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Assessing Farmers' Perception of Soil Erosion Risk in Northern Jordan

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Abstract

Socioeconomic factors and farmer's perception of soil erosion and conservation were examined with special reference to Wadi Kufranja catchment, northern Jordan. Field data were collected through a household field survey, and soil erosion loss was calculated and mapped using the Revised Universal Soil Loss Equation (RUSLE), within a GIS/RS environment. *In-situ* field measurements of soil erosion were also conducted to assess splash, sheet and runoff soil erosion. The estimated potential average annual soil loss is 10 ton·ha^{-1} year for the watershed. 42.1% (5317. 23 ha) of the watershed area was estimated to have moderate soil loss (5 - 25 ton·ha^{-1}·years $^{-1}$). Soil erosion risk is severe to extreme over 31.2% (3940.56 ha) of the catchment, whereas the calculated soil loss is 25 - 50 and >50 ton·ha^{-1}·year^{-1}. The measured sheet and splash soil erosion in W. Kufranja was 10 ton·ha^{-1}·year^{-1} from tillage land, and 3 ton·ha^{-1}·year^{-1} from the fallow land, with an average ranges from 8 to 10 ton·ha^{-1}·year^{-1}. Similarly, the maximum measured soil erosion on the eastern margin of W. Kufranja was 12.7 ton·ha^{-1}·year^{-1}, while the minimum soil erosion was 2.9 ton·ha^{-1}·year^{-1}. The collected household socioeconomic/conservation data have been subjected to multivariate statistical analysis. Through factor analysis, the twenty one variables were reduced into four significant factors which account for 69.7% of the variation in the original variable. Stepwise multiple regression analysis revealed that the total variance explained by three independent variables was 0.585 ($R = 0.765$, $R^2 = 0.585$). Out of the total variance, forest clearance explained 34.7%, fallow land 7.7%, and land use/land cover 16.1% respectively. The F-value for forest clearance, fallow land, and land use/land cover are significant at 0.1% level. Most of the farmers aware that poor land management, deforestation, overgrazing, traditional cultivation (cultivation up-and-down the slope, and mono-cropping), and population pressure, are the major direct and indirect causes of soil erosion. By contrast, vegetative measures (*i.e.*, afforestation and tree planting), adoption of structural soil and water conservation measures (terraced farming, check dams and gully control), and crop system management were recommended to control soil erosion.

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Keywords

Soil Erosion Perception, GIS, Terrain Units, Soil Conservation, Factor Analysis, Stepwise Multiple Regression

1. Introduction

Soil degradation by accelerated erosion is a serious environmental problem in the highlands region of Jordan. Erosion of topsoil leads to declining soil quality and productivity, thus restricting the area of potential future agriculture. Rapid population growth, the associated population movements into rural areas, and land use practices and land cover changes since the 1950's, have led to soil degradation. Eroded soil materials from the denudational slopes are deposited over wadi floors, agricultural lands, irrigation canals, even on roads, and more seriously in reservoirs constructed across the wadis draining to the rift. Several studies were carried out to estimate soil erosion in Jordan on local, regional, and national scales [1]-[3]. *In situ* field measurements of runoff soil erosion and splash erosion were carried out (1985/1986 and 2003/2004) in the upper and lower Wadi Kufranja and Jerash area close to the wadi [4] [5]. However, the main causes of land degradation in Jordan have been outlined at regional [6], and national levels [7]. It can be concluded that the principal causes of land degradation and desertification in Jordan are: soil erosion by water and wind, land use changes, poor vegetal cover, exploitation of underground water and soil salinity, over grazing, and rapid urbanization. Thus, loss of soil fertility and productivity are the main consequences of land degradation in Jordan [8].

Recently, the revised Universal Soil Loss Equation (RUSLE) model has been employed in conjunction with RS and GIS technology to estimate the annual soil loss in different areas in central and northern Jordan [9] [10] and southern Jordan, [11]. Moreover, Alkharabsheh *et al.*, [12] assessed the impact of land cover changes on soil erosion hazard in the southern part of the Yarmouk catchment using remote sensing and GIS. They concluded that the differences in erosion risk between 1992 and 2009 were considerable, and mainly attributed to changes in land cover/land use which influenced soil erosion rates significantly in northern Jordan. The influence of physical environmental factors on soil erosion loss was investigated recently by Farhan *et al.*, [13], and it was reported that soil erosion was sensitive to specific physical factors such as slope, elevation, aspect, and terrain units. In the present investigation, socioeconomic determinants and farmers' perceptions of soil erosion and soil conservation measures were explored. Perception in this context is recognized as the process by which individuals and communities explain and organize their impressions to create a meaningful experience of the real world. Simply, it refers to the way communities try to understand the environment, and based on their experience with land resources, how they exploit this in making their living [14] [15]. The data collected through the household survey, and other data on estimated/measured soil erosion [4] [5] [10] were utilized to assess the status and people's perception of soil erosion, and to identify socioeconomic determinants of soil erosion, through factor analysis and stepwise multiple regression.

2. Study Area

Wadi Kufranja catchment constitutes the present study area. It is located in the northern highlands of Jordan, and lies between 32˚14' to 32˚22' north latitudes and 35˚21' to 35˚47' east longitudes (**Figure 1**). The watershed area is 126.3 km^2 (12,630 ha), with elevations 1137 m a.s.l (above sea-level) to −329 m b.s.l (below sea-level) over a short distance of only 23 km. The upper wadi consists of maturely dissected terrain, with broad valley forms and smooth interfluves. In the middle and lower parts, rejuvenation resulted in a narrow, incised, steep-sided gorge. The longitudinal profiles of northern Jordan wadis generally exhibit four major irregularities. It is believed that these irregularities represent rejuvenation stages that took place during the Oligocene-Miocecne and Pleistocene. The flat summits around Ajlune, Anjara and Kufranja towns represent the remnants of Tertiary and/or Pleistocene erosion surfaces [16]-[18]. Slope category of 0˚ - 5˚ is restricted to the wadi alluvial fan (the Ghor), west of Krayma and scattered summit surface east of Krayma, meanwhile slope categories of 5˚ - 10˚ and 10˚ - 15˚ dominate in the scattered narrow strips which constitute the remnants of erosion surfaces, the structural benches and the upper convex slopes. The steep slope categories of 15˚ - 20˚, 20˚ -30˚ and >30˚ characterized most lower wadi-side slopes in the upper, middle, and lower parts of the watershed. Large and small scars and hummocky

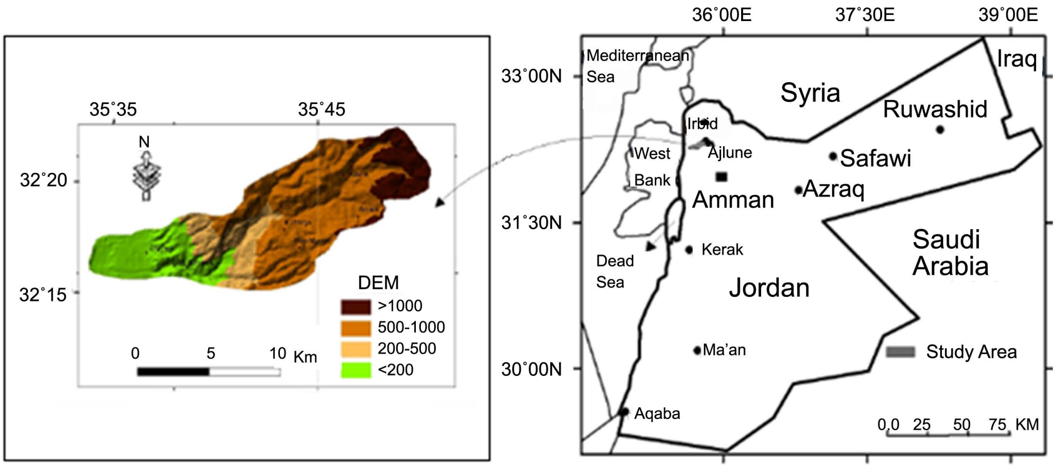


Figure 1. The study area.

topography indicate past landside events, probably of Pliocene and Quaternary age (<5 Ma) [16] [19]. The geology is dominated by Upper Cretaceous marly clay and marly limestone of the Ajlun series, which closely influences the basin soils. 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. About 10% of the watershed is bare rock, and truncation of upper soil horizons is widespread; thus fully developed soil profiles are rare. Erosion exposes more loosely structured subsoil, which accelerates further erosion [20]. Climate is of the "dry Mediterranean" type in the upper catchment and "semi-arid and arid" types in the lower parts. Mean annual rainfall ranges from 630.5 mm (Ajlune station) to 267.8 mm (Wadi Kufranja station, east of Krayma) close to the Ghor. 95% of the precipitation falls from November to March (70% in Dec-Feb).Winter monthly temperatures of 3˚C - 5˚C are recorded in higher parts of the watershed; summer months average 22˚ - 25˚C. In Krayma (in the Ghor, the Jordan Rift-floor) the average annual temperature is 24˚C, with summer months reaching 40+˚C. Frost-days number 5 - 15 per year [17] [21].

Land-cover types vary from natural vegetation (forests) mixed with crop-land. Four scattered associations of forests are distinguished throughout the watershed [22]: broad-leaved forest of Kermes oak, broad-leaved forest of decideous oak (or) coniferous forest of Aleppo pine, and mixed forest of oak and wild olive. The land use / cover of the watershed comprises 7.52% residential and commercial areas, 18.53% forest, 51.23% mixed agricultural, 13.30% open rangeland and 9.42% bare soil [23]. The forests and other vegetation types in northern Jordan have suffered severe anthropogenic interventions. Overgrazing of rangeland (mainly by goats), and the collection of fuel-wood and charcoal-wood are the main causes underlying forest degradation. The effect of cultivation patterns and land cover changes is that the soil surface is bare during the moist winter months. Low rainfall interception by vegetation allows destructive splash erosion [20]. At present, shallow landslides, occasionally deep-seated landslides, soil slumping, and minor mudflows are repetitive phenomena following intense rainfall. Previous investigations [19] [24]-[29], indicate that such movements are triggered primarily by the combined influence of hill-slope disturbance by intensive human activities, soft rock formation, poor land management, and recurrent heavy/intense rainstorms. Such processes increase soil erosion rates.

3. Materials and Methods

Data were obtained from a variety of sources including remote sensing, DEM, and GIS for estimating soil erosion loss; field measurements of soil erosion, and from a household questionnaire survey. The basic methods/ tools employed to assess soil erosion are illustrated (**Figure 2**) as follows:

3.1. Soil Erosion Estimation

Soil erosion in northern Jordan was conducted over the past two decades using different soil erosion estimation

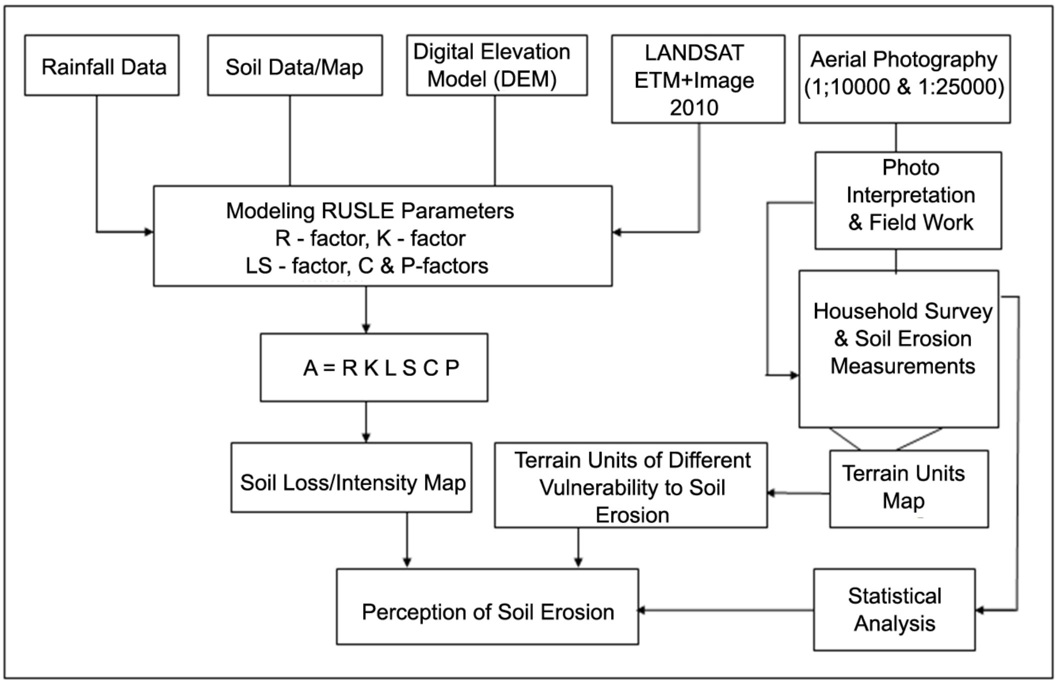


Figure 2. Methodology of the study.

techniques such as: *in-situ* field measurements, and soil erosion estimation using geospatial technology (remote sensing and GIS).

3.1.1. Estimation of Soil Erosion Loss Using the RUSLE Approach

Several different empirical and physical process based models have been developed since 1930s to predict soil loss [30] at local, watershed, and regional scales. Recently the Revised Universal Soil Loss Equation (RUSLE) [31]-[34] is considered the most effective model employed to estimate soil loss worldwide. It uses elaborate methods to compute soil erosion factors, predicting annual soil loss by rain-splash and surface runoff over all types of land-use and cover-type. The protocol is considered essential for planning soil conservation [35]. Five parameters are manipulated in the model, in raster format: rainfall erosivity, soil erodibility, slope length and steepness, cover-type and management, and support practice. The equation is written as:

$$A = R \times K \times LS \times C \times P$$

where,

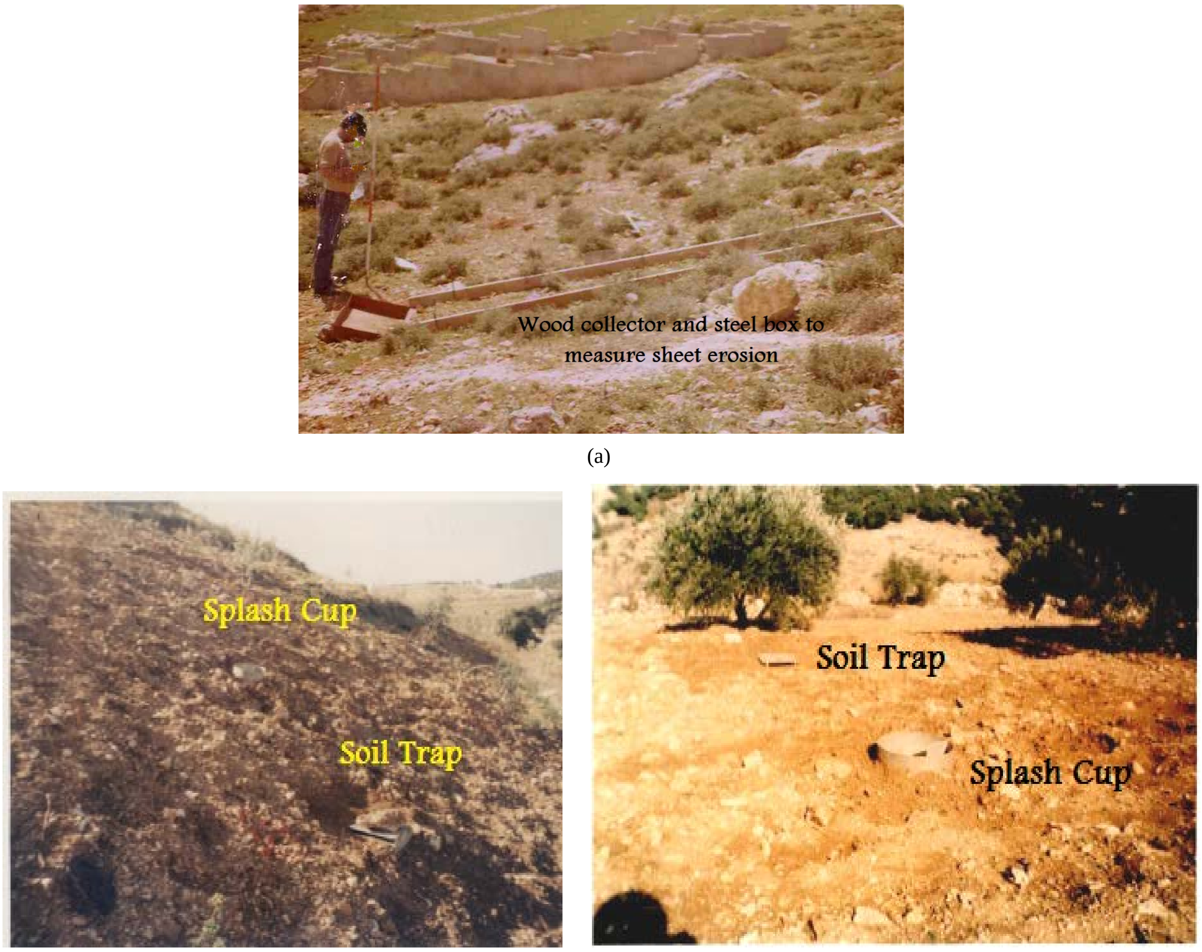
A: the computed soil loss per unit area [ton·ha^{-1}·year^{-1}], R: runoff erosivity factor (rainfall and snowmelt) in [MJ mm ha^{-1}·hr^{-1}·year^{-1}], K: soil erodibility factor (soil loss per erosion index unit for a specified soil measured on standard plot, 22.1m long, with uniform 9% (5.16˚) slope, in continuous tilled fallow) [ton·ha·hr·ha^{-1} MJ^{-1}·mm^{-1}], L: slope length factor (ratio of soil loss from the field slope length to soil loss from standard 22.1m slope under identical conditions) (dimensionless), S: slope steepness factor (ratio of soil loss from the field slope to that from the standard slope under identical conditions) (dimensionless), C: cover-management factor (ratio of soil loss from a specified area with specified cover and management to that from the same area in tilled continuous fallow) (dimensionless), and P: the support practice factor (ratio of soil loss with a support practice-contour tillage, strip-cropping, terracing-to soil loss with row tillage parallel to the slope (dimensionless).

The RUSLE model was applied with Arc GIS 10.1 and ERDAS Imagine 8.5, along with LANDSAT ETM+ 2010 to estimate soil erosion loss [10] [11]. Aerial photographs of scale 1:10,000 (1978), and 1:30 000 (1992) were utilized to compile the terrain units map through photo-interpretation methods and field survey [36]. Land use/cover information for the watershed was revised and updated using Google Earth Pro (2011). Rainfall data for calculation of rainfall erosivity (R) were obtained from the Ministry of Water and Irrigation, and the soil data were acquired from 1995 national soil survey maps/reports [37]. NDVI values generated and mapped from a LANDSAT image were used to determine the C factor, and to verify land use/cover information. The GIS Tool

Box was employed to compute the parameters of the RUSLE model and to compile soil erosion loss map.

3.1.2. Field Measurements of Soil Erosion

Two plots for field measurements of sheet, runoff (soil traps) and splash soil erosion [38] [39] were established in W. Kufranja [4], one plot installed on tillage land, and the other assigned on fallow cultivated land (**Figure 3**). Field measurements were conducted during the winter of 1985/1986. Beni Taha [5] also, carried out field measurements to estimate runoff and splash soil erosion on the eastern margins of W. Kufranja to the west of Jerash city. Two of the four plots were installed close to the eastern margin of W. Kufranja watershed. The measurements were carried out during the winter of 2002/2003. In both case studies, the physical factors affecting soil erosion were evaluated using stepwise regression analysis. The selected sites for soil erosion measurements varied in terms of morphological characteristics (slope form (convex, concave, or straight), gradient (degrees); aspect, length of slope (m), location on slope (upper, middle, or lower), vegetation and land use, conservation measures, fallow or tillage (contour ploughing, or up-and-down slope ploughing), stone abundance%, and soil texture.



(a) (b) (c)

Figure 3. Soil erosion equipments installed to measure sheet, rain splash, and runoff erosion.

3.1.3. Terrain Unit Mapping

The terrain mapping unit (TMU) (or homogenous domain) approach was elaborated by Meijerink [36] as a method for data acquisition and storage. It makes use of the interactions between geology, geomorphology, hydrology, vegetation and soils. For the purpose of the present investigation definitions of terrain units proposed by Meijerink [36] were adopted as given below:

A TMU represents a natural division (or) portion of land surface containing a set of ground conditions which differ from the adjoining units, and it's boundaries can be easily demarcated [40] [41]. The unit can also be recognized on aerial photographs, and verified by field check. Terrain units are normally differentiated on the basis of photographic properties and landform attributes as they appear and can be recognized in the stereo model and the field. A TMU is also identified as a unit where a group of interrelationships among landform, lithology and soil are dominant. Moreover, a TMU differs from another adjacent unit because either the landforms are evidently different, or the phenomena associated with the landform differ. Thus, and in terms of GIS, a TMU may be described as the geographic location (polygons) of entities which are related to a unique set of attributes. Terrain unit mapping was accomplished based on the interpretation of aerial photographs associated with a field check. The landform type, hydrology, vegetation and soil conditions of the unit were considered essential in the process of mapping these units. A terrain unit is thus necessary to establish a data-base of the environmental data needed to describe a given process or phenomenon, and to build up a predictive or explanatory model of the spatial or temporal distribution of such a phenomenon. The procedures of terrain units mapping using remote sensing techniques are discussed in details by van Zuidam [42] [43], Verstappen [44], Speight [40] and Meijerink [36].

3.1.4. Famers' Perceptions and Socioeconomic Determinants of Soil Erosion: Household Survey

The study watershed consists of 2295 farms distributed over 18 villages and towns [45]. Six villages accommodate between 5 and 10 farms, therefore the farm sample was drawn from the remaining 12 villages. The sample size was determined according to the following Yamane's formula [46]:

$$n = \frac{N}{\left(1 + N \times e^2\right)} \tag{1}$$

where:

n is sample size, N is total no. of households and e is the significance level (in our case the significance level is 7%). The resultant sample size was 187 farms which represent the whole watershed. A structured questionnaire was designed and distributed to collect information on socioeconomic conditions of farmers, soil erosion status, soil and water conservation, and the perception of soil erosion extent, causes and impacts, and the awareness of soil conservation measures and practices. The information also covers the household characteristics, land ownership, income and expenditure, and the awareness of governmental soil erosion projects including cost. The collected information is considered an essential factor when making decisions on soil and water conservation projects and practices [47]. Two categories of information were collected by means of the questionnaire survey (**Table 1**): the socioeconomic variables/determinants of soil erosion, farmers' perceptions of soil erosion, soil conservation types, cost, and effectiveness of installed measures across the watershed. However, appropriate questions were included in the questionnaire and aimed to reveal the direct and indirect causes of soil erosion as perceived by the farmers. Also, a final question asked the farmers to record their suggestions regarding the appropriate conservation measures needed to minimize soil erosion in W. Kufranja.

Factor analysis was employed to condense the original variation, measured in terms of a large number of variables (21 variables), into variation in terms of a few factors, each of which contributes a known amount to the total variation It is performed on the standardized variables using correlation matrix to dismiss the effect of different measurement units on the determination of factor loadings. Factor loadings represent a simple correlation between properties of each factor. Eigenvalues illustrate the amount of variance explained by each factor. Factors with eigenvalues > 1 explained more the total variation in the data than farmers' socioeconomic characteristics and perception of soil erosion, while factors with eigenvalues <1 explained less the total variation than the individual farmer. Thus, only factors with eigenvalues >1 were considered for interpretation of results [48] [49]. **Table 1** illustrates the 21 variables with their characteristics, and employed in factor and stepwise regression analysis. The soil erosion rate for each farm was derived from the soil erosion loss map, and considered the dependent variable.

Some important socioeconomic variables were eliminated in the present analysis. All households in W. Kufranja for example, are owned only by males. Therefore, the gender variable does not contribute to variation in perception. All farmers also inherited their farms through successive generations, thus, household size is generally small (1.5 - 2.5 ha only) due to continuous fragmentation of the agricultural lands. This process is expected

Table 1. Socioeconomic and soil conservation variables.

Socioeconomic/soil conservation variables	Measurement level	Value
Dependent variable/Soil erosion rate	$ton \cdot ha^{-1} \cdot year^{-1}$	Continuous
Covariates:		
X1. Age (years)	Number	Discrete
X2. Educational level	≥Grade 6	Discrete
X3. Distance between house and the farm	Km	Continuous
X4. Size of agricultural holding	Dunum	Discrete
X5. Total of farm capital	Assets/JD	Continuous
X6. Farm annual economic/revenue	Total household income/JD	Continuous
X7. Farm annual expenditure	Farm expenditure/JD	Continuous
X8. Farm labor	Number	Discrete
X9. Farm accessibility	Easy/difficult	Dummy
X10. Dependency ratio	Number	Discrete
X11. Adopted method(s) of soil conservation	0 (or) 1	Dummy
X12. Indigenous knowledge/practical experience in soil conservation	0 (no), 0.3 (low), 0.6 (moderate), 1 (high)	Continuous
X13. Proper training in soil conservation	Frequency/year (or)years	Discrete
X14. Awareness of soil conservation cost	1 (yes), 0 (no)	Dummy
X15. Beneficial from governmental conservation projects	1 (yes), 0 (no)	Dummy
X16. Does government help farmers in their conservation efforts	1 (yes), 0 (no)	Dummy
X17. Are you willing to participate in conservation measures cost	1 (yes), 0 (no)	Dummy
X18. Does forest clearance accelerate soil erosion	1 (yes), 0 (no)	Dummy
X19. Does land cover and land use changes accelerate soil erosion	1 (yes), 0 (no)	Dummy
X20. Does fallow land accelerate soil erosion	1 (yes), 0 (no)	Dummy
X21. Does climate change accelerate soil erosion	1 (yes), 0 (no)	Dummy

to affect long-term investment in soil conservation activity, and encourage soil erosion. Hence, the law of agricultural land parceling and the resultant lands fragmentation has been excluded from the analysis, since most households are homogeneous in terms of size, and cultivation practices.

4. Results and Discussion

4.1. Soil Erosion Rates

The data layers (maps) extracted for K, LS, R, C, and P factors of the RUSLE model were integrated within the raster calculator option of the Arc GIS spatial analyst in order to quantify, evaluate, and generate the soil erosion loss map for Wadi Kufranja [10]. Such an assessment is essential to examine the farmers' perception of soil erosion loss, and soil conservation measures, and to evaluate the socioeconomic factors of soil erosion for future agricultural and soil conservation planning. The magnitude and spatial distribution of crop management factor C show values between 0.01 and 0.2. The highest (poor land cover management) almost coincide with the lowest NDVI values, (0.22 - 0.05), since the forest protects soils against erosion, while the open rangeland exposed to plowing has a high C-value (0.35). Similarly, the mixed rain-fed areas have a C-value of (0.2). The model showed logical results after applying the assumed C values for each land-cover class, with a trend of increasing erosion with low vegetation cover. Moreover, it was possible to reveal three classes of P factor by considering land use/cover-type and support factors. P factor ranges from 0.19 to 1.0, the higher values in areas east of Krayma with no conservation practices (forest/natural vegetation), and other major settlements in the catchment. By contrast, maximum P values correspond to crop-land with contour, and terrace tillage in the upper catchment. P values decrease towards the upper catchment, where in flat land units slope length decreases. This explained lower P values in the irrigated lands compared to open rangeland, since irrigated farms occupy mainly flat/ undulating lands. Average annual soil loss of 10 ton·ha^{-1}·year^{-1} was estimated for the whole catchment, and the final soil loss map indicates a minimum P value of 0.0 to a maximum of 1865 ton·ha^{-1}·year^{-1} [10]. The Wadi Kufranja watershed was classified into five soil erosion loss classes, and the potential soil erosion loss (**Table 2**) increases from the upper to the lower reaches of the catchment. Soil erosion is very severe east of the Krayma area and accounts for 31.2% of the total watershed soil loss. The upper part of the watershed is well forested with some mixed agricultural cover, hence it is of low erosion loss. The distribution of soil erosion loss classes (**Figure 4**) show that 26.7% of the watershed has minimal soil loss, 36.5% is low, 5.6% and 7.9% is moderate and severe respectively, while 23.3% of the watershed is exposed to extreme soil erosion.

The results of the present investigation in the Wadi Kufranja watershed are comparable with similar studies carried out in north Jordan [10] [11] [13] [50], where similar terrain, climatic conditions, and historic land mismanagement prevail. Moreover, the estimated soil erosion levels are consistent with those results reported from other Eastern Mediterranean watersheds using the RUSLE approach, where relatively similar environmental conditions exist [51]-[54]. The present results emphasize the necessity for well executed research on soil erosion and improved conservation methods. The measured sheet and splash soil erosion in W. Kufranja was 10 ton·ha^{-1} year^{-1} from tillage cultivated lands, and 3 ton·ha^{-1}·year^{-1} from the fallow land, with average ranges from 8 - 10 ton·ha^{-1}·year^{-1} [4]. Similarly, the measured maximum soil erosion on the eastern margin of W. Kufranja was

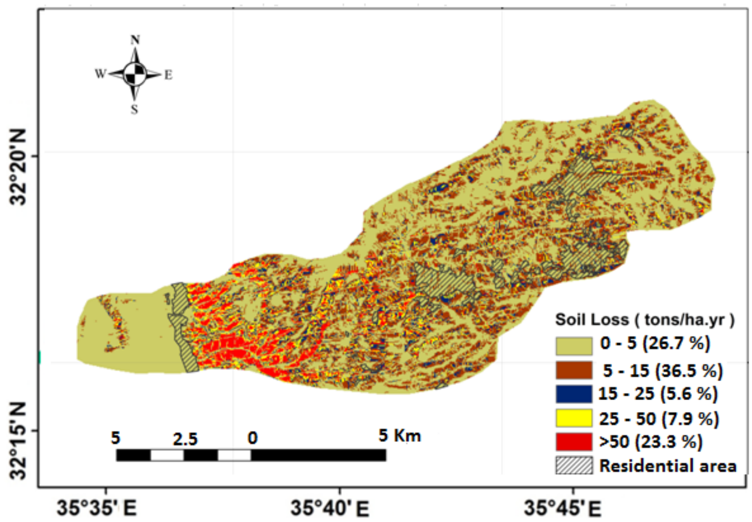


Figure 4. Soil erosion loss categories.

Table 2. Area and proportion of each soil loss classes.

Erosion loss class	Numeric range (ton·ha^{-1}·year^{-1})	Percentage (%)	Area (ha)
Minimal	0 - 5	26.7	3372.21
Low	5 - 15	36.5	4609.95
Moderate	15 - 25	5.6	707.28
Severe	25 - 50	7.9	997.77
Extreme	>50	23.3	2942.79

Source: Farhan *et al.*, (2013).

12.7 ton·ha^{-1}·year^{-1}, while the minimum soil erosion measured was 2.9 ton·ha^{-1}·year^{-1}. It is concluded that vegetation and land use, rainfall intensity during the storm event (mm/hr^{-1}), the amount of rainfall for the storm event (mm), conservation measures, and slope form, are the most variables influencing soil erosion [5].

The measured and calculated soil erosion per year from the different plots in Jerash area are comparable to those estimated by adopting the RUSLE model [10], and the suspended sediment yield calculated using Fournier's model [4]. Such comparison indicates the reliability of the RUSLE model in estimating soil erosion rates in northern Jordan. However, all previous studies concluded that the RUSLE model, combined with RS and GIS technologies, and field measurements of soil erosion are efficient tools in providing the decision makers with essential information for water and soil conservation to maintain future agricultural sustainability. Yet to control soil erosion, conservation measures should be executed at the farm, hillslope or watershed scale (*i.e.* W. Kufranja catchment). Moreover, the implementation of conservation measures to specific terrain units subjected to severe soil erosion loss is of high priority. The terrain unit is considered an appropriate manageable land unit in both soil conservation and other applications [44]. Vegetation cover as well as slope, soil and land use/land cover is major impact factors in soil erosion. Combined with the generated map, this shows the spatial patterns of soil loss rates (**Figure 4**), all these variables can be employed to assess the priority areas for soil conservation [55]. Planning the future conservation interventions is another important target. **Figure 5** illustrates the spatial distribution of 19 terrain units in W. Kufranja. It is obvious that 55.06% of soil erosion occurred on five terrain units of moderate and steep slopes [13]. The valley-side slopes exhibit the highest rate of soil erosion compared with flat terrain units. The alluvial terrain units experience the lowest rate (**Table 3**). It is noticeable that soil erosion is closely controlled by slope: the steeper the slope, the more severe the erosion. Terrain units of steep and long slopes characterized by low vegetation cover thus, exhibit much higher rates of erosion compared to flat/undulating terrain units [56]-[58].

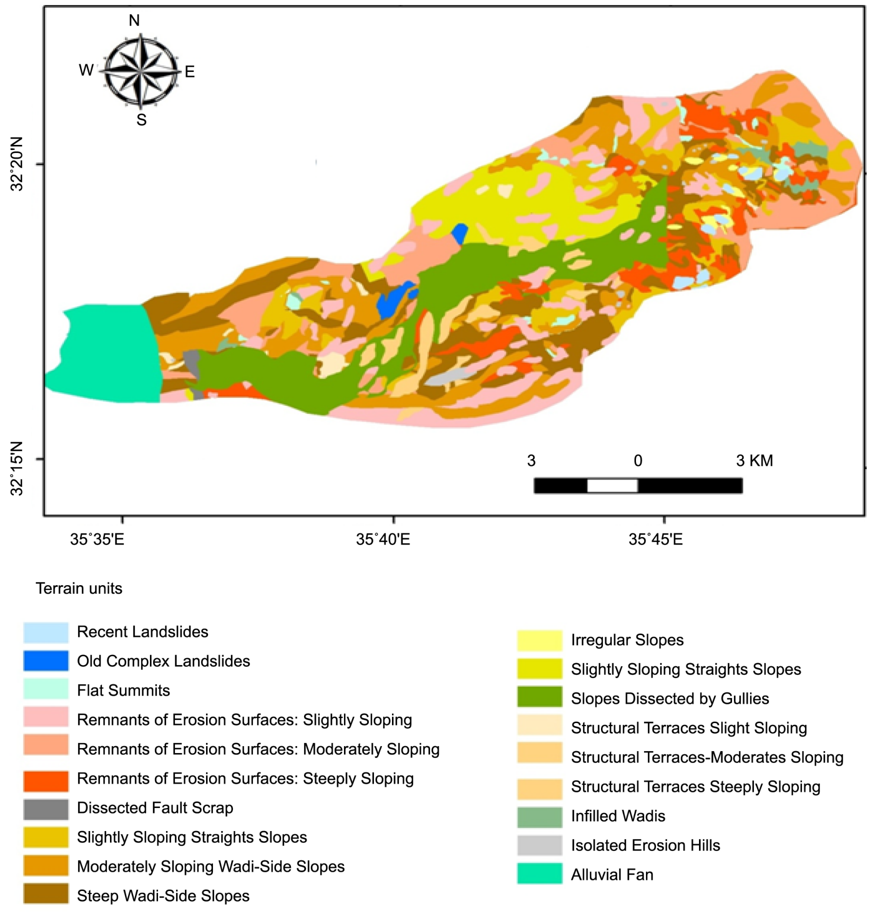


Figure 5. Terrain units of W. Kufranja.

Table 3. Spatial variation of soil erosion with different terrain units in W. Kufranja.

Terrain units	Soil Loss Categories Tones/ha/year^{-1} (Area %)				
	Minimal	Low	Moderate	Severe	Extreme
	0 - 5	5 - 15	15 - 25	25 - 50	>50
Moderately Sloping Wadi-Side Slopes	11.16	1	0.73	1.04	0.09
Steep Wadi-Side Slopes	9,6	0.58	0.88	1.24	0.07
Slightly Sloping Wadi-Side Slopes	5.16	0.26	0.21	0.07	0
Remnants of Erosion Surfaces: Steeply Sloping	5.07	0.17	0.23	0.23	0
Remnants of Erosion Surfaces: Moderately Sloping	9.04	0.17	0.27	0.2	0.07
Alluvial Fan	6.46	0	0.03	0	0
Isolated Erosion Hills	0.34	0.03	0.07	0.04	0
Structural Terraces Slight Sloping	0.83	0	0.02	0.03	0
Structural Terraces-Moderates Sloping	0.75	0.03	0.21	0	0
Structural Terraces Steeply Sloping	1.74	0.29	0.22	0	0
Old Complex Landslides	0.41	0	0.23	0.09	0
Irregular Slopes	0.4	0	0.16	0.03	0
Slightly Sloping Straights Slopes	6.47	0.41	0.35	0	0
Slopes Dissected by Gullies	9.41	0.77	1	2.26	1.13
Flat Summits	0,58	0.04	0.03	0	0
Infilled Wadis	0.64	0	0.07	0.06	0
Recent Landslides	0.84	0	0.03	0.02	0
Remnants of Erosion Surfaces: Slightly Sloping	9.9	0.57	0.58	0.09	0
Dissected Fault Scrap	0.13	0	0	0.14	0

Source: Farhan *et al.* [14].

The old landslide terrain unit is considered as degraded terrain, where it shows a low rate of soil loss generally, although relatively steep (10˚ - 15˚, 15˚ - 20˚, and 20˚ - 30˚ slope categories) and a high amount of rainfall are dominant. The soil erosion rate decreases here because the change in land use/cover from bare soil/rangeland to forest and shrubs stabilized the landslide areas. The flat summit terrain shows the lowest rate of soil erosion. Also, soil erosion is high on the remnants of erosion surfaces although flat to slightly sloping terrain are common (**Table 3**). This is explained by the dominance of "rainfed farming" practiced over these terrain units. It has been reported recently that "mixed rainfed" farming is one of the major reasons behind the high and very high soil erosion rates characterizing this terrain [12].

4.2. Farmers' Perceptions of Soil Erosion

With reference to the perceptions of farm households participating in the present survey, it was possible to identify five major direct causes of soil erosion in W. Kufranja: poor land management (42.3% of the respondents), deforestation and grazing, land use abuse and traditional cropping system, urbanization and natural causes (**Figure 6**). As pointed out earlier, 36.5% of the watershed is exposed to low soil losses (<15 ton·ha^{-1}·year^{-1}), whereas 36.8% of the watershed has experienced moderate, severe, and extreme soil erosion (15 - >50 ton·ha^{-1} year^{-1}. These very high soil erosion rates are attributed mainly to improper soil management, poor conservation practices, and traditional cultivation. Deforestation (for fuel and charcoal-wood), overgrazing, and destruction of vegetation cover were perceived by 32.6% of the respondents as causes of soil erosion, and land use/land cover change, tillage practices (up-and-down the slope)and traditional sole cropping by 13.6% of the respondents and, development of infrastructure, urbanization and natural erosion by 11.5%.

Indirect causes of soil erosion are comparably quite crucial since, these severely affect soil erosion through direct causes. Population pressure, land tenure and continuous fragmentation of agricultural land, poverty, traditional farming, and education were perceived as indirect causes of soil erosion in the area under consideration (**Figure 7**). About 66.9% respondents perceived population pressure and land tenure as major indirect causes of soil loss, while poverty, traditional farming, and education were perceived as major indirect causes by 30.1% of the respondents. The respondents were asked to give their opinion about the effective soil measures for controlling soil erosion. **Figure 8** illustrates the conservation measures suggested by farmers. 40.8% of respondents were convinced that afforestation and tree plantation are essential to reduce soil loss, while 38.5 of the farmers believed that structural solutions, such as the construction of stone terraces and check dams, the utilization of organic manure, controlling cropping intensity and fallow period are vital to conserve soil and water across different sloping terrain units of the watershed. Stone bunds are considered the most popular conservation measures adopted here, where historical soil erosion, intensive agriculture, and agricultural terraces are characteristic of the Levantine highlands (including Jordan) since the Iron Age [59]-[61]. 20.7% of respondents thought that efficient land management is needed to rehabilitate intensively exploited soil resources. The effect of conservation structures installed (mainly stone bunds-contour stone terraces, termed locally *masateb*, and check dams) during the 1970s of the last century [62] [63] caused a significant decline in soil erosion rates.

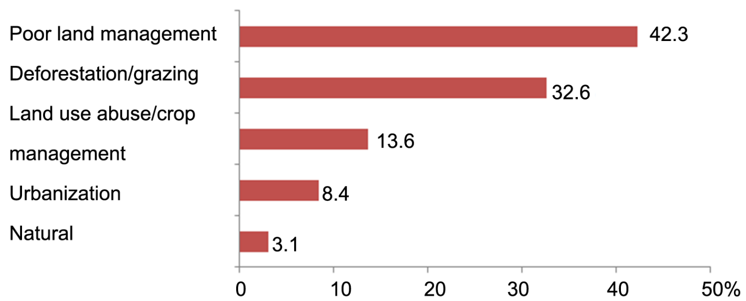


Figure 6. Direct causes of soil erosion.

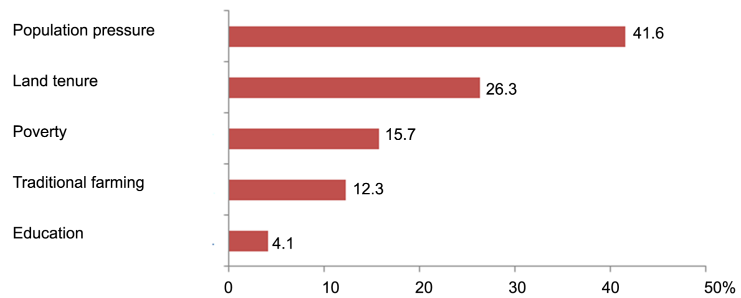


Figure 7. Indirect causes of soil erosion.

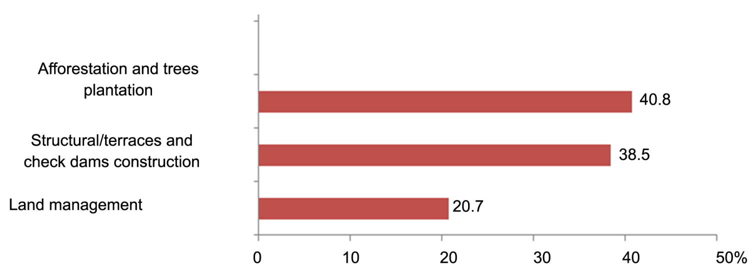


Figure 8. Suggested conservation measures to control soil erosion.

Recent studies indicates that through applying soil conservation measures in central and northern Jordan, the annual erosion rate has decreased from 78 ton·ha^{-1}·year^{-1}, before installation of soil conservation structures, to 33 ton·ha^{-1}·year^{-1}, 20 years after installation of conservation structures [64]. Irrespective of installation of efficient conservation structures, improvement of cropping practice is essential to mitigate soil erosion. Contour strip intercropping cultivation at a proper planting density (*i.e.* 350 plants m^{-2}) was found recently to be promising farming practice to reduce runoff and soil erosion [65]. Likewise, experimental results on soil erosion control and moisture conservation, showed that the presence of rock fragments on the soil surface were highly effective in reducing runoff and soil loss [66].

4.3. Socioeconomic Determinants of Soil Erosion

The relation between socioeconomic/soil conservation variables was examined using factor analysis and multiple stepwise regression. Factor analysis was employed to reduce the large number of variables, and to condense the original variation measured in terms of 21 variables, into variation in terms of a few factors, each of which contributes to a known amount to the total variation. Through factor analysis, the 21 variables were reduced into four significant factors which account for 69.7% of the variation in the original variables. **Table 4** illustrates the cumulative contribution of the successive four rotated factors produced in the analysis.

The loadings of the rotated factors are shown in **Table 5**. Factor I exhibits relatively high positive loadings on five variables: age of farmers, distance, farm capital, farm revenue, and farm expenditure. By contrast, the variable farm labor is negatively loaded on factor I. Traditionally, the higher the number of family members, the more farm labor can be provided to help in farming and soil conservation activities. However, due to a continuous decrease in household size, most of the household owners are working at present in governmental jobs, leaving farm activities to workers hired on a temporary basis. Similarly, old farmers customarily used to con-

Table 4. Relative importance of the first four factors.

Factor Number	Eigenvalue	Percentage of variance	Cumulative percentage of total variance
I	6.752	30.6	30.6
II	4.683	20.2	50.8
III	2.351	11.4	62.2
IV	1.761	7.5	69.7

Table 5. Basic factors and factor loading on socioeconomic/soil conservation variables.

Factor no.	Factor lable	Factor loading
Factor I:	Farm economic characteristics	
Age	(1)	0.461
Distance	(3)	0.646
Farm capital	(5)	0.610
Farm revenue	(6)	0.776
Farm expenditure	(7)	0.883
Farm labor	(8)	−0.617
Factor II:	Education and conservation knowledge	
Forest clearance	(18)	0.562
Dependency ratio	(10)	0.551
Education	(2)	0.502
Conservation methods	(11)	0.488
Factor III:	Government policy in soil conservation	
Government help	(16)	0.636
Conservation cost	(14)	−0.466
Proper training	(13)	−0.454
Factor IV:	Land use/land cover changes	
Fallow land	(20)	0.571
Land use, land cover	(19)	0.439

struct the conservation measures such as stone bunds, the most common structural measure in our region historically. By contrast, young farmers have abandoned this technique beginning in the 1970s. Factor I reflects the economic characteristics of the households. Factor II shows positive loading on forest clearance, dependency ratio, education, and adopted method(s) of conservation methods. Young and educated household owners are clearly aware of soil erosion hazards due to forest clearance and overgrazing. They are also familiar with different conservation methods installed in that area by the German Agricultural Technical Cooperation Team and the Jordanian Ministry of Agriculture Jordan four decades ago. Such conservation measures at that period of time were provided almost cost-free for each household. This may explain the farmers' unwillingness to invest in conservation measures, or to participate in paying for soil conservation costs. Factor II is considered an indicator of education and conservation knowledge, since the aforementioned four variables are correlated positively with factor II. The third factor accommodates positive loading on governmental help, conservation cost, and proper training in soil conservation. Therefore, it is considered as the government policy in soil conservation. Factor IV loaded positively on fallow land, and land use/land cover, hence, it is an indicator of land use/land cover changes. Factor IV is labeled as the land use/land cover factor. With the rotated factor solution illustrated above, the role of socioeconomic variables in household spatial variability was clearly explored, although, most farmers and farms are homogeneous in terms of several socioeconomic variables such as: farms ownership, gender, household size, land tenure, land parceling and the resultant land fragmentation.

Stepwise multiple regression analysis was employed to identify the predictor variables of soil erosion. (the dependent variable) among the socioeconomic/soil conservation variables (the independent variables). The model used is in the form given below:

$$Y_i = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + \cdots + b_j X_j \quad (2)$$

where:

$Y_{i\,=}$ soil erosion loss (ton·ha^{-1}·year^{-1}) estimated for each household parcel,

a = is a constant (the point where the line crosses the Y axis when $X = 0$,

b = regression coefficient,

$X_1, \cdots, X_j$ = the independent variables (X_1 - X_{21}).

The results of stepwise regression are illustrated in **Table 6**. From this table, the total variance explained by the three independent variables is 0.585 (R = 0.765, R^2 = 0.585). Out of the total variance, forest clearance explained 34.7%, fallow land 7.7%, and land use/land cover 16.1% respectively. The F value for forest clearance, fallow land, and land use/land cover are significant at 0.1% level. This indicates that 58 percent of variation in the dependent variables is explained by the recognized predictor variables (forest clearance, fallow land, and land use/land cover).

It is clear that anthropogenic factors such as: long and continuous human interference with land resources, deforestation and overgrazing in the past and present, land use changes and farming practices, poor conservation measures, and fragmentation of holdings are major causes of soil erosion [10] [20] [22]. Although household size is relatively large (6 - 8 members), most of the families do not provide farm labor as was the common practice in the past until the 1970s. Instead farm owners hire on the average three part-time workers to carry out necessary farm activities along with the restoration of old stone bunds and the checking of stone dams across the gullies on the farm. However, young farmers (<55 years old) are found to be more educated, and thus better aware of soil erosion problems, and more knowledgeable about soil conservation techniques and innovative farming practices, however, they are not willing to pay for or invest in soil conservation (construction of new facilities, or the renewal of older once practiced conservation measures) to reduce soil erosion. Irrespective of age, all farmers believe that the government should pay or invest in soil conservation installation. The household survey reveals that financial capital (average 45 250 JD), and farm income (average 3200 JD) seem adequate to facilitate the required credit needed to invest in soil conservation, or to improve existing structures. As farmers grow older and are unable to carry out agricultural activities, they tend to rent out their farms, in a situation

Table 6. Regression of the estimated soil erosion on the independent variables.

Variables	R	R^2	Increase in R^2 %	F value for variable	Sig. %
Forest clearance	0.589	0.347	34.7	13.875	0.1
Fallow land	0.651	0.424	7.7	3.928	0.1
Land use/land cover	0.765	0.585	16.1	11.489	0.1

where most of the younger generation also choose either higher education/professions, or join the army rather than practice farming. Moreover, farmers who cultivate land owned by others may be less likely to invest in soil conservation [47]. Tenants also lose part of their income as rent for the land, which acts as a serious financial obstacle for soil conservation, or the improvement of other aspects of the farm land. It can be concluded, that most farmers will abandon their farms in the future, although security of land tenure is very high in the W. Kufranja watershed.

5. Conclusions

The present results of the RUSLE model reveal the severity of soil erosion in Wadi Kufranja watershed. The mean soil loss estimated for the catchment was 10 $ton \cdot ha^{-1} \cdot year^{-1}$, with the five erosion risk classes, ranging from 0.0 to 1865 $ton \cdot ha^{-1} \cdot year^{-1}$. Areas of 53.1723 km^2 (5317.23 hectares) and 39.4056 km^2 (3940.56 hectares) were classed as suffering moderate or very severe soil erosion. Similarly, the measured sheet and splash soil erosion in W. Kufranja was 10 $ton \cdot ha^{-1} \cdot year^{-1}$ from tillage cultivated lands, and 3 $ton \cdot ha^{-1} \cdot year^{-1}$ from the fallow land, with an average ranging from 8 to 10 $ton \cdot ha^{-1} \cdot year^{-1}$. The measured maximum soil erosion on the eastern margin of W. Kufranja was 12.7 $ton \cdot ha^{-1} \cdot year^{-1}$, while the minimum soil erosion measured was 2.9 $ton \cdot ha^{-1} \cdot year^{-1}$. Vegetation and land use abuse, traditional cultivation, lack of conservation measures, and rainfall intensity for storm events (mm/hr^{-1}), are considered the most significant factors influencing soil erosion. Subsequently, several terrain units in the middle and lower reaches of the catchment must be prioritized for conservation, where high soil erosion rates predominate. Here, the combined effect of K, LS, and C factors, also accounts for high soil erosion loss across the study area. The household survey recognized poor land management, deforestation and overgrazing, land use abuse and traditional cropping system, urbanization and natural causes, as the major direct causes of soil erosion. Whereas, population pressure, land tenure and continuous fragmentation of agricultural land, poverty, traditional farming, and education were perceived as the major indirect causes of soil erosion.

Four significant factors, accounting for 69.7% of the variation in the original variables were revealed through factor analysis. Factor I reflects the economic characteristics of the households, while factor II is considered an indicator of education and conservation knowledge. Factor III represents the government policy in soil conservation, while factor IV is described as the land use/land cover factor. Stepwise regression shows that forest clearance, fallow land, and land use/land cover are contributing for 16.1% of the variation in the original variables. Stepwise regression indicates that 58 percent of variation in the dependent variables is explained by forest clearance, fallow land, and land use/land cover. The F-values for these predictor variables are significant at 0.1%. The R-squared value (0.585) denotes that about 58 percent variation in the dependent variable (soil erosion rate) is explained by the predictors (forest clearance, fallow land, and land use/land cover) for W. Kufranja watershed.

According to farmers' perceptions, structural measures which have been practiced for a long time are considered the most efficient soil conservation measures adopted to reduce soil erosion. However, to be effective, structural measures by themselves must be integrated with agronomic measures. Contour stone terraces (or stone bunds) are used both on hillslopes, grazing and barren lands for soil and water conservation, and for afforestation purposes in both high and low rainfall conditions. The terraces break the slope and reduce the velocity of surface water. Similarly, check dams are normally constructed on gullies and small ravines formed by erosive activity of water (**Figure 9**). Ideally, a check dam must be located in a narrow part of a gully with high banks, where it can collect water and sediments, and might be used for cultivation, and tree planting (for afforestation). Such a procedure reduces runoff velocity and erosive activity. Continuous storage of water behind a check dam often improves soil moisture of the adjoining areas, thus improving the natural vegetation cover which in turn increases the cohesion of soil against erosion. However, as reported above soil erosion is not a recent problem for Jordan, it has been present in the highlands of the country since the Iron Age. The destruction of vegetation and the resultant high rates of soil erosion probably date back to the Neolithic and, the Nabateans (≈from 120 BC), may have already lived in a landscape that is very similar to the one existing today. It is obvious that the farmers of W. Kufranja are familiar with soil conservation measures and they have practiced these for a long time. When the government launched the soil conservation project during the 1970s, they obtained the conservation structures installed during the project free of cost. Therefore, at present, some 90% of the farmers are unwilling to pay for or to share in the cost of conservation structures to control soil erosion across the watershed.

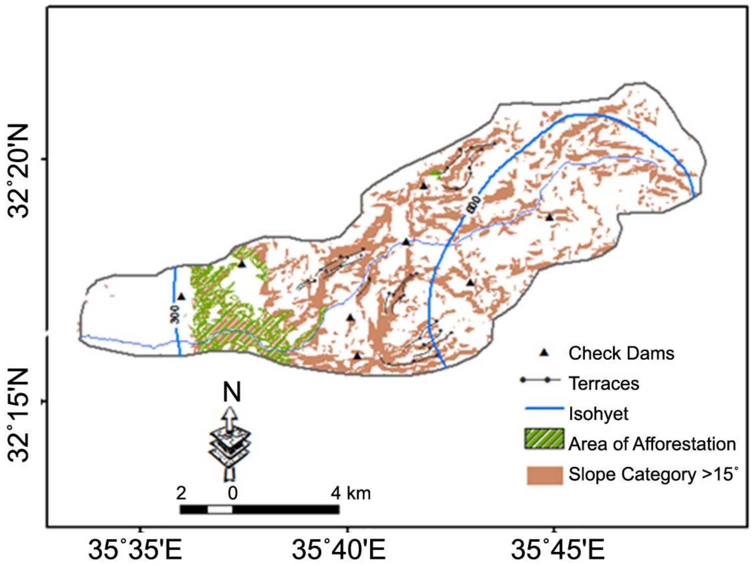


Figure 9. Soil conservation measures suggested to control soil erosion in W. Kufranja. (Based on photo interpretation and fieldwork).

In view of such attitudes, the authors suggest that government may offer the farmers soft loans encouraging them to restore and renew the old damaged conservation structures, and to install new structures. Vegetative measures are also recommended by respondents to prevent further forest degradation. In this context, forest plantation could be expanded in the watershed between 100 to 400 m a.s.l (**Figure 9**). The annual rainfall in this part of the catchment is ≈300 mm, and the slope ranges between 12˚ and 50˚. In 2010, the estimated bare ground across the catchment was 11.9% km^2, and about 6.6 km^2 of this area was suitable for reforestation. This means that there is an excellent opportunity to reduce surface runoff and soil erosion in this part, which in turn can increase the recharge of sub-surface aquifers.

The farmers' perceptions and socioeconomic determinants of soil erosion in the present case study are based on geospatial techniques (GIS and RS), field measurements of soil erosion, and a household survey. Few significant variables were employed. Thus, it is possible to extend the adopted techniques using large parameters to generate more precise information which can help in formulating more efficient soil conservation plans. A long-term monitoring program for soil erosion estimation, and evaluation of the impact of conservation structures in reducing soil loss and improving farms productivity, are essential in order to achieve sustainable agriculture.

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