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Integrated Environmental Analysis using GIS for Rational Planning of Conservatory Management of Slopes Application in the Ouergha Basin (Morocco)

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Abstract

The objective of this work is the realization of a map spatializing proposals of management and planning of lands, with a view to their rational management within the framework of a sustainable development. It was based on a diagnosis of the natural environment that allowed the analysis and identification of constraints to the development of the watershed of Ouergha (North of MOROCCO). The methodology consists of an analysis of the collected data through field surveys of farmers. For example, spatial data was organized into thematic layers of information on soils, land use, geology, erosion patterns and topography. The integration of these and other survey data into a Geographical Information System (GIS) has resulted in a management and land management map. The latter can serve as a basic document in the choice of the orientations, actions and development which will be taken by the actors of the development of the zone.

Keywords: Land Management and Management Map, GIS, Soil and Water Conservation, Ouergha, Morocco.

Introduction

The Ouergha watershed, as elsewhere throughout the Rif region, rational land management actions to increase crop yields and conserve natural resources must necessarily include all the appropriate anti-erosion techniques to curb the adverse effects erosion, which is an important factor in land degradation. In this sense, Rooze et al., (2012) analyze the three stages of evolution of research on water erosion and erosion control in the Maghreb countries.

In a first stage (1945-1970), in Morocco, after a report of the effects of erosion, DRS works on lands very degraded by water erosion were carried out. In a second stage (1965-1985), erosion is quantified notably by the Heusch team. Finally, during the last stage, since 1985, teams from ENFI, the Faculty of Humanities and Humanities of Rabat and IRD described thirty traditional systems of water management and soil fertility on the Rif and Atlas mountains. Several actions and projects to fight against erosion and for the development of agriculture succeeded one another in the studied perimeter and the surrounding areas.

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The main purpose of the present work is to present the approach followed, with the final result being the establishment of the management and land management map in the selected perimeter. Its realization results from an analysis and integration of the different morpho-geo-pedological characteristics influencing the productivity of the grounds and constituting as many themes organized in a geographic database using the GIS tool. This article begins with an analysis of the physical context of the studied perimeter. Then we present the methodology adopted for the realization of the land management and land management map.

The studied perimeter is located in the Ouergha basin, which is located north of Morocco the perimeter totals approximately 6190Km^2. The province of Taounate covers part of the Rif's chain and its southern borders, the geological formations characterizing this province represent in part structural units of this chain and the neogenic formations within the mountains or the South Rifain corridor (Fig. 1). The structural sets of the outer Rif are represented by Late Miocene post-nappe formations. The numerous outcrops of chaotic material attributed to the Triassic are one of the characteristics of this region and consist mainly of variegated saliferous clays, gypsum dolerites, and constitute a level of detachment on which the whole Rifain chain has slipped (Suter 1965).

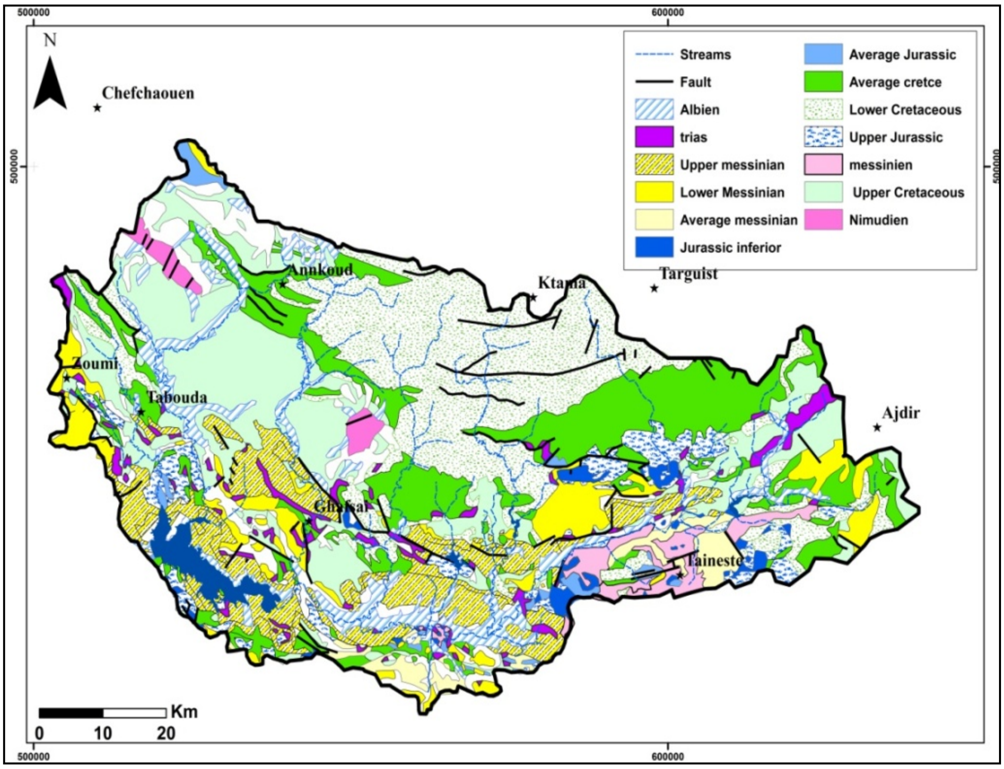

Figure 1. Geological map of the Ouergha watershed

The Ketama unit has a schisto-sandstone flysch of the lower Cretaceous some kilometers thick. The Ketama unit, consisting mainly of Jurassic and Cretaceous series, is affected by two phases of schistosity and two metamorphisms (the first phase is Oligocene age lower-Miocene inferior and the second phase is Late Miocene age (Adrieux, 1971 Frizon De Lamotte, 1985).

The Tangier unit is considered as the more detached cover of the Ketama unit; it is formed by Middle and Upper Cretaceous shales and limestones. The formations of the Tangier Unit are often in overlapping contact on the black clays of the Ketama Unit. The Tangier unit is slightly deformed and consists mainly of Upper Cretaceous lands similar to those of Tangier inland. Several outcrops of Tertiary age cover are known (Lespinasse, 1977).

The Aknoul aquifer is characterized by its superior structural position in the building of the intrafrust aquifers. In Taounate province, this water table straddles Ketama and Senhadja units. Unrevised ante-Senonian outcrops are rare. Black flysch type pelites, however, appear to Bab Hatri. They are very homogeneous, with little sandstone and rarely contain bands of marl or light marly limestones comparable to those found in the Cretaceous flysch of other intra-Riface nappes. It is most likely Aptien-Albien (Leblanc, 1980). The Ouezzane aquifer is interpreted as a syn-orogenic basin located at the front of ramp propagation anticlines (Tejera de Leon, 1993).

Digital Terrain Model (DTM) processing shows the peculiarity of the topo-hydrographic configuration characterized essentially by an elongated shape and a geomorphological heterogeneity (fig.2). The Ouergha watershed has a mountainous character with altitudes varying between 83 m and 2450 m. It shows a diversity of reliefs, with structural forms, closed depressions, ravines and forms of accumulation represented by alluvial terraces.

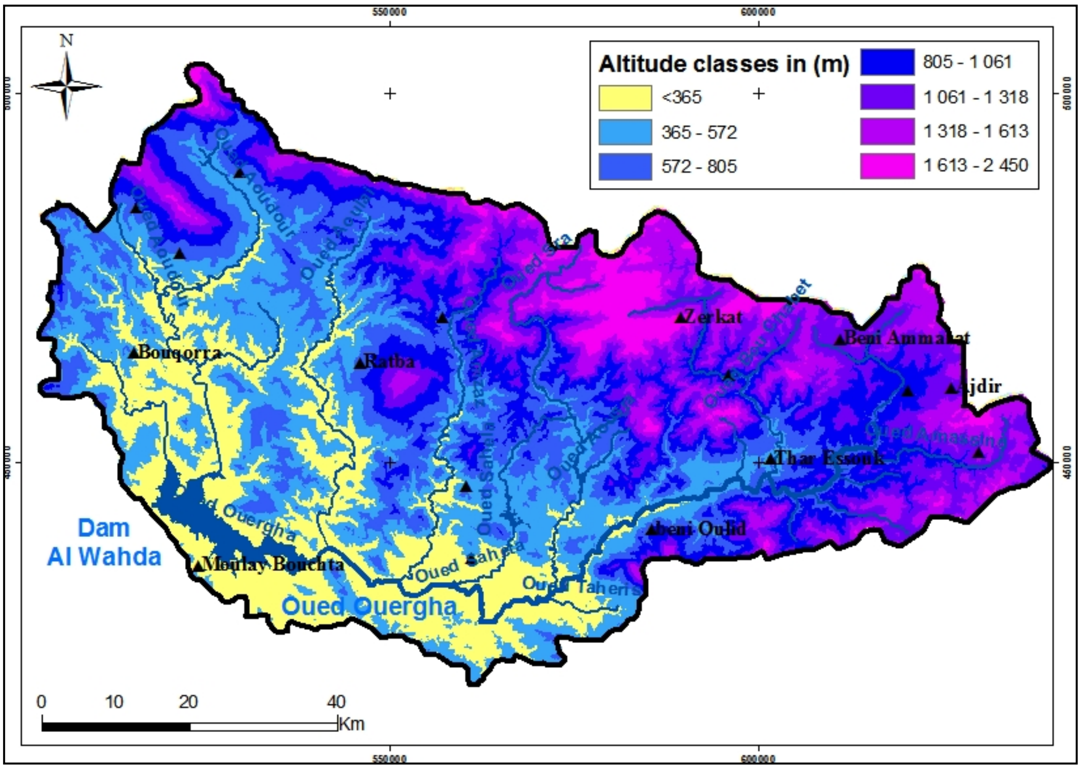

Figure 2. Map of Altitude Classes of the Ouergha Watershed

From the terrain map, relief is considered as a major factor reflecting the ability of a watershed to runoff. The main characteristics of the watershed are:

- The following two slices [800, 1000 m], [1300, 1600 m], which shows the mountainous nature of the basin;
- The lowest altitudes extend over the downstream part of the watershed.

Material and Methods

All maps were captured, processed and analyzed using the GIS tool, including Arc-gis software. The combination of these thematic layers with the aid of the aforementioned tool has led to the production of the management and soil management map (Fig. 3). Because they are all geo-referenced in the same coordinate system, their superposition and confrontation allowed the delineation of the map units of the resulting map. The latter is obtained following the thematic combination of all these layers analyzed in raster mode. In fact, once the superposition has been completed, the values of the homologous pixels in each of the layers are analyzed and grouped together into classes that are as homogeneous as possible, responding according to their characteristics to specific needs in terms of management and planning. These classes therefore correspond to the different map units of the map of Figure 3.

The units of the map of the figure therefore correspond to categories of land whose recommendations take into account the variability of their local spatial characteristics presented in the maps below (geological, lithological, morphological, terrain and elevation maps, land cover) and their constraints.

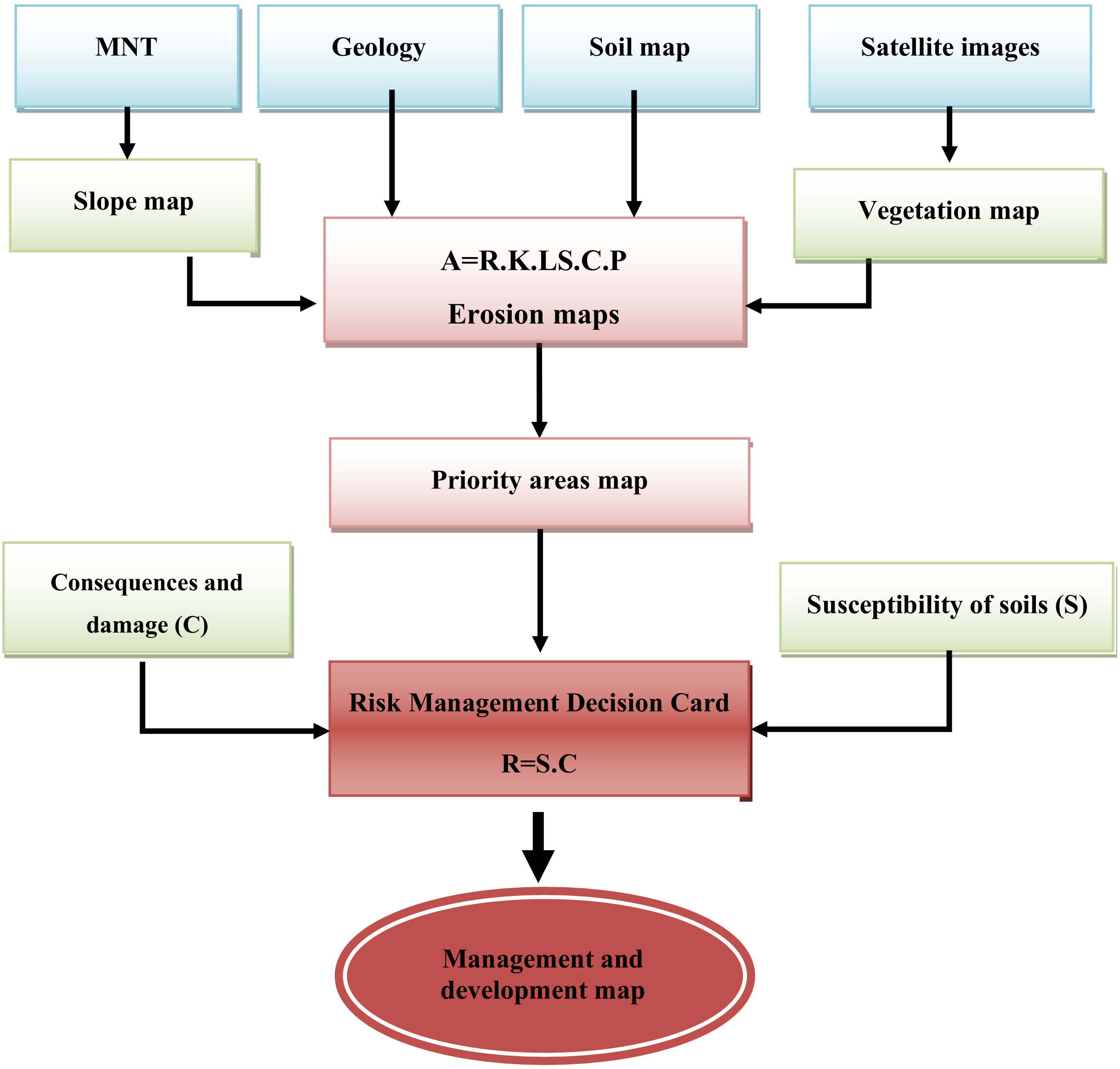

Figure 3. Combination of different thematic maps using GIS

The slope classes selected are: 0-8.5%, 8.5-16%, 16-24%, 25-33% and 33-74%. These classes are adopted because the slope value of 8.5% is considered as the limit between mechanizable farmland (<8.5%) and non-mechanizable farmland (> 8.5%). The slopes are quite important, those of less than 16% total 25%, including a relief of low hills and a few flats. On the other hand, those between 16 and 74% represent 58% and characterize a more rugged relief (Fig. 4).

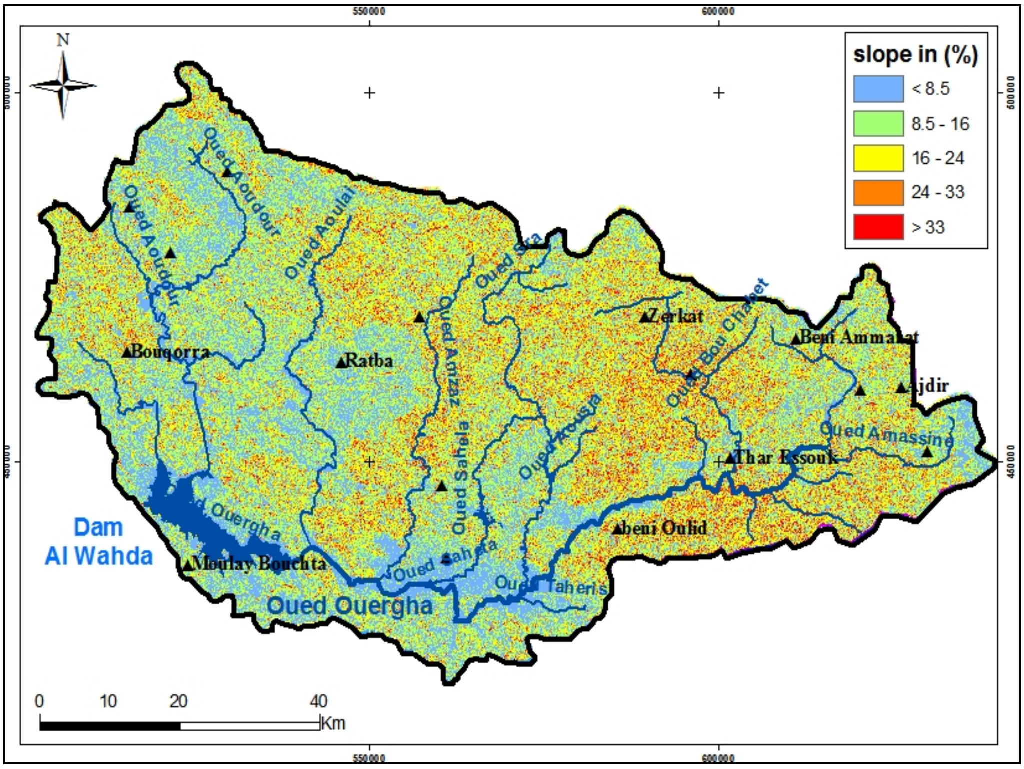

Figure 4. Map of the slopes of the Ouergha watershed.

Land occupation was obtained as a result of satellite imagery processing and bung classification. Indeed, six main types of land use spread over the entire study area. (Jaouda et al., 2018).

Soil degradation: In the Rif, water erosion in the Ouergha catchment area is important and constitutes a major constraint. It manifests itself in varying forms and intensities. And this for structural and climatic and anthropogenic litho logical reasons. The geological shows the significant extension of soft substrates of different ages that are susceptible to erosion such as marls, pelites, marno-schists and to some extent marl-limestones. Medium to strong slopes favor erosion processes. In fact, slopes exceeding 16% total more than 50% of all slope classes. The low vegetation cover poorly protects the soil against runoff caused by aggressive rains. Finally, overgrazing and inadequate land uses are also factors that promote land erosion (Jaouda et al., 2018).

The various forms of water erosion found in the study area are a reflection of a significant specific degradation. From a qualitative point of view, the forms of water erosion acting on the slopes are essentially the trickling water runoff, grills, gullies, landslides, solifluxing flows. Badlands are quite common and are observed locally. Erosion is weak or nil on low extensional plains, especially those found in some depressions and at the alluvial terraces of important wadis such as Ouergha and its tributary Oued Amzaz. From the hydrographical point of view, the perimeter is drained by the main wadi, Oued Ouergha and its tributaries Wadis Amzaz, Aoulai, Aoudour, Sra and Sahla and (Fig. 5):

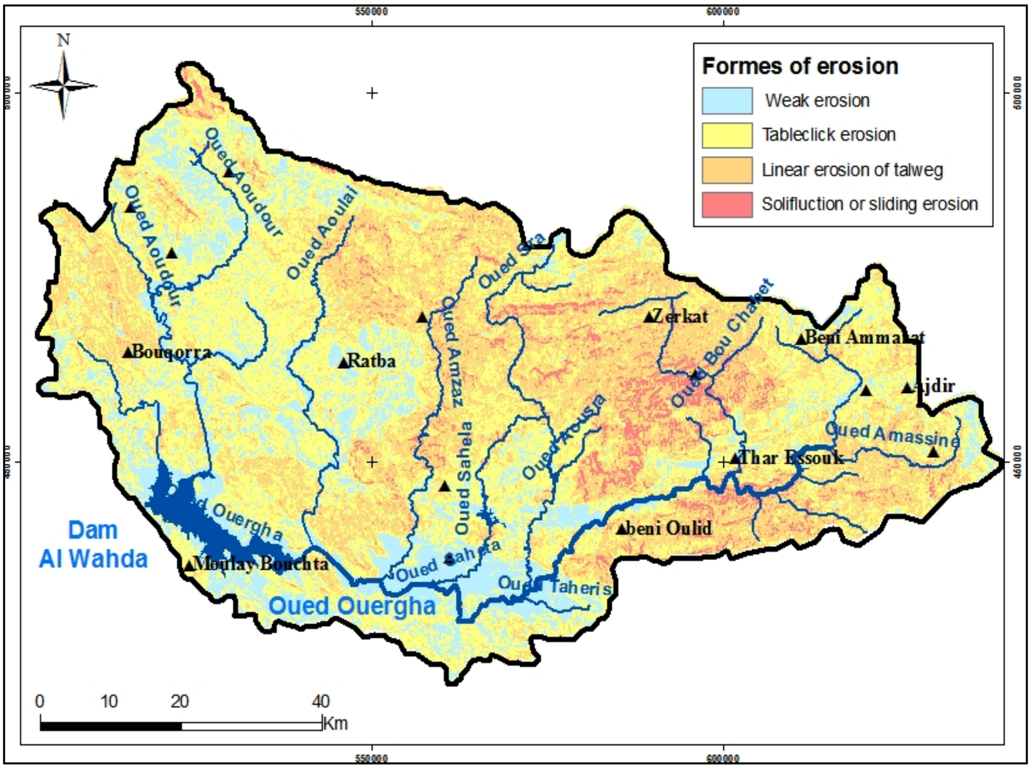

Figure 5. Map of the main forms of water erosion

The analysis of the soil loss map gives the map of the priority areas of the Oued Ouergha watershed (fig.6). The distribution of vulnerable zones shows a real spatial heterogeneity linked mainly to the typology of soils and to the socio-economic vulnerability that characterizes the Ouergha watershed.

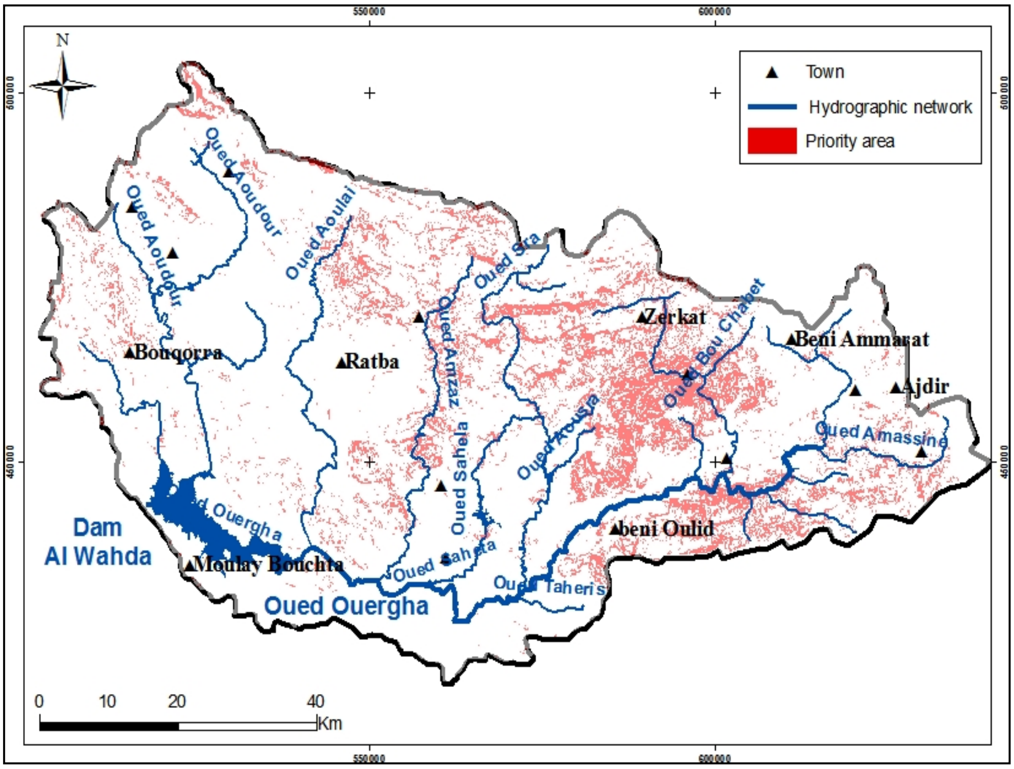

Figure 6. Priority areas of the Ouergha watershed

Priority areas, with a socio-ecological vulnerability, occupy 35% of the total surface area of the Oued Ouergha watershed. The majority of the rural communes in the study area require territorialized spatial planning interventions associated with specific socio-development programs.

The response of the Ouergha catchment denotes a spatial homogeneity to the rainfall hazards in terms of land loss also revealing high peak flows for the different return periods. The analysis of cumulative curves made it possible to distinguish classes of homogeneous susceptibility for the Ouergha catchment. The reference hazard zoning obtained defines four levels of susceptibility (Fig. 7).

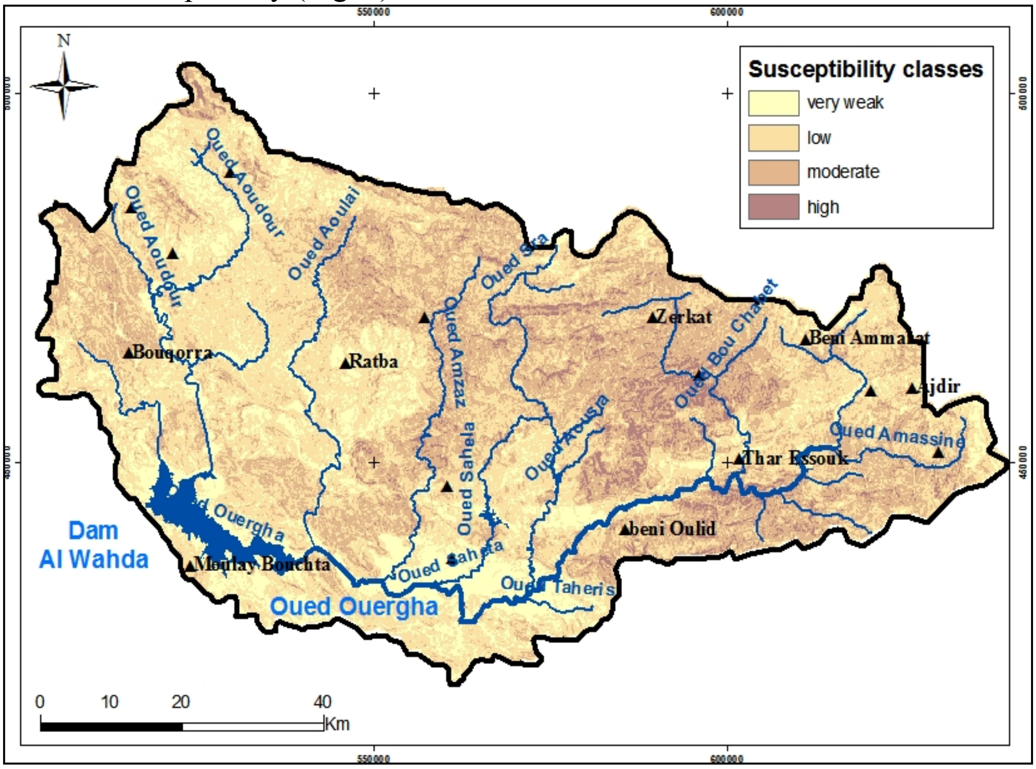

Figure 7. Soil Susceptibility of the Ouergha Watershed

This exploratory approach amply demonstrates the ability of the system to automatically generate hazard zoning and that almost a third of the watershed has moderate to strong levels of suspensability. This four-level hazard can be combined with a vulnerability defined in four levels. This would allow for risk maps.

Potential consequences: Analysis of the land data shows that the local economy is mainly built on the primary sector (mixed farming and livestock farming). The structural damage and direct operation (CSF) map is the result of the superposition of land loss issues to human activities related to it (agricultural cost).

The map of potential damage (vulnerability) is based on the results of the field data and thus allows structuring the cost of erosion and highlighting large areas of vulnerability (Fig. 8).

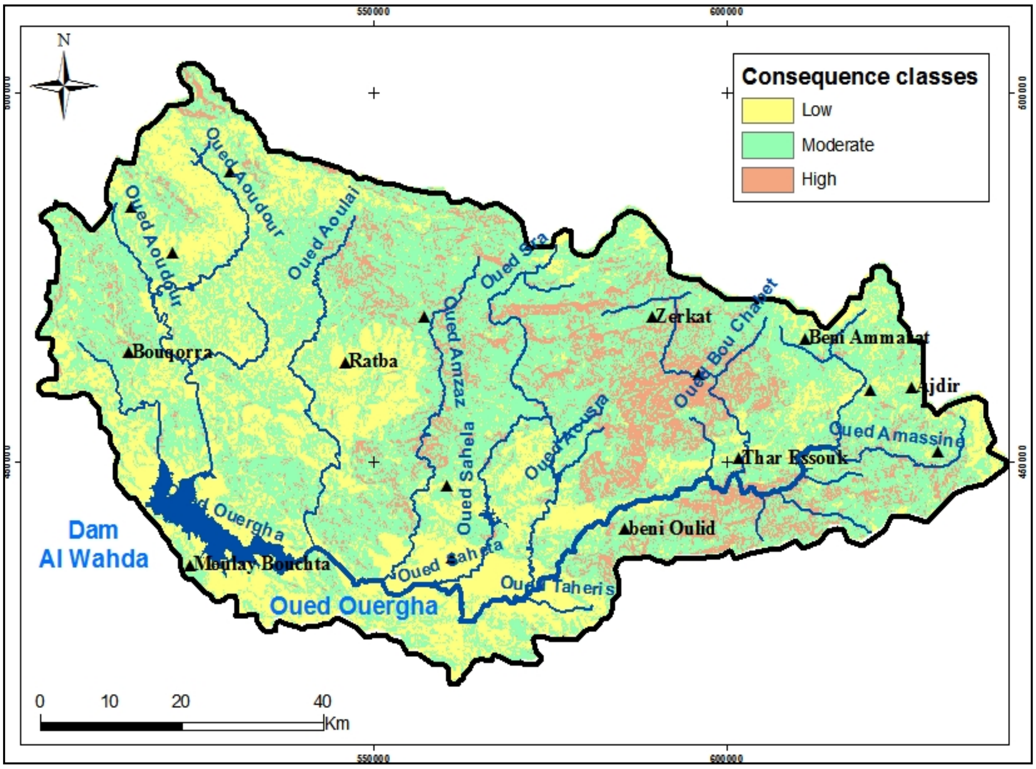

Figure 8. Consequences and damage of the Ouergha watershed

Results and discussion

The risk decision map obtained from the spatial cross-referencing of susceptibility maps and potential consequences (Figure 10).

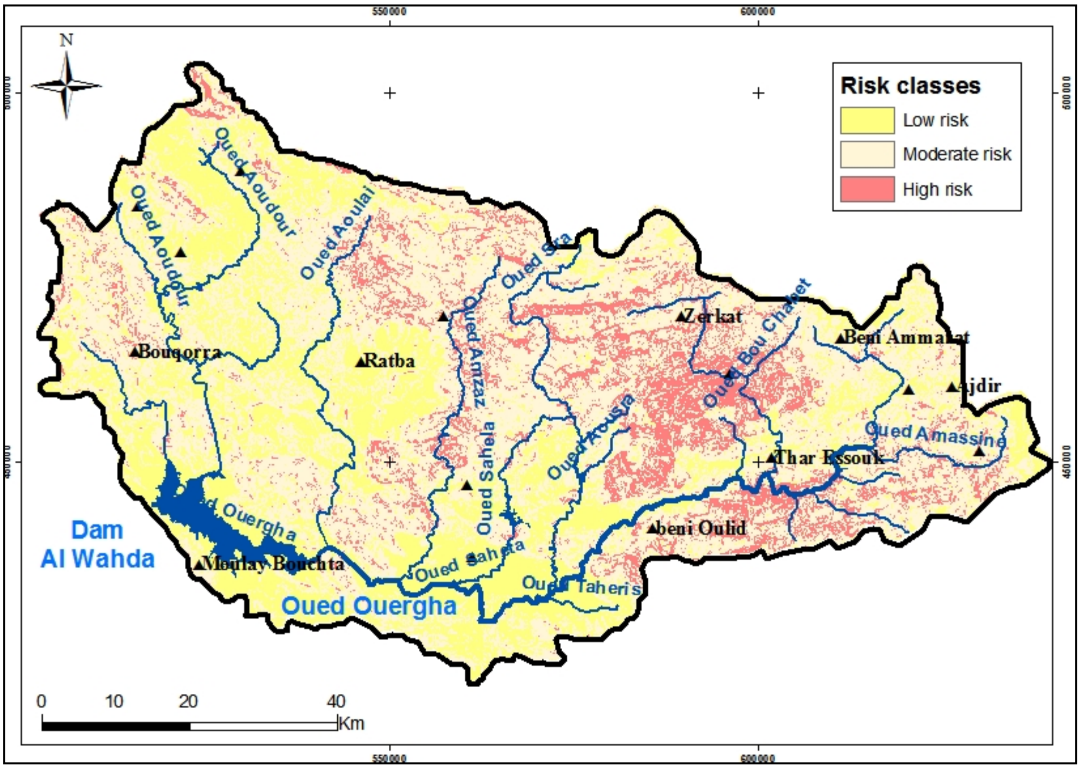

Figure 10. Erosion Risk Management Decision Card

The priority management approach of major risk areas is based on the choice of operational actions (biological treatment and or mechanical correction of ravines) compatible with the intrinsic stakes of the Oued Ouergha slopes (fig.11).

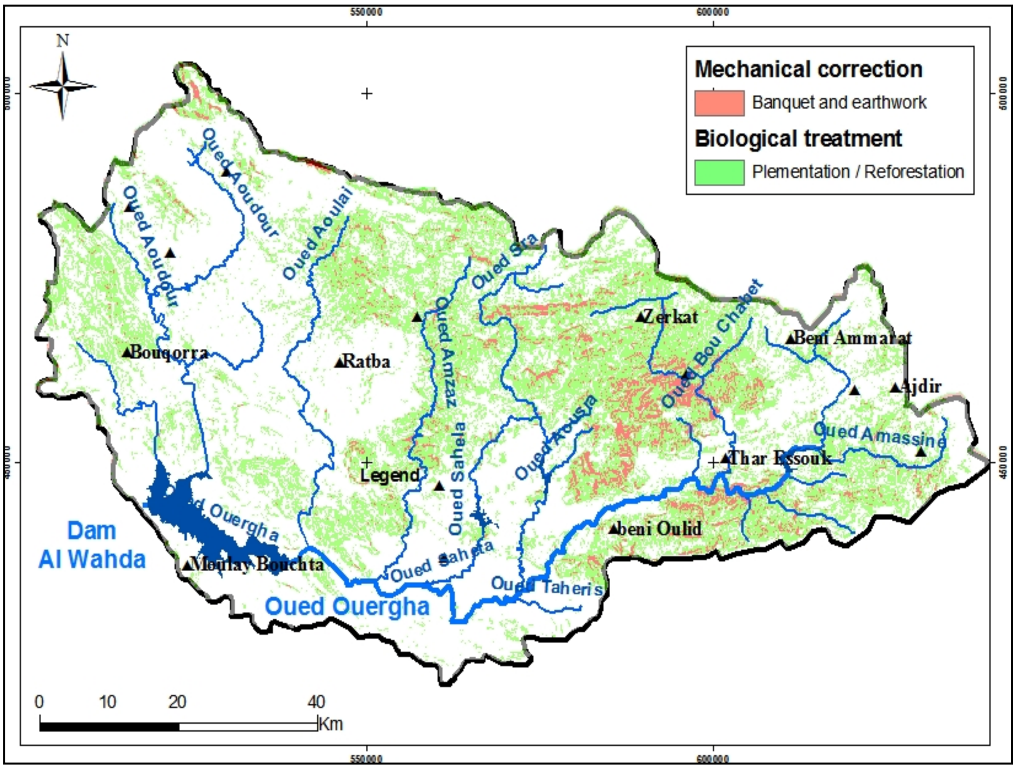

Figure 11. Decision Map of the Priority Action Plan

The analysis of the spatial aggregation obtained in the environment is based on the exploitation of the spatial autocorrelation of each entity (pixel) with respect to the neighboring entities in a spatial dataset. As a result, the statistical significance of spatial autocorrelation is analyzed based on an approach of evaluating the statistical hypothesis based on the spatial data set obtained. For this purpose, the spatial modeling of the correlation structure is synthesized in the spatial connectivity decision map.

The advantage of mechanical engineering is the reduction of erosion at the Ouergha watershed, which will reduce:

- The risk of flooding of agglomerations and the destruction of public, industrial and private infrastructures;
- The siltation rate of the AL WAHDA dam;
- Maintenance work on basic infrastructure and downstream equipment.

Other socio-economic impacts:

- • Improvement of the incomes and living conditions of the populations;
- • Creation of levers for other socio-economic projects;
- • Opening of the douars by the opening and the rehabilitation of the tracks;
- • Improvement of water supply and electricity.

The biological treatment actions, through the implementation of planting and reforestation, are planned in areas with a high statistical correlation between the hazard and the vegetation cover rate. However, the mechanical treatment actions, by earthworks, benches, stabilization and gully corrections, are particularly suitable for areas with strong spatial aggregation between erosive hazard and topographic factors. In addition, biological actions (fruit plantation, regeneration and reforestation of degraded areas) are prescribed for

22% of the watershed. On the other hand, the mechanical actions intended to reduce the effect of the slope and the installation of the isohypse structures (benches, ditches and earthworks) are programmed on an area 9% of the watershed of Oued Ouergha.

The execution of the intervention programs allows an improvement of the agricultural, fodder and forestry productions. The increase in agricultural production mainly concerns arboriculture and cereals. The increase in fodder production mainly concerns rangeland improvement, reforestation and forest restoration operations.

The restoration of the natural balance, through the reconstruction and rehabilitation of natural forest ecosystems and the development of rangelands, will allow the development and resettlement of natural vegetation. This will result in preservation and improvement of the flora and fauna in the area. Mechanical erosion control measures will protect and conserve soil capital and improve the quality of surface water and groundwater recharge.

Conclusion

The integrated and in-depth diagnostic conducted in the study area has enabled the development of a local spatial database using the GIS tool. The use and analysis of these spatial data led to the development of a management and land management map. Its realization results from an analysis and integration of the different morpho-geo-pedological characteristics influencing the productivity of the lands and constituting as many organized themes in the spatial database. The latter can be updated and fed as needed by other complementary information. It can help development officials in the area to guide and make decisions on the wise use and conservation of lands subject to major degradation processes.

The proposed management program consists of biological actions and mechanical gully correction measures. Thus, biological treatment concerns the watershed of Oued Ouergha, concerns mainly upstream in the sub-basins of Sahla, Amzaz and Sra. Thus, the program of biological actions corresponds to the work of fruit plantations on private land and regeneration and reforestation works for the reconstitution of degraded forests. Moreover, a quarter of the proposed biological interventions (29,935 ha), located mainly on slopes with steep slopes, must be combined with mechanical treatment actions to attenuate the amplitude of soil losses and the conservation of water resources.

Thus, the planned mechanical actions are mainly programmed for the zones at major risk of the erosive hazard, especially at the central level of the Ouergha watershed, notably the Amzaz and Sra sub-catchment and correspond to the setting up of benches, terraces and stabilization of the ravines. It should be noted that, in order to preserve biodiversity, the Action Plan obtained includes as a priority the restoration of ecological balances and the reconstruction of degraded soils to reverse the degradation trends and to control the potential risks related to soil loss. and siltation of the Al Wahda Dam downstream.

In conclusion, the results with spatial references obtained indicate that spatial analysis, based on the objectivity of the calculations carried out in a GIS environment, is effective both for the mapping of natural risks, the geo-treatment of social vulnerability ecological and the production of thematic maps relating to the master plan of strategic and operational management of watersheds. Nevertheless, research work must continue to introduce temporal composting in a decision-making perspective and the implementation of territorialized planning actions.

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