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SPATIAL AND SEASONAL WATER QUALITY VARIATION OF *YAN OYA* IN TROPICAL SRI LANKA

M. H. J. P. GUNARATHNA[1], M. K. N. KUMARI[2], K. G. S. NIRMANEE[3] & G. Y. JAYASINGHE[4]

[1,2,3]Department of Agricultural Engineering and Soil Science, Faculty of Agriculture,
Rajarata University of Sri Lanka, Puliyankulama, Anuradhapura, Sri Lanka

[4]Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna,
Mapalana, Kamburupitiya, Sri Lanka

ABSTRACT

A study was conducted to investigate spatial and seasonal variation of selected vital physicochemical parameters in *Yan Oya* of Sri Lanka. Water samples from seven locations along the *Yan Oya* were collected monthly, during 2014/15 representing pre monsoonal, monsoonal and post monsoonal rainy periods. Results revealed that pH, temperature, electrical conductivity, total dissolved solids, total suspended solids, dissolved oxygen, sodium absorption ratio, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, ammoniacal and nitrate nitrogen were within safe limits for aquatic life, environment and irrigation during monsoonal and post monsoonal rainy periods. Further, significant variations of physicochemical parameters within the pre, post and monsoonal rainy periods were observed. Out of the measured parameters, significant spatial variation was recorded only for ammoniacal and nitrate nitrogen, whereas it was closely related with the land uses. Total river discharge was 479 million cubic meters and huge nutrient load was drained to sea especially during the stormy flow periods. Water quality in *Yan Oya* river basin is in acceptable level and minimal impact of land uses was observed. However, with the development of agriculture and homesteads in future, it expected to be changed. Hence, more attention should be paid to maintain the low lying scrub areas, which act as a buffer zone along the river.

KEYWORDS: GIS, Land Use, Nutrient Load, Physicochemical Parameters, River Basin

INTRODUCTION

Water, the most vital natural resource is one of the major basic needs of human beings. It is available in two basic forms categorized as surface water and groundwater. Surface water has the easiest access in fulfilling basic requirements. Due to this, almost all the major human civilizations were centered on river basins.

Characteristics and level of physical, chemical and biological substances in water determine the quality of the water. Water quality can highly affect the agriculturein irrigation, industrial uses and domestic purposes including drinking. Good quality water is most important to prevent the health hazards and to improve life standards. The quality of water can be assessed by analyzing physicochemical parameters and it would also help to identify potential sources of pollutants. Frequent monitoring of physicochemical parameters of surface water resources is vital in better management of water resources as well as aquatic habitats and the environment. Studying of physicochemical parameters in Sri Lankan rivers was reported by many authors. Athukorala et al., (2013) and Wickramaarachchi et al., (2013) reported the analysis of physicochemical variation of water with respect to different land uses and sediment analysis, respectively in *Kelani* river in their separate studies. Welagedara et al., (2014) reported a study about water quality variations in *Mahaweli, Kalu, Kelani, Walawe, Menik* and *Gin* rivers in Sri Lanka. Perera et al., (2014) Madushanka et al., (2014) and Chandradasa et al., (2013) reported seasonal and spatial water quality variations in upper *Malwathu Oya*in their respective studies.Islam et al., (2015) reported the water quality variation in *Menik*river. Amarasekara et al., (2009) Bandara et al., (2010), Kotabewatta (2013), Weerasekara et al., (2015) and Rathnayake (2015) reported water quality studies in some tributaries of *Mahaweli* River. However no recent studies were reported in physicochemical variation of water in *Yan Oya*.

Yan Oya (River) originates in the hilly areas of *Dambulla* and *Sigiriya*, flows towards the North- Eastern region of Sri Lanka and escape to the sea as a fourth order stream. The catchment area of *Yan Oya*is 1538 km^2 which is positioned entirely in the dry zone of Sri Lanka. *Yan Oya*fulfills the water requirement of nearby communities including irrigation of their crops. Further, it dischargesabout 482 MCM to sea annually, mostly contributed by the second inter monsoonal rains and north east monsoonal rains (Manchanayake and MaddumaBandara, 1999). Drainage water of agricultural lands (mainly paddy fields) and homesteads enters *Yan Oya* in several places and this may affect to the quality of water. Stilllimited attention has been drawn to study the water quality in *Yan Oya*; therefore, this study was designed to assess the spatial and seasonal variation of water quality in *Yan Oya*basin.

MATERIAL AND METHODS

Sampling Locations

Water samples from seven locations along the middle part of the *Yan Oya* were collected. Characteristics of land use, major water inputs and special features of sampling points are listed in the Table 1.

Table 1: Sampling Locations (SL) and Characteristics of Respective Sub Watersheds

Sl. No.	Remarks
01	Located 3 km away from the *Huruluwewa* reservoir Major water input is drainage water of paddy fields in the commanding area of *Huruluwewa* reservoir It also receives spilled water during the spilling period of the reservoir
02	Located 3.5 km away from the sampling point 01 Major water input is drainage water of paddy fields of a tank cascade system and drainage water of homestead areas of *Yakalla* town
03	Located 4.5 km away from the sampling point 02 Major water input is drainage water of paddy fields and drainage water of homesteads areas of *Galenbindunuwewa* town
04	Located 6 km away from the sampling point 03 Major water input is drainage water of paddy fields and shrub-lands
05	Located 4.5 km away from the sampling point 04 Major water input is drainage water of paddy fields of a tank cascade system and drainage water of homestead areas of small villages
06	Located 11.5 km away from the sampling point 05 Major water input is drainage water of paddy fields and drainage water of homestead areas of small villages Just before the sampling point 06, *Yan Oya* is covered by forest buffer area
07	Located 14 km away from the sampling point 06 Major water input is drainage water of paddy fields and drainage water of homestead areas of small villages It is the same place of gauging location of Irrigation Department of Sri Lanka

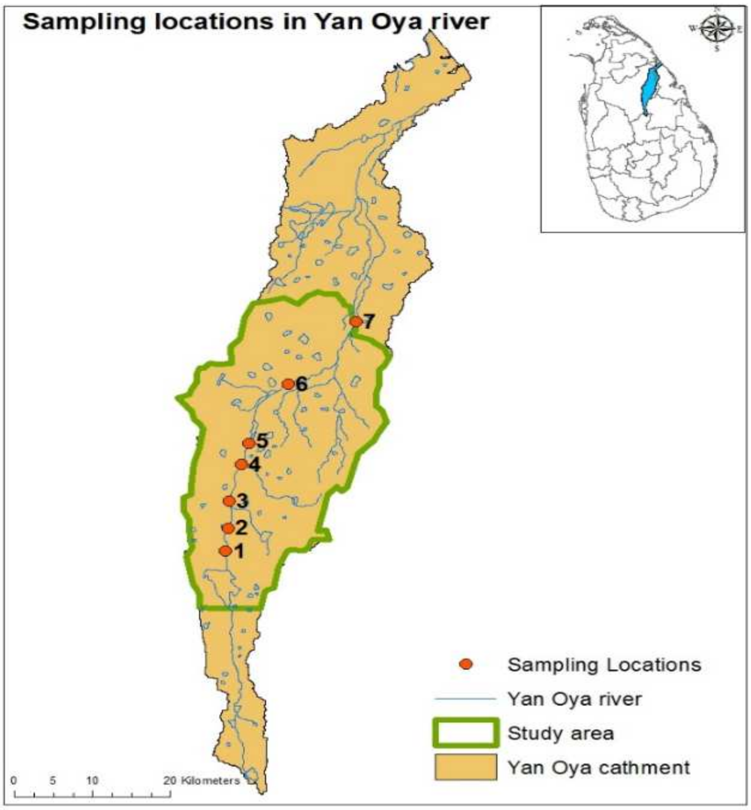

Figure 1: Study Area and Sampling Locations

Rainfall and Stream Flow Data

Rainfall data of *Huruluwewa* gauging station and rainfall and stream gauging records of *Horowpothana* gauging station were gathered from Meteorological Department of Sri Lanka and Irrigation Department of Sri Lanka, respectively.

Water Sampling and Analysis

Sampling was done monthly in 2014/15, representing pre monsoonal period, north east monsoonal rainy period and post monsoonal period. Total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen level (DO), pH and temperature were measured *in-situ* using instruments mentioned in Table 02. Location of each sampling point was recorded using Magellan Triton 300 handheld GPS unit. Before taking a sample, sampling bottles were rinsed thoroughly with the water being sampled. After collecting the water samples, the bottles were kept air tight, labelled properly, transported to the laboratory of Agricultural Engineering and Soil Science and stored for further analysis while, following the procedures explained in APHA guidelines for standard methods for examination water and wastewater (APHA, 1992).

Available nitrate nitrogen, ammoniacal nitrogen, available phosphorus, calcium, magnesium, sodium, potassium concentrations and total suspended solids (TSS) were measured using the methods listed in the Table 2 as procedures explained in APHA guidelines. Sodium absorption ratio (SAR) was calculated using the measured data.

Monthly river discharge in MCM was gathered from the gauging station of Irrigation Department of Sri Lanka, which is located at *Horowpothana*, which is as same as last sampling point (07) of this study. Based on the discharge data, discharged amounts of potassium, available phosphorus and nitrogen (as nitrate or ammoniacal) in the water released to the sea were estimated.

Table 2: Instruments and Methods used for Water Quality Analysis

Water Quality Parameter	Instrument / Method
Temperature	DO meter (EUTECH, CyberScan DO 300)
Dissolved Oxygen	DO meter (EUTECH, CyberScan DO 300)
Turbidity	Turbidity meter (EUTECH, TN 100)
pH	Multi parameter analyzer (HATCH, Sension 156)
Electrical Conductivity (EC)	Multi parameter analyzer (HATCH, Sension 156)
Total dissolved solids (TDS)	Multi parameter analyzer (HATCH, Sension 156)
Ammoniacal nitrogen	4500 NH_3 F Phenate method
Nitrate nitrogen	Salicylic Acid method
Available phosphorus	UV visible spectrophotometer (UVD 2960)
Ca^{2+} concentration	Atomic absorption spectrophotometer (BUCK Scientific)
Mg^{2+} concentration	Atomic absorption spectrophotometer (BUCK Scientific)
Na^{+} concentration	Flame photometer (Sherwood, Model 360)
K^{+} concentration	Flame photometer (Sherwood, Model 360)
Total suspended solids	Oven dry method

GIS Analysis

Sub watershed areas of respective sampling locations were delineated using hydro tool of Arc Map 10.2.1 software of ESRI. Elevation data derived from Google earth pro software were used to make 5 m interval contours, which requires in the delineation process.

Land Use Pattern

Land use data of year 2014 were obtained from the Department of Land Use and Planning of Sri Lanka. Land use types at sub watershed levels were extracted and land uses were categorized into four major groups as agricultural and homestead (paddy, chena, upland perennials and plantations), Forests and scrubs (forests, forest plantations, scrubs and marshy lands), water bodies (tanks, ponds, streams, etc.) and others (gravel pits, roads, rocks, etc.) for further analysis.

Statistical Analysis

Statistical analyses were carried out to compare the water quality parameters in pre monsoonal, monsoonal and post monsoonal rainy periods. September, December and February were taken to represent the pre monsoonal, monsoonal and post monsoonal rainy periods, respectively. Further, statistical analysis was carried out to identify the spatial variation of water quality parameters. All statistical analyses were carried out following the ANOVA procedure.

RESULTS AND DISCUSSIONS

pH

pH determines the solubility and biological availability of some nutrients. Significantly lower pH levels were recorded in monsoonal rainy period (7.1) compared to the pre (7.5) and post monsoonal periods (7.9). Pre monsoonal period also recorded significantly lower pH levels, compared to the post monsoonal period. During the study period pH varied within the safe limits for irrigation water uses and for aquatic life (6 – 8.5) (CEA, 2001).

Water Temperature

Temperature exerts a major influence on biological activities and growth of fish and other aquatic life. During the study period, water temperature was within the optimum temperature range (24 – 30 ^{0}C) for many species of warm water fishes. Pre monsoonal period (29.5^{0}C) recorded significantly higher water temperature compared to monsoonal rainy period (27.3^{0}C) and post monsoonal period (27.0^{0}C). It was resulted by the warm environment with less amount of water in the river during the pre monsoonal period.

Turbidity

The level of turbidity is a function of geology and topography of the watershed, land uses and characteristics of rainfall. Turbidity levels varied between 11.1 – 236.0 NTU during the study period. Significant differences in turbidity levels were recorded during the monsoonal rainy period (93.6 NTU) compared to pre monsoonal (46.3 NTU) and post monsoonal (43.9 NTU) periods. In the monsoonal rainy period, most of the sampling locations recorded relatively higher turbidity levels. In pre monsoonal period some locations recorded higher turbidity levels, compared to the other sampling locations, which may have been resulted by the disturbances by people and animals in times of water scarcity.

Dissolved oxygen (DO)

Dissolved oxygen refers to the level of free, non-compound oxygen present in water. It is an important parameter in assessing water quality due to its influence on the aquatic species. Sources of dissolved oxygen in water include the atmosphere and photosynthesis and it varies according to the temperature and salinity of water. It also depends on the decomposition of dead and decaying material present in the water (Gupta and Gupta, 2006). Desirable concentration of dissolved oxygen for most fish is 5 ppm and above (Bwala and Omoregie, 2009).Significantly lower concentration of DO was recorded in the pre monsoonal period (2.9 mg/l) compared to the monsoonal (11.9 mg/l) and post monsoonal (11.2 mg/l) rainy periods. High DO levels in monsoonal and post monsoonal rainy periods reflect the more physical movements of water compared to the pre monsoonal period. During the premonsoonal period, low DO levels recorded in all the sampling locations, however, no deaths of fishes were observed. Although, it was not significant, decreasing trend of DO levels were recorded in the post monsoonal period and it could be due to the chemical and biological oxidation process in water induced by sediment inflows loaded with organic materials.

Electrical Conductivity

Electriacal conductivity of water is due to the dissolved salts present in the water. Significantly lower level of EC was recorded in the monsoonal rainy period (199.3µS/cm) compared to the pre monsoonal (1113.4µS/cm) and post monsoonal (519.6µS/cm) periods. Post monsoonal period also recorded significantly lower EC levels compared to the pre monsoonal period. Low electrical conductivity levels during the monsoonal rainy periods could be expected due to the dilution effect of high rainfall and runoff. Based on EC values of water, restriction levels for use as an irrigation water source can be classified as, no restriction (<700 µS/cm), slight to moderate restriction (700 – 3000 µS/cm) and severe restriction (>3000 µS/cm) (Ayers and Westcot, 1985). During the pre-monsoonal period, all sampling locations fell into slight to moderate restriction level for irrigation use.

Total Dissolved Solids

Significantly lower levels of TDS were recorded during monsoonal rainy period (169.3 mg/l) compared to the pre monsoonal (846.9 mg/l) and post monsoonal (443.7 mg/l) periods Post monsoonal period also recorded significantly lower TDS levels compared to the pre monsoonal period. The main reason for the low TDS levels during the monsoonal rainy period could be the dilution effect. During the pre-monsoonal period, TDS levels recorded high variation (SD=352.7mg/l) due additions from stagnated waters during that period. In the pre monsoonal period, TDS level was higher than the ambient water quality standards (500 mg/l) (CEA, 2001). Therefore, use of this water for irrigation during pre monsoonal period has to be limited to avoid the unfavorable influences.

Total Suspended Solids

Total suspended solids varied between 100 – 1400 mg/l during the study period. However, significant variation of TSS between the pre, post and monsoonal rainy periods were not observed.

Ammoniacal Nitrogen

The primary source of ammoniacal nitrogen is the fertilizers, basically the urea used for crop production within the catchment. The level of ammoniacal nitrogen varied between 0.7 – 4.9 mg/l during the study period. Significantly lower concentrations of ammoniacal nitrogen recorded in pre monsoonal (2.3 mg/l) and post monsoonal (1.8 mg/l) periods compared to the monsoonal rainy period (2.6 mg/l). However, highest ammoniacal nitrogen concentration (2.8 mg/l) was recorded in November, which is the usual crop establishment period of paddy in the area. This increment proved the possibility of adding washout of urea fertilizers into the runoff water that flowed over the paddy fields in the catchment.

Nitrate Nitrogen

Nitrogen is the nutrient applied in largest quantities for crop production. In addition to fertilizer, nitrogen occurs naturally in the soil in organic forms from decaying plant materials, animal residues and domestic sewage. Nitrate nitrogen levels varied between 0.4 – 7.4 ppm during the study period. Significantly lower concentration of nitrate nitrogen was recorded in pre monsoonal (3.0 mg/l) and post monsoonal (3.3 mg/l) periods compared to the monsoonal rainy period (4.9 mg/l). Despite the dilution effect, nitrate nitrogen levels were increased during monsoonal rainy period due to washout of fertilizers and household sewage into the surface water bodies through surface runoff. During the study period, nitrate nitrogen concentrations varied within the range of ambient water quality standards of Sri Lanka (CEA, 2001).

Available Phosphorus

The most common source of available phosphorus in water bodies are weathering of phosphorus bearing rocks, domestic discharges and fertilizers used for agricultural activities. Available phosphorus levels varied between 0.009 – 0.096 mg/l during the study period. No significant differences were observed in available phosphorus among pre, post and monsoonal rainy periods. Neitherany relationship among the available phosphorus, cropping patterns and fertilizer application was observed. The reason for the low concentration of available phosphorus could be the slow releasing nature of phosphorus compared to other elements. Probably the major phosphorus source would be weathering process of phosphorus containing rocks than the applied fertilizers.

Potassium

Potassium usually adds to the water from the fertilizers applied to the crops within the catchment. Significantly lower concentrations of potassium were recorded in the post monsoonal period (4.3 mg/l) compared to the pre monsoonal (6.1 mg/l) and monsoonal (5.0 mg/l) rainy periods. However highest potassium concentration (7.0 mg/l) was recorded in November. The main reason for the increase of potassium concentration could be the washing out of fertilizers, applied during the crop establishment period. However, low potassium concentration was recorded during the peak of monsoonal rainy period possibly due to the dilution effect.

Sodium

Primary source of sodium in water is the weathering of rocks and soils. Significantly higher concentration of sodium was recorded in the monsoonal rainy period (85.2 mg/l) compared to the pre (59.2 mg/l) and post (47.3 mg/l) monsoonal periods. High soluble nature of sodium sources in rocks and soils and the household wastes could be the main reasons for higher concentration of sodium.

Calcium

Calcium is found in all natural waters. Calcium combined with carbonates form calcium carbonate ($CaCO_3$), which contributes for the hardness of water. Significantly higher concentration of calcium was recorded in pre (195.5 mg/l) and post (242.6 mg/l) monsoonal periods compared to the monsoonal rainy period (125.3 mg/l). Low calcium concentration found can be attributed to dilutioneffect. Calcium concentration of post monsoon period was significantly higher compared to pre monsoonal period. This may have been resulted by the release of $Ca^{2+}$from the sediments and suspended materials accumulated in the water body through soil erosion.

Magnesium

Magnesium, found in water in measurable levels could also contribute to hardness of water by combining with carbonate ions and with sulphate ions to form magnesium carbonate and magnesium sulphate, respectively.Significantly higher concentration of magnesium was recorded in pre (26.4 mg/l) and post (20.5 mg/l) monsoonal periods compared to the monsoonal rainy period (6.9 mg/l). This is also resulted by dilution effect due to heavy rainfall and runoff.

Sodium Absorption Ratio (SAR)

Significantly higher sodium absorption ratio was recorded during monsoonal rainy period (10.5) compared to the pre (5.7) and post (4.1) monsoonal periods. SAR of pre monsoonal period was also significantly higher compared to the post monsoonal period.

Discharge Volume of Water

Figure 1 shows the variation of cumulative rainfall (CRF) in two gauging stations within the catchment. *Huruluwewa* (Hu) rain gauge station, located at the upper part of the catchment showed early starts of rainfall, compared to *Horowpothana* (Ho), which is located at the lower part of the catchment. Stream flow varied between 1.21 – 7.71 m during the study period. Based on the stream flow data at *Horowpothana*, the discharge volume of river runoff during the study period was 479.26 MCM.

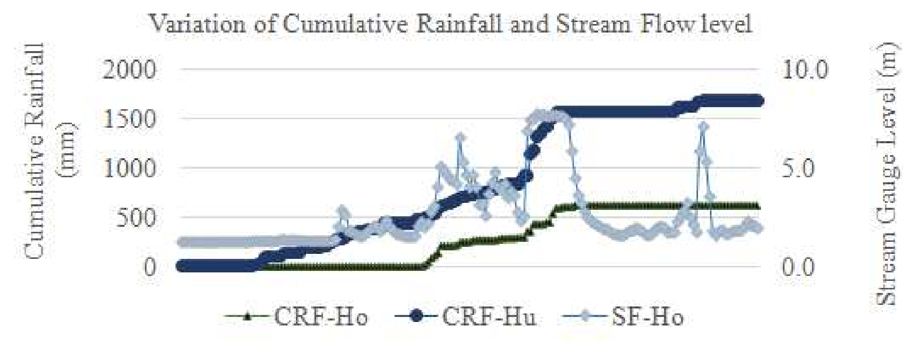

Figure 2: Variation of Cumulative Rainfall and Stream Flow Levels in Yan Oya

Quantification of Discharged Amount of Nutrients

Based on the results, potassium discharge varied form 569 kg of K/day during the base flow period to 53428 kg of K/day during the storm flow period. Available phosphorus was discharged from 1 kg of P/day during the base flow period to 60 kg of P/day during the storm flow period. Discharged amount of nitrogen (as nitrate or ammoniacal) varied from 86 kg of N/day during the base flow period to 17358 kg of N/day during the storm flow period.

Relationship between Land Use and Water Quality

Land uses of respective sampling points were analyzed and shown in Table 3. Although high variation of land uses were identified among respective sub watersheds, quite similar pattern of land uses were observed in total watershed area of sampling points. All measured parameters, except nitrate and ammoniacal nitrogen didn't show any significant variation among the sampling points.

Variation of nitrate and ammoniacal nitrogen along the river is shown in Figure 4. Nitrate nitrogen concentration is slightly increasing in sample points 01 to 03. Sampling point 04 showed significant reduction of nitrate nitrogen concentration compared to the sampling point 03. Even though the nitrate nitrogen concentration has gradually changed after the sampling point 04, no significant variation was observed among the adjacent sampling points. Increase of ammoniacal nitrogen levels were recorded at sampling points 01 to 02. Sampling point 04 recorded significantly low ammoniacal nitrogen concentration compared to point 03. Sampling point 07 recorded significantly low ammoniacal nitrogen concentration compared to sampling point 06. Sampling points 01 to 03, which are more closer to the agricultural land uses showed higher concentration of ammoniacal nitrogen, which is directly associated with the application of urea fertilizer. Further, nitrate nitrogen probably derived through oxidation of ammoniacal nitrogen also showed higher concentrations in initial sampling points. These concentrations decreased at sampling point 04. It may be due to the uptake and assimilation by low lying scrubs and marshy lands closer to the sampling point. Despite of nearby agricultural land uses to the river, sampling point 05 recorded low concentrations of nitrate and ammoniacal nitrogen, probably due to the higher oxidation and uptake and assimilation by low lying scrub area closer to that point. Although the river passed by low lying scrub areas, sampling point 06 recorded slightly higher ammoniacal and nitrate concentrations, probably due to the nearby agricultural land uses. Similar to the sampling point 05, sampling point 07 also recorded low concentrations of nitrate and ammoniacal nitrogen, resulted by the uptake and assimilation from low lying scrub areas. These results revealed that the nitrogen concentration of river is directly linked with close- by land use types. This proves that quick movement of ammoniacal and nitrate nitrogen compared to other nutrients.

Gyawali et al., (2013) recorded significant spatial variation of water quality parameters such as temperature, electrical conductivity, and total suspended solids and dissolved oxygen level with different land uses. Further, Gyawali et al., (2013) recorded significant spatial variation only for temperature and dissolved oxygen with different land uses. Athukorala et al., (2013) recorded significant variation of water quality in different land uses in Kelani River, Sri Lanka. Amarasekara et al., (2009) reported remarkable addition of nutrients in homesteads compared to agricultural land uses and forest areas in hill country of Sri Lanka. The selected study area is mainly comprised of homesteads and industrial land uses. During the study period, no significant variations were observed among all the measured physicochemical parameters except nitrogen, due to mixed type of land uses, flat terrain and rural localities in sub watershed areas in *Yan Oya* Basin.

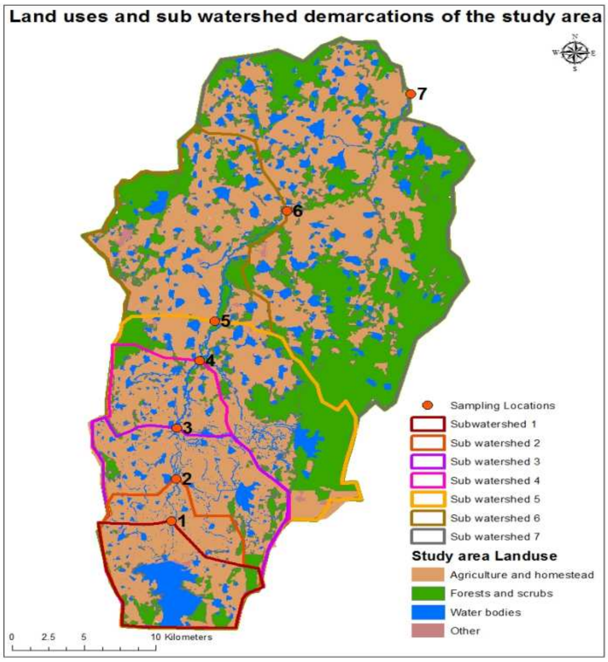

Figure 3: Land Use and Sub Watershed Demarcations of the Study Area

Table 3: Different Land Uses in Sub Watershed Level

Sampling Point No.	Sub Watershed Area for the Respective Sampling Point					Total Watershed Area Above the Respective Sampling Point				
	Total (Km^2)	Agric. & Homes. %	Forest & Scrub %	Water Bodies %	Other %	Total (Km^2)	Agric. & Homes. %	Forest & Scrub %	Water Bodies %	Other %
1	69.6	51.8	22.6	24.0	1.6	69.6	51.8	22.6	24.0	1.6
2	28.5	89.2	3.5	5.5	1.7	98.1	62.6	17.1	18.7	1.6
3	82.3	78.7	10.7	8.9	1.7	180.4	70.0	14.2	14.2	1.7
4	50.5	76.5	12.0	10.4	1.1	230.9	71.4	13.7	13.4	1.6
5	121.1	45.2	43.7	10.1	1.0	352.0	62.4	24.0	12.3	1.4
6	148.8	59.8	28.2	9.7	2.3	500.8	61.6	25.3	11.5	1.6
7	359.5	45.0	47.2	7.4	0.3	860.4	54.7	34.4	9.8	1.1

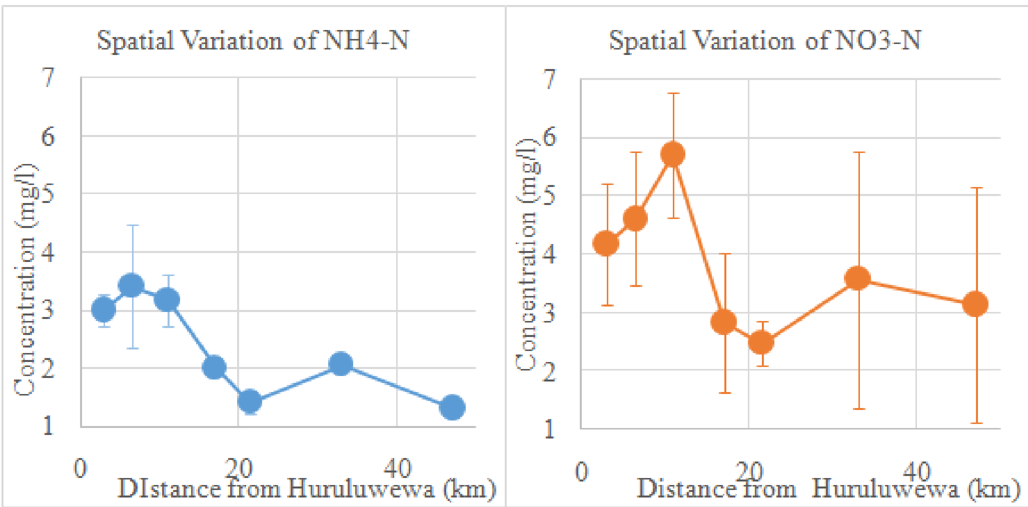

Figure 4: Spatial Variation of Ammoniacal Nitrogen and Nitrate Nitrogen in *Yan Oya* Basin

CONCLUSIONS AND RECOMMENDATIONS

All the measured physicochemical parameters were within safe limits for aquatic life, environment and irrigational water use during the monsoonal and post monsoonal rainy periods. Some restrictions were observed only for electrical conductivity, total dissolved solids and dissolved oxygen levels during pre monsoonal period. Physicochemical parameters showed significant variations among the pre, post and monsoonal rainy periods. Significant spatial variation was observed only for ammoniacal and nitrate nitrogen and they were closely related with the land use. Total river discharge was measured as 479 MCM and discharged amounts of potassium, available phosphorus and nitrogen (as nitrate or ammoniacal) varied from 569 - 53428 kg of K/day, 1 - 60 kg of P/day and 86 - 17358 kg of N/day during the study period.

Compared to the published data on water quality of Sri Lankan rivers, water quality in *Yan Oya* river basin is in acceptable level and minimal impact from land uses were observed. However, this could be changed with future development of agriculture and homesteads. Therefore, in development plans, more attention should be given to maintain the low lying scrub areas, which act as a buffer zone along the river to maintain the water quality in acceptable level in future.

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