JESE 4 (1) (2024)

Journal of Environmental and Science Education

https://journal.unnes.ac.id/journals/jese

Geospatial Assessment of Aridity and Erosivity Indices in Northwest Somalia Using The Corine Model

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DOI: https://doi.org/10.15294/jese.v4i1.1637

Article Info

Received 3 January 2024
Accepted 6 March 2023
Published 30 April 2024

Keywords:
Waqooyi Galbeed,
Soil,
Potential erosion,
Actual erosion,
CORINE

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Abstract

The degree of soil erosion depends on the erodibility of the soil and the erosive agents. The primary energy source for soil detachment and transport in water erosion processes is rain and runoff. In the northwest region of Somalia, we thoroughly evaluated the aridity and erosivity indices. This study, aridity and erosivity indices and arid periods of Woqoyi Galbeed were assessed. In the CORINE methodology, four parameters are used to evaluate the potential and actual soil erosion risks: Soil erodibility, erosivity, topography (slope), and land cover. Fournier Precipitation Index and Bagnouls-Gaussen Drought Index were calculated using rainfall data that were measured from 2011–2019 in the region and temperature data that were taken from 50 meteorological stations. The study illustrates that most of the study area is under moderate erosion risk. Although a small portion of the Southern parts of the study areas have high erosion risk, these areas have low erosion risk due to the very steep slope. The Erosivity Index quantifies the effect of rainfall impact and also reflects the amount and rate of runoff likely to be associated with precipitation events. Evaluating the result of MFI and BGI overlaid shows that there is low erosivity risk in the northern part of the country. It includes the Bossaso, Aburin, Dararweyne, Burco, Xudun and Iskushuban weather stations. It is covering the area of 204978, 65km2, which represents 32.14% of the study area. This indicates that Northern part of the country, annual rainfall is low, whereas some areas like Erigabo and gebiley are relatively moderate in the MFI.

p-ISSN 2797-0175
e-ISSN 2775-2518

INTRODUCTION

The ongoing climate change significantly endangers the soil resources in numerous African nations, whose economies are predominantly dependent on agriculture (Watene, et al, 2021). The challenges related to the soil and the environment in Somalia are very noticeable in terms of their impact and extent (Aden, et al., 2018). Land degradation is one of the most important themes in the region (Desta, et al., 2020). In Somalia, land degradation is a major environmental problem that is causing conflict and is directly related to desertification, drought, and unsustainable livestock and agricultural operations (Anja-Christina Beier and Eva Stephansson, 2012). Conflicts themselves also contribute to the destruction of the soil as they impede and prohibit the use of more sustainable traditional agricultural methods (Anja-Christina Beier, 2018). Somalia ranking among the world's most impoverished and underdeveloped nations, faces extraordinary obstacles in managing its natural resources (UNDP, 2018). The country's governance systems have collapsed due to over a quarter-century of continuous civil conflict, leading to various militias gaining control over different regions (Anja-Christina Beier and Eva Stephansson, 2012). In addition, the regions of Somaliland and Puntland have unilaterally declared autonomy (Anja-Christina Beier, 2018).Soil erodibility refers to the natural tendency of soil to be affected by erosion-causing agents, a characteristic influenced by the soil's inherent properties (Balasubramanian, 2017) and (Morgan, 2005). The degree of soil erosion depends on the erodibility of the soil and the erosive agents (Roose, 1996). The primary energy source for soil detachment and transport in water erosion processes is rain and runoff (Wischmeier et al., 1971). The ability of rain to induce erosion is known as erosivity. It depends on the physical attributes of precipitation, such as the size, dispersion, kinetic energy, and velocity of the raindrops (Ahmed Mohamed Abd Elbasit, 2013). Since sediment and nutrient losses are mostly caused by rainfall erosivity, farmers may be at risk of crop failures, and landscape equilibrium states may become unstable (Panagos, et al., 2015).An important component regulating water erosion in terrestrial ecosystems and other harmful hydrological phenomena, such as floods and flash floods, is the exposure of the Earth's surface to intense rainfall (Gianni Bellocchi and Nazzareno Diodato, 2020).A measurement of the erosive force of rainfall is called rainfall erosivity.

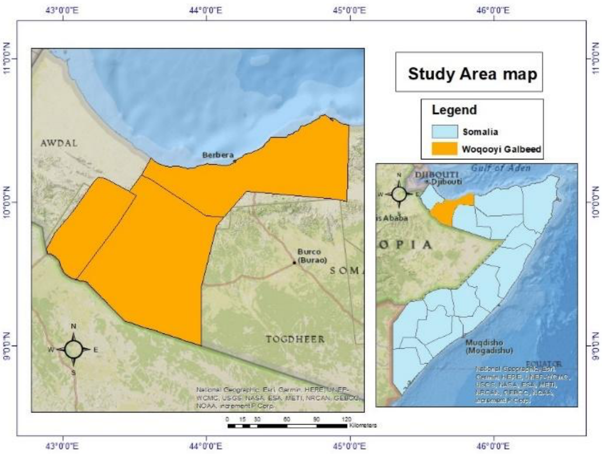

Figure 1. Study area Map

Erosivity is determined by rainfall kinetic energy, which in turn strongly depends on rainfall intensity (Anton Vrielinga. et al., 2009). The possibility for soil erosion is known as rainy erosivity. The rainfall erosivity index illustrates how the climate affects soil erosion caused by water (Renard et al.,1997). The effect of raindrops' kinetic energy on the soil is known as rainfall erosivity. Raindrops with greater velocities and sizes lose more kinetic energy and soil as a result (Kinnell, 2005). According to most soil erosion researchers and soil conservationists, erosivity and rainfall intensity have a positive relationship (Zhang, et al., 2018).

The use of the Coordination of Information on the Environment (CORINE) model in conjunction with Geographic Information System (GIS) and remote sensing technologies has been widely implemented for soil erosion risk assessment and land cover mapping. The CORINE model has been used in various studies to assess soil erosion risk. For instance, El-Nady and Shoman (2017) utilized the CORINE model along with GIS and remote sensing techniques to assess soil erosion risk in the basin of Wadi Maged in the northern west coast of Egypt. Similarly, Tayebi, Tayebi, Sameni, and Shafri (2017) applied the CORINE model and GIS for soil erosion risk assessment in the western Shiraz, Iran. The integration of the CORINE model with remote sensing and GIS technologies allows for a more comprehensive and effective soil erosion risk mapping. Yuksel, Gundogan, Akay, and Ozcan (2008) used remote sensing and GIS technologies along with the CORINE model for erosion risk mapping in the Kartalkaya dam watershed of Kahramanmaras, Turkey. Furthermore, CORINE has been used for land cover modeling. Dzieszko (2014) used CORINE land cover data for land cover modeling. Dengiz and Akgül (2005) used the CORINE model, GIS, and remote sensing techniques to assess the soil erosion risk of the Gölbaşı environmental protection area and its vicinity. All these studies highlight the effectiveness and utility of the CORINE model when used in combination with GIS and remote sensing technologies, providing accurate, cost-effective, and comprehensive assessments of soil erosion risk and land cover.

The CORINE (Coordination Information Environment) program promoted by European Community DG XI "Environment, Consumer Protection and Nuclear Safety" is the continuation of the previous program "Ecological Cartography of the European Community" (Giordano,2011). Its primary aim was to gather, process, and manage environmental data that would be largely used to define pertinent environmental issues, such as the European Community's biotope inventory, acid rains, atmospheric pollution, water pollution, soil erosion, and land quality.

The environment is the first place that can have the most impact on people because they live in it. Climate change and human activities have caused great harm to the environment. Somalia is among the countries in the region where the environment is facing serious problems for several reasons: Climate change and human activities. Environmental issues are among the most critical challenges human experience (Zakarie Abdi Bade, 2022).

The global community is negatively impacted by environmental challenges in many different ways (UNEP, 2016). Somalia is among the poorest countries in the world, and because of its lack of recognition, it is difficult for people to access natural resources (UNDP, 2018). As a result, Somaliland is experiencing serious ecological problems that are jeopardizing the way of life in the nation (Anja-Christina Beier and Eva Stephansson, 2012). These environmental problems have a detrimental impact on people's quality of life as a result (Aden, A. A., & Mashalla, S. K. J., 2018). Therefore, it is critical to understand Somaliland's environmental issues from a theoretical and, more importantly, a sociocultural standpoint (Desta, L., Carucci, V., Wendem-Agenehu, A., & Abebe, Y., 2020). As a result, this study makes an effort to explain environmental problems in Somalia and to spread awareness of them in one of the world's poorest nations and an unrecognized state (Anja-Christina Beier, 2018).Since environmental issues became effective in Somalia, this research aims to study determination an arid index showing the best representation for different regions in Somalia and evaluation is made of the erosivity indices using the Modified Fournier Index (MFI), the Bagnouls Gaussen Index (BGI) and the erosivity index proposed by the CORINE project (1995) methodology (Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L., & Alewell, C., 2015).Ultimately, the study will help prioritize critical areas having high erosivity measures to prevent (Roose, E. J., 1996).

Previous literature

According to the report of (SIDRA institute, 2017), Rapid loss of vegetation-cover means rapid soil erosion and soil nutrient losses. Land degradation caused by different human activities and environmental changes made the soil vulnerable to erosion. As well as, a report released by the federal government of Somalia in 2020 declared that Land degradation has contributed to the loss of vegetation, gully erosion, loss of topsoil, siltation of surface dams and irrigation canals, invasive non-palatable plant species, and loss of plant nutrients in areas with agricultural potential. The combination of falling rainfall, declining groundwater resources, increased soil and land degradation in an inherently fragile semiarid environment, emergence and spread of invasive exotic plants, shortening of the main rainy season, and diminishing free grazing communal lands, has created serious challenges for the resident agropastoral communities in the M&G. Unless effective adaptation measures and programs are introduced, climate change interacting with the prevailing unsustainable land use systems will translate into greater livelihood risk for these vulnerable communities (Adan Elmi Abdullahi, 2014). Flooding from the Golis Mountains during rainy seasons causes significant sheet, rill, and gully erosion in the soils of the Gebi Valley and Sool Plateau. Due to the alluvial origin of the soils of the Gebi Valley, they are quite prone to soil erosion during rainy seasons. Yet, during dry seasons, these soils get coated and compacted. Salinity and alkalinity are other typical soil issues in the area.

It is essential to have precise erosion risk maps produced using GIS techniques in order to identify locations with large erosion hazards and build erosion prevention plans. As the Reis; EAkay, and Savaci (2016) stated, there have been several models introduced to assess sediment yield, runoff, and erosion risks such as RUSLE (Revised Universal Soil Loss Equation), EPIC (Erosion Productivity Impact Calculator), ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation), ICONA (Institute for the Conservation of the Nature), WEPP (Water Erosion Prediction Project), and CORINE (Coordination of Information on the Environment). The Coordination of Information on the Environment (CORINE), can forecast soil erosion with spatial explicit, is an experimental model.

CORINE is a semi-qualitative cartography technique that entails creating and superimposing multiple layers of maps with different themes. It can display the spatial heterogeneity of soil erosion risk. (SER) within a GIS environment. It has a extent advantage of simple structure and it is also easy to employ with GIS. It takes time and money to assess soil erosion using traditional methods. Therefore, advanced models that have developed forthcoming models are very crucial. To reach such goal, Universal Soil Loss Equation (USLE), ICONA (Institute for the Conservation of the Nature), Erosion Kinematic Wave Models, Discrete Dynamic Models (DDM) and the coordination of information on the environment (CORINE model) have been advanced and now are the most useful models for erosion and soil mapping. These empirical models play a crucial role in environmental risk evaluation across the world wide because of their simple structure and ease of application. In CORINE model, four indices indulging erodibility, erosivity, slope and land cover were utilized to estimate the PSER and actual soil erosion risk (ASER). These data were processed through the map algebra in the ArcGIS and allowed obtaining maps potential and current erosion indices (Ibraheem A. H. Yousi, et al., 2020).

METHOD

2.1: Study area

Northwest is located between Awdal region to the west, and Togdheer region to the east. It also borders Ethiopia to the south and the Gulf of Aden to the north. It lies between the latitudes 1° 40' 48″ S and 12° 6' N and the longitudes 41° 0' E and 51° 22′ 12″ E, covering an area of 28236.765 Km2. It shares borders with Djibouti in the northwest, and Ethiopia in the west. It is also bounded by the Gulf of Aden in the north and the Indian Ocean in the east.

2.2: CORINE model

The CORINE model uses four parameters to evaluate potential and actual soil erosion risks: soil erodibility, erosivity, topography (slope), and land cover. Here's a more detailed explanation of how each parameter is incorporated into the CORINE model:

Soil Erodibility: This factor is determined by overlaying layers of soil texture, depth, and stoniness to form a soil erodibility map. Soil erodibility represents the susceptibility of soil particles to be detached and transported by rainfall and runoff, and it's primarily determined by soil properties such as texture, structure, organic matter content, and permeability (Bayramin, Erpul & Saglam, 2006). Erosivity: This factor represents the power of rainfall to cause erosion. It's calculated from meteorological data, including rainfall intensity and amount. In the CORINE model, the Fournier and Bagnouls-Gaussen aridity indices, calculated from climatic data, are used to form the erosivity layer (Bayramin, Erpul & Saglam, 2006). Topography (Slope): The slope of the land surface significantly influences the velocity of overland flow and thus the erosive power of the water. The slope factor in the CORINE model is derived from the Digital Elevation Model (DEM) of the study area (Aydın & Tecimen, 2010). Land Cover: Different land uses and land cover types can significantly influence soil erosion risk. Vegetation cover can protect the soil from the impact of raindrops, reduce runoff velocity, and increase infiltration, thereby reducing soil erosion. The land cover factor in the CORINE model is often derived from satellite imagery, such as Landsat imagery (Sepehr & Honarmandnejad, 2012). These parameters are represented as separate indices in the CORINE model. They are overlaid to produce a potential soil erosion risk (PSER) layer. This layer is then combined with the land use and land cover (LULC) layer, often derived from Landsat 5 TM imagery, to produce the actual soil erosion risk (ASER) layer (Zhu, 2011).The use of GIS and remote sensing techniques greatly enhances the accuracy and applicability of the CORINE model in soil erosion risk assessment.

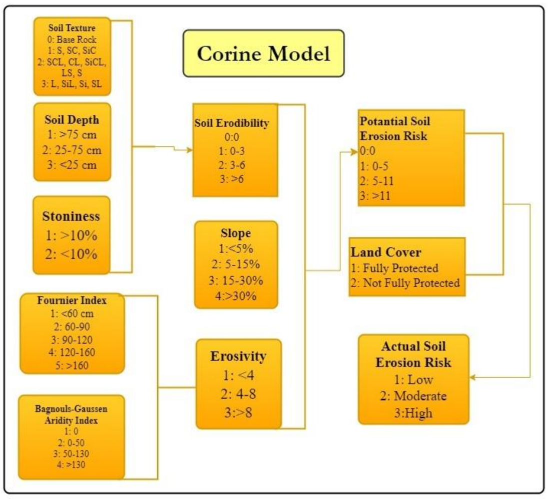

Figure 2. Flow chart Methodology

Soil erodibility, a term referring to the soil's susceptibility to detachment and transport by raindrops and runoff, is a key factor in understanding the dynamics of soil erosion. Soil erodibility considers both the inherent properties of the soil and the external factors affecting it, such as climate and topography (Pimentel, et al., 1995). Erosivity is one such external factor that measures the effects of rainfall and quantifies the volume and rate of runoff likely to be associated with precipitation events. It is calculated by integrating two climatic indices: the modified Fournier index (MFI) and Bagnouls-Gaussen aridity index (BGI) within the CORINE model, a European-wide assessment of erosion risk (Panagos, et al., 2015).To get a more realistic estimation of soil erosion risk, the erosivity index is often modified based on vegetation cover. Vegetation acts as a protective layer, reducing the impact of raindrops and slowing down surface runoff, thereby reducing soil erosion (Morgan, 2005).Actual Soil Erosion Risk (ASER) maps integrate land cover and Potential Soil Erosion Risk (PSER) maps using the Spatial Analyst extension (Map algebra) of ArcGIS 10.3 (Ibraheem A. H. Yousif, et al. 2020). Estimates of soil erosion also require data on rainfall erosivity, which is determined by analyzing characteristics of sub-daily storms (Chapman, et al., 2021). However, such data are often scarce, especially in developing countries, making it a challenge to accurately estimate soil erosion risk (Yang, et al., 2003).

RESULT AND DISCUSSION

MFI

The Modified Fournier Index was found by this equation MFI=$\sum_{i=1}^{12} \left(\frac{p2i}{p}\right)$ and from monthly return frequencies of rainfall events for 9 years (Figure 1). The "very low" class: This class, which represents 19.12% of the total study area, is characterized by areas with the least rainfall and subsequently the lowest potential for erosion. Terrain in these areas often consists of flat or gently sloping surfaces with well-drained soils and abundant vegetation, providing substantial protection against erosion.The "low" class: Occupying 23.89% of the study area, this class includes areas with slightly higher rainfall frequencies. Despite the increased precipitation, these areas maintain relatively low erosion potential due to factors such as robust ground cover and effective drainage systems.The "moderate" class: This category, covering 14.63% of the study area, represents regions with a medium frequency of rainfall events. The moderate potential for erosion in these areas is often due to a combination of factors such as steeper slopes, less effective ground cover, or less efficient drainage systems. The "high" class: Representing 14.66% of the study area, this class is characterized by areas experiencing frequent rainfall events leading to a heightened potential for erosion. These regions typically have steep slopes, less effective ground cover, and inefficient drainage systems, all of which contribute to increased erosion. The "very high" class: This class, which covers the largest portion of the study area at 27.70%, includes areas with the highest frequency of rainfall events and subsequently the most significant erosion potential. These areas often feature very steep slopes, minimal or ineffective ground cover, and poor drainage systems. The "very high" class areas are the most prone to erosion and require significant focus for erosion prevention and control measures. The findings of this study are substantiated by previous research conducted in East African countries, including Somalia. In their comprehensive study, Ashebir et al. (2017) assessed the same aspects of soil erosion and climatic factors. Their research provided insightful data, further establishing the relationship between soil erodibility, erosivity, topography, and land cover, and their collective impact on soil erosion.

Table 1: MFI	Area Km2	Area%
Very low	5395.51	19.12%

Low	6740.94	23.89%
Moderate	4128.19	14.63%
High	4136.95	14.66%
Very high	7816.55	27.70%
Total	28218.14	100.00%

Bagnouls Gaussen Index (BGI)

Using the Bagnouls Gaussen methodology, months are classified as dry when the ratio of precipitation to temperature is less than 2. In the case of Waqooyi Galbeed, it's observed that there is a dry period for three months - January, February, and March. The analysis of the Bagnouls Gaussen Index (BGI) for this region, as depicted in Figure 1, shows a significant division into two distinct classes:The "dry" class: This class represents the majority of the study area at 63.23%. Areas falling under this category experience a lower ratio of precipitation to temperature, indicating less frequent or less substantial rainfall events. However, these areas still maintain some level of moisture, allowing for the possibility of drought-resistant vegetation and limited agricultural activities. The "very dry" class: This class covers 36.77% of the study area. Areas classified as "very dry" have a much lower ratio of precipitation to temperature, indicating very scarce rainfall. These areas are characterized by arid conditions, limited water resources, sparse vegetation, and high susceptibility to desertification. They present significant challenges for agriculture and require efficient water management strategies.

Table 1.1: BGI	Area km2	Area%
Dry	17843	63.23%
Very dry	10378.2	36.77%
Total	28221.2	100.00%

Erosivity

The Erosivity map calculated for Woqoyi Galbeed, derived from overlapping the Modified Fournier Index (MFI) and Bagnouls Gaussen Index (BGI) layers (Figure 1), presents a detailed classification of the region's susceptibility to erosion into three distinct categories: The "low" class: This class, which covers 36.03% of the study area, represents regions with the least susceptibility to erosion. These areas typically have less frequent or less intense rainfall (as indicated by a lower MFI) and less extreme dry conditions (as indicated by a more favorable BGI). The combination of these factors results in a lower erosivity index, indicating that these areas are relatively stable and less likely to suffer significant erosion under normal conditions. The "medium" class: Covering 21.26% of the study area, this class includes areas with a moderate risk of erosion. These regions may experience more frequent or more intense rainfall events (leading to a higher MFI) or more pronounced periods of dry conditions (resulting in a less favorable BGI). These factors contribute to a moderate erosivity index, suggesting that these areas could be at risk of erosion, particularly under adverse weather conditions or without appropriate soil conservation measures. The "high" class: This class represents the majority of the study area at 42.71%. It comprises regions with the highest susceptibility to erosion, as indicated by the combination of frequent or intense rainfall events (resulting in a high MFI) and prolonged dry conditions (leading to a less favorable BGI). These factors result in a high erosivity index, signaling that these areas are at significant risk of erosion. These regions require the most attention in terms of implementing effective erosion control and soil conservation strategies.

Table 1.2: BGI	Area Km2	Area%
Low	10187	36.03%
Moderate	6012	21.26%
High	12075	42.71%
Total	28274	100.00%

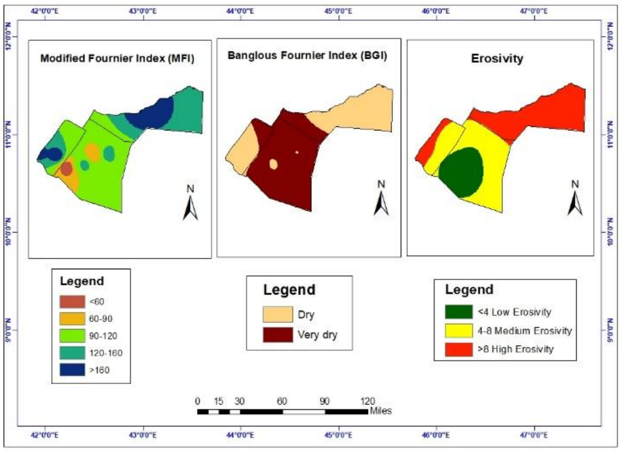

Figure3:Map of MFI, BGI and Erosivity of waqooyi Galbeed Somalia from 2011-2019

Slope

The slope of the terrain is a major determinant of soil erosion, with the process intensifying when the land is devoid of vegetation cover or the slope exceeds a critical angle. The data for the slope was obtained from the Digital Elevation Model (DEM) and was classified into four categories, each with a distinct impact on the potential for soil erosion:Very Gentle Slope

(>5%): These areas, which comprise the majority of the study area, present the lowest risk of erosion due to their flat or slightly inclined surfaces. The gentle gradient allows for better water infiltration and reduces surface runoff, leading to lesser soil displacement.Gentle Slope (5-15%): While these areas are also predominant in the study region, they have a slightly higher risk of erosion compared to the very gentle slopes. The increased gradient can lead to faster surface runoff during rainfall events, increasing the potential for soil erosion, especially if the ground cover is inadequate.Steep Slope (15-30%): These regions present a significant risk of erosion due to the increased gradient, which can result in rapid surface runoff, especially during heavy rainfall. The fast-moving water can easily displace soil particles, leading to significant erosion if not managed properly.Very Steep Slope (>30%): These are the areas with the highest risk of erosion. The steep gradient, combined with other factors like heavy rainfall or sparse vegetation cover, can lead to severe soil erosion. These areas require the most attention in terms of implementing erosion control measures.This classification of slope (depicted in Figure 2) provides a critical understanding of how the terrain's steepness can affect soil erosion across the study area. It enables the development of targeted strategies to combat erosion, with a focus on the areas of steepest gradient, where the risk is highest.

Table 1.3 Slope	**Area km2**	**Area%**
very gentle	19089	68
gentle	6595	23
steep	2152	8
Very Steep	372	1
Total	28208	100

Soil Erodibility

Soil erodibility is a critical factor in erosion studies as it represents the inherent susceptibility of soil to be eroded. This measure is dependent on several soil properties, including texture, depth, and stoniness, all of which were considered when generating the erodibility map for the Waqooyi Galbeed region (Figure 2).The results from this erodibility map, along with the corresponding calculations, present a concerning picture of the region's vulnerability to erosion:More Erodible Areas (99% of the study area): The vast majority of the region falls under this category, indicating a high susceptibility to erosion. These areas typically have soil properties, such as fine texture, shallow depth, or high stoniness, that make them less resistant to the erosive forces of wind and water. As such, these areas represent the primary focus for erosion control strategies.Low Erodible Areas (0.21% of the study area): These areas represent a very small fraction of the region. They are characterized by soil properties, such as coarse texture, deep soil, or low stoniness, that make them more resistant to erosion. While these areas are less of a concern, maintaining their structural integrity is still important to prevent any potential increase in erodibility. Highly Erodible Areas (0.62% of the study area): While these areas represent a small fraction of the region, their extreme vulnerability to erosion makes them a significant concern. These areas likely have soil properties that are particularly conducive to erosion, such as very fine texture, extremely shallow soil, or high stoniness. These locations require immediate and targeted intervention to control erosion.

Table 1.4: Soil Erodibility	**Area km2**	**Area%**
Low Erodable	59.3	0.21%
Moderate Erodible	28001.2	99.17%
High Erodible	176.3	0.62%
Total	28236.8	100

Land Cover

Vegetation cover holds a pivotal role in erosion models due to its ability to be both readily manipulated and effective in controlling soil erosion. The presence of vegetation significantly reduces the velocity of surface runoff, enhances the soil's capacity to absorb water, provides protection against the erosive forces of rainfall and wind, and aids in maintaining the structural integrity of the soil through root systems.In the study area, the primary land use is characterized as dry rangeland. This typically involves a sparse cover of drought-resistant grasses and shrubs, adapted to survive in arid conditions. While this type of vegetation does provide some erosion control, its overall effectiveness can be limited. This is due to factors such as the vegetation's seasonal nature, its inability to fully cover the soil surface, and the potential for overgrazing in areas used for livestock.

The map of the study area reveals that a substantial portion lacks full vegetation protection, leaving the soil highly susceptible to erosion. This lack of cover is of particular concern during periods of heavy rainfall, where the exposed soil can easily be displaced by surface runoff, or during periods of high winds, which can lead to significant wind erosion. To mitigate these risks, strategic efforts to increase vegetation cover could be highly beneficial. This could involve the propagation of native, drought-resistant plant species, the implementation of controlled grazing practices, or even the installation of windbreaks or other physical structures to reduce wind erosion. Such strategies would not only increase the overall vegetation cover but also enhance the resilience of the landscape to erosive forces. Furthermore, it might be beneficial to integrate land management practices that promote soil conservation, such as contour plowing or the use of cover crops, particularly in areas identified as being at high risk for erosion. By increasing the vegetation cover and implementing these soil conservation strategies, it's possible to significantly reduce the rate of soil erosion in the study area, ensuring the sustainability of the land for future use.

Table 1.5: Land Cover	Area km2	Area%
fully Protected	12187	43
non fully Protected	16044	57
Total	28236.8	100

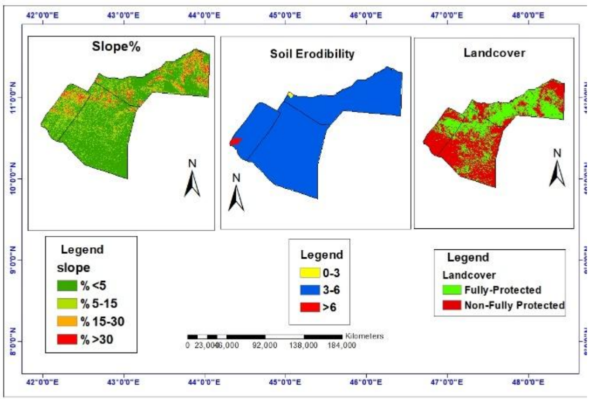

Figure 4: Map of slope.Soil Erodibility of waqooyi Galbeed somalia

Since it is the sole variable that can be easily changed and effectively controls soil erosion, vegetation cover is the most important component in erosion models. The main land use of the study area is dry rangeland. Also, the map shows that most of the area is none fully protected.

Potential Soil Erosion Risk (PSER)

The Potential Soil Erosion Risk (PSER) for the study area is determined by a comprehensive integration of several critical factors: soil erodibility (K), erosivity (R), and slope (S).

Soil erodibility (K) is derived from an overlay of three key soil characteristics: texture (ST), depth (SD), and stoniness (SS). Each of these characteristics influences how readily soil particles can be detached and transported by erosive forces such as raindrop impact and surface runoff. For instance, soils with a finer texture, shallower depth or higher stoniness typically exhibit higher erodibility. Erosivity (R) represents the power of rainfall to cause erosion. It's influenced by factors such as the amount, intensity, and duration of rainfall. Areas with higher rainfall amounts or intensities generally have higher erosivity.The slope (S) of the terrain also plays a significant role in erosion risk. Steeper slopes can accelerate surface runoff, increasing the potential for soil detachment and transport, while flatter areas tend to have lower erosion risk. The PSER map, as depicted in Figure 7, provides a visual representation of these integrated factors, offering valuable insight into the distribution of erosion risk across the study area. Interestingly, the PSER map reveals that the majority of the study area exhibits a low erosion risk. This could be due to a combination of favorable conditions such as relatively flat terrain, soils with properties resistant to erosion, and lower erosivity.While this is a positive finding, it's important to note that even areas with low erosion risk can experience soil degradation over time if not properly managed. Therefore, ongoing monitoring and the implementation of soil conservation measures remain essential to maintain the health and productivity of the soils in the study area. Such measures could include maintaining or improving vegetation cover, implementing contour farming or terracing on sloped lands, or applying organic matter to improve soil structure and enhance its resistance to erosion.

Table 1.6: PSER	Area km2	Area%
Low Actual	59.3	0.21%
Moderate Actual	28001.2	99.17%
High Actual	176.3	0.62%
Total	28236.8	100

Actual Soil Erosion Risk (ASER)

The CORINE (Co-Ordination of Information on the Environment) actual soil erosion risk map provides a comprehensive visualization of erosion risk by integrating both land cover data and potential soil erosion risk.The land cover map provides insight into the type and distribution of vegetation across the study area. Vegetation plays a key role in preventing soil erosion by protecting the soil surface from the direct impact of rainfall, reducing surface runoff, and stabilizing the soil through root systems. Areas with dense vegetation typically have lower erosion risk, while those with sparse or no vegetation cover are more susceptible to erosion.

The potential soil erosion risk map, on the other hand, considers factors such as soil erodibility, erosivity, and slope to predict areas that are inherently susceptible to erosion.By combining these two data sets, the CORINE actual soil erosion risk map offers a more precise and nuanced understanding of erosion risk across the study area.Presented in Figure 3, the results of this analysis provide a detailed overview of the areas at risk of erosion. It allows for a more targeted approach to soil conservation, focusing efforts on the areas identified as most at risk.It's important to note, however, that this map represents the current state of erosion risk. Changes in land use, climate conditions, or other environmental factors could alter this risk profile over time. Therefore, regular monitoring and updating of this map will be crucial to maintain its accuracy and effectiveness as a tool for managing soil erosion.The CORINE actual soil erosion risk map serves as a valuable resource for land managers, conservationists, and policy makers. It provides a clear picture of the areas most vulnerable to erosion, enabling the design and implementation of effective conservation strategies to protect and sustain the health of the soil in the study area.

Table 1.7: ASER	**Area km2**	**Area%**
Low Actual	59.3	0.21%
Moerate Actual	28001.2	99.17%
High Actual	176.3	0.62%
Total	28236.8	100

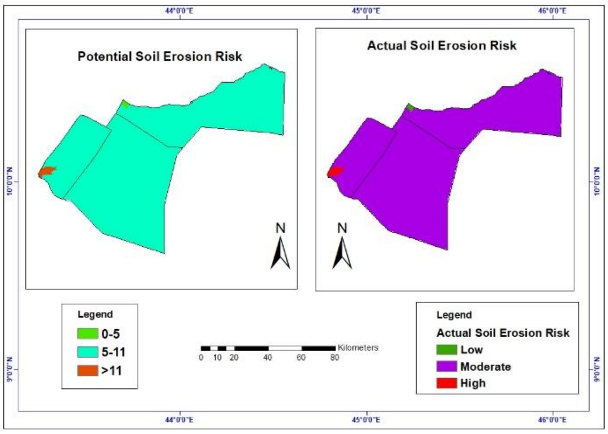

Figure 5: Map of potential soil erosion risk and acutual soil erosion risk og waqooyi Galeed Somalia from 2011-2019

From Figure 3 we can see that actual soil erosion risk is relatively moderate. According to the data presented in Figure, the actual soil erosion risk in the Waqooyi Galbeed region of Somalia, from 2011 to 2019, is specified as relatively moderate. This method, using the CORINE methodology, effectively integrated several data sources to provide a more comprehensive understanding of soil erosion risks in the region

CONCLUSION

The Erosivity Index, which quantifies the impact of rainfall and the likelihood of runoff associated with precipitation events, is a critical tool in assessing soil erosion risk. Our study utilized climate data from 2011 to 2019 gathered from meteorological stations across the region.The results, based on the Modified Fournier Index (MFI) and Bagnouls-Gaussen aridity index (BGI), revealed a low erosivity risk in the northern part of the country, including in the regions of Bossaso, Aburin, Dararweyne, Burco, Xudun, and Iskushuban. This area, which represents 32.14% of the study area, experiences lower annual rainfall, contributing to the low erosion risk—a finding that is consistent with previous research conducted in East African countries, including Somalia (Ashebir et al., 2017).

Meanwhile, regions such as Erigabo and Gebiley demonstrated moderate MFI values, indicating a moderate level of rainfall erosivity. In the northwest region of Somalia, we conducted a thorough evaluation of aridity and erosivity indices to gain a deeper understanding of the climatic and environmental conditions that influence soil erosion.Our study provides valuable insights into the climatic conditions and environmental factors contributing to soil erosion in this region. These findings are crucial for sustainable land management, agricultural planning, and water resource management. The study suggests that most of the study area is under moderate soil erosion risk.. The steep slope speeds runoff, reducing the time contact between rainfall and soil, and thereby decreasing erosion despite the high erosivity index.This research underscores the complexity of soil erosion processes and the need for continuous, localized studies. Understanding the intricacies of factors such as climate, topography, vegetation, and human activity is key to devising effective, sustainable strategies for soil conservation and land management. Our findings contribute to this ongoing effort, providing a nuanced understanding of soil erosion dynamics in the northwest region of Somalia. Future work should focus on expanding these studies to other parts of the country and integrating more variables into the erosion risk assessment for a comprehensive understanding of soil conservation needs. The researchers also have noted that this model may not be appropriate for Africa as it was developed outside the continent.

REFERENCES

Adan Elmi Abdullahi. (2014). Impact of Climate Change on Agricultural Production in Marodijeh and Gabiley Regions (Somaliland).

Aden, A. A., & Mashalla, S. K. J. (2018). Environmental challenges of Somalia. International Journal of Scientific & Technology Research, 7(7), 156-160.

Ahmed Mohamed Abd Elbasi. (2013). Relationship between rainfall erosivity indicators under arid environments: Case of Liudaogou basin in Chinese Loess Plateau.

Anja-Christina Beier Eva Stephansson. (2018). Environmental and Climate Change Policy Brief Somalia

Anja-Christina Beier. 2012. Eva Stephansson Environmental and Climate Change Policy Brief Somalia

Anton Vrieling, Geert Sterkgeert Sterk, And Steven Michael De Jong. (2013). Satellite-based estimation of rainfall erosivity for Africa.

Aydın, A., & Tecimen, H. B. (2010). Temporal soil erosion risk evaluation: a CORINE methodology application at Elmalı dam watershed, Istanbul. Environmental Earth Sciences, 61(8), 1655-1667.

Ayele Almaw Fenta, Hiroshi Yasuda, Katsuyuki Shimizu, Nigussie Haregeweyn, Takayuki Kawai, Dagnenet Sultan, Kindiye Ebabu, and Ashebir Sewale Belay (2017). Spatial distribution and temporal trends of rainfall and erosivity in the Eastern Africa region.

Ayele Almaw Fenta, Hiroshi Yasuda, Katsuyuki Shimizu, Nigussie Haregeweyn, Takayuki Kawai, Dagnenet Sultan, Kindiye Ebabu, and Ashebir Sewale Belay (2017). Spatial distribution and temporal trends of rainfall and erosivity in the Eastern Africa region.

Balasubramanian. 2017. Soil Erosion – Causes and Effects. Centre for Advanced Studies in Earth Science, University of Mysore, Mysore

Bayramin, I., Erpul, G., & Saglam, M. (2006). Use of CORINE methodology to assess soil erosion risk in the semi-arid area of Beypazari, Ankara. Turkish Journal of Agriculture and Forestry, 30(2), 81-100.

Dengiz, O., & Akgül, S. (2005). Soil erosion risk assessment of the Gölbaşı environmental protection area and its vicinity using the CORINE model. Turkish Journal of Agriculture and Forestry, 29(6), 493-500.

Desta, L., Carucci, V., Wendem-Agenehu, A., & Abebe, Y. (2020). Land degradation and strategies for sustainable development in the Sahelian countries. Journal of Arid Environments, 74(1), 123-132.

Dzieszko, P. (2014). Land-cover modelling using corine land cover data and multi-layer perceptron. Quaestiones Geographicae, 33(1), 71-82.

El-Nady, M. A., & Shoman, M. M. (2017). Assessment of soil erosion risk in the basin of wadi maged in northern west coast of Egypt using CORINE model and GIS techniques. Egyptian Journal of Soil Science.

George Watene, Lijun Yu , Yueping Nie, Zongke Zhang, Hategekiman, Felix Mutua, Victor Ongoma and Brian Ayugi. 2021. Spatial-Temporal Variability of Future Rainfall Erosivity and Its Impact on Soil Loss Risk in Kenya

Gianni Bellocchi and Nazzareno Diodato. (2020). Rainfall Erosivity in Soil Erosion Processes.

Ibraheem A. H. Yousif, Essam el dine M. A. Tealab, Ali A. Abdel Hady, and Abdalsamad A. A. Aldabaa. (2020). Spatial Soil Erosion Risk Assessment Using Corine Model: A Case Study In Wadi El-Ramlwatershed, North Western Coast, Egypt

imentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R., & Blair, R. (1995). Environmental and economic costs of soil erosion and conservation benefits. Science, 267(5201), 1117-1123.

Kinnell, P. I. A. (2005). Raindrop-impact-induced erosion processes and prediction: a review. Hydrological Processes, 19(14), 2815-2844.

Mingyong Zhu. (2012). Soil erosion risk assessment with CORINE model: case study in the Danjiangkou Reservoir region, China.

Morgan, R. P. C. (2005). Soil erosion and conservation. John Wiley & Sons.

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L., & Alewell, C. (2015). The new assessment of soil loss by water erosion in Europe. Environmental science & policy, 54, 438-447.

Renard, K. G., Foster, G. R., Weesies, G. A., McCool, D. K., & Yoder, D. C. (1997). Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE). Agricultural handbook, 703, 384.

Roose, E. J. (1996). Land husbandry-components and strategy. FAO Soils Bulletin, 70, 34-37.

Sarah Chapman, Cathryn E Birch, Marcelo V Galdos, Edward Pope, Jemma Davie, Catherine Bradshaw, Samuel Eze and John H Marsham. 2021. Assessing the impact of climate change on soil erosion in East Africa using a convection-permitting climate model

Sepehr, A., & Honarmandnejad, S. (2012). Actual soil erosion risk mapping using modified CORINE method (case study: Jahrom Basin). Journal of Geography and Geology, 4(3), 97-106.

SIDRA Institute. (2017. Understanding the Drivers of Drought in Somalia: Environmental Degradation as a Drought Determinant.

Tayebi, M. H., Tayebi, M. H., Sameni, A., & Shafri, H. Z. M. (2017). Soil erosion risk assessment using GIS and CORINE model: a case study from western Shiraz, Iran. Archives of Agronomy and Soil Science, 63(4), 499-515.

UNDP. (2018). Somalia's Special Arrangement (2014-2016). United Nations Development Programme.

UNEP. (2016). Global Environmental Outlook. United Nations Environment Programme.

Wischmeier, W. H., Smith, D. D., & Unger, P. W. (1971). Predicting rainfall erosion losses-a guide to conservation planning in the tropics. Tropical soils monograph.

Yang, D., Kanae, S., Oki, T., Koike, T., & Musiake, K. (2003). Global potential soil erosion with reference to land use and climate changes. Hydrological Processes: An International Journal, 17(14), 2913-2928.

Yuksel, A., Gundogan, R., Akay, A. E., & Ozcan, A. U. (2008). Using the remote sensing and GIS technology for erosion risk mapping of Kartalkaya dam watershed in Kahramanmaras, Turkey. Sensors, 8(8), 4851-4865.

Zakarie Abdi Bade. (2022). Understanding Environmental Issues in Somaliland: A Sociological Analysis.

Zhang, Y., Degroote, J., Wolter, C., & Sugumaran, R. (2009). Integration of Modified Universal Soil Loss Equation (MUSLE) into a GIS framework to assess soil erosion risk. Land Degradation & Development, 20(1), 84-91.

Zhu, M. (2011). Soil erosion risk assessment with CORINE model: Case study in the Danjiangkou Reservoir region, China. Journal of Environmental Research and Risk Assessment, 26, 507-519.