Assessing the Influence of Physical Factors on Spatial Soil Erosion Risk in Northern Jordan

Yahya Farhan[1], Dalal Zregat [1]and Samer Nawaiseh [2]

[1] Department of Geography, The University of Jordan, Amman, Jordan
[2]Department of Geography. Yarmouk University, Irbid, Jordan
yahyafarhan2100@yahoo.com

Abstract: The influence of physical factors on spatial soil erosion risk was assessed for Wadi Kufranja watershed (126.3km^2), north Jordan highlands. Such research is significant for monitoring future land use/cover changes, including agricultural expansion and deterioration of forest resources. The spatial relationships between soil erosion risk / intensity map and the environmental factors affecting soil erosion were investigated. The results indicate that soil erosion is highly correlated to specific terrain units, slope categories, elevation zones, land use/cover type, and aspect over the catchment. 67.7% of minimal to low soil loss area occurred on slope categories 0-6º and 6-15º, and 23.5% of moderate to severe soil erosion occurred on terrain characterized with the same slope categories, while, 6.45% of areas are exposed to severe soil loss, and this occurred on 15-25º slope category. 33.22% of soil erosion was distributed on southern slopes, while 62.8% of soil erosion occurred in areas of elevation ranging between 500 and 1100 m a.s.l. 46.87% of soil erosion was found in mixed agricultural land, 22.3 in forest areas, and 17.31% in open rangeland and bare soils. By contrast, five terrain units display an area of 55.06% of soil erosion, while, the alluvial fan areas exhibit the lowest soil erosion loss. The reported results provided viable information essential to control soil erosion, reduce soil loss, and achieve sustainable agricultural development.

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1.Introduction

Soil erosion by water is a serious environmental problem in the northern Jordan highlands. Erosion of topsoil leads to declining soil productivity, thus restricting the area of potential future agriculture. Rapid population growth (2.8% per year), urbanization, improper land use practices, including inappropriate plowing, rotations, inadequate management of plant residues and land fragmentation accelerate soil degradation in the rainfed agricultural region of Jordan **(Khresat, 2013).** Eroded soil materials pose great hazard to agricultural lands, irrigation canals, water resources, roads, and more seriously to the reservoirs which distributed over the highland region. However, effective soil conservation measures to minimize the negative impacts of soil erosion loss can be implemented only if the intensity and spatial distribution of soil erosion risk are known **(Bahadur, 2012; Wu and Wang, 2011).** Over the last four decades, several studies and reports using different techniques, were carried out to estimate soil erosion in Jordan on local, regional and national levels **(Natural Resources Authority, 1965; McDonald and Hunting, 1965; FAO et al., 1979; Harza, 1980; Al-Sheriadeh, et. al., 2000; Beni Taha, 2004; Mazawdeh, 2013)**. Recently, the Universal Soil Loss Equation (USLE) and the revised model (RUSLE) have been employed in conjunction with RS and GIS technology to predict the annual soil loss in different parts of northern highlands**(Al-Zitawi, 2006; Al-Alawi and Abu Jamous, 2009; Farhan and Al-Bakri,2012; Farhan, et al., 2013)**. The impact of land use /cover changes on soil erosion risk in northern Jordan was assessed recently. It has been concluded that a change from forest land to cultivation leads to general decline in the physical and chemical properties of soil, which in turn contributes to substantial soil erosion, reduction of soil fertility and land degradation **(Alkharabsheh, et. al., 2013; Khresat, et al., 2008).** Several attempts were done elsewhere to explore the relationship between soil erosion and selected landforms **(Jha, et al., 2009; Kumar and Kishwaha, 2013;Ghosh, et al., 2013)**, slope morphology **(Lufafa, et al., 2003)** and landslides **(Pradhan, et al., 2012),** but more consistent research was carried out recently to assess the relationship between specific environmental factors and soil loss in China, (**Yue-Qing et. al, 2008; Wu and Wang, 2011**), Thailand **(Bahadur, 2012)** and South Africa (**Manjoro, et al., 2012)** respectively. In the present study, it is intended to explore the relationship between soil erosion loss and the physical factors along with the terrain units identified in the watershed based on landforms and morphological criteria. A terrain unit in this context is considered normally a single landform (**Van Zuidam, 1979)**. Hence the objective of the present study is to evaluate the influence of physical factors on spatial soil erosion risk, and to assess soil erosion risk for each terrain unit recognized in the catchment. The resultant information is valuable for implementing future watershed management and conservation schemes so as to reduce soil loss.

2.Study area

The study area is located in the northern highlands of Jordan. The watershed lies between 32° 14' to 32° 22'N and 35° 21' to 35° 47'E (Figure 1). The target area covers 126.3 km^2 (12,630 ha), with elevations 1173m asl (above sea-level) to ~329m bsl (below sea-level) over a distance of only 23 km. With respect to geologic and soil characteristics, Wadi Kufranja catchment contains various rocks and soil units. It is dominated by the Upper Cretaceous marly clay and marly limestone, or the Nodular and Echinoidal limestone units, which strongly influences the basin landslides and soil slumping **(Farhan, 1986).** Red Mediterranean shallow soils ("terra rossa") cover the largest area in the watershed, while other types comprise brown limestone soils of the limestone outcrop, Rendzinas, alluvial (wadi) soils, variable types on slopes, and soils of the alluvial fan at the bottom of Wadi Kufranja, west of Krayma town. Topographically, 70% of the watershed is considered hilly and mountainous. Thus slopes are generally medium and steep except for the summit areas in the upper and middle catchment, and the alluvial fan at the eastern margin of "the Ghor" in the rift. Accordingly, fully developed soil profiles are rare **(Beaumont and Atkinson, 1969**). Climate conditions vary widely from the upper part to the lower part of the watershed. It is classified as "dry Mediterranean" in the upper catchment and "semi-arid" in the lower catchment and "arid" in the alluvial fan at the rift. Mean annual rainfall ranges from 630.5 mm at Ajlune town to 267.8 mm at Wadi Kufranja station close to the Ghor. Most climatic stations in the catchment record 30 - 50 rain days per year **(Fisher et al., 1969).** Severe storms with maximum daily intensity of 2.1 – 5 mm hr^{-1} are common **(Farhan, 2002).** Severe soil erosion is therefore predictable. 95% of the precipitation falls from November to March. Winter monthly temperatures of 3°-5°C are recorded in higher parts of the watershed; summer months average 22° - 25°. In Krayma (at the apex of the alluvial fan, the Jordan Rift-floor) the average annual temperature is 24°, with summer months reaching 40+^{o}C. Frost-days number 5 - 15 per year **(Fisher et al., 1969).** Land use/cover types vary from natural vegetation (forests) mixed with crop-land. Rainfed agriculture is practiced on most of the catchment, while the lands along the main wadi course and the alluvial fan are mostly irrigated. The slopes of the catchment are utilized for olives and other fruit trees, with or without proper conservation measures. Four scattered associations of forests exist throughout the watershed (**Atkinson and Beaumont, 1971)**: i. broad–leaved forest of *Quercus coccifera* (Kermes oak), ii. broad–leaved forest of *Quercus aegilops* (Decideous oak (or) *Q. Ithaburensis*), iii. coniferous forest of *Pinus halepensis* (Aleppo pine), and iv. mixed forest oak and *Olea europaea* (Wild Olive).

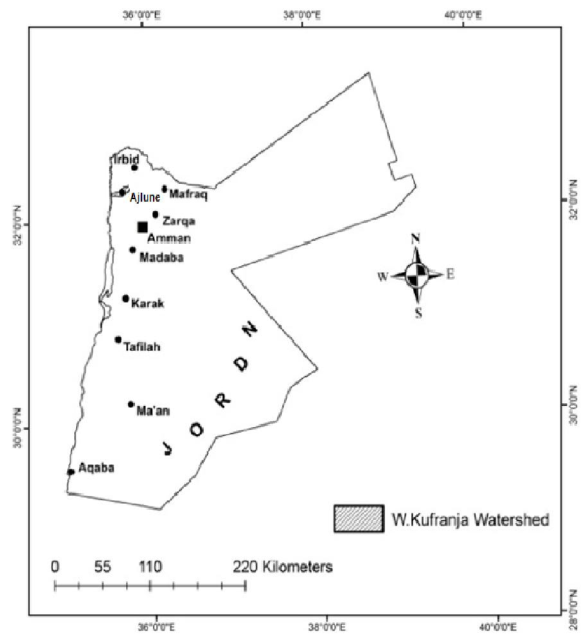

Figure 1. The study area

These forests have suffered destructive human activities. Overgrazing especially by goats, which graze the stubble of wheat, barley, and field crops (tomatoes, lentils, chick-peas), vines and olives. Collection of fuel- and charcoal-wood is a major cause of forests degradation. The worst effect of rainfed cultivation pattern and land cover changes is that the soil surface is bare during the moist winter months. Low rainfall interception by vegetation allows destructive splash and sheet erosion **(Beaumont and Atkinson, 1969).**

3.Materials and Methods

In this study, the RUSLE model was adopted with Arc GIS 10.1 and ERDAS Imagine 8.5, along with LANDSAT ETM+ image (2009). Land use / cover information for the watershed was revised and updated using Google Earth bro (2011) to produce the land use/cover map. To generate the soil loss/intensity map, rainfall data for calculation of rainfall erosivity(R) was provided by the Ministry of Water and Irrigation. The soil data and the maps of soil units and the associated information, were obtained from the National Soil Map and Land Use

Project **(Ministry of Agriculture, 1995),** along with 115 soil samples were analyzed (for texture and organic matter), then the data utilized to compute K factor using the equation proposed by **Wischmeier and Smith (1978).** Aspect and slope categories were calculated from the Digital Elevation Model (DEM), derived from ASTER, and resolved to 30m. Elevations zones also derived from the ASTER DEM. The normalized difference vegetation index (NDVI) (by computing the ratio[Band 4 - Band 3] / [Band 4 + Band 3]) was derived from the LANDSAT image of 2009, and used to calculate the spectral ground – based data which shows the highest correlation with the above-ground biomass **(Lin et al., 2002).** The relationship between C and NDVI was determined as C= (-0.7388 x NDVI + 0.4948), where the C value in each land cell can be specified.

The crop management factor (C) values for each land use/cover-type were inferred based on **Wischmeier and Smith (1978)** and related studies in northern Jordan **(Essa, 2004; Al-Zitawi, 2006).**Terrain units were recognized and mapped using photo-interpretation and field survey, and terrain units map was compiled based on the methodology proposed by **Meijerink (1988).** The GIS Tool Box was employed to compute RUSLE factors, and to generate the soil erosion risk categories map **(Farhan et al., 2013)** and other related important maps employed in this investigation: terrain units, elevation, slope categories, aspect, and land use/cover (Figure 2). Finally, the tables of correlation between soil erosion loss and the physical factors (elevation, slope, aspect, land use/cover, and terrain units) influencing soil erosion were calculated (Tables 2 – 6).

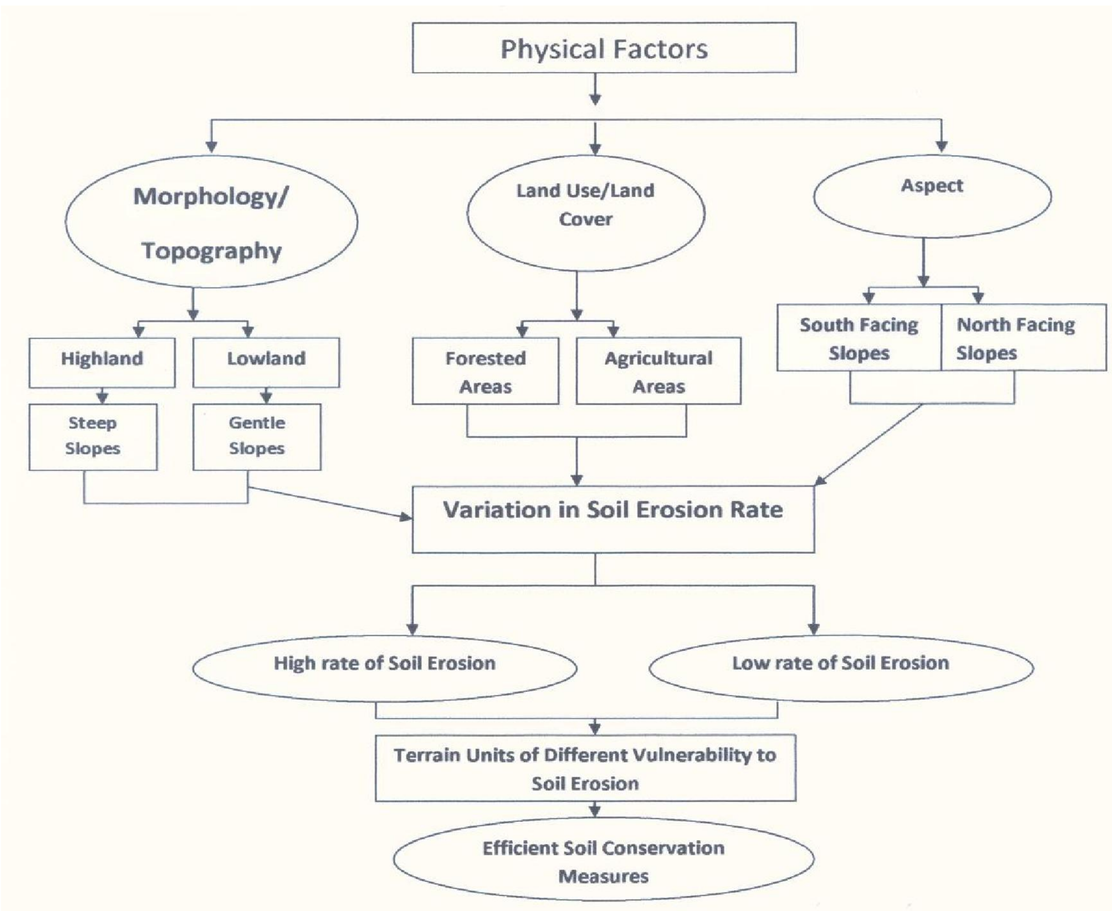

Figure 2. Geographical – physical factors affection soil erosion

4.Results and discussion

4.1 Soil erosion risk and intensity map

The soils covering the flats and slopes in Wadi Kufranja are mainly eroded by water erosion especially runoff, rain splash and sheet erosion. Gravity erosion such as old landslide complexes and recent shallow landslides/slumping are existed between Kufranja and Ajlune towns. The data layers (maps) extracted for K, LS, R, C, and P factors of the RESLE model were integrated within the raster calculator option of the Arc GIS spatial analyst in order to quantify, and generate the map of soil erosion risk and intensity map for the watershed. Given the physical factors, areas of soil erosion loss/intensity of different categories were calculated. The prominent environmental factors that influence soil erosion (slope, elevation, aspect, land use/land cover, soil type and terrain units) were linked to soil erosion to identify erosion risk zones **(Yue-Qing et al, 2008).** The Wadi Kufranja watershed was classified into five soil erosion risk categories (Figure 3). The area and proportion of soil erosion risk classes are illustrated in Figure 3 and Table(1). Potential soil erosion risk increases from the upper to the lower reaches of the catchment. Soil erosion is very severe east of Krayma area and accounts 31.2% of the total watershed soil loss. The upper part of the watershed is well forested with some mixed agricultural cover, and hence is classified as low erosion risk. The distribution of risk classes show that 26.7% of the watershed has minimal soil loss, 36.5% is low, 5.6% and 7.9% is moderate to severe, while extreme soil erosion occupies 23.3% of the watershed. Also, 42.1% (5317.23 ha) of the catchment area was predicted to have a moderate risk of erosion, with soil loss between 5-25 ton ha^{-1} $year^{-1}$ (Table 1). Risk of erosion is severe to extreme over 31.2% (3940.56 ha) of the catchment where calculated soil loss is 25-50 and >50 ton ha^{-1} $year^{-1}$ respectively. Severe and extreme soil erosion pose serious problem in Wadi Kufranja and other similar wadis in the north western-highlands of Jordan.

The results of soil erosion risk, severity, and land use/cover-type should assist decision-makers in identification of priority areas in urgent need of conservation and land-management practices.

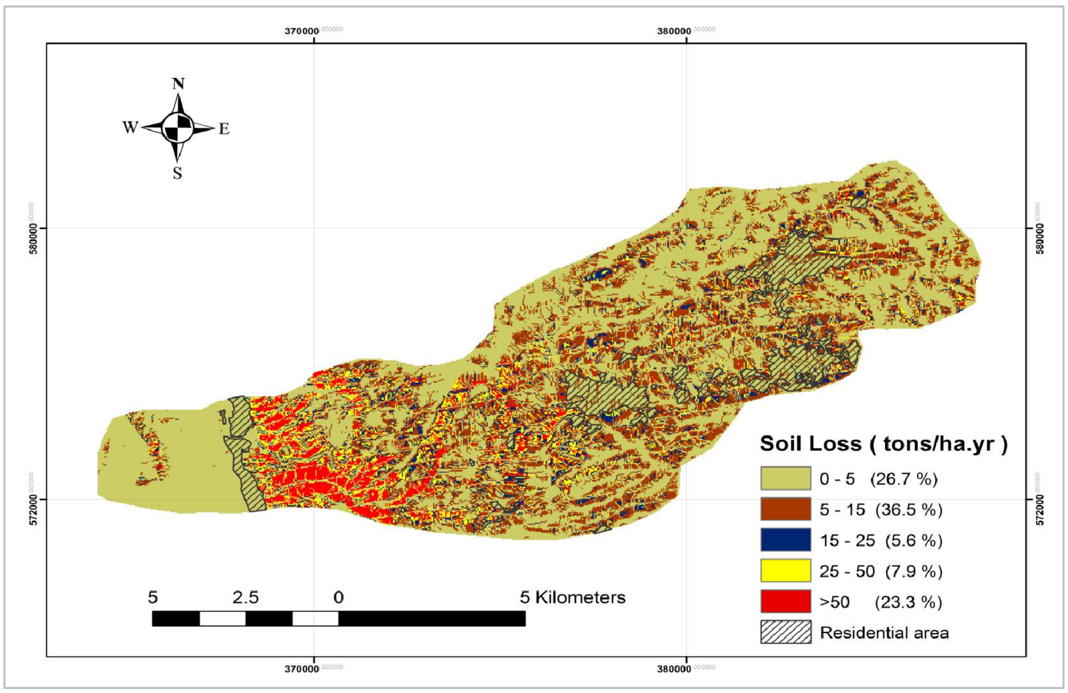

Figure 3. Spatial distribution of erosion risk categories(Farhan et al.,2013)

Table 1: Area and proportion of soil erosion risk classes(Farhan et al.,2013)

Erosion risk class	**Numeric Range (ton ha^{-1} $year^{-1}$)**	**Percentage (%)**	**Area (ha)**
1. Minimal	0-5	26.7	3372.21
2. Low	5-15	36.5	4609.95
3. Moderate	15-25	5.6	707.28
4. Severe	25-50	7.9	997.77
5. Extreme	>50	23.3	2942.79

4.2 Relationship between soil erosion and terrain units

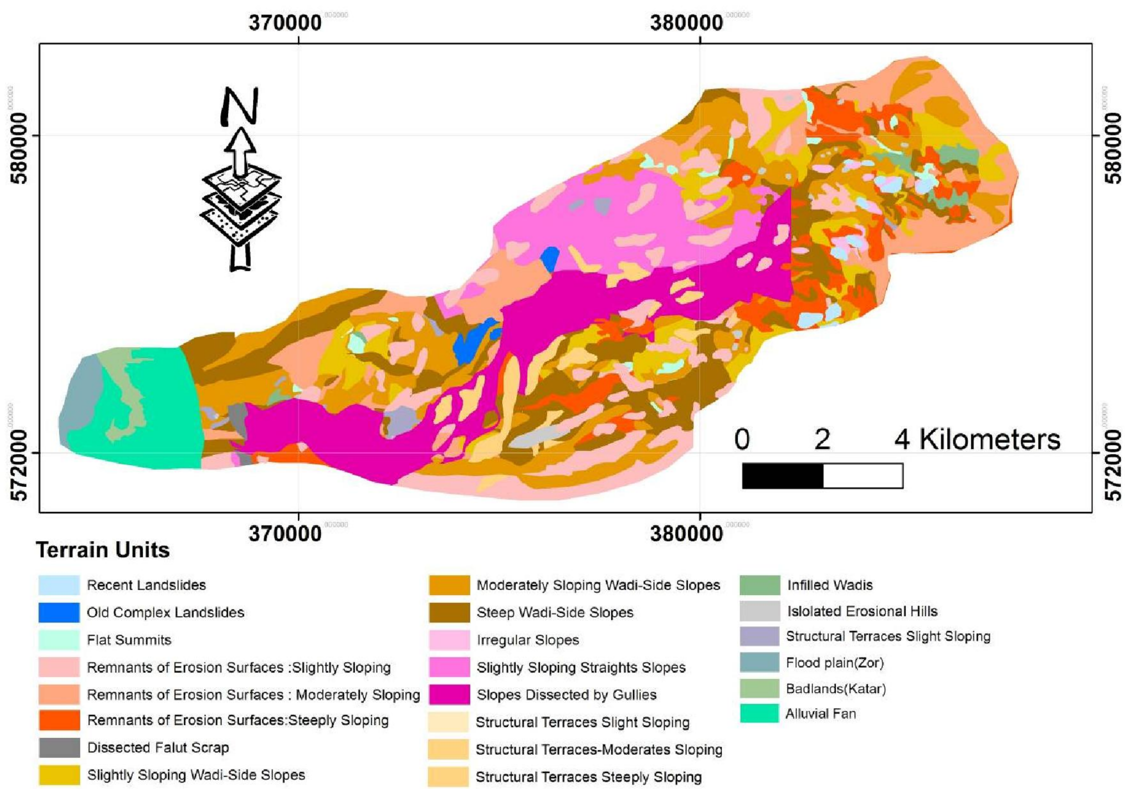

Figure 4. Terrain units

Table 2 : Spatial variation of soil erosion with different terrain units in W. Kufranja

No.	Terrain units	Soil Loss Categories Tones/ha/year^{-1} (Area %)				
		Minimal	Low	Moderate	Severe	Extreme
		0 - 5	5 – 15	15 - 25	25 - 50	>50
1	Moderately Sloping Wadi-Side Slopes	11.16	1	0.73	1.04	0.09
2	Steep Wadi-Side Slopes	9,6	0.58	0.88	1.24	0.07
3	Slightly Sloping Wadi-Side Slopes	5.16	0.26	0.21	0.07	0
4	Remnants of Erosion Surfaces: Steeply Sloping	5.07	0.17	0.23	0.23	0
5	Remnants of Erosion Surfaces: Moderately Sloping	9.04	0.17	0.27	0.2	0.07
6	Alluvial Fan	6.46	0	0.03	0	0
7	Isolated Erosion Hills	0.34	0.03	0.07	0.04	0
8	Structural Terraces Slight Sloping	0.83	0	0.02	0.03	0
9	Structural Terraces-Moderates Sloping	0.75	0.03	0.21	0	0
10	Structural Terraces Steeply Sloping	1.74	0.29	0.22	0	0
11	Old Complex Landslides	0.41	0	0.23	0.09	0
12	Irregular Slopes	0.4	0	0.16	0.03	0
13	Slightly Sloping Straights Slopes	6.47	0.41	0.35	0	0
14	Slopes Dissected by Gullies	9.41	0.77	1	2.26	1.13
15	Flat Summits	0,58	0.04	0.03	0	0
16	Infilled Wadis	0.64	0	0.07	0.06	0
17	Recent Landslides	0.84	0	0.03	0.02	0
18	Remnants of Erosion Surfaces :Slightly Sloping	9.9	0.57	0.58	0.09	0
19	Dissected Fault Scrap	0.13	0	0	0.14	0

Photo-interpretation and field survey revealed that the Wadi Kufranja watershed is composed of 19 terrain units with different physical characteristics (Figure 4).55.06% of soil erosion by area occurred on five terrain units characterized by moderate and steep slopes. The wadi–side slopes experience the highest rate of soil erosion, greater than the flat terrain units. The alluvial fan lands exhibit the lowest rate(Table 2). It is clear that soil erosion is closely related to slope: the steeper the slope, the more severe erosion occurs. Terrain units of steep slopes associated with low vegetation cover have much higher rates of erosion compared to terrain units of flat facets (**Jabbar and Chen, 2005;Wu and Wang, 2011; Bahadur, 2012)**. The old landslide complexes terrain unit is considered as degraded terrain, where it exhibits low rate of soil loss generally, although relatively steep slopes (10-15°,15-20°,and 20-30° slope categories) and a high amount of rainfall are dominant. Soil erosion risk decreases here because the change in land use/cover from bare soil/rangeland to forest land stabilizes the landslide areas. Soil erosion risk is also high on the remnants of erosion surfaces although flat to slightly sloping terrains are common. This is explained by the agricultural activity, of "rainfed farming" practiced over these terrain units. It has been recently postulated **(Alkharabsheh, et al., 2013)** that "mixed rainfed" farming is one of the major reasons behind the high and very high soil erosion rates dominating these terrains. The flat summits terrain unit exhibits the lowest rate of soil erosion. The effects of soil and water conservation on the structural benches of slightly, moderate, and steep slopes, and irregular slopes were remarkable. Surface runoff rates on conserved cultivation plots here were reduced, thus reducing soil erosion rates compared to non-conserved areas.

4.3 Relationship between soil erosion and slope/aspect

The worst effect of "mixed rainfed" farming practiced in the northern Jordan highlands, and land cover changes that took place over the last 50 years is that the soil surface is bare during the rainy season months. Low rainfall interception by poor vegetation coverage allows destructive splash erosion, sheet erosion, and gully erosion to become a widespread phenomenon across all slope categories (Table 3), recognized throughout the Wadi Kufranja watershed **(Beaumont and Atkinson, 1969)**. 67.7% of minimal and low soil loss area occurred.

Table 3 : Spatial variation of soil erosion with slope categories in W. Kufranja

Slope/degrees	Soil Loss Categories Tones/ha/year^{-1} (Area%)				
	Minimal	Low	Moderate	Severe	Extreme
	0-5	5-15	15-25	25-50	>50
0 – 6	67.38	8.59	0.17	0.05	0.004
6 – 15	0.35	3.73	10.97	0.06	0
15 – 25	0.06	0.01	0.067	6.45	1.037
25 – 35	0.001	0	0	0.01	0.507
> 35	0	0	0	0	0.022

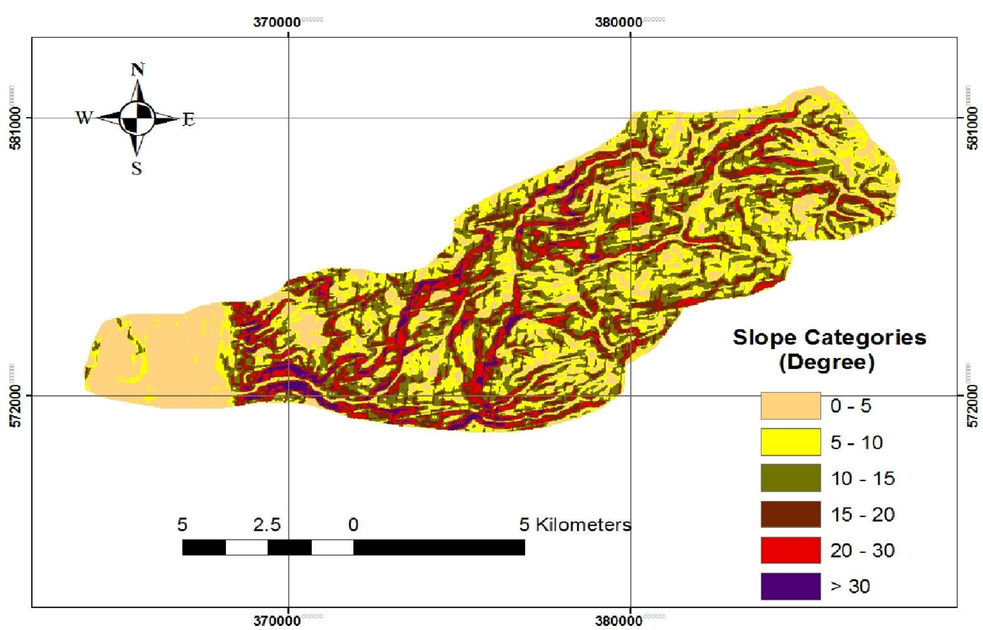

Figure 5. Slope categories in W. Kufranja

Table 4: Spatial variation of soil erosion with aspect in W. Kufranja.

Aspect	Soil Loss Categories Tones/ha/year^{-1} (Area %)				
	Minimal	Low	Moderate	Severe	Extreme
	0 - 5	5 – 15	15 - 25	25 - 50	>50
Flat	23.38	4.61	3.73	2.04	0.58
North	0.72	0,03	0.02	0.03	0.01
Northeast	0.47	0.13	0.1	0.08	0
East	3.82	1.07	0.99	0.55	0.09
Southeast	4.67	1.39	1.3	0.79	0.23
South	6.65	1.55	1.33	0.73	0.16
Southwest	9.88	1.69	1.57	1.08	0.20
West	6.16	1.58	1.42	0.66	0.12
Northwest	7.64	1.52	1.2	0.52	0.15

6.45% of the area is exposed to severe soil loss, and this occurred on the 15-25º slope category. Slight to severe erosion occurs mainly on slope categories 0-5° and 6-15°.Very severe erosion also characterizes slope category 15-25°(Figure 5 and Table 3). Similarly, slope categories of 0-6° and 6-15° are influenced by slight to moderate soil erosion rates. Therefore, areas with slope between 6 and 25° are the major contributor to soil loss. Soil conservation measures should be taken into account to control serious soil loss. Regardless of the "mixed rainfed" farming pattern, soil erosion is closely related to slope, where the steeper the slope, the more is severe the erosion. Slope lands exceeding 30° account for only a small amount in terms of soil erosion, due to forest and bush coverage. This point should be born in mind when considering areas for conservation planning **(Hoyos, 2005).** A close relationship exists between soil erosion and aspect, where 33.22% of soil erosion areas are distributed on the southern slopes, or the sunny and semi sunny slopes (Table 4 & Figure 6). With variability of soil moisture and heat conditions, the southern slopes are more favorable for agricultural cultivation, which finally leads to corresponding soil erosion **(Wu and Wang, 2011).**

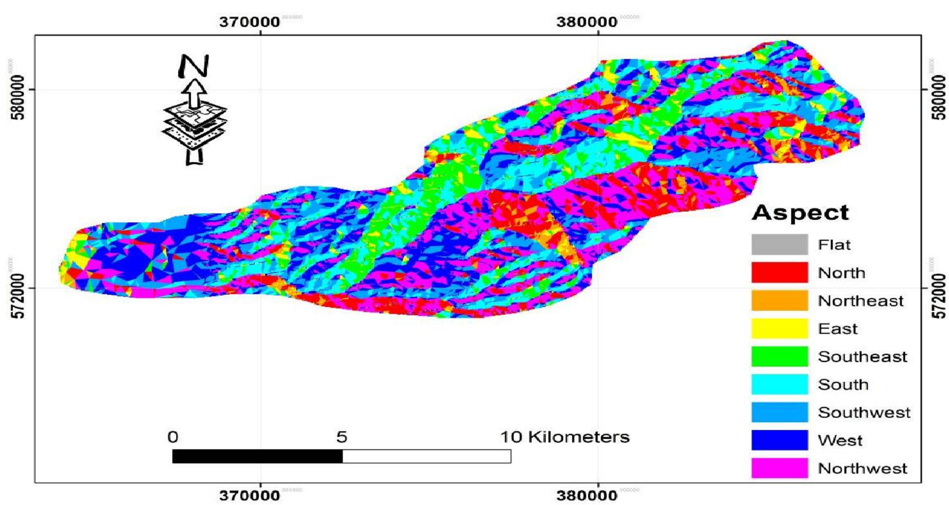

Figure 6. Aspect in W.Kufranja

4.4 Relationship between soil erosion and elevation

The Wadi Kufranja catchment exhibits two distinct elaborated soil erosion zones based on elevation / topographic setting. The lower the elevation, the more severe the soil erosion is. The 500 m point of elevation is the divide between the two zones (Figure 7). Areas of elevation above 500 m, account for 63% of total erosion area, while areas below 500 m of elevation contribute 36% of total erosion area, although very severe erosion is characteristic of the lower zone. This is attributed to the presence of :(i) a badlands terrain unit (west of Krayma) which is composed of fragile Lisan marl, (ii) the presence of weakly dissected fault /erosional steep slopes, and (iii) the dominance of open rangeland and bare soils with slope category of 20-30°. The badlands terrain unit accounts for 10.56% of the total erosion area. By contrast, the elevation zone between 700 and 900 m contributes 28.24% of the total area (Table 5). In particular, higher erosion rates occur between elevations of 700 and 1100 m irrespective of the dominance of scattered forest areas. Here, the main "mixed rainfed" farming distributed evenly over the catchment area between 500 and 1100 m of elevation. Moreover, the highest rainfall erosivity (R-values)(413 – 487 MJ. Mm.ha^{-1}.hr^{-1}.year^{-1}), and soil erodibility (K – factor values) (0.056 – 0.063), prevail in the upper catchment around the humid areas of Kufranja – Ajlune – Anjara towns **(Farhan et al., 2013)**, and a large quantity of human disturbances exist in the catchment between 500 and 1100 m. Based on the spatial pattern of of soil loss in relation to elevation, an efficient conservation strategy is recommended as the key for erosion control practice to reduce soil loss.

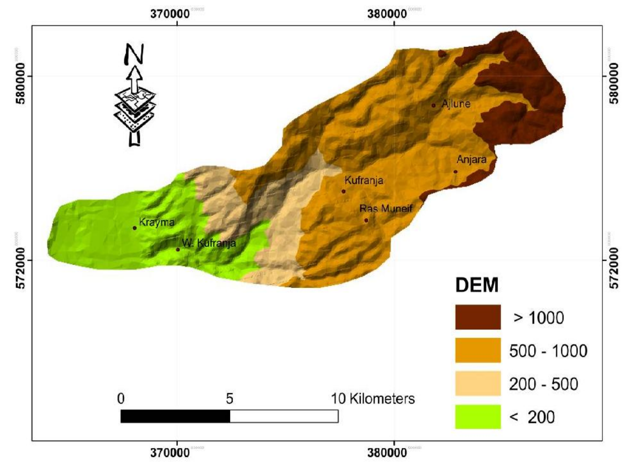

Figure 7. Elevation ranges in W. Kufranja

Table 5: Spatial variation of soil erosion with altitude in W.Kufranja

Elevation(m)	Soil Loss Categories Tones/ha/year^{-1} (Area %)				
	Minimal	**Low**	**Moderate**	**Severe**	**Extreme**
	0 - 5	**5 – 15**	**15 - 25**	**25 - 50**	**>50**
-300 - -100	9.45	0.23	0.37	0.41	0.19
-100 – 100	1.8	0.29	1.06	2.28	0.88
100 – 300	4.51	1.22	1.73	1.15	0.30
300 – 500	4.70	1.86	1.89	1.02	0.12
500 – 700	10.8	2.39	1.84	0.70	0.03
700 – 900	20.1	4.64	2.95	0.54	0.01
900 – 1100	13.6	2.94	1.82	0.42	0.02

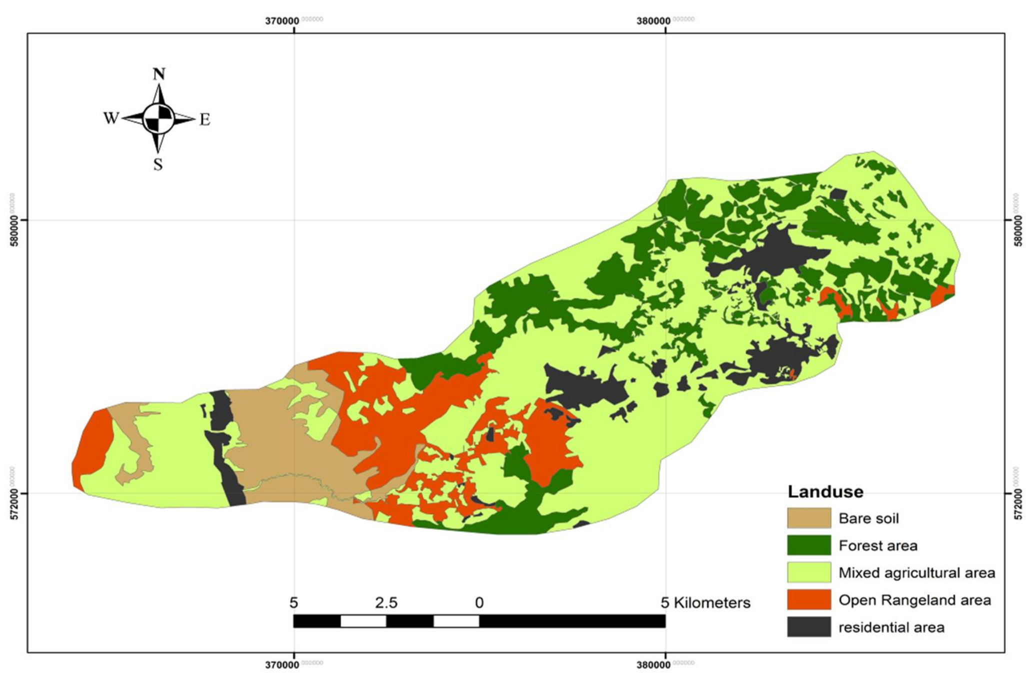

Figure 8. Land use / cover in W. Kufranja

Table 6: Spatial variation of soil erosion with different land use / cover in W. Kufranja

Land use Land/cover	Soil Loss Categories Tones/ha/year^{-1} (Area %)				
	Minimal	Low	Moderate	Severe	Extreme
	0 - 5	5 – 15	15 - 25	25 - 50	>50
residential area	10.14	0	0	0	0
Forest area	22	0.34	0.03	0	0
Mixed agricultural area	41.1	3.5	2	0.27	0
Open Rangeland area	5	0.65	2.54	1.49	0.05
Bare soil	1.7	0.03	0.70	4	1.15

4.5 Relationship between soil erosion and land use/cover

It is now accepted that land use / cover and topography are the two major factors influencing soil erosion, with variation in soil loss rates due to soil erodibility factor(K – values) having much less of an influence **(Bahadur,2012**). Similarly, the rainfall erosivity factor(R–values) plays an important role in the overall rate of loss."Mixed rainfed" cultivation which has been practiced widely in the catchment(between 500 and 1100 m a.s.l) has the highest rate of soil erosion, and accounts for 48.18% of the erosion area(Figure 8), followed by forest area (23.37%), and open rangeland and bare soils(18.31%). Average contributions of different land use / cover in relation to erosion areas are listed in Table(6). The average soil loss from "mixed rainfed" cultivation across the watershed is much higher when compared with forest area, and open rangeland, and bare soils. The forest areas covered only 18.53% of the watershed, while the "mixed rainfed" covers 51.23% of the watershed, which suggests that soil erosion in the mixed agricultural areas is very serious in the wadi. Recently, the conversion of forest to areas of agricultural land in the middle and the upper reaches of the watershed increased water erosion. It is concluded **(Hurni, 1993**) that the expansion of cultivated areas, and intensified use resulting from reduction and almost complete abandonment of fallow system, led to intensified soil degradation and sediment loss from Wadi Kufranja catchment. The aforementioned findings are disturbing, considering that the Ministry of Water and Irrigation has begun construction of a dam west of Kufranja that will collect storm-water runoff and base-flow. Annual sediment yield of the catchment contributing to the reservoir has not been determined by the **Ministry of Water and Irrigation (2010),** and in light of the present findings, the predicted large sediment yield will seriously threaten the life of the reservoir behind this dam. The present findings also demonstrate that the substantiality and intensity of the required conservation planning approaches for the catchment are of high priority in order to effectively reduce soil loss. This approach must be integrated with a plan to improve farming practices in the Wadi Kufranja watershed, and over the northern Jordan highlands.

Conclusion

The present determination of RUSLE parameters has revealed a soil erosion problem over the Wadi Kufranja basin, along with significant spatial variation in the patterns of soil erosion loss. Soil erosion occurs in different zones of the catchment: the upland and lowland, different terrain units, different slope categories, and different land use / agricultural practice. A remarkable variation in soil erosion loss displays in areas ranging between 500 and 1100 m of elevation, and areas below 500 m. The first zone, accounts for 63% of the total area, while the second zone contributes 36% of total erosion area. Such findings have been recently verified, where **Zhang et. al.,(2013)** reported that high values indicating soil erosion sensitivity are associated with areas having greater relief(maximum elevation). Wadi–side slopes (denudational slopes) and remnants of erosion surfaces are the critical terrain units suffering from high soil erosion rates. Moderate to steep wadi–side slopes terrain units dominated the catchment, thus rendering soil erosion a serious problem on such terrain units. Similarly, slightly and moderately sloping remnants of erosion surfaces also suffer high rates of soil erosion due to the farming systems of "mixed rainfed" farming practiced in areas with poor conservation measures, thus accelerating soil erosion. Unfortunately, most of the farmers in Jordan practice up-and-down ridging which have produced a high level of erosion compared with contour ridge practice. Recent experimentations also indicate that intercropping of barley and vetches at planting density of 350 plants m^{-2} resulted in the lowest soil loss**(Sharaiha and Ziadat, 2007**). Therefore, intercropping of this kind is a promising tool to reduce runoff coefficients and soil losses. Slope categories have significant effects on soil erosion, which occurs principally on 0.0-6°, 6-15° and 15-25° slope categories, accounting for 96.65% of the total erosion area. Soil erosion shows high sensitivity in relation to aspect, where 33.22% of the soil erosion areas are distributed on the southern sunny and semi-sunny slopes. “Mixed rainfed” cultivation areas have the highest rate of soil erosion, and account for 48.18% of the erosion area, followed by forest areas(23.37%), and open rangeland and bare soils (18.31%). Slope categories of 6-15°,15-25°,and 25-30°, and elevations between500 and 1100 m a.s.l are proposed as the key erosion control and conservation practices to reduce soil loss in the catchment. Proper conservation schemes must be instituted across the “mixed rainfed” agricultural land, where soil erosion is severe. This procedure is essential to ensure future sustainability of farming practice. Forest plantation could be expanded in the catchment between elevations100 to 400 m. Here, the annual rainfall is around 300 mm, and the slope ranges between 12° and 50°. In 2010, the estimated bare ground across the catchment is 11.9 km^2, and about 6.6 km^2 of this area is suitable for reforestation to minimize soil loss. It is highly recommended from **practical point of view** to integrate RS/GIS technologies with physical factors, to plan for monitoring soil erosion on a regional scale, and to evaluate environmental factors that influence soil erosion loss. Such methodology and the resultant information are valuable for managing and planning land use/cover in order to achieve sustainable future agriculture development.

References

1. Alkharabsheh M, M, Alexandrisis G, B, Misopolinos and Silleos N. Impact of land cover change on soil erosion hazard in northern Jordan using remote sensing and GIS. Procedia Enviornmental Sciences, 2013;19 (3) : 912-921
2. Al-Sheriadeh M, Malkawi A,H, Al-Alhamdan and Abdulrahman N. Evaluating sediment yield at King Talal Reservoir from landslides along Irbid-Amman highway.Engineering Geology, 2000;56(3-4):361-372.
3. Al-Alawi M, Abujamous M. Estimation of soil erosion in Jordan by using GIS. In: De Amicis, R. et al. (eds.) GeoSpatial Visual Analytics: Geographical Information Processing and Visual Analytics for Environmental Security, Springer Science & Business Media, Berlin, Springer-Verlag, B.V. 2009: 439-450.
4. Al-Zitawi F. I. Using RUSLE in prediction of soil loss for selected sites in north and north west of Jordan. MSc Thesis, Jordan University of Science and Technology, Irbid, Jordan, 2006, 105p.
5. Atkinson K. and Beaumont P. The Forests of Jordan, Economic Botany,1971; 25 (3):305-31
6. Bahadur K. C. Spatio-temporal patterns of agricultural expansion and its effect on watershed degradation: a case study from the mountains of Nepal. Environmental Earth Science, 2012;65:2063–2077.
7. Beaumont P. and Atkinson K. Soil erosion and conservation in Northern Jordan. Journal Soil and Water Conservation,1969;24:144-147
8. Beni Taha O. Soil Erosion in Jerash area, Central Jordan, Unpublished dissertation in partial fulfillment of the requirements for the Master of Arts, University of Jordan, Amman, Jordan (In Arabic), 2004,106p
9. Essa S. GIS modeling of land degradation in northern Jordan using LANDSAT imagery. PhD dissertation, University of United Arab Emirates, Al-Ain,2004.
10. FAO, UNEP, and UNESCO. A provisional methodology for soil degradation assessment, FAO, Rome, 1979; 84p
11. Farhan I. A. and Al-Bakri F.T. Use of GIS and Remote Sensing to Assess Soil Erosion in an Arid to Semiarid Basin in Jordan. Proceedings of the International Conference on Sediment transport: Modeling in Hydroslogical Watersheds and Rivers, Turkey, Istanbul, 2012; 145-152.
12. Farhan Y. Landslides in Central Jordan with special reference to the March 1983 rainstorm, Singapore Journal of Tropical Geography,1986; 7(2): 80-96.
13. Farhan Y. Slope stability problems in Central and Northern Jordan. The Arab World Geographer, 2002; 5 (4): 265-290.
14. Farhan Y. Zreqat D. and Farhan I. Spatial estimation of soil erosion risk using RUSLE approach, RS and GIS techniques: A case study of Kufranja watershed, Northern Jordan. Journal of Water Resources and Protection, 2013;5(12):1247 – 1261.
15. Fisher W. Bowen–Jones H. Atkinson K. Beaumont P. Smith K. and Stevens J. Soil and land potential survey of the highlands of North-West Jordan, University of Durham, 1969: 50p
16. Ghosh K. Kumar De S. Bandyopadhyay S.and Saha S. Assessment of soil loss of the Dhalai River Basin, Tripura, India using USLE. International Journal of Geosciences. 2013;4 :11 - 23
17. Harza. Report on dam heightening, Amman, Jordan Valley Athority, 1980; 11
18. Hoyos N. Spatial modeling of soil erosion potential in a tropical watershed of the Colombian Andes.Catena,2005;63:85-108
19. Hurni H. Land degradation, famine, and land resources scenarios in Ethiopia, In: Pimental, D.(ed.), World Soil Erosion and Conservation.

Cambridge, U.K: Cambridge University Press, 1993:27 – 61.
20. Jabbar M. T. and Chen X. Soil degradation risk prediction integrating RUSLE with Geo–information techniques, the case of Northern Shaanxi Province in China. American Journal of Applied Sciences, 2005;2: 550 - 556
21. Jha P. Nitant H.C. and Mandal D. Establishing permissible erosion rates for various landforms in Delhi State, India. Land Degradation & Development, 2009;20: 92 – 10
22. Khresat S. Soil erosion and land degradation in the highlands of Jordan. Geophysical Research Abstract, 15, EGU: 2013 – 171.
23. Khresat S. Al-Bakri J. and Al-Tahhan R. Impact of land use / cover change on soil properties in the Mediterranean region of northwestern Jordan. Land Degradation & Development. 2008; 19:397 – 407.
24. Kumar S. AND Kushwaha S. Modelling soil erosion risk based on RUSLE-3D using GIS in a Shivalik sub – watershed, Journal of Earth System Science. 2013;122: 389 – 398.
25. Lin C.-Y. Lin W.-T. and Chou W-C. Soil erosion prediction and sediment yield estimation: the Taiwan experience. Soil and Tillage Research, 2002;68:143-152.
26. Lufafa A. Tenywa M.M. Isabirye M. Majaliwa M.J.G. and Woomer P. Prediction of soil erosion in a lake Victoria basin catchment using GIS – based Universal Soil Loss model. Agricultural System,2003;76 :883 – 894
27. Manjoro M. Kakembo V. and Rowntree K.M. Trends in soil erosion and woody shrub encroachment in Ngqushwa District, Eastern Cape Province, South Africa. Environmental Management, 2012; 49:570 – 579.
28. McDonald Partners and Hunting Technical Services, Ltd. East Bank Water Resources Summary Report, Central Water Authority, Amman**,** 1965:58p.
29. Mazawdeh O. Soil erosion susceptibility of Wadi Al-Shalala. MA Thesis, Faculty of Graduate Studies, University of Jordan (In Arabic), 2013: 124p.
30. Meijerink A. M.J., Data acquisition and data capture through terrain mapping units, ITC Journal, 1988;7(1)44.
31. Ministry of Agriculture, Jordan. The Soil of Jordan. Report of the National Soil Map and Land Use Project. Ministry of Agriculture, Hunting Technical Services Ltd., and European commission. 1995
32. Ministry of Water and Irrigation-Jordan. Valley Authority. Final design for the construction of Kufranja dam, Energoprojekt, Belgrade, 2010: 54p.
33. Natural Resources Authority. Report on floods in Jordan, Unpublished, 1965:18p.
34. Pradhan B. Chaudhari A. Adinarayana J. Buchroithner M. Soil erosion assessment and its correlation with landslide events using remote sensing data and GIS: a case study at Penang Island, Malaysia. Environmental Monitoring Assessment, 2012;184: 715 – 727
35. Sharaiha R. and Ziadat F. Alternative cropping systems to control soil erosion in arid to semi-arid of Jordan. African Crop Science Conference Proceedings.2007; 8:1559-1565
36. Van Zuidam R. Terrain analysis and classification using aerial photographs: a geomorphological approach. ITC, Enschede, Neths., 1979:310p.
37. Wischmeier W. H. and Smith, D. D. Predicting rainfall erosion losses: a guide to conservation planning. Agricultural Handbook, No. 537, US Department of Agriculture, Washington, DC, 1978.
38. Wu X. and Wang X. Spatial influence of geographical factors on soil erosion in Fuyang County, China. Procedia Environmental Sciences, 2011;10: 2128 – 2133.
39. Yue-Qing X, Xiao-Mei S. and Xiang-Bin K. Adapting the RUSLE and GIS to model soil erosion risk in a mountain karst watershed, Guizhou Province, Cuina, Environmental Monitoring Assessment. 2008;141:275-286.
40. Zhang R. Liu X. Heathman G.C. Yao X. Hu X. and Zhang G. Assessment of soil erosion sensitivity and analysis of sensitivity factors in the Tongbai – Dabie mountainous area of China, 2013;101 :92-98.

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