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Variation of soils erodibility according to physico-chemical and biogeographic parameters in Allal Al Fassi watershed, Middle Atlas, Morocco.

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Abstract

In order to the conservation of soil resources and the preservation of water and biodiversity, the study of the variation of soil erodibility according to physico-chemical and biogeographical parameters in Allal Al Fassi watershed is of great importance. The measurement of soil erodibility according to the Wischmeier and Smith model requiring a series of physico-chemical analyses of several intrinsic soil parameters (texture, structure, permeability, organic matter content, etc.) is performed on 9 transects with 150 samples. The first, the results are combined with the biogeographical parameters of the soils (slope, pedology, lithology and land use) and then are submitted to a multivariate statistical analysis, were able to highlight both the qualitative and quantitative characteristics of the watershed. Soil erodibility in Allal Al Fassi watershed is moderately strong, ranging from 0.05 to 0.38 t. ha. h. $ha^{-1}MJ^{-1}.m^{-1}$. Statistical analysis shows that soil erodibility (K) is closely related to texture, organic matter content and especially land use. It is more important in farmland, unlike soils occupied by matorral. Soils become more erodible when the silty fraction dominates and clay and organic matter levels decrease.

Keywords: *Allal Al Fassi watershed, Erodibility, Physico-chemical parameters, Biogeographic parameters, Multivariate statistics, Middle Atlas, Morocco.*

1. Introduction

Human activity has caused a sharp increase in the erosion rate of natural and agricultural soils, by destroying over time the balance between their formation and stability. The gradual decrease of soil resources, consequence of this destruction, has been the origin of the decline of historical civilizations [1]. Global annual soil losses are estimated at 35.9 billion tons for year 2012 [2,3]. The Mediterranean region is particularly subject to soil erosion due to its climate. It is submitted to long dry periods followed by heavy erosive rains, on steep slopes and few developed and fragile soils. In some parts of the Mediterranean region, erosion has reached an irreversible stage and in others parts no soil remains [4]. Soil erosion is one of the main environmental problems affecting the sustainability of Mediterranean agro-forestry systems [5,6,7]. The intensity of water erosion, sediment producer, is influenced by the characteristics of watershed parameters such as lithology [8], relief [9,10], climate and vegetation [11]. The variation and interaction of these causal parameters of soil water erosion affect the pedological heritage, often with serious socio-economic and ecological consequences. This effect results in stripping of the organo-mineral layer of the soils leading to a significant decrease in fertility [12,13] and an enrichment of restraint with sedimentary inputs, downstream, followed by a progressive reduction in their useful volume often leading to their filling up and death. Cumulative sediment inputs can also have an impact on water quality, mainly when they are loaded with nutrients, causing eutrophisation [14,15,16], on biodiversity and clogging of the wadi bed downstream of dams during emptying [17,18]. In Morocco, the protection of watersheds through the fight against water erosion became then one of priorities of the Office of High Commissioner for Water and Forests and Fight against Desertification [19]. The latter has set 1.5 million hectares as a priority and urgent tranche to be treated by 2020, including the Allal Al Fassi watershed upstream of the restraint. After dam's construction on the upper course of Oued Sebou and in a watershed with a climatic context ranging from semi-arid to humid, under the influence of thunderstorm flow, the restraint's Allal Al Fassi has suffered the combined effects of nature and human activities. By opting for the problem to which the watershed is subject, the objective of this study is to determine the causal parameters responsible for water erosion and to analyse their interactions in order to have visibility on siltation rate of restraint. The physico-chemical and biogeographic parameters of the soils are integrated in the understanding of the variation in erodibility (K), calculated using the revised universal soil loss equation (RUSLE) [20]. The combination of the model with Geographic Information System tools (ArcGIS) allows the precise spatialization of soil erodibility over large areas [21,22,23] and contributes significantly to soil conservation management, erosion control and general watershed management [24]. The whole is subjected to multivariate statistical analysis to apprehend the combinations and interactions between the different parameters in the erodibility process.

1. Materials and methods

2.1. Presentation of Allal Al Fassi watershed

The watershed of Allal Al Fassi, on the upper course of Oued Sebou, constitutes one of its subwatersheds upstream and covers the provinces of Boulemane, Sefrou, Taza and Ifrane on an area of 5352 Km2 (Figure 1). The Allal Al Fassi watershed lies entirely in the Middle Atlas chain. The geological formations are diversified, from Paleozoic to Quaternary age, with predominance of Lias limestones and dolomites [25,26]. It is considered as an altitude zone, where 88% of the total area is above 1000m with an average of 1549m, having a mountain peak located at 2959m and an outlet of 344m. The majority of its lands has a slight to moderate slopes, around 84% of the watershed has a slope less than 14%. Its compactness index which is about 1.77 shows that's well drained. It's the combination of Oued Guigou, Oued Zeloul and Oued Maaser, which are the main sustainable streams thanks to the contribution of water

ressources such as Ain Sebou, Ain Timerdine and Ain Ouender. Many bioclimatic stages co-exist in Allal Fassi watershed varying from humid with cold winter to semi-arid. Such variety brings a diversity in plant species consisting mainly of holm oak (Quercus rotundifolia), cedar (Tetraclinis articulata), red juniper (Juniperus phoenicea), Atlas cedar (Cedrus atlantica) and Aleppo pine (Pinus halepensis) [19].

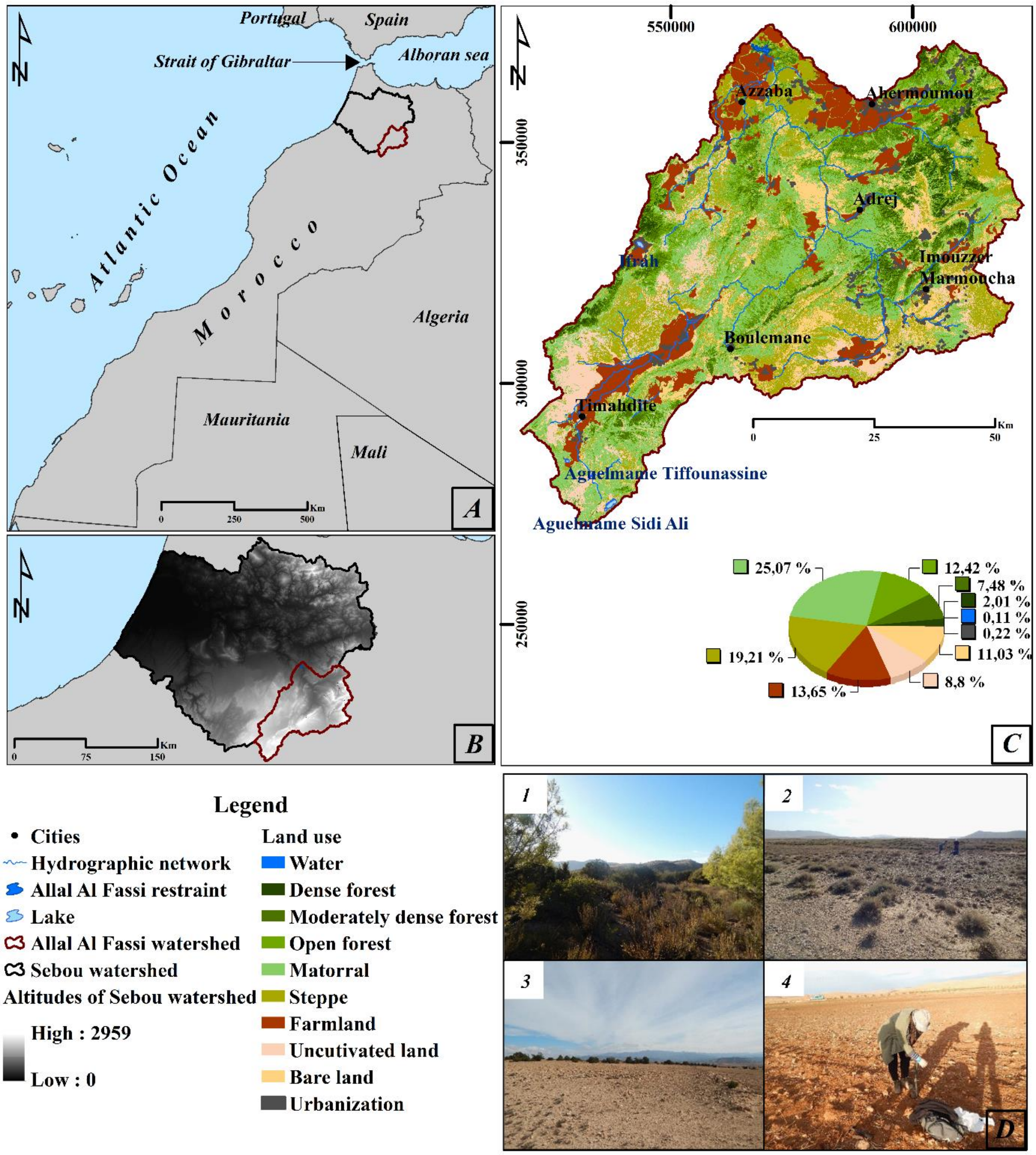

Figure 1: (A) Location of the Allal Al Al Fassi watershed in Morocco. (B) Sebou watershed. (C) Land use in the Allal Al Fassi watershed (2019). (D) Pictures of the main land uses in the study watershed (1) Matorral in the Ahermoumou site, (2) Steppe in the Serghina site, (3) Uncultivated land in the Imouzzer Marmoucha site, (4) Farmland in the M'Dez site.

2.2. ***Sampling***

The erodibility factor K, calculated according to the revised universal soils losses equation RUSLE, is one of five factors which are related to climate, soil, topography, vegetation and management. This study focuses on the erodibility factor K [20] and the physicochemical and biogeographic parameters of soils (Figure 2). To achieve, nine sampling transects have been chosen to be representative of the entire watershed (Timahdite, Ahermoumou, Immouzzer Marmoucha, Serghina, Taarart, M'Dez, Tighboula and El Menzel). This resulted in 150 samples. In the field, the sampling strategy was based on a transect approach where the samples were spaced 5 or 10 meters aligned along steepest slope and direction of water flow in order to follow its action on the soil surface. Samples are taken at a depth of 15 to 30 centimetres, using an auger consisting of a T-handle connected by an extension to a steel cylinder seven centimetres in diameter and thirty centimetres in height.

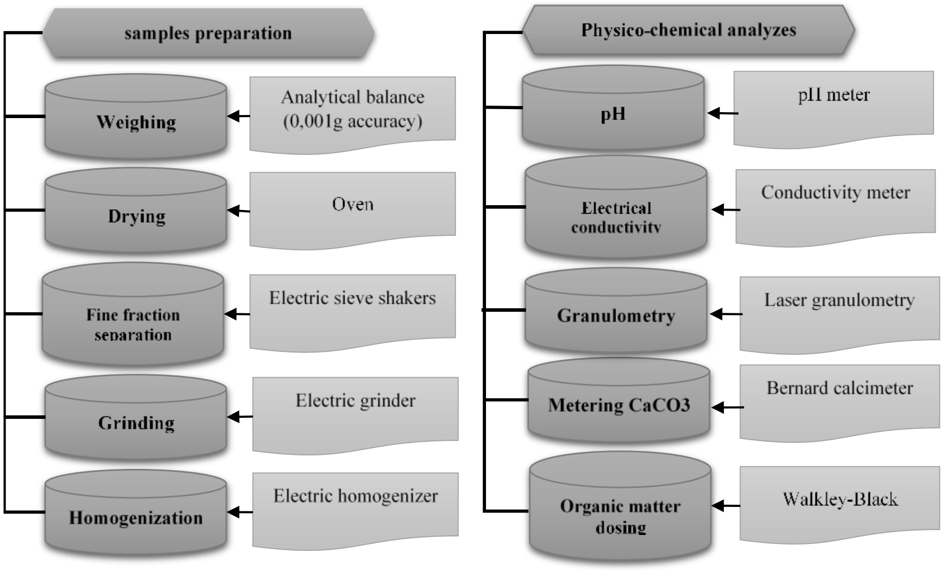

Figure 2: Flowchart of K erodibility calculation by the RUSLE method

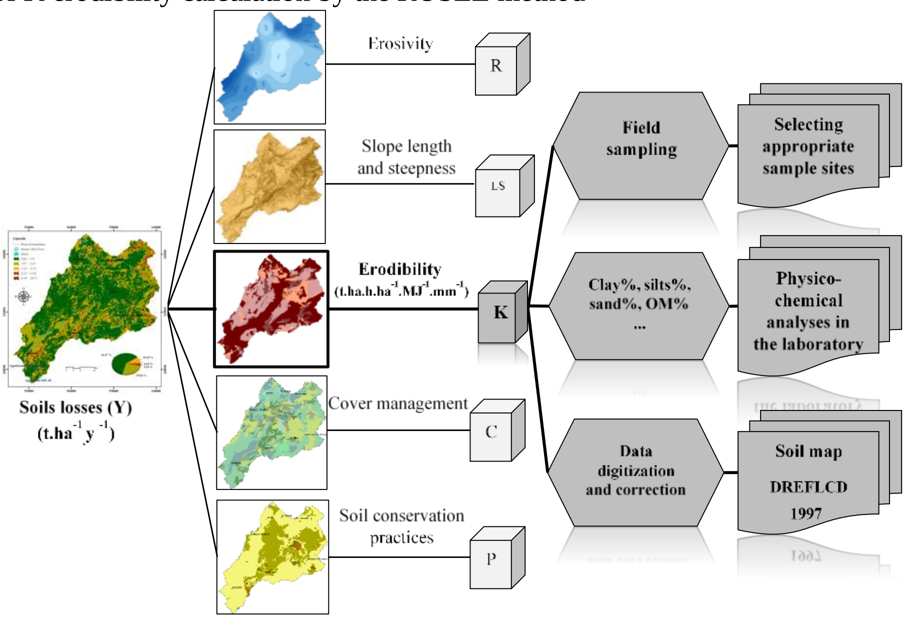

Figure 3: Materials and methods for the preparation and physico-chemical analysis of soil samples.

The cylinder is driven manually into the ground in a clockwise rotational movement. Once it has been pushed in along its entire length, if substrate is not reached, it is removed and the sample is packed in appropriate containers (plastic bags). Some samples are subdivided according to depth into five sub-samples. The samples are observed and described in the field (including grain size, structure and colour). In laboratory, the samples taken are first dried in the open air, weighed and then sieved using an electric sieve shaker and a 2 mm mesh sieve to separate the fine fraction from the coarse fraction. For physico-chemical analyses, the fine fraction recovered is dried in an oven at 100°C for 24 H, crushed using an electric mill and homogenised by an electric homogeniser (Figure 3).

*2.3. **Physico-chemical analyses***

Particle size analysis, content of organic matter and carbonates dosage and pH and electrical conductivity measurement were carried out on the fine fraction (≤ 2mm). The laser diffraction particle size analyzer ANALYSETTE 22 NanoTec was used to determine the grain size. The pH and electrical conductivity were measured using a Consort-C562 multi-parameter. Before measuring pH, the soil samples were dissolved (10g of sample in 25 ml distilled water) and stirred with a glass rod for one minute to form a soil suspension that was suitable for measuring the concentration of dissociated H+ ions in the supernatant liquid [27]. For measurement of electrical conductivity, 10g of each sample is dissolved in 100ml of distilled water and stirred with a magnetic stirrer for 2 hours. This allows the entire sample to be suspended and achieves an equilibrium between the solid and liquid phases. The solution is then left to stand for half hour before measurement [28]. Carbonate content is determined using Bernard's calcimeter [29], which measures the volume of carbon dioxide (CO2) released by the action of hydrochloric acid (HCl) on the calcium carbonates (CaCO3) contained in the soil sample. Dosage of organic matter content is based on carbon dosage, one of its most important constituents. The latter is determined by the Walkley-Black [30] method, which assumes that potassium dichromate oxidizes the carbon in the soil. The potassium dichromate changes colour according to the quantity of reduced products. This colour change can be compared to the quantity of organic carbon present in the soil (Figure 3). The results of physico-chemical analyses (organic matter content, percentages of sands and silts) allowed to calculate the erodibility K (Table 1). It is calculated according to the equation of Wischmeier and Smith [31] where M is the percentage of silts and fine sands, M0 is the percentage of organic matter, Ss is the soil structure code and P is the soil permeability code (Figure 4). The erodibility K equation was adjusted by Dumas [32] to correct for some imperfections, especially reduction of runoff energy. Where K is erodibility factor calculated by Wischmeier and Smith [31] and X is percentage of coarse elements greater than 2mm (Figure 4).

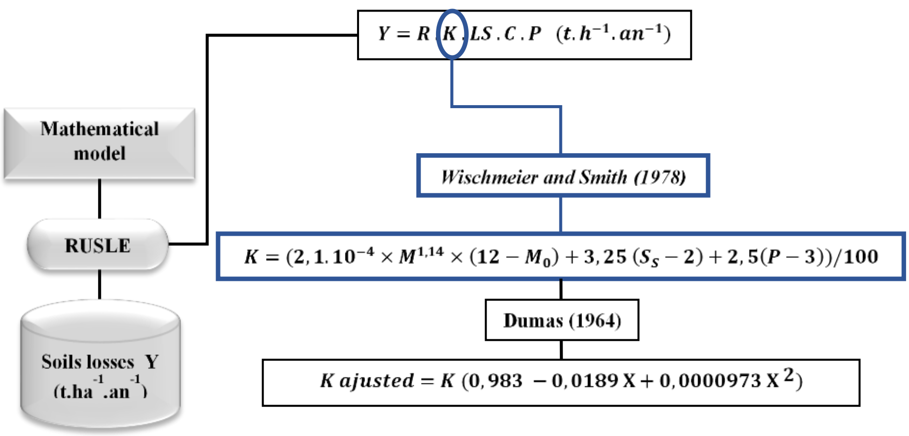

Figure 4: Equations for calculating erodibility K.

2. Results and discussions

Soils in Allal Al Fassi watershed are classified in 10 different classes (entisols, aridisols, vertisols, mollisols, inceptisols, alfisols, C1 complex, C2 complex, C3 complex, and C4 complex). The resulting soil map was digitized from the map produced by the High Commissioner for Water and Forests and Fight against Desertification [19] and corrected from bibliographic data [33,34] and field data (Figure 5). From erodibility calculate of the different soil samples of each transect, an adjusted K value is assigned to each soil class in the watershed (Figure 4). Knowing that expresses the susceptibility of each soil class to particle detachment and transport, it ranges from 0.05 to 0.38 with value 0 for the soils least susceptible to water erosion and value 0.38 for the most susceptible soils. The distribution of soil erodibility allowed to highlight erodibility classes over the entire watershed area. 22.24% of the latter is occupied by soils with low erodibility (0.051-0.185), 19.15% is occupied by soils with medium erodibility (0.185 - 0.278) and 34.61% is occupied by soils with high (0.278 - 0.316) to very high erodibility (0.316 - 0.380) (Figure 6). According to nature and structure of soils in the watershed, the lowest erodibility value corresponds to structured and evolved soils (vertisols, alfisols and mollisols) and the highest value corresponds to less structured and few evolved soils (entisols, Aridisols and C2 and C3 complexes).

Table 1: Characteristics and K-adjusted erodibility of some soil samples from the Allal Al Fassi watershed

Echantillon	Clay %	Silt %	Sand %	Texture	F<2mm %	F>2mm %	O.M. %	Code P	Code Ss	K	K ajusted
TIM-E1	32,1	66,5	1,4	Fine silt-clay	83,63	16,37	2,29	6	2	0,37	0,262
TIGH-E1	21,3	68,6	10,1	Fine silt	62,69	37,31	1,47	3	2	0,40	0,167
SEGH-E1	26,7	64,8	8,5	Fine silt	95,57	4,43	0,65	3	2	0,38	0,339
MNZ-E1	24,1	69,6	6,3	Fine silt	92,85	7,15	2,70	3	4	0,41	0,351
MDZ-E1	13,0	71,8	15,2	Fine silt	67,51	32,49	1,87	3	2	0,46	0,218
IMZM-E1	37,2	58,6	4,2	Fine silt-clay	61,84	38,16	1,18	6	3	0,37	0,151
TAAR-E1	17,3	72,0	10,7	Fine silt	77,22	22,78	0,63	3	2	0,49	0,294
AHER-E1	30,1	66,9	3,0	Fine silt-clay	88,00	12,00	2,26	6	3	0,42	0,325
R-AHER1	30,1	66,9	3,0	Fine silt-clay	95,48	4,52	3,02	6	3	0,40	0,357
R-IMZ1	35,9	60,6	3,5	Fine silt-clay	60,62	39,38	1,36	6	3	0,39	0,150
R-TAAR1	20,1	69,2	10,7	Fine silt	99,61	0,39	0,64	3	3	0,50	0,469
R-MNZ1	22,7	70,1	7,2	Fine silt	90,72	9,28	3,09	3	3	0,37	0,305
R-TIGH1	22,7	67,6	9,7	Fine silt	55,20	44,8	1,38	3	3	0,43	0,141
R-SEGH1	28,5	66,9	4,6	Fine silt-clay	99,10	0,9	0,17	6	3	0,50	0,483
R-TIM1	32,0	65,9	2,1	Fine silt-clay	83,36	16,64	2,31	6	3	0,40	0,281
R-MDZ1	12,8	69,8	17,4	Fine silt	56,59	43,41	1,82	3	3	0,48	0,168

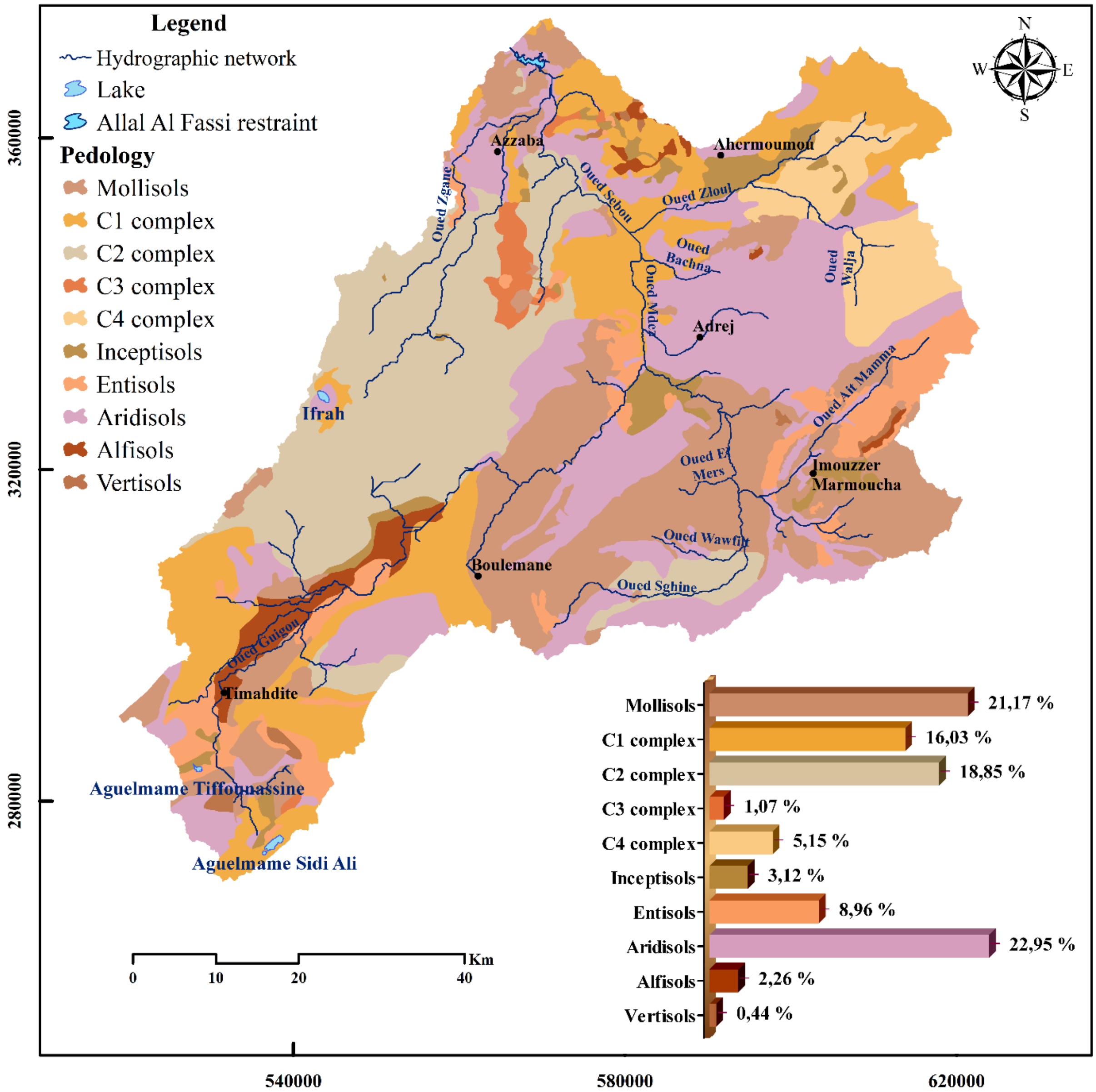

Figure 5: Soil map of Allal Al Fassi watershed.

*3.1. **Soil erodibility according to physico-chemical and bio-geographical parameters***

The analyses results carried out in the laboratories are used to understand the actions, correlations and combinations of factors on soil erodibility in Allal Al Fassi watershed. Grain size analysis allowed the proportion of fine fraction (≤2mm) to be determined, which varies between 35.33 and 99.87% with an average 83.45%, and the calcimetry indicated a CaCo3 content that varies between 14.81 and 71.07%. The majority of soil samples (70.86%) have a fine silt texture with an average silt content of 65.06%. 20.47% of the samples have a silt-clay texture, 7.08% have a sandy-clay texture. Organic matter contents are low and vary between 0.02 and 5.09%. The soils are generally neutral with basic tendencies and a high cation exchange capacity (Table 2). Soil erodibility in the watershed shows a perfect but opposite correlation, positive with fine fraction (r=0.83) and negative with coarse fraction (r=-0.38). It should be noted that few physico-chemical soil parameters show a significant correlation with K erodibility. This is positively correlated with the percentage of silts (r=0.36), if silts content increases the erodibility increases. If the effect of clays (r=-0.46), organic matter (r=-0.12) and CaCO3 (r=-0.16) is associated, erodibility is negatively correlated, and if their

rates increase, erodibility decreases, which evokes in the first place the effect of organo-mineral complex in the structure and maintenance of the intrinsic balance of soils and resistance to the effects of water erosion (Figure 7).

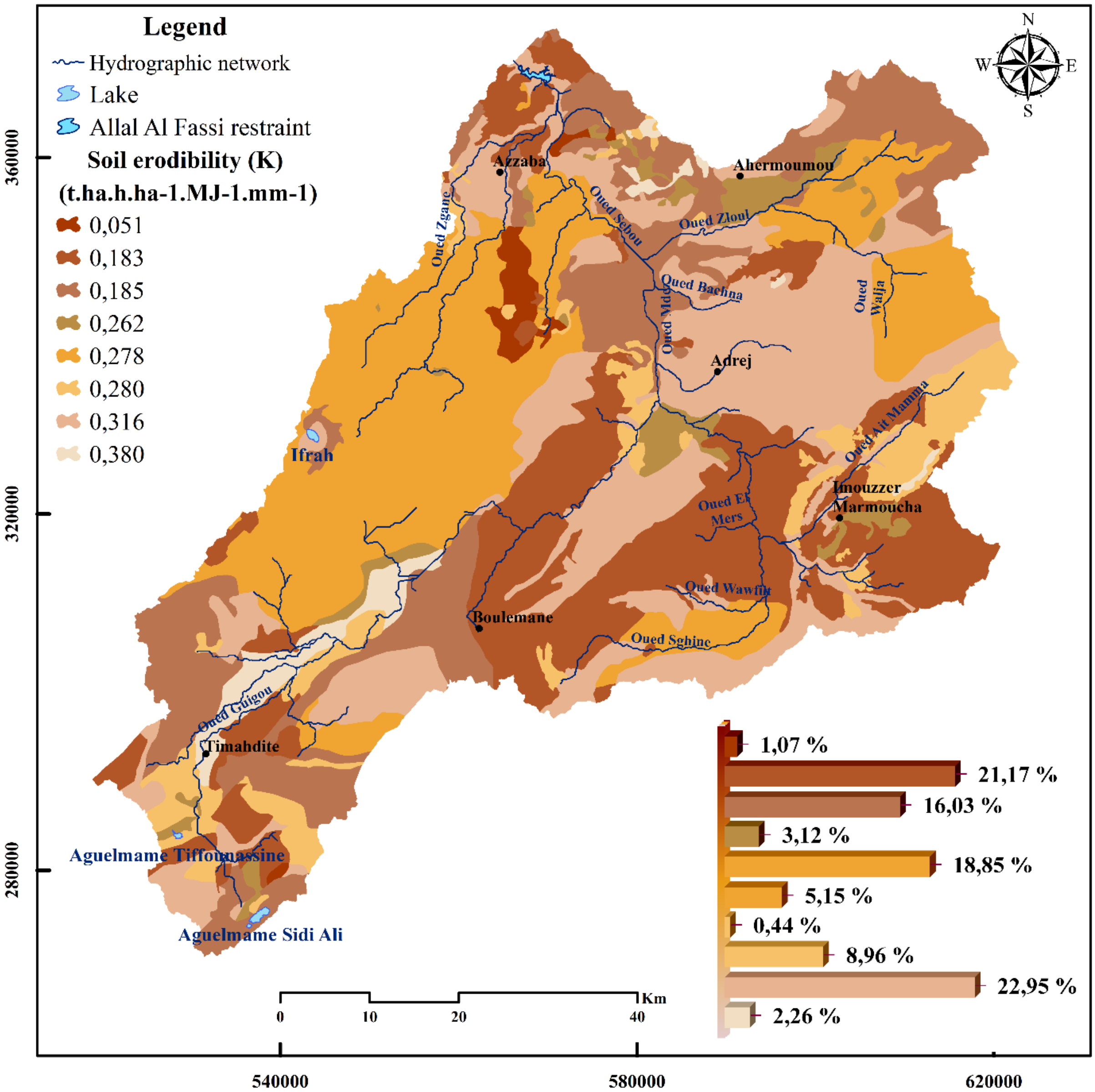

Figure 6: Soil erodibility map of Allal Al Fassi watershed.

Table 2: Summary statistics of physico-chemical parameters and soil erodibility in Allal Al Fassi watershed.

	Slope %	pH	EC	Clays %	Silts %	Sands %	$CaCO_3$ %	OM %	F<2mm %	Density g /cm3	K ajusté
Average	9,92	8,05	279,58	25,94	65,06	9,00	40,25	1,90	83,45	1,17	0,28
Standard deviation	5,32	0,50	168,72	9,93	9,75	7,40	13,16	1,07	13,93	0,42	0,09
Coeff. of variation (%)	53,67	6,2	60,35	38,3	15	82,2	3,27	5,6	16,69	35,71	3,37
Minimum	0	7,09	114	12,8	3	0,1	14,81	0,02	35,33	0,10	0,05
Maximum	21,34	9,32	1296	94,90	81,20	35,80	71,07	5,09	99,87	2,38	0,48

	K	D	Slope	LS	CaCO3	OM	F>2mm	F<2mm	clays	Silts	sands	pH	EC
K		-0,11	-0,23	-0,14	-0,16	-0,12	-0,83	0,83	-0,46	0,36	-0,01	-0,05	-0,17
D	-0,11		0,24	0,23	-0,05	0,27	-0,06	0,06	0,08	-0,02	-0,09	0,10	0,06
Slope	-0,23	0,24		0,67	-0,38	0,53	0,30	-0,30	0,17	0,28	-0,59	-0,43	0,04
LS	-0,14	0,23	0,67		-0,04	0,24	0,06	-0,06	0,33	0,01	-0,45	-0,12	0,03
CaCO3	-0,16	-0,05	-0,38	-0,04		-0,39	0,08	-0,08	0,15	-0,40	0,33	0,36	-0,02
OM	-0,12	0,27	0,53	0,24	-0,39		0,03	-0,03	-0,11	0,40	-0,38	-0,39	0,14
F>2mm	-0,83	-0,06	0,30	0,06	0,08	0,03		-1,00	0,07	-0,01	-0,09	-0,09	0,01
F<2mm	0,83	0,06	-0,30	-0,06	-0,08	-0,03	-1,00		-0,07	0,01	0,09	0,09	-0,01
clays	-0,46	0,08	0,17	0,33	0,15	-0,11	0,07	-0,07		-0,72	-0,40	0,19	0,15
Silts	0,36	-0,02	0,28	0,01	-0,40	0,40	-0,01	0,01	-0,72		-0,35	-0,36	-0,08
sands	-0,01	-0,09	-0,59	-0,45	0,33	-0,38	-0,09	0,09	-0,40	-0,35		0,22	-0,10
pH	-0,05	0,10	-0,43	-0,12	0,36	-0,39	-0,09	0,09	0,19	-0,36	0,22		-0,09
EC	-0,17	0,06	0,04	0,03	-0,02	0,14	0,01	-0,01	0,15	-0,08	-0,10	-0,09	

Figure 7: Correlation matrix of erodibility K with physico-chemical parameters and slope of soils in Allal Al Fassi watershed.

Soil texture shows significant variances with K erodibility. The fine fraction weighs significantly on erodibility, more the fine fraction is abundant more the erodibility is important. The percentage of clays also shows significant variances with the erodibility, the higher percentage of clays corresponds to the lower erodibility. This evokes their role of cement wich play in the microaggregates, constituents of soil structure and responsibles for their stability, due to their high cation exchange capacity which conditions reactivity with humic substances [35]. Silty soils are the most sensitive to erodibility, particularly those that are poor in clays and organic matter [36] (Figure 8). The variance of erodibility K according to soils organic matter content shows that they are negatively correlated. Erodibility is greater for low organic matter contents, which explains the effect of organic matter in the formation of organo-mineral complexes [37] that stabilize soils and oppose water erosion [38,39,40,41]. The apparent density of soils significantly affects erodibility, which increases for less dense soils. Knowing that as they develop and evolve, soils become more structured and have fewer voids and so more denser and more resistant to water erosion [42] (Figure 8). The ANOVA results show significant differences in erodibility for the three properties, texture, land use and lithology. It is thus modest on soils under matorral and farmland while it is significant on soils under steppe and uncultivated soils. Erodibility becomes more important in the case of sols in fine silty texture, soils occupied by steppe or farmland, and soils on alternating marl and sandstone substrates (Figure 9). Soils become less erodible when the silty fraction decreases, compared to the different proportions of the sandy and clay fractions, which is theoretically most vulnerable to water erosion [43]. Knowing that this vulnerability begins with the rebounding of particles under the action of rain "splash effect" [44,45], then by the closure of structural porosity [46] and finally by the redistribution of fine particles by runoff and sedimentation in flapping laminates. The fine fraction and clay contents present totally opposite effects to erodibility, given that the second is included in the first. The clay content decreases erodibility, the silt content increases erodibility and the sand content remains in an intermediate situation.

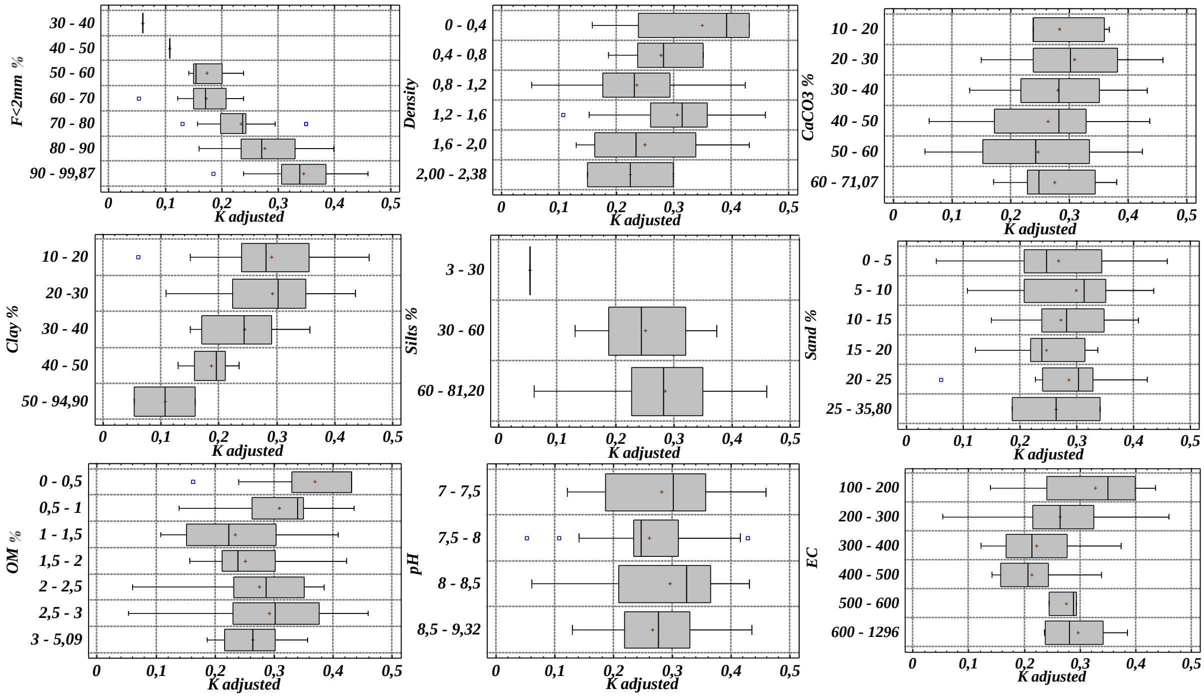

Figure 8: Variance of erodibility according to physico-chemical parameters of the soils in Allal Al Fassi watershed.

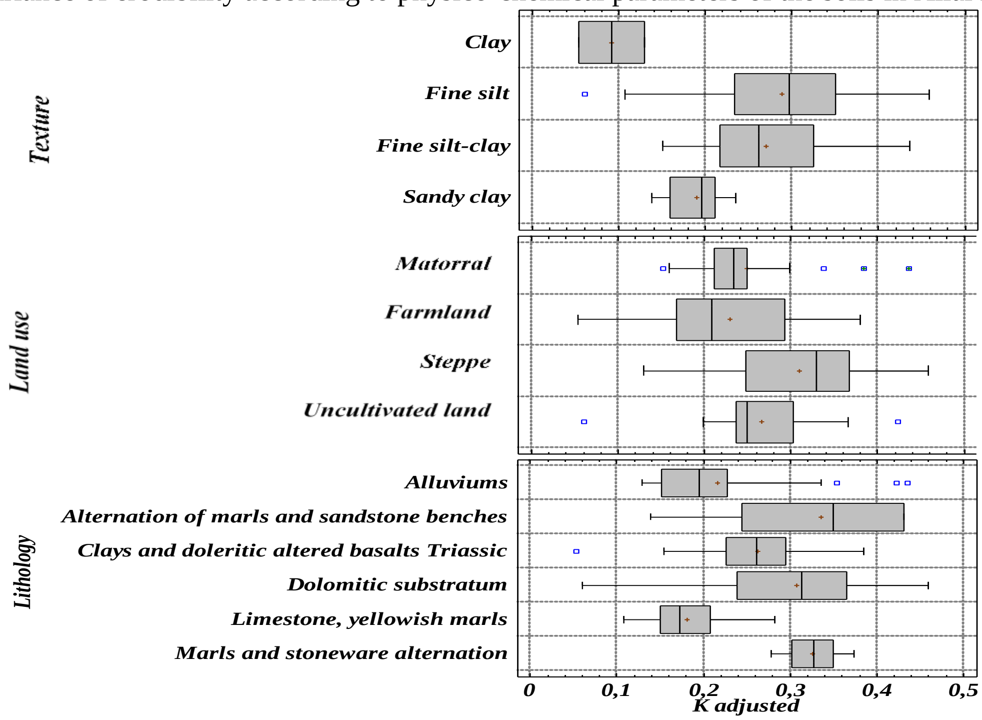

Figure 9: Variance of erodibility according to soil texture, land use and lithology in Allal Al Fassi watershed.

The soil erodibility is lowered under the effect of the contents of organic matter and CaCO3. The latter mainly resulting from the precipitation of carbonates in solution during repeated infiltration of rainwater through the soil, participates in the cohesion of particles. The soils density which theoretically is the result of arrangement and cohesion of clays, silts, sands, organic matter and CaCO3, reduces erodibility when its value is high. However, it should be noted that the indifference of pH and EC parameters on erodibility. In the case of types of land use, erodibility

decreases on agricultural and under matorral soils. The soils on limestone substrate and / or yellow marl or on alluviums are most protected in Allal Al Fassi watershed (Figure 9).

3.2. *Variations of soil parameters and erodibility according to land use*

Three types of land use are selected to analyse variations in the physico-chemical parameters and soil erodibility (Figure 10). Among these land uses are soils under matorral where erodibility is relatively low compared to those on farmland or uncultivated soils. This is logical because plants protect soils from the mechanical effect of rainfall and provide litter that protects them on the surface and humifies them at depth. Whereas cultivated or uncultivated soils without vegetation are affected by the rains and organic matter accumulates in small quantities. Cultivated soils are also characterised by successive labours which homogenise the soil profile. pH which depending of antagonistic effects of $CaCO_3$ rate in this generally calcareous environment and of organic matter rate, is relatively neutral for sub-matorral soils, which tends to be basic for cultivated soils. To this added that of the organomineral complexes responsible for the cationic exchanges which are well manifested in soils under matorral [47].

The rates of fine fraction and clays in the three cases of land use show no more significant differences. However, it should be noted that slight decrease and increase respectively in the rates of fine fraction and clays are the result of successive labours which exposes the various constituents to water erosion and mainly the silty fraction.

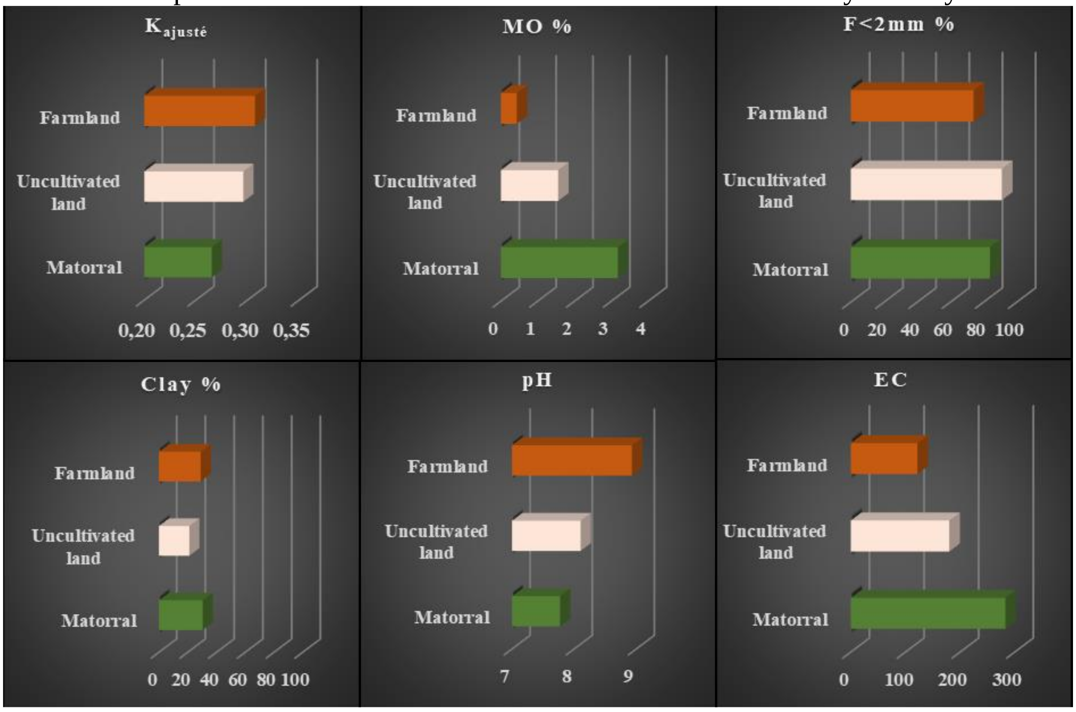

Figure 10: Variations in erodibility and some soil parameters under three land uses.

3.3. *Main parameters variations according to depth and some land uses*

In this case, it been chosen fine fraction, clay and organic matter contents and pH as parameters and farmland, uncultivated soils and soils under steppe as land cover. In farmland, soils characterized by labours during the year which destroy structure and disrupt different horizons, the fine fraction content remains constant independent of depth. Unlike uncultivated soils where the fine fraction is greater on surface, in the upper horizons (from 0 to 10 cm), which could be due either to surface compaction by pastoralism, or to disrupt followed by sedimentation in flapping laminates during water erosion. In the case of soils under steppe safe from human actions, the distribution of fine fraction along the profile is not constant but moderate. Where it is high, it could indicate an accumulation horizon. The

organic matter content is slightly higher for understeppe soils than for uncultivated ones, mainly due to the presence of vegetation, unlike cultivated soils which are weak. In the top part which contains enough organic matter could be witness the horizons differentiation of the soil profile. In contrast to cultivated soils where there is no trend in clay content, understeppe and uncultivated soils have slightly increasing clay contents in depth. This is probably due to the relative stability of soil profiles marked by vertical leaching during rainfall followed by clay accumulation. Overall, pH value of the soils of Allal Al Fassi watershed located in a carbonate environment should be basic and would only decrease in the presence of organic matter. In case of the two types of unplowed soils, this trend is marked in their upper parts (Figure 11).

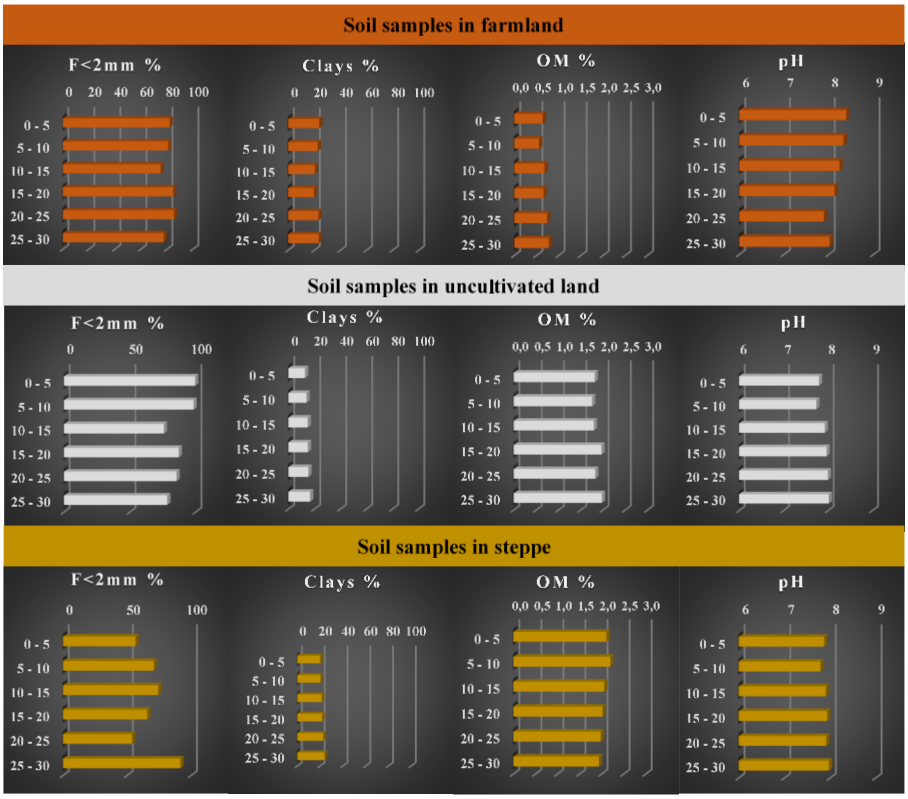

Figure 11: Evolution of some parameters according to depth of soil under three land uses

*3.4. **Transect Ahermoumou***

As mentioned above, the study of physicochemical and biogeographic parameters of the soils of Allal Al Fassi watershed is based mainly on the results of transect analyzes. Ahermoumou transect is one of nine transects that can be representative. It was carried out along a north facing slope with a moderate and irregular slope (average slope of 15%) and covered with mollisols. The transect ends in the North in an alluvial plain. 18 soil samples are taken there in three types of land use, from number 1 to number 11 are under matorral, from number 12 to number 15 in farmland soil and from number 12’ to number 14’ in uncultivated soil (Figure 12). The grain size analysis of fine fraction (≤2mm) of soil samples from Ahermoumou transect, shows irregular and sinuous variations in particular the percentages of fine fraction, clays, silts and sands.

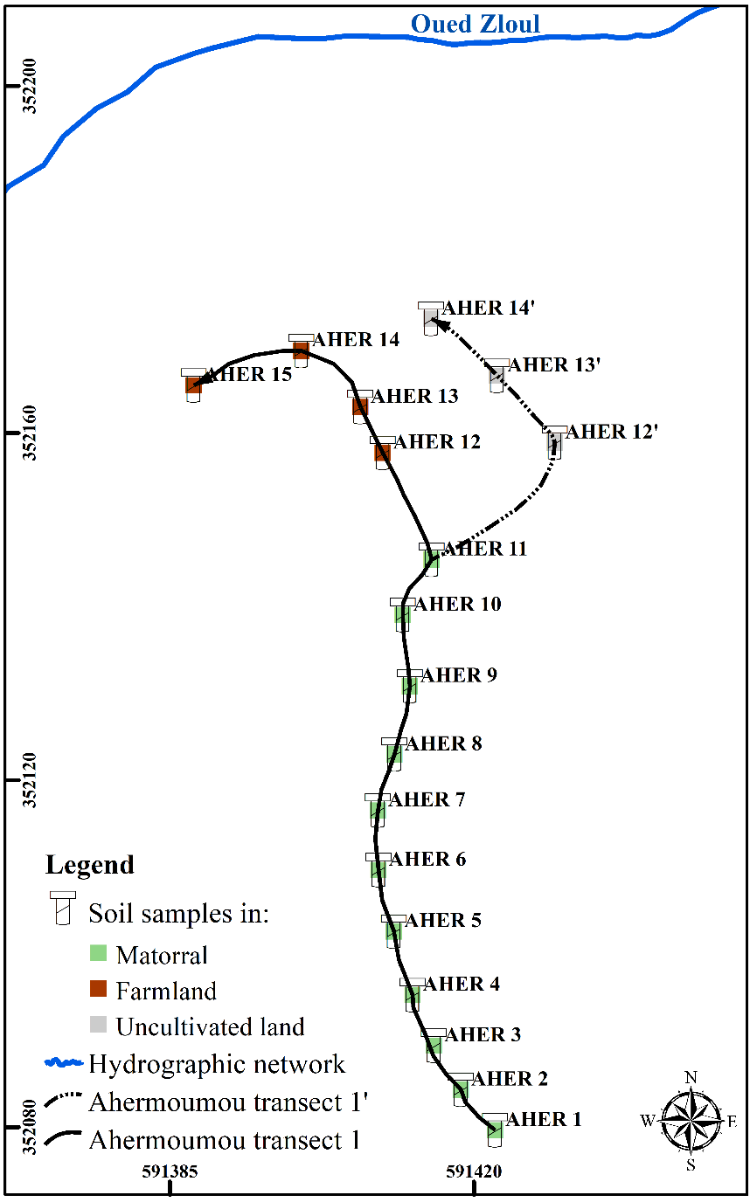

Figure 12: Situation of soil samples along Ahermoumou transecs.

The percentage of clays presents a peak (95%) for Aher8 sample at the expense of silts percentage (3%), which agrees with a slight drop in organic matter percentage and a drop in erodibility K. This is due to the presence of flat at Aher8 sampling site, facilitating the accumulation of clays and probably the action of pedogenesis (Figure 13). The curve of organic matter percentage shows that the percentage is higher in soils samples under matorral than those in farmland soils or uncultivated soils. It decreases with altitude from Aher1 sample (2.26%) to Aher10 sample (5.09%) and drops to Aher12 sample (1.91%). This drop of organic matter percentage could be due to a change of land use type (matorral, farmland or uncultivated soil), to a variation of density of plant cover (in matorral, number of shrubs feet per surface) and to a change of substrate (mollisols on limestones under matorral and farmland soils or uncultivated soils on alluvial deposits). Knowing that the apparent density of soils expresses its structure and porosity, in particular its aggregation and adhesion [48]. In Ahermoumou transect, the apparent density of different soil samples is relatively high for farmland soils compared to soils under matorral or uncultivated soils. These samples have a particular composition which could justify this increase which is manifested by a clay content of around 30%, a silt content of 65% and a very small amount of organic matter

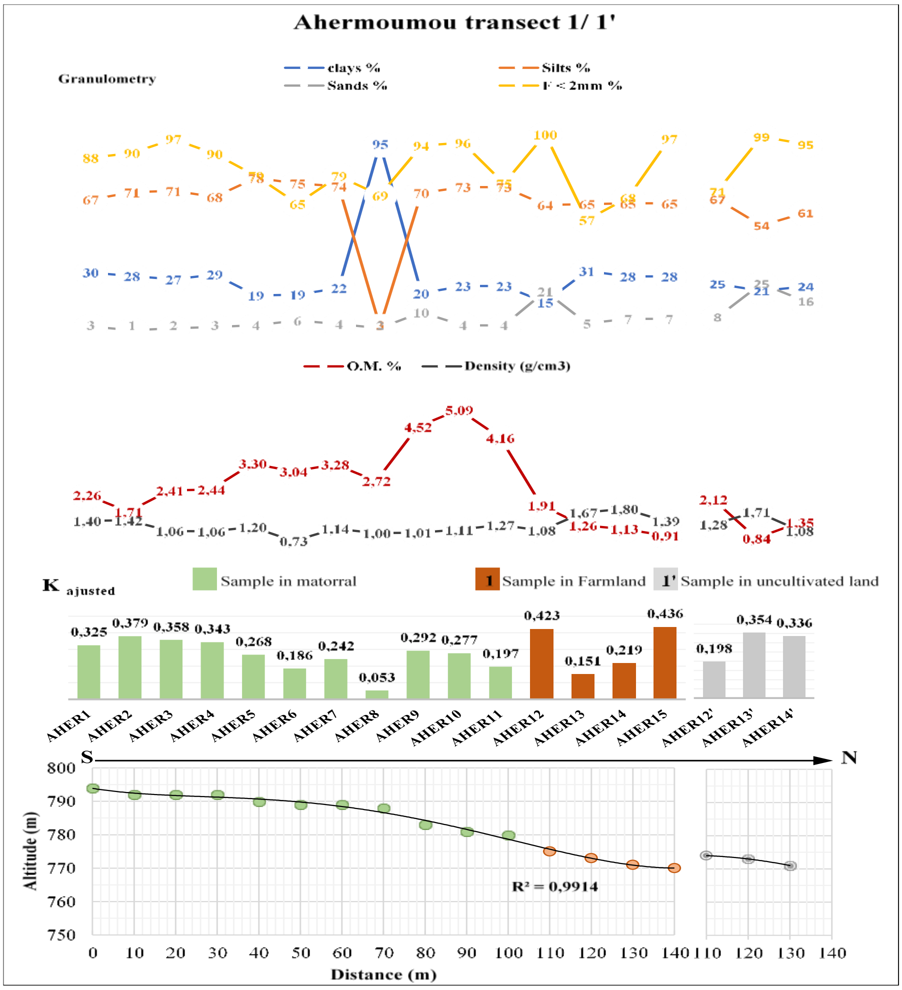

Figure 13: Parameters and erodibility of each soil sample of the Ahermoumou transect.

3. Conclusion

The study of soil erodibility according to physicochemical and biogeographic parameters in Allal Al Fassi watershed allowed to raise several questions, in which answers are understand this erodibility phenomenon in a context that is both natural and subject to human action. The K erodibility calculation of different soil samples, using the revised universal soils losses equation RUSLE, contributed to attribution an adjusted K value for each soil type. It varies between 0.05 and 0.38 t. ha. h. $ha^{-1}MJ^{-1}.m^{-1}$ depending on nature and structure of soils, it is low for structured and evolved soils (vertisols, alfisols and mollisols) and high for less structured and disrupt soils (entisols, aridisols and C2 and C3 complexes). From the combinaison of the erodibility calculation results with the physico-chemical and biogeographic parameters, relationships between them were defined. Analysis of matrix correlation and simple linear relationships, using the Pearson correlation index, shows that erodibility is strongly correlated positively with fine fraction and negatively with coarse fraction. It is positively correlated with silts percentage and negatively correlated with percentages of clays, organic matter and CaCO3, suggesting the effect of organo-mineral complex in sols structure and maintenance of intrinsic balance and resistance to water erosion. The ANOVA analysis shows that erodibility presents significant variances with fine fraction, clays and organic matter percentages and apparent density. It decreases for densest soils that are most evolved, best structured and most resistant to water erosion. This analysis

indicated that erodibility is important when fine fraction is abundant and clay and organic matter percentages are low. Erodibility shows significant differences with texture, land use and lithology. It is relatively low on undermatorral soils and high on understeppe, farmland and uncultivated soils. However, the sols texture dominated by fine silts and the alternating marl and sandstone substrates play in its favour. The analysis of variation of physico-chemical parameters (fine fraction, clay and organic matter contents and pH) according to depth in three soil types (farmland soils, uncultivated soils and soils under steppes) highlights the effects of natural phenomena such as pedogenesis, vegetation cover and substrate nature and human activities phenomena.

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