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Linkages between Catchment Landscape Dynamics and the Natural Flow Regime

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Abstract: Landscape structure plays an important role in the functional aspects of an ecosystem, which include hydrological and bio-geo chemical cycling. Alterations in landscape structure with the irreversible land use changes have influenced the surface water and groundwater hydrology. Anthropogenic activities due to unplanned developmental activities to meet the growing demand of burgeoning population in developing world have accentuated deforestation, etc. Current communication focuses on quantifying land use dynamics and hydrological parameters in Sagra taluk, Shimoga district, Karnataka. Sagara taluk topographically consists of Ghats in the west and the plain-lands towards the east with rainfall varying from 1500 mm near the plains to over 4500 mm towards the Ghats. Land use analysis between 1973 and 2012 shows that horticulture (plantation) has increased from 10.7% to 37.2% whereas forests have decreased from 57.3% to 42.5% in 4 decades. Ghat portion i.e., western portion of Sagara was dominated by forests and horticulture (Areacanut, Banana, Ginger, etc.), whereas the plains in the east were dominated by agriculture (Paddy, Jowar). Hydrological investigations were carried out for 16 months covering all seasons during 2014 and 2015 in the select catchments of Sharavathi and Varada river basins. The study results reveal that (i) ground water fluctuations vary from <0.6m (along the downstream of lakes with good forest cover) and 1.2m (with good forests in the upstream) to 1.5 m (in the catchment dominated by degraded forests), (ii) perennial streams occur in pristine forests as forested catchment aid as sponge and retains the water during monsoon and steadily releases in the lean seasons. The analysis of regional hydrology with landscape dynamics provided insights to the role of forests with native vegetation in sustaining the water in streams and lakes. This also helped in understanding watershed management strategies to sustain and maintain desired environmental flow, while catering to domestic and agricultural demands.

Keywords: *Landscape dynamics, Land use, Hydrology, Remote Sensing data, Spatial analysis*

1. Introduction

Fresh water ecosystems are fragile and form the key foundation elements for the social, cultural and economic wellbeing of human race. Fresh water ecosystems namely rivers, lakes, floodplains, wetlands, and estuaries provides necessary goods and services as clean food, water, fiber, energy and supporting benefits supporting the economy and livelihood that are necessary for human health and wellbeing [1]. The increasing fresh water demands and large scale withdrawal from the fresh water ecosystems for meeting various societal needs such as domestic, irrigation, industrial, power, etc., have led to large scale compromise and degradation in the natural flows conditions across India and World [2]. Harnessing rivers /streams for irrigation, drinking etc. is associated with greater cost [3] i.e., due to human centric planning for utilization of water have not taken into consideration the need of water for the aquatic, terrestrial and riverine ecosystems that support native species and sustained ecosystem that provided important goods and services. These natural flow regimes determines the quality as well as health of the river and flow regime is the primary driving force that influences riverine and aquatic ecosystems, habitats, spices richness and diversity, river morphology, biotic life, river connectivity. Based on the premise that the health of the river deteriorates if the flow is below a threshold the concept of minimum flow in rivers came into practice in 1970s, many studies since then led to the understanding of the need of various elements of natural flow regime. The concept of environmental flow helps to understand, check the negative impact of large scale withdrawals of water from a natural system, and gives an idea the minimum flow to be maintained to sustain ecology and biodiversity, which is referred as Environmental Flows. This is necessary to maintain the health and biodiversity of water bodies, including rivers, coastal waters, wetlands (mangroves, sea-grass beds, floodplains) and estuaries [2, 4, 5].

The ecological flow has been investigated in many countries and also across countries such as China [6], India [7], Spain [8], Tanzania [9], Korea [10, Russia-

China-Kazakhstan [11], South Africa [12], etc. Assessing environmental flow in rivers ranging from simple approaches based on limited data to highly complex and intensive approaches involving multidisciplinary studies involving experts from various domains namely ecology, hydrology, lithology, etc. these methods [13, 14, 15] can be further classified under four sub categories namely Hydrological method, Hydraulic rating method, Habitat simulation method and Holistic method.

Analysis of Environmental flow in streams and rivers are necessary to ensure that the need of humans and that of environment are met, based on which other potential users such as industries etc., can be accommodated to abstract water [12], in determining the health of river, manage flow and protect the water bodies and river networks [6], maintain and enhance the ecological character and functions of floodplain, wetland and riverine ecosystems that may be subject to stress from drought, climate change or water resource development [17, 18].

Study of water resource availability to cater the demands based on the ecological flow and domestic requirements in each of the river basin is carried out by integration of the hydrological model with a water balance model and remote sensing data into a GIS [18, 19]. Remote sensing techniques [20, 21, 22] have advantages such as wider synoptic coverage of the earth surface with varied temporal, spatial and spectral resolutions. Classifications of these data through already proven classification algorithms [23, 24, 25, 26] provide land use information. Land use information derived from remote sensing and GIS, is integrated with the hydro-meteorological information to study the role of landscape on local hydrology. Role of Landscape dynamics along with Hydro-meteorological studies has been carried out at a larger scale at in various parts of the country such as Krishna basin [19, 27], Western Ghats [25, 28], Cauvery river basin [29] etc., using the satellite based inputs and other associated parameters such as rainfall, runoff, evaporation, transpiration, ground water monitoring and so on in determining famine, drought, cyclones, silt, flood monitoring etc that helps in defining the carrying capacity in each river basin [30, 31, 32, 33, 34, 35].

The objective of this communication is to understand the role of landscape on surface and subsurface hydrological variations across seasons by continuous monitoring of selected wells, rivers and streams of select catchments in Sagara Taluk of Shimoga District, Karnataka.

2. Study Area

Sagara taluk as depicted in Figure 1 is located in Shimoga district of Karnataka state. Sagara taluk has an area of 1933 km2, extending from 13.8549^{O} N to 14.3427^{O} N latitude and 74.6259^{O} E to 75.2955^{O} E longitude. Figure 2 depicts drainage map of Sagara taluk which shows that the western portion of Sagara taluk has highly undulating terrains (Ghats) whereas the eastern portion of the taluk is less undulating, these topographic feature leads to formation of rivers and dense drainage networks along the western side, whereas interconnected lakes in the eastern side, which either leads to river Sharavathi in the West or river Varada in the east. Variations in topography has also led to formation of various natural and manmade landscapes such as evergreen forests, deciduous forests, scrub lands, grass lands, rivers, lakes, reservoirs, agriculture, horticulture and so on. Some of the forests in Sagara taluk are classified under the sacred groves, these groves are part of relic forest with rich biodiversity, higher ability to withhold water during the monsoon and steadily release during the post monsoons. Rainfall variations across seasons and space are as presented in Figure 3 and Figure 4 respectively. Rainfall in sagara is due to the south west monsoons, mostly occurring between June and October, spatially annual rainfall varies from 4500mm at the Ghats to 2000mm towards the plains .Temperature in Sagara taluk fluctuate between 15OC during winter (December) to 32OC during summer (April) and evapotranspiration follows the thermal regime across seasons i.e., 3 mm/day during the monsoons about 4 mm/day in the winter and about 5mm/day during the summer. Variations in temperature and PET across seasons are presented in Figure 5. Soils texture varies from clayey to loamy clayey. Population in the taluk is about 206112 people as per 2011 census [36], which has increase at a decade rate of 2.55% from 2001.

3. Data used and Method Involved

In order to understand the land use dynamics, Landsat and IRS series of data during 1973 to 2012 were analysed along with field data (collected using GPS) and other collateral information from the Survey of India topographic maps [37] (1: 250000, 1: 50000), revenue cadastral maps, French institute vegetation maps [38], India biodiversity portal [39], Google earth [40], Bhuvan [41] respectively. Land use analysis was carried out using the maximum likelihood classifier [42, 43, 44, 45, 46, 47, 48] Well water depths were monitored and stream flow (discharge measurements) was quantified using the area velocity method [31, 32, 49] in the select catchments to understand the water availability status in Sagara Taluk.

4. Results and Discussions

Land use analysis was carried out using Landsat series and IRS series of satellite data to understand the landscape dynamics of Sagara taluk and the results area as presented in Figure 6 and Table 1. Land use analysis between 1973 and 2012 indicate that forest cover has reduced from 57.3% in 1973 to about 45.5% in 2012.

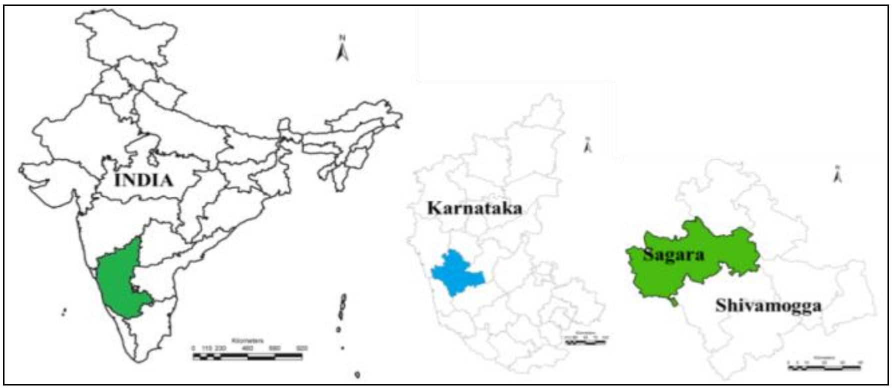


Figure 1 *Study Area (Sagara Taluk)*

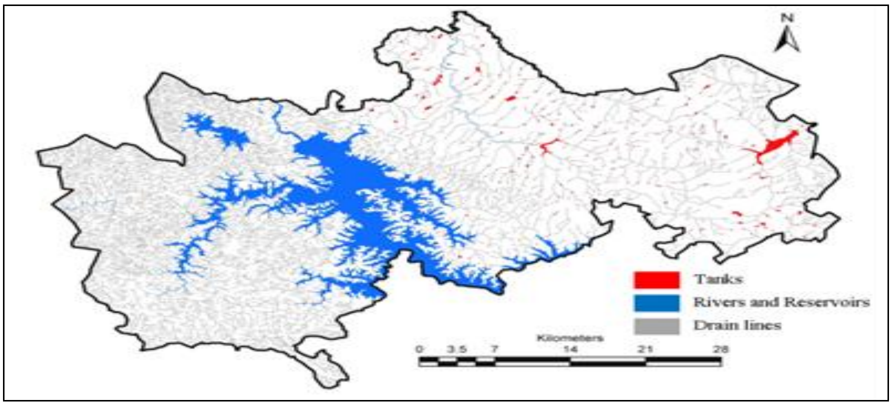


Figure 2 *Drainage Network*

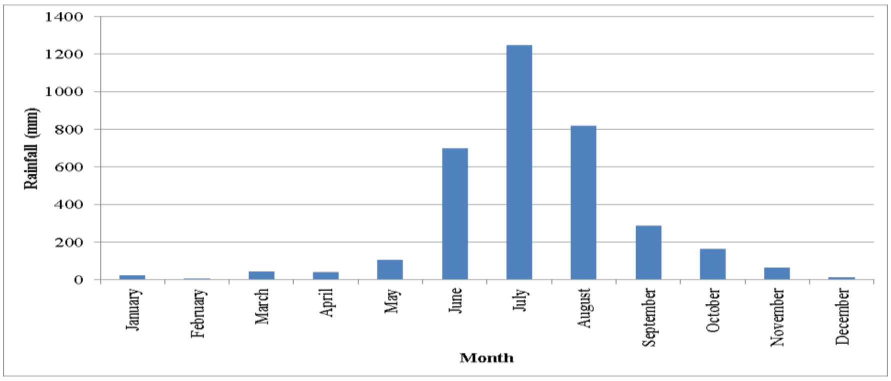


Figure 3 *Seasonal Rainfall Pattern*

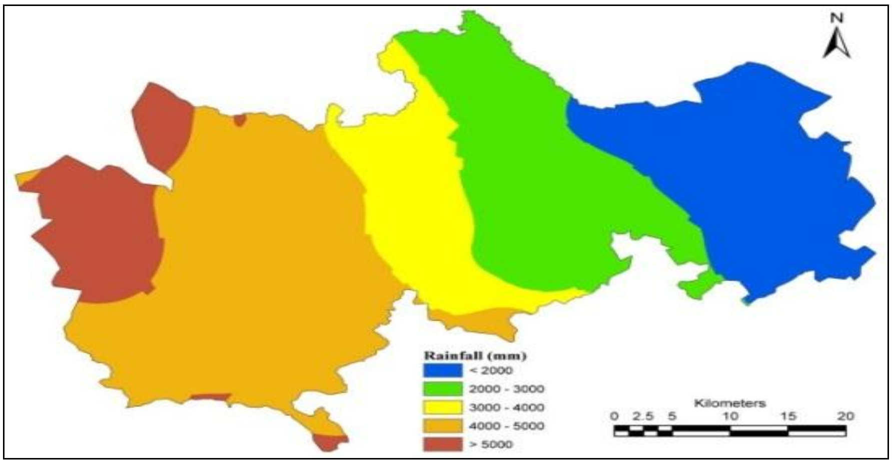


Figure 4 *Spatial Rainfall Pattern*

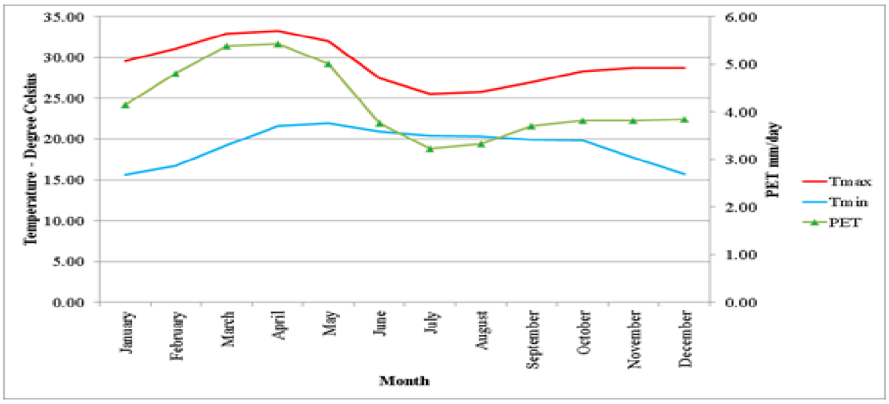


Figure 5 *Seasonal Temperature and PET dynamics*

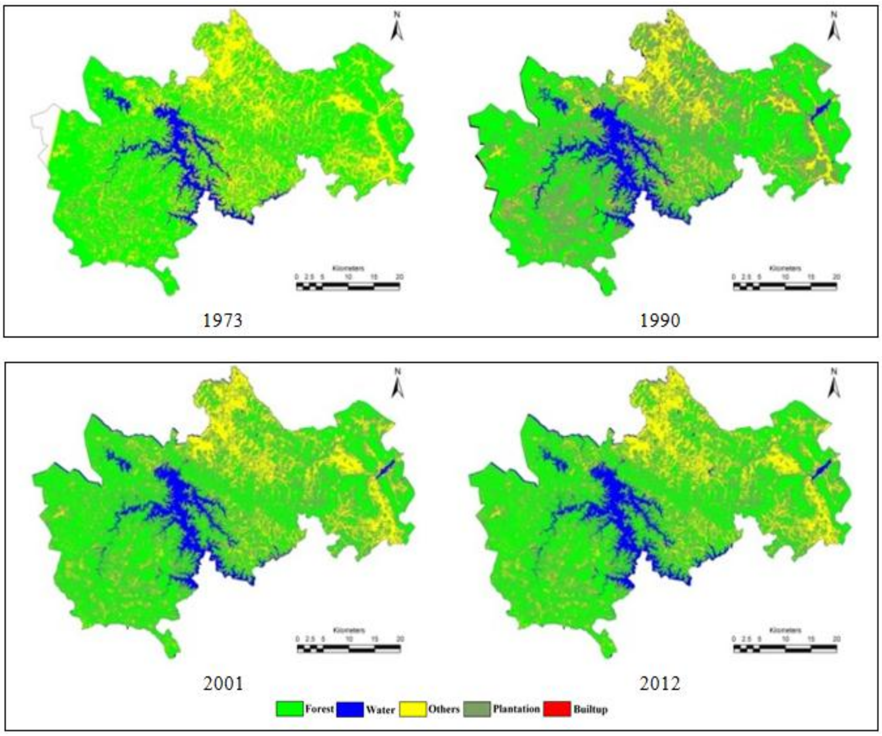


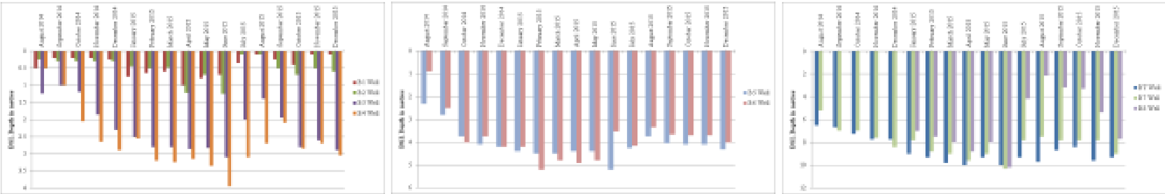
Figure 6 *Land use dynamics*

Table 1 *Land use dynamics of Sagara (all units in %)*

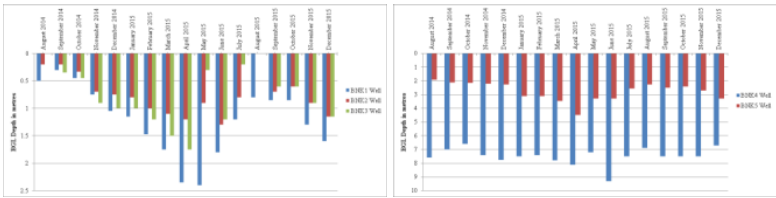
Year	Built up	Forest	Water	Others	Plantations
1973	0.08	57.29	4.90	26.98	10.76
1990	0.11	44.17	7.71	12.13	35.87
2001	0.13	46.03	6.35	10.73	36.77
2012	0.18	42.57	6.81	13.29	37.20

Ground water dynamics were assessed in the wells located in catchments and in the vicinity of Baruru, Lavigere, Pandavarakoldu, Hosagunda, Yelakundali lakes respectively and is depicted in Figure 7. The results indicate the availability of water in wells is correlated with its proximity to forests and lakes, evident from lower deviations. Wells farther away from lakes and also forested catchments, had poor ground water table, indicating the lower quantum of water in the well with large variations across seasons.

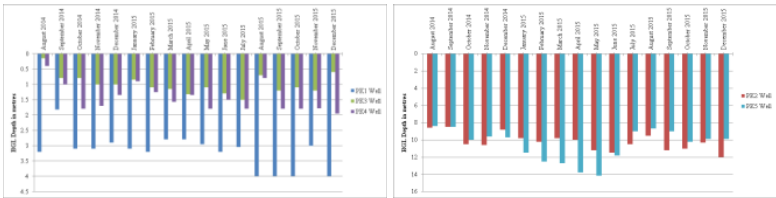
Discharges were measured using area velocity method at Varadamoola, Bilisiri, Hulkodu, YenneHole and Varada are presented in Figure 8. Discharges were normalized and compared across seasons w.r.t catchments. Results indicate streams at Hulkodu (i.e., sacred grove with pristine evergreen forest cover) were perennial with higher water yield during post and pre monsoon periods compared to other (with degraded landscape and mixed land use types). Intermittent stream flows of 7 to 11 months at Varadamoola, Bilisiri, Yennehole and Varada confirm the silent role played by native vegetation in sustaining water in streams. Average seasonal flow for each of the gauged streams were quantified and compared as depicted in Figure 9 and Table 2, Comparative assessment of the 5 gauging stations showed that Hulkodu had richer water resource throughout with nearly 5 times higher availability in the post monsoons and 10 times higher availability in the pre monsoon (Table 2).



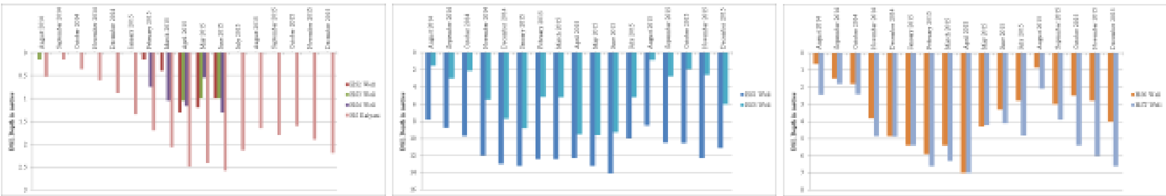
a. Baruru



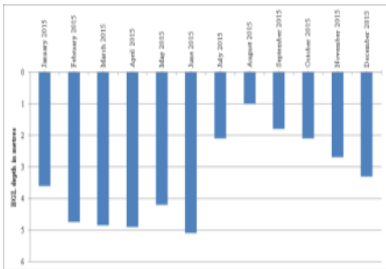
b. Lavigere



c.Pandavarakodlu

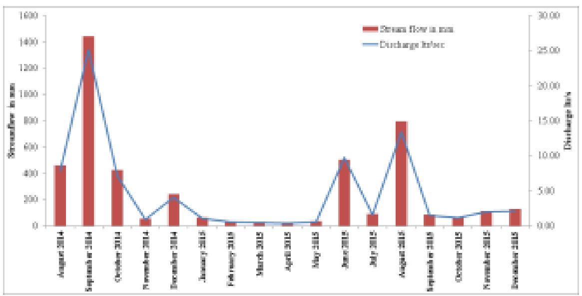


d. Hosagunda

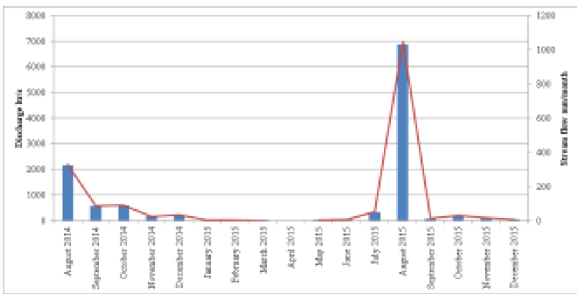


f. Yelakundali

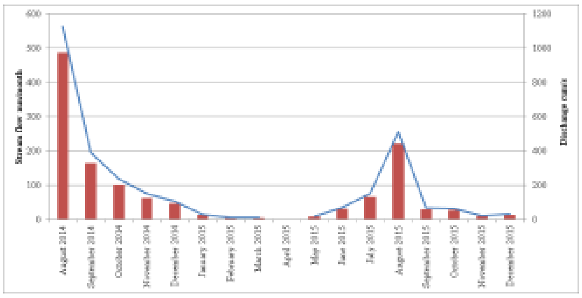
Figure 7 *Ground Water Dynamics*



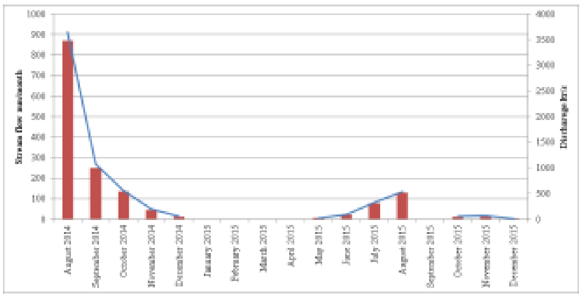
a. Hulkodu



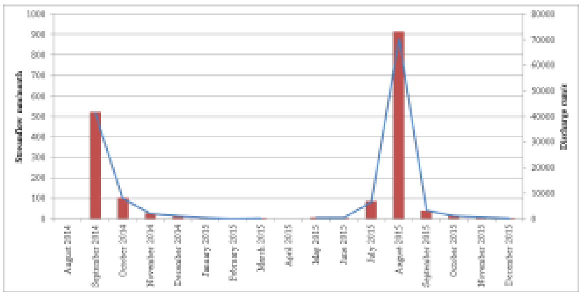
b. Bilisiri



c. Varadamoola

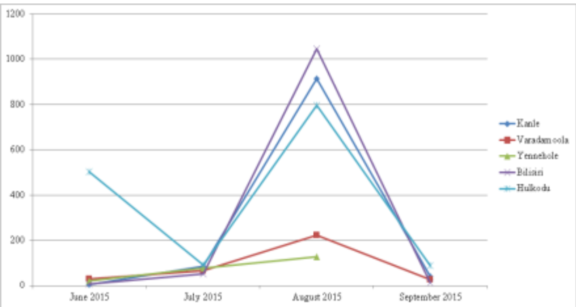


d. Yenneholé

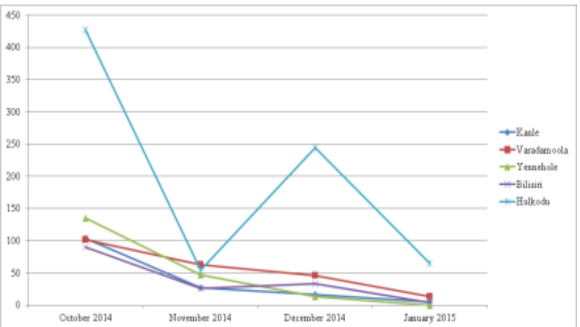


e. Varada River (at Kanle)

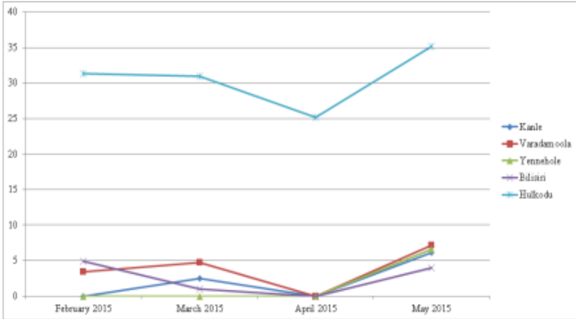
Figure 8 *Stream flow Dynamics*



a. Monsoon



b. Post Monsoon



c. Pre Monsoon

Figure 9 *Comparative assessment of stream flows*

Table 2 *Comparative assessment (all units in mm)*

Season /Watershed	Monsoon	Post Monsoon	Pre Monsoon
Kanle	261.00	25.68	2.15
Varadamoola	165.97	38.82	3.80
Yennehole	269.44	32.17	1.66
Bilisiri	256.03	29.67	2.46
Hulkodu	563.90	157.04	30.62

5. Conclusions

Hydrological and land cover status investigations in select streams of Sagara taluk emphasise the role of native vegetation (in the respective watershed) has aided in ensuring sustainability of water, evident from the presence of perennial streams. While, streams with degraded watershed regions were predominantly seasonal with less quantity of water. Temporal remote sensing data with GIS effectively aided in assessing the landscape structure. Land use changes during 1973 and 2012 show an increase in plantation from about 10.7% to 37.2% at cost of native forests (declined from 57.3% to 42.5%). Hydrological analysis in the catchments proved that presence of pristine forest cover in the catchment are responsible for streams being perennial and also higher water yield (> 5 times compared to degraded landscapes) even during the non-monsoon season. Similarly ground water table with lower deviations (< 1.2 metre deviation), were in case of wells with Lakes in the upstream, highlights the role of lakes in marinating ground water levels. This study emphasise the need for holistic approaches in monitoring as well as management of water bodies in the region.

6. Acknowledgements

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