9-0.5	<0.5
SAR 12-20	and EC_w		>2.9	2.9-1.3	<1.3
SAR 20-40	and EC_w		>5.0	5.0-2.9	<2.9
Specific ion toxicity (Affects sensitive crops)					
Sodium (Na)					
Surface irrigation		SAR	<3	3-9	>9
Sprinkler irrigation		meq l^{-1}	<3	>3	
Miscellaneous effects (On susceptible crops)					
Nitrate (NO_3-N)		mg l^{-1}	<5	5-30	>30
Bicarbonate (HCO_3^-) (Overhead sprinkler only)		meq l^{-1}	<1.5	1.5-8.5	>8.5
pH			Normal range 6.5-8.4		

EC_w, Electrical conductivity of water, recorded at 25⁰C ; SAR, Sodium absorption ratio

Variation of EC, salinity and sodicity hazard

Electrical Conductivity (EC) denotes the total ionized constitutes of water which is a measure of dissolved salts in water. Average EC of the tested samples varied from 183 to 478 µS/m which are in desirable range and can be used for irrigation without any restriction (Table 02). Dry zone area is generally characterized by high EC due to higher mineralization to groundwater (Rubasinghe *et al*., 2015). Comparatively lower value (mean = 310 µS/m) recorded in the present study may be attributed to the recharging of surface water from *Mahaweli* canal system in the area. Sodium concentration is a vital parameter in classifying irrigation water as it affects the permeability of soil and induces infiltration problem. Sodium hazard is also usually expressed in terms of the sodium adsorption ratio (SAR). Groundwater could be classified based on SAR as excellent (0-10), good (10-18), doubtful (18-26) and unsuitable (>26) (Richards, 1954). According to the present analysis, SAR of agro well water of *Mahaweli H* area varied from 0.44 to 1.12 and therefore, the water is excellent for irrigation in terms of SAR. According to FAO guidelines, SAR < 3 (Table 02) has no any restriction to use even for sprinkler irrigation. Therefore, the Agro-well waters in *Thalaw*a block has no any restriction to use as an irrigation source for any crops in terms of SAR. Plotting the data on the US salinity diagram of irrigation water quality (Figure 02) shows that water samples are low sodium hazard and low to medium salinity hazard. It indicates that agro-well water can be used for irrigation on almost all types of soil. Moreover, Sodium percentage (SP) calculated for groundwater in each agro-wells was plotted against conductance in Wilcox diagram (Wilcox, 1948) (Figure 03) and shows that almost all groundwater samples are excellent and good for irrigation. The Kelly ratio is also used to determine the hazardous effect of sodium on water for irrigation use. In this study region, it varied from 0.23 to 0.79 with an average of 0.37 (Table 01). Kelly ratio > 1 is considered to be unsuitable for irrigation as they can turn the excess level of Na^+. Therefore, agro-well water at *Thalawa* block is within the safe limit in terms of Kelly ratio.



Note: Sodium hazard (SAR), S1: Low, S2: Medium, S3: High, S4: Very high; Salinity hazard: C1: Low, C2: Medium, C3: High, C4: Very high

Figure 02: Rating of GW samples in relation to salinity and sodium hazard

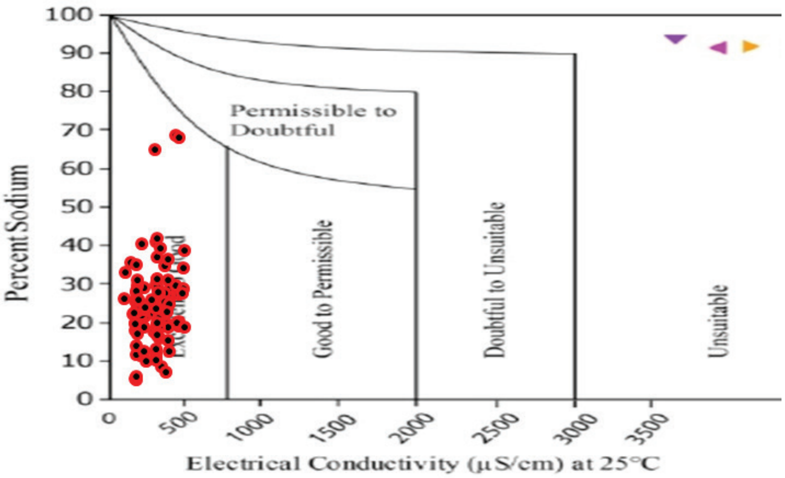


Figure 03: Rating of GW samples on the basis of electrical conductivity and percent sodium (after Wilcox 1948)

The RSC indicated the excess of carbonates and bicarbonates over calcium and magnesium in irrigation water. The data presented in Table 01 revealed that RSC values of irrigation water varied from 0.91 to 2.49 meq/l. RSC less than 1.25 meq/l are considered safe and waters with RSC of 1.25-2.50 meq/L are within the marginal range. If it is > 2.5 considered as unsuitable (Eaton, 1950; Sutharsiny *et al*., 2012). According to this classification, 50 % of the wells are safe and rest 50 % of the wells are within marginal range. Moreover, variation of $HCO_3^-$and CO_3^{2-} are shown in Table 01. According to Carrow *et al*., 2008, HCO_3^- values can range widely, but as a general guideline, bicarbonate > 120 mg/l and CO_3^{2-} > 15 mg/l start to become concern, especially when sodium concentration are > 100 mg/L (Carrow *et al*., 2008). Though the study period, average HCO_3^- of agro well water are > 120 mg/L, CO_3^{2-} and Na^+ concentration are less than the 15 and 100 mg/l respectively. Therefore, there is a very less potential to form sodic soil if this water is used continuously for irrigation.

Variation of nutrient parameters

Nitrogen (NH4-N and NO3-N), Phosphorus and Potassium are major plant nutrients and these nutrients present in water can be beneficial for irrigation but need to be accounted for in the overall fertilization program of crops. However, these nutrients accumulations showed the eutrophication of the wells specially, wells which are not lined and excessive presence of some nutrient parameter may also be harmful to specific crops.

NO_3-N concentration of agro wells ranged from 0.51 to 5.7 mg/l and NH_4- N varied from 0.41 to 0.77 mg/l (Table 1). According to FAO guidelines, sensitive crops may be affected by nitrogen (NO_3-N) concentrations above 5 mg/l. Therefore, waters of well D1HD2FC14, D1FC10-168 having higher NO_3^- level may become concern when cultivating N sensitive crop. Phosphorus concentrations should be as low as possible (lower than 1.0 mg/L) to avoid causing algal blooms. As per the average results of agro well water, water is good in quality that may not show considerable eutrophication in terms of P. However, continuous monitoring may require specially unlined wells in the area because maximum P concentration (1.78) recoded in well D4FC48-544 can be caused to eutrophication which may ultimately result in lowering the water holding capacity of these large diameter agro-wells.

Farmers who cultivate in this area use micro irrigation techniques for irrigation. One important problem of micro irrigation is clogging of drippers, sprinklers and tube walls. Potential clogging agents are physical suspended solid (sand, silt, clay and organic matter), chemical precipitation (calcium or magnesium carbonate, heavy metal hydroxides or oxides or carbonate and fertilizer) and biological (algae and bacteria) agents (Ayers and Westcot, 1985). The recorded high levels of nutrients in these agro wells result in excess algae and bacteria growth that may ultimately lead to clogging problems in micro irrigation systems.

Variation of heavy metals

This study also tested the concentration of few heavy metals as the people in the area suffer from chronic kidney disease of unknown etiology (CKDu) (Jayathilake *et al*., 2013; Jayasumana *et al.*, 2013). Heavy metals specially Cd and As are said to be causative factors for CKDu. Therefore, waters of wells were tested for heavy metals. However, the results show that the heavy metals are in minute quantities and are below the WHO standard (Table 1). FAO has recommended maximum Cd, As and Pb level in irrigation water for long term use as 0.01, 0.1 and 5 mg/l (Ayres and Westcot, 1976), hence the water of these wells are well suitable for irrigation.

Irrigation water quality index

Irrigation Water Quality Index (IWQI) based on the six indices: MH, RSC, Na %, SAR, was calculated from equations 6 and 7. Ideal value of the nth parameter in water represented by 'Vi' in Eq. 10 was considered as '0' for all indices. The weightage assigned to these indices are given in Table 3, and the classification of the groundwater samples based on IWQI is given in table 4. Average IWQI for agro-well water varied between 32.6 and 87.77 with a mean of 48.17. IWQI value varied temporally in different agro wells and minimum and maximum values for each agro-wells and their suitability based on the mean IWQI for irrigation is shown in Table 4. Water of 6 agro-wells can be classified as good and 3 well waters are poor and one is very poor according to the classification by Brindha and Kavitha (2015). Considering the average value for the *Thalawa* block (48.17), water of this block can be classified as good.

Table 03: Weight of each parameter and the suitable limit for irrigation

Parameter	Unit	Suitable limit for irrigation	Unit weight	Reference
MH	No unit	50.0	0.040	Szabolcs and Darab (1964)
RSC	Meq/l	2.5	0.811	Eaton (1950)
Na %	%	60	0.033	Wilcox (1955)
SAR	No unit	18	0.112	Richard (1954)
EC	µs/cm	2250.0	0.0009	Freeze and Cherry (1979)

Table 04: IWQI of different Agro-wells and their suitability for irrigation

Well No.	Average IWQI	Max IWQI	Min IWQI	Suitability
WELL N0 - D1FC1-03	53.88	126.80	2.31	Poor
WELL N0 - D1FC10-168	36.37	67.20	1.70	Good
WELL N0 - D1HD2FC14	36.60	84.17	1.55	Good
WELL N0 - SD6FC34-374	36.21	80.00	2.99	Good
WELL N0 - SD6FC42-481	32.60	59.65	0.69	Good
WELL N0 - D4FC48-544	87.77	164.51	5.44	Very poor
WELL N0 - D4FC57-645	53.77	133.51	2.26	Poor
WELL N0 - D4FC55-624	56.61	110.27	3.27	Poor
WELL N0 - D2FC24-237	46.24	110.98	2.39	Good
WELL N0 - D2FC27-285	41.61	101.44	2.40	Good
Average for the area	48.17	164.51	0.69	Good

(IWQI 0-25 : Excellent, 26 -50: Good, 51-75 : Poor, 76 – 100: very poor, > 100 : Unsuitable, adopted from Brindha and Kavitha 2015)

Relationship among irrigation water quality Parameters

This study also tested the relationship among water quality parameters and also with depth to water level of agro-wells, using spearman's rho correlation coefficient (Table 5). The correlation analysis showed that depth to water table has a weak positive correlation with pH, Na^{+}, Mg^{2+}, K^{+}, Ca^{2+}, As, and SAR. As well as depth to water table has a week negative correlation with HCO_3^{-}, NO_3^{-}, PO_4^{3-} and RSC (Table 5). EC and pH were not highly correlated with any investigated major ions. But, EC showed weekly positive correlation with CO_3^{2-}, HCO_3^{-}, PO_4^{2-}, Na^{+}, Mg^{2+}, Ca^{2+} (r = 0.3, 0.54, 0.33, 0.38, 0.32 and 0.24) and approximate similar correlation was observed by Houatmia *et al*., (2016). pH showed weekly positive correlation with Mg^{2+} and K^{+} (r =0.21, 0.21) and negatively correlated with CO_3^{2-}, HCO_3^{-}, PO_4^{2-} (r =-0.52, -0.35, -0.46) than other investigated ions (Table 5). The concentration of these ions in groundwater depends on the mineral dissolution and solubility, ion exchange, evaporation, anthropogenic activities, following the topographical features and water flow-path condition (Houatmia *et al*., 2016). Na^{+} showed highly positive correlation with Mg^{2+}, $Ca^{2+}$and K^{+} (r = 0.94, 0.89 and 0.69) and Pb ions showed a strongly positive correlation with Na^{+}, Mg^{2+}, Ca^{2+} (r = 0.74, 0.68 and 0.81) which may indicate the influence of evaporation and agricultural activities.

Variation of Water level

Auto water level meter was used to measure the depth to water in each well during 10 month period and depth variation is shown in Figure 04. Further Figure 04 shows the total rainfall during the last 30 days before each sampling date. Shallow water table (more ground water potential) was observed in D4FC48-544 well whereas the deepest water level was recorded in D4FC57-645.

The graph shows that during October 2016, June and July 2017 rainfall has not been recorded but, the water table depth has not that much higher compared to the other dates. Only the month January showed that water level has increased (depth to water table has decreased) in almost all wells with the rainfall. Therefore, this graph infer that variation of water levels of these wells are associated both with the variation of rainfall and water availability of the *Mahaweli* canal system. In addition, we analyzed the relationships between the number of days water allocated for canals system and water depth of wells and also water depth at the sampling date with total rainfall of previous 15 days using simple liner regression (Figure 05).

Table 05: Correlation matrix of the hydro-chemical parameters

	DWT	EC	pH	CO_3^{2-}	HCO_3^{-}	NH_4^{+}	NO_3^{2-}	PO_4^{2-}	Na^{+}	Mg^{2+}	K^{+}	Ca^{2+}	Cd	Pb	As	RSC	SAR	SP
DWL	1.000																	
EC	0.01	1.00																
pH	0.19*	-0.14	1.00															
CO_3^{2-}	-0.17	0.30**	-0.52**	1.00														
HCO_3^{-}	-0.20*	0.54**	-0.35**	0.65**	1.00													
NH_4^{+}- N	-0.02	-0.05	-0.10	0.18	0.29**	1.00												
NO_3^{2-} -N	-0.37**	-0.08	-0.14	0.03	-0.01	0.34**	1.00											
PO_4^{2-} P	-0.29**	0.33**	-0.46**	0.67**	0.54**	0.07	0.09	1.00										
Na^{+}	0.34**	0.38**	0.12	-0.00	-0.02	-0.33**	-0.33**	-0.19	100									
Mg^{2+}	0.29**	0.32**	0.21*	-0.08	-0.05	-0.25*	-0.29**	-0.32**	0.94**	1.00								
K^{+}	0.27**	-0.06	0.21*	-0.14	-0.22*	-0.12	-0.27**	-0.28**	0.69**	0.72**	1.00							
Ca^{2+}	0.32**	0.24*	0.01	0.08	-0.05	-0.35**	-0.31**	-0.22*	0.89**	0.86**	0.59**	1.00						
Cd	0.16	0.02	0.04	0.09	0.13	0.00	-0.17	0.04	0.05	0.03	-0.034	0.04	1.00					
Pb	0.11	0.19*	-0.02	0.09	-0.15	-0.54**	-0.21*	-0.01	0.74**	0.68**	0.46**	0.81**	-0.09	1.00				
As	0.24*	0.02	0.35**	-0.49**	-0.46**	-0.11	-0.18	-0.30**	0.15	0.14	0.18	0.01	0.07	-0.04	1.00			
RSC	-0.45**	0.22*	-0.35**	0.50**	0.63**	0.20*	0.29**	0.64**	-0.48**	-0.52**	-0.47**	-0.49**	-0.09	-0.25*	-0.48**	1.00		
SAR	.033**	0.48**	0.02	0.24*	0.35**	0.19	-0.27**	0.15	0.49**	0.36**	0.28**	0.25*	0.18	0.02	0.21*	-0.12	1.00	
SP	-0.02	0.17	-0.06	0.13	0.25*	0.29**	-0.05	0.21*	-0.11	-0.24*	-0.11	-0.36**	0.09	-0.39**	0.13	0.27**	0.54**	1.00

**. Correlation is significant at the 0.05 level , **. Correlation is significant at the 0.01 level ; DWT – Depth to water table (m)*

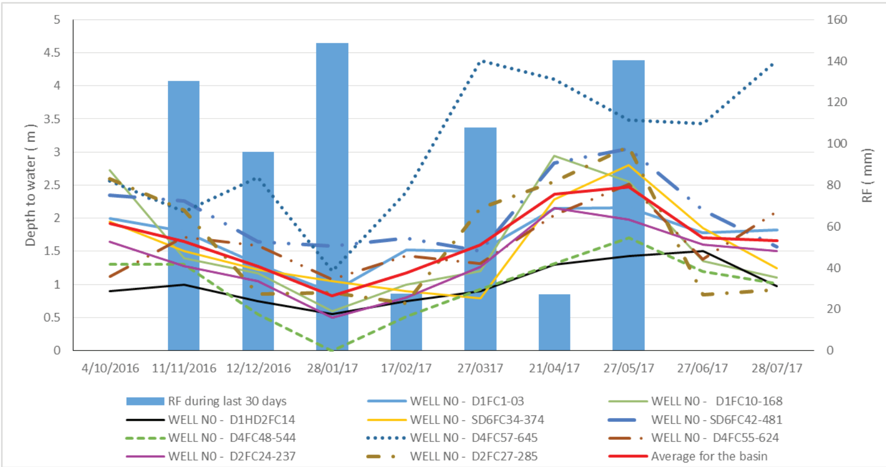


Figure 04: **Temporal variation of water level in different wells and rainfall of the *Thalawa* block during October 2016 to July 2017.**

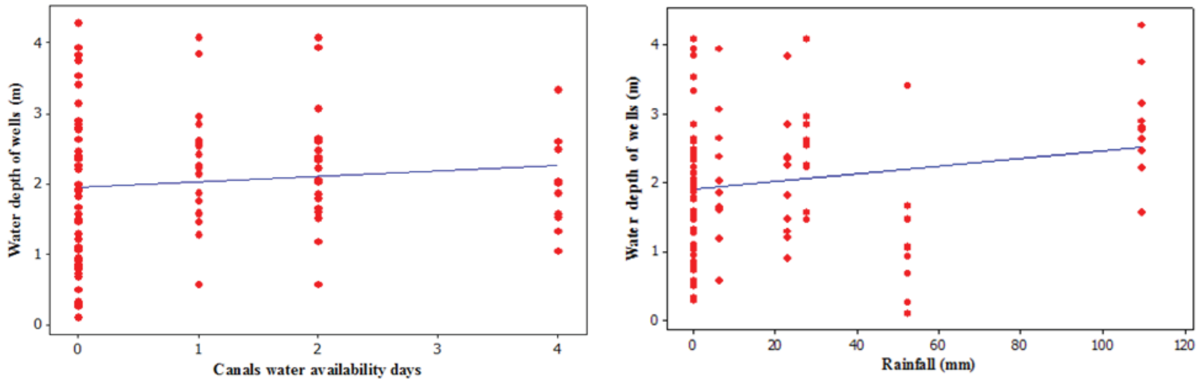


Figure 05: **Variation of depth of water of agro-wells with the canal water availability days and rainfall of the area.**

These analysis showed that water depth (WD) increases with rainfall (WD = 0.9025+ 0.0056 RF (R^2 = 0.04) and also canal water availability days (WD =1.8549+0.0851 DAYS (R^2=0.037). Villholth and Rajasooriya (2010) pointed out that in the dry zone hard rock areas where tank cascade system and *Mahaweli* water diversions dominate shallow surface and groundwater interactions are evident. This study is also an evidence to the surface and groundwater interactions of *Mahaweli* water diversion areas.

CONCLUSIONS

Water in almost all agro-wells in *thalawa* block was of good quality for irrigation for any crops in terms of pH, EC, SAR, SP, heavy metals and nutrient parameters. According to HCO_3^- concentration, 50 % of the wells are safe and rest 50 % of the wells are within marginal range. But, there is a very little possibility to generate sodic soils if these waters are used continuously for irrigation as the SP is quite low. However, considering the combined effect of few water quality parameters using IWQI, three wells can be classified poor to very poor in quality for irrigation. In none of the wells water studied cannot be classified as unsuitable as per the IWQI. It can be concluded that there is higher potential to use agro well water in *Thalawa* block for any crops with very little danger of increasing problem to the soils and growing crops. This study also showed that there is ample water available in agro-wells for further cultivation even during dry spells and the water level of wells vary both with the rainfall and canal water availability.

Data availability statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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