Integrated Studies on Tank Catchment Management Using Remote Sensing and Geographical Information System

(A case study for Byramangala tank catchment, Ramanagaram district, Karnataka, India)

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***Abstract* - Water is the basis of life on earth. It is the main component of the environment and an essential element for human life. Water is also fundamental for sustaining a high quality of life and for economic and social development. But the essential resource is under threat. Increasing demand and untreated waste water discharge aggravates the stress on water bodies. It now appears that one of the main factors limiting the future economic and human development will undoubtedly be water.**

Lakes and reservoirs are vital parts of fresh water ecosystems of any country. The water quality of a lake is a reflection of the condition of its catchment. The intensive agricultural practices and landuse changes due to residential development in the catchment has reduced the inflow into these reservoirs. The lakes and reservoirs, all over the country without exception, are in varying degrees of environmental degradation.

The study area viz., Byramangala tankcatchment has an areal extent of 340 sq.km. It is encompassed by East longitude 77^0 23'45"- 77^0 34'16" and North latitude 12^0 45'00"- 13^{0}02' 40"covered in the survey of India topographic maps No. 57 H/5, H/9 and G/12 of scale 1:50000. The paper discusses the integrated catchment studies for better management of reservoir. The physico-chemical and bacteriological analyses of surface and ground water samples in the reservoir and its catchment reveal that water is polluted at certain locations. Water samples were analyzed for irrigation requirements. USSL diagram and Piper trilinear diagram were plotted for the classification of water samples. Spatial distribution of water quality parameters was carried out using GIS Arc-Info software. Remote sensing data are used for mapping land use and land cover. Physical and chemical analyses of soil samples in the catchment area reveal low fertility index in certain locations, Morphometric analyses were carried out for the entire catchment to determine the linear, areal and relief aspects of the catchment. Double-ring infiltrometer was used for field infiltration measurements. Evapotranspiration studies were carried out using Penmen-Monteth method. Soil erosion potential zone mapping was done using Universal Soil Loss Equation (USLE) which shows severe erosion at certain locations in the catchment area. Estimation of runoff was carried out using SCS-Curve number method using GIS. The Integrated Reservoir Management approach will be an effective tool for sustainable management of lakes and reservoirs. The paper also discusses various management plans for effective governance of reservoirs through integrated reservoir catchment management approach.

Keywords:- Reservoir catchment, Water and soil quality, Soil erosion, Remote sensing and GIS

INTRODUCTION

Many of the present cities, earlier emerged as settlements, along water bodies. The relation between settlements and water is unique and important. The paradigm here is water and is considered a source, which sustains life, nurtures occupations and supports religious beliefs. The water bodies in an urban set up include the rivers, streams, nallahs, lakes, tanks, wells, etc.

Lakes are vital parts of fresh water ecosystems of any country. A fresh water lake when maintained free from pollution can offer many beneficial uses in an urban area. Urban lakes more commonly act as thermal cooling, reaction centres and de-stressing points in the highly-stressed urban life. Nowadays due to pressure from activities like urbanization, industrialization, as well as the asthetical beauty of the water body, the commercial value of the surrounding area is improved. Lakes provide life to various forms of aqui flora and fauna livelihood for fishermen community, food for the local populace, pollution sink, ground water recharge leading to rise in the water table and as flood mitigators. The urban population can free themselves from the polluted urban air and find solace in the cool air by the lake side and relax in recreational activities such as swimming, boating, fishing and strolling along the lake shores.

The ill-effects of neglecting catchment management have caused urban ecological imbalance, pollution, unhygienic conditions, and floods during rains. The trends of development and increased land demands have caused encroachment of tank beds, sewage disposal into tanks and nallahs. As a result of increased population growth, intensified use of surface waters exploitation of adjoining lands and properties, and other human pressures, inland lakes increasingly are being threatened.

Restoration means returning of an ecosystem to a close approxiamation of its condition prior to disturbance. This ensures that the ecosystem structure and function are recreated or restored, and that natural dynamic ecosystem processes operate effectively again. The physical, chemical and biological integrity of surface water is achieved by-correcting nonpoint source pollution problems and restoration of all types of habitats with priority to the habitats of endangered species. The most wide spread problems facing lakes in Bangalore are sewage from domestic sector, effluents from industrial sector (point sources), and agricultural nonpoint runoff of silt and associated nutrients and pesticides. This has led to eutrophication, due to excessive inputs of nutrients and organic matter. Hydrologic and physical changes and siltation from catchment activities have resulted in special decline. Lakes are sinks for incoming contaminants that recycle and maintain the impaired conditions. There is an urgent need to take up the restoration of lakes.

Lake revival/rejuvenation/restoration is a much talked about subject in the recent times. Lakes are being destroyed by putting the lake land for different uses in its entirety and the peripheral area encroached upon or the inlet valleys changed/diverted/destroyed.In case the lake land is untouched it is used as a dumping yard for the solid wastes/waste water (sewage, sullage)/effluent from the urban developments in the catchments of the water body.

The above factors hassled to either loss of the lake in its entirety or reduction in the area of the water body or the lake being deprived of aquatic life and choked with aquatic weeds leading to depletion of dissolved oxygen and release of obnoxious gases due to anaerobic reaction in the lake water. Mosquitoes breeding leads to various vector diseases on the surrounding areas of the lake.

Due to inadequate infrastructure facilities for waste disposal in the urban areas the urban lakes get polluted due to there natural topography and as collection points for the waste from the haphazard urban settlements. As a result of this and a number of other compounding factors most of the urban lakes are getting degraded beyond the point of recovery. Encroachments, accumulation of silt, weed infestation, discharge of domestic sewage, industrial effluents are the main causes for degradations of these lakes. Declining water quality, nuisance algae blooms, excessive weed growth, deteriorating fisheries, sediment infilling, eutrophication, contamination, bund erosion, water-use conflicts, impaired scenic qualities and upward appreciation of property values around the lake due to rapid urbanization are common problems being experienced by lake overseers as a result of human activities. These and other critical problems are avoidable. The lakes are prone to the causes of deterioration and degradation.

STUDY AREA

The Vrishabhavati a fourth order upstream river drains an aerial extent of 545 sq. km before it joins Suvarnamukhi river at Bhadragundamadoddi (North latitude 12^0 39' 40" and East longitude 77^0 25' 00") of Kanakapura taluk. The river Suvarnamukhi is one of the major tributaries of the river Arkavati in Karnataka, part of the Cauvery Basin. But, the study area is scaled down to the Vrishabhavathi stream system terminating at Byramangala tank. This has an aerial extent of 340 sq.km. It is encompassed by East longitude 77^0 23'45"-77^0 34'16" and North latitude 12^0 45' 00"- $13^0$02' 40". The topographic coverage of the area is in the survey of India topographic maps No. 57 H/5, H/9 and G/12 on scale 1:50000.

Fig 1 Satellite image of Byramangala tank

Byramanagala tank is located in Bidadi hobli of Ramanagaram distsrict. The catchment area includes Bangalore urban areas which comes under Bhruhauth Bangalore Mahanagara Palike and villages of Bangalore rural area, Rajajinagar Industrial area, Peenya Industrial area and Kumbalgod Industrial area and the Bidadi Industrial are located in this tank catchment area. The Vrishabhavathi river which runs in the catchment, carries urban /domestic sewage, industrial sewage and storm water from urban, semiurban and rural areas. The agricultural wastes resulting from intensive farming in the rural areas of the catchment also enter the tank. The study reveals that the tank is highly polluted and the sediments are also contaminated. The annual rainfall data of 789mm and average monsoon rainfall of 551mm were collected from the records of the rain gauge installed at Byramangala. The minimum annual inflow to the tank is $23.92M^3$ and maximum annual inflow is $114.5x10^9$ M^3. The withdrawal from canal is recorded as 34.97M m^3 cum and the reservoir losses are noted up to 5.42M m^3. The details of tank indicated FRL as $24.10Mm^3$, live storage at FRL as $22.01Mm^3$, dead storage at sill level of sluice as 2.09Mm3 and water spread area at FRL as 430.25ha. The spillway of tank is of broad crested type located at right flank. The length of spillway is of 150.5m, its flood lift is recorded as 0.9m and discharge capacity is of 230cumecs.The bund constructed for Byramangala tank is of earthern type and its height at the deepest point is recorded as 22.85m. The length of the bund is recorded as 2286m and top width of the bund as 3.66m.

The MWL of the tank is noted as 32.9m its FRL as 32m and its sill level as 22.85m.The Reservoir is provided with 2 channels,viz., Left Bank canal and Right bank canal. The left bank canal is 26.4 km in length and Right bank canal is 8.4 km in length having a command area of 1330 ha and right bank canal is 8.4 km having a command area of 444ha. Reconnaissance survey reveals that the soil in the command area is polluted with the application of sewage water.

Fig 2 Polluted water flowing through the left bank canal
Studies on Geology and Geomorphology of the study area

At the head reaches, the Southerly flowing Vrishabhavathi flows over the laterite profile. From the sources of origin upto N13^0 parallel, the stream flows on deep chemically weathered saprolite profile. Downstream of N 13^0 parallel and up to the road bridge to the SSE of the Kumbalagodu (E 77$^°$ 27' : N 15$^°$52'20")it flows over the banded gneissic suite of formation. Beyond Kumbalagodu, the stream cuts and flows through granitic gneiss dipping steep easterly. On the left bank, the granitic gneisses are traversed by parallel system of basic dykes which are trending NW – SE. In the lower reaches of the stream near Byramangala tank, these basic dykes cross over to the right bank with well marked evidence of off – setting , suggesting that this span of the stream flow is trained by NE – SW system of faulting. The water divide separating the Vrishabhavathi from the Arkavati river system is marked by regional N-S fractures that are implaced by dykes. The main river of Vrishabhavathi finds its source on the South-East slope of topographic point 926m to the NNE of Peenya. It flows southwards through Rajajinagar of Bruhat Bangalore Mahanagara Palike (BBMP). The urbanization in the area has distorted the flow course of the first and the second order streams and also the original course of Vrishabhavathi River in certain pockets. The present setting of the main stream has a definite landscape. It maintains a well carved landscape in the downstream and gets drained by subsidiary drainages. Prominent among these tributaries is the 'Nagarabhavi torai'. Distortion of the original drainage course at upstream of Kumbalagodu owing to urbanization has resulted in not exhibiting or well integrated spatial pattern of the stream system. Distinct evidence of the stream system having been structurally controlled is noted in the downstream part of Kumbalagodu. The main stream has carved out a deep rock cut valley between Kumbalagodu and Ampapura. The land use and land cover map is shown in Fig 3.The drainage map is shown in Fig 4

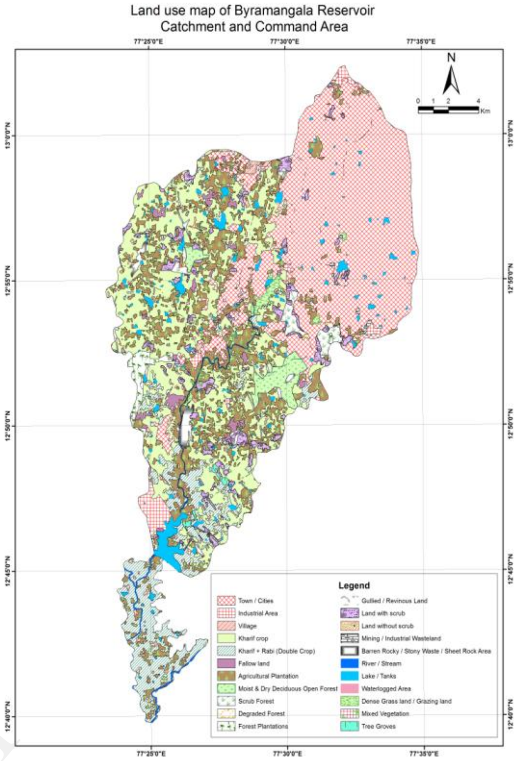

Fig 3. Land Use and land Cover Map of Byramangala tank Catchment and Command area.

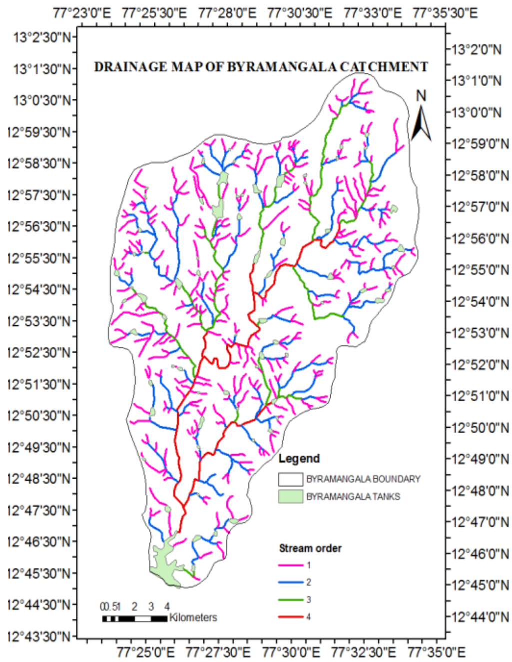

Fig 4. Drainage Map of Byramangala catchment area.

Methodology

The physico-chemical and bacteriological analyses of surface and ground water samples in the tank and its

catchment reveals that water is polluted at certain locations. Water samples were analyzed for irrigation requirements and USSL diagram and Piper trilinear diagram were plotted for classification of water samples and spatial distribution of water quality parameters is carried out using GIS Arc-Info software. Remote sensing data were used for mapping land use and land cover. Physical and chemical analyses of soil samples in the catchment area reveal low fertility index in certain locations, Morphometric analyses were carried out for the entire catchment to determine the linear, areal and relief aspects of the catchment. Double- ring infiltrometer was used for field infiltration measurements. Evapotranspiration studies were carried out using Penmen-Monteth method. Soil erosion potential zone mapping is done using Universal Soil Loss Equation (USLE) which shows severe erosion at certain locations in the catchment area. Estimation of runoff is carried out using SCS-Curve number method using GIS.

MORPHOMETRIC CHARACTERISTICS OF THE CATCHMENT AREA

The morphometric analysis of drainage basin and its stream channel system can better be achived through the measurements of linear, areal relief aspects of the channel network and contributing ground slopes.Drainage network map and slope maps were prepared using Survey of India

Sl No	Catchment Parameters	Units	Values
1	Catchment Area (A)	Sq.km	340.13
2	Perimeter of the Catchment (P)	km	80.01
3	Catchment Stream Highest Order		4
4	Maximum Length of catchment	km	35.28
5	Maximum width of Catchment	km	18.55
6	Cumulative Stream segment		476
7	Cumulative stream length	Km	432.26
9	Drainage density	km/Sq.km	
8	Length of overland flow	km/ Sq.km	1.27
10	Constant of channel maintenance	Sq.km/km	0.71
11	Stream frequency	No/Sq.km	1.40
12	Bifurcation ratio		4.15
13	Length ratio		1.86
14	Form factor		0.53
15	Shape factor		3.66
16	Circularity ratio		0.82
17	Elongation ratio		0.59
18	Compactness coefficient		1.22
19	Total Catchment relief	Km	0.13
20	Relative Relief		0.001
21	Ruggedness Number		0.18

(SoI) toposheets on 1:50,000 scale. The various morphometric parameters are presented in Tables1 and 2.

Table 1.Catchment morphometric characteristics

Table2.Drainage characteristics of the catchment

Stream order	1	2	3	4
No. of Segments N_u	339	109	23	5
Total Length (Km) L_u	218.2	1202.	51.23	46.22
Bifurcation ratio (R_b)	-	3.11	4.74	4.60
Mean Length (Km)M_{sm}	0.64	1.10	2.23	8.53
Cumulative Length(Km) $\sum L_u$	339	448	478	476
Stream Length Ratio R_L	-	0.58	0.50	0.26
Drainage Density (Km/Sq.km) D_d	1.27			

The elongation ratio of the catchment is 0.59 which is associated with strong relief and steep ground slopes. The length of overland flow is 1.27 km/km^2 which indicates surface runoff entering the stream will be quicker. The value of drainage density is 1.27 which indicates the catchment area is coarse textured. The value of constant of channel maintenance is 0.71 km^2/km which confirms the presence of structurally controlled stream system within the catchment.

WATER AND SOIL QUALITY ASPECTS.

Ground water samples were collected from the catchment and command areas of the tank and surface water were collected from the lakes and the reservoir durning April 2011,August2011 and January 2012. Physico-chemical and biological analysis was carried out for the water samples collected from various locations using standard procedures recommended by APHA-1994. The results can be used for classifying water for irrigation requirements and drinking water purposes.

The suitability of ground water for irrigation purposes depends upon its mineral constituents.The general criteria for judging the quality are (i)Total salt concentration as measured by electrical cponductivity (ii)Relative proportion of sodium to other principal cations as expressed by SAR,(iii) Soluble sodium percentage.(iv)Residual sodium carbonate and (v) Residual sodium bi carbonate.

Wilcox (1995) classified groundwater for irrigation purposes based on percent sodium and electrical conductivity.Eaton(1950) recommended the concentration of residual sodium carbonate to determine the suitability of water for irrigation purposes. The US Salinity Laboratory of Department of Agriculture adopted certain techniqes based on which the suitability of water for agriculture is explained.

$$\mathbf{\%Na = (Na^{+}\ X\ 100/\ (Ca^{+2} + Mg^{+2} + Na^{+} + K^{+})}$$

where the quantities of Ca, Mg, Na and K are expressed in milliequivalents per litre(epm).

The classification of water samples with respect to soluble sodium percent is shown in Table 3. In water having high concentrations of bicarbonate,there is a tendency for calcium and magnesium to precipitate as water as the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate. RSC is calculated using

$$\mathbf{RSC= (HCO_3^{-} + CO_3^{-2}) – (Ca^{+2} +Mg^{+2})}$$

where all the ions are expressed in epm

According to the US Department of Agriculture, water having more than 2.5epm of RSC is not suitable for irrigation purpose. RSC classification of Water samples of the study area is presented in the Table-4

A better measure of the sodium hazard for irrigation water is sodium adsorption ratio(SAR) which is used to express reactions with the soil. SAR is computed as

$$\mathbf{SAR= Na^{+}/[(Ca^{+2}+Mg^{+2})/2]½}$$

Where all ionic concentrations are expressed in epm

The classification of water samples from the study area with respect to SAR is presented in Table 5. The total concentration of soluble salts (salinity hazard) in irrigation water can be expressed in terms of specific conductance. Classification of water based on salinity hazard is presented in Table 6.

Table 3.Soluble sodium percentage.

Sodium%	Water class	Percentage of Water samples
< 20	Excellent	2.3%
20-40	Good	61.9%
40-60	Permissible	35.8%
>60	Not suitable	NIl

Table 4: Classification of water based on RSC(Residual sodium carbonate)

RSC(epm)	Remarks on water quality	Water samples
<1.25	Good	All the samples belongs to this category
1.25-2.5	Moderate	Nil
>2.5	Unsuitable	Nil

The Physical and chemical analysis of soil samples were carried out at 15 locations as shown in Table8.The chemical analysis of soil samples reveals that soil is deficient in Zn at various locations and having low percentage carbon and available phosphorous.

Table 5: Classification of water for sodium hazard based on USSL Classification

Sodium Hazard class	SAR	Remarks on water quality	Water samples
S1	10	Excellent	Range 1.2 to 4.21 All water samples belongs to this category
S2	10-18	Good	NIL
S3	18-26	Moderate	NIL
S4	>26	Unsuitable	NIL

Table6: Classification of water for salinity hazard

Salinity hazard class	EC (micro-mohs/cm)	Remark on water quality	Water samples
C1	100- 250	Excellent	NIL
C2	250-750	Good	NIL
C3	750- 2250	Moderately good	873-2198 41 Samples (97.6%)
C4	2250-6000	Unsuitable	2545 4 samples (2.4%)
C5	>6000	Highly Unsuitable	NIL

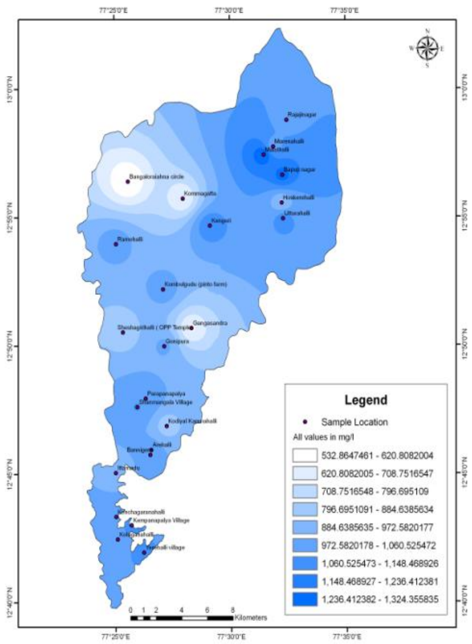

Fig 5 Spatial distribution of TDS in the ground water samples of the tank catchment and command area.

Table 7 Water quality based on irrigation water requirements in the catchment and command area.

Sample no	Sodium Adsorption Ratio	Ca+Mg meq/l	Soluble sodium percentage (SSP) %	Magnesium Hazard meq/l	Chlorides meq/l	Residual Sodium carbonate RSC in meq/l	Permeability Index	Kelley's Ratio
BM-W1	3.3949	5.057	51.6322	0.3172	4.8295	-0.008	73.1237	1.0675
BM-W2	3.5431	4.2905	54.7416	0.3336	4.7731	-0.0065	76.5747	1.2095
BM-W3	3.2234	4.4313	51.9866	0.3007	4.4684	0.0447	74.9099	1.0828
BM-W4	3.1087	4.6015	50.6113	0.3450	4.2173	0.0024	73.6411	1.0248
BM-W5	2.9420	5.5337	46.9312	0.2750	3.9691	-0.0049	69.4808	0.8843
BM-W6	1.5213	7.804	27.8009	0.4258	3.9630	-2.4372	49.2334	0.3851
BM-W7	1.5036	11.0427	24.2390	0.3836	9.8222	-8.2055	35.7952	0.3199
BM-W8	2.9731	8.4636	41.9494	0.5278	4.5248	0.4844	62.4664	0.7226
BM-W9	2.7094	12.274	35.3524	0.3170	7.8430	-2.685	51.6623	0.5468
BM-W10	3.9522	5.4806	54.4159	0.2762	5.5122	0.0018	73.8908	1.1937
BM-W11	1.2096	12.3296	19.5878	0.4330	5.1229	-4.5919	37.7296	0.2436
BM-W12	2.2306	6.2574	38.6701	0.3995	2.9113	0.1265	63.4341	0.6305
BM-W13	2.4992	10.3028	35.5075	0.4822	5.6984	-1.8587	53.6974	0.5506
BM-W14	1.4507	6.9882	27.9568	0.4473	1.4951	0.0021	55.2139	0.3881
BM-W15	1.2603	8.285	23.6412	0.4001	2.3216	-1.3177	47.9686	0.3096
BM-W16	2.3456	9.3809	35.1292	0.5489	4.8662	-1.6326	54.3781	0.5415
BM-W17	1.0955	7.1769	22.4303	0.2567	1.6531	-0.8899	49.5307	0.2892
BM-W18	1.4236	5.1528	30.7217	0.6785	1.7744	-0.002	61.2356	0.4435
BM-W19	2.4735	8.6521	37.2890	0.3195	5.4276	-2.449	55.3410	0.5946
BM-W20	2.6551	8.8645	38.6718	0.3591	5.1450	-1.9025	56.9264	0.6306
BM-W21	2.9635	9.4386	40.5502	0.4227	5.9946	-1.6524	58.1256	0.6821
BM-W22	2.8051	10.9647	37.4614	0.3984	6.5249	-2.4895	54.0659	0.5990

Table8 Results of chemical analysis of soil samples in the Study area.

Sample no	Name of the village	pH	EC mmh os/cm	Organic Carbon	Available Phosphorus (P) Kg/acre	Av. Potash (K) Kg/acre	Available Micro nutrients			
				%			Zn ppm	Cu ppm	Mn ppm	Fe ppm
BM-S1	Byramangala farm	6.9	0.37	0.64 M	70 H	230 H	2.63 S	3.6 S	58.2 S	92 S
BM-S2	Byramangala village	6.0	0.19	0.82 H	8 L	224 H	1.78 S	2.4 S	51.3 S	69 S
BM-S3	Kempanapalya Village	6.5	0.1	0.46 L	9 M	96 M	5.94 S	1.9 S	27.9 S	63 S
BM-S4	Yerehalli village	6.8	0.21	0.67 M	32 H	156 H	2.1 S	3.5 S	53.1 S	107 S
BM-S5	Shanmangala Village	8.0	0.14	0.64 M	10 M	206 H	1.58 S	2.5 S	51.3 S	78 S
BM-S6	Kombulgudu	7.1	0.2	0.6 M	60 H	160 H	12.61 S	9.8 S	50.7 S	72 S
BM-S7	Gonipura	7.9	0.21	0.57 M	15 M	320 H	4.17 S	2.5 S	54.1 S	26 S
BM-S8	Ramohalli	6.9	0.05	0.37 L	4 L	232 H	2.12 S	1.4 S	38.8 S	43.4 S
BM-S9	Gangasandra	6.9	0.04	0.41 L	5L	256 H	3.24 S	1.7 S	45.2 S	21.9 S
BM-S10	Tippur	7.1	0.02	0.25 L	4 L	116 M	1.19 S	1.3 S	32.7 S	20.4 S
BM-S11	Parasanapalya	8.3	0.13	0.53 M	16 M	268 H	1.55 S	3.7 S	47.0 S	8.8 S
BM-S12	Byramangala -2	7.1	0.02	0.21 L	4 L	60 L	2.74 S	0.9 S	29.6 S	25 S
BM-S13	Kaniminike Colony	6.6	0.12	0.40 L	4 L	100 M	1.18 S	2.5 S	44.2 S	33.0 S
BM-S14	Margondanahalli	8.1	0.29	0.61 M	17 M	298 H	4.09 S	2.9 S	64.1 S	28 S
BM-S15	Malathalli	7.9	0.15	0.28 L	7 L	252 H	2.29 S	1.9 S	48.8 S	40.4 S

H-High, L-Low, M-Medium, S-Sufficient, D-Difficient

FIELD INFILTRATION MEASUREMENTS

Infiltration characteristics of soil are very important for scientists, engineers and planners. Hydrologists mostly need infiltration data for the estimation of peak rates and volumes of runoff in the planning of dams, culverts and bridges etc. It is also useful for minimizing the erosional hazards. Most important use of infiltration is to the agriculturists and ecologists who are concerned with the availability of soil moisture in the root zone of crops and plants. Hortons equation is used to characterize the infiltration rate in the catchment area of the present study. Double Ring Infiltrometer is used for infiltration measurements. The Hortons equation is as shown below.

$$f_p=f_c+(f_o-f_c)e^{-kt}$$

where fo is the infiltration rate at the beginning of the storm, fc is the ultimate or final infiltration capacity attained when the soil profile becomes saturated, fp is the infiltration capacity at time't' and k is an empirical constant. Horton suggested the above equation for separating rainfall into rainfall excess and infiltration. This equation is applicable only when the rainfall rate exceeds fp. The constant k depends upon both the basin and rainfall characteristics; fo depends upon initial moisture condition of the basin and fc varies depending upon the season.

Table 9 Field infiltration studies

Sl no	Location	Horton's equation
1	Kodial Karenahalli	$F = 8.28+76.709\ e^{-17.762}$
2	Kaniminike	$F = 7.80 +9.846\ e^{-8.014}$
3	Gonipura	$F = 8.18 + 14.373e^{-8.9023t}$
4	Jnanabharathi	$F = 5.94 + 7.108e^{-7.0549t}$

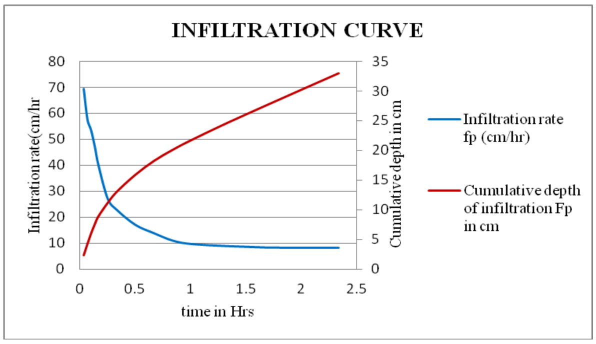

Fig 7 Infiltration Rate curve for Kodiyal Karenahalli

EVAPOTRANSPIRATION MEASUREMENT

Evapotranspiration (ET) includes water that is needed for both evaporation and transpiration.ET is defined by the US Geological Survey as the water lost to the atmosphere from the ground surface, evaporation from the capillary fringe of the ground water table, and the transpiration of groundwater by plants whose roots tap the capillary fringe of the groundwatertable. Evapotranspiration is considered to be one of the key elements in the water cycle that needs to be quantified to achieve better water management. In the present study Penman-Monteith method FAO-56 is used for the computation of Reference evapotranspiration.The max and minimum values of monthly evapotranspiration for 3 locations for past 5years is shown in Table 10. The FAO-56 Penman-Monteith Equation for computation of reference evapotranspiration is shown below.

$$ET_o=\frac{0.408\Delta(R_n-G)+\gamma\frac{900}{T+273}U_2(e_s-e_a)}{\Delta+\gamma(1+0.34u_2)}$$

Table 10 Monthly ET_Ovalues in mm/month for various locations

Location	Byramangala		Kanimineke		Margondahalli	
Year	Min	Max	Min	Max	Min	Max
2008	84.05	128.24	84.1	128.25	84.16	128.28
2009	74.68	122.42	74.72	122.47	74.90	122.44
2010	69.78	128.31	69.81	128.36	69.79	128.33
2011	83.85	124.29	83.89	124.33	83.86	124.31
2012	86.94	128.86	86.99	123.91	86.96	123.88

(All units are in mm)

SOIL EROSION STUDIES

The soil loss in the Byramangala catchment area is estimated using Universal Soil Loss Equation (USLE).The inputs for the model such as soilmap, landuse landcover map and slope map were derived from satellite images of IRS PAN+ LISS –III after suitable ground truth studies.The slope map is prepared from SRTM data. Following formula is used in computation of Soil loss.

A=RKLSCP

where, A is the computed soil loss in tons/hectare/year, R is the rainfall factor which is also called as erosion index, EI which is taken from Isopleths for the present study it is taken as 250, K is the soil erodibility factor which depends on the soil type. For the present study the weighted average value is calculated as 0.31.Lis the slope length factor and S is the slope steepness factor and the value of LS for the present study is calculated using Arc-Info GIS software. C is the crop management factor which is derived using land use and land cover map. P is the conservation practice factor. Since the study area comprises of field bunds the conservation factor is taken as unity.The above map layers were overlayed using Arc-Info GIS software and soil loss is computed in the catchment The soil loss in the catchment varies between 0 to 50 tonns per hectare per year. The soil erosion map is shown as Fig-8.

RUNOFF ESTIMATION USING SCS-CN METHOD

The SCS Curve Number method (USDA, 1977) is the most enduring method for estimating the volumes of direct,i.e., surface runoff from ungauged small catchments. In the present study SCS Curve Number method is used to estimate the surface runoff. The weighted curve number is derived by superimposing Hydraulic soil Group (HSG) classification map and land use and land cover map using GIS Arc-Info Software. The weighted Curve number of 71 obtained for the catchment is used to estimate the Runoff using the following equation.

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$S = \left|\frac{25400}{CN} - 254\right|$$

where Q is the runoff in mm, P is the Rainfall in mm and S is the maxium soil water retention parameter and CN is the weighted curve number for the Catchment. The seasonal runoff is estimated using the seasonal rainfall data. For monsoon rainfall of 589mm for the year 2012 the estimated runoff is 124.03mm.

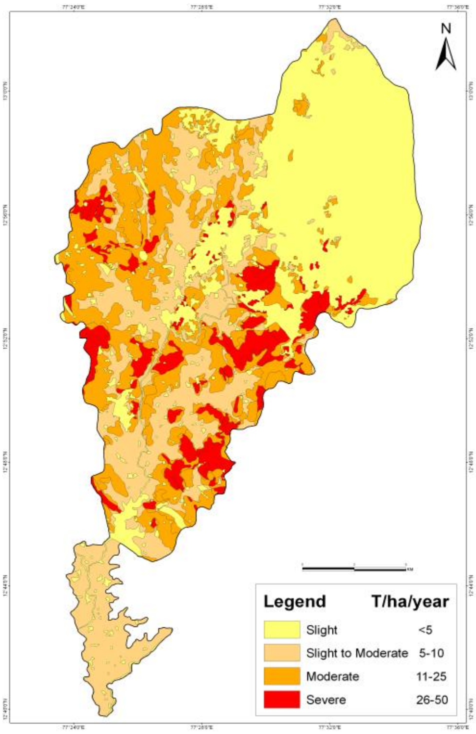

Fig 8 Soil erosion map of Byramangala tank catchment.

CONCLUSIONS

The results of the morphometric analysis help in priotorising the sub-catchments. The morphometric characters derived will help better management of the reservoir catchment which further helps in the management of the reservoir. The results of analysis of water and Soil samples at various locations of catchment area revel that water is not suitable for irrigation and potable purpose and soil samples at various locations are deficient of Zinc, low organic carbon and low phosphorous, hence precautions should be taken to identify pollution potential zones and take preventative measures. From the results of field infiltration studies it is concluded that soils of the study area have medium to high infiltration capacities. It is observed from the computations of ET_O by Penman-Monteith method for 5 years duration is between 69.78mm/month to 128.86 mm/month. From soil erosion studies it is concluded that very severe erosion is observed in the catchment area hence proper measures are to be taken to prevent further soil erosion, which also helps in reduction of sediment upload into the reservoir. Thus SCS-CN method is an effective tool for estimating the runoff into the reservoir and also helps to analyse the reasons for reduced inflow into the reservoirs due to the various land use changes. The remote sensing and GIS is an effective tool for management of tank catchment which in turn helps in the governance of reservoir.

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