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Modeling of Water Erosion in the M'Goun Watershed Using OpenGIS Software

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***Abstract*—**Water erosion is the major cause of the erosion that shapes the earth's surface. Modeling water erosion requires the use of software and GIS programs, commercial or closed source. The very high prices for commercial GIS licenses, motivates users and researchers to find open source software as relevant and applicable as the proprietary GIS. The objective of this study is the modeling of water erosion and the hydrogeological and morphophysical characterization of the Oued M'Goun watershed (southern flank of the Central High Atlas) developed by free programs of GIS. The very pertinent results are obtained by executing tasks and algorithms in a simple and easy way. Thus, the various geoscientific and geostatistical analyzes of a digital elevation model (SRTM 30 m resolution) and their combination with the treatments and interpretation of satellite imagery information allowed us to characterize the region studied and to map the area most vulnerable to water erosion.

***Keywords*—**Central High-Atlas, hydrogeology, M’Goun watershed, OpenGIS, water erosion.

I. Introduction

FREE software from geographic information system or "OpenGIS" such as Saga GIS, Grass or QGIS are very popular with many users, researchers, and developers. They show great interest in environmental or geoscientific studies. The many extensions they contain, the ease of manipulation of the algorithms and the good functioning of most modules make them tools of invaluable utility and richness, especially, as their licenses are free.

The objective of this study is to show that open source GIS is as good as proprietary software. It proposes a methodology for the characterization of the wadi M'Goun watershed with cartography and a modeling of the rate of water erosion risk using, only, software "OpenGIS".

The watershed that is the subject of this study is located in the southern flank of the Central High Atlas and belongs to the upstream zone of the great Draa Basin. It is located 100 km northeast of Ouarzazate and is adjacent to Kelaat M'Gouna and Boumalne Dades Valley, as shown in Fig. 1. It includes one of the highest summits of North Africa: Ighil n'Mgoun (4071 m). The climate of the M'Goun valley is semi-arid to subhumid, dry in summer and rainy in winter and spring. Upstream, most of the precipitation is in the form of snow on the summits. Flows are, rather, torrential type and stormy rainfall often generates floods on alluvial plains. Water erosion, in this context, is manifested by landslides, landslides, ravines, soil and shoreline wreckage and the destruction of infrastructure (bridges and roads).

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II. Material and Method

To identify the characteristics of the wadi M'Goun watershed and to highlight the areas that are most vulnerable to water erosion, a combination and interpolation of a GIS with the satellite imagery processing has been done. In this study we used:

- An SRTM digital elevation model with 30 m resolution.
- Landsat 8 scenes.
- The geological map of Jbel SARGHO-DADES at 1/200 000.
- The Annual rainfall.
- The software used is all open source: Saga GIS [1], QGIS, Integrated Land and Water Information System (ILWIS), Grass, and Inkscape.

The methodology of this study is summarized in Fig. 2.

III. Results and Discussion

The DEM file is pre-processed using Saga GIS and applying the Fill Sinks module [1], with altitudes varying from 1500 m downstream of the watershed up to 4000 m at its upstream end. Areas at very high altitudes are located in the northern and western parts of the watershed. The hypsometric map is drawn after the reclassification and vectorization of the DEM file. The hypsometric curve depends on the variation of the orogenic elevation during a geomorphic cycle [5]. The hydrographic network which ensures the superficial drainage of the M'Goun watershed is dendritic type according to the Howard classification [6]. The orientation pink of the network sections shows very precise directions with a privileged north-south and east-west dominance. These directions go in parallel with those of the major African Craton, which indicates that the gullying follows preferentially the sensitive zones such as the faults present in the sector.

Table I summarizes the characteristics of the watershed, which has a fan-shape with an average altitude of 2456 m, massivity and orography coefficients respectively equal to 2.21 and 47.85 and a concentration-time approximately 8 h. The longest distance traveled by the mainstream is 90.29 km (see Table I). The topographic profile of the latter shows a very steep slope over 2 km upstream then a steep to moderate slope over 30 kilometers followed by 20 kilometers where anomalies are observed. These anomalies can be explained by the passage of the stream through deep gorges. The main trend sinuosity index is 1.87, indicating a significant sinuosity (see Table II).

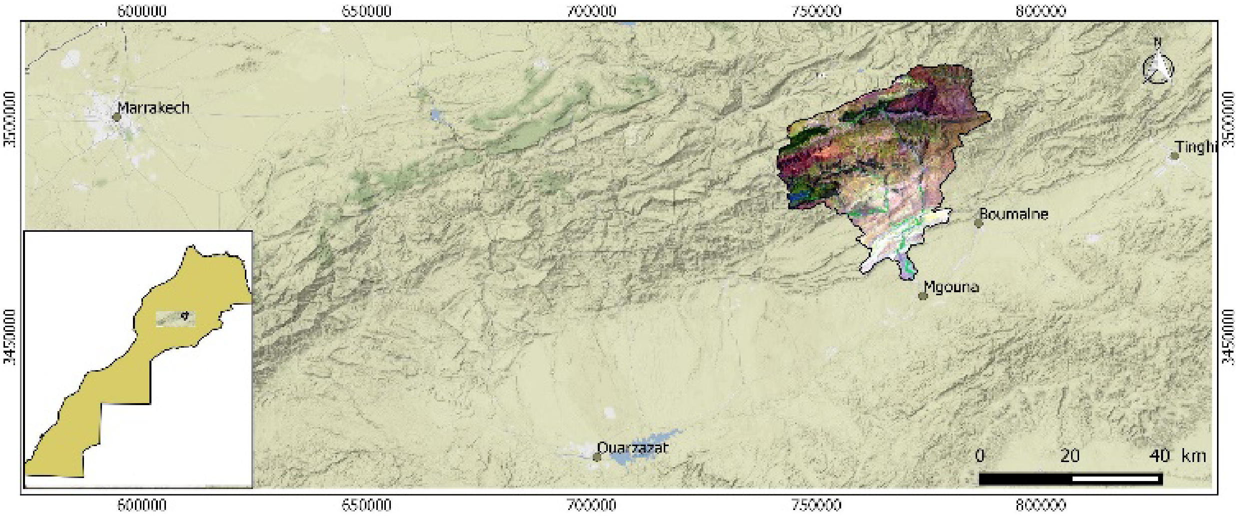

Fig. 1 Situation map of the study area

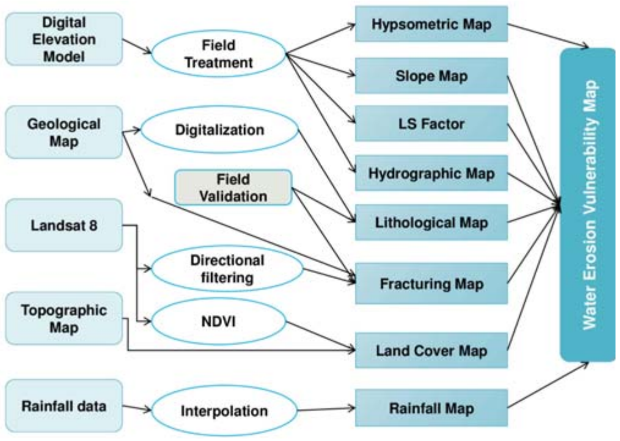

Fig. 2 Methodological chart of the erosion maps

TABLE I
CHARACTERISTICS OF THE WATERSHED

Outlet X	771328
Outlet Y	3463104
Perimeter (km)	278.21
Area (km^2)	1260.68
Mean Elevation (m)	2456.12
Elevation Range (m)	2613.09
Mean Flow Distance (km)	51.55
Maximum Flow Distance (km)	90.29
Concentration time (h)	8.32
Basin Type (Gravelius)	rectangular
Equivalent Rectangle (A)	134.41
Equivalent Rectangle (B)	4.69
Orographic Coefficient	47.85
Massivity Coefficient	2.21
Drainage Density (m/km^2)	670.50

TABLE II
CHARACTERISTICS OF THE LONGEST FLOW PATH

Start Height	3382.07 m
End Height	1494.8 m
Path Length	90,2914 km
Vertical Difference (Start to Finish)	-1887.3 m
Max Path Slope	59.28°
Straight-Line Distance	48.522 km
Sinuosity	1.87

According to the topographic wetness index (TWI) module [5], the topographic slope mapping of the watershed of Fig. 3, shows three areas with a high percentage of steep slopes: north, north-west, and north-west, and central part. The modal class best represented is that which lies between 16° and 24°, as shown in Fig. 4, and is observed in altitudes between 2300 m and 2600 m. The slight slope classes represent a high percentage dominate down-stream of the basin. The steep slopes make the watershed vulnerable to water erosion, which is demonstrated by the divergence and drainage of sediments on the slope's foothills.

The mapping of NDVI factor, as shown in Fig. 5, highlights areas with different values. Positive values close to zero correspond to bare soils not covered by vegetation, with a reflectance in the red slightly higher or of the same order of magnitude as that of the near infrared, while values greater than 0.1 indicate the presence of a plant cover, scattered tree forests, orchards, fields, and polycultures in alluvial valleys and flood plains. The scattering of the points in Fig. 6 shows that NDVI values are between -0.04 and 0.44 with a concentration for classes between 0.04 and 0.14; this concentration is specifically related to certain hypsometric zones.

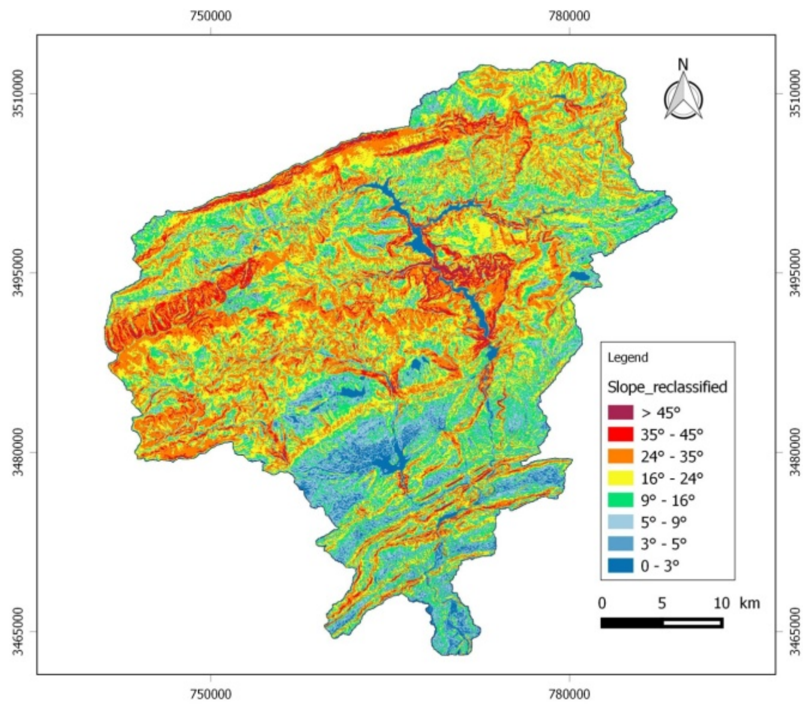

Fig. 3 The map of topographic slopes

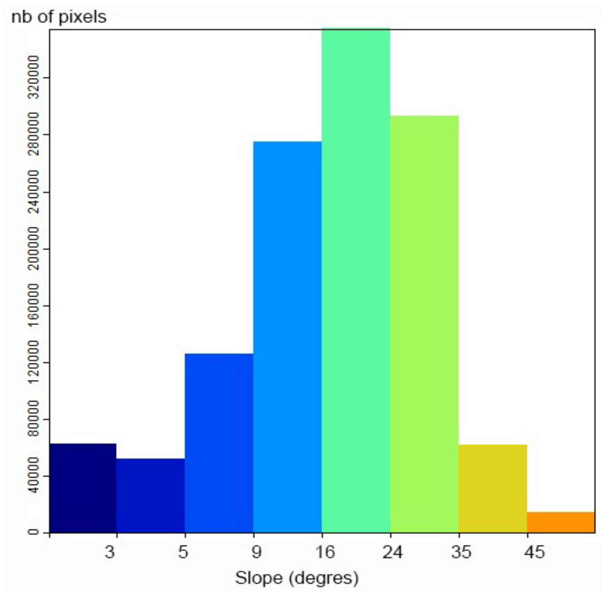

Fig. 4 Histogram of slopes

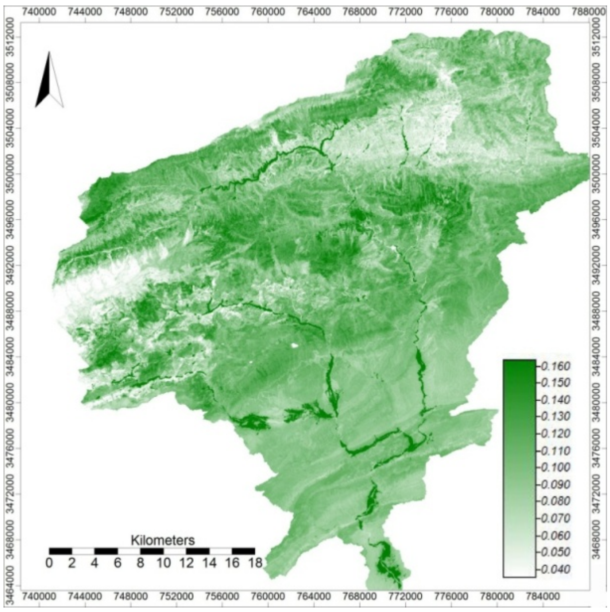

Fig. 5 The mapping of NDVI factor

The topographic wetness index map, which is used to quantify the effect of the topography on the hydrological processes, shows high values synonymous with zones relatively wet compared to the other zones, especially in the upstream valley of the stream main water, see Fig. 7.

The LS factor mapping used the Universal Soil Loss Equation (USLE) by calculating slope lengths [5]-[7] and its graphical representation highlights the ratio of soil loss under certain hydrogeological conditions. The values observed between 10 and 16 reflect the areas at high risk of water erosion in the M'Goun watershed, as shown in Fig. 8.

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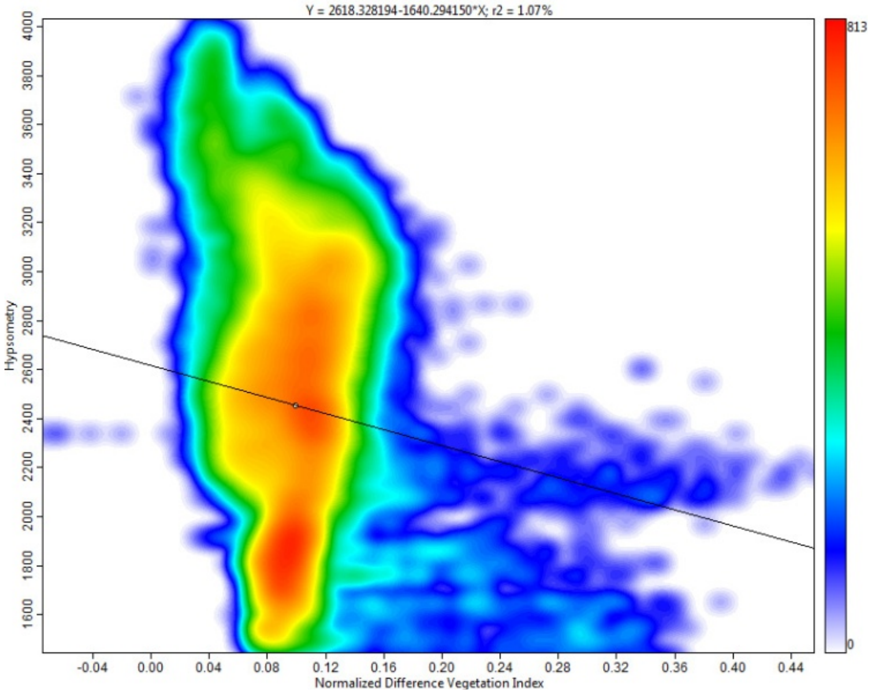

Fig. 6 Diagram of NDVI Factor

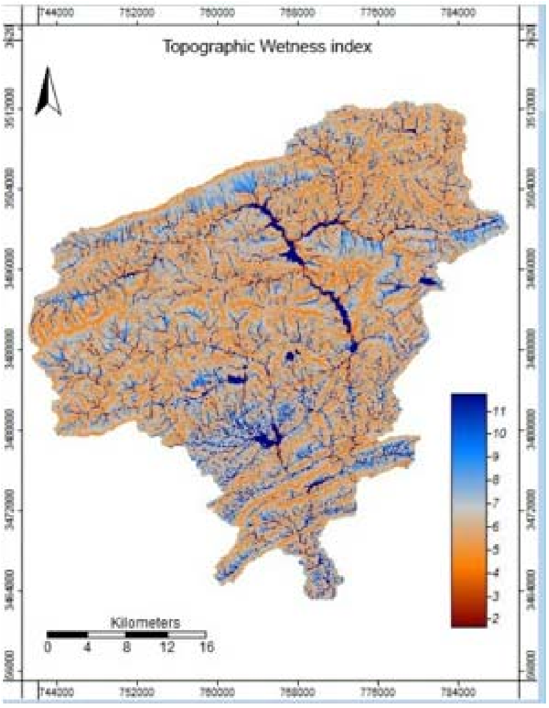

Fig. 7 The map of Topographic Wetness index

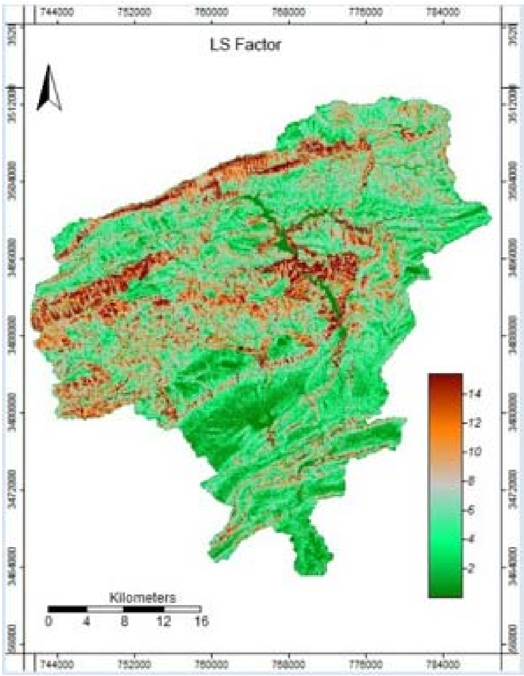

Fig. 8 The LS factor map

The superimposition of the different maps, various indices, and factors under the QGIS open source program, allowed the creation of a map that delineates the zones potentially vulnerable to the risk of water erosion (see Fig. 9). The high-risk areas are located in the upstream and central parts of the basin, characterized by high altitudes, steep slopes, intense fracturing, bare soils, and carbonate or carbonato-evaporitic lithology. In the downstream part, it is rather, the presence of the Cretaceous, Eocene and Paleocene cliffs and abrupt ones which favor, as well, landslides as the degradation of grounds under the effect of the water erosion. To that end, the lithology of the soils and the LS factor appear as the determining agents in the natural phenomenon of water erosion.

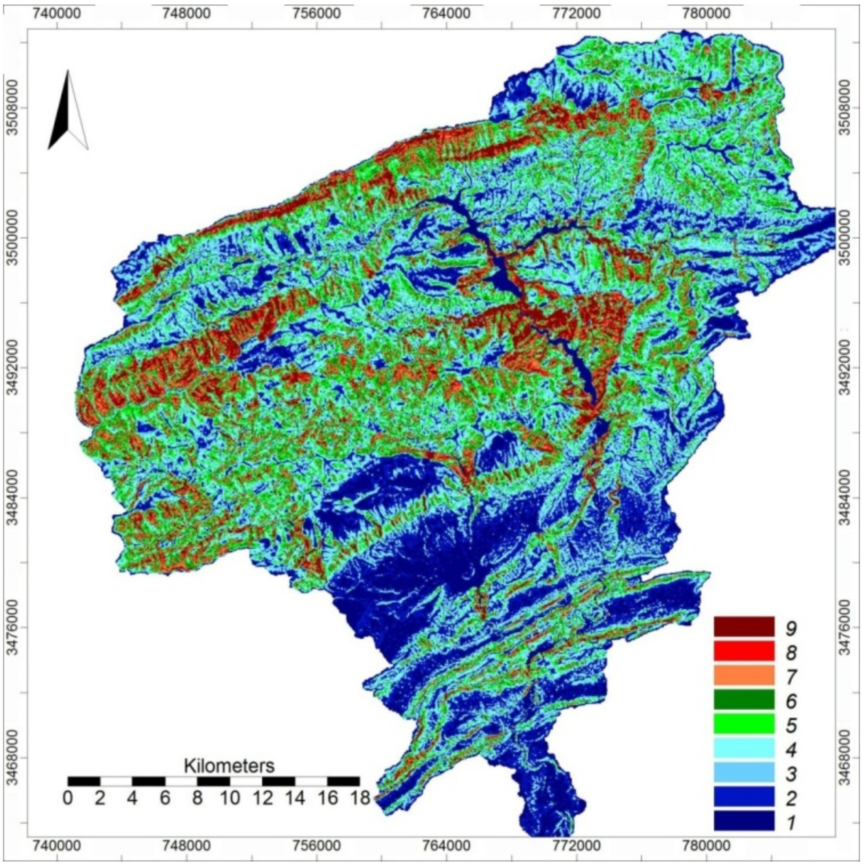

Fig. 9 Map of M'Goun watershed's water erosion rate

IV. Conclusion

The objective of this study is to show that the OpenGIS software performs as well as their commercial counterparts. Indeed, the results obtained are very relevant and highly convincing. The thematic maps and the calculations of the various factors led to express the vulnerability to water erosion in the M'Goun watershed. Thus, modeling that combines hypsometry, topography, vegetation, geology, and hydrogeology have been successful with the use of open source Saga GIS, Grass, and ILWIS. Under QGIS, the design of the hard copy documents has allowed very well architected files for printing.

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