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RESEARCH ARTICLE

MORPHOMETRIC PARAMETERS AND RUNOFF INFILTRATION BASED PRIORITIZATION OF KADALUNDI RIVER BASIN, KERALA, INDIA USING GIS

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ABSTRACT

Morphometric analysis of a river basin is useful for understanding the hydrological and geomorphological behavior of a river basin. The hydrological and geomorphological characteristic of any river is closely related to its morphology indicating its shape, drainage pattern, stream order, bifurcation ratio etc. Each and every river basin has its own unique morphometric characteristics which make it differ from other river basins. The present study is based on the morphometric analysis of Kadalundi river basin using geospatial technology. Kadalundi river basin is a sixth order stream. The drainage pattern is complex with considerable variation in spatial arrangements, which are controlled by topography, slope, rock type and structural deformations. There exist a relationship between the morphological characteristics of a basin and its runoff potential and infiltration capacity. This relationship is utilized to understand the hyrological potentiality of Kadalundi river basin. Based on the runoff potential and infiltration capacity the sub basins are categorized as area of low, moderate and high priority. This study is more useful for planning and implementing river basin development plan in Kadalundi river basin.

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INTRODUCTION

The morphometric study of a river basin helps in the estimation of dynamic characteristics of a river basin. River basin is the basic logical unit considered to study the geo-hydrological behavior of a river system, which is distinguished from its neighboring basin by ridges and highlands that form divides. The nature of stream flow in a basin is not only dependent on the function of its hydrologic input, but also based on the physical, vegetative and climatic characteristics of that particular river basin. Hence in order to have an overall assessment of a river basin, morphometric analysis is the preliminary study carried out in any research work considering river basin as a study area. Basin morphometric analysis is a method of mathematically quantifying different aspects of a drainage basin. It is the most common and most efficient technique to have a systematic study of not only the geometry of a river basin, but also to know about its linear, areal and relief aspects (Strahler 1964). The basin morphometric analysis is an important study in any hydrological investment such as assessment of groundwater potential, groundwater management, pedology and environmental assessment. Geomorphologists and hydrologists have recognized that there exists close relationship between runoff and geographical characteristics of the river basin. Several important hydrologic phenomena can be correlated with the physiographic characteristics of drainage basins such as size, shape, slope of drainage area, drainage density, size and length of the contributories etc (Hajam *et al*., 2013). There are several studies conducted to study basin morphometry and its related hydrological, geomorphological and environmental assessment. Morphometric studies in the field of hydrology were first initiated by Horton (1945) and Strahler (1950). They incorporated several quantitative morphometrical parameters such as stream segments, basin length, basin perimeter, basin area, altitude, volume, slope and profiles of the land which reflect the nature of development of the basin. This modern approach of quantitative analysis of drainage basin morphology was given several inputs by Horton, the first pioneer in this field. Horton's law of stream length indicated that a geometric relationship existed between the numbers of stream segments in successive stream orders. Similarly the law of basin areas indicated that the mean basin area of successive ordered streams formed a linear relationship when graphed. These laws of Horton were subsequently modified and developed by several geomorphologists like Moriswara (1957, 1958), Strahler (1952, 1957, 1958 and 1964), Schumm (1956), Scheidegger (1965), Shreve (1967), Gregory (1968) and Walling (1973). Subsequently stream profile analysis and

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stream gradient index by Hack (1973) added another dimension in morphometric analysis. Books by Keller and Pinter (1966) further propogated the idea of morphometric analysis. With the application of Remote Sensing and GIS, the morphometric analysis of river basin in remote areas could be easily carried out. Hence the fastly emerging Spatial Information Technology – Remote Sensing, GIS and GPS - are effective tools to overcome most of the problems of land and water resource planning and management on the account of usage of conventional methods of data process.

Study area

The Kadalundi river is formed by the confluence of its two main tributeries, the Olipuzha and the Veliyar. The Olipuzha takes its origin from the Cherakkombhanmala and the Veliyar tributary from the forests of Eratakombanmala. The total length of the river is 130 Km, with a drainage area of 1099 sq. km. The river flow towards Chaliyar and joins into the Arabian Sea at about 5 Km south of Chaliyar river. The Pooraparamba river, a small stream, is also included in this basin, as its length is only 8 km with a drainage area of 23 sq.km. The estuary is situated in Kadalundi and Vallikunnu panchayats. The total drainage area of the basin is 1122 sq. km. Fig. 1 shows the location map of Kadalundi River Basin.

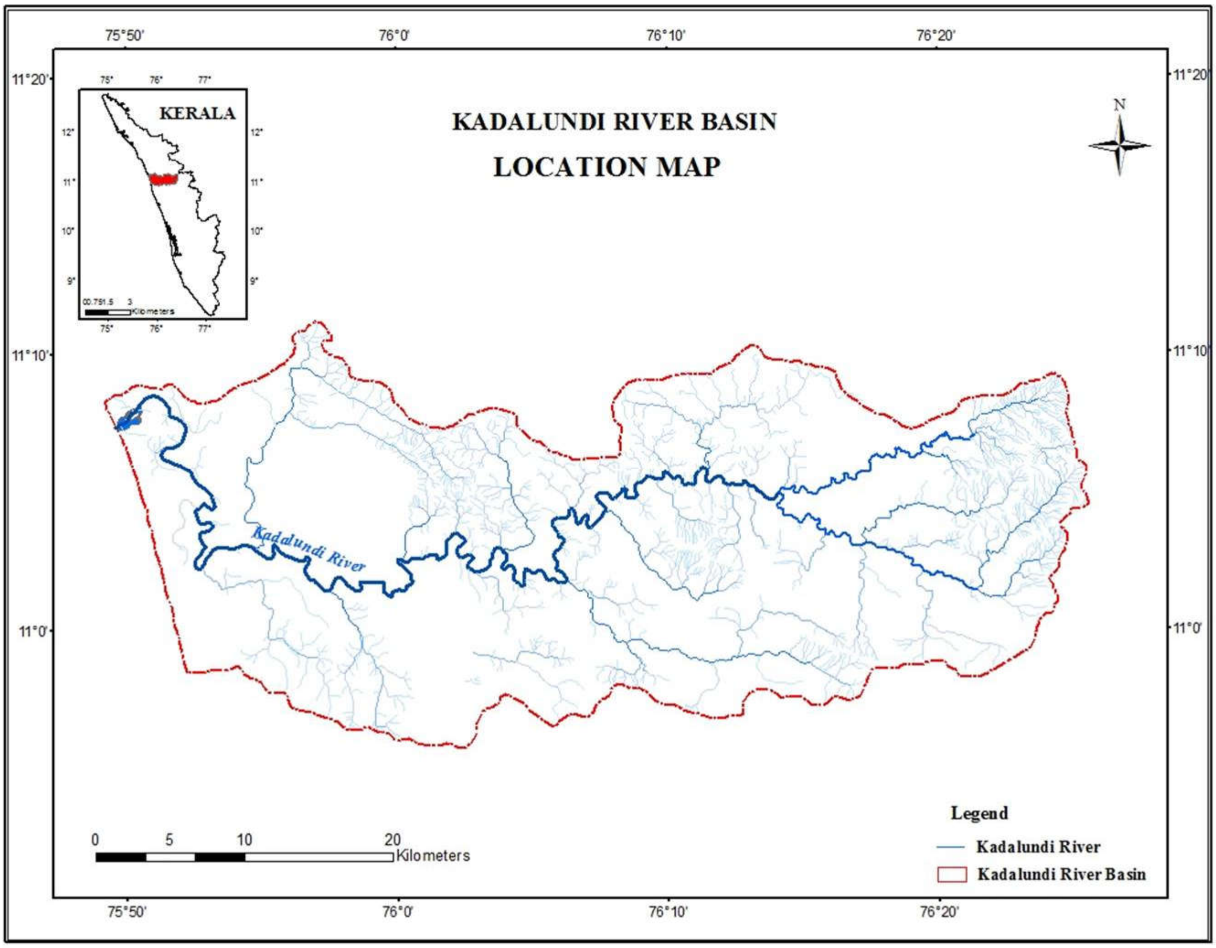

Fig. 1. Study area

MATERIALS AND METHODS

In the present research work both primary and secondary data are used. The Survey of India (SOI) topographic sheets of (49 M 14, 49 M 15, 49 M 16, 58 A 2, 58 A 3, 58 A 4, 58 A 6, 58 A 7, 58 A 8, 58 A 10, 5858 A 11) of scale 1: 50,000 are used to derive the outline boundary of Kadalundi river basin, drainage, contours etc. In this study, the quantitative analysis of morphometric characteristics, namely basin area, basin perimeter, basin length, number of stream orders, stream frequency, stream length, mean stream length, stream length ratio, bifurcation ratio, length of the overland flow, drainage density, drainage texture, form factor, circularity ratio, elongation ratio, relief ratio, basin relief, relative relief and ruggedness number are carried out on the Kadalundi river basin. The following Table 1 shows the morpometric parameters used for the study of morphometric characteristics of Kadalundi river basin. Based on the values derived for parameters the level of runoff potentiality and infilteration capacity is assessed and based on which each sub basin is ranked based on low, moderate and high priority.

RESULTS AND DISCUSSION

Fig 2 shows the map of stream ordering done for Kadalundi river with the help of ArcGIS 10.1 software. Based on the contour placement and the stream flow, the sub basins within the Kadalundi river basin are delineated. Since the number of sub basins are large at 1st and 2nd order stream level, only basins with higher than 3rd order category are considered for the present analysis. It should be noted that a discussion on higher order sub basins includes all lower order sub basins coming under it. For example there are three 5th order sub basins namely Olipuzha, Veliyar and Ammanikad todu sub basins. In Olipuzha sub basin itself there are 143 1st order streams, 36 2nd order streams, 11 3rd order streams and 43 4th

order streams. However for analytical purpose all these are included as a single unit and only overall parameter value is considered and explained. The same is applicable for the eight 4th order sub basins as well as eleven 3rd order sub basins. Fig. 3 shows the 3rd order, 4th order and 5th order individual sub basins in Kadalundi river basin which are considered for analysis in the present study. The Kadalundi river basin is a 6th order river basin, with dendritic stream pattern.

Runoff potential and infilteration capacity based ranking of 22 sub basins

A detailed study of morphometry can be applied in analyzing number of hydrogeomorphic processes. Here the previous morphometeric parameters are used to identify the runoff potential and infiltration capacity of different 5th order, 4th and 3rd order sub basins in Kadalundi river basin. There exist

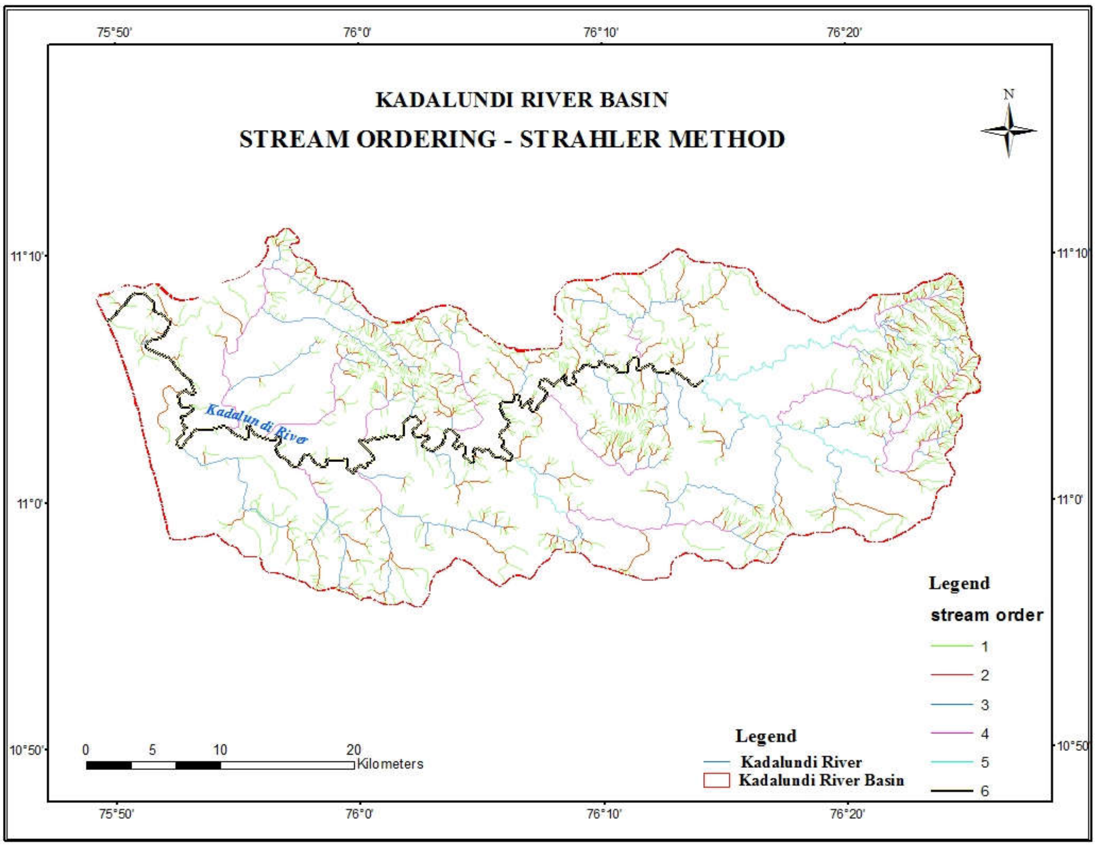

Fig. 2. Stream ordering order

Table 1. Morphometric Parameters and Their Mathematical Expressions

Sl. No	Morphometric Parameter	Mathematical Formula	References
	Linear Aspects		
1	Stream Order (U)	Hierarchical rank	Strahler (1964)
2	Number of Stream (Nu)	Nu = N1+N2…..+N6	Horton (1945)
3	Stream Length in km (Lu)	Lu = L1+L2…..+N6	Horton (1945)
4	Stream Length Ratio (RL)	RL = Lu/ Lu-1	Horton (1945)
5	Mean Stream Length (Lum)	Lum = Lu/Nu	Strahler (1964)
6	Bifurcation Ratio (Rb)	Rb = Nu/Nu+1	Horton (1945)
7	Mean Bifurcation Ratio (Rbm)	Rbm = Rb1+Rb2..Rbn/Rbn	Strahler (1953)
	Areal Aspects		
1	Basin Area in Sq km (A)	Area calculation	Schumm (1956)
2	Basin Perimeter in km (P)	Perimeter calculation	Schumm (1956)
3	Length of the basin in km (Lb)	Length calculation	Schumm (1956)
4	Drainage density (Dd)	Dd = Lu/A	Horton (1932)
5	Stream frequency (Fs)	Fs = Nu/A	Horton (1932)
6	Circularity ratio (Rc)	Rc = 12.57 * (A/P^2)	Miller (1953)
7	Elongation ratio (Re)	Re = $2/Lb*\sqrt{(A/\pi)}$	Schumm (1956)
8	Form factor (Ff)	Ff = A/Lb^2	Horton (1932)
9	Drainage texture (T)	T = Nu/P	Horton (1932)
10	Drainage intensity (Id)	Id – Fs/Dd	Faniran (1968)
11	Length of overland flow (Lo)	Lo = 1/Dd*0.5	Horton (1945)
12	Constant of channel maintenance (Ccm)	Ccm = 1/Dd	Schumm (1956)
	Relief Aspects		
1	Maximum Relief in m (Z)	Maximum hight calculation	
2	Minimum Relief in m (z)	Minimum hight calculation	
3	Basin relief in m (H)	H = Z - z	Strahler (1957)
4	Relief ratio (Rh)	Rh = H/Lb	Schumm (1956)
5	Relative relief (Rhp) Index	Rhp = H*100/P	Melton (1957)
6	Ruggeness number (Ru)	Ru = H * Dd	Schumm (1956)

a direct relationship between morphometric parameters and infiltration capacity of a sub basin. Nine parameters having positive and negative influence on the runoff potential and infiltration capacity are taken for ranking sub basins. The parameters which have negative or inverse relationship with infiltration have positive relationship with runoff and vice versa. The parameters having positive relation with infiltration that is higher the value of parameters higher the rate of infiltration is length of overland flow and constant of channel maintenance. Those with inverse relationship that is higher the value lower the infiltration are circularity ratio, elongation ratio, form factor, drainage density, stream frequency, drainage texture, relief ratio. The parameters having inverse relationship with infiltration capacity (direct relationship with runoff) are ranked from smallest to largest value and those with direct relationship are ranked from the largest to the smallest value. After that the ranks scored for all parameters by each sub basin are added together. This sum value is taken for prioritization of sub basins based on infiltration capacity and runoff potential. The sub basins with minimum sum values have been given least priority as they have more infiltration capacity and less runoff and the sub basins with maximum values have been given high priority as they have less infiltration and more runoff.

Morphometric parameters and ranking of 5th order sub basins

Table 2 shows that Ammanikad Todu has good infiltration capacity and low runoff potential while the other two have moderate infiltration potential. Hence Veliyar and Olipuzha come under moderate priority category while Ammanikad Todu is under low priority category.

Morphometric parameters and ranking of 4th order sub basins

Table 3 shows that Kaka Todu, Kuttipurampuzha and Arimbra Todu has good infiltration capacity and low runoff potential while the Mankada Todu, Tanur Todu and Cherur Todu have moderate infiltration and slightly high runoff potential. It is noted that Urangan Todu and Veliya Todu are comparatively having poor infiltration capacity and high runoff than the other 4th order sub basins. Hence in this case the Urangan Todu and Veliya Todu come under high priory category.

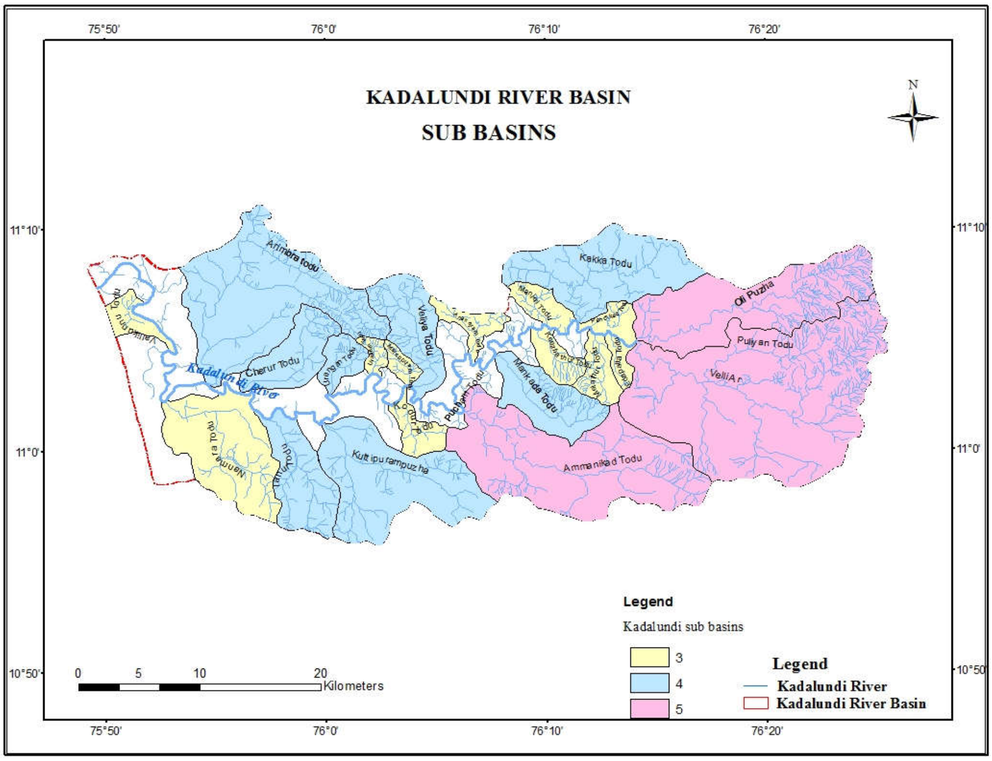

Fig. 3. Sub Basins

Table 2. Ranking of sub basins based on infiltration capacity and runoff potential

Sub basins	Circularity ratio	Elongation ratio	Form Factor	Drainage Density	Stream Frequency	Drainage Texture	Relief Ratio (Rhp) Index	Length of Overland Flow	Constant of Channel Maintenance	Total Rank
Veliyar	3	3	3	2	2	3	2	2	2	22
Ammanikad Todu	2	2	2	1	1	1	1	1	1	12
Olipuzha	1	1	1	3	3	2	3	3	3	20

Table 3. Ranking of sub basins based on infiltration capacity and runoff potential for 4th order sub basins

Sub basins	Circularity ratio	Elongation ratio	Form Factor	Drainage Density	Stream Frequency	Drainage Texture	Relief Ratio (Rhp) Index	Length of Overland Flow	Constant of Channel Maintenance	Total Rank
Arimbra Todu	1	1	1	5	3	8	4	5.5	5	33.5
Cherur Todu	7	2	2	4	5	5	6	4	4	39
Urangan Todu	8	7	7	7	8	3	8	7	7	62
Veliya Todu	2	3	3	8	7	7	5	8	8	51
Kaka Todu	4.5	5	5	2	1	1	2	2	2	24.5
Mankada Todu	6	4	4	3	6	6	7	3	3	42
Kuttipurampuzha	4.5	8	8	1	2	2	3	1	1	30.5
Tanur Todu	3	6	6	6	4	4	1	5.5	6	41.5

Table 4. Ranking of sub basins based on infiltration capacity and runoff potential for 3rd order sub basins

Sub basins	Circularity ratio	Elongation ratio	Form Factor	Drainage Density	Stream Frequency	Drainage Texture	Relief Ratio (Rhp) Index	Length of Overland Flow	Constant of Channel Maintenance	Total Rank
Nanmara Todu	6	2	2	2	1	4	5.5	2	2	26.5
Vallikunnu Todu	1	11	11	1	2	2	1	1	1	31
Urakam Todu	11	10	7	11	11	11	11	11	11	94
Malappuram Todu	10	8	4	10	10	10	10	10	10	82
Kodur Todu	3	6.5	1	5	3	3	4	5	5	35.5
Anakayam Todu	8.5	1	5.5	7	6	7	7	7	7	56
Manjeri Todu	7	4	9	6	7.5	8	5.5	6	6	51
Keezhathur Todu	8.5	5	8	9	9	5	9	9	9	71.5
Pandikad Todu	4	9	10	4	5	6	2	4	4	40
Edapatta Todu	2	6.5	3	3	4	1	3	3	3	28.5
Melathur Todu	5	3	5.5	8	7.5	9	8	8	8	62.5

Table 5. Ranking of sub basins based on infiltration capacity and runoff potential sub basins

Sl. No	Category	Area in sq. km.	Percentage of share
1	High	72	6
2	Moderate	354	32
3	Low	526	47
4	Other	170	15
	Total	1122	100

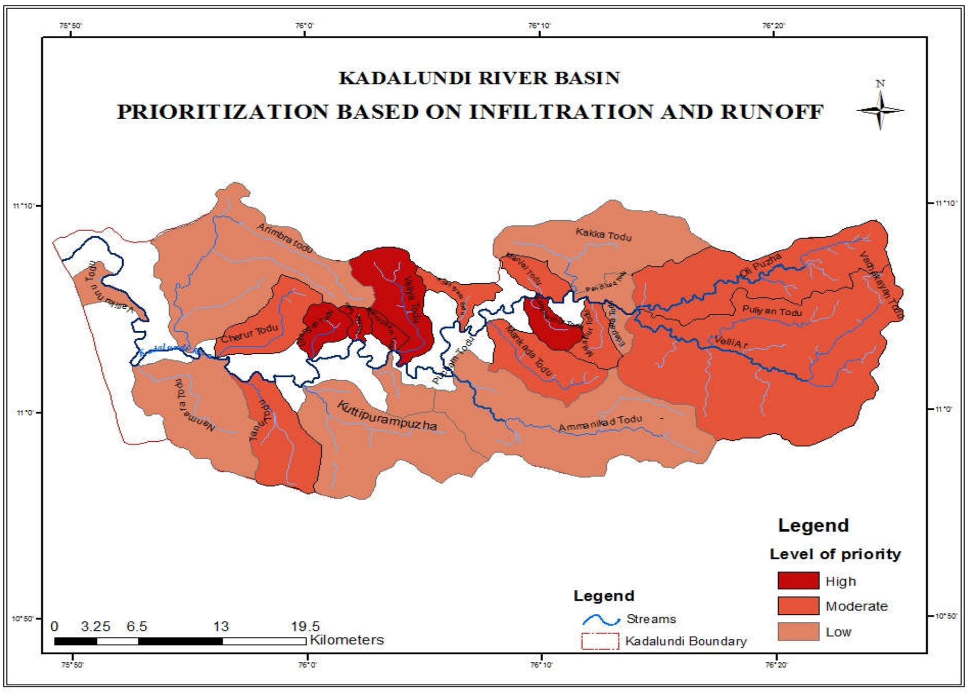

Fig. 4. Prioritized area in Kadalundi river basin

Morphometric parameters and ranking of 3rd order sub basins

Table 4 indicates that Urakam Todu, Anakayam Todu, Malappuram Todu and Keezhathur Todu sub basins are ranked as high priority area, Vallikunnu Todu, Manjeri Todu and Pandikad Todu as moderate priority area and Nanmara Todu, Kodur Todu and Edapatta Todu as low priority area. Fig 4 shows all the basins of study area as per their priority. Table 5 shows the distribution of the area. The total area under low priority shares 47 % of the total Kadalundi river basin whereas the area under moderate priority is 32 % and area under high priority is only 6 % of the total Kadalundi river basin. In this analysis 15 % of Kadalundi river basin is not taken under consideration. Fig 4 shows that the area of high priority is concentrated in the centre part of the area, whereas the moderate priority areas are found more in the eastern part and close to the high priority area in the central part of Kadalundi river basin. Low priority based area are found more in the western and central part of the Kadalundi river basin. Table 5 shows the distribution of the area based on prioritatization. The total area under low priority shares 47 % of the total Kadalundi river basin whereas the area under moderate priority is 32 % and area under high priority is only 6 % of the total Kadalundi river basin. In this analysis 15 % of Kadalundi river basin is not taken under consideration. Fig. 4 shows that the area of high priority is concentrated in the centre part of the area, whereas the moderate priority areas are found more in the eastern part and close to the high priority area in the central part of Kadalundi river basin. Low priority based area are found more in the western and central part of the Kadalundi river basin.

Conclusion

The morphometric analysis is an essential study for any hydrological or geomorphologic investigation related to any river basin. There is a direct relationship between the morphometric characteristics of a basin and its runoff potential and infiltration capacity. Hence before undertaking any development plan, or for any assessment, a detailed enquiry of the morphological characteristics is to be done for knowing the river basin as a whole. In the present study the morphometric analysis carried out was very helpful to assess the runoff potential and infiltration capacity of sub basins in Kadalundi river basin. The Kadalundi river basin is in general have moderate to high priority area indicating more concern while implementing development plans than the area under less priority.

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