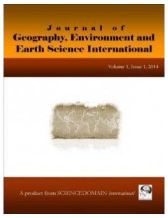


*Journal of Geography, Environment and Earth Science International*

*14(2): 1-11, 2018; Article no.JGEESI.40322*
*ISSN: 2454-7352*

# Mapping Soil Erosion Risk Using RUSLE, GIS, Remote Sensing Methods: A Case of Mountainous Sub-watershed, Ifni Lake and High Valley of Tifnoute (High Moroccan Atlas)

**Kacem Lamyaa[1*], Agoussine M'bark[2], Igmoullan Brahim[1], Amar Hicham[3] and Mokhtari Soraya[4]**

*[1]Geosciences and Environment Laboratory, Department of Earth Science, Faculty of Science and Technical, Cadi Ayad University, Avenue Abdelkrim Khattabi, BP594, 40000 Marrakech, Morocco.*
*[2]Department of Industrial Engineering, National School of Applied Science, Ibno Zohr University, B.P. 1136 Agadir, Morocco.*
*[3]Laboratory of Data Processing, Applied Mathematics, Artificial Intelligence, Faculty of Sciences, Recognition of Seismic Waves and Structure of the Earth, Rabat, Morocco.*
*[4]Department of Toubkal National Park, Regional Direction of Water and Forest and Fight against Desertification / High Atlas, Ex-Villa Jeanette, City Boukar, Bab Doukkala Marrakech, Morocco.*

***Authors' contributions***

*This work was carried out in collaboration between all authors. Author KL designed the study, performed the soil sampling and analysis, wrote the protocol and wrote the manuscript. Authors AM and IB supported the management the fieldwork. Author AH designed and managed the maps production. Author MS made available the field equipments. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/JGEESI/2018/40322
Editor(s):
(1) Ahmet Sayar, Associate Professor, Computer Engineering Department, Kocaeli University, Turkey.
Reviewers:
(1) Vinod Kumar, DAV University, India.
(2) Abrar Yousuf, Punjab Agricultural University, India.
(3) Sezgin Hacisalihoglu, Turkey.
(4) Sibaway B. Mwango, Mlingano Agricultural Research Institute, Tanzania.
Complete Peer review History: http://www.sciencedomain.org/review-history/23871

***Original Research Article***

***Received 12th January 2018***
***Accepted 21st March 2018***
***Published 28th March 2018***

## ABSTRACT

It is important to combine different methods to quantify the soil loss in a mountainous sub-watershed. Geographic Information System (GIS), Remote Sensing and Revised Universal Soil Loss Equation (RUSLE) were adopted to estimate the annual soil loss in the highest watershed in

**Corresponding author: E-mail: lamyaa.kacem@gmail.com;*

Morocco. The High valley of Tifnoute is a part of a national park of Toubkal and constitutes a best choice for such application. The availability of some ecological resources (Lake ifni) and the population that suffers from yearly loss of their agricultural areas constitute a primary need for erosion mapping, which make it's the first one in the study area. The deterioration of ecological heritage and agricultural fields by sediment filling are the major problems in the study area.
The RUSLE factors (R, K, LS, C and P) were computed using Tropical Rainfall Measuring Mission (TRMM), soil analysis, topographic map, remote sensing and digital elevation model (DEM). The resultant map of annual soil erosion with RUSLE method show a real problem of soil loss in the study area, and high soil erosion zones are located in the middle and in upstream of the watershed. The sediments transported constitues a big problem for Ifni lake located in downstream of the sub-watershed. The article highlights the application of RUSLE, GIS and RS methods in the mapping of annual soil loss estimation in mountainous area. The results constitue an essential database to offer a planning of conservation practices to control soil erosion.

*Keywords: Soil erosion; GIS; remote sensing; RUSLE; TRMM; mountainous watershed.*

## 1. INTRODUCTION

Soil erosion risk constitutes a serious environmental problem. Many regions in Morocco have a serious problem of soil degradation with erosion processes, especially in mountainous areas. The erosion has a manifold environmental impact by negatively affecting water supply, reservoir storage capacity, agricultural productivity, and freshwater ecology [1,2,3]. Water erosion is the major type of physical land degradation in the global perspective [4]. In mountain basins sediments – related processes and associated hazards, from erosion and shallow land sliding on basin slopes the sediments transport and deposition in the water network [5].

The Ifni lake is the highest mountainous one in Morocco at an elevation of 2320 m, and is considered as a natural tower of water in High Moroccan Atlas. Unfortunately, this area is under severe erosion risk. In order to protect the Ifni lake, it is essential to determine the areas threatened by soil loss and potential erosion rate. To assess the risks of soil erosion and to determine appropriate land use and management for this soil loss prediction is important [6,7]. Often, estimation of soil erosion loss is difficult due to the complex interplay of many factors, such as climate, land cover, soil, topography, and human activities [8,9]. Many methods have been developed to quantify or to mapping soil erosion risk, but the most method used that the Universal Soil Loss Equation (USLE) [10], or the Revised Universal Soil Loss Equation (RUSLE) [11,12]. However, the combined use of erosion models such as USLE/RUSLE and GIS has been proved to be an approach for estimating the spatial distribution of erosion [13,14,15,16,12]. The (RUSLE) equation is used also in mountainous area [17,18]. The RUSLE model were introduced to improve its applicability in mountainous area [19,20,21,22]. Also, remote sensing techniques and GIS provide new approaches to meet the requirements of resource related modeling, and reduce [23].

The area study is a part the National park of Toubkal, it is a mountainous region. To estimate the soil loss we combined of RUSLE, GIS and remote sensing method. The present study is the first in this area, so it was difficult to collect the data base.

To calculate the RUSLE factors we used different methods: the Tropical Rainfall Measuring Mission (TRMM) used to determine R factor. The land cover (C factor) was elaborate from a Landsat ETM+ (Enhanced Thematic Mapper) image with supervised classification under ENVI 4.6 (Environment for Visualizing Images) software. To calculate the Soil erodibility factor (K), 35 soil samples were carried and analyzed. Finally, the digital elevation model (DEM) used to produce the (LS) factor. Thus, the objective of this research was to map erosion risk using RUSLE model, GIS, Remote Sensing methods in the highest watershed in Morocco. However, the database elaborate in this study can be used to purpose a planning of protection the sub-watershed and the water resources in the highest mountainous lake in Morocco.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The high valley of Tifnoute is a semi-arid mountainous region, located on the southern flank of the Toubkal Mountain at latitudes 30°59'55'' to 31'5'38'' N and longitudes 7°48'3'' to 7°56'12'' W (Fig. 1). Ifni Lake is a small sub-watershed covers an area of 18 km², and the high Tifnoute valley sub-watershed with 70 km². The region characterized by Ifni Lake the highest natural lake in Morocco with elevation sitting at 2320 m above the sea level [24].

The area is characterized by highly elevations, which the maximal altitude is 4104 meter above the sea level. Drainage pattern map proved that is dendritic, with a high density. The watershed also indicates a fast hydrological answer with high potential [25]. The soil cover is poor and the texture is sandy -loam and loams. Geologically, the slopes are very strong and the area falls in volcanic and metamorphic rocks. The Tifnoute valley region is underlain by Neoproterozoic rocks of the current Bleida Group which correspond to the lower formations of the Cryogenian Age [26].

#### 2.1.1 Description of RUSLE model

Apart from rainfall and runoff, the rate of soil erosion from an area is also strongly dependent up on its soil, vegetation and topographic characteristics [27]. The combination of RUSLE equation, GIS and remote sensing make mapping of erosion risk easy [12]. The input data are topographic map, erodibility map, land cover using (ETM+) images treaty under ENVI (version 4.6), and digital elevation model (DEM) with 27*27 resolution. The different raster are superposed in ArcGIS 9.2 software for spatial analysis. The RUSLE equation (1) expressed by five factors [28]:

$$A=R*K*LS*C*P \tag{1}$$

Where A is the average soil erosion (t $ha^{-1}$ $year^{-1}$), R is the rainfall erosivity factor (MJ mm /$ha^{-1}$ $h^{-1}$ $year^{-1}$), K is the soil erodibility factor (t ha h /$MJ^{-1}$ $ha^{-1}$ $mm^{-1}$), L is the slope length factor (m), S is the steepness factor (%), C is the cover management factor and P is the conservation practice factor. The P, LS, and C factors are dimensionless.

#### 2.1.2 Calculation of RUSLE factors

***Rainfall erosivity factor (R):*** R factor is the quantitative expression of the erosivity of local average annual precipitation and runoff causing soil erosion [29]. There are many methods to calculate the R factor. In the present study, TRMM has been used. TRMM method is a joint mission between NASA and the Aerospace Exploration Agency designed to study tropical rainfall and was launched on 27 November 1997 [30]. The data from TRMM can be used to find the location of rain as well as the rainfall intensity [31].

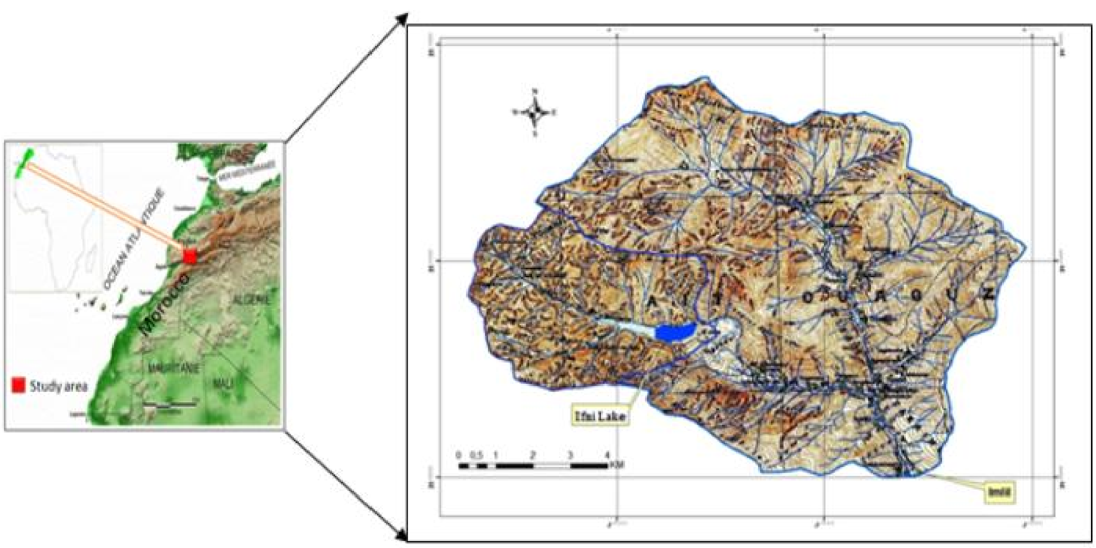


**Fig. 1. Location of study area**

The unavailability of precipitation data in the study area forced us to calculate the R factor with an average annual rainfall in global navigation satellite from 2005 to 2008. The type of (TRMM) used is 4*4 km resolution. We calculated the average annual rainfall from TRMM, and the [32] equation (2) was used to calculate the R factor.

$$R = 0.0483*p^{1.610} \quad (2)$$

Where R is the rainfall erosivity factor (MJ mm /ha$^{-1}$ h$^{-1}$ year$^{-1}$) and *P* is the annual rainfall (mm) calculated by TRMM model.

***Soil erodibility factor (K):*** The soil erodibility factor K is the rate of soil loss per rainfall erosion index unit as measured on a standard soil plot, and often determined using inherent soil properties [33,34]. The erodibility is function of texture, organic mutter, and permeability of soil. To elaborate the K factor map, a total of 35 soil samples were carried from the study area and analyzed to determine the soil characteristic.

The factor K values for the watershed area were calculated from the soil analysis by the formula (3) of [10]:

$$K=2.1*M^{1.4}*10^{-6}(12\text{-}OM) + 0.0325*(b\text{-}2) + 0.025*(c\text{-}3) \quad (3)$$

Where M= (% fine sand + silt)*(100-% clay), Organic Matter (OM) in %, (b) is soil structure index, (c) is soil permeability index.

The soil analysis was carried in Geosciences and environment laboratory, Science and Technical Faculty, Cadi Ayad University Marrakech - Morocco. To determine the soil texture, the samples had two phases of analysis: a mechanical sifting with wet sieving process and a phase of classification by laser diffraction. The organic matter was calculated by chemical technique [35], soil structure and permeability were determinate by Nomograms method [36].

***The Topographic factors slope length and steepness (LS):*** One of the key factors in soil loss is topography, especially, when the ground slope exceeds a critical angle [37,38]. In order to determine (LS) map factor we used a digital elevation model (DEM) (Fig. 2) for the study area from the topographical sheet with 27 meter resolution. The steepness and flow accumulation were derived from the DEM using hydrology and spatial analyst extension under ArcGIS. LS factor was determined by the equation (4) by [39,40].

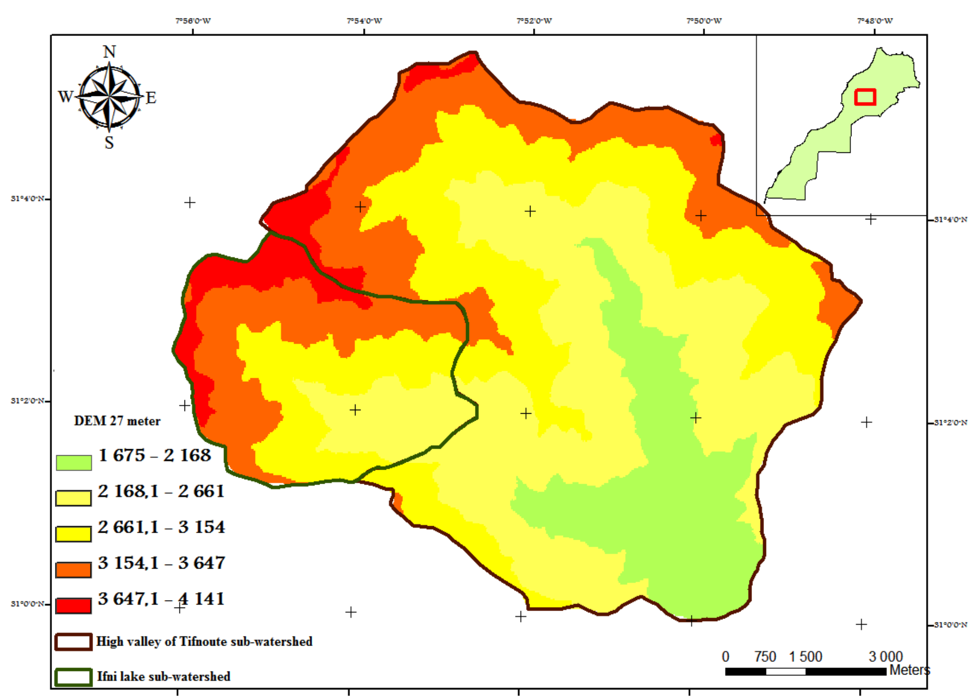


**Fig. 2. Digital elevation model**

$$LS = \text{Pow}([\text{Flow Accumulation grid}] * 10 / 22.13, 0.4) * \text{Pow}(\text{Sin}[\text{Slope grid}] * 0.01745) /0.0896, 1.4) * 1.4 \quad (4)$$

Where LS combined slope length and slope steepness, flow accumulation is the accumulated upslope contributing area per unit contour for a given cell. Cell size grid for this study is 27 meter and slopes are in degree.

***Land Cover factor (C):*** Land cover vegetation protects the soils and ensures the damping of the rain drops, the deceleration of the streaming and the infiltration. The soil losses decrease with cover vegetal [41,42]. The soils under forest cover have higher water retention and infiltration rate, and lower dispersion and erosion rates, relative to bare and agricultural soils [43,44,45]. The land cover was elaborate from a Landsat ETM+ image with 30*30 m resolution, and an analysis based to the supervised classification using ENVI 4.6 software. We exported the polygons generated by areas classes, and ArcGIS was used to elaborate the land cover map.

***Practice Management Factor (P):*** The (P) factor map was derived from the land cover and the field investigation in the study area. In the study area the P factor equal to 1 because the absence of conservation practices.

## 3. RESULTS AND DISCUSSION

### 3.1 RUSLE Factors

To calculate the rainfall erosivity factor (R) we exploited the data of world model of type Tropical Rainfall Measuring Mission (TRMM) of the period 2005-2008, this method gives us monthly values of precipitation on study area. The annual precipitation calculated in TRMM ranged between 211 and 504 mm. Results of TRMM precipitation values were compared to values obtained by Mokhtar Soussi the nearest weather station for a period 2005 – 2008. The results showed that the rainfall erosivity R factor ranges between 267 and 1084 MJ mm $ha^{-1}$ $h^{-1}$ $y^{-1}$ (Fig. 3).

The results of analysis soil showed that the dominate texture is sandy -loam and loams with 7% a maximum of organic matter, and the K values obtained ranged from 0.02 to 0.09 (t ha h /$MJ^{-1}$ $ha^{-1}$ $mm^{-1}$) (Fig. 4). Therefore, the LS factor in the study area varies from 0 to 5 (Fig. 5). Totally of sub-watershed area has LS factor less than 5 with high slops higher than 35°, the topography factor especially influences the soil loss in the study area.

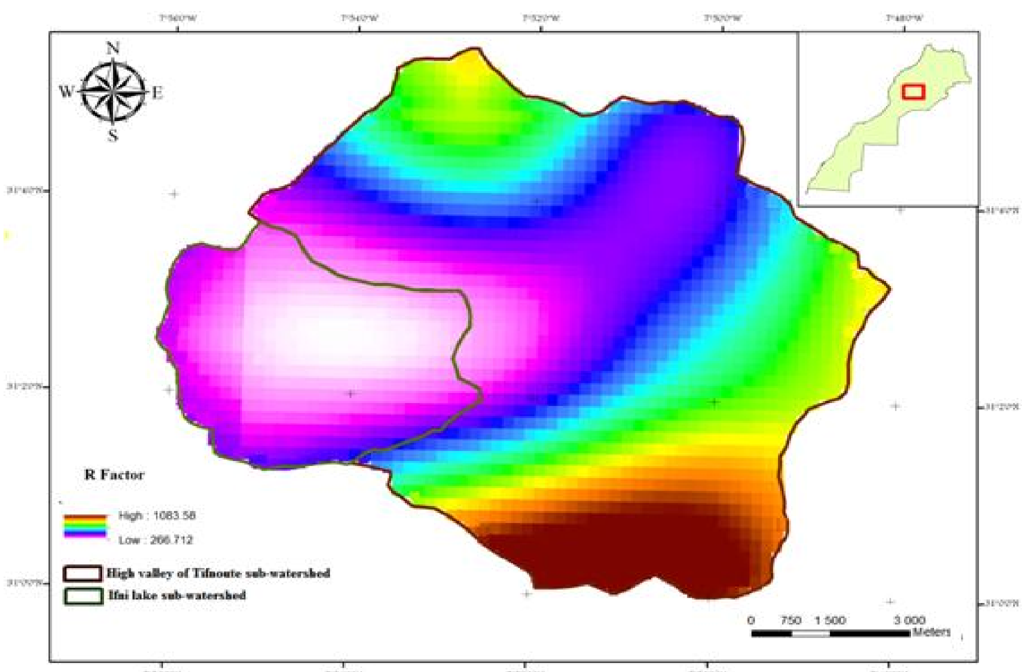


**Fig. 3. Map of rainfall erosivity factor (R) based on TRMM**

The results of classification we allowed to extract C factor for each of the land cover entities (Table 1). The map of Land cover factor (Fig. 6) shows that 96% of total surface of study area is a bare land, and just 3% with vegetation, the verification for each land cover in the study area confirm the results showed by model.

### 3.2 Annual Soil Loss

The map of spatial distribution of soil loss results from the multiplication of all calculated RUSLE factors (R,K,LS,C ,and P) under same DEM pixel (Fig. 7), this map showed that the quantity of sediments ranges from 1 to 200 (t $ha^{-1}$ $year^{-1}$). The results in (Table 2) give us a general idea about the proportion of soil loss for each class in the study area. The higher values are observed in the Ifni lake sub-watershed and in Northwest of high valley of Tifnoute sub-wtaershed. Furthermore, the study area is dominated by volcanic-metmorphic rocks. The area is not protected by vegetation; soil texture is crumbly and easy to be tranported by water, poor crop management and performing the relief .these conditions accelarate the erosion process in the high valley of Tifnoute. Lastly, we would like to proof the implementing conservation practices is very important to protect this study area.

### 3.3 Soil Conservation Practices

We purpose some practices to reduce the soil erosion in the study area, the practices will protect the Ifni lake and the population agglomeration. We can use 2 types of practices (Fig. 8):

- Dry stones to slow the transport of sediments upstream of the population agglomeration and at the Ifni lake.
- The terraces in culture (cultivated banks) to support the action of the dry stones upstream population agglomerations.

**Table 1. Cover classes and C factor for each land cover entities**

| Cover classes | C factor |
|---|---|
| Ifni lake | 0 |
| Dispersed vegetation | 0,01 |
| Vegetation | 0,1 |
| Bare land | 1 |

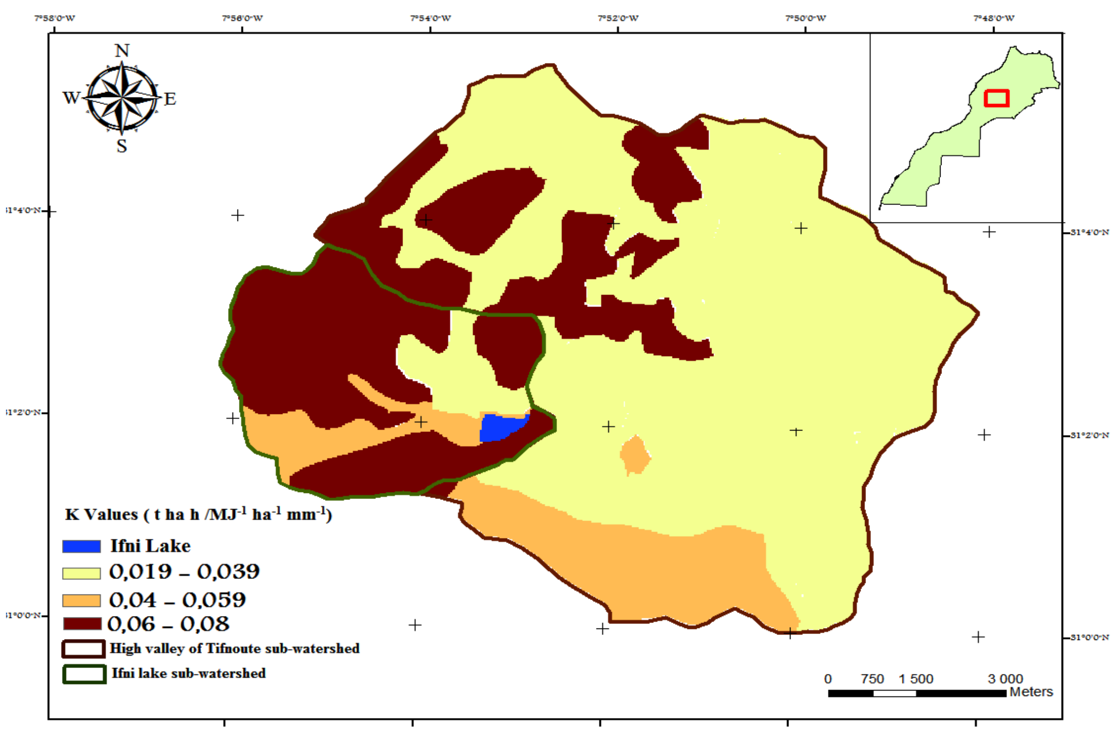


**Fig. 4. Map of soil erodibility factor (K)**

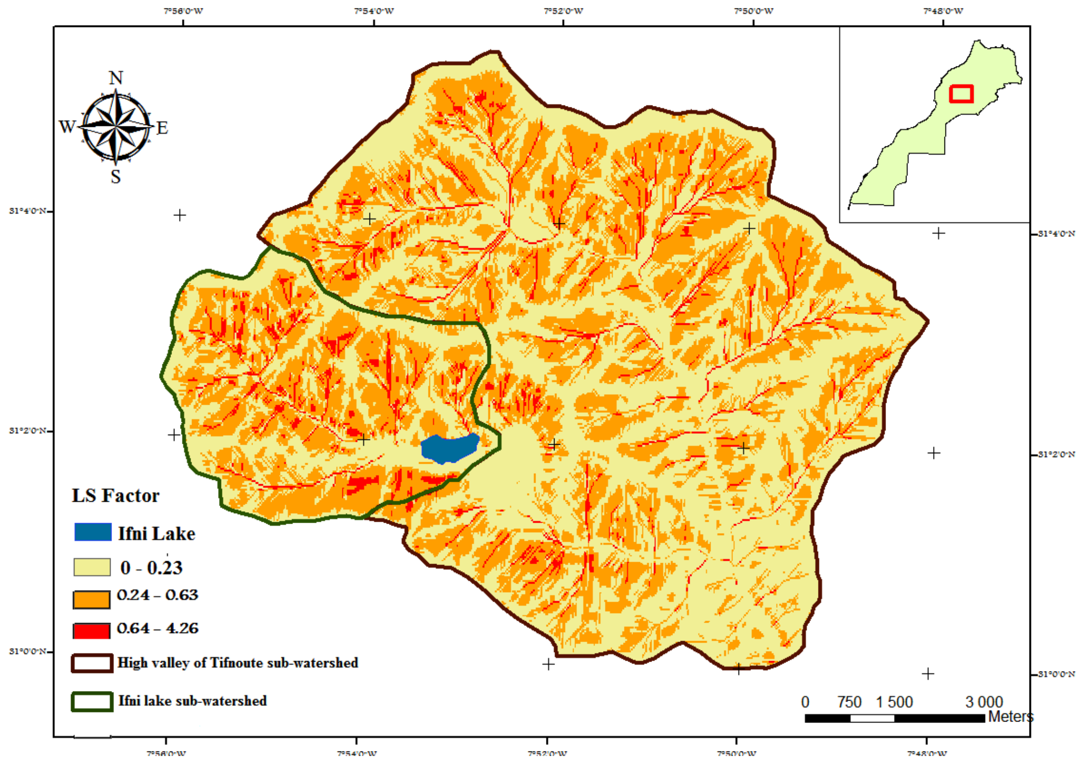


**Fig. 5. Map of slope length and steepness factor (LS)**

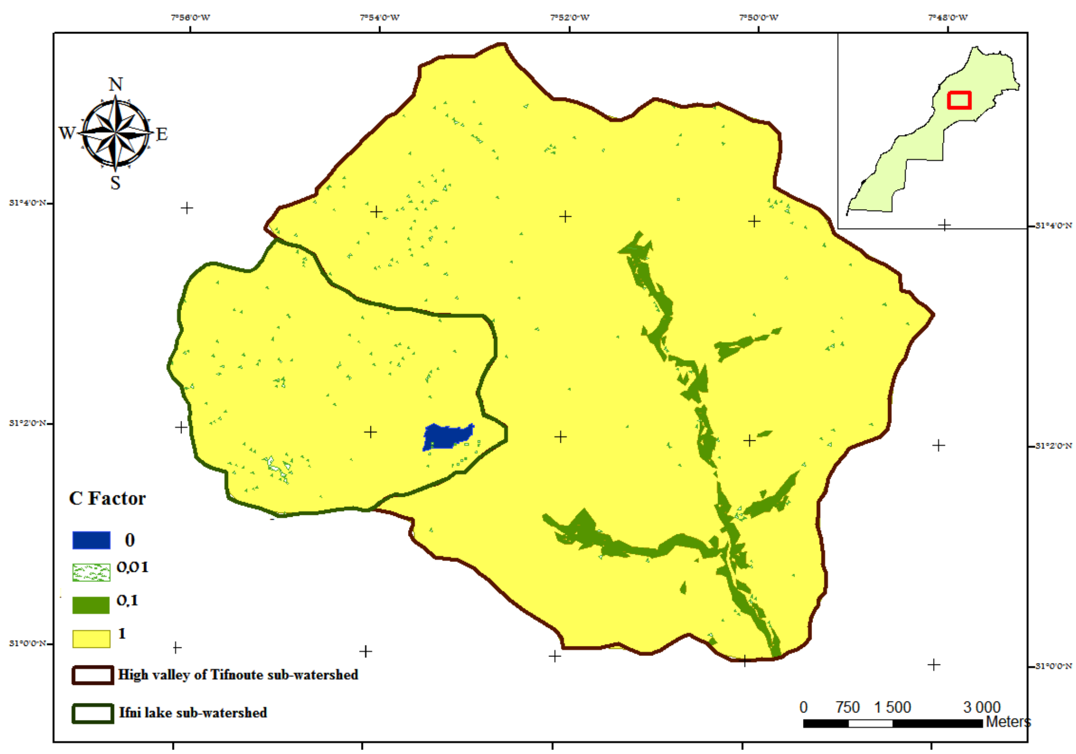


**Fig. 6. Map of land cover factor (C)**

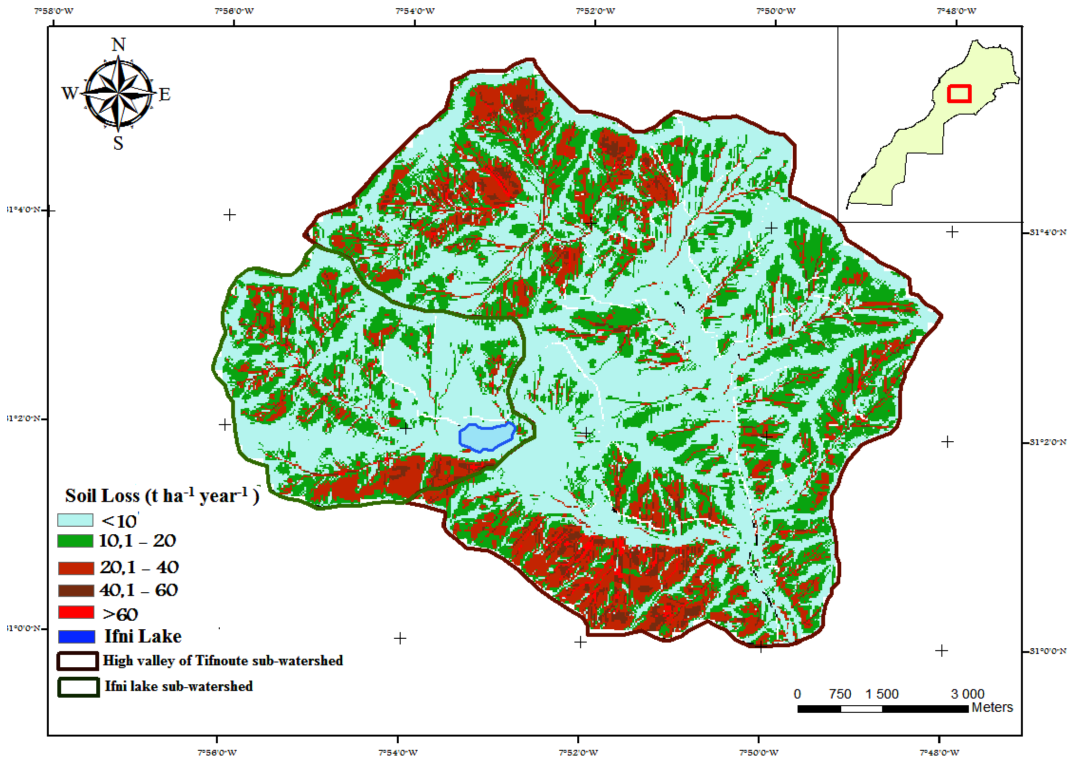


**Fig. 7. Map of annual soil loss in the study area (t ha$^{-1}$ year$^{-1}$) with RUSLE method**

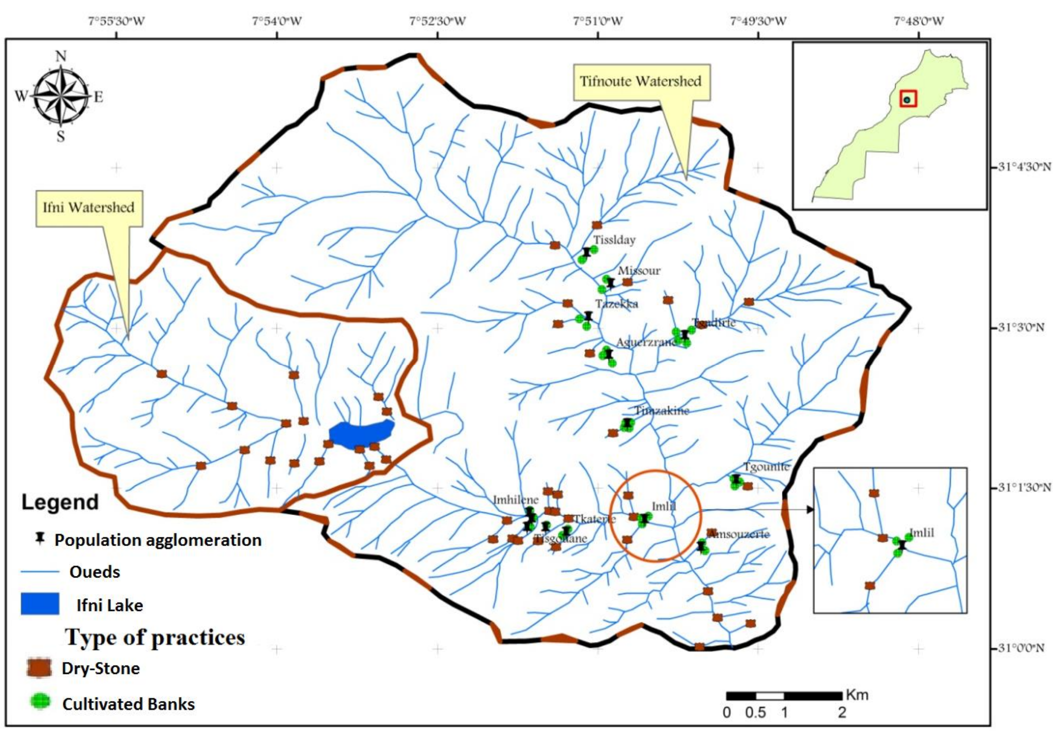


**Fig. 8. Map soil conservation practices to reduce the soil erosion in the study area**

**Table 2. Soil erosion proportion for each class in the study area with RUSLE method**

| Erosion risk class | Rate of soil loss (t $ha^{-1}$ $year^{-1}$ ) | (%) of area in high valley of Tifnoute | (%) of area in Ifni lake |
|---|---|---|---|
| Very low | <10 | 48,35 | 56,05 |
| low | 10,1 - 20 | 30,32 | 28,15 |
| Moderate | 20,1- 40 | 16,24 | 13,52 |
| High | 40,1-60 | 3,78 | 1,83 |
| Very high | >60 | 1,31 | 0,46 |

## 4. CONCLUSION

This study shows that the RUSLE combined to GIS, remote sensing (RS) applying in the study area can give us an interesting results of soil loss modeling in the mountainous sub-watershed. Generally, it is difficult to calculate erosivity factor (R) of RUSLE equation because there is no data base in the study area. Therefore, in this study we used Tropical Rainfall Measuring Mission (TRMM) data to calculate R factor and this method gives us a real information. Also, the supervised classification using under ENVI to established the land cover (C) factor, gives a correct map which we verified it in the study area .While the current research proved that we can use RUSLE method to elaborate a map of soil loss erosion in a Mediterranean mountainous sub-watershed. Also, this study constitutes an important database which can be used to planning a protection system in this area.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Woo Myeong BO. Soil erosion control in South Korea. Journal of Soil and Water Conservation. 1982;37:149-150.
2. Kefi M, Yoshino K, Zayani K, Isoda H. Estimation of soil loss by using combination of erosion model and GIS-case of study watersheds in Tunisia. Journal of Arid Land Studies. 2009;19:287 -290.
3. Sharma A, Kamlesh N, Tiwari PB, Bhadoria S. Effect of land use land cover change on soil erosion potential in an agricultural watershed. Environ Monit Assess. 2011;173:789-801.
4. Krishna KC, Bahadur. Mapping soil erosion susceptibility using remote sensing and GIS: A case of the upper nam watershed, Nan Province, Thailand. Environ Geol 2009;57:695–705.
5. Vijith H, Suma M, Rekha VB, Shiju C, Rejith PG. An assessment of soil erosion probability and erosion rate in a tropical mountainous watershed using remote sensing and GIS. Arab J Geosci. 2012;5:797–805.
6. Oliveira P, Sobrinho TA, Rodrigues DB, Panachuki E. Erosion risk mapping applied to environmental zoning. Water Resources Management. 2011;25:1021-1036.
7. Fan JR, Chen Y, Yan D, Guo FF. Characteristics of rainfall erosivity based on tropical rainfall measuring mission data in Tibet, China. J Mt Sciences. 2013;10:1008-1017.
8. Lu D, Li G, Valladares GS, Batistella M. Mapping soil erosion risk in Rondonia, Brazilian Amazonia: Using RUSLE, remote sensing and GIS. Journal of Land Degradation and Development. 2004;15: 499-512.
9. Jinghu P, Yan W. Estimation of soil erosion using RUSLE in Caijiamiao watershed, China. Nat Hazards. 2014;71:2187–2205.
10. Wischmeier WH, Smith DD. Predicting rainfall erosion losses: A guide to conservation planning, agricultural handbook 537, US department of agriculture: Washington DC; 1978.
11. Renard K, Foster G, WeesiesG, McCool D, Yoder D. Predicting soil erosion by water : guide to conservation with the revised universal soil loss equation (RUSLE) ,handbook 703 .US department of agriculture : Washington DC 404; 1997.
12. Kushwaha NL, Yousuf A. Soil erosion risk mapping of watersheds using RUSLE, remote sensing and GIS: A review. Research Journal of Agricultural Sciences. 2017;8(2):269-277.
13. Xu YQ, Shao XM, Kong XB, Peng J, Cai YL. Adapting the RUSLE and GIS to model soil erosion risk in a mountains karst

watershed, Guizhou Province, China. Environ Monit Assess. 2008;141:275-286.
14. Kouli M, Soupios P, Vallianatos F. Soil erosion prediction using the revised universal soil loss equation (RUSLE) in GIS framework, Chania Northwestern Crete, Greece. Environmental Geology 2009;57:483-497.
15. Sujata B. Estimation of soil erosion using remote sensing and GIS and prioritization of catchment. International Journal of Emerging Technology and Advanced Engineering. 2012;7.
16. Demirci A, Karaburun A. Estimation of soil erosion using RUSLE in a GIS framework: A case study in the Buyukcekmece Lake watershed, northwest Turkey. Environ Earth Sci. 2012;66:903–913.
17. Xu YQ, Shao XM, Kong XB, Peng J, Cai YL. Adapting the RUSLE and GIS to model soil erosion risk in a mountains karst watershed, Guizhou Province, China. Environ Monit Assess. 2008;141:275-286.
18. Leidig M, Mand R, Gloaguen. Erosion estimation in the Himalayan Mountains using remote sensing data. Grazer Schriften der Geographie und Raum Forschung. 2010;45:117-124.
19. Millward AA, Mersey JE. Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed. CATENA 1999;38:109-129.
20. Tao C, Rui-qing N, Ping-xiang L, Liang-pei Z, Bo D. Regional soil erosion risk mapping using RUSLE, GIS, and remote sensing: A case study in Miyun Watershed, North China .Environ Earth Sci. 2011; 63:533–541.
21. Veljko P, Ljubomir Z , Ratko K, Aleksandar D, Darko J, Vesna M, Mladen T. Spatial modeling of soil erosion potential in a mountainous watershed of South-eastern Serbia. Environ Earth Sci. 2013;68:115–128.
22. Qing T, Yong X, Sean JB, Yang L. Assessment of soil erosion using RUSLE and GIS: A case study of the Yangou watershed in the Loess Plateau, China. Environ Earth Sci. 20157(3):1715–1724.
23. Kumar V, Sharma A, Bhardwaj1 R, Thukral1 AK. Monitoring and characterization of Soils from river bed of Beas, India, using multivariate and remote sensing techniques. British Journal of Applied Science & Technology. 2016;12(2):1-12.
24. Kacem L, Agoussine M, Igmoullan B, Mokhtari S, Amar H. Feature interaction of lake water and springs and evaluation of hydrochemical water composition of the highest natural mountain lake of Morocco: Ifni lake (High Atlas Mountains, Morocco - North of Africa).Water Resources – Springer. 2016;43(2):395-401.
25. Kacem L, Igmoullan B, Mokhtari S, Amar H, Agoussine M. Morphometric characterization of upstream mountainous watershed using geographic information system GIS: high valley of Tifnoute High Moroccan Atlas. Journal of Biodiversity and Environmental Sciences. 2014;5:62-66.
26. Thomas RJ, Chevallier LP, Gresse PG, Harmer RE, Eglington BM, Armstrong RA, De Beer CH, Martini EJ, De Kock GS, Macey PH, Ingram BA. Precambrian evolution of the Sirwa window, anti- atlas orogen, Morocco. Precambrian Research 2002;118:1-57.
27. Manoj K, Jain, Umesh C, Kothyari. Estimation of soil erosion and sediment yield using GIS. Hydological Sciences Journal. 2000;45(5).
28. Renard K, Foster G, WeesiesG, McCool D, Yoder D. Predicting soil erosion by water :guide to conservation with the revised universal soil loss equation (RUSLE) ,handbook 703. US department of agriculture: Washington DC. 1997;404.
29. Farhan Y, Dalal Z, Ibrahim F. Spatial estimation of soil erosion risk using RUSLE Approach, RS ,and GIS technique : A case study of Kufranja Watershed, Northern Jordan. Journal of Water Resource and Protection. 2013;5:1247-1261.
30. Zhu Q, Chen XW, Fan QX, Jin HP, Li JR. A new procedure to estimate the rainfall erosivity factor based on tropical rainfall measuring mission (TRMM) data. Technological Sciences. 2011;54:2437-2445.
31. Gu Hh, Yu Zb, Yang Cg,Ju Q, Lu Bh, Liang C. Hydrological assessment of TRMM rainfall data over Yangtze river basin. Water Science and Engineering 2010;4:418-430.
32. Renard KG, Freimund JR. Using monthly precipitation data to estimate the R factor in the revised USLE. Journal of Hydrology 1994;157:287-306.
33. Parysow P, Wang GX, Gertner G, Anderson AB. Spatial uncertainty analysis for mapping soil erodibility based on joint

sequential simulation. Catena. 2003;53:65-78.

34. Arekhi S, Darvishi BA, Shabani A, Fathizad H, Ahamdyasbchin S. Mapping soil erosion and sediment yield susceptibility using RUSLE, remote sensing and GIS (Case study: Cham Gardalan Watershed, Iran). Advances in Environmental Biology. 2012;6:109-124.
35. Aubert G. Soil analysis methods. Edition C.R.D.P Marseille. 1978;189.
36. Wall GJ, Coote DR, Pringle EA. RUSLE-CAN Revised universal soil losses equation for application to Canada. Handbook evaluation of soil losses caused by hydrous erosion in Canada. Head office of research, agriculture and agroalimentary Canada, No of contribution AAC2244F. 2002;117.
37. CORINE. Soil erosion risk and important land resources in the southeastern regions of the European community. EUR 13233, Luxembourg, Belgium. 1992;32-48.
38. Yuksel A, Gundogan R, Akay EA. Using the remote sensing and GIS technology for erosion risk mapping of Kartalkaya dam watershed in Kahramanmaras. Turkey. Sensors. 2008;8:4851-4865.
39. Breiby Todd. Assessment of soil erosion risk within a subwatershed using GIS and RUSLE with a comparative analysis of the use of STATSGO and SSURGO soil databases. Papers in resource analysis. Saint Mary's University of Minnesota Central Services Press. 2006;8:22.
40. Moore I, Burch G. Physical basis of the length-slope factor in the universal soil loss equation. Soil Science Society of America Journal. 198650:1294-1298.
41. Soutter M, Mermoud A, Musy A. Engineering of water, soil process and installations, Press Polytechnic and Academic. 2007;316.
42. Evelyne P, Pascal D, Gwenaëlle P. Modelling of the hydrous erosion of the soil on a catchment area of the south-west of Madagascar, Fiherenana. Vertigo the Electronic Review in Environmental Science. 2011;10:3.
43. Khera KL, Kahlon MS. Impact of land use patterns on soil erosion in sub-montane Punjab. Indian Journal of Soil Conservation. 2005;33:204-206.
44. Singh MJ, Khera KL. Soil erodibility indices under different land uses in lower Shiwaliks. Tropical Ecology. 2008;49:113-119.
45. Rawat JS, Joshi RC, Mesia M. Estimation of erosivity index and soil loss under different land uses in the tropical foothills of Eastern Himalaya (India). Tropical Ecology. 2013;54:47-58.

---



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://www.sciencedomain.org/review-history/23871*