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Toprak Kayıp Modellerinin Somali İçin Değerlendirilmesi

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ÖZET

Toprak erozyonu, dünyanın birçok yerinde hem tarımsal üretkenliği hem de doğal ekosistemleri etkileyen önemli bir çevre sorunudur. Erozyon kaynaklı toprak kayıpları, halihazırda birçok sosyoekonomik sorunla boğuşan bir ülke olan Somali'de gıda güvenilirliği ve arazi bozulması endişelerini şiddetlendirmektedir. Bu araştırmanın amacı, sürdürülebilir arazi yönetimi ve kaynak planlaması için değerli bilgiler sağlayarak, Somali'deki erozyon riskini değerlendirmek için potansiyel tekniklerin bir incelemesini içerir. Çalışma, uzaktan algılama verileri, coğrafi bilgi sistemi (CBS) teknikleri ve hidrolojik modelleme kullanarak erozyon risk faktörlerini ve ülke genelindeki mekânsal dağılımının incelenebileceğini vurgular. Bu amaçla topografik veriler, toprak özellikleri, arazi kullanımı ve arazi örtüsü verileri, yağış modelleri ve bitki örtüsü indeksleri Somali'de erozyona eğilimli alanları ve hassas noktaları belirlemek için kullanılabilir. Ayrıca, tahmine dayalı modelleri kalibre etmek ve doğrulamak için tarihsel erozyon verileri analiz edilebilir. Somali arazilerinde süre gelen ormansızlaşma, kötü tarım uygulamaları ve aşırı otlatma gibi insan faaliyetlerinin erozyon riskini artırmadaki rolüne bağlı olarak hassas alanların yıllar içerisinde izlenmesi önerilmektedir. Somali genelinde çevresel sürdürülebilirliği koruyabilen verimli erozyon yönetimi tekniklerini uygulamaya koymak için karar vericiler nezdinde kullanılabilecek metodolojilere odaklanılmalıdır.

Soil Loss Models for Somalia

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ABSTRACT

Soil erosion stands as a significant environmental concern impacting both agricultural productivity and natural ecosystems across various regions worldwide. The soil losses attributed to erosion exacerbate concerns about food security and land degradation in Somalia, a country already grappling with numerous socio-economic challenges. This study aims to evaluate the erosion risk in Somalia by examining potential techniques that offer valuable insights for sustainable land management and resource planning. Emphasizing the utilization of remote sensing data, geographic information system (GIS) techniques, and hydrological modeling, the research highlights the exploration of erosion risk factors and their spatial distribution nationwide. Topographic data, soil properties, land use and land cover data, precipitation models, and vegetation indices could be employed to identify erosion-prone areas and sensitive points in Somalia. Furthermore, analyzing historical erosion data can aid in calibrating and validating predictive models. Continuous monitoring of sensitive areas over the years is recommended, considering the role of human activities such as ongoing deforestation, poor agricultural practices, and excessive grazing, which contribute to escalating erosion risks on Somali lands. Decision-makers should focus on methodologies that can be utilized to implement efficient erosion management techniques ensuring environmental sustainability across Somalia.

1. Introduction

Soil loss contributes to land degradation, which contributes to environmental change (Oldeman et al., 1991; Lal et al., 1998). Through changes in the soil profile, soil loss influences the ability of land to dampen atmospheric heat, agricultural productivity, surface water quality, and landscape beauty (Feddema, 1998; FAO, 2003; Gisladottir and Stocking, 2005). Land managers use site-specific methods of control to stop soil erosion by identifying eroding sites or regions with early signs of erosion. Soil erosion is one of the most important environmental and public health problems that human society is currently facing globally.

Soil erosion destroys approximately 10 million ha of cropland each year, reducing the amount of cropland available for food production. Crop loss is a significant issue because there are more than 3.7 billion malnourished people in the world, according to the World Health Organization. According to Pimentel D. (2006), the rate of soil renewal is 10 to 40 times slower than the overall soil loss from land areas, endangering future environmental quality and human food security. East Africa is particularly vulnerable to soil erosion due to its steep topography, fragile soils, and heavy rainfall (Wynants, 2019). Land managers in Somalia are concerned about soil loss because of its impact on biomass production, surface water quality, and landscape beauty. The likelihood of soil loss is increased by clearing vegetation, using inadequate land management techniques, and the negative effects of urbanization. Currently, soil loss research appears to be focusing on improving estimation accuracy (Lim et al., 2005). As a result, there is an expanding gap between the importance of controlling soil loss and research priorities. In order to control accelerated soil erosion, it is necessary to apply and integrate existing research methods for estimating the amount and rate of soil loss. The aim of the study is to evaluate the erosion risk in Somalia and to provide information on techniques that can be used to estimate soil losses.

2. Methods and Materıals

This research employs a desktop review methodology, predominantly drawing upon secondary sources and pre-existing literature pertaining to assessment of erosion risk and prediction of soil losses in Somalia. The existing body of academic research on land use and land conservation measures has played a crucial role in informing this study, offering valuable conceptual frameworks and empirical evidence that serve as a foundation for further investigation. This research was informed by an extensive review and analysis of a diverse selection of pertinent journal articles, conference papers, and other scholarly publications. In essence, this study primarily relies on the examination and integration of pre-existing secondary sources, including previous academic research, statistical databases, and empirical soil loss models focused publications pertaining to the prioritization of conservation efforts in particular regions have both been made possible by the integration of GIS and soil loss models.

2.1. Overview of Erosion

Soil erosion is one of the most serious problems confronting agriculture on a global scale. In particular, in agricultural and rangelands, it poses a serious threat to soil resources, productivity, and ultimately food and fiber production. Although the current problem has existed since the beginning of settled agriculture, its importance and effects on human welfare and the environment as a whole have significantly increased over time. Despite the temporary increase in yield that they frequently cause, continued high rates of soil erosion and the use of fertilizers and other inputs will ultimately lead to a decline in crop productivity. These problems are referred to as erosion's side effects. Environmental pollution is also a result of soil erosion. Floods, reservoir sedimentation, and poor water quality are all effects of erosion downstream. A reduction in soil quality is always accompanied by a reduction in water and, in some cases, air quality. These are the off-site effects of erosion (Lakew & Belayneh, 2012).

2.2. Global Awareness of Soil Erosion

Water erosion is influenced not only by human activities but also by physiographic factors such as rainfall intensity, terrain characteristics, soil texture, and runoff. Understanding soil erosion from water is the subject of extensive international research due to its significance. Numerous methods have been used to evaluate soil erosion, from small farmland scales to regional scales. In recent years, the use of numerical modeling for assessing soil erosion has grown significantly, gaining significant attention and interest from researchers all over the world. The use of numerical models to assess soil erosion has several advantages. For starters, it helps researchers understand and connect the processes of sediment production, transport, and deposition, enhancing their understanding of erosion dynamics (Ding & Richards, 2009).

2.3. Soil Erosion Modelling

In the past decade, the estimation of soil loss and sediment yield has successfully used a variety of erosion and sediment transport models. Erosion modeling is crucial because soil erosion field surveys take a very long time. If measurement is done in the field, it is difficult to analyze the response to land use change and even the management of erosion over long periods of time, and it takes a lot of time to build an adequate database (Morgan, 2005). Erosion prediction models address these limitations by making accurate predictions across a wide range of environmental conditions. The estimations' validity can be checked by comparing them to the measurements (Morgan, 2005). Morgan (1994), identifies two primary reasons for using erosion models: first, to understand the underlying processes and their interconnections; and second, to estimate soil loss for conservation development. Since the 1930s, scientists have struggled to predict and assess soil erosion, and numerous models have been developed (Lal, 2001). Physical process-based, semi-empirical, and empirical models are the three main types of soil loss prediction models. Empirical models frequently have a statistical basis and rely heavily on observed data. Semi-empirical models bridge the gap between physically process-based models by using spatially lumped equations for the continuity of water and sediment. Physical process-based models, on the other hand, strive to adequately capture the underlying principles that control erosion. These models show the incorporation of numerous erosion-influencing elements, such as the intricate interconnections between various causes and their temporal and geographical changes (Jha & Paudel, 2010).

2.3.1. RUSLE modelling

Erosion models are used to forecast soil erosion. Soil erosion modeling allows for the representation of complex interdependencies that impact erosion rates within a watershed. RUSLE is the result of several factors, including soil, climate, vegetation, topography, and human activity, and it is used to calculate the rate of soil loss from hillslopes (Shi et al. 2004; Teng et al. 2018). RUSLE is a useful tool for assessing the potential for soil erosion at different spatial scales. These studies demonstrate RUSLE's versatility and applicability in quantifying soil erosion risks across large geographic areas, allowing for informed decision-making and effective soil conservation strategies. RUSLE is straightforward to apply (Gao, 2008). Consequently, it may be employed in places with insufficient data, particularly in developing nations, and it can also be quickly altered when paired with GIS to enable its use at a variety of spatial scales and certain regional locations under different environmental situations (Zhou et al., 2008). RUSLE's utility as a tool for assessing soil erosion risk extends to capturing erosion spatial variability at both watershed and basin scales. Previous versions of the tool were used by Cohen et al. (2005) to assess erosion risk in a Kenyan basin and by Irvem et al. (2007) in Turkey's Seyhan River Basin. These studies demonstrate how the tool and its predecessors can be used to visualize erosion patterns and identify regions that are more vulnerable to erosion, allowing for more focused conservation efforts and wise land management choices. The USLE erosion model was applied by Yılmaz (2006) in the 722 km^2 amldere Dam Basin, which supplies water to Ankara. The average annual soil loss in the basin was found to be 7.3 tons per hectare, with vegetation and topography being the main contributors to soil erosion there. All parameters were integrated and included in the model by the researcher. He determined that the annual soil loss on 47% of the land was less than 3 t ha-1 year-1 based on the model findings, and he indicated that the fact that the area was covered with vegetation had a significant impact on this conclusion. RUSLE includes general database sets from which the user can choose. Climate, crop (plant data representing above- and below-ground characteristics), and operations (farming and soil disturbance factors) databases are included. Due to the breadth of the information in these database sets, the user may require additional sets or modify an existing set to better describe a specific site where a soil loss estimate is required (Renard & Ferreira, 1993). To determine soil loss for a specific region, six primary parameters are used. Each parameter is a mathematical estimate of a condition that influences the intensity of soil erosion at a specific location. The predicted erosion values provided by this model may vary significantly due to varying weather conditions (Renard et al., 1997). RUSLE is used to calculate erosion values in order to provide a more accurate estimation of long-term averages. RUSLE has emerged as a valuable tool for planning erosion control activities and evaluating soil losses in agricultural watersheds. This model is based on the simple equation A=R*K*LS*C*P, where A represents the average annual potential soil loss in tons per hectare per year. The equation incorporates several important erosion assessment factors. R denotes the rainfall runoff erosivity factor, K the soil erodibility factor, LS the slope length and degree factor, C the land cover management factor, and P the conservation practice factor. The model's integration of GIS-based techniques, which allow for the estimation of factor values at the grid cell level, makes it particularly efficient. It enables accurate calculations and assessments throughout the study area by utilizing spatial analysis and data processing capabilities. This model is frequently used by researchers and land managers to direct planning for erosion control and assess potential soil losses. This highlights its usefulness in assisting decision-making procedures aimed at reducing soil erosion and maintaining agricultural landscapes (Renard et al., 1997).

2.3.2. CORINE model

The CORINE Model is an experimental model that has the capability to provide spatially accurate predictions of soil erosion. It is a semi-qualitative cartographic approach that includes developing and combining multiple thematic map layers within a GIS framework. This model demonstrates the geographical variations in soil erosion risk. The CORINE model's GIS implementation is relatively simple and benefits from its straightforward structure. The model has been successful in identifying areas at high risk of erosion, particularly in Mediterranean regions (Gobin et al., 2003). Zhu (2012) conducted a comprehensive study to address soil erosion and protect soil and water resources in the Danjiangkou area of China. This study used GIS and RS techniques to integrate the SER, DRR, and CORINE models. The primary goal was to identify areas at high risk of erosion (based on the SER) and develop appropriate erosion control strategies. According to the findings, approximately 59.1% of the study area had a low erosion risk, 31.2% had a medium risk, and 2.3% had a high risk. This study demonstrates the efficacy of using integrated models and spatial analysis tools to identify erosion-prone areas and inform targeted erosion mitigation efforts. Dindarolu and Canpolat (2013) conducted a study at Kuzgun Dam Lake to identify areas where soil losses occur and to make management recommendations to address the issue. The CORINE model evaluated soil characteristics based on land use conditions using Landsat satellite images of Erzurum Province, and the model identified areas that were or may be degraded. According to the map results, 39% of the soils are at moderate risk of degradation, while 34% are at severe risk. Researchers discovered that 53% of the basin's soils are at risk of severe degradation based on model results. Furthermore, they claimed that, while forested lands are protected from loss, studies should be conducted to prevent loss on agricultural lands and grazing fields with steep slopes.

2.3.3. Soil loss estimation model of Southern Africa (SLEMSA)

The SLEMSA soil loss model is widely used in African environments (Elwell & Stocking, 1982). It is a modeling technique or framework that makes no universal claims but rather mechanistic descriptions of the system. The SLEMSA framework is a methodical procedure for developing models to predict sheet erosion on arable land in southern Africa. The SLEMSA framework is a methodical procedure for developing models to predict sheet erosion on arable land in southern Africa. The framework was intended to be used to build a variety of sub-models, each tailored to a specific set of land, climate, and land-use conditions. Despite the fact that the current set of sub-models for calculating SLEMSA factors used by the Zimbabwe Agricultural Services were developed specifically for the Zimbabwean highveld, they are now being used to provide the best estimates of sheet erosion throughout Zimbabwe and elsewhere in southern Africa in the absence of additional data (Elwell, 1996). In a study on the applicability of SLEMSA in mountainous areas, Hudson (1987) discovered that estimates of soil loss were very sensitive to variations in slope steepness (S) and rainfall energy (E). A weakness of the model is the apparent overestimation of soil loss values due to the co-linearity between the slope steepness (S) and slope length (L) factors. The problem worsens as the slope steepness increases, indicating that the topographic sub-model should be modified if SLEMSA's predictive ability in nugget terrain is to be improved. The study also demonstrated the inodel's relative insensitivity to changes in slope length. SLEMSA calculated absolute soil loss values that were 20 times higher than the actual measurements. Hudson (1987) modified the slope subroutine, which greatly increased the applicability of SLEMSA in mountainous terrain. This is demonstrated by the slope length (L) factor, the combination of the modified L and rainfall energy (E), and the inclusion of a complex slope profile factor. Because it acts as an index of the spatial distribution of soil loss, SLEMSA is regarded as a useful model for distinguishing between regions with a high and low potential for erosion. The application of the Water Erosion Assessment Program (SWEAP) model to the SOTER (soil and terrain) database at a scale of I: 000 000 by ISRIC (1995) provided confirmation of this. The erosion risk assessment models USLE and SLEMSA are currently part of the SWEAP model subsystem. Both models were modified to work with the SOTER database's capabilities and constraints.

2.3.4. Geographic information system and modelling of soil erosion

Numerous scientific studies have been conducted over the last decade using GIS and RS technologies to evaluate soil erosion over large areas (Sheikh et al., 2011). These studies have shown that these approaches are effective and cost-effective in providing accurate information about eroded areas, including soil types, lithological units, and vegetation, at a reasonable cost. Several integrated models combining GIS and remote sensing for predicting water and soil erosion have also been published (Fullen, 2003; Merritt et al., 2003). Remote sensing can be analyzed in the Arc GIS software environment in conjunction with GIS (Karabulut et al., 2008). GIS is becoming increasingly important in landscape planning and conservation. Estimating erosion in an area is a broad and useful strategy in soil conservation and planning studies, and more effective and accurate data can be collected using GIS technology (Okatan et al., 2007).

3. Conclusion

Empirical soil loss models have been a critical component of soil erosion research and management in Somalia. Empirical soil loss models are mathematical equations that predict soil erosion based on variables like rainfall, land cover, soil type, slope, and land management practices. These models help researchers, policymakers, and land managers understand and forecast the extent of soil erosion, which is a major environmental issue in Somalia due to the negative effects it has on agricultural productivity, water quality, and ecosystem health. Several empirical soil loss models have been developed and applied in Africa, the most widely used being the Universal Soil Loss Equation (USLE) and its revised version, the Revised Universal Soil Loss Equation (RUSLE), and the Soil Loss Estimation Model of Southern Africa (SLEMSA). These models have been adapted and calibrated to account for the diverse soil and climate conditions found throughout Africa. They provide useful information about soil erosion hotspots, assisting in the identification of erosion-prone areas and the implementation of targeted soil conservation and land management strategies. This is most likely why none of the empirical soil loss models were properly adapted and validated over time and across a wide range of local conditions. The latter is required for models to be used routinely in order to accurately and confidently predict soil loss values. However, the research shows the value of empirical models in soil conservation research and planning. It has contributed to a better understanding of the factors that influence erosion in Somalia. This is critical for the direction of soil conservation research. It serves as a foundation for future modeling efforts. It also provides insights into data collection and, in some cases, measured values for some model input data. Over the next ten years, erosion modeling will face the most challenges, including the need to model erosion in a spatial and temporal context and integrate erosion models and/or their results with other land assessment models and/or techniques. Because the use of empirical soil loss models to predict absolute values is limited due to a lack of verification, process-based models are the obvious method for accurately estimating soil erosion values. These models use physically sound equations and factors to accurately reflect the underlying erosion processes. With relative confidence, empirical models could be used as screening models, particularly in a spatial context and typically through the use of a GIS. There are already several examples of empirical models being spatially applied, such as USLE/RUSLE or parts (factors) of the models. Typically, it is challenging to manually calculate slope length and other topographic data. Other instances of the spatial application of USLE and RUSLE include Flacke, Auerswald & Neufang (1990), Mitasova & Iverson (1996), and Busacca et al. (1993). In South Africa, Pretonus & Smith (1998) created a land use planning decision support system with the risk of erosion as the main criterion, among other tools, in a GIS environment. Pretorius (1998) created RUSLE-based late-dewadation monitoring and auditing techniques with the aid of remote sensing and GIS technology. The use of these models in Africa has also been associated with the advancement of Geographic Information Systems (GIS) technology, which facilitates the spatial analysis of soil erosion risk across large areas. The better visualization of erosion patterns and the prioritization of conservation efforts in particular regions have both been made possible by the integration of GIS and soil loss models. If data requirements could be met, process-based models could be used to generate quantified estimates of soil loss and sediment yield in field-size areas and catchments. The results could be used to assess the quantitative land resource base. These models must be calibrated using field research and process-based modeling techniques with measured local input data. This motivation would help to establish this technology for erosion prediction in East Africa. In Somalia, the use of empirical soil loss models has had both successes and setbacks. On the plus side, these models have helped policymakers and land managers develop effective erosion control and land conservation strategies. These models enable a more targeted approach to soil conservation by identifying vulnerable areas, allowing for more efficient resource and effort allocation. The availability and quality of data required for accurate application of these models, on the other hand, are critical factors. Some African regions may lack reliable data on factors such as rainfall, land use, and soil characteristics, which can affect the model's precision. Efforts should be made to improve data collection and sharing mechanisms in order to improve the accuracy of soil loss assessments. Additionally, Africa's diverse socioeconomic and cultural contexts must be recognized. Implementing soil conservation measures may necessitate community cooperation and understanding. Cultural practices, land tenure systems, and economic conditions can all have an impact on the adoption and effectiveness of conservation efforts. As a result, it is critical to involve local communities and stakeholders in the planning and implementation of soil erosion control measures. Furthermore, climate change is expected to change rainfall patterns and intensities, potentially altering soil erosion rates in different areas. As a result, soil loss models must be regularly updated and adjusted to account for changing climate conditions. To summarize, empirical soil loss models have been useful in addressing soil erosion issues and providing a scientific foundation for soil conservation strategies in East Africa. To ensure their long-term effectiveness, however, ongoing efforts to improve data availability, involve local communities, and adapt to changing climate conditions are required. In order to develop sustainable soil erosion control measures tailored to the specific needs of Somali regions, it will be critical to integrate technological advances and local knowledge.

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Conflict of Interest

No potential conflict of interest was reported by the author(s).

Authors' Contributions

The authors declare that they have contributed equally to the article.

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