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Classification of Groundwater Suitability for Irrigation in the Ulagalla Tank Cascade Landscape by GIS and the Analytic Hierarchy Process

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Abstract: The tank cascade system (TCS) has been used for over 2000 years for water management in Sri Lanka. Since surface water is limited in the dry zone of Sri Lanka, agricultural production, especially of upland crops, relies on groundwater for irrigation. We sampled 29 wells in the Ulagalla cascade, a prominent TCS near Anuradhapura city in the dry zone of Sri Lanka, in Yala (dry) and Maha (wet) seasons, the two main cropping seasons in Sri Lanka. We evaluated the suitability of groundwater for irrigation using the analytic hierarchy process and geographical information system. Water quality did not vary notably between seasons. However, it deteriorated with the onset of high intensity heavy rain, especially during the Maha season. A water quality zoning map indicated that groundwater in 4% and 96% of the study area is suitable and moderately suitable for irrigation, respectively. Irrigation water quality in tank cascade landscapes and similar environments can be assessed using this methodology and our results.

Keywords: dry zone; empirical Bayesian kriging; Maha season; Sri Lanka; tank cascade system; Yala season

1. Introduction

Fresh surface water resources are unevenly distributed throughout the world and are becoming scarce owing to rapid population growth, industrialization and human activities [1]. So people have turned to groundwater as a major source for drinking, domestic, and irrigation purposes [2]. Although quality is as important as availability, it is often ignored, especially in developing regions. Since the irrigation water with poor quality harms both the soil and crop productivity [3,4], various studies have evaluated the quality of groundwater for irrigation [5–7]. Quality is determined through the use of a number of parameters and indices: electrical conductivity (EC), total dissolved solids (TDS), nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), sodium adsorption ratio (SAR), total hardness (TH), magnesium adsorption ratio (MAR), Kelly's ratio (KR), and chloride [8–11]. A comprehensive assessment of groundwater suitability for irrigation requires the integration of these indices.

Geographical information system (GIS) is a powerful tool for assessing environmental changes, the quality and the availability of water and for managing water resources [12]. Spatial analysis extension in GIS allows us to interpolate environmental parameters between known values through the use of techniques such as inverse distance weighted, ordinary kriging, universal kriging, empirical Bayesian kriging (EBK), spline, and trend surface analysis [13–16].

Multi-criteria decision-making tools can support the resolution of complex problems by evaluating activities using multiple criteria, as in disaster management and environmental management studies [17]. In recent years, a tool named the analytic hierarchy process (AHP), developed by Saaty [18], has been used in environmental planning and management studies [19–21].

The tank cascade system (TCS), used mainly in the dry and intermediate zones of Sri Lanka since the third century BCE, is considered as one of the most efficient traditional water management systems in the world, and is still an essential element of water management for agriculture in Sri Lanka [22,23]. The key concept of the TCS is recycling and reuse of water through a network of tanks organized within micro-catchments to store and convey water (by gravitational flow) originating from ephemeral rivulets [24]. TCSs collect rainwater, maintain water content of the soil and groundwater, control soil erosion, and maintain the ecological balance [9]. During the last few decades, the usage of groundwater in the dry zone of Sri Lanka has rapidly increased owing to the inability of surface water resources to cater to growing demand, hastening the deterioration of water quality in the tank cascade landscape [23].

The Ulagalla cascade is a major TCS located near Anuradhapura city, in the dry zone of Sri Lanka. Although the cascade has not been studied comprehensively, elevated concentrations of nutrients were observed in the adjacent Thirappane and Mahakanumulla cascades [25], showing that not only the quantity but also the quality of irrigation water poses problems for sustainable farming. This highlights the need to examine water quality comprehensively and to pay more attention to continuous monitoring and management of groundwater quality in tank cascade landscapes. However, no scientific protocol has yet been developed to assess the suitability of groundwater for irrigation in tank cascade landscapes or similar environments.

Although mapping is used worldwide to demarcate areas with suitable groundwater for irrigation in regions with a continuous water table [26,27], regions without a continuous water table have been neglected. Further, no attempt has been made to map irrigation water suitability zones in tank cascade landscapes or similar environments. Hence, we used GIS and AHP to model spatial and temporal variations in irrigation water quality in a tank cascade landscape, and established a protocol to classify the groundwater suitability for irrigation.

2. Materials and Methods

2.1. Study Area

The Ulagalla cascade is a linear cascade in the low country dry zone (DL_{1b}) in the north central province of Sri Lanka, located at 8°5′–8°14′N latitude and 80°31′–80°34′E longitude, and covers about 51 km^2 of area. The cascade comprises 19 interconnected small tanks (Figure 1).

The study area is underlain by charnockite, granitic gneiss, and undifferentiated Highland Series rocks (Figure 2a). The major aquifer type in the tank cascade landscape is a shallow regolith aquifer of 2–10 m in thickness. The groundwater potential is limited owing to a low groundwater storage capacity and the transmissivity of the underlying crystalline basement [28]. Groundwater has been extracted for irrigation and domestic purposes for more than 2000 years from dug wells [29]. The farmers in the dry zone draw irrigation water from large-diameter "agro-wells", as agricultural activities are prominent in this area. Commonly grown upland crops (e.g., chilli, eggplant, okra, banana, etc.) are grown under rainfed "*chena*" cultivation. Other main land uses are paddy, forest, and homestead (Figure 2b). Two major growing seasons are recognized in Sri Lanka: the Maha (wet) season and the Yala (dry) season. The Maha season, from October to February, receives rainfall from the second inter-monsoon (depression and cyclonic storms in the Bay of Bengal) and north-east monsoon. The Yala season, from April to August, receives rainfall from first inter-monsoon (Convective type) and the south-west monsoon [30,31]. We assessed groundwater quality parameters over 12 months to investigate seasonal variations in irrigation water quality.

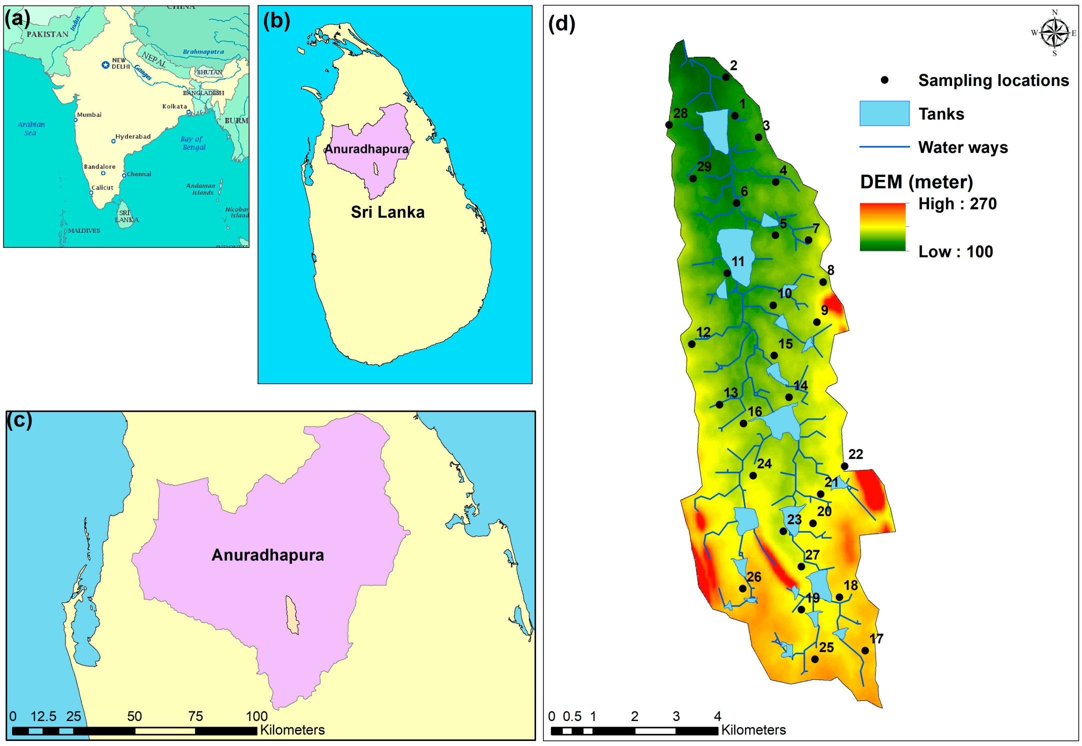

Figure 1. Location map of the Ulagalla cascade: (**a**) South Asia; (**b**) Sri Lanka; (**c**) Anuradhapura district; (**d**) sampling locations.

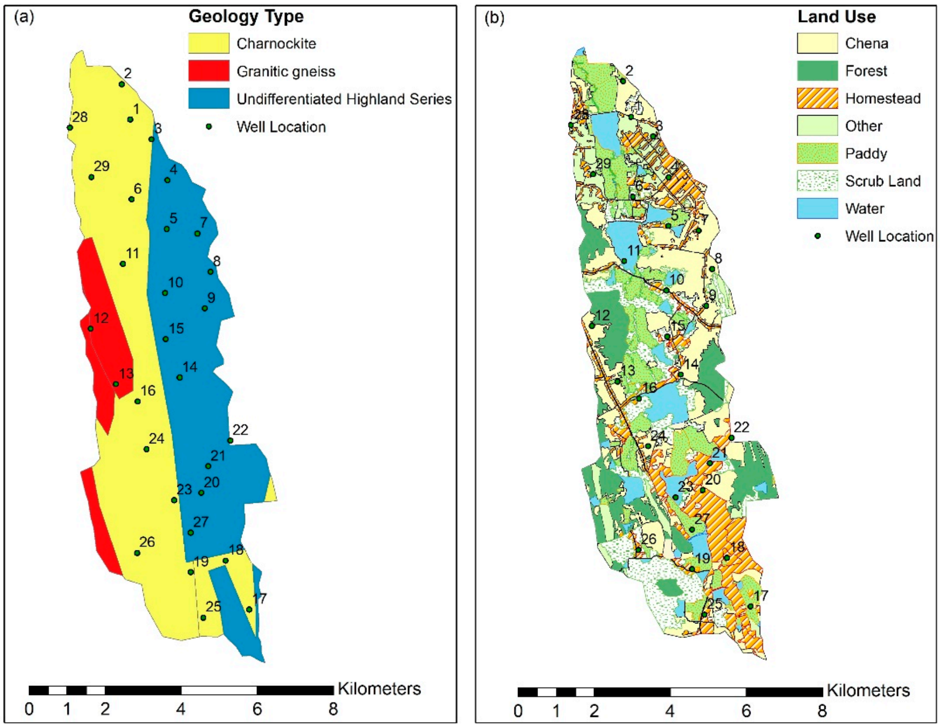

Figure 2. (**a**) Geological map and (**b**) land use map of the Ulagalla cascade.

2.2. Cascade Boundary Demarcation and Groundwater Sampling

To demarcate the extent of the Ulagalla cascade boundary, we used 1:50000-scale topographic sheets published by the Survey Department of Sri Lanka and the Shuttle Radar Topography Mission 30-m digital elevation model [32].

We randomly selected 29 active agro-wells to give a homogeneous distribution within the study area (Figure 1) and samples were collected for 12 consecutive months starting from April 2016. Samples were collected in acid-cleaned high-density polyethylene bottles rinsed several times with the groundwater to be sampled. The bottles were tightly closed, labelled, and transported out of direct sunlight to the laboratory, where they were stored at 4 °C. They were analysed by standard procedures [33]. EC, TDS, and pH were measured in situ with a HQ 40 d multiparameter analyser (Hach, CO, USA). Sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), and calcium (Ca^{2+}) ions were determined by inductively coupled plasma optical emission spectrometry (iCAP 7400 ICP-OES, Thermo Scientific, Cambridge, UK). Alkalinity as $CaCO_3$ was analysed by acid base titration. Chloride (Cl^-) was determined by standard $AgNO_3$ titration. Available phosphorus (PO_4^{3-}) was determined by the ascorbic acid method [34]. Nitrate-nitrogen (NO_3^--N) was analysed by the salicylic acid method [35]. Sulphate (SO_4^{2-}) concentration was measured by method 8051 SulfaVer 4 (powder pillows) [36].

The research methodology is presented in Figure 3.

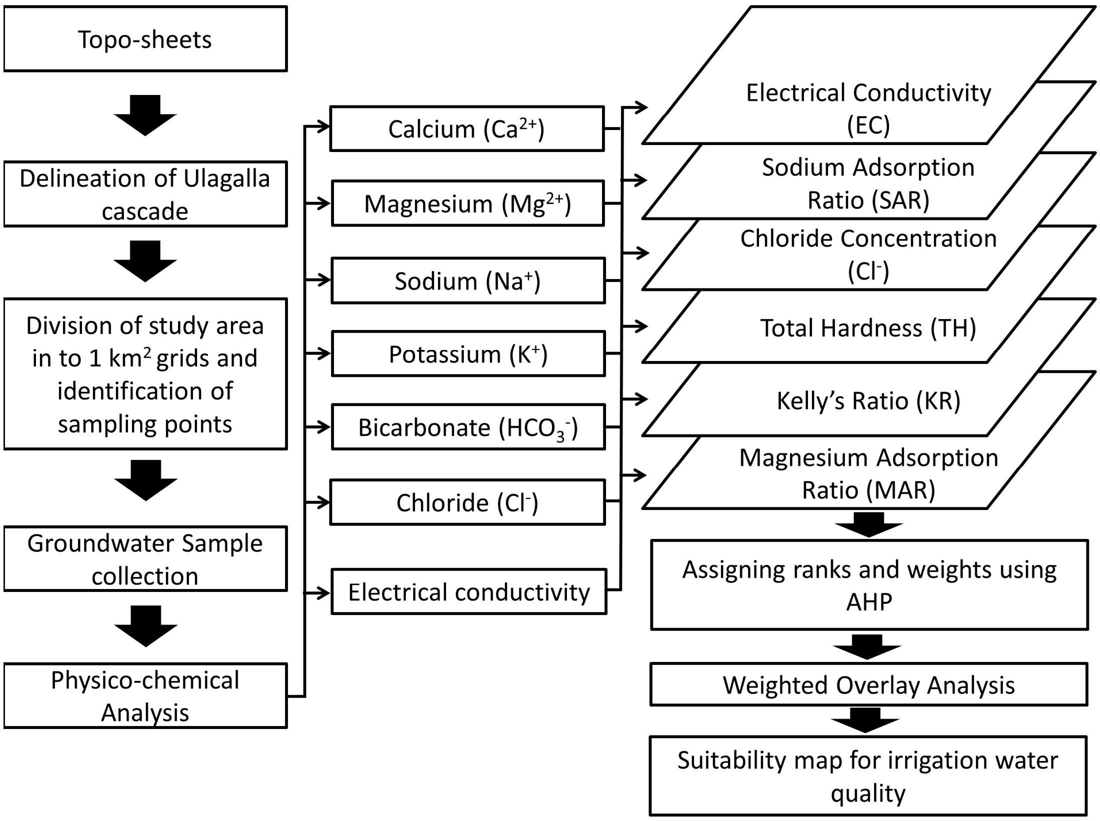

Figure 3. Flow chart of the methodology used in this research.

2.3. Indices of Irrigation Water Quality

We selected six water quality indices important for field crops grown in the study area. We estimated chloride concentration, electrical conductivity (EC), sodium adsorption ratio (SAR)

(Equation (1)) [37], magnesium adsorption ratio (MAR) (Equation (2)) [38], Kelly's ratio (KR) (Equation (3)) [39] and total hardness (TH) (Equation (4)) [40] as:

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

$$\mathrm{MAR} = \frac{\mathrm{Mg}^{2+} \times 100}{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}} \tag{2}$$

$$\mathrm{KR} = \frac{\mathrm{Na}^{+}}{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}} \tag{3}$$

$$\mathrm{TH}(\mathrm{CaCO}_3)\mathrm{mg/L} = 2.49(\mathrm{Ca})\mathrm{mg/L} + 4.1(\mathrm{Mg})\mathrm{mg/L} \tag{4}$$

where all concentrations in Equations (1)–(3) are expressed in meq of solute per L of solvent.

2.4. Spatial Interpolation

Kumari et al. [41] compared the performance of deterministic and geostatistical methods used to interpolate irrigation water quality in the tank cascade landscape. They reported EBK as the best interpolation method for the Ulagalla cascade. Gunarathna et al. [15,16] also reported that EBK was the best method to interpolate irrigation water quality based on EC, pH and TDS. Since EBK is a straightforward and robust method that uses a number of semivariograms instead of just one [42], we used it here.

2.5. Analytic Hierarchy Process (AHP)

The AHP is recognized as a powerful decision support tool in natural resource management studies. It structures complex problem hierarchically and examines each level of the hierarchy individually. It uses pairwise comparison matrices to compare all possible pairs of criteria and determine which criterion has the highest priority [43]. Criteria are scaled from 1 to 9 (Table 1), where 1 indicates equal importance and 9 indicates highest priority. A reciprocal value (e.g., 1/9) indicates the reciprocal comparison. To confirm the consistency of priority ratio, the consistency index (CI) is calculated (Equation (5)).

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{5}$$

where $\lambda_{\max}$ is the largest or principle eigenvalue of the matrix and n is the number of criteria in the matrix. To ensure that the pairwise comparison matrix is consistent, the consistency ratio (CR) is calculated [44] as:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{6}$$

where the value of the random consistency index (RI) is given by Saaty [45] (Table 2). If CR ≤10%, it is acceptable. If CR ≥10%, the AHP may not give meaningful results, and the subjective judgment of the pairwise ranking must be revised [18].

We used six criteria that influence irrigation water quality: EC, SAR, MAR, TH, Cl^-, and KR. Since each criterion relies on different measured parameters and reflects a different aspect of water quality, they need to be given weights, which must be assigned with great care. As the AHP has proved a powerful decision support tool in this regard [43], we invited 10 experts in irrigation water quality from universities and the Department of Agriculture in Sri Lanka to prioritize these criteria for upland crops commonly grown in the study area in an AHP Excel template (www.scbuk.com/ahp.html). The names of the criteria or requirements were entered in the template and the experts were asked to work through the matrix, comparing criteria in pairs. Once the pairwise ranking was completed, a normalized matrix was calculated and the consistency was checked with the CR. All the CR values were within the acceptable limit (ranged from 2 to 9%), so the computed weights were valid. As the experts' opinions are likely to be subjective, we used the average values of the respective weights as the final weights.

Table 1. Relational scale for pairwise comparisons (from Bozdag [43]).

Importance	Description	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one criterion over the other
5	Strong importance	Experience and judgment strongly favour one criterion over the other
7	Very strong importance	Experience and judgment very strongly favour one criterion over the other
9	Extreme importance	The evidence favouring one criterion over another is of the highest possible validity
2, 4, 6, 8	Intermediate values	When compromise is needed
Reciprocals	Values for inverse comparison	If criterion *i* had one of the above numbers assigned to it when compared with criterion *j*, then *j* has the reciprocal value when compared with *i*

Table 2. Random consistency indices (RI) for different numbers of criteria (from Saaty [45]).

Number of Criteria (*N*)	Random Consistency Index (RI)
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.54
13	1.56
14	1.57
15	1.59

Next, we divided water quality parameters and indices into subgroups and assigned ranks according to Ayers and Wescot [46] (Table 3). Considering the effect of each parameter or index on irrigation water quality, we ranked subgroups on a scale of 1 to 3 as follows: 1, no harmful effect on irrigation water quality; 2, moderate effect; and 3, harmful effect. EC <0.7 dS/m has no unfavourable effect on irrigation water quality, so it is ranked 1; 0.7≤ EC ≤3 dS/m is moderately suitable, so it is ranked 2; and EC >3 dS/m is unsuitable, so it is ranked 3. MAR and KR have only two classes: MAR <50 and KR <1 are ranked 1, and MAR >50 and KR >1 are ranked 3. TH has four classes [46]; hence, TH <75 is ranked 1, values of 75–150 and 150–300 are ranked 2, and TH >300 is ranked 3. Values of all wells for each criterion were spatially distributed in ArcGIS software using the EBK interpolation method and reclassified as above ranks. All reclassified layers were combined and the weighted overlay method was performed. The cell values of each reclassified layer were multiplied by their weights obtained by AHP. Irrigation suitability maps (monthly variation, seasonal variation, and overall) of the study area were obtained by calculating the total irrigation water suitability score (IW) as:

$$\mathrm{IW} = \sum_{i=n}^{i=1} F_i \times W_i \quad (7)$$

where F_i is the value of reclassified layer of respective water quality criterion, W_i is the weight of the respective criterion obtained from AHP, and n is the total number of criteria. The irrigation suitability maps showed areas as suitable (IW = 1.00–1.33), moderately suitable (IW = 1.34–2.33), or unsuitable (IW = 2.34–3.00).

Table 3. Irrigation water quality restriction classes and ranks of irrigation criteria in the Ulagalla cascade.

Irrigation Criterion	Range	Water Class/Restriction	Rank
EC	<0.7	none	1
	0.7–3	slight to moderate	2
	>3	severe	3
SAR	<3	none	1
	3–9	slight to moderate	2
	>9	severe	3
Cl^-	<140	none	1
	140–350	slight to moderate	2
	>350	severe	3
MAR	<50	suitable	1
	>50	unsuitable	3
KR	<1	suitable	1
	>1	unsuitable	3
TH	<75	soft	1
	75–150	moderate	2
	150–300	hard	2
	>300	very hard	3

3. Results and Discussion

3.1. Hydrochemistry of Groundwater in the Ulagalla Cascade

The pH, EC, and major ions of the groundwater samples in the Ulagalla cascade are summarized in Table 4. Most of the parameters recorded a wide range and a high SD. The groundwater in all of Sri Lanka except the far north is drawn mainly from hard metamorphic aquifers. Hence, the mineral composition depends mainly on the metamorphic rocks. This indicates the influence of mineral dissolution associated with seasonal rainfall and anthropogenic activities [47].

Table 4. Descriptive statistics of chemical parameters in groundwater during Yala and Maha seasons.

Water Quality Parameter [a]	Yala season Max	Min	Mean	SD	Maha season Max	Min	Mean	SD
pH	8.8	6.2	7.7	0.4	9.3	6.8	7.9	0.4
EC	4300.0	172.4	1267.1	787.4	4310.0	337.0	1274.4	803.0
Na^+	329.4	5.9	130.4	70.6	363.8	23.0	139.3	80.5
K+	15.5	0.2	2.4	2.5	20.7	0.2	2.9	2.8
Ca^{2+}	386.2	6.4	78.1	73.2	280.1	4.3	65.6	45.7
Mg^{2+}	202.6	1.5	46.3	39.0	284.2	5.1	55.7	44.6
HCO_3^-	175.0	37.5	87.4	20.4	215.0	27.5	84.9	23.2
Cl^-	2020.0	20.0	312.9	340.1	2120.0	40.0	351.2	334.9
SO_4^{2-}	84.0	1.0	30.6	15.2	94.0	2.0	34.7	18.7
NO_3-N	17.6	0.1	1.5	2.5	25.2	0.1	1.4	3.3
PO_4^{3-}	1.5	0.0	0.3	0.3	0.6	0.0	0.1	0.1

[a] mg/L except EC, μS/cm; Max-maximum, Min-minimum, SD-standard deviation.

Cl^- content showed wide variation (20 to 2120 mg/L; Table 4). Cl^- is one of the important parameters that govern groundwater quality. Generally, weathering of silicate-rich rocks, excess application of fertilizer, seawater intrusion, and animal and human waste contribute Cl^- to groundwater [48,49]. Since charnockite is prominent in the study area (Figure 2a), it can contribute

Cl^- through mineral dissolution. Since a major portion of the cascade is still under rural settlement with lowland and upland cropping and lacks urban settlements and industry, the effect of industrial effluent on groundwater quality is minimal. The wells with elevated Cl^- concentration occurred in coconut plantations and home gardens. Hence, fertilizer (KCl), applied for coconut cultivation, and the improper disposal of household wastewater might be the main sources. Nutrient concentrations, notably NO_3-N and phosphate, are not yet problematic, but the continuous application of excess fertilizer can lead to problems. Hence, continuous monitoring and good management practices are essential.

The major cations of the groundwater in the Ulagalla cascade decreased in the order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, and the major anions decreased in the order of $Cl^- > HCO_3^- > SO_4^{2-} > NO_3$-N $> PO_4^{3-}$ during both seasons.

3.2. Weighting of Criteria for Irrigation Water Quality

The relative weights assigned by each expert for each criterion were averaged and the average relative weights were used (Table 5) to generate the irrigation suitability maps of the Ulagalla cascade.

Table 5. Average relative weights assigned to irrigation criteria in the Ulagalla cascade.

Irrigation Criteria	EC	SAR	Cl^-	MAR	KR	TH
Average relative weights	0.27	0.25	0.16	0.11	0.11	0.10

Salinity, measured as EC, is considered the most influential water quality criterion [50]. It has been identified as the major constraint in the dry zone of Sri Lanka, where it reduces crop productivity [51]. The group of experts gave it the highest weight of 0.27. SAR indicates soil alkalinity and has a direct relationship with Na adsorption to soil—a high value indicates decreased infiltration [52]. It was given the second highest weight. High concentrations of Cl^- can be toxic to sensitive crops such as citrus and leafy field crops [53]. As Cl^- is not adsorbed to soil, the Cl^- in irrigation water readily moves with soil water. It causes leaf burn and drying, and in severe conditions, leaf drop [52]. The Cl^- concentration was given a weight of 0.16. Both MAR and KR were given a weight of 0.11, and TH was given a weight of 0.10. Although hardness of irrigation water does not have any direct effect on crop growth, hardness triggered by HCO_3^- affects soil, which ultimately can affect crop growth.

3.3. Irrigation Water Quality Zoning in the Ulagalla Cascade

No major difference in water quality zoning was observed between seasons. Most of the cascade falls in the moderately suitable category (Figure 4).

Understanding the seasonal variation of groundwater quality is important in management decisions. However, for planning or policy decisions, we need an overall idea about the groundwater quality of the area. Hence, we developed the overall irrigation water suitability map of the cascade by overlaying the 12 months irrigation suitability maps (Figure 5) to demarcate suitable, moderately suitable and unsuitable areas for irrigation. In the overall irrigation water suitability map, 4% of the cascade is suitable, and 96% is moderately suitable for irrigation (Figure 5).

Although there was no major difference in irrigation water quality between seasons, the monthly zoning maps showed greater variation in several months of the Maha season than in the Yala season (Figure 6).

Since irrigation water quality is directly affected by rainfall, we examined the rainfall pattern, and found that the pattern during the study period differed from the monthly average over the period of 1980–2017 (Figure 7). The Maha season begins in October with second inter-monsoonal rainfall occurring due to the influence of weather systems like depression and cyclonic storms in the Bay of Bengal. It contributes around 38% of the annual rainfall in Anuradhapura [31]. October typically features high intensity rainfall, and the subsequent runoff can explain the deterioration in irrigation water quality then (Figure 6). This result shows the "first-flush" phenomenon. Particularly in dry zones, salts tend to accumulate on the soil surface with evaporation [47]. This situation was aggravated at the end of the Yala season, as no rainfall was recorded in August or September (Figure 7). These accumulated salts washed off in the heavy rain during the period October–November, when heavy rain can fall in thunderstorms on many parts of the island [47], causing a clear deterioration in irrigation water quality (Figure 6).

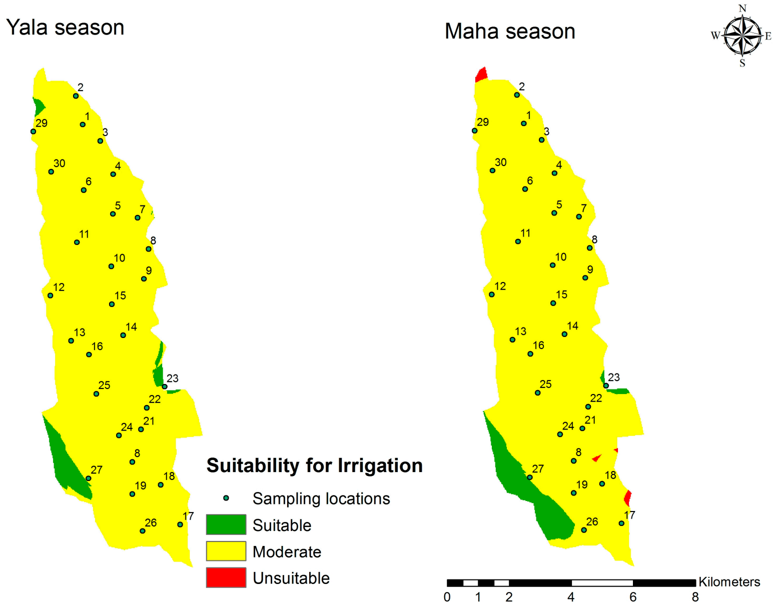

Figure 4. Comparison of irrigation water quality in the Ulagalla cascade between Yala and Maha seasons.

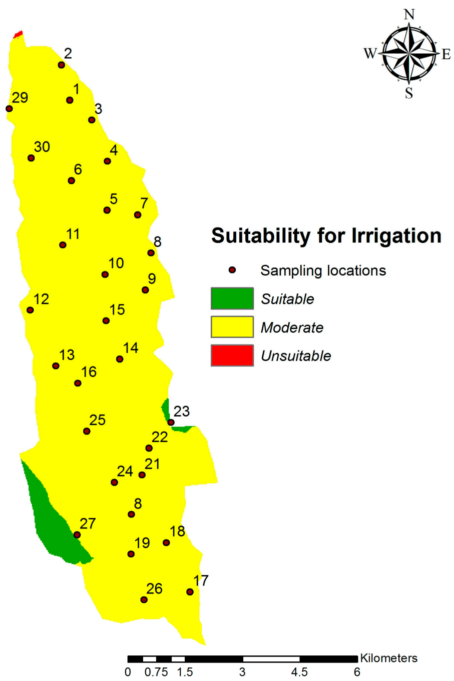

Figure 5. Overall irrigation water suitability map of the Ulagalla cascade.

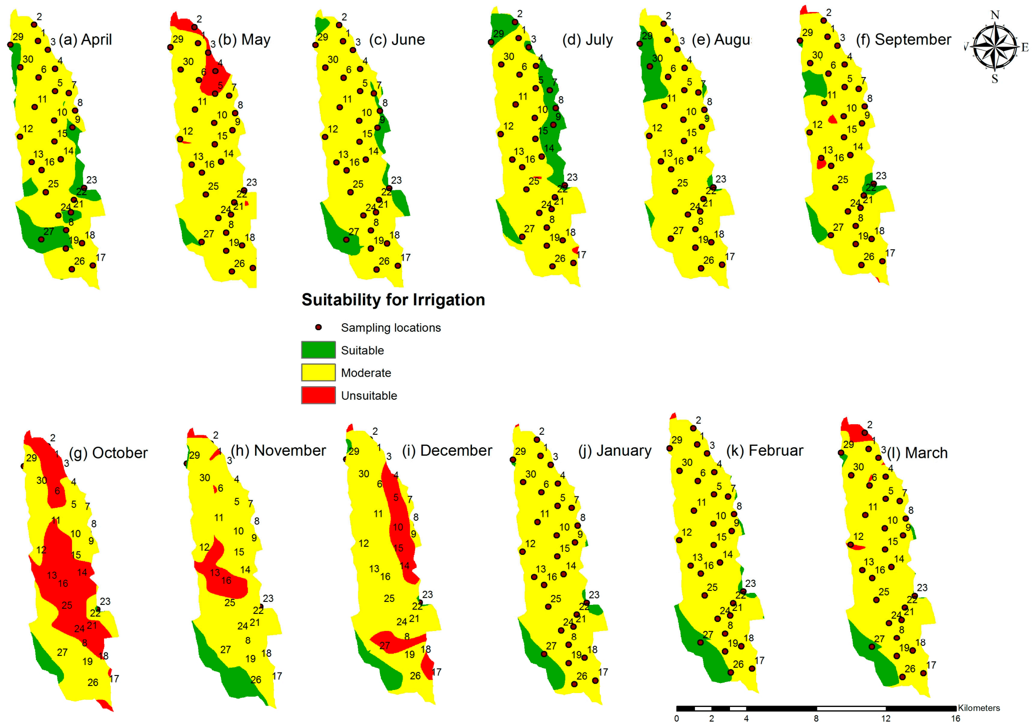

Figure 6. Monthly variation in irrigation water quality in the Ulagalla cascade.

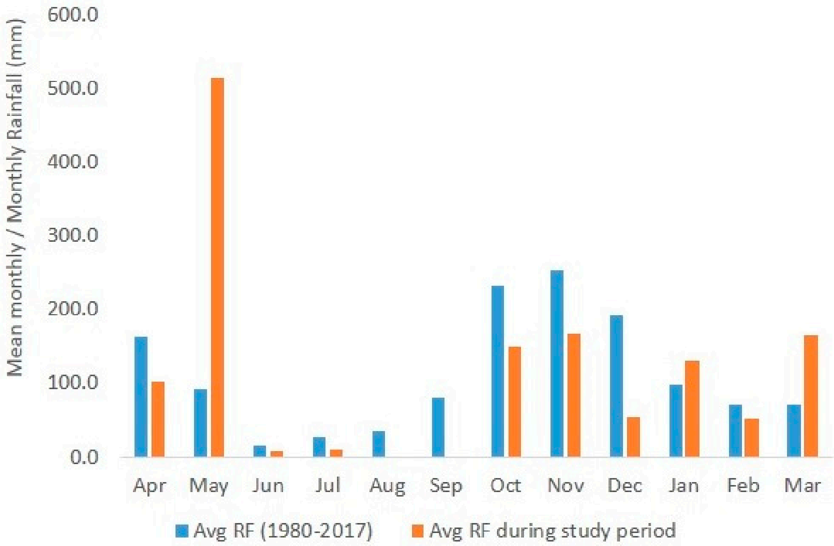

Figure 7. Monthly average rainfall (RF) during the period 1980–2017 and monthly rainfall during the study period.

A similar pattern was observed during the Yala season. In general, the Yala season receives less rainfall than the Maha season [31]. However, during the study period, it received more rainfall than the Maha season. From April to August (except in May), most of the groundwater in the Ulagalla cascade was moderately suitable for irrigation (Figure 6a–e). In May, high intensity heavy rainfall caused substantial runoff with a high concentration of contaminants (Figure 6b), reducing irrigation water quality at the bottom (northern end) of the cascade. These results confirm that irrigation water quality in this area is influenced by heavy rainfall rather than by total rainfall, not only at the beginning but also in the middle of the rainy season.

During sampling, we noted that wells 1, 2, 5, 9, 15 and 19 were unlined (Table 6). Lined wells are typically ringed with a brick or concrete wall (1.0–1.5 m height) [54]. Unlined wells can be contaminated through direct runoff. Farmers should be encouraged to build at least a brick wall around their agro-wells to exclude runoff and improve irrigation water quality.

Table 6. Characteristics of sampling locations in the Ulagalla cascade.

Well No.	Location		Construction of the Well
	Longitude	Latitude	
1	80°32′28″E	8°13′35″N	unlined
2	80°32′21″E	8°14′5″N	unlined
3	80°32′47″E	8°13′18″N	lined
4	80°33′1″E	8°12′43″N	lined
5	80°33′0″E	8°12′1″N	unlined
6	80°32′30″E	8°12′27″N	lined
7	80°33′27″E	8°11′58″N	lined
8	80°33′38′E	8°11′25″N	lined
9	80°33′33″E	8°10′53″N	unlined
10	80°32′59″E	8°11′6″N	lined
11	80°32′23″E	8°11′32″N	lined
12	80°31′55″E	8°10′36″N	lined
13	80°32′16″E	8°9′49″N	lined
14	80°33′11″E	8°9′54″N	lined
15	80°32′60″E	8°10′27″N	unlined
16	80°32′35″E	8°9′34″N	lined
17	80°34′11″E	8°6′36″N	lined
18	80°33′51″E	8°7′18″N	lined
19	80°33′21″E	8°7′8′N	unlined
20	80°33′30″E	8°8′16″N	lined
21	80°33′36″E	8°8′38″N	lined
22	80°33′55″E	8°9′0″N	lined
23	80°33′7″E	8°8′9″N	lined
24	80°32′43″E	8°8′53″N	lined
25	80°33′32″E	8°6′29″N	lined
26	80°32′35″E	8°7′24″N	lined
27	80°33′21″E	8°7′42″N	lined
28	80°31′37″E	8°13′28″N	lined
29	80°31′56″E	8°12′46″N	lined

3.4. Groundwater Quality for Irrigation: Present Status and Future Implications in the Tank Cascade Landscape

Since groundwater in most of the cascade is only moderately suitable for irrigation (Figure 5), urgent attention is required to manage this valuable resource sustainably. Salinity is the major constraint in dry zones [5,55]. However, water hardness is higher in dry zones than in wet zones [47,56], and during the study period, it varied from 47 to 1842 mg/L. Therefore, special care should be taken when micro-irrigation systems such as drip irrigation are introduced, as clogging has already demotivated the farmers in the area. Farmers must be trained in the maintenance and operation of drip irrigation systems [57], so extension officers have to pay attention to irrigation suitability maps when introducing new irrigation methods or crops, and need to alert farmers to salinity control measures.

A groundwater management policy needs to be implemented soon to assure the sustainable use of the resource. Attention must be given to continuous monitoring and management of groundwater quality, especially in areas with restrictions for irrigation purposes. The systematic evaluation of all major cascade systems will help the sustainable use of groundwater resources. Our approach can be used to develop a system of irrigation water suitability classification in Sri Lanka, and researchers can use it in developing techniques for mapping irrigation water quality zones.

4. Conclusions

We aimed to demarcate the suitable areas for irrigation in the Ulagalla cascade. We used AHP to understand the relative importance of six irrigation water quality criteria, and developed an irrigation water suitability map using weighted overlay in GIS.

Monthly variations in irrigation water quality revealed that the first flush associated with surface runoff is prominent in the study area following high intensity heavy rainfall in both seasons, but there was no distinct difference in quality between seasons.

Only 4% of the groundwater in the Ulagalla cascade is suitable for irrigation, and 96% is moderately suitable. Our results can be incorporated in the decision-making process of agricultural production and environmental planning in the study area. We recommend this AHP- and GIS-based water quality zoning procedure for research in tank cascade landscapes and similar environments.

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