Soil Erosion Assessment Using EPM Model in Onsar Wadi Basin in the Prerif Mountains, Morocco

Évaluation de l'érosion des sols à l'aide du modèle EPM dans le bassin de l'Oued Onsar dans les montagnes du Prérif (Maroc)

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Abstract

The study assesses water erosion in the Prerif area in northern Morocco using GIS, remote sensing, and applying the Erosion Potential Model (EPM), also known as the Gavrilovic model. By analysing data layers on lithology, aspect, slope, precipitation and land use, the study quantifies erosion rates and their spatial distribution. The field work and modelling reveal important approaches to analyse, study and quantify soil erosion. The results demonstrated a moderate erosion (500-1500 $\mathrm{m}^3/\mathrm{km}^2/\mathrm{year}$) affecting over 50% of the Onsar Wadi Basin (OWB), covering around 53 km^2. Areas with severe erosion impact about 4% of the OWB, with erosion rates exceeding 20,000 $\mathrm{m}^3/\mathrm{km}^2/\mathrm{year}$. The findings aim to inform strategies and predicting areas at risk of erosion for mitigating erosion's adverse effects on natural resources.

Keywords: Water Erosion. Assessment. EPM. Rif Mountains. Morocco.

Résumé

L'étude évalue l'érosion hydrique dans la région de Prerif au nord du Maroc en utilisant le SIG, la télédétection et en appliquant le Modèle de Potentiel d'Erosion (EPM), également connu sous le nom de modèle Gavrilovic. En analysant les couches de données sur la lithologie, la pente, les précipitations et l'occupation du sol. L'étude quantifie les taux d'érosion et leur répartition spatiale. Le travail de terrain et la modélisation révèlent des approches importantes pour analyser, étudier et quantifier l'érosion du sol. Les résultats ont mis en évidence une érosion modérée (500-1500 $\mathrm{m}^3/\mathrm{km}^2/\mathrm{an}$) qui affecte plus de 50% du Bassin d'Onsar Wadi (OWB), couvrant environ 53 km^2. Les zones avec un impact d'érosion sévère

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environ 4% de l'OWB, avec des taux d'érosion dépassant 20 000 $\mathrm{m^3/km^2/an}$. Les résultats visent à éclairer les stratégies et à prédire les zones à risque d'érosion pour atténuer les effets néfastes de l'érosion sur les ressources naturelles.

Mots-clés: Érosion hydrique. Évaluation. EPM. SIG. Montagnes du Rif. Maroc.

1. Introduction

Erosion is a multifaceted phenomenon and complex process in which soil materials are transported by dynamic agents including water runoff and gravity on slopes, creating erosion-induced sediment yield (Ffolliott et al., 2013). Soil erosion has become one of the main causes of land degradation, and a major global environmental concern, because of the effect of surface waters and mass movements. It is becoming a challenge that threatens dry and semi-arid areas, particularly in mountainous basins due to mass movements and surface erosion that allow soil to be transported (Roose & De Noni, 2004). To achieve erosion protection, the factors that influence erosion, such as lithological conditions and soil material, climate, runoff, topography, surface cover, land use need to be considered. Soil erosion is a complicated process, with evident social and environmental impacts that potentially threaten human life.

In northern Morocco, especially in semi-arid zones has undergone decades of significant degradation aspect related mainly to the growth of populations, overexploitation and the pressure on natural resources. One of the aspects of this deterioration is the soil degradation, which has accelerated at an alarming rate and threatening to drive desertification and the potential siltation of dams (El-fengour et al., 2018; El Motaki et al., 2019). The value of these research findings is being influenced by multiple factors. The study area is characterized by limited rainfall and fragile ecosystems, facing major challenges, especially the forms and magnitude of erosion, a process exacerbated by successive dry years (Cheddadi et al., 2016; El Motaki et al., 2019), and exacerbated by increasing human pressures, due to the population density in the area.

Erosion in the Moroccan Prerif is one of the most striking and worrying geomorphological processes for the territorial dynamics of this mountainous region in the north of the country (Hmamouchi et al., 2020). The marly and schistose formations, particularly friable, combined with steep slopes and a rainfall regime marked by intense episodes, create favorable conditions for active erosion acting in different forms: sheet erosion, landslides, or even complex mass movements (El Fellah & Mastere, 2015). The extension of agricultural land on unstable slopes, progressive deforestation, and overgrazing accentuate soil degradation and considerably reduce protective plant cover. Thus, the region records erosion rates among the highest in Morocco, leading to a massive transport of sediments towards the valleys and significant sedimentation at the level of wadis and dams (Abdellaoui et al., 2002).

The environmental impacts of this erosive dynamic are multiple. It decreases the productive capacity of agricultural land due to the lack of nutrients in the soil, accentuating, in the long term, the phenomena of sterilization and loss of fertility. On the other hand, the increase in sedimentation in watercourses reduces the storage capacity of hydraulic infrastructures, worsens the quality of their waters, and alters the local aquatic ecosystems (Tribak et al., 2009). Besides, the increase in landslides and instabilities in slopes represents a permanent threat for housing, rural roads, transport networks, and public facilities (El-Fengour et al., 2020).

On the social level, erosion enhances the vulnerability of local populations whose livelihoods are largely based on rain-fed agriculture and extensive livestock farming (El Motaki et al., 2019). The decline in agricultural productivity, the increasing costs of maintaining damaged infrastructure, as well as land insecurity induced by continuous land degradation, exacerbate the economic difficulties of rural households. In some villages, erosive phenomena contribute to the gradual abandonment of marginal lands, promoting rural exodus, loss of agro-pastoral heritage, and increased pressure on urban centers (Ftaita et al., 2012). All these impacts underpin the urgent need to apply an integrated soil and natural resource management strategy, matching hillside development with reforestation, sustainable grazing management, and agricultural practices that are adapted to the fragile conditions of the Prerif.

The increasing severity of amputation and deforestation in the Prerif areas of the Central Rif leads to soil loss, reduced agricultural productivity, and increased sedimentation of water infrastructure, especially in the southern margins of the Central Rif that contains the largest water structures, such as the Al Wahda and the Idriss I Dams, the area includes the largest number of dams in Morocco, which exceeds 18 dams of different types and sizes (Mosaid et al., 2024). This exacerbates and accelerates the shortening of the lifetime of these dams due to the acceleration of erosion processes due to the violence of the upstream dynamics.

The objectives of this paper are to determine the major processes of soil erosion and sediment production and to map water erosion at OWB in Central Rif Mountains (Figure 1), especially the Prerif, Morocco by applying the EPM for evaluating the quantity of sediment loss based on different parameters used in a semi-arid environment for providing appropriate solutions for proper management and reducing erosion impacts in the region to ensure the sustainability of natural resources and strengthen the socio-economic situation of the concerned population.

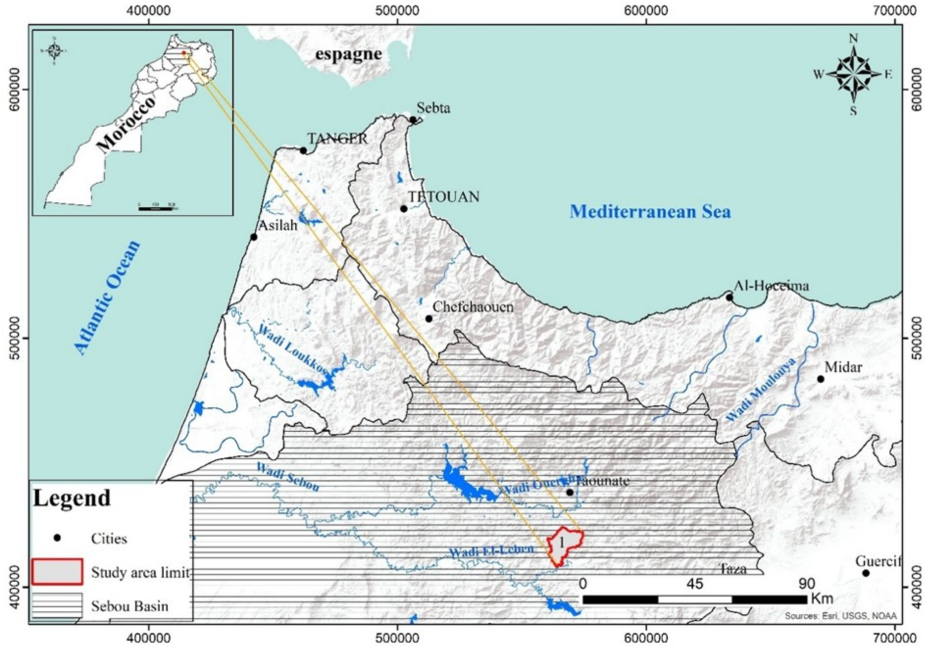

Figure 1. Placement of Onsar Wadi Basin in northern Morocco.
Source: made by the authors.

2. Methods

The EPM model can accurately estimate erosion rates and identify regions at risk of land degradation particularly in mountainous areas which makes it particularly well-suited to the accurate assessment of erosion rates. By integrating many parameters serves as the database through this model for assessing erosion rate (Gavrilovic et al., 2004). The application of the Gavrilovic model relies on a range of parameters for mapping and integrating the necessary parameters, related to the catchment characteristics including slope, lithology composition, vegetation status, climatic conditions. The EPM results are averaged soil erosion loss in $\mathrm{m}^3/\mathrm{km}^2/\mathrm{year}$ based on the analytical formulation shown in Equation 1.

$$W = T \times H \times \pi \times \sqrt{Z^3} \tag{1}$$

Where,
W: is the volume of soil erosion (m^3/km^2/year),
H: is average annual precipitation in basin [mm],
Z: is erosion intensity,
T: is the coefficient of temperature (Equation 2).

$$T = \sqrt{\frac{t_0}{10} + 0.1} \qquad t_0\text{: Average annual temperature in (°C)} \tag{2}$$

The EPM is based on two fundamental processes of the spatial modelling of water erosion and the estimation of the quantity of soil lost per year (Gavrilović, 1972). The first phase involves studying the qualitative assessment of erosion (Z). This outcome constitutes a significant indicator for the subsequent phase, which examines the quantitative assessment of annual erosion (Figure 2). Z is an erosion coefficient relay on four factors contorting erosion process (rock, soil, topography, vegetal cover and land use), (Equation 3).

$$Z = Y \times X_a \times \left(\phi + \sqrt{Ja}\right) \tag{3}$$

Where:
Ja: is the mean slope.
X_a: is a soil protection coefficient.
Y: is a soil erodibility coefficient.
ϕ: is a coefficient of type and extent of erosion.

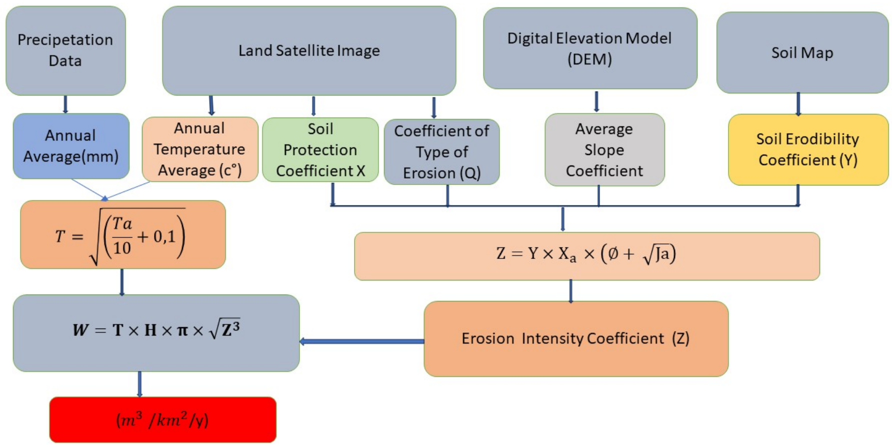

Figure 2. Organization of EPM adopted for determining Z and W indexes.
Source: made by the authors.

2.1. EPM inputs

2.1.1. Geomorphological Structure

The geological factor is one of the indicators that increase or reduce rock sensitivity to erosion (Tangestani, 2006); Soil structure, texture, organic matter content and permeability are the main characteristics to calculate this factor. To determine this factor, this study is based on the available geological map to calculate the sensitivity of rocks and their degree of resistance to erosion according to EPM model.

2.1.2. Topography enhances the slopes fragility in OWB

The slope factor (Ja) is derived from the topography and considered as a fundamental element in quantifying soil erosion and sediment production, and is of great importance within the EPM, due to its strong association with enhancing or reducing the volume and violence of surface water runoff (Figure 3). In addition, the increasing role of raindrops, as well as the increase in water flow velocity is controlled by the nature of the terrain, where the flow force increases towards the bottom, allowing for the uprooting and transport of sediments (Roose, 2008), and vice versa, the water speed and its ability to uproot and transport decrease as the slopes weaken. The relative difference in elevation exceeds 550 m in the OWB, on slopes with very friable materials from formations dominated by shale rocks. The coefficient was used the DEM (Digital Elevation Model) to extract the coefficient; classify slopes into five categories ranging from 0 to 26 to more than 95% (Table 1).

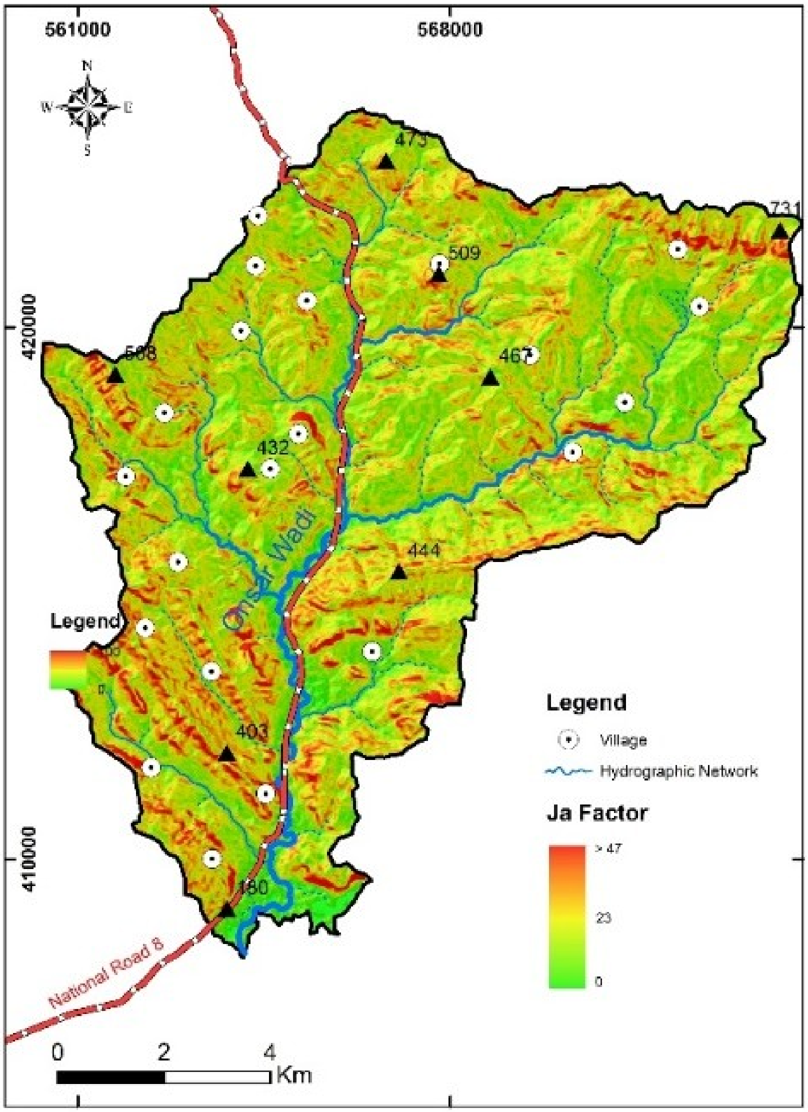

Figure 3. Slope coefficient (Ja (%)).
Source: made by the authors.

Table 1. Average slopes coefficient (J_a).

Classes of J_a	**Area km^2**	**%**
Very low	23	19
Low	38	32
Moderate	34	29
High	19	16
Very high	5	4

The OWB is dominated by steep slopes; it is due to the nature of the extremely high terrain formed by low mountains and hills (Maurer, 1968), the distribution of slope classification categories demonstrates that more than 50% of the area of the OWB has slopes ranging from moderate to steep and very steep. The sensitivity of the area's topography to erosion is further enhanced by the fact that most of the slopes are oriented east, south, southeast and southwest, with an area exceeding 55% making more than half of the study area constantly exposed to sunshine and warm air masses from the east (Table 2).

Table 2. Distribution of slope exposures of OWB.

Exposure of slopes	**Km^2**	**%**
Flat area	1	1
North	7	6
North-west	14	12
East	12	10
Southeast	14	12
West	22	19
South West	17	14
West	11	9
North West	20	17

2.1.3. Soil Protection Coefficient (Xa)

The Xa factor is categorized according to the type of dominant vegetation cover and the type of land use (Zorn & Komac, 2009). As a result, the Xa factor is therefore one of a decisive indicator as it is given a specific value according to the EPM (Table 3), because of its relation to soil protection against erosion as a natural barrier. The EPM includes the role of vegetation to prevent soil erosion. To determine Xa factor in assessing the severity of erosion, the study followed up the methodology based on the density, height, season by calculating the Normalized

Difference Vegetation Index (NDVI). Xa values are varied also by land practices (Zorn & Komac, 2009). It varies from a minimum of 0.05 for the mixed and dense forest cover category to a maximum of 1.0 for the bare soil category, according to EPM guide (Table 3).

Table 3. Soil erosion protection coefficient values (X_a) according to EPM.

Coefficient of soil protection	X_a **factor**
Mixed and dense forest and thin forest with a grove	0.05–0.2
Coniferous forest with little groves, scarce bushes, bushy prairie	0.2–0.4
Damaged forest and bushes, pasture	0.4–0.6
Damaged pasture and cultivated land	0.6–0.8
Badlands, areas without vegetal cover	0.8–1.00

Source: Gavrilovic, 1988.

To determine the Xa factor values utilized by the EPM (Figure 4), Soil protection coefficient depends on the modified NDVI ($XaNDVI$), based on the proposed methodology (Zorn & Komac, 2009), after adjusting the vegetation cover coefficient, X_a (Equation 4).

$$X_a = \big(X_a \cdot \mathrm{NDVI} - 0.61\big)\,(-1.15) \tag{4}$$

X_a: coefficient of soil protection
$X_a\mathrm{NDVI}$: Adjusted vegetation cover factor

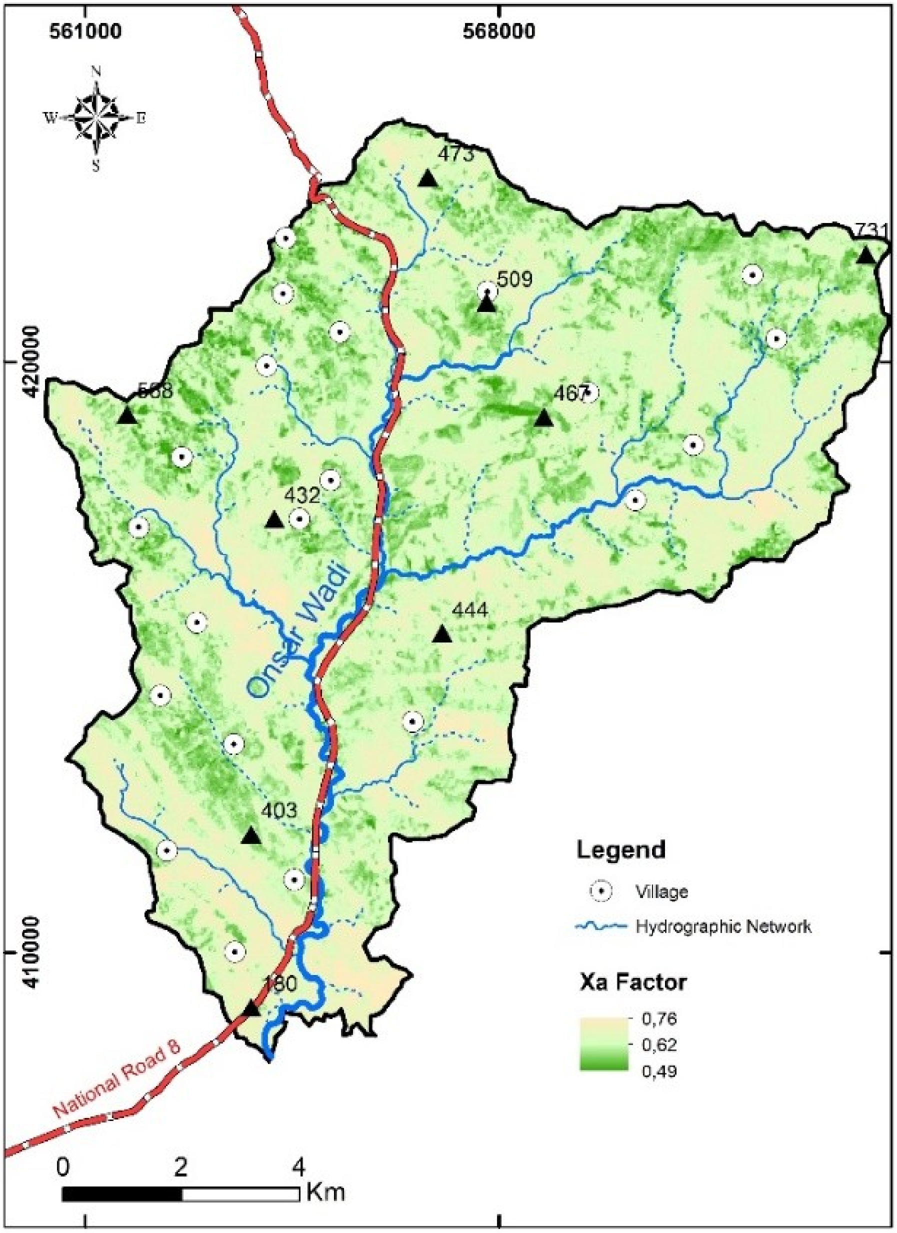

Figure 4. Vegetation cover factor X_a.
Source: made by the authors.

The evolution coefficient of erosion in the OWB varies from one area to another. It depends on the factors responsible for erosion, since the highest value reached 0.77 and 0,6, it represents the most prevalent areas of high erosion in the basin which occupies 80% of the total area, and corresponds to areas with low vegetation cover, steep slopes, fragile rocks, agriculture activity and tillage effects. This category extends mainly to the whole part of the basin while the lowest value reaches 0.41 and occupies 18% of the OWB area because of low slopes and some vegetation resulting from certain tree plants, extended as scattered areas between the upper, middle and lower parts of the basin.

2.1.4. Soil Erosion Coefficient (Y)

The EPM's factor (Y) reflects the soil's erodibility to water erosion as a major factor in the EPM (Figure 5). It is based on the sensitive soil properties such as texture, structure, and its permeability are to separation and transportation brought on by surface runoff or water splash (Behera et al. 2020; Bou-Imajjane et al. 2020). Through this study, we calculated erosion coefficient for soil erodibility (Y) by using the relation of Wishmier (Equation 5).

$$Y = (2.1 \times M1.14 \times 10^{-4} \times (12 - a) + 3.25 \times (b - 2) + 2.5 \times (c - 3))/100 \quad (5)$$

Table 4. The soil category in the function to Y.

Soil type	Y **factor**
Very high resistance and cohesion	0.1–0.3
Medium strength and cohesion	0.3–0.5
Low resistance	0.5–0.6
Aggregate debris and coarse sediment deposits	0.6–0.8
Fine sand, very low resistance soil	> 0.9

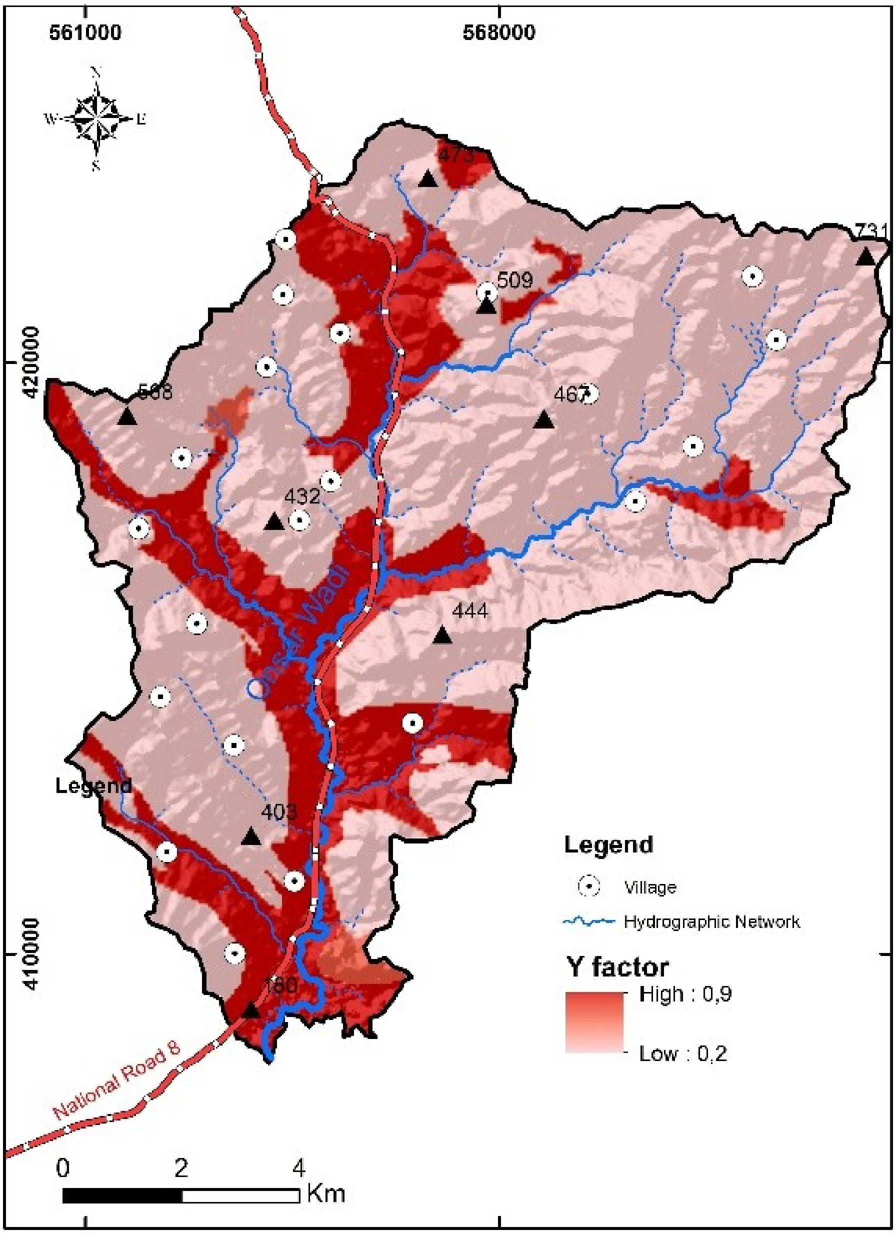

Figure 5. Soil Erodibility Coefficient (Y).
Source: made by the authors.

Strong erosion susceptibility is observed in various areas of the basin because the soil in this area is dominated by slope soils and soils associated with the structure which are characterized by fragile rocks, particularly limestone and flesh are spatially limited to the peaks, which are prevalent in the area (El Bouzidi, 1987). As a result, two main types of soils can be distinguished, developed and degraded; developed soil is found in flat areas, is restricted, and is concentrated near river depressions, while degraded soils are found over the strong slopes that are dominant and heavily susceptible to erosion.

Gavrilovic's values for the erosion coefficients in the Onsar watershed (Figure 6) vary between 0.2 as the highest resistance, and it is limited in watershed, concentrated in the north. The second type of soil of medium strength and cohesion between 0.46 and 0.6. These categories represent the most part of the study area. The third type of soil of strength and cohesion is characterized by its low resistance. It is concentrated along to rivers depressions, while the developed soils prevail over the strong slopes, which are dominant, but are exposed to erosion to a large extent. Its values vary between 0-7 and 0-9.

2.1.5. Current Erosion Indicator φ

Extracting the current erosion index (φ) requires extensive and comprehensive field work. This factor identifies the area affected by erosion (Gavrilovic, 1988) (Table 5). It requires multiple field work to observing the erosion evolution in the watershed. In addition, for using aerial photographs and high-resolution satellite imagery (1 m), GIS allow the calculation of this index based on Landsat images by dividing the square root of the third band (TM3) by the maximum radiation value ($Q_{\max}$), and the results are translated according to the radiation ratio, as the radiation ratio increases significantly with the severity of erosion, φ identifies the areas affected by erosion. The φ factor (Equation 6).

$$\varphi = \sqrt{\frac{\mathrm{TM3}}{\varphi_{\max}}} \tag{6}$$

Where:
TM3: Band 3 of Landsat image,
$\varphi_{\max}$: The maximum value of the radiance.

Table 5. Types of soil erosion determined by the current erosion indicator (φ).

Coefficient of type and extent of erosion	φ
Little erosion on watershed	< 0.20
Erosion between 20–50% of the watershed	0.2–0.4
Erosion in River, gullies, ravines and alluvial deposit, karstic erosion	0.4–0.6
50–80% of catchment area affected by surface erosion and landslides	0.6–0.8
Entire watershed affected by erosion	0.8–1.0

The current erosion coefficient in the OWB varies depending on the factor responsible for erosion, as the highest value for the Basin El Ansar watershed reaching 0.77, corresponding to areas of high erosion severity, and corresponds to area with low vegetation cover, steep slopes, and fragile rocks, and is mainly prevalent in the southern part of the basin (Figure 6) while the lowest value reached 0.41 in area with low erosion severity, due to low slopes and moderate vegetation cover, and is prevalent in the form of scattered areas between the upper, middle, and lower parts of the basin.

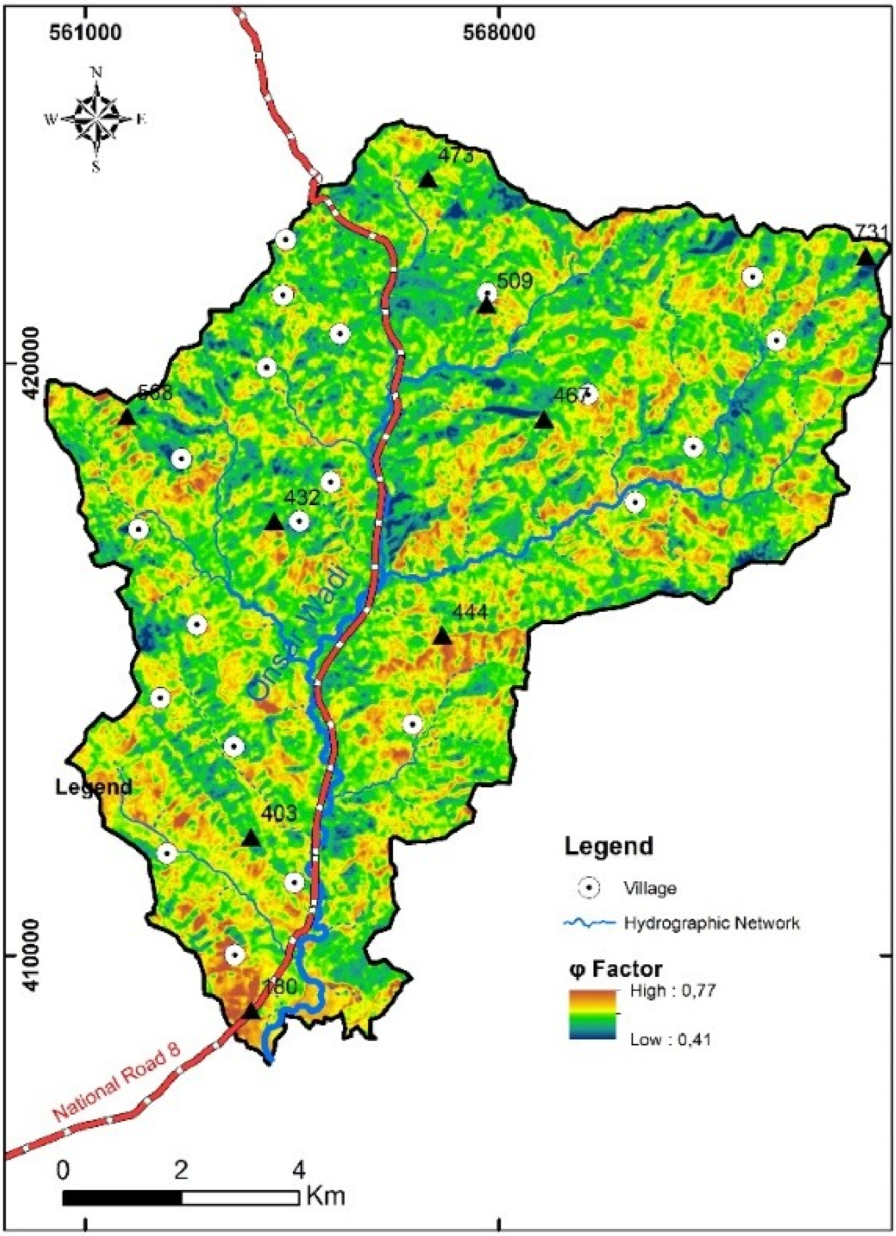

Figure 6. Coefficient of type and extent of current erosion (φ).
Source: made by the authors.

3. Results and Discussion

3.1. Potential erosion index in the OWB (Z)

The result of the qualitative assessment for the potential erosion (Z) constitutes only a coefficient for the quantification of erosion (W), is produced by integrating many parameters and layers of coefficient maps in the GIS, by incorporating the map of the coefficient of rock susceptibility to erosion (Y), the soil protection coefficient (Xa), the slope coefficient (Ja), and finally the erosion development coefficient (φ), and thus it is a direct reflection of the various factors controlling this phenomenon, and through it it is possible to know the stable areas, and the most dynamic and sensitive areas to erosion (Table 6). This coefficient demonstrates the potential erosion in the watershed and through it, it is possible to monitor the levels of erosion over time.

Table 6. Classification of the erosion categories according to the Z coefficient value in the EPM model.

Erosion classification	Erosion intensity	Z coefficient value	Average of values of coefficient Z	Qualitative of erosion category
1	Very intense	$Z > 1$	$Z = 1.25$	Excessive erosion (gullies, rills, rockslides, etc.)
2	Intense	$0.81 < Z < 1$	$Z = 0.85$	Heavy erosion (a bit milder then excessive)
3	Average	$0.41 < Z < 0.8$	$Z = 0.55$	Medium erosion
4	Little	$0.20 < Z < 0.40$	$Z = 0.30$	Slight erosion
5	Very little	$0.01 < Z < 0.19$	$Z = 0.10$	Very slight erosion

The results obtained illustrate that part of the OWB is situated in the zone of high and very high erosion potential, with values greater than 1, these zones belong to areas of steep and very steep slopes, as well as medium slopes, where vegetation cover is limited (Figure 7). These zones are located in the southern, south-western and eastern parts of the basin. The zones of low erosion are distributed over a smaller area than the other zones, and their extent corresponds to areas with low slopes, high vegetation cover, and the dominance of resistant rocks. The stable zones are limited and distributed in the lower part of the watershed and in scattered areas in the upper and northern parts with value 0.1.

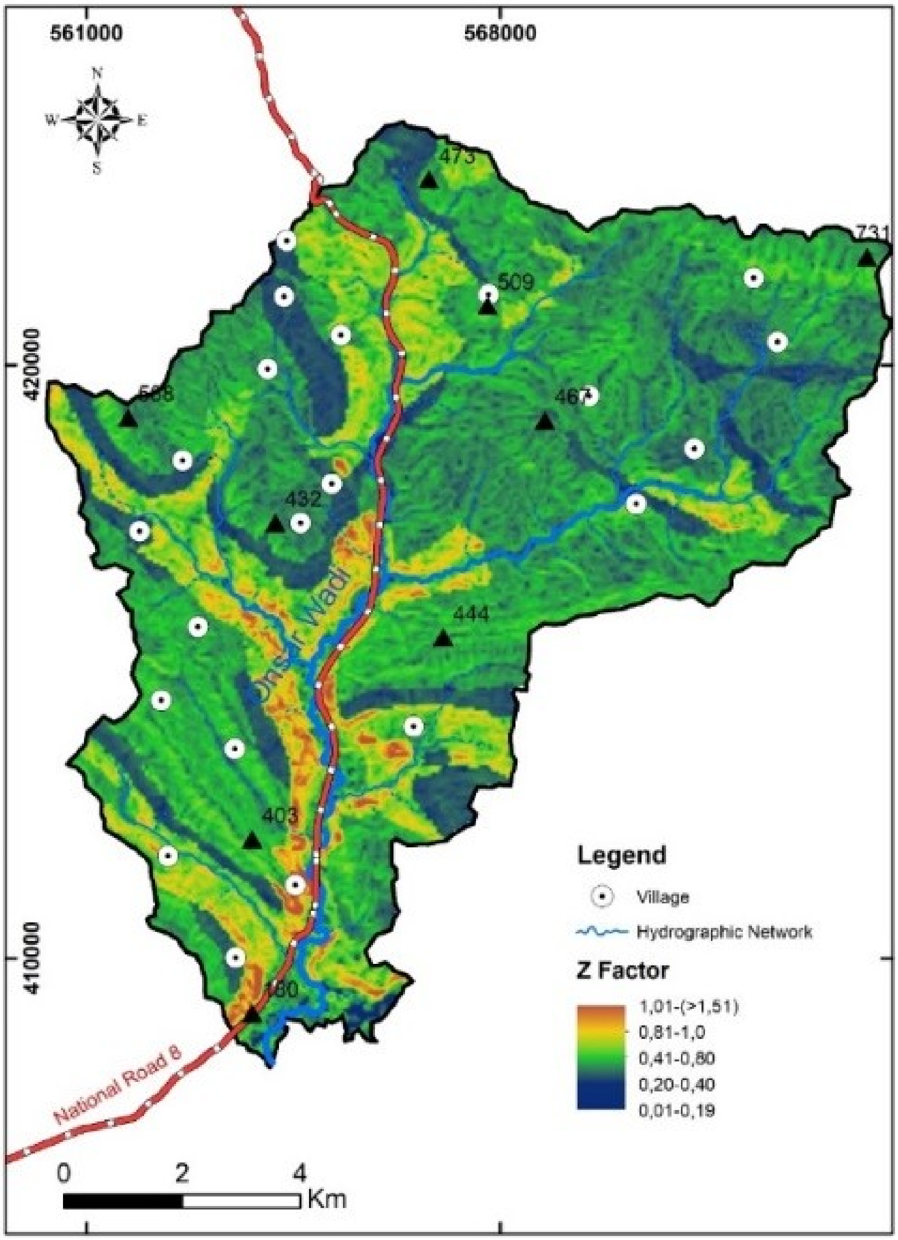

Figure 7. Erosion intensity coefficient (Z).
Source: made by the authors.

3.2. Precipitation (H)

Precipitation is the significant driver of water erosion, since it depends primarily on the intensity of rainfall (Nunes & Nearing, 2011). The effect of precipitation factor is related to the extent of the contribution of other factors. In this study, precipitation data used were extracted from several monitoring stations located in the OWB. Through the analysis tools available in the GIS, where the distribution of rainfall was obtained between 1951 and 2023 to build a construction database relying on the inverse distance weighting (IDW) interpolation method to extract the precipitation index (Figure 8).

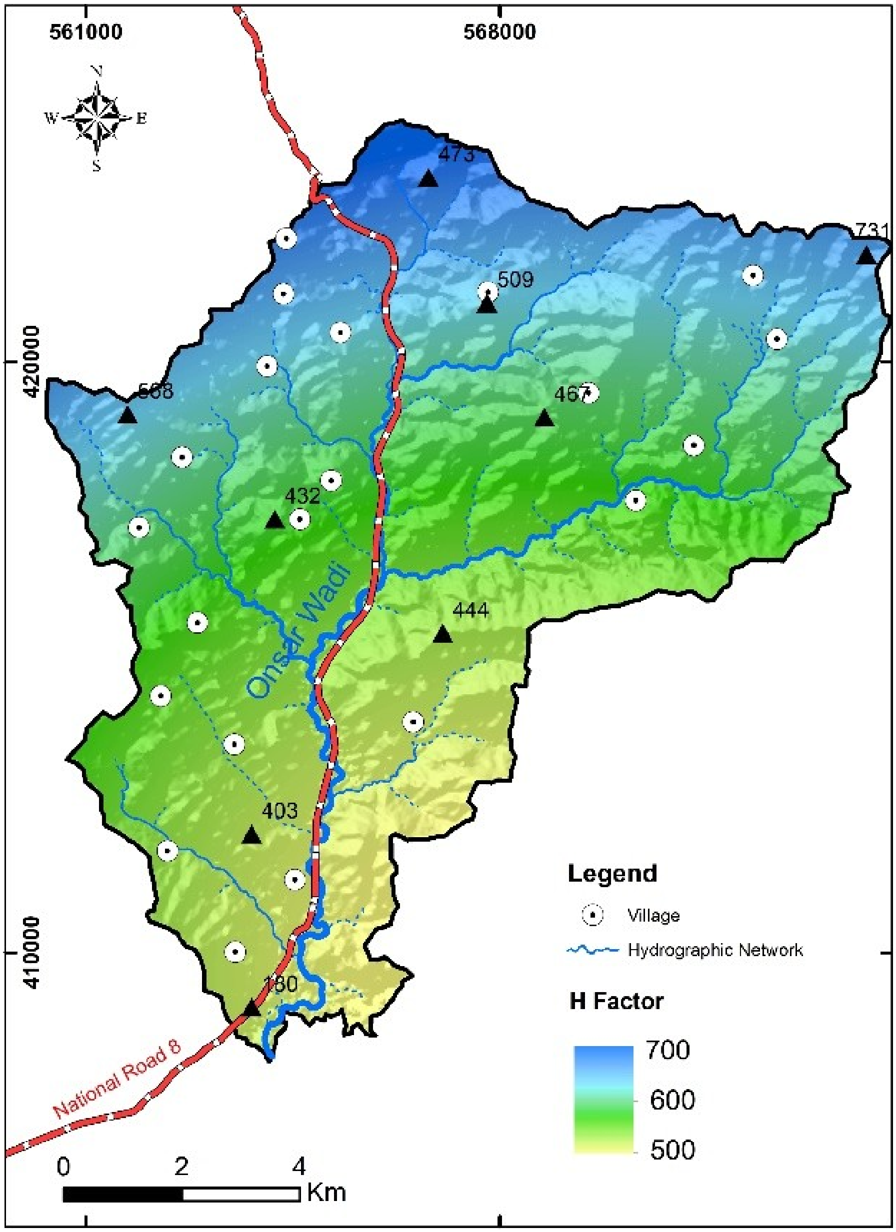

Figure 8. Annual precipitation average (H).
Source: made by the authors.

The spatial distribution of the rainfall reflects the unequal distribution of annual average of the precipitation in the OWB, as the highest values are recorded in the northern part of the basin, reaching about 700 mm, while the rates gradually decrease towards the south and southeast, reaching less than 500 mm as the lowest value. This distribution is explained by the topographic factor represented by the altitude that increases towards the north and decreases towards the south. This difference is leading to a variation in the severity of water erosion and a difference in the resulting shapes.

3.3. Temperature coefficient (T)

Temperature is an essential factor in influencing the water balance in the soil (Figure 9), by increasing the intensity of evaporation and transpiration when it increases. The dynamics of the clays in the prevailing clay rocks in the OWB also lead to cracks in the fragile clay lithology, thus contributing to the disintegration of the soil and surface formations. Accordingly, temperature is one of the factors affecting erosion according to the EPM.

Due to the absence of accurate temperature data at most monitoring stations nearby the study area, based on a set of Landsat 5 and 8 satellite images for different years (1990-2023) and different seasons, the analysis calculated the temperatures for all images, through three integrated stages (Vujacic et al., 2015), (Rizqi, 2020).

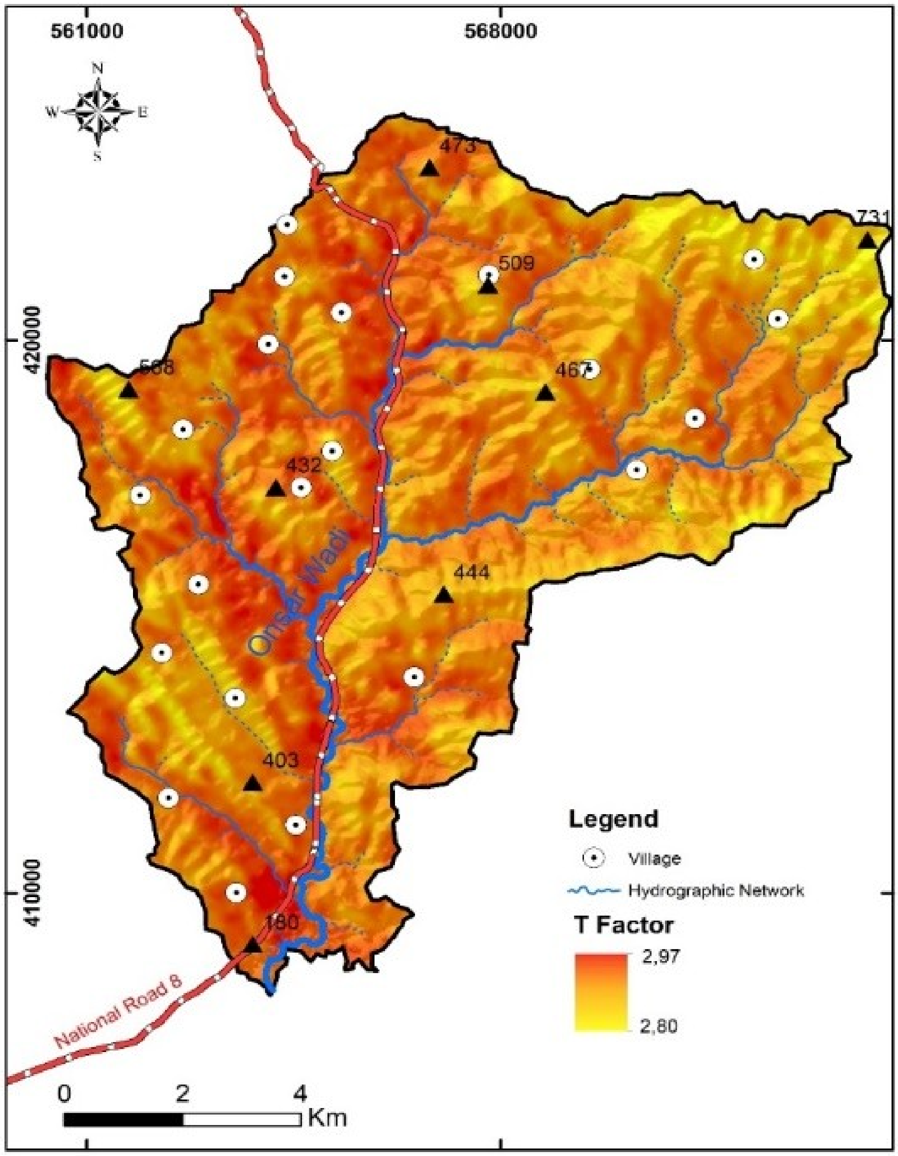

Figure 9. The temperature coefficient of the Basin Onsar Basin according to the EPM model.
Source: made by the authors.

The first stage: Specific ranges were used to transform the pixel values to estimate the radiation by reprojecting the data (Efthimiou & Lykoudi, 2016), where:

$$\text{Radiance} = \frac{(L_{\max} - L_{\min})}{(Qcal_{\max} - Qcal_{\min})}(DN - Qcal_{\min}) + L_{\min} \quad (7)$$

$L_{\max}$ = maximum radiation value
$L_{\min}$ = minimum radiation value

$Qcal_{\max}$ = highest value taken by the pixel
$Qcal_{\min}$ = lowest value taken by the pixel

The second stage: Converting from radiation Radiance to Kelvin temperature (Equation 8).

$$T = \frac{K_2}{tn\left(\frac{K_1}{\text{Radiance}}\right) + 1} \tag{8}$$

The values K1 and K2 are constant, changing with the satellite. For LANDSAT5-TM, the values reach:

K1=607.76 and K2=1260.56, while for a LANDSAT 8 (OLI) the values are: 774.8853 and 1321.0789, as well respectively.

The third stage: obtaining the annual average temperature for all images, which is calculated automatically, we applied the rule specified in the EPM equation to this average (Equation 9):

$$T = \sqrt{\frac{C}{10} + 0,1} \tag{9}$$

The temperature coefficient result shows the difference in temperature distribution in the Basin El Ansar watershed, due to two main factors: the slope orientation and elevation. It is observed that the sunny slopes facing south and east have higher temperatures, reaching the highest values. Due to the topography of the area, some slopes with higher temperatures are exposed to longer periods of sunshine than others, while the temperature decreases relatively on the slopes facing west and north. In addition, the temperature decreases with height, as higher values are registered in the higher area, and lower values are recorded in the lower parts of the basin.

3.4. Average of annual soil losses (W)

The results of the quantitative assessment of the amount of soil loss annually ($\mathrm{m}^3/\mathrm{km}^2/\mathrm{year}$) according to the EMP model are obtained by combining the three coefficients (Z, T and H) (Figure 10). The combination of various factors according to EPM model (Figure 10) allows to produce spatial distribution of the soil loss estimation by water erosion (Equation 10).

$$W = T \times H \times \pi \times \sqrt{Z^3} \tag{10}$$

Where: T is temperature coefficient (°C), H is annual precipitation (mm), $\pi =$ 3,4, $Z =$ erosion coefficient.

Table 7. Annual soil loss in Basin Onsar watershed.

Classes of W ($m^3/km^2/yr$)	Intensity	Area (%)
≤ 50	Inconspicuous erosion	8
≤ 50–500	Very low erosion	20
500–1 500	Low erosion	46
1 500–5 000	Moderate erosion	13
5 000–20 000	High erosion	9
$> 20\,000$	Very high erosion	4

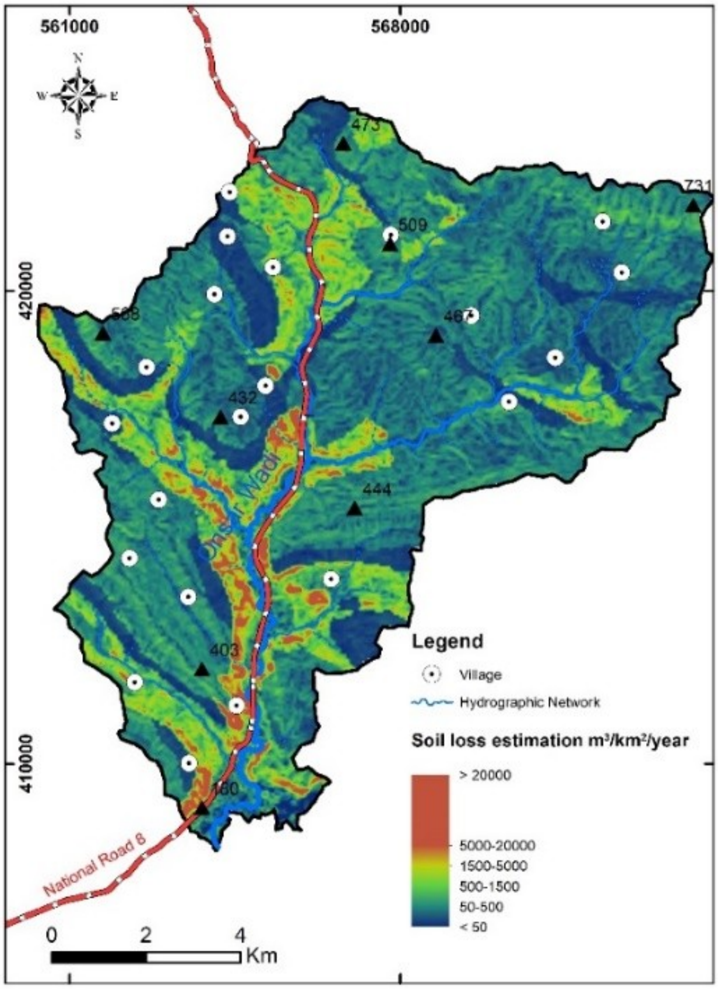

Figure 10. Annual volume of eroded sediment (W).
Source: made by the authors.

The results of the assessment of water erosion and the extent of soil degradation in the OWB, concluded that it is subjecting to erosion of varying intensity and extent, with around 50% of the basin area experiencing moderate erosion between 500 and 1500 $\mathrm{m}^3/\mathrm{km}^2/\mathrm{year}$ over an area of more than 53 km^2. This erosion is mainly prevalent in the western part of the basin and in the east, as well as in scattered areas, mainly in the center of the basin. While catastrophic erosion, on the other hand, covers around 4% of the basin, in the form of scattered areas, particularly on the slopes of the OWB, with an estimated surface area of 3 km^2. The area affected by generalized erosion covers around 26 km^2, equivalent to 22% of the total area.

4. Discussion

The applying of Gavrilović's EPM method allowed a qualitative and quantitative soil loss assessment of the OWB. This study demonstrates advanced levels of erosion in the watershed, in the middle of a region known as the most productive of sediments in Morocco (A. Faleh, 2009), (Al Bouzidi, 2008), where the slopes are experiencing significant deterioration, which has increased the rate of abandonment of a number of farms by the local population, as a result of the lost capacity for agricultural productivity.

Analysis of the databases of factors contributing to the various forms of erosion, for each of the lithological characteristics, slopes, vegetation cover, climatic condition, and soil uses for the OWB, show that the strength and significance of erosion forms, which are distributed according to the type of the bedrock substratum and its resistance to water erosion. As major factors make these areas more susceptible to soil erosion.

The extent of the areas exposed to soil degradation in the OWB in the Rif region, posed a major challenge to the study in order to determine the amount of soil resources lost, in order to understand the extent of potential soil loss for developing effective mitigation strategies to protect these vital environmental resources, and thus reducing their risks and impacts in their various dimensions on the local population.

5. Conclusions

The implementation of Gavrilovic's EPM equation allowed to map the spatial distribution of areas susceptible to soil erosion by using a geographic information system (GIS). This model involves the integration of several factors related to climate annual precipitation (Pa), temperature (T), soil protection (Xa), topographic features (slope Ja), erodibility factor (Y), and the degree of erosion (φ). For estimating the soil losses in the OWB both quantitatively and qualitatively. The study's findings indicate that the average of soil losses is estimated at 500 m^3/ha/yr, with a maximum of more than 20000 m^3/ha/yr are concentrated along the Wadi.

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