ASSESSMENT OF THE VEGETATION COVER CHANGE IMPACTS ON WATER EROSION, USING PAP/RAC METHOD IN UPSTREAM OF "OULJET SOLTANE" DAM, CENTRAL PLATEAU-MOROCCO

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ABSTRACT:
The aim of this paper is to evaluate the impact of forest cover dynamics on the erosion at Kharouba watershed in the Moroccan Central Plateau. Our methodology is based on the diachronic analysis of the land cover between 1986 and 2016, using treatments of aerial photographs from 1986 and a Google Earth satellite imagery at a high resolution from 2016. The land cover maps obtained were used to establish erosion status maps between 1986 and 2016, based on methodology PAP/RAC. Our study highlights the regressive evolution of vegetation cover. This decline has stressed the increased water erosion risk in Kharouba watershed causing the spread of the areas that are vulnerable to water erosion from 36 % in 1986 up to 41 % in 2016.

Key-words: *Vegetation cover, erosion, watershed, methodology PAP/RAC*

1. INTRODUCTION

Soil erosion is a degradation process of natural resource that has remarkably grown over time. In fact, rapid landscape changes, due to demographic pressure and climate changes, magnify the surface runoff process, and therefore, the soil degradation (Heusch, 1970; Al Karkouri et al., 2000; Naimi et al., 2005).

In Morocco, several research studies have been dedicated to understand the erosion process in the Moroccan mountains through the modeling of soil loss in several watersheds (Laouina, 1998; Moufaddal, 2002; Damnati et al., 2013; Simonneaux et al., 2015; Iaaich et al., 2016; Briak et al., 2016).

Results, at the Beht watershed, show that the area at risk amounts to 87 %, with an annual siltation rate of 1.40 Mm3 / year (El Gaatib, 2015). Kharouba watershed, located in the central part of Beht, has an average specific degradation; estimated at 4.10t / ha/year. The outlets losses are measured at 60 thousand tons per year (HCEFLCD, 2007). This situation could pose a real threat to the siltation of the under-construction Ouljet Soultane dam.

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This watershed has valuable forest resources covering more than 87 % of its area. However, this forest patrimony suffered over time significant amount of pressures: mainly illegal logging, overgrazing and climate changes, consequently intensifying erosion and land degradation. In this context, the present work aims to highlight the gravity and the erosion phenomena evolution and to evaluate impacts of vegetation cover change on water erosion at Kharouba watershed.

2. STUDY AREA AND DATA

Kharouba watershed covers an area of about 19888.5 ha and is located in the central part of Beht (**Fig. 1 and 2**). It is characterized by the dominance of primary geological formations. The area has an accentuated relief, a semi-arid to sub-humid climate, marked by strong spatial and temporal rain variability. These factors associated with land use and anthropogenic actions promote its vulnerability to erosion.

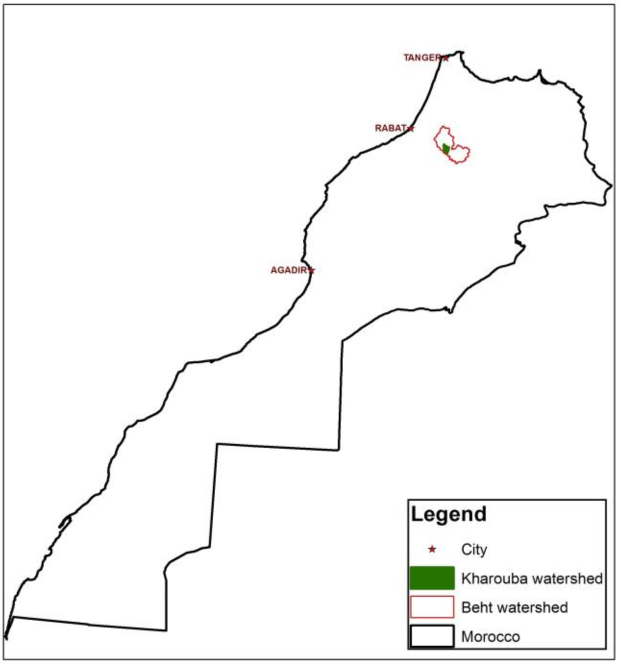

Fig. 1. Location Map of the studied area.

The average specific degradation for Kharouba watershed is estimated at 4.10t /ha/year. Losses at the watershed outlet are estimated at 60 thousand tons per year (HCEFLCD, 2007). In terms of land use, Kharouba watershed is dominated by forest formations covering more than 87 % of its area (**Fig. 3**). These formations are mainly based on *Tetraclinis articulata* and *Quercus rotundifolia* (Dallahi et al., 2016; Dallahi et al., 2017).

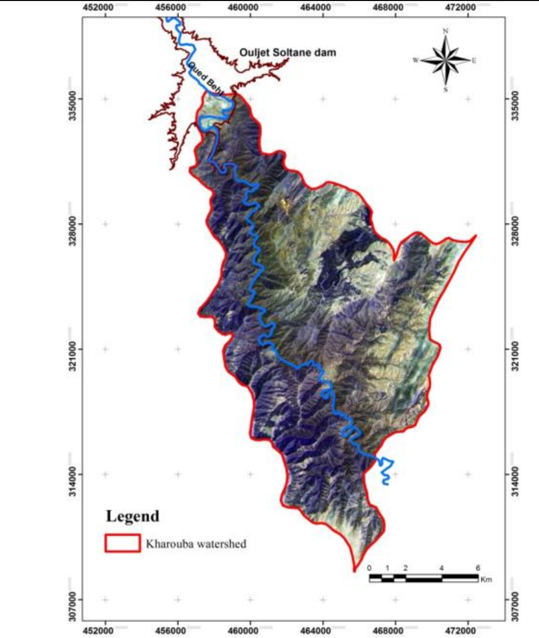

Fig. 2. Location Map of the Kharouba watershed

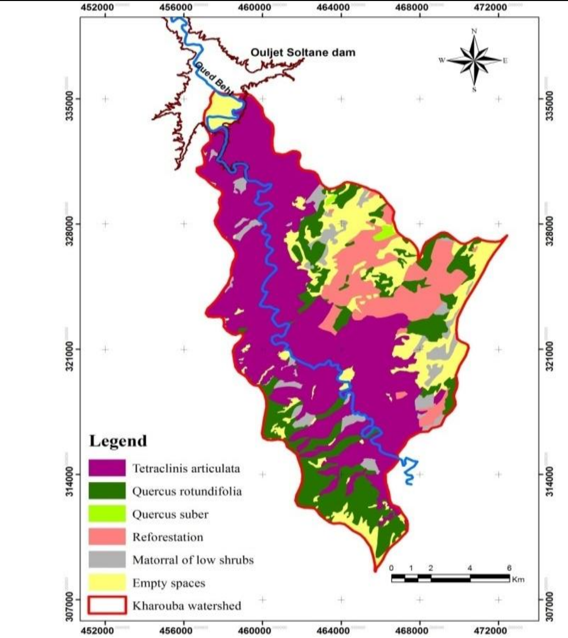

Fig. 3. Vegetation cover map (2016)

3. METHODOLOGY

From a methodological approach, this work consists, firstly, in a diachronic analysis of the vegetation cover using aerial photographs from 1986 and a Google Earth satellite imagery at a high resolution from 2016 to quantify the spatio-temporal dynamics of the vegetation cover. Secondly, we relied on the predictive approach of the PAP / CAR method (PAP/RAC, 1997), to set up an erosion status map on two different dates, providing thus the map canvas of the potential and the general patterns of erosion.

The predictive approach of the PAP/RAC method is mainly a data processing according to the following operations (**Fig. 4)**:

- Slope and lithofacies mapping;
- Erodibility mapping by overlaying the slope and the lithofacies maps;
- Land and vegetation cover mapping for 1986 and 2016;
- Soil protection maping of 1986 and 2016 by overlaying the land and vegetation cover maps;
- Erosion status mapping by overlaying erodibility and soil protection level maps.

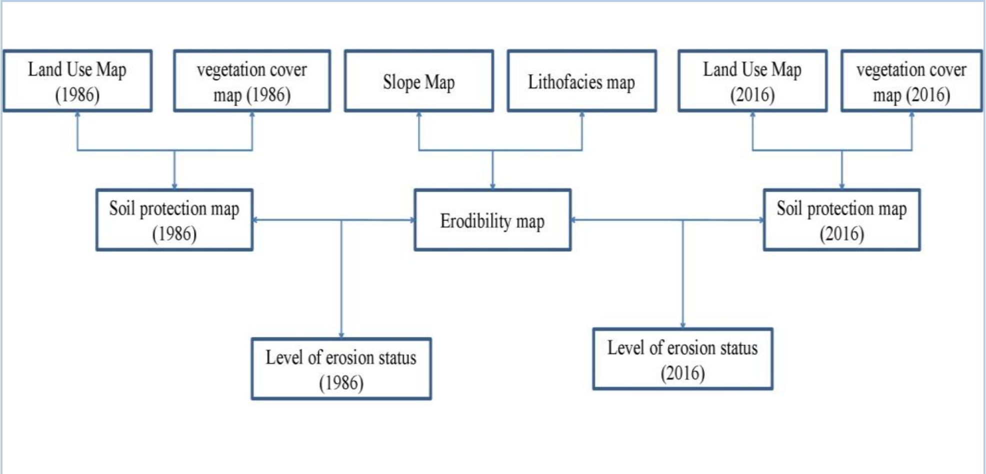

Fig. 4. Main operational sequence of erosion mapping procedures (PAP/RAC, 1997).

4. RESULTS AND DISCUSSIONS

4.1. Results of the vegetation diachronic analysis

The diachronic analysis is based on the comparison of the composition and the surface of the plant's formations on two different dates. The different area's loss and gain in term of strata are shown in **Table 1**.

Table 1.

Confusion matrix for mapping land cover change.

	1986							
	strata	**Ta**	**Qr**	**Qs**	**R**	**M**	**V**	**Total (2016)**
2016	**Ta**	10898	0	0	0	0	0	10898
	Qr	0	2559	0	0	0	0	2559
	Qs	0	0	97	0	0	0	97
	R	303	655	0	1150	54	0	2162
	M	730	212	2	0	145	0	1089
	V	2629	191	10	57	9	186	3082
	Total (1986)	14560	3617	109	1207	208	186	///

The table analysis exhibits the significant regression that the different plant formations have experienced. Indeed:

- The *Tetraclinis articulata* (Ta) area declined from 14560 ha in 1986 to 10898 ha in 2016, a fall of 25 %. Its average regression rate is 118 ha/year. Empty spaces and matoral of low shrubs took over this stratum superficy.
- *Quercus rotundifolia* (Qr) reported a 34 % reduction in 2016 compared to 1986. The regression pace is up to 34 ha. The majority of this stratum was planted by *Pinus Pinaster* (R).

- *Quercus suber* (Qs) declined by 12 ha, or 11 % of its area. It has been largely transformed to empty spaces.
- The matorral (M) benefited from the forest trees degradation, it gained an area of 881 ha. Their average growth rate is estimated at 28 ha/year.
- Empty land (V) increased over an area of 2896 ha. Their extension is mainly at the expense of *Tetraclinis articulata* and *Quercus rotundifolia*.

4.2. Soil protection maps analysis

Each type of vegetation cover provides a degree of soil protection that corresponds to a specific class. The Soil Protection Map reflects the type and the density of the vegetation cover in Kharouba watershed.

The diachronic analysis of Kharouba watershed's soil protection map, between 1986 and 2016, exhibit the regressive evolution that the vegetation cover has undergone a in terms of area and especially density. Indeed, the high-density vegetation is declining in favour of an average or even low vegetation cover density. This regression mainly concerned the high density *Tetraclinis articulata* whose surface area has been slashed from around 2699 to 760 ha.

This situation has led to the increase in areas of low to very low protection, which expanded from 26 % of the total watershed area in 1986 to 33 % in 2016. On the other hand, the high and very high protection levels have a regressive evolution, their percentages dropped from 51 % in 1986 to 47 % in 2016 (**Fig. 5 and 6**). This regressive evolution of the soil protection levels is the result of several factors including illegal logging, overgrazing and climate changes.

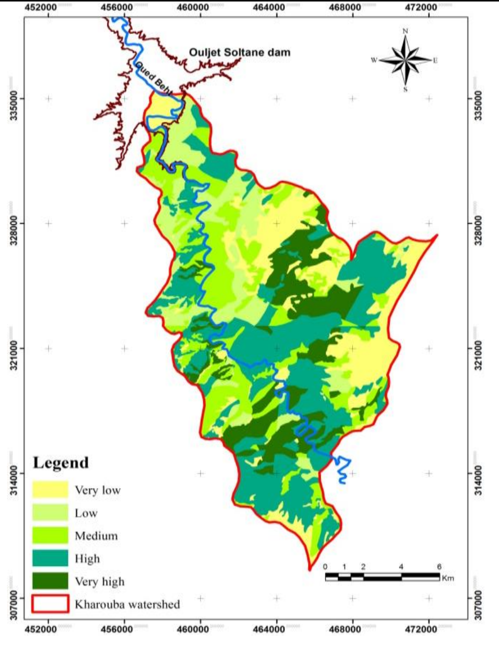

Fig. 5. Soil protection map (2016)

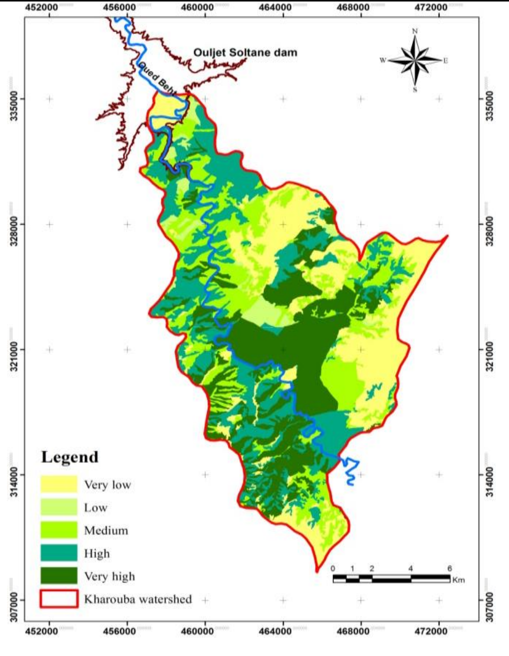

Fig. 6. Soil protection map (1986)

The analysis of the soil protection levels' distribution depending on the vegetation cover nature and density shows that soils with high protection are mainly located in *Tetraclinis articulata* and in dense to medium-dense *Quercus rotundifolia* forests with a very developed undergrowth. However, the low protection soil can be found in very degraded rangelands, bare soils and bad-lands.

4.3. Erodibility map analysis

The distribution analysis of the erodibility levels (**Fig. 7 and 8**) reveals that the most representative class is the one belonging to the strong class with 38 % of the total study area, followed by the class of medium erodibility whith 26 %. On the other hand, low to moderate erodibility affects only 18 % of the total kharouba Watershed area.

In addition, the erodibility map indicates that zones where the slope is steep, erodibility is always high to extreme. This can notably be observed at the southern and south-eastern part of the watershed. However, in the north, north-west and the middle of the watershed, the situation is less worrying due to the dominance of weak to moderate levels of erodibility.

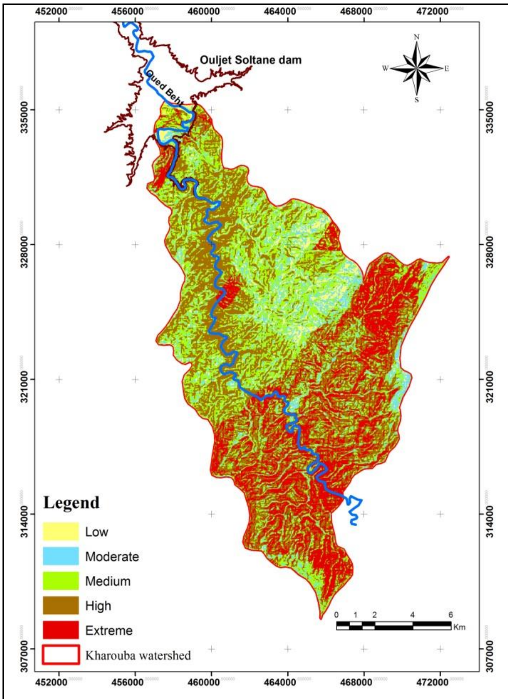

Fig. 7. Erodibility map

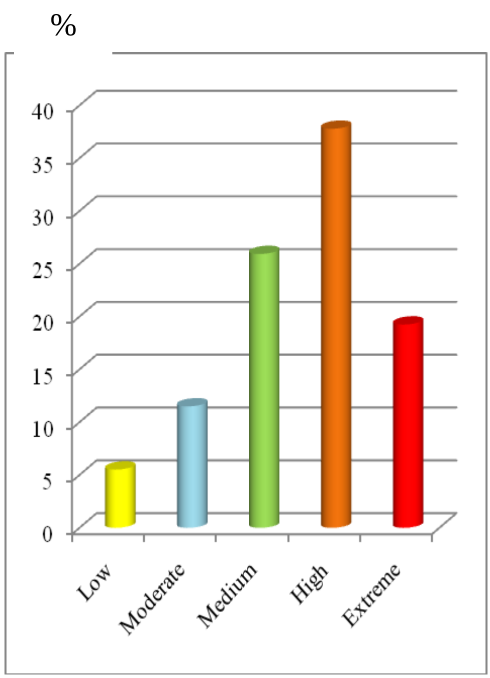

Fig. 8. Levels of erodibility

4.4. Erosion status map analysis

The mapping of the erosion states of 1986 and 2016 is obtained by overlaying erodibility and soil protection level maps of 1986 and 2016. The erosional status maps analysis (**Fig. 9 and 10**) shows that erosion is active and apparent over more than 63 % of the total watershed area. It takes different kinds of erosion, including sheet erosion and gullying.

Areas of high erosive risk correspond particularly to rough terrain with fairly high soil friability rate and low to very low recovery rate.

The dynamics of erosion status analysis exhibit an increase of the high and extreme states expanding from 36 % of the total area in 1986 to 41 % in 2016. This increase mainly concerned the southern and northern part of Kharouba watershed, more particularly in areas where the vegetation cover and notably *Tetraclinis articulata* was severely degraded, in addition to the zones at the edge of Oued Beht. This is due to the dominance of sedimentary formations. Similarly, the erosion map analysis shows that areas marked by important vegetation cover are not very sensitive to erosion.

Our results highlight the predominant role of the vegetation cover in the overall decrease of the erosion rate. This vegetation protects the soil surface against the raindrops impact, slows down the speed of runoff water and maintains good soil porosity, making it highly resistant to erosion (Sabir et al., 1994; Zhou et al., 2008; Fletcher, 2017; Hou et al., 2016).

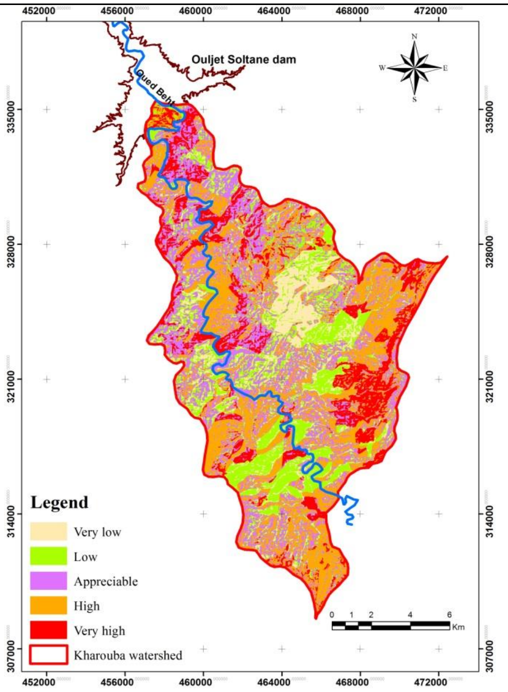

Fig. 9. Erosion status map (2016)

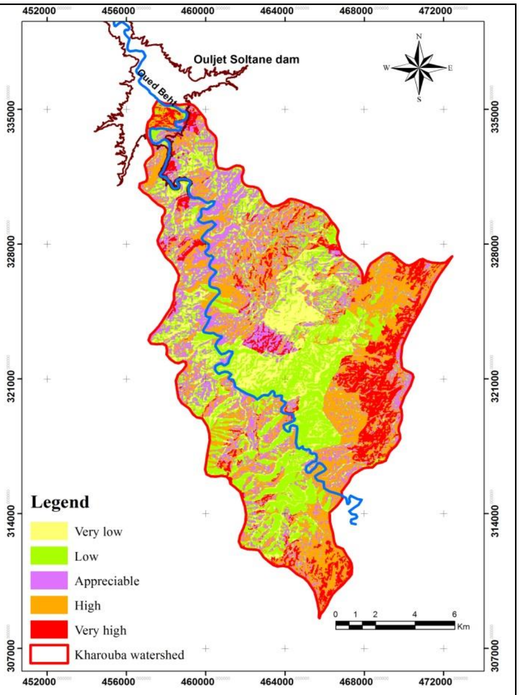

Fig. 10. Erosion status map (1986)

5. CONCLUSIONS

Kharouba watershed, in upstream of "Ouljet Soltane" dam, covers an area of about 19 888.50 hectares and is largely dominated by forests along with land suitable for grazing and uncultivated land. It offers valuable forest resources due to its rich floristic diversity.

The evaluation of the forest cover dynamics impacts on water erosion in this watershed pinpoints the regressive evolution of the vegetation cover between 1986 and 2016. This decline has stressed the increased water erosion risk in Kharouba watershed causing the expansion of areas that are vulnerable to water erosion from 36 % in 1986 to 41 % in 2016.

Given the situation, it is necessary to intervene to fight against erosion, based on an innovative approach that relies on the improvement of the living conditions of the local population in order to reduce the pressure on the forest resources while ensuring their conservation and development.

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