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Effect of vegetation types on highway erosion in Kalaya basin (North Morocco)

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Abstract
The aim of this work is based on the study of runoff (R) and sediment concentration (SC) under different types of plantations at Kalaya catchment located in the north of Morocco. In this context, measurement campaigns on the ground by rainfall simulation are planned to test the impact of land use on water erosion. Our choice covered five experimental plots: a bare soil plot (witness), a plot with spontaneous vegetation, a plot with annual crop Sulla (*Hedysarum coronarium L.*), a parcel planted by the shrub *Atriplex.nummularia* and parcel planted by the shrub Genet of Spain (*Spartium junceum*). The results obtained show very high rate of soil sediment (Er) to reach 12.5 kg/m^2/h in bare soil. On the other hand, the soil losses meseared under Genet of Spain (*Spartium junceum*) is 0.66 g/m2/h, accompanied by the cultivation Sulla (*Hedysarum coronarium L.*) which has a rate of 0.86 g/m2/h. This demonstrates the role of the land cover in reducing the risk of erosion. Thus, we have concluded that the best facilities for the basin are Genet of Spain and the Sulla.

Key words: Water erosion, runoff, detachability, vegetation cover, north of Morocco.

1. Introduction
In recent years, land degradation and soil erosion are considered as the main natural disease in Mediterranean environments [1, 2]. This natural hazard is defined as a process of detachment and subsequent transport and deposition of the detached soil material [3], it is a phenomena getting importance in impact and seriously damaging lands and infrastructure. Soil erosion has also an impact on ecosystem services such as water quality and quantity, carbon stocks, biodiversity, agricultural productivity and recreational activities [4, 5 & 6]. The loss of soil as a result of erosion can lead to decline in organic matter and nutrient contents, breakdown of soil structure and reduction of the water-holding capacity [7]. Thus, the erosion losses are the highest in Mediterranean region and especially in North of Morocco [8, 9]. The main cause of this alarming situation is by anthropogenic activities and a combination of natural forces especially the topography, land management, the effects of the aggressiveness of rain, surface runoff supported by fragile soils and reduced vegetation cover which leads to land degradation and threatens road infrastructure [10, 6 & 11]. In these seasonally dry environments, the relationships between soil and plant communities play a major role in preventing soil erosion [12]. It is generally accepted that vegetation cover has long been recognized as a key factor in runoff production and protection against erosion, as vegetation increases infiltration and reduces the kinetic impact of raindrops while the organic carbon they provide increases the soil aggregation [13, 14 & 12]; therefore, the maximum amount of vegetation cover was crucial to reducing surface runoff and soil erosion [15]. So, it seems interesting to take stock of knowledge about the role of vegetation in protecting the surface from water erosion in various climate conditions and different spatial scales [16, 17 & 18].
This work contributes to this research effort by studying water and sediment loss under different types of vegetation used in highway talus at the anti-erosion arches in Tangier-Ksar Sghir in north of Morocco.

2. Materials and methods

2.1. Study area

The experimental arches are situated in the Kalaya basin which extends over an area of 38 km^2, and geographically located between 35° 39' and 35° 44' North, and longitude between 5° 37' and 5° 46' West with an average altitude of 135 m. The site is crossed A4 highway linking the Tanger-Med port of Tangier (Fig. 1).

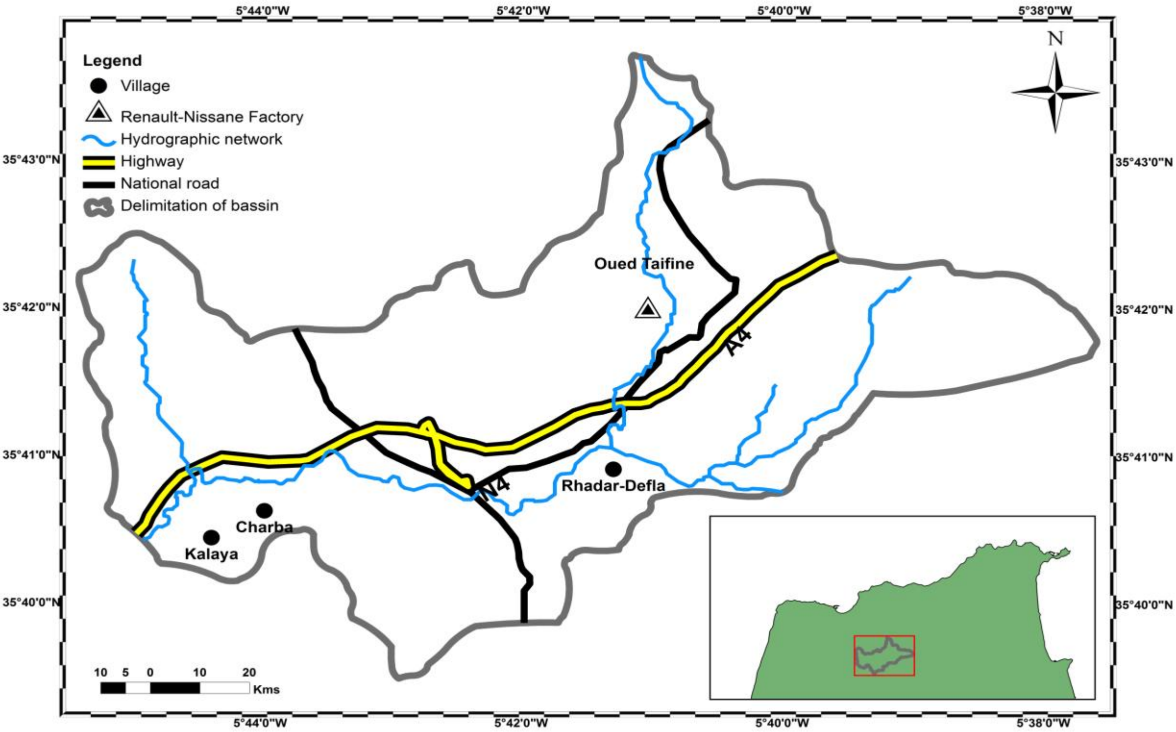

Figure 1: Location of Kalaya watershed and the study area

Kalaya basin is moderately rainy, with an average annual rainfall of 667 mm. Generally, the rainy season starts from November to March with a total rainfall of 511 mm, while the dry season has seen rain near 156 mm (Fig. 2). The temperature is relatively moderate as it has an annual average around 18 °C (Fig.3).

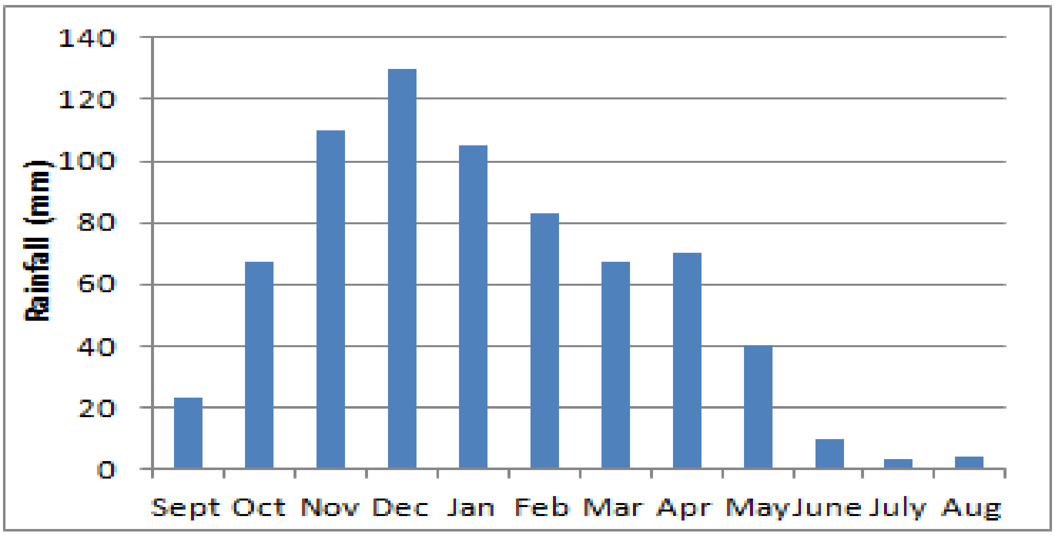

Figure 2: The monthly average of rainfall in Kalaya

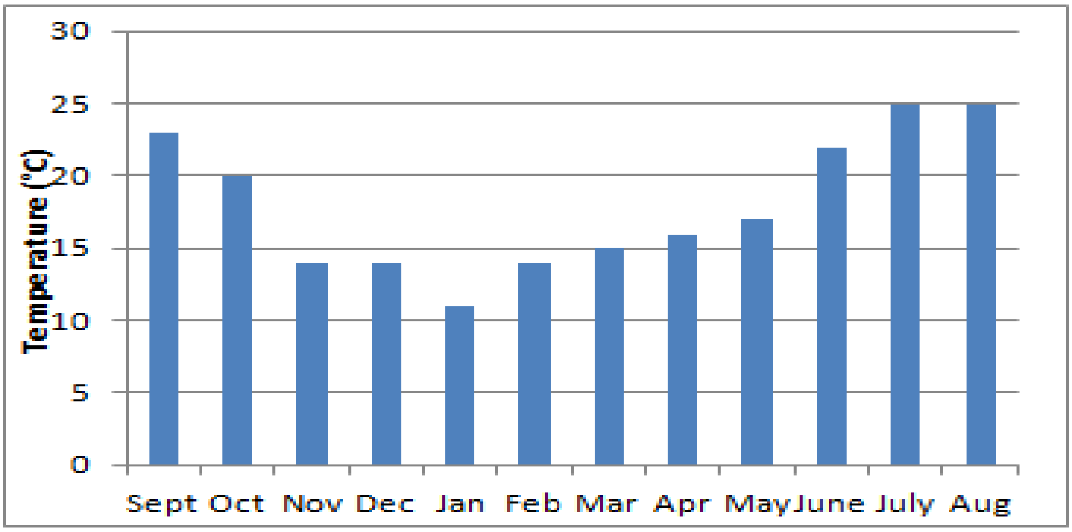

Figure 3: The average monthly temperature in Kalaya

2.2. Methodology

The approach is based on the use of experimental plots from 0,6m² on which the erosive dynamics and the different situations of surface were analyzed using a rainfall simulator (Fig. 4) to perform simulations of artificial rainfall in order to measure the induced runoff and soil loss [19].

To test the impact of land used on water erosion, our choice has focused on five plots: a plot of bare soil (control), a plot with natural vegetation, a plot with annual crop Sulla (*Hedysarum coronarium L.*), a plot planted with shrub *Atriplex.nummularia* and parcel planted with shrub Genet Spain (*spartium junceum*). It should be noted that we put these plots in the same conditions (same intensity of rain is 60 mm/h, the same slope is 33% and in the same period), we simulated a raindrops of 25 minutes while operating in-situ measurements of runoff. In addition, we collected samples to quantify the sediment losses.

Figure 4: Rainfall simulator

3. Results and discussion

3.1 Effect of rain intensity on runoff and sediment runoff

The figures below the shows observations made under simulated rainfall intensity of 60 mm/h for 25min rain.

a. Parcel 1: bare soil.

The measurement of figure 5 confirms that during the simulation test, the cumulative runoff is very important and has reached a rate of about 51.6 mm/h. An evolution was noticed 2.25 mm/s a runoff coefficient (ke) 86% the rain becomes runoff. This is in concordance with Barthes [19] who finds that on bare soil produces high amount of runoff.
Figure 6 shows a high concentration of sediment (583.49 g/l) after 25 minutes in bare soil.

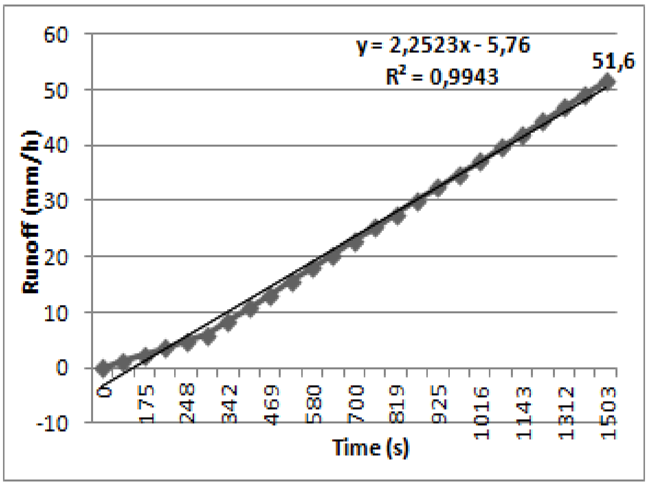

Figure 5: Effect of rainfall intensity on runoff under bare soil

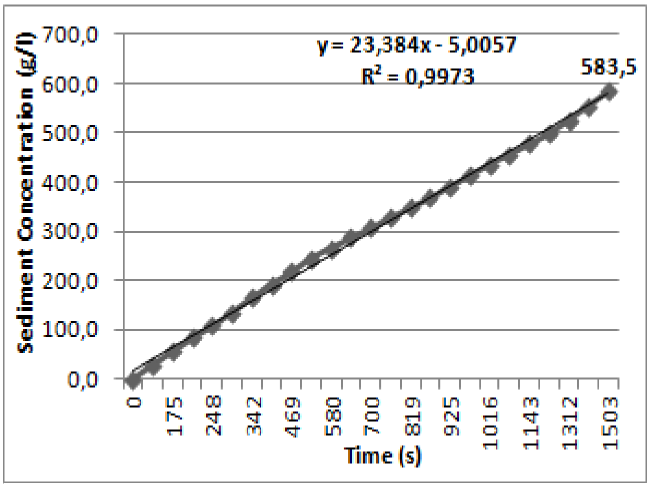

Figure 6: Effect of rainfall intensity on the sediment concentration under bare soil

b. Parcel 2: Shrub Atriplex nummularia.

Figure 7 concern a plot planted with shrub *Atriplex nummularia*. Runoff reached a cumulative average of 26.52 mm/h, with an increase of 1.44 mm/s. Indicating that 44% of rainfall becomes runoff.
With regard to Figure 8, the cumulative soil losses reached 148.65 g/l after 25 min of rainfall intensity (60 mm/h).

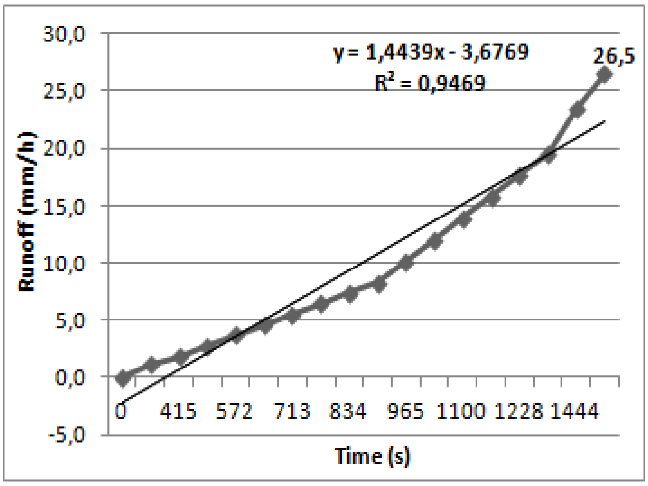

Figure 7: Effect of rainfall intensity on runoff under *Atriplex nummularia*

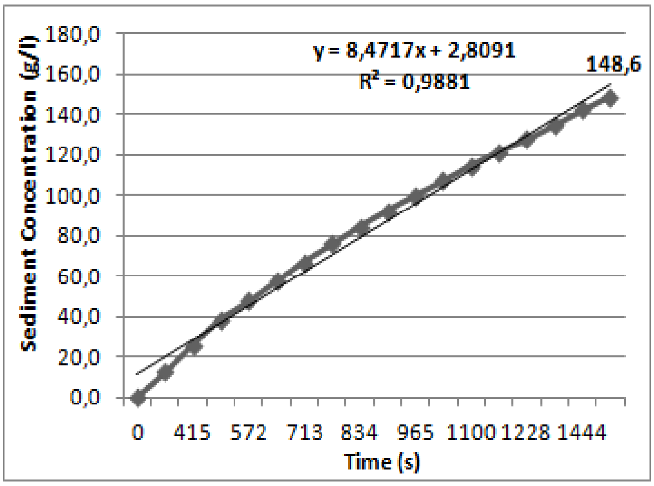

Figure 8: Effect of rainfall intensity on the sediment concentration under *Atriplex nummularia*

c. Parcel 3: Spontaneous Vegetation

Figure 9 shows a runoff rate about 40.6 mm/h. This result shows that 67.7 % of rain is transformed to runoff.
In figure 10, the cumulative sediment reached 82.3 g/l.

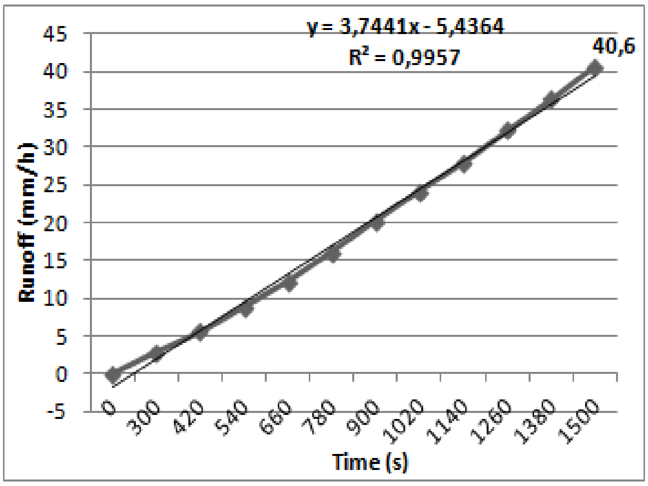

Figure 9: Effect of rainfall intensity on runoff under Spontaneous Vegetation

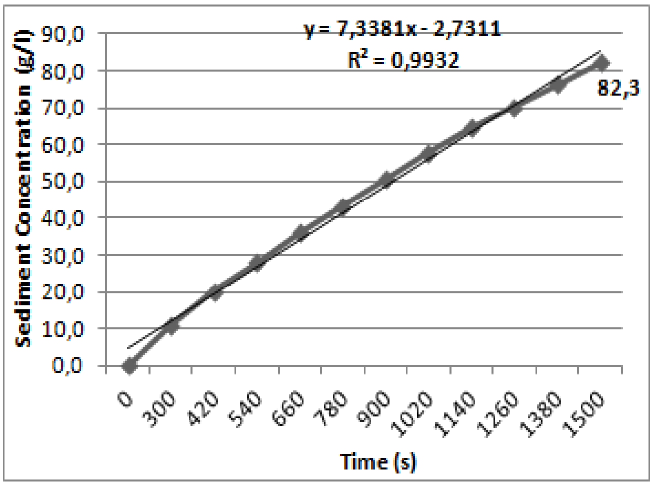

Figure 10: Effect of rainfall intensity on the sediment concentration under Spontaneous Vegetation

d. Parcel 4: Shrub Genet Spain (Spartium Junceum).

The evaluation test Genet Spain (*spartium Junceum*), the rate of runoff noticed is 18.8 mm/h (Fig. 11), with an increase of 1.88 mm/s. Indicating that 31.33% of rainfall becomes runoff.
Figure 12 shows an improvement in the flow of sediment in the range of 8.38 g/s, while the cumulative rate moved to 84.5 g/l.

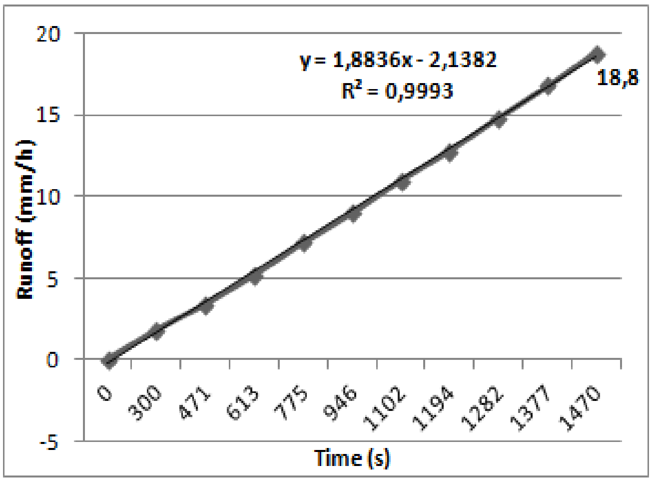

Figure 11: Effect of rainfall intensity on runoff under *Spartium Junceum*

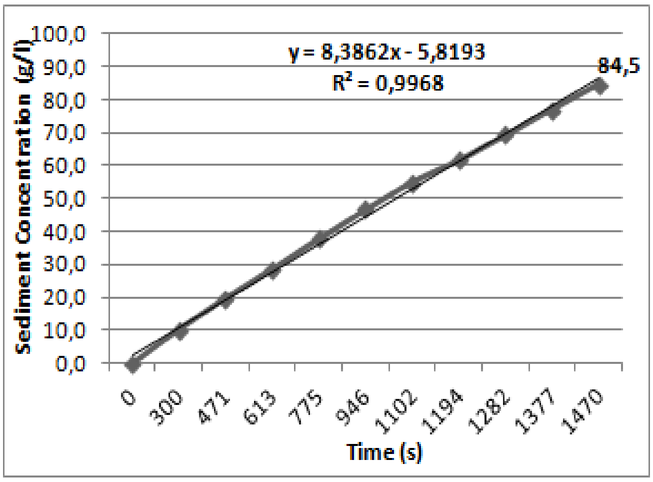

Figure 12: Effect of rainfall intensity on the sediment concentration under *Spartium Junceum*

e. Parcel 5: annual crop Sulla (Hedysarum coronarium L.).

In terms of plot planted by the annual Sulla (*Hedysarum coronarium L.*) culture, we have discovered an accumulated runoff of 23 mm/h, is an order of 2.09 mm/s. This explains 38.33% of rain turns into water flow (Fig. 13).
Figure 14 reflects an increase of 8.20 g/s sediment concentration, or cleared accumulated 89.8 g/l.

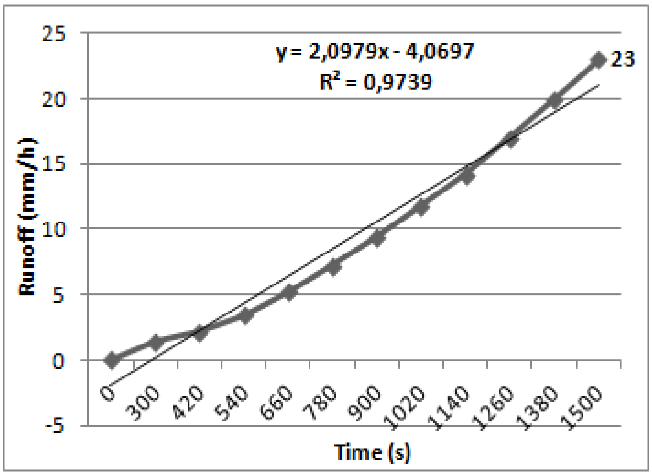

Figure 13: Effect of rainfall intensity on runoff under *Hedysarum coronarium L.*

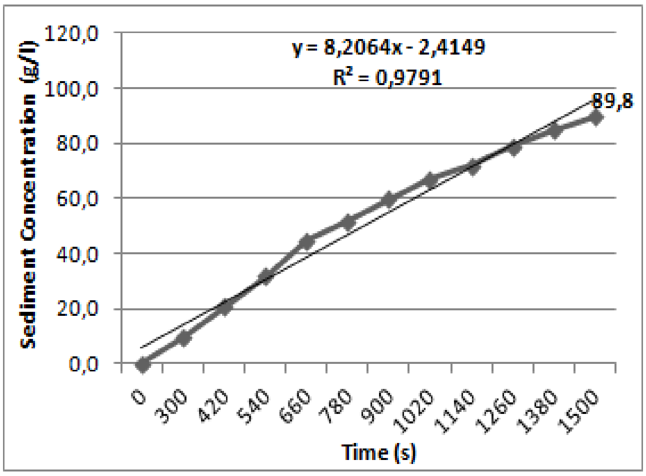

Figure 14: Effect of rainfall intensity on the sediment concentration under *Hedysarum coronarium L.*

3.2 Comparison of experimental plots

Regarding the plot planted with natural vegetation, it appears that despite of the rate of concentration (82.26 g/l), the rate of runoff was high and close to that achieved under bare soil. For the parcel of *Atriplex nummularia*, where the rate of runoff was low against a very high concentration. *A. nummularia* did not develop sufficiently to give appreciable soil protection [20].
In general, the kinetic energy of raindrops is the foundation of rainfall runoff, the latter occurs when the soil ceases to absorb all of the rain. In our case, we used an intensity of 60 mm/h as the erosive intensity in the area [21]. Automatically the value of the runoff coefficient increases. This increase is relatively small for the soil covering with Genet of Spain (GE) and Sulla. The shrub GE is known for its relatively rapid growth. However, it is a shrub introduced to the area and it would be wise to find similar species adapted to local conditions. For Sulla culture is characterized by its high sensitivity to cold (below -4 °C) and strong resistance to drought, so the climatic conditions in the northern area studies are very favorable for this crop. This is approved by Martiniello [22] & Talamucci [23] confirmed that Sulla is very adapted to Mediterranean basin. However, this species forage and it would be better to find a similar but not forage crop.

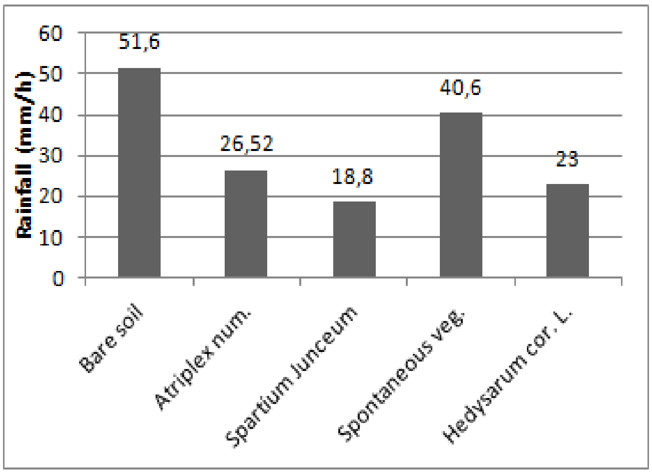

Figure 15: Runoff rates for different sites

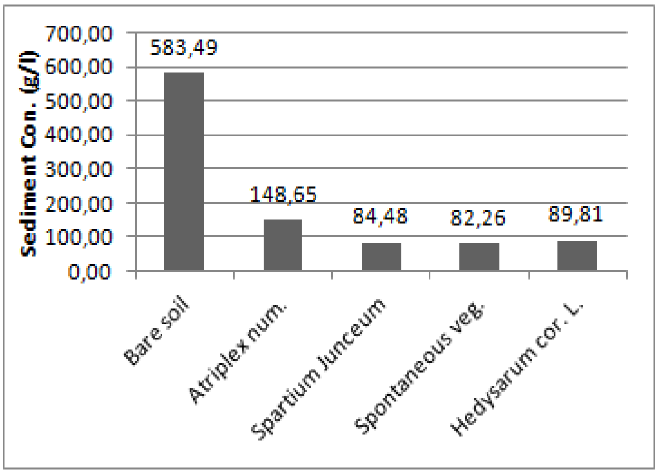

Figure 16: The sediment concentration rate for different sites

3.3 Detachability / erosion

According to Valentine [24], the detachability is defined as the ability of a soil to separate the solid particles that can be transported by water. Figure 17 shows the erosion rate as calculated by the Genet of Spain is 0.66 kg/m^2/h, with the crop Sulla having a rate of 0.86 g/m^2/h. These results are lower than the rate of soil erosion that reached 12.5 kg/m^2/h under bare soil. This emphasizes the role of soil cover in reducing the risk of erosion. The arches under Genet of Spain and Sulla, which has a lower rates of sediment compared to bare soil. Many researchers confirmed that the vegetation is a key factor in soil erosion processes [25, 26, 27 & 28]. There, Sabir & Roose [29] considered the ground cover as effective in reducing erosion that dissipates the energy of raindrops, it reduce the flow of water to the soil surface and maintains a good surface porosity avoiding superficial crusting. Generally, the use of the effective vegetation to reduce the impact of water erosion is a widely used practice [20, 28 & 17].

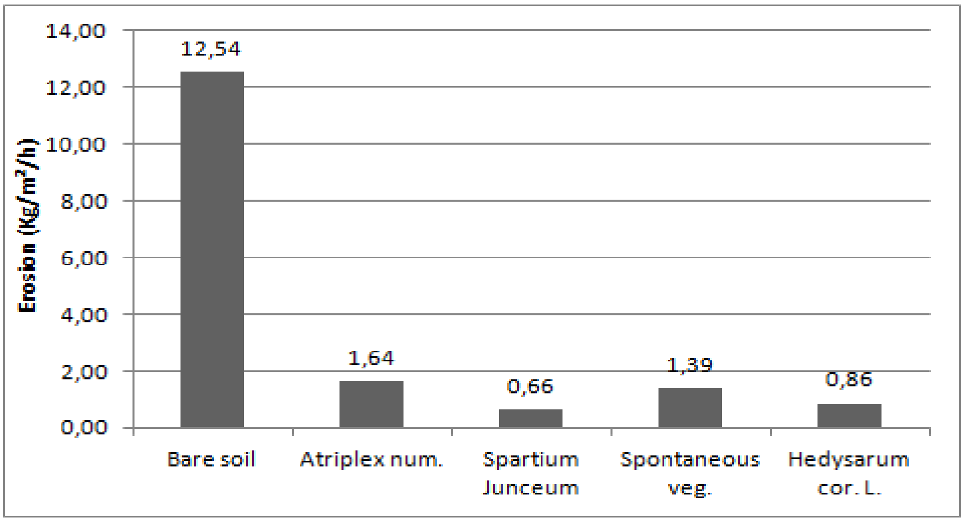

Figure 17: The erosion rate for each experimental

Conclusion

The ground cover in the north of Morocco (*Kalaya basin*) protects the soil from raindrop influence and decrease capping phenomenon. This ground cover slow down the water flow in the surface in order to be infiltrate into the ground. However, the simulated rain on bare soil produce a very high runoff and soil loss. The vegetation cover forms also a physical obstacle against the rain; consequently, soil loss will be minimal. According to our study on the vegetation cover, Genet of Spain and Sulla are efficacious and helpful to absorb the energy of rainfall and runoff. Thus, it would be wise to characterize this vegetation in order explain and justify their impact on the water erosion reduction.

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