

Assessment of Morphometric and Hydrological Properties of Small Watersheds in East Java Regions

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Abstrak

Artikel ini menyajikan identifikasi, penilaian dan visualisasi sifat fisik, topografi, morfometrik dan hidrologi daerah aliran sungai kecil di Wilayah Jawa Timur. Empat puluh empat (44) DAS digunakan untuk analisis. Sifat fisik (yaitu, jenis tanah dan penggunaan lahan) diperoleh dengan memotong lapisan GIS dengan batas daerah aliran sungai. Kemudian ASTER G-DEM2 digunakan untuk menurunkan sifat morfometrik daerah aliran sungai. Selain itu, sifat hidrologis diperoleh dengan menganalisis data curah hujan dan debit yang tersedia. Parameter yang dipilih adalah untuk mewakili setiap properti daerah aliran sungai. Akhirnya, korelasi sederhana antara sifat-sifat fisik, topografi, morfometrik, dan hidrologi daerah aliran sungai. Hasil penelitian menunjukkan bahwa beberapa DAS menunjukkan kesamaan dan perbedaan pada parameter morfometrik dan hidrologi.

Kata kunci: Kesamaan, fisik, topografi, morfometrik, hidrologi, DAS

Abstract

This paper presents identification, assessment and visualization of physical, topographic, morphometric and hydrological properties of small watersheds in East Java Region. Forty-four (44) watersheds used for the analysis. Physical properties (i.e., soil type and land use) are obtained by cropping the GIS layers with a watershed boundary. Then the ASTER G-DEM2 was used to derive morphometric properties of the watersheds. Furthermore, hydrological properties are derived by analyzing available rainfall and discharge data. Parameters selected were to represent each watersheds property. Finally, the simple correlation between physical, topographical, morphometric and hydrological properties of the watersheds. The result shows that some watersheds show the similarity and differences in morphometric and hydrological parameters.

Keywords: Similarity, physical, topographical, morphometric, hydrological, watershed

1. Introduction

Hydrological process on the watersheds is driven by rainfall as the main input. Physical properties of the watersheds (i.e., a soil layer, topography, land uses) also affect the magnitude response of the watershed to produce run-off. Some hydrological models count, consider and involve the physical properties of the watersheds to calculate run-off produced by rainfall events. One approach elaborated by classifying watershed properties. Classification approached by selecting similar properties of the watersheds and grouping to several categories (classes). Although, nature is naturally heterogeneous or diversifies and probably it is impossible to find two watersheds that

almost (100%) similar. However, some level of variability could be assumed to be similar by some criteria. Some similarities among watersheds may exist in the form of physical, topographic, morphometric, and hydrological properties. The similarity approach can be used to compare and to evaluate some watersheds properties. The similarity concept can also integrate into the modelling process.

Furthermore, by considering the similarity concept, hydrological process on certain watersheds can be identified. Physical properties of watersheds include form and size, river network, topography, land use, soil and geological layers. Each property probably has a strong impact on run-off production or the rainfall

process. Some researchers have been works in order to quantify some of these properties and include in the modelling process. Morphometric properties resume the quantitative relation between topography and river networks on the watershed. Interaction among morphometric, land use and soil layer determine the watershed response when rainfall event occurs. Morphometric properties can be used to conduct an analysis of ground-water resources potential and to manage the watershed. Many hydrological phenomena have a significant correlation with form and area, slope, drainage density, and other watershed properties. The amount of runoff on the watershed also depends on the structure and properties of river morphometric and catchment area. Generally, the morphometric analysis uses length, area and relief aspects of river network and watershed to derive parameter (Pande and Moharir, 2015).

Furthermore, grace the advance of GIS, Digital elevation model (DEM), hydro-informatics and remote sensing technology, more morphometrical, and other related parameters (such as bifurcation ratio, drainage density, slope factor, soil wetness-index, etc) can be derived automatically. Generally, the main input for morphometrical analysis is DEM. The DEM is widely available from many suppliers. For moderate resolution, the DEM can be downloaded directly from the website (for example ASTER GDEM2 available at pixel resolution 30 x 30 m can be download from <https://asterweb.jpl.nasa.gov/gdem.asp> (ASTER GDEM Validation Team, 2011). More satellite vendor such as ESA (<https://sentinel.esa.int/web/sentinel/home>) offers sentinel image series that can derive DEM by 10m x 10m in pixel resolution. Otherwise, the DEM can also be derived by interpolation method from topographical input data, such as the work initiated by (Indarto,

Table 1. Morphometric parameters adopted from (Altaf, Meraj, & Romshoo, 2013; Khare et al., 2014)

No.	Morphometric Parameters	Description	References
Linear Aspect			
1	Stream order (U)	Hierarchical order	Strahler, 1964
2	Stream length (Lu)	Length of the stream	Horton, 1945
3	Mean stream length (Lsm)	$L_{sm} = L_u / N_u$ where L_u =Stream length of order 'U' N_u =Stream length of next lower order. N_{u-1} =Stream length of next lower order.	Horton, 1945
4	Stream length ratio (RI)	$RI = L_u / L_{u-1}$ where L_u =Total stream length of order 'U', L_{u-1} =Total stream length of order 'U-1', N_{u-1} =Stream length of next lower order.	Horton, 1945
5	Bifurcation ratio (Rb)	$R_b = N_u / N_{u+1}$; where, N_u =Total number of stream segment of order 'u'; N_{u+1} =Number of the segment of next higher order	Schumm, 1956
Relief Aspect			
6	Basin relief (Bh)	The vertical distance between the lowest and highest points of the watershed.	Schumm, 1956
7	Relief ratio (Rh)	$R_h = B_h / L_b$; Where, B_h =Basin relief; L_b =Basin length	Schummn, 1956
8	Ruggedness number (Rn)	$R_n = B_h \times D_d$ Where, B_h =Basin relief; D_d =Drainage density	Schumm, 1956
Areal Aspect			
9	Drainage density (Dd)	$D_d = L / A$ where the L =Total length of streams; A =Area of watershed	Horton, 1945
10	Stream frequency (Fs)	$F_s = N / A$ where N =Total number of streams; A =Area of watershed	Horton, 1945
11	Texture ratio (T)	$T = N_1 / P$ where N_1 =Total number of first-order streams; P =Perimeter of watershed	Horton, 1945
12	Form factor (Rf)	$R_f = A / (L_b)^2$; where, A =Area of watershed, L_b =Basin length	Horton, 1945
13	Circulatory ratio (Rc)	$R_c = 4\pi A / P^2$; where, A =Area of the watershed, $\pi=3.14$, P =Perimeter of watershed	Miller, 1953
14	Elongation ratio (Re)	$R_e = 2\sqrt{A/\pi} / L_b$; where, A =Area of the watershed, $\pi=3.14$, L_b =Basin length	Schumm, 1956
15	Length of overland flow (Lof)	$L_{of} = 1 / D_d^2$ where, D_d =Drainage density	Horton, 1945
16	Constant channel maintenance (C)	$C = 1 / D_d$ where, D_d =Drainage density	Schumm, 1956
17	Index infiltration (IF)	$I_F = F_s \times D_d$ where, Stream frequency (Fs), Drainage density (Dd)	Horton, 1945
18	Compactness constant (Cc)	$C_c = 0.2821 \times P / A^{0.5}$ Where, A = Area, P = Basin perimeter, km	Horton, 1945

Wahyuningsih, Usman, & Rohman, 2008). Furthermore, The DEM is used as input to determine the watershed boundary, river network, morphometric parameters, and another indicator relevant to topography and terrain, hydrology, and soil, such as the work of (Indarto et al. 2008; Tarboton, Bras, and Rodriguez-Iturbe, 1991). This function is facilitated more detail by many of GIS and remote sensing software, such as Terrain Analysis System (TAS) (Lindsay, 2005) and the success of software named as Whitebox_GAT (Lindsay, 2016).

Table (1) lists the 18 morphometric parameters obtained from the previous study by other researchers (Khare, Mondal, & Mishra, 2014). Those parameters consist of linear, areal and relief aspect of morphometrics. Linear aspect considers only one dimension of morphometrics properties (i.e. Length). Some examples of a linear aspect of morphometrics are stream order (U), stream length (Lu), Mean stream length (Lsm), stream length ratio (RI), and bifurcation ratio (Rb). An areal aspect of morphometric count the properties that interact between the linear dimension of the river network and the area dimension of the watershed. Some example of areal aspect of morphometric properties are : drainage density (Dd), stream frequency (Fs), Texture ratio (T), form factor (Rf), Circulation ratio (Rc), Elongation Ratio (Re), Length of overland flow (lof), Constant Channel Maintenance (C), Index infiltration (IF), Basin shape (Bs), Compactness constant (Cc). Relief aspect of morphometric determine the properties that count interaction between topography and river network. Example of relief aspect is basin relief (Bh), Relief ratio (Rh), and Ruggedness number (Rn).

Early studies initiated by (Hermingler, Kumar, & Foufoula-Georgiou, 1993; Horton, 1933; Horton & Robert, 1945); (Miller, 1953), (Schumm, 1956), and (Strahler, 1964) discussed the importance of each morphometrical parameters in relation with hydrological processes on the watershed. Further studies conducted by many researchers in India and another part of the world do the example of how morphometric parameters derived from remote sensing data or GIS Data. Some researcher use the morphometrical properties as criteria to determine the priority level for conservation (Guth, 2011), (Toth, 2013), (Gajbhiye, Mishra and Pandey, 2014), (Chandniha and Kansal, 2014), (Rai et al., 2014), (Khare et al., 2014), (Singh and Singh, 2014), (Meshram and Sharma, 2015), (Umrikar, 2016), and (Soni, 2016). The objective of this study is: (1) to quantify the variability of physical and hydrological properties of the watersheds, (2) to find the relation between physical and hydrological properties of the watersheds.

2. Methods

2.1 Study site and input data

The study was conducted in the region of East Java Province. About 45 watersheds on the regions were used for this study (Figure 1).

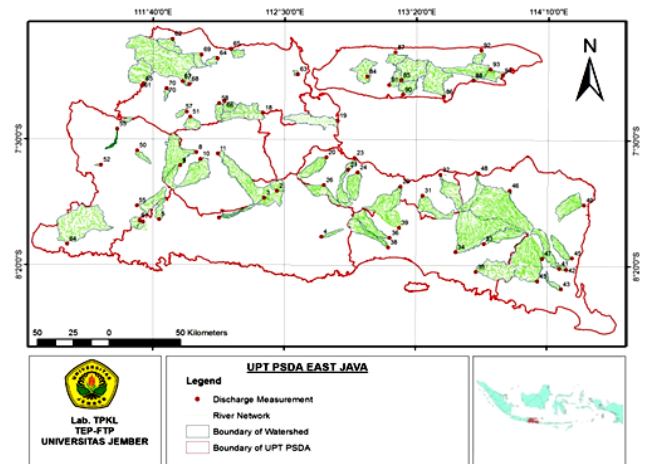


Figure 1. Location of watersheds used for this study

Watershed boundaries are determined from the DEM (Aster GDEM2) using an existing algorithm in the GIS Software. Then physical properties of the watersheds (i.e. land use, soil type, hydro-geological layers) are presented in the form of (%) areas occupied per total watershed area. The land use layer is downloaded from RBI Digital Maps of National Agency of Geospatial Information or *Badan Informasi Geospasial (BIG)*. Other layers to describe the physical properties of the watersheds are obtained from the existing database on the *Lab.TPKL (Laboratorium Teknik Pengendalian dan Konservasi Lingkungan)*. Furthermore, daily discharge and rainfall data obtained from an existing database. The data are collected initially from *UPT Dinas PU-Pengairan Provinsi Jawa Timur*. The UPT is a sub-administratif unit for water resources management. Region of East Java province is composed of nine (9) UPT boundaries. The data were collected since 2004 through many schemes of cooperation including research collaboration, a student internship, undergraduate and post graduate thesis.

2.2 Statistical analysis of hydrological data

Firstly, the daily flow data from the outlets were used to derive the statistical resume of daily discharge data i.e: Maximum, Minimum, Mean, Median, Mean Daily Baseflow (MDBF), Percentile 10, 25, 33, 66, 75, 90, and 95% (P10, P25, P33, P66, P75, P90, and P95). The mean and Median is a measure of central tendency. Mean is calculated as the average of the records (sum of values/number of days). The Median is the "middle" value for the entire record: it is the value exceeded 50% of the time. For flow data, the median is usually much lower than the mean daily flow because the distribution of discharge data is negatively *skewed* with a lower limit of zero and no upper limit. The Percentile value is the value that is exceeded a certain percentage. For instance, the 10th percentile is the value that is exceeded by 10% of the records. Then, the statistical distribution values i.e: Standard deviation (StDev), coefficient of variance (Cv), Kurtosis (Ku), Skewness (Skew), Variability (Var), Standard deviation of the log of daily flows (S_Log), Lane Variability Index (Lane), Base Flow Index (BFI), and Flood Flow Index (FFI) were

also calculated to represent hydrological properties of the daily discharge data. All of those value are calculated using the Time Series Module of the *River Analysis Package (RAP)* (Marsh, 2003).

The standard deviation (STDev) is a measure of how widely the values are dispersed from the mean value. For a small catchment stream, the base flow will be typically very low, with a dramatic change in discharge during a storm event. Most of the discharge thus occurs during a storm. However, most of the days are low flow. Hence the median flow is low, and the much larger event-based discharges elevate the mean flow. As a consequence, the skewness of a small catchment would be higher than that of a large catchment. Similarly, the Skewness of an unregulated stream will tend to be higher than that of a regulated stream (depending on the flow release strategy). The measure of variability (Var) used is based on the use of the median as a measure of central tendency. Variability is calculated as the range divided by the median. The user defines the range in terms of the percentile range of flows. The default setting for the range is the difference between the 10th and 90th Percentile values.

Flow data is often logged to reduce the skew, S_{Log} is a measure of the distribution of this transformed data, as such it describes the skew of the input data (Gordon et al., 1992).

$$S_{\log} = \frac{\log(X_5) - \log(X_{95})}{3.29} \quad (\text{eq. 1})$$

where: X₅ and X₉₅ are the 5th and 95th percentile values respectively

The Lane's variability index (Lanes) is described as the standard deviation of the logarithms of the 5th, 15th, 25th, ..., 85th and 95th percentile values. Lanes variability index is unsuitable for data sets with more than 5% zero values (i.e. 95th percentile = 0) or data sets dominated by zeros (Gordon et al., 1992).

Another indicator used in this study is an index of variability (Iv) or slope of flow duration curve (Sfdc). One approach to calculate Sfdc is by using a segment of fdc from percentile 33 (P₃₃) to percentile 66 (P₆₆), it is assumed that this segment is relatively linear (Pallard, Castellarin and Montanari, 2009; McMillan et al., 2016) (Taylor et al., 2009). Than Sfdc is calculated using equation (2).

$$Iv = S_{fdc} = \frac{\ln(P_{33\%}) - \ln(P_{66\%})}{(0.66 - 0.33)} \quad (\text{eq. 2})$$

where :

- S_{fdc} = slope of FDC,
- Q_{33%} = flow at percentile 33%, and
- Q_{66%} = flow at percentile 66%.

The steepest slope in FDC curve shows that the river is subject to high variation in flow regime. The contrary, gentle slope in FDC curve indicates that the flow regime is relatively stable from time to time (during one year). The stability of the flow regime formed by the

combination of rainfall events that distributed spatially around the part of the watershed area and rainfall event that consistently occur along the year. The gentle slope of FDC also shows that the contribution of groundwater portion to the river flow is significant. An example of the use of Sfdc to study the river flow regime have been published and applied by (Castellarin, 2014). Practically, flow duration curve (FDC) analysis was calculated by Hydro-office software (Gregor, 2012) and plotted using Excel.

2.3 Statistical analysis of rainfall data

Secondly, the same analysis is also conducted for daily rainfall data. Average daily rainfall data from each watershed are then entered to *River Analysis Package (RAP)* to calculate several values of statistical resume and distribution. Then, monthly and annual rainfall is derived from daily rainfall data using Time Series Manager Module (TSM) in RAP (Marsh, 2004; Marsh, Kennard, Arthington, Stewardson, & Arene, 2005). Analysis of rainfall data is conducted on RAP to obtain a statistical value of rainfall data. Finally, the statistical value obtained from the analysis of daily discharge and rainfall data is then compared between watersheds.

2.4 Morphometric analysis of the watershed

The Aster GDEM2 (<http://asterweb.jpl.nasa.gov/gdem.asp>) (ASTER GDEM Validation Team, 2011) was clipped by watershed boundaries to describe watershed topography. Then, a series of DEM treatment and watershed delineation was processed for each watershed. Furthermore, watersheds areas are then derived automatically from the DEM on the top of GIS using Hydrological *Function*. Finally, the main topographical areas of the watersheds are then determined automatically from the DEM. Topographical properties are then compared among the watersheds. Secondly, the morphometric parameters of each watershed are processed from the DEM, using. Then, 18 morphometric parameters are obtained from these processes (Table 1). Finally, morphometric parameters are compared among the watersheds.

2.5 Interpretation

Simple statistical method was used to find the possible relationships between hydrological, physical, topographic and morphometric parameters. In this study, simple correlation based on a coefficient of determination was conducted to find the relationships: (1) among morphometric parameters, (2) among hydrological (discharge and rainfall) parameters, (3) between hydrological vs morphometric parameters. In this case, the simple statistical criteria's based on the value of standard deviation (St.Dev) and coefficient of variance (Var) were used to identify the variability. If the values of **St.Dev** and **Coef. Var** less than << 1, the existing variability is categorized as "similar" , it means that a certain level of "similarity" exists. Well, it not 100% similar, because the nature is always vary at certain scale of observation. This approach justified only to classifie the same level of varibility in the same class

of “similarity. Contrary, if the level of variability which measured by **StDev** and **Coef. Var** is more than $>> 1$; then the existing variability is categorized as “different”. Furthermore, this simple criterion is used to compare both of hydro-meteorological and morphometric parameters. This definition of similarity may be vague for other scientific field, however because in hydrology the phenomena are always varies in space and time, the simplification by classifying certain level of variability into single class and called “similar” is probably useful for practical reasons to handle some irregularities in hydrology.

3. Results & Discussion

3.1 Main properties of the watersheds

Table.1 summarized the main properties (i.e. area, perimeter, total stream length, and strahler stream ordering number) of the 45 watersheds used in this study. Size of the watershed range from 17,55 to 752,00 km² and the average of the catchment area is 170,56 km². It can be stated that all of the watersheds are categorized as small watersheds. The perimeter of the watershed ranges from 21 to 177 km. Total stream length range from 13 to 1047 km. The order of river network analysed using strahler method range from 2 to 6. The altitude value range from 0 to 3000 m above sea level.

3.2 Hydrological properties of the watersheds

3.2.1 Daily discharge data

Table 3 resume the statistical value of daily discharge data obtained from the watersheds. Mean daily discharge for all watersheds is recorded between 0,16 to 299,87 m³/day. Maximum daily discharge data range from 8 to 7489 m³/day. Each watershed shows the variability, in term of daily discharge data, as indicated by the value of maximum, minimum, mean, median, percentile 10, percentile 90, and MDBF (Table 3). Similar appears on Standard deviation of the log of daily flow and Lanes variability index. It's show the rate of change in daily discharge distribution and described as a standard deviation of percentiles. The discharge data is normalized by the ratio between maximum to mean discharge, minimum to mean, minimum to maximum, and standard deviation to mean discharge.

3.2.2 Daily rainfall data

Due to the limit of data availability, only rainfall data from 26 watersheds are selected, compared and visualized. Table 4, present the result of statistical analysis for averaged daily rainfall data from the watersheds. Table 4 show the values obtained for statistical resume (i.e. mean, median, standard deviation, the coefficient of variation, skewness, and maximum). The similarity appears for the value of coefficient of variation and skewness. This shows the same distribution of variability and degree of skewness of daily rainfall data. The watershed are subject to similar climatic regime that force the similarity in daily rainfall data.

Table 2. Main properties of the watersheds

Water shed Code	Watershed Names	Area (km ²)	Perimeter (km)	Stream Length (km)	Stream orde
1	Lahar-Bacem	87,00	72,67	23,59	3
2	Cubanrondo-Lebaksari	62,00	38,00	4,05	4
3	Sayang-Jabon	45,00	35,00	3,50	4
4	Sumber Ampel-Baros	27,00	37,00	5,59	3
5	Bagong-Temon	63,00	50,00	3,40	4
6	Keser-Keser	44,00	34,00	2,70	4
7	Duren Kebak	18,00	21,00	6,92	3
13	Lamong-Simoanggrok	246,89	107,96	27,39	4
19	Surabaya-Perning	218,00	125,26	37,08	4
20	Kadalpang-Bangil	143,20	67,59	32,00	4
24	rejos	148,90	62,44	28,00	5
26	Welang-Purwodadi	159,80	107,80	29,00	5
29	Kramat-Probolinggo	234,90	94,41	48,00	5
31	Pekalen-Condong	168,20	85,89	15,00	4
32	Rondodingo-Jurangjero	181,50	84,47	22,00	5
33	Mayang	150,00	80,00	30,00	4
34	Rawatamtu	673,00	177,00	56,00	5
35	Sanenrejo	292,00	94,00	35,00	5
36	Asen-Sentul	167,00	87,00	33,00	4
38	Mujur	137,00	88,80	34,00	4
39	Wonorejo	132,00	63,00	19,00	4
40	Bajulmati	191,00	74,00	19,00	5
41	Boma Atas	156,00	96,00	22,00	4
42	Bomo Bawah-	184,00	110,00	31,00	4
43	Setail-Kradenan	37,00	54,00	16,00	3
44	Tambong-Pakistaji	99,00	63,00	6,00	4
45	Karangdoro	514,00	122,00	26,00	5
46	Kloposawit	752,00	153,00	18,00	6
48	Deluwang-Demung	119,00	104,00	28,00	4
50	Madiun Nambangan	36,72	35,67	5,19	3
55	Madiun Ngawi	18,34	49,00	18,00	2
57	Kedungpring-	645,62	152,90	16,05	5
59	Keang-Ngindeng	133,04	70,77	14,40	4
65	Bengawan Solo-CEPU	214,00	83,00	13,11	5
70	Gondang-Setren	20,53	34,70	1,00	3
71	Kerjo-Pejok	56,70	45,19	2,51	4
80	Gembul-Merakurak	61,67	44,68	1,47	4
81	Klero-Genaharjo	37,90	34,59	9,62	3
83	Prumpung-Belikanget	102,30	64,41	4,42	4
84	Blega Telok	160,00	80,29	18,00	4
85	Kemuning-Pangilen	271,00	101,00	7,16	5
86	Samiran-Propo	297,78	112,34	30,19	5
90	Sampang	101,55	63,20	2,40	3
92	Klampok-Ambunten	49,96	39,93	5,07	4
	max	752,00	177,00	56,00	6,00
	min	18,00	21,00	1,00	2,00
	average	174,03	77,29	18,40	4,09
	St. dev	170,99	35,62	13,42	0,80
	CV	0,98	0,46	0,73	0,20

Table 3. Daily discharge properties

		Discharge on all watersheds					
	Discharge (m ³ /S)	Max	Min	Mean	ST. Dev	CV	QualEval
Discharge for each watershed	Maximum	7489,00	8,00	427,44	1178,34	2,76	different
	Mean	299,87	0,16	15,30	46,17	3,02	different
	Median	125,05	0,09	7,63	19,60	2,57	different
	Stdev	384,05	0,24	23,06	61,90	2,68	different
	Skewness	10,07	0,87	2,39	1,58	0,66	different
	Variance	-1,08	-32,58	-5,81	5,77	-0,99	different
	P10	855,64	0,67	39,39	131,76	3,34	different
	P20	538,00	0,20	24,34	82,35	3,38	different
	P30	324,03	0,16	15,63	49,48	3,17	different
	P33	264,00	0,14	13,21	40,41	3,06	different
	P40	199,00	0,12	10,55	30,60	2,90	different
	P50	125,05	0,09	7,24	19,42	2,68	different
	P60	81,78	0,07	5,23	13,08	2,50	different
	P66	59,98	0,01	4,23	10,01	2,37	different
	P70	52,88	0,00	3,84	8,91	2,32	different
	P80	40,54	0,00	3,14	8,22	2,62	different
	P90	23,15	0,00	1,75	4,92	2,81	different
	P95	19,90	0,00	1,36	3,96	2,92	different
	V_Lane	0,82	0,07	0,32	0,17	0,54	Similar
S_log	0,77	0,07	0,30	0,16	0,52	Similar	
lvar (SFDC)	13,04	-6,83	1,34	4,21	3,13	different	

Table 4. Statistical resume of daily rainfall

Watershed Names	Mean (mm/day)	Median (mm/day)	ST. Dev	Cv	Skewness	Maximum (mm/day)	Minimum (mm/day)
Lahan Bacem	21,33	15,00	20,67	0,97	1,80	137,00	1,00
Cuban_rondo_lebaksari	19,86	14,00	18,65	0,94	2,22	149,00	2,00
Sayang_Jabon	20,91	12,00	22,98	1,10	1,73	123,00	1,00
Bagong_temon	21,57	14,00	20,79	0,96	1,83	114,00	2,00
Kadalpang_bangil	5,42	0,00	11,05	2,04	3,15	95,00	0,00
Rejoso	3,13	0,00	7,64	2,44	3,53	80,00	0,00
Welang_purwodadi	17,79	10,00	20,84	1,17	2,27	224,00	1,00
Kramat_Probolingo	19,82	15,33	16,86	0,85	1,94	147,00	1,00
Pekalen Condong	20,51	17,00	15,47	0,75	1,62	125,00	1,00
Rondodingo-Jurangjero	22,35	18,33	16,22	0,73	1,97	145,00	1,00
Mayang	5,59	1,00	9,46	1,69	2,83	107,25	0,00
Rowotamtu	4,95	1,43	7,79	1,58	2,67	98,29	0,00
Sanenrejo	4,26	0,00	10,39	2,44	3,82	105,00	0,00
Mujur	5,47	1,67	8,87	1,62	3,52	124,17	0,00
Boma_Atas	3,15	0,00	8,37	2,66	5,24	145,00	0,00
Bomo_Bawah	4,64	0,00	9,26	2,00	3,02	90,50	0,00
K.setail-kredenen	8,34	3,00	13,75	1,65	3,05	125,00	0,00
Karangdoro	4,86	0,50	8,82	1,82	3,01	94,50	0,00
Kloposawit	4,42	1,00	7,11	1,61	3,04	113,94	0,00
Deluwang	6,78	0,00	16,26	2,40	3,17	147,78	0,00
madiun-nambangan	25,72	14,50	37,98	1,48	3,09	182,00	1,00
keang-ngindeng	20,20	14,00	17,60	0,87	1,63	105,00	1,00
gondang satren	17,81	10,00	18,45	1,04	1,79	90,00	1,00
kemuning-pangilen	20,98	15,00	19,80	0,94	1,95	169,00	1,00
samiran-propo	3,07	0,00	5,65	1,84	2,85	55,29	0,00
klampok-ambunten	26,91	15,00	33,57	1,25	2,80	175,00	1,00
Max (mm/day)	26,91	18,33	37,98	2,66	5,24	224,00	2,00
Min (mm/day)	3,07	0,00	5,65	0,73	1,62	55,29	0,00
Mean (mm/day)	13,07	7,41	15,55	1,49	2,68	125,64	0,36
Standar deviation	8,56	7,11	7,92	0,58	0,85	36,44	0,58
CV	0,66	0,96	0,51	0,39	0,32	0,29	1,62

3.2.3 Monthly rainfall data

It is also noted, that as part of tropical climate regions, two seasons are still distinguishable in this region (rainy and dry seasons). Rainy seasons occur from October to April and dry seasons normally occur from May to September (Indarto, Susanto, & Diniardi, 2012). The amount of rainfall received during the rainy seasons is very important because more than 70% volume of total rainfall event occurs during the rainy season. The amount of rainfall from the existing 12 months is too varied. This will influence the value of statistical resume for monthly rainfall (i.e. mean, median, standard deviation, the coefficient of variation, skewness, and maximum) as shown in **Table 5**.

3.2.4 Annual rainfall data

The same effect is observed in annual rainfall value (**Table 6**). We can note from table 5 that value of standard deviation and coefficient of variation are relatively similar in a few watersheds (i.e: Sayang-Jabon, Mayang, Rowotamtu, Keang-Ngindeng, Samiran-Propo).

3.3 Morphometrical properties of the watersheds

3.3.1 Linear aspect

Table 7 present the result of statistical analysis for the linear aspect of morphometric parameters among the 44 watersheds. Some morphometric parameters are

Table 5. Statistical resume of Monthly rainfall

Watershed Names	Mean (mm/month)	Median (mm/month)	STDev	Cv	Skewness	Maximum (mm/month)	Minimum (mm/month)
Lahan Bacem	20,57	19,91	9,36	0,46	0,79	58,00	2,00
Cuban_rondo_lebaksari	17,53	17,73	6,85	0,39	0,05	31,53	5,00
Sayang_Jabon	17,84	17,80	9,93	0,56	0,32	45,00	1,00
Bagong_temon	21,54	19,90	10,97	0,51	1,39	58,33	3,00
Kadalpang_bangil	5,46	3,00	6,03	1,10	0,97	23,07	0,00
Rejoso	3,15	1,28	3,94	1,25	1,36	17,71	0,00
Welang_purwodadi	16,43	16,00	7,38	0,45	0,22	35,73	1,00
Kramat_Probolingo	18,46	18,32	7,12	0,39	0,32	40,52	1,00
Pekalen Condong	18,76	19,58	6,76	0,36	0,01	46,25	2,25
Rondodingo-Jurangjero	20,97	19,85	7,16	0,34	0,85	54,00	4,00
Mayang	5,61	4,84	4,80	0,86	0,67	19,96	0,00
Rowotamtu	4,97	4,20	4,48	0,90	0,83	22,47	0,00
Sanenrejo	4,27	2,44	4,61	1,08	0,96	18,26	0,00
Mujur	5,48	5,14	4,24	0,77	0,68	19,74	0,12
Boma_Atas	3,14	1,98	3,34	1,06	1,06	12,13	0,00
Bomo_Bawah	4,66	3,62	4,57	0,98	0,88	17,75	0,00
K.setail-kredenen	8,85	8,58	6,08	0,69	0,38	25,88	0,00
Karangdoro	4,87	3,94	4,36	0,90	0,61	16,25	0,00
Kloposawit	4,45	3,00	4,50	1,01	0,94	19,23	0,00
Deluwang	6,81	3,19	8,80	1,29	1,68	40,10	0,00
Madiun-nambangan	21,29	15,23	27,41	1,29	5,21	167,50	7,00
Keang-ngindeng	17,62	18,86	6,40	0,36	-0,13	30,53	4,50
Gondang satren	15,15	13,93	7,68	0,51	0,24	30,88	2,50
Kemuning-pangilen	19,68	18,80	10,79	0,55	1,02	67,50	1,00
Samiran-propo	3,07	1,16	3,51	1,14	0,69	11,44	0,00
Klampok-ambunten	24,48	15,65	20,28	0,83	1,15	67,00	4,00
Max (mm/month)	24,48	19,91	27,41	1,29	5,21	167,50	7,00
Min (mm/month)	3,07	1,16	3,34	0,34	-0,13	11,44	0,00
Mean (mm/month)	12,12	10,69	7,74	0,77	0,89	38,34	0,91
St.Dev	7,56	7,52	5,32	0,32	0,99	31,31	1,71
CV	0,62	0,70	0,69	0,42	1,11	0,82	1,87

Table 6. Statistical resume of Annual rainfall

Watershed Names	Mean (mm/year)	Median (mm/year)	STDev	Cv	Skewness	Maximum (mm/year)	Minimum (mm/year)
Lahan Bacem	22,16	22,17	4,93	0,22	0,45	33,91	14,06
Cuban_rondo_lebaksari	19,95	20,58	2,79	0,14	-1,08	22,52	16,14
Sayang_Jabon	20,91	20,85	0,64	0,03	0,48	21,73	20,20
Bagong_temon	21,90	19,59	5,25	0,24	1,60	27,92	18,20
Kadalpang_bangil	5,32	5,79	2,20	0,41	-0,52	9,36	1,09
Rejoso	3,10	3,28	1,24	0,40	-0,68	5,18	0,00
Welang_purwodadi	18,72	18,34	4,28	0,23	1,06	30,16	12,46
Kramat_Probolingo	20,02	19,99	2,07	0,10	-0,46	22,93	16,09
Pekalen Condong	20,52	20,36	2,10	0,10	0,36	24,29	17,17
Rondodingo-Jurangjero	22,57	22,44	2,13	0,09	-0,02	25,72	18,72
Mayang	5,54	5,50	0,81	0,15	0,66	7,40	4,12
Rowotamtu	4,90	4,95	0,94	0,19	0,34	7,61	2,92
Sanenrejo	4,09	3,96	1,18	0,29	-0,35	5,86	2,00
Mujur	5,47	5,65	1,59	0,29	0,09	8,05	3,13
Boma_Atas	2,84	2,96	2,06	0,73	0,26	6,75	0,00
Bomo_Bawah	4,64	4,39	2,83	0,61	-0,05	8,94	0,00
K.setail-kredenen	9,46	10,22	3,56	0,38	-0,63	13,74	1,62
karangdoro	4,86	5,63	2,17	0,45	-1,63	6,94	0,00
kloposawit	4,37	4,43	1,49	0,34	-2,00	6,65	0,00
deluwang	7,04	6,01	3,28	0,47	1,02	15,59	3,30
madiun-nambangan	24,90	17,62	13,93	0,56	1,71	40,96	16,11
keang-ngindeng	20,20	20,31	0,95	0,05	-0,51	21,09	19,20
gondang satren	16,87	16,67	3,60	0,21	0,25	21,16	13,00
kemuning-pangilen	20,78	18,67	4,53	0,22	1,60	31,78	15,79
samiran-propo	3,07	3,29	0,82	0,27	-1,37	3,78	1,90
klampok-ambunten	28,49	24,93	13,66	0,48	1,27	47,55	16,54
Max (mm/year)	28,49	24,93	13,93	0,73	1,71	47,55	20,20
Min (mm/year)	2,84	2,96	0,64	0,03	-2,00	0,00	0,00
Mean (mm/year)	13,18	12,64	3,27	0,29	0,07	17,69	5,57
St.Dev	8,69	7,96	3,37	0,18	0,99	12,37	7,54
CV	0,66	0,63	1,03	0,61	13,94	0,70	1,36

categorized similar and others are different based on the same criteria as used to compare hydrological properties (SdDev and Coef.Var).

Table 7 shows the statistical value of linear aspect. The stream order (U) and the stream length ratio (RI) has similar values. Stream order is a branching position based on the parent river in a watershed. Forty-four watersheds located in East Java have orders between 2 to 6. Stream length ratio (RI) is the ratio of the total length of the river from the high order to the low order value. The value of RI range between 0,34 to 4,32. Low RI values indicate the low cycle rate of geomorphological changes and vice versa. The value of Bifurcation ratio (Rb), Stream Length (Lu), Mean

Stream Length (Lsm) tend to be different amongs the watersheds.

3.3.2 Relief aspect

Table 8 shows the statistical value of 44 watersheds based on the relief aspect parameters (Bh , Rh and Rn). The three parameters of relief aspect are differents amongs watersheds. Basin relief (Bh) is defined as the result of the difference between upstream and downstream to the length of the main river. The high value of Bh shows the distance between the upstream and downstream of the river is greater and vice versa.

The ruggedness number (Rn) identifies the complexity of

Table 7. Morphometric parameter – linear aspect

Morphometric parameter	Max	Min	Mean	St.dev	CV	Qualitative evaluation
Stream Ordo (<i>U</i>)	6	2	4,09	0,80	0,196	Similar
Bifurcation ratio (<i>Rb</i>)	9	1,28	2,75	1,71	0,62	Different
Stream Length (<i>Lu</i>)	56	1	18,40	13,41	0,72	Different
Mean Stream length (<i>Lsm</i>)	15,33	0,62	1,59	2,15	1,35	Different
Stream length ratio (<i>Rl</i>)	4,321	0,34	0,98	0,62	0,63	Similar

Table 8. Morphometric parameters – Relief aspect

Morphometric parameters	Max	Min	Mean	St.dev	CV	Qualitative evaluation
Basin relief (<i>Bh</i>)	3,83	0,061	1,84	1,16	0,63	Different
Relief ratio (<i>Rh</i>)	2,08	0,001	0,27	0,40	1,47	Different
Ruggedness number (<i>Rn</i>)	5,63	0,067	2,46	1,74	0,71	Different

the relationship between the altitude and density of the river network. The *Rn* value is very varying from 0,067 to 5,63. Watershed having high *Rn* number show higher risk of erosion. The higher value of the *Relief ratio (Rh)* correspond to the higher risk of sedimentation rate and vice versa.

3.3.3 Areal aspect

Table 9 shows the statistical values of 44 watersheds based on areal aspect parameters. The drainage density (*Dd*), stream frequency (*Fs*), circulation ratio (*Rc*), length of overland (*Lof*), constant channel (*C*) has similar values. Drainage density (*Dd*) shows the density of stream per area of watershed. If the value of $Dd < 0,62$ it is indicated that the watershed tends to have more risk of flooding and if the value of $Dd > 3,10$ indicate the watershed condition that more risk to drought. In table 9, the value of *Dd* range from 0,12 to 1,93.

Stream frequency (*Fs*) is an index to shows the total number of streams of all orders per unit area. *Fs* has been related to permeability, infiltration capacity, and relief of watersheds (Montgomery D.R. & Dietrich W.E., 1992). Further, it is noted that *Fs* decreases as the stream number increases. The low value of *Fs* indicate good vegetation coverage of watershed and more infiltration capacity (Altaf et al., 2013). The value of *Fs* vary from 0,5 to 6,43. The average, StDev and CV value of *Fs* is relatively low at majority of the watersheds. It is indicate the good vegetation cover among watersheds.

The Circulation ratio (*Rc*) is the opposite of elongation ratio. The higher vaue of circulation ratio (*Rc*) indicate the higher the rate of water flow in the watershed. In table 9, the *Rc* value vary between 0,03 to 0,17. The relatively low value of *Rc* indicate the watersheds having slow responds to flow. Small values of *length of overland flow (Lof)* correspond to the condition of watersheds having more steepest slopes and shorter river paths, contrary high value of *Lof* show the watershed condition having flatty slope and more longer river path. *Lof* value range from 0,062 to 1,64.

The texture ratio (*T*) is the total number of stream segments of all orders per perimeter of that area (Horton 1945). In the present study, texture ratio varied from 0,24 to 5,71. The lower values of texture ratio indicate that the basin is plain with lower degree of slope and low infiltration capacity. The high texture ratio illustrates the shape of a watershed that has a high slope and high infiltration capacity (Gajbhiye et al., 2014). The form factor (*Rf*) describes the ratio of watershed area and length of the river, the higher the value of *Rf* indicate the shape of the watershed becomes more rounded. Elongation ratio (*Re*) is the ratio between the diameter of watershed roundness to the maximum length of the watershed.

The reciprocal of the drainage density (*Dd*) is constant of channel maintenance (*C*) and signifies how much drainage area is required to maintain a unit length of channel. Low values of *C* is associated with weakest or very low-resistance soils, sparse vegetation and mountainous terrain, while high value of *C* is associated with resistance soils, vegetation and comparably plain terrain (Altaf et al., 2013). The value *C* is vary from 0,52 to 8,06.

3.4 Interpretation

3.4.1 Morphometric vs Morphometric properties

Table 11 shows a simple analysis using coefficient correlation to find the relation among morphometric properties. The analysis comprises all morphometric parameters from the watersheds.

It is shown that some morphometric parameters have a strong correlation to other parameters. For example: Stream length (*Lu*), Drainage Density (*Dd*), stream frequency (*Fs*), Texture ratio (*T*) are related to each other. This relationship shows a correlation between the number of surface water deposits in a watershed with the infiltration rate based on area, river network, elevation, contained assistance, and infiltration capacity.

Table 9. Morphometric parameters - Areal aspect

Morphometric parameters	Max	Min	Mean	St.dev	CV	Quality Eval
Drainage density (Dd)	1,92	0,12	1,28	0,31	0,24	Similar
Stream frequency (Fs)	6,43	0,50	1,23	0,85	0,69	Similar
Texture ratio (T)	5,71	0,24	1,57	1,11	0,70	Different
Form factor (Rf)	28,53	0,05	2,86	5,79	2,02	Different
Circulation ratio (Rc)	0,17	0,03	0,103	0,03	0,32	Similar
Elongation ratio (Re)	5,14	0,33	0,60	0,70	1,16	Different
Length of overland (Lof)	1,65	0,06	0,68	0,21	0,31	Similar
Constant channel maintenanant (C)	8,06	0,52	1,06	1,11	1,05	Similar
Area (A)	752	18	174,03	170,98	0,98	Different
Perimeter (P)	177	21	77,29	35,623	0,46	Different

Table 10. Morphometric parameters of watersheds

Watershed Names	Limer aspect					Relief Aspect			Areal aspect									
	Stream Orize (L)	Bifurcation ratio (Rb)	Stream Length (Lu)	Mean Stream lengt (Lsm)	Stream length ratio (RL)	Basien relief (Bh)	Relief ratio (Rh)	Ruggedness number (Ru)	Drainage density (Dd)	Stream frequency (Fs)	Texture ratio (T)	Form factor (Rf)	Circulation ratio (Rc)	Elongation ratio (Re)	Length of overland (Lof)	Constant channel (C)	Area (A)	Perimeter (P)
Lahar-Bacem	3,00	1,54	23,59	1,58	0,83	1,53	0,06	2,40	1,57	1,04	0,39	0,16	0,07	0,67	0,64	0,64	87,00	72,67
Cubanrondo-Lebaksari	4,00	2,75	4,05	0,96	0,34	1,38	1,31	1,68	1,22	1,05	0,87	3,77	0,17	0,52	0,82	0,82	62,00	38,00
Sayang-Jabon	4,00	1,77	3,50	1,08	0,44	1,64	0,82	2,39	1,46	1,00	0,66	3,67	0,15	0,44	0,68	0,68	45,00	35,00
Sumber Ampel-Baros	3,00	1,73	5,59	2,46	0,51	1,85	0,33	2,97	1,61	0,63	0,24	0,86	0,08	0,34	0,62	0,62	27,00	37,00
Bagong-Temon	4,00	5,71	3,40	1,06	0,48	1,13	2,08	1,29	1,14	0,94	0,60	5,45	0,10	0,56	0,88	0,88	63,00	50,00
Keser-Keser	4,00	1,98	2,70	0,80	0,55	0,90	0,33	0,89	0,98	1,20	0,79	6,04	0,15	0,65	1,02	1,02	44,00	34,00
Duren Kebak	3,00	1,71	6,92	1,23	2,32	0,72	0,10	0,74	1,03	1,17	0,52	0,38	0,16	0,62	0,97	0,97	18,00	21,00
Lamong-Simoangrok	4,00	1,71	27,39	0,88	0,90	0,17	0,01	0,20	1,15	1,22	2,79	0,33	0,08	0,55	0,58	0,87	246,89	107,96
Surabaya-Pemring	4,00	1,67	37,08	0,90	1,03	0,07	0,00	0,08	1,16	1,31	2,28	0,16	0,06	0,55	0,58	0,86	218,00	125,26
Kadalpang-Bansil	4,00	2,29	32,00	1,59	1,07	3,30	0,11	5,18	1,57	1,02	1,09	0,14	0,13	0,41	0,78	1,57	143,20	67,59
rejos	5,00	4,22	28,00	1,32	0,71	2,72	0,10	4,43	1,63	0,56	1,17	0,19	0,15	0,39	0,82	1,63	148,90	62,44
Welang-Purwodadi	5,00	3,21	29,00	1,17	0,85	2,27	0,08	3,20	1,41	1,06	0,81	0,19	0,06	0,45	0,71	1,41	159,80	107,80
Kramat-Probolinggo	5,00	2,00	48,00	1,28	0,97	2,59	0,07	3,78	1,46	1,03	1,29	0,10	0,11	0,44	0,73	1,46	234,90	94,41
Pekalen-Condong	4,00	1,66	15,00	1,24	0,89	2,95	0,08	3,89	1,32	0,50	0,98	0,75	0,09	0,48	0,66	1,32	168,20	85,89
Rondodingo-Jurangjero	5,00	3,63	22,00	1,65	1,29	0,29	0,09	0,34	1,17	0,99	1,07	0,38	0,10	0,54	0,58	1,17	181,50	84,47
Mayang	4,00	6,26	30,00	1,46	1,06	2,61	0,09	3,89	1,49	1,06	1,00	0,17	0,09	0,43	0,74	0,67	150,00	80,00
Rawatantu	5,00	2,43	56,00	1,39	1,00	2,74	0,05	3,78	1,38	1,00	1,90	0,21	0,09	0,46	0,69	0,73	673,00	177,00
Sanenrejo	5,00	1,82	35,00	0,89	1,16	1,17	0,03	1,15	0,98	1,17	1,84	0,24	0,13	0,65	0,51	1,02	292,00	94,00
Asen-Sentul	4,00	2,02	33,00	1,02	1,40	2,64	0,08	3,96	1,50	1,96	1,95	0,15	0,09	0,42	0,75	0,67	167,00	87,00
Mujur	4,00	3,23	34,00	0,81	0,95	3,61	0,11	5,63	1,56	1,85	1,32	0,12	0,07	0,41	0,78	0,64	137,00	88,80
Wonorejo	4,00	1,77	19,00	1,42	1,02	1,63	0,09	2,35	1,44	0,98	1,03	0,37	0,13	0,44	0,72	0,69	132,00	63,00
Bajulanati	5,00	9,00	19,00	1,40	0,38	2,20	1,10	3,43	1,56	0,96	1,24	0,53	0,14	0,41	0,64	0,64	191,00	74,00
Boma Atas	4,00	2,72	22,00	1,73	0,61	3,20	0,15	4,90	1,53	1,01	0,82	0,32	0,07	0,42	0,65	0,65	156,00	96,00
Bomo Bawah-Rogojampi	4,00	2,43	31,00	1,62	0,64	3,20	0,10	4,80	1,50	0,99	0,84	0,19	0,06	0,42	0,67	0,67	184,00	110,00
Setal-Kradenan	3,00	7,50	16,00	15,33	0,70	1,50	0,09	2,89	1,93	0,95	0,33	0,14	0,05	0,33	0,52	0,52	37,00	54,00
Tambong-Pakistaji	4,00	2,33	6,00	2,01	0,85	1,20	0,20	0,73	0,61	6,43	5,71	2,75	0,10	0,39	1,65	1,65	99,00	63,00
Karangdoro	5,00	2,03	26,00	1,29	0,50	3,20	0,12	4,45	1,39	1,01	2,10	0,76	0,14	0,46	0,72	0,72	514,00	122,00
Kloposawit	6,00	6,63	18,00	1,65	0,52	3,10	0,39	4,32	1,39	0,85	2,35	2,32	0,13	0,46	0,72	0,72	752,00	153,00
Deluwang-Demung	4,00	2,25	28,00	1,84	1,14	2,50	0,09	3,09	1,24	0,93	0,54	0,15	0,04	0,52	0,81	0,81	119,00	104,00
Madun Nambangan	3,00	1,68	5,19	1,67	0,65	3,08	0,59	4,34	1,41	1,41	1,45	1,36	0,12	0,45	0,71	0,71	36,72	35,67
Madun Ngawi	2,00	1,29	18,00	2,17	1,54	0,12	0,01	0,23	1,85	1,85	0,69	0,06	0,03	0,35	0,92	0,54	18,34	49,00
Kedungpring-Kedungpring	5,00	2,17	16,05	0,87	0,98	1,21	0,08	1,21	0,99	0,99	4,19	2,51	0,11	0,64	0,50	1,01	645,62	152,90
Keang-Ngindeng	4,00	2,45	14,40	1,30	1,05	2,43	0,17	2,87	1,18	1,18	2,22	0,64	0,11	0,54	0,59	0,85	133,04	70,77
Bengawan Solo-CEPU	5,00	1,78	13,11	0,93	0,93	0,31	0,17	0,39	1,27	1,29	3,33	1,25	0,12	0,50	0,63	0,79	214,00	83,00
Gondang-Setren	3,00	2,69	1,00	0,94	0,70	0,06	0,02	0,07	1,10	1,02	0,61	20,53	0,07	0,58	0,55	0,91	20,53	34,70
Kerjo-Peajok	4,00	2,06	2,51	0,92	0,88	0,16	0,08	0,19	1,18	1,18	1,48	9,00	0,11	0,54	0,59	0,85	56,70	45,19
Gembul-Merakurak	4,00	3,81	1,47	1,30	1,15	0,40	0,10	0,43	1,09	0,96	1,32	28,54	0,12	0,58	0,54	0,92	61,67	44,68
Klero-Genaharjo	3,00	1,54	9,62	0,77	1,00	0,44	0,29	0,45	1,02	1,29	1,42	0,41	0,13	0,63	0,51	0,98	37,90	34,59
Prumpung-Belikanzet	4,00	1,96	4,42	0,94	0,82	0,28	0,14	0,31	1,12	1,09	1,72	5,24	0,10	0,57	0,56	0,89	102,30	64,41
Blega Telok	4,00	1,67	18,00	1,07	0,89	2,56	0,14	2,88	1,13	0,98	1,94	0,49	0,10	0,57	0,56	0,89	160,00	80,29
Kemuning-Panellen	5,00	2,69	7,16	0,89	1,01	2,57	0,36	2,97	1,15	1,28	3,45	5,29	0,11	0,55	0,58	0,87	271,00	101,00
Samiran-Propo	5,00	1,65	30,19	0,96	1,02	3,83	0,13	4,59	1,20	1,19	3,14	0,33	0,09	0,53	0,60	0,83	297,78	112,34
Sampang	3,00	2,02	2,40	0,62	1,25	1,95	0,81	0,24	0,12	1,51	2,42	17,63	0,10	5,14	0,06	8,07	101,55	63,20
Klampok-Ambunten	4,00	1,83	5,07	1,93	4,32	3,71	0,73	4,25	1,15	1,14	1,43	1,94	0,13	0,56	0,57	0,87	49,96	39,93
Mean	4,09	2,76	18,40	1,60	0,98	1,84	0,27	2,46	1,28	1,23	1,58	2,87	0,10	0,60	0,68	1,06	174,03	77,29
Stdev	0,80	1,71	13,42	2,16	0,62	1,17	0,41	1,75	0,31	0,85	1,11	5,80	0,03	0,71	0,21	1,12	170,99	35,62
CV	0,20	0,62	0,73	1,35	0,63	0,63	1,47	0,71	0,24	0,69	0,70	2,02	0,32	1,17	0,31	1,05	0,98	0,46
QualEval	Similar	Different	Different	Different	Similar	Different	Different	Different	Similar	Similar	Different	Different	Similar	Different	Similar	Similar	Different	Different

Table 11. Morphometric vs morphometric properties

				Linier Aspect					Relief Aspect					Areal Aspect						
	A	P	U	Lu	Rb	Lsm	RI	Bh	Rh	Rn	Dd	Fs	T	Rf	Rc	Re	Lof	C	Cc	
A	1	.886**	.717**	.491**	0,128	-0,138	-0,147	0,290	-0,181	0,260	-0,005	-0,114	.461**	-0,216	0,067	-0,060	-0,118	-0,068	-0,117	
P		1	.661**	.701**	0,066	-0,113	-0,153	.333*	-0,312*	.315*	0,061	-0,080	.417**	-.326*	-0,288	-0,065	-0,140	-0,063	-0,090	
U			1	.401**	0,269	-0,242	-0,146	.312*	-0,014	.298*	-0,021	-0,116	.397**	-0,196	.314*	-0,202	-0,002	-0,130	-0,196	
Lu				1	0,010	-0,018	-0,039	.383*	-.431**	.464**	.379*	-0,113	0,011	-.527**	-.318*	-0,213	0,000	-0,155	-0,114	
Rb					1	-0,250	0,115	.370*	0,204	0,293	-0,124	-0,161	0,038	0,043	-0,105	0,011	-0,099	0,277		
Lsm						1	-0,035	0,003	-0,075	0,097	.398**	-0,18	-0,210	-0,123	-0,287	-0,118	-0,044	-0,122	.381*	
RI							1	0,091	-0,094	-0,015	-0,175	0,050	0,021	-0,007	0,034	0,091	-0,067	0,078	-0,276	
Bh								1	0,059	.950**	0,284	-0,114	-0,014	-.358*	-0,006	-0,036	0,007	0,013	0,094	
Rh									1	-0,017	-0,162	-0,055	-0,147	0,183	.339*	0,205	0,039	0,165	0,248	
Rn										1	.539**	-0,193	-0,160	-.443**	-0,051	-0,258	0,067	-0,202	0,160	
Dd											1	-.353*	-.510**	-.471**	-0,263	-.645**	0,112	-.635**	0,252	
Fs												1	.609**	-0,003	-0,083	0,027	.651**	0,119	0,081	
T													1	-0,006	0,105	0,132	0,149	0,179	-.317*	
Rf														1	0,112	.425**	-0,256	.381*	-0,156	
Rc															1	0,028	0,097	0,055	-0,155	
Re																1	-.477**	.962**	-0,134	
Lof																	1	-.351*	.326*	
C																		1	-0,191	
Cc																			1	

Table 12. Morphometric vs Hydrological properties

	Hydrological properties										
	Max	Min	Mean	Median	Stdev	Skew	Var	V_Lane	S_log	Ivar(SFDC)	
A	-0,08	0,09	0,07	0,11	0,03	0,05	0,03	0,20	0,25	-0,28	
P	-0,12	-0,13	0,08	0,13	0,02	0,03	0,09	0,19	0,24	-.373*	
U	-0,16	-0,22	0,10	0,15	0,02	0,03	0,04	0,06	0,10	-0,25	
Rb	-0,15	-0,16	-0,13	-0,12	-0,16	-0,25	0,24	-0,06	-0,03	-0,21	
Lu	-0,13	-0,08	0,02	0,07	-0,04	-0,18	0,25	0,18	0,22	-.435**	
Lsm	0,03	-0,07	-0,03	-0,04	-0,02	-0,08	0,08	0,09	0,12	-0,08	
RI	-0,08	.617**	0,00	0,05	-0,01	0,07	-0,02	-0,10	-0,12	.386**	
Bh	0,09	-0,17	-0,24	-0,21	-0,19	-0,03	0,11	0,03	0,03	-0,02	
Rh	0,08	-0,01	0,09	0,07	0,10	-0,06	0,04	-0,23	-0,26	0,22	
Rn	0,10	-0,20	-0,21	-0,18	-0,16	-0,08	0,14	0,06	0,07	-0,09	
Dd	0,10	-0,24	0,08	0,07	0,10	-0,11	0,13	0,19	0,21	-0,25	
Fs	0,02	-0,05	0,04	0,02	0,05	-0,02	0,02	0,13	0,15	-0,08	
T	0,07	-0,11	0,24	0,24	0,22	0,27	-0,14	0,23	0,24	-0,08	
Rf	-0,10	-0,03	-0,10	-0,12	-0,11	0,02	-0,05	-0,19	-0,21	0,18	
Rc	0,03	0,37	-0,01	0,01	-0,01	0,03	-0,10	-0,15	-0,17	0,18	
Re	-0,06	0,29	-0,06	-0,06	-0,07	-0,10	0,07	-0,15	-0,18	0,01	
Lof	0,00	0,19	0,01	-0,02	0,02	-0,04	-0,08	0,16	0,19	-0,15	
C	-0,08	-0,05	-0,08	-0,07	-0,09	-0,16	0,13	-0,15	-0,18	-0,05	
Cc	-0,17	0,04	-0,17	-0,19	-0,19	-0,12	0,02	-0,19	-0,16	0,08	

** . Correlation is significant at the 0,01 level (2-tailed).

* . Correlation is significant at the 0,05 level (2-tailed).

3.4.2 Morphometric vs hydrological properties

Table 12 shows coefficient of correlation established to link hydrological properties and morphometric parameters. The hydrological properties represented by statistical values (i.e : Max, Min, Mean, Median, StDev, Skew, Var, V_lane, S_log, Ivar). It is show that no correlation or less correlaion exits between hydrological properties and morphometrical parameters.

It is difficult to interpret the correlation of hydrological properties and the morphometric parameters from table 11. Total stream length (Lu) and stream length ratio (RI) have a moderate correlation with in hydrological variability index. However this does not prove something more clearly.

Furthermore, table 12 shows other trial to interpret the correlation of hydrological properties and morphometric paremeters. The hydrological variables

are demonstrates through some dimensionless number, i.e: ratio of minimum to mean discharge, maximum to mean dischare, maximum to minimum discharge and standard deviation to mean discharge. Correlation values (both positif and negative number) more than [$\pm 0,3$] are marked as black-bold number. The correlation coefficients show more important between most of the morphometric parameter values and the ratio of maximum to minimum discharge value. However, more detailed discussion should be addressed to explaine this potential relationship.

Tabel 12. Morphometric parameters vs Hydrological properties

	Ratio of hydrological properties			
	Minimum to mean	maximum to mean	maximum to minimum	St.Dev to mean
A	-0,153	-,300*	0,989	-0,279
P	-0,266	-,369*	0,994	-,369*
U	-0,210	-,371*	0,950	-,323*
Rb	-0,094	-0,267	0,412	-,328*
Lu	-0,154	-0,282	0,968	-,319*
Lsm	-0,033	-0,019	0,644	-0,042
RI	,305*	-0,009	-0,386	0,045
Bh	-0,156	-0,034	0,993	-0,098
Rh	-0,037	0,192	-0,348	0,187
Rn	-0,160	-0,060	0,995	-0,126
Dd	-0,129	-0,111	0,936	-0,117
Fs	-0,017	-0,097	-0,850	-0,073
T	-0,160	-0,163	0,999*	-0,107
Rf	-0,062	-0,083	-0,350	-0,076
Rc	,327*	0,208	-0,957	0,297
Re	0,000	-0,020	-0,901	-0,102
Lof	0,220	-0,073	-0,937	0,020
C	-0,018	-0,062	-0,897	-0,168
Cc	0,130	0,017	-0,984	0,083

** Correlation is significant at the 0,01 level (2-tailed).

* Correlation is significant at the 0,05 level (2-tailed).

4. Conclusion

Data on discharge & rainfall in each watershed can explains the hydrological properties variability of small watersheds. Most of the hydrological variables are relatively different both for discharge and rainfall. Furthermore, some morphometric parameters of the watersheds can be derived from the processing of DEM data. Variability amongs watersheds is also shown in morphometric parameters. It is difficult to explaine the corelation between morphometric and hydrological properties. The relationships between the morphometric parameters show a very strong, strong or insignificant relationship. The interpretation of corellation between hydrological properties and morphometric parameters probably more explicit by using a dimensionless number of discharge ratio.

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