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

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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 kans and non-kans 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, Ferme kán (TK) and Hulkok kán (HK) has excellent water quality whereas KNK (Kodkani) has very poor water quality. The pollution load was high in post 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 by 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 part 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). Kathalekan (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

<table>
<thead>
<tr>
<th>Torme Kan</th>
<th>Hulkot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibuthi NonKan</td>
<td>Vibuthi falls</td>
</tr>
<tr>
<td>Yaana Kan</td>
<td>Yaana NonKan</td>
</tr>
<tr>
<td>Kathalekan forest</td>
<td>Kathalekan</td>
</tr>
</tbody>
</table>

**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
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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 as 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 Kathalekan 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 large 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).
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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

<table>
<thead>
<tr>
<th>PC</th>
<th>Eigenvalue</th>
<th>% variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.71</td>
<td>42.81</td>
</tr>
<tr>
<td>2</td>
<td>2.98</td>
<td>16.54</td>
</tr>
<tr>
<td>3</td>
<td>2.09</td>
<td>11.55</td>
</tr>
<tr>
<td>4</td>
<td>1.69</td>
<td>9.41</td>
</tr>
<tr>
<td>5</td>
<td>1.36</td>
<td>7.58</td>
</tr>
</tbody>
</table>

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).

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).

<table>
<thead>
<tr>
<th>WQI</th>
<th>Water quality Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25</td>
<td>Excellent water quality</td>
</tr>
<tr>
<td>26-50</td>
<td>Good water quality</td>
</tr>
<tr>
<td>51-75</td>
<td>Poor water quality</td>
</tr>
<tr>
<td>76-100</td>
<td>Very poor water quality</td>
</tr>
<tr>
<td>&gt;100</td>
<td>Unsuitable for drinking</td>
</tr>
</tbody>
</table>

**Figure 5:** Water Quality Index (WQI) values of different stations during monsoon, post-monsoon and pre-monsoon season.
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 benthic algal population. Decreased water flow, settling of sediments and soil erosion during monsoon will increase the values of ionic, organic and nutrients 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

<table>
<thead>
<tr>
<th>Sampling Stations</th>
<th>WQI</th>
<th>Water Quality Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibuthi kan (VK)</td>
<td>74</td>
<td>Poor water quality</td>
</tr>
<tr>
<td>Mabgi (VNK)</td>
<td>30</td>
<td>Good water quality</td>
</tr>
<tr>
<td>Yaana kan (YK)</td>
<td>70</td>
<td>Poor water quality</td>
</tr>
<tr>
<td>Yaana non-kan (YNK)</td>
<td>53</td>
<td>Poor water quality</td>
</tr>
<tr>
<td>Kallabbe (KKHS)</td>
<td>30</td>
<td>Good water quality</td>
</tr>
<tr>
<td>Kathalekan (KK1)</td>
<td>48</td>
<td>Good water quality</td>
</tr>
<tr>
<td>Kathalekan (KK2)</td>
<td>58</td>
<td>Poor water quality</td>
</tr>
<tr>
<td>Kathalekan (KK3)</td>
<td>46</td>
<td>Good water quality</td>
</tr>
<tr>
<td>Kathalekan (KK4)</td>
<td>58</td>
<td>Poor water quality</td>
</tr>
<tr>
<td>Kathalekan (KK5)</td>
<td>74</td>
<td>Poor water quality</td>
</tr>
<tr>
<td>Kodkani (KNK)</td>
<td>77</td>
<td>Very poor water quality</td>
</tr>
<tr>
<td>Torme kan (TK)</td>
<td>22</td>
<td>Excellent water quality</td>
</tr>
<tr>
<td>Hulkodu kan (HK)</td>
<td>14</td>
<td>Excellent water quality</td>
</tr>
</tbody>
</table>
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 influe

CONCLUSION


