WATERSHED PRIORITIZATIONFOR NATURAL HAZARD SUSCEPTIBILITYASSESSMENT OF RIVER KILANGE BASIN, ADAMAWA STATE, NIGERIA

By

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ABSTRACT

In this paper, geospatial techniques were adopted for the generation of morphometric parameters which were used to prioritize River Kilange Basin for natural hazard susceptibility. Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data of the basin was acquired on line and processed to generate seventeen sub-basins within the watershed. Twenty three parameters were obtained by using geospatial or quantitative techniques as appropriate for watershed prioritization. The twenty three parameters were grouped into five: drainage network, area parameters, watershed geometry, drainage texture and relief characteristics. The mean of the values that were obtained from each of the parameters in each sub-watershed were used to prioritize the watersheds for soil erosion and floods hazard into four classes; very high risk, high risk, moderate risk and low risk. The results revealed that the watersheds on high relief like Sanganare, Sensen, Song, Upper Kilange Giraba and Fa'ah were more prone to soil erosion. In contrast, those watersheds on low relief were found to be more vulnerable to flood. Hence, watershed on high relief fell under very high risk for soil erosion, while, those on low relief like Wuro De, Konchi, Upper and lower Lokko among others have higher priority for floods. It was recommended that constant monitoring and prioritization of sub-basins for effective watershed management should be periodically carried out for sustainable utilization and disaster risk reduction. The watersheds with higher priority in each of the two assessed hazards (floods and soil erosion) should be given more attention in the watershed management than those with less priority.

Key words: Kilange basin, Natural hazards, Morphometric parameters, Watershed prioritization.

INTRODUCTION

Study of watershed is important in many ways: scientific development and management of water resources (Vaibhav, Pawan and Kireet, 2018), explore the geomorphic history, evolution and characteristics of landforms, and development of drainage networks (Yahya, Omar and Ali, 2016), conservation of natural resources including soil, water, vegetation, as well as socio-cultural resources for enriching livelihood of rural peoples (Ravindra and Vijay,2017),watershed prioritization for soil and water conservation (Ajin et al., 2013), facilitates hydrological prospecting, assessment of the potential of groundwater recharge, and mapping of flood prone areas (Yahya, Omar and Ali, 2016).

Despite the tremendous benefits of watershed to man, most watershed are now being degraded due to population increase, urbanization and other anthropogenic activities like farming, animal grazing and bush burning. Natural factors especially climate change are also contributing to the degradation of some watersheds. Kilange Basin is not an exception. Kilange Basin is located in the savanna vegetation belt in Nigeria. Therefore, watersheds are utilized for many purposes like water provision for domestic and agricultural practices, fishing, vegetation resources (timber, pastures for animals, medicinal plants), fertile soils and wetlands for cultivation, among others. Hence, the need to assess the environmental conditions of the basin for sustainable utilization cannot be overemphasized. Among the several methods for watershed management is watershed prioritization which involves delineation of sub-watersheds within a large drainage basin and prioritization of the sub-basins for potential zones for implementation of conservation measures and proper planning and management of such watersheds.

Hazard is the probability of the occurrence of a potentially damaging phenomenon within a given period of time and space, potential threats to people, infrastructure and the environment that arise from the intersection of human systems, natural processes, and technological systems, Large parts of the world are subjected to one or more natural hazards(Robert 2009).The two most common natural hazards in Kilange Basin are soil erosion and flooding (Upper Benue River Basin Development Authority [UBRBDA], 1982). Lokko Basin which is one of the sub-basins of Kilange watershed has been widely reported to have caused a lot of havoc to the inhabitants through flooding (Ibrahim, 2009; Dzarma, 2018).

In this study, the morphometric parameters of the Kilange Basin were analyzed and the results were used to prioritize the sub-basins for susceptibility to soil erosion and floods. Since watershed prioritization is essential for proper planning and management of the natural resources for sustainable development, integration of morphometric parameters through the use of remotely sensed data and GIS technique provides powerful tool for extraction and analysis of spatial information.

THE STUDY AREA

River Kilange is one of the largest tributaries to River Benue from the northern part in Adamawa State. The Kilange catchment, with entire basin within Adamawa State, covers a total land area of 5329.95 square kilometres which is about 14.02% of the land area of the State. The catchment occupies some parts of eight Local Government Areas (LGAs); Fufore, Girei, Gombi, Hong, Maiha, Mubi North, Mubi South and Song. None of these eight LGAs has its entire land area in the basin. The relief of Kilange Basin was classified into five as shown in Figure 1.

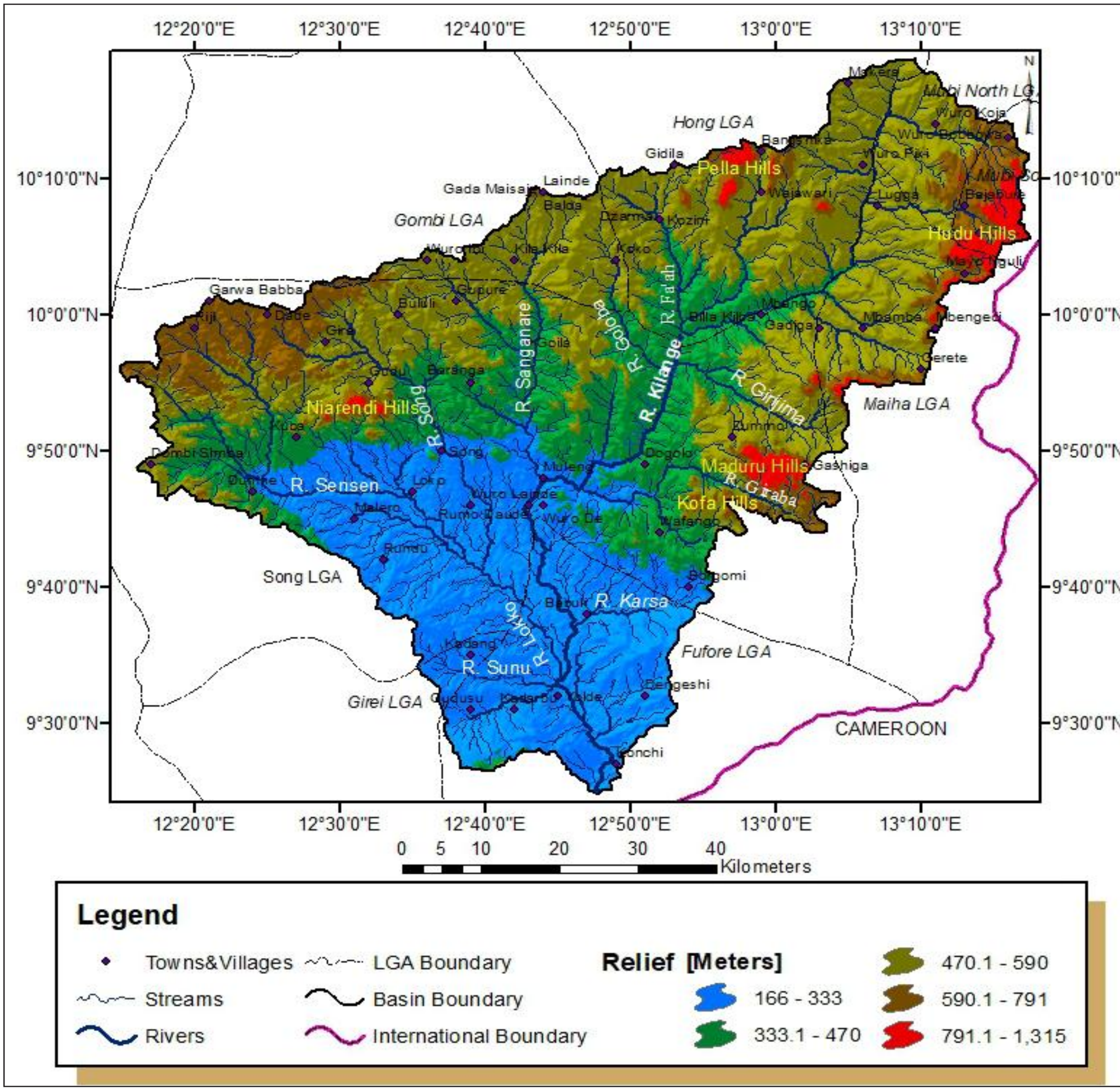

Figure 1 The Relief of Kilange Basin
Source: Processed from SRTM DEM data

(i) The low floodplain. This is the lowest region of the basin with elevation ranging from 166-333m above sea level. The entire portion of the basin in Fufore and Girei LGAs fall within this region. *(ii) The high floodplain* has its elevations from 333.1-470 m, mainly found along the main river valleys. This high floodplain was found to be the least inhabited within the catchment (Fig.1). *(iii) The plain* consist the areas with elevation from 470.1 – 590m above sea level. *(iv) The upland* with elevations between 590.1- 791 are found at the foot of mountain ranges. Riji, Bade, Bangishka, Gashiga settlements are all in upland area. *(v) The mountain ranges* which include Hudu hills of Mandara mountain range in Maiha-Mubi South LGAs, Maduru hills in South of Zummo settlement, Niarendi hills, Kofa hills near Wafango settlement all in Song LGA and Pella hills in Hong LGA. The mountain ranges have their elevations between 791.1 to 1315m above sea level.

Drainage

The largest River in the catchment is River Kilange which takes its source from Mararaba in Hong LGA and flows southward through Hong, Maiha, Song and Fufore LGAs before joining River Benue near Bilachi in Fufore LGA. The total length of the main River Kilange is about 149.18 km. River Song takes its source from Dade and flows eastward before joining River Sensen (which takes its source from Riji) near Manawachi in Song LGA. The two rivers (Song and Sensen) join to become River Lokko which is the largest tributary to River Kilange. Other main tributaries are: River Sanganare, Gojoba, Fa'ah Giraba and Girijima, Karsa and Sunu (Figure 1).

MATERIALS AND METHODS

Delineation of Basin and mapping of Rivers and Streams

The basin extraction module of ArcGIS 5 was used to extract the Kilange Basin land area from SRTM DEM data (earthexplorer.usgs.gov). Hydrology modules of the spatial analyst tools of ArcGIS 5 software were used to fill the DEM, generate the flow direction and flow accumulation before the basin was extracted and polygonized using the extract by mask tool and conversion from raster to polygon tool of ArcGIS 5 software respectively. The slope of the basin was also generated from the DEM using the raster surface module of ArcGIS software. The rivers and streams within the basin were delineated from the SRTM DEM data using the flow accumulation and stream order module of ArcGIS software.

Rainfall Mapping

The shape file of the basin was used to extract the study area from the Global WorldClim data of 1950-2000 and TAMSAT rainfall data from 2001 to 2016. The two rainfall data were merged together using the image calculator of ArcGIS software, while 47 villages within the basin were captured and the rainfall values of each of the villages were obtained from the spatial rainfall data. The rainfall of the villages was interpolated using the ordinary Kringing method. The output map was classified into five: high, moderately high, low, moderately low and very low as shown in Figure 2a.

Delineation of sub-basins

The DEM of the basin was exported into Global Mapper V 13 where the watershed module was used to delineate the sub-basins. Stream drainage area of 200 $km^2$was used, that is, any drainage that is as large as 200 km^2 should be delineated so as to have as many sub-basins as possible. Other sub-basins which are not up to 200 km^2 but do not belong to any other watershed like Lower Fa'ah, Lower Sensen, and Muleng were also delineated. Fifteen (15) metre depth was specified as the maximum depth of depression on the DEM that was to be filled before creating the flow network. The higher the value, the longer it takes to fill the depressions. 15 metre was considered as more appropriate. Seventeen (17) sub-basins were delineated from the entire basin with a total size of 5329.95 km^2 (Figure 2b) while Figure 2c shows the stream orders of the Kilange basin.

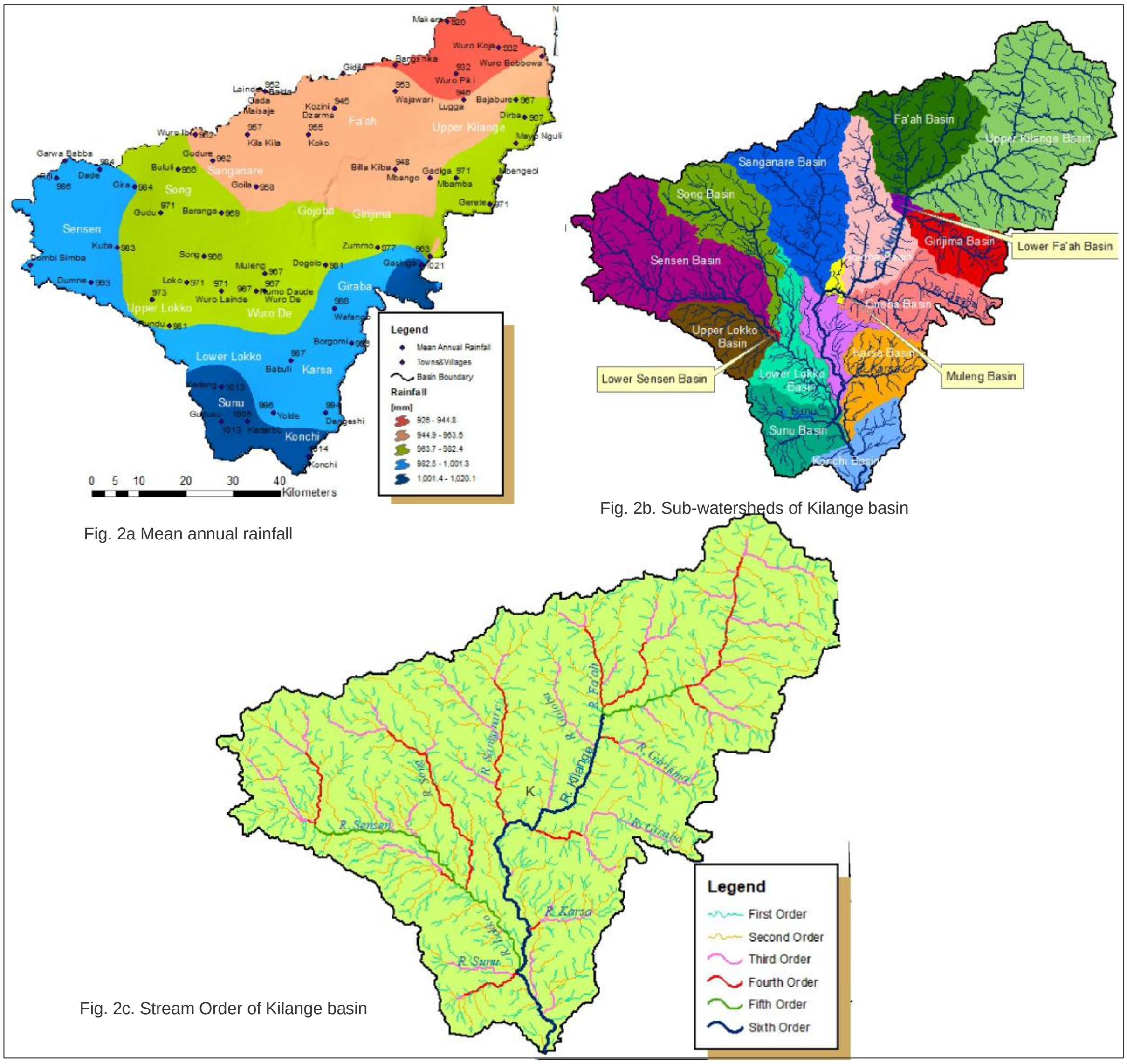

Fig. 2a Mean annual rainfall

Fig. 2b. Sub-watersheds of Kilange basin

Fig. 2c. Stream Order of Kilange basin

Source: Authors' Analysis (2019)

Morphometric Analysis

Quantitative technique was used to derive the values of most of the (i) Linear aspects (ii) Geometric aspects (iii) Relief aspects and (iv) Aerial aspects: Table 1 shows the different morphometric parameters, the formula as well as the results and remarks of each parameter. Twenty three morphometric parameters, their description, formula and sources which were grouped into five: drainage network, watershed area, watershed geometry, drainage network and relief characteristics were considered for this study as shown in Table 1.

Table 1 Description of Morphometric Parameters, Formula and Sources

A		**Drainage Network**	
S/N	**Morphometric Parameters**	**Description**	**Formula and Sources**
1	Stream Number (Nu)	The number of streams of each order in a given watershed (Sandeep, 2016)	Nu = N1+N2+…Nn Where N is the number of stream in a stream order
2	Stream Length	Basin length is defined as straight line distance from a basin mouth to the outlet point [Mayuri and Arunima 2016, Ikusemoran, Yelwa and Abdussalam 2018)	Calculate geometry module of ArcGIS 5 (Ikusemoran, Yelwa and Abdussalam 2018)
3	Bifurcation Ratio (Rb)	It is the ratio between the total number of first order streams to that of the next higher order streams in the basin (Ravindra and Vijay (2017).	Rb=Nu/Nu-1. Nu = the number of the first order & Nu+1 = number of the first order stream in the next order. (Ravindra and Vijay (2017).
4	Circulatory Ratio(Rc)	The ratio of the basin area (A) and the area of a circle with the same perimeter as that of the basin (Sandeep, 2016)	$Rc=4\pi(A/P^2)$. π is 3.14, A is the area & P is the perimeter (Sandeep, 2016)
5	Rho Coefficient	The Rho coefficient is defined as the ratio of stream length ratio and bifurcation ratio (Mayuri and Arunima 2016)	RL/Rb. RL = the Stream length ratio & Lb, = bifurcation ratio (Mayuri and Arunima 2016)
6	Lemniscate (k)	Lemniscate Ratio is a measure to describe how closely the actual drainage basin shape approaches the loop of a lemniscates (Yahya, Omar, and Ali 2016)	Lb^2/A. Lb = the basin length & A = the area of the basin (Yahya, Omar, and Ali 2016)
		Relief Characteristics	
7	Basin Relief	Basin relief of any point is the difference in elevation between the highest and the lowest point in a drainage basin (Sandeep, 2016)	H-h. H = the maximum height & h minimum height (Sandeep, 2016)
8	Relief Ratio	Rh is the dimensionless height–length ratio between the basin relief (R) and the basin length	R/Lb. R = the basin relief & Lb = the basin stream length
9	Ruggedness Number	Ruggedness number is used to measure surface roughness or unevenness of the basin	Dd*H/1000.Dd is drainage density & H = Basin relief
10	Gradient Ratio	Gradient ratio suggests channel slope from which runoff volume could be evaluated (Vaibhav, Pawan, and Kireet, 2018).	Es - Em/LbEs = the elevation of the source and Em = the elevation of the mouth of the stream (Vaibhav et al., 2018).

S/N	Morphometric Parameters	Description	Formula and Sources
B		**Watershed Geometry**	
11	Basin Area	The area of a drainage basin is defined as the total area of the basin projected upon a horizontal plane.	Calculate geometry module of ArcGIS 5
12	Basin Perimeter	Basin perimeter is the outer boundary of watershed, that is, the distance measured around the shape of a basin.	Calculate geometry module of ArcGIS 5
13	Form Factor Ratio (Ff)	Form factor is a dimensionless ratio of the area (A) of a drainage basin to the square of its maximum length (Lb) (Mohd and Haroon, 2014).	$A/Lb^{2.}$ Where A is the area and Lb is the basin length (Mohd and Haroon, 2014).
14	Elongation Ratio	Elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Mayuri and Arunima, 2016).	$\sqrt{(4\times A/P)}/Lb$. Where A is the Area and P is the perimeter of the Basin (Mayuri and Arunima 2016).
15	Lemniscate (k)	It describes how closely the actual drainage basin shape approaches the loop of a lemniscates basin (Yahya, Omar and Ali, 2016)	Lb^2/A Lb is Basin Length and A is Area of the Basin basin (Yahya, Omar and Ali 2016)
C		**Drainage Texture**	
16	Stream Frequency (Fs)	The stream frequency or channel frequency (Fs) is the total number of stream of the orders per unit area (Mayuri and Arunima, 2016)	Nu/A. Where Nu is the total number of streams and A the area of the basin
17	Drainage Texture (Dt)	Drainage texture is the total number of stream segments of all orders per perimeter of that area (Mohd and Haroon, 2014).	Nu/P. Nu =total streams of all orders and P= Perimeter of the basin
18	Drainage Density (Dd)	Drainage density can be regarded as the total length of the streams of all orders per drainage area (Mohd, and Haroon, 2014).	Lu/A. Lu = the total length of streams and A = area of the basin (Mohd and Haroon, 2014).
19	Drainage Intensity (Di)	Drainage intensity indicates runoff, flooding, gully erosion, landslides and denudation of the basin (Mayuri and Arunima, 2016).	Fs/Dd. Fs = stream density & Dd = drainage density
20	Length of overland flow	The length of sheet flow of water over the ground before it gets concentrated into definite stream channels (Sandeep, 2016)	1/2Dd. Dd = the Drainage Density (Sandeep, 2016)
21	Channel Maintenance	It is the length of water over the constant of channel maintenance	1/Dd. Dd = Drainage density(Ayele, Hiroshi, Katsuyuki, Nigussie and Kifle, 2017)
22	Texture Ratio	Texture ratio indicates morphometric structure, runoff and drainage texture of the basin, it depends on the lithology, infiltration capacity and relief of the catchment (Ravindra and Vijay, 2017).	Dd*Fs Dd = drainage density &Fs = Stream frequency. (Ravindra and Vijay, 2017).

RESULTS AND DISCUSSION

The calculated values of each parameter in each sub-basin as well as the mean value of each of the seventeen sub-basins are presented in Table 2.

A Drainage Network Parameters

(i) Stream Order

The higher streams order of network, the greater run off and infiltration, therefore, hazard increases with increasing stream order (Mostafa, 2015). Figure 2c shows the stream order of the entire Kilange Basin, while Table 2 shows the number and length of stream order in each of the seventeen sub-basins.

(ii) Stream Length

The cumulative lengths of all the streams in each of the stream order and each of the sub-basins are presented in Table 3. Stream length indicates surface run-off characteristics like slopes steepness, lithology and topography (Ikusemoran, Yelwa and Abdussalam, 2018), longer streams have permeable bedrock and well-drained network (Ravindra and Vijay, 2017). Upper Kilange, Sensen and Sananganare have the highest stream lengths within the basin (Table 3) and hence might be more prone to erosion than floods

(iii) Stream Numbers

The total number of streams in all the stream order and in all the sub catchment is 1,226 (Table 3). This decreasing stream orders agree with the law of stream numbers (Mostafa, 2015).

(iv) Bifurcation Ratio (Rb)

High Rb values in sub-watersheds suggest the significant influence of structural elements on the drainage network and presence of highly dissected subwatersheds. By contrast, low Rb values of sub-watersheds are the characteristics of structurally less disturbed watersheds with minimal distortion in drainage pattern (Ayele et al., 2017). The mean bifurcation ratio in Sanaganare and Upper Kilange sub basins are higher than others which indicate mountainous or highly dissected watersheds of these two catchments as revealed from the relief map in Figure 1. These mountainous and dissected watersheds might be more prone to soil erosion than the other sub basins.

Table 2. Values of the Morphometric Characteristics of the Sub-watersheds in Kilange Basin

WS	Drainage Network				Area Parameters		Watershed Geometry						Drainage Texture							Relief Characteristics				
	Lu	Nu	Rb	Rho	A	P	Lm	Lb	Cr	Er	Cc	Ff	Fs	Dd	Dt	Tr	Di	Lof	Cm	R	Rr	Rn	Gr	**Cp**
1	470.22	166	2.76	0.23	713.24	163.91	5.39	61.99	0.33	0.53	0.03	0.19	0.23	0.66	1.01	0.15	0.35	0.76	1.52	883	14.24	0.59	6.92	
	16	**16**	**15**	**13**	**16**	**16**	**6**	**1**	**13**	**12**	**14**	**11**	**9**	**12**	**14**	**11**	**5**	**6**	**6**	**15**	**10**	**17**	**8**	**11.39**
2	3.78	2	0.00	0.00	3.75	9.83	3.63	3.69	0.49	0.64	0.37	0.28	0.53	1.01	0.20	0.54	0.52	0.50	0.99	16	4.33	0.02	2.17	
	1	**1**	**1**	**1**	**1**	**1**	**12**	**17**	**6**	**6**	**1**	**6**	**17**	**17**	**2**	**17**	**17**	**1**	**1**	**1**	**1**	**1**	**1**	**5.65**
3	231.58	82	2.45	0.16	353.99	124.37	6.27	47.11	0.29	0.49	0.05	0.16	0.23	0.65	0.66	0.15	0.35	0.77	1.53	826	17.53	0.54	9.38	
	13	**12**	**10**	**10**	**13**	**14**	**4**	**6**	**15**	**15**	**7**	**15**	**9**	**11**	**8**	**11**	**5**	**7**	**7**	**14**	**11**	**15**	**11**	**10.57**
4	143.12	45	2.63	0.47	209.60	67.17	4.60	31.06	0.58	0.63	0.05	0.22	0.21	0.68	0.67	0.14	0.35	0.74	1.47	268	8..63	0.18	4.41	
	7	**6**	**13**	**15**	**7**	**4**	**9**	**11**	**2**	**8**	**7**	**9**	**6**	**16**	**9**	**6**	**5**	**5**	**5**	**3**	**4**	**5**	**3**	**7.17**
5	170.20	48	0.80	1.01	236.91	114.50	9.97	48.59	0.23	0.41	0.07	0.10	0.20	0.72	0.42	0.14	0.28	0.69	1.38	304	6.26	0.22	4.75	
	9	**7**	**4**	**17**	**8**	**13**	**1**	**4**	**17**	**17**	**4**	**17**	**4**	**15**	**5**	**6**	**2**	**2**	**2**	**7**	**2**	**7**	**4**	**7.57**
6	323.34	140	3.15	0.12	554.29	132.08	4.09	47.63	0.40	0.59	0.03	0.24	0.25	0.58	1.06	0.15	0.43	0.86	1.72	473	9.93	0.27	7.58	
	15	**15**	**16**	**5**	**15**	**15**	**10**	**5**	**10**	**9**	**14**	**8**	**12**	**6**	**15**	**11**	**13**	**12**	**12**	**10**	**6**	**10**	**10**	**11.04**
7	188.99	88	2.46	0.03	350.29	109.08	7.45	51.07	0.37	0.50	0.04	0.13	0.25	0.54	0.81	0.14	0.46	0.93	1.85	577	11.30	0.31	5.60	
	11	**13**	**11**	**3**	**12**	**11**	**2**	**3**	**11**	**13**	**11**	**16**	**12**	**3**	**11**	**6**	**15**	**14**	**14**	**11**	**8**	**11**	**6**	**9.91**
8	259.42	110	2.62	0.49	454.82	103.26	2.58	34.24	0.54	0.71	0.03	0.39	0.24	0.57	1.07	0.14	0.42	0.88	1.75	819	23.92	0.47	17.26	
	14	**14**	**12**	**16**	**14**	**10**	**15**	**10**	**4**	**3**	**14**	**3**	**11**	**5**	**16**	**6**	**12**	**13**	**13**	**13**	**15**	**12**	**16**	**11.35**
9	572.98	221	3.52	0.13	1061.57	172.68	2.62	52.7	0.45	0.68	0.02	0.38	0.21	0.54	1.28	0.11	0.39	0.93	1.85	927	17.59	0.50	13.72	
	17	**17**	**17**	**6**	**17**	**17**	**14**	**2**	**8**	**5**	**17**	**4**	**6**	**3**	**17**	**3**	**16**	**15**	**14**	**17**	**12**	**14**	**15**	**11.87**
10	7.17	3	0.00	0.00	18.57	19.86	1.11	4.54	0.59	0.91	0.15	0.90	0.16	0.39	0.15	0.06	0.41	1.28	2.56	102	22.47	0.04	11.67	
	2	**2**	**1**	**1**	**2**	**2**	**17**	**16**	**1**	**1**	**3**	**1**	**2**	**2**	**2**	**1**	**9**	**16**	**16**	**2**	**13**	**2**	**12**	**5.48**
11	9.94	4	0.60	0.15	26.67	30.10	1.39	6.08	0.37	0.76	0.16	0.72	0.15	0.37	0.13	0.06	0.41	1.35	2.70	273	44.90	0.10	28.72	
	3	**3**	**3**	**8**	**3**	**3**	**15**	**15**	**11**	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**9**	**17**	**17**	**4**	**17**	**3**	**17**	**6.87**
12	133.82	58	2.30	0.13	208.73	67.59	3.25	26.05	0.57	0.69	0.04	0.31	0.28	0.64	0.86	0.18	0.44	0.78	1.56	766	29.40	0.49	12.28	
	6	**9**	**9**	**6**	**6**	**5**	**13**	**14**	**3**	**4**	**11**	**5**	**15**	**10**	**13**	**15**	**14**	**8**	**8**	**12**	**16**	**13**	**13**	**9.91**
13	126.18	28	2.27	0.22	177.94	95.21	6.59	34.25	0.25	0.47	0.07	0.15	0.16	0.71	0.29	0.11	0.23	0.70	1.41	305	8.91	0.22	7.07	
	5	**4**	**8**	**12**	**5**	**9**	**3**	**9**	**16**	**16**	**4**	**13**	**2**	**14**	**4**	**3**	**1**	**3**	**3**	**8**	**5**	**7**	**9**	**7.09**
14	195.6	80	2.73	0.46	308.02	113.73	5.23	40.15	0.30	0.52	0.05	0.19	0.26	0.63	0.70	0.16	0.41	0.79	1.59	902	22.47	0.57	13.87	
	12	**11**	**14**	**14**	**11**	**12**	**7**	**7**	**14**	**14**	**7**	**11**	**14**	**8**	**10**	**14**	**9**	**9**	**9**	**16**	**13**	**16**	**14**	**11.57**
15	170.44	68	1.41	0.15	241.83	80.23	5.66	36.99	0.47	0.57	0.05	0.18	0.28	0.70	0.85	0.20	0.40	0.71	1.43	302	8.16	0.21	6.00	
	10	**10**	**5**	**8**	**9**	**8**	**5**	**8**	**7**	**11**	**7**	**14**	**15**	**13**	**12**	**16**	**8**	**4**	**4**	**6**	**3**	**6**	**7**	**8.52**
16	98.06	32	2.20	0.06	163.31	69.40	4.91	28.41	0.43	0.58	0.06	0.20	0.20	0.60	0.46	0.12	0.33	0.83	1.67	282	9.93	0.17	2.92	
	4	**5**	**7**	**4**	**4**	**6**	**8**	**13**	**9**	**10**	**6**	**10**	**4**	**7**	**6**	**5**	**3**	**11**	**11**	**5**	**6**	**4**	**2**	**6.32**
17	154.99	51	2.14	0.16	246.42	77.91	3.91	31.04	0.51	0.64	0.04	0.26	0.21	0.63	0.65	0.14	0.33	0.79	1.59	405	13.05	0.26	5.15	
	8	**8**	**9**	**10**	**10**	**7**	**11**	**12**	**5**	**6**	**11**	**7**	**6**	**8**	**7**	**6**	**3**	**9**	**9**	**9**	**9**	**9**	**5**	**8.00**

Lu= Stream Length, Nu=Stream Number, Rb= Mean Bifurcation Ratio, Rho= Rho Coefficient, A=Basin Area, P=Basin Perimeter, Lm=Lenmiscate, Lb=Basin Length, Cr, Circulatory Ratio, Er=Elongation Ratio, Cc= Compactness Coeeficient, Ff= Form Factor, Fs=Stream Frequency, Dd=Drainage Density, Dt=Texture Ratio, Di=Drainage Intensity, Lof= Length of overland Flow, Cm= Constant of Channel Maintenance, R=Basin Relief, Rn= Ruggedness Number, Gr= Gradient Ratio. Cp= Compound Value.

1=Sensen Basin, 2= Lower Sensen Basin, 3= Song Basin, 4=Upper Lokko Basin, 5= Lower Lokko Basin, 6=Sangananare Basin, 7=Gojoba Basin, 8=Fa'ah Basin, 9= Upper Kilange Basin, 10=Lower Fa'ah Basin, 11=Muleng Basin, 12=Girijima Basin, 13=Wuro De Basin, 14=Giraba Basin, 15=Karsa Basin, 16=Konchi Basin, 17=Sunu Basin

Source: Authors work (2019)

Table 3. Numbers and Lengths of Streams in each Sub-basin

Sub-Basins		1st		2nd		3rd		4th		5th		6th		Total	Total	
	Area	Nu	Lu	Nu	Lu	Nu	Lu	Nu	Lu	Nu	Lu	Nu	Lu	Nu	Lu	MLr
Sensen	713.24	119	227.72	36	139.22	8	57.76	2	17.78	1	32.74	0	0	166	470.22	0.63
L/Sensen	3.75	1	0.09	0	0	0	0	0	0	1	3.69	0	0	2	3.78	0
Song	353.99	64	108.46	14	62.75	3	33.88	1	26.49	0	0	0	0	82	231.58	0.38
Upper Lokko	209.60	37	79.76	6	59.52	1	0.62	1	3.38	0	0	0	0	45	143.12	1.24
Lower Lokko	236.91	33	86.24	11	43.45	0	0	2	15.77	2	24.74	0	0	48	170.20	0.81
Sanganare	554.29	111	169.09	25	88.12	3	33.44	1	32.69	0	0	0	0	140	323.34	0.37
Gojoba	350.29	69	96.08	16	37.32	2	31.22	0	0	0	0	1	24.37	88	188.99	0.08
Fa'ah	454.82	86	131.23	16	57.67	5	32.16	2	36.63	1	1.73	0	0	110	259.42	1.28
U/Kilange	1061.57	169	309.77	38	168.48	10	37.87	3	37.87	1	18.59	0	0	221	572.98	0.45
Lower Fa'ah	18.57	3	7.17	0	0	0	0	0	0	0	0	0	0	3	7.17	0
Muleng	26.67	3	6.77	1	3.17	0	0	0	0	0	0	0	0	4	9.94	0.09
Girijima	208.73	45	79.52	10	24.43	2	25.10	1	4.77	0	0	0	0	58	133.82	0.31
Lokko	177.94	22	53.54	3	35.54	1	1.04	1	1.81	0	0	1	34.25	28	126.18	0.49
Giraba	308.02	62	108.58	15	40.27	2	35.11	1	11.50	0	0	0	0	80	195.6	0.31
Karsa	241.83	50	97.17	14	46.52	4	26.75	0	0	0	0	0	0	68	170.44	0.21
Konchi	163.31	25	55.61	5	22.73	1	5.98	0	0	0	0	1	13.74	32	98.06	0.13
Sunu	246.42	37	80.15	10	36.69	2	16.99	1	12.94	0	0	1	8.22	51	154.99	0.34
Total	**5329.95**	**936**	**1696.95**	**220**	**865.88**	**44**	**337.92**	**16**	**201.63**	**6**	**81.49**	**4**	**80.58**	**1226**	**3259.83**	

Nu=Number of streams, Lu = Lengths of Streams, MLr = Mean Length Ratio

Source: Authors work (2019)

Table 4 Bifurcation Ratio of each Sub-watershed in Kilange Basin

	Sub Basin	1	2	3	4	5	6	Rb1	Rb2	Rb3	Rb4	Rb5	Total	Mean
1	Sensen	119	36	8	2	1	0	3.31	4.5	4.00	2.00	0.00	13.81	2.76
2	Lower Sensen	1	0	0	0	1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Song	64	14	3	1	0	0	4.57	4.67	3.00	0.00	0.00	12.24	2.45
4	Upper Lokko	37	6	1	1	0	0	6.17	6.00	1.00	0.00	0.00	13.17	2.63
5	Lower Lokko	33	11	0	2	2	0	3.00	0.00	0.00	1.00	0.00	4.0	0.80
6	Sanganare	111	25	3	1	0	0	4.44	8.33	3.00	0.00	0.00	15.77	3.15
7	Gojoba	69	16	2	0	0	1	4.31	8.00	0.00	0.00	0.00	12.31	2.46
8	Fa’ah	86	16	5	2	1	0	5.38	3.20	2.50	2.00	0.00	13.08	2.62
9	Upper Kilange	169	38	10	3	1	0	4.45	3.8	3.33	3.00	0.00	14.58	3.52
10	Lower Fa’ah	3	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Muleng	3	1	0	0	0	0	3.0	0.00	0.00	0.00	0.00	3.00	0.60
12	Girijima	45	10	2	1	0	0	4.50	5.00	2.00	0.00	0.00	11.50	2.30
13	Wuro De	22	3	1	1	0	1	7.33	3.00	1.00	0.00	0.00	11.33	2.27
14	Giraba	62	15	2	1	0	0	4.13	7.50	2.00	0.00	0.00	13.63	2.73
15	Karsa	50	14	4	0	0	0	3.57	3.50	0.00	0.00	0.00	7.07	1.41
16	Konchi	25	5	1	0	0	1	5.00	5.00	1.00	0.00	0.00	11.00	2.20
17	Sunu	37	10	2	1	0	1	3.70	5.00	2.00	0.00	0.00	10.70	2.14

Source: Authors work (2019)

(v) Rho Co-efficient

Rho coefficient indicates storage capacity of drainage network which is largely determined by some factors like climatic, geologic, geomorphic, biologic and anthropogenic (Mayuri and Arunima, 2016).Sub-watersheds having high value of Rho coefficient are subject to a greater risk of being eroded by excess discharge during flood (Ayele et al., 2017). Upper Lokko, Fa’ah, and Giraba sub catchments all have high Rho co-efficient and therefore are likely to be more prone to erosion and flooding. Sub catchments like Lower Sensen, Lower Fa’ah which are located in the floodplains (Figure 1) have zero Rho value which means less soil erosion but more floods.

B Areal Parameters

(i) Basin Area

Basin area plays a decisive role in determining aspect, size and shape of the basin (Manoj and Anilkumar, 2015). Lag time will be longer in the larger basin than the smaller ones, which meansless flood occurrence in larger basin and vice-versa. The larger the basin, the greater the volume of rainfall it intercepts, and the higher the peak discharge that result (Mayuri and Arunima, 2016). Table 4 shows that Upper Kilange, Sensen and Sanganare sub-basins; are the largest among the seventeen sub-basins in the catchment, hence, with possibility of less flood occurrence.

(ii) Basin Perimeter

The length of the outer boundary of a basin is known as basin perimeter. The length of a basin perimeter depends on the size of the basin. In Kilange basin, large sub basins like Upper Kilange, Sanganare and Sensen also have higher basin perimeters as shown in Table 2.

C Watershed Geometry

(i) Basin Length

Basin length is defined as distance from a basin mouth to the outlet point (Sandeep, 2016). The sub basins with long basin lengths include Sensen, Upper Kilange, and Gojoba with 61.99, 52.7 and 51.07 kilometres respectively.

(ii) Form Factor (Rf)

Except Lower Fa'ah and Muleng basins with 0.90 and 0.72 form factor values respectively, on Table 3, none of the sub basins have higher than 0.6. Drainage basins with form factors between 0-0.6 are said to be slightly elongated with flatter peak flow and longer duration (Ikusemoran, Yelwa and Abdussalam, 2018). Hence most of the sub basins in Kilange watershed are slightly elongated with flatter peak flow and longer duration.

(iii) Circulatory Ratio

Circularity ratio indicates flow of discharge and erosion (Ravindra and Vijay, 2017).The value of circulatory ratio varies from 0 (in line) to 1 (in a circle). Low Rc value implies elongated basin shape while high Rc value indicates near circular shape (Sandeep, 2016). Rc values approaching 1 indicates that the basin shapes are like circular and as a result it gets scope for uniform infiltration and takes long time to reach excess water at basin outlet (Mayuri and Arunima,2016). Only five (5) sub basins in Kilange catchment have more than 0.5 Rc, that is, Lower Fa'ah with 0.59, Upper Lokko with 0.58, Girijima with 0.57 and Sunu with 0.51. Therefore, most of the sub catchments can be said to be of elongated shapes as revealed in Figure 2b.

(iv) Elongation Ratio

Analysis of elongation ratio indicates that the areas with higher elongation ratio values have high infiltration capacity and low runoff (Bharadwaj et al., 2014).Values close to 1.0 are the regions of very low relief, whereas values range between 0.6 to 0.8 are usually associated with high relief and steep ground slope (Ikusemoran, Yelwa and Abdussalam, 2018). These values can be grouped into three categories viz., circular (>0.9), oval (0.9-0.8), and less elongated (<0.7) (Ikusemoran, Yelwa and Abdussalam, 2018). Therefore in Kilange basin, all the sub basins (Table 3) exceptLower Fa;ah (0.91), Muleng (0.76) and Fa'ah (0.71) have less than 0.7 elongation ratio which implies the sub basins are more of elongation than oval or circular. These three sub basin have their basins tending towards oval as evidenced from the shape of these basin in Figure 2b.

(v) Compactness Co-efficient

High compactness coefficient indicates less elongation and high erosion whereas low compactness shows more elongation and less erosion (Ravindra and Vijay, 2017). Table 3 revealed that only three out of the seventeen sub basins have relative high compactness, that is, Lokko central (0.37), Kilange central (0.15) and Muleng (0.16) which are the three smallest basins. Moreover, these three sub basins are located at the confluences of rivers (Figure 2b). Therefore, since most of the catchment areas have low compactness, more elongation and less erosion are expected in most parts of the basin.

D Drainage Texture

(i) Drainage Texture

Drainage texture depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development (Bharadwaj et al., 2014). Drainage texture are classified into five classes i.e., very coarse(<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8) (Bharadwaj et al., 2014).Looking at the Drainage Texture of all the drainage basins in Table 2, they all fall below 2 which mean that generally, the drainage texture of the basin is very coarse. However, Sensen, Sanangare, Fa'ah, and Upper Kilange, (Table 2) have higher values of 1.01, 1.06 and 1.07and 1.28 respectively which shows that the four sub basins are more coarse than the other sub basins.

(ii) Texture Ratio

Drainage lines are numerous over impermeable areas than permeable areas (Mayuri and Arunima, 2016). Low texture ratio values have coarse textures than those with higher values. Kilange and Muleng have lower texture values than the other sub basins which suggest that the two sub-basins have more coarse texture than the other sub basins. Drainage Basin which is moderately coarse with its permeable landscape is as well prone to gully erosion especially along steep slopes and impervious areas due to poor drainage systems capable of initiating and sustaining gully development in the area (Oyatayo et al., 2017)

(iii) Drainage Intensity

Generally, the drainage intensity of Kilange basin is generally low with the highest as 0.52. Low drainage intensities influences soil erosion because though watersheds with low drainage intensities are less vulnerable to soil erosion but are highly prone to floods (Oyatayo et al., 2017). Constant flooding can therefore results into gullying processes from run off on the steep sided slopes and impervious rock areas especially during the raining seasons as opined by Oyatayo et al. (2017) that longer surface runoff makes a basin to be susceptible to flooding and erosion.

(iv) Drainage Density

Low drainage density is more likely to occur in regions of highly permeable subsoil material under dense vegetative cover, and where relief is low. In contrast, high Dd is favoured in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (Bharadwaj et al., 2014). The drainage density of Kilange basin is generally low, which signifies high permeability and low relief as shown in the relief map of the area (Figure 1). Among the Kilange sub basins, Lower Fa'ah and Muleng have the least drainage density with 0.39 and 0.37 respectively.

(v) Stream Frequency

Sub-watersheds with dense forest show less frequency of streams in drainage network whereas agricultural lands show higher frequency (Ravindra and Vijay, 2017). Like the drainage density, the stream frequency of the entire basin is generally low with all values less than 1 and except Lower Sensen, none of the values is up to 0.5. The large uninhabited land area especially in song LGA part of the Basin might be responsible for the general low stream frequency of the Basin.

(vi) Length of Overland Flow

Higher value of Lg is indicative of low relief and low value of Lg an indicative of high relief. The greater the Lo, the greater, in general, is the infiltration and the less the direct surface runoff. Moreover, relatively shorter Lo is characteristics of areas with steeper slopes and fine texture that lead to high surface runoff generation. In the entire Kilange Basin, the mean of the Lo is 0.84 km which is considered high with gentle slopes, long flow paths more infiltration and less run off. Only two sub basins (Lower Fa'ah and Muleng) have their Lg value more than 1. These two sub-basins are located in a very low terrain as shown in (Figure 1). However, sub basins like Upper Kilange, Gojoba, Sanganare and Fa'ah which have mountainous parts of their land area, have their Los larger than that of the basin average and hence, the sub-basins have higher relief.

(vii) Lemniscate

Low values of lemniscate represent basin nearly rounded and prevailing vertical and lateral erosions, while highest values represent elongated basins (Mostafa, 2015). In Kilange Basin, Muleng, Lower Fa'ah, Lower Sensen and Fa'ah sub catchments have low lemniscate values which suggests their round shapes as revealed in Figure 2b. Sensen, Gojoba, Wuro De and Song catchments have high lemniscate values, hence, their shapes are elongated (Figure 2b).

(xiii) Constant of Channel Maintenance (Cc)

Low values of Cc indicate limited percolation/infiltration and hence more surface runoff, while higher value of Cc reveals a surface of high permeability and indicates relatively higher infiltration rates, moderate surface runoff, less dissection and watershed (Anjali and Punwatkar, 2017, Choudhari, Nigam and Sapana,2018). Table 3 shows that Lower Sensen, Lower Lokko and Wuro De sub-basins have low values of Cc. These sub-basins with low Cc are located mainly along the main Kilange stream. These low values suggest limited percolation/infiltration and hence more surface runoff due to their locations within the basin.

E Relief Parameters

(i) Relative Relief

Among the sub-basins of the Kilange watershed, with very high relative relief are Upper Kilange (927m), Giraba (902m), Sensen (883m), Song (826m); all these sub basins because of their steep slopes are prone to soil erosion. However, Lower Sensen, Karsa, Konchi among others which are located mainly in the low floodplains have low relative relief and hence, more prone to floods than soil erosion.

(ii) Relief Ratio

Low relief ratios indicate that the recharge capabilities of the basin are low and chances of high ground water potential (Oruonye, 2016). Similarly, Kaliraj, Chandrasekar and Magesh (2014) attributed low value of Rh mainly to resistant basement rocks and low degree of slope. Oruonye (2016) considered relatively high Rh values as indicative of high intensity of erosion processes operating along the hillslopes as well as sediment transport capacity. Runoff is generally faster in sub-watershed with high Rh producing more peaked discharges and hence greater erosive power. The sub basins of Kilange watershed has Muleng, Girijima, Fa'ah and Giraba as the highest relief ratio which have more chances of been eroded.

(iii) Ruggedness Number

Low Rn suggests less prone to soil erosion and intrinsic structural complexity in association with relief and drainage density (Adegoke and Bulus, 2015). Higher indicates irregular topography, lithological heterogeneity, high drainage density and high soil erosion (Ayele et al., 2017). The Kilange catchments has Sensen, Giraba, Song and Upper Kilange as the sub catchments with high Rn, These are the sub catchments with high relief as shown in the relief map in Figure 1. Lower Sensen, Lower Fa'ah, Konchi and Upper Lokko are among the sub basins with low Rn and hence gently sloped with less soil erosion.

(iv) Gradient Ratio

Higher value of gradient ratio represents higher channel slope associated with steep V-shaped channel. The high gradient ratios in Fa'ah (from Pella hills), Girabi and Girijima (from Maduru hills), and Upper Kilange from Hudu hills are results of the presence of mountain ranges in these sub-basins (Figure 1). The sub basins with low gradient ratios are Lower Sensen, Konchi as well as Lower and Upper Lokko which are all located in low terrain (Figure 1).

SOIL EROSION AND FLOOD SUSCEPTIBILITY ASSESSMENT

Soil Erosion Susceptibility Assessment

The results of the analyzed morphometric parameters are used in this paper to determine the vulnerability of soil erosion after which the sub-watersheds were prioritized. For instance, the bifurcation ratios of Kilange basin were higher in Upper Kilange, Giraba, Sanaganare, Song, Sensen and Fa'ah than the other sub-watersheds. Since the higher the bifurcation ratio, the higher the relief and the more prone to soil erosion, these sub-watersheds with higher bifurcation ratio are found to be higher in altitudes and steeper in slope (Figure 1) and therefore more prone to soil erosion.

Similarly, the Rho coefficients with higher values denotes high relief and hence, more vulnerable to soil erosion. Some parameters such as form factors, elongation ratio, circulatory ratio, stream frequency among others also revealed the shapes of some sub-watersheds like Sanganare, Song, Sensen, Gojoba and Upper Kilange to be more elongated and therefore more vulnerable to soil erosion. Other parameters like drainage intensity, drainage density, length of overland flow and compactness coefficient also support the vulnerability of places with high relief to be prone to soil erosion. Low length of overland flow for instance leads to steeper slopes and high surface runoff and erosion than basins with high length of overland flow (Dzarma, 2018). Low compactness coefficients also results into limited percolation and infiltration and hence leads to more soil erosion (Ravindra and Vijay, 2017). The prioritization of Kilange sub-basins for soil erosion is shown in Figure 3a.

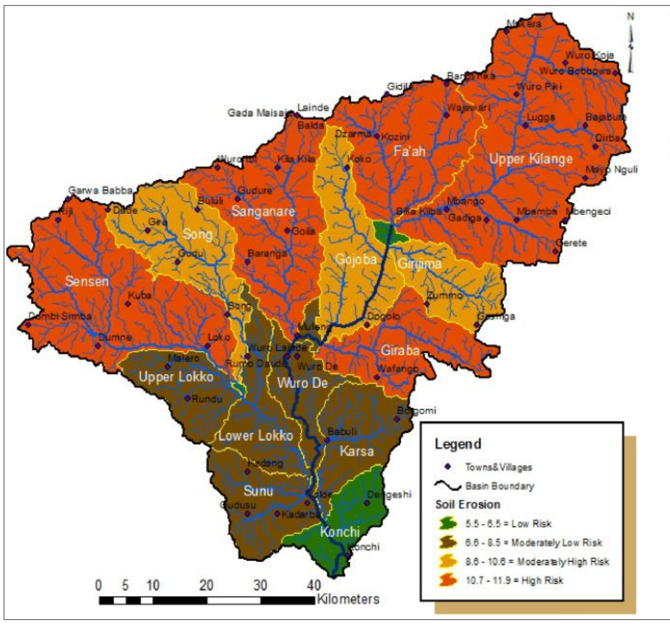

Fig. 3a. Kilange Basin Soil Erosion Risk

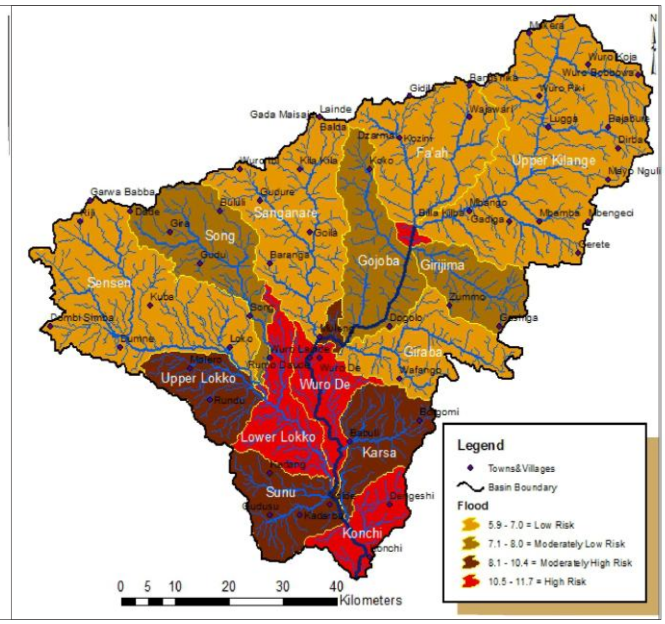

Fig. 3b. Kilange Basin Flood Risk

Source: Authors' Analysis (2019)

Table 5. Soil Erosion Vulnerability Classes in Kilange Basin

High Risk	Moderately High Risk	Moderately Low Risk	Low Risk
Sensen, Sangananre, Giraba, Fa'ah, Upper Kilange and Song	Girjima and Gojoba	Lower Lokko, Wuro De, Upper Lokko, Karsa and Sunu	Konchi, Muleng, Lower Fa'ah and Lower Sensen

Source: Authors' work (2019)

Figure 3a shows that the sub basins with high relief and elongated shapes which are more prone to soil erosion fall under either very high risk or high risk classes. The very high risk watersheds (Sensen, Sanganare, Giraba, Fa'ah, Upper Kilange and Song) coincide with the watersheds with high relief and elongated shapes as shown in Figs.1and 2b respectively. Gojoba sub-watersheds though located in low relief but elongated in shape fall under high risk class. All other sub-basins on low relief but with more of circular shapes than elongated fall under either moderate or low risk classes. The high watersheds that were classified as very high risk have been found to be prone to soil erosion especially the Upper Kilange Basin (Tukur, Bashir and Mubi, 2004; Adegoke and Bulus, 2015; Sunday et al., 2018). Infact, Tukur, Bashir and Mubi (2004), in their study of land degradation in this part of the state reported that the area was the first in present day Adamawa State to have started soil conservation practices.

Flood Susceptibility Assessment

The watersheds with more of circular shapes than elongated and which are also located in low relief were found to be more prone to floods and therefore, fall under high or moderately high risk flood susceptibility classes as shown in Figure 3b.

Table 6 Flood Vulnerability Classes in Kilange Basin

High Risk	Moderately High Risk	Moderately Low Risk	Low Risk
Konchi, Lower Lokko, Wuro De, Lower Sensen, Muleng, and Lower Fa’ah	Upper Lokko, Karsa and Sunu	Song, Girjima, Gojoba	Sensen, Sangananre, Giraba, Fa’ah, Upper Kilange

Source: Authors’ work (2019)

The geospatial techniques for generation of watersheds parameters have no doubt improved on the hitherto manual techniques in terms of accuracy, time and cost saving. The high relief and the elongated watersheds of the basin such as Song, Upper Kilange, Sensen, Sanganare among others were all found to be more vulnerable to soil erosion than floods, while the watersheds on low relief which are mostly circular like Karsa, Sunu, Lower and Upper Lokko, Wuro De, Muleng, Lower Sensen and Lower Fa’ah were more vulnerable to floods than soil erosion. Since the high relief of the Kilange Basin especially Upper Kilange sub-basin has been long subjected to environmental degradation and for the fact that flood has been devastating in Lokko Basin, prioritization of the watersheds for proper and effective management cannot be overemphasized.

CONCLUSION

Geospatial techniques for generation of morphometric parameters for prioritization of River Kilange watersheds for natural hazards susceptibility has been demonstrated in this paper. It was revealed in this paper that analysis of morphometric parameters of a watershed can be used to determine the vulnerability as well as prioritize watersheds for natural hazards vulnerability especially floods and soil erosion. Sub-watersheds with elongated and high relief were found to be at risk to soil erosion, while those with circular shape with low relief were vulnerable to floods. This paper therefore, can be a reference, sources of data and information as well as a guide for watershed prioritization for natural hazard management. Incorporation of other criteria other than morphometric parameters like soils, landuse and landcover among others for vulnerability of natural hazards in a basin as well as prioritization of the sub-basins for watershed prioritization is suggested for further studies.

It is therefore recommended that constant assessment and prioritization of sub-basins for effective watershed management and sustainable utilization and disaster risk reduction. The use of geospatial technique for watershed prioritization should be encouraged because of its advantages like ability to cover large areas and in short period, time and cost saving as well as accuracy and reliability of results. The watersheds with higher priority in each of the two assessed hazards (floods and soil erosion) should be given more attention in the watershed management than those with less priority.

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