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Morphometric Analysis and Watershed Prioritization in Relation to Soil Erosion of Dabus Watershed, Abbay River Basin, Ethiopia

By: - Ayana Asrat

A thesis submitted to the School of Graduate Studies of Jimma University, Jimma Institute of Technology in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Hydraulic Engineering.

February 12,2023

Jimma, Ethiopia

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Main Advisor: Mr. Tolera Abdissa (Ass. Professor)

Co-advisor: Mr. Nasir Gebi (Ass. Professor)

February 12,2023
Jimma, Ethiopia

Declarations

I hereby declare that the Thesis entitled "**Morphometric Analysis and Watershed Prioritization in Relation to Soil Erosion of Dabus Watershed, Abbay River Basin, Ethiopia**" is my original work, which I submit for partial fulfillment of the degree of Master of Science in Hydraulic Engineering to school of graduate studies, Hydrology and Hydraulic Engineering Chair, Jimma Institute of Technology, Jimma University. The Thesis conducted under the guidance of a main advisor, **Mr. Tolera Abdissa** (Ass. Professor), and co-advisor, **Mr. Nasir Gebi (**Ass. Professor**.).**

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Approval sheet

We the examiners' board approve that this thesis entitled with **"Morphometric Analysis and Watershed Prioritization in Relation to Soil Erosion of Dabus Watershed, Abbay River Basin, Ethiopia"** is the work of Ayana Asrat Duressa. We hereby recommend for the acceptance by a school of Graduate Studies of Jimma University in partial fulfillment of the requirements for Degree of Master of Science in Hydraulic Engineering.

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Mr. Nasir Gebi (Ass. Professor) ________________ __________________

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As the member of Board of Examiners of the M.Sc. Thesis Open Defense Examination, we certify that we have read, evaluated the Thesis prepared by Ayana Asrat Duressa and examined the candidate. We recommended that the Thesis could be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Hydraulic Engineering.

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Chairperson Signature Date

Dedication

This thesis is dedicated to my beloved Family!

Abstract

Environmental deterioration is currently one of the most important challenges, culminating in the extinction of ecosystems and the loss of vital natural resources. Prioritization is a strategy of organizing the multiple watersheds in a catchment in the order of treatment and soil conservation measures to be performed out. The identification of essential watersheds or the prioritization of sub-watersheds was required for effective and long-term watershed management programs and natural resource allocation. Morphometric analysis is a key to understand the hydrological process of a drainage basin and is a means of mathematically quantifying different aspects of hydrological characteristics of a river basin. Traditional morphometric parameter determination methods are time consuming, extremely expensive, and tedious. However, development of Geographical Information System (GIS) and remote sensing technology makes the procedure easier, cheaper, and faster. The present study aims to prioritize watershed based on morphometric analysis and soil erosion susceptibility in Dabus river Catchment(DRC), located in Upper Blue Nile basin, Ethiopia using geospatial data. For this study, the Digital Elevation Model (DEM) data with spatial resolution 12.5mx12.5m and Topographic map of the study area was obtained from Ethiopian basin development authority(EBDA). The DEM data was used to determine the stream network and delineate the Sub-watershed along the watershed border. The fundamental parameters (stream order, stream number, stream length, basin area, basin perimeter, and elevation) were retrieved using GIS software. All geomorphometric parameters were acquired and computed using fundamental geomorphometric parameters and DEM data. Based on computed fundamental parameters using DEM data and ARC GIS software, the derived parameters were determined using mathematical formulae and methodologies that have already been devised. The combined use of remote sensing and GIS might aid in quantifying rate of soil erosion at different levels and in identifying regions that may be at danger of erosion. Fourteen DRC sub-watersheds were prioritized and ranked based on their susceptibility to soil erosion employing morphometric parameters. Morphometric characteristics influencing soil erosion were employed as ranking criteria, with compound values derived for final prioritizing. The compound parameter values for each sub watershed were calculated to generate the final priority classifications, which were classified as Very high, high, Medium, and Low. As per analysis result, the sub-watershed SW1, SW7 and SW10 with a covering total area of 2390.75 km^2 ,2555.77 km^2 and 1642.71 km^2 respectively received the very high priority classes where as SW3, SW4, SW 6 and SW 13 covering total area 2213.87 km^2, 1899.07 km^2, 949 km^2 and 865 km^2 received high priority classes. To reduce soil erosion risk appropriate immediate management measures must be implemented for very high and high-priority rank sub-watersheds Likewise, the sub-watersheds in the Medium priority classes SW11 (458.82Km^2) and SW5 (552.22km^2) indicate a moderate land degradation area. Sub watersheds in low priority classes SW2 (333.44km^2), SW8(164.89km^2), SW9(328.72 km^2) and SW14 (334.16km^2) imply low soil erosion.

Keywords: *Dabus River Catchment(DRC), Geographical information system(GIS), Morphometric parameters, Prioritization, Soil erosion.*

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Acronyms

ASTER DEM	Advanced space-borne thermal emission and reflection digital elevation model
BNB	Blue Nile Basin
Br	Bifurcation ratio
Cr	Circularity ratio
Dd	Drainage density
DEM	Digital Elevation Model
Dt	Drainage Texture
EBDA	Ethiopian basin development Authority
ENMSA	Ethiopian National Metrological Service Agency
Er	Elongation Ratio
FAO	Food and Agricultural Organization
Ff	Form factor
GERD	Grand Ethiopian Renaissance Dam
GIS	Geographic Information System
DRB	Dabus r river basin
DSWs	Dabus sub watersheds
DWs	Dabus watersheds
DRC	Dabus river catchment
Lb	Basin Length
Lm	Mean stream Length
Lolf	Length of overland flow
Ls	Stream length
Lsr	Stream length ratio
m.a.s.l	meters above sea level
MoWRIE	Ministry of Water Resources, Irrigation, and Energy
Ns	Number of stream
Rb	Basin Relief
Rn	Ruggedness number
Rr	Relief ratio
Rr'	Relative relief
RS	Remote sensing
SES	soil erosion susceptibility
Sf	Stream Frequency
So	Stream Order
SPR	Sediment Production Rate
SRTM	Shuttle Radar Topography Mission
SW	Sub watersheds
SYI	Sediment Yield Index
USLE	Universal Soil Loss Equation

CHAPTER ONE
INTRODUCTION

1.1. Background

Environmental degradation has now become one of the world's most critical issues, resulting in both ecosystem and valuable natural resource losses. It is a major ecological and agricultural concern with a broad economic, political, and social ramification. The sustainability of agricultural output is threatened by a number of reasons, with land degradation ranking as one of the main ones (Kumar et al, 2021). Due to several human-caused circumstances and a lack of resources, it is accelerated in much of the world, particularly in developing countries. High rates of soil erosion, as well as the loss of both quantity and quality of water resources, are largely caused by inefficient land use and management practices, rapid population growth, traditional agricultural practices, ineffective conservation measures, deforestation and overgrazing (Negese, 2021). Identifying potential regions of environmental hazards for appropriate management interventions to address the primary causal variables at their precise locations is indeed critical from an economic, managerial, and sustainability point of view (Debelo & Tadele, 2017; Jothimani et al., 2020).

In order to maintain long-term prosperity and food security, watershed management in Ethiopian highlands requires immediate augmentation and preservation of natural resources. In this context, watershed degradation is caused by unsustainable management, as seen by significant erosion, sedimentation, and a threat to freshwater availability. In order to increase soil productivity and prevent further soil erosion losses, it is critical to determine the key sediment-producing source locations within a watershed that require priority attention (Mohammed et al., 2018b).

In Ethiopia, watershed management programs (WMP) demand a substantial commitment from the national or regional government in terms of resources (financial and human), multi-sector partners, and stakeholder involvement. Due to time and resource constraints, it is challenging to carry out rehabilitation and conservation activities simultaneously everywhere in a WMP. Therefore, it is crucial to study the local watersheds and rank them according to the risk of erosion. In this context, evaluating soil erosion is important for determining the scope and severity of the issue as well as identifying sites that are more sensitive. However, prioritization is required in order to choose the most relevant watershed for more appropriate treatments. It is a method of arranging the many watersheds in a catchment in order of treatment and soil conservation measures to be performed.

Nowadays, to estimate soil erosion rate and prioritize potential land management strategies, GIS and remote sensing-based soil erosion estimating models are necessary (Markose & Jayappa, 2016).

The satellite images from the remote sensing technique are highly helpful in the analysis of drainage basin morphology because they give a synoptic view of a wide area and are a practical way for morphometric analysis. In a Geographical Information System (GIS) setting, morphometric parameters including drainage basin area, drainage density, drainage order, relief, and network diameter are determined using the digital elevation model (DEM) data of the area. Additionally, GIS has been used to calculate and delineate the morphometric characteristics of the basin. In order to create information on geomorphometric properties, such as the topology of stream networks and quantitative descriptions of drainage texture, pattern, shape, and relief characters, the RS and GIS can be employed successfully(Singh et al., 2021).

In regards to the potential for surface and ground water, morphometric analysis provides quantitative information regarding hydrogeology, erosion-prone regions, and watershed characteristics. Consequently, it is important in any hydrological study, including groundwater evaluation, groundwater management, watershed management, and environmental assessment. Quantitative parameters of the drainage network of the basin are incredibly useful, in the definition of the hydrological model, watershed prioritization, management of natural resources and regeneration (Choudhari et al., 2018a).

In this regard, the purpose of this study was to assess the morphometric characteristics of the Dabus River in the Abbay River Basin (Ethiopia) that technically and financially feasible for soil conservation and management purposes. Therefore, it has applied a framework of morphometric parameters including Fundamental (Basin perimeter, Basin area, stream order, Number of streams, Stream length, Elevation), linear (Mean stream length, Drainage density, Stream length ratio, Stream frequency, Drainage texture, length of Overland flow, Bifurcation ratio), relief (Basin relief, Relief ratio, Ruggedness number, Relative relief) for Watershed prioritization. Likewise, areal parameters such as, Basin length, Form factor, Circulatory ratio, Elongation ratio, applied with the goal of, watershed management, preventing soil erosion and defining sub-watershed priorities. To determine morphometric parameters for the study area and a sub-basin of the river that is prone to erosion a combination of topo sheet, remotely sensed digital elevation model, and ArcGIS toolbox is the most effective tools.

1.2. Statement of the problem

Watershed degradation has now become one of the most critical issues, resulting in both ecosystem and valuable natural resource losses. It has far reaching effects that endangers agricultural productivity, loss of fertile soil due to erosion and subsequently diminish the economic growth of the country (Regasa, 2021). Ethiopia is one of Sub-Saharan African(SSA) countries, which is characterized by significant land degradation, soil erosion and sedimentation due to multitude factors among which poor landscape management, overgrazing, deforestation, and urbanization are the determinant factors (Belayneh et al., 2019).

The Upper Blue Nile Basin (Abbay River Basin) is vital to Ethiopia because of its high population, enormous development potential, and vast natural resources. Ethiopia's large population expansion will raise demand for natural resources, particularly land and water, in each area. Ethiopia is also facing significant challenges in terms of economic development, urbanization, and environmental degradation. The Upper Blue Nile Basin in general (Wakjira, 2021) and the Dabus River watershed in particular have been damaged by soil erosion and sedimentation processes. Haregeweyn et al. (2017) found that 39% of the Upper Blue Nile basin is undergoing significant erosion, which might threaten the long-term viability of downstream reservoirs, including the Grand Ethiopian Renaissance Dam.

Dabus watershed is one among main tributaries of the Upper Blue Nile river features steep and long slope topography, with high land deterioration problem that resulted from poor land management, land overuse, traditional farming and cropping practices, deforestation, overgrazing and ineffective management methods. The Grand Renaissance dam, built downstream of the Dabus River, is being threatened by highland tributaries' severe soil erosion(Diriba ,2021). This substantially introducing a threat to downstream users, reservoir sedimentation, fertile soil nutrient loss, and consequently subjected to high runoff discharge (Erena & Adeba, 2021). Therefore, it is necessary to control and manage areas that result in erosion and sedimentation.

In recent past decades in Upper Blue Nile basin several studies were conducted by various researchers including Dibaba et al. (2021) Gashaw et al.(2018) to determine appropriate locations for water collecting and other soil and water management structures. Haregeweyn, et al.,(2017) stated that Erosion is more seriously affecting the upper blue Nile basin. Additionally, noted that the Abbay basin in Ethiopia's UBNR basin experienced erosion at a rate of up to 200 t/ha/year, while Tiruneh & Ayalew, (2016) indicated an annual erosion rate more than 100 t/ha as around 0.95 percent in Ethiopia's UBNR basin. Dabus is the UBNR basin's highest-yielding sub basin in terms of sediment production(Subash et al., 2017). As a result, the Dabus sub-basin of the UBNR basin has the highest rate of soil erosion, according to Nesredin&Bilal, (2021). About 173.09 t/hec million tons of soil might be lost from the sub-basin each year, with soil degradation for the entire sub-basin projected to be greater than 10 metric tons per hectare.

However, the country efforts to address soil degradation and improve productivity, requires up to date research findings. Prioritizing sub-watersheds towards soil erosion in environmental affects is the greatest watershed management approaches that protect soil, land, and water resources (Dibaba et al., 2021). Thus Morphometric analysis can help with watershed prioritization, natural resource management, and conservation (Tukura et al., 2021). In Ethiopia, several studies have explored the use of morphometry as a potential determinant for appropriate watershed management planning in watershed prioritization. Regrettably, just a few studies were conducted at UBNB of Ethiopia. Therefore, this study aimed to use geospatial methodologies to select watersheds in the Dabus Catchment based on morphometric analysis and soil erosion susceptibility to improve and manage watershed resources.

1.3. Objectives of the study

1.3.1. General objective

The general objective of the study is to prioritize watershed based on morphometric analysis and soil erosion susceptibility in Dabus Catchment using geospatial approaches.

1.3.2. Specific objectives

The Specific objectives of the study are

1. To analyze the morphometric parameters of Dabus river catchment
2. To identify the erosion - prone area in the watersheds
3. To prioritize and map the Sub-watersheds susceptible to soil erosion based on morphometric parameters

1.4. Research questions `

This study was conducted to answer the following questions:

1. What is hydrological behavior of the catchment?
2. Which parts of watershed is main source of environmental degradation?
3. Which areas of the watersheds require the most attention in terms of conservation efforts?

1.5. Significance of the study

Prioritizing watersheds is a key for controlling runoff, soil depletion, landslides, and flooding vulnerability. The present study was attempt to prioritize sub watersheds and produce priority map of Dabus catchment, upper Blue Nile basin /Abbay basin, Ethiopia by employing the frame work of morphometric analysis and soil erosion susceptibility parameters. It performs geomorphometric analysis, evaluate various basin restrictions, create a more efficient environment, and analyze spatial data relating to river basins using GIS and DEM data.

It also provides useful data and information for the formulation of watershed management plans for the country's major watersheds in general, and the Dabus catchment in particular to environmentalists, regional planners. farmers, and government officials, hydrologists, and geomorphologists. Additionally, it is a practical approach to watershed management, natural resource development, stabilizing steep slopes against land sliding to reduce future flooding by minimizing soil erosion and soil and water conservation. Also, it presents an effective feature for defining areas for planning soil erosion management and conservation measures.

1.6. Scope of the study

The study was conducted on the Dabus watershed, the sub basin of upper Blue Nile Basin and focused on erosion hazard analysis factors and was used to prioritize sub-watersheds. It covers the entire sub-watershed of the DRCs, which delineated to the Dabus Rivers using geographic information systems, remote sensing techniques, and morphometric analysis.

CHAPTER TWO

LITERATURE REVIEW

2.1. General Overview

Water resources planning, conservation, and better management are essential for long-term growth of country. Watershed management is important for the conservation of water and soil resources as well as their long-term sustainability(Choudhari et al., 2018a). Drought, flood, excessive runoff, poor infiltration, soil erosion, human health, and low productive yield can all be alleviated by implementing better watershed management strategies. It is very important in the highlands, where land management decisions could have a big impact on downstream areas in terms of hydrology, as well as sediment transport(Heal, 2019a).However watershed deterioration has been a big problem all around the world (Jaleta Negasa, 2020) especially in underdeveloped countries, this is a pressing issue that requires immediate attention (Mengistu & Assefa, 2019a). Watershed development's major goal is to save land and water. However, the watershed's other economic and social development follows as a result (Tefera et al., 2020).

Soil erosion is a well-recognized environmental concern that endangers man's well-being and general growth, both on and off the site. Soil erosion caused by water and wind is a global issue that affects both rural and urban regions. It is generally a natural process that occurs over geological durations; but, when (and when) the natural pace is greatly enhanced by anthropogenic activity, rapid soil erosion becomes a degrading process and hence an obvious hazard to soil. The Ethiopian rural population's over-reliance on natural resources, particularly land, as a source of income is the root cause of land and other natural resource degradation. Ethiopia is recognized as the world's most eroding country, with yearly soil loss ranging from 16 tones/ha/year to 300 tones/ha/year. The Blue Nile River, which flows from the Ethiopian Plateau's high slopes, is the largest source of sediment loads in the Nile basin. Soil erosion from the basin's upstream and subsequent sedimentation in the downstream area is a massive concern that threatens the Nile basin's current and future water resource development. (Yalew et al., 2016).

2.2. Watershed Prioritization

In a watershed management program, it may not be practical to treat the whole watershed using land treatment methods, especially in the case of vast watersheds(Mohammed et al., 2018a). Selection and implementation of some few locations or sub-watersheds with a comparatively high degree of degradation are necessary for development planning and preservation activity execution based on the amount of need and degradation status(Abdeta et al., 2020). Faced with the vastness of degradation issues and a lack of financial resources combined with poor experience, a scientific approach to land resource management necessitates the development of appropriate technique for identifying priority regions for treatment(Gurjar et al., 2017).

Prioritizing and promoting the long-term use of the region's terrestrial ecosystems, is one of the most important principles for effective and productive watershed preservation(Obeidat et al., 2021). Several researchers have attempted to prioritize watershed using various techniques including remote sensing and GIS technology and numerous empirical methods like USLE/MUSLE. These studies support the use of geographic information systems (GIS), remote sensing (RS), and morphometric analysis as effective techniques for ranking distinct sub-watersheds in terms of treatment and soil conservation priorities(Mohammed et al., 2018a) .

The prioritizing idea, on the other hand, has been shown to be extremely useful in understanding the morphology and fluvial characteristics of different watersheds, as well as in developing efficient water harvesting systems throughout a watershed (Singh et al., 2021). Because the majority of basins are either ungauged or lack appropriate data, research into the geomorphologic properties of such basins becomes significantly more relevant. The integration of geomorphologic elements with basin hydrological variables provides a simple approach for understanding the hydrological behavior of diverse basins.

Ethiopia has developed a number of recommendations and approaches to handle soil and water preservation in the past, with the overall objective of poverty reduction through increased productivity (Schmidt & Tadesse, 2019). In spite of significant expenditures in soil and land management in the upper Blue Nile basin, soil loss reduction studies are limited (Ebabu et al., 2019) .The Dabus river basin, one of the tributaries of the Blue Nile River, is threatened by extreme soil erosion and its consequences (Kidane et al., 2019). The sub watershed is situated in the UBNB headwaters to south and is marked by potentially irrigable land. Its agro climatic conditions are suited for agriculture and water operations. In addition, the most serious problems in the watershed are the extension of agricultural lands and urbanization on the rate of woodland and community areas, as well as the cultivation of steep lands and overgrazing without proper supervision(Erena & Adeba, 2021).

However, the catchment's ability to implement soil and water management methods was severely limited, and the characteristics that influence the activities have yet to be thoroughly investigated. As a result, prioritizing sub-watersheds based on soil erosion risk and morphometric parameters will help to protect soil, land, and water resources. This provide a comprehensive overview of the current catchment, since it allows for an evidence-based interplay between the watershed and the people in the neighborhood, allowing for more preventive measures to protect the catchment's water assets and land suitability. Therefore, this research intends to use geospatial methodologies to select watersheds in the Dabus Catchment based on morphometric analysis and soil erosion susceptibility.

2.2.1.Morphometric analysis-based watershed prioritization

Despite the fact morphometric parameters analysis of watershed has far reaching application, for example, environmental monitoring, assessment and modelling.to natural resources management and planning(Pandey et al., 2021). In this regards, morphometric analysis can aid with drainage basin evaluation, flood frequency analysis, natural resource management and conservation, and erosion prevention, among other things (Singh et al., 2021) .The results of morphometric watershed analysis could be employed as a key tool in water resource management, soil erosion control, and landslide susceptibility mapping watershed prioritization and evaluation of groundwater potential (Belayneh et al., 2019).

The assessment of morphometric parameters necessitates the creation of a pattern map, the arrangement of various streams, the evaluation of the catchment area and perimeter, the length of drainage channels, drainage density and frequency, bifurcation ratio, texture ratio, circulatory ratio, and constant channel maintenance, which all contribute to a better understanding of drainage basins(Obeidat et al., 2021; Tukura et al., 2021). The fundamental, linear, and form parameters of drainage networks, in connection with contributing ground slopes, can be measured for morphometric analysis (Jothimani et al., 2020; Vanlalchhuanga et al., 2021) . Using GIS software and a mathematical technique established by Miller(1953),Horton, (1955),Strahler(1957), all geomorphometric parameters have been acquired and computed using fundamental geomorphometric parameters and DEM data.

Furthermore, morphometric analysis can aid with drainage basin evaluation, flood frequency analysis, natural resource management and conservation, and erosion control (Prabhakar & Srinivas, 2016). Soil erosion susceptibility assessment is the framework for identifying and analyzing the risk of soil erosion(Nwilo et al., 2021;) parameters employed, slope, soil and geology, vegetation and land use in relation to climatic condition , preservation practice and erosion rating (Puno & Puno, 2019). Soil erosion can be mapped using RS and GIS (Kumar et al., 2021) to detect regions at danger of substantial erosion and offer information on the estimated value of soil loss at different places(Setiawan & Nandini, 2021). Soil erosion studies using RS techniques, backed up by GIS, secondary data, and ground truth information, are used to prioritize watersheds for the creation of soil conservation structures(Farhan & Anaba, 2016). Also, for Identification of crucial erosion-prone regions in a watershed in order to implement management strategy with limited resources (Andualem et al., 2020). As a result, morphometric analysis based on GIS technology is a competent instrument for geo-hydrological research for identifying and planning ground water potential zones and watershed management.

Morphological analysis is the detailed description of a watershed's geometry and stream channel system in order to examine the drainage system's linear features, the watershed's shape, and the relief characteristics of the channel network. The morphometric analysis was completed successfully by measuring the basin's linear, form, relief, gradient of the channel network, and contributing ground slope. It gives a quantitative description of the basin geometry to comprehend original slopes or inequalities in material hardness, compositional controls, current diastrophism, and the watershed basin's geological and geomorphic history. Its characteristics directly or indirectly represent the entire watershed's causal elements impacting runoff and sediment loss. Even without considering the soil map, morphometric analysis is a useful technique for prioritizing sub-watersheds. The construction of dams and reservoirs is a significant success in water resource management, but it also causes significant disruption to river ecology and morphology. Thus, morphometric study to identify significant erosion prone locations is vital for reducing such disruptions. Furthermore, it is responsible for selecting and implementing optimal management techniques for the priority classes of the designated upper river basin sub-catchment.(Bajirao et al., 2019).

2.3. Previous study on watershed prioritization

A number of studies have been conducted morphometry for prioritizing watersheds. For instance Debelo & Tadele, (2017), Mohammed et al, (2018a),Tukura et al, (2021) , and Obeidat et al., (2021) used different morphometric parameters to perform prioritizing. The fast growth of geospatial technology has lately become a useful tool for overcoming many challenges related with the identification and interpretation of basin morphometric characteristics and designing an appropriate land and water resource plan for the basin area. Geo processing methods and remote sensing data or DEM data demonstrate that they are capable tools for morphometric analysis and assessment of linear, slope, areal, and relief aspects of morphometric parameters. For proper planning and administration of the development plans for both water and land resources, it is necessary to examine high level characteristics of drainage and environment.

Debelo & Tadele, (2017) performed morphometric analysis using a GIS system to locate and evaluate erosion prone areas on the upper Blue Nile basin , specifically in the Didessa and Jema sub basins. Morphometric basin analysis employing geo-processing techniques in GIS has been proven to be useful for the extraction of river basins and their drainage networks. In a GIS environment, the dendritic stream pattern was digitized. Strahler's categorization system was used to categorize the obtained watersheds. Arc SWAT software was used to outline the watershed and basin boundaries for each sub basin. Remote sensing data or DEM data combined with spatial techniques seem to be a competent tool used in morphometric analysis and evaluation of linear, areal, and relief aspects of morphometric parameters and drainage management planning.

According to Tukura et al, (2021); Prioritization of sub-watershed, in Genale Dawa river basin ,welmal watershed plays an essential part in the efficient conception and execution of soil protection and sediment erosion management programs. Morphometric evaluation of watersheds is the most effective way for determining the connection of different features in the watershed. As a result, elevated drainage and environmental characteristics must be analyzed for appropriate planning and management of water resource development plans and soil resource development plans. The stream's morphometric characteristics were evaluated and estimated using conventional procedures and techniques used by various academic scholars such as Horton (1945), Miller (1953), and Strahler (1964). GIS based on study of all based on morphological characteristics and the erosional development of the land by the streams has been improved, and findings are highly valuable for designing watershed management and ecological restoration.

In the Sari watershed, Setiawan and Nandini,(2021) have selected sub-watersheds based on the integration of geomorphometric characteristics and land use/land cover datasets in West Nusa Tenggara's semiarid region. The quantitative study of morphometric characteristics has been discovered to be extremely useful in watersheds prioritizing for soil management, as well as managing natural resources at the local scale. Topographic data were used to outline the drainage system, allowing the Geospatial Technology to precisely identify water divides and Strahler’s stream ordering approach was employed to categorize the streams. Prioritization was accomplished by giving rankings to specific indicators and calculating a compound value parameter (CP). Watersheds with the highest CP were considered low priority, whereas those with the lowest CP were considered high priority.

According to Mohammed et al, (2018a) quantitative study of morphometric characteristics is extremely useful in watershed prioritizing for soil and water conservation, as well as natural resource management at the sub-watershed level. As a result, a thorough examination of the linear and shape parameters of morphometric analysis for all sub-watersheds in a Catchment, as well as their priority for soil and water resource management, is performed. Topographic data were used to delineate the drainage system, allowing the GIS to precisely locate water divides. The stream number and length of a Catchment follow Horton's rule of stream numbers and lengths. The high drainage density value indicates that the area is comprised of impervious subsurface materials, scarce vegetation, and high mountainous terrain, which results in increased runoff water and a higher degree of subdivision. Prioritization was accomplished by giving rankings to specific indicators and calculating a compound value parameter (CP). Watersheds with the highest CP were considered low priority, whereas those with the lowest CP were considered high priority. As a result, a priority index of high, medium, and lesser significance was created. High priority implies that the watersheds are more prone to soil erosion, making them great candidates for soil conservation interventions to safeguard the land from future degradation and to avert environmental hazards.

According to Salvi et al, (2017); The morphometric study of the watershed and drainage basin is significant in understanding the geo-hydrological behavior of the drainage basin and expresses the catchment's dominating temperature, geology, geomorphology, and morphological antecedents. Morphometric analysis was performed using Geographical Information System (GIS) techniques to examine the geo-hydrological properties of river basins, and an effort was made to locate ground water potential zones using geo-morphometric specifications. The morphometric variable is concerned with linear, areal, and relief characteristics. The total number and length of stream segments is greatest in first order streams and decreases with increasing stream order. The bifurcation ratio varies over subsequent orders, indicating geo-structural control.

Jothimani et al, (2020) used morphometric analysis and a statistical correlation matrix-based weighted sum approach to conduct a prioritization in the Kulfo River basin, Rift valley, South Ethiopia. Geospatial analysis was used to do morphometric study on the watershed. According to the results, the high drainage density of sub watersheds predicts increased surface runoff. The morphometric study also shows that the region is more susceptible to weathering because of the very-coarse to coarse drainage roughness. Morphometric analysis is a useful technique for prioritizing sub-watersheds even when the soil map is not used.

Kadam et al(2019) aimed to prioritize soil erosion in a watershed by combining morphometry with weighted sum analysis (WSA) and sediment production rate (SPR). The quantitative analysis of morphometric features has shown to be particularly effective in watershed prioritization for soil and water conservation, as well as natural resource management. As a result, a thorough examination of the linear and shape parameters of morphometric analysis for all sub-watersheds in a Catchment, as well as their priority for soil and water resource management is needed. The characteristics used for analysis are stream length, bifurcation ratio, drainage density, stream frequency, drainage texture, form factor circularity ratio, elongation ratio, compactness ratio, and so on.

Also Arefin et al,(2020) argued that :an attempt has been made to study and characterize the drainage morphometry and its influence on hydrology. Data from the Shuttle Radar Topography Mission (SRTM) were utilized to create a Digital Elevation Model (DEM) and slope maps. GIS was utilized to assess the linear, areal, and relief aspects of morphometric characteristics. The basin is dominated by lower order streams. The greater mean Bifurcation ratio of sub-watersheds implies that geological formations impact the drainage pattern only minimally i.e. lack of structural control Shorter length of overland flow suggests that short flow routes with steep ground slopes represent places with more run-offs and less infiltration, whereas long stream paths with moderate ground slopes reflect areas with fewer runoff and far more infiltration. The bifurcation ratio suggests that there is no major structural control over the development of the drainage. The relief ratio reflects the discharge capacity and groundwater potential of the sub watersheds. Such studies are also extremely beneficial for planning the building of rainwater collecting facilities and watershed management.

Gudu Tufa, (2018), assessed morphometric analysis of Kito and Awetu River sub-basins, in southeastern part of Ethiopia. To examine morphometric properties, a topographic map and remote sensing data (digital elevation model) were employed. The morphologic properties of the drainage basin have a significant impact on hydrological processes such as runoff, soil degradation, and sedimentation conveyance. The drainage basin with the highest form factor is often circular in shape and has a higher peak discharge for a shorter period of time. A low form factor watershed has elongated shape and a lower peak flow over a longer period of time. Basin features, are significant in basin management, site selection for water resource projects, groundwater assessment, and flood planning. watershed's morphometric study gives a detailed description of the drainage system, which is an important aspect of hydrological characterization. The analysis finds that both sub-basins are vulnerable to surface runoff and soil erosion, although the rivers are lengthy and simple to control when floods come. Quantitative assessment of morphometric parameters is critical for evaluating and selecting the basin for soil and water conservation.

Using morphometric analysis and LULC (land use/land cover) factors Puno & Puno(2019) prioritized Muleta watersheds in Mindanao, Southern Philippines. Watershed geomorphometric analysis is critical in any hydrological process involving the management and conservation of soil and water resources in the watershed. Adequate data on watershed hydrologic behavior is necessary because watersheds management must prioritize programs and activities for the conservation, development, and sustainability of all natural resources. Priority was allocated based on the estimated value of the specified geomorphometric feature with a direct/indirect impact on soil erodibility.

2.4. Morphological modeling process

In the recent past decades there is anticipatable scientific conformations that revealed remote sensing and geographic information systems (geospatial analysis model) is becoming effective methods for studying basin watershed morphometry (Benzougagh et al., 2022). In other words, a satellite-data (remotely sensing) has monumental blessings and applications for environmental monitoring and watershed management as a result of it can record information in period of time macroscopically, multi-temporally multi-spectrally, dynamically and repetitively (Husain & Kumar, 2021).Thus, geospatial data-driven watershed morphometric analysis and soil erosion evaluation and identifying sub-watersheds more affecting is very important. In this manner, watershed prioritizations were based on morphometric analysis using both linear and shape parameters(Prabhakar & Srinivas, 2016). Jothimani et al. (2020) calculated the various drainage geomorphic parameters of the Kulfo River basin's sub-watersheds using remotely sensed data from Advanced Space-Borne Thermal Emission and Reflection Digital Elevation Model (ASTER–

DEM),the author applied Arc GIS in connection with statistical correlation matrix-based weighted sum approach.

Some scholars have also utilized GIS and remote sensing data to analysis watershed prioritization based on morphometric parameters analysis from different satellite platforms (Husain & Kumar, 2021). Coupling of remote sensing data and GIS technologies has proven to be an effective tool for water resource development and management projects, as well as watershed characterization and prioritization (Farhan & Anaba, 2016). Similarly, according to Jhariya et al., (2018) a morphometric study of the basin conducted utilizing GIS geospatial techniques are shown to be pertinent for the extraction of river basins and their watershed. The Strahler categorization method was used to categorize the obtained drainage basin. The ability of geo processing techniques and remote sensing or DEM data to analyze and evaluate the fundamental, linear, areal, and relief aspects of morphometric parameters is illustrated.

Morphological analysis is an essential tool for examining the topography and hydrological condition of a watershed area. Morphological factors within a given predicted value immediately reflect a catchment's runoff generation and erosion risk. The watershed's erosive status directly reflects the decrease of land use and land cover in the watershed. Once the erosive state has been identified, the watershed can be repaired by minimizing erosion through watershed management methods (Rawat et al., 2017).

Natural resource availability, such as land and water, is declining as the world's population grows. As a result, managing and planning of these natural resources is critical. Detail information regarding morphology and other features is required for proper scientific planning and management of these resources. As a result, geomorphic properties of a watershed are often employed for constructing regional hydrological models to solve different hydrological challenges caused by insufficient data. GIS applications are far more efficient, time-saving, and suited for spatial planning. GIS can manipulate and extract massive databases and manage complicated challenges. With the development of computers, GIS became more automated, and the technology is now capable of not only processing enormous datasets, but also of solving many complex problems in addition to enabling data retrieval and searching. It should be noted that this study demonstrates the potential and usability of GIS technologies for prioritizing Sub-watersheds based on morphometric parameters. (Lukyanchuk et al., 2020)

In general, the use of geo-information techniques is the most significant tools for watershed creation, management, and prioritization of sub-watersheds for soil and water conservation. They have impressive outcomes as they provide quick, cost-effective, capability to analysis huge data from large areas , continuous assessment and monitoring capability of the technologies including watershed prioritization (Arefin et al., 2020). For the reasons stated above, the current study used remote sensing and GIS techniques to identify priority conservation sites for the morphometric analysis of parameters and soil erosion susceptibility parameters. As a result, this study was conducted to analyze the morphometric characteristics and soil erosion risk levels in DWs and give sub-watershed priority using a remote sensing data set.

2.4.1.The role of GIS and Remote Sensing in watershed prioritization

Remote sensing technology (data collecting on objects utilizing electromagnetic radiation from aircraft/satellites) addresses the needs for reliability and rapidity(Lukyanchuk et al., 2020). The GIS technology provides suitable alternatives for efficient management of large databases whereas the drainage characteristics of basins and sub-basins have been studied using conventional methods (Horton, 1955;Chorley, 1995). It offer precise information on the land use/cover (crop land, forest, wastelands, grasslands, etc.), soils up to the episode layer (gully erosion, rill erosion etc.), slope gradient ,drainage, geology, land cover of watersheds, which is highly valuable in prioritizing watersheds(Gumma et al., 2016).

In addition, geospatial data has served as a catalyst in watershed management planning and development as satellite imagery provides a quick and cost-effective tool to examine huge watersheds due to its broad and repeated coverage(Bajirao et al., 2019). Because of its inherent advantages, such as synoptic view (large area covered in single shot), repetitive coverage, multi-spectral nature, ability to study inaccessible areas, cost and time effectiveness, it has become a very powerful tool for surveying, monitoring, and management of natural resources at various levels(Pande, 2017). Geographic information systems (GIS) technology presents practical solutions for the effective management of huge databases, whereas conventional methods have been employed to explore the drainage characteristics of basins and sub-basins.

The amount and types of applications and analyses that a GIS may do in a watershed are as varied as the geographic datasets available. GIS is defined by its capacity to combine several layers of geographically oriented data. The amount and types of applications and analyses that a GIS may do in a watershed are as varied as the geographic datasets available. It allows for the digital integration of spatial (map) and non-spatial (tabular, etc.) data, is also particularly beneficial in watershed study and efficient tool for creating a digital database including a variety of thematic maps (such as land use/land cover, slope, rock varieties, landforms, and so on) as well as non-spatial data(Benzougagh et al., 2022).

Numerous scholars have undertaken morphometric analysis using remote sensing and GIS methodologies Kumar et al., (2021), the findings of their investigations revealed that remote sensing and geographic information systems are effective instruments for the study of basin morphometry. Additionally, the use of remote sensing data in conjunction with GIS technology has shown to be an effective tool for projects involving the management and development of water resources, as well as the classification and ranking of watersheds (Mangan et al., 2019).

2.5. Watershed Characteristics and their relation to soil erosion

2.5.1.Geomorphological characteristics.

Geomorphological analysis describes the topological characteristics of the drainage basin geometry in order to fully understand its slope, area-and other watershed attributes (Rawat et al., 2017) . Morphometric investigations were first conducted in the mid-twentieth century using a traditional approach based on manual topographic map analysis(Moid1 et al., 2019). In addition, this technique of watershed geophysical analysis could be very beneficial in drainage basin evaluation, flood inundation assessment, sustainable use of natural resources and conservation, and soil erosion protection (Tukura et al., 2021). Analyzing river morphometric using the traditional method is a time-consuming and labor-intensive process (Benzougagh et al., 2022). However, with the development of techniques like Remote Sensing (RS) and GIS, morphometric parameter analysis has been attracted much more attention in recent years (Chorley, 1995; Choudhari et al., 2018). Different applications of RS and GIS have been found in the fields including environment and agriculture sectors (Kawo & Karuppannan, 2018). Various tools for improved environment and ecosystem management were also offered by RS and GIS (Pal & Ziaul, 2016).

Several studies have used RS data and GIS technologies in watershed morphologic-characteristics evaluation to establish baseline information for watershed management strategies (Hussain et al., 2022). Watershed prioritization is a crucial phase in the process of managing watersheds in terms of value for money, project characteristics, and strategic development priority(Worku et al., 2020).

Watersheds can be prioritized based on a variety of parameters including yield loss, land use, land cover, morphometric characteristics, population and socioeconomic status (Prabhakar & Srinivas, 2016)

Morphometric analysis is critical for understanding the hydrological behavior of a watershed, which is necessary for natural resource development and management (Malik et al., 2019). Watershed morphometric analysis assists in understanding linear, areal, and relief parameters of watershed attributes (Sukristiyanti et al., 2018). In the past few decades, numerous scholars have been attempted watershed prioritization-driven from morphometric parameters analysis approach using geospatial analysis techniques (Rawat et al., 2017). According to the formula proposed by Horton, (1955) and Rai et al.(2017) classification morphometric parameters were grouped into three groups, namely, linear, areal and relief aspect The linear aspect of morphometric parameters such as stream order, stream number, stream length, mean stream length, stream length ratio, bifurcation ratio and mean bifurcation ratio have been adopted for this study. Beside this, areal aspect of morphometric parameters such as basin area, drainage density, stream frequency, form Factor, length of overland flow, basin shape, compactness coefficient, drainage texture, elongation ratio, and circulatory ratio was also used for the analysis purpose. Moreover, relief aspect category of morphometric parameters including basin relief, relief ratio, ruggedness number and channel gradient-was utilized for this the study area to prioritize the sub-watersheds more at risk of soil erosion.-for the delineated watershed area were calculated.

Further, Soil erodibility is directly related to morphological parameters of watershed like bifurcation ratio, drainage texture, drainage density, stream frequency, length of overland flow, relief ratio, and ruggedness number (Balasubramanian et al., 2017). In this regard, other soil erodibility parameters such as form factor, compactness coefficient, circulatory ratio, and elongation ratio, have an inverse relationship (Meshram & Sharma, 2017) with soil erosion susceptibility of a given watershed. Hence, detail analysis of aforementioned watershed morphometric parameters and soil erosion susceptibility of Dabus watershed have been prioritized.

2.6. Soil erosion and Watershed management practice in Ethiopia

Soil erosion is one of the main environmental problems that endangers human existence and impedes socioeconomic growth that is sustainable on a global scale(Gupta, 2019). In addition to depleting land resources, soil erosion also pollutes the environment, prevents water resources from being used and recycled, damages the ecosystem, and causes natural disasters (Kidane et al., 2019).

In Sub-Saharan Africa (SSA), soil deterioration brought by water erosion is a source for attention because around 75% of the population depends on subsistence agriculture for a survival (Nigussie et al., 2017). Ethiopia has one of the highest rates of soil erosion among the SSA nations (Gessesse et al., 2016). Similar to this, Nadew' et al., (2019) has been found that soil loss from water in Ethiopia's Upper Blue Nile River (UBNR) Basin poses a severe danger to the country's economy. According to Haregeweyn, et al (2017), soil erosion has caused financial losses because the majority of Ethiopians are dependent on agriculture and sustainability of downstream reservoirs, especially GERD, would be threatened by sedimentation if this erosion rate continues. Therefore, it is crucial to give priority to the watersheds when treating them with effective soil and water erosion control strategies. The areal parameters (Cr, Er, and Ff) are used to indicate the basin shape, which can be elongated or circular, and in conjunction with some linear (Dd, Dt, Br, Sf) and relief parameters (Br, Rr, Rn, Rr') show river flow discharge, subsoil permeability, infiltration rate, and groundwater resource potential of the sub watersheds. As a result, morphometric analysis using GIS is a competent tool for geo-hydrological studies for identifying and planning ground water potential zones and watershed management.

Watershed management is the process of planning and implementing measures in a watershed to ensure a variety of ecosystem services, including water for agricultural and domestic purposes, as well as the preservation of biodiversity (Dile et al., 2018). Watershed development and management programs have been part of government plans in developing nations, since 1970s and also Ethiopian watershed management had a similar historical viewpoint to that of other developing countries (Regasa, 2021) before that, indigenous, independent, and community-managed interventions contributed to watershed development and management(UNFCCC, 2021). In Ethiopia, since 1970 formally launched Watershed administration packages that generally focused on massive watersheds, often in Ethiopia's highland, which are severely degraded (Chimdesa, 2016) that purposed to put natural resource protection and development plans in place and became more regulated and improved for poverty reduction and environmental conservation (Bekele et al., 2018). By the late 1980s most of the adopted measures underperformed due to top–down approaches (low community involvement), a small selection of watershed practices (weak coordination), and large/unmanageable watersheds (Gebregergs et al., 2021).

Nevertheless, not all areas of Ethiopia have seen the same performance or level of effectiveness with regard to technology for conserving soil and water. In order to ensure sustainable watershed development, food security, and socioeconomic development, nationwide soil and water conservation campaigns have been recently promoted in Ethiopia (National Planning Commission, 2016). Almost every human activity has the potential to impact the quality and amount of water in our rivers and streams. Watershed management aids in the reduction of soil degradation, reservoir deposition, severe floods, loss of open space, and the enhancement of water quality. Soil conservation is a collection of suitable land use and management methods that increase soil fertility and long-term employment while minimizing soil erosion and other forms of land deterioration. Watershed management can be achieved with soil and water conservation strategies. Even though resource scarcity is a well-known problem in Ethiopia, the study pinpoints erosion sensitive areas to lower soil erosion rates. Additionally, they provide the information needed for the government, authorities, agencies in charge of safeguarding natural resources, developers, and other parties involved to provide severely degraded areas attention.

CHAPTER THREE

METHODS AND MATERIALS

3.1. Description of the study area

3.1.1. Geographical location

UBNB is one of the largest river basin in terms of discharge volume and second largest in terms of area which is contributing more than half of the main Nile's long-term River flow. It originates from Lake Tana and discharges to Sudanese border between 7º40´ N to 12º 00´N, and 34º25´0 E to 39º49´0 E with elevation ranging from 483 to 4248 m a.s.l. It covers a total area of 199,812 km^2 and comprises 16% of the area of Ethiopia and with has mean annual discharge of 48.5 cubic kilometers 1912-1997; 1536m3/s. The basin drains a large portion of the central and southwestern Ethiopian Highlands. The Blue Nile River and its tributaries have severely dissected the Ethiopian Plateau, with a typical slope to the northwest. The Didessa and Dabus tributaries, which discharge to the basin's southwestern, produce around one-third of total flow.

The Abbay Basin (also known as the Upper Blue Nile) in Ethiopia includes a variety of sub basins one of which, Dabus chosen for this study because it discharges Blue Nile's high water flow and sediment output. It is a north-flowing tributary of the Blue Nile river in southwestern Ethiopia; located at range of latitude of 9º00’00’’ to 10º45’00’’N, and longitude of 34º30’00’’ to 35º40’00’’E and it joins its parent stream at 10º36’38’’N and 35º08’58’’E. The study location is directly west of Addis Abeba, on the major road connecting Addis-Nekemte –Asosa. It covers a surface area of 14793.81 km^2

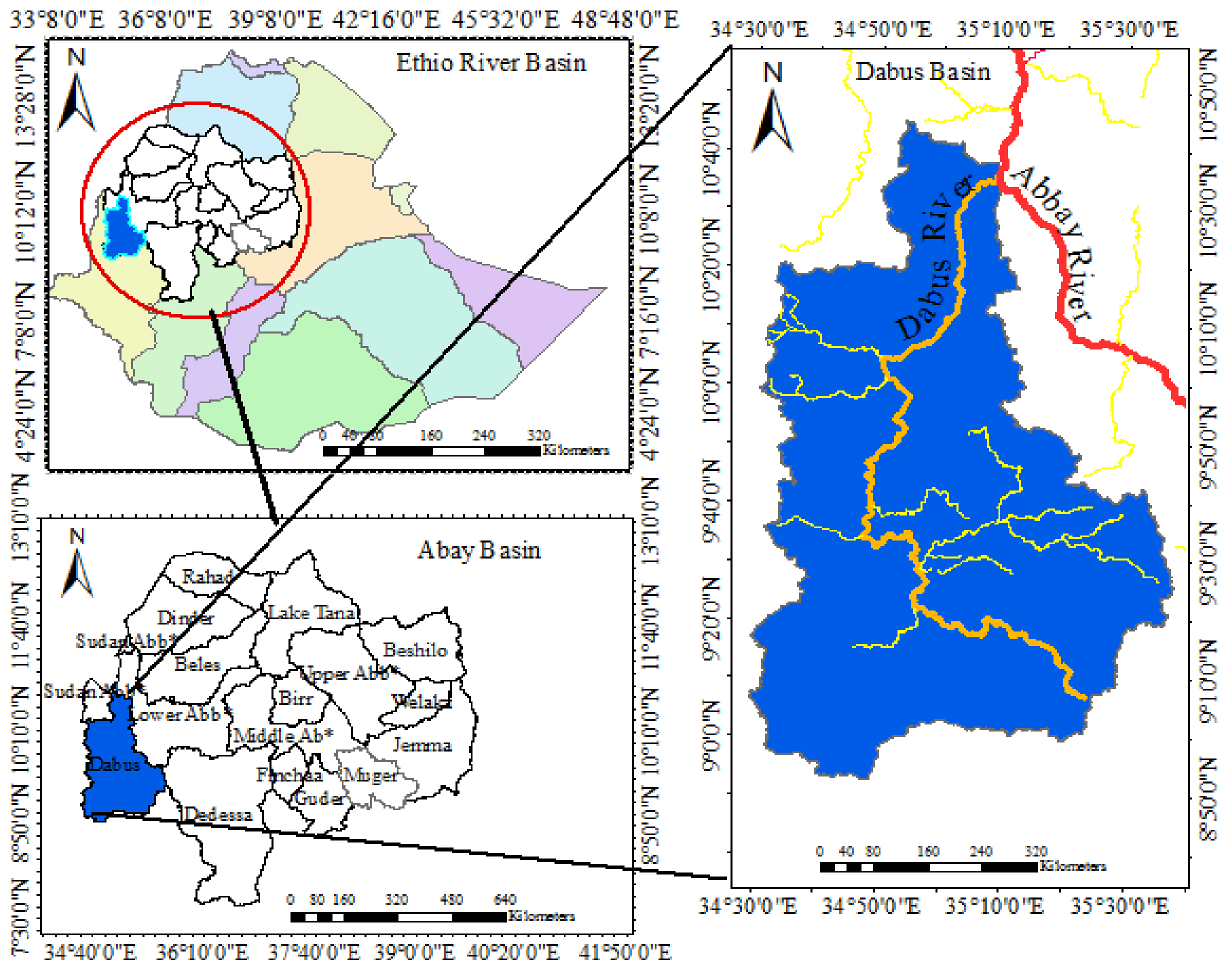

Figure 3. 1 Location map of Study area or Dabus sub basin

Dabus sub basin covers 19 woredas of Our countries shown in Figure3.2 below: Asosa Region (Bambasi, Asosa, Kemosha, Menge, Oda Godere, Sherkole, Sirba Abaya), Oromia Region (Gidami, Jima Horo, Begi, Gawo Dale, Dale Sadi, Mana Sibu, Ayira Guliso, Yubdo, Najo, Boji, Jarso, Agelo Meti).

3.1.2.Topography

The study area is part of Ethiopia's moist subtropical agro ecological zone. Dabus sub-basin is between 556 and 3123 m.a.s.l. The high land in the eastern part of the sub-basin are higher in altitude, greater than 1,500 m.a.s.l up to 3,120 m.a.s.l. The lowland in the northern parts of the sub-basin have lower in altitude less than 900 m.a.s.l. The sub-basin flows for most of its length northwards. Most of the tributaries that feed the sub-basin is originated from central and south western parts of wollega. The topography of the watershed is mountainous steep slope areas with high surface runoff. Some of the watershed topographic factors that have been determined to effect sediment output include catchment size, relief, and drainage density. The morphometric analysis and annual soil loss estimation, which are sub-watersheds of the Dabus sub-basin, have a diverse landscape with a diversity of land characteristics.

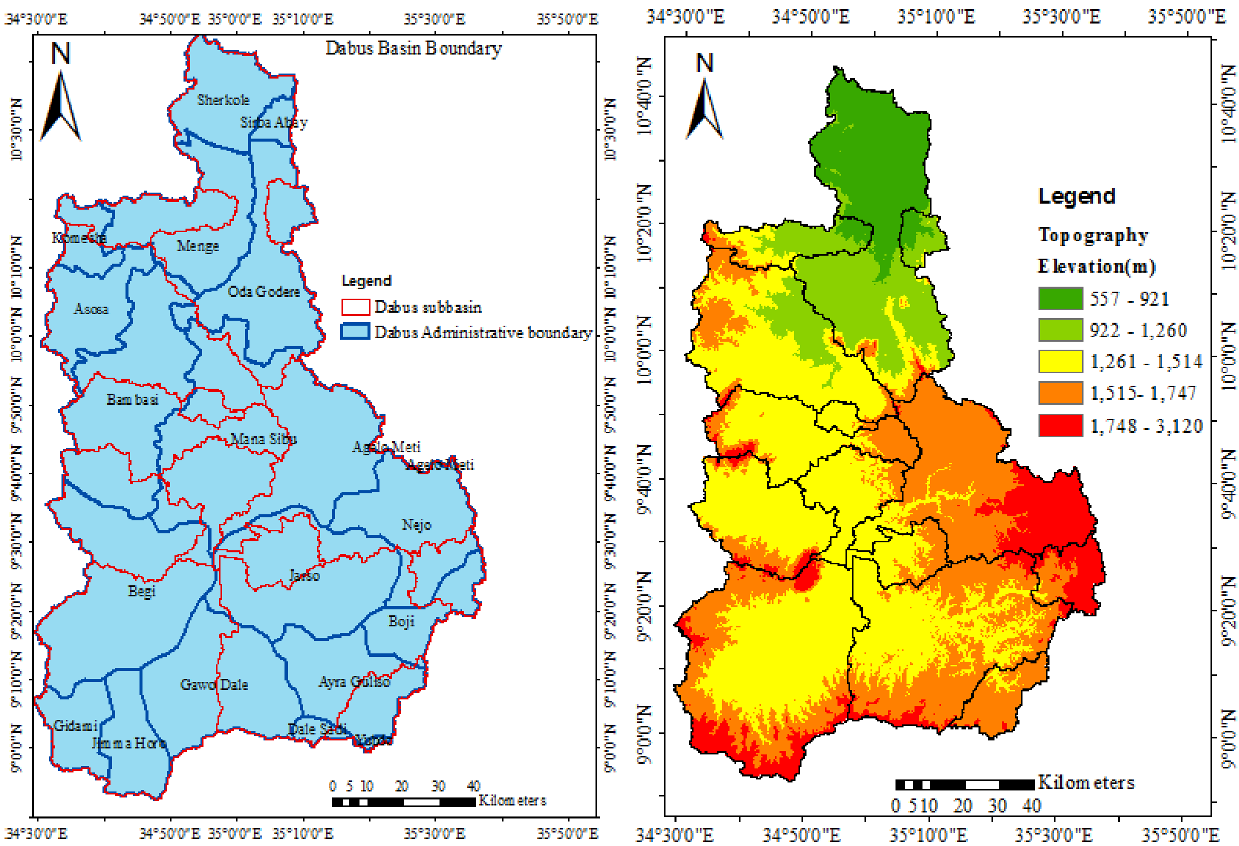

Figure 3. 2 Administrative Structure and Topography of Dws

3.1.3.Temperature and rain fall

Despite its proximity to the equator, Dabus sub-basin climate ranges from cold to moderately hot in the highlands and lowlands. Mean annual temperature varies from 14 ºC -26ºC. The sub basin has an annual rainfall ranging between 1166 mm and 1884 mm. The sub basin's rain fall trend is monomial, with wet seasonal duration decreasing as we move north and north-west. The rainy season in the subbasin's southwest extends from April or May to October or November (Asrat and simane., 2017). Lower annual rainfall between 941 mm and 1043 mm in the lowlands and along the river, and higher rainfall greater than 1044 mm in other parts of the basin is observed(Nadew' et al., 2019).

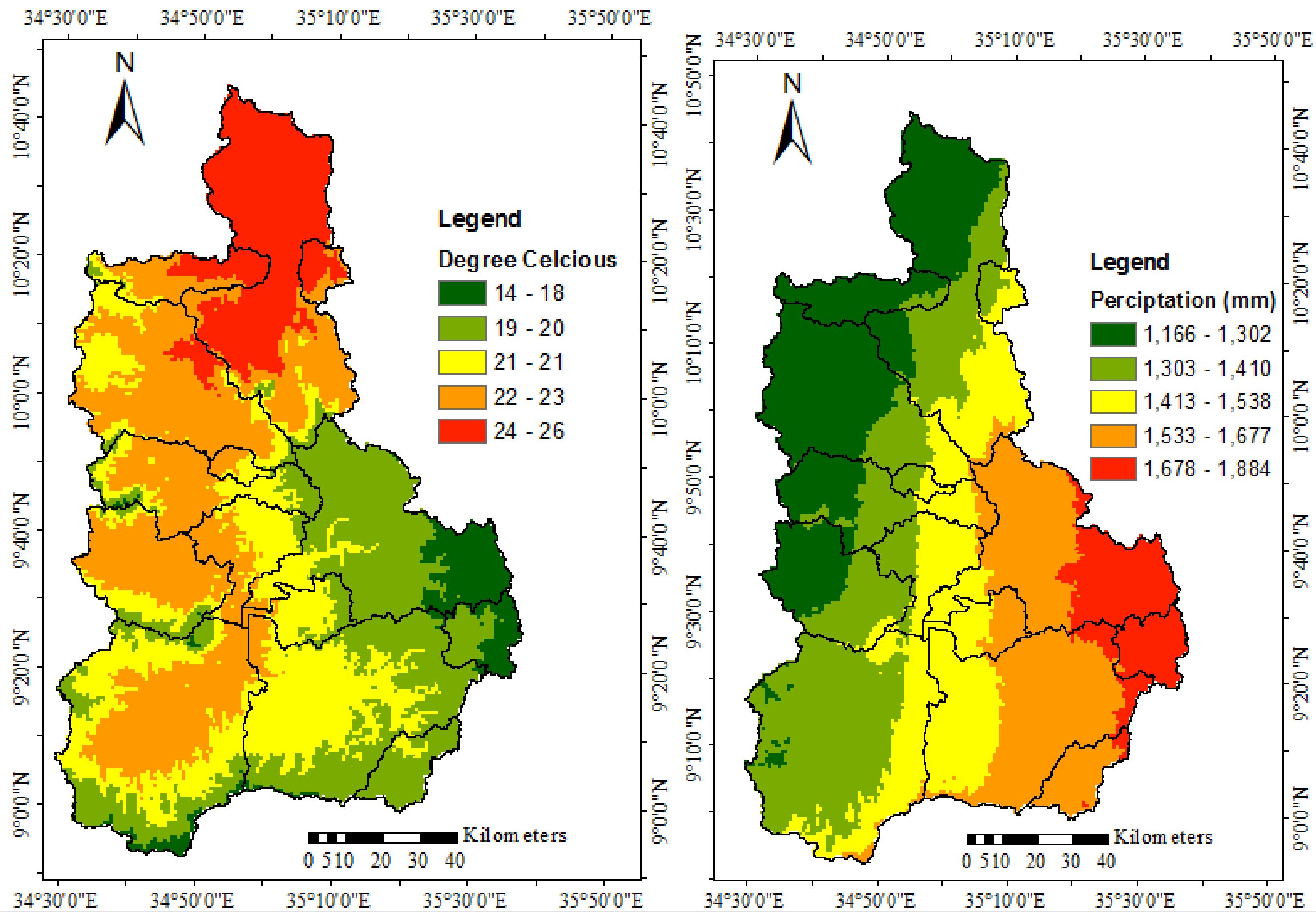

Figure 3. 3 Mean annual temperature and Rainfall Distribution in DWs

3.1.4.Geology and soil

The study area is one of Ethiopia's most sensitive lowland agro-ecologies to climate variability and change. Basalt and granodiorites and diorites dominate the sub basin's geology, with presence of Granite, marble, and alluvium deposits. The soils of the Dabus sub-basin are highly diverse, reflecting variations in landscape and other soil-forming elements like climate and vegetation. The sub-primary basin's soils are Chromic Cambisols with presence of Chromic Luvisols, Chromic Vertisols Dystric Gleysols, Dystric Nitisols, Eutric Cambisols, Eutric Fluvisols, Eutric Nitisols, Eutric Regosols, Leptosols, Orthic acrisols, Orthic Luvisols, Pellic Vertisols and Phaeozems. Cambisols are soils with a high base saturation Soil data were obtained from the FAO world soil map using the Arc GIS Map window. The soil data utilized in this study contains a global map of soil that has been restricted to the Dabus sub-basin. These soils appear to have a variety of productivity-limiting properties, including acidity, depth, and permeability (Duguma, 2022)..

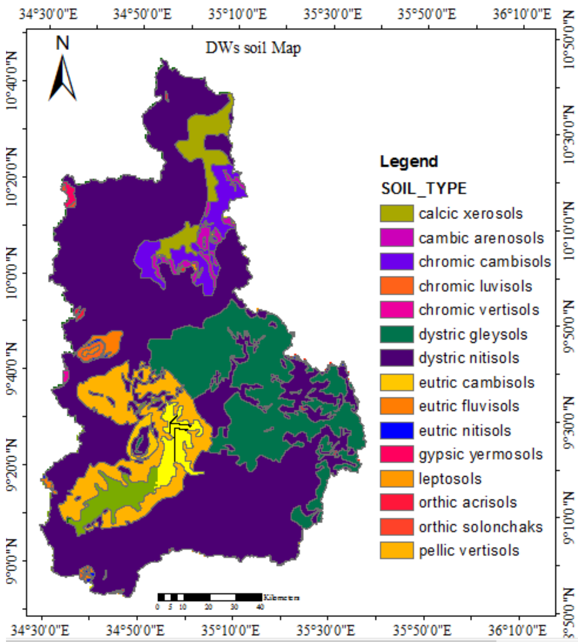

Figure 3. 4 Major soil type in DWs

3.1.5. Land use land cover

The principal land uses in this watershed are Wooded grass land and intensively cultivated lands in a variety of forms, including perennial swamp, ramped grassland, distributed high forest, cultivated land with dispersed trees and bushes, and seasonally cultivated fields. ArcGIS was used to categorize the land use classification in the study area.

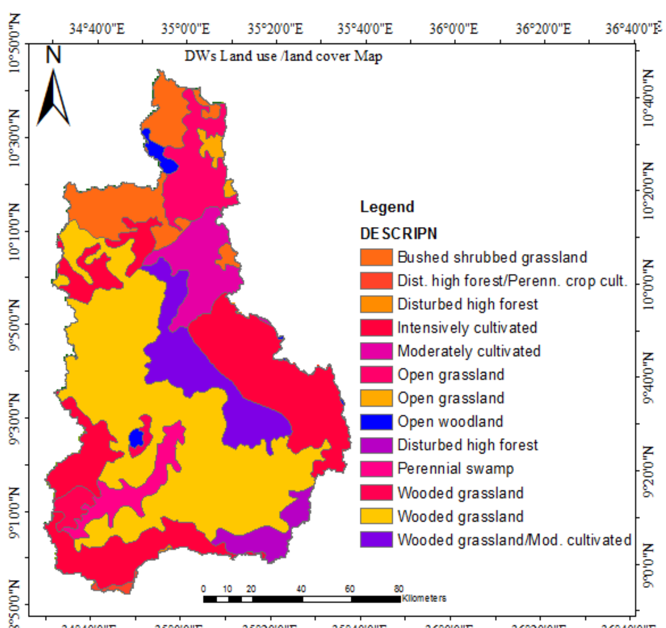

Figure 3. 5 DWs major land use

Sub-humid tropical woodlands have been reduced to ruins as a result of conversion to farming and grazing.

3.2. Data source and types

The primary focus of this study was to identify and prioritize sections of the watershed that were prone to erosion by morphometric analysis of the Dabus-sub-basins. For this study, the Digital Elevation Model (DEM) data with spatial resolution 12.5mx12.5m and Topographic map of the study area was obtained from Ethiopian Basin development authority(EBDA). Using topographic maps, the Basin area, boundaries of the sub-watersheds, and drainage system/pattern of the study area were all identified. Both topographic maps and DEM has been used to delineate the boundary of Dabus watershed. The DEM data were used to determine the stream network and delineate the Sub-watershed along the watershed border. Delineation was regarded as constructing a boundary that indicates the relevant region for a certain control point or outlet that was used to identify the boundaries of the study area and/or to split the study area into sub-areas. Watershed delineation is a feature of feature extraction, which is the act of separating a watershed into discrete land and channel segments in order to assess watershed characteristics. Several geo-processing methods, including Fill, Flow Direction, and Flow Accumulation, were used in a GIS context to define watersheds.

Using GIS software and a mathematical technique established by Miller,(1953) ,Horton, (1955), Schumm(1956), Strahler, (1957) all geomorphometric parameters were acquired and computed from fundamental geomorphometric parameters and DEM data. The number and lengths of streams of each distinct order, the drainage area, the perimeter and length of the entire basin, and the elevation were all extracted characteristics from the DEM and computed using the ARCGIS 10.7.1 software. These calculations were then confirmed using Microsoft Excel sheets.

GIS technology has been employed as an analytical tool. With regard to soil erosion analysis and erosion risk assessment, GIS technology has significant potential for application as an aid to the soil erosion inventory. GIS may be used to scale up to regional levels and quantify the variations in soil loss estimates provided by different scales of soil mapping employed in the model as a data layer. Using GIS databases, more up-to-date information may be retrieved, or previously inaccessible information can be calculated, and complicated analysis can be done. It is still largely used to create maps, although it is capable of much more. This knowledge can help you have a better understanding of a location, make better decisions, or prepare for future events and situations. The main reason for employing a GIS is because the erosion process varies regionally, hence cell sizes that allow for spatial variation should be employed. Although manually entering data is impractical, GIS may be used to acquire and retrieve databases.

3.3. Data analysis

3.3.1. Software, tools, and procedures

The use of Advanced space-borne thermal emission and reflection digital elevation model (ASTER DEM) and topo-sheets paired with GIS technologies help the geomorphometric studies, mini-watershed classification, and drainage network identification (Farhan & Anaba, 2016). In this study, Arc-GIS were utilized to extract, digitize, and estimate attribute and spatial databases in the drainage analysis. GIS has evolved as a strong tool for managing geographical and non-spatial geo-referenced data for input and output preparation and display, as well as integration with models. In regards to soil erosion modeling and erosion risk assessment, GIS software has significant potential for application as an aid to the soil erosion inventory. For the morphometric analysis of watershed characteristics of the DWs, RS data and GIS applications were combined. The combined use of remote sensing and GIS might aid in quantifying rate of soil erosion at different levels and in identifying regions that may be at danger of erosion. Further, the preprocessed DEM were used for the extraction and quantification of morphometric parameters. For more effective planning and management, studies utilizing high resolution elevation data were encouraged in order to better understand the properties of the DRCs drainage basins.

GIS and RS were used in the morphometric study. For the creation and assessment of morphometric parameters, data and procedures are essential (Shreedhara et al., 2020). The quantitative approach developed by various researchers were deployed to compute the soil erosion susceptibility for the study area and soil erosion vulnerability has been generated using Arc GIS environment. Thus, the sub-watersheds have been ranked by giving the greatest value to the linear and relief characteristics and the lowest value to the shape parameters as the basis for the ranking. Morphometric analysis of linear, areal and relief parameters were employed for prioritization of the sub-watersheds, and a priority map were produced based on each parameter.

Using GIS databases, more up-to-date information may be retrieved, or previously inaccessible information can be estimated, and complicated analysis was conducted. This knowledge may lead to a greater understanding of a location, assist in making the best decisions, or anticipate future occurrences and situations. Most commonly, this tool can quickly analyze geographic information such as: mapping where items are, mapping maximum and lowest values, mapping density, mapping change (overlay analysis), and so on. The key rationale for employing a GIS is because the erosion process varies spatially, hence cell sizes that allow for spatial variation should be employed. Ground measurement data from multiple watershed sample sites, as well as important reports from the research region, were also employed as supplementary sources of information for the GIS analysis.

3.3.2. Watersheds morphometric parameters extraction

Fundamental, linear, areal and relief aspects of watersheds are included in morphometric parameters, which are referred to as indicators of soil erodibility and recognized as an indication for soil erosion risk evaluation(Kumar et al., 2021). The morphometric analysis was run using those geometrical characteristics as input. The Fundamental parameters that was used to define the geometrical parameters (Elevation, area, perimeter, length, and number of streams) were digitally acquired using GIS software for each sub watersheds separately. These Fundamental characteristics were utilized as input for morphometric analysis.

For this investigation, the most essential quantitative morphometric characteristics used were classified under fundamental, linear, relief and areal parameters. They have a direct or inverse link with runoff, peak discharge, and soil erosion risk due to their direct or inverse interaction with these factors(Meshram & Sharma, 2017; Obeidat et al., 2021). Based on computed fundamental parameters using DEM and ARC GIS 10.7.1 software, the derived parameters were determined using mathematical formulae and methodologies that have been already devised by different scholars. Visual interpretation techniques were used to delineate geology, landforms, soil borders, and degraded areas depending on the tone, texture, shape, drainage pattern, color, and differential erosion properties of satellite data in conjunction with drainage morphometry.

For this study, the morphometric parameters of DRWs analysis and soil erosion prone-area prioritization was estimated using, Fundamental, linear, areal and relief aspects of the watershed. These parameters had been collected from Miller(1953), Horton, (1955), Schumm(1956) and are selected based on data availability, the details of the Morphometric parameters and data requirements are summarized in Table 3.1 below (Strahler, 1957; Debelo & Tadele, 2017; Gudu Tufa, 2018; Mohammed et al., 2018a; Mangan et al., 2019; Jothimani et al., 2020; Tukura et al., 2021; Vanlalchhuanga et al., 2021 Benzougagh et al., 2022).

Table 3.1 Watershed morphometric attributes of study

No	Morphometric parameters		Formulas
1	Fundamental	Basin area(A)	Arc GIS
2		Basin perimeter(p)	Arc GIS
3		Stream length(Ls)	Arc GIS (Horton, 1955; Waiyasusri & Chotpantarat, 2020)
4		Number of stream(Ns)	Hierarchical rank
5		Elevation	Arc GIS
6		Stream order(So)	Hierarchical order(Strahler, 1957)
7	Linear	Length of overland flow(Lf)	$\frac{1}{2*Dd}$ (Horton, 1955; Choudhari et al., 2018b)
8		Mean stream length(Lm)	$\frac{Ls}{Ns}$ (Horton, 1955; Mangan et al., 2019)
9		Stream length ratio(Lsr)	$\frac{Ls}{L(s-1)}$ (Horton,1955;Strahler, 1957)
10		Bifurcation Ratio(Br)	$\frac{Ns}{N(s+1)}$ (Horton, 1955; Tukura et al., 2021)
11		Drainage density(Dd)	$\frac{Ls}{A}$ (Horton, 1955; Obeidat et al., 2021)
12		Drainage texture(Dt)	$\frac{\sum(Ns)}{P}$ (Horton, 1955; Setiawan & Nandini, 2021)
13		Stream frequency(Sf)	$\frac{\sum Ns}{A}$ (Strahler, 1957; Debelo & Tadele, 2017)
14	Areal	Basin length(Lb)	$1.312XA^{0.568}$ (Schumm , 1956; Gudu Tufa, 2018)
15		Form factor(Ff)	$\frac{A}{lb^2}$ (Horton, 1955; Tukura et al., 2021)
16		Elongation ratio(Er)	$\frac{2X\sqrt{A}}{Lbx\sqrt{\pi}}$ (Schumm & A., 1956; Sinshaw et al., 2021)
17		Circulatory ratio(Cr)	$\frac{2x\pi}{P^2}$ (Miller, 1953; Singh et al., 2021)
18	Relief	Basin relief(Rb)	$E_{max} - E_{min}$ (Strahler, 1957; Abdeta et al., 2020)
19		Relief ratio(Rr)	$\frac{Rb}{Lb}$ (Schumm , 1956; Shreedhara et al., 2020)
20		Ruggedness number(Rn)	$RbxDd$ (Schumm , 1956 ; Balasubramanian et al., 2017)
21		Relative relief(Rr”)	$\frac{Rb}{P}$ (Schumm, 1956; Moid1 et al., 2019)

3.3.3. Priority Map Generation and compound values(Cp)

At the watershed level, numerous morphometric parameters in a GIS system were used to efficiently prioritize watersheds, for soil and water conservation (Mohammed et al., 2018a). The soil erosion susceptibility for the study area was computed using the quantitative approach devised by various researchers (Miller, 1953; Horton, 1955;Chorley, 1995), and had been constructed using Arc GIS 10.7.1. A multiple spatial overlay analysis were used to produce a soil erosion susceptibility map (Farhan & Anaba, 2016). This analysis was carried out using the ESRI ArcGIS 10.7.1 software, the "Spatial Analyst" analysis module, and the Raster Calculator function, which allows the incorporation of mathematical equations into Arc GIS. The Raster Calculator feature in the spatial analysis module "Spatial Analyst" allows mathematic equations to be integrated into a GIS environment. Prioritizing a sub-watershed entails ranking various sub-catchments in accordance with the order in which they should be treated with conservation technologies by taking the quantity of soil loss into consideration(Singh et al., 2021).

To evaluate the combined effect of morphometric parameters on the hydrological behavior at the sub-watershed scale, a comparative ranking approach was adopted. In order to determine the sub-watershed features vulnerability to soil erosion, Compound values (Cp) were assigned to them. Priorities are established using morphometric variables that gauge how vulnerable the sub-watershed is to erosion. All of the sub-watersheds were then given ranks based on the Cp. Sub-watersheds were ranked based morphological characteristics, which were evaluated in accordance with Drainage density(Dd) Bifurcation ratio(Br), length of overland flow(Lolf), Drainage texture(Dt), stream frequency(Sf), Circularity ratio(Cr), Elongation ratio(Er), Basin relief(Br), Relative relief(Rr’), Relief ratio(Rr) and Ruggedness number(Rn). The ranks given to parameters with identical values were consistent. Following the ranking of all morphometric variables in all of the sub-watersheds, it was determined that each watershed's values had gained a compound value(Cp). The true effect of all the factors on watersheds to soil erosion was then determined by averaging the ranks of all values. In order to make judgments on where to execute conservation initiatives and programs with limited funds within the sub watersheds, this study measure geomorphometric factors in relation to the watershed's sensitivity to erosion danger.

According to the overall average of these characteristics, the sub-watersheds with the lowest rating value received the most priority, followed by those with the following highest value and so on. For parameters with the same values, equivalent rankings were assigned. The estimated compound parameters of each sub-watershed are shown in increasing order, from the lowest value to the greatest value. These derived compound parameters may be divided into four groups as follows: Very high (VH), High(H, medium (M) and low(L) (Vanlalchhuanga et al., 2021).

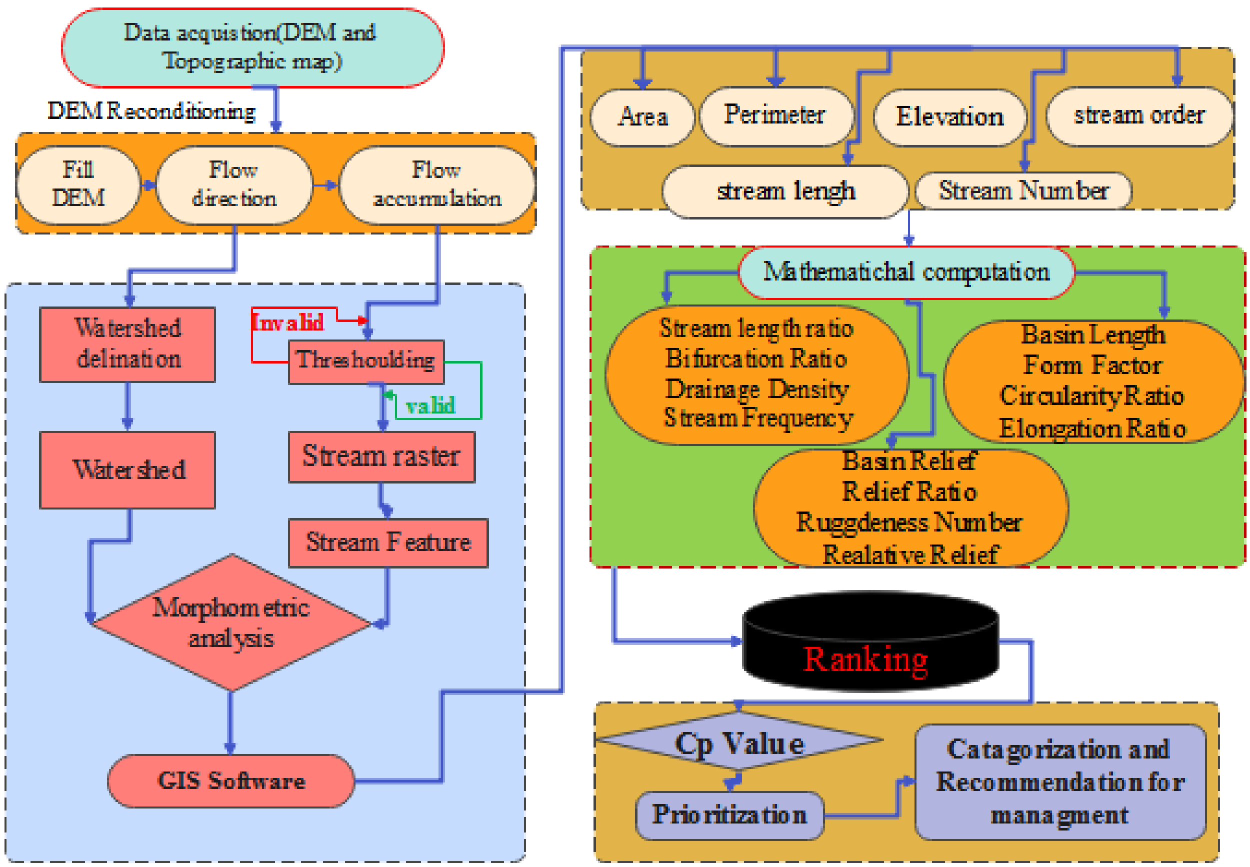

Figure 3. 6 Conceptual work flow frame of the study area

After assigning ranking based on every single parameter, rated values for each watershed were averaged to arrive at a composite value. Based on the average value of these parameters, the sub watershed having the least value of composite rating is assigned the highest priority denoted by 1; the sub watershed with next highest value of composite rating is assigned a priority denoted by number 2, and so on. The sub watershed that got the highest value of composite number is assigned the last priority number. Lastly, the final priority classifications were given into three major classes i.e. Very high, High priority, Medium priority and Low priority. The high priority of the sub watersheds indicates most vulnerable areas to soil erosion that needs to give great attention for reclamation process and action plan for soil conservation.

The highest priority number is given to the sub watersheds with the greatest compound number value. For soil degradation, a lower value of the compound parameter was most likely possible. This signifies that the least value is given the highest priority based on compound value. Similarly, the next higher value is allocated to the following priority, and so on. For hydrological model analysis determining the behavior of where the water comes from and where it is going is important for morphometric characterization through watersheds delineation. Delineation explained as creating a boundary that represents the contributing area for a particular control point or outlet that is used to define boundaries of the study area, and/or to divide the study area into sub-areas. Watershed delineation is part of the process known as watershed segmentation, i.e., dividing the watershed into discrete land and channel segments to analyze watershed behavior. It is required for basin modeling and watershed characterization report. Because the final priority indicates a lower degree of erosion, suitable conservation measures for the long-term sustainability of soil and water resources are not strongly recommended (Balasubramanian et al., 2017). Lastly, the classification of findings produced the priority map of sub watersheds soil erosion vulnerability.

CHAPTER FOUR
RESULT AND DISCUSSION

4.1. Morphometric Parameters Quantitative Analysis

The quantitative morphometric analysis provides information on the hydrological properties of the watershed and explains the features of the basin. Morphometric parameters are used to prioritize more vulnerable sub-watersheds because they have a direct or indirect association with soil erosion risk. According to Puno & Puno (2019), morphometric parameters such as linear aspects (Bifurcation ratio, length of overland flow, drainage density, drainage texture, and stream frequency) and relief aspects (Basin relief, Relief Ratio, Ruggedness number and Relative relief) have direct effects on soil erosion. In other words, the higher the value of these parameters of sub-watersheds were ranked first. In contrast, the areal parameters (Form factor, elongation ratio, and circularity ratio) have the reverse effect (Mohammed et al., 2018b). As a result, the parameter with the lowest value was assigned the greatest rank (1) and vice versa.

The GIS window was used to examine hydrological, topographical, and geological processes using data from the earth observation system (E.0.S). Furthermore, the geological, topographical, and hydrological processes of the basin have been examined using metric parameters generated from the basin described in table (3.1). As a result, to analyze the features and properties of the drainage networks, morphometric analysis was performed for 14 sub-watersheds of the Dabus watershed as shown in Figure (4.1) below. This provides a detailed description of the links between various land surface processes and diverse components of the land system such as geomorphology, hydrology, and geology (Maniragaba, et al., 2021). To evaluate and quantify the erosive potential in all Dabus River basin sub-watersheds, 17 geomorphic characteristics comprise linear, areal, and Relief analyzed accurately and precisely by merging quantitative and spatial techniques with the assistance of GIS software to increase the study's reliability. The descriptions of the basin features are provided in the following computations and evaluations.

Following the methods used in recent past studies (Setiawan & Nandini, 2021; Vanlalchhuanga et al., 2021), the specifics of the complete ranking process of sub watersheds based on morphometric parameters were carried out. The drainage networks in the Dabus river basin transport water and sediments from the basin through Dabus River, which is recognized as the maximum order of the basin. Dabus river basin is a 5^{th} order basin with a total area of 14793.81

km^2 and a perimeter of 1002.61 km. The total number of stream is 1611, where 1st, 2nd. 3rd, 4th and 5th accounts 50.9%, 25.7%, 14.9%, 6.83% and 1.68% respectively.

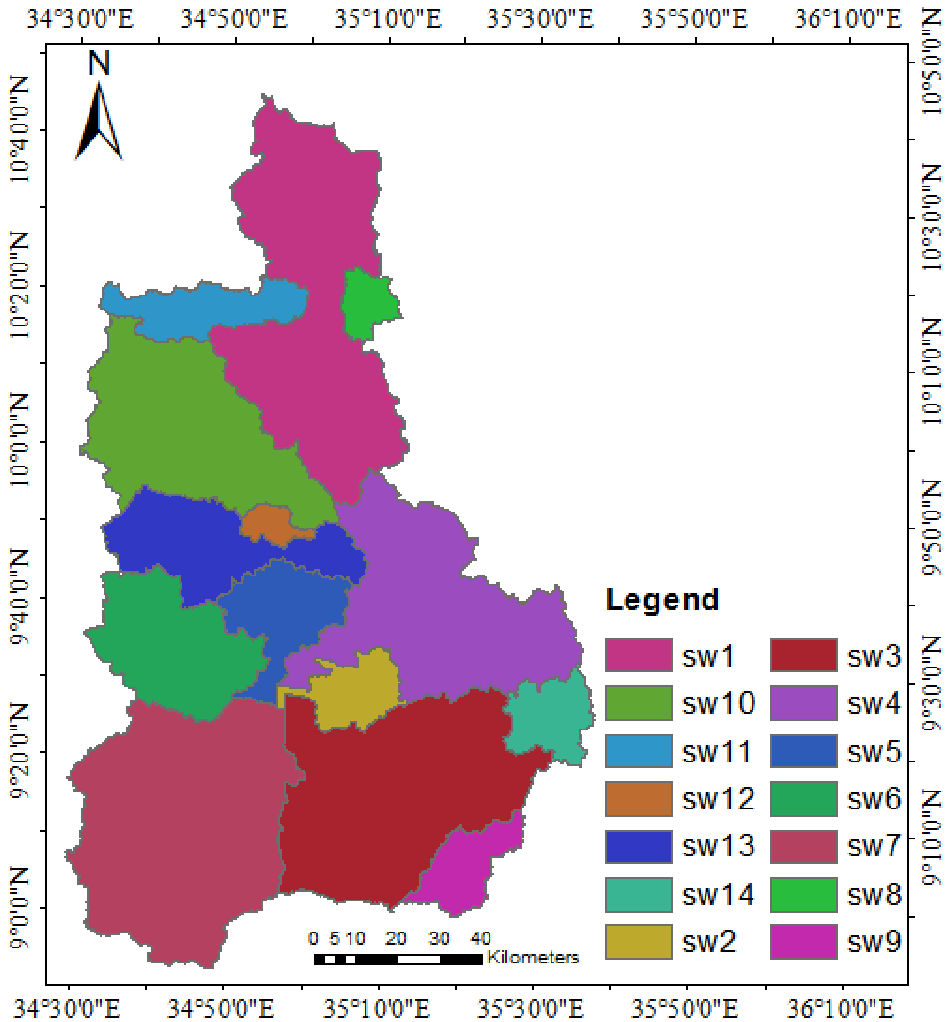

Figure 4 1 Sub watersheds classification of DWs

4.2. Fundamental parameters

4.2.1.Basin area(A), Perimeter(P) and elevation (E)

The basin area is a crucial hydrological component as it determines the amount of water that might be produced by rainfall. It has a significant effect on the size of the storm hydrograph, as the perimeter also determine the size and shape of the sub basin. The total watershed area and perimeter of Dabus watershed is 14793.81 km^{2}and 1002.61 km respectively, that of sub watershed is shown in Figure 4.2 below. This model shows elevation ranges from 513 m to 3165m.a.s.l. and

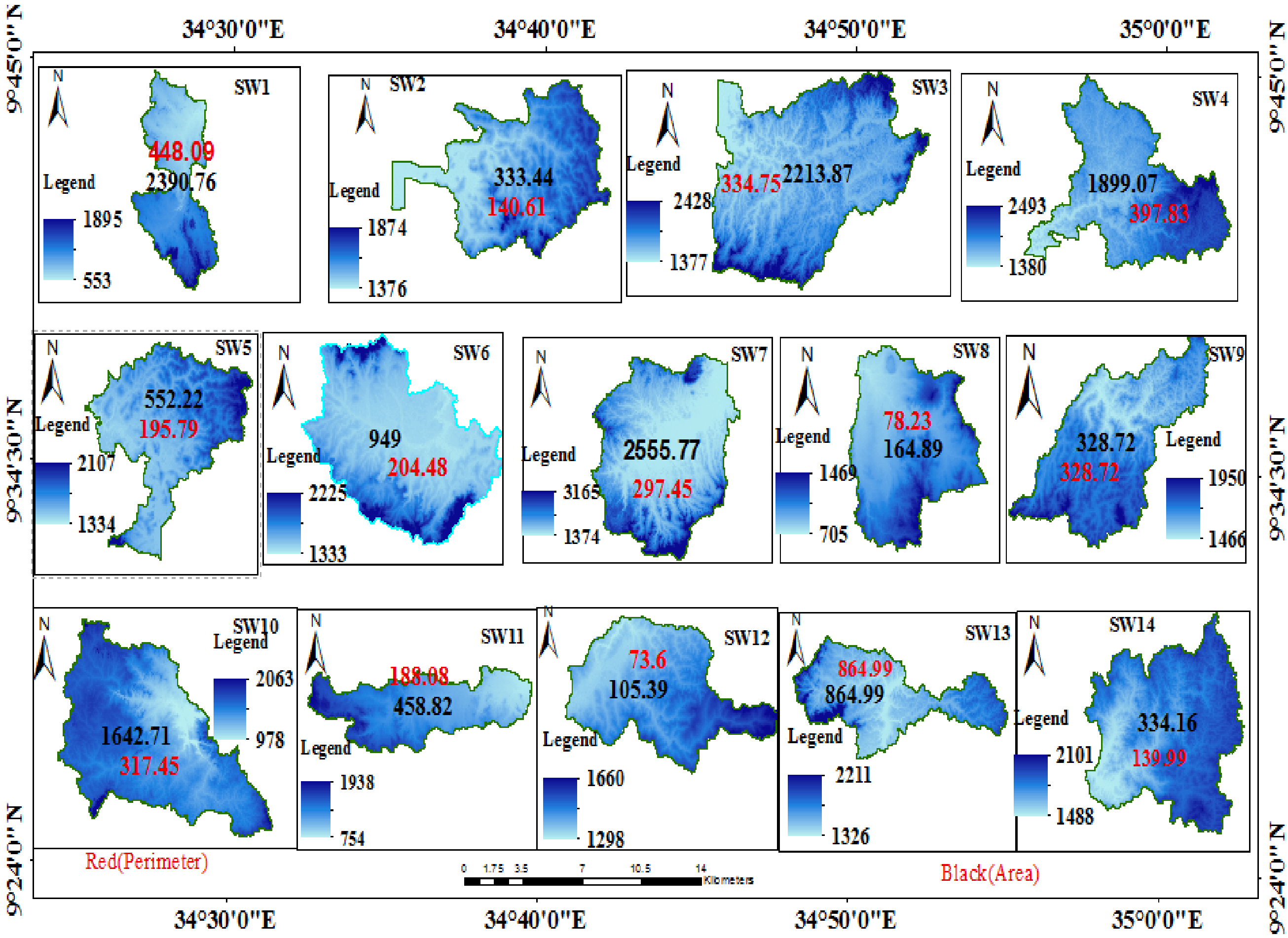

Figure 4 2 Dabus basins delineated sub basin

4.2.2.Stream order (S_o)

The preliminary work of the drainage basin's morphometric assessment is begun by exhibiting stream orders. In order to illustrate drainage pattern, a variety of parameters have been created. To explore the areas of drainage system, we follow the stream order by Strahler (1964) approach. Stream order by Strahler (1964) method is used to analyze the drainage pattern of the area. According to Strahler, the shortest, unbranched fingertip streams are referred to as first order, and when two first order channels converge, they produce a second order channel segment. The higher order is conserved when two channels of different orders connect. In the present study, SW4, SW7 and SW10 are 5th order, SW1, SW3, SW5, SW6, SW9, SW11 and SW13 are 4th order, SW2, SW8, SW11, SW12 and SW14 are 3rd order. Figure (4.3) below illustrates the basin as a 5th order basin, with the river Dabus at the top of the hierarchy and first order mostly dominating in number.

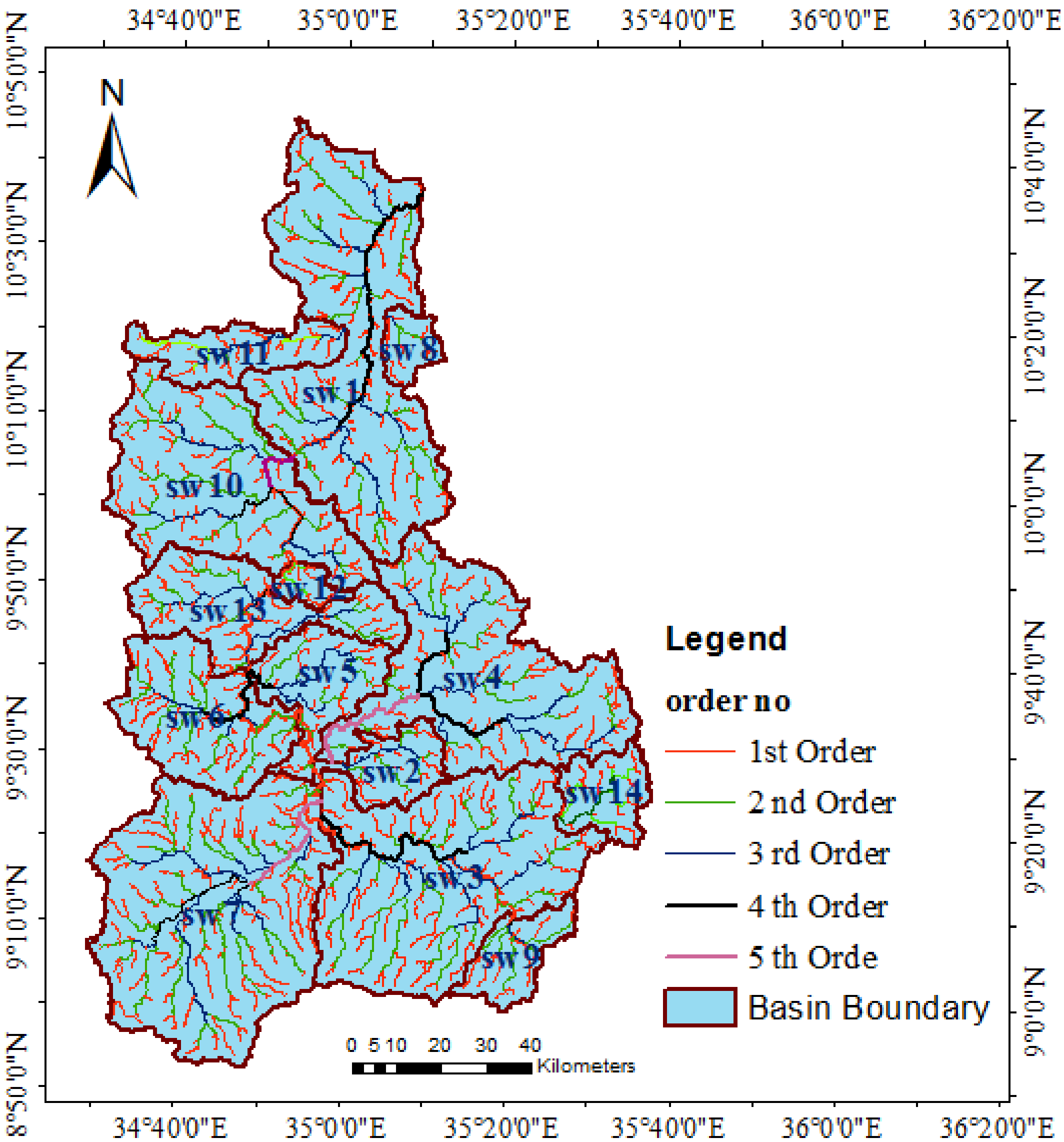

Figure 4 3 DWs stream order map

4.2.3.Stream Number(S_n)

Stream number is the total number of streams in each order within a watershed. It has an inverse relation to the stream order. In comparison to watersheds with low stream numbers, high stream number watersheds have more runoff and faster peak (Bhat et al., 2019). In this study, for each sub-watershed of the Dabus watershed, the table below displays the total number of streams in all orders. The observation shows that DRCs has up to 5th order tributaries. Where 1st, 2nd, 3rd, 4th and 5th stream has 820, 414, 240, 110 and 27respectively in numbers and total number of stream is 1611 as shown table below. The maximum and minimum number of the stream number were 255 and 11 for SW1 and SW12 respectively.

4.2.4.Stream length(S_L)

Stream length is the length of streams of different orders and indicates the contributing area of a watershed of a certain order (Obeidat et al., 2021). It is a good indicator of the topography of the land surface. Longer streams are often suggestive of mild slopes, whereas comparatively short streams reflect places with finer texture and steep slopes(A. Strahler, 1957). The length of a stream from its entry to its drainage boundary was computed Using Arc GIS software. In order to get the overall stream length of the watershed, this distance was determined for each stream order within the watershed and added together. The Table (4.1) shows the stream lengths of the Dabus watershed in order.

Table 4 1 Order wise stream number and stream length of the study area

Sub	**Stream order Vs (stream Number and length)**											
	I		II		III		IV		V		**Total**	
watershed	Sn	Sl	Sn	Sl	Sn	Sl	Sn	Sl	Sn	Sl	Sn	Sl
sw1	145	407.17	73	236.97	36	110.91	34	71.17	0		288	826.22
sw2	19	63.74	10	32.92	8	23.09	0		0		37	119.75
sw3	121	444.49	58	218.16	37	120.31	20	51	0		236	833.96
sw4	98	315.35	41	144.19	30	111.07	16	47.58	9	36.95	194	655.14
sw5	29	88.25	13	52.71	8	46.82	4	8.38	0		54	196.16
sw6	57	202.04	30	128.08	15	23.7	11	24.3	0		113	378.12
sw7	132	525.81	77	314.21	29	132.81	11	39.58	12	35.48	261	1047.89
sw8	9	41.69	4	15.37	4	3.72	0		0		17	60.78
sw9	17	65	11	52	3	6	1	1	0		32	124.00
sw10	93	250.12	48	172.72	29	76.25	9	33.1	6	13.94	185	546.13
sw11	30	94.94	14	41.13	14	31.72	0		0		58	167.79
sw12	6	25.21	4	15.35	1	0.15	0		0		11	40.71
sw13	46	176.25	20	63.46	20	66.01	4	5.39	0		90	311.11
sw14	18	56.48	11	35.79	6	23.96	0		0		35	116.23
Total	820	2756.54	414	1523.06	240	776.52	110	281.50	27	86.37	1611	5423.99
ercent(%)	50.90	50.82	25.70	28.08	14.90	14.316	6.83	5.19	1.68	1.592	100	

As shown in the following Figure. 4.4, total stream length decreases as stream order increases. This means the 1st order stream has maximum length and the 5th order stream has a minimum length.

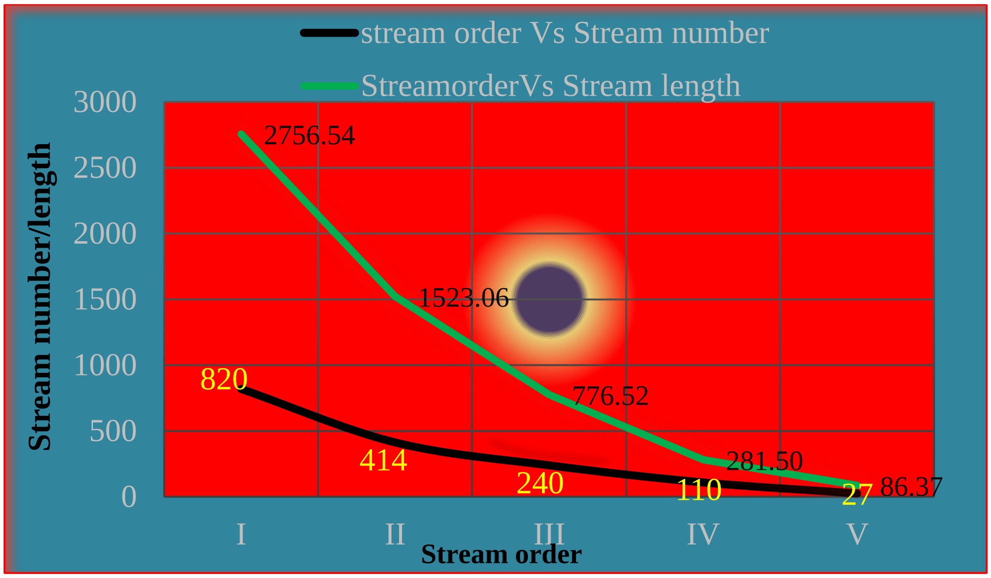

Figure 4 4 stream length vs stream order

4.2.5. Mean Stream Length(L_{Sm})

It is a defining attribute of the drainage network elements and the corresponding basin surfaces. Horton's law of stream length approach has been used to compute the mean stream length of various orders. It can be calculated by dividing the total length of the stream (LS) by the number of stream segments (NS) in the defined order

Table 4 2 mean stream length of all orders

Sub watershed	Mean Stream Length of all orders					
	I	II	III	IV	V	Total
sw1	2.81	3.25	3.08	2.09	0.00	11.23
sw2	3.35	3.29	2.89	0.00	0	9.53
sw3	3.67	3.76	3.25	0.36	0	11.05
sw4	3.22	3.52	3.70	2.97	4.11	17.52
sw5	3.04	4.05	5.85	2.10	0	15.05
sw6	3.54	4.27	1.58	2.21	0	11.60
sw7	3.98	4.08	4.58	3.60	2.96	19.20
sw8	4.63	3.84	0.93	0	0	9.40
sw9	3.82	4.73	2.00	1.00	0	11.55
sw10	2.69	3.60	2.63	3.68	2.32	14.92
sw11	3.16	2.94	2.27	0	0	8.37
sw12	4.20	3.84	0.15	0	0	8.19
sw13	3.83	3.17	3.30	1.35	0	11.65
sw14	3.14	3.25	3.99	0	0	10.38
Average	3.45	3.76	2.98	1.64	0.67	**12.67**

The mean stream length Dabus sub watersheds is 12.67 km and for each order of sub watersheds described in table 4.2. It indicates that the 2nd order stream is longer than the other.

4.3. Linear parameters

4.3.1.Stream Length Ratio(Lsr)

Stream length ratio exhibits a substantial relationship with surface flow discharge and basin erosion stage. It is the ratio of the given mean stream length (*Lms*) to the next smaller order's mean stream length (L_{ms-1}) (Horton 1945). The value of the mean stream length ratio is 1.11 for Dabus watershed and varies from 0.48 (sw12) to 1.13 (sw14) for sub watersheds (Table 4.3). According to this parameter, sub-watershed 14 has higher surface runoff and stream erosion than other sub-watersheds.

4.3.2. Bifurcation Ratio(Br)

Bifurcation ratio is the ratio of the number of stream segments in one order to those in the next higher order. It is correlated with the branching structure of a drainage network. In contrast to places where geology is dominant, Strahler (1957) proved that the bifurcation ratio has a small range of variation for distinct regions or different environmental situations. A strong structural control over the drainage pattern is evidenced by higher Rb values, whereas a weaker structural control and unchanged drainage patterns are indicated by lower Rb values for the sub-watersheds (Debelo & Tadele, 2017; Rai et al., 2017).

Table 4 3 Stream length and Bifurcation ratio of DSWs

Sub Watershed	Lsr	Br	Lsr	Br	Lsr	Br	Lsr	Br	**Average**	
	II/I	I/II	III/II	II/III	IV/III	III/IV	V/IV	IV/V	Lsr	Br
sw1	0.58	1.99	0.95	2.03	0.68	1.06			0.74	1.69
sw2	0.98	1.90	0.88	1.25				_	0.93	1.58
sw3	1.02	2.09	0.86	1.57	0.78	1.85		_	0.89	1.83
sw4	1.09	2.39	1.05	1.37	0.80	1.88	1.38	1.78	1.08	1.85
sw5	1.33	2.23	1.44	1.63	0.36	2.00		_	1.04	1.95
sw6	1.20	1.90	0.37	2.00	1.40	1.36		_	0.99	1.75
sw7	1.02	1.71	1.12	2.66	0.79	2.64	0.82	0.92	0.94	1.98
sw8	0.83	2.25	0.24	1.00		_		_	0.54	1.63
sw9	1.24	1.55	0.42	3.67	0.50	3.00		_	0.72	2.74
sw10	1.34	1.94	0.73	1.66	1.40	3.22	0.63	1.50	1.02	2.08
sw11	0.93	2.14	0.77	1.00		_		_	0.85	1.57
sw12	0.91	1.50	0.04	4.00					0.48	2.75
sw13	0.83	2.30	1.04	1.00	0.41	5.00			0.76	2.77
sw14	1.04	1.64	1.23	1.83					1.13	1.73
Average	1.03	1.97	0.80	1.90	0.79	2.45	0.94	1.40	0.87	1.99

The value of Br ranges from minimum of 1.57 for Sw11 to maximum of 2.77 for Sw13 and mean bifurcation ratio is 1.99 for the study area as shown in Table (4.3). The result indicates that the drainage network was neither distorted or disrupted by the geologic features.

4.3.3.Drainage density(Dd)

Drainage density presents a landscape analysis as well as infiltration capacity, runoff potential, and land cover. It is the ratio of the sum of all channel segment lengths for all orders inside a basin to the basin area. High drainage density is caused by weak or impermeable underlying material, mountainous terrain, and sparse vegetation(Choudhari et al., 2018b). In contrasts Shreedhara et al(2020) showed that area of highly permeable subsurface material beneath dense vegetation and low relief is likely to originate from the low drainage density. Low vegetation, good underlying material, and low roughness are all indicators of lower Dd in a basin, whereas high Dd is produced by the opposite circumstances. As it can be seen in the table 4.4 below, the drainage density in this research area ranges from 0.33 to 0.41 $per\ km$. This low drainage density result suggests that the watershed has a subsoil that is extremely permeable, low relief, little runoff, and high infiltration capacity. The average drainage density of Dabus watershed is 0.37per km

4.3.4.Drainage texture(Dt)

Drainage texture is one among the most important parameters of the drainage morphometry. It refers to the total number of stream segments in all categories within that area's perimeter. Several natural elements, such as the climate, rainfall, vegetation, rock, soil type, and infiltration rate, have an impact drainage density of sub basin. (Shreedhara et al., 2020). According to Gela (2018) drainage textures are classified from very coarse to very fine in different classes, <2 (very coarse), 2-4 (coarse), 4-6(moderate), 6-8 (fine) and >8 (very fine). Regions with vegetative cover leads to higher infiltration capacity, which gives lower Dt and shows coarse texture. Inversely, soft and weak rocks without vegetative covers leads to more runoff, gives higher Dt and shows a fine texture. In this study, Dt varies from 0.15 for sub watershed 12 to 0.88 for sub watershed 7, as shown in Table (4.4) below. It indicates that all sub watersheds fall under very coarse texture that tends to higher infiltration capacity.

4.3.5.Stream Frequency(Sf)

The term "stream frequency" (Sf) refers to the proportion of a catchment's total number of streams (Nu) to its catchment area (A). The nature and structure of the rocks, vegetation cover, kind and amount of rainfall, and soil permeability all affect the occurrence of stream segments (Prabhakar

& Srinivas, 2016). High subsurface impermeability, little vegetation, high relief conditions, and low infiltration capacity are connected to high stream frequency, and vice versa. Among sub watershed of Dabus SW8 was observed with lowest Fs (0.09 per km), which indicate that it has highest infiltration capacity and lowest soil erosion susceptibility in terms of stream frequency(Sf) only. Inversely, SW10 was observed with highest Fs (0.126 per km). The other sub watersheds Fs with their assigned ranks shown in Table (4.4) below.

4.3.6.Length of over land flow(L_{olf})

The distance water travels over land before condensing into a stream channel is referred to as the "length of overland flow" (Lolf). It is the movement of precipitated water over the landscape leading to the stream channels(Gudu Tufa, 2018). Low value of L_{olf} indicates high relief (Prabhakar & Srinivas, 2016), short flow paths, more runoff, and less infiltration which leads to more vulnerable to the flash flooding(Mohammed et al., 2018a). Meanwhile, a high value of L_{olf} means gentle slopes and long flow paths, more infiltration, and reduced runoff. Table (4.4) has sub water- shed wise information about the length of overland flow of Dabus watershed. Sub-watershed 7 has minimum (Lolf=1.22km) and sub-watershed 10 has maximum (Lolf =1.50 km) among 14 sub-water shed of Dabus water sheds.

Table 4 4 Linear morphometric parameters directly related to soil erosion

Sub watershed	Area(km2)	Perimeter(km)	Drainage density(D_d)	Drainage texture(Dt)	Stream frequency(Sf)	Length of over land flow(Lolf)
sw1	2390.75	448.09	0.35	0.64	0.12	1.46
sw2	333.44	140.61	0.36	0.26	0.111	1.39
sw3	2213.87	334.75	0.38	0.71	0.107	1.32
sw4	1899.07	397.83	0.34	0.49	0.102	1.45
sw5	552.22	552.22	0.36	0.28	0.098	1.41
sw6	949	204.47	0.4	0.55	0.119	1.25
sw7	2555.77	297.44	0.41	0.88	0.103	1.22
sw8	164.89	78.23	0.37	0.22	0.096	1.36
sw9	328.72	135.32	0.38	0.24	0.113	1.33
sw10	1642.71	317.45	0.33	0.58	0.126	1.50
sw11	458.82	188.08	0.37	0.31	0.109	1.37
sw12	105.39	73.36	0.39	0.15	0.104	1.29
sw13	865.00	276.09	0.36	0.33	0.104	1.40
sw14	334.16	139.99	0.35	0.25	0.108	1.44

Figure (4.5) displays the ranking and final score of each of the eleven sub-watersheds that were evaluated for Table (4.4). Therefore, erodibility and the linear parameters are directly related. Sub-watersheds were ranked in order of highest linear parameter value, which was assigned rank 1, then second-highest value, and so on.

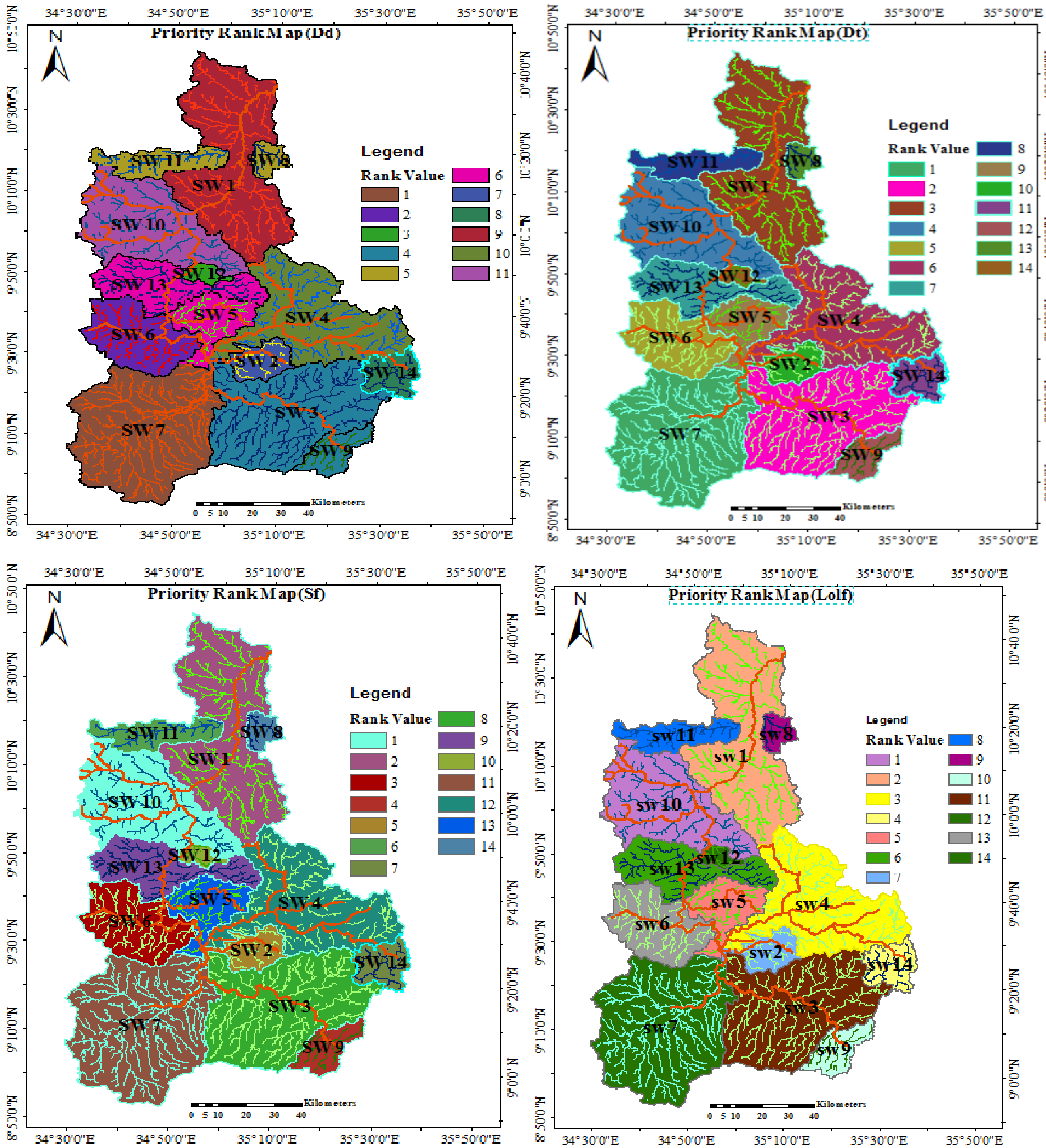

Figure 4 5 Linear morphometric parameters priority rank map, Dd, Dt, Sf and Lolf

4.4. Areal parameters

4.4.3.Basin length (L_b)

Basin length (L_b) is distance from the watershed outlet to the basin division measured along the main channel. It measures of surface runoff properties, where longer streams suggest gentler slopes. It displays the watershed's channel, which carries the most of the water. Because, it is measured along the main flow direction, the basin length serves as a fundamental input variable when determining the key shape parameters. In this regard, the length of Dabus sub watershed is the longest at SW 7(113.1km) and lowest at SW 13 (18.43km).

4.4.4.Form factor(F_f)

Form factor (Ff) is a dimensionless parameter that is used to express the shape of a basin in numerical form. Elongated basins have larger lengths with smaller F_f value whereas circular basins have intermediate Ff value, which are close to one and short wide basins have the largest Ff value. Greater form factor basins are often circular and have higher critical flows for a shorter length, whereas elongated basins with a lower form factor have lower peak flows for a longer period of time(Sukristiyanti et al., 2018). In this study, F_f ranges from 0.2 to 0.308 as shown in Table (4.5), suggesting dominance of elongated shape for the sub watersheds thus characterized by low peak flow for longer duration. Smaller also values of F_f shows flatter peak flows for long duration (Choudhari et al., 2018a).

4.4.5.Circularity ratio (C_r)

Circularity ratio (Cr) illustrates the form of the basin, suggesting the rate of infiltration and the amount of time needed for the extra water to reach the basin outlet. It is the ratio of the area of the basins to the area of circle having the same circumference as the perimeter of the basin. It is affected by factors such as stream length and frequency, geological formations, land use and cover, climate, relief, and basin slope (Prabhakar & Srinivas, 2016). Higher values of Cr indicate that the watershed is circular, that the terrain has moderate to high relief, and that the surface is permeable. They also indicate that there is less time for surface runoff to infiltrate the ground. In contrast, Low Cr indicates an impermeable surface with low relief and a lengthy surface.

In the present study (Table 4.5), the C_r values for all Dabus sub-watersheds ranges from 0.143 to 0.363 for sw13 and sw7 respectively, which shows that the watersheds are almost elongated.

Furthermore, it shows that the sub watersheds' geologic strata are made of very uniform and highly permeable geologic materials.

4.4.6. Elongation ratio(E_r)

It is ratio between the diameter of a circle with the same size as the drainage basin and the longest possible length of the basin(Schumm & A., 1956). It is highly important index in the analysis of basin shape and contributes in giving insight into the hydrological structure of a drainage basin. According to A. Kumar et al (2021) values of E_r can be classified into three categories, namely, less elongated (< 0.7), oval (0.7–0.9), and circular (> 0.9). As the E_r value rises, the basin become increasingly circular and more prone to floods because of the short concentration times, and vice versa. In the discharge runoff, a circular basin is more effective than an elongated basin D. Kumar et al., (2021), because it will yield the shortest time of concentration. The research area's Er value shown in table (4.5), which indicates that the basin has an elongated shape that makes it less likely to flood and a moderate to slightly steep slope.

Table 4 5 DWs morphometric parameters inversely related to soil erosion

Sub watershed	**Relief parameters**			
	Basin length	**Form Factor**	**Circularity Ratio**	**Elongation Ratio**
	Bl	**Ff**	**Cr**	**Er**
sw1	108.878	0.202	0.150	0.507
sw2	35.564	0.264	0.212	0.579
sw3	104.227	0.204	0.248	0.509
sw4	95.531	0.208	0.151	0.515
sw5	47.365	0.246	0.181	0.560
sw6	64.420	0.246	0.285	0.540
sw7	113.085	0.229	0.363	0.504
sw8	23.840	0.200	0.339	0.608
sw9	35.277	0.290	0.226	0.580
sw10	87.978	0.264	0.205	0.520
sw11	42.633	0.212	0.163	0.567
sw12	18.488	0.252	0.246	0.627
sw13	61.117	0.308	0.143	0.543
sw14	35.61	0.232	0.214	0.579
Dabus Basin	306.577	0.009	0.960	0.009

The outcomes from Table (4.5) were used to analyze watershed characteristics and rank the watershed's potential. The areal parameters of elongation ratio, circularity ratio, and form factor are inversely correlated to the erodibility(Mangan et al., 2019). As evidently displayed in Figure

4.6 below watersheds that were most susceptible to erosion were given the highest ranking based on these criteria, and vice versa.

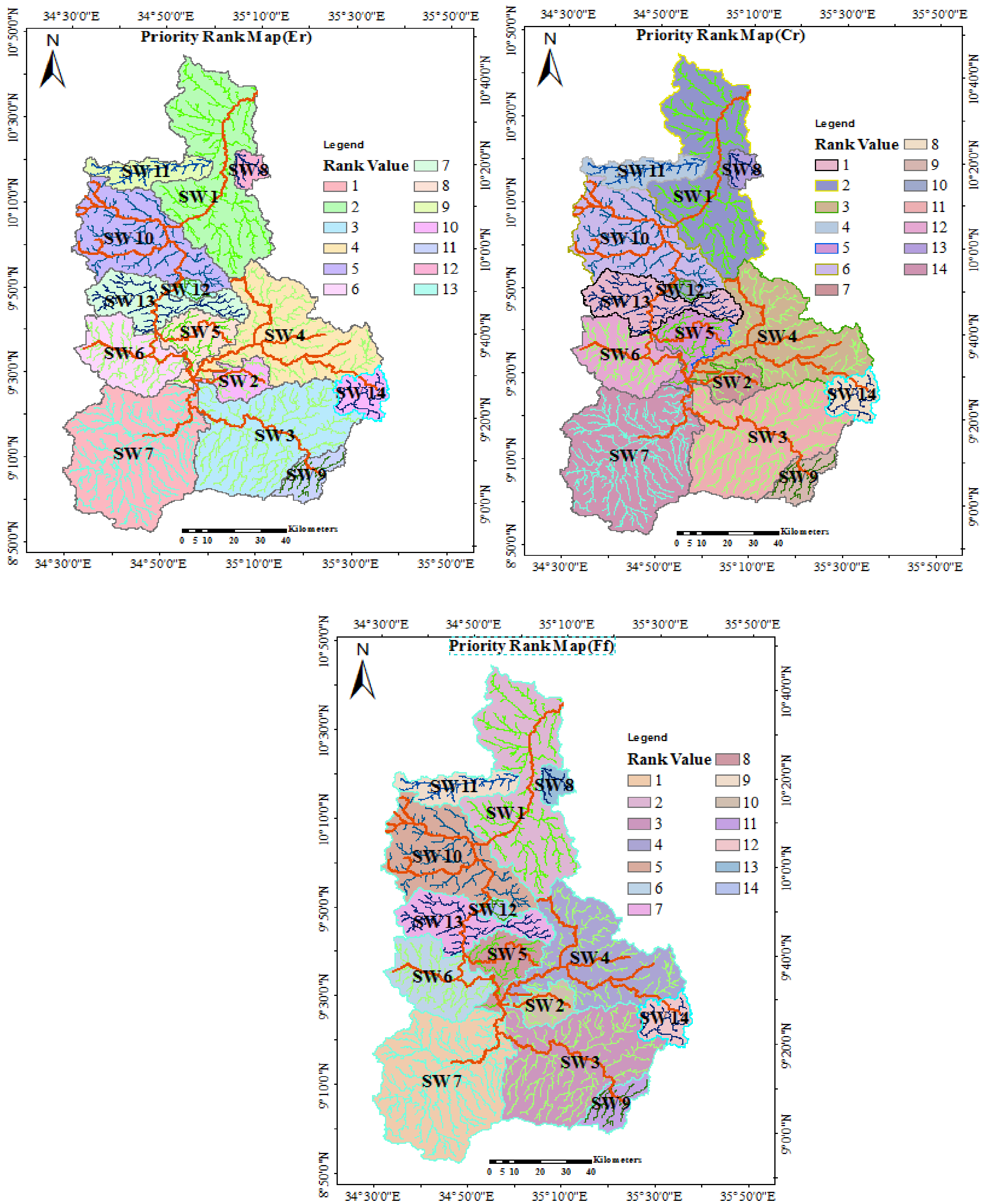

Figure 4 6 Areal morphometric parameters priority rank map, Cr, Er and Ff

4.5. Relief parameters

4.5.1. Basin relief (R_b)

The relief parameters influence the stream gradient, which directly regulates the gravity of water flow, runoff, channel erosion, and the lag time for the water to peak during high flow events. Basin relief is the elevation difference between the highest point on the drainage divide and the sub basin's discharge point. It is an important parameter in understanding the characteristics of landforms and the geomorphic processes The maximum and minimum elevation in Dabus water shed is 3123 and 556 meter m.a.s.l. The basin relief of the study area is 2.612 km and that of the sub water shed shown in Table (4.6) below.

4.5.2. Relief Ratio (R_r)

Relief ratio is the ratio of a basin's overall relief to its longest dimension that is parallel to its major drainage line (Schumm & A., 1956). It determines both the overall steepness of a drainage basin and the rate of erosion occurring on its slopes. High values Rr are found in regions with high reliefs and steep slopes, whereas Rr relief indicates the presence of rocks below the surface that are visible as small ridges and mounds with a lower slope (Meshram & Sharma, 2017). This study observed that SW8 and SW3 has the maximum and minimum Rr, respectively. This implies that SW3 is more susceptible to erosion as compared to SW10.

4.5.3.Ruggedness Number(R_n)

The Ruggedness Number(R_n) is employed to measure the streams' risk of severe flooding. R_n and soil erosion susceptibility are directly related, so that the soil erosion susceptibility also increases with increasing R_n values (Shreedhara et al., 2020). In terms of Rn, SW12 has the lowest value (0.139), indicating that it is least susceptible to erosion. SW7 has highest value (0.734), showing that is most vulnerable due to its high rate of erosion.

4.5.4. Relative relief ($R_{r'}$)

Relative relief ($R_{r'}$) analyzes the drainage basin topography. It is the ratio of the watershed's perimeter to its highest relief and can be used to show the size of a basin's relief without considering the sea level(Ali et al., 2018). A high Rr' value implies a high relief area with a steeper slope that is prone to erosion. (Setiawan & Nandini, 2021). Watersheds with greater relative relief have greater runoff potential than others. Dabus Basin has $R_{r'}$ values 0.009 and the $R_{r'}$ values for sub watersheds ranges from 0.002 for (SW5) to 0.01 for (SW8). Sub watershed having high Rr’ have the higher runoff potential than others. So that SW8 have high $R_{r'}$ values which implies it is more susceptible to erosion and larger potential for runoff than others.

Table 4 6 DWs Relief parameter values

Sub watershed	**Relief parameters**			
	Basin Relief	**Relief Ratio**	**Ruggedness number**	**Relative relief**
	Rb	**Rr**	**Rn**	**Rr'**
sw1	1.342	0.012	0.464	0.003
sw2	0.498	0.014	0.179	0.004
sw3	1.051	0.010	0.396	0.003
sw4	1.113	0.012	0.384	0.003
sw5	0.773	0.016	0.275	0.004
sw6	0.892	0.014	0.355	0.004
sw7	1.791	0.016	0.734	0.006
sw8	0.764	0.032	0.282	0.010
sw9	0.484	0.014	0.183	0.004
sw10	0.980	0.011	0.326	0.003
sw11	1.184	0.028	0.433	0.006
sw12	0.359	0.019	0.139	0.005
sw13	0.885	0.014	0.318	0.003
sw14	0.613	0.017	0.213	0.004
Dabus Basin	**2.612**	**0.009**	**0.960**	**0.009**

Regarding the relief component of geo-morphometric, the important requirements for comprehending the relationship between geomorphometric and erosion interactions have been examined. Relief morphometric parameters, like linear morphometric parameters, have a direct association with soil erodibility; the greatest value of these characteristics indicates the watershed's most erodible soil. Thus, the sub-watershed revealed that the relief parameters with the greatest value had been ranked first, followed by those with a second higher value, and so on, with the lowest value having been ranked last as shown in Figure 4.7 below.

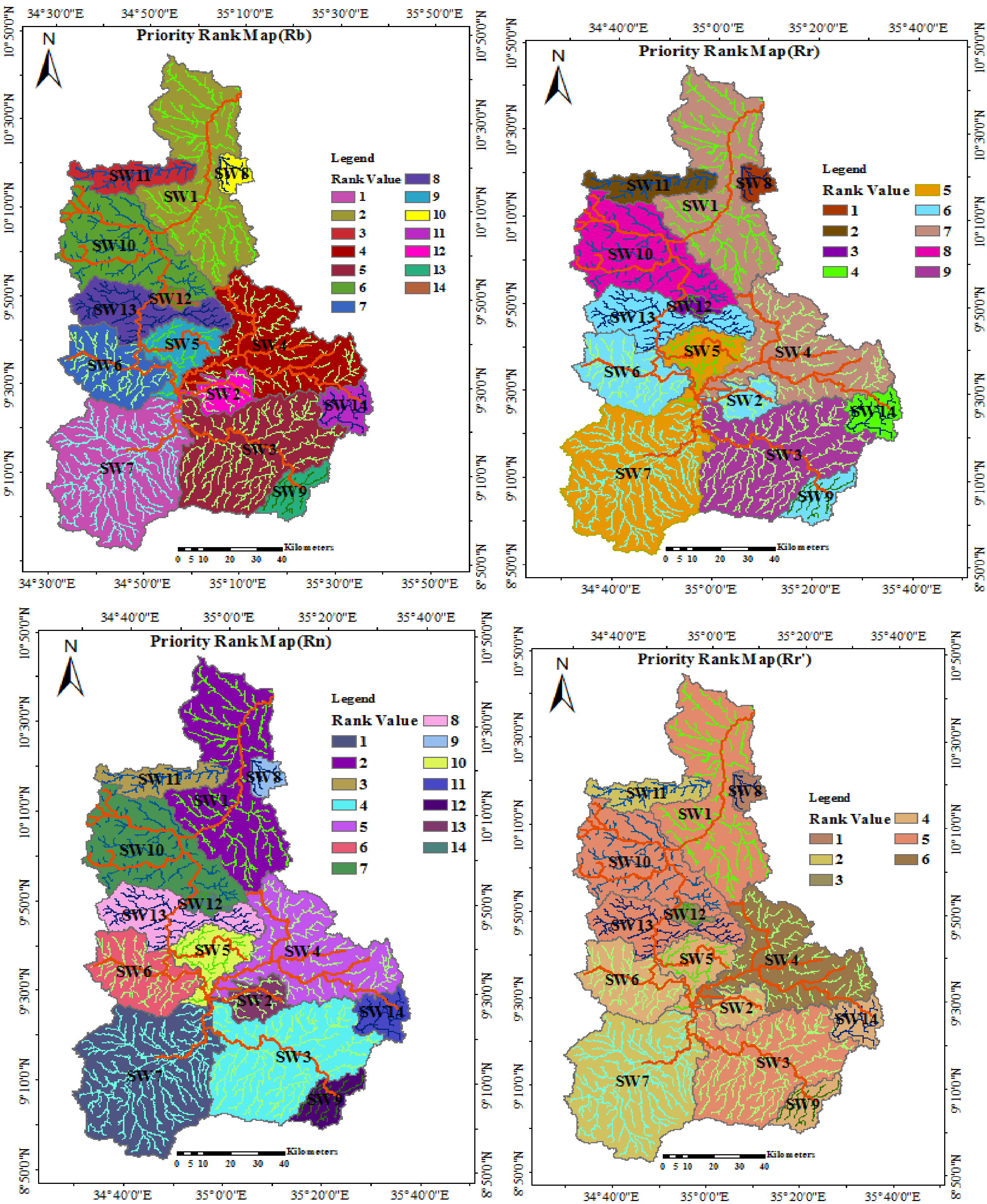

Figure 4 7 Relief morphometric parameters priority rank map, Rb, Rr, Rn and Rr"

4.6. Sub-watershed prioritization and compound values(Cp)

Sub-watershed prioritization is critical for watershed management and analyzing a watershed's vulnerability to flooding and soil erosion. It entails rating distinct sub-basins in order of importance for treatment with conservation technologies, based on their morphological characteristics (Arulbalaji & Padmalal, 2020). Sub-watershed prioritization for this study was done as per watershed prioritization methodologies adopted by Waiyasusri & Chotpantarat 2020 based on morphometric parameters. This Prioritization is based on the degree of erosion vulnerability of the sub-watershed as determined by morphometric parameters. In order to examine watershed priorities, the entire region was divided into 11 sub-watersheds. With the watershed characteristic variation of the Dabus watershed stated, we determined the morphology and prioritizing capacity in order to examine the watershed factors that contribute to watershed erosion.

The compound value was employed to attempt sub-watershed prioritizing. The compound value is determined by combining rank values of all parameters and then dividing by the total number of parameters (Vanlalchhuanga et al., 2021). In this study, Table (4.7) show that no individual parameter can explain the level of erosion vulnerability of sub-watersheds.

Table 4 7 Rank of sub watershed and their compound values

No	Morphometric	Sub Watersheds													
	Parameter	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10	SW11	SW12	SW13	SW14
1	Dd	0.346	0.359	0.380	0.340	0.360	0.400	0.410	0.370	0.380	0.330	0.370	0.39	0.36	0.35
	Rank	9	7	4	10	6	2	1	5	4	11	5	3	6	8
2	Dt	0.643	0.260	0.710	0.490	0.280	0.550	0.880	0.220	0.240	0.580	0.310	0.15	0.33	0.25
	Rank	3	10	2	6	9	5	1	13	12	4	8	14	7	11
3	Sf	0.120	0.111	0.107	0.102	0.098	0.119	0.103	0.096	0.113	0.126	0.109	0.104	0.105	0.11
	Rank	2	5	8	12	13	3	11	14	4	1	6	10	9	7
4	Ff	0.202	0.264	0.204	0.208	0.246	0.229	0.200	0.290	0.268	0.212	0.252	0.308	0.232	0.269
	Rank	2	10	3	4	8	6	1	13	11	5	9	14	7	13
5	Lof	1.460	1.392	1.320	1.449	1.408	1.255	1.219	1.356	1.325	1.504	1.367	1.294	1.400	1.437
	rank	2	7	11	3	5	13	14	9	10	1	8	12	6	4
6	Cr	0.150	0.212	0.248	0.151	0.181	0.285	0.363	0.339	0.226	0.205	0.163	0.246	0.143	0.214
	Rank	2	7	11	3	5	11	14	13	9	6	4	10	1	8
7	Er	0.507	0.579	0.509	0.515	0.560	0.540	0.504	0.608	0.580	0.520	0.567	0.627	0.543	0.601
	Rank	2	10	3	4	8	6	1	13	11	5	9	14	7	12
8	Lsr	0.737	0.929	0.891	1.082	1.045	0.991	0.939	0.536	0.720	1.025	0.850	0.476	0.759	1.132
	Rank	11	7	8	2	3	5	6	13	12	4	9	14	10	1
9	Br	1.69	1.58	1.83	1.85	1.95	1.75	1.98	1.63	2.74	2.08	1.57	2.75	2.77	1.73
	Rank	11	13	8	7	6	9	5	12	3	4	14	3	1	10
10	Rr	0.012	0.014	0.010	0.012	0.016	0.014	0.016	0.032	0.014	0.011	0.028	0.019	0.014	0.017
	Rank	7	6	9	7	5	6	5	1	6	8	2	3	6	4
11	Rn	0.464	0.179	0.396	0.384	0.275	0.355	0.734	0.282	0.183	0.326	0.433	0.139	0.318	0.213
	Rank	2	13	4	5	10	6	1	9	12	7	3	14	8	11
12	Rr''	0.003	0.004	0.003	0.002	0.004	0.004	0.006	0.010	0.004	0.003	0.006	0.005	0.003	0.004
	Rank	5	4	5	6	4	4	2	1	4	5	2	3	5	4
Compound value		4.83	8.25	6.33	5.75	6.83	6.33	5.17	9.67	8.17	5.08	6.58	9.50	6.08	7.75

Sub watersheds were prioritized based on their compound values (Cp), which were determined by ranking each individual morphometric parameter that has a direct or indirect impact on soil erosion. Directly related parameters (linear parameters) and Relief parameters highest values are assigned first rank, while for the indirectly related parameters (shape parameters) lowest values assigned first rank. Finally, compound values (Cp) determined by averaging all parameters rank of individual sub watersheds. Following a successful determination of the watershed's vulnerability and priority, the sub-status watershed's was highlighted at the watershed level. Sub watersheds with the lowest compound factor received higher rankings during sub watershed prioritization, and vice versa.

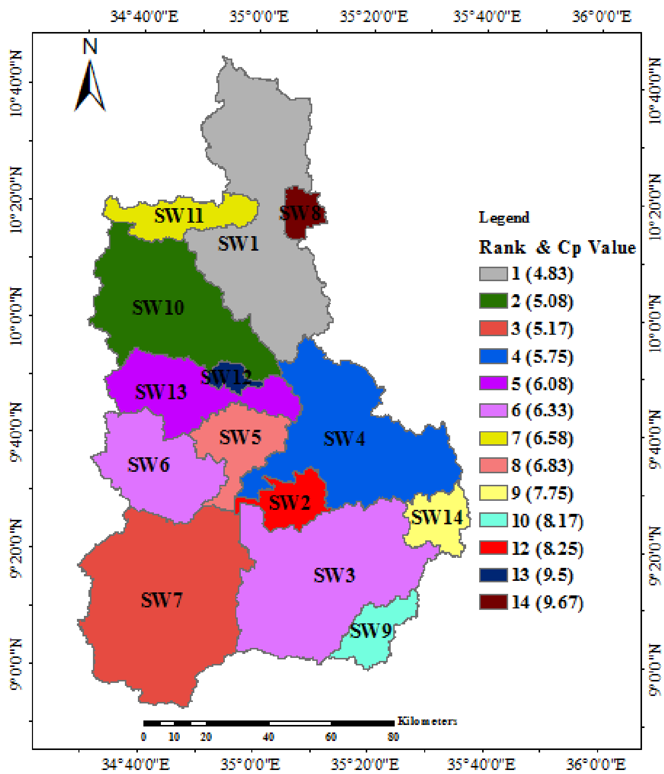

Figure 4 8 Ranking and cp Values

To quantify the susceptibility of each watershed to soil erosion potential, these compound values were generated for each rank of the morphometric result. The Morphometric analysis results were used to categorize each sub watershed, allowing for targeted implementation(Gumma et al., 2016; Puno & Puno, 2019; Amare et al., 2020; Vanlalchhuanga et al., 2021). On the basis of priority and rank, sub-watersheds investigated for this study were divided into four categories shown in Figure (4.8) below: Very high (≤ 5.5), high (5.51-6.5), Medium (6.51-7.5), and low (≥7.51). The highest and lowest priority rankings for sub-watersheds are 4.83 and 9.67, respectively. Priority for soil conservation treatments has been given to the sub-watershed with the most soil loss, and likewise for the sub-watershed with the least soil loss according to Markose & Jayappa (2016). This signifies that the highest priority represents the greatest degree of runoff, peak flow, and soil erosion hazards in that sub-watershed. As a result, adequate land and water management methods must be planned for each sub watershed based on its sensitivity rating.

Very high priority: Very high priority represents the extremely high degree of deterioration in a specific sub-watershed, interventions for soil and water conservation may be envisioned in sub-watersheds. Sub-watersheds SW1(4.83), SW7(5.17) and SW10 (5.08), are designated under very high priority out of 14 sub-watersheds. Those watersheds generally consist of high relief and steep slopes, sparse vegetation, low infiltration and high discharge of run off. These can be classified under very severe erosion susceptibility zone. Thus, need immediate attention to take up best management for soil and water conservation measures such as contour binding, bench terracing, gully control structures and grass waterways to protect the topsoil loss. As a result, immediate action was required to put the most effective soil and water conservation measures in place.

High priority: High priority indicates high soil erosion in the specific sub-watersheds, and it becomes a promising opportunity for implementing soil conservation strategies. There are two sub watersheds (SW6 (6.33), SW 4 (5.75), SW3 (5.83), SW13(6.08)) falling under high priority. Following very high priority Sub watersheds, soil and water conservation measures can be applied to high priority sub watersheds.

***Medium priority*:** There are four sub watersheds falling under medium priority which encompasses 23.2% of the total area. i.e. SW5(6.83) and SW 11(6.58)) classifieds under medium priority watersheds. These sub watersheds were under moderate priority (survivable range), indicates relatively moderate soil erosion zone, consist of moderate slopes and moderate values of morphometric analysis result. but they still require adequate treatment following to a high level of priority.

Low priority: Five sub watersheds SW9(8.17), SW14 (7.75), SW2(8.25), SW12(9.5) and SW8(9.67) are classified under low priority. These sub-watersheds, on the other hand, do not demand immediate soil and water conservation, which is considered essential since low priority sub-watersheds are less likely to develop land degradation. Likewise, the sub-watersheds in the Medium priority classes indicate a moderate land degradation area. These watersheds can be categorized under very slight erosion susceptibility zone and may need application of agronomical measures such as Contour farming, mulching practices, Strip cropping and Mixed cropping to protect the sheet and rill erosion.

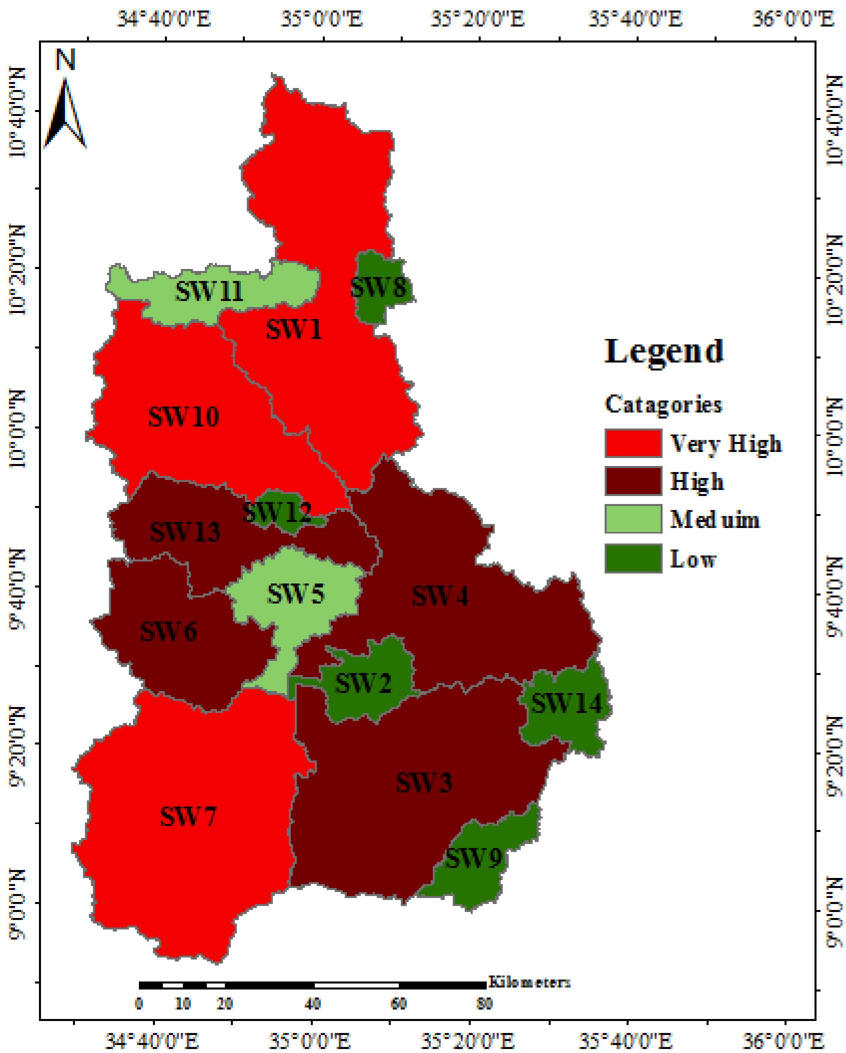

Figure 4 9 DWs prioritization map

4.7. Environmental management strategies

Sub basins are prioritized in order to find the important areas with the highest rates of erosion activity and to enable the implementation of the necessary conservation measures to minimize soil erosion in the area. For soil resource conservation, the sub watersheds with a severe rate of soil erosion require immediate attention. This research sought to prioritize potential causes of soil erosion in the DWs. According to the results, not every sub-watershed was determined to have an equal risk of soil erosion. In this way, prioritization helped us locate sub-watersheds in the catchment that are more vulnerable to soil erosion. Therefore, the development of suitable soil and water conservation measures employing remote sensing and GIS techniques must be prioritized for preservation over the whole DWs to reduce the amount of soil erosion, decrease the sediment discharge into the GERD reservoir, protect steep slopes against landslides, and reduce future flooding risk.

It was clearly shown Figure 4.9 that three sub water sheds (SW1, SW7 and SW10) covering 45% of the total area were more susceptible to soil erosion because of their very high priority. Therefore, in order to prevent the degradation of the land and water, the immediate conservation measures are needed in these sub-watersheds. SW6, SW4, SW3 and SW13 that covering about 40.06% of the DWs falls under high priority. As a result, depending on the priority rank, it is suggested that management actions to prevent soil losses and preserve natural resources within SWs.

The problem of watershed degradation is that these processes of change are accelerated and their negative impacts become more pronounced. For example, soil erosion is a natural process, but it can be accelerated by overgrazing, deforestation, the expansion of road networks, and inadequate soil and moisture conservation measures on cultivated lands. The more rapid erosion quickly reduces the depth of fertile topsoil, creates gullies in the land, and causes sedimentation of streams. However, managing the water and other natural resources is an effective and efficient way to sustain the local economy and environmental health. Almost every activity on the land has the potential to affect the quality and quantity of water in our waterways. Watershed management helps to reduce soil erosion, reservoir sedimentation, flood damage, decrease the loss of green space, and improve water quality. Soil Conservation is a combination of the appropriate land use and management practices that promote the productivity and sustainable use of soils and in the process minimizes soil erosion and other form of land degradation. Soil and water conservation practices are the primary step for watershed management.

As a result, if erosion management measures are implemented for a very high and high priority class, we may be able to greatly lower the erosion rate from the basin, which is approximately 85% of the sub-basin. The sub watersheds grouped under very high and high priority class need an immediate attention to take up mechanical soil conservation measures like gully control structures and grass waterways, construction of contour bunds, contour ploughing, terraces building, and agro forestry or furrow practice and other soil-moisture conservation practices. Whereas two sub watersheds (SW5 and SW11) covering 7 % of the whole area are under medium priority, five sub watersheds (SW9, SW14, SW2, SW12 and SW8) covering 8% of the whole areas are under low priority in these sub-watersheds, there is no immediate need for conservation These watersheds can be categorized under very slight erosion susceptibility zone and may need application of agronomical measures such as Contour farming, mulching practices, Strip cropping and Mixed cropping to protect the sheet and rill erosion measures.

Deterioration and deposition may be greatly decreased if management techniques are used in this erosion hotspot zones. Soil and water conservation measures can thus be implemented first to the highest priority sub-watershed, followed by other sub-watersheds in the order of conservation. The initial step in this research is to plan for prevention so that DRCs do not experience more soil and water erosion in the future.

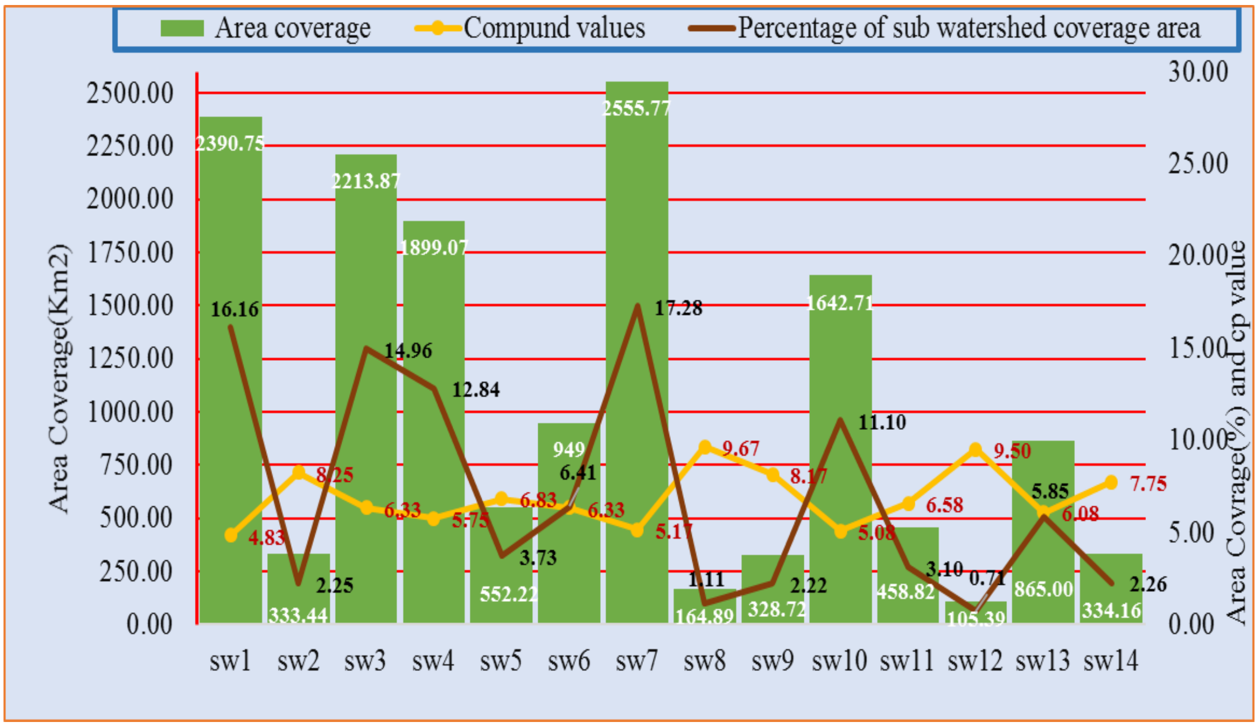

Figure 4. 10 The graph percentage area coverage and compound values

According to Vanlalchhuanga et al(2021), aspects of life such as crop rotation, unsuitable agricultural, illegal logging, and so on, in addition to natural factors, will be accelerated by using sensible agricultural techniques, agroforestry, contour farming in sloppy lands, terrace plantation, preventing overexploitation, converting plains into farming land, and building check dams. Similar to Jhariya et al(2018)'s findings on watershed prioritizing of the Bindra watershed employing remote sensing, geographic information system, and multi-criteria decision watershed prioritization. It was shown that mechanical methods such as bench terraces, slope terracing, gully plugging, scrub wooden dams, check dams, gabion check dams, seepage tanks, and boulder bunds may be used in appropriate areas. Sub-watersheds with medium and low priority can be considered subsequently for technological treatments, however practical preservation methods should be implemented in all sub-watersheds through good governance and farmer education.

According to the present study's finding, seven watershed regions (SW1, SW3, SW4, SW6, SW7 SW10 and SW13) should be incorporated in watershed management plans as promptly necessary (very high and high priorities). To avoid significant environmental degradation, appropriate management measures must be undertaken as a highest concern throughout the watershed zone of the DRCs.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study was primarily concerned with the Watershed Characterization and prioritization for soil erosion for Morphometric Analysis of the Dabus sub basin Using GIS software. Prioritization of sub-watersheds using GIS and RS provides a complete representation of the watershed's soil erosion sensitive areas. Morphometric analysis is an essential method for describing the physical and quantitative aspects of a watershed. Furthermore, it has been utilized to prioritize sub-watersheds for optimal natural resource management. Identifying key watersheds is an important step since different watersheds display varied hydrological characteristics depending on their Morphometric parameters that characterize the shape and topography of a certain watershed are investigated and assessed in terms of area, length, stream pattern, flow direction, and perimeters. The morphological activity of the watershed was shown by the linear, areal, and relief features, and their characteristics were particularly useful in indicating the prioritization of every sub catchment. Remote sensing and geographic information system (GIS) approaches were more effective in understanding the physical properties of the different sub watersheds. In order to understand the characteristics of soil erosion potential, priority ranks were established for each sub-watershed based on the value of the Morphometric analysis result.

Morphometric parameters fundamental, linear, areal, and relief aspects were studied. The Fundamental parameters that was used to define the geometrical parameters (Elevation, area, perimeter, length, and number of streams) were digitally acquired using GIS software for each sub watersheds separately. The quantitative morphometric analysis of the Dabus river watershed is performed in 14 sub-watersheds utilizing GIS techniques to determine the fundamental characteristics like stream number(Ns), stream length(Ls) Basin area(A), Basin perimeter(P), Elevation(E) linear aspects such as stream order(So), bifurcation ratio(Br), Drainage density(Dd), Drainage texture(Dt), stream frequency(Sf) , aerial aspects such as Form factor (Ff) circulatory ratio (Cr) and elongation ratio (Er) and Relief parameters such as Basin relief(Rb), Relative Relief(Rr), Ruggedness number(Rn) and Relative Relief(Rr'). The linear and relief parameters were shown to be directly connected to erodibility. Sub-watersheds were ranked in order of highest linear and relief parameter value, which received rank 1, then second-highest value, and so on. The inverse is true for Areal aspect parameters.

A combination of the full morphometric analysis result was constructed and classified as Very High(VH), High(H), Medium(M), and Low(L) using average compound values to locate erosion trimmed zones. As per analysis result, the sub-watershed SW1, SW7 and SW10 covering total area of 2390.75 km^2, 2213.8 km^2 .and 1642.71km^2 respectively received the very high priority classes where as SW6, SW4, SW3 and SW13 covering total area 949 km^2, 1899.07 km^2, 2213.87 km^2 and 865 km^2 received high priority classes. This shows the presence of a zone with substantial soil erosion. Likewise, the sub-watersheds in the Medium priority classes SW5(552.22 km^2) and SW11(458.82 km^2) indicate a moderate land degradation area. Sub watersheds in low priority classes SW9(328.72 km^2), SW14(334.16 km^2), SW2(333.44 km^2), SW12(105.39 km^2) and SW8(164.89 km^2) imply low soil erosion. The findings demonstrate that assessing numerous morphological features in a GIS system can be used efficiently for drainage prioritization, soil protection, and natural resource administration at the basin level.

The entire study area was divided into 14 sub-watersheds and prioritized using morphometric criteria. Following the prioritization of critical sub-watersheds, a wide watershed management strategy must be developed and implemented. Based on the compound parameter values, 14 sub-watersheds were divided into four groups. Depending on their compound values ,45% of the catchment area of the Dabus watershed falls under very high priority, 40 % fall under high priority, 7% fall under medium priority and 8% falls under lowest categories classes. The findings show that the study of multiple morphometric characteristics within a GIS framework may be successfully employed for watershed prioritizing, soil and water conservation, and natural resource management at the watershed level. To reduce the danger of possible soil loss, appropriate immediate management measures must be implemented for very high and high-priority rank sub-watersheds. The combined use of remote sensing and GIS might aid in quantifying rate of soil erosion at different levels and in identifying regions that may be at danger of erosion.

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5.2. Recommendation

The morphometric evaluations of various watersheds illustrate their respective qualities in terms of hydrological responsiveness. Although it was challenging to apply conservation strategies to the entire area of watersheds at once, it was necessary to prioritize each of the sub-watersheds. The priority parameters have been defined based on the average compound value as Very High Priority, High Priority, Medium Priority, and Low Priority. The sub watershed with the lowest average compound value has the Very high priority, while the watershed with the highest average compound value receives the lowest priority. This study highlights the applicability of GIS techniques for morphometric analysis and prioritization of the Dabus sub basins.

In this regard, our research finds that sub-watersheds SW1, SW7 and SW10 have very high sensitivity to soil erosion, while SW6, SW4, SW3 and SW13 have high vulnerability, so these seven sub-watersheds need to give highest priority in soil and water resource conservation above medium and low ranking sub-watershed. Sub-watersheds in the Medium priority classes SW5, and SW11 show significant land degradation and must be given second priority for reclamation and conservation. sub-watersheds in low priority classes SW9, SW14, SW2, SW12 and SW8 have a low risk of land degradation, they should be given the lowest priority in sub-basin conservation programs.

Furthermore, as from the analysis result table, the larger areas of Dabus Sub basin were more vulnerable to soil erosion potential. On the other hand; this study also validates; larger areas of the Ethiopian highlands were more vulnerable to soil erosion than the lowlands. Therefore, Suitable soil erosion, control measures are required in those watersheds to preserve the land from further erosion. If soil erosion, control measure for watershed management should applied to those sub watersheds, soil erosion from the highland areas and reservoir sedimentation at the downstream will be reduced, the rainwater will be harvested and the ground water will be recharged.

In general, applying sustainable land management strategies for watershed management to those sub watersheds prevent soil erosion from highland areas and reservoir sedimentation downstream, absorb rain water, and recharge ground water. As a result, these studies were immensely useful for watershed and catchment management programs of the upstream sub basin in order to offset the effects of reservoir sedimentation problems downstream of the Blue Nile basin, such as the Grand Ethiopian Renaissance project. It would be preferable if similar research was conducted in Ethiopia's other sub basins for soil and water resource planning and management programs, as identifying erosion sources is useful for adopting watershed management practices and thus increasing agricultural productivity for the development of our country, Ethiopia.

This research may be used to advise related studies, disseminate research findings to end users, and assist producers in risk management. As a result, these studies are extremely important for watershed and catchment management programs upstream of the sub basin in order to mitigate the effects of reservoir sedimentation concerns downstream of the Blue Nile basin, such as the Grand Ethiopian Renaissance project. For watershed prioritization in the current study, only morphologic characteristics generated from a composite dataset of DEM and derived mathematical computation were employed. Furthermore, with the integration of rainfall estimation and sediment production, land use land cover, and soil characteristics elements, complete watershed management plans and strategies may be performed.

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APPENDIX

Annex I: Dabus sub watersheds Morphological Parameters

		SW1			
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	145	407.17	2.81		1.99
2	73	236.97	3.25	0.58	2.03
3	36	110.91	3.08	0.95	1.06
4	34.00	71.17	2.09	0.68	
sum	288	826.22	2.87		1.27
	Maximum	Minimum	5.00	8	12.00
Elevation	1895	553.00			
		SW2			4
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	19	63.74	3.35		1.90
2	10	32.92	3.29	0.98	1.25
3	8	23.09	2.89	0.88	
sum	37	119.75			
	Max imum	Minimum			
elevation	1874	1376			
		SW3			
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	121	444.49	3.67		2.09
2	58	218.16	3.76	1.02	1.57
3	37	120.31	3.25	0.86	1.85
4	20	51	2.55	0.78	
sum	236	833.96			
	maximum	Minimum			
elevation	2428	1377			
		SW4			
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	98	315.35	3.22		2.39
2	41	144.19	3.52	1.09	1.37
3	30	111.07	3.70	1.05	1.88
4	16	47.58	2.97	0.80	1.78
5	9	36.95	4.11	1.38	
sum	194	655.14			
	maximum	Minimum			

elevation	2493	1380			
SW5					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	29	88.25	3.04		2.23
2	13	52.71	4.05	1.33	1.63
3	8	46.82	5.85	1.44	2.00
4	4	8.38	2.10	0.36	
sum	54	196.16			
	maximum	Minimum			
elevation	2107	1334			
SW6					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	57	202.04	3.54		1.90
2	30	128.08	4.27	1.20	2.00
3	15	23.7	1.58	0.37	1.36
4	11	24.3	2.21	1.40	
sum	113	378.12			
	maximum	Minimum			
elevation	2225	1333			
SW7					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	132	525.81	3.98		1.71
2	77	314.21	4.08	1.02	2.66
3	29	132.81	4.58	1.12	2.64
4	11	39.58	3.60	0.79	0.92
5	12	35.48	2.96	0.82	
sum	261	1047.89			
	maximum	Minimum			
Elevation	3165	1374			
SW8					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length(Slm)	Stream length ratio(Slr)	Bifurcation Ratio(Br)
1	9	41.69	4.63		2.25
2	4	15.37	3.84	0.83	1.00
3	4	3.72	0.93	0.24	
sum	17	60.78			
	maximum	Minimum			
Elevation	1469	705			
SW9					

Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	17	65	3.82		1.55
2	11	52	4.73	1.24	3.67
3	3	6	2.00	0.42	3.00
4	1	1	1.00	0.50	0
sum	32	124			
	maximum	Minimum			
Elevation	1950	1466			
SW10					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	93	250.12	2.69		1.94
2	48	172.72	3.60	1.34	1.66
3	29	76.25	2.63	0.73	3.22
4	9	33.1	3.68	1.40	1.50
5	6	13.94	2.32	0.63	0
sum	185	546.13			
	maximum	Minimum			
Elevation	2166	1186			
SW11					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	30	94.94	3.16		2.14
2	14	41.13	2.94	0.93	1.00
3	14	31.72	2.27	0.77	0
sum	58	167.79			
	maximum	Minimum			
Elevation	1938	754			
SW12					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	6	25.21	4.20		1.50
2	4	15.35	3.84	0.91	4.00
3	1	0.15	0.15	0.04	0
sum	11	40.71			
	maximum	Minimum			
Elevation	1660	1301			
SW13					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	46	176.25	3.83		2.30

2	20	63.46	3.17	0.83	1.00
3	20	66.01	3.30	1.04	5.00
4	4	5.39	1.35	0.41	0
sum	90	311.11	0	0	0
	maximum	Minimum			
Elevation	2211	1326			
SW14					
Stream order	stream number(NS)	stream length(Ls)	Mean stream length	Stream length ratio	Bifurcation Ratio(Br)
1	18	56.48	3.14		1.64
2	11	35.79	3.25	1.04	1.83
3	6	23.96	3.99	1.23	0
sum	35	116.23			
	maximum	Minimum			
Elevation	2101	1488			