Ecological status of lotic ecosystems in *kans* and non- *kans* of central Western Ghats

Sincy.V[1]., Asulabha. K. S[1]., Vinay. S[1], Vishnu, D. M[1]., Srikanth, N[1]., Subashchandran, M. D[1]., Ramachandra, T. V[1,2,3*].

[1] Energy and Wetland Research Group, Centre for Ecological Sciences
[2] Centre for Sustainable Technology (astra)
[3] Centre for Infrastructure Sustainable Transport Urban Planning, (CiSTUP)
Indian Institute of Science, Bangalore 560012
*email id: cestvr@ces.iisc.ernet.in, Phone number: 080 22933099
Web page: http://wgbis.ces.iisc.ernet.in/energy/, http://wgbis.ces.iisc.ernet.in/grass/, http://wgbis.ces.iisc.ernet.in/foss/

Abstract– Forests and streams provide valuable ecosystem services. In this study, the physico-chemical characteristics of 13 streams in various *kans* and non-*kans* of Central Western Ghats were monitored. The values showed both spatial and seasonal variations. All the values were below the permissible limits except turbidity which indicates good water quality prevailing in these *kan* and non-*kan* forests. PCA analysis revealed that VK, VNK, YK and YNK are influenced by TDS, EC, total alkalinity, total hardness, calcium, magnesium and salinity. KK2, KK5 and HK are influenced by BOD, COD and potassium. The cluster analysis grouped the *kans* and non-*kans* to three different groups based on their physico-chemical characteristics. Furthermore, WQI was also conducted to find out the potability of these select streams. According to WQI results, Torme *kan* (TK) and Hulkod *kan* (HK) has excellent water quality whereas KNK (Kodkani) has very poor water quality. The pollution load was high in post-monsoon compared to monsoon and pre-monsoon seasons. Thus, WQI helps the public and decision makers in better understanding of water quality data and adopting appropriate conservation measures.

Keyword– *Central Western Ghats, Streams, Sacred groves, WQI, Multivariate analysis*

INTRODUCTION

Forests help to maintain the environmental balance by ameliorating climate as it influences rainfall interception, evapotranspiration, rate of soil infiltration and storage, checks soil erosion, improves the quality and quantity of water. Watershed (the land area draining into a stream or river) management is of great concern as vegetation can strongly influence downstream water quality and quantity. Increasing vegetation of an area will stabilize soil, ensures even water flow throughout the year and lowers surface run-off, lessens the danger of flooding, allows water to percolate through the soil and recharges groundwater supplies. Thus, groundwater sources will be increased (Young,1982). The catchments with thick forest cover having evergreen, semi-evergreen and moist deciduous trees have reduced runoff and erosion but increased infiltration rates and stream flow compared to poor forest covers and monoculture plantations (Ramachandra, 2014). Variations in climate and forest disturbances affect stream flow (Zhang and Wei, 2012) through changes in precipitation trend (Kelly et al., 2016). The quality of surface water depends on mineralogy of the watershed, climate, topography etc. (Zarei and Bilondi, 2013). Soil texture and soil depth both play an important role in determining the rate at which water flows into streams (Waring and Running, 1998). Water course forests have high biomass and greater carbon sequestration potential with stream/swamp forest (SSF) having higher tree endemism (45%), total endemic tree population (71%), above ground biomass (349 t/ha) and carbon sequestration potential (131 t/ha) (Chandran et al., 2009).

Sacred groves (or *kans*) are patches of forests preserved for their spiritual and religious significance (Ray et al., 2015). Sacred groves inhabit medicinal as well as rare/endemic plants (Boraiah et al., 2003). These sacred groves are protected by people to avoid the perceived wrath of the resident God so trees are not cut and twigs, flowers and fruits are not plucked (Jeeva et al., 2006). Larger groves serve as safety forests offering sustenance and ecological services (Subash and Hughes, 2000) like water, soil and biodiversity conservation, nutrient cycling as well as microclimate regulation (Ray et al., 2014). The physico-chemical characteristics of streams directly influence the life inhabiting it bringing about changes in the community structure and composition of aquatic biota as well. Ramachandra et al., 2015 established the linkages between lands use practices, water quality and diatom species composition in the streams and reported that diversity and species composition of diatoms changes with LULC pattern.

Numerous studies have been carried out in Western Ghats on stream (Ramachandra et al., 2015; Ramachandra et al., 2016), forests (Ray et al., 2015), soil (Saira et al, 2014), fish (Sreekantha and Ramachandra, 2005; Sreekantha et al., 2007; Bhat et al., 2012), aquatic insects (Balachandran et al., 2012), etc. Various statistical tools like multivariate analysis are applied to water quality data to underline the factors affecting water quality in lotic ecosystems. PCA helped in identifying factors causing variations in water quality that affects ecosystem and proved as an important tool for water quality analysis (Parinet et al., 2004; Shrestha and Kazama, 2007; Bhat et al., 2014). Cluster analysis helped in grouping of sampling sites bearing similar water quality characteristics (Oketola, 2013). The application of Water Quality Index (WQI) is a useful tool that helps in the overall assessment of water quality of a waterbody and helps the public to adopt measures for water quality and watershed management (Thakor et al., 2011; Ramesh and Krishnaiah, 2015).

OBJECTIVE OF THE STUDY

The main objective of the study is to understand the seasonal changes in the physical, chemical and nutrient parameters in select streams of Central Western Ghats.

MATERIALS AND METHODS

Study Area: The Western Ghats is a series of hills starting from southern tip of Gujarat and extending from Satpura Range in the north traversing through the states of Maharashtra, Goa, Karnataka and Kerala (distance of 1,600 km covering an area of 1,60,000 sq.km). For this study, 13 streams in various *kans* and non-*kans* of Central Western Ghats have been selected (figure 1). Vibuthi falls which is located near Yaana, along the banks of the Gangavali river is a famous tourist spot so the stream and its surrounding habitat is subjected to pollution and other anthropogenic pressure. Vibuthi falls is 50 kms from Sirsi in north Kanara district and around 8 kms away from Yaana. Yaana is famous for the two unique massive rock structures namely, Bhairaveshwara Shikhara (120 m) and Mohini Shikhara (90 m) with a temple of Lord Shiva (cave temple) that makes the place a pilgrimage centre and tourist attraction. The huge rocks are composed of solid black, crystalline karst limestone. Vibuthi *kan* (VK) catchment has a mixed land use with forests (evergreen to semi evergreen type) while the non-*kan*, Mabgi (VNK) catchment is dominated by evergreen forests followed by deciduous forests (moist – dry). Yaana *kan* (YK) and its non-*kan* (YNK) are dominated by forests (evergreen to semi evergreen species). Kathale*kan* (KK1- KK5) is dominated by old evergreen forests with the presence of endemic and endangered faunal and floral species whereas the non-*kan* i.e., Kodkani (KNK) has a mixed land use, dominated by evergreen forests and agricultural fields. Torme (TK) is dominated by evergreen forests whereas Hulkodu (HK) is swampy and evergreen in nature.

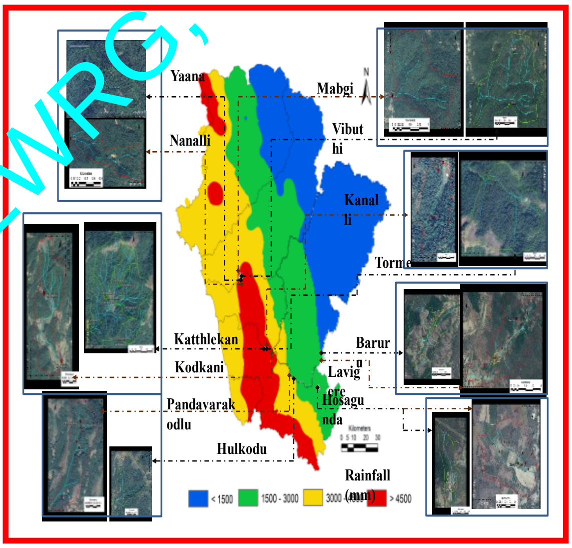
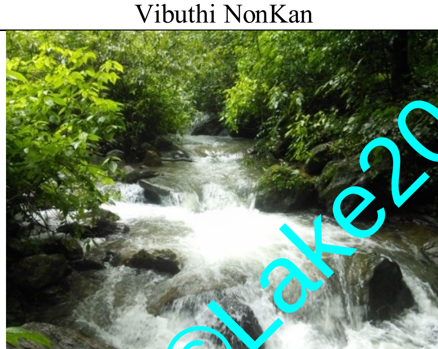
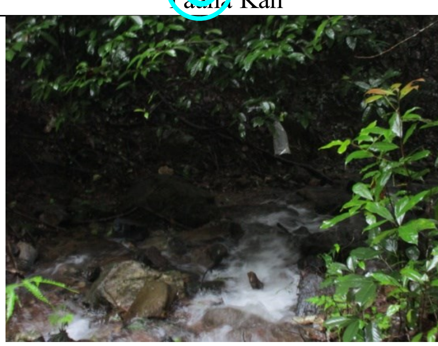
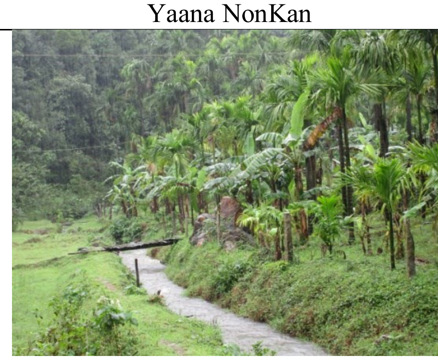


Figure 1: Map showing the streams sampled in Central Western Ghats

WATER QUALITY ANALYSIS

Water samples were collected from different *kans* and non- *kans* for the analysis of physico-chemical parameters in polypropylene bottles (table 1).

Table 1: Sampling sites

 Torme Kan	 Hulkod
 Vibuthi NonKan	 Vibuthi falls
 Yaana Kan	 Yaana NonKan
 Kathalekan forest	 Kathale*kan*

Analysis of Physico-Chemical Parameters: Water quality parameters such as water temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), salinity and dissolved oxygen (DO) were measured at on-site itself. The other parameters like turbidity, total hardness, calcium and magnesium, total alkalinity, chloride, orthophosphate, nitrate, biochemical oxygen demand (BOD), chemical oxygen demand (COD), sodium (Na) and potassium (K) were analyzed in laboratory using standard methods prescribed by Trivedi and Goel (1986) and APHA (1998).

Statistical Analysis: Water quality data sets of select streams were also subjected to multivariate techniques like cluster analysis (CA) and principal component analysis (PCA). All these statistical computations were made using PAST3 software. Water Quality Index (WQI) was also applied to select streams in Central Western Ghats using ten water quality parameters (pH, TDS, dissolved oxygen, electrical conductivity, total hardness, total alkalinity, chloride, calcium, magnesium and nitrate). The calculation of WQI was made using a weighted arithmetic index method (Yogendra and Puttaiah, 2008).

RESULTS AND DISCUSSION

Water temperature: Water temperature plays an important role in governing in-stream processes such as metabolism, organic matter decomposition and solubility of gases, finally affecting stream biota (Johnson, 2004). Water temperature varied diurnally and seasonally, ranging from 21.9 – 26.2°C.

Total Dissolved Solids (TDS): TDS was found to be higher during rainy season (Singh et al., 2013). The concentrations of major ions are correlated with each other but negatively correlated with discharge (Peters, 2009). The concentration of TDS varied from site to site, ranging from 18.21 – 73.67 mg/l.

Electrical Conductivity (EC): Higher the electrical conductivity, higher will be the amount of ions in solution (Vaishali and Punita, 2013). These dissolved solids determine the chemical properties of water affecting the productivity of aquatic ecosystems and also interfere with the distribution of organisms (Bashir et al., 2015). EC showed a similar trend to TDS with values ranging from 37.67 – 149.82 µS/cm.

Salinity: Salinity shows the amount of salts present in water. Both salinity and conductivity are related as these are caused by the presence of dissolved ions. Streams and rivers fed by saline run-off and groundwater, affects the quality of water used for irrigation as well as drinking purposes. Here, the salinity varied from 10.96 – 53.17 ppt.

pH: pH determines the acidic/alkaline nature of water. Here, pH varied from 6.53 – 7.51. pH of river Pravara shows slightly alkaline nature which ranged from 6.49 - 7.87 (Deshmukh, 2015). Variation in pH causes some solutes to precipitate and also interferes with the solubility of ions and suspended matter (Gadhia et al., 2012). The presence of huge amount of organic matter lowers pH as the carbon-dioxide released during organic matter decomposition reacts with water forming carbonic acid.

Dissolved oxygen (DO): DO depend upon atmospheric diffusion, photosynthesis by autotrophs and rate of respiration and decomposition activities (Bashir et al., 2015). In this study, DO levels ranged between 5.06 – 6.87 mg/l. The dissolved oxygen ranged from 2.02 to 12.09 mg/l in Aiba stream and it was found to be maximum during dry season due to intense sunlight contributing to an increased rate of photosynthesis (Atobatele and Olutona, 2013). During monsoon, low DO was recorded in river Baldi due to the presence of huge amount of suspended particles that absorbs sunlight and raises water temperature, lowering photosynthetic rate (Singh and Sharma, 2016).

Biochemical oxygen demand (BOD): The oxidization of organic matter by microbes leads to a decrease in dissolved oxygen levels resulting in an increased biochemical oxygen demand (Singh et al., 2013). The concentration of BOD ranged from 3.96 – 10.02 mg/l. An increase/decrease in DO affects streams as dissolved oxygen interferes with the oxidation-reduction state of chemical compounds like ammonia, nitrate, sulphite, sulphate, ferric and ferrous ions (Sincy et al., 2012).

Chemical oxygen demand (COD): COD gives the amount of oxygen required for chemical oxidation of organic matter and other oxidizable inorganic substances with the help of strong chemical oxidant. The range of COD present in these streams was found as 8.46 – 20.19 mg/l. Variations in COD occurs due to changes in various organic and inorganic materials like calcium, magnesium, potassium, sodium, etc. (Ramachandra et al., 2016). COD showed strong negative correlation with DO and turbidity and positive correlation with BOD, conductivity, total dissolved solids, pH, alkalinity etc. (Vaishali and Punita, 2013).

Turbidity: The suspended particles in water (clay, silt, plankton, algae, etc.) cause turbidity which reduces light penetration and absorb more light, resulting in an increase of water temperature. Turbidity varied widely from 2.03 – 31.72 NTU. Turbidity was maximum during pre – monsoon season due to high amount of suspended particulate matter, decreased water level and various anthropogenic activities whereas minimum turbidity was recorded during post – monsoon season due to settlement of silt, clay and heavy suspended particles (Namdeo et al., 2013).

Total alkalinity: Alkalinity is ability of river/stream to resist changes in pH. The carbondioxide – bicarbonate – carbonate equilibrium is the major buffering mechanism in freshwater (Abir, 2014). Total alkalinity varied among different sites and seasons, ranging from 37.56 – 108.11 mg/l.

Chloride: High chloride concentrations indicate organic pollution and also salts of sodium, potassium and calcium contribute chlorides in water (Ramachandra et al., 2015). The concentrations of chloride in select streams varied from 14.67 – 16.25 mg/l.

Total hardness, Calcium and Magnesium: Hardness is caused by major cations like calcium and magnesium and anions like bicarbonate, carbonate, sulphate and chlorides (Das et al., 2014). Calcium is an important micronutrient in freshwater bodies and is required by molluscs and vertebrates. Magnesium is essential for chlorophyll production in plants and acts as a limiting factor for the growth of phytoplankton. The concentrations of hardness, calcium and magnesium ranged from 15.55 – 75.17 mg/l, 2.85 – 20.31 mg/l and 2.06 – 5.97 mg/l respectively.

Ortho-phosphate: The sources of phosphate include natural (weathering of phosphorous bearing rocks and minerals) as well as anthropogenic sources (domestic discharges, agricultural runoff). Increased levels of phosphorus will be consumed by plants and microorganisms for growth and metabolic activities, finally causing dissolved oxygen depletion and increase in the turbidity (Perera et al., 2014). The release of dissolved reactive phosphorus (DRP) from streambed sediments occurs when DO concentrations are very low (Perrie, 2015). In this study, ortho-phosphate levels varied from 0.028 – 0.052 mg/l.

Nitrate: Nitrate is the oxidized form of nitrogen and end product of aerobic decomposition of the organic nitrogenous matter. Nitrate act as nutrients in aquatic ecosystems entering water bodies through animal wastes (including birds and fish), runoff from fertilized agricultural field etc. Nitrate concentrations ranged from 0.133 – 0.226 mg/l. Nitrate concentrations decreased during high rainfall due to dilution of stream water (Girardi et al., 2016). The nitrate concentration ranged from 0.12 - 0.24 mg/l in Kundaman Kadavu to 1.78 - 2.61 mg/l in Pallichal during pre-monsoon and monsoon season respectively (Sujitha et al., 2012).

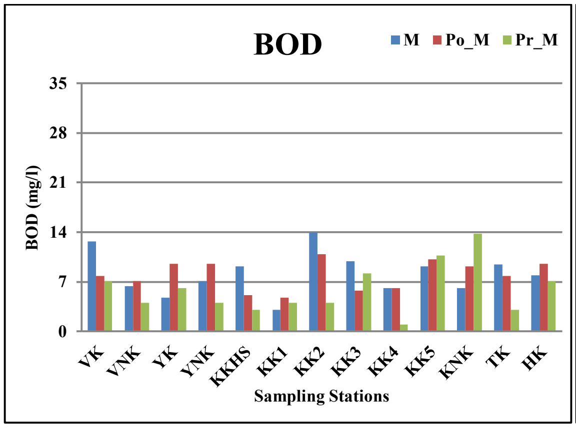
Sodium and Potassium: The concentration of sodium and potassium in surface waters is usually below 50 mg/l and 10 mg/l respectively (Ramachandra and Ahalya, 2001). Sodium and potassium ranged from 5.54 – 13.07 mg/l and 0.13 – 1.49 mg/l respectively.

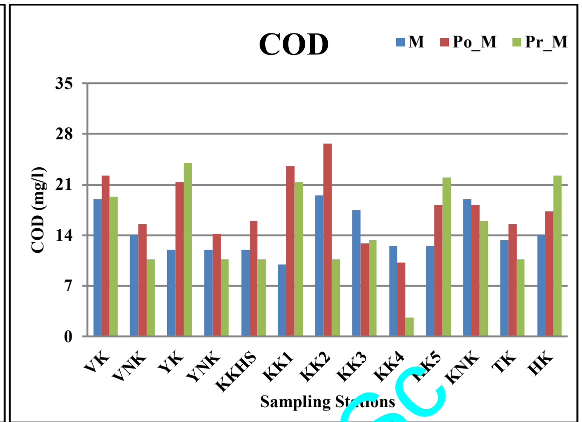
Water temperature varied seasonally with higher temperature in pre-monsoon and post-monsoon seasons compared to monsoon season. VK had higher TDS, EC, salinity, total hardness, calcium and magnesium in pre-monsoon season compared to all sites and other seasons. Among all the sites, KK2 had higher COD, sodium, potassium (pre-monsoon) and BOD (monsoon). pH was higher in Kathale*kan* forests (KK1 – KK5 and KNK) especially in post-monsoon season. TK had higher DO and chloride contents (pre-monsoon) whereas, KKHS had higher nitrate (pre-monsoon). YK had higher total alkalinity and calcium in pre-monsoon season, whereas, YNK had higher turbidity and ortho-phosphate in monsoon season (figure 2).

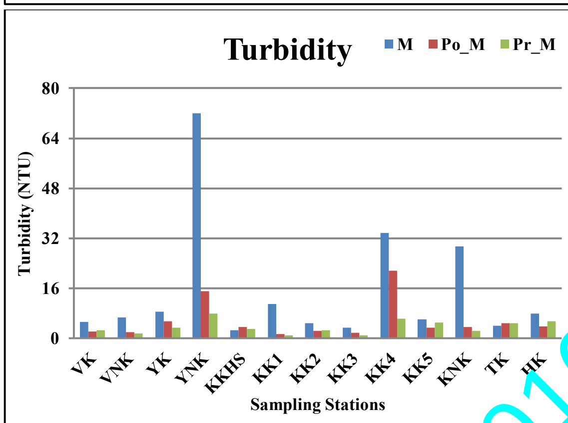
In monsoon, higher turbidity, phosphate and BOD were evident with lower TDS, EC, pH, COD, DO, alkalinity, total hardness, calcium, magnesium, sodium, potassium and salinity. Turbidity, phosphate and BOD are very high because of rain water runoff. But all ionic contents are very low due to dilution with rain water. The oxidization of organic matter by microbes leads to a decrease in dissolved oxygen levels resulting in an increased biochemical oxygen demand. The rain water run-off from the surrounding area brings in huge amounts of phosphate during rainy season (Singh et al., 2013). Post-monsoon season had low chloride and nitrate concentrations with higher water temperature, pH and COD. Here, nitrate values are low because of its uptake by benthic algae as a nutrient. In pre-monsoon season, lower concentrations of turbidity, water temperature, ortho-phosphate and BOD whereas higher concentrations of TDS, EC, DO, alkalinity, chloride, total hardness, nitrate, calcium, magnesium, sodium, potassium and salinity were recorded. In pre-monsoon season, ionic contents are very high because of decline in water level, increased evaporation rate and increased algal growth.

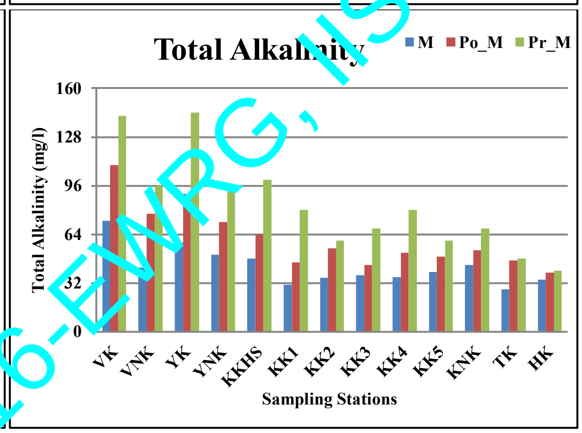
All the physico-chemical parameters are inter-related and inter-dependent. All the values were below the permissible limits except turbidity. Variations in water chemistry and flow regime cause adverse impacts on stream ecosystems (Yurtseven et al., 2016). An increase in bicarbonate ion, specific conductance, iron and magnesium and a decrease in dissolved oxygen and pH were evident when the rate of leaf-fall increased in forested ecosystems (Anderson, 1976). These variations in physico-chemical characteristics affect aquatic life in aquatic ecosystems interfering with species growth, survival, composition, abundance and overall ecosystem productivity. In Tons river, phytoplankton showed positive correlation with conductivity, transparency, pH, total hardness and DO whereas negative correlation with temperature, velocity, TDS and BOD (Ishaq et al., 2013).

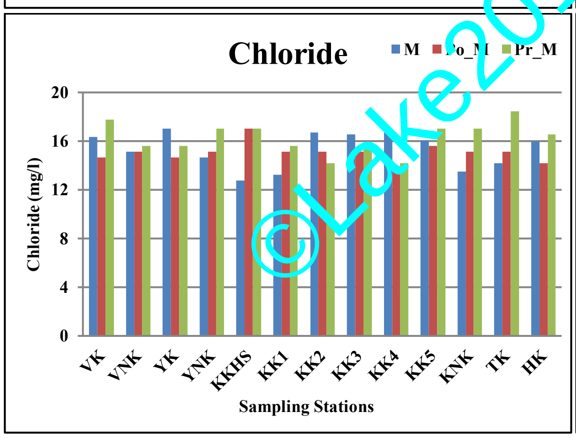

Water Temperature
M
Po_M
Pr_M
WT (°C)
35
31
27
23
19
15
VK
VNK
YK
YNK
KKHS
KK1
KK2
KK3
KK4
KK5
KNK
TK
HK
Sampling Stations
Salinity
Salinity (ppt)
80
64
48
32
16
0
TDS
TDS (mg/l)
120
96
72
48
24
EC
EC (µS/cm)
250
200
150
100
50
pH
9
8.3
7.6
6.9
6.2
5.5
DO
DO (mg/l)
10
8
6
4
2

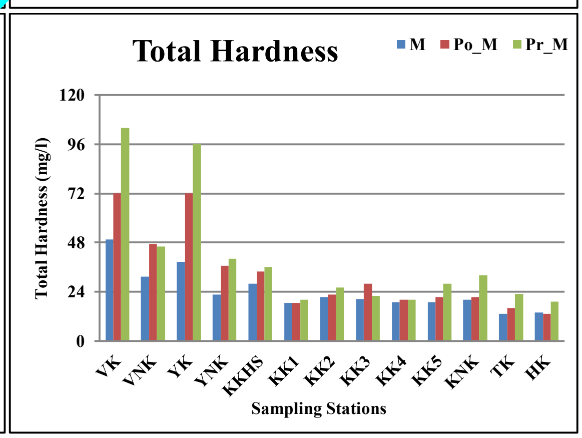

BOD
M
Po_M
Pr_M
BOD (mg/l)
0
7
14
21
28
35
VK
VNK
YK
YNK
KKHS
KK1
KK2
KK3
KK4
KK5
KNK
TK
HK
Sampling Stations


COD
M
Po_M
Pr_M
COD (mg/l)
0
7
14
21
28
35
VK
VNK
YK
YNK
KKHS
KK1
KK2
KK3
KK4
KK5
KNK
TK
HK
Sampling Stations


Turbidity
M
Po_M
Pr_M
Turbidity (NTU)
0
16
32
48
64
80
VK
VNK
YK
YNK
KKHS
KK1
KK2
KK3
KK4
KK5
KNK
TK
HK
Sampling Stations


Total Alkalinity
M
Po_M
Pr_M
Total Alkalinity (mg/l)
0
32
64
96
128
160
VK
VNK
YK
YNK
KKHS
KK1
KK2
KK3
KK4
KK5
KNK
TK
HK
Sampling Stations


Chloride
M
Po_M
Pr_M
Chloride (mg/l)
0
4
8
12
16
20
VK
VNK
YK
YNK
KKHS
KK1
KK2
KK3
KK4
KK5
KNK
TK
HK
Sampling Stations


Total Hardness
M
Po_M
Pr_M
Total Hardness (mg/l)
0
24
48
72
96
120
VK
VNK
YK
YNK
KKHS
KK1
KK2
KK3
KK4
KK5
KNK
TK
HK
Sampling Stations

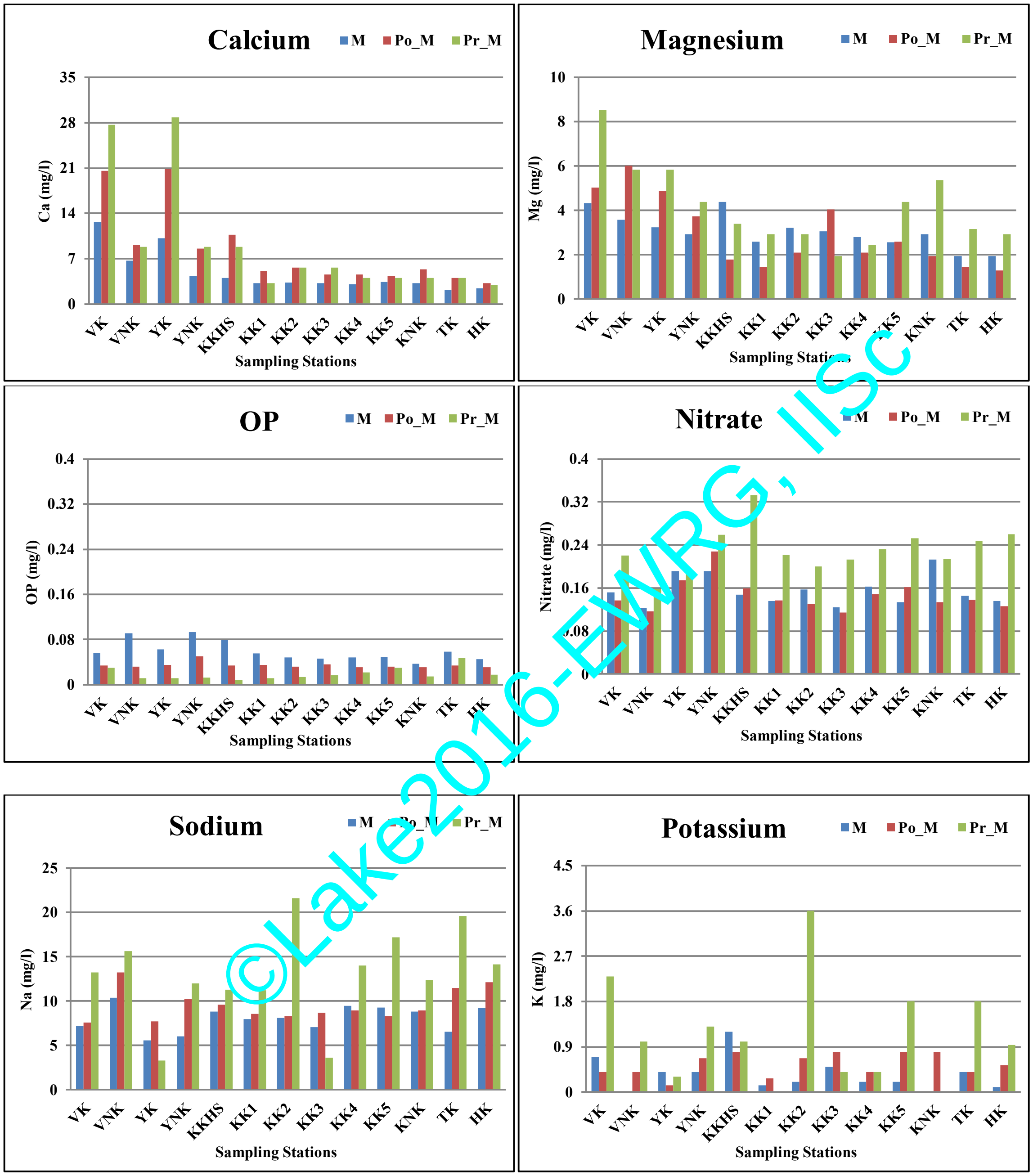


Figure 2: Seasonal variation in physico-chemical parameters of streams in Uttara Kannada and Shimoga districts.

Principal Component Analysis (PCA): PCA was performed to extract the most important physico-chemical parameter affecting water quality of streams in *kan* and non-*kan* regions. Eigenvalues obtained through PCA shows the significance of factors with a value equal to or greater than 1.0 is considered highly significant. The factor loadings are further classified as strong/moderate/weak. Based on the eigenvalues scree plot, about 18 physico-chemical parameters were reduced to 5 main factors (factor 5) from the leveling off point(s) in the scree plot. The remaining factors have eigenvalues of less than unity. The table 2 shows the corresponding eigenvalues and total variance for each factor extracted.

Table 2: Eigenvalues and corresponding total variance on significant principal components

PC	Eigenvalue	% variance
1	7.71	42.81
2	2.98	16.54
3	2.09	11.55
4	1.69	9.41
5	1.36	7.58

The first factor corresponding to the largest eigenvalue (7.71) accounts for approximately 42.81% of the total variance. The second factor corresponding to the second eigenvalue (2.98) accounts for a 16.54% of the total variance and so on. In case of PCA, VK, VNK, YK and YNK are influenced by TDS, EC, total alkalinity, total hardness, calcium, magnesium and salinity. KK2, KK5 and HK are influenced by BOD, COD and potassium (figure 3).

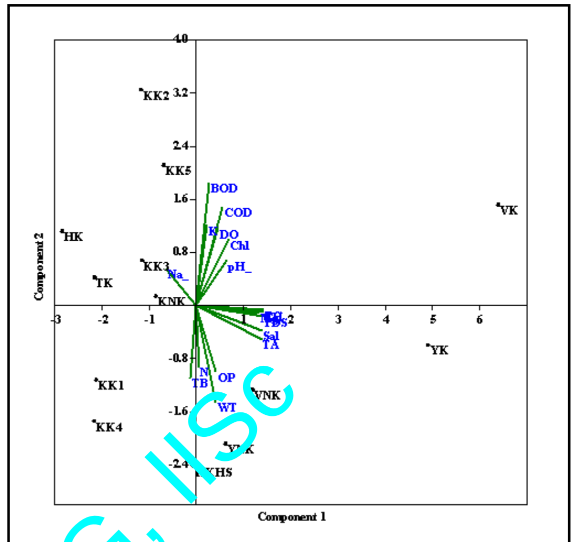


Figure 3: Principal component analysis for physico-chemical parameters of select streams in Central Western Ghats

Cluster Analysis (CA): CA is useful to classify the variables into groups based on their similarity which is illustrated by a dendrogram (Tree diagram). CA was carried out using Ward's method with squared Euclidian distances. In case of cluster analysis, three groups were evident.

Group 1 includes VK and YK that has high TDS, EC, pH, DO, BOD, COD, alkalinity, chloride, total hardness, calcium, magnesium, salinity with low turbidity and sodium. These sites have evergreen forest cover so, rich in nutrients and ionic contents. Also, there is higher level of human disturbances (VK and YK are famous places for tourism).

Group 2 includes YNK, VNK and KKHS with high water temperature, turbidity, ortho-phosphate, nitrate, sodium and potassium but low pH, DO, BOD and COD. These sites have mixed land use with agricultural and horticultural activities in the surrounding areas. Thus, phosphate, nitrate and potassium levels are higher.

Group 3 includes HK, TK, KK2, KK5, KK4, KNK, KK1 and KK3 with low water temperature, total alkalinity, ionic (TDS, EC, chloride, total hardness, calcium, magnesium, potassium and salinity) and nutrient (ortho-phosphate and nitrate) contents. These sites have thick evergreen forests with less human interaction compared to group 1 and 2.

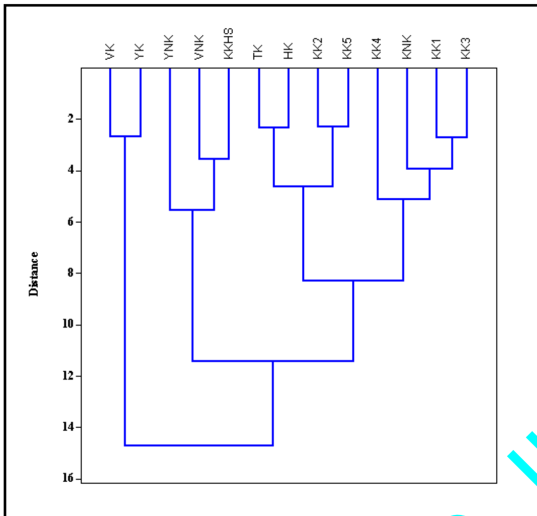


Figure 4: Hierarchical clustering analysis (Wards method) of 13 streams (*kans* and non-*kans*) in Central Western Ghats based on physico-chemical parameters.

Water Quality Index (WQI): Water quality index was determined on the basis of 10 different physico-chemical parameters like pH, TDS, dissolved oxygen, electrical conductivity, chloride, total alkalinity, total hardness, calcium, magnesium and nitrate. The WQI and its corresponding water quality status are listed in table 3.

Table 3: Water Quality Index (WQI) and status of water quality (Devi et al., 2015; Babu and Selvanayagam, 2015)

WQI	Water quality Status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

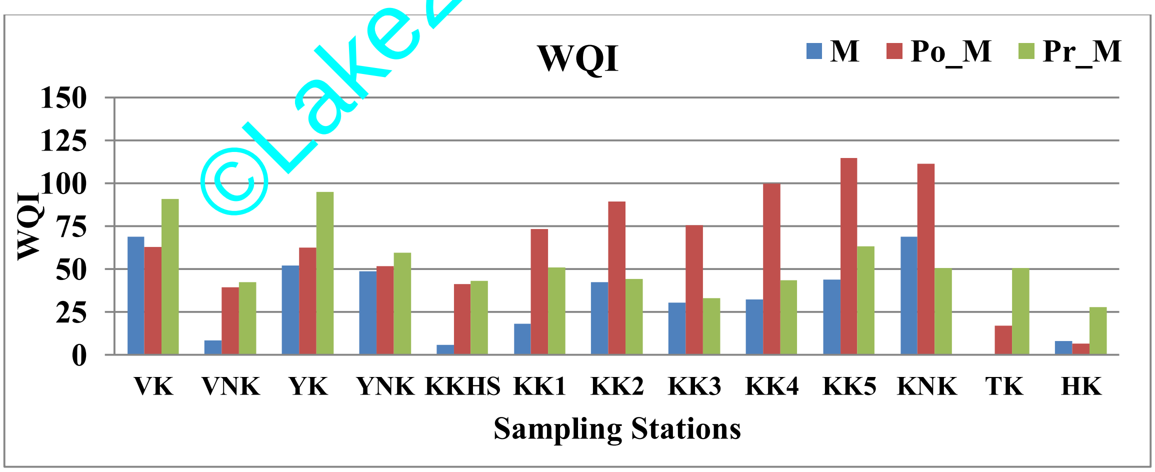


Figure 5: Water Quality Index (WQI) values of different stations during monsoon, post-monsoon and pre-monsoon season

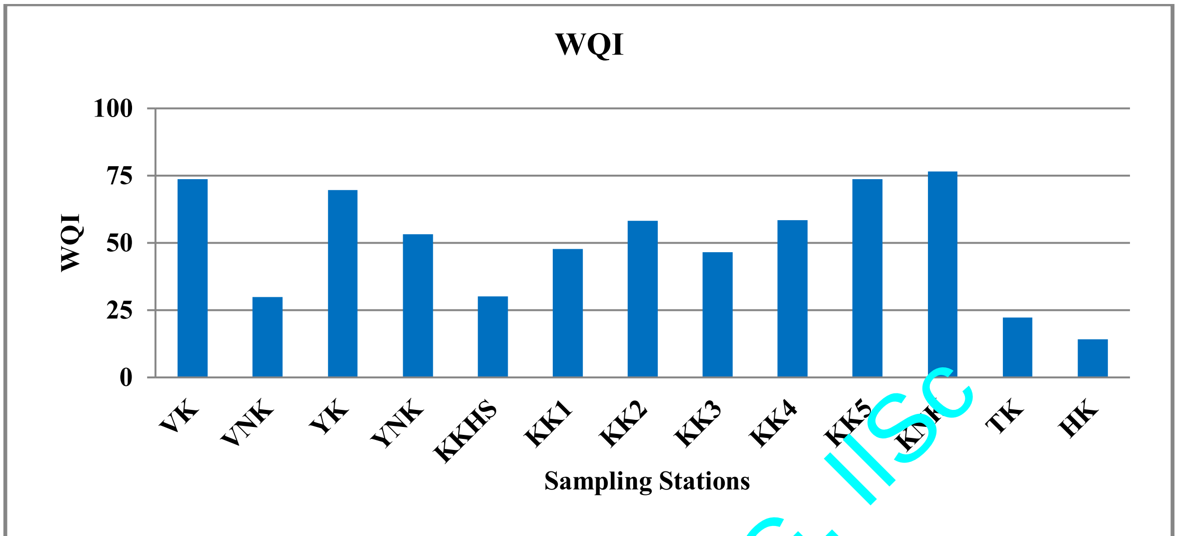


Figure 6: Graphical representation of average value of Water Quality Index (WQI) of select streams in Central Western Ghats

The pollution load was highest in post-monsoon compared to monsoon and pre-monsoon seasons as per WQI (figure 5). The variations of WQI values at all stations are due to fluctuations in the quantity and quality of water and bethic algal population. Decreased water flow, settling of sediments and soil erosion during monsoon will increase the values of ionic, organic and nutrient of water in post-monsoon. According to WQI results (figure 6 and table 4), Torme *kan* (TK) and Hulkod *kan* (HK) has excellent water quality as these are pristine ecosystem with evergreen forests subjected to very less human disturbances. VNK, KKHS, KK1 and KK3 have good water quality. KNK (Kodkani) has very poor water quality as it has mixed land use, dominated by evergreen forests and agricultural fields. Vibuthi kan and Yaana kan have poor water quality as those are highly disturbed area because of eco-tourism activities. KK2, KK4 and KK5 have poor water quality because of agricultural and horticultural activities near to stream.

Table 4: WQI and water quality status of select streams in Central Western Ghats

Sampling Stations	WQI	Water Quality Status
Vibuthi *kan* (VK)	74	Poor water quality
Mabgi (VNK)	30	Good water quality
Yaana *kan* (YK)	70	Poor water quality
Yaana non-*kan* (YNK)	53	Poor water quality
Kallabbe (KKHS)	30	Good water quality
Kathale*kan* (KK1)	48	Good water quality
Kathale*kan* (KK2)	58	Poor water quality
Kathale*kan* (KK3)	46	Good water quality
Kathale*kan* (KK4)	58	Poor water quality
Kathale*kan* (KK5)	74	Poor water quality
Kodkani (KNK)	77	Very poor water quality
Torme *kan* (TK)	22	Excellent water quality
Hulkodu *kan* (HK)	14	Excellent water quality

CONCLUSION

Water quality analysis showed both spatial and seasonal variations among 13 streams flowing through *kans* and non-*kans* of Central Western Ghats. All the parameters except turbidity are within the permissible limits of BIS standards. PCA helped to understand the factors affecting the water quality of sampling stations. PCA analysis revealed that VK, VNK, YK and YNK are influenced by TDS, EC, total alkalinity, total hardness, calcium, magnesium and salinity. KK2, KK5 and HK are influenced by BOD, COD and potassium. The cluster analysis grouped the *kans* and non-*kans* to three different groups based on the ionic, nutrient and organic contents. WQI results revealed that Torme *kan* (TK) and Hulkod *kan* (HK) have excellent water quality whereas KNK (Kodkani) has very poor water quality. The pollution load was higher in post-monsoon compared to monsoon and pre-monsoon seasons. Variations in water quality of streams are due to variations in discharge, flow rate, climate, land use, soil, aquatic organisms etc. Thus, statistical analysis helps in better understanding of water quality data and appropriate conservation measures has to be adopted to protect these *kans* and non-*kans* of Central Western Ghats.

ACKNOWLEDGEMENT: We are grateful to (i) NRDMS Division, The Ministry of Science and Technology, Government of India, (ii) The Ministry of Environment, forests and climate change, Government of India and Indian Institute of Science for the sustained and financial support to ecological research.

REFERENCES:

1. APHA, Standard Methods (20 Ed.) for the examination of water and wastewater, APHA, AWWA, WPCE, Washington DC, 1998.
2. Atobatele, E.O. and Olutona, G. O., 2013, Spatio-seasonal physico-chemistry of Aiba stream, Iwo, Nigeria. *African Journal of Biotechnology*, vol. 12(14), pp. 1630-1635.
3. Bashir, T., Kumar, A. and Vyas, V., 2015, Assessment of various ecological parameters of Bhagner stream- A tributary of River Narmada in the central zone, India. *International Journal of Research in Natural and Applied Science*, vol. 5(1), pp. 1-6.
4. Bhat, S.A., Meraj, G., Yaseen, S. and Pandit, A.K., 2014, Statistical assessment of water quality parameters for pollution source identification in Sukhnag stream: an inflow stream of LakeWular (Ramsar Site), Kashmir Himalaya. *Journal of Ecosystems*, pp. 1-18.
5. Boraiah, K.T., Vasudeva, R., Bhagwat, S. A. and Kushalappa, C.G., 2003, Do informally managed sacred groves have higher richness and regeneration of medicinal plants than state-managed reserve forests? *Current Science*, vol. 84(6), pp. 804–808.
6. Chandran, M.D.S. and Hughes J.D., 2000, Sacred groves and conservation: The comparative history of traditional reserves in the Mediterranean area and in South India. *Environment and History*, vol. 6(2), pp. 169–186.
7. Chandran, M.D.S., Rao, G.R., Gururaja, K.V. and Ramachandra, T.V., 2010, Ecology of the swampy relic forests of Kathalekan from Central Western Ghats, India. *Bioremediation, Biodiversity and Bioavailability*, vol. 4(1), pp. 54-68.
8. Das, B.K., Boruah, P. and Kar, D., 2014, Study of Seasonal Variation of Water Quality of River Siang in Arunachal Pradesh, India. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, vol. 8(2), pp. 11-20.
9. Deshmukh, B. S., 2015, Physico-chemical characteristic of Pravara River, *International Journal of Research Studies in Biosciences (IJRSB)*, vol. 3(10), pp. 14-18.
10. Devi, W. S., Singh, R. and Meitei, N.S., 2015, Assessment of water quality index of Nambol River, Manipur, India. *Universal Journal of Environmental Research and Technology*, vol. 5, (3), pp. 165-172.
11. Girardi, R., Pinheiro, A., Garbossa, L. H. P. and Torres, E., 2016, Water quality change of rivers during rainy events in a watershed with different land uses in Southern Brazil. *Brazilian Journal of Water Resources*, vol. 21(3), pp. 514-524.
12. Ishaq, F., Khanna, D.R. and Khan, A., 2013, Physico-chemical and phytoplanktonic characteristics of river Tons at Dehradun (Uttarakhand), India. *Journal of Applied and Natural Science*, vol. 5(2), pp. 465-474.
13. Jeeva, S., Mishra, B.P., Venugopal, N., Kharlukhi, L. and Laloo, R.C., 2006, Traditional knowledge and biodiversity conservation in the sacred groves of Meghalaya, Indian. *Journal of Traditional Knowledge*, vol. 5(4), pp. 563–568.
14. Kelly, C. N., McGuire, K.J., Miniat, C.F. and Vose, J.M., Stream flow response to increasing precipitation extremes altered by forest management. *Geophysical Research Letters*, vol. 43, pp. 3727-3736.
15. Namdeo, A.K., Shrivastava, P. and Sinha, S., 2013, Ecological Evaluation of Seasonal Dynamism in Physicochemical Characteristics of Tropical Reservoir in Central India. *Universal Journal of Environmental Research and Technology*, vol. 3(2), pp. 152-157.
16. Ogunfolakan, A., Nwokeocha, C., Olayemi, A., Olayiwola, M., Bamigboye, A., Olayungbo, A., Ogiogwa, J., Oyelade, O. and Oyebanjo, O., 2016, Rapid ecological and environmental assessment of Osun sacred forest grove, southwestern Nigeria. *Open Journal of Forestry*, vol. 6, pp. 243-258.

17. Oketola, A.A., Adekolurejo, S.M. and Osibanjo, O., 2013, Water quality assessment of river Ogun using multivariate statistical techniques. Journal of Environmental Protection, vol. 4, pp. 466-479.
18. Parinet, B., Lhote, A. and B., Legube, 2004, Principal component analysis: an appropriate tool for water quality evaluation and management—application to a tropical lake system. *Ecological Modelling*, vol. 178, pp. 295–311.
19. Parinet, B., Lhote, A. and Legube, B., 2004, Principal component analysis: an appropriate tool for water quality evaluation and management – application to a tropical lake system. *Ecological Modeling*, vol. 178, pp. 295–311.
20. Perera, P.A.C.T., Sundarabarathy, T.V., Sivananthawerl T. and Edirisinghe, U., 2014, Seasonal Variation of Water Quality Parameters in Different Geomorphic Channels of the Upper *Malwathu Oya* in Anuradhapura, Sri Lanka. *Tropical Agricultural Research*, vol. 25(2), pp. 158–170.
21. Perrie, A., Morar, S., Milne, J.R. and Greenfield, S., 2012, River and stream water quality and ecology in the Wellington region State and trends. Greater Wellington, Regional Council, Te Pane Matua Taiao~~, pp. 19-160~~.
22. Ramachandra, T. V., Asulabha, K. S., Sincy, V., Vinay, S., Bhat, S. P. and Aithal, B. H., Sankey Lake: Waking for an immediate sensible action, ENVIS Technical Report 74, CES, Indian Institute of Science, Bangalore, 2015.
23. Ramachandra, T. V., Asulabha, K. S., Sincy V., Bhat, S. P. and Aithal, B. H., Wetlands: Treasure of Bangalore, ENVIS Technical Report 101, Energy & Wetlands Research Group, CES, Indian Institute of Science, Bangalore, 2016.
24. Ramachandra, T.V. and Ahalya, N., Essentials of limnology and geographical information system (GIS), Energy and Wetlands Research Group, Centre for Ecological Sciences, Indian Institute of Science, Bangalore, 2001.
25. Ramachandra, T.V., 2014, Hydrological responses at regional scale to landscape dynamics, Journal of Biodiversity, vol. 5, pp. 11-32.
26. Ramachandra, T.V., Chandran, M.D.S., Joshi, N.V., Karthick, B. and Mukri, V.D., 2015, Ecohydrology of lotic systems in Uttara Kannada, Central Western Ghats, India. In: Ramkumar, M., Kumaraswamy, K. and Mohanraj, R. (Eds.), *Environmental Management of River Basin Ecosystems*, Springer Earth System Sciences, 621-665.
27. Ramachandra, T.V., Chandran, M.D.S., Vinay, S., Sudarshan, B., Vishnu, D.M., Rao, G.R., ShrikanthNaik and Aithal, B.H., 2016. Sacred Groves (Kan forests) of SagaraTaluk, Shimoga District. Sahyadri Conservation Series: 54, ENVIS Technical Report 102, Environmental Information System (ENVIS), Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India.
28. Ramachandra, T.V., Vinay, S., and Aithal, B.H., 2016. Environmental flow assessment in a lotic ecosystem of Central Western Ghats, India. *Hydrology Current Research*, vol. 7, pp. 1-14.
29. Ramesh babu, K. and Selvanayagam, M., 2015, Water quality index of Kolavai Lake, Chengalpet, Tamil Nadu, India. *International Journal of Chemical Concepts*, vol. 1(1), pp. 15-18.
30. Ramesh. N. and Krishnaiah. S., 2015, Determination of water quality index of an urban waterbody of Bellandur lake in Bangalore city, Karnataka, India. Journal of Information, Knowledge and Research in Civil Engineering, vol. 3(2), pp. 175-182.
31. Ray, R., Chandran, M.D.S. and Ramachandra, T.V., 2014, Biodiversity and ecological assessments of Indian sacred groves. Journal of Forestry Research, vol. 25(1), pp. 21–28.
32. Ray, R., Chandran, M.D.S. and Ramachandra, T.V., 2015, Hydrological importance of sacred forest fragments in Central Western Ghats of India. *Tropical Ecology*, vol. 56, pp. 87-99.
33. Shrestha, S. and Kazama, F., 2007, Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji River Basin, Japan. *Environmental Modelling & Software*, vol. 22, pp. 464-475.
34. Sincy, V., Mahapatra, D.M. and Ramachandra, T.V., 2012, Nutrient removal of secondary treated water through algal ponds. *Proceedings of the Lake 2012: National Conference on Conservation and Management of Wetland Ecosystems, School of Environmental Sciences, Mahatma Gandhi University, Kottayam, Kerala*, pp. 1-10.
35. Singh, A., Meetei, N.S. and Meitei, L.B., 2013, Seasonal variation of some physico-chemical characteristics of three major rivers in Imphal, Manipur: A comparative evaluation, *Current World Environment*, vol. 8(1), pp. 93-102.
36. Singh, N. and Sharma, R.C., 2016, Assessment of physico-chemical parameters of Mountain River Baldi, Garhwal Himalayas. *International Journal of Fisheries and Aquatic Studies*, vol. 4(2), pp. 88-93.
37. Sujitha, P.C., Dev, D.M., Sowmya, P.K. and Priya R.M., 2012, Physico-chemical parameters of Karamana river water in Trivandrum district, Kerala, India. *International Journal of Environmental Sciences*, vol. 2(3), pp. 1417–1434.

38. Thakor, F.J., Bhoi, D.K. Dabhi, H.R., Pandya, S.N. and Chauhan, N.B., 2011, Water quality index (W.Q.I.) of Pariyej Lake Dist. Kheda – Gujarat. Current World Environment, vol. **6**(2), pp. 225-231.
39. Trivedi, R. K. and Goel, P. K., Chemical and biological methods for water pollution studies. Published by Environmental Publications, Karad, 1986.
40. Vaishali, P. and Punita, P., 2013, Assessment of seasonal variation in water quality of River Mini, at Sindhrot, Vadodara. *International Journal of Environmental Sciences*, vol. 3(5), pp. 1424-1436.
41. Warning, R.H. and Running, S.W., Forest ecosystems analysis at multiple scales. Published by Academic Press, a division of Harcourt Brace & Company, California, 1998.
42. Yogendra, K. and Puttaiah, E.T., 2008, Determination of water quality index and suitability of an urban water body in Shimoga town, Karnataka. Sengupta, M. and Dalwani, R., (Editors), *Proceedings of Taal 2007: The 12th World Lake Conference*, pp. 342-346.
43. Young, R.A., Introduction to forest science. Published by John Wiley & Sons, Inc., Canada, 1982.
44. Yurtseven, I., Serengil, Y. and Pamukçu, P., 2015, Seasonal changes in stream water quality and its effects on macroinvertebrate assemblages in a forested watershed. *Applied Ecology and Environmental Research*, vol. 14(1), pp. 175-188.
45. Yurtseven, I., Serengil, Y. and Pamukçu, P., 2016, Seasonal changes in stream water quality and its effects on macroinvertebrate assemblages in a forested watershed. *Applied Ecology and Environmental Research*, vol. 14(1), pp. 175-188.
46. Zarei, H. and Bilondi, M.P., 2013, Factor analysis of chemical composition in the Karoon River basin, southwest of Iran. Applied Water Science, vol. 3, pp. 753–761.
47. Zhang, M. and Wei, X., 2012, The effects of cumulative forest disturbance on stream flow in a large watershed in the central interior of British Columbia, Canada. *Hydrology and Earth System Sciences*, vol. 16, pp. 2021–2034.