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GEOGRAPHIC INFORMATION SYSTEM APPROACH ON MANAGEMENT PRIORITIZATION OF GUBAWAN WATERSHED, BASILAN, PHILIPPINES USING MORPHOMETRIC ANALYSIS

ENFOQUE DEL SISTEMA DE INFORMACIÓN GEOGRÁFICA SOBRE LA PRIORIZACIÓN DE LA GESTIÓN DE LA CUENCA DE GUBAWAN, BASILAN, FILIPINAS USANDO ANÁLISIS MORFOMÉTRICO

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Abstract: The research study was conducted in the Gubawan watershed, Basilan province. The watershed has a total area of 19,348.48 hectares (193.48 km^2). The study aims to characterize the watershed in terms of morphometric analysis and rank it according to management prioritization. Digital Elevation Model (DEM) is used and processed in GIS software to produce maps and other data. Some linear and shape morphometric parameters are used in the evaluation for ranking. The study revealed that sub-watersheds (SW5) and (SW1) ranked first and seventh. High-risk sub-watershed was given priority in terms of management prioritization to reduced soil erosion, enhanced infiltration, and promote conservation farming.

Keywords: GIS, Morphometry, Management prioritization, Gubawan watershed, Basilan.

Resumen: El estudio de investigación se llevó a cabo en la cuenca de Gubawan, provincia de Basilan. La cuenca tiene una superficie total de 19.348,48 hectáreas (193,48 km2). El estudio tiene como objetivo caracterizar la cuenca en términos de análisis morfométrico y clasificarla de acuerdo con la priorización de manejo. El modelo de elevación digital (DEM) se utiliza y procesa en el software GIS para producir mapas y otros datos. Algunos parámetros morfométricos lineales y de forma se utilizan en la evaluación para la clasificación. El estudio reveló que las subcuencas (SW5) y (SW1) ocuparon el primer y séptimo lugar. Se dio prioridad a la subcuenca de alto riesgo en términos de priorización de la gestión para reducir la erosión del suelo, mejorar la infiltración y promover la agricultura de conservación.

Palabras clave: SIG, morfometría; priorización de la gestion; cuenca de Gubawan; Basilan.

INTRODUCTION

The geographic information system (GIS) and remote sensing were intensively applying in hydrological investigations of the river basin. These methods are proven efficient and timesaving in characterizing various basin morphometric parameters. it may be a reliable and ideal tool for generating spatial information which can be a prerequisite for planned and balanced development at the watershed level [1], Besides, morphometric analysis of a watershed provides a quantitative description of the drainage system is a prime aspect of the characterization of watersheds [2]. Drainage density varies with relative age, differing geology, catchment basin and enables comparisons of basins and streams. Moreover, it provides distinct characteristics and facilitates proper management of the watershed and sustainable development of natural resources [3]. It's an instinct hydrological entity that allows surface runoff to a defined channel, drain, stream, or river at some extent [4]. Appropriate use of land and water resources of a watershed for optimum production with minimum hazard to natural resources such as flooding and proper management of watershed through modification of the inherent system could reduce the risk impact on the lower stream [5]. Contrastingly, the impact and frequency of natural disasters seem to have increased because of environmental degradation, such as deforestation, intensified land use, and the increasing population, spontaneous rapid settlement development, uncontrolled construction of buildings, and Landuse changes [6]-[7]. It caused widespread erosion, soil degradation, lower agricultural production, reduced water quality, and degraded environments [8]. The management prioritization concept helpful understand the morphology of individual sub watersheds and highlight the management strategies to minimize and control soil erosion in the different sub watershed areas [9]. Morphometric analysis for management prioritization is very important for water resource modelers and flood management [10]. Therefore, the study aims to characterize each sub watershed in terms of morphometry and rank each sub watershed in terms of management prioritization in the context of soil erosion. The study will provide a scientific explanation of the prioritization management measures of the Gubawan watershed to local government units and the other stakeholders.

METHODOLOGY

Study Area

The Gubawan watershed (Figure 1) has a total delineated land area of 19,348.48 hectares (193.48 km2) bounded within 1220 2' 16" West, 1220 12' 14" East, 60 41'15" North, and 60 31' 35" South. It is within the Lamitan City area and parts of Ungkaya Pukan municipality on the South crossing the sub-watershed 4, Tuburan and Akbar Municipalities on the North at sub-watershed 7, and a small portion of sub-watershed (SW1) falling within Isabela City area. The area is mainly planted with coconut and rubber trees, as they are the main crops of the province. Under modified corona climate classification, the study area is under type III climate classification where seasons are not very pronounced, relatively dry from November to April, and wet during the rest of the year [11]-[12]. Lamitan City has a significant rainfall with an average of 1725 mm and an average temperature of 27 0C. The soil type mostly Luvisols, which are greatly affected by water erosion and loss infertility [13]. The study area mostly ranged from 0 to 200 m and has a small part that has the highest elevation ranged from 800 to 1000 m on the southwest of the watershed (Figure 2).

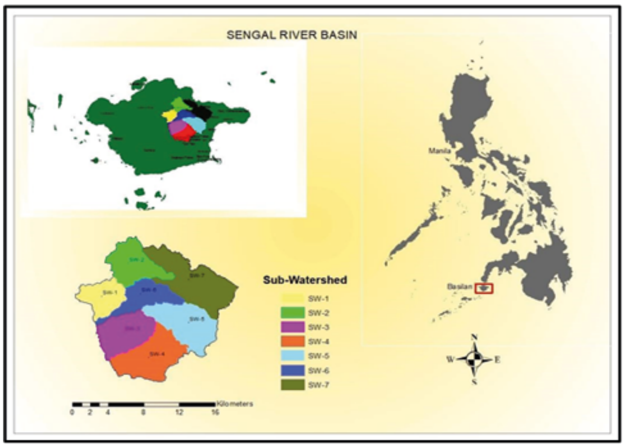


Figure 1. Gubawan watershed, the Study Area

Empirical Equations for Morphometric Analysis

Table 1. Empirical Equations used for the Computation of Morphometric Parameters

Parameters	Formula	References
Stream Order (U)	Hierarchal Rank	[14]
Stream Length (Lu)	Length of stream	[15]
Stream Number		
Bifurcation Ratio (Rb)	Rb =Nu/Nu + 1	[16]
Basin Length		
Drainage Density (Dd)	Dd = TLu /A	[15]
Stream Frequency (Fs)	Fs = N/A	[15]
Texture ratio (T)	T = N1/P	[15]
Length of Overland Flow (Lq)	Lq = 1/2Dd	[15]
Form Factor	Ff = A/Lb2	[15]
Shape Factor	Sf = 1/Ff	[15]
Elongation Ratio (Re)	Re = (2/Lb) [(A/π)0.5]	[16]
Compactness Constant	Cc = P/(4πA)0.5	[15]
Circularity Ratio	Rc = 4πA/ P2	[17]

Drainage Network Generation

Drainage was generated from Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) 30m x 30m resolution of digital elevation model (DEM) in GIS environment [18].

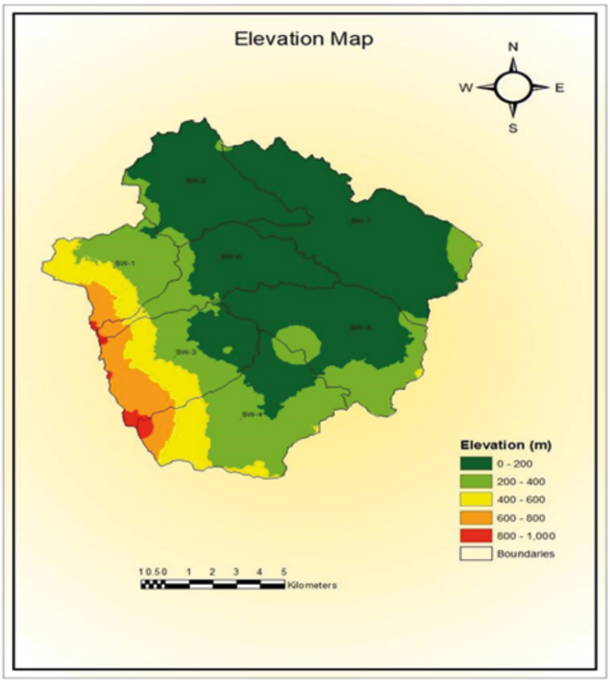


Figure 2. Elevation Map of Gubawan Watershed

RESULTS AND DISCUSSION

Watershed Geometry

Area

Drainage area (A) is a lead watershed characteristic for hydrologic analysis and design [19]. It is another main parameter like the length of the stream drainage [20]. The seven (7) Gubawan sub-watershed areas (Table 3) were established and generated through GIS software.

Perimeter

The watershed perimeter is the outer boundary of the basin that enclosed its area. It is measured along the divides between basins and used as an indicator of basin size and shape [20]. Similarly, the perimeter is also established and generated through GIS software. The Gubawan seven (7) sub-watersheds perimeters are shown in Table 3.

Morphometric Analysis

Stream Order

In the catchment area analysis, stream orders are the primary step to work out [21]. The stream orders of the study area consistent with method of classification [2]. The order wise stream numbers of the Gubawan watershed in Table 2. The variations in stream order and therefore the watershed area was primarily thanks to physiographic and structural conditions of the region, while SW1 has the very best number of stream order I and total streams, SW5 has the sole order IV stream which is greater size and capacity.

Stream Length

The stream lengths are computed supported the law proposed [15]. It's indicative of the contributing area of the watershed of a given order [22]. The stream length per stream order was generated from the digital elevation model (DEM) using the GIS platform. The stream length numbers for various orders during a sub watershed are tally, and their lengths from mouth to drainage divide are measure with the assistance of GIS software. The length of stream segments is maximum for first order streams and reduces because the stream order increases shown in Table 2.

Stream Number

The stream number gradually decreases because the stream order increases. it's the amount of stream segments of varied orders and is inversely proportional to the stream order [23]. The number of streams in every order and therefore the total number of streams are computed in (Table 2) using GIS tools. the whole streams altogether sub watersheds were 341, as shown in table 2.

Table 2. GIS Generated Stream Order and Stream Length of Seven (7) Gubawan Sub-Watershed

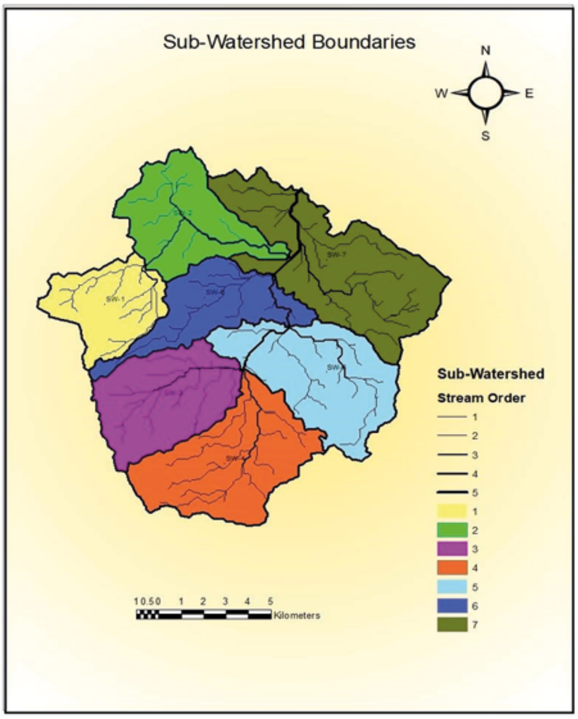
SW	Steam Order				Stream Length (Km)					
No.	I	II	III	IV	I	II	III	IV	Stream Order	Stream Length
1	11	7	3	0	12.97	8.43	1.42	0	21	22.82
2	18	8	4	0	12.46	9.15	2.28	0	30	23.89
3	17	7	7	0	14.87	11.78	5.06	0	31	31.71
4	23	11	6	0	29.2	13.7	5.34	0	40	39.24
5	46	15	10	1	15.43	12.48	5.06	0.06	72	33.03
6	19	13	1	0	15.15	8.22	0.11	0	33	23.48
7	62	38	10	0	30.87	11.23	7.54	0	106	49.64
Total	196	95	49	1	121.95	69.99	31.81	0.06	341	223.81

Basin Length

The basin length is the distance measured along the main channel from the watershed outlet to the basin divide. It is the fundamental input parameter to count the prime shape parameters of sub-watersheds. The results indicated that basin length varies from 5.26 to 9.46 km, as shown in table 3.

Bifurcation Ratio

The lower values are indicative of a structurally stable watershed without any distortion in the drainage patterns [24]-[25]. It states that Rb was not the same from one order to its next order. The bifurcation ratio (Rb) serves as an index for the hydrograph shape in the identical watershed [26]. These irregularities depend upon the geological and lithological development of the drainage basin [2]. Table 3 showed that in bifurcation ratios (Rb) of Gubawan sub-watersheds, SW1 has a minimal bifurcation ratio of 1.14, where SW6 has a maximum ratio of 4.82 indicates that these sub-watersheds do not exercise a dominant influence on the drainage pattern.



Importar imagen Figure 3. Drainage Network of Seven (7) Gubawan Sub-Watershed

Drainage Density

Drainage density refers to the closeness within the spacing of channels [27]-[28]. It's a measure of the whole length of the stream segment of all orders per unit area. Slope gradient and relative relief are the foremost morphological factors controlling drainage density. [2] indicated that low Dd occurs where basin relief is low, while high Dd is favored where basin relief is high. For Gubawan sub-watersheds, the values vary from SW3 of 1.01 to SW1 of 1.21 km/km2, as presented in table 3. Higher drainage density is related to the basin's shaky and impermeable subsurface material, sparse vegetation, and alto relievo. Low drainage density results in coarse drainage texture, while high drainage density results in fine drainage texture, high runoff, and erosion potential of the basin area [2].

Stream Frequency

The Fs values for the Gubawan sub-watersheds were 1.17 for SW1 and a couple of .63 1/km2 for SW7 (Table 3), rock bottom, and highest value respectively. it's mainly counting on the lithology of the basin and reflects the feel of the drainage network. the worth of stream frequency (Fs) for the basin exhibits a direct correlation with the drainage density value of the world indicating the rise in stream population concerning increase in drainage density [22].

Texture Ratio

Texture ratio is that the whole number of stream segments of all orders per perimeter of that area [21]. within the Gubawan sub-watersheds, the feel ratio varied from 0.55 to 1.59 (Table 3). The lower values of texture ratio indicate that the basin is obvious with a lower degree of slopes and a lesser risk of erosion.

Length of Overland Flow

Length of overland flow may be a length of flowing water over the bottom before it gets concentrated into stream channels [29]. It equals half the Inverse of the drainage density [21]. The length of overland flow (Lg) values of 0.39 for SW1 and 0.50 for SW2 (Table 3). Higher values of Lg indicate more infiltration and small runoff.

Form Factor

Form factor indicates the flow intensity of a basin of an outlined area [21]. The smaller the price of the form factor, the more elongated the basin. Basins with high-form factors experience enormous peak flows of shorter duration, whereas elongated watersheds with low-form factors experience lower peak flows of extended periods. the shape factor (Ff) values within the study area ranged from 0.22 for SW6 to 1.51 for SW7 (Table 3), rock bottom, and highest value respectively

Shape Factor

The shape factor is often defined because the ratio of the square of the basin length to the world [21] and is in inverse proportion with the shape factor (Rf). Shape factor indicates a ranged from 0.66 (SW7) to 4.50 (SW6) (Table 3). A smaller value of the form factor indicates a better risk of erosion of the sub-watershed.

Elongation Ratio

The elongation ratio may be a measure of the form of the basin and, it depends on the climatic and geologic types. Re values of Gubawan watersheds ranged from 0.53 (SW6) to 1.38 (SW7) (Table 3). The larger elongation ratio showed high infiltration capacity and low runoff, whereas lower Re values high susceptibility to erosion and sediment load [30].

Compactness Constant

The compactness coefficient values differ among seven sub-watersheds within the study area. rock bottom value was computed in SW3 of 1.26 while the very best one in SW6 of 1.86 as presented in table 3. the very best value indicates less erodibility of the basin.

Circularity Ratio

The circulatory ratio is influenced by the lithology, stream frequency, and gradient of varied orders [2]. The basin shape tells the speed of infiltration and time taken for the surplus water to succeed in the basin outlet depending upon the geology, slope, and vegetative cover of the world. rock bottom Rc value is 0.26 for SW6, while the very best is 0.63 for SW3 (Table 3). It indicates that SW3 is a smaller amount elongated with a consistent rate of infiltration and hence the surplus run-off takes an extended time to succeed in the basin outlet.

Table 3. Computed Value of Morphometric Parameters of Gubawan Sub-Watershed

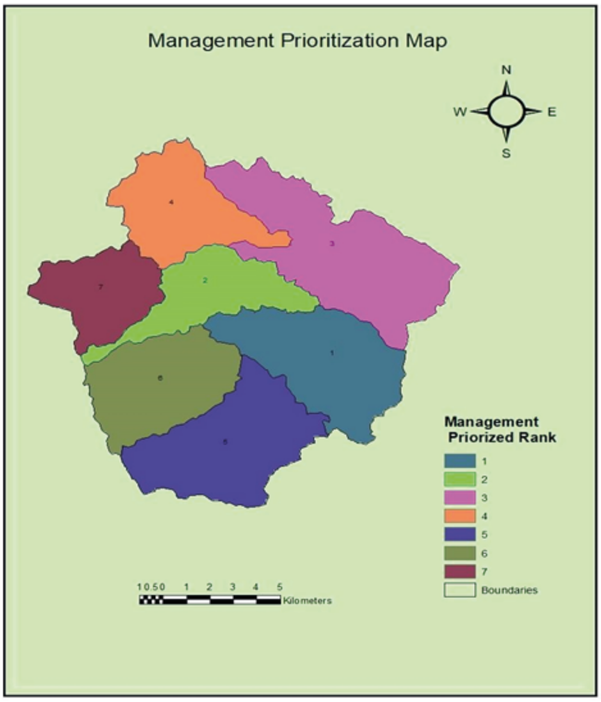
Parameters	Unit	Sub-watershed						
		1	2	3	4	5	6	7
A	(Km2)	17.95	23.75	26.15	32.64	31.24	19.91	41.85
P	(Km)	19.98	25.39	22.87	29.11	28.90	29.44	41.51
L	(Km)	22.82	23.89	31.71	39.24	33.03	23.48	49.64
N		21	34	31	41	71	33	110
N1		11	18	17	23	46	19	62
Lb	(km)	5.36	7.48	6.69	7.26	6.22	9.46	5.26
Rb		1.30	1.61	1.14	1.31	3.64	4.82	1.81
Dd	(km/km2)	1.27	1.01	1.21	1.20	1.06	1.18	1.19
Fs	(No./km2)	1.17	1.43	1.19	1.26	2.27	1.66	2.63
T		0.55	0.71	0.74	0.79	1.59	0.65	1.49
Lo		0.39	0.50	0.41	0.42	0.47	0.42	0.42
Ff		0.62	0.42	0.58	0.62	0.81	0.22	1.51
Sf		1.60	2.36	1.71	1.61	1.24	4.50	0.66
Re		0.91	0.74	0.86	0.89	1.01	0.53	1.38
Cc		1.33	1.47	1.26	1.44	1.46	1.86	1.82
Rc		0.57	0.46	0.63	0.48	0.47	0.29	0.31

Management Prioritization

For management prioritization, rank first the highest value, then second to the next highest value, and so on, on the linear parameters (Light blue color, Table 4). Conversely, ranking first for the lowest value, second for the next lowest, and so on, on the shape parameters (Light green color, Table 4). The compound parameter values of the seven (7) sub-watersheds of the Gubawan watershed are computed, and the prioritization rating in Table 4. The sub-watershed 5 with a compound parameter value of 3.50 received the highest priority, followed by sub-watershed (SW6), having a compound parameter value of 3.60. The final prioritized map of the study area in Figure 4. Thus, soil conservation measures apply first to sub-watershed (SW5).

Table 4. Rank of Morphometric Parameters

Parameters	Sub-watershed						
	1	2	3	4	5	6	7
Rb	6	4	7	5	2	1	3
Dd	1	7	2	3	6	5	4
Fs	7	4	6	5	2	3	1
T	7	5	4	3	1	6	2
Lo	7	1	6	4	2	4	4
Ff	4.5	2	3	4.5	6	1	7
Sf	3	6	5	4	2	7	1
Re	5	2	3	4	6	1	7
Cc	2	5	1	3	4	7	6
Rc	6	3	7	5	4	1	2
Common Parameter	4.85	3.9	4.4	4.05	3.5	3.6	3.7
Prioritized Rank	7	4	6	5	1	2	3



Importar imagen Figure 4. Management Prioritization Map of Gubawan Sub-Watershed

CONCLUSION

Application of Geographic Information System (GIS) and remote sensing are an effective tool for characterizing watershed in terms of morphometric analysis leading to management prioritization. The study reveals that sub-watershed (SW5) with a compound parameter value of 3.50 received the highest priority, followed by sub-watershed (SW6), having a compound parameter value of 3.60. The highest priority indicates the greater degree of soil erosion in the particular sub-watershed, and it becomes vital for applying soil conservation measures. However, sub-watersheds (SW5), (SW6), and (SW7) were too closed in terms of compound parameter values which indicated that these three sub-watersheds should give almost equal attention when it comes to management prioritization.

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