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Land Degradation Risk Assessment in the Palestinian Central Mountains Utilizing Remote Sensing and GIS Techniques

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INTRODUCTION

Land degradation is a multiple socio-economic cause factors that have increased largely during the last few decades (Wakindiki and Ben-Hur , 2002). Scientifically, the main attributor to land degradation is soil erosion by runoff water (Angima et al., 2003). Soil erosion, especially in areas with high rates of soil erosion can cause large modifications in the hydrology of the area under question, resulting in negative social and economic consequences (i.e. flooding, construction and plants damages, loss of agricultural lands and a decrease in tenure size, etc.) (Pimentel , 2000).

Land degradation is a phenomenon that exists in different countries as well as caused by different factors; natural and socio-economic. Some countries suffer from this phenomenon mainly due to social and economic factors such as poverty, land fragmentation resulting from inheritance, low standard of living and earning, low level of education and health conditions that is prevailing. Some other countries are suffering from land degradation as a result of natural factors such as rainfall characteristics (i.e. rainfall amount, intensity, and rainfall frequency of occurrence), geomorphologic aspects of the area, soil properties as well as the surface features characteristics (i.e. slope characteristics). It is obvious that most of the countries that are suffering land degradation caused by natural factors are characterized by steep-sided and mountainous area that enhances soil erosion greatly. In addition, soil erosion is being amplified by the intermittent and high intensity rainfall events that exceed the capacity of the soil surface to infiltrate and though resulting in runoff and soil erosion. In the world, it is estimated that about 80% of the current degradation to agricultural land is caused by soil erosion (Angima et al., 2003). Areas with high rates of soil erosion can cause large hydrologic modifications and though resulting in negative social and economic consequences (i.e. flooding, construction and plants damages, and loss of agricultural lands, etc.) (Pimentel , 2000). In addition, soil erosion is attributed to the partial loss of the agricultural lands through continuous decrease in lands' fertility status (i.e. loss of the soil chemical and physical characteristics that support the land fertility and keep it in an acceptable productive level). In addition, soil erosion and land degradation has an influence on the suitability of the land for different land uses other than agriculture, for example using the land for urban, industry and other touristic activities.

The emergence of soil erosion models has enabled the study of soil erosion, especially for conservation purposes in effective and acceptable level of accuracy. The Revised Universal Soil Loss Equation (RUSLE) is a model that has the ability to predict the long term average annual rate of soil erosion on a field slope as a result of rainfall pattern, soil type, topography, crop system and management practices (Foster et al., 2002; Wischmeier and Smith , 1978). Furthermore, the RUSLE can be combined with the Geographic Information System (GIS) in order to identify soil erosion susceptible spots over a large watershed area in a quick, efficient and accurate method (Cox and Madramootoo , 1998; Shi et al., 2004). The RUSLE is almost a straightforward empirically based model that requires several variables to be measured and observed in order to estimate soil erosion. The model needs data on rainfall, soil structure, soil texture, slope length, slope steepness as well as any existing crop management and erosion control practices (Adinarayana et al., 1999). Once these data are available, information on soil erosion can be computed quite easily. With exception of the rainfall erosivity factor (R) and the soil erodibility factor, the model relies on several dimensionless coefficients. These coefficients provide accurate results, especially after the adjustment made recently to the model (changes from USLE to RUSLE) (Foster et al., 2002; Renard et al., 1991), which made the model not necessarily relying on physical measurements that can be quite costly and time consuming. In addition, the RUSLE does not estimate remote deposition and gully erosion, which is considered as a disadvantage of the model. Finally, the RUSLE is based on long-term average rainfall conditions for specific regions in the USA (Brady and Weil , 2002; Wischmeier and Smith , 1978). In order to apply the model to other countries, the RUSLE should be adjusted according to the prevailing rainfall, soil type, and crop and soil management practices. Without the adjustment of the model, it will not produce accurate results of the average annual rate of soil loss.

Another predictive model is the Morgan model. This model is similar to the RUSLE. The Morgan model separates the soil erosion process into a water phase and a sediment phase (Morgan , 1986; Morgan , 2001). Furthermore, it compares the predicted rate of detachment with the transport capacity of the overland flow; the lower value of the two processes (detachment and transport) is then considered as the rate of soil erosion by the Morgan model. Hence, the model determines whether detachment or transport is the limiting factor (Morgan et al., 1984). If the transport capacity of the overland flow is higher than the soil detachment, the soil detachment value will be considered as the rate of soil erosion. Likewise, if the rate of soil detachment is higher than the transport capacity of the overland flow, the value of soil particles transported by overland flow is considered as the rate of soil erosion. The Morgan model uses less dimensionless coefficients than the RUSLE, hence, it seems that it would produce more accurate results. On the other hand, more quantitative measurements are required for the model that may not be easily available in the developing countries, which have limited technical and financial capacity to acquire the necessary data for the Morgan model.

One of the most ambitious, powerful and sophisticated model of erosion is the Water Erosion Prediction Project (WEPP) (Brady and Weil , 2002; Bhuyan et al., 2002). WEPP calculates the daily rates of hydrologic plant-growth and litter-decay processes. In theory, the model can predict exactly how rainfall will interact with the soil on a site during an individual rainstorm or for the course of a full year (Li Zhang et al., 1996; Flanagan and Nearing , 1995). If enough data is available, the model can predict both on-site and off-site effects of raindrop impact, splash erosion, interril and rill formation, gully erosion and sediment deposition. This makes the model a powerful tool and has the potential to predict very accurate data on soil erosion. Unfortunately, the limited data in the developing countries of the world makes it difficult to these countries for proper utilization of this model.

The RUSLE was chosen over other methods because of its ease of implementation, reliance on easily accessible data and its relatively accurate results. Besides, the quality and the availability of the data in the study area propose the RUSLE as the most appropriate model to be used.

Parallel to the progress attained in modeling of land degradation by soil erosion such as using the Revised Universal Soil Loss Equation (RUSLE), significant progress in watershed management, using Geographic Information Systems (GIS) and remote sensing techniques for the spatial delineation of different land cover- land uses in large watershed areas, has taken place in the last twenty years. The progress has been accelerated by the introduction of new improvements in GIS and remote sensing technologies. The progress is also enhanced by the needs, worldwide, of a user-friendly tool for the assessment of land degradation by soil erosion, high input output efficiency of such techniques, time saving and low to moderate technological requirements, the current increases of the available and necessary input data (i.e. land use and land cover data, elevation and other geo-morphological data), as well as the ease of attaining necessary data especially in the developing countries with limited finance for such purpose (Mellerowicz et al., 1994; Molnar and Julien , 1998). As a consequent, the use of RUSLE-GIS-remote sensing assessment of land degradation is considered as a good tool for the identification of high erosion risk areas on watershed scales ‘’hot spots’’, in addition to the possibilities for suggesting quick alternative solutions for the management and conservation of endangered watersheds, and at the same time taking into consideration the uniqueness and the site specificity and characters of different watersheds in modeling the risk and the potential of land degradation by soil erosion (Millward and Mersey , 1999).

Assessment of land degradation, especially in the developing countries of the Mediterranean, is difficult due to the lack of necessary data and insufficient funding for such an assessment. As a result, proper conservation and management practices are difficult to adopt in these “ at risk” watersheds (Upadhyay , 1991; Arhonditsis et al., 2002). In such areas where land degradation is prevailing, the data available on land degradation, its causes and its main results are either qualitative or absent, which is considered as a major obstacle to any future development as well as hindering an appropriate land uses for sustainable use of resources (Upadhyay , 1991; Arhonditsis et al., 2002).

Assessment of land degradation, especially in these developing countries is though important for conserving their available natural resources for future generation (i.e. land and water). The assessment could also be the first step towards increasing the awareness of governmental, non-governmental institutions, as well as the inhabitants of the region for revealing influential factors that are contributing to land degradation, in addition to adopting rational laws and standards for sustainable and efficient land use.

Risk assessment of soil erosion as the main cause of land degradation is though important for the nation's natural resources conservation. In addition, the assessment is also important for future planning and management of the available natural resources so as to insure its sustainability for the future generation.

Application of the RUSLE-GIS based model for land degradation-soil erosion assessment, in certain watershed areas, offers an easy way to understand and implement the functional view of the model on a micro scale level (Wischmeier and Smith , 1978). The use of RUSLE, accompanied by raster-based GIS layers, enabled the model to predict erosion potential on a small area basis, which is an effective tool to identify the spatial pattern of soil loss on a micro-scale basis, and hence, to isolate small areas with high risk of erosion. In addition, it will compose an easy way for the identification the role of each individual RUSLE variable that is contributing to the existing erosion (Millward and Mersey , 1999).

The Central Palestinian Mountains are, like other mountainous areas of the Mediterranean region, subjected to sudden drastic environmental and socio-economic changes. These changes lead to the partial and/or complete abandonment of large agricultural areas in the region with noticeable but non-quantified land degradation and soil erosion. The abandonment of some of the old adopted soil and land conservations (i.e. terraces, stone bunds, anti-contour plowing, etc.) causes an increase in soil erosion and land degradation. In addition, this part of the Mediterranean has witnessed special political and military critical conditions that have dramatic influences on the socioeconomic situation of the inhabitants in general, as well as on the peasants in specific (Issac et al., 1997). Confiscation of the Palestinians' agricultural land is practiced heavily, especially during the last 10 years (Palestinian Central Bureau of Statistics , 2004a). The construction of new and intensive bypass road networks (Palestinian Central Bureau of Statistics , 2003; Palestinian Central Bureau of Statistics , 2004a), the newly formed separation wall between the Palestinian built-up areas and the adjacent agricultural land (Palestinian Central Bureau of Statistics , 2004b), and finally the many physical (checkpoints) as well as political obstacles (confiscation and area-closure orders) that has been practiced by the Israeli Authority (Palestinian Central Bureau of Statistics , 2004c; The Applied Research Institute of Jerusalem , 1994; Palestinian Central Bureau of Statistics , 2004b), all of these factors contributed to the current deterioration of the peasants' socio-economy, which is envisaged by increasing poverty rate, loss of the farmers' accessibility and ownership as well as land fragmentation due to confiscation (Palestinian Central Bureau of Statistics , 2003; Palestinian Central Bureau of Statistics , 2004a; Palestinian Central Bureau of Statistics , 2004c), all of these factors are being seen as the human part-contribution to land degradation, which if not tackled properly, could lead to the complete deterioration of the agricultural sector, the backbone of the Palestinian economy. It is estimated that the average land holding size in the Palestinian Area is less than 4 hectares (The Applied Research Institute of Jerusalem , 1994). This small tenure is the resultant of the aforementioned political situation as well as land fragmentation due to inheritance. Land fragmentation due to inheritance is heavily practiced as the result of the Islamic traditional law of inheritance, where the fathers' land is divided between siblings once the father died.

The study area

Generally speaking, the study area is characterized by semi-arid and sub-humid conditions with severe runoff and soil erosion as a result of simultaneous erratic rainfall events and long drought periods with poor vegetative cover, resulting in soil surface exposure to the natural rainfall and its deleterious effects of (Johnson and Lewis , 1995). These factors are being considered as the natural-physical factors contributing to land degradation and soil erosion.

The study area is a small watershed in the Central Palestinian Mountains. The topographic aspects naturally bound this watershed so that water divides comprise the delineating line of the watershed within which soil erosion can be modeled. The watershed area extends over diverse climatic and geomorphologic characteristics. It is characterized by a typical terrestrial Mediterranean ecosystem, especially the western part of the watershed (Figure 1).

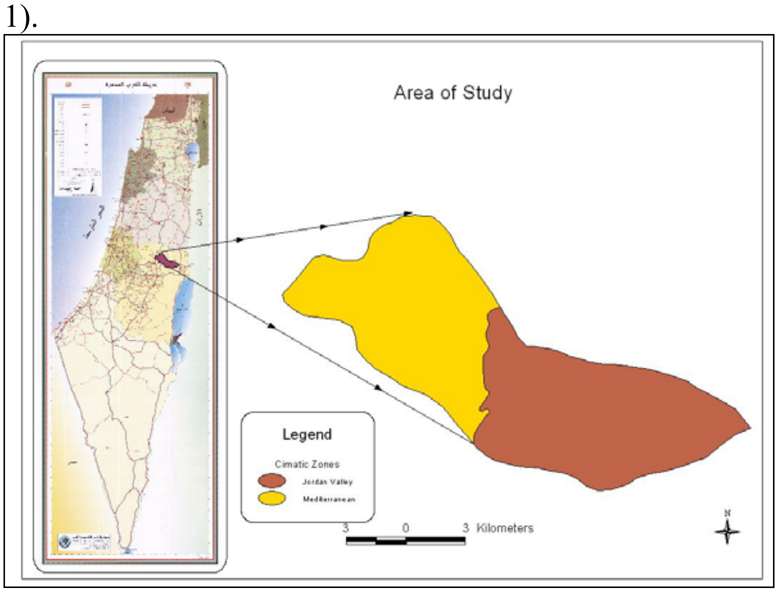

Figure 1: Location of the study area along with the major climatic zones prevailing.

In general, the area is characterized by shallow soil (<50 cm), a moderate to steep slope, and limited water and land resources for agriculture. This deficiency in agricultural land has been recompensed by the construction of an extensive system of old terraces, aiming to conserve soil moisture and minimize soil erosion in order to suite the land for agricultural purposes.
The watershed has a total area of 128878 dunums, and is located 6 kilometers northeast of the Ramallah Governorate in the West Bank (Figure 1). The elevation ranges from -225 m below sea level to 1000 m above sea level (Figure 2).

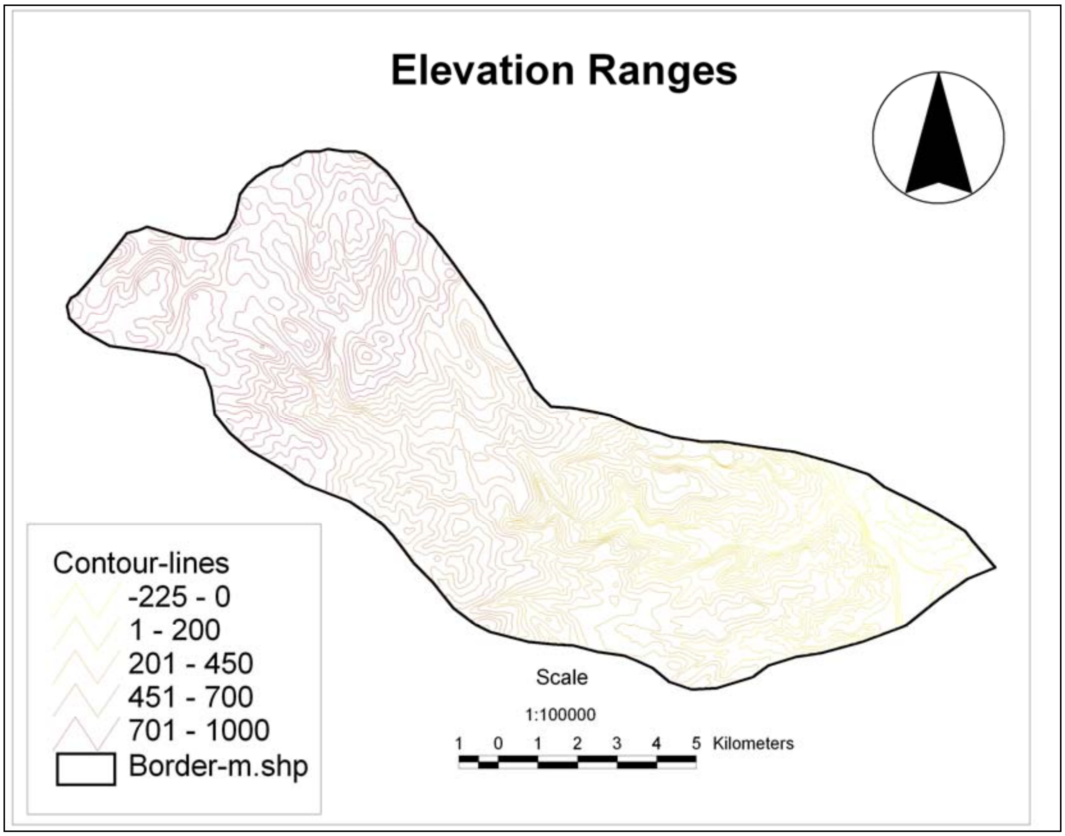

Figure 2: Elevation ranges in the study area.

A well marked summer and winter season characterizes the study area. The mean annual rainfall ranges from 600 mm in the western part of the watershed to 166 mm in the eastern part of the watershed (Figure 3). Most of the rainfall (more than 90% of the annual rainfall) occurs in the winter season and falls mainly during October to April (Ministry of Transport , 1998) with no summer rainfall occurrence. The mean monthly temperature is 17.1 ºC and 22.4 ºC in the western and eastern part of the watershed, respectively (Figure 4). July, August and September are the hottest months of the summer time

(Ministry of Transport , 1998). Due to the high temperature prevalence, the mean annual potential evapotranspiration ranges from 861 to 1223 mm in the western and eastern parts of the study area respectively (Land Research Center , 1999). According to USDA classification, the soil temperature and moisture regimes are Thermic and Xeric respectively in the western part of the watershed, whereas they are Hyperthermic and Aridic in the eastern part (Sternberg and Shoshany , 2001; Goldreich and Karni , 2001; Soil Survey Staff , 1998). The geological formation consists mainly of limestone, marl and dolomite dated to the Turonian age (Abed , 1999). According to USDA classification, the soil of the western part of the watershed is classified as Xerorthent (Land Research Center , 1999; Dan et al., 1976), with clay loam to clay of the surface (0-15 cm).

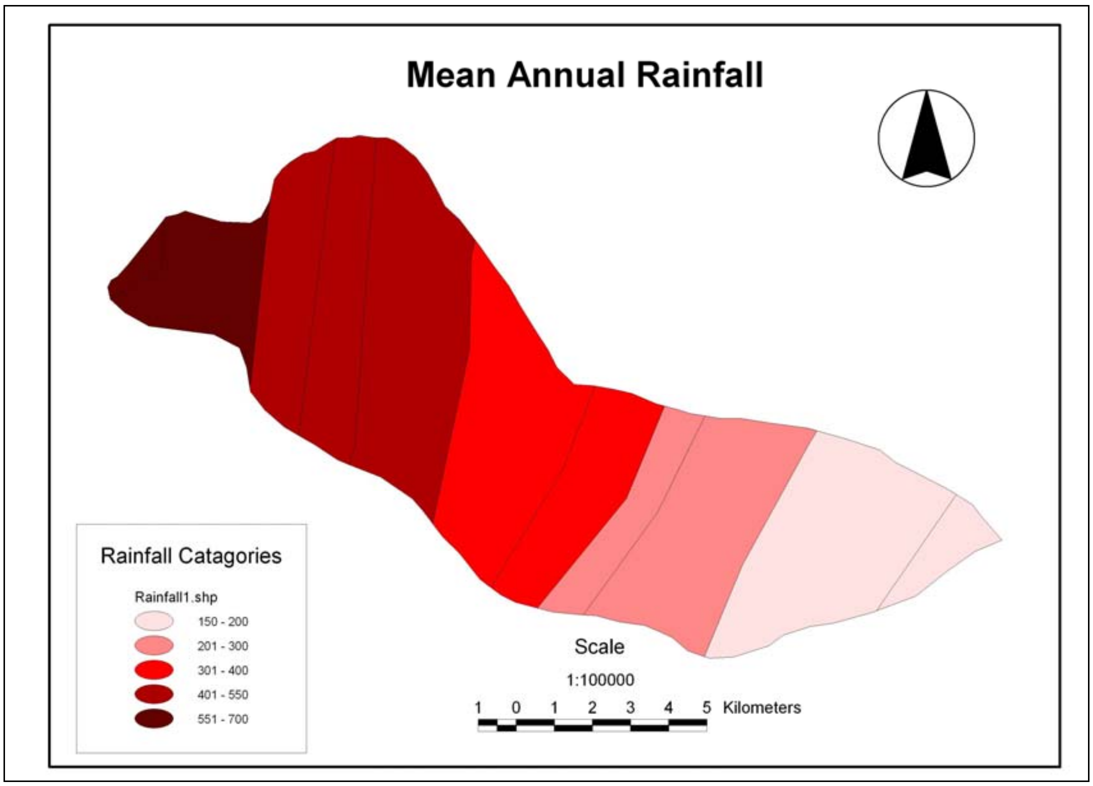

Figure 3: Mean annual rainfall in the study area.

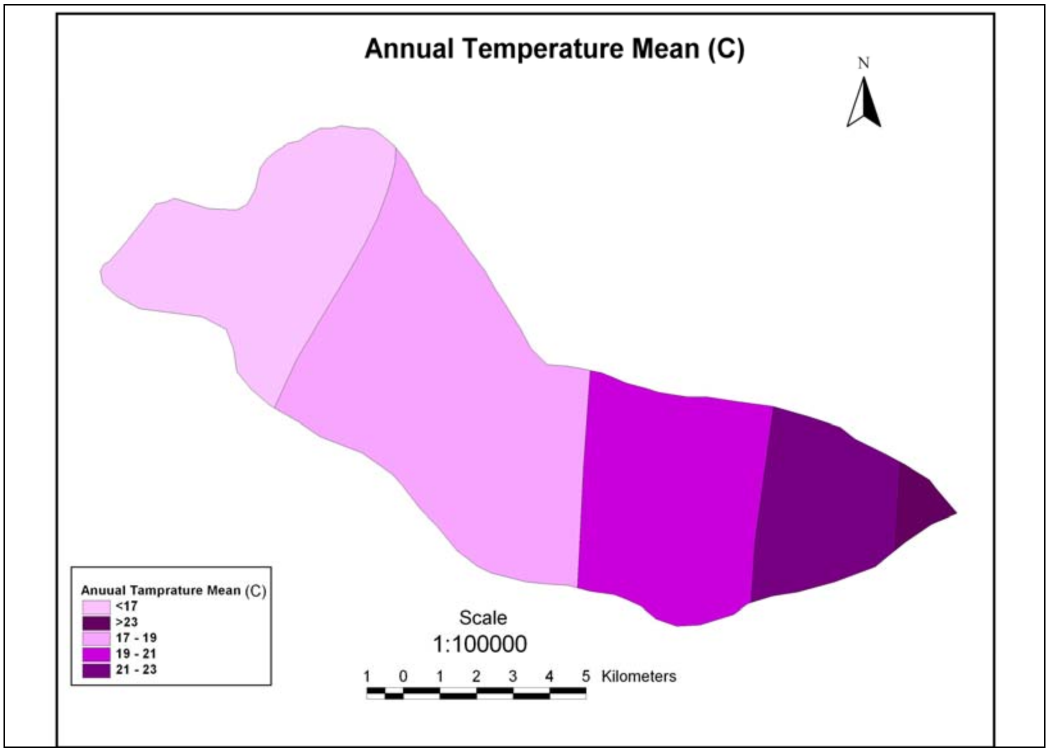

Figure 4: Mean annual temperature in the study area.

The soil of the eastern part of the watershed is classified as Natrargid whereas it is classified as Xerorthent in the western part, the surface layers are loam to clay loam. The soil depth varies according to the location; less than 50 cm in the hilly and sloppy areas, and more than 100 cm in low inclination areas. Nevertheless, the watershed has minor soil types in addition to those major ones mentioned previously, with different soil physical and chemical properties.

Generally speaking, the study area, like other parts of the West Bank, has the following characteristics:

1. Rainfall fluctuates within and among different years.

2. The study area has only a maximum of 50-60 rainy days during the winter season.

3. About 60% -70% of the total annual rainfall is lost through evaporation and evapotranspiration, which is, as mentioned before, due to the prevalence of high temperature and windy weather.

4. Lack of good and protective vegetative cover (i.e. grasses and forests) is the common characters, especially at the beginning of the winter season, which might lead to high rate of soil erosion.

Soil erosion modeling on a watershed level

Land degradation by soil erosion has negative effects on the standard of living of the inhabitants, especially in countries where agriculture is considered as the main source of peoples' income and food (Feoli et al., 2002). In such agricultural countries, preservation of the country's main resource is though important; hence, studying soil erosion is an important step towards the nations' resources risk assessment so as to ensure sustainable land use, and to reduce land degradation by soil erosion to minimum level. Land managers and policy makers are in needs to approximate the extent and the type of soil erosion risk on land and the ongoing degradation that is being subjected to, which will enable the evaluation of the effect of different alternative tillage practices, the compliance with environmental regulations and pollution, the development of sediment-control plans for construction projects and to estimate the number of years it will take to silt-in a dam (Brady and Weil , 2002). This will provide different strategies, plans and activities aiming at the achievement of sustainable and efficient low-cost management of the nation's soil resources.

Studies on soil erosion concluded that this phenomenon is caused by four main factors; these are slope, soil properties (i.e. soil erodibility), rainfall characteristics and land uses (Shirimail et al., 2001). Most of the erosion models depend on these factors. The emergence of soil erosion models has enabled the study of soil erosion, especially for conservation purposes, accurately and effectively. The RUSLE is a model that has the ability to predict the long term average annual rate of soil erosion on a field slope as a result of rainfall pattern, soil type, topography, crop system and management practices (Wischmeier and Smith , 1978). Furthermore, the RUSLE can be combined with the Geographic Information System (GIS) in order to identify high soil erosion spots over a large watershed area in a quick, efficient and an acceptable accurate method (Cox and Madramootoo , 1998; Shi et al., 2004). The RUSLE is almost a straightforward empirically based model that requires several variables to be measured and observed in order to estimate soil erosion. The model needs data on rainfall, soil structure, soil texture, slope length, slope steepness as well as any crop management and erosion control practices (Adinarayana et al., 1999). Once these data are available, information on soil erosion can be computed quite easily. With exception of the rainfall erosivity factor (R) and the soil erodibility factor, the model relies on several dimensionless coefficients. At the same time, the RUSLE does not estimate remote deposition and gully erosion, which is considered as a disadvantage of the model. Finally, the RUSLE is based on long-term average rainfall conditions for specific regions in the USA (Brady and Weil , 2002; Wischmeier and Smith , 1978). In order to apply the model to other countries, the RUSLE should be adjusted according to the prevailing rainfall, soil type, crop and soil management practices. Without adjustment of the model, it will not produce accurate results of the average annual soil loss.

As mentioned before, the RUSLE was in favour of other models (The Morgan model and the Water Erosion Prediction Project -WEPP) due to its easy implementation, its reliance on easily available data, its relative accuracy, and its compatibility with GIS for assessing the risk of soil erosion over large watershed areas. Besides, the available data and its type for the study area suggest the RUSLE to be, comparatively, the most proper model to be used.

The Revised Universal Soil Loss Equation (RUSLE)

Although the last two decades witnessed the development of different models for erosion risk assessment, this study is intending the use of the Revised Universal Soil Loss Equation (RUSLE) for this assessment. The main reasons are: (i) RUSLE is easily adaptable to other environmental conditions due to its simplicity, and its statistical relationships between input and output variables (Renard et al., 1991; Morgan , 1986; Soil and Water Conservation Society , 1994), (ii) RUSLE is a predictive tool used for assessing land degradation by soil erosion on hill slopes as well as on fields' plots (Foster et al., 2002; Morgan , 1986; Renard et al., 1996), and (iii) the availability of data and the their accessibility (i.e. type, quality, and availability of agro-climatic and other short-term erosion data for the study area) proposes the RUSLE as the most apt model for land degradation assessment by soil erosion among other models.

The RUSLE includes the following variables (Foster et al., 2002; Renard et al., 1991; Wischmeier and Smith , 1978):

A = R*K*LS*C*P

A = the potential long-term average annual soil loss in ton ha^{-1} per year
R = the rainfall erosivity factor (MJ mm ha^{-1} h^{-1})
K = the soil erodibility factor (ton h MJ^{-1} mm^{-1})
LS = the slope length-steepness factor
C = the crop management factor
P = the support practice factor

Farmers' socio-economy, perception and soil conservation

Many researchers often see Land degradation as the consequence of the social and economic factors of the final beneficiaries (i.e. the farmers). Socio-economy refers to the environmental, economic, social and institutional relationships and patterns, which compose the concept of development (Sheng , 1989). Social and economic factors form a situation where people interact with certain problems through roles, regulations, and social relationships represented by gender, age, ethnicity, traditions, culture, inheritance and other social factors

(Lubwama , 1999). Despite the familiarity of farmers in the developing countries with different type of soil-water conservation practices, the farmers perception, adoption and willingness to adopt these conservation measures has been hampered by several issues which include socio-economic ones (Lubwama , 1999; Barrow , 1990). In the Tigray region of Ethiopia, where soil erosion is severe and the stone terraces were the main adopted soil conservation practices, it was found that household capacity to invest in soil conservation measures, the risk of investment, social and institutional settings and household demographic characteristics including population growth along with their urban expansion requirements, all of these factors affected farmer capacity to adopt and the current adoption of soil conservation measures such as stone terraces (Gebremedhin et al., 2003). Beside, farmers' willingness to adopt terraces was influenced by the land productivity and opportunity cost of labors. The political situation in a certain country comprises also a limiting factor for the adoption of conservation measures to reduce the effect of soil erosion. The study of these factors, with their interactions, is though important to identify the most influential ones on farmers' understanding, perception and adoption of soil conservation.

Objectives of the study

The main aim of this study is to monitor land degradation in the Eastern Heights of the Palestine Central Mountains, which will be achieved through modeling of soil erosion (RUSLE) that could be utilized for predicting the scale and extent of land degradation in the study area. The scale and extent of degradation is not only related to soil erosion; it is also a function of the type, density and distribution of the vegetation cover, which are currently subjected to many threats amongst is the overgrazing activities that are taking place in this fragile ecosystem. Land degradation is also a function of other natural, social, and economic factors that are interrelated to each other. Hence, land degradation is a multi-causal effects phenomenon with complicated qualitative (i.e. land uses, tenure size, urban expansion, etc.) and quantitative (i.e. soil organic matter, soil texture, etc.) relationships.

The objectives of the study can be abbreviated as follow:

1. To use the RUSLE-GIS based model, supported by remote sensing techniques, to assess the risk of erosion depending on an appropriate grid dimension basis.
2. To classify the watershed study area into different categories according to the degree and risk of erosion and based on the predicted (modelled) annual soil loss potential.
3. To study the effectiveness of using different conservation practices (i.e. terraces) as well as different canopy covers for soil conservation and the reduction of the erosion risk.

4. To identify the high erosion risk areas in the watershed (hot spots) and accordingly, propose simple and low cost conservation and management practices.
5. To reveal the possibility of having a simple method to calculate rainfall erosivity factor (R) of the RUSLE, based on available data in the area.
6. To monitor the major land use- land cover (including the natural vegetation of the study area) changes that have taken place through time (1950 till nowadays) in the watershed, so as to identify those influential factors contributing to soil erosion and land degradation.

7. To publish a series of reports and possible articles in specific journals related to the various topics, for example, *The Journal of Arid Lands* and in *Soil and Water Conservation.* The usual readership of such publications are university faculty and researchers, and their students as well as professionals in the fields of agriculture, management and land degradation including field researchers and managers of Non-Government Organizations (NGOs).

8. To classify the risk of soil erosion in the study area according to different land use- land cover, which will enable the selection and the application of appropriate land use with minimum erosion.

Materials and methods

Auxiliary data

Literature review was conducted to reveal what has been achieved in the study area with regard to land degradation, the contributing factors to land degradation, and the natural and socio-economic settings that are prevailing in the study area. The review revealed that, in many cases, very limited data on land degradation are available both on the micro scale as well as on the regional settings. In general, it can be said that many of the required information prior to conducting the research were not available. Some other data (natural and socio-economic data) are available but with some parts missing, especially on the micro-scale or the village scale (i.e. Data on the current land use, management practices, family size, tenure size, income, etc.).
Among the available data collected and found to be useful for the purpose of this study are the following:

1. Contours elevation lines for different parts of the study area were obtained from the British Mandate Survey maps of 1944 (Figure 5). The preparation of the contour lines is essential for future uses such as derivation of the Digital Elevation Model for the Watershed (DEM). The DEM is an important input for the calculation of the slope steepness and slope length of different parts in the study area.

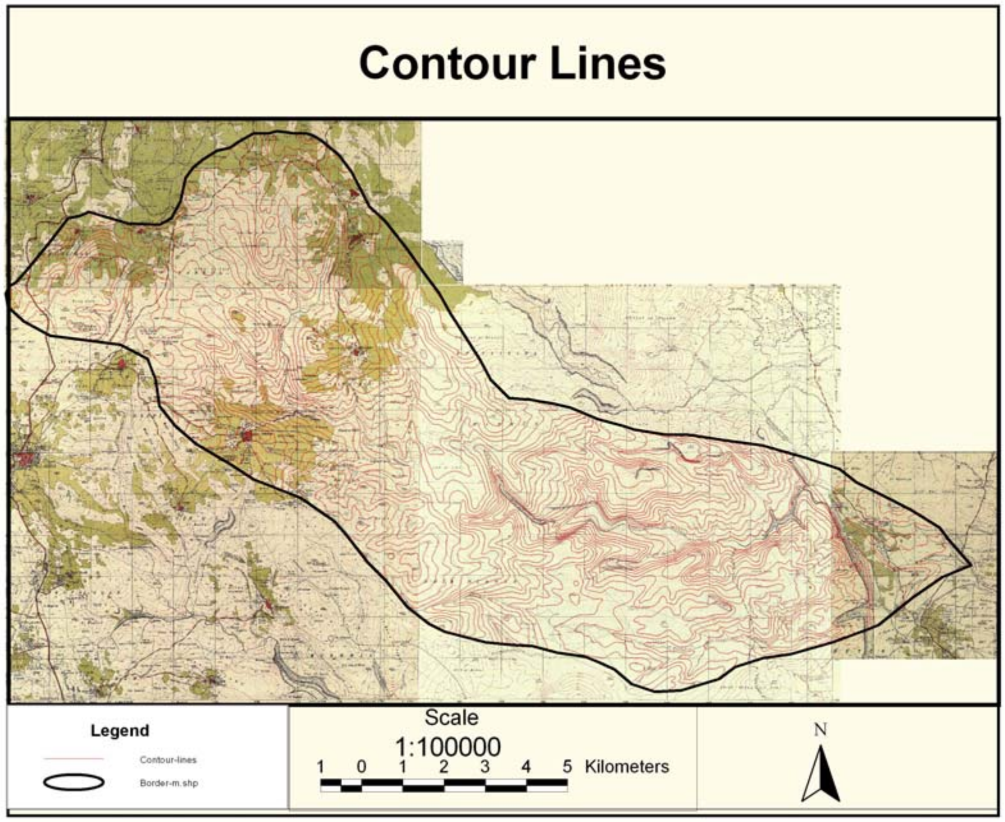

Figure 5: British Mandate map for the study area.

2. General survey of the natural vegetation was conducted. The survey included data on different land uses, rainfall categories, soil types and slope steepness and plant cover data (i.e. type, density and distribution). Such data are important to correlate them with different soil erosion categorical data that will be basically the result from the soil erosion model.
3. For detailed information on different land uses/land cover, spot image of the study area for the year 2003 was used. The spot image were rectified and correlated to the local Palestinian Grid. Erdas Imagine software was used to extract data on different land uses/ land cover using the supervised method of remotely sensed land use data. In this method of remote sensing, the data is extracted from the spot image using the manual method and thereafter, such data are compared with the actual field data for different type of the existing land use/ land cover (supervised method).

Soil sampling, analysis and rainfall measurements

Reconnaissance field survey was done at the beginning of the work. The aim of this field survey was to collect data on the geomorphology, soil structure, actual steepness, exposure of different locations, and the existing natural vegetation so as to provide a comprehensive and actual description of different locations in the study area.

Prior to identification of the location and number of soil samples required to cover different parts of the study area, the following activities were done before conducting the fieldwork fro soil sampling and collection:

- Land use map was prepared from recent spot image and using remote sensing technique (Figure 6).

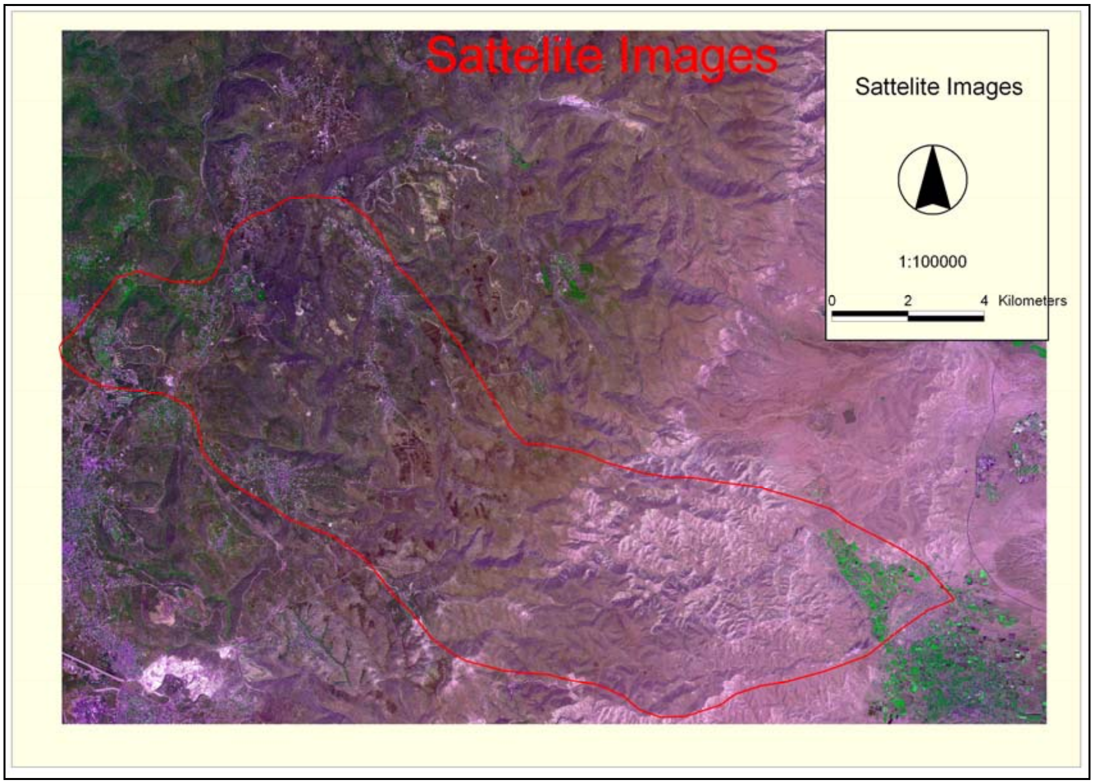

Figure 6: Landsat TM image for the study area.

- Major soil types in the study area were digitized from the Israeli Soil Survey map (Dan et al., 1976) (Figure 7).

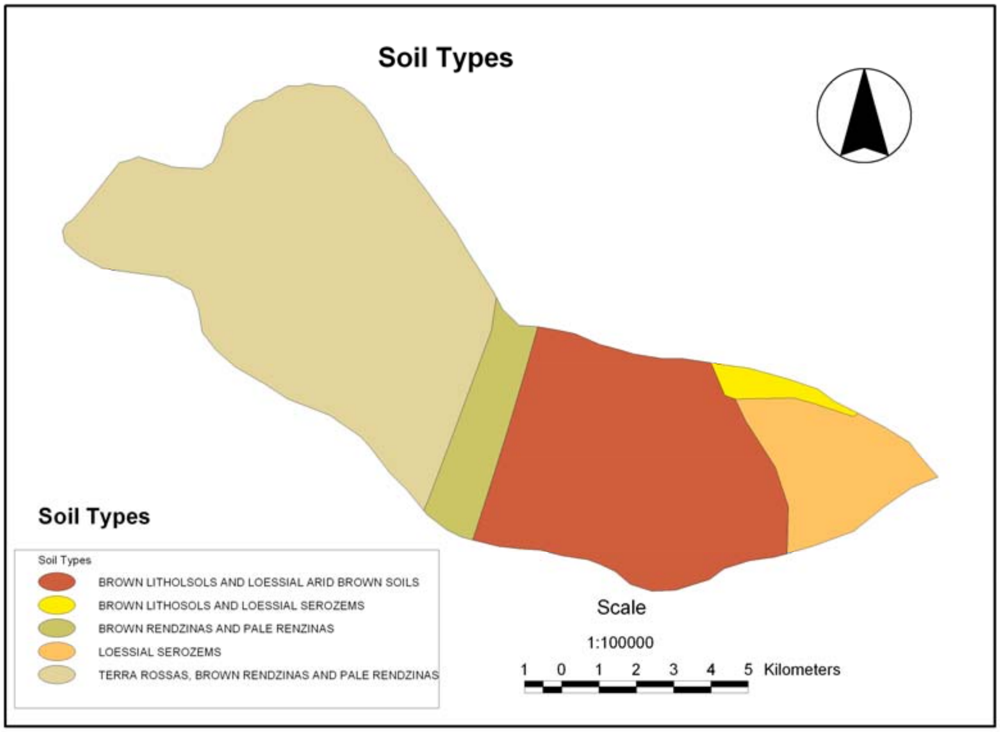

Figure 7: Major soil types and soil association exist in the study area.

- Major isohyets (rainfall categories and divisions) were extracted and digitized from the available data (i.e. Department of meteorology and other published data from different sources) (Figure 3).

- Different categories of slope steepness were derived using Arcview GIS techniques based on the digitized contour lines, (Figure 8).

- In order to identify the appropriate number and location of soil samples, Automatic intersection of the four different categories of data or themes: soil types, rain and slope gradients categories as well as with different land uses prevailing in the area was done using the GIS techniques. The intersection process resulted in a total number of about 178 samples. But due to the fact that some soil types can not be found under annual rainfall of less that 400 mm, the actual total number of soil samples that satisfy all the four data sets was about 43 samples (Figure 9) from different

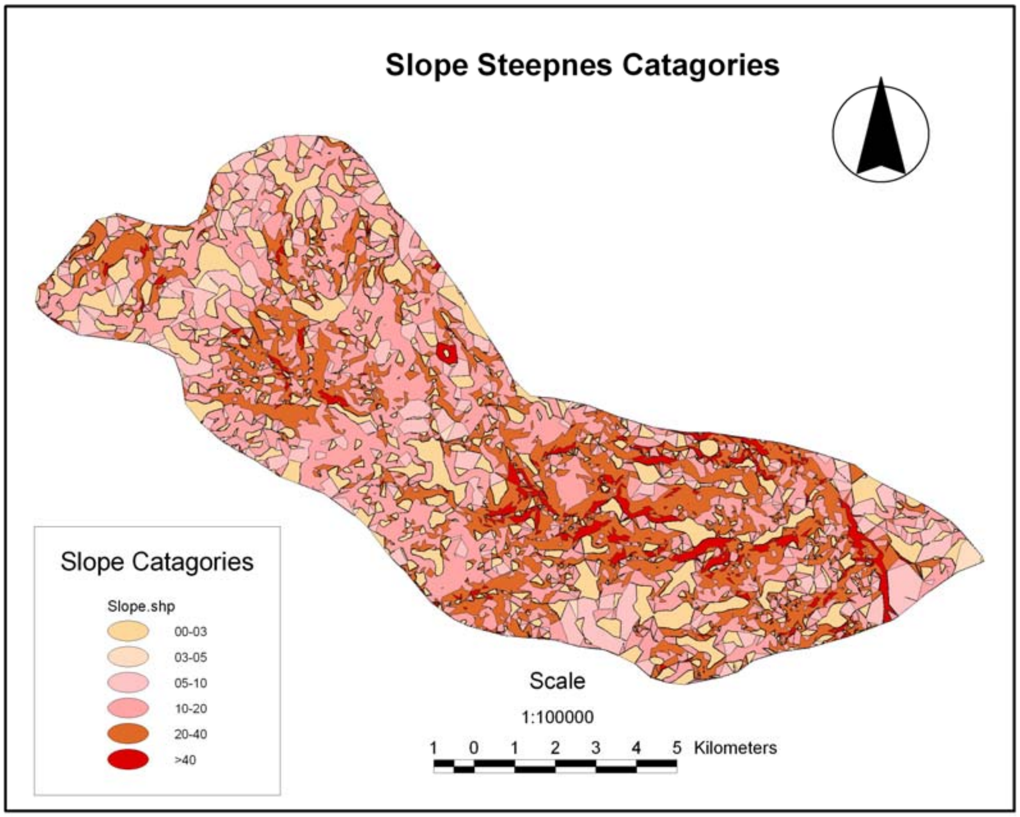

Figure 8: Different categories of slope steepness in the study area.

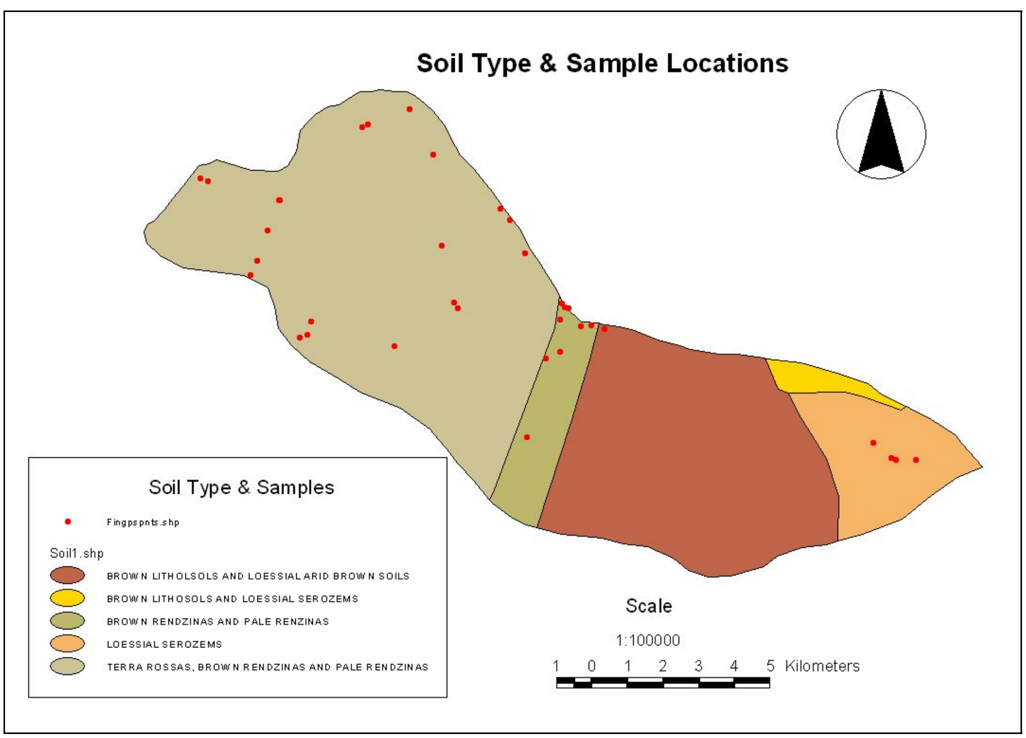

Figure 9: Major soil types along with the locations of different soil samples.

locations along the watershed area (***See Appendix number 1 for the different combinations of land uses, soil types, rain and slop categories***). Following the identification of the total number of soil samples and their properties, only one soil sample was allocated on the map, the selected location of the soil samples was chosen in accordance to the following criteria:

a. Representative of all soil that have similar characteristics.
b. Close to road network so as to increase accessibility to the sample location and the consequent collection of the sample.
c. Should be far from restricted areas in the watershed (i.e. military installation, settlements, etc.).

These soil samples represent the three major soil types exist in the area; Aridisols, Entisols, and Inceptisols. Collected soil samples were air dried and sieved for later analysis. Soil organic matter content for the collected samples were analyzed using the Walkley-Black method (Nelson and Sommers , 1982), whereas soil particle size distribution was determined using the pipette method (Bouwer , 1986). These soil analyses will be used later for the calculations of the RUSLE soil erodibility factors (K-factors) at different locations of the study area and then to derive soil erodibility grid surface for the whole watershed.

Rainfall measurements were conducted using two main automatic rain-stations inside the study area; the first station was allocated in Dura al Qari' and the second in the Eastern slope of the study area. Rainfall measurements will be accomplished during the winter season. In addition, auxiliary rainfall data were collected from other sources (i.e. meteorological department, Birzeit University meteorological station, etc.); these rain station are either automatic or manual and they are located either inside or surrounding the watershed study area such as the one at Birzeit, An Nabi saleh, Dir Dibwan, El Bireh, Jericho, and Jerusalem.

The automatic rain-stations is a 0.2 mm tipping bucket device, connected to a recorder data logger measuring rainfall at 30-minute intervals for the requirements of the RUSLE model procedures so as to calculate the rainfall erosivity factor (R). These rainfall data from different rain stations will be used to create rainfall erosivity grid surface for the whole watershed (***See Appendix number 2 for detailed rainfall measurements from the two automatic station inside the watershed area***).

Areas occupied by terraces all over the study area were identified using remote sensing techniques (Figure 10). The identification of the terraced area as well as their characteristics (i.e. spacing, length, height, drainage, etc.) is important for the proper identification of the existing management practices factor of the RUSLE.

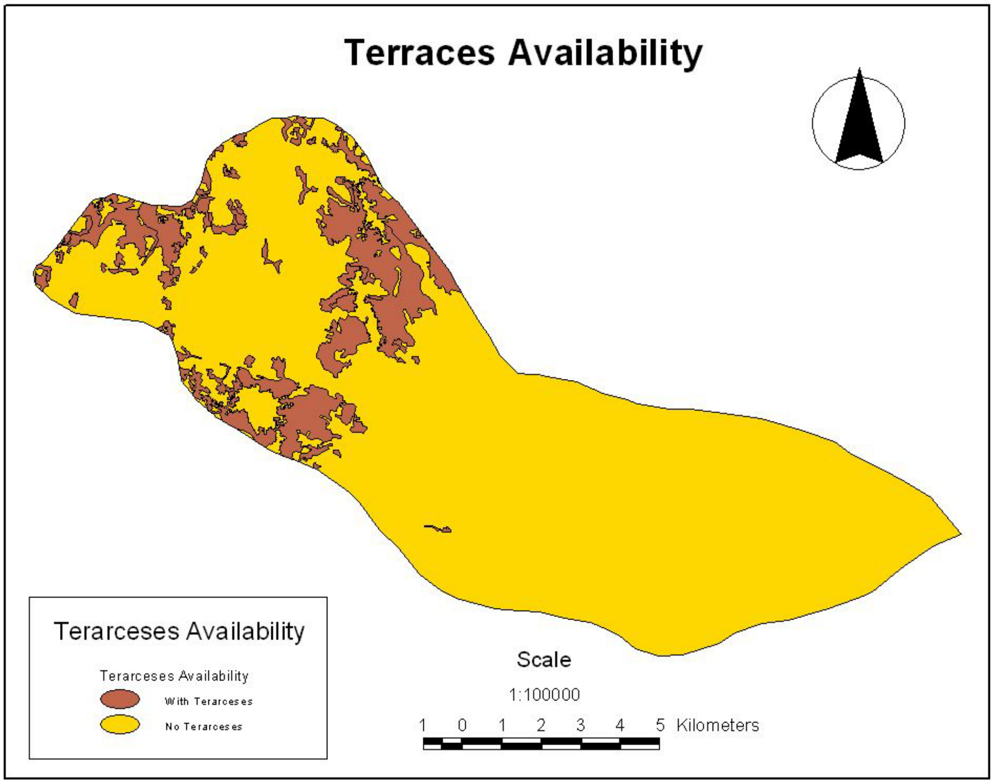

Figure 10: Available terraces used to promote agriculture in the study area.

Twelve small erosion plots (1 m^2) were setup in proper area that is accessible to the researchers and having suitable characteristics (i.e. slope, soil type, rainfall, etc.). Six plots were cultivated with wheat, whereas the other six were left bare. Measurements of the soil erosion from the 12 1-m2 plots was done, the samples were oven dried and weighed for each plot and for each rainfall events with different rainfall characteristics. These erosion data are necessary to validate and correct the quantitative output of the RUSLE model for assessment of land degradation due to soil erosion. In addition, these data are important to describe plant coverage and growth during the whole period of the wintertime, which is necessary to simulate the effect of land cover in the modeling process of soil erosion. And finally these data would give a quantitative comparison between cultivated and non-cultivated areas with respect to the rate of soil erosion and hence the rate of land degradation.

In addition, plant coverage and growth stages during the whole period of the wintertime were also identified especially in the cultivated plots with winter wheat, which is necessary to simulate the effect of land plant cover in the soil erosion risk assessment by RUSLE model. And finally these data would give a comparative quantitative data for the rate of soil erosion between different land uses (cultivated and non-cultivated plots/ areas) and though would reflect quantitatively the rate of natural land degradation at different parts of the study area.

Natural vegetative cover investigation

Detailed survey of the natural vegetation was conducted at the end of Spring Season. The main objectives of the survey are to figure out and measure various vegetation characteristics (quantitative and qualitative data) such as:

a. Identification of the different existing types of the natural vegetation.
b. Density of different types of the existing natural vegetation was also measured in situ using the Braun-Blanquet method (Ulrich , 2003; Culmsee and Deil , 2003) . In this method 1-m^2 areas were identified in each major soil type and land uses randomly, the identified area was bounded by a 1*1 m quadrant followed by the identification of all existing type and the density of these types. Such qualitative and quantitative identification of the type and density is essential for later stages in the study, which will enable the correlation of different types and density with different category of soil erosion rates that will be calculated using the RUSLE model. In addition, such data are essential to trace out most important type of natural vegetation existing in different areas, and which types are mostly overgrazed and which are not.
c. Total biomass of the natural vegetation was calculated. For calculating the total biomass, the natural vegetation coverage was harvested and dried out and then weighed for total biomass of the natural vegetation per 1m^2. A total number of twenty-m^2 -squares was collected and biomass was determined for these samples as representative samples for different natural vegetation of the study area.

A database was created to hold different data that were collected during the field trips such as data on geomorphology, soil structure, actual steepness, location exposure, and the existing natural vegetation. The database was linked spatially with the map of the study area using GIS technique. This linkage is important to store and explore different data within a geographic context, in addition to the possibility of overlapping and intersection of different data with each other.

Calculation of The RUSLE- Factors

Calculation of the major natural factors contributing to land degradation by soil erosion, which are constituting the main input for the RUSLE model for erosion risk assessment, were done using the normal procedures that are documented in different sources (Renard et al., 1996; Foster et al., 2002; Renard et al., 1991; Wischmeier and Smith , 1978), these factors are the following:

d. Rainfall erosivitiy factor (R-factor): Calculation of rainfall erosivity, based on 30-minute measurement of rainfall was done using Wischmeier formula (Wischmeier and Smith , 1978; Morgan , 1986) for each rainfall event and for all the rainfall stations inside and outside the watershed study area (***For the calculated rain-events R-factor during the whole winter season see appendix number 3***)
e. Soil erodibility factor (K-factor).
f. Slope length and steepness factors (LS-factors).
g. Crop factor (C-factor).
h. Management factor (P-factor).

Historical background on the study area

The historical data of the study area was studied, concentrating on the main land uses and land use changes, using chronological sequence of the data available for the area in question. For this purpose, a detailed historical data were collected. These data include the following subjects:

- Built-up area from past to current time (size and direction of expansion).
- Population and population density.
- Land uses and land use changes at different time horizon, emphasizing on agricultural land use and other land uses that are negatively affecting agriculture (i.e. built up, industry, and mining).
- The number of animals through time so as to correlate the animal husbandry with overgrazing activities taking place in the area, and the consequent terraces' destruction that are taking place as a result of the terraces deterioration in different villages and at different time.

THE QUESTIONNAIRE

PREPARATION OF THE QUESTIONNAIRE

The questionnaire was designed to provide data on different factors associated with natural, social and economic factors contributing to land degradation. The questionnaire was divided into seven main parts (***Appendix number 4***); these main parts are the following:

1. General information (Village name, questionnaire number, education level).
2. Land use prevailing in different villages of the study area.

3. Socio-economic information.
4. Institutional support to agricultural sector.
5. Environmental awareness.
6. Land tenures and land fragmentation.
7. Land pricing and its relation to land use changes.

The design of the questionnaire took into consideration the following general guidelines for the achievement of highest degree of precision and accuracy:

a. Informative and comprehensive: the questionnaire contains different social, economic and human induced land uses within a specified geographical area that are necessary so as to have a comprehensive view of the area in question. In addition, different type of collected data in the questionnaire are, to some extent, linked either directly or indirectly to each other, for example, if the questionnaire reveals the availability of terraces for soil and water conservation, this would be correlated to the degree of environmental awareness of the peasants and also to socio-economic conditions of the peasants.

b. Scale dependent: which means that the data that were included into the questionnaire can be on micro scale (pixel size of 30*30 m^2) or macro scale (part of peasant's property and\ or the surrounding area of the villages existing in the watershed and other adjacent areas of the villages).

c. Accuracy: where control questions were incorporated in some parts of the questionnaire so as to check the credibility of the answers obtained for some crucial questions. For example asking about whether the farmers are selling their land for other land uses rather than agriculture, and then as a control question asking the same farmers whether adjacent farmers are practicing such behavior.

TESTING THE QUESTIONNNAIRE

A pre-test of the questionnaire was carried out through field survey that was conducted by the team members. As a result, the team discovered some questions that should be cancelled, some other points to be modified, and new other points that did not appear into the questionnaire and they are important to be included into the final questionnaire. In addition to testing and the final adjustment of the questionnaire, the team members have practiced filling the questionnaire in proper way and exact time frame.

EVALUATION AND FINALIZATION THE QUESTIONNNAIRE

After getting all the comments from the preliminary field survey, the team has an intensive discussion about different parts of the questionnaire, including some parts to be added. As a first step, each part of the questionnaire was evaluated separately by examining each question of this part, after getting approval of all the team members; the second part would be examined and approved and so on till the final part of the questionnaire. According to this multiple interrelated correlation, new questions emerged and some others were modified.

FILLING THE QUESTIONNNAIRE

After finalization of the questionnaire, a total of 150 questionnaires were filled out from 12 villages (Figure 11). The total number of questionnaire in each village was set to be 10% of the total number of families that are working in agriculture, hence, the number of questionnaires filled is different from one village to another.

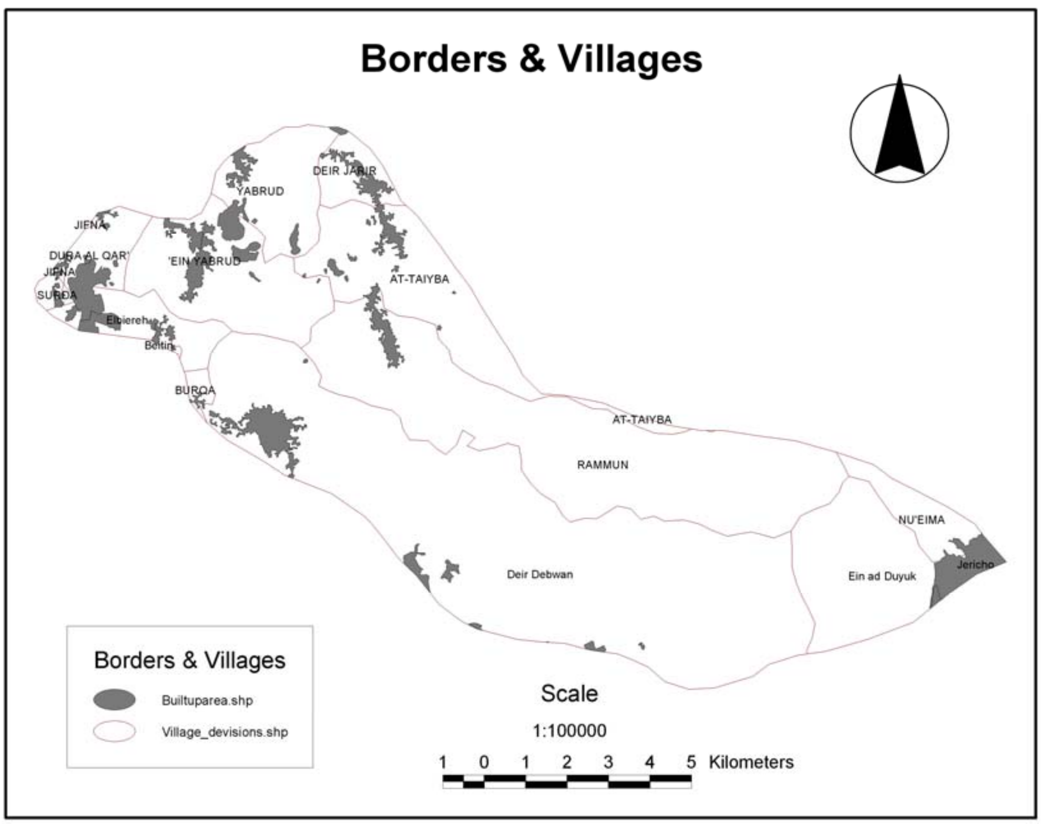

Figure 11: Village boundary areas along with the different village built-up areas existing in the study area.

PREPARARTION OF THE QUESTIONNAIRE FOR ANALYSIS

After getting all the questionnaires filled, a coding process was conducted for different answers of each question; computerizing the data using the statistical Package for Social Science (SPSS) software followed up this process. Intensive analysis (including multiple correlations, chi square analysis, cross tab analysis, graph presentations of different correlations, etc.) has been accomplished so as to identify the most influential socio-economic factors on land degradation. According to the answers obtained from the questionnaire, classification of the natural vegetation into palatable and non-palatable for animal grazing has been also done. The classification would be of importance for the protection of the vegetative cover and for soil and water conservation as well as for management and protection of the natural habitat.

RESULTS AND DISCUSSION

Soil Erosion Modeling by RUSLE

RUSLE R-factor and Annual Rainfall

Generally speaking, the study area lacks detailed and historical climatic data that are necessary for the calculation of rainfall erosivity factor, which is an important component of modeling soil erosion by RUSLE procedure. For facilitating the computation of the rainfall eorsivity factor of the RUSLE (R-factor), correlation of the available rainfall data, generated at 30-minute interval from the automatic rain stations, with the monthly rainfall data available from old rainfall records, would be facilitate future calculation of the R-factor by other researchers as well as in other similar watersheds that have almost the same rainfall patterns. To achieve this, the available Rainfall erosivity (EI30) based on 30-minute measurements for the automatic stations, and for the available calendar years, was calculated on daily basis, the daily EI30's were summed up for each month, station and year. A polynomial regression analysis between the calculated monthly rainfall erosivity, and the long-term average monthly rainfall (20 years average), which is available from other manual rain stations located wither inside or outside but adjacent to the watershed, were done. The regression revealed highly significant ($P<0.01$) relation between monthly average rainfall and monthly rain erosivity factor for the area in question (Figure 12), which is a useful relation for the application of RUSLE in this watershed area as well as other similar areas.

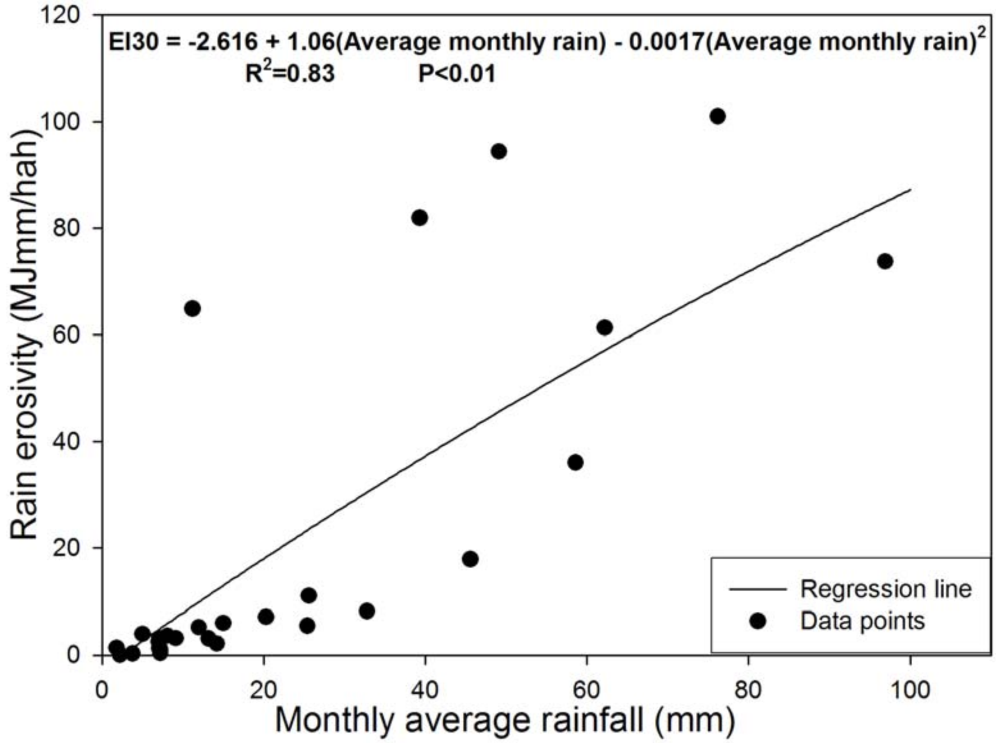

Figure 12: Nonlinear regression relation between monthly rainfall erosivity and the average monthly rainfall for the watershed area.

The regression equation was used to find the monthly rainfall erosivity (EI30) for the stations that is either located inside or adjacent to the watershed area; the monthly EI30s were summed up for each station to find the annual rainfall erosivity (R). These data, along with the location of the rain stations were used to create a rainfall erosivity gird surface utilizing ArcView Spatial Analyst (Figure 13), covering the whole area of the watershed. The delineation of each area with its specific R factor will be used to calculate the annual soil loss by RUSLE.

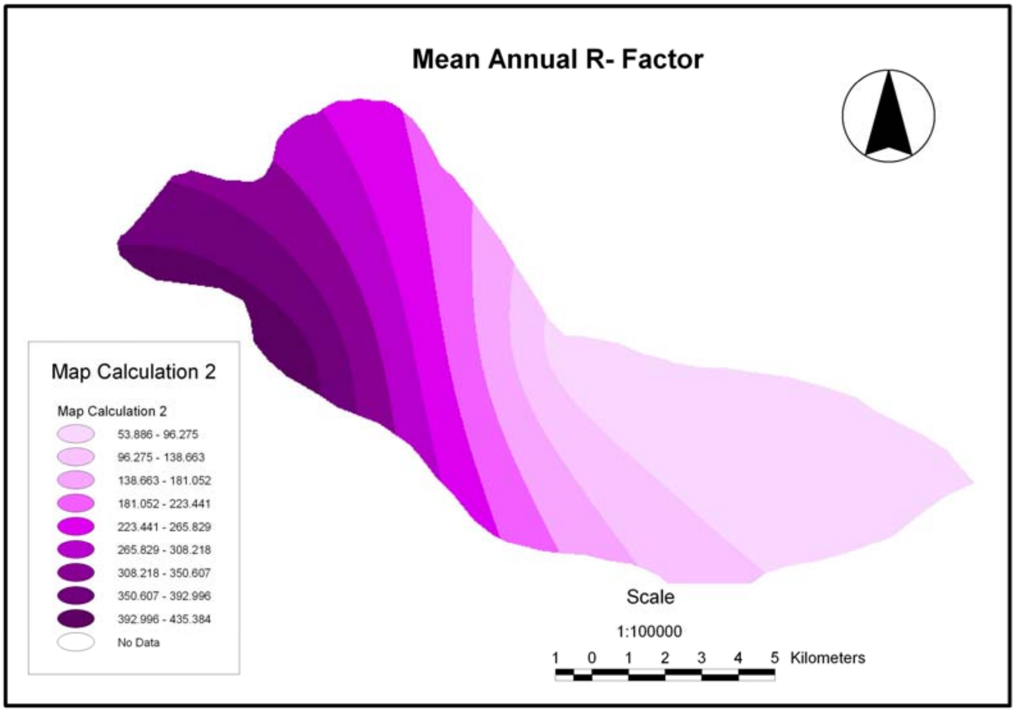

Figure 13: Mean annual rainfall erosivity grid surface for the study area.

A detailed view of the monthly average rainfall erosivity revealed that more than 75% of the total erosive rainfall as presented by the percent erosivity from total rainfall erosivity occurs during the period from November to February (Figure 14). During this period, the canopy cover (i.e. height and density) is almost small and negligible (Figure 14), which leaves the soil surface unprotected against raindrop impacts, resulting in high risk of erosion during these low vegetatively-covered months. The high erosion risk during these rainy months would cause further deterioration to land, and this situation necessitates the application of certain management practices, especially during this critical period, which will minimize runoff, erosion, and conserve more soil moisture for better plant growth. Among the effective management practices that could be applied to minimize erosion and protect the soil surface are the following:

1. The addition of either green or dry plant residue on the soil surface so as to provide protection to the soil surface, especially during the rainy periods with high rain erosivity potentials.
2. It is necessary that the existing management in the area at the end of harvest, which is mainly concentrating on grazing the plant residue completely, especially for field crops, would be changed so as to keep the minimum amount of residue necessary for protecting the soil surface against direct rain drop impacts. Besides, such addition of the plant residue would increase the fertility status of the soil and also the physical strength of the soil aggregates.

3. Planting the field crops earlier in the season with the addition of some water for irrigation (complementary irrigation) would give the plant more chances to establish the minimum vegetative cover before the onset of rainfall, leaving the soil surface intact and protected against the raindrop impacts, especially during November and December, where the wheat canopy is very short and dispersed (< 10 cm height) (Figure 14).

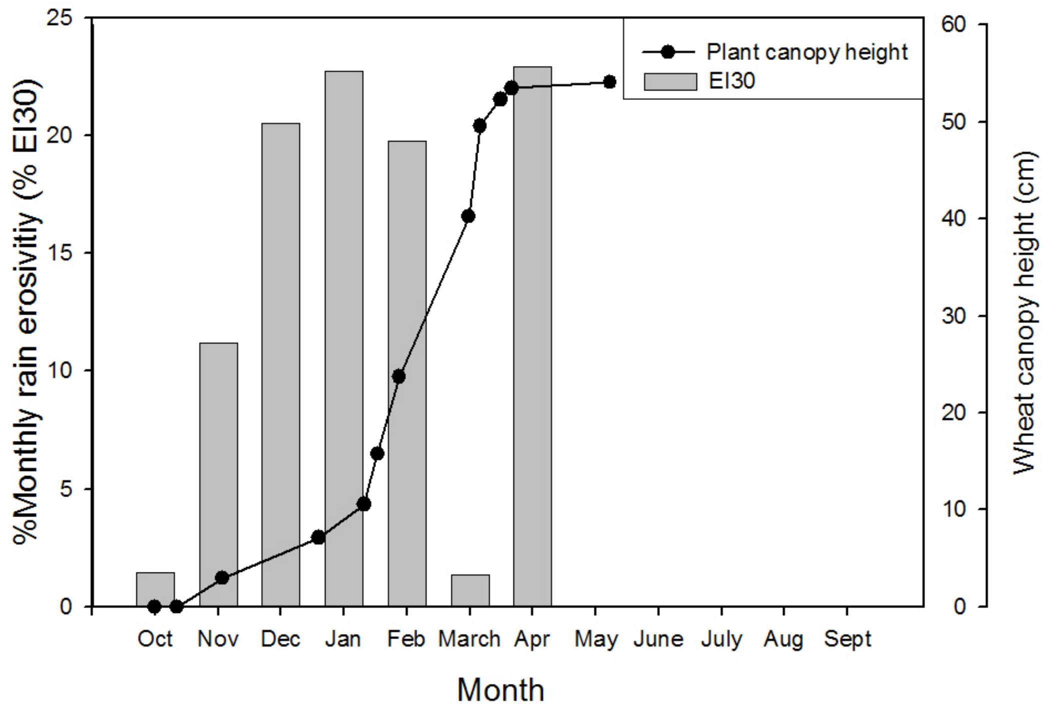

Figure 14: Monthly rainfall erosivity distribution and wheat canopy height during the winter season.

Soil Erodibility Factor (K) and K-surface

The derivation of soil erodibilty factor (K-factor) utilized similar procedures as those used for the R-factor. The locations of the 43 soil samples were assigned spatially, according to the different major soil types in the watershed (Figure 9). The K factor was calculated according to the following equation used by RUSLE model following up different literatures (Foster et al., 2002; Renard et al., 1996; Wischmeier and Smith , 1978):

$$\mathbf{K = [\ 2.1*10^{-4}\ (12\text{-}OM)\ M^{1.14} + 3.25\ (S\text{-}2) + 2.5\ (p\text{-}3)]\ /100} \qquad \textbf{(1)}$$

Where K is the soil eordibility (Mg h MJ^{-1} mm^{-1}), M is the silt % (0.002-0.1 mm)*(%silt + sand), S is the class of the structure (1-4), P is the permeability class of the soil (1-6), and OM is the soil organic matter (%). For more details on the K-factor and its derivation, the reader is advised to go through the previous researches and papers on RUSLE (Foster et al., 2002; Renard et al., 1996; Wischmeier and Smith , 1978; Angima et al., 2003; Engel , 1999; Hussein , 1998a).

The calculated 43 point K-factors were used to create a soil erodibility grid surface for the whole watershed area (Figure 15), using ArcView spatial analyst (Applegate , 1999). The K-surface shows a range of 0.013 to 0.045 Mg h MJ^{-1} mm^{-1}. To assure accuracy, five K surface points, which are extracted from the grid surface interpolation by Arcview spatial analyst, were compared to five K-point soil samples that were calculated previously by the RUSLE equation. The result indicated a good approximation of the point surface K-factor to the RUSLE calculated point K-factor. The standard error of estimate between the point and the surface K-factor is $8.4*10^{-5}$ Mg h MJ^{-1} mm^{-1}, which is very small compared to the mean K-value (1.7% of the mean value of the actual K-factor) with an acceptable level of accuracy.

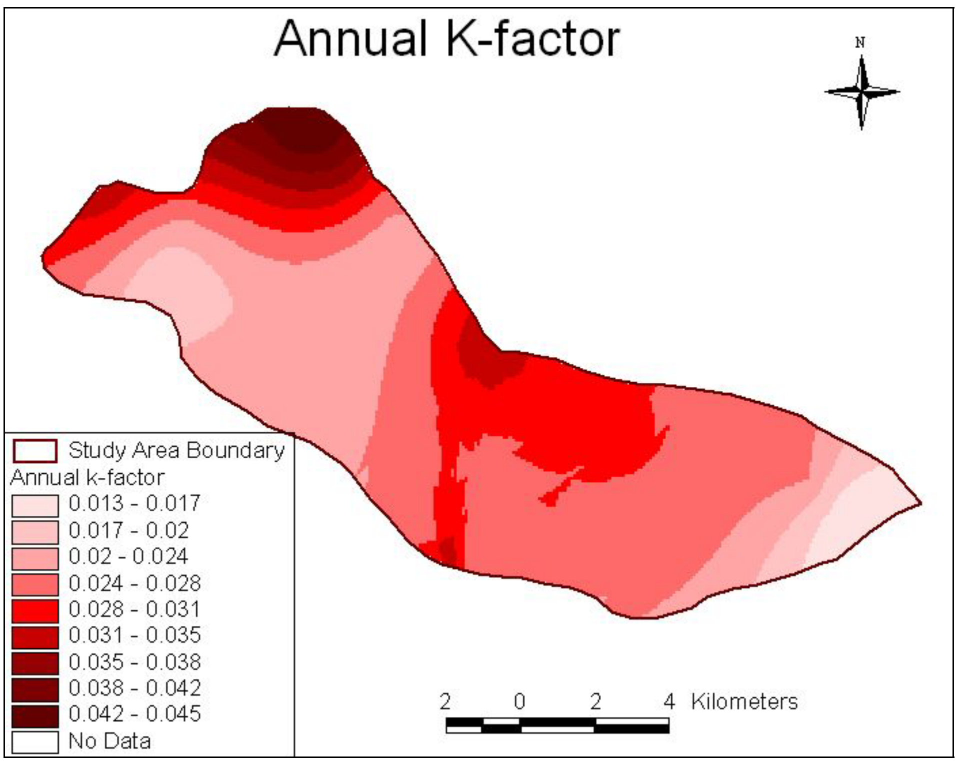

Figure 15: Mean annual soil erodibility grid surface (K-factor) for the study area

The Digital Elevation Model (DEM) and the RUSLE LS-factor

The derivation of the LS factor for RUSLE depends on the generation of a 30-meters DEM. The creation of the DEM was basically based on digitizing 25-m contour lines, which is an attribute of a 1:20,000 topographic map of the study area. The vector elevation map (contour lines) was converted to a DEM raster map (Figure 16) and projected using the Universal Transverse Mercator

Zone 36 North with a Datum of WGS84. The derivation of the DEM surface utilized the Spatial Analyst 1.0a technique of ArcView GIS 3.2 (Applegate , 1999). Consequent derivation of the slope steepness factor (Figure 5b) used the procedure of Spatial Analyst that was described by Engel (Engel , 1999).

The slope length factor (λ) was estimated using flow accumulation grid file, which was created by using the hydrologic modeling extension 1.1 of ArcView GIS 3.2, following the procedures cited by Engel (Engel , 1999). The maximum allowable slope length (λ) derivation was limited to the maximum slope length allowed by the RUSLE, which is 300 ft or 91.4 meters equivalent (Wischmeier and Smith , 1978; Foster et al., 2002). The derivation of slope length, by ArcView spatial analyst, depends on the theoretical background mentioned by Moore and Wilson (Moore and Wilson , 1992). The method assumed that the slope length (λ) is equivalent to the area upslope that is contributing to erosion per unit width of contour. In other words, it is equivalent to the specific catchment's area (A_s) presented as m^2 m^{-1}.

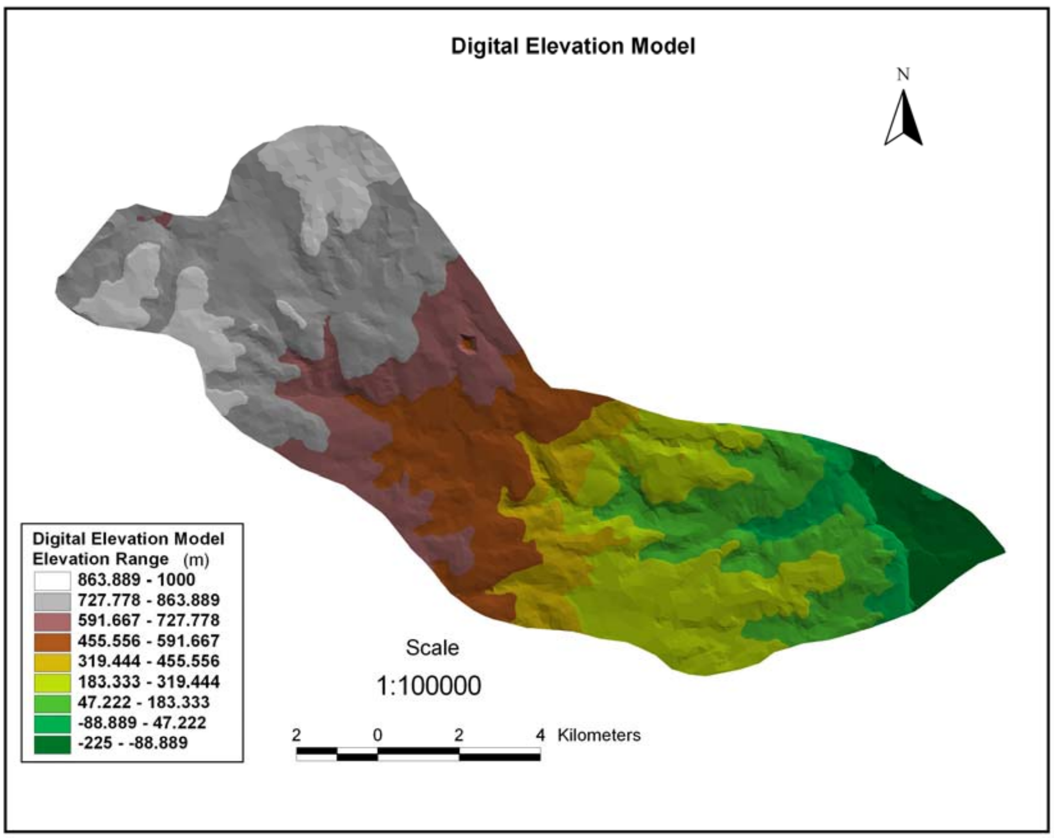

Figure 16: The Digital Elevation Model (DEM) for the study area.

To estimate the accuracy of the created DEM, as well as the slope steepness factor created by spatial analyst, twenty well-distributed random points were taken, and the original elevation and slope steepness were measured from the elevation contour lines map and from a field survey, respectively. The estimated elevation and slope steepness were obtained from the DEM and the slope-steepness grid file, respectively. The standard error of estimate between the measured and estimated points for the elevation is 0.48 m, whereas that of the slope steepness is 0.51º. This emphasizes the accuracy of the generated DEM and the close relationship of the derived slope steepness and length to the actual measured ones. With a wide range of slope steepness (0.02º to 50º) and elevation (-230 up to 1000 meter) in this watershed area, the resultant error of the interpolation technique seems to be acceptable. In addition, the resultant output seems to be accurate and reflects reality.

The final estimation of the RUSLE LS-factor has utilized the theoretical and technical procedures that were described by Moore (Moore and Burch , 1986b; Moore and Burch , 1986a; Moore and Wilson , 1992). The equation that was used to compute the LS-factor following up the procedures mentioned previously is as follow (Moore and Wilson , 1992; Engel , 1999):

$$\mathbf{LS = (A_s * Cell\ size/22.13)^{0.4} * [\sin\theta /0.0896]^{1.3}} \quad \mathbf{(2)}$$

Where A_s is equivalent to the derived slope length (λ) from the DEM (Figure 16), the cell size is unit less and equals to that used in the DEM (30 meters), and θ is the slope steepness (S) derived from the DEM (Figure 16). Application of the previous equation to calculate the final RUSLE LS-factor produced the corresponding LS-factors for different cells of the DEM (Figure 17).

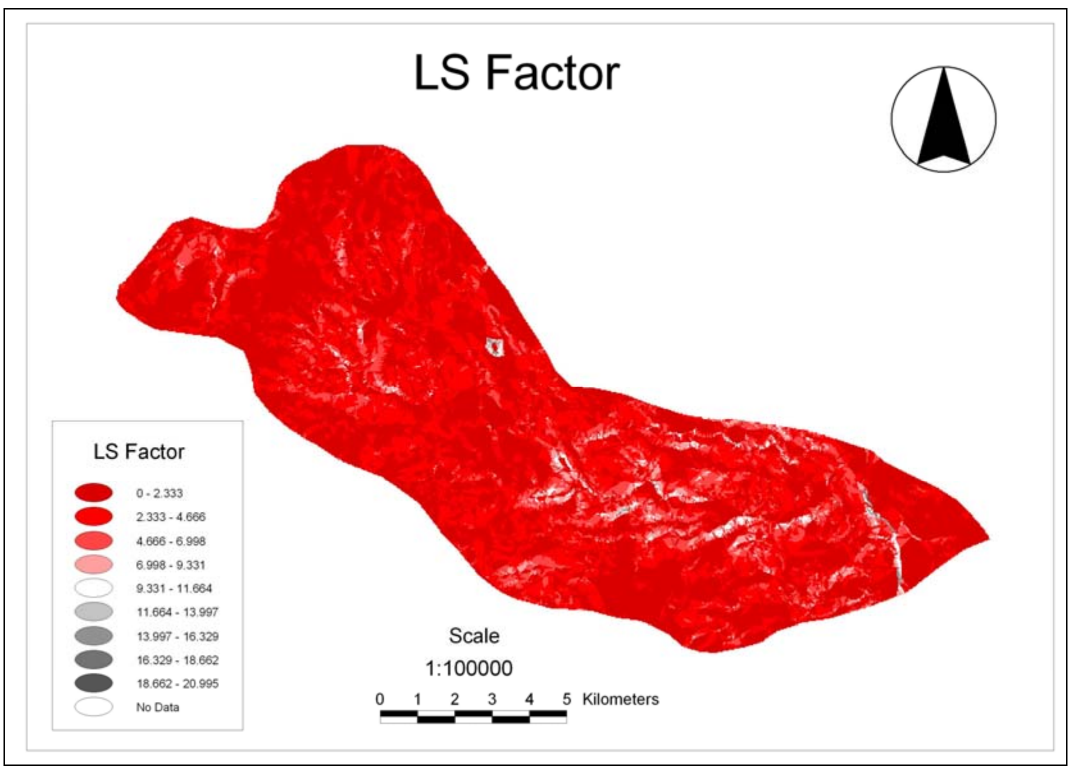

Figure 17: The slope steepness (S) and length (L) multiplications (LS-factor).

The Land Cover and RUSLE C-factor

The land cover map utilized a geo-referenced Landsat Thematic Map (Landsat TM) image for the whole area and its surroundings for the year 2003 and during the end of the winter season and the beginning of the spring season (end of March). This date is important in that it shows all possible combination of winter season land uses, since the winter plantation begins in November and is harvested in June, and hence, all the different combinations of the green coverage during the winter season is easy to differentiate at this time (March). The computer-aided analysis and interpretation of the Landsat TM was done using ERDAS Imagine 8.2 software (ERDAS Inc. 1995). The work was achieved using a multi-window environment; thus the image of an area could be presented in various presentations of spectral bands. The smallest cell size mapped using Landsat TM was 30 meters* 30 meters. To check the land cover accuracy and delineation of different land use exist in the watershed, field verifications for specified land uses were investigated and checked against the remotely sensed land uses. This will add more accuracy to the Landsat TM data by establishing a linkage with detailed ground-truth data extracted from field survey.

The RUSLE C-factor is a measure of the cropping and management practices effect (either positively or negatively) on soil erosion (Renard et al., 1996). For the RUSLE to generate C-factors for different management practices existing in the area, data on the type of crop, pre-planting preparations (cultivation, residue cover, manure addition…etc.) planting date, crop growth stages, harvest date, and other plant characteristics are required (Foster et al., 2002). Such data were obtained from field experimentation as well as from field visits during different field surveys conducted in the study area.

The analysis of the Landsat TM, along with its field verification, revealed two major crops in the watershed; wheat and barley, and olive groves (Figure 18).

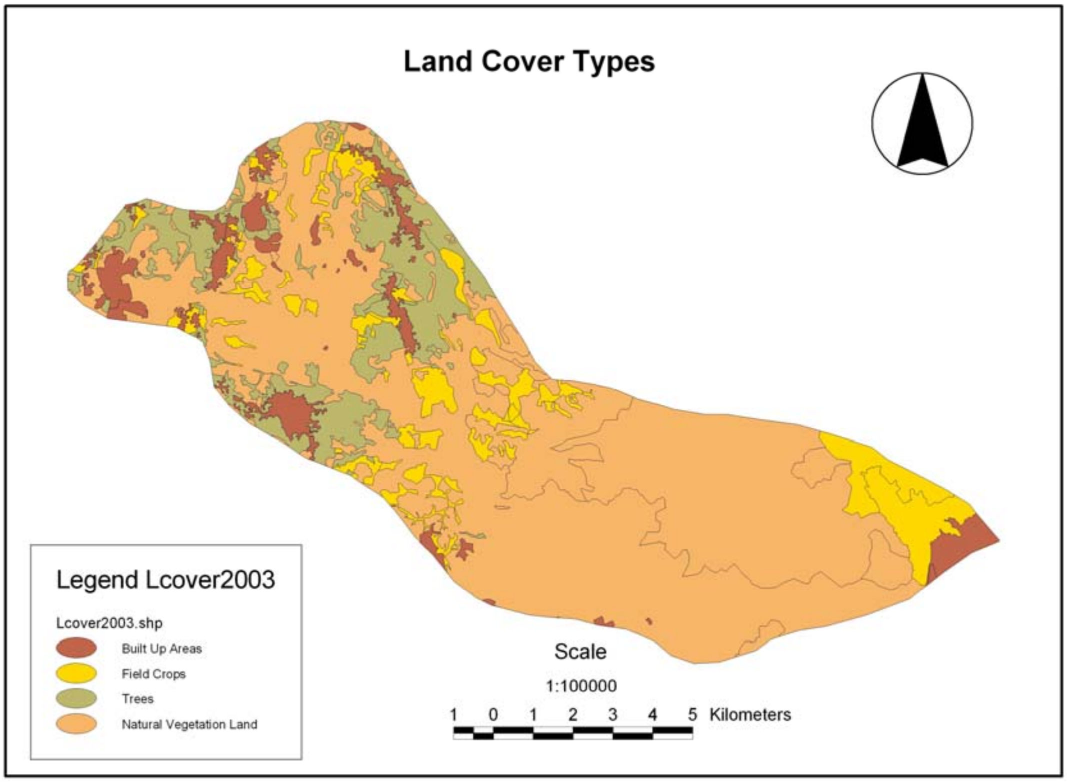

Figure 18: Major land cover/ land uses in the study area.

Observations of the management practices in the area showed that farmers were using the entire residue, especially those related to wheat and barley, for grazing animals. This will leave a minimum amount of plant residue on the soil surface. The main management practice is the use of chisel plow at the beginning of October for wheat and barley plantations. The chisel plow is used three times for olive grove plantations; one in November after harvesting and before winter, the second in March for weeding, and the last is in May, also for weeding. Plant height was measured in situ at different growth stages, especially for wheat and barley and olive groves.

According to RUSLE, the C-factor must be calculated according to the proportion of R-factor on a half-month basis (Wischmeier and Smith , 1978; Renard et al., 1996). The application of RUSLE program, for cereal (wheat and barley) and olive plantations, implies feeding the RUSLE database with the existing management practices and plant canopy characteristics. The RUSLE database performs different repeated iteration on 15-day intervals for the calculation of different soil loss ratios (SLR). The results for both types of crop are shown in Tables 1 and 2. For bare lands with no or with negligible vegetative cover, the C-factor is set to unity, whereas the C-factor for urban areas is given a zero value, which means that all the urban areas will be excluded from the final calculation of soil erosion. For natural grassland, the C-factor was assumed to be similar to that of cereals, with the exception that its canopy cover is less, thus resulting in a higher C-factor (Figure 19).

Table 1: Half month Soil Loss Ratio generated from the RUSLE simulation for both wheat-barley and olive plantation in the Western part of the study area.

Month	Period	%EI30	Soil Loss Ratio (SLR)*EI30 Wheat & barley	Soil Loss Ratio (SLR)*EI30 Olive groves
Jan.	1-15	17.60	0.8742	0.0117
	16-31	2.90	0.1555	0.0019
Feb	1-15	14.97	0.6502	0.0100
	16-28	0.98	0.0414	0.0007
March	1-15	0.81	0.0307	0.0006
	16-31	0.00	0.0000	0.0000
Apr.	1-15	26.38	1.0100	0.0246
	16-30	0.32	0.0139	0.0007
May	1-15	0.00	0.0000	0.0000
	16-31	0.00	0.0000	0.0000
June	1-15	0.00	0.0000	0.0000
	16-30	0.00	0.0000	0.0000
July	1-15	0.00	0.0000	0.0000
	16-31	0.00	0.0000	0.0000
Aug	1-15	0.00	0.0000	0.0000
	16-31	0.00	0.0000	0.0000
Sep.	1-15	0.00	0.0000	0.0000
	16-30	0.00	0.0000	0.0000
Oct.	1-15	0.00	0.0000	0.0000
	16-31	0.54	0.0000	0.0000
Nov.	1-15	1.89	0.0000	0.0000
	16-30	9.88	0.6416	0.0505
Dec.	1-15	0.00	0.0000	0.0000
	16-31	23.71	4.4846	0.0178
Annual C-factor			***0.0790***	***0.0503***

Table 2: Half month Soil Loss Ratio generated from the RUSLE simulation for both wheat-barley and olive plantation in the Eastern part of the study area.

Month	Period	%EI30	Soil Loss Ratio (SLR)*EI30 Wheat & barley	Soil Loss Ratio (SLR)*EI30 Olive groves
Jan.	1-15	16.58	0.8573	0.0132
	16-31	2.49	0.2005	0.0023
Feb	1-15	31.36	2.1581	0.0253
	16-28	2.47	0.6209	0.0087
March	1-15	1.37	0.4849	0.0068
	16-31	0.00	0.0000	0.0000
Apr.	1-15	21.96	1.0865	0.0157
	16-30	1.49	0.2186	0.0032
May	1-15	0.00	0.0000	0.0000
	16-31	0.00	0.0000	0.0000
June	1-15	0.00	0.0000	0.0000
	16-30	0.00	0.0000	0.0000
July	1-15	0.00	0.0000	0.0000
	16-31	0.00	0.0000	0.0000
Aug	1-15	0.00	0.0000	0.0000
	16-31	0.00	0.0000	0.0000
Sep.	1-15	0.00	0.0000	0.0000
	16-30	0.00	0.0000	0.0000
Oct.	1-15	0.00	0.0000	0.0000
	16-31	0.00	0.0000	0.0000
Nov.	1-15	1.33	0.0978	0.0028
	16-30	1.33	0.4045	0.0113
Dec.	1-15	0.00	0.0000	0.0000
	16-31	19.63	2.7032	0.0412
Annual C-factor			***0.0883***	***0.0752***

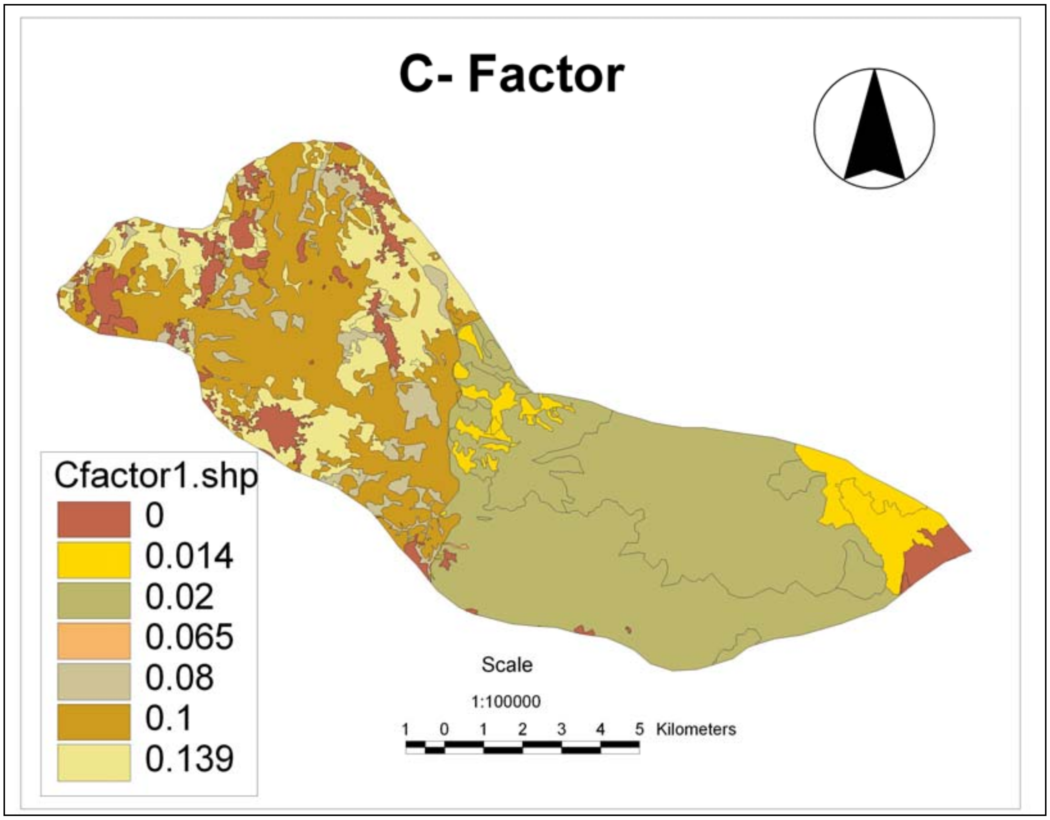

Figure 19: RUSLE crop management factors (C-factors) according to different land cover/ land uses in the study area.

The Support Practice Map and RUSLE P-factor

RUSLE describes the effect of contouring, tillage practices and terracing on soil erosion by the support practice (P) (Renard et al., 1996; Foster et al., 2002). For the watershed in this study, the only support practice existing is terracing. Previous literatures found that terracing affects sheet and rill erosion by breaking the slope length into shorter distances, and hence, decreasing runoff and the associated erosion (Wischmeier and Smith , 1978; Renard et al., 1996; Foster et al., 2002). The RUSLE computation of P-factor depends on the spacing between successive terraces (Wischmeier and Smith , 1978; Renard et al., 1996; Foster et al., 2002). A maximum benefit, which is reflected by the P value, of terracing is assigned for terraces interspacing of 110ft or 33.5 meters (Renard et al., 1996). An increase in the spacing above that value will cause a gradual increase in the P-value, indicating a lower efficiency of terraces in reducing runoff and erosion (Wischmeier and Smith , 1978; Renard et al., 1996; Foster et al., 2002).

Intensive field observations showed that all the terraces in the watershed area have gentle slope (0-2%), spacing of less than 33.5 meters, and with underground outlets. The P-factor for such specifications is assigned a value of 0.55 by the RUSLE.

To delineate areas with terracing practice in the watershed area, a geo-referenced Landsat Thematic Map (Landsat TM) image for the whole area and its surroundings for the year 2003 along with field observations were used. Analysis of the Landsat TM resulted in the identification of all the areas with terracing (Figure 20). Areas without support practices (i.e. without terracing) have been assigned a unit P-factor, which means that these areas have maximum risk of erosion due to the absence of any support practice. Areas with terraces have been given a 0.55 P-factor value depending on the terraces characteristics, the interspacing, and the driangae properties. The resultant land cover map and the associated P-factors were used to generate a grid surface for the P-factor, utilizing ArcView spatial analyst.

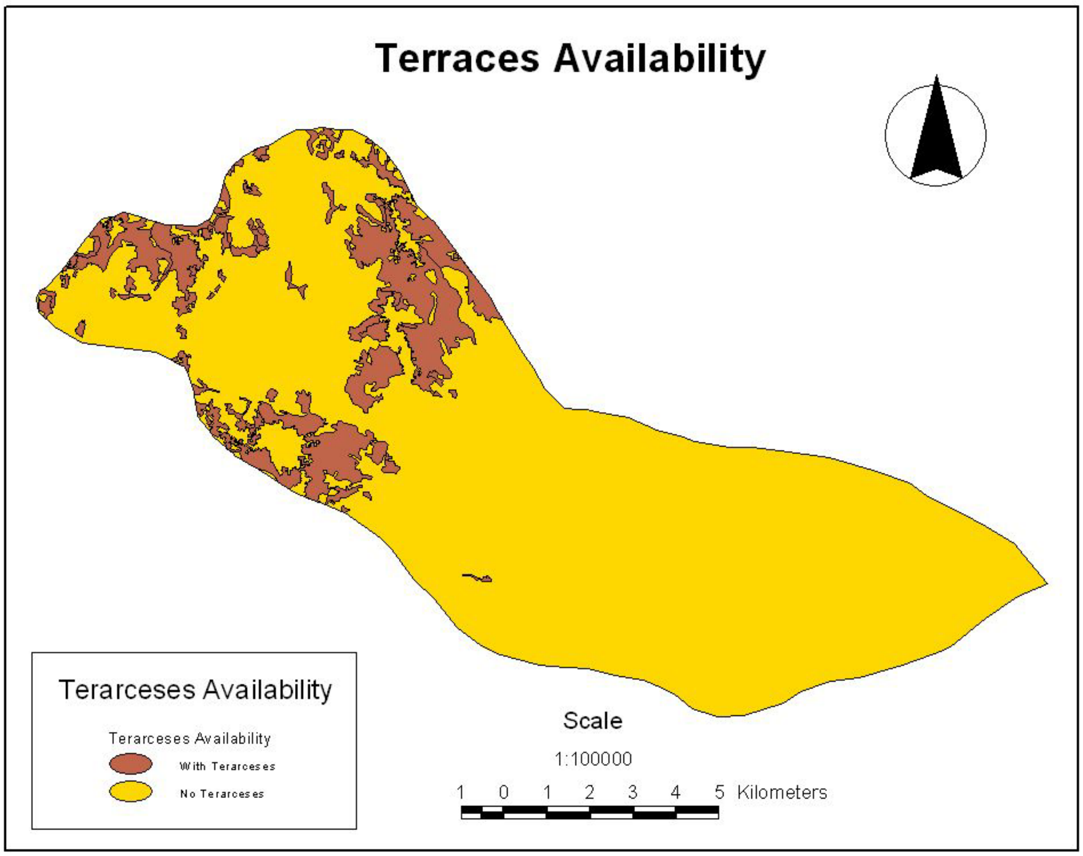

Figure 20: Areas occupied by terraces as the main management practices prevailing in the study area.

Average Annual Soil Loss

The RUSLE equation was run using the different grid surfaces created by ArcView spatial analyst. In order to ease the presentation of the output data, the map will show two main categories (Figure 21);equal or less than 5 Mg ha^{-1} and greater than 5 Mg ha^{-1}. The largest size among soil loss categories is that belongs to the 0-5 Mg ha^{-1} per year (Figure 21).

Many researchers use the term soil loss tolerance (SLT) in soil erosion studies. SLT denotes the maximum allowable soil loss that will sustain an economic and high level of productivity (Wischmeier and Smith , 1978; Renard et al., 1996; Foster et al., 2002). The normal soil loss tolerance values range from 5 Mg ha^{-1} to 11 Mg ha^{-1} per year for different soils and under different environmental condition.

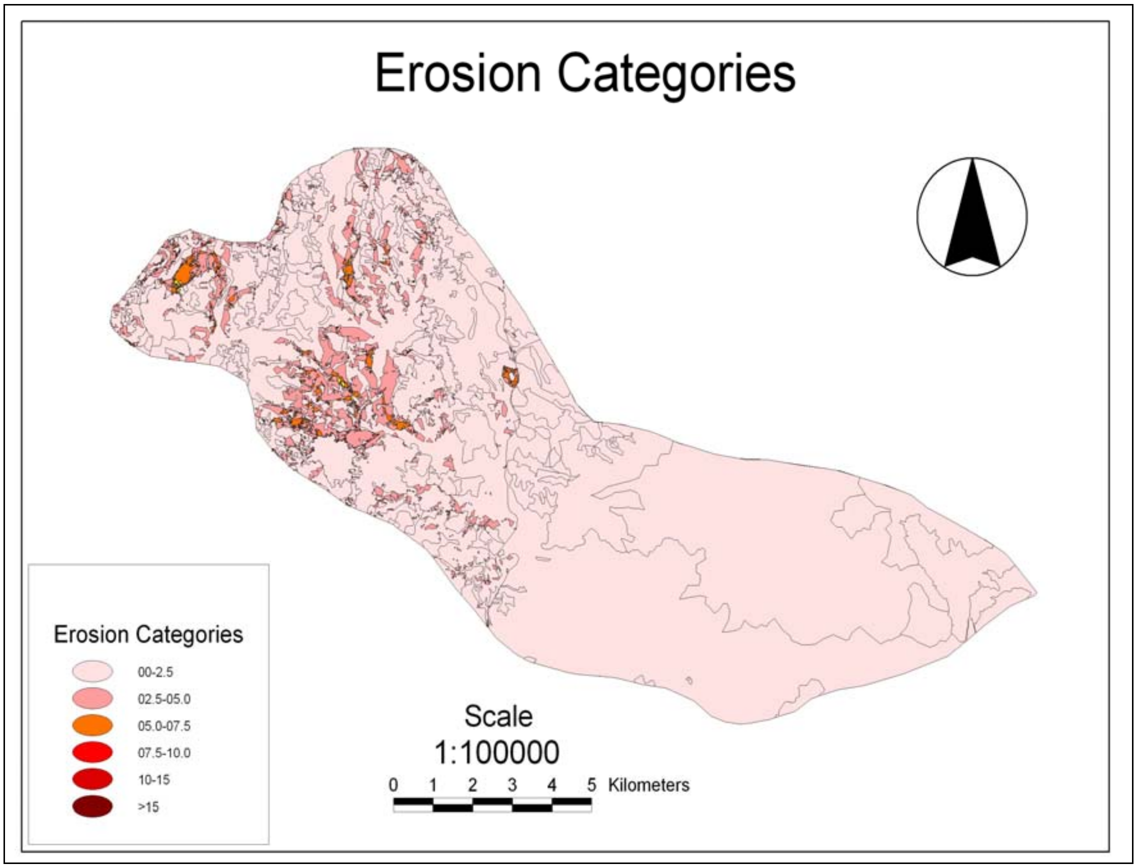

Figure 21: Annual soil loss output from RUSLE simulation.

The assignment of a range depends on the judgment of how much erosion will be harmful to the soil. Consequently, soils with shallow depth and fragile ecosystem are assigned the lower level of SLT (Foster et al., 2002). For soils with large depth and good physical characteristics, the upper limit of SLT is used.

In the study area, most of the soils' types have shallow to moderate depth (less than 100 cm), with low organic matter (1-3%), weak aggregates and fragile ecosystem (high evaporation, steepness, tense rainfall, etc.) For this reason, the lower limit of SLT will be used to assess the high erosion risk areas. Areas with higher soil loss potential than the SLT are shown in Figure 22. Categorization of different erosion potential followed up the FAO basic

classification of desertification (FAO and UNEP , 1984), with some modification to suite the uniqueness of the study area (Table 3).
Cell by cell calculations from the map of the soil erosion risk revealed that the total area with a soil loss potential higher than the SLT is 3724 dunums (Table 3 and Figure 22), which comprises 2.9% from the total area of the watershed. The results of the average soil erosion in the watershed (≈ 4.5 Mg ha^{-1}) also fit well with an assessment of soil erosion done in the northern part of Iraq, where areas with similar ecosystem have an average annual soil loss of about 5 Mg ha^{-1} (Hussein , 1998a). In general, the results followed up the same trend in other similar areas of the Mediterranean, where the average annual soil loss was estimated at 5-10 Mg ha^{-1} (Martinez-Casasnovas et al., 2002).

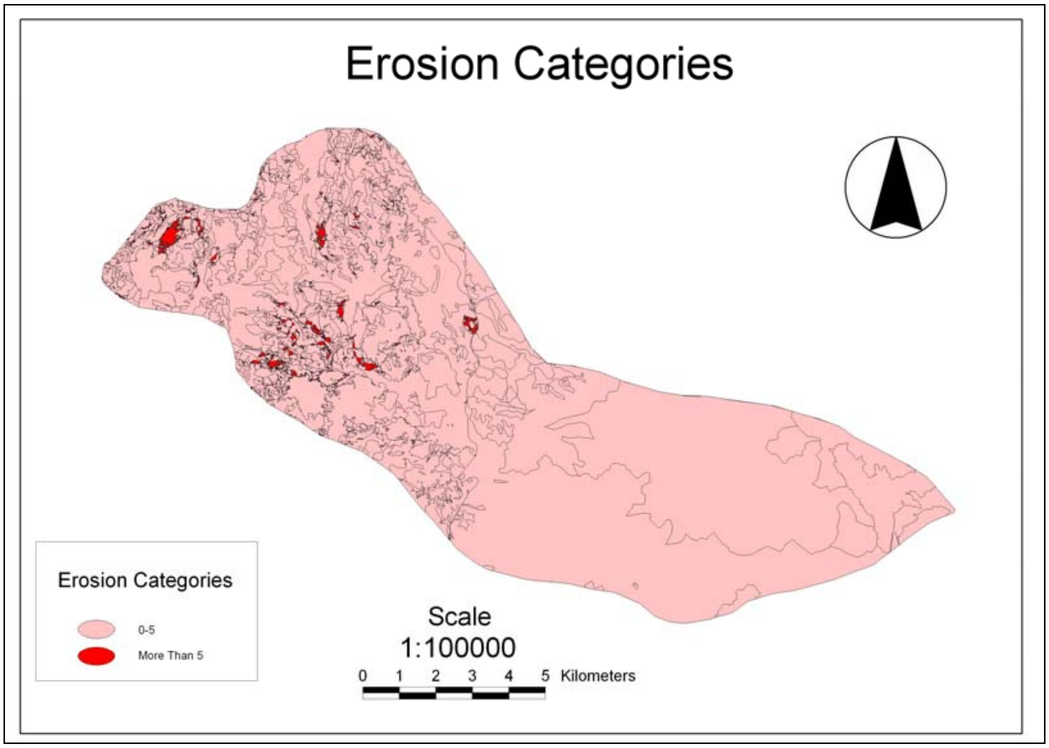

Figure 22: Annual soil loss according to level assigned to the soil loss tolerance.

Table 3: Different categories of annual soil loss potential with the total area, proportion from the total watershed area and different erosion categories.

Annual soil loss range (Mg ha^{-1})	Area (dunum)	% From total area	Erosion potential
0 - 2.5	118536	91.9	Slight
2.5 - 5.0	6369	4.9	Moderate
5.0-7.5	3214	2.5	High
7.5 - 10.0	307	0.3	Very High
10.0 - 15.0	237	0.2	Extreme
> 15.0	236	0.2	Very extreme

Most of the areas having higher soil loss than 5 Mg ha^{-1} (i.e. more than the SLT) are located in the western part; (Figure 22). A detailed investigation showed that the most pronounced RUSLE factor that enhanced soil erosion and caused high soil loss potential are the slope length (L) and steepness (S) factors. This is because the majority of the area that have higher soil loss than 5 Mg ha^{-1} are accompanied with a length factor greater than 3 cells (equivalent to λ of 90 meters), and slope steepness (θ) greater than 12° (about 18%) . Besides, areas with soil loss greater than 5 Mg ha^{-1}, in the western part of the watershed, are accompanied with relatively higher soil erodibilty factor (K > 0.02 Mg h MJ^{-1} mm^{-1}), and rain erosivity factor (R > 200 MJ mm ha^{-1} h^{-1}), which resulted in higher soil loss as compared to the surrounding areas.

The annual soil loss values generated by the RUSLE model were subjected to errors, included in different data and different GIS layers that are created by ArcView software. Some of these included errors in digitizing the contour map, soil layer, land cover as well as the support practices (terracing) from aerial photographs. The processing of these different layers, by multiplication, into ArcView will result in the magnification of the total error term. Nevertheless, the subdivision of the watershed into small cells (900 m^2) increased the accuracy of RUSLE prediction, and enabled the point-specific identification of areas with high erosion potential. The assessment of soil erosion risk potential comprises a valuable tool for planning successful and sustainable management practices, especially for those areas with severe erosion potential. The assessment is particularly useful in poor countries with limited financial resources, since it provides quick, efficient and targeted research output, aiming at the implementation of soil conservation measures in areas with greatest impacts on mitigation of soil erosion.

Finally, the identification of areas with high soil loss potential (Figure 22) necessitates the application of certain conservation and management practices. Although the use of terraces is effective in reducing erosion, farmers cannot afford the high cost of their construction, in addition to the difficulties encountered as a result of their constructions in steep and hilly areas. Cheap, easy, practical and affordable methods to farmers, in order to control the high soil loss rate, are though important. One alternative could be the use of stone lines to break the slope length into shorter distances, reducing overland flow velocity and the associated soil erosion (Gritchley et al., 1994). The use of contour tillage and grass strip barriers could be another practical solutions. This practice would reduce the effect of slope steepness and length by counteracting the overland flow direction, reducing its velocity, provide surface protection against raindrop impact, and form barriers to trap eroded soil material a long the slope (Goldreich and Karni , 2001; Angima et al., 2003; Renard et al., 1996).

Generally speaking, the removal of plant residue, plowing the olive groves several times, the lack of vegetative cover during the critical period of rainfall with high erosivity, and the lack of support practices (contour planting, strip cropping and other vegetative barriers) that could reduce the effect of runoff on steep areas, all should be avoided in the high soil loss potential areas, which has been identified in our assessment.

Upon changing one or more of the above-mentioned practices, a check should then be undertaken to test for efficiency. This process can be done easily by adjusting the RUSLE-GIS database and rerunning the model again, which will provide a judgment on the efficiency of each single management and conservation practices, and ensures that the most efficient, practical and cheaper one will be adopted in the area.

TESTING AND VALIDATION OF THE RUSLE FACTORS

Rainfall erosivity factor (R)

Table 4 shows the annual R-factor for the year 2005/2006 as well as the long term average (more than five years). These annual values represent the two extremes of rainfall erosivity; dry and wet years. Studies on rainfall erosivity factor in similar area of the Mediterranean showed nearly similar R-factor, ranging from 800 to 1100 MJ mm ha^{-1} h^{-1} (Upadhyay , 1991). Other studies in the northern part of Iraq showed erosivity twice in the magnitude as that in the study area, where the range was 600 to 2000 MJ mm ha^{-1} h^{-1} (Hussein , 1998b). This difference in erosivity is attributed mainly to the different characteristics of rainfall in both study areas, especially those related to rainfall intensity.

Table 4: Maximum 30-minutes intensity (I30), yearly and 5-years average rainfall erosivity.

	I30 (mm h^{-1})	R (MJ mm ha^{-1} h^{-1})
2000 season	**10.5**	**351**
2001 season	**29.5**	**1006**
2005 season	**12.7**	**874**
5-years average	**15.4**	**760**

Figure 23 shows the rainfall erosivity distribution on half-month basis for the study area. In general, most of the erosive rain occurs in short period (January and February), which is applicable on yearly as well as 5-years average basis.

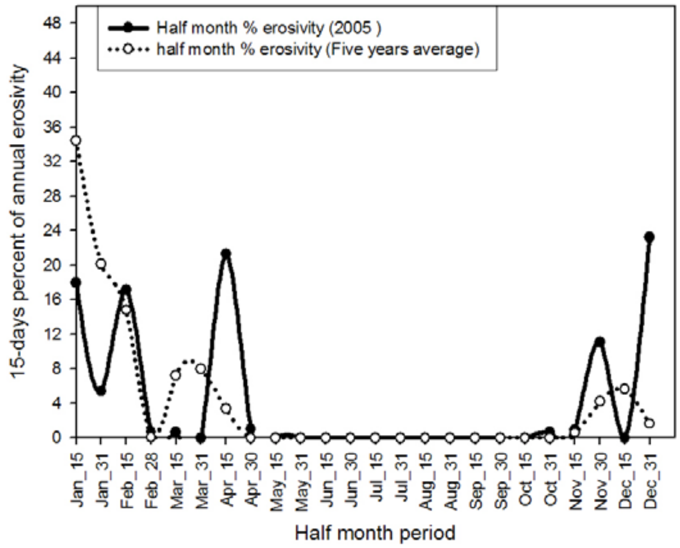

Figure 23: Rainfall erosivity distribution for the 2005 season and the 5-years average distribution.

About 70% of the annual rain erosivity occurs during the first 60 days beginning from January 1st (Figure 24), the remaining occurs during March and December. In general, January is the most erosive month of the year, with about 55% of the annual rain erosivity (Figure 24). During this period, the plant canopy height is less than 5 cm, with poor protection against direct raindrop impact. The combination of high erosivity with poor vegetative cover at this time causes a detrimental effect: increasing soil aggregate slacking and disintegration, with a final increase in runoff and erosion (Barthes and Roose , 2002).

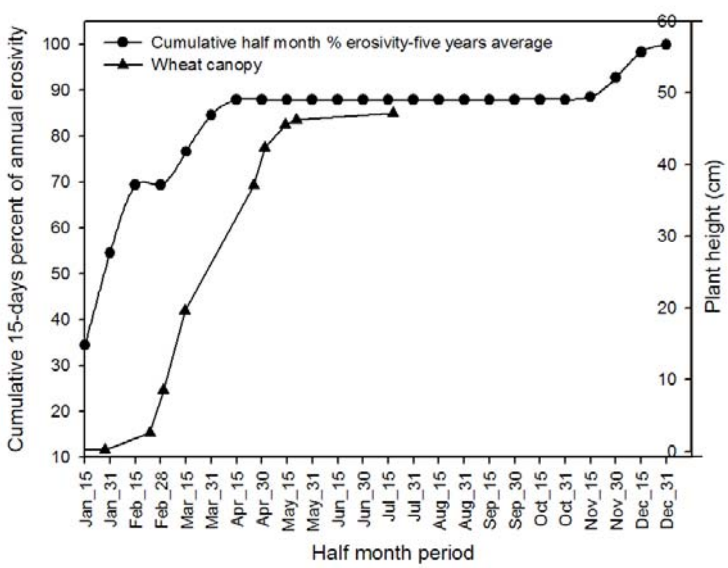

Figure 24: Cumulative half-month rainfall erosivity, based on 5-year average distribution, and wheat canopy height on half month basis for 2005 season.

Soil erodibility factor (K)

RUSLE K-factor depends on a combination of soil and climatic parameters developed under specific conditions in the USA, which might not be suitable to different conditions in other parts of the world, such as in the study area. Besides, the RUSLE K-factor assumes a constant value with time. Antecedent soil moisture, spatial and temporal soil and rainfall variability results in dynamic K-factor with time and space, which is not accounted for in the RUSLE K-factor, especially when applied to climatic conditions differ from those in the USA (Renard et al., 1996; Wang et al., 2001). Hence, adjustment of K-factor is necessary.

Field measurement of soil moisture tension and temporal K-factor (Figure 25), emphasized the aforementioned facts, and necessitates the adjustment of K-factor at different time. In general, Figure 25 shows that K-factor is highest at lower SMT. The highest K-factor occurs in December and January (Figure 25). The spatial change of K-factor according to different soil types is not possible to check in this study. This is because of the large area of the watershed and the difficulties of movement as well as the needs for more devices to check for the relation between soil moisture tension and the associated K-factors.

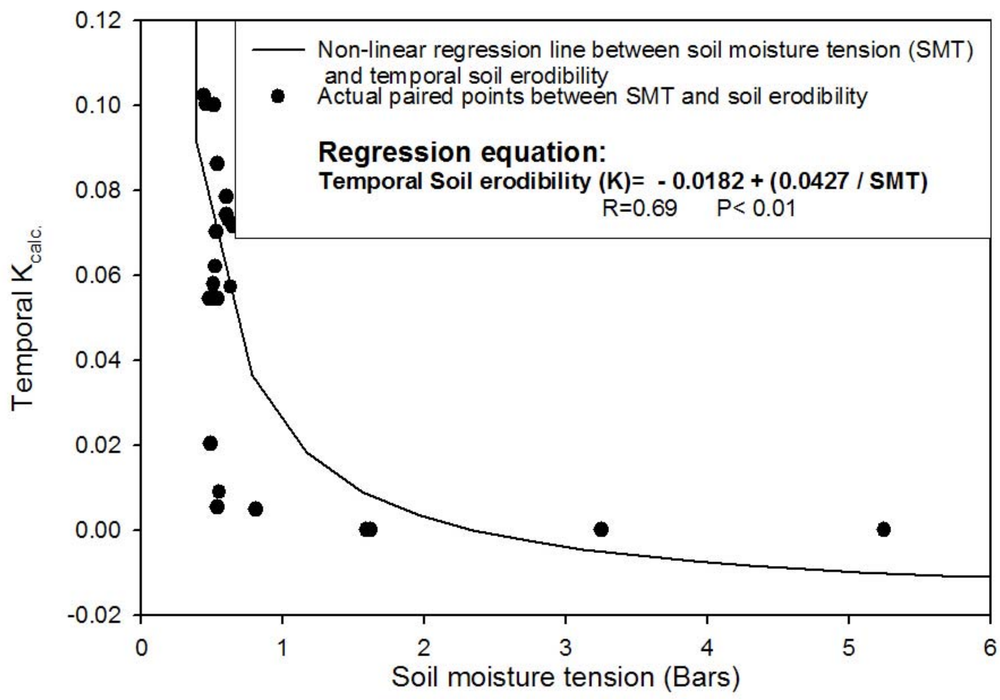

Figure 25: Cumulative storms' K-factors at different soil moisture tension during the winter season.

Available measurements, from natural runoff plots in the study area, indicate that the RUSLE K-factor overestimates measured K-factor of the area by 2.5-24 times (Table 5), which is the result of the aforementioned reasons.

Results from other studies in the Mediterranean region showed RUSLE K-factors that are almost similar to the findings of this study (Arhonditsis et al., 2002; Hussein , 1998a). Research from the northern part of the Middle East, specifically in Iraq, showed a nearly 10 times lower value of measured K-factor than RUSLE K-factor (Hussein , 1998a), which is consistent with what the findings of this study. These previous researches have applied the same method of calculating RUSLE K-factor, as this study did. Besides, they did not account for variations in K according to soil and climate variability.
To account for temporal variability in K-factor, a regression analysis between the ratios of cumulative measured-K to RUSLE K-factor and the soil moisture tension was achieved. The regression shows a highly significant correlation ($P<1\%$) between both factors (Figure 26).

Table 5: RUSLE calculated and measured annual soil erodibility factor (K) for the different experimental plots in the two locations.

Plot number	Organic matter (%)	RUSLE-calculated K (Mg h MJ^{-1} mm^{-1})	Measured K (Mg h MJ^{-1} mm^{-1})	Ratio of RUSLE K factor to Measured K-factor
1	2.4	0.043	0.015	2.9
2	2.8	0.024	0.001	24
3	3.7	0.032	0.007	4.5
4	2.6	0.045	0.018	2.5
5	3.1	0.044	0.011	4
6	3.5	0.015	0.001	15

The equation represents a good tool for estimating the real K-factor at any time of the winter season, provided that soil moisture tension at that time is known. The overall measured K-factor at the end of the season could be estimated by measuring the soil moisture tension at that time, in addition to knowledge on RUSLE K-factor from the normal RUSLE calculation. The only error of this equation is its limited range in soil moisture tension (0.25- 0.75 bar), beyond this range; the equation cannot predict the magnitude of the measured K-factor.

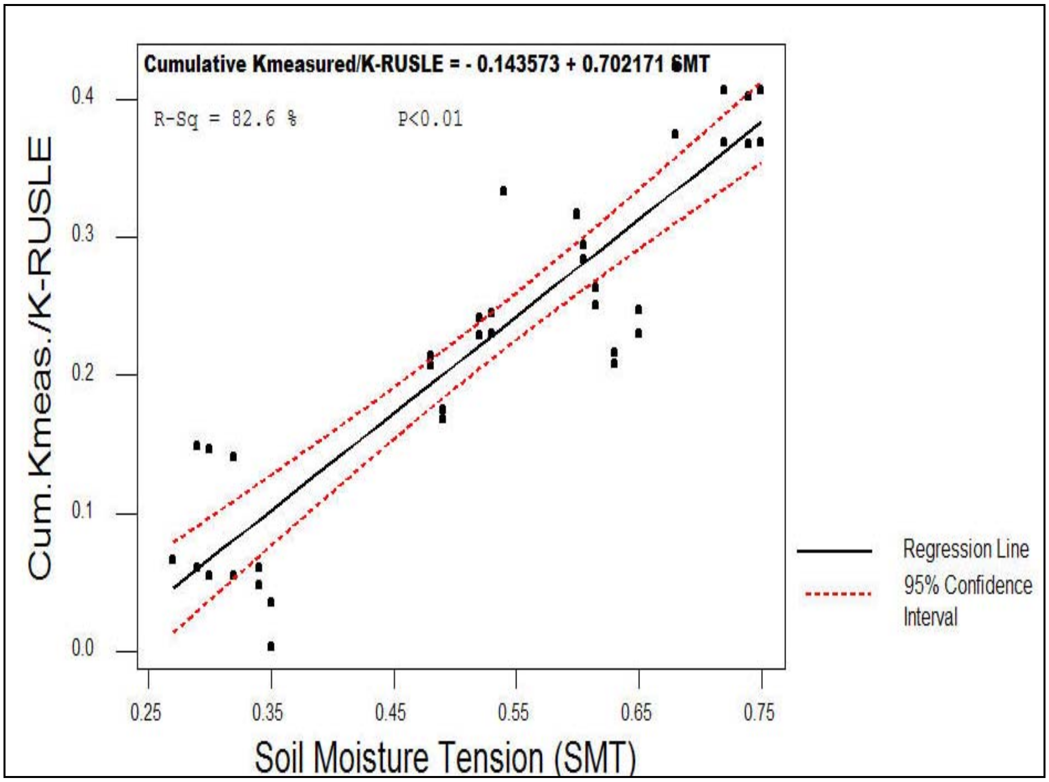

Figure 26: Linear regression relation between the ratios of the cumulative measured K-factor to the cumulative RUSLE K-factor with the temporal soil moisture variations.

Slope length and steepness factor (LS)

RUSLE LS-factor was derived originally from experimental data on slopes not exceeding 18º and length of 91.4 meters (300 ft). Beyond these ranges, the relationship of LS factor cannot be judged for accuracy, since the calculation of the LS-factor will deviate from the original range of the experimental data (Wischmeier and Smith , 1978). Table 6 shows the LS-factor with the associated sub factors used in different equations for the RUSLE calculation of the LS-factor.

Table 6: Slope length and steepness factor with their associated sub factors derived from different RUSLE equations. Values are the mean of six replicates.

Parameter	
ß	**0.51**
m	**0.34**
λ	**14.99**
LS-factor	**0.36**

Previous researches done on the calculation of m factor, which has been conducted from direct measurements of interrill erosion and splash erosion into similar ecosystem area, showed closely related ß and m to those calculated by the RUSLE, where the measured ß and m is 0.51 and 0.34 (Abu Hammad et al., 2004; Abu Hammad et al., 2003). Hence, RUSLE provides a good approximation for the ratio between erosion by overland flow and splash erosion. Consequently, RUSLE calculated LS-factor is a good approximation to the measured LS-factor for the study area.

Crop management factor (C)

The C-factor reflects the effect of any surface cover related to management as well as human related activities on soil erosion (Renard et al., 1991), hence, it is one of the important RUSLE factor.

Actual measurement of the C-factor indicates a higher C value than the RUSLE calculated one (Table 7). The measured C value is 1.4 times the RUSLE C-factor. The reason could be the deviation of the RUSLE calculated sub factors from the actual conditions of the study area. For example, RUSLE approximates soil moisture sub-factor (SM) according to a fixed soil moisture replenishment-depletion pattern, whereas this pattern is different in the study area (Figure 27). RUSLE assumes a linear ascending C-factor over the rainy season, regardless of the nature of the rain (i.e. intensity, amount, etc.), and the variation in soil moisture over the season due to the variations in different climatic parameters (i.e. temperature, wind and humidity). Whereas under actual condition of the study area; variations during the season might produce variations in the C factor. The differences between RUSLE and measured C-factor occur mainly when soil moisture tension is below one bar, whereas differences are negligible above that range of SMT (Figure 27).

Table 7: Average RUSLE calculated and field measured crop management factor (C) during the winter season of 2005.

Parameter	
Average calculated C*	**0.359**
Average field measured C*	**0.515**

*: Values are average of twelve replicates.

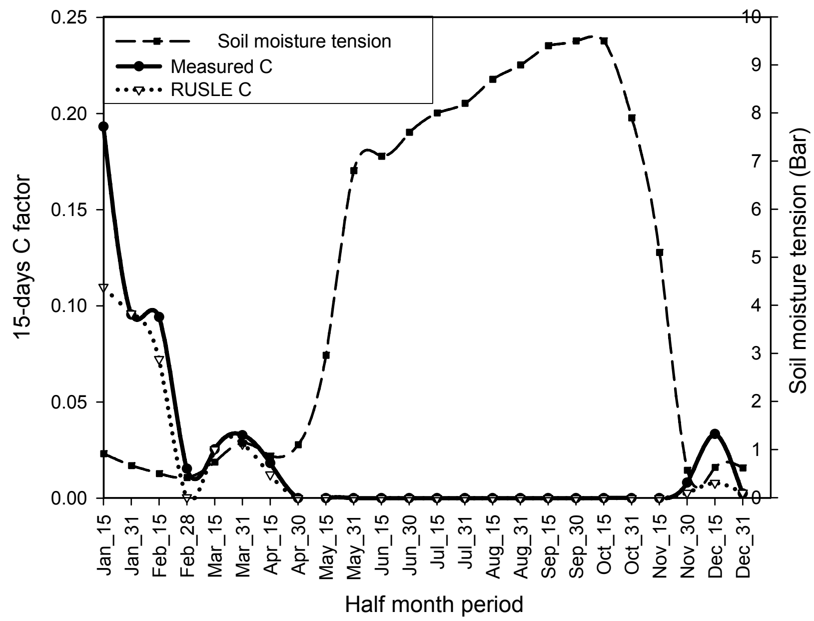

Figure 27: Actual soil moisture variations (replenishment-depletion) pattern for the study area, with measured C-factor and RUSLE C-factor based on 15-days periods.

Most of the differences between the RUSLE C-factor and the measured one took place during January to March. The differences were negligible during the rest of the season.

Antecedent soil moisture is important since it has a substantial effect on soil hydraulic properties (i.e. infiltration rate, hydraulic conductivity and permeability), hence soil hydraulic properties affecting soil erodibility by affecting soil aggregate stability and the ability of the soil to move water throughout its profile, both vertically and horizontally. The influence of the existing management practices through the C-factor is influential due to the protective effect to the soil surface as well as the enhancement of soil aggregations and other associated soil physical properties (Renard et al., 1996; Marceau and Hay , 1999; Foster et al., 2002). As a consequent, relationship between the measured C-factor, the RUSLE C-factor and the SMT is essential to adjust for the effect of soil moisture variations at different time of the season, especially during high moisture content with weak topsoil aggregate stability. Exponential regression, for the difference between measured C and RUSLE C-factor with SMT, reveals a highly significant relationship between these parameters ($P<0.01$), with R^2 of 0.55 (Figure 28). This relationship is useful for the adjustment of RUSLE C-factor to suit the actual conditions of the study area. The Figure also emphasizes the aforementioned fact: that the main differences between both C factors occur only under nearly saturated conditions (SMT < 1 bar). Rearranging the equation of Figure 28 gives the following equation:

$$\mathbf{C_{measured} = C_{RUSLE} +(5*10^{-4}+ 0.0933*exp^{(-3.97*SMT)} -1*10^{-4}*SMT)} \quad \mathbf{(3)}$$

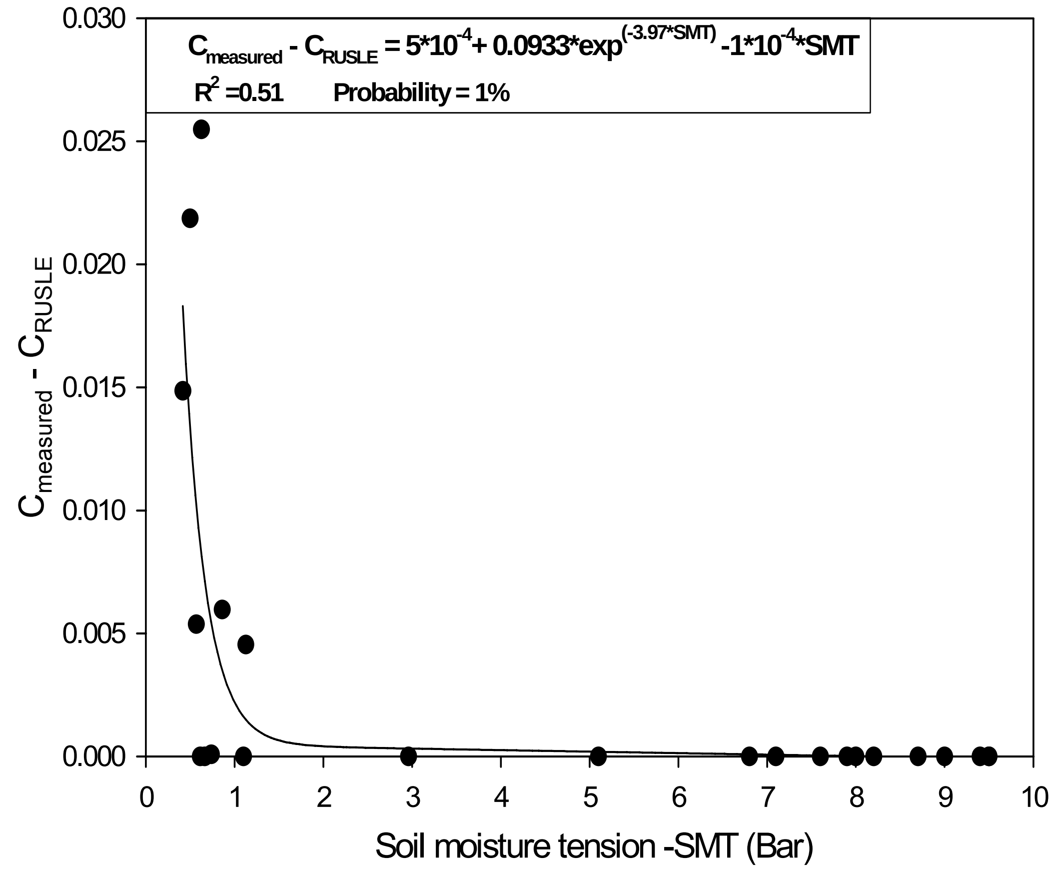

Figure 28: Exponential regression relationship for the difference between measured C and RUSLE C with the soil moisture tension (SMT).

Conservation practices factor (P)

The conservation practice factor is mainly related to certain soil conservation measure, which will reduce the effect of slope on soil erosion (Mati and Veihe , 2001). RUSLE computation of the P-factor for terraces, depends on the spacing between successive terraces. The result shows that RUSLE P-factor overestimates the actual P-factor (Table 8) by almost 2.8 times (RUSLE P is 0.55, and average measured P is 0.21). Adjustment of the RUSLE P-factor is necessary, so as to increase its accuracy to predict the actual effect of terraces in the study area. The adjustment can be done using the following simple equation:

$$\mathbf{P_{measured} = 0.32 * P_{RUSLE}} \qquad \mathbf{(4)}$$

Table 8: RUSLE calculated P factor, and actual measured P factor for the experimental field plots. Values for measured P are the mean of two replicates.

Plot number	RUSLE P factor	Measured P factor	Ratio between RUSLE P & Measured P
1	0.55	0.11	5
2	0.55	0.33	1.7
3	0.55	0.20	2.8
4	0.55	0.13	4.2
5	0.55	0.23	2.4
6	0.55	0.22	2.5

Testing and calibration of the RUSLE model

The process of testing a model aims to define uncertainties related to the prediction of the model, whereas calibration of the model aims to choose the best set of parameters, so as to increase its accuracy and predictability for the actual conditions, and finally to achieve good fit between simulated and measured values (Grayson and Bloschl , 2001).

RUSLE testing indicates an overestimation of the actual soil loss (Figure 29). The average simulated RUSLE soil loss is 4.8 Mg ha^{-1}, while the average measured soil loss is 2.6 Mg ha^{-1}. The ratio between the total measured soil losses to RUSLE simulation is 0.54. Hence, RUSLE is overestimating the actual soil loss by almost tow times.

The Nash-Stucliffe efficiency coefficient (R_s^2) is a measure of the model efficiency. Nash- Stucliffe coefficient avoids the influence of different scales of the model output values on the model performance and efficiency (Nash and Shutcliff , 1970; Refsgaard , 1997; Christiaens and Feyen , 2001b), and hence, R_s^2 is a measure of the deviation of simulated values from the measured ones. R_s^2 is calculated according to the following formula:

$$\mathbf{R_s^2 = 1\text{-}[\sum (Q_{simulated}\text{-} Q_{measured})^2 / \sum (Q_{simulated}\text{-} Q_{measured\text{-}mean})^2] \qquad (5)}$$

The calculation of R_s^2, for the simulated RUSLE soil erosion with the measured soil erosion from the field plots, indicates low efficiency of the RUSLE model (R_s^2 = 0.24) under the investigated conditions.

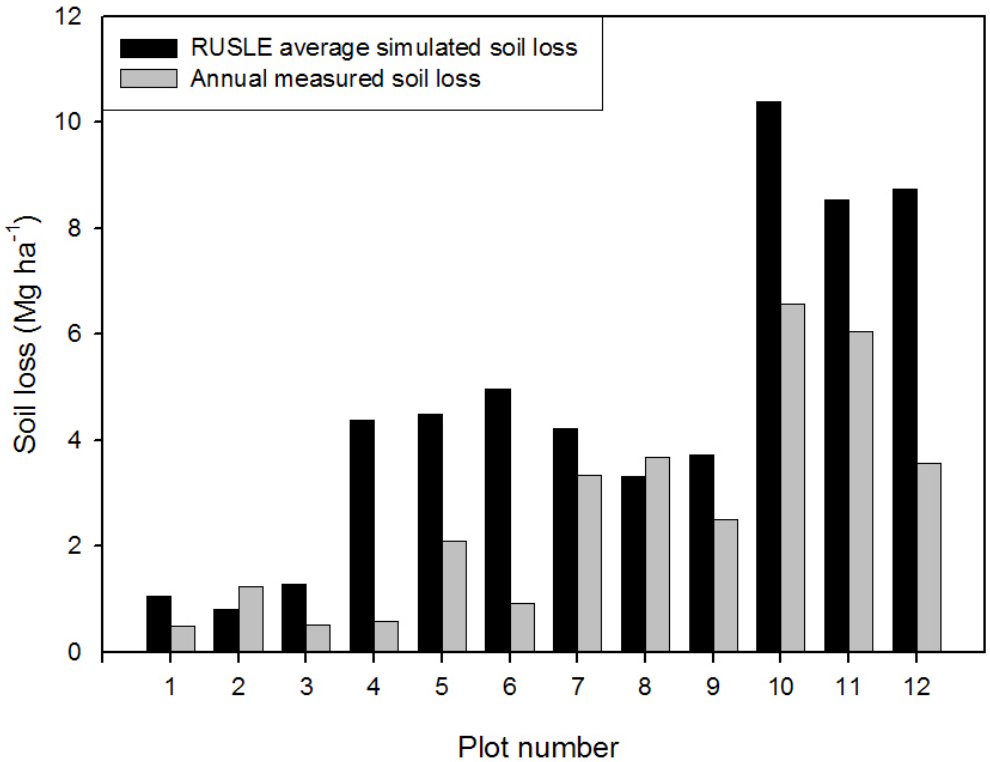

Figure 29: Measured and RUSLE simulated annual average soil loss, for different experimental plots during 2005. Terraced plots from are 1 to 6 and non-terraced plots are from 7-12.

To optimize the prediction potential of the RUSLE soil loss estimates, which aims at increasing the fit between simulated and measured values, RUSLE equation will be modified according to the calibration, which was done in previous sections of the report and for different RUSLE factors. Accordingly, the final modified RUSLE equation will be as follows:

$$A = R_{5\text{-years average}} * [(K_{RUSLE} *(-0.144 + 0.702*SMT)] * LS * C_{RUSLE} + (5*10^{-4} + 0.0933*\exp^{(-3.97*SMT)} - 1*10^{-4}*SMT) * (0.32* P_{RUSLE}) \quad (6)$$

For the calculation of adjusted K and C factors, the SMT is assumed to be 0.5 bar all the time, which is a valid assumption, since the average soil moisture tension during the whole rainy season did not exceed 0.5 bar.

The result of the RUSLE calibration process, using the adjusted RUSLE factors, shows close values of RUSLE predicted soil loss and measured ones (Figure 30), where the average adjusted RUSLE value is close to the measured one (1.6 and 2.63 Mg ha^{-1}, respectively). The ratio between the total measured soil losses to adjusted RUSLE value is 1.6. Though, adjusted RUSLE is underestimating the actual soil loss by about 60%. The calculation of R_s^2

indicates an acceptable efficiency of the adjusted RUSLE model (R_s^2 = 0.42) with the new adjusted factors under the prevailing conditions of the study area. Further adjustment and future detailed researches are needed for more accurate and precise calibration of different RUSLE factors to obtain more convenient soil erosion risk assessment in the study area and other similar area, taking into consideration the specificity of the climatic and geomorphologic factors.

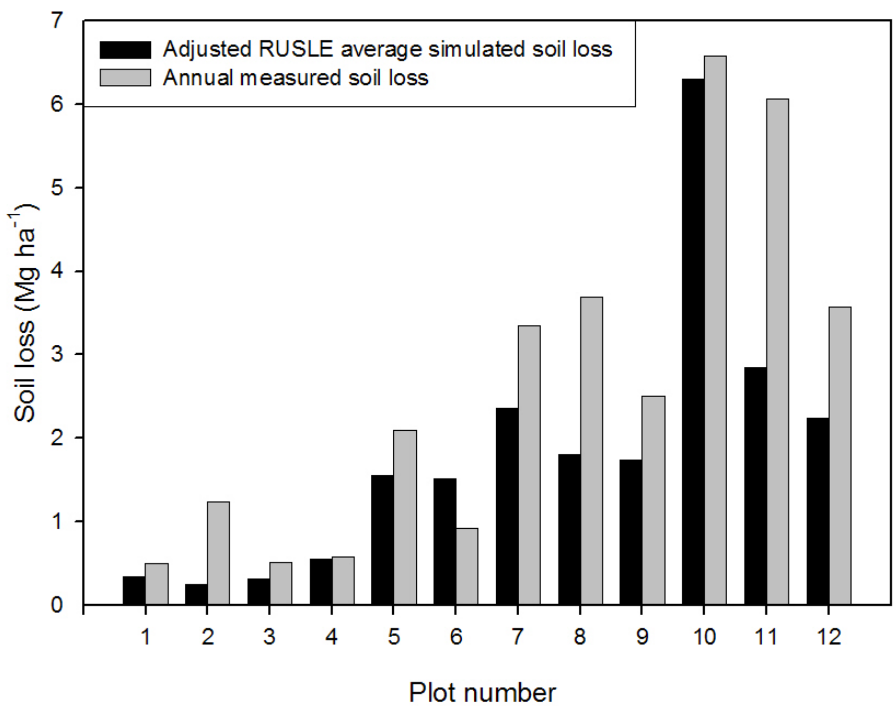

Figure 30: Measured and Adjusted RUSLE average annual soil loss for different experimental plots during 2005. Terraced plots are from 1 to 6 and non-terraced plots are from 7-12.

SOCIOECONOMIC FACTORS AFFECTING LAND DEGRADATION BY SOIL EROSION

Land soil cover is one of the basic components of agriculture, especially in the developing countries of the world, especially those countries having limited natural resources. In many of these countries, land is currently subjected to land degradation that is the result of different factors amongst is soil erosion and human-related factors (i.e. overgrazing, random expansion of built up areas, pollutions, etc.). Soil erosion, particularly in the developing countries, creates serious social, economic and ecological problems (Graaf , 1993; Anderson and Thampapillai , 1990) resulting in severe land degradation. The word ‘degradation’ in its Latin derivative means reduction to a lower rank (Blaikie and Brookfield , 1987). When soil degradation occurs, an associated qualitative and quantitative decline in its productivity will also occur (Anderson and Thampapillai , 1990; Blaikie and Brookfield , 1987).

Degradation by soil erosion is a three-stage process; the detachment of soil particles by raindrop impact; the transportation of the detached particles by runoff water; and the deposition of these particles in other areas (Morgan , 1986; Sfeir-Younis and Dragun , 1993). Such processes usually interact with each other (Graaf , 1993). However, human interference is one of the important factors that is affecting the rate and type of existing soil erosion (Blaikie and Brookfield , 1987; Johnson and Lewis , 1995). Human interference may or may not be deleterious in its effect (Graaf , 1993). In some cases, human interference may result in the restoration, conservation, and improvement of the soil properties and create favorable ecosystems (Graaf , 1993). Land degradation necessitates that soil conservation be an important part of the agricultural production system. Soil conservation is not only limited to the technical part of solving the problem of land degradation, soil conservation may also include any set of social and economic measures aimed at the control of land degradation (Graaf , 1993). Farmers' perception of land degradation is one of the detrimental social factors, it is an important factor in understanding, as well as adopting different alternatives for controlling land degradation (Graaf , 1993). The farmers' perception of land degradation includes, but is not restricted to, the farmers' awareness of the problem, their attitudes on how to solve the problem, and the farmers' socioeconomic interactions along with their economic capacity to solve the problem (Graaf , 1993; Kikula , 1989).
Under the arid and semi-arid conditions of the Mediterranean, the land is heavily degraded, especially in the sloppy areas where grassland, woodland and forests have been replaced by other Mediterranean annuals since hundreds of years and as a result of the social, political and economic changes that were and still occurring (Cocks and Osman , 1996).

Due to its mountainous nature, the study area has numerous stonewalled terraces that are accompanying the sides of the steep mountains. Many of these terraces were initially built thousands of years ago. Most of these terraces are being used for agricultural purposes as they were used in ancient times, specifically the cultivation of olive groves and vineyards (Edelstein and Gat , 1981; Ron , 1966). These agricultural terraces cover about 30% of the mountains in the study area.

The main technical reason for using terraces is that terraces cause a reduction of the slopes steepness and length, decreasing the role of the natural slope and length function in the erosion process. Due to the slope steepness and length reduction, terraces ease erosion as a result of increasing the infiltration rate, reducing the overland flow's velocity, quantity and its associated energy (Wakindiki and Ben-Hur , 2002; Gachene et al., 1997).

Palestine in general and the study area in specific are subjected to negative environmental and socioeconomic changes, especially after Oslo agreement in 1993. These changes led to either partial or complete abandonment of large terraced areas. The abandonment of terraces caused terraces deterioration and a consequent increase in soil erosion and land degradation. Added to the deriving forces of land degradation are the fragile ecosystem prevailing in the area where its mainly characterized by semi-arid conditions, erratic rainfall events and long drought periods with poor vegetative cover, resulting in severe runoff and soil erosion (Soil and Water Conservation Society , 1994).

Study area, Agro-climate and settlements pattern

The study area was selected based on the presence of soil conservation techniques, in addition to the similarities in land use, topography, as well as the prevailing management practices. Besides, the study area has been chosen so as to represent two main climatic and geomorphologic characteristics for comparison between diverse ecosystems as well as socioecono0mic settings related to the prevailing environmental conditions.

Based on the mentioned criteria, twelve villages in the study area were chosen to conduct the field survey of the socioeconomic factors affecting land degradation (Figure 11). The study area represents a typical terrestrial Mediterranean ecosystem with limited arable lands. The shortage of arable land has been compensated by the construction of an extensive system of terraces to minimize soil erosion, and suit the land for agricultural uses. Terraces are mainly concentrating in the western part of the study area due to the diverse and rough geomorphology existing in this part, whereas in the eastern part, terraces are not common due to the nature of the topography as well as the prevailing climate (mostly the area is level with low amount of rainfall not exceeding 150 mm annually).

The total area of the watershed is about 128.9 km^2 with a total population of 36,284 in 2006, constituting about 3% of the total watershed population. The total built up areas of the surveyed villages is about 8.7 km^2, comprising about 6.4% of the total watershed area**.**

The villages that have been surveyed acquire diverse geomorphologic and climatic characteristics. The watershed area has a shallow (< 50 cm) to moderate (50-100 cm) soil depth and moderate to steep slope (7-14º and >14º respectively). The elevation ranges from -230 m to about 1000 m above sea level in the eastern and western part of the watershed, respectively. Distinctive summer and winter season characterizes the area. The mean annual rainfall ranges from 150 mm to more than 600 mm in the eastern and the western part of the watershed area, respectively. Most of the rainfall (>90% of the mean annual rainfall) occurs in the winter period during October to April (Ministry of Transport , 1998), and there is no rainfall during the summer. The mean monthly temperature is 21 ºC and 17 ºC in the eastern and western part, respectively. This caused a high mean annual potential evapotranspiration of >2000 mm especially in the eastern part of the watershed area (Land Research Center , 1999). July, August and September are the hottest months of the summer season (Ministry of Transport , 1998). According to USDA classification, the soil temperature and moisture regimes are Thermic and Xeric respectively in the western part, whereas its hyperthermic and aridic in the eastern part (Sternberg and Shoshany , 2001; Goldreich and Karni , 2001; Soil Survey Staff , 1998). The geological formation consisted mostly of limestone, marl and dolomite of the Turonian age (Abed , 1999). According to USDA classification, most of the soil of the watershed area is classified as Xerorthent in the western part and natrargid in the eastern part(Land Research Center , 1999; Dan et al., 1976), with clay to clay loam soil texture of the surface and sub-surface layers (0-15 cm and below 15 cm), respectively. Whereas in the eastern part, the soil texture is mainly silty loam to silty clay loam, for the surface and sub-surface layers, respectively.

Natural grassland and Woodland shrubs comprise the largest area of the watershed followed by olive groves and field crops (Table 9). During the wintertime, natural grassland has thick surface coverage in the western part, whereas the surface coverage at the same time period is sporadic and thin in the eastern part. During the summer time, most of these grasslands disappeared due to lack of soil moisture, overexploitation by the inhabitants as well as overgrazing in both parts of the watershed area.

Table 9: Different land uses existing in the study area.

Land use category	**Area (km^2)**	**% Of total watershed area**
Field crops	14.124	11.0
Natural grassland and Woodland shrubs	89.828	69.7
Olive groves	16.660	12.9
Built up areas	8.753	6.4

Land ownership, geomorphology, farmers' perception and adoption of soil-moisture conservation (terraces)

Pearson correlation coefficient measures the strength of the relation between two variables, whether this relation is positive (i.e. directly proportional) or negative (i.e. inversely proportional). Pearson's correlation coefficients between land ownership, geomorphology of the land, farmers' perception and adoption of soil conservation measures such as terraces, and the farmers' willingness to adopt soil conservation practice (terraces), are presented in Table 10. Table 10 reveals significant correlations between land ownership and the farmers' adoption of terraces (0.219). This relation means that the adoption of soil conservation measures increases by increasing the privately owned land by the farmers and vice versa, which is considered an important incentive for the farmers to take care of his land if it is owned by him, while when the land is not owned by the farmers, he will loose the interests to preserve it and he will concentrate only on getting more and more benefits from it (more productivity); once the land loose its value, the farmers would move to another land to get benefits from it. Table 10 also shows a positive relation between adoption of terraces and the geomorphology of the land. This statistically significant relationship emphasizes that topography (steepness of the topography), the shape and size of the topography as well as the soil surface cover (i.e. land uses) has key factors on the farmers' decision on whether to adopt terraces or not. Land with steep, concave or convex slope with tiny vegetative cover acquires more importance to be rehabilitated and terraced than leveled and non-sloppy areas. The adoption of soil conservation has also significant negative relation with the productivity of the land (from the farmers' point of view) that has conservation practices as well as with the farmers' continuous maintenance of such conservation practices (i.e. terraces). Such negative relations mean that farmers with high productivity of their land do not perceive well the benefit of soil conservation, which might be due to their small experience in such conservation practices as well as their lack of interests (due to the high productivity of their land); in addition, these farmers do not maintain such terraces because they do not feel it is necessary to do so due to the high productivity their land has. Another important and significant relation can be found between the farmers' adoption of terraces and the farmers' needs for different inputs for maintaining such terraces, although the relation is in the negative direction. This negatively directed correlation reveals that farmers' would adopt terraces in a lower rate as their needs from different inputs for conducting conservation increase and vice versa. As a consequent of such negative relation, it is obvious that incentives are necessary to encourage farmers to adopt conservation measures. Such incentives could come from either the private (NGOs) or the public sectors (the governmental institution).

Table 10: Pearson correlation coefficients between land geomorphology, ownership with farmers' adoption, perception and incentives for adoption of soil conservation measures (terraces).

Different studied variables	Land ownership	Farmers' adoption of soil conservation
Farmers' adoption of terraces (soil conservation)	0.219 [a]	_____
Geomorphology	0.198 [b]	-0.104
Farmers' perception of the benefit of soil conservation	-0.025	0.006
Productivity of land with and without terraces (farmers' perception)	0.055	-0.269 [a]
Farmers' maintenance of soil conservation	0.047	-0.508 [a]
Farmers' needs for maintenance (incentives)	-0.035	-0.152 [a]

[a] Significant at $P \leq 0.01$.
[b] Significant at $P \leq 0.05$.

Unfortunately, there are no systematic methods of supporting farmers with their basic needs to encourage them on the adoption of soil conservation from both type of institutions; private and public.

Generally speaking, land ownership and geomorphology, land productivity with and without soil conservation, the needs to maintain and utilize existing conservation practices are important variables affecting the farmers' perception, willingness and adoption of the conservation measures. To identify the most influential set of variables among the different variables, logistic regression was carried out between these variables. The output regression equation (equation 6) indicates that farmers who adopted terraces for soil-moisture conservation were mainly those privately owning the land and those who are getting more benefits (high productivity) from such conservation practices. Private ownership encourages the farmers and provides them with more incentives to conserve and manage their own land in the proper way (Figure 31). Land rent is a common practice in the area for people who cannot afford the high land price. The system of land ownership motivated the farmers to apply soil-moisture conservation measure because they became sure of reaping the benefits (Moore and Burch , 1986b), whereas the system of land renting was found to decrease the farmers' motivation for applying soil conservation, mainly due to the loss of insurance that they will reap the benefit at the end of any conservation process (Moore and Burch , 1986b; Moore and Burch , 1986a).

***Farmers who adopt soil conservation (terraces)* = -1.635 - 0.978 * (high productivity "code = 1") + 0.720* (private ownership "code = 1") (7)**

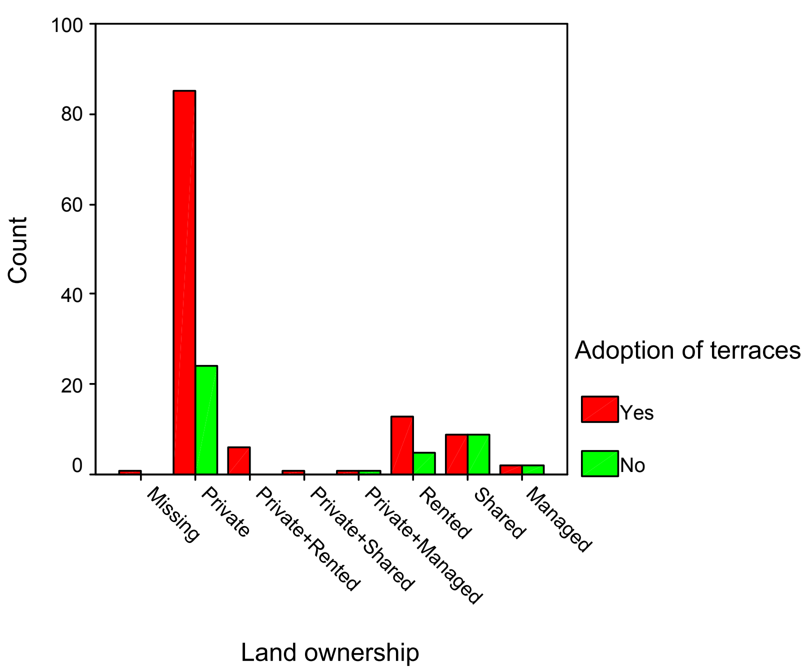

Figure 31: Count of privately and rented land with and without adopting soil-moisture conservation (terraces).

With regard to the effect of the farmers' perception of the benefit of soil conservation on the adoption of such conservation measures, logistic regression indicates that farmers, who have level land with deep soil, perceives the benefit of soil conservation more than other farmers in the sloppy area with shallow soil depths (equation 3). About 40% of the farmers who have level and deep soil farms perceived all the beneficial components of using terraces (Figure 32), whereas only 20% of the farmers with sloppy, mountainous and shallow soil depth farms perceived the same benefits. The main reason, for such a difference in perception of the benefits of soil conservation (terraces), is that farmers with soil conservation are getting direct benefits from such techniques (increase in productivity and the net profit), whereas farmers with no conservation are lacking these benefits and though they do not perceive well the benefits of terraces. This result emphasizes the effect of the direct benefits of soil conservation (terraces) on the farmers' perception and willingness to adopt soil-moisture conservation measures (Moore and Burch , 1986a).

***Farmers' perceived the benefits of soil conservation* = 2.882 + 0.112 * (level and deep soil "code= 1")** **(8)**

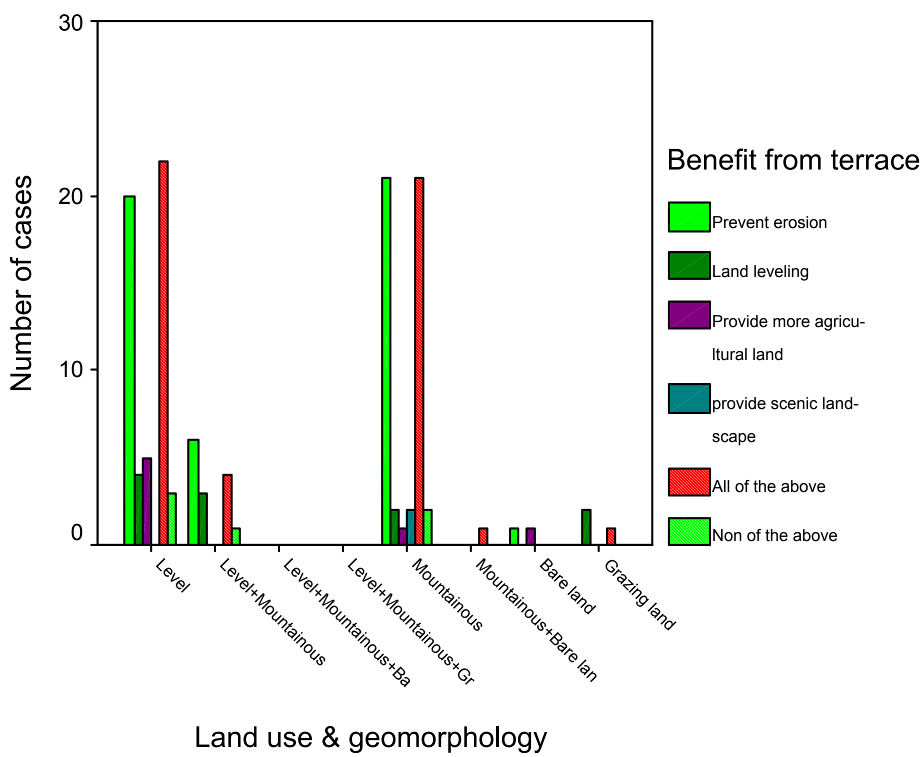

Figure 32: Geomorphologic categorization of all the farms in the study area with the farmers' perception of the benefit of soil-moisture conservation measures (terraces).

Relation of tenure size, land fragmentation and institutional support with soil conservation

Land fragmentation due to the traditional law of inheritance is increasing especially in village areas with large family members (i.e. brothers and sisters) (Christiaens and Feyen , 2001a). The process of land redistribution that is taking place in the study area, mainly by inheritance, is considered as an important factor undermining the decision-making for achieving a sustainable land use and to better conserve the lands by the application of different land use strategies, which will ultimately hinder the investment in soil conservation. Redistribution is also increasing the uncertainties and insecurities of farmers' returns from any future investment on soil conservation (ERDAS Inc. 1995). Hence, the farmers' willingness and adoption of different soil conservation measures can be negatively affected by decreasing their tenure size through inheritance. In turn, the decrease in the farmers' tenure size may result in a decrease in the expected benefits. A high risk of profit-failure is also accompanied with small tenure size, especially when soil conservation with high initial costs is applied. The analysis of farmers' adoption of soil conservation, the maintenance needs for such conservation and the different land tenure characteristics is shown in Table 11. The analysis indicates significant correlation between the farmers' tenure size, the price of agricultural land, the degree of interests in agricultural land, and with the farmers' adoption and maintenance of soil conservation. All the aforementioned correlations show a positive direction type of relationship except with the relation between tenure size and the farmers' maintenance of soil conservation, where it is a negative relation. This means that a decrease in the tenure size is associated with an increase in the farmers' maintenance of soil conservation measures (Table 11).

Table 11: Pearson correlation coefficients between farmers' adoption of soil conservation and conservation maintenance with land tenure characteristics.

Studied variables	Farmers' adoption of soil conservation	Farmers' maintenance of soil conservation
Farmers' tenure size	-0.044	-0.099 [b]
Numbers of the family members (brothers & sisters)	0.061	-0.099
Price of agricultural land	0.335 [a]	-0.038
Agricultural land sold for construction's purposes	0.087	0.147
Degree of interest in agricultural land	0.053	0.166 [b]

[a] Significant at P≤0.01.

[b] Significant at P≤0.05.

When small size tenure farmers anticipate the same or lower benefits from the application of soil conservation, with the association of high risk of failure to get a desirable yield that would support the substantial installation cost, maintenance of soil conservation will be apriority of the small tenure farmers' decision making (FAO and UNEP , 1984). At the same time, farmers with large tenure size, with comparatively higher and more stable economic status, have less willingness to adopt conservation measures due to the presence of other economic alternatives compared to the small tenured-farmers who do not have such alternatives. The reason can be attributed to the economic durability of both types of farmer; smallholder farmers are less economically durable than large holder farmers, especially in the long-term run (Abu Hammad et al., 2003).

Land fragmentation, mainly due to inheritance, is one of the important factors affecting the development of the agricultural sector. Land fragmentation hinders the application of mechanization and efficient agricultural production. Results show that about 30% of the interviewed farmers have a tenure size of less than 0.5 ha (Figure 33). Most of these farmers have a large number of close-family members (4-8 and more than 8, see Figure 33) with the right of inheritance (brothers and sisters), which reduces the farmers' ancestors' large property. At the same time, only 10% (accounts for only 15 farmers) of the interviewed farmers have a property size of greater than 5 ha (Figure 33), most of them is either farmers with a small (1-3 family members) or intermediate (4-8 members) family size or they are rich farmers. Rich farmers can afford to buy more land and increase their tenure size. An important effect of the tenure size, which is also contributing to the weakness of the agricultural sector, is

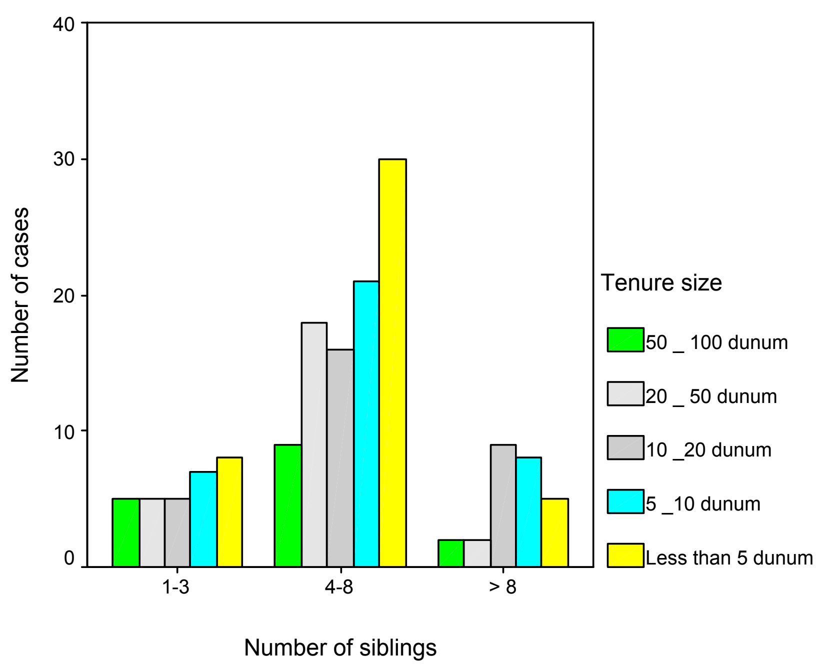

Figure 33: Number of cases for different categories of farmers' siblings with their related tenure size.

that smallholder farmers are more likely to sell their land than large holders (Figure 34). About 50% of the farmers, who were involved in selling agricultural land for construction purposes, are among those farmers with tenure size of less than 1 ha (Figure 34). Whereas only 15% of the farmers involved in selling the land are among those having a property size of larger than 5 ha. Again, this is mainly due to the durability and the economic status of both farmers. Large size tenure farmers are more financially durable and richer than smallholder farmers. The main incentive for smallholder farmers to sell their land is the immediate profit represented by the high land price.

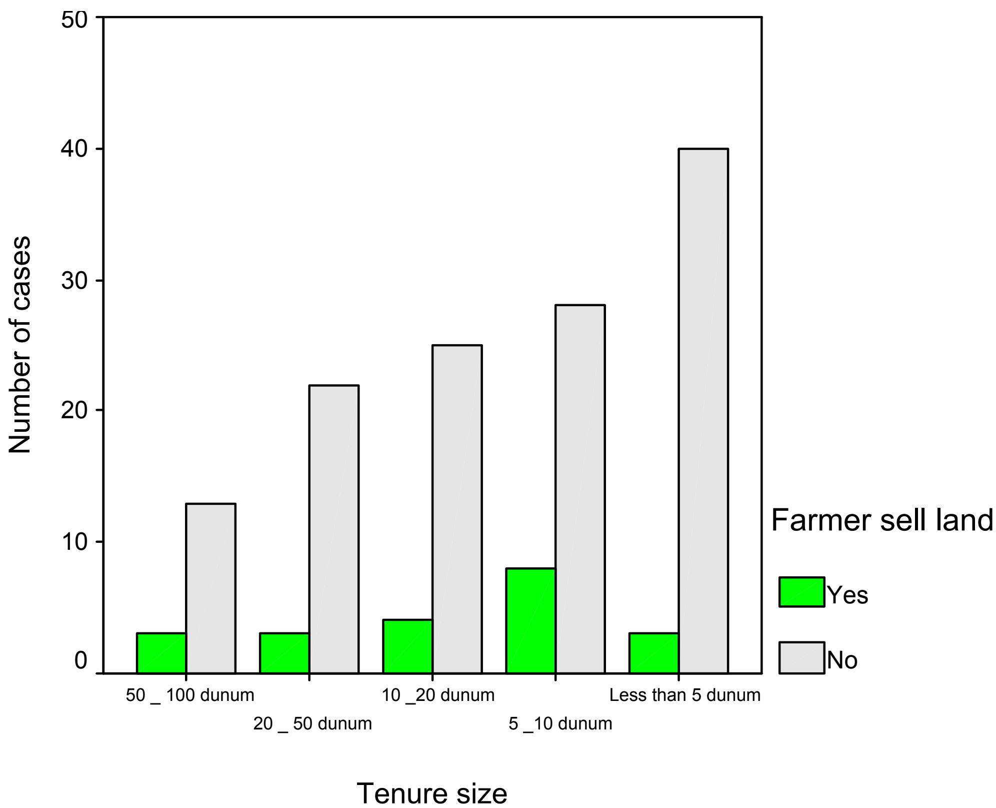

Figure 34: Number of cases for different categories of the farmers' tenure size, with the option whether farmers sell their land or not.

As the price of land increases, farmers intend to sell their small tenure for construction purposes. The attitude of the smallholder farmers should alarm the public and private institutions that are interested in the preservation and development of the agricultural sector. The attitude of the smallholder farmers necessitates a counter action, by the private and governmental institutions, to either reduce or eliminate this phenomenon. This action might be the initiation of new regulations concerning land uses and land fragmentation, in addition, incentives especially to smallholder farmers might be an effective tool to counter act the farmers selling his land for other uses.

Even though 90% of the interviewed farmers are not getting any direct or indirect support from both public and private institutions, these farmers are still involved in conservation activities for their land through terrace constructions (Figure 35). The lack of any kind of incentives for soil conservation, either direct or indirect, is a major driving force for the farmers to sell their own land (Martinez-Casasnovas et al., 2002). Another possible reason for this attitude is that these farmers need many agricultural inputs to properly preserve and develop their agricultural lands (Figure 36), which they cannot afford due to their low economic situation. Most of the farmers indicated the needs for financial support through a long-term loan system; however, this is not common in the study area. Besides, a necessary infrastructure, marketing and storage facilities for the agricultural products are either insufficient or lacking in most of the cases (Figure 36). The overall effects of the aforementioned factors are: (i) the low agricultural production due to improper conservation, tillage and other inputs, (ii) the weak economic capacity of the farmers for conservation and development of their lands, and (ii) the high risk of losses encountered by the smallholders' farmers as a result of the imbalance in their competition capacity with other large holders' farmers. The final attitude of the farmers, especially the poor ones, would be giving up their land ownership for immediate profits by selling their lands. A comparison of the farmers' attitude of selling the land with the support they are getting emphasized the farmers' trend to abandon agricultural activities for other activities that are profitable (Figure 37). About 75% of the farmers who did not get any support sold part or all of their agricultural land for construction (Figure 37), mainly because of the high prices offered.

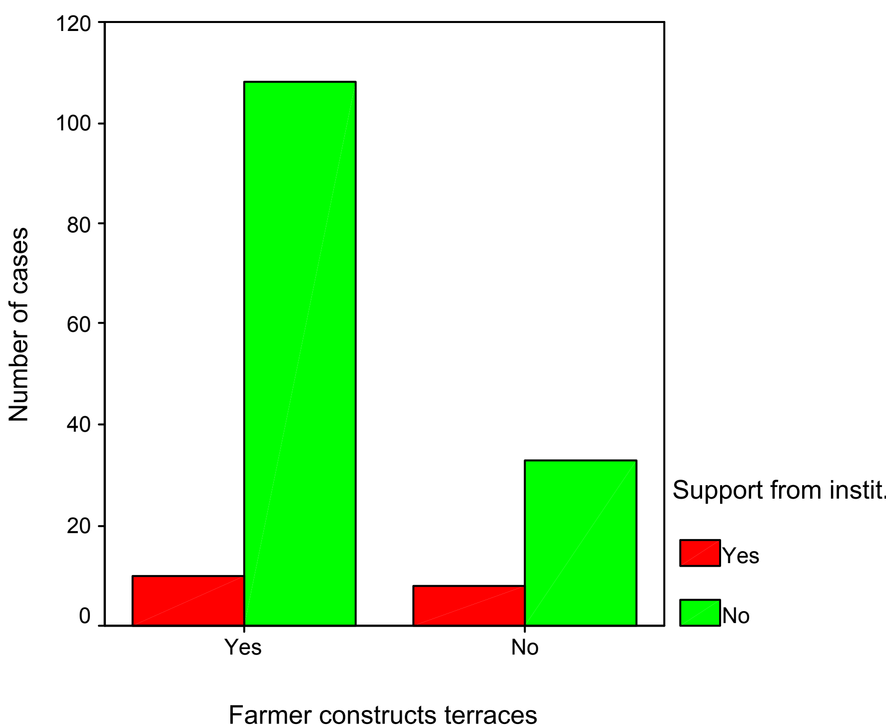

Figure 35: Number of farmers' who adopt conservation practices (terraces) with and without getting outside institutional support.

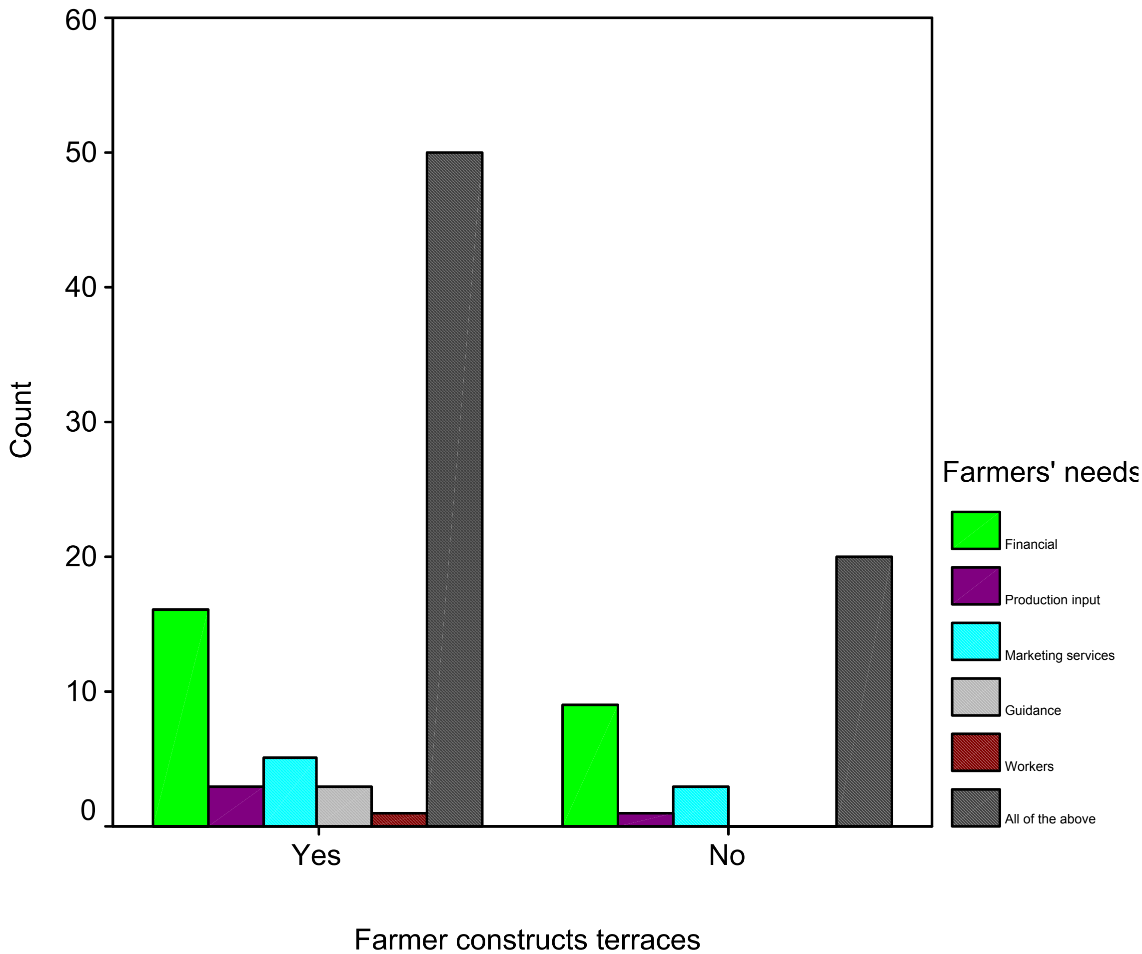

Figure 36: A comparison for the farmers' needs of different agricultural inputs with the farmers' adoption of conservation measures.

Unplanned shifting of agricultural land to other type of land uses, particularly to construction for urban uses, would bring negative consequences on the environment. More urban expansion would bring more pressure on the existing natural resources, especially the agricultural land, with more pollution and overexploitation of the agricultural lands to satisfy the increasing needs of the population, which will end up with more deterioration of the existing natural resources (Pimentel , 2000; Hussein , 1998a).

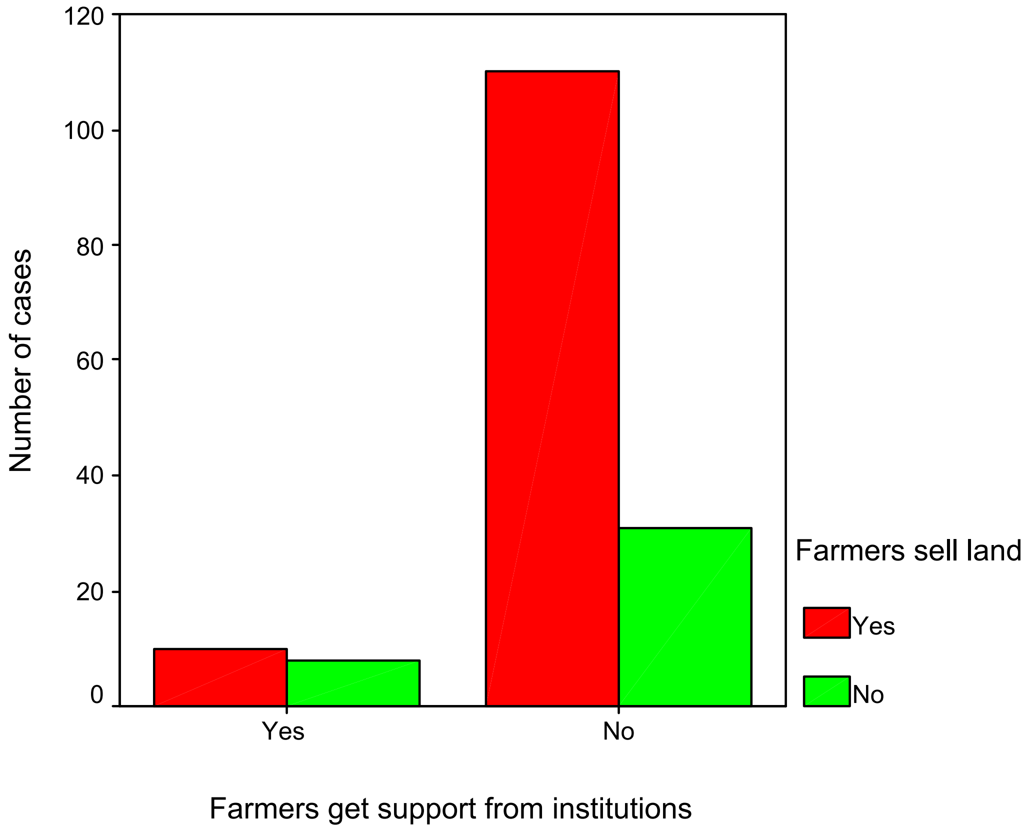

Figure 37: Farmers' behaviors of selling the land with and without getting any type of support.

Among the necessary steps, that can reduce the farmers' attitude and decrease the effects of land use changes on the agricultural sector, are the following recommendations and actvities: (i) enhance the role of the private sector, which can be done by increasing the governmental support, control, and the creation of new institutions, as well as developing the existing ones (Sternberg and Shoshany , 2001), (ii) provide a framework for proper legislations, aiming at the protection of the environment and ensuring sustainable use of the resources (Goldreich and Karni , 2001), (iii) enhance the principle of the participatory approach of the community, which includes the community participation in the formulation of the agricultural policies and strategies (Nash and Shutcliff , 1970), as well as the foreseen activities to achieve such policies, (iv) develop the loan system of the agricultural sector. The development can be done by the direct support of pioneer and high-returns' projects, the introduction of new and non-traditional methods of support, and the creation of a comprehensive system for insurance in the agricultural sector, (v) provide incentives, along with the necessary regulations, aiming at the reduction of agricultural land fragmentation and its consequences on the environment, and (vi) develop a comprehensive and a well maintained service system for the agricultural sector. This system should include agricultural infrastructure (i.e. roads, storage and transport facilities) and services (i.e. marketing and agro-industrial capabilities).

HISTORICAL LAND DEGRADATION IN THE STUDY AREA

Population, urban expansion and land uses

The study area has been subjected to large increase in population during the last 70 years (Table 12). The most influential and high increase occurred during the last 7 years (from 1997 to 2004), which marked the Oslo agreement and the consequent increase in the economic activities prevailing in the area, as well as the partial release of political crisis that were existing before Oslo agreement, which led to an increase in the economic, health and social situations that cause a final and abrupt increase in the total population. It is estimated that the total population has increased by about 4 times the magnitude since 1931, with about 4% annual growth rate during the same period (Table 12). From this change of population, the period after Oslo agreement has contributed largely to such abrupt increase of population and estimated at more than tow times the magnitude of that existing in 1961. The large and drastic change in population is accompanied by a remarkable land use changes, especially those related to

Table 12: Population growth in different villages of the study area since 1931.

Population number / Name of built up area	1931	1945	1961	1997	2004
Rammon	744	970	1186	2248	2992
Silwad	1635	1910	3215	5121	6760
An nwei'ma	149	240	240	840	1092
Yabrud	254	300	349	487	642
Dura al Qari'	303	370	576	1937	2553
'Ein Yabrud	788	930	1501	2514	3315
Deir Jarir	847	1080	1474	3042	4010
At tayba	1125	1330	1677	1496	1982
Deir Dibwan	1688	2080	2812	4894	6457
'Ein siniya	288	330	431	533	702
Beitin	566	690	1017	2153	2844
Ad Doyook	291	730	730	588	764
Total population	***8678***	***10960***	***15208***	***25853***	***34113***

built up areas. The consequent results of built up area expansion on the expenses of other type of land uses would affect future potential of the study area, especially the potential for agricultural production for food self sufficiency (Plaut , 1980). Chronological analysis of the available data on different land uses in the study area (since 1940 to 2003) indicates that the area has been subjected to drastic land use changes (Figure 38). Amongst the most influential land use that is contributing to land degradation is the expansion of built up areas on the expenses of other land uses (i.e. field crops, pasture and natural vegetation areas). It is estimated that the built up areas existing in the study area has been increased by almost 51 times the magnitude of that in 1940 (Table 13). This expansion resulted in negative environmental consequences; amongst the most important consequences are the following:

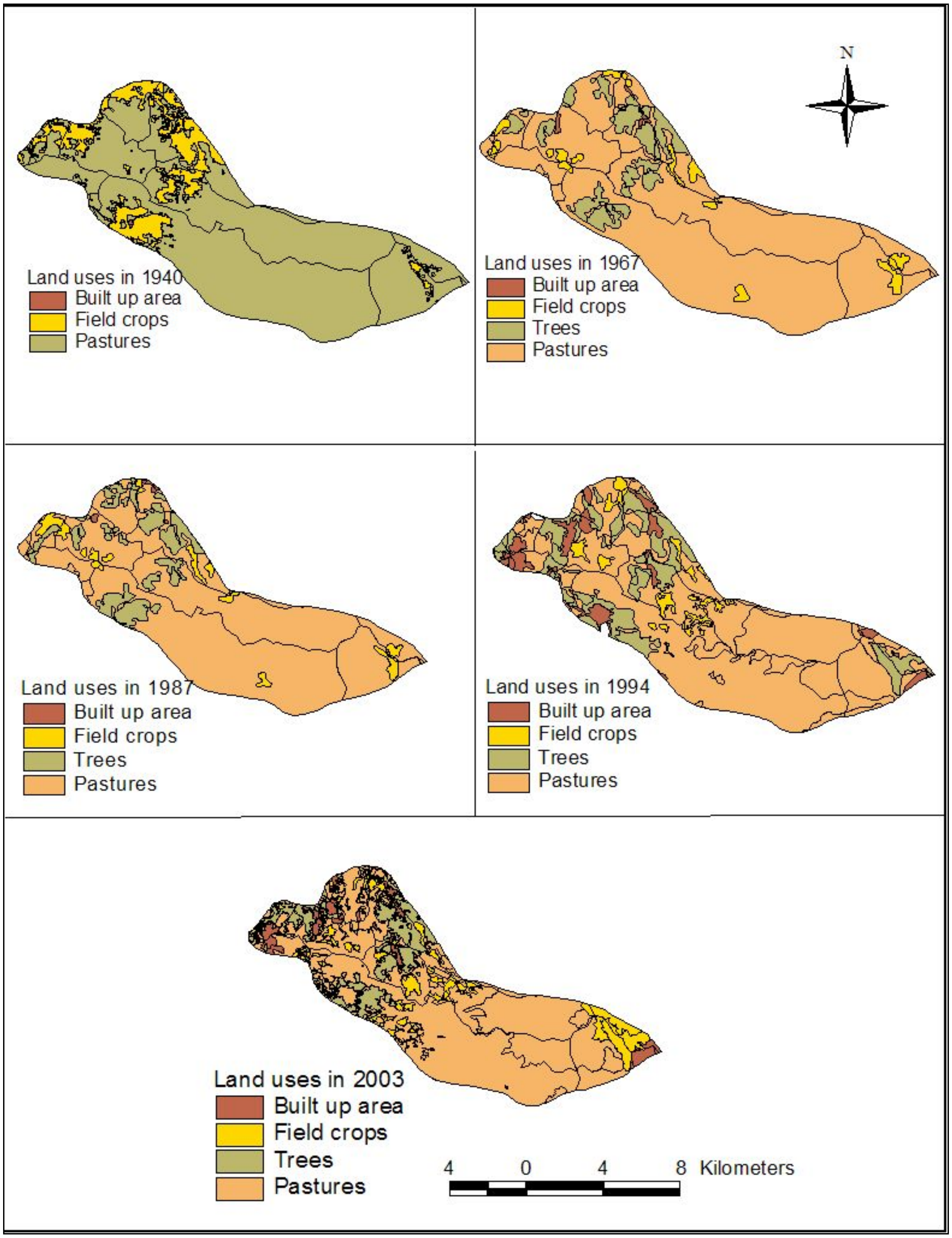

Figure 38: Different land uses in the study area during different time periods (1940 to 2003).

1. Increase the sources of pollutions (Shuqing et al., 2006), especially those related from different activities located in the built up (i.e. pollution due to sewage water, solid waste and industrial solid and waste water, etc.).
2. Increase the pressure on other available land resources due to the decrease in the land devoted to such land uses (i.e. agricultural land, nature reserves and biodiversity areas, etc.). Such pressure causes the over exploitation of some of the available resources, such as water and biodiversity genetic resources.
3. Due to the rapid expansion of built up area in comparatively short period of time (i.e. about 60 years time frame), a random and unplanned use of resources, accompanied by random development of land uses, which can be noticed by the lack of land use plans, city planning as well as the inappropriate uses of available lands inside and adjacent to the built up areas.
4. Decrease the area devoted to other land uses, such as those devoted to grazing (natural pastures) and the consequent overgrazing activities associated with the decrease in the grazing area. For example, the area devoted to pasture has reduced by about 15% (equivalent to 16000 dunums), field crops area decreased by about 40% (equivalent to about 6970 dunums), and the trees, specifically those cultivated with olives has increased by about 20% (equivalent to about 2928 dunums). The increase in olive plantation can be explained on the basis of increasing dietary needs of the increasing population, which necessitates the increase in cultivated olives to cope with the increasing demand of the population, in addition to the low production inputs needed for olive plantation (i.e. cultivation, harvesting, pesticides and fertilization, etc.). Whereas the decrease in other land uses can be explained on the basis of the lack of land for urban expansion, especially that most of the urban expansion is concentrating in level areas located in the plains (such as al Balo' plain and Tormos 'Ayya plain). These plains are well known of their high suitability for field crops cultivation where it has been practiced since long time.

Amongst the most important effect of land use changes is over grazing that is taking place in the study area. It is estimated that the total livestock (goats and sheep) existing in the study area is about 45870, comprising about 46% of the total livestock existing in Ramallah Governorate (the total number of sheep and goats is about 100500 heads). A rough estimate of the grazing density (number of sheep and goats per dumun) indicates that in 2003 the grazing density is about 0.5 head per dunum. The annual grazing capacity of pasturelands is estimated at about 30 kg of dry matter per dunum (Qannam , 1997). The annual amount of dry matter required by one head of sheep or goat is estimated at about 500 kg (Qannam , 1997). Thus, the size of area needed per one sheep or goat is about 16 dunums per year (500÷30) to satisfy its basic needs as well as to provide its dietary requirements for moderate production. Hence, the total number of the existing livestock (45870 heads of sheep and goats) needs about 764500 dunums of natural grazing land. The total area available for grazing is only about 94000 dunums, resulting in a deficit of about 670000 dunums. Thus, adding more pressure on the natural grazing area and leading to extreme over grazing. This situation has led to either the total disappearance or the high risk of threats to many natural plants, especially those plants which are known of its palatability (***For more details on palatable plants exist in the study area see Appendix number 5***). This situation has led to the concentration of unpalatable natural plants (***See Appendix number 6 for the unpalatable plants that exist in the study area***) in the area, which are known of their low protection against rainfall impacts on soil surfaces, and though leading to high risk of erosion and land degradation.

Table 13: Different land uses existing in the study area during different time periods.

	Different land uses (Dunums)				
Year	1940	1967	1987	1994	2003
Built up area	146.1	532.7	448.8	7094.6	7556.4
Field crops	18094.0	5362.8	5718.0	5261.8	11123.8
Trees	……	13116.5	14648.2	21228.8	16044.4
Pastures	110567.8	109884.8	108094.9	95013.4	94029.7

Adding to the scene, the increasing poverty rate in the area has led to worsen the situation, that is resulting in many of the inhabitants of the area are collecting medical plants for commercial purposes, which has led to more deterioration in the situation of the natural vegetation and so enhance the rate and the degree at which land degradation is taking place.

Analysis of the questionnaire with regard to the palatable plants for grazing animals as well as for commercial use, indicates that about 30% of the surveyed farmers are grazing the plants residue after harvest (Figure 39), which is a common practice in the area, causing the sharp low organic matter content of the soil, and hence a decrease in the fertility status as well as in the physical characteristics of the soil (i.e. weak aggregation), which contributes more to the ongoing process of land degradation (Pimentel , 2000; Morgan , 1986).

The analysis of the questionnaire indicates also that about 20% of the surveyed farmers are involved in collection of certain medical plants for commercial uses (Figure 40). Such commercial use of these plants adds more pressure on the surrounding environment, where large quantities of these plants are being collected for such purpose. Medical plants are well known of their characteristics in protecting the land against the direct rainfall impacts, and hence, decreasing land degradation by soil erosion. In addition, many of the inhabitants of the study area are also gathering medical plants for their own household use, adding more pressure on the natural vegetation and increasing the threat to lands. Most of the medical plants that are being collected either for commercial or for household use are Chamomile and common mallow (Figure 41), as indicated by the farmers themselves.

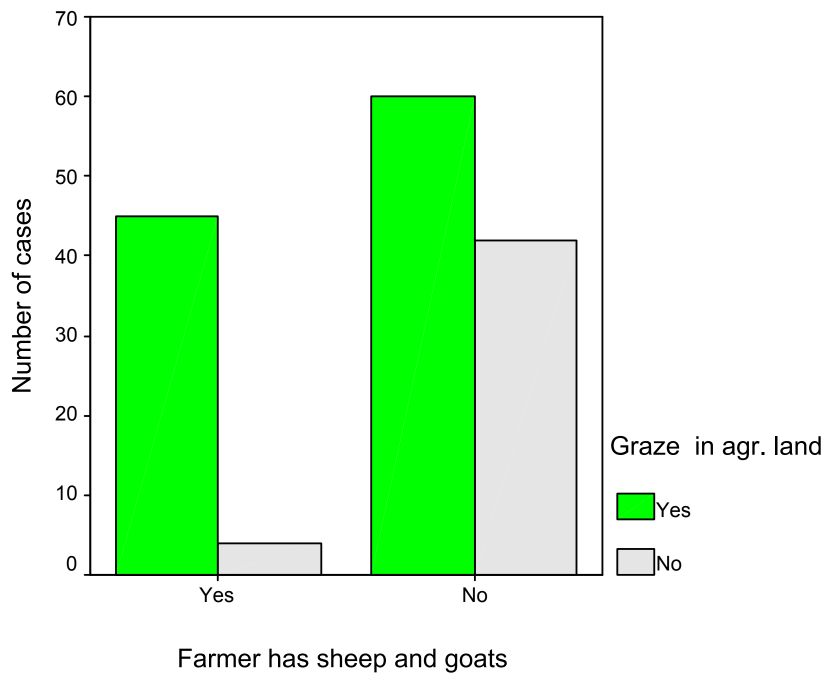

Figure 39: Relation of sheep and goats farmers ownership with the common practice of grazing plant residue.

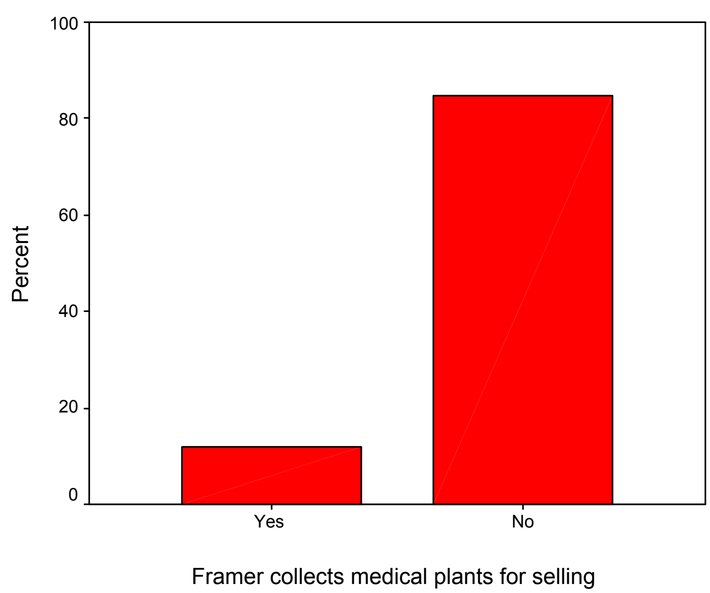

Figure 40: Collection of medical plants for commercial use by the farmers.

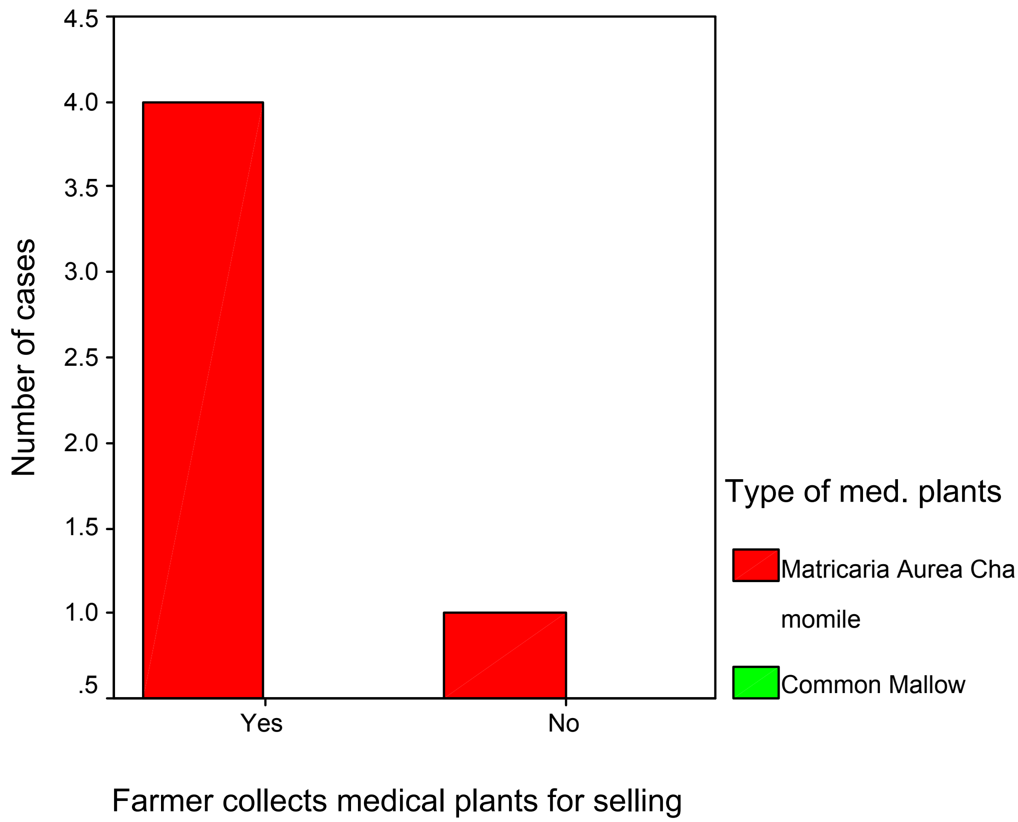

Figure 41: Type of the most heavily collected medical plants for commercial use by the farmers.

Added to the many reasons and causes of land degradation that is taking place in the study area, an important factor can also be mentioned which is the use of herbicides for getting red of the undesirable weeds (Figure 42). In fact this practice is increasingly become a common practice of the framers, especially those who have another source of income other than agriculture. This practice is being done for these farmers to reduce the time needed for land preparation and weeding by replacing the normal plowing for weed control with the use of herbicides. The use of herbicides affects all type of weeds, including those that might have positive effects on the soil physical properties (structure and nutrients) as well as soil fauna, especially those having symbiotic relationship with different types of plants (i.e. rhizobium bacteria). In addition to the effects on soil properties and plant types and density, the use of herbicides might cause pollution of ground and surface water, especially those type that are well known of their resistance to biological depletion or those that need long time to reduce their concentration.

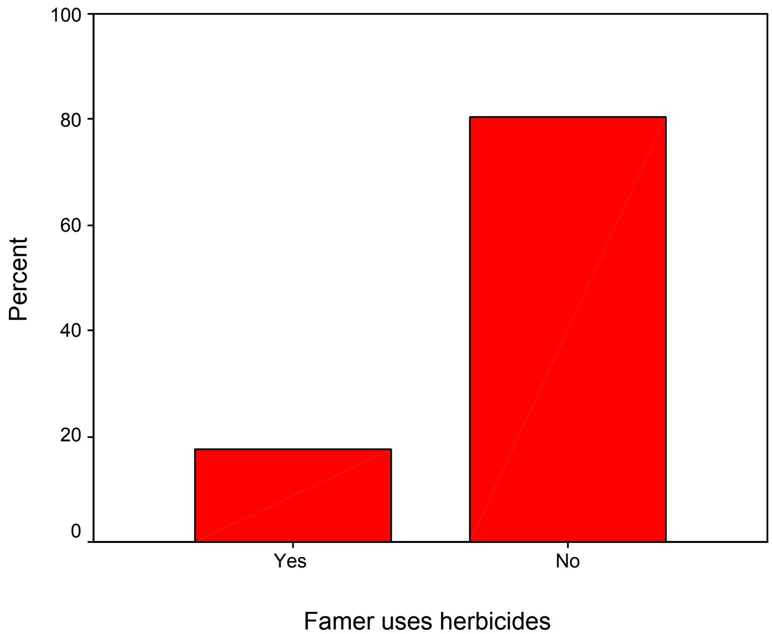

Figure 42: Number of farmers using of herbicides for substituting cultivation practices (plowing).

CONCLUSIONS

Existing soil management and practices are important means to reduce land degradation by soil erosion, especially under the semi-arid conditions of the study area. The calculation of the different RUSLE factors, along with the validation process that took place by the use of plot-soil erosion measurements, is also important for enabling future use of such model by land use planners and conservationists. Generally speaking, the study revealed the following conclusions:

1. RUSLE overestimated the annual soil loss in the study area, which could reach almost tow times the measured soil loss.
2. Adjustment of RUSLE factors (K, C, and P) according to the local conditions of the study area is necessary, so that RUSLE simulation of soil loss will be more reliable and accurate.
3. The adjusted RUSLE, for the study area, gave very close values to the measured ones (1.60 Mg ha^{-1} and 2.63 Mg ha^{-1}, for simulated and measured respectively). It underestimates the measured value by 60%.
4. It is recommended, for more reliable calibration of RUSLE to the Mediterranean conditions of the study area, to conduct more long-term soil loss experimentation and measurements, especially for the rainfall erosivity (R) and soil erosdibility (K) factors, so that more precise and reliable RUSLE factors can be derived.
5. Calibrated RUSLE equation, may serve as a good tool for land use planners, and for future management practices of the area. It also

constitutes a base for future researches of soil erosion in the study area as well as other areas with similar conditions.

6. The socio-economy of peasants in the study area has an influence on land degradation that is taking place.
7. Adoption of soil conservation measures in the study area was found to significantly correlate well, but in the negative direction, with the land productivity, whereas it significantly correlates with land geomorphology (i.e. degree of steepness and soil depth) and the type of ownership.
8. Private ownership of the land was the most influential incentive for the farmers to either maintain existing soil conservation measures or adopt new ones.
9. More than 60% of the interviewed farmers, who either have soil conservation measures or do not have, perceived the positive environmental impacts of these measures.
10. Farmers' tenure size has significant correlation, but in the negative direction, with the farmers' maintenance of the existing conservation measures.
11. The adoption of terraces in the study area has a significant positive relation with the price of agricultural land offered for non-agricultural uses.
12. Land use changes, especially form agricultural and natural vegetative areas to urban type of uses, necessitates the need for comprehensive planning as well as incentives to minimize this phenomenon and reduce its negative impacts.
13. Most of the land use changes took place in the study area were devoted to the increasing demand on built up area as a result of the high population growth achieved in the last 10 years.
14. In addition to the natural causes of land degradation (i.e. soil erosion) the study area is also being subjected to human induced land degradation as a result of the misuse of resources (i.e. heavy collection of medical plants) as well as the adoption of inappropriate management and conservation practices (i.e. the use of herbicides, overgrazing, methods of terracing and contour plowing, etc.).
15. These human induced land degradation activities necessitate programs for environmental awareness directed t o the farmers themselves, in addition, to a set of standards, laws and bylaws focusing of mismanagement, land fragmentation, and the misuse of the available land resources.

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APPENDICES

Appendix number 1: Different combinations of land uses, soil types, rain and slop categories used for soil sampling.

***Appendix number 4*:** The questionnaire to study factors contributing to land degradation in different villages of the study area

استبيان تدهور الأراضي وأسبابها في جبال فلسطين الوسطى

جزء المعلومات العامة

اسم القرية:

المستوى التعليمي للمبحوث:

☐ غير دارس ☐ ابتدائي ☐ إعدادي ☐ ثانوي ☐ جامعي

رقم الاستبانة المتسلسل:

الجزء ألأول: استخدامات الأراضي

1. هل أرضك

☐ ملك خاص ☐ مستأجرة ☐ مشاركة ☐ مدارة

2. تستخدم الأرض لزراعة الـ

☐ زيتون ☐ أشجار فاكهة ☐ خضراوات ☐ محاصيل حقلية ☐ غير ما ذكر (وضح)

3. هل يتعاون أفراد العائلة في إعداد الأرض وزراعتها وحصادها

☐ نعم ☐ لا ☐ بعض الأحيان

4. ما هي المشاكل التي تواجهها للحفاظ على أرضك وإدارتها

☐ قلة المردود المادي للأرض ☐ ألانجراف ☐ قلة الدعم المادي للحفاظ على الأرض ☐ أسباب سياسية (مستعمرات ومصادرة أراضى) ☐ غير ذلك (وضح)

5. هل طبيعة أرضك

☐ مستوية ☐ جبلية ☐ بور ☐ رعوية

6. هل أراضيك تحتوي على مصاطب زراعية

☐ نعم ☐ لا

7. هل هنالك عدد كبير من المصاطب والجدران في قريتك

☐ نعم ☐ لا ☐ لا أدري

8. هل هذه المصاطب والجدران أنشئت

☐ حديثا ☐ قديما ☐ بعضها حديث وبعضها قديم ☐ لا أدري

الجزء الثانى: الجانب الاقتصادي الاجتماعي للمزارعين

9. هل تفضل السكن في القرية أم المدينة

☐ القرية ☐ المدينة

10. إن السبب في مكوثك في القرية هو

□ اقتصادي □ اجتماعي □ غير ذلك (وضح)

11. هل يوجد عندك أغنام؟ (*إذا كانت الإجابة لا الرجاء الانتقال إلى سؤال 13*)

□ نعم □ لا

12. ما عدد رؤوس الأغنام؟--------------------------

13. هل ترعى الأغنام الموجودة في القرية في أرضك أو في الأراضي المجاورة في نهاية الموسم الزراعي؟

□ نعم □ لا

14. ما هي أنواع النباتات الطبيعية التي ترعاها الأغنام في منطقتك؟

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15. ما هي أنواع النباتات الطبيعية التي لا تأكلها الأغنام في منطقتك؟

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16. هل تجمع النباتات الطبيعية بقصد البيع؟ (*إذا كانت الإجابة لا انتقل إلى السؤال 18*)

□ نعم □ لا

17. ما هي أنواع النباتات الطبيعية التي تجمعها بقصد البيع من منطقتك؟

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18. ما هو عدد الأفراد الذين يعملون في العائلة؟ ------------------------------

19. ما هو عدد الأفراد الذين يعملون في الزراعة في العائلة؟---------------------------

20. هل يعمل أحد أفراد العائلة خارج القرية (المدينة) *(إذا كانت الإجابة لا الرجاء الانتقال إلى سؤال 24)*

□ نعم □ لا

21. ما هو عدد أفراد العائلة الذين يعملون خارج القرية: ---------------------

22. هل يشارك هذا الفرد/ الأفراد في الأعمال المطلوبة للحفاظ على الأرض واستغلالها *(إذا نعم الرجاء الانتقال إلى سؤال24)*

□ نعم □ لا

23. إن لم يكن يعمل في الأرض، فما هو السبب في اعتقادك

□ عدم توفر الوقت اللازم □ عدم وجودة أصلا في القرية □ عدم اقتناعة بهذا العمل □ أسباب أخرى (اذكرها)

الجزء الثالث: الدعم المؤسساتي للأراضي الزراعية

24. هل هنالك دعم مباشر أو غير مباشر تتلقاه من المؤسسات

□ نعم □ لا

25. هل هذة المؤسسات

□ حكومية □ غير حكومية □ كلاهما

26. ما هي طبيعة هذا الدعم

□ مادي □ مدخلات إنتاج □ بنية تحتية □ خدمات تسويق □ إرشاد □ كل ما ذكر

27. **ما هي بنظرك الاحتياجات اللازمة لدعم القطاع الزراعي**

☐ مادية ☐ مدخلات انتاج ☐ بنية تحتية ☐ خدمات تسويق ☐ إرشاد ☐ كل ما ذكر ☐ غير ذلك (حدد)

28. **هل سبق وأن قمت باستصلاح جزء من أراضيك (*إذا كانت الإجابة لا انتقل إلى سؤال 30*)**

☐ نعم ☐ لا

29. **ما هي مساحة الأرض المستصلحة (دونم)؟---------------------------**

<u>الجزء الرابع: الوعي البيئي</u>

30. **في نظرك، لماذا تُعمل هذه المصاطب والجدران**

☐ منع انجراف التربة ☐ تسوية الأرض ☐ توفير مساحة زراعية اكبر ☐ حفظ رطوبة التربة ☐ إعطاء شكل جميل للأرض ☐ كل ما ذكر ☐ لا شيء مما ذكر

31. **إذا كان هنالك مصاطب زراعية في أرضك، فهل تقوم بصيانتها دوريا؟ (*إذا كانت الإجابة نعم انتقل إلى سؤال 33*)**

☐ نعم ☐ لا

32. **إن لم تقم بصيانتها دوريا، فإن السبب هو**

☐ عدم فائدتها المادية والعملية ☐ عدم توفر المال اللازم لذلك ☐ لا شيء مما ذكر

33. **هل لاحظت أن إنتاج هذه المصاطب مقارنة بمناطق لا يوجد فيها مصاطب**

☐ أكثر ☐ أقل ☐ لا فرق

34. **كيف تتم حراثة هذه المصاطب؟**

☐ بالحيوانات ☐ بالتراكتور ☐ يدويا ☐ لا تحرث

35. هل تقوم بتسميد هذه المصاطب؟

□ نعم □ لا

36. ما هو نوع السماد الذي تسمد بة هذة المصاطب؟

□ زبل بلدي □ سماد كيماوي □ كلاهما

37. هل تستخدم مبيدات الأعشاب بدل الحراثه في أرضك؟

□ نعم □ لا

<u>الجزء الخامس: تفتت ملكية الأراضي</u>

38. هل مساحة الأراضي التي ملكها جدك

□ أكبر من 100 دونم □ 50- 100 دونم □ 20- 50 دونم □ أقل من 20 دونم

39. هل مساحة أرضك التي تملكها حاليا

□ 50- 100 دونم □ 20- 50 دونم □ 10- 20 دونم □ 5- 10دونم □ أقل من 5 دونم

40. كم عدد إخوتك وأخواتك؟--------------------

41. كم عدد أعمامك وعماتك؟-------------------

<u>الجزء السادس: سعر الأراضي وأثرة على الاستخدام</u>

42. هل أسعار الأراضي الزراعية في قريتك

□ أكثر من 20000 دينار □ 5000- 20000 دينار □ 2000- 5000 دينار □ أقل من 2000 دينار

43. هل حصل وقمت ببيع ارض لآخرين لاستخدامها في البناء؟

□ نعم □ لا

44. هل يقوم المزارعون في قريتك ببيع أراضيهم لآخرين لاستخدامها في البناء؟

□ نعم □ لا

45. إذا كانت بعض الأراضي الزراعية تستخدم حاليا للبناء، فهل لاحظت ان العناية بالاراضي الزراعية المتبقية

□ قل □ زاد □ لا يوجد فرق

Appendix number 5: Palatable plants exist in the study area.

Palatable Species			
	Latine name	**English common name**	**Arabic common name**
1	Campanula Strigosa	Strigose Bell Flower	زهرة الجرس
2	Erodium malacoides	Mallow Stork's Bill	ابرة العجوز
3	Lamium moschatum	Musky Archangel	قريصة الدجاجة
4	Linum mucronatum	Yellow Flax	كتان أصفر
5	Linum pubescens	Pink Flax	كتان زهري
6	Calendula arvensis	Field Marigold	عين البقر
7	Anthemis Palestina	Palestine Chamomile	اقحوان فلسطيني
8	Scandix Pecten-veneris	Shepherd's Needle	مش الراعي

9	Ridolfia segetum	Ridolfia	ينسون بري
10	Ferula communis	Common Giant Fennel	كلثم
11	Eryrgium Creticum	Syrian Eryngo	قرصعنة
12	Malra Sylvestris	Common Mallow	خبيزة
13	Tribulus Terrestris	Puncture vine	ضرس العجوز
14	Vicia Peregrina	Narrow-leaved	جلبان
15	Vicia narbonesis	Broad leaved vetech	فول ابليس
16	Vicia ervilia	Bitter vetch	كرسنة برية
17	Trigonella kotschyi	Trigonel	حلبة برية
18	Tetragonolobus Palestinus	Palestine Winged Pea	سيسعة، جلثون، سيبعة
19	Pisum Syriacum	Dwarf Pea	بازلاء برية
20	Onobrychis crista - galli	Cock's - Comb	ضرس العجوز
21	Medicago spp.	Medick	نفل
22	Medicago orbicularis	Flat-pedded Medick	رغيف الراعي
23	Lathyrus incoripicuus	Small - Flowered	جلبان
24	Lathyrus cicera	Flat-pedded Pea	سيسعة
25	Hippocrepis Unisiliquosa	Horse - shoe Veteh	الدريس، حذوة الفرس
26	Astragalus hispidulus	Milk Veteh	عسقف، القرين البرسيم
27	Stipa capenss	Twisted - awned spear grass	سبل، الصمعة
28	Polypogon monspeliensis	Annual Beard grass	ذيل الثعلب
29	Poa bulbosa	Bulbous Meadow - grass	قباع
30	Phalaris spp.	spiked grass	شعير الفار
31	lolium temulentum	Annual Darnel	زوان، شليم
32	Hordeum spp	wild barley	الشعير البري
33	Cynodon dactylon	Bermuca grass	نجيل

34	Brornus tectorum	Downy brome grass	الشويعرة
35	Avena sterilis	Wild oats	شوفان بري
36	Aegilops spp.	Goat grass	حشبش الغنم أو الفار
37	Roemeria hybrida	Roemeria	نعيمة
38	Trigonella stellata	Star Trigonela	نفل
39	Trifolium purpureum	Purple Clover	برسيم
40	Sisymbrium septulatum	Large-flowered Rocket	سليحي أصفر
41	Sinapis arvensis	Charlock	خردل
42	Erucaria boveana	Erucaria	أبيض سليحي
43	Diplotaxis erucoides	Dwarf Rocket, White Rocket	حويرنة
44	Carrichtera annua	Cress Rocket	فقنبيرة (رشاد بري)
45	Lactoca orientalis	Oriental Lettuce	خس شرقي أو ربحلة
46	Gundelia tournefortii	Gundelia	عكوب
47	Crepis sancta	Hawkweed	صفيرة

Appendix number 6: Unpalatable plants exist in the study area.

Unpalatable species			
	Latine name	**English common name**	**Arabic common name**
1	Acanthus Syriacus	Bear's Breech	شوك كف الدب
2	Amaranthus blitoides	Amaranth	طباق
3	Arum Palaestinum	Palestine Arum	لوف
4	Eminium Spiculatum	Eminium	ذبح
5	Calotropis procera	Calotropis (Sodom-apple)	عشير

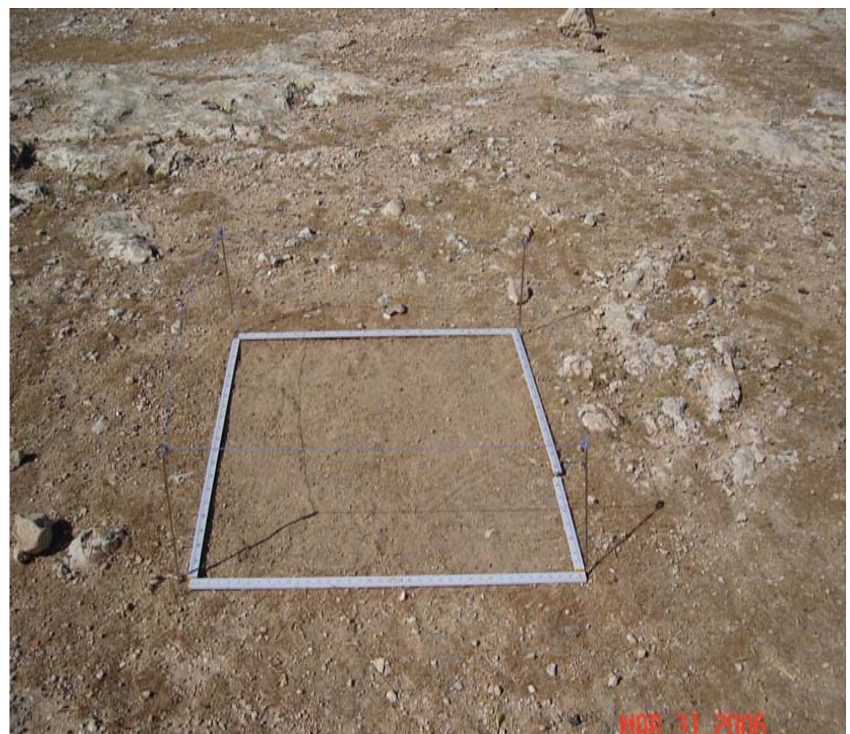
6	Alkanna strigosa	Strigose Al Kanet	هواء جوي، جوه
7	Anchusa aegyptica	Egyptian Al Kanet	حمحم مصري
8	Anchusa Italica	Italian Al Kanet	حمحم ايطالي
9	Echium judaeum	Judean Viper's Bugloss	حمحم الغور
10	Podonosma orientalis	Golden - Drop	مصيص
11	Capparis spinosa	Egyptian caper	الغبار ، كبار
12	Herriaria hirsuta	Hairy rupture - wort	عبره، ام لبيد
13	Carthamus tenuis	Slender safflower	قوس
14	Echinops polyceras	Globe Thistle	شوك الجمال الازرق
15	Gundelia tournefortii	Gundelia	عكوب، كعوب
16	Cardaria draba	Hoary pepperwort	فنبيرة
17	Citrullus colocynthis	Colocynth	حنظل، بطيخ الحية
18	Ecballium elaterium	squirting Cucumber	فقوس الحمار
19	Euphorbia hierosolymitana	Spurge	حلبوب
20	Iris atropurpuraea	Purple Iris	السوسن، كحيلة الكلب
21	Ballota undulata	Common black horehound	رسا، خويخه
22	Ajuga orientalis	Eastern Bugle	عشبة الدم الشرقية
23	Phlomis viscosa	Jerusalem Sage	مصيص، مرمية الحمار
24	Asphodeline lutea	Yallow Asphodel	عنصل
25	Asphodelus fistulosus	Asphodel	غيصلات
26	Sarco Poterium spinosum	Spiny Burnet	نتش (بلان)
27	verbascum sinaiticum	Mullein	عمية (عورور)

28	Xanthium spinosum	Burweed spiny cockelbun	شبيط
29	Solanum alatum	Red-berried nightshade	عنب الحية
30	Cuscuta monagyna	Eastern Dodder	الحامول الشرقي
31	Prosopis fracta	Mesquite	الينبوت
32	Chiliadenus iphionoides	Common varthemia	شيله، كتبله
33	Urginea maritima	Squil	بصيل
34	Paronychia argentea	Silvery Witlow-wort	رجل الحمامة
35	Carlina hispanica	Corybed Carlina Thistle	ساق العروس
36	Cichorium pumilum	Dwarf Chicory	علك ، هندباء برية
37	Piconom acarna	Yallow Cnicus	الفار شوك
38	Scolymus maculatus	Spotted Golden Thistle	أو قوص أصفر سنارية
39	Scolymus hispanicus	Spanish Oyster Plant	سنارية إسبانية
40	Phlomis brachyodon	Desert phlomis	أذانة

Appendix number 7: Samples pictures showing some indication of land degradation in the study area.

Soil crusting

Overgrazing



Effect of steepness, pollution and weak vegetative cover on land degradation