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Morphometric Analysis of Kala Oya River Basin, Sri Lanka Using Geographical Information Systems

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Abstract— **Morphological characteristics of river basins are assessed widely by means of morphometric analysis which is a mathematical quantification of different aspects of river basins. In the present study, Kala Oya River Basin of Sri Lanka was morphometrically analyzed to assess its flood characteristics based on the morphological characteristics with the help of Geographical Information Systems and the methods available in scientific literature. Further, the soil and topographical conditions like land use and terrain characteristics of the basin were also identified. Results of the study revealed that the Kala Oya River Basin has a 6th order river network according to Strahler's classification with a dendritic drainage pattern and coarse drainage texture. The obtained low values of bifurcation ratio, circularity ratio, elongation ratio and form factor values revealed that a lower and extended peak flow for a longer duration would result from the basin. The drainage density, stream frequency and drainage intensity values indicated that the basin has highly permeable soil, good vegetation cover and lower relief where a low rate of runoff could be resulted reducing the risk for both soil erosion and flooding. The analyzed relief aspects revealed that the basin is less susceptible for severe soil erosion. Confirming the results of the morphometric analysis, the basin area was with 85% of Reddish Brown Earth and Low Humic Gley Soils soil types which are permeable soils and 66% of vegetation cover and a lower relief as more than 95% of the basin was below 200 m and the highest point was also below 1000 m. However, the findings of rainfall analysis for the basin revealed that there were increasing patterns in receiving heavy rainfalls greater than 50 mm/day and maximum rainfall amounts during a day over last 30 years. Similarly, flood occurrences also showed increasing patterns with time. Thus, sustainable management plans should be made in advance to cope with the potential floods that can occur due to high rainfall events and/or due to the degradation of protective vegetation cover, although the studied Kala Oya River Basin is morphometrically capable enough to reduce the flood risk.**

Index Terms— **Flood characteristics, Geographical Information Systems, Kala Oya River Basin, Morphometric analysis, Soil and topographical conditions**

I. Introduction

The origin and circulation of the waters of the earth has been a subject of speculation since ancient times. Measurement and quantitative expression of drainage basin has begun with the work of James Hutton in 1775 as cited by Garde [1]. However, the modern approach of quantitative analysis of drainage basin morphology has commenced by Horton [34], the first pioneer for developing several Laws on stream flows. Horton's laws were subsequently modified and developed by several geomorphologist, most notably by Strahler [2] [3] [4] [5], Schumm [6], Morisawa [7], Scheidegger [8], Gregory [9], Gregory and Walling [10]. Recently published a number of books by Bloom [11], Keller and Pinter [12] further propagated the morphometric analysis.

Morphological features of river basins are widely assessed by determining morphometric parameters of the river basins [13]. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface of the shape and dimensions of its landforms [14]. This is the most common technique in basin analysis, as morphometry forms an ideal areal unit for interpretation and analysis of fluvially originated landforms where they exhibit an example of open systems of operation. In fact, morphometry incorporates quantitative study of the area, altitude, volume, slope profiles of the land and drainage characteristics of the area concerned. Morphological characteristics of river basins are dealt with the form of the streams and adjoining areas as brought about by erosion, transportation and deposition of sediment by the running water [1]. According to Strahler [5], systematic description of the geometry of a drainage basin and its stream channel requires measurement of linear aspects of the drainage network, areal aspects of the drainage basin and relief (gradient) aspects of the channel network and contributing ground slopes.

The morphological characteristics of various basins have been initially studied by many scientists [15], [16], [2], and [5] using conventional methods viz, using strings, planimeter, etc. With the emergence of Spatial Information Technology (SIT) *viz*, Remote Sensing (RS), Geographical Information System (GIS) and Global Positioning System (GPS), estimation of morphological characteristics of river basins have become more convenient for many researchers [13], [17], [18], [19], [20], [21] and [22] as those methods have effective and efficient tools to overcome most of the problems of land and water resources planning and management on the account of usage of conventional methods of data processing. GIS techniques are widely used at present for assessing various terrain and morphological parameters of the drainage basins and watersheds, as they provide a flexible environment and powerful tools for the manipulation and analysis of spatial information.

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Morphological characteristics of river basins have long been believed to be important indices of surface processes. These parameters have been used in various studies of geomorphology and surface-water hydrology, such as flood characteristics, sediment yield, and evolution of basin morphology. For instance, it has been discovered that higher the drainage density, faster the runoff and the more significant the degree of channel abrasion for a given quantity of rainfall [23]. Further, the author has stated that the measurement of drainage density provides hydrologists and geomorphologists with a useful numerical measure of landscape dissection and runoff potential. In homogeneous bedrock, bifurcation ratio influences the landscape morphometry and plays an important control over the "peak" of the runoff hydrograph [24]. Waugh [25] noted that as the ratio is reduced the risk of flooding within the basin increases. Strahler [5] noted that the shape of a drainage basin may conceivably affect stream discharge characteristics. Jain and Sinha [26], Okoko and Olujimi [27] and Ifabiyi [28] reported that the morphological characteristics of drainage basins play a key-role in controlling the basins hydrology. Jones [29] has reported that morphological characteristics affect catchment stream flow pattern through their influence on concentration time. Morphological characteristics of drainage basins thus provide not only an elegant description of the landscape, but also serve as a powerful means of comparing the form and hydrological processes of drainage basins that maybe widely separated in space and time [30].

II. STUDY AREA

The Kala Oya is a river which originates in the Matale Hills and falls to the sea North of Vanathavillu off Puttalam, traversing the Wilpattu National Park. Among 103 major river basins spread in Sri Lanka, Kala Oya River Basin processes the third longest river in Sri Lanka, Kala Oya [31]. There are about 600 small irrigation tanks and large reservoirs *viz* Kala Wewa, Balalu Wewa, Rajangane Reservoir, Angamuwa Reservoir, Usgala Siyambalangamuwa Reservoir, Kandalama Wewa, Dewahuwa Wewa, Ibbankatuwa Reservoir, Dambulu Oya Reservoir and Katiyawa Tank. The average annual rainfall over the basin is 1192 mm and the discharge volume to the sea is 386 MCM leading to a runoff/rainfall ratio of 12% [31]. The basin more or less is within Dry Zone of Sri Lanka while a small area of the upper catchment of the basin is only within Intermediate Zone of Sri Lanka. The basin extends within IM_{1b}, IM_{3b}, IL_3, DL1b, DL_{1c}, DL_{1f} and DL_3 Agro-ecological Regions. The basin is totally within 0 - 500 m elevation level and only a few mountains are above 500 m level. As classified by Cooray [32], the geology of the basin falls under Highland Complex, Wanni Complex and Limestone.

III. MATERIALS AND METHODS

River basin boundary map published by the Department of Agrarian Services, Sri Lanka in 2012; Soil map of Sri Lanka published in National Atlas of Sri Lanka by the Survey Department of Sri Lanka in 2007; Map of Topography of Sri Lanka generated using Shuttle Radar Topography Mission (SRTM) data available in http://earthexplorer.usgs.gov and 11 topographic map sheets *viz* Wilpattu (24), Tantirimale (25), Kalpitiya (29), Kalaoya (30), Anuradhapura (31), Puttalam (34), Galgamuwa (35), Kekirawa (36), Polonnaruwa (37), Dambulla (42) and Elahera (43) in 1:50,000 scale published by the Survey Department of Sri Lanka in 2007 were used for the study.

The ArcGIS-9.3 software package was used in preparing all digital layers used in the study and all the maps were prepared in Sri Lanka National Grid based on TM coordinate system. River basin boundary of the selected Kala Oya River Basin in the Dry Zone of Sri Lanka were digitized based on the river basins boundary map published by the Department of Agrarian Services, Sri Lanka (2012) and then it was verified with the help of contour map published by the Survey Department of Sri Lanka (2007).

The digital layers of the hydrological network and land use pattern of the river basin were obtained by digitizing 11 topographic map sheets. Further, the digital layer of soil types of selected basin was prepared by scanning and digitizing the Soil Map available in the National Atlas of Sri Lanka [31]. The Digital Elevation Models and slope maps were generated using Shuttle Radar Topography Mission (SRTM) data obtained from http://earthexplorer.usgs.gov.

Linear, areal and relief aspects of morphological parameters were assessed using GIS Software analysis tools and different models developed and published through the scientific literature in Geomorphology (Table 1).

Further, areal share of the different soil and land use types spread in the river basin were calculated as percentages using the information produced by the attribute tables of the digital layers with soil types and land use. Moreover, terrain conditions of the selected basin were identified by preparing elevation and slope maps.

Rainfall data at different gauging stations located in the upper catchment area of the river basin obtained from the Meteorological Department of Sri Lanka and the flood records at downstream area of the basin obtained from the web site of the Disaster Management Centre of Sri Lanka [33] were further used to assess the hydrological characteristics and flood potentials of the selected river basin.

Table 1: Methods used for the morphometric analysis

Morphometric Parameter	*Method*	*Reference*
Linear Aspects		
Stream order (U)	Hierarchical rank	[5]
Number of Streams (N_U)	$N_U = N_1+N_2…+N_6$	[34]
Stream length in km (L_U)	$L_U = L_1+L_2….+L_6$	[34]
Mean stream Length (L_{UM})	$L_{UM} = L_U / N_U$	[5]

Bifurcation Ratio (R_B)	$R_B = N_U/N_U+1$	[6]
Stream length Ratio (R_L)	$R_L = L_U / L_U\text{-}1$	[15]
Areal Aspects		
Area in km² (A)	Area calculation	[6]
Perimeter in km (P)	Perimeter calculation	[6]
Basin length in km (L_B)	Length calculation	[6]
Drainage density (D_D)	$D_D = L_U /A$	[34]
Stream frequency (F_S)	$F_S = N_U/A$	[34]
Circulatory ratio (R_C)	$R_C = 12.57*(A/P^2)$	[35]
Elongation ratio (R_E)	$R_E = 2/L_B*\sqrt{(A/\pi)}$	[6]
Form factor (R_F)	$R_F = A/L_B^2$	[34]
Drainage texture (D_T)	$D_T = N_U/P$	[15]
Length overland flow of (L_O)	$L_O = 1 / D_D*0.5$	[15]
Relief Aspects		
Basin relief in m (H)	$H = Z - z$	[3]
Relief ratio (R_H)	$R_H = H / L_B$	[6]
Relative Relief (R_{HP})	$R_{HP} = H*100 / P$	[37]

IV. RESULTS AND DISCUSSION

A. Linear aspects of Kala Oya river basin

The stream links and the nodes (confluences) characterize 'Linear aspects' of the basin and they are basically associated with the stream orders which represent the hierarchical ranking of the stream segments from the origin of those in the basin to the outlet [38]. Table 2 shows the stream orders (U) obtained according to Strahler's [2] classification and the number of streams in each order (N_U) of the studied Kala Oya river network.

Table 2: Linear Aspects of Kala Oya river basin

Stream Order (U)	N_U	L_U (km)	L_{UM} (km)	R_B	R_L
1	717	764.55	1.07		2.06
2	200	438.29	2.19	3.59	2.38
3	43	224.31	5.22	4.65	1.70
4	12	106.50	8.88	3.58	3.41
5	3	90.83	30.28	4.00	1.38
6	1	41.87	41.87	3.00	
Total	976	1666.35			

As per the Table 2, Kala Oya stream network is with a total number of 976 stream segments extending up to 6th order together with numerous small tanks and several large tanks or reservoirs in the basin (Fig. 1).

The decreasing N_U with the increasing U in the basin confirm the Horton's [15] and Strahler's [3] findings. Gregory and Walling [10] have found that the increasing order of network is associated with greater stream flow values.

The stream length (L_U) is one of the significant features of the basin, as it reveals surface runoff characteristics. Streams of relatively smaller lengths indicate that the area is with high slopes. Longer lengths are indicative of flatter gradient [15]. Usually, the total lengths of stream segments are highest in the first order streams, and it decreases as the stream order increases [15] and Kala Oya river basin also shows similar pattern (Table 2). The mean stream length of each order (L_{UM}) is a characteristic property related to the drainage network components and its associated basin surfaces and L_{UM} value are increasing with increasing order [5]. The studied river network also confirms that finding (Table 2).

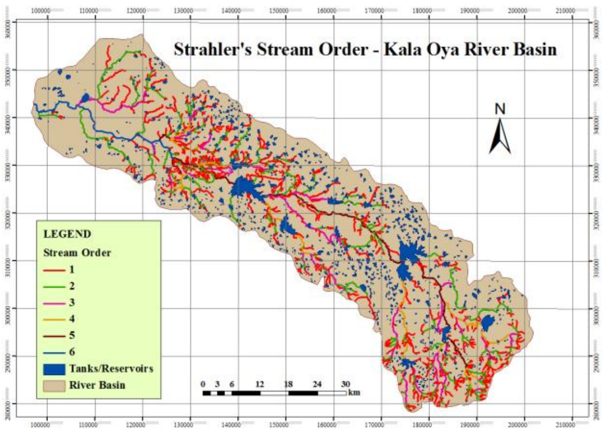

Fig. 1: Strahler's Stream Orders of Kala Oya River Basin (Source Data for Stream Network: 1:50,000 Topographic Map Sheets published by Survey Department of Sri Lanka, 2007)

The R_B is a dimensionless property and generally ranges from 3.0 to 5.0 [3] and the R_B values of all 6 orders of the studied river network are within this range (Table 2). It can also be observed that R_B is not same from one order to the next order in the studied basin. According to Strahler [5] these irregularities are dependent upon the geological and lithological development of the drainage basin. The lower values of R_B are characteristics of the watersheds, which have suffered less structural disturbances [5]. Further, Chorley *et al.* [24] has noted that the lower the bifurcation ratio, the higher the risk of flooding, particularly of parts and not the entire basin. Hence, the almost higher R_B values together with the elongated shapes of the studied river basin would result a lower and extended peak flows, which will reduce the risk of flooding within the basin.

As Horton [15] stated that the stream length ratio (R_L) tends to be constant throughout the successive orders of a basin. But, the R_L values of the studied basin are varying among the orders without showing any consistency (Table 2). According to Singh and Singh [39] changes of stream length ratio from one order to another order indicate their late youth stage of geomorphic development in the streams of the area. In river basins, R_L ranges between 1.5 and 3.5 and is typically 2 [40] and the obtained R_L values for the studied basin also show similar evidences (Table 2).

Finally, a dendritic drainage pattern can be identified in the basin and it is probably the most common drainage pattern identified in Sri Lankan river basins as well as in the world. This is characterized by irregular branching of tributary streams in many directions and at almost any angle usually less than 900. Dendritic patterns develop on rocks of uniform resistance and indicate a complete lack of structural control. This pattern is more likely to be found on nearly horizontal sedimentary rocks or on areas of massive igneous rocks. They may also be seen on complex metamorphosed rocks [1].

B. Areal aspects of Kala Oya river basin

The areal aspects are the two dimensional properties of a basin that basically explain the shape parameters. The basin shape has a significant effect on stream discharge characteristics and finally on the flood characteristics of the basin. Table 3 shows the results of the calculated different areal aspects of the studied river basin.

Table 3: Areal aspects of Kala Oya river basin

Parameters	Values
Area in km^2 (A)	2850.00
Perimeter in km (P)	319.00
Length of the basin in km (L_B)	116.60
Drainage density (D_D)	0.58
Stream frequency (F_S)	0.34
Drainage texture (D_T)	3.06
Length of overland flow (L_O)	0.86
Circulatory ratio (R_C)	0.35
Elongation ratio (R_E)	0.52
Form factor (R_F)	0.21

Basin area (A) and perimeter (P) are important parameters in quantitative geomorphology. Perimeter is an indicator of watershed size and shape [34]. Horton [34] introduced the drainage density (D_D) as an important indicator of the linear scale of landform elements in stream eroded topography. The D_D indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channels for the whole basin [34]. Strahler [5] stated that D_D values may be 1 km/km2 through very permeable rocks, whereas they increase to over 5 km/km2 through highly impermeable surfaces. It has been observed from D_D measurements made over a wide range of geologic and climatic types that a low D_D is more likely to occur in regions of highly permeable subsoil material under dense vegetative cover and where relief is low. A high D_D is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low D_D leads to coarse drainage texture while high D_D leads to fine drainage texture [5]. The D_D of the basin is low (Table 3) according to Strahler [5] and it has resulted from a permeable land surface with less slope and good vegetation cover prevailing in the basin as explained by Strahler [5].

The stream frequency (F_S) introduced by Horton [34] is an indicative of stream network distribution over the river basin. Kale and Guptha [41] have found that the F_S value may range from less than 1 to 6 or even more depending on the lithology of the basin. In the present study, the F_S value of the basin (Table 3) is less than 1.0 indicating a low value. This reveals that the basin possesses low relief and almost flat topography as stated by Horton [34] and also as confirmed by the identified low relief conditions of the studied basin (Fig. 4 and Fig. 5).

The drainage texture (D_T) is one of the important concepts of geomorphology which means the relative spacing of drainage lines. The D_T depends on the underlying lithology, infiltration capacity and relief aspect of the terrain. According to Smith [16] the D_T depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development. Further he explained that, the soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. Sparse vegetation of arid climate causes finer textures than those developed on similar rocks in a humid climate. Smith [16] has classified the drainage texture into five different textures i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). Based on this classification, Kala Oya has a coarse drainage texture (Table 3).

The length of overland flow (L_O) refers to the length of the runoff of the rain water on the ground surface before it gets concentrated into definite stream channels [15]. The overland flow is higher in the semi arid regions than in the humid and humid temperate regions; in addition, absence of vegetation cover in the semi arid regions is primarily responsible for lower infiltration rates and for the generation of higher surface flow [41]. Thus the resulted low L_O value (Table 3) gives evidences for the existence of good vegetation covers in the basin.

Miller [35] described that the circularity ratios range from 0.4 to 0.5 which indicates strongly elongated basins and permeable homogenous geologic materials. Higher the value of R_C, greater the circular shape of the basin and vice-versa. The R_C is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. In the studied river basin, R_C value 0.35 (Table 3) indicates that the basin is almost elongated in shape. As per Miller [35], the elongated basins have low discharge of runoff and highly permeable soil conditions and this is confirmed by prevailing more Reddish Brown Earth and Low Humic Gley Soils soil type which result permeable soils (Fig. 2).

As stated by Schumm [6], elongation ratio (R_E) is a very significant index in the analysis of the basin shape which helps to give an idea about the hydrological character of a drainage basin. Analysis of elongation ratio has indicated that the areas with higher elongation ratio values have high

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infiltration capacity and low runoff. As elongated basins produce flatter peak flows for longer durations, they are more efficient in the discharge of runoff than the circular basins [39]. Strahler [5] states that this ratio runs between 0.6 and 1.0 over a wide variety of climatic and geologic types and further he has classified the basins with the help of the elongation ratio viz, circular (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (less than 0.5). According to this classification, Kala Oya belongs to the elongated category (Table 3). According to Singh and Singh [39] these types of elongated basins develop flatter peak of flows for longer durations and thus there are less chances for the generation of flash floods.

The form factor (R_F) is the quantitative expression of drainage basin outline form [34]. The values of form factor would always be less than 0.7584 (for a perfectly circular basin). It Smaller the value of form factor, more elongated will be the basin. The R_F value of the studied basin is 0.21 (Table 3) indicating that the basin is elongated in shape. The elongated basins with low R_F indicate that the basins have flatter peak of flows with longer durations. According to Singh and Singh [39] flood flows of such elongated basins are easier to manage than that from the circular basins. As evident by the flood records of Disaster Management Centre of Sri Lanka [33], all these basins have faced flood incidences in different severities during the past 33 years and those can be more frequent and intensified with predicted climate change as reported by World Bank [42]. However, those emerging floods would be easier to manage from these elongated basins by adopting suitable measures.

C. Relief Aspects of Kala Oya River Basin

Relief aspects of drainage basin relate to three dimensional features of the basin involving area, volume and altitude of vertical dimension of landforms wherein different morphometric methods are used to analyze terrain characteristics. Table 4 shows the results of the analyzed relief aspects of the studied river basin.

Table 4: Relief Aspects of Kala Oya River Basin

Parameter	Value
Basin relief in m (H)	900
Relief ratio (R_H)	0.01
Relative relief (R_{HP})	0.28

Schumm [6] has stated that relief ratio (R_H) is a measure of the overall steepness of a river basin and it is an indicator of the intensity of the erosion process operating on the slope of the basin. Low value of relief ratios are mainly due to the resistant basement rocks of the basin and low degree of slope. The RH of the Kala Oya river basin is 0.01 (Table 4) and thus this river basin is morphometrically less susceptible to soil erosion.

The relative relief (R_{HP}) is an important morphometric variable used for the overall assessment of morphological characteristics of the terrain. Based on Melton's (1957) classification (low = 0 – 100; moderate = 100 – 300 and high = above 300), the RHP value of the river basin belongs to low relative relief category and it is confirmed by Fig. 4 and 5.

D. Soil conditions

The prominent soil type in the Kala Oya river basin is Reddish Brown Earth and Low Humic Gley Soils which is available in 85% of the basin area (Figure 2). According to Handbook of Soils of Sri Lanka [43] the Reddish Brown Earth great soil group is characteristic with well, moderately well and imperfectly drained; sandy loam to sandy clay loam surface soil texture and sandy clay loam to sandy clay with gravel sub soil texture and the Low Humic Gley great soil group has poor and very poor drainage; sandy loam to sandy clay loam surface soil texture and sandy clay loam to sandy clay or clay sub soil texture. Therefore, it is clear that, the major soil type available in the studied Kala Oya river basin is mostly with sandy clay surface soils and sub soils which would exhibit well drained (permeable) to weekly drained soil conditions.

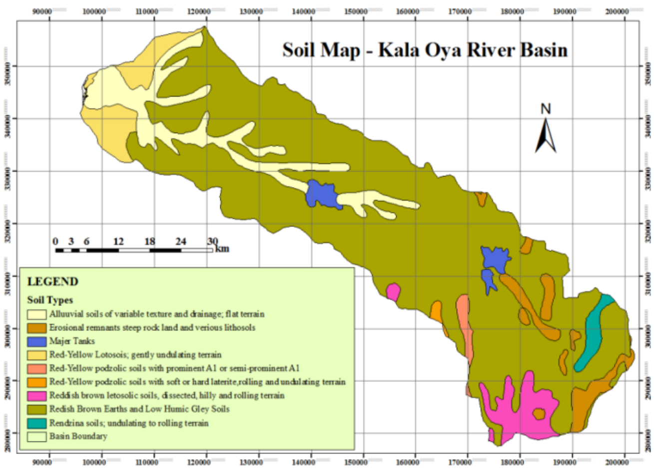

Fig. 2: Soil map of Kala Oya river basin
(Source Data for Soil Types: 1:10,00000 Soil Map, National Atlas of Sri Lanka published by Survey Department of Sri Lanka, 2007)

E. Land Use Conditions

As evident by Fig. 3, 66% of Kala Oya river basin is covered with both natural and cultivated vegetation and thus confirms the results obtained for lower D_D.

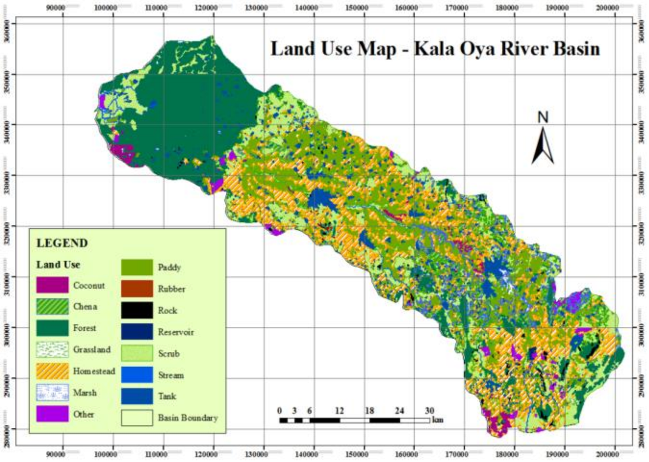

Fig. 3: Land use map of Kala Oya river basin
(Source Data for Land Use: 1:50,000 Topographic Map Sheets published by Survey Department of Sri Lanka, 2007)

F. Terrain Conditions
The Fig. 4 reveals that more than 95% of the Kala Oya basin is below 200 m elevation and the highest point of the basin is 900 m. It is found that almost all slopes of Kala Oya river basins are below 20^0 slopes (Fig. 5).

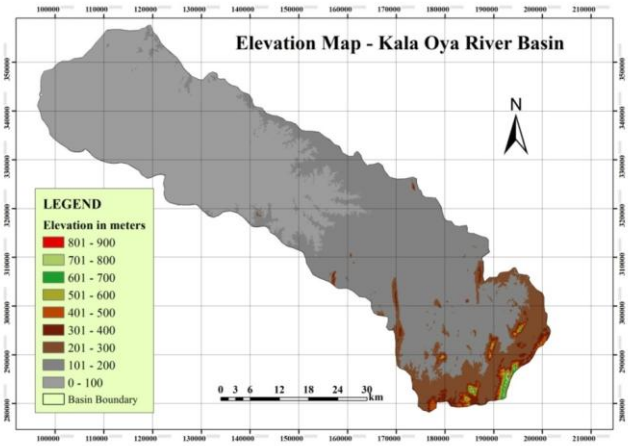

Fig. 4: Elevation Map of Kala Oya River Basin
(Source Data for Elevation: Shuttle Radar Topography Mission (SRTM) data available in http://earthexplorer.usgs.gov)

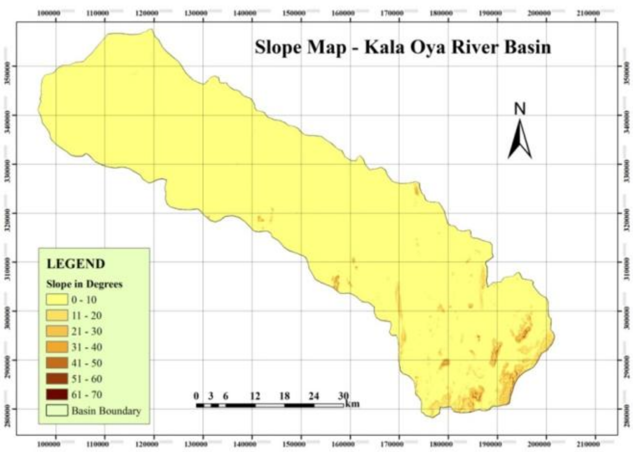

Fig. 5: Slope Map of Kala Oya River Basin
(Source Data for Slope: Shuttle Radar Topography Mission (SRTM) data available in http://earthexplorer.usgs.gov)

G. Rainfall and flood occurrence patterns
The average annual rainfall values calculated from last 33 years rainfall data obtained from Maha Illuppallama and Anuradhapura rain gauge stations located in the studied basin are 1360 mm and 1268 mm, respectively. It is apparent that from 1980 to 1992, these stations have received rainfalls below the average except in year 1984. However, after year 1992, these stations have received more rainfalls above the average. Hence, there is an increase of receiving more rains over the studied river basin in recent decades.

According to Trenberth [44], a rainfall event exceeding 50 mm/day can be considered as a heavy rainfall event which leads to floods. The average number of such events occurred per year during last 33 years at Maha Illuppallama and Anuradhapura are 6 and 5, respectively. Accordingly, these stations have experienced heavy rainfall events below the average of those events from 1980 to 1992 years and above the average of those events after year 1990. Therefore, it is apparent that there are increasing patterns of receiving heavy rainfall amounts greater than 50 mm/day over the rain gauge stations located in studied river basin in recent years.

According to flood records obtained from the Disaster Management Centre of Sri Lanka (http://www.disinventar.lk) during last 33 years, the average numbers of flood events occurred per year is 1 in Puttalam Districts. More number of flood events has occurred in Kala Oya river basin in the recent decade.

Therefore it can be said that, the number of flood events have increased in the recent years, together with higher number of heavy rainfall events and receiving more rains in the studied river basin. As revealed by Nissanka, et al. [45] the variability of seasonal rainfall during the recent decade (2001-2010) has increased compared to the previous decade (1991- 2001) in most places of Sri Lanka across all three climatic zones leading to more frequent flood conditions. Thus, the increased number of flood events occurred in the recent decade may have been resulted from the increased rainfalls received due to the predicted climate change and due to ever degrading natural vegetation covers and replacing them with more impervious layers with urbanization and other development activities. Therefore, though the studied Kala Oya river basin is morphologically capable of reducing the flood risk, sustainable management plans should be made in advance to cope with the potential floods that can be expected in this basin in the future.

V. CONCLUSIONS

Morphological parameters help to assess and compare the characteristics of river basins. Data derived using GIS are very helpful to analyze morphological characteristics effectively. In this study, studied Kala Oya river basin possesses dendritic drainage patterns with 6th order river network. The higher bifurcation ratios of stream network indicate that lower and extended peak flows would be generated from this basin reducing the risk of flooding.

When considering the areal aspects, the basin has low drainage density value owing to highly permeable soils and thick vegetative covers present in the basin. Further, lower value of stream frequency confirms that surface runoff is not quickly removed from this river basin. The lower circularity ratio value also indicates that the basin has low discharge rate and highly permeable sub soil conditions as the basin is almost elongated in shape. Similarly, all lower elongated ratio and form factor values confirm that basin is elongated and thus it tends to develop water flow showing flatter peak with longer duration.

The results of relief aspects of morphological parameters reveal that the Kala Oya basin has both lower relief ratio and relative relief values and thus the basin is less susceptible for severe soil erosion. The terrain conditions of river basin confirm the findings of relief aspects since the basin has relatively flat topography.

The identified permeable soil conditions; good vegetation covers and low relief conditions confirm the findings of morphological parameters of the basin. Therefore, this Kala Oya basin is well capable of absorbing more water into soil and good in recharging groundwater and thus have flatter peak of flow for longer duration while reducing risk for both soil erosion and flooding. If any flood will be emerged, that could be managed easily from this type of elongated basin than from circular basins by adopting suitable precautionary measures.

The findings of rainfall and flood occurrence patterns reveal that number of flood events has increased in the recent decade together with receiving increased amounts of rainfall and occurring increased number of high rainfall events. Therefore, though studied Kala Oya river basin is morphologically capable of reducing the flood risk, sustainable management plans should be made in advance to cope with potential floods that can occur due to the changes in land use conditions with urbanization and development activities and also due to possible high rainfalls events which can be expected from predicted climate change.

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