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Investigation of Effective Factors on Runoff Generation and Sediment Yield of Loess Deposits Using Rainfall Simulator

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1. Introduction

Erosion is a process in which soil materials are transported by water, wind and gravity. This phenomenon is one of the environmental issues which has undesirable effects on all natural ecosystems and is considered as a serious risk for well- being of human. The amount of erosion in Iran in 1951, 1961, 1971, 1981 and 1991 has been estimated to be 0.5, 0.75, 1, 1.5 and 2.2 billion Ton/Year, respectively (Ahmadi, 2006). This trend emphasizes that knowledge about erosion process for presenting suitable measures for decrease of erosion in Iran is very important.

Many studies have been performed for proper recognition and quantification of the effective factors and processes of erosion and by combining these factors, equations for prediction of soil erosion are developed, but many effective factors and processes of erosion are still unknown.

Important Quaternary deposits on northeastern parts of Iran, in Kopeh- Dagh Geological Zone, are Loess deposits which are widespread and significant from the view point of agriculture and animal husbandry. Iranian loesses are part of Eurasian loesses belt which spread from north Europe to Central Asia to China and belong to Pleistocene. A major part of Iranian loesses are present between Atrak and Gorganrood Rivers in Golestan Province with thickness of about 70 meters which cover Tertiary and Mesozoic Geological Units (Frechen et al., 2009). Primary loesses have originated from periglacial regions of higher latitudes, then northerly winds have transported these materials which after passing Turkmanestan Kavir and forming widespread sand dunes on these areas, lots of silt particles have been transported to the south as suspended materials. These wind storms have lost their power. After encountering Kopeh- Dagh Mountain Ranges in northeast part and Alborz Ranges in north part, these wind storms have lost their power and materials have been deposited in area of Golestan Province (Ahmadi and Feiznia, 2006).

Due to the structural nature and abundance of terrigenous particles (silt- size grains) and chemical salts, usually loesses are erodible and cause in- site and off- site damages(Pashaee, 1998).
Therefore, investigation of effective factors on sediment production of loesses and identification of most important factors on each erosion feature for proposing more effective measures for erosion control in region where dry- farming and range lands are widespread and play an important role in the economy of Golestan Province are very helpful. Due to the fact that loess deposits are widespread in Golestan Province, especially in Gorganrood Catchment which are exploited improperly (dry- farming in sloped lands and overgrazing of rangelands), the amount of yearly erosion in some subcatchments of Gorganrood Catchment reaches about 20 t/h/y of which a major part is from surface and gully erosions (Golestan Province Watershed Management, 2003).
Although scattered studies about erosion and sediment production of loesses in Iran have been performed, but comprehensive studies from the view point of effective factors in sediment production, prioritization of each factor and determination of the amount of their effects, have not been performed yet. The objective of this research is determining the effective factors on erosion of loesses on surface and rill erosion features. For this purpose, portable rainfall simulator with 1 m^2 plot was used. Rainfall Simulator has two advantages. First, the speed of performance of research projects increases notably, because waiting for the occurrence of rainfall is not needed. Second, by controlling some of the most important rainfall parameters, the results of study are usually more accurate and reliable. By using rainfall simulator, analogy, reasoning and statistical relationships of the results obtained from natural rainfall close to considered conditions are not necessary and similar rainfalls can be simulated in order to obtain repeatable results (Refahi, 2001).
The results from the study about the effective factors on erodibility of non- loessic areas cannot be generalized for loessic regions including northern part of Iran. Therefore, it is necessary that research and investigations would be performed in this region with respect to particular status and conditions of the area, in order to be able to identify the main effective factors on erosion and sediment production of loesses in predominant erosion features of the region and subsequently, with applying suitable measures, the erosion of these deposits would be controlled.
The research has been performed with the objective of determination of effective factors on erosion and sediment production of loesses and proposing regression models between sediment production of loesses and some of their physical and chemical characteristics, using field rainfall simulator in semi- arid climatic condition of Sarab Drainage Basin on surface and rill erosion features. With regard to the prevailing conditions of the area, it is tried to determine the most important effective factors on erosion and the amount of their effectiveness.

2. Loess deposits

For the first time in the world in 1823, a scientist, Leonhard from Heidelberg University, found a sample of yellow silty loam in an area called Harlas near Heidelberg and due to prevalence of local name, called it Loess and introduced it to the world. People of the area used the term "Loesch" for a soft soil which is probably cognate with English word "Loose", meaning soft. In 1911, Oberochov studied these sediments in more detail. This Russian geologist is actually pioneer in recognition of loess and loess- like sediments (Rozoycki, 1991).

Despite of many studies which have been performed on loesses, a comprehensive and acceptable, international definition of loesses does not exist yet which can be due to complex formation, physical characteristics and diversity of loesses on the surface of the earth. Therefore, many researchers express loess according to their own objective and subjective. Loess and loess- like deposits cover about %10 of the earth surface. The main areas covered by loesses are: China, Central Asia, east and central Europe, parts of North America, Argentina and New Zealand (Rozoycki, 1991).
One of the effective sedimentary processes in Quaternary of Iran is combined glacial-aeolian processes which formed loess deposits. Loess deposits of Golestan Province have the area of more than 320000 ha, of which 220000 ha are located in Gorganrood Catchment (Khaje, 2003). By researching paleosoles of Iran, Kehl et al. (2005) proposed that the formation of paleosoles formed in interglacial and more arid periods after interglacial phases of Quaternary period.
According to the definition, typical loess or real loess is a porous, non-layering, yellow and homogenous sediment which has undergone a little diagenesis and its particles are mostly coarse-grain silt. Different perspectives have caused naming loess different terms such as rock, sediment, formation or soil.
Loesses which have been transported and deposited in a new place by different processes, mainly water, have been called "Reworked Loess". Some of the most typical differences of these loesses with true loesses are that reworked loesses are heterogeneous and layered. Usually these deposits have undergone erosion and sedimentation phases and fine to coarse gravels may also be found in them. Paleosoles which are present as interlayes in some loesses are red horizons which have been formed due to climatic changes in Quaternary and formation of warm and humid climatic conditions.
Mineralogical composition of most of loesses includes: Quartz, Feldspar, Calcite, Dolomite, Mica and Clay minerals. Due to chemical weathering of ferroginous minerals and formation of iron oxide and hydroxide, the color of loesses is usually yellow and rarely brown (Okhravi and Amini, 2001). They usually form highly sloped even vertical walls. Due to the fact that particles of loesses are angular, their porosity is high, but due to the abundance of silt particles, low permeability and absence of cement between the particles, they are usually erodible and produce high amount of runoff. Loessic deposits of the studied area are usually relatively resistant in arid conditions but in contact with water, they are highly unstable and erodible. These deposits usually have considerable thicknesses that can be observed in road-cuts (Picture 1).

3. Application and importance of loesses of the area

In general, loesses deposits have economical, industrial and scientific applications. Economic application of loesses is mainly from the view point of soil fertility and high productivity of agricultural products. Loessic area are mainly dry-farming lands and are allocated to cultivation of products such as wheat, barley, sun flower, grain, etc. From the view point of industry, loesses are used in manufacture of brick and pottery. There are a number of factories in the studied area which are producing bricks. Scientifically, the loesses are considered as the most important continental materials which are proxy indicators of Quaternary climatic changes. The study of loesses is also important in Archeology. The evidence obtained from central Asia is also indicator of this fact that most archeological findings from loesses are related to mild climatic conditions (Liu, 1988).

Picture 1. View of loess thickness in the studied area (route to Gharnagh village)

4. Literature review

In recent years, a lot of attention has been oriented toward investigations of amount of erosion and sediment production, using rainfall simulator in the field. Despite of difficulties and high cost of working in the field, if erosion could be measured and monitored there, more actual data are obtained. Generally runoff and soil loss can be measured in different scales such as drainage basin, large plots (bigger than 10 m^2) and small plots (smaller than 10 m^2) (Barthes and Roose, 2002).

Standard runoff plots (SPR) and rainfall simulators (RS) are two field research methods for measuring sediment and runoff productions. In SRP, runoff and erosion are measured in natural rainfall which is costly and timely. The RS method is not as accurate as SRP method but repeatability, time and cost savings are its privilages (Victora et al., 1998).

In continue, some studies performed on this subject with emphasize on ones preformed on loesses will be reviewed.

- Due to the fact that loesses are widespread in China and they are important in agriculture of this country, numerous researches are studying different aspects of Chinese loesses.
- Rozoycki (1991) by publishing book of "Loess and Loess-like deposits", investigated central Asian loesses, explained the formation of these deposits and in: "Inventory map of Eurasian Loesses" indicated Gorgan Plain as one of the important regions of Iranian loesses.

- Bissonnais et al. (1995) in studying relationship between sediment, runoff and erosion characteristics in loess lands using rainfall simulator, found that the amount of produced sediment has direct relationship with the amount of clay, organic matter and texture of the deposits.
- Keli et al. (2002) determined erodibility of loess deposits, China, in experimental plots and by use of K-factor of USLE and found that changes in erodibility is related to grain size and the amount of organic matter of the deposits and slope of plot.
- Qiangguo (2002) investigated the relationship between erosion and human activities in loess plateau of China and found that some human activities such as plowing before rainfall season are important in loss of structure in loesses and increase of erosion.
- Khaje (2003) investigated sedimentology, sedimentary environment and sediment production of Quaternary Deposits in Gorganrood Catchment and found that the loesses can be subdivided into critical, intermediate and stabilized once, according to sediment production.
- Sheklabadi and Charkhabi (2003) investigated the amount of runoff and sediment production in soils with different parent materials using field rainfall simulator and found that the highest amount of correlation exists between the amount of erosion and amounts of cations, sodium absorption ratio and clay.
- Zhang et al. (2004) studied erodibility of agricultural lands of loessic areas in China using K factor of USLE and found that meaningful relationship exists between erodibility and percentage of clay. They presented this relationship as a regression equation
- Schiettecatte et al. (2005) in investigation of the effect of simulated rainfalls on physical properties of soils in agriculture landuse in Henan Province of China using field plots, found that there is meaningful difference between porosity and erodibility before and after simulated rainfall and there is not considerable changes in the rest of properties of soils such as retainment of water in soil and resistance to infiltration.
- Feiznia et al. (2005), by investigating the effect of some environmental factors on sediment production of loesses and comparing the rate of sediment production in different areas of loesses, indicated that sediment production is highly related to Domarten Aridity Index and percentage of organic matter and the rate of sediment production in loesses of arid regions is considerably higher than loesses of humid areas.
- Fernandeze and Avega (2006), by investigating the effective variables on runoff and sediment using rainfall simulator in 1 m^2 in Spain, indicated that there is a direct relationship between soil humidity and the amount of erosion and indirect relationship between runoff and amount of erosion.
- Zhenge (2006), by using lengthily data of runoff on experimental plot in Loess Plateau of China, indicated that accelerated erosion caused by vegetation degradation is due to intensification effects of rainfall and slope so that after degradation of forest erosion is more than 100t/h/y.
- Yu et al. (2006), while investigating the relationship of different factors with sediment in loessic regions, proposed regression equations for estimation of erosion and sediment and indicated that in the studied area, rainfall intensity was more important in sediment production then vegetation.
- Zheng et al. (2007)studied the effect of vegetation on runoff and sediment production in plot, slope and small and large drainage basins and found that the increase of vegetation in plot scale is more effective in lowering sediment production than lowering runoff, but in larger scales of slope and drainage, these relationships change.

- Zhou and Shangguan (2007) investigated the effect of Rye roots and stems (in different growth stages) on loess erosion using rainfall simulator and concluded that with the growth of plant, the amount of runoff and erosion decreases considerably and erosion rate and average permeability linear correlation with root density in the soil.
- Wei et al. (2007) studied the effects of landuse and rainfall regime on runoff and erosion of loessic hills in semi-arid regions, using 14 years field measurements and investigation of 131 rainstorms and found that bushes in comparison to forest and grasslands, played a considerable role in lowering erosion.
- Rhoton and Duiker (2008) compared erodibility of loessic soils in upper and lower parts of slope using laboratory rainfall simulator with a plot of 0.36 m^2 area and found that the lower parts of slope are more erodible and the amount of iron oxide is the most important factor in erodibility.
- Vitharana et al. (2008), in investigating loessic regions of Europe, concluded that slope, the percentages of clay, silt, humus and calcium carbonate are suitable criteria for the selection of suitable measure for lowering erosion in agricultural lands.
- Zhang et al. (2009) studied the effect of climatic change on soil erosion in Loess Plateau of China in two time intervals of 10 to 20 years and indicated the kind of agricultural measures such as protective ploughing, decreases the effects of climatic change on soil erosion.
- Hasanzade Nafuti et al. (2009), by using rainfall simulator on marly formation, indicated that SAR, EC, and K^+ ion are the most important factors in sediment productions of marly units.
- Zhou et al., 2010 studied the effect of grazing on physical characteristics and soil erodibility, in the area and found that intense grazing and trampling decrease permeability, retainment of water in the soil and stability of aggregates and therefore, increase runoff and sediment production.
- Ribolzi et al. (2010) investigated the effect of slope on the amount of changes in landscape of the soil surface and sediment production using field rainfall simulator with 1 m^2 plot and Laser scanning technology and concluded that the changes in landscape are more considerable in steeper slopes. Also in steeper slopes with other conditions being constant, runoff and sediment productions are higher.

By investigating the literature, it is distinguished that physical and chemical properties of the soil and morphometric characteristics of the area, play important role in erosion but the importance of these factors vary in different regions. In some studies, models for prediction of erosion and sediment production have been proposed using integration of factors. But, despite of these efforts, many effective factors on erosion and sediment production and the way they relate to each other, are still unknown.

5. Material and methods

5.1 The studied area

Iranian loesses are located in northeast of Iran, comprising of North Khorasan and Golestan Provinces. The studied area is Sarab subcatchment of Gorganrood Catchment in 55° 17' 54' to 56° 04' 32" east longitude and 37° 22' 43" to 37° 47' 31" north latitude, having an area of 223000 hectares, with semi-arid climatic conditions. This subcatchment is covered with loess sediments and sometime soil over loess sediments. Figure 1 shows the location of the studied semi-arid loesses in Sarab Drainage Basin and the location of Sarab Drainage Basin in Gorganrood Catchment.

6. Physiographic characteristics

By using 1:50,000 topographic maps of Army Geographic Institute, the boundary of the drainage basin was determined. Then different information layers and data including contour line with elevation difference of 100 meters, drainage network, road, villages and residential areas distributions, were digitized and entered into GIS environment. Coordinate systems were change from longitude and latitude into UTM using sphericity of WGS 84. The studied area is located in UTM zone #40. The map of elevation (Figure2) indicates that the maximum elevation of the basin is 2169 meters which is located on southeast dividing line and minimum elevation is 59 meters which is located on outlet of the drainage. The maximum elevation of the areas of loessic deposits is 1250 meters in western part of the area and the minimum elevation is 120 meters in southwest part of the area.

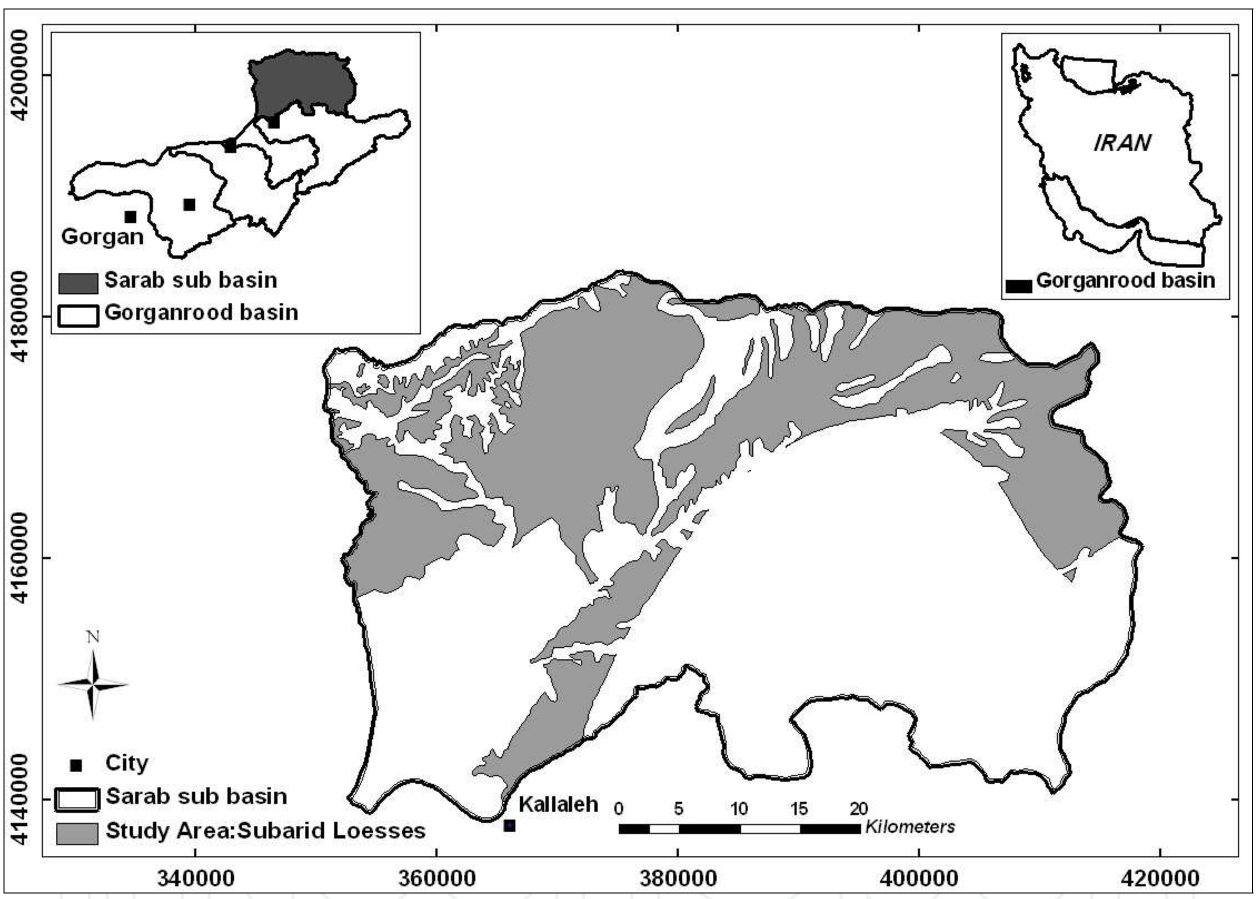


Fig. 1. The location of the studied semi-arid loesses in Sarab Drainage Basin and the location of Sarab Drainage Basin in Gorganrood Catchment

7. Climate

Sarab Drainage Basin is located in the extreme northeast part of Gorganrood Catchment. For investigating climatic conditions of the studied area, statistical data of stations within and around the basin were used. After controlling and completion of the data, statistical period was chosen from 1971 to 2002 in which most of the stations had data. The highest mean monthly precipitation of basin is from March which is 65 millimeters and the lowest from July which is 14 millimeters. Winter season is with the highest amount and summer season with the lowest amount of precipitation. Also evapotranspiration potentials of the basin vary from 880 to 990 millimeters in year.

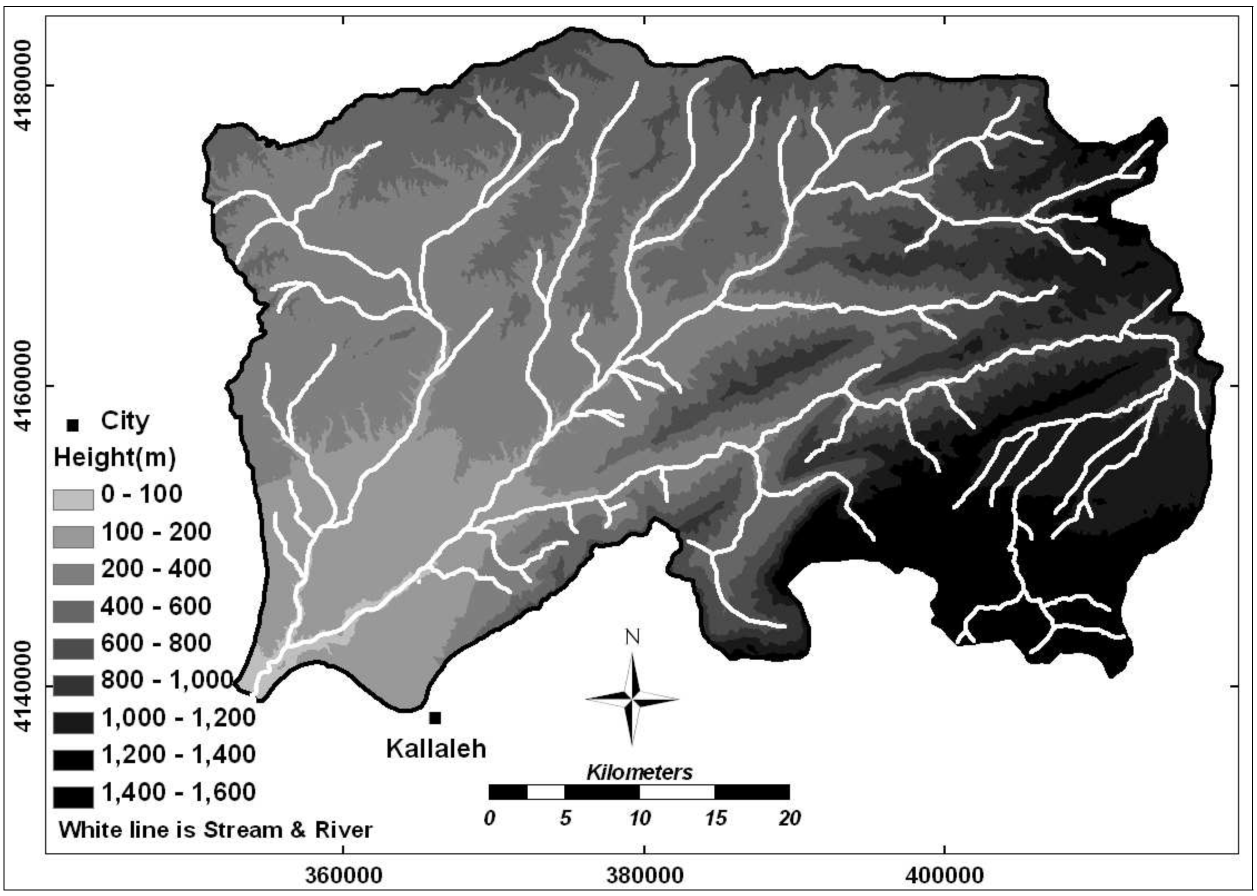


Fig. 2. Map of elevation of Sarab Drainage Basin

Considering the existing data, two methods of Domarten and Amberge climatic classifications were used. Figure 3 shows climatic classification of Sarab Drainage Basin which is prepared using climatic classification of Gorganrood Catchment (Jamab Consulting Engineering Co., 1996) and was corrected later on (Golestan Province Watershed Management, 2007). Vegetation and geomorphological conditions of the area confirm this classification.

For studying the intensity and the amount of precipitation in different time periods, statistical data of climatic station of Tamer Village which belongs to Ministry of Energy, is located in the studied area and has suitable statistical data(suitable quality and duration of data) was used. Figure 4 shows Intensity-Duration-Frequency curves of this station.

8. Geology

Diverse geological formations are not present in Sarab Drainage Basin and more than half of the area of basin is covered with loess deposits (Figure 5). Due to the fact that a part of basin is located in Kopeh-Dagh and a part of basin in Alborz Geological Zones, stratigraphic characteristics of geological units of the basin in these zones are gathered and indicated in Table1.

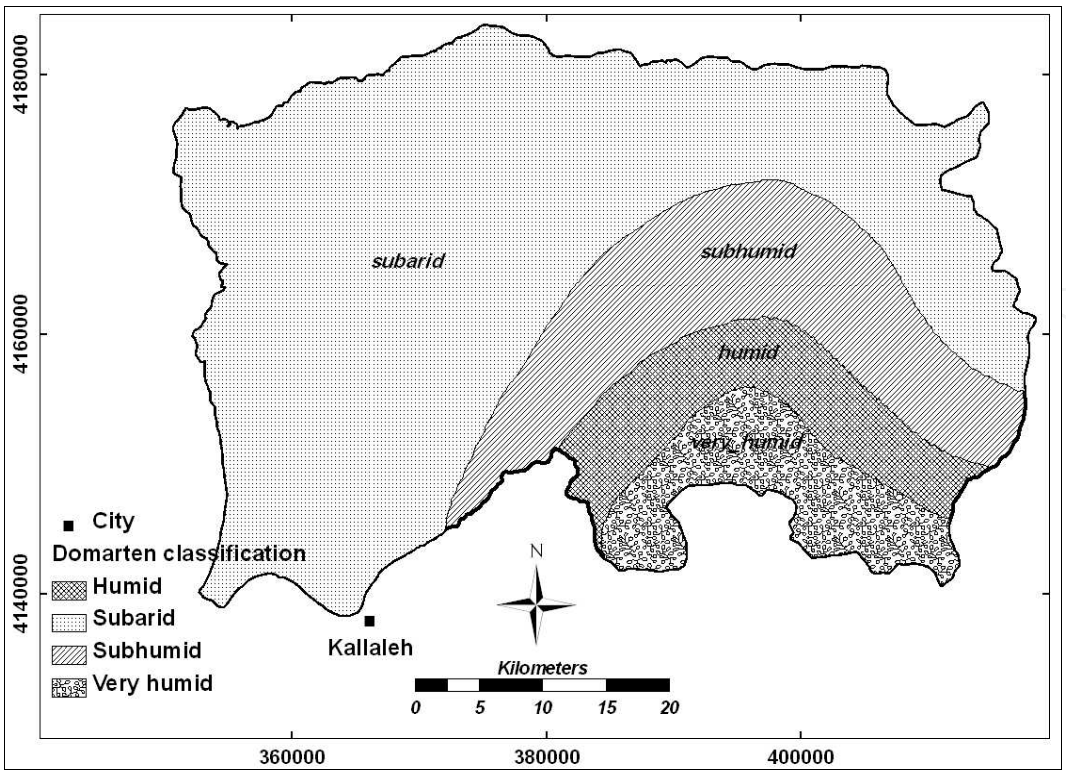


Fig. 3. Climatic classification map of Sarab Drainage Basin using Domarten Index (Jamab Consultant Engineering Co., 1996)

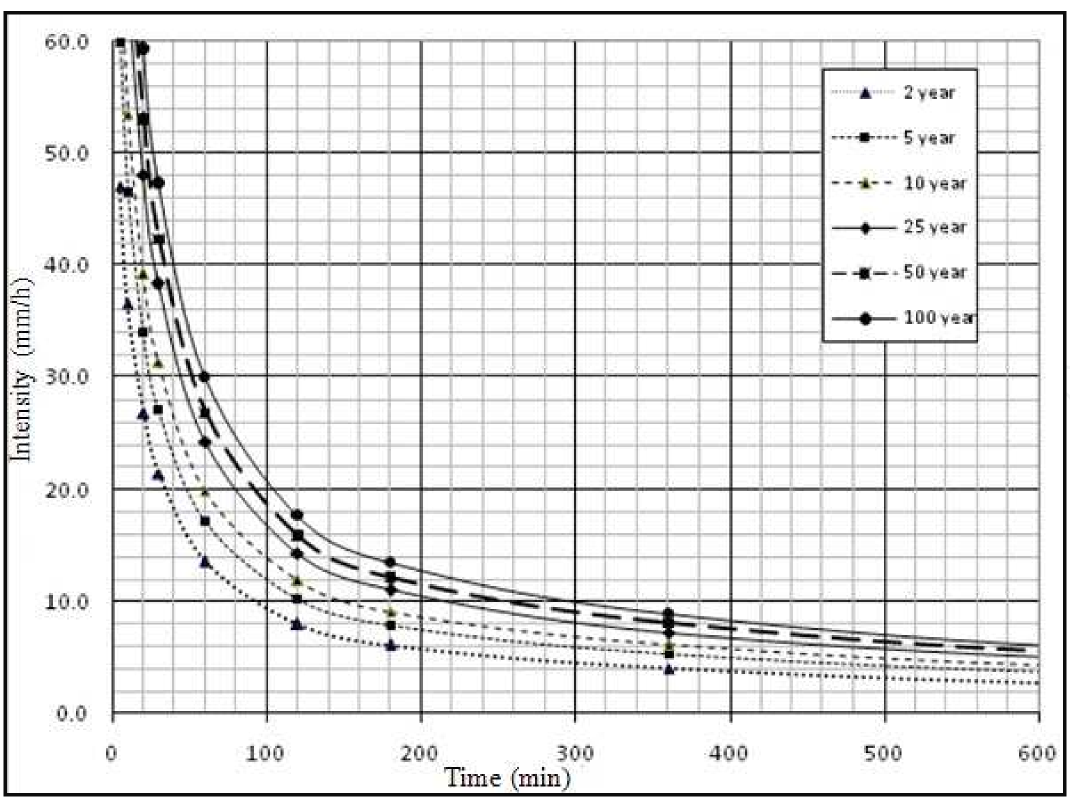


Fig. 4. Intensity-Duration-Frequency curves of Tamer Station (Golestan Province Watershed Management, 2007)

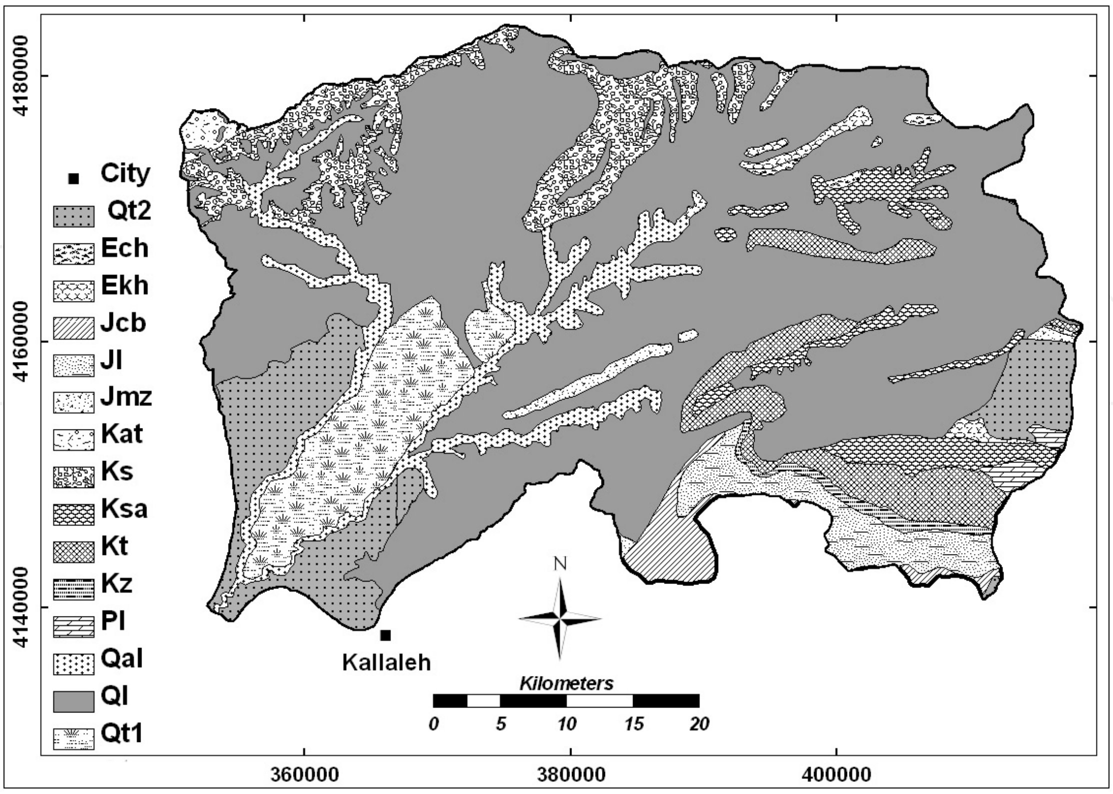


Fig. 5. Geological map of Sarab Drainage Basin

9. Research methods

Different phases of the research and the methods which were followed are listed below:

- Collecting necessary basic data including air photos, landsat images, geology and topographic maps and climatic data of the area.
- Preparing inventory map of loesses in semi-arid climate of Sarab Drainage Basin using geologic map and climatic classification using Domarten method.
- Preparing landuse map using landsat images, air photos and field visits and controls.
- For identification and separation of different erosion features on loesses and preparation of erosion features map, processing of Landsat ETM (2002), interpretation of air photos and numerous field controls and checking were used.
- Preparing slope map in four predominant classes consisting of 0-%10, 10-%20, 20-%30 and more than %30 classes using GIS facilities. Slope steeper than %40 are rarely found in the area. Also in slopes steeper than %35, agricultural activities are not present.
- Calibration of rainfall simulator equipment for rainfall with 32 millimeters per hour intensity(rainfall intensity of 30 minute with return period of 10 years for the studied area with regard to statistical data of Tamer Climatological Station). Researches have shown that due to higher frequency of occurrence and threshold for runoff production is important in erosion and sediment studies (Saghafian, 2003).
- After extraction of the regions of semi-arid loesses in Sarab Drainage Basin using geological map and climatologic classification map of the area, land unit map was prepared by combining landuse, slope and erosion features (except gully and bank erosions) maps in the regions of semi-arid loesses of Sarab Drainage Basin in GIS environment. The total of 23 land units with more than 300 polygons were obtained.

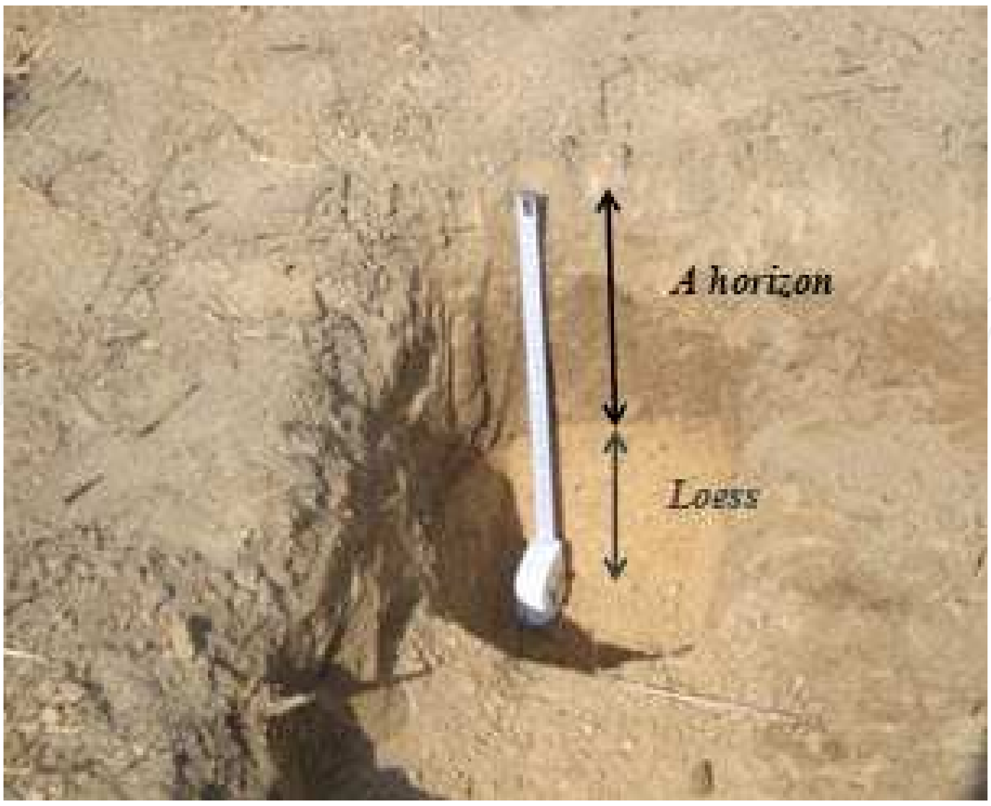
These units are similar in view points of geology, climate, slope, the kind of morphological processes and prominent erosional features (Ahmadi, 2006). Among polygons of each unit, the polygon that is accessible, has higher area and is good indicator of other similar polygons were selected for rainfall simulator tests. In each land unit, rainfall simulator analyses were performed in three repetitions (total 69 cases) and the produced runoff and sediments were collected and measured (Picture 2). After the analyses, the depths which were wetted by penetration of rainfall, were measured in 3 points of the rainfall simulator plot. Rainfall simulator unit produced rainfalls with constant intensity of 32 millimeters/hour with 30 minutes duration using urban water of Kalaleh in each plot. The time of field tests was late summer after harvesting of dry-farming wheat and before ploughing of cultivated lands for next cultivation. In these times residue of agricultural lands are used by livestock. In rangelands, the growth period was terminated and exploitation of rangeland was started. In most parts of the dry-lands, wheat has been cultivated and the tests of agricultural lands were performed in these areas.

Zone	**Age**	**Symbols**	**Lithology**	**Formation**	**Area**	
					(ha)	**(%)**
Alborz and Koppeh Dagh	Quaternary	Q^{al}	Recent alluvium (River beds)	--	12996	5.94
		Q_{t2}	Younger Terraces	--	17042	7.78
		Q_{t1}	Older Terraces	--	14184	6.33
		Q^{l}	Loess deposits	--	126110	56.30
		P_{l}	Conglomerate and Sandstone	--	1094	0.49
Koppeh Dagh	Paleogene	E^{kh}	Shales	Khangiran Formation	1700	0.76
		E^{ch}	Limestone	Chehl Kaman F.	618	0.28
	Cretaceos	K^{at}	Shales	Atamir F.	1207	0.54
		K^{s}	Shales	Sanganeh F.	14736	6.58
		K^{sa}	Marl	Sarcheshmeh F.	8314	3.71
		K^{t}	Limestone	Tirgan F.	11013	4.92
		K^{z}	Sandestone	Zard F.	1552	0.69
	Jurassic	J^{mz}	Limestone	Mozduran F.	1581	0.71
		J^{cb}	Limestone and Marl	Chamanbid F.	4013	1.79
Alborz	Jurassic	J_{l}	Limestone and Oolitic Lst.	Lar F.	7158	3.20

Table 1. Stratigraphic characteristics and area of geological units of Sarab Drainage Basin

Picture 2. Collecting runoff at the outlet of plot

- Estimation of the percentage of vegetation including live and litter and determination of the tests. For measuring the percentage of vegetation cover in the area where rainfall simulator was used, a square quadrate of 1m×1m was used which gives reasonable results in these areas (Moghaddam,2007). It should be mentioned that due to structural and physical conditions of loesses, there is no rock and rock debris on the surface.
- Due to the fact that maximum wetted depth was 12 centimeters, for determining physical and chemical properties of the samples in the laboratory, samples (total of 69 samples) were taken from the top 20 centimeters materials adjacent to each plot .Also adjacent to each plot, loess was sampled for determination of apparent specific weight (bulk density) with steel cylinder having the volume of 360 cubic centimeters. In each land unit, a profile was dug to determine the depth of A-horizon (Picture 3).
- Runoff and sediment of each plot were collected in special bottles and transferred to the laboratory. After separation of sediments and drying of samples in Ovon for 24 hours and 105 degree centigrade temperature (Feiznia, 2008), the amount of produced sediments at the end of rainfall was measured.
- In area where rainfall simulator was used, descriptive table was completed (Table2),in which information about geographic coordinate, slope percentage, elevation, depth of A-horizon, wetted depth, the time of runoff appearance and other necessary information of each sample, were entered. Despite of the fact that slope of the land unit was known, percentage of the slope in the area where rainfall simulator was used, was accurately measured.
- After transferring samples to the laboratory, the samples were sieved using a sieve with 2 mm apertures, and the weight percentage of gravel in each sample was measured which was low(due to the nature of loesses). Then, the following physical and chemical analyses were performed on each sample: Apparent specific weight(bulk density), percentage of moisture during performance of the test, sediment concentration of runoff



Picture 3. Measurement of the depth of A-horizon in each land unit

samples, percentages of clay, silt and sand in surface materials by hydrometric method, acidity using pH meter in saturated mud, electrical conductivity using Electro conductivity meter in saturated extract, percentage of organic matter by oxidation method, percentage of gypsum, percentage of equivalent calcium carbonate by Calcimetry, cations by flame photometry and titration with EDTA (Ethylene Diamine Tetra Acetic acid), anions by Titrometry, cation exchange capacity by Bour Method and determination of kind and percentage of clay minerals by X-Ray Diffraction Analysis.

- Controlling data and repetition of tests when required.
- The results were analyzed using SPSS and Excel softwares by the following methods:

1. Fore investigating the fact that whether the runoff and sediment production have normal distribution or not (this investigation is necessary for searching the regression models), Kolmogrove-Smirnov Test was used (Kalantari, 2006).
2. For investigating the effect of two predominant landuses of rangeland and dry-farming cultivation on the amount of sediment, Independent T-Test was used (Bihamta and Zare Chahouki, 2008).
3. For investigating the changes of runoff and sediment production of loesses in different slope classes, One Way Variance Analysis (ANOVA) was used. For determining the fact that which slope classes are different from each other, the method of Clustering of Means used. For this, Duncan Method was used in order to be able to compare all slopes classes dually (Bihamta and Zare Chahouki, 2008).
   For determining logical relationships among different variables, correlation and regression analyses were used. Correlation investigates the relationship between variables with sediment and runoff productions and regression investigates the relationship of effective factors with the amount of sediment produced. Due to the fact

<table>
<tr><th colspan="2">Parameters</th><th>Quantity or Quality</th><th>Explanation</th></tr>
<tr><td colspan="2">Time</td><td></td><td></td></tr>
<tr><td colspan="2">Region</td><td></td><td></td></tr>
<tr><td colspan="2">Work unit</td><td></td><td></td></tr>
<tr><td colspan="2">Treatment</td><td></td><td></td></tr>
<tr><td colspan="2">longitude</td><td></td><td>UTM</td></tr>
<tr><td colspan="2">latitude</td><td></td><td>UTM</td></tr>
<tr><td colspan="2">(m)♀ Elevation</td><td></td><td></td></tr>
<tr><td colspan="2">Weather condition</td><td></td><td></td></tr>
<tr><td colspan="2">Slope direction</td><td></td><td></td></tr>
<tr><td colspan="2">Erosion type</td><td></td><td></td></tr>
<tr><td colspan="2">Landuse type</td><td></td><td></td></tr>
<tr><td colspan="2">Dominant species</td><td></td><td></td></tr>
<tr><td colspan="2">Locality slope (%)</td><td></td><td></td></tr>
<tr><td rowspan="4">Land cover (%)</td><td>Vegetation cover</td><td></td><td></td></tr>
<tr><td>cover Litter</td><td></td><td></td></tr>
<tr><td>Rock and Pavement cover</td><td></td><td></td></tr>
<tr><td>Bare Soil cover</td><td></td><td></td></tr>
<tr><td colspan="2">Experiment duration(cm)</td><td></td><td></td></tr>
<tr><td colspan="2">Simulated rain intensity(mm/h)</td><td></td><td></td></tr>
<tr><td colspan="2">Runoff production time(min)</td><td></td><td></td></tr>
<tr><td colspan="2">Total runoff volume(cm^3)</td><td></td><td></td></tr>
<tr><td colspan="2">Depth of A-horizon in the soil(cm)</td><td></td><td></td></tr>
<tr><td colspan="2">Depth of wetted zone(cm)</td><td></td><td></td></tr>
<tr><td colspan="2">Photo No.</td><td></td><td></td></tr>
<tr><td colspan="2">Team members</td><td></td><td></td></tr>
<tr><td colspan="2">Other explanations</td><td colspan="2"></td></tr>
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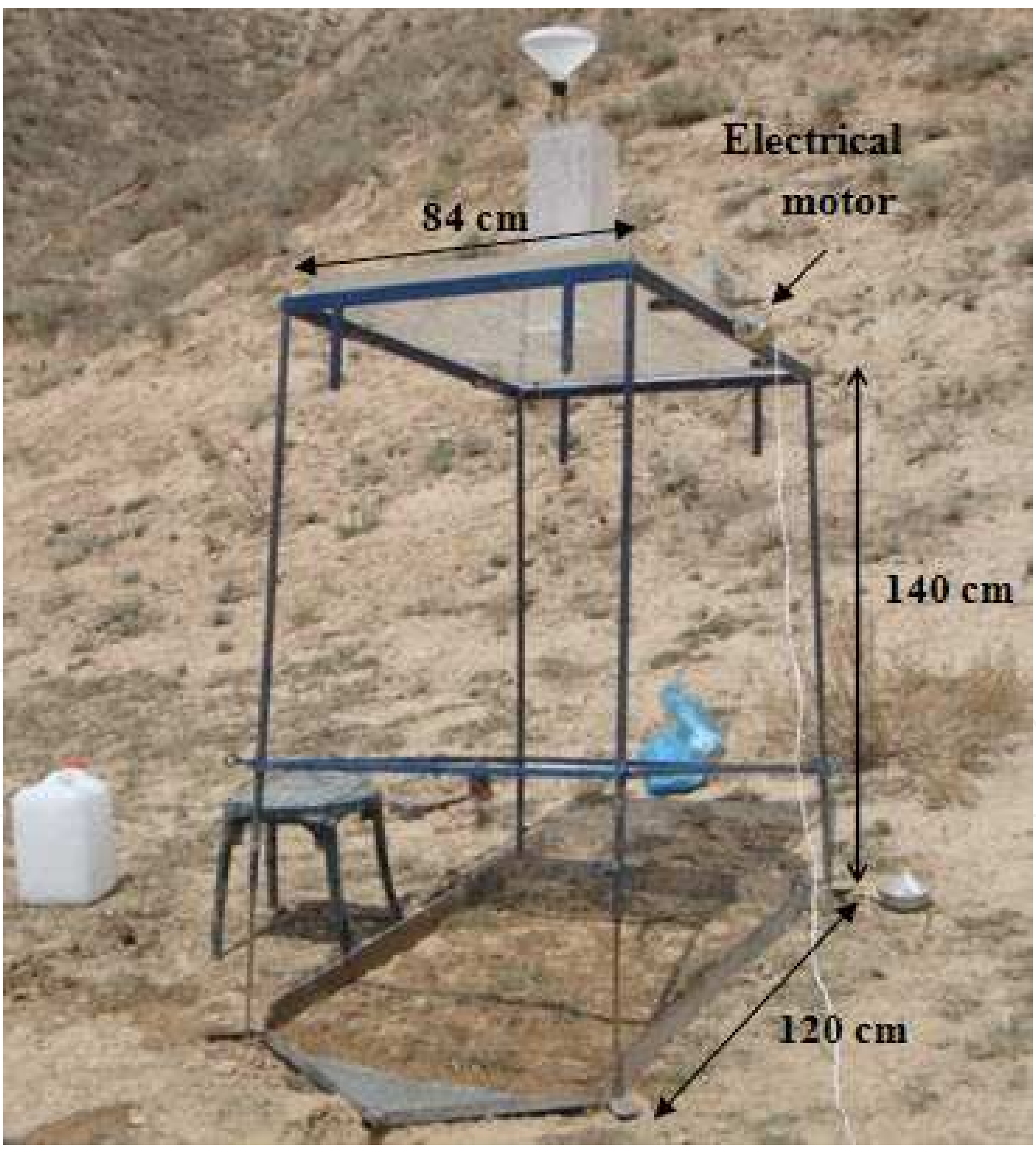
Table 2. Descriptive information of the areas in which rainfall simulator tests were performed

that the data have interval scale nature, for determination of correlation between variables with sediment and runoff productions, Pearson Correlation Coefficient was used. This coefficient usually changes between +1 and -1, in which the number indicts the slope and the sine shows the direction of linear relationship (Bihamta and Zare Chahouki, 2008).

4. For predicting the variations of the amount of produced sediments from physical and chemical characteristics and determination of the share of each on explanation of sediment production, multiple regression method was used. For doing this, first the factors that have significant correlation with the amount of produced runoff and sediment were selected as independent variables and the amount of produced runoff and sediment of each plot as dependent variable in Stepwise method regression analysis. In this method, the most important variable are entered into regression equation one by one and this function is continued until the error of significant test reaches %5(Kalantary,2006). For observation of co-linearity between the present variables in the extracted models, Variance Inflation Factor (VIF) was considered (Montgomery et al., 2001).

10. Specification of rainfall simulator

In general, these equipments are classified into two main types. In some of them, the initial falling velocity of raindrops is zero. In other type, rain drops fall from nozzles which are under pressure and have initial velocity. The equipment which was used in this research is type one from Soil Conservation and Watershed Management Research Center which has been designed and fabricated according to climatic conditions of Iran and can simulate intensities of 5 to 80 mm per hour (Picture 4). It has a plot with dimensions of 84 cm× 120 cm in which all of the resulted runoff and sediments are directed to the outlet where they can be collected(Picture 5). The equipment can be regulated and installed in different slopes. The specifications of the rainfall simulator are shown in Table 3. This equipment produces rain drops which fall without initial velocity under gravity force.



Picture 4. Rainfall Simulator which was used in this research

Picture 5. Plot of rain fall simulator

Dimension	84cm×120cm×160cm
Elevation of falling drops above slope	1.45m
Average aperture diameter	0.66 mm
Area of plot	1.008 m^2
Initial velocity of drops	0
Number of capillary tubes	204
Length of tubes	8 mm
Voltage of electrical motor of equipment	12 volts
Capacity of reservoir of equipment	80 liters

Table 3. Specification of rainfall simulator

11. Different parts of the equipment are as follows

a. The reservoir and the splashing part of the rainfall simulator are made of Plexiglas with thickness of 8 mm. The capacity of these two parts is 80 liters.
b. 12 volts electrical motor is located on special small balls for easier movement of the reservoir. This prevents falling of drops in one point.
c. The metal stand of the equipment slides and is adjustable from 140 to 180 centimeters in order for the reservoir and falling plate to be adjusted on the slope for being completely horizontal and the equipment to be used on slopes.
d. Metal frame of plot: This frame is hammered on the ground, just under the part which produces rainfall. All resulted runoff and sediment from rainfall are collected and directed to the outlet which are collectable.

12. Clay minerals in loesses

Clay minerals are the main factors in attachment of silt particles in loesses, therefore, play important role in erodibility and physical-chemical properties of loesses (Khormali and Kehl, 2010). About 23 samples from the top 20 centimeters of materials (one sample from each land unit) were analyzed for determination of clay minerals by X-ray diffraction (XRD) method. In general, clay minerals are about %10 in different samples. The rest are other minerals, majority of them are Quartz, then Feldspar and Carbonate calcium. For purization of clay and removing chemical substances which act as cement, sodium acetate normal in 80 degrees centigrade, for oxidation of organic matter, oxygen peroxide %30 and for removing Iron oxide, sodium dithionate were used. Then pure clay of each sample was separated using sedimentation method.

For the peaks of XRD to be obvious, facilitating identification of clay mineral types, five analyses with different treatments were performed as follows (Moore and Reynolds,1989):

1. XRD of normal tile(raw sample)
2. XRD of tile saturated with KCl(which later on indicated as K)
3. XRD of tile saturated with KCl and heated to 550 degrees Centigrade for four hours(KT)
4. XRD of tile saturated with $MgCl_2$(MG)
5. XRD of tile saturated with $MgCl_2$ – Ethylene Glycol(MGG)

Figure 6 shows a XRD difractogram from land unit A-SRE-1.

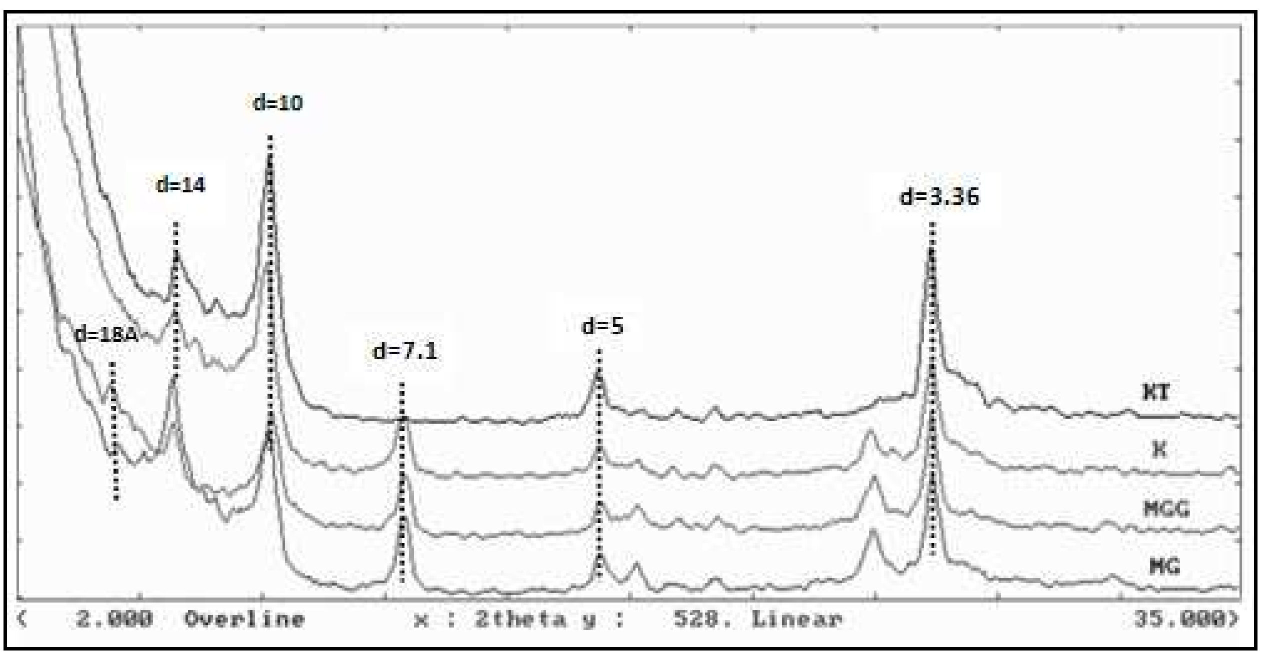


Fig. 6. XRD difractogram of loess of land unit A-SRE-1. letters MG, MGG, K and KT written on peaks show $MgCl_2$, $MgCl_2$ - Ethylene Glycol, KCl and KCl-heated treatments of clay tiles.

13. Results

13.1 Erosion features of loesses

In the studied area, different erosional features with different intensities are present. Water erosion is the main erosion processes of the area and terraces of wind erosion were not observed. Erosional features of the area are described below (Figure 7):

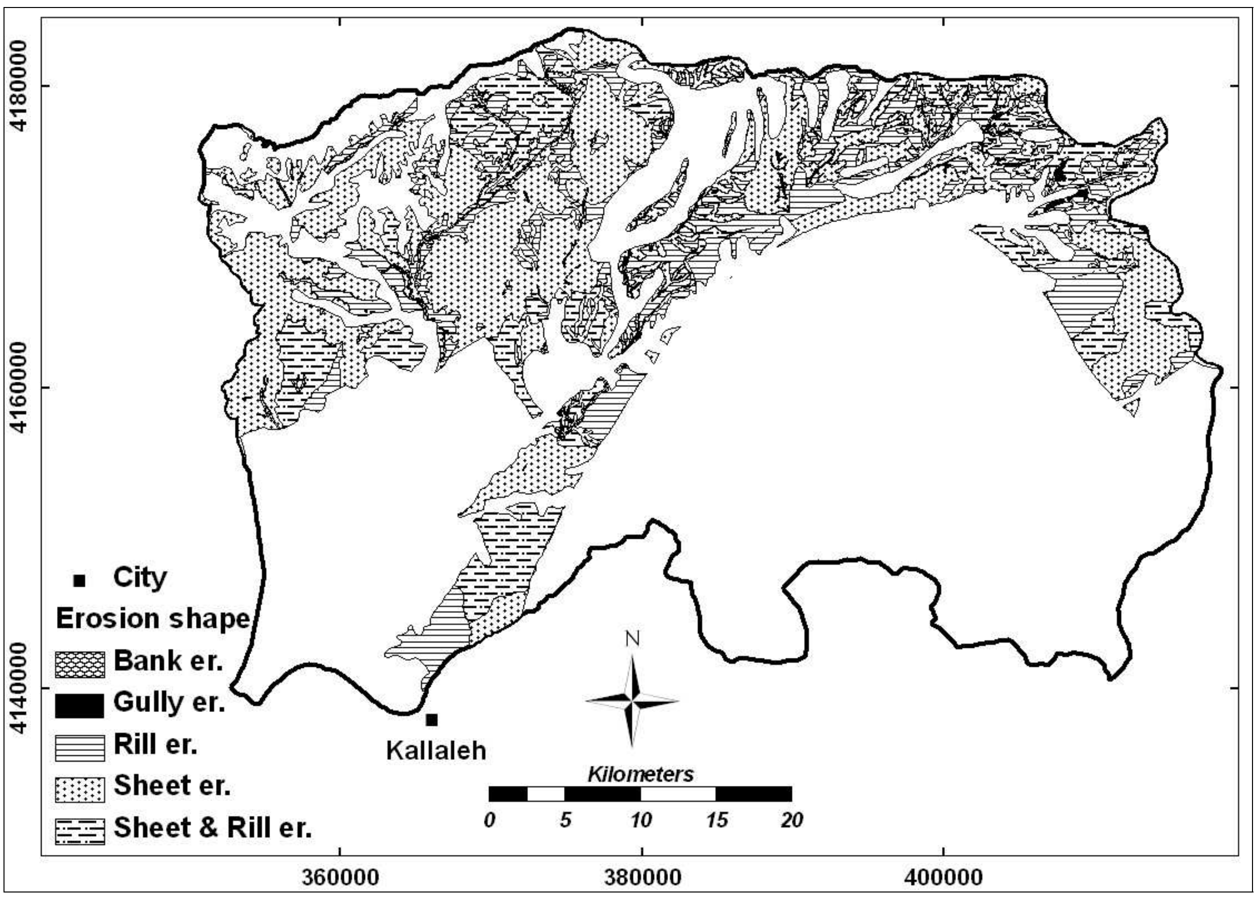


Fig. 7. Map of erosional features of studied area

a. Surface Erosion

Due to abundance of silt-size particles and lack of cement between particles, loesses are usually friable and shortage of vegetation causes particle susceptibility to rain drop impact and surface runoff which appear as surface erosion throughout the studied area, This feature is one of the most prominent erosional features in the area, is seen both in rangelands and dry- farming lands and play important role in sediment production of the area. During rainfalls, sediment-laden water flows are observed at the foot of slopes. With regard to the amount of surface flow, slope, vegetation cover of soil, intensity of surface erosion are different in different parts of the area. Surface erosion in rangeland is seen as the appearance of roots (Picture 6) and in cultivated land as light sports or shortage of crops in growing seasons in some parts of agricultural lands (Picture 7). This kind of erosion acts slowly but finally most of the fertilized surface layer of soil is lost and the underlying loess sediment is appeared. Transported materials, from surface erosion are usually fine clay and organic matter.

Picture 6. Surface erosion in rangelands (route to Islamabad Village)

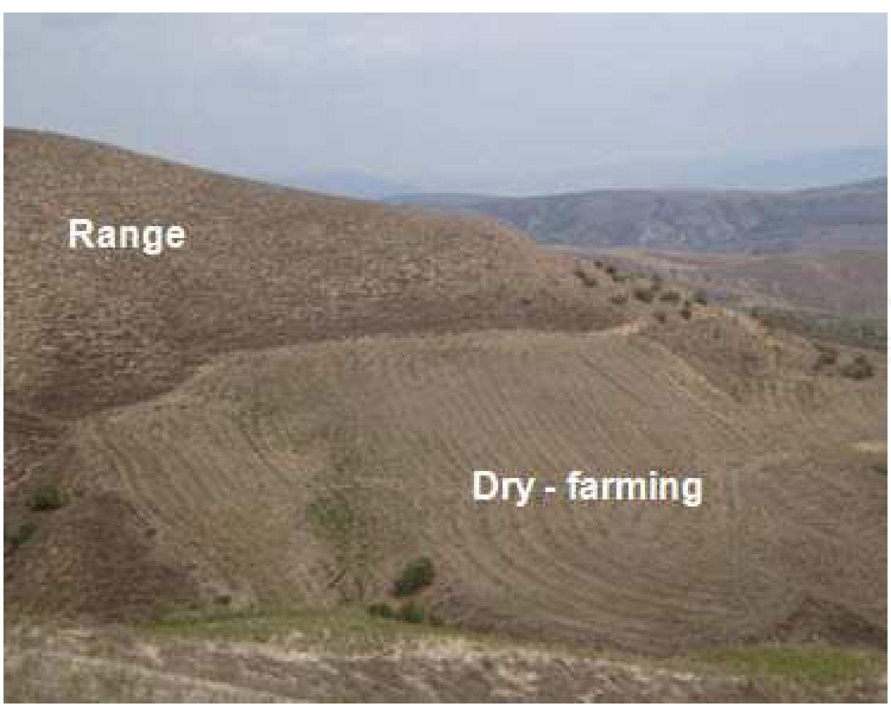
Picture 7. Surface erosion in dry-farming land (south of Dahane Village)

Due to the presence of excess livestock, overgrazing and entrance of livestock to rangeland in inappropriate times, tracks appear as notable and visible lines (microterrace) on slopes (Picture 8). Due to the pressure of over population of livestock, soil is compacted and losses its infiltration capacity and vegetation growth, therefore, runoff and consequently erosion are increased.

Picture 8. Microterrace on rangelands (Route to Oghchi Village)

b. Rill erosion

Rill erosion is not usually seen on loesses of the area and is mostly limited to sloped cultivated lands (Picture 9), because water is concentrated in rills resulting from ploughing and flows down the slope with higher velocity. The depths of rills may be 20-40 centimeters, but with later ploughing, there is usually no sign of rills on the slopes.



Picture 9. Rill erosion in dry – farming lands due to ploughing in the direction of slope (Route to Roshan Dareh Village)

c. Gully erosion

Contrast to rill erosion, gully erosion is the prominent erosion feature in the studied area, which in addition to soil loss, causes major damages to agricultural lands, roads, houses and other establishments. Gully erosion starts as headcuts in most parts of the area and it happens suddenly. In some parts, stepped gullies are observed which in time change to single gully. In addition to the nature of loesses and their erodibility, degradation of ranges and agricultural lands, increase runoff volume which causes formation of big gullies(Picture 10). The walls of gullies are falling, collapsing and retreating which cause increase of the area and volume of gullies and intensification of damages. In some parts of gullies, vegetation growth has stabilized the substrate. In regard to the gathered information from residences and local experts, the rate of gully advancement in the area is different and may reaches 10 m/y.

Picture 10. Gully erosion (Gharnagh Village). Advancing headcut toward the village is shown in the picture with arrow.

d. Bank Erosion

In the studied area, especially in low-slope regions, meandering processes (Picture 11), mainly along the main drainages, have caused bank erosion (Picture 12) which vanishes agricultural lands adjacent to drainages each year. The exterior part of the curve of river is undercut due to impact of water flow and nature of loesses and falls down in blocks.

Picture 11. Meander (near Tamer Village). Flow direction is shown with arrow in the picture

Picture 12. Bank erosion (adjacent to Haji Beik Village)

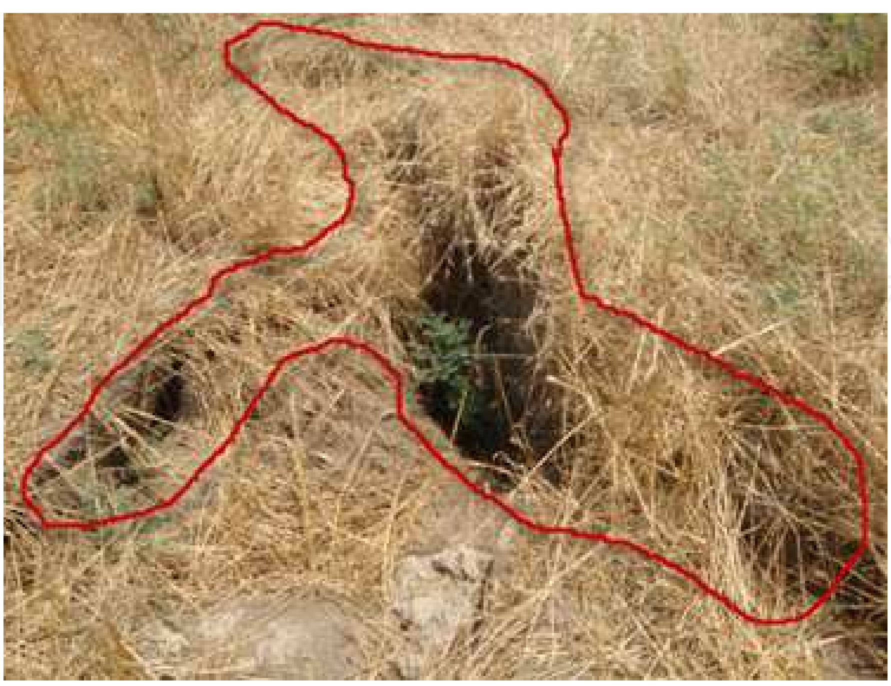
e. Mass Movements and Landsliding

Due to semi-arid climatic conditions and low rainfall, mass movements are not frequent in the area and are formed after bank erosion along drainages (Picture 13). After undercutting and degradation of walls, loess slope slides as rotational slides to river-bed, due to high slope and lack of cement between loess particles.

Picture 13. Landslide in the studied area (Rout to Oghchi Village)

f. Tunnel Erosion

One of the erosional features seen in the area is tunneling or piping (Picture 14) which after spread of the dimension of tunnels and collapse of their roofs, gullies are formed. Porosity and chemical characteristics of the loesses and also hydraulic slope for flow of water in loesses are the major factors in development of tunnel erosion. This erosion is intensified with the animal activities such as mice. Due to animal activities, holes are formed at the surface. The holes are connected in the subsurface to form channels in which water flows and transports soil and sediment and their dimensions are increased. Finally their roof collapse and gullies are developed.



Picture 14. Tunnel erosion or piping in loesses (Route to Oghchi Village)

14. Slope

Figure 8 shows slope map of the area. Class slope of 10 to %20 is most widespread one in the studied area. In slopes higher than %30, agricultural lands are less present due to difficulty in access and agricultural activities. The weighted mean of the slope of the studied area is %16.5 .

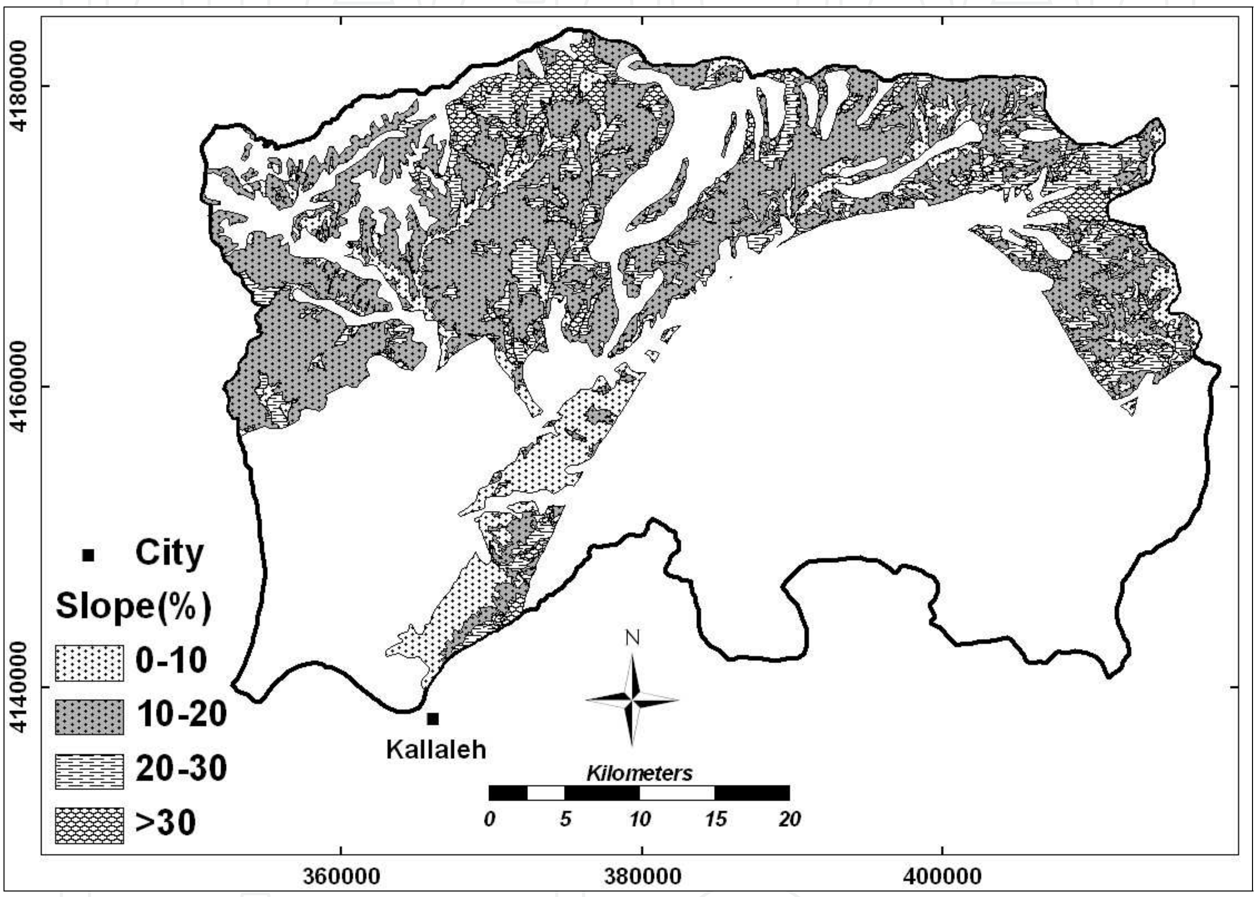


Fig. 8. Slope map of the studied area

15. Landuse

Landuse of the Sarab Drainage Basin are: Cultivation, range, forest and residential areas (villages) (Figure 9). Forest makes a small part in southeastern part of the basin and consists of *Quercus*, *Ulmus* and *Acear* species. There is also hand-planted forest consisting of *Pinus* species. In semi-arid zones, there is no forest and dry-farming lands mainly consisting of wheat, barley, sunflower and watermelon are present which due to not performing fallow, lack of vegetation after harvesting, ploughing in the direction of slope and nature of loesses, they are highly erodible. Rangeland mainly consist of *Artimisia*+*Dactylis glomerata*, *Artimisia* +*Poa bulbusa*, *Carpinus*+*Artimisia* and *Poa bulbusa*+*Medicago sativa* which due to not paying attention to the season for exploitation, they are overgrazed by tribal and villagers livestock and are erodible.

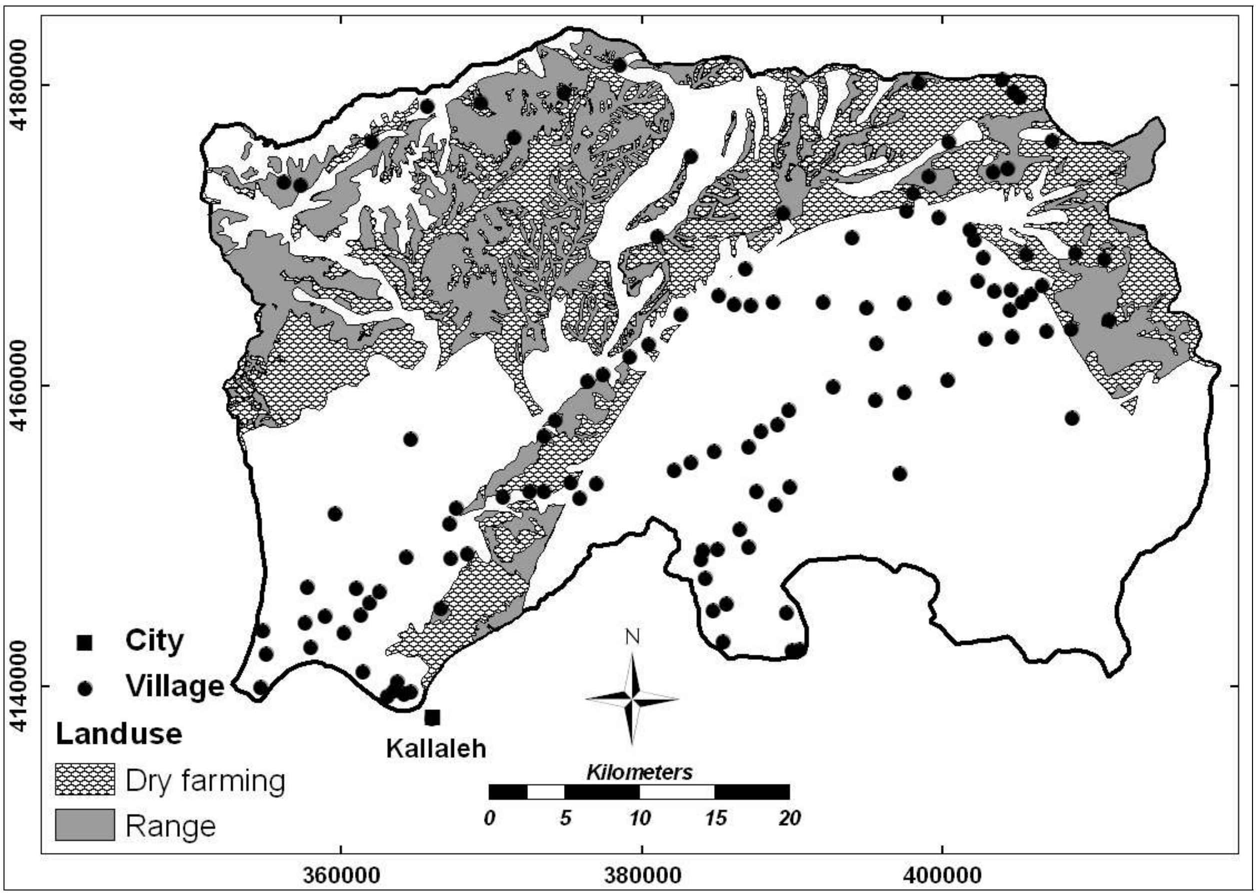


Fig. 9. Landuse map of the studied area

16. Land units

Figure 10 shows the land units of the area which are 23 units and more than 300 polygons. Each land unit is assigned letters and numbers. The first letter of the name of land unit is land use (A for dry-farming cultivation and R for rangelands). The second letter is for erosional features (SE surface erosion, RE rill erosion and SRE for surface and rill erosion) and latest number is for slope class (1 for class 0-%10, 2 for 10-%20, 3 for 20-%30 and 4 for more than 30 percent). Among the polygons, the ones which are accessible, having the largest area and are good indicators of similar polygons, were chosen (Figure 11), Rainfall simulator analyses were performed on each one with three repetitions and the resulted runoff and sediment were collected and measured.

17. Results of field and laboratory analyses

Table 4 shows the mean and variation coefficient of all measured variables including physical and chemical properties of the samples and variables measured in the field. The amount of electrical conductivity is usually bellow 3 ms/cm, the abundance of silt-size particles is more than %55 is completely evident and in some samples reaches %70. In contrast, abundance of clay particles is not more than %30 and the mean amount of sand in all samples is less than %20. Gypsum is not present in many samples or is little. Carbonate anion is not present.

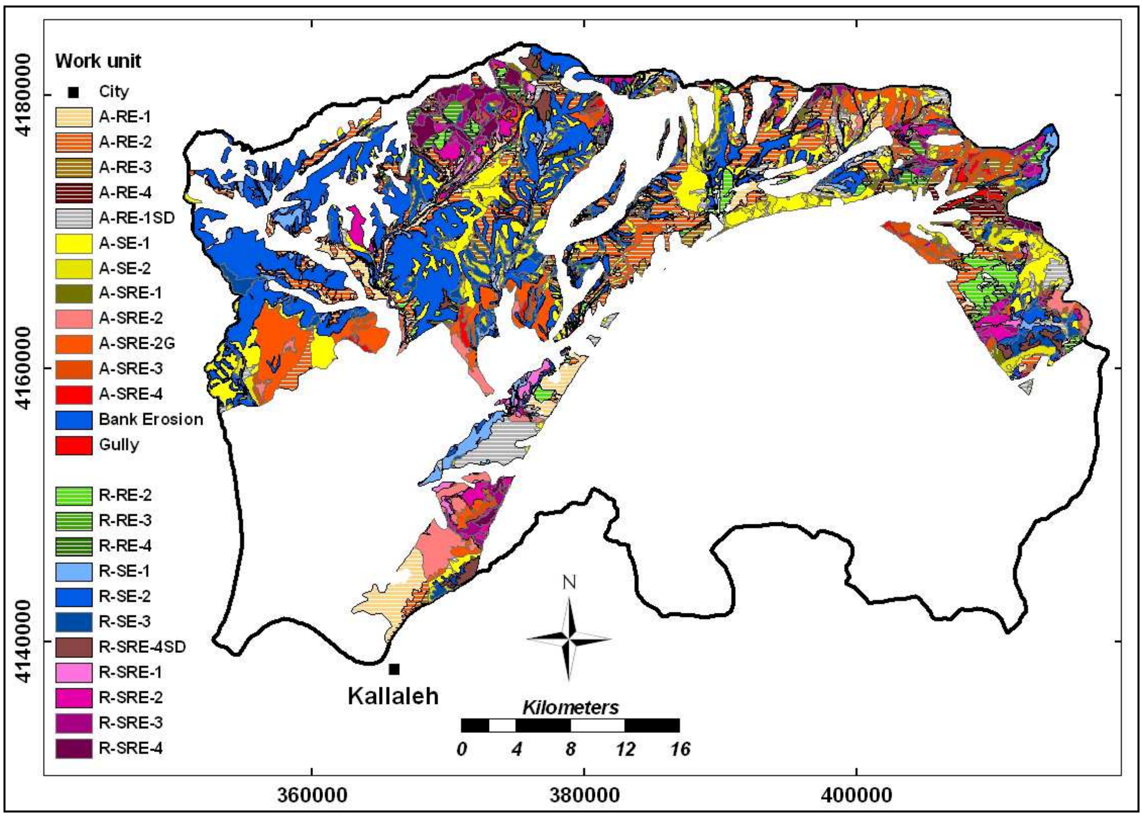


Fig. 10. Land units map of the studied area

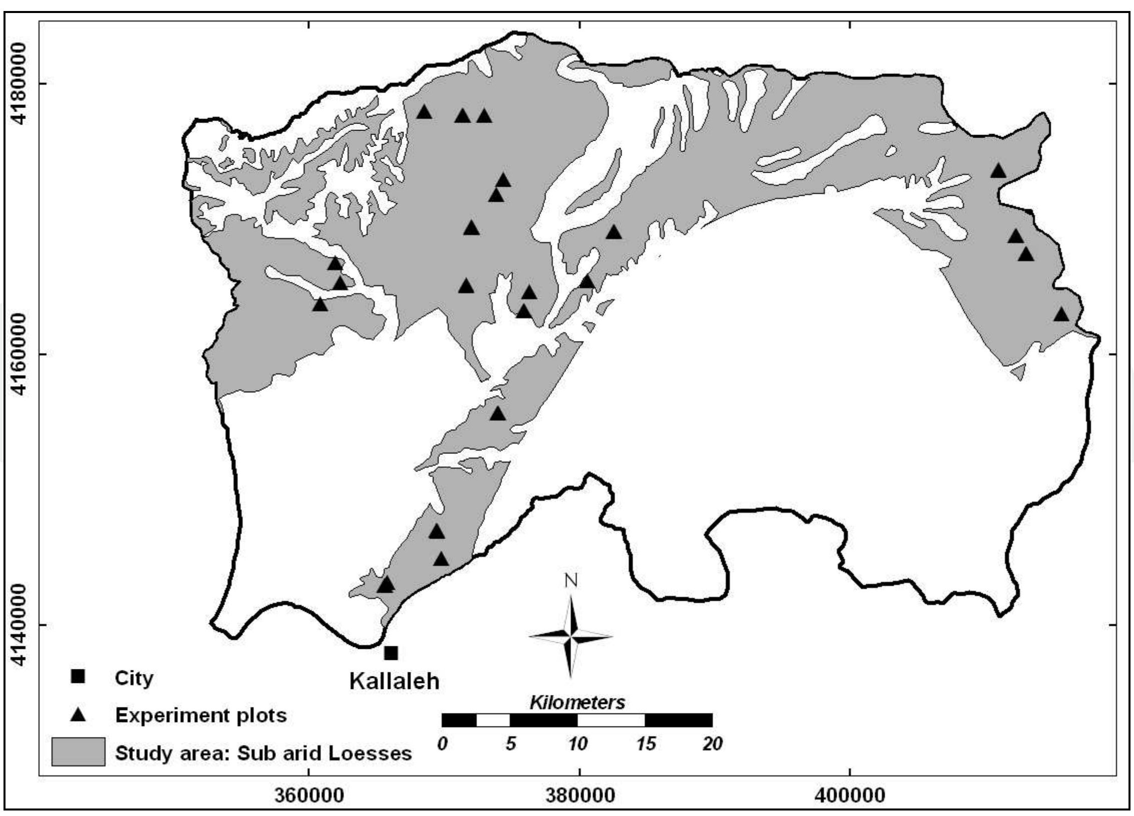


Fig. 11. Map showing the location of rainfall simulator analyses

Variable	Unit	N	Mean	Coefficient of variation (%)
Total runoff volume	cc	69	1653.61	39.92
Turbidity	gr/lit	69	17.51	61.73
Plot sediment	gr/m^2	69	32.36	85.83
Slope	%	69	19.46	49.27
Land cover	%	69	23.19	26.40
A-horizon depth	cm	69	19.83	46.07
Humidity	%	69	6.48	23.27
Bulk density	gr/cm^3	69	1.34	4.41
EC	ms/cm	69	2.20	17.99
pH		69	7.93	1.68
Organic mater	%	69	1.54	19.62
$CaSO_4$	meq/100s	69	0.78	121.05
Sand	%	69	19.36	22.55
Clay	%	69	28.88	13.55
Silt	%	69	51.75	8.91
CEC	cmol/kg	69	17.16	12.16
equivalent calcium carbonate	%	69	14.48	17.68
Ca^{++}	meq/lit	69	15.28	18.37
Mg^{++}	meq/lit	69	12.80	31.36
K^+	meq/lit	69	0.36	52.07
Na^+	meq/lit	69	26.11	46.97
Sum of cations	meq/lit	69	54.55	25.38
CO^{3--}	meq/lit	69	0.00	-
HCO^{3-}	meq/lit	69	3.42	19.20
SO^{4--}	meq/lit	69	35.66	39.29
Cl^-	meq/lit	69	15.39	46.08
Anion sum	meq/lit	69	54.48	28.71
SAR		69	7.00	46.13
ESP		69	8.14	48.60
Illite	%	69	31.30	13.60
Chlorite	%	69	25.43	16.43
Kaolinite	%	69	19.35	19.27
Smectite	%	69	22.17	17.50
Mixed layer Clay Minerals	%	69	2.61	159.62

Table 4. Descriptive statistics of all measured variables

work unit	Geo-logy	Erosion type	Slope	treatment	Sample no.	Runoff	Turbi-dity	Plot sediment
			%			cm³	gr/lit	gr/m2
A-RE-1	Loess	Rill erosion	0-10	1	1	570	10.44	5.95
				2	2	800	9.52	7.62
				3	3	710	12.12	8.61
A-RE-1SD	Loess	Rill erosion	0-10	1	4	590	12.95	7.64
				2	5	410	7.88	3.23
				3	6	510	10.25	5.23
A-RE-2	Loess	Rill erosion	10-20	1	7	1,060	21.07	22.33
				2	8	1,320	15.96	21.07
				3	9	1,620	17.33	28.07
A-RE-3	Loess	Rill erosion	20-30	1	10	1,790	37.23	66.64
				2	11	1,970	28.41	55.97
				3	12	2,330	23.78	55.41
A-RE-4	Loess	Rill erosion	30-40	1	13	2,470	38.83	95.91
				2	14	2,850	35.63	101.55
				3	15	2,700	28.39	76.65
A-SE-1	Loess	Sheet erosion	0-10	1	16	1,040	12.18	12.67
				2	17	1,160	11.23	13.03
				3	18	970	9.75	9.46
A-SE-2	Loess	Sheet erosion	10-20	1	19	1,380	19.12	26.39
				2	20	1,500	13.96	20.94
				3	21	1,190	15.15	18.03
A-SRE-1	Loess	Sheet & rill	0-10	1	22	820	11.31	9.27
				2	23	570	9.87	5.63
				3	24	750	13.56	10.17
A-SRE-2	Loess	Sheet & rill	10-20	1	25	940	23.96	22.52
				2	26	1,400	25.44	35.62
				3	27	1,500	19.22	28.83
A-SRE-2G	Loess	Sheet & rill	10-20	1	28	1,550	26.82	41.57
				2	29	1,710	20.47	35.00
				3	30	1,410	21.24	29.95
A-SRE-3	Loess	Sheet & rill	20-30	1	31	1,910	36.74	70.17
				2	32	1,410	34.10	48.08
				3	33	2,100	27.72	58.21
A-SRE-	Loess	Sheet & rill	30-40	1	34	2,200	50.85	111.87
				2	35	2,370	47.50	112.58
				3	36	2,400	45.56	109.34

Table 5. Data from work unit in Agriculture landuse

Clay minerals of loesses are smectite (18 A° peak in MGG), illite (10 A° peak), kaolinite (considerable decrease of 7.1 A° peak in KT relative to other treatments) and chlorite (14 A° peak in all treatments). Clay minerals in the order of decreasing amount are as follows: Illite, Chlorite, Smectite, Kaolinite and low amount of Mixed-layered clay minerals. In areas reaching arid climate, Smectite increases. Tables 5 and 6 show runoff volume, sediment concentration and sediment production of each plot in 3 repetitions in each land unit. Table 7 shows the average runoff and sediment in dry-farming and range Landuse.

work unit	Geology	Erosion type	Slope %	treatment	Sample no.	Runoff cm^3	Turbi-dity gr/lit	Plot sediment gr/m2
R-RE-2	Loess	Rill erosion	10-20	1	37	1,160	8.65	10.03
				2	38	1,420	7.23	10.27
				3	39	1,310	10.24	13.41
R-RE-3	Loess	Rill erosion	20-30	1	40	1,670	16.63	27.77
				2	41	1,750	12.80	22.40
				3	42	1,550	15.62	24.21
R-RE-4	Loess	Rill erosion	30-40	1	43	2,140	21.02	44.98
				2	44	2,280	22.63	51.60
				3	45	2,420	16.57	40.10
R-SE-1	Loess	Sheet erosion	0-10	1	46	1,469	2.45	3.60
				2	47	1,120	3.16	3.54
				3	48	1,000	2.25	2.25
R-SE-2	Loess	Sheet erosion	10-20	1	49	2,220	6.44	14.30
				2	50	1,820	5.61	10.21
				3	51	1,600	8.39	13.42
R-SE-3	Loess	Sheet erosion	20-30	1	52	2,530	12.80	32.38
				2	53	1,750	11.53	20.18
				3	54	2,180	10.41	22.69
R-SRE-1	Loess	Sheet & rill	0-10	1	55	970	3.15	3.06
				2	56	740	5.20	3.85
				3	57	1,050	3.90	4.10
R-SRE-2	Loess	Sheet & rill	10-20	1	58	1,930	10.56	20.38
				2	59	2,340	14.75	34.52
				3	60	1,870	8.81	16.47
R-SRE-3	Loess	Sheet & rill	20-30	1	61	2,010	16.03	32.22
				2	62	2,340	18.10	42.35
				3	63	2,090	17.18	35.91
R-SRE-4	Loess	Sheet & rill	30-40	1	64	2,740	16.34	44.77
				2	65	2,420	19.70	47.67
				3	66	2,980	14.55	43.36
R-SRE-4SD	Loess	Sheet & rill	30-40	1	67	2,550	16.82	42.89
				2	68	2,280	21.25	48.45
				3	69	2,420	22.52	54.50

Table 6. Data from work unit in rangeland landuse

Variable	Unit	Landuse	N	Mean
Runoff observation time	min	Dry-farming	36	8.42
		Range	33	6.36
Moisture depth	cm	Dry-farming	36	5.50
		Range	33	3.33
Total runoff	cm^3	Dry-farming	36	1443.8
		Range	33	1882.3
Runoff	mm	Dry-farming	36	1.44
		Range	33	1.88
Runoff coefficient	(%)	Dry-farming	36	9.02
		Range	33	11.76
Turbidity	gr/lit	Dry-farming	36	22.37
		Range	33	12.22
Plot sediment	gr/m^2	Dry-farming	36	38.64
		Range	33	25.51

Table 7. Average runoff and sediment in dry-farming and range landuses

18. Discussion

Investigation of the results indicates that the elevation of resulted runoff from produced rainfall on the plots varies from 0.41 to 2.98 mm and runoff coefficient from 2.6 to %18.6 . Sediment concentration which is due to runoff and sediment production together is between 2.25 to 50.8 gr/lit and sediment production from 3.06 to 112.5 gr/m^3. If unit change for a plot having the highest amount of sediments, the amount of sediment production for this type of rainfall is 1.125 ton/hectare which is considerable.

Kolmogrove-Smirnov Test shows that runoff and sediment production data have normal distribution. In independent t-test, with regard to the amount of significant for Levene Test which is lower than 0.05, the variance is not equal in two landuses, therefore with regard to significant of this part which is 0.028, there are differences between sediment production in two cultivations and rangeland landuses so that in dry-farming cultivation, the amount of sediment production is %50 more than rangeland which is due to decrease of soil structure stability due to yearly cultivation activities and overgrazing(Zhou et al., 2010). Of course deep ploughing decreases runoff volume but increases erosion and sediment production. Figure 12 shows sediment variations in two prominent landuses in the area.

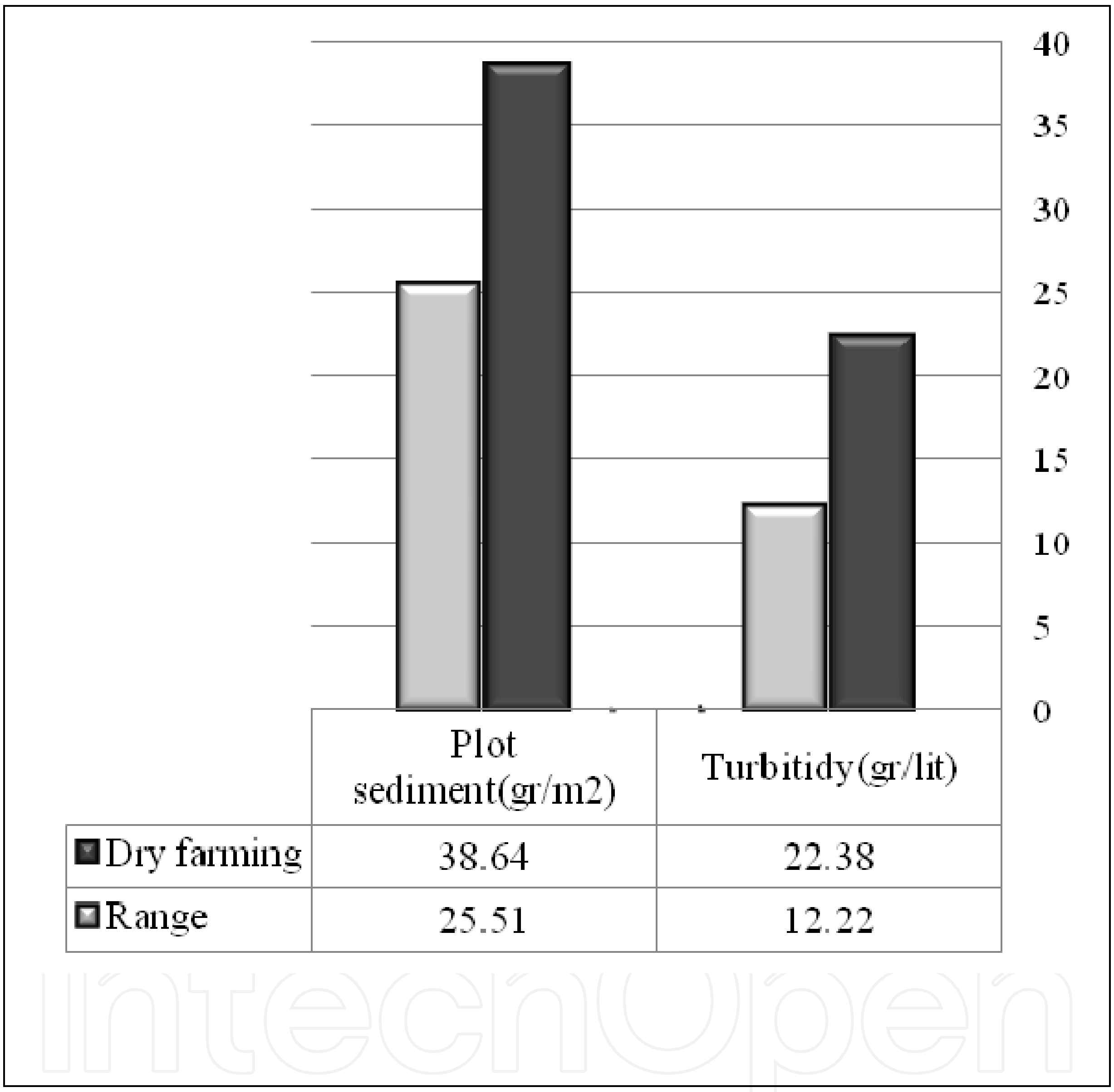


Fig. 12. Mean sediment concentration and sediment production in rangeland and dry-farming cultivation

In ANOVA Test, due to the fact that the level of significant is lower than 0.01, there are significant differences in runoff and sediment production between different slope classes. For determining which slope classes are different from each other, Clustering of Mean Method was used. The results of Duncan Method indicates the notable effect of slope on the amount of runoff and sediment production, so that each slope class is clustered in a separate group and is indicative of meaningful difference between slope classes. Figure 13 and 14 show mean amount of runoff and sediment in different slope classes, respectively.

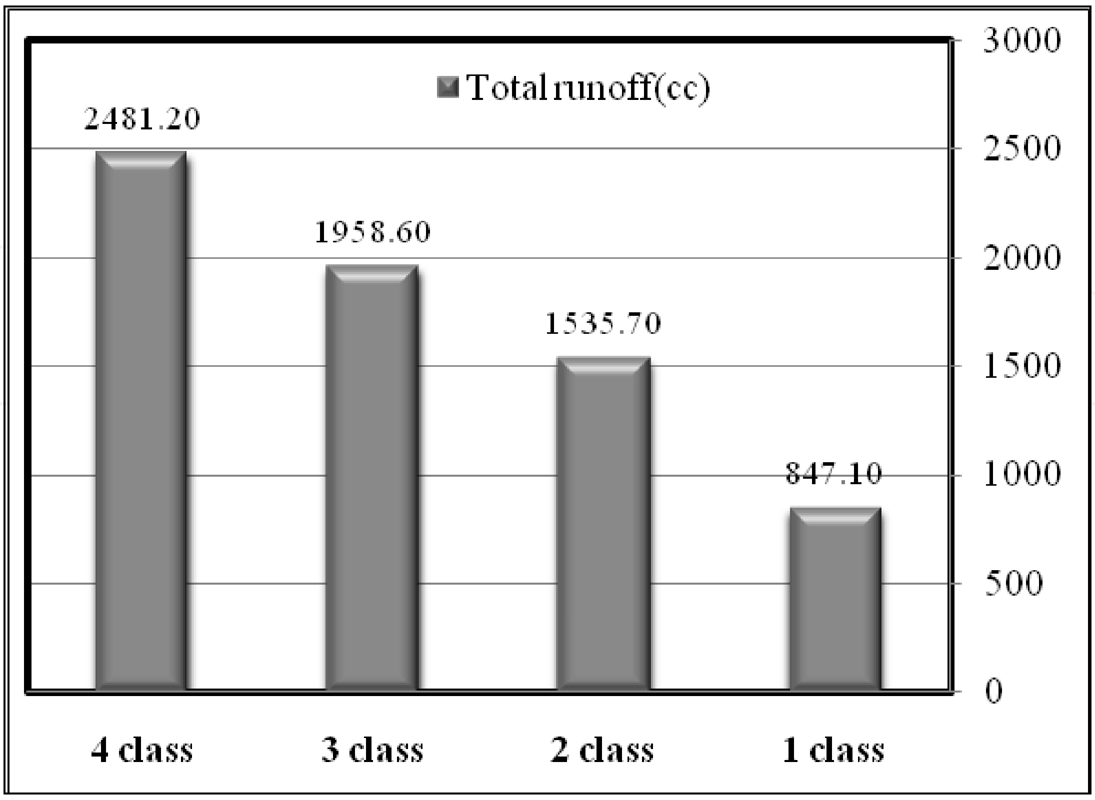


Fig. 13. Mean runoff production in each slope classes

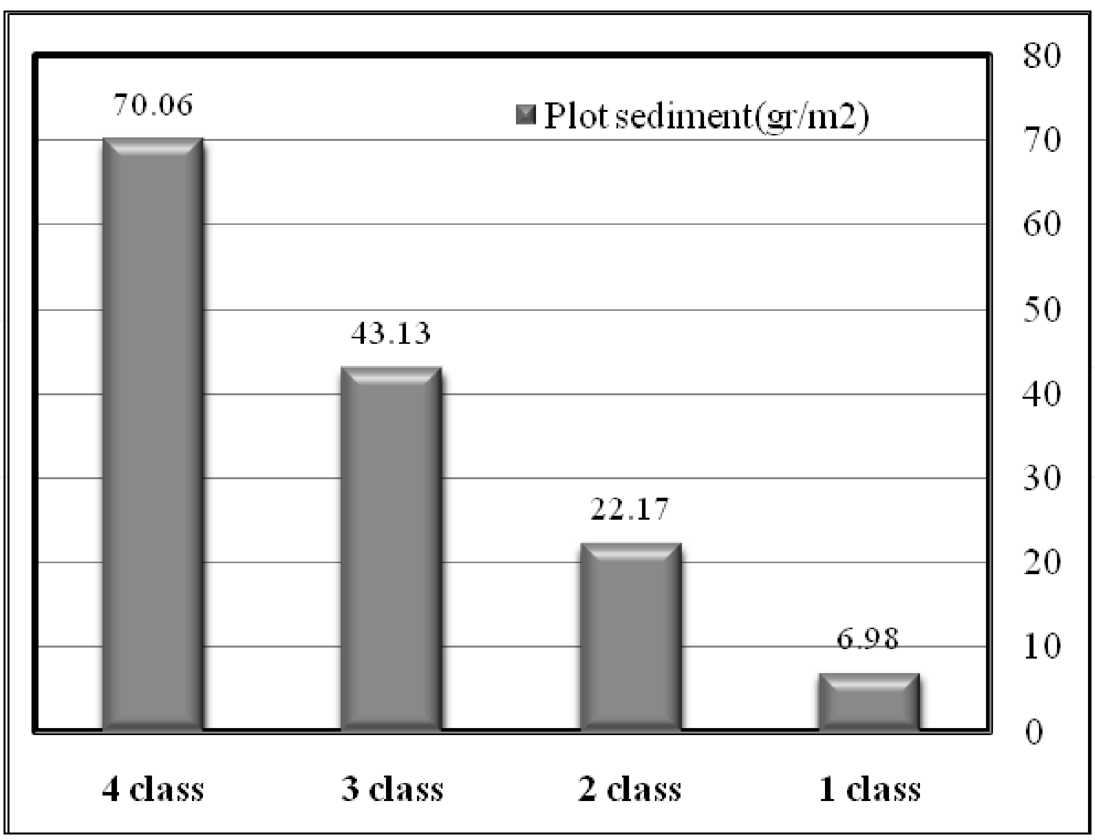


Fig. 14. Mean sediment production in each slope class

Depended variables / In depended variables		Total runoff	Turbidity	Plot sediment
	Unit	cm^3	gr/lit	gr/m^2
slope	%	.880(**)	.665(**)	.80 (**)
Land cover	%	-.298(*)	-.273(*)	-.36 (**)
A-horizon depth	cm	-.428(**)	-.107	-.25 (*)
humidity	%	.27 (*)	.24 (*)	.21
Bulk density	gr/cm^3	-.11	.04	-.04
EC	ms/cm	.24 (*)	.04	.10
pH		.30 (*)	.21	.31 (**)
Organic mater	%	-.31 (**)	-.16	-.28 (*)
$CaSO_4$	meq/100s	-.15	-.19	-.17
Sand	%	-.25 (*)	-.17	-.26 (*)
Clay	%	-.35 (**)	-.27 (*)	-.33 (**)
Silt	%	.54 (**)	.39 (**)	.53 (**)
CEC	cmol/kg	-.16	.46 (**)	.27 (*)
equivalent calcium carbonate	%	.28 (*)	.02	.06
Ca^{++}	meq/lit	.09	-.42 (**)	-.29 (*)
Mg^{++}	meq/lit	-.23 (*)	-.22	-.23
K^+	meq/lit	.29 (*)	.10	.16
Na^+	meq/lit	.46 (**)	.18	.30 (*)
Sum of Cations	meq/lit	.36 (**)	.01	.14
CO_3^{--}	meq/lit	.(a)	.(a)	.(a)
HCO_3^-	meq/lit	.20	-.01	.05
SO_4^{--}	meq/lit	.32 (**)	.02	.11
Cl^-	meq/lit	.23	.20	.25 (*)
Anion sum	meq/lit	.40 (**)	.11	.22
SAR		.48 (**)	.27 (*)	.38 (**)
ESP		.48 (**)	.28 (*)	.38 (**)
Illite	%	.12	.10	.13
Chlorite	%	.26 (*)	.13	.20
Kaolinite	%	-.53 (**)	-.20	-.33 (**)
Smectite	%	.17	.26 (*)	.29 (*)
Mixed layer Clay Minerals	%	-.04	-.15	-.12

(**) Correlation is significant at the 0.01 level (2-tailed). (*) Correlation is significant at the 0.05 level (2-tailed).

Table 8. Pearson Correlation coefficient between different measured variables with runoff volume, sediment production and sediment concentration

Table 8 shows Pearson Correlation Coefficient between different measured variables with runoff volume, sediment production and sediment concentration. With statistical investigation, it was found that slope with %80 and %88 correlation coefficients, has the highest direct relationship with the amount of produced sediment and runoff, respectively, these results are similar to a part of Ribolzi et al. (2010) results. After that is the amount of silt with %53 correlation coefficient with sediment production and %54 correlation coefficient with runoff production. Materials having higher amount of silt are easily dispread and transported and are more erodible (Meyer and Harmon, 1984). The amount of clay has negative relationship with sediment and runoff production. With increase in the amount of sand, permeability is increased and lower amount of runoff is produced, in addition, despite having low adhesion and easy to be separated due to their coarser sizes, sand grains resist to transportation by runoff and produce lower amount of sediment. This result is similar to Vanesland et al. (1987) result. Vegetation cover has a negative correlation coefficient of %36 and the highest adverse relationship with sediment production and meaningful negative relationship with runoff. The reason is decrease of rainfall drop energy and velocity of surface runoff by vegetation (Yu et al. 2006). Percentage of Kaolinite has the highest negative correlation coefficient with runoff volume (%53). Other variables have weaker relationship with sediment and runoff productions. Chemical characteristics also affect runoff and sediment production so that the amount of organic matter has reverse relationship with sediment and runoff productions. In the studied area, the effect of Mg^{++} ion on decreasing sediment production is lower than Ca^{++} ion, so that it does not have meaningful correlation. Two factors of SAR and ESP, although they are not in regression models, have positive relationships with runoff and sediment production. These two are affected by other characteristics such as cations which are important in soil aggregate stability, soil infiltration and formation of surface crusts. The investigation of correlation matrix shows that none of the parameters can solely describe all observed variations in the amount of sediment.

Model no.	Dependent variable	Adjusted R^2	Sig.	Regression Model	Standardized regression model
1	Runoff(cm^3)	0.812	.000	$Y_{Run.}$= 54.254Sl– 31.937Ka+18.704Co+ 739.80	$Y_{Run.}$= 0.788Sl– 0.180Ka + 0.118Co
2	Sediment concentration (gr/lit)	0.771	.000	$Y_{Turb.}$= 0.798Sl+ 2.153CEC– 1.084Ca-18.393	$Y_{Turb.}$= 0.707Sl+ 0.416CEC– 0.282Ca
3	Total sediment(gr/m^2)	0.809	.000	$Y_{Sed.}$= 2.144Sl+ 3.792CEC– 2.071Ca+ 0.968Si – 92.90	$Y_{Sed.}$= 0.740Sl+ 0.285CEC– 0.209Ca+ 0.161Si

$Y_{Run.}$ = Total runoff volume (cm^3), Sl = slope (%), Ka = kaolinite mineral (%),
Co = Chlorite mineral (%), $Y_{Turb.}$= turbidity(gr/lit), CEC= cation exchage capacity(c mol/kg),
Ca= Calcium cation(meq/lit), $Y_{Sed.}$= Total sediment (gr/m^2), Si= silt (%)

Table 9. Regression analyses and obtained models for runoff and sediment

For anticipating variation of sediment production based on physical and chemical properties and determination of share of each variable on explanation of the amount of sediment production, Multiple regression analysis was used. For observing the phenomena of Co-linearity between variables in the extracted models, Variance Inflation Factor (VIF) was noted. In the obtained model VIF for all variables is less than the critical threshold (10) which indicates the absence of co-linearity between independent variables and that presence of all of them in the model is also meaningful. In Table 9, the summary of obtained models for produced runoff volume, sediment concentration and sediment production are shown.

19. Conclusion

Although it seems that a lot of factors are effective on runoff and sediment production of loesses, but investigation of the results show that a few number of key parameters are more important in the studied area and that other parameters have indirect effect on this matter. Slope is the most important factor in sediment and runoff production. Presence of Kaolinite decreases and the increase in the amount of silt increases sediment and runoff productions. Meyer and Harmon (1984) and Vanesland et al. (1987) also found similar results. Among chemical properties which were analyzed in this research, CEC and SAR have direct relationship and calcium cation, the amount organic matter have reverse relationships with sediment production. These are similar to a part of Hasanzade Nafuti et al. (2009), Vitharana et al. (2008) and Mahmoodabadi et al. (2009) results. Among clay mineral, smectite having week bounds between layers and being highly expandable, has direct relationship and Kaolinite being a stable clay mineral, has negative relationship with runoff and sediment production. Zhang et al. (2004) in studying loesses of China found similar relationships between erosion of loesses and the kind and amount of clay minerals. The results of regression analyses show that between the amount of runoff and sediment productions as dependent variables and independent variables with significant correlation, there is a significant relationship at %1 level. Among independent variables, only four factors: Percentage of slope, CEC, soluble Calcium cation and amount of silt, have important role in sediment production and slope and kaolinite and chlorite percentages have important role in runoff production so that these factors control %80 of sediment variations and %81 of runoff volume variations and other %20 relates to factors which are not studied in this research. Among the variables which were entered in the model, slope factor is more important so that one unit change in standard diversion of this factor produces 0.74 unit change in standard diversion of sediment production and 0.79 unit change in standard deviation of runoff volume which is because of its effect on increase of velocity, surface runoff and rain drop impact (Toy et al., 2002). Silt from the view point of size and cohesion is susceptible to erosion. CEC is effective on size and stability of soil aggregation. Calcium cation causes chemical bounds between aggregates and flocculates the grains, therefore has inverse relationship with sediment production of loesses.

In investigation of physical and chemical characteristics of loesses between surface and rill erosional features, it is found that there are not significant differences between these characteristics and the formation of special kind of erosion feature is mainly affected by slope amount and landuse type. The range lands are under overgrazing and without a plan throughout the year. This subject has caused many problems for natural reproduction of important and effected rangeland plants, the result of which being acceleration of erosion and sediment production. Construction of roads for access to cultivated lands across rangelands also has caused accelerated erosion. Also in recent years with promotion of technology, native people of the area use tractor and plough the lands in the direction of slope. These also cause intensification of erosion and sediment production.

20. Suggestion

The independent variables which were studied in this research explain only part of sediment production of loesses. Therefore, is necessary that in future researches, the role of Micro-organisms, Atterberg Limits and aggregate stability would also be studied. With regard to chemical properties of loesses and their erodibility, finding suitable measures for decreasing erosion and runoff through selection of suitable chemical fertilizers in cultivated lands which cause improvement of chemical characteristics of loesses, is recommendable. Performing landuse Planning on loesses and investigating economical and social conditions of the region for adjusting present landuses with the capability of loess are also important. Development of agro-forestry is also an effective way to control erosion of loesses.

21. References

Ahmadi, H., 2006. Applied Geomorphology, vol. 1, University of Tehran Press, 688p.(in Persian)

Ahmadi, H., Feiznia, S., 2006. Quaternary Formations (Theorical and Applied Principles in Natural Resources), University of Tehran Press, 627p. (in Persian)

Barthes, B., Roose, E., 2002. Aggregate stability as an indicator of soil susceptibility to runoff and erosion; validation at several levels, Catena, 47, 133 –149.

Bihamta, M. R., Zare Chahouki, M. A., 2008. Principles of Statistics for the Natural Resources Science, University of Tehran Press. 300p.(in Persian)

Bissonnais, Y. L., Renaux, B., Delouche, H., 1995. Interaction between soil properties and moisture content in crust formation, runoff and interrill erosion from tilled loess soils, Catena, 25, 33-48.

Feiznia, S., 2008. Applied sedimentology with emphasis on soil erosion & sediment production, Agriculture and Natural Resources University of Gorgan Press. 356p.(in Persian)

Feiznia, S., Ghayumian, J., Khaje, M., 2005. The study of the effect of physical, chemical, and climate factors on surface erosion sediment yield of loess soils (Case study in Golestan Province). Pajohesh va Sazandegi Journal, 66, 14-24.(in Persian)

Fernandeze, C., Avega, J., 2006. Runoff and soil erosion after rainfall simulations in burned soils. Forest Ecology and Management, 23,375-377.

Frechen, M., Kehl, M., Rolf, C., Sarvati, R., Skowronek, A., 2009. Loess chronology of the Caspian Lowland in Northern Iran, Quaternary International, 198, 220–233.

Golestan Province Watershed Management, 2003. Report for technical helps to soil conservation in Loess Region. 75p.(in Persian)

Golestan Province Watershed Management, 2007. Assessment of watershed plan in Shordare Basin, 170p.(in Persian)

Hasanzade Nafuti, M., Feiznia, S., Ahmadi, H., Peirovan, H. R., Ghayumian, J., 2009. Investigations of the effects physical and chemical characteristics of Marls on sediment yield using rainfall Simulator physical model. Scientific Research Journal of Engineering Geology of Iran, 1, 35-48.(in Persian)

Jamab (Consulting Engineering Co.), 1996. Integrated water project for Iran, Gorganrood Catchment Report, Ministry of Energy, Iran. (in Persian)

Kalantari, K., 2006. Data processing and analysis in socio-economic research. Sharif Publication. 388p.(in Persian)

Kehl, M., Sarvati, R., Ahmadi, H., Frechen, M., Skowronek, A., 2005. On loess deposits of northern Iran, Quarterly Geographical Journal of Territory, 1(4), 1-11.

Keli Z., L. Shuangcai, Wenying, P., 2002. Erodibility of agricultural soils in the loess plateau of china, 12th ISCO Conference Beijing 2002, pp. 1-10

Khaje, M., 2003, Study of sedimentology, sedimentary environment and sediment production in Gorganrood Catchment (Il Chashmeh and Ghurchay), Ph.D. Thesis, Azad Islamic University, Science and Research Branch.(in Persian)

Khormali, F., Kehl, M., 2010. Micro morphology and development of loess-derived surface and buried soils along a precipitation gradient in Northern Iran. Quaternary International Journal, Number of pages15, Article in press.

Liu, T., 1988. Loess in China, Springer Verlag Publication, 224p.

Mahmoodabadi, M., Charkhabi, A. H., Refahi, H., 2007. The effect of soil physical and chemical properties on runoff generation and sediment yield using rainfall simulator, Agricultural Engineering Research Journal, 8, 1-16.(in Persian)

Meyer, L. D., Harmon, W., 1984. Susceptibility of agricultural soils to interrill erosion, Soil science society of America Journal, 48, 1152- 1157.

Moghaddam, M., 2007. Range and Range Management, University of Tehran Press. 350p.(in Persian)

Montgomery D. C., Pech, E., Geffry, G., 2001. Introduction to linear regression analysis, Third edition, Jon Wiley & Sons publication, 350p.

Moore, D., Reynolds, R., 1989. X-ray diffraction and the identification and analysis of clay minerals, Oxford University Press, 332p.

Okhravi, R., Amini, A., 2001. Characteristics and provenance of the loess deposits of the Gharatikan watershed in Northeast Iran, Global and Planetary Change, 28,11–22.

Pashaee, A., 1998. Investigation of physical and chemical characteristics and source of loess deposits in Gorgan and Rasht Areas. Journal of Geological Science, 23 &24, 67-78.(in Persian)

Qiangguo, C., 2002. The relationship between soil erosion and human activity on the loess plateau, 12th ISCO Conference Beijing 2002.

Refahi, H., 2001. Soil erosion and control, University of Tehran Press. 551p.(in Persian)

Ribolzi, O., Patin, J., Bresson, L.M., Latsachack, K.O., Mouche, E., Sengtaheuanghoung, O., Silvera, N., 2010. Impact of slope gradient on soil surface features and infiltration on steep slopes in northern Laos, Geomorphology, Number of Pages 11.(Article in press)

Rhoton, F., Duiker, S., 2008. Erodibility of a soil drainage sequence in the loess uplands of Mississippi, Catena, 75, 164–171.

Rozoycki S. Z., 1991. Loess and loess-like deposits, The Publishing House of the polish academy of Sciences, Wroclaw, 187p.

Saghafian, B., 2003. Investigation and determination of criteria for rain simulator construction based on climatic conditions of Iran, Soil conservation and Watershed Management Research Center Press.85p.(in Persian)

Schiettecatte, W., Jin, K., Yao, Y., 2005. Influence of simulated rainfall on physical properties of a conventionally tilled loess soil, Catena, 64, 209-221.

Sheklabadi, M., Charkhabi, A., 2003. Runoff generation and sediment yield in soil with different parent materials(Galabad Basin, Ardestan), Journal of Olum va Fonune Keshavarzi va Manabe Tabiee, 2, 88-100.(in Persian)

Toy, T., Foster, G., Renard, K., 2002. Soil erosion: Processes, Prediction, Measurement and Control, John Wiley & Sons Publication, 338p.

Vanesland, A., Lal, R., Gabreiels, D., 1987. The erodibility of some Nigerian soils: A comparison of rainfall simulator result with estimates obtained from the wishmeier nomograph, Hydro. Process, 1, 255-265.

Vitharana, V., Mervenne, M., Simpson, D., 2008. Key soil and topographic properties to delineate potential management class for precision agriculture in the European loess area, Geoderma, 143, 206-215.

Victora, C., Kaceevas, A., Flora, H., 1998. Soil erodibility assessments with simulated rainfall and the USLE nomograph in soil from Uruguay. Proceedings of 16th World Congress of soil science. Montpellier. France. Symp. No. 31.

Wei, W., Chen, L., Fu, B., 2007. The effect of land uses and rainfall regimes on runoff and soil erosion in the semi-arid loess hilly area, China, j. of Hydrology, 335, 247- 258.

Yu, X., Zhang, X., Li, J., Zhang, M., Xie, Y., 2006. Effects of vegetation cover and precipitation on the process of sediment produced by erosion in a small watershed of loess region, Acta Ecologica Sinica, 26(1), 1-8.

Zhang k., Li, S., Peng, W., Yu, B., 2004. Erodibility of agricultural soil on loess plateau of China, soil and tillage research, 76, 157-165.

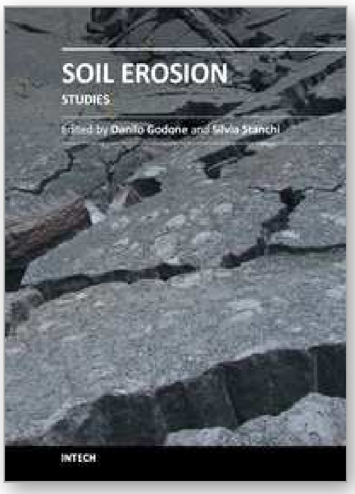
Zhang, X., Liu, W., Li, Z., Zheng, F., 2009. Simulating site-specific impacts of climate change on soil erosion and surface hydrology in southern loess plateau of China, Catena, 79, 237–242.

Zhenge, F., 2006. Effect of Vegetation Changes on Soil Erosion on the Loess Plateau, Pedosphere, 16(4), 420-427.

Zheng, M., Qiangguo, C., Hao, C., 2007. Effect of vegetation on runoff-sediment yield relationship at different spatial scales in hilly areas of the loess plateau, North China, Acta Ecologica Sinica, 27(9), 3572-3581.

Zhou, C., Shangguan, P., 2007. The effects of ryegrass roots and shoots on loess erosion under simulated rainfall, j. of Catena, 70, 350-355.

Zhou, C., Gan, T., Shangguan, P., Dong, B., 2010. Effects of grazing on soil physical properties and soil erodibility in semiarid grassland of the Northern Loess Plateau (China), Catena, 82, 87–91.



Soil Erosion Studies

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Soil erosion affects a large part of the Earth surface, and accelerated soil erosion is recognized as one of the main soil threats, compromising soil productive and protective functions. The land management in areas affected by soil erosion is a relevant issue for landscape and ecosystems preservation. In this book we collected a series of papers on erosion, not focusing on agronomic implications, but on a variety of other relevant aspects of the erosion phenomena. The book is divided into three sections: i) various implications of land management in arid and semiarid ecosystems, ii) erosion modeling and experimental studies; iii) other applications (e.g. geoscience, engineering). The book covers a wide range of erosion-related themes from a variety of points of view (assessment, modeling, mitigation, best practices etc.).