The impact of soil erosion on environments: A case study of the Oued Beht Watershed (Morocco)

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Abstract. Soil erosion poses a significant environmental challenge in the Oued Beht watershed, Morocco, impacting local ecosystems and water quality. This study investigates the causes and effects of soil erosion in this region, utilizing Geographic Information System (GIS) tools and field techniques to analyze land use changes, agricultural practices, soil properties, and precipitation patterns. The findings establish a clear link between soil degradation and declining water quality in nearby aquatic environments. Major contributors to soil erosion include intensive agriculture, climate change, deforestation, vegetation degradation, and steep terrain. To predict future erosion rates, models were used, emphasizing the need for proactive management strategies. To address these issues, the study suggests implementing sustainable agricultural practices and soil conservation measures like agroforestry, vegetative buffer strips, and slope management. These measures can effectively reduce soil erosion and its adverse effects on water quality. The study underscores the importance of integrated management approaches to preserve biodiversity and soil fertility in the region. The findings provide crucial information for policymakers to adopt sustainable land conservation and management policies, ensuring the protection of aquatic ecosystems and environmental sustainability in the Oued Beht watershed.

Keywords: Soil erosion, Watershed, Oued Beht, Environments, GIS.

1.Introduction

Soil erosion is an age-old phenomenon significantly impacting human civilization and the pursuit of a better quality of life. It can be caused by natural factors or result from socio-economic development over the years. The materials eroded by erosion have effects both at the erosion site and beyond, harming both flora and fauna. These effects can be exacerbated by inter- and intra-ecosystem reactions [1, 2].

Soil erosion issues in the Mediterranean uplands have been known in Morocco for over 50 years. Due to population growth, deforestation, and overgrazing, there is a degradation of the vegetative cover, leading to increased runoff, gully erosion, riverbank scouring, hillside landslides, and accelerated sedimentation in reservoirs [3]. In regions with a growing population, agricultural production, urbanization, and human activities make soil erosion a major problem [4]. Among the factors responsible for soil erosion is poor land management, which damages the soil and leads to water runoff instead of adequate infiltration [5].

Soil erosion is characterized by three actions: soil detachment, transport, and deposition, which result in the displacement of the topsoil layer rich in organic matter, nutrients, and soil life.

This can occur on the erosion site over time or be transported off-site, where it accumulates in drainage channels. Unprotected sloping areas are particularly vulnerable [6]. Erosion pollutes nearby water bodies, reduces the productivity of agricultural lands, and disrupts water quality and recreational activities.

1.1 Study Area

The Oued Beht watershed, which contains two dams, the upstream El Kansera Dam, and the central Ouljet Essoltane Dam, covers an area of 6196.26 km2. The study area has an elongated shape oriented in the NW-SE direction. To the north, it is bordered by Sidi Kacem and Sidi Slimane, to the northeast by Meknes, to the east

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by El Hajeb, Ifrane, and Jbel Hebri, to the south by Mrirt and Oued Oum Rabia, and to the west by Oulmes and Khemisset.

The Oued Beht is a sub-basin of the Oued Sebou basin. The watercourses of this river originate in the northern central region of Morocco and the western Middle Atlas. It joins the lower Oued Sebou after crossing the central Rif southern trench, where it receives contributions from a number of significant tributaries, then the Pre-Rif and the southern part of the El Gharb plain, which is part of the western central Rif southern trench (Fig.1).

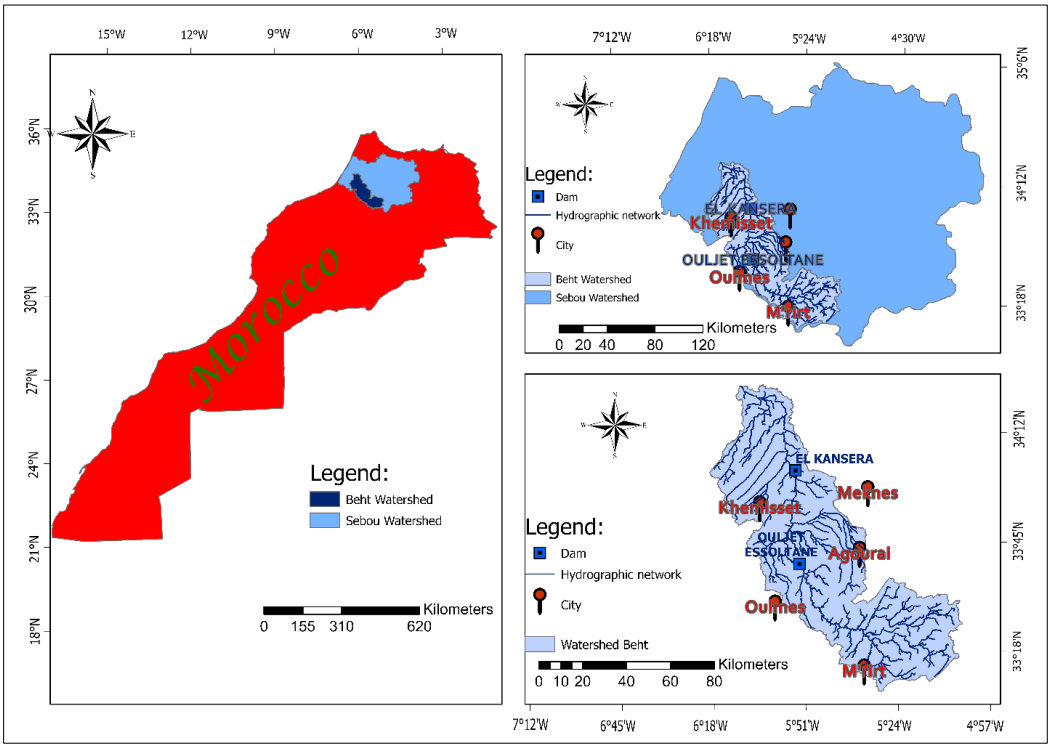

Fig. 1. Location of the Oued Beht watershed.

From a geological perspective, the study area comprises formations ranging from the Paleozoic to the Quaternary. The geological formations of the Paleozoic basement and cover dip beneath Upper Miocene formations in the central Rif southern trench. The Miocene formations are unconformably overlain by the deposits of the fluvial terraces of the Oued Beht, which are stratified and nested [7].

The watershed is situated on three geological and structural domains: the Hercynian Central Morocco [8, 9, 10], the Middle Atlas Causse, and the southern Rif trench. It is entirely established on the impermeable formations of the Primary and Permo-Triassic of the Central Massif. The Quaternary basalts over which the Oued Beht flows at its source are of little significance to be considered [11].

In the vast Paleozoic complex, of Ordovician, Silurian, and Carboniferous age, shales make up the bulk of the formations and sometimes show intercalations of quartzites and limestones. Further north, but upstream of El Kansera, the red saline clays of the Permo-Triassic appear, associated with a few limited extent basalts [9], (Fig. 2).

The climate is Mediterranean with two seasons: a wet and cold season, and a dry and hot one. Annual average precipitation is irregular, with a yearly mean of 700 mm across the entire basin [12]. Rainfall is unevenly distributed throughout the year and varies significantly from one year to another and from one month to another. These rains often occur in the form of thunderstorms and are characterized by occasionally violent floods [13].

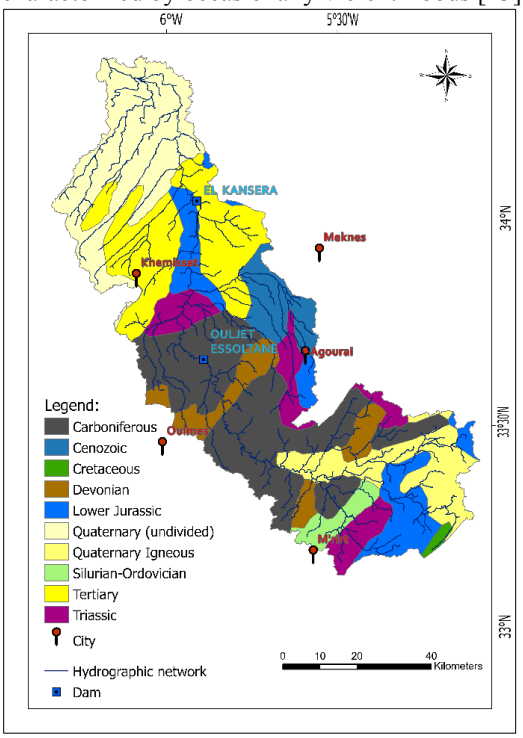

Fig. 2. Geological map of the Oued Beht watershed.

1.2 Erosion in the Oued Beht Watershed

Several predominant features define the current dynamics of the Oued Beht watershed, and among these, water erosion holds a central position. This type of erosion is responsible for the significant soil's loss, which are subsequently trapped in reservoirs. It is influenced by various factors, including the composition of geological formations, especially surface layers, soil nature, terrain slope, slope orientation, and land use practices.

1.2.1 Tools and Methodology

The methodology established to achieve our objectives primarily aims to create comprehensive maps of soil losses due to water erosion. This approach necessitated the mapping and integration of all the necessary parameters into a Geographic Information System (GIS) for the application of an empirical model. Furthermore, we utilized spatial analysis techniques to assess the damages caused by water erosion in this watershed (Fig.3).

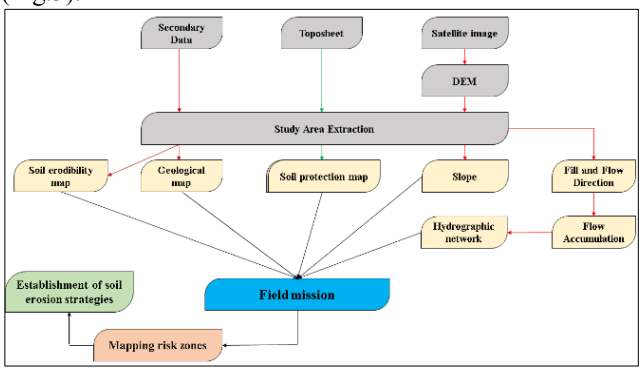

Fig.3. Flow chart of methodology.

2.Results and discussion

Using technologies such as Geographic Information Systems (GIS) and remote sensing, we have developed soil protection maps and erosion status maps. These maps play a fundamental role in assessing potential damages caused by erosion and conducting environmental impact studies related to soil management. They are crucial for analyzing the environmental impacts of erosion, especially with regard to water quality and soil loss (Fig.4 & 5).

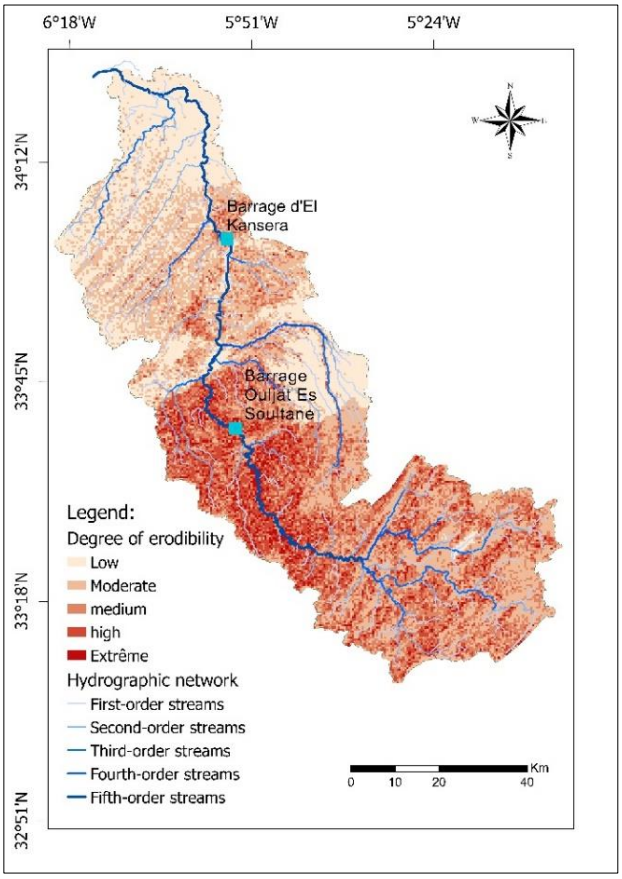

Fig.4. Soil erodibility map of study area.

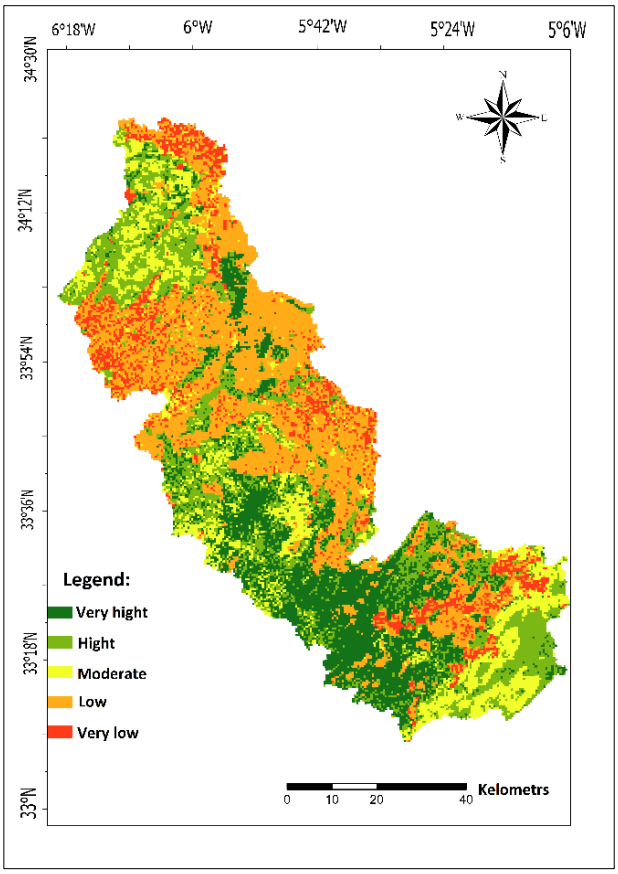

Fig.5. Soil protection map.

Erosion is a natural phenomenon that occurs when the force of moving water dislodges and displaces soil particles, causing a gradual loss of the soil's top layer. However, due to human intervention, such as deforestation, intensive agriculture, and urbanization, this natural process is significantly exacerbated [14]. This acceleration of water erosion has detrimental consequences for the environment, including promoting river sedimentation, water pollution, and an increased risk of flooding.

2.1 Soil Sedimentation

When erosion occurs, soil particles are detached and carried by runoff to rivers. This can lead to the accumulation of sediments in rivers, lakes, and reservoirs, a phenomenon known as soil sedimentation. Sedimentation reduces water storage capacity and can result in serious issues such as decreased water quality, aquatic life destruction [15], and a reduction in reservoirs' ability to provide drinking water (Fig.6).

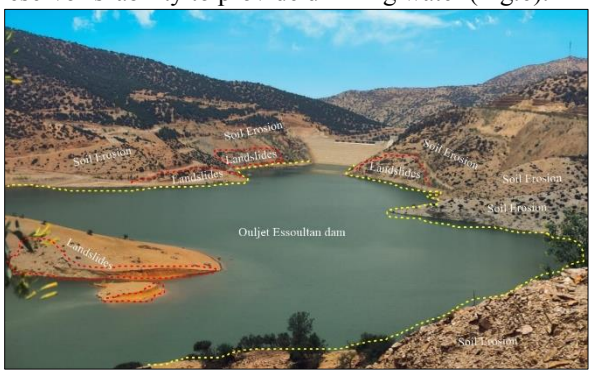

Fig.6. Soil Sedimentation and risks associated with the Ouljet Essoultane dam.

2.2 Water Pollution

Soil erosion not only transports soil particles but also contaminants like pesticides, fertilizers, oils, and heavy metals to water bodies. These pollutants can have devastating effects on aquatic ecosystems, leading to the proliferation of harmful algae, fish deaths, water quality deterioration [16], and a threat to human health if rivers are used as a source of drinking water (Fig.7).

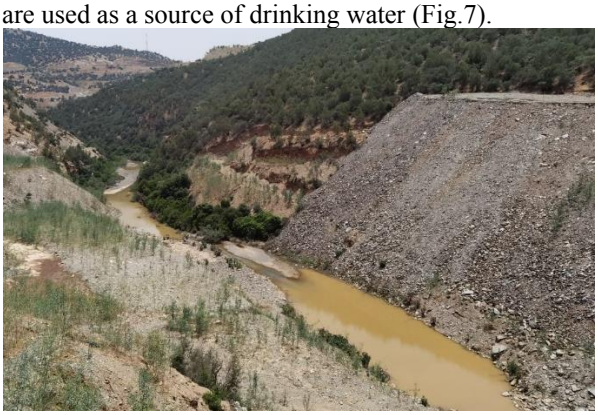

Fig.7. Water Pollution in Beht Watershed.

2.3 Flooding

Erosion can also contribute to flooding by increasing surface runoff. When protective vegetation is removed, heavy rain can lead to more severe flooding as the water cannot be absorbed by the soil. Sediments carried by erosion can clog drains and rivers, raising the risk of floods [17, 18]. Floods have devastating consequences for populations, infrastructure, and ecosystems.

2.4 Landslides

Soil erosion can weaken the slopes of hills and mountains by removing vegetation and exposing soil to weathering [19]. This increases the risk of landslides, which are devastating events that can cause significant human and material losses. Landslides are often triggered by heavy rains, and increased erosion raises the likelihood of these catastrophic events (Fig. 8).

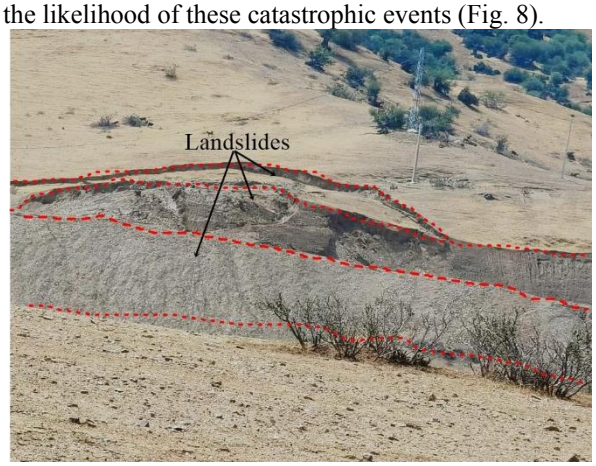

Fig. 8. Landslides in Beht Watershed.

2.5 Soil Degradation

Soil erosion contributes to the degradation of agricultural land and natural ecosystems. Eroded soils lose their fertility, water retention capacity [20], and ability to support vegetation, leading to a decrease in agricultural productivity and biodiversity loss. Soil degradation has long-term economic and environmental repercussions (Fig. 9).

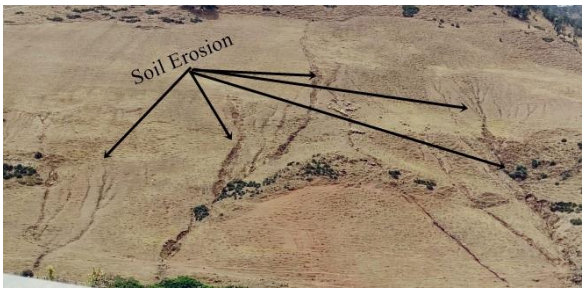

Fig.9. Soil Degradation in Beht Watershed.

Erosion has significant impacts on the environment, including soil sedimentation, water pollution, flooding, landslides, and soil degradation [21]. To minimize these impacts, it is essential to implement sustainable land

management practices, restore vegetation, control unplanned urbanization, and raise awareness about the importance of soil conservation. Preserving soils is crucial for the health of our planet and its inhabitants.

3.Conclusion

The consequences of erosion, a natural process aggravated by human activities, have wide-ranging environmental implications. This study investigated the multifaceted effects of erosion on soil sedimentation, water pollution, flooding, landslides, and soil degradation, highlighting the urgent need for mitigation measures.

Erosion-induced soil sedimentation poses a threat to plant growth and agricultural soil quality. Implementing sustainable agricultural practices and promoting soil conservation are crucial in addressing this issue. Water pollution, directly linked to erosion, adversely affects aquatic ecosystems and water quality, emphasizing the importance of implementing watershed management strategies.

Erosion exacerbates flooding by reducing the soil's capacity to absorb water, while unplanned urbanization and deforestation further amplify flood risks. Effective flood management policies should include measures to protect against erosion. Landslides, triggered by soil instability caused by erosion, present significant risks that necessitate preventive actions such as reforestation and soil stabilization.

To tackle the impact of erosion comprehensively, concrete actions are required. These actions encompass soil conservation practices, the protection of buffer zones, ecosystem restoration initiatives, and raising public awareness. By implementing these measures, we can ensure a sustainable future for generations to come.

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