PROCEEDINGS: **Lake 2018: Conference on Conservation and Sustainable Management of Riverine Ecosystems,** [THE 11TH BIENNIAL LAKE CONFERENCE], 22-25th November 2018
Venue: V.S. Acharya Auditorium, **Alva's Education Foundation**, Moodbidri,
http://ces.iisc.ernet.in/energy; energy.ces@iisc.ac.in: ENVIS Technical Report 166

HYDRO-ECOLOGICAL FOOTPRINT OF SHARAVATHI RIVER BASIN

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ABSTRACT

Hydro-Ecological footprint of a river basin refers to the hydrological regime that caters to biotic and environmental water requirements. Eco-Hydrological footprint provides information about the ecological status of water in addressing water usage with the availability. Mismanagement of the catchment and anthropogenic over exploitation of water resources have led to immense pressures on the natural ecosystems. In the current study, we focus on Sharavathi river basin, which originates in the Western Ghats and flows about 128 km towards Arabian Sea. Land use assessment in Sharavathi basin shows forest cover of 42.8%, which are dominated towards the Ghats. The uplands (plains towards the east) are dominated by agriculture activities, whereas the valleys in the Ghats show high horticulture activities. Monitoring of hydrologic regime of rivers/streams along with land use dynamics and topographic conditions reveal that in a natural landscape dominated by native species of vegetation, at least 25 to 30% of total flow occurs during post monsoon catering to the biotic water demand in the respective catchment. Also, higher species diversity are found in the stream catchments with the perennial streams and also catering the domestic and environmental needs. Hydro-Ecological footprint in Sharavathi basin shows sufficient water availability during all seasons in the streams dominated by native forests, which are in Ghats and Coasts. However, transition zones between Ghats and Plains, and Plain lands with large spatial extent of monoculture, and agricultural activities have led to water scarcity over 4 months and 6 months respectively. Ghats and Coasts have perennial streams as against the eastern transition where the stream flows were intermittent to seasonal. This highlights the vital ecological function of a catchment in sustaining the hydrologic regime when the landscape is covered with the vegetation of native species. The presence of perennial streams in sub-catchment dominated by native vegetation compared to the seasonal streams in the catchment dominated by anthropogenic activities with monoculture plantations, highlights the linkages of biodiversity, ecology and hydrologic regime with the landscape dynamics in the catchment.

Keywords: Eco-Hydrological footprint, Sharavathi, Endemic species.

INTRODUCTION

Environmental flow refers to the hydrologic regime that sustains biota with adequate quantity and quality of water [1]. Flow regimes or temporal flow pattern of river/stream/estuary/groundwater, *etc.* is described by several components namely i) duration, ii) timing, iii) magnitude, iv) frequency, v) the rate of change of flow [2]–[4].. Flow regimes play a decisive role in determining i) structure, components and composition of biota, ii) functions of aquatic, wetland, and riparian ecosystems [5]. It is necessary to maintain the appropriate flow conditions such as floods, high flow and low flow conditions to sustain the health of the aquatic ecosystems - lakes, streams, rivers, sub-surfaces, estuaries, etc. with the associated ecosystems, and habitats, sustaining people’s livelihood [6], [7], to ensure sustained functionalities and use of resources [8]. A well maintained natural ecosystem has better water retention capability through subsurface flows, soil water storage, evapotranspiration etc. giving an edge over degraded catchments [9], [10]. Flow regimes are key drivers for riverine and dependent ecosystems that are governed by climate(meteorology), vegetation (landscape), geology, soil, topography, catchment characteristics and also anthropogenic interventions [3], [11].

Eco-hydrological footprint assessment entails estimation of carrying capacity of a river basin considering water availability and demand of water for sustenance of biotic components. Water resource carrying capacity (WRCC) of a catchment provides a theoretical basis and means of operation for sustainable development while accounting for the system’s supportive and assimilative capacity without affecting the ecological and biological functions, integrity and productivity [12]–[14]. Uneven spatial and temporal distribution of water resources with varied climatic regimes have led to variability in water availability from local to global scales. United Nations World Water Assessment Programme 2015 [15] has predicted that by 2050, the global demand of water would increase by 55%, while fresh water resources either surface or ground water resources depleting due to irrational mismanagement with growing demands of burgeoning population, agriculture, and other socio-economic activities. This would induce imbalances among water users and uses increasing risks of water allocations devoid of ecological requirements and disrupting the local/regional ecosystems. Developing countries in the tropics are facing imbalance in resource supply and demands due to rapid deforestation [16], [17] with the unplanned developmental activities. Burgeoning population with an enhanced demand of natural resources, have led to the over exploitation of natural resources such as water, forest, land *etc.* Anthropogenic activities coupled with skewed policies in the form of logging, afforestation by plantation trees, dam constructions, and conversion of lands for other uses have resulted in the disappearance of pristine forests and wetlands [18]. This structural changes in the forest ecosystem has affected the functional aspects namely hydrological cycle, bio-geo chemical cycles and nutrient cycling there by impacting the assimilative and supportive capacity [19], [20]. Increase in the magnitude and frequency overland flows [21], reduction in the aerodynamics roughness, leaf area, root zone depth consequently reducing evapotranspiration, soil infiltration capabilities [22]–[25] occurs with clearing of forest lands for agricultural and other land use practices. In the mature climax forests, the annual surface transpiration reduces with increase in understory transpiration, due to increasing storage of water in the subsurface, stream become perennial with sustained yield [26]. This makes it very important to safeguard and maintain the exiting forests patches to preserve hydrological regime which caters biotic (ecological and societal) demands.

Eco-hydrological footprint highlights the interaction among water resources, and humans with the environment. In order to achieve sustainability in the water basins the water resource should be managed to cater both natural and human environment without hampering the natural resources. The environmental demand involves maintaining ecological flows and forest water requirements (such as transpiration, etc.), human (including domestic, industrial, agriculture) demands. Conservation of the natural ecosystems would ensure sustenance of natural resources and contributes significantly to the region's economy. A well maintained natural ecosystems has better water retention capability through subsurface flows, soil water storage, evapotranspiration *etc.* giving an edge over degraded catchments [9], [10].

This communication focusses on eco-hydrological footprint of a Sharavathi river basin in the Western Ghats through assessment of hydrologic regime along with the demand of the biotic components. Insights of eco-hydrological footprint assessment will aid in the land use management with the improved water use efficiency, appropriate cropping pattern, restrictions on irrational land use changes towards the sustainable development of the river catchment.

STUDY AREA

River Sharavathi is spread across Uttara Kannada and Shimoga districts of Karnataka (Figure 1). Originating at Ambutirthha (Tirthahalli) (Figure 2) [27], Sharavathi flows for a distance of nearly 128 km [28] before it joins Arabian Sea at Karki (Honnavar) (Figure 2). Tributaries of Sharavathi include, Nandiholé, Haridravathi, Sharmanavathi, Hilkunjiholé, Nagodiholé, Hurliholé, Yenneholé, Mavinaholé, Gundabalaholé, Kalkatteholé, Kandodiholé and many more. Sharavati river has a catchment area of 3042 sq.km spread across districts of Uttara Kannada (Honavara, Siddapura, Kumta) and Shimoga (Sagara, Hosanagara, Tirthahalli). The variations in the terrain have led to the formation of various water falls such as the Jog falls, Apsarakonda, Mavinagundi falls, Dabbe fall etc. The plain regions of the catchment are dominated by lakes whereas the Ghats are dominated by streams. Alterations in the physical integrity through the construction of series of dams have also altered the estuary productivity and diversity. Population in the catchment has increased from 319380 in 2001 to 353800 in 2011[29] and is projected to increase to 388190 in the year 2021 at a growth rate of 9.72% per decade. Population density in the catchment is 124.2 persons per square kilometer as on 2018. Major Population is contained at towns such as Honnavar, Sagar, Talguppa. Rainfall assessment in Sharavati river catchment (Figure 3) indicates that rainfall in the catchment is orographic. Temporal pattern of rainfall in Sharavathi shows nearly 77% of the rainfall occurs due to the South West monsoon. Average annual rainfall in the catchment is about 4230 mm and varies between 1600 mm at the plains of Shimoga and Hosanagara to over 5500 mm at the Ghats of Sagar, Siddapur, Honnavar and Hosanagara talluks. Coastal belt of Honavar receive annual rainfall of 3500 mm and 4000 mm.

Figure 1: Sharavati River Location

Figure 2: Sharavathi River network overlaid on Google Earth

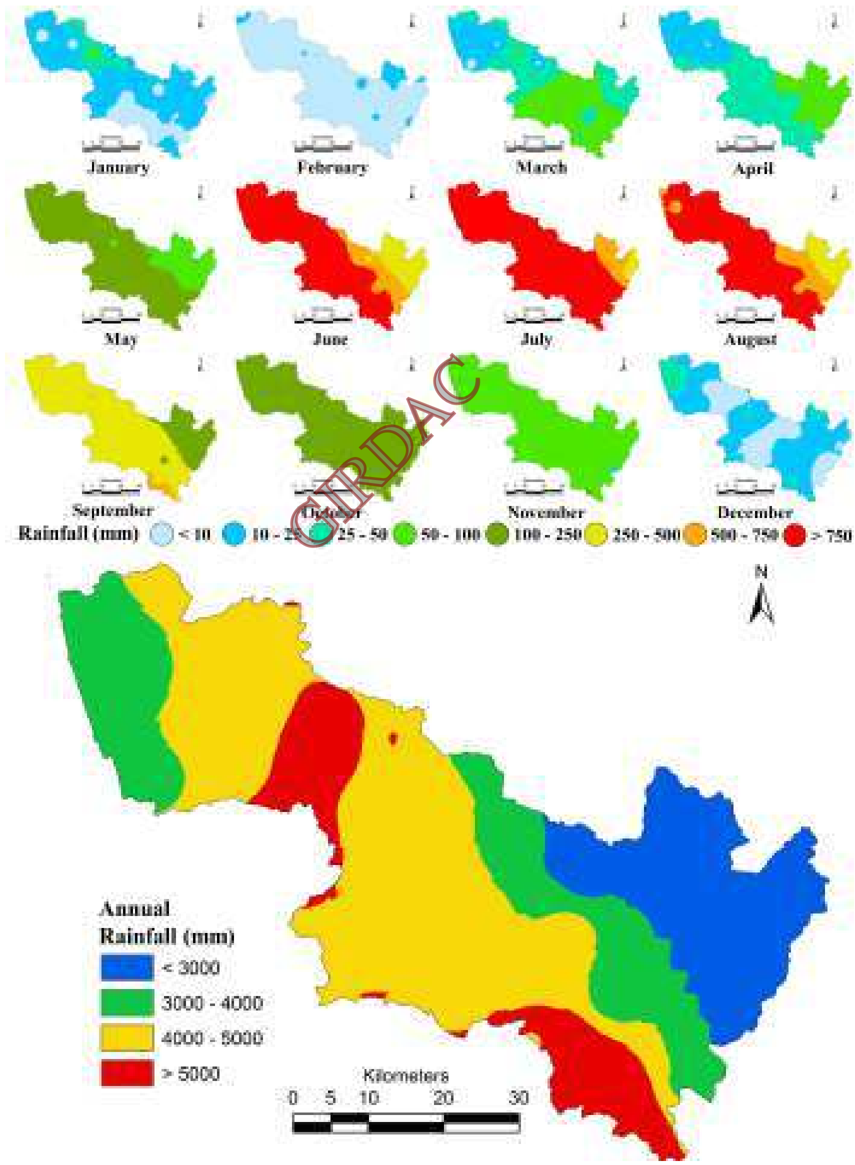

Figure 3: Rainfall variations in Sharavathi basin

DATA:

Optical remote sensing data acquired through Landsat OLI sensors for 2016 was used to assess the landscape dynamics [30]. Long term rainfall data between 1901 to 2010 were collected from the Directorate of Economics and Statistics [31] across rain gauging stations spread across the regions - Uttara Kannada, and Shimoga districts. Population data were obtained between 1991 and 2011 from Census of India [29], Livestock population and Crop data across all the three districts were obtained from respective district at a glance [32]. Temperature data were downloaded from WorldClim [33], extra-terrestrial solar radiation from FAO [34]. Crop calendar and growth phase wise crop water requirements was acquired from Agriculture Department of Karnataka and National Food Security Mission [35], [36]. Digital Elevation Model from SRTM [30], [37]. In addition to these data, Virtual data such as Google Earth[38], NRSC-Bhuvan [39], Survey of India Topographic sheets [28], French Institute maps[40] were used for the spatial analysis.

METHOD:

Method involved in understanding the overall water footprint and to understand the sustenance of water resource as depicted in figure 4. Assessment of eco-hydrological footprint in the catchment involved the following:

i. ***Land Use Analysis***: Land use in the catchment plays a decisive role in the hydrological processes such as infiltration, surface and subsurface flows and storages, etc., which define the hydrologic regime. Assessment of constituents in the landscape under different vegetation type such as agriculture, forest, plantation helps in assessing the water demand in these sectors. Land use analysis was carried out using supervised classifier based on Gaussian Maximum likelihood algorithm [41]–[43]. SRTM DEM, SOI (the Survey of India; http://thesurveyofindia.gov.in) Topographic maps were used to delineate sub basins in the river catchment.

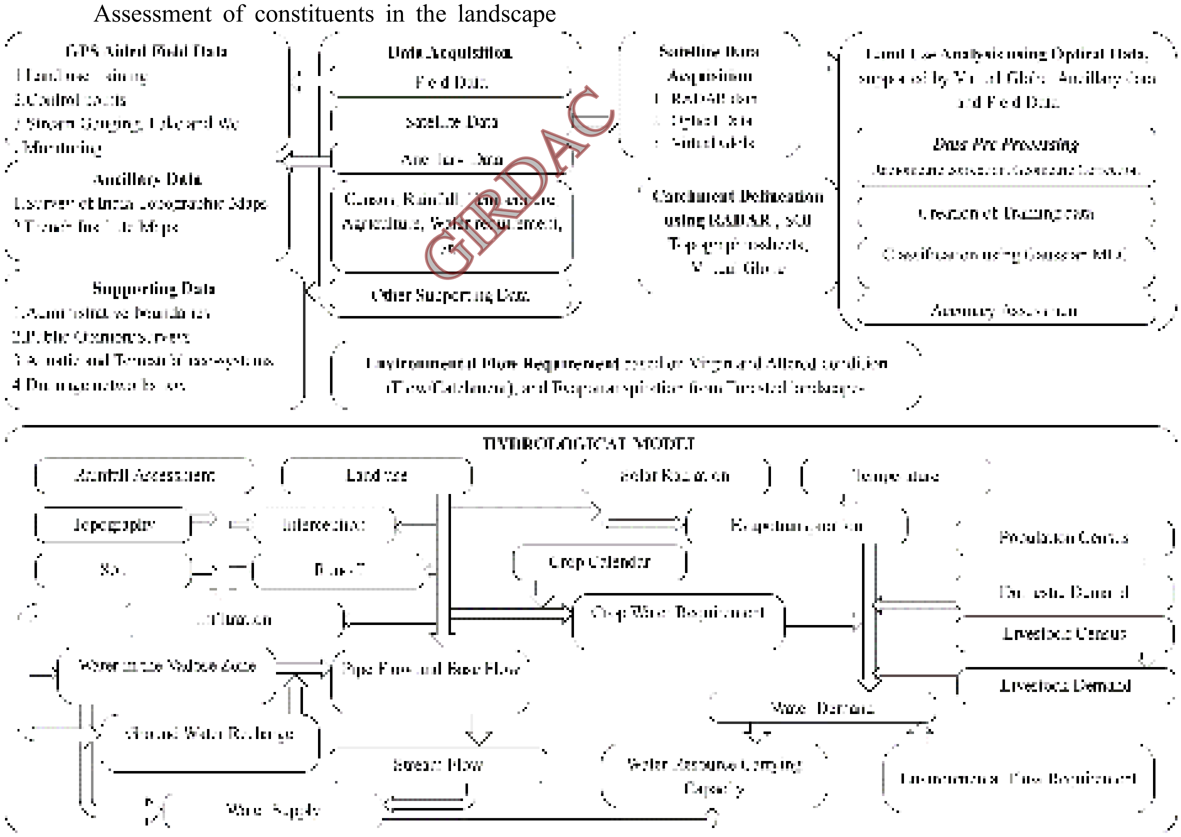

Figure 4: Method

ii. ***Assessment of Hydrological footprint***: Hydrologic footprint is a function of land use, climatic factors (such as rainfall, surface and subsurface flows, ground water, vadose water), *etc.* Spatial and temporal (monthly variability) patterns of rainfall is assessed using data from all rain gauge stations of 110 years. Net rainfall in each sub basis were quantified based by deducting interception storage in each land use. Runoff in the basin was quantified using Rational equation [44], runoff coefficients were based on the earlier field estimations carried out in Sharavati basin and Aghanashini basin [45]. Infiltration is quantified as difference between Net rainfall and runoff (overland flow). Ground water recharge was estimated using Krishna Rao equation[46] which considers rainfall as a parameter. Water in the hypomorphic zone (vadose zone) was estimated as difference between net rainfall, runoff and ground water recharge. Subsurface flows were derived[45] based on soil and lithological characteristics of the catchment.

iii. ***Assessment of ecological water footprint***: Ecological footprint was derived as function of ecological, agriculture, domestic and livestock water demands. Based on the cropping pattern, growth phase and water requirement for each crop, agriculture water demand was quantified. Based on the livestock census and water requirement for each animal per day was used to estimate water demand for livestock. Similarly, water demand for domestic sector is assessed based on the population and per capita water demand. Evapotranspiration from forests were used as a part of terrestrial natural water demand and quantified using maximum, minimum temperatures and extra-terrestrial solar radiation[46]–[48] based on the modified Hargreaves [49] method. Environmental flow was arrived based on long-term field measurements carried out at specific sub catchments of Sharavathi river basin.

iv. ***Quantification of Eco-hydrological footprint***: Eco-Hydrological footprint is evaluated using eco-hydrological indices developed in the model to understand the role of forests in maintaining the hydrological cycle and catering the biotic demands. Eco-hydrological index is quantified as the ratio of infiltration to evapotranspiration in the catchment. Lower the values of infiltration i.e., less than 1 indicates poor water availability and values greater than 1 indicated better water availability sustaining the domestic and ecological demands.

v. ***Assessment of Eco-hydrological status***: Month wise hydrological supply and ecological demand were analysed to understand the eco-hydrological status. The region indicates deficit situation if supply is below demand and surplus situation if supply is higher than the demand.

RESULTS AND DISCUSSIONS

Land use of Sharavathi basin is depicted in Figure 5 and Table 1. Sharavati river has 3 major storage structures namely Linganamakki, Mahatma Gandhi, Balancing reservoir and Gersoppa. The water bodies in Sharavati cover about 6.9% of the catchment area. Forests of Sharavathi (Figure 6) cover about 42.8% of catchment area of which evergreen forests cover 19.6%, deciduous forest cover 14.6%. Sharavathi eastern regions are comparatively flat as against the Ghats and are rich with tropical savannas whereas the Ghats are dominated by evergreen forest patches with deciduous species. Due to presence of diversion works, the valleys are rich in horticulture and agriculture which together contribute to 26.1%. Monoculture such as Cashew, Acacia, Eucalyptus, Teak are found across the basin, contributing to 22.1% of Sharavati landscape. Built up area in the catchment is about 1%, concentrated primarily at the Coastal City of Honavar, Talaguppa.

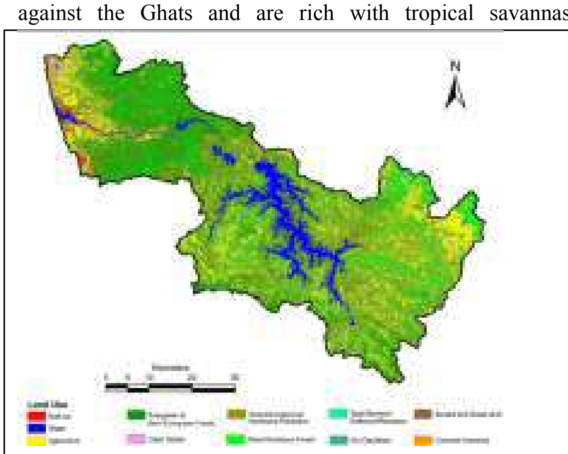

Figure 5: Sharavati Basin Land use

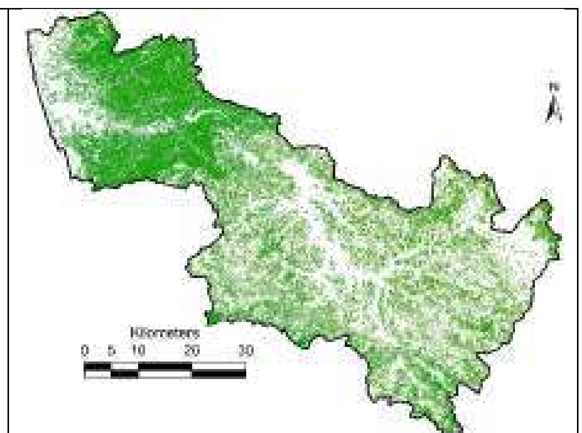

Figure 6: Forest cover of Sharavati basin

Flow measurements were carried out at 10 stations as depicted in figure 7. Closer to the coasts in the transition zones towards the Ghats, Chikkolli and Gundbala rivers were monitored, whereas towards the Ghats five streams in Kattalekan, two in Kodkani and one at Hulkodu were monitored. Chikkolli is sub water shed of Gundbala river catchment, similarly Kattalekan sites1, 2 and 3 are sub catchments of stream Kattalekan site 5. Among all the watersheds Hulkodu was the smallest with an area nearly 9 hectares, followed by Kattalekan site 2 with 11 hectares, whereas Gundbala has highest catchment area of 130.6 sq.km. Land use variation along these stream catchments are as shown in figure 8 and described in tables 2 and 3. Land use assessment shows that all the catchments have good forest cover over 60%. Kodkani site 1 and site 2 had forest cover close to 61% and 63% respectively with

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evergreen forest cover close to 48.5%, agriculture lands in the valley zone contributed to over 18.3% and 22.1% of the catchment area, grasslands on the hilltops in both catchments covered nearly 9.5% of the area. Hulkod being smallest of the gauged catchments had evergreen forest covering 68.5% and grasslands covering 31.5% towards the hilltops. All other seven catchments had forest cover over 84%. Gundbala and Chikkolli is dominated with horticulture activities and agriculture in the valley zones contributing 7 to 10% of the catchment area. Of the five stations monitored at Kattalekan, field observations revealed that only Kattalekan site 4 and Kattalekan site 5 had horticulture and agriculture activities. Stream flow dynamics across the selected catchments are depicted in Figures 9 to 11. and summarized in tables 2 and 3. Streams gauged at sites namely Kattalekan site 2 (Kattalekan 2), Kattalekan site 4 (Kattalekan 4), Kattakekan site 5 (Kattalekan 5) and Hulkodu were perennial with high yield post monsoons. The ratio of non-monsoon yield to rainfall was found to be in the range of 10 % to 13% in these perennial streams. Drafting of water for horticulture in Kattalekan site 5 catchment has reduced water yield in pre monsoons, which is evident from flows compared at Kattalken 2. Kattalekan site1 and site 3 were intermittent with flow duration of 8 to 10 months. Measurements at Kattalekan showed that Kattalekan 2 had highest water yield during summer followed by Kattalekan 4 and 5 (Figure 7.17). Gundbala, Chikkolli, Kodkani 1 & 2 have flow duration of 10 to 11 months, with streams drying in month of April, this could be attributed to exploitation of water for horticulture though pumping from the neighboring stream/rivers. non-monsoon water yield in the catchment of Gundbala, Chikolli, Kodkani 1 and Kodkani 2 ranges between 5 to 11% of annual rainfall.

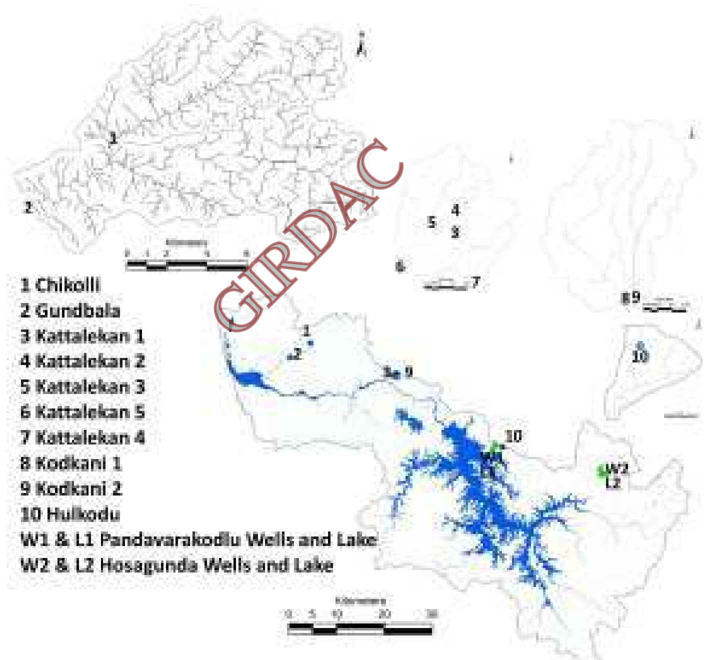

Figure 7: Monitoring stations in Sharavathi river basin

Table 1: Land use statistics of Sharavati river basin

Land use	Area
Built up	1.0%
Water	6.9%
Crop land	14.1%
Open Space	1.1%
Deciduous	14.1%
Evergreen - Semi Evergreen Forest	19.6%
Scrub/Grass land	9.1%
Acacia/Eucalyptus/Casuarina	13.6%
Teak/Bamboo/Cashew	8.5%
Arecanut/Coconut	12.0%

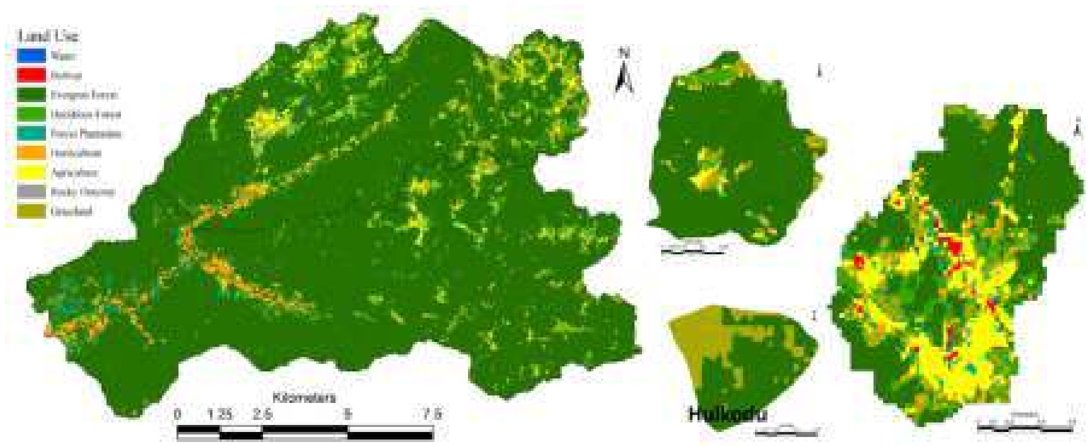

Figure 8: Land use – Sharavathi Catchments

Table 2: Features of stream catchment monitored – Sharavathi - 1

Location	Kattalekan 1	Kattalekan 2	Kattalekan 3	Kattalekan 4	Kattalekan 5
Rainfall (mm)	5025	4954	4976	4997	5013
Area in sq.m	259697	112813	275980	162098	1134055
Land use					
Water	0.0%	0.0%	0.0%	0.0%	0.0%
Built up	0.0%	0.0%	0.0%	0.0%	0.0%
Evergreen Forest	92%	87%	79%	84%	86%
Deciduous Forest	0%	6%	9%	2%	4%
Forest Plantation	0%	1%	0%	2%	0%
Horticulture	2%	3%	3%	5%	2%
Agriculture	0%	1%	3%	2%	3%
Rocky outcrop	0%	0%	0%	0%	0%
Grassland	5%	2%	5%	5%	5%
Catchment Characteristics					
Flow Duration (months)	8	12	10	12	12
Post Monsoon Flow (mm)	309.363	487.513	583.864	450.618	511.166
Pre Monsoon Flow (mm)	0.000	154.775	15.003	53.581	54.892
Total non-monsoon flow to rainfall ratio	6.2%	13.0%	12.0%	10.1%	11.3%
Order of Stream	1	1	1	1	2
Average Catchment Slope	30%	38%	28%	30%	27%
Average Catchment Elevation (m)	564	600	574	563	553

To derive Ecological flow requirements in Western Ghats, undisturbed catchments were considered. Ecological flow in the catchments are estimated as function of observed non monsoon flows to the modeled stream flow as well as function of observed non-monsoon flow to the total rainfall in the catchment. Based on Mean Annual Runoff (MAR) i.e., annual stream flow in the catchment, Eflow ranges between 25% (Kattalekan 5) to 30% (Hulkodu).(table 4).

Table 3: Features of stream catchment monitored – Sharavathi – 2 and 3

Location	Chikkolli	Gundbala	Kodkani 1	Kodkani 2	Hulkod
Rainfall (mm)	4790	4702	4739	4677	3300
Area in sq.m	50018380	130602038	1530056	886720	89910
Land use					
Water	0.2%	0.2%	0.2%	0.1%	0.0%
Built up	0.1%	0.1%	2.1%	1.5%	0.0%
Evergreen Forest	76%	83%	48%	49%	68%
Deciduous Forest	7%	5%	14%	12%	0%
Forest Plantation	3%	2%	3%	2%	0%
Horticulture	3%	3%	4%	3%	0%
Agriculture	6%	4%	18%	22%	0%
Rocky outcrop	0%	0%	0%	1%	0%
Grassland	3%	2%	10%	9%	32%
Catchment Characteristics					
Flow Duration (months)	10	11	11	11	12
Post Monsoon Flow (mm)	281.6	221.0	296.7	479.7	308.9
Pre Monsoon Flow (mm)	10.5	21.4	30.7	47.3	48.1
Total non-monsoon flow to rainfall ratio	6.1%	5.2%	6.9%	11.3%	10.8%
Order of Stream	5	6	3	2	1
Average Catchment Slope	30%	28%	18%	21%	25%
Average Catchment Elevation (m)	29	19	524	523	670

Table 4: Environmental flow in Undisturbed catchments

Catchment	Rainfall (mm)	Total flow (MAR – mm)	Observed Non monsoon flow (mm)	Eflow (%MAR)	Eflow (%Rainfall)
KK4	3572	1998	504	25%	14%
KK5	3574	2252	566	25%	16%
KK2	3497	2200	642	29%	18%
Hulkodu	2424	1188	357	30%	15%

Stepwise regression was carried out in order to understand the role of various factors influencing stream flow duration. Flow duration shows good correlation with catchment slope (+), evergreen forest cover (+), deciduous forest cover (-). Step wise multivariate (multi regression) analysis carried out considering combination of various parameters that had significant impact on flow duration such as Slope, Evergreen forest cover, Deciduous forest cover, and monoculture. Multivariate statistical model defining flow duration is as represented in equation 1. The multivariate model had 'R^2'0.72 and 'r' of 0.82 signifying predicting capability.

$$FD = 11.08 - 2.44(Sl) + 1.73(Eg) - 9.03(De) - 6.31(Fp) \quad \text{eq.1}$$

Where FD - Flow duration in months,

Sl – Average catchment slope (fraction),

Eg – Evergreen forest area in catchment (fraction),

De – Deciduous forest area in catchment (fraction),

Fp – Area under forest plantation in catchment (fraction).

Evaluation of regression equation against measured values shows predictable accuracy of model with Nash-Sutcliffe efficiency 0.67 and percent bias ~1%.

Average Rainfall in the catchment is about 4230 mm. Interception loss in the basin ranges between 450 mm and 1400 mm with an average of 1047 mm. Net rainfall in Sharavathi basin is about 3183 mm i.e., about 9262 Million

Cubic meters. Riverscape of Sharavathi has over 42.8% forest dominated towards Ghats indicating relating to higher Infiltration and lower monsoon yield. Runoff in the basin is about 3075 Million cubic meters and Infiltration of 5370 Million cubic meters. Ground water recharge in the catchment ranges between 274 mm to 1250 mm in the plains and Ghats respectively, on an average 897 mm in contributed to ground water recharge accounting to 2577 Million cubic meters. Water available in the hypomorhpic layer is about 2693Million cubic meters. Pipeflow in the basin is about 743 Million cubic meters whereas baseflow is about 207 Million cubic meters both together contributing to a sub-surface flow of 950 Million cubic meters.. Agriculture demand in the basin is about 1798 Million cubic meters. Livestock demand in the basin is about 7.9 Million cubic meters. Domestic water requirement in the basin is about 18.5 Million cubic meters across the basin. Both livestock and human population combined together has a domestic footprint of 26.4 Million cubic meters.

Terrestrial demand is function of evapotranspiration from forested landscapes, which is about 1795 Million cubic meters during non-monsoons could be catered by the water in the hypomorphic layer (vadose water). Annual average flow in the basin considering runoff and sub-surface flows is about 4025 Million cubic meters, with respect to which, Environmental flow is about 1207 Million cubic meters. Demand footprint of the basin is about 4827 Million cubic meters and of this 3619 Million Cubic meters is the water footprint in agriculture, domestic, livestock and evapotranspiration from forests. Eco-Hydrological Footprint (Figure 12) shows water scarce situation in sub-basins located in the eastern transition zone at Shimoga and Hosanagara whereas sub-basins in the Ghats show sufficient water availability to cater domestic, irrigation, horticulture, livestock, and ecological needs. Presence of dense forest cover in the Ghats make it more favorable to cater most of the Environmental flow demands in each sub-basin and ecological flow demands in the river downstream.

Streams in the Sharavathi river showed sufficient water availability during all seasons when the catchment was dominated by native vegetation in the Ghats and Coasts, whereas the transition zones between Ghats and Plains, and Plain lands with the large-scale monoculture plantations and agricultural activities are witnessing water scarcity of 4 to 6 months respectively. Ghats and Coasts have perennial streams as against the eastern transition where the stream flows were intermittent to seasonal. Based on the duration of flow in the streams, they are grouped into 4 categories (A, B, C, D). Perennial streams are categorised under A (with 12 months flow), intermittent river are with 9-11 months flow (category B), 8 to 6 months (category C), where as seasonal streams were classified under D category. Accordingly the Ghats and coasts have perennial river system as against the upper plainlands (Figure 13).

Flora and faunal distribution in Sharavathi river catchment is as depicted in figure 13. Considering ecology and hydrological regime in the catchments, it is evident that higher species diversity occurs in the sub catchments with the perennial streams and catering the domestic and environmental/ecological needs. This also highlights that streams are perennial in the catchment dominated by native vegetation with higher endemic plant species confirming the linkage between ecology, hydrology with the land use dynamics.

CONCLUSION

Sharavthi river catchment's physical integrity is altered with the implementation of unplanned developmental projects such as the construction of series of dams, which has led to reduction in forests to 42.8% (2016), dams and reservoirs cover about 6.9% of the catchment area. These structural alterations of the landscape in the basin have altered the natural hydrologic regime. Assessment of water footprint indicates the requirement of 4025 million cubic meters for the societal and livestock demand, 3619 million cubic meters for terrestrial ecosystems and environmental flow of 1207 million cubic meters (to sustain aquatic biota). The terrestrial demand is met by percolated water in hypo-morphic zone, supply in the basin would be function of surface and subsurface flows. Eco-hydrological footprint emphasizes the role of forests on infiltration and evapotranspiration capabilities. Hydrological footprint shows sustained water supply catering societal and environmental demands in the catchment dominated by native forest cover of endemic flora. Inter annual variability of supply and demand foot prints indicate that the sub basins between coasts and Ghats are with perennial river streams, whereas the transition zones between Ghats and plains towards the eastern portions showed deficit of water for 6 to 10 months with intermittent and seasonal flow. Occurrenec of streams with 12 months flow in the ecologically senstive region (1 and 2) confirms of linkages of hydrologic regime with the ecological senstivness of a region. This highlights that streams are perennial in the catchment with forest cover > 60% and with higher endamic plant speciesconfirming the linkage between ecology, hydrology with the land use dynamics in the catchment. This provides invaluable insights to the catchment management in an era dominated by mismanagement of river catchment with the enhanced deforestation process, inappropriate cropping and poor water efficiency

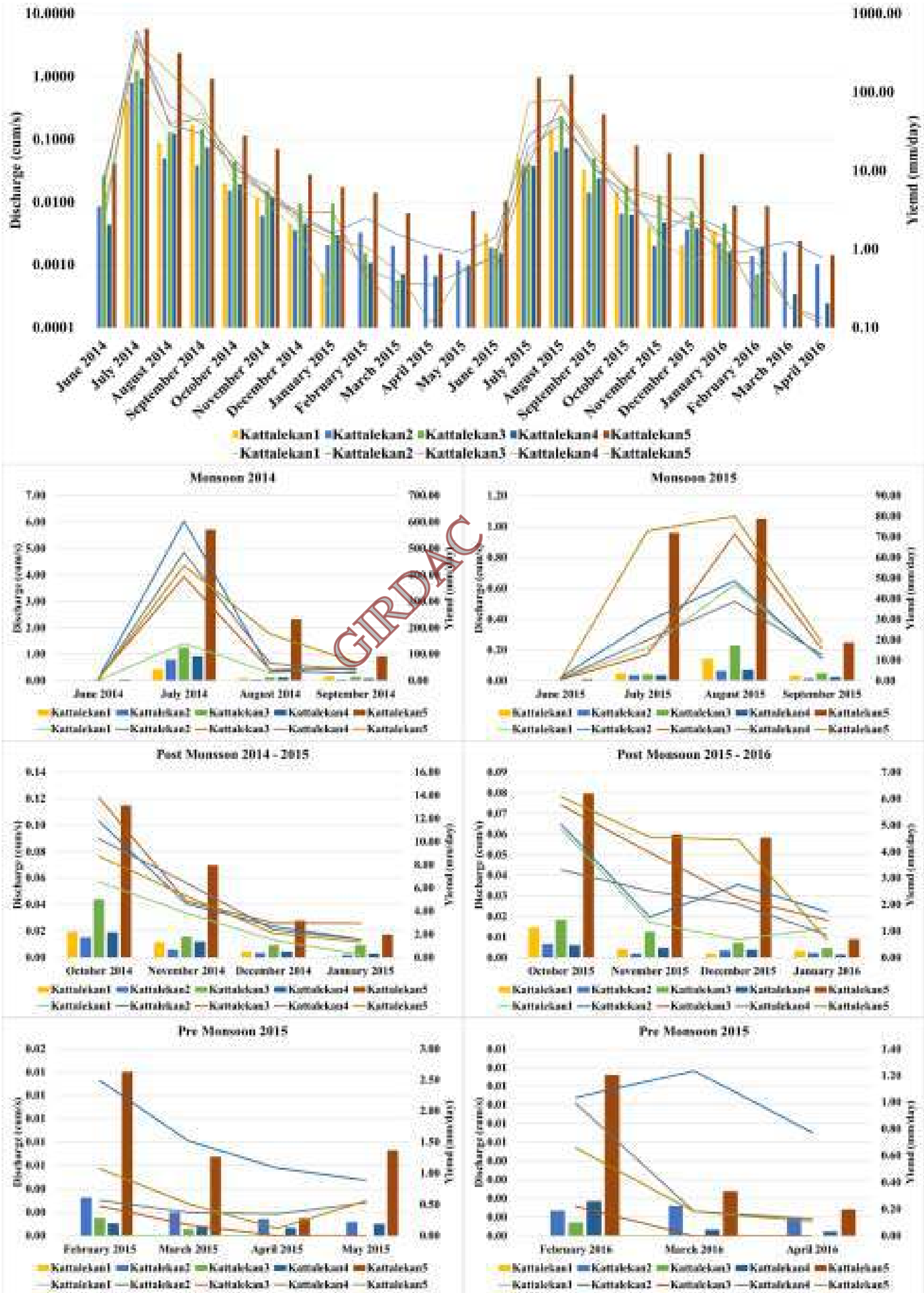

Figure 7.9: Stream Flow Dynamics (Monthly and Seasonal) in Sharavathi - 1

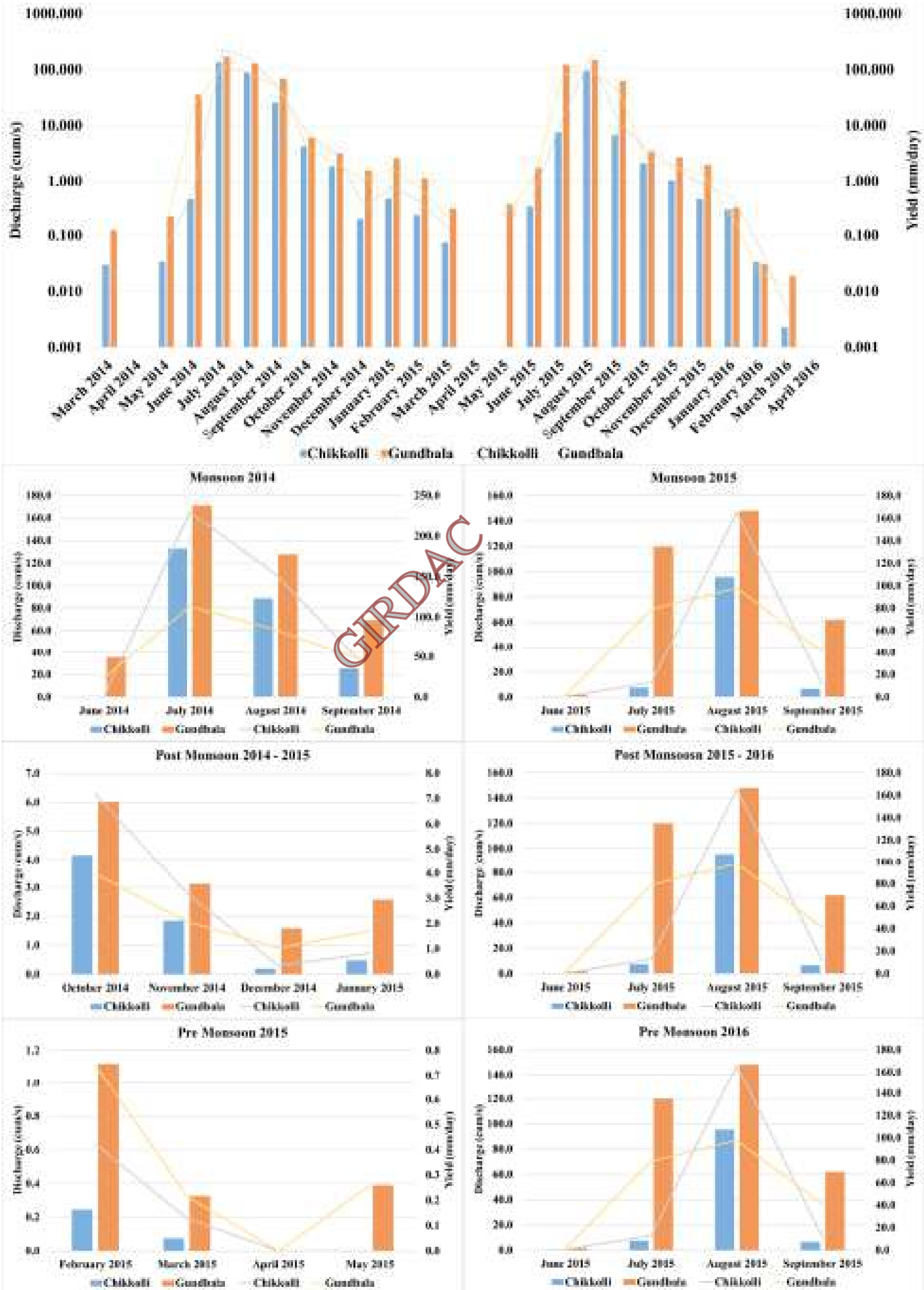

Figure 7.10: Stream Flow Dynamics (Monthly and Seasonal) in Sharavathi - 2

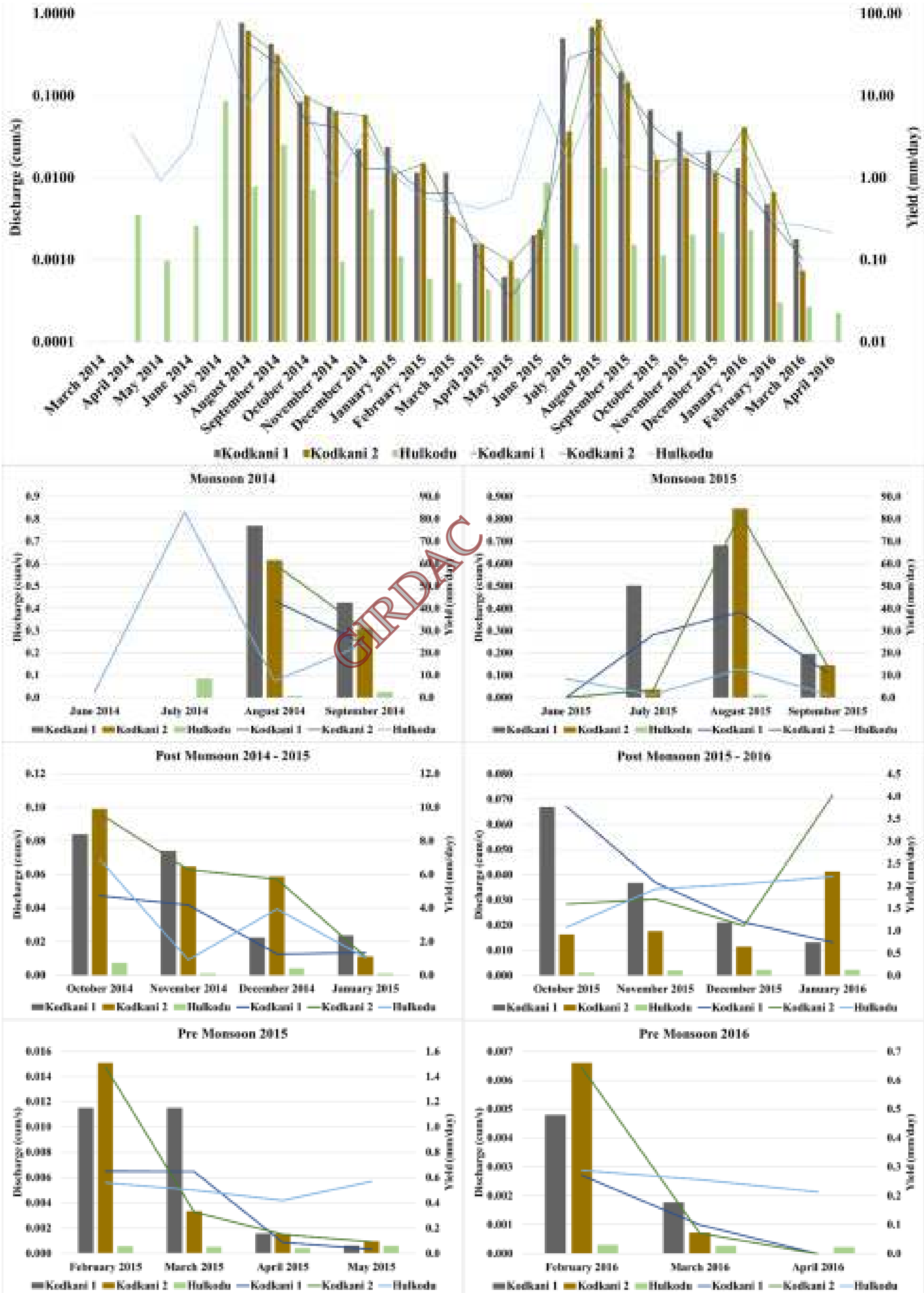

Figure 11: Stream Flow Dynamics (Monthly and Seasonal) in Sharavathi – 3

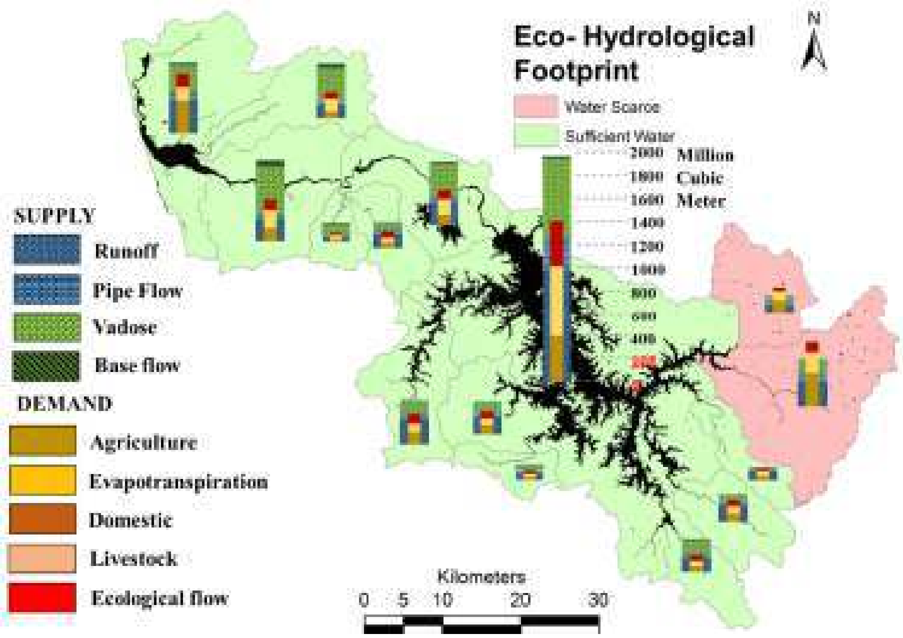

Figure 12: Eco-Hydrological footprint of Sharavathi river basin

Figure 13: Endemic Flora and Fauna distribution in Sharvathi river basin, and river grading

ACKNOWLEDGEMENTS:

We acknowledge the sustained financial support for ecological research in Western Ghats from (i) NRDMS division, The Ministry of Science and Technology (DST), Government of India, (ii) Indian institute of Science and (iii) ENVIS division, The Ministry of Environments, forests and Climate Change, Government of India. We thank Vishnu Mukri and Srikanth Naik for the assistance during field data collection.

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