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Plot-Scale Effects on Soil Loss under Semi-Arid Areas

¹Mohammad Reza Roshani, ²Abdossaleh Rangavar, ³Mohammad Reza Javadi

¹M.Sc Student of Watershed Management, Islamic Azad University Nour Branch, Iran.

²Khorasan Razavi Agricultural & Natural Resources Research Center, Iran.

³Assistant professor, Islamic Azad University Nour Branch, Iran.

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ABSTRACT

Background: In Earth and ecological sciences, an important, crosscutting issue is the relationship between scale and the processes of runoff and erosion. Plot scale studies are widely used to determine runoff and soil erosion model's basic data. **Objective:** The present study aims to investigate the role of the surface area of experimental plots in the assessment of soil loss. For this purpose, five different watersheds were selected with the varying features of surface area, vegetation cover; soil type and typography from Kalat Research Site, 100km northeast of Mashhad, and plots with lengths of 2, 5, 10, 15, 20 and 25 and fixed width of 2 m were installed. Sediment storage tanks were installed at the outlets of the watersheds and their plots. **Results:** The amount of sediment in the outlet of the five watersheds and their 24 experimental plots measured and calculated after 22 rainfalls between the years of 2006 to 2010. The correlation between the sedimentation yields of each rainfall event was determined for each watershed/plot along with the optimal plot area for sedimentation assessment. **Conclusion:** Statistical analysis of the results indicated that there was a signification correlation at $P < 0.01$, particularly in third degree functions, between the area of watersheds and experimental plots in Kalat Researc Site which represents semi-arid areas of the province. Therefore, in similar conditions, utilizing a plot with minimum surface area can save time and money when assessing the rate of sedimentation and soil loss of a region.

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INTRODUCTION

Soil erosion also depends on scale (Mariano *et al*, 2010). Understanding the influence of scale on hydrological and ecological processes has been an active area of research for at least the last several decades, but remains a significant challenge (Cammeraat, 2002, YYassif, 2004, Newman *et al*, 2006). Studies and observations have shown that soil erosion is drastically on the increase in most regions of the country inflecting irreparable damage. The current situation necessitates protection schemes in the form of watershed management plans (Rangavar *et al*. 2004). Soil erosion is a serious problem that stems from a combination of agricultural intensification, land cover removal and intense rainstorms. Erosion may also be exacerbated in the future in many parts of the world because of climatic change towards a more vigorous hydrologic cycle (Amore *et al.*, 2004; Sadeghi *et al.*, 2008). Many planning and management techniques have been developed to reduce soil loss and sediment transport to hydrologic drainage networks. The quantification of soil erosion processes at various temporal and spatial frames is crucial to the understanding of material transport over land surface (Brenot *et al*, 2008). Soil erosion is a serious threat posed by factors such as intensification of agricultural activities, vegetation cover removal and heavy rainfall. Precise estimation of sedimentation rate of various parts of watersheds is the backbone of any planning for fighting erosion and reducing sedimentation. Logically a realistic estimation requires data on water discharge and sedimentation but since most of the country's watersheds lack the relevant statistic data, experimental methods are employed. Taking into account a number of important factors based on observations, measurements, experiments and statistical methods, the inventor of such methods related the mentioned factors to soil loss (Rafahi, 2000). All such methods have external origins and are indigenous the area they were designed for. Therefore, their application in other countries, such as Iran, entails an assessment of their functionality, making it necessary to conduct comprehensive and continuous studies on soil erosion in various climatic conditions. On the other hand, any kind management scheme or precise planning regarding soil conservation and prevention of soil erosion entails stoppage or reduction of

Corresponding Author: Mohammad Reza Roshani, Islamic Azad University Nour Branch, Iran.

E-mail: Roshani18598@Gmail.com. Tel:+989155056742

damages. In order to achieve this, the main contributing factors to soil erosion are identified and then conservation plans of various proportions are designed and implemented. Naturally, various methods can have different results depending on their area of operation. As a result, devising a suitable and effective method requires considerable studies and experimentations (Ranavar, 2004). scale effects on soil erosion estimation dealing with a large number of variables, i.e. vegetation, management, soil, topography and climate (Amore *et al.*, 2004).

Considering the importance of the issue, over the years, various methods have been employed which were mostly qualitative but they have gradually become quantitative which in turn developed to include multi-factorial equations. Among such methods of studying soil erosion is the use of experimental plots to collect and measure runoff and sediment for the purpose of assessing water and soil loss and also determining the contributing factors to water erosion and erosion mechanism. Experimental plots cover an area of a watershed in order to control the factors influencing the measurement experiments. This is done via walls made of metal, wood, concrete or soil. There are channels and containers, usually made of metal or cement, installed at the lower parts of these plots to collect runoff and sediment (Rangavar *et al.*, 2004). The soil erosion plot and rainfall simulator are two research tools widely used in erosion studies worldwide. As a result, rainfall simulation experiments with different specifications and set up patterns are frequently used to study soil erosion processes worldwide (Sharpley and Kleinman, 2003; Shekl Abadi *et al.*, 2003; Boix Fayos *et al.*, 2006; Sadeghi *et al.*, 2007; Fernandez Galvez *et al.*, 2008; Leys *et al.*, 2010; Sadeghi *et al.*, in press, 2011; Mayor *et al.*, 2011; Delmas *et al.*, 2012).

A review of the available literature on the dimensions of such experimental plots designed to measure soil and surface loss reveals that there is not enough data on the subject. There have been numerous studies conducted throughout the world employing plots ranging from a few hundred centimeters to several hectares with various outcomes. The studies conducted by Walling (1983), Osterkamp and Toy (1997), Poesen and Hooke (1997), Cammeraat (2002 and 2004), de Vente and Poesen (2005) and Puigdefábregas (2005) show how the geomorphic and hydrologic processes which influence the delivery, transport and storage of sediment depend on the plot scale.

Studies (Evans, 1993), stressing the importance of the scale, show that the specific mean soil loss rates from field-sized areas are much lower than those from plot-sized areas. Cerdan *et al.* conducted a study using 440 and 480sqm plots in Normandy watershed, France, and then compared the data with a 90 hectare and 1100 hectare watershed. They discovered a significant difference between the two. Biox-fayos *et al.* (2006) experimented on 1, 30 and 82sqm plots and also 0.24sqm round plots in a watershed in a Spain. After comparing the results they observed differences due to varying factors influencing erosion at the level of plots. They concluded that the estimated amount of runoff and sediment in the sub watershed and its surrounding watershed was far less than that of plots situated in a watershed. In a study entitled Measuring Soil Erosion Using Erosion Plots, Biox-fayos *et al.* (2006) found out that soil erosion plots of various types and sizes are extensively used in studies on geomorphologic processes related to soil erosion. Depending on the characteristics of such plots and their suitability in mirroring the characteristics of the ecosystem and eventually the purpose of the study, various results might be obtained.

Cerda *et al.* (2009) investigated the impact of plot size on soil erosion in Rainfed farmlands, Eastern Spain, and concluded that soil erosion depends on plot size in slope scale. The reason is that soil erosion due to changes in permeability is a scale dependent process. Sedimentation potential depends on factors such as vegetation cover, coarseness and erosion speed. Different types of land use can also affect the influence of plot size. For example, plot size might be less important in areas with uniform vegetation cover or in wastelands. Furthermore, soil displacement is more intensive in areas with sparse vegetation cover. There is also more soil erosion in smaller plots where there is an appropriate dependency on runoff re-infiltration.

Raclot *et al.* (2009) also analyzed a runoff and erosion dataset of 18 rainfall events from fields of approximately 1200 m² and 3200 m² with different vegetation covers and tillage practices in a Mediterranean area. Results showed that the erosion rates observed at catchment scale were significantly lower than those observed at the scale of individual fields.

By analyzing the soil loss data of plots with varying length and studying the models which are extensively used in soil erosion process such as the empirical universal soil loss equation USLE and revised USLE (RUSLE), Bargalo and Fero (2020) suggested that soil loss i.e. the mass of soil lost by water erosion per unit surface area, increases with slope length, although contrasting experimental results may be found in the literature.

Leys *et al.* (2010) showed that the difference in runoff and erosion response between conservation and conventional tillage increases with the length of the plot/field considered. It was also proved that the relative scale effect is more important for erosion than for runoff. The occurrence of significant runoff transmission losses along the hillslope was experimentally found as the main reason behind such findings

Bargalo (2011) investigated the influence of plot size on soil loss in two stations in Italy in order to experimentally measure the role of plot width and length on the amount of collected runoff, sediment

concentration and soil loss using the data collected from bare plots with differing widths (2 to 8m) and length (11 to 22m). The experiment showed that the difference between the width and length of the plots was not statistically significant at 1% area. Soil loss showed greatest changes in relation to plot size and the most influence was observed in width=11.6m and length=25m. The impact of plot length and width differs based on erosion factors.

Ranavar *et al.* (2008) studied the influencing factors on soil erosion and runoff potential to revive and increase the productivity of worn out pastures via agroecology using experimental plots (width=2m, length= 5, 10, 15, 20, 25m).

Boshra Se Ghale *et al.* (2007) investigated the accuracy of 12 experimental plots of varying lengths (width=2m), in two directions of north and south, in the assessment of soil sedimentation. The location was a watershed in Kalat Soil Conservation Research Site. The study showed that in small watersheds, the accuracy of the estimation of soil sedimentation varies based on the plot length. The suitable plot length for the assessment of the amount of runoff and sediment is the average length of watershed slope, more than 20m.

An investigation of the existing literature regarding the application of experimental plot in soil erosion indicates that despite of the attempts made for the standardization of soil conservation and hydrology research methods, plots of differing surface areas are used in such studies. There is simply not enough data regarding appropriate plot sizes. Therefore, in a study aimed at assessing the accuracy of plots with different surface areas in estimation of soil loss due to rainfall, five small watersheds were studied in a soil conservation research site in the north-east of the country.

MATERIALS AND METHODS

2-1-Description of study area:

Kalat Soil Conservation Research Site (36°41'01" N latitude, 60°15'30" E longitude) with the area of approximately 50 ha, 100km north-east of Mashhad, is located in the eastern part of Kopet Dagh watershed, Khorasan Razavi province. Kopet Dagh sediment watershed is like a narrow strip in the north-east of Iran which covers considerable parts of Turkmenistan and northern Afghanistan (figure 1).

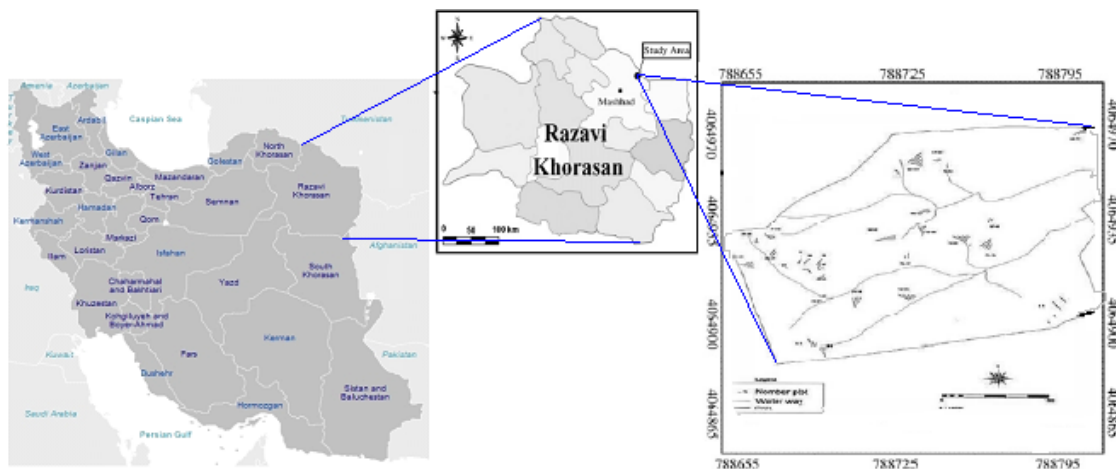


Fig. 1: the location of Kalat Soil Conservation Research Site in Khorasan Razavi province

The amount of precipitation (on average 257mm), average temperature (15°C) and area's Domarten coefficient (10.2) is indicative of semi-arid climate (Rangavar 2004). From the geological point of view, the area is covered with uniform shale which consists of thin layer of sandstone, the soil in other areas belongs to plateau physiography which comprises of Entisol and aridisol classes. The dominant vegetation cover of the site is *Artemisia sieberi* – *Poa bulbosa*. In addition, in some areas *Poa bulbosa* - *Artemisia sieberi* – *Carex stenophylla* and sometimes annual species such as *Poa bulbosa* – *Carex stenophylla* are dominant. The vegetation cover percentage varies between 0 to 80% throughout the area (Rangavar, 2004).

In this area, Kalat Research Site, which enjoys diverse soil, vegetation cover and topography, 80 experimental plots were installed with metal walls (length=5, 10, 15, 20 and 25m, width=2m) in the form of 23 groups located in areas with different types of vegetation cover, slope and soil depth in order to assess the amount of runoff and sediment. There were runoff/sediment tanks at the lower end of the plots and two rain gauges were also installed in the station to record data regarding the intensity, duration and amount of each rainfall event.



Fig. 2: metal plots installed in the deep soil of Kalat Site

2-2-Methodology:

In the first step, five watershed with varying surface areas were selected to install runoff/sediment tanks on their outlets. The watershed were coded (A_1 , A_2 ...) and their features were carefully studied. In total, 24 plots (width=2m, length=5, 10, 15, 20, 25m) with different conditions and equipped with runoff/sediment containers were selected. They had a systematic installation but their distribution was random (figure 3).



Fig. 3: Watershed A_2 and the position of the plots and sediment tanks

2-3-Measuring Precipitation and Sedimentation:

Measuring soil erosion in deserts is carried out for different reasons such as soil conservation and understanding and controlling the erosion process. After the installation of the plots and their runoff/sediment tanks as well as the runoff/sediment tanks situated at the outlets of the study watersheds, measurements are taken after each rainfall event by trained personnel.

In order to investigate the possible role of the shower characteristics on the function of the plots, shower characteristics and the resulting sedimentations were analyzed for 22 rainfall events during the years of 2006 to 2010. In the selection of the rainfall event, special care was taken to consider enough intervals between each rainfall in order to prevent any possible interference caused but the residual humidity of the soil from previous rainfall event.

2-4-Analyses:

Following each rainfall event, samples containing sediment mixtures with the approximate volume of 2 liters, proportionate to the amount of sediment concentration, were drawn by trained personnel. In the case of the containers which had less than 2 liters runoff, the total size of the samples was calculated before sending them to laboratory for analysis. In the laboratory, samples were first properly mixed using an electric mixer, in the case of deposited samples the operation was done manually, and then 50cc of the solution was poured in a graduated cylinder through a funnel. The sample was then transferred to a Petri Dish, with a known weight. The next stage was to place the samples in an oven at 110 centigrade for 24 hours (Rangavar, 2004; Putjaroon and

Pongboon, 2004). After extracting the sample from oven, it was reweighed (accuracy=0.0001) and the actual weight of the dry substance was ascertained, after subtracting the weight of the Petri dish, from which the degree of muddiness was calculated based on grams per liter. The resulting data was at the scale of unit area so that comparisons could be made (Rangavar, 2004; Turkelboom and Trebil, 1998).

The data related to the sediments of watersheds and their plots along with other required information (physical, vegetation cover etc.) was put into a database using Excel and then transferred to SPSS Ver15 for further analysis. The average amount of the soil transferred from each plot during 22 rainfall event was divided by the plot unit area so that the unit of soil loss was unified for plots with varying proportions. Eventually, the amount of transferred soil in each area unit (square meter) was used in the calculations. The amount of soil loss of each watershed and the related plots was compared to others using a descriptive-inferential method in order to establish the optimal area of the plot. In the descriptive methods the special sedimentation of plots and watersheds were quantitatively studied and in the inferential method the relationship between the special sedimentation of watersheds and plots was investigated using ANOVA. Since data normalization is implicit in the analysis of various regression methods, assuming that the data was normal, the comparison between the sedimentation of watersheds and the inside plots was carried out. Eventually, considering the significance level and better R^2 , the model which could best represent the relationships between the special sedimentation of plots and watersheds and the representative plot, based on the area of the desired plot, were chosen. The total watershed sediment load was also calculated considering the surface area of the watershed multiplied by the special sediment of the watershed.

The physical measurements of the five watersheds indicated that is smallest watershed (A_1) was 1190sqm and the biggest (A_5) was 16917sqm. The average slope varied between 29.46% (A_5) to 63.5% (A_2).

The experimental results of soil decomposition showed that in Kalat Research Site none of the soil samples of the watersheds contained cobbles which were 3 inches (7.62cm) or larger in diameter, based on USDA, CSSC, ASTM classifications. The total percentage of the existing gravels in the watersheds, ranges between 2 to 40% and finegravels which based on USDA system they have a diameter of 2 to 13mm have the largest presence (10.4%). Also, the sand component ranges from 16.09 to 42.04%, silt from 46.02 to 67.43% and clay from 8.46 to 16.48. Based on these findings and using the Soil texture triangle it can be concluded that for the most part, the soils of the study watershed s fall in the silty loam texture class. The amount of the silt component (58.88%) is larger than the amount of the other two components; sand (average 28.84%) and clay (average 12.28%). Studies indicated that increase in the silt component results in an increase in soil erodibility (Rafahi, 2000). Studies of Vishmire and Manring reveal that slight changes in the silt percentage generally result in considerable changes in soil erodibility factor (K) (Rafahi, 2000). Results of the decomposition of sand to its components revealed that from the five components of very fine, fine, coarse and very coarse sand, very fine sand with a range of 6.48% and 16.24% has the largest amount which from the point of view of the size belongs to the silt part of the soil.

The PH of the soil in the study watersheds was between 7.67 to 7.85 which is due to the fact that the soil in the area is for the most part shallow and young and most of the and since the parent materials are calcareous and contain significant amounts of $CaCO_3$, compared to other salts (Noorbakhsh and Karimian, 1997).

Table 1, demonstrates the most important physicochemical characteristics of the soil in the five watersheds of Kalat Research Site.

Table 1: physicochemical analysis of the soil parameters

| Total sand % | sand (1-2mm) % | sand (0.5-1mm) % | sand (0.25-0.5mm) % | sand (0.1-0.25mm) % | sand (0.05-0.1mm) % | silt (0.002-0.05mm) % | Clay (<0.002mm) % | O.M % | CaCO ₃ % | Ca(s) Cmol/Kg | Na(s) Cmol/Kg | CEC Cmol/Kg | SP % | EC ds/m | PH | Watershed code |
|--------------|----------------|------------------|---------------------|---------------------|---------------------|-----------------------|-------------------|-------|---------------------|---------------|---------------|-------------|-------|---------|------|----------------|
| 42.04 | 4.13 | 4.98 | 6.20 | 10.94 | 15.80 | 46.02 | 11.93 | 0.75 | 8.71 | 9.64 | 0.04 | 8.06 | 32.35 | 2.07 | 7.85 | A ₁ |
| 21.68 | 3.49 | 5.32 | 3.11 | 3.28 | 6.48 | 64.41 | 13.91 | 1.22 | 2.36 | 3.57 | 0.03 | 11.30 | 37.60 | 0.71 | 7.67 | A ₂ |
| 29.72 | 1.97 | 4.87 | 5.25 | 7.08 | 10.22 | 61.82 | 8.46 | 0.83 | 1.87 | 18.65 | 0.04 | 12.26 | 40.03 | 2.89 | 7.77 | A ₃ |
| 34.65 | 3.53 | 4.68 | 3.76 | 6.46 | 16.24 | 54.72 | 10.60 | 1.57 | 5.98 | 8.13 | 0.03 | 10.60 | 38.30 | 1.81 | 7.85 | A ₄ |
| 16.09 | 0.58 | 1.45 | 2.02 | 3.06 | 8.98 | 67.43 | 16.48 | 1.76 | 1.86 | 2.55 | 0.04 | 12.70 | 43.11 | 0.64 | 7.80 | A ₅ |

Comparison of the special sedimentation data of the watersheds and their plots revealed that the amount of soil loss in the plots is far more than the level of soil loss in the watershed (Figure 4).

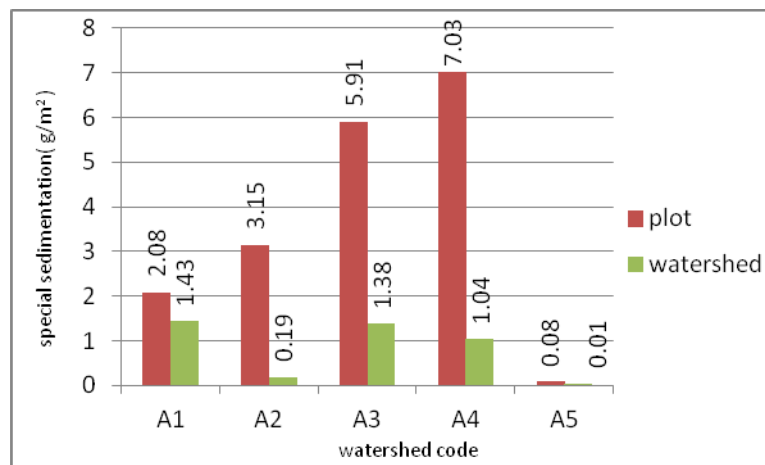


Fig. 4: comparison of the special sedimentation of the plots and surrounding watersheds

Table 2, present the general results of correlation coefficients and significance levels between the special sedimentation of the five watershed s and their plots during 22 rainfall events in the form of linear second degree and third degree functions. Coefficient of determination (R^2) was used to investigate the correlation between the special sedimentation of plots and the surrounding watershed s at 1% and 5% levels. Correlation coefficients indicated that third grade functions have a higher coefficient of determination compared to other two correlations. Therefore this function was adopted to present the correlation between the special sedimentation of the watershed and the special sedimentation of their plots.

Table 2: correlation coefficients and significance levels of the special sedimentation of watersheds and their plots

| Watershed code | Plot number | Plot area(m ²) | Number of data | Function | | |
|----------------|-------------|----------------------------|----------------|---------------------|---------------------|---------------------|
| | | | | Linear | Second degree | Third degree |
| A ₁ | 69 | 10 | 22 | 0.009 ^{ns} | 0.021 ^{ns} | 0.024 ^{ns} |
| | 70 | 20 | 22 | 0.001 ^{ns} | 0.043 ^{ns} | 0.538** |
| | 71 | 30 | 22 | 0.008 ^{ns} | 0.068 ^{ns} | 0.116 ^{ns} |
| | 72 | 40 | 22 | 0.201* | 0.331* | 0.564** |
| A ₂ | 16 | 20 | 22 | 0.324** | 0.530** | 0.561** |
| | 17 | 10 | 22 | 0.352** | 0.380* | 0.844** |
| A ₃ | 26 | 10 | 22 | 0.015 ^{ns} | 0.033 ^{ns} | 0.173 ^{ns} |
| | 27 | 20 | 22 | 0.600** | 0.688** | 0.697** |
| | 28 | 40 | 22 | 0.470** | 0.695** | 0.697** |
| | 29 | 20 | 22 | 0.223* | 0.743** | 0.744** |
| A ₄ | 31 | 40 | 22 | 0.001 ^{ns} | 0.039 ^{ns} | 0.068 ^{ns} |
| | 32 | 10 | 22 | 0.873** | 0.913** | 0.976** |
| | 33 | 10 | 22 | 0.027 ^{ns} | 0.353* | 0.364* |
| | 34 | 20 | 22 | 0.143 ^{ns} | 0.166 ^{ns} | 0.166 ^{ns} |
| | 35 | 30 | 22 | 0.089 ^{ns} | 0.182 ^{ns} | 0.182 ^{ns} |
| | 36 | 40 | 22 | 0.291* | 0.341* | 0.425* |
| | 37 | 20 | 22 | 0.220* | 0.225 ^{ns} | 0.245 ^{ns} |
| A ₅ | 38 | 30 | 22 | 0.065 ^{ns} | 0.142 ^{ns} | 0.166 ^{ns} |
| | 6 | 30 | 22 | 0.051 ^{ns} | 0.051 ^{ns} | 0.124 ^{ns} |
| | 7 | 20 | 22 | 0.000 ^{ns} | 0.000 ^{ns} | 0.000 ^{ns} |
| | 8 | 10 | 22 | 0.100 ^{ns} | 0.139 ^{ns} | 0.201 ^{ns} |
| | 9 | 30 | 22 | 0.946** | 0.969** | 0.988** |

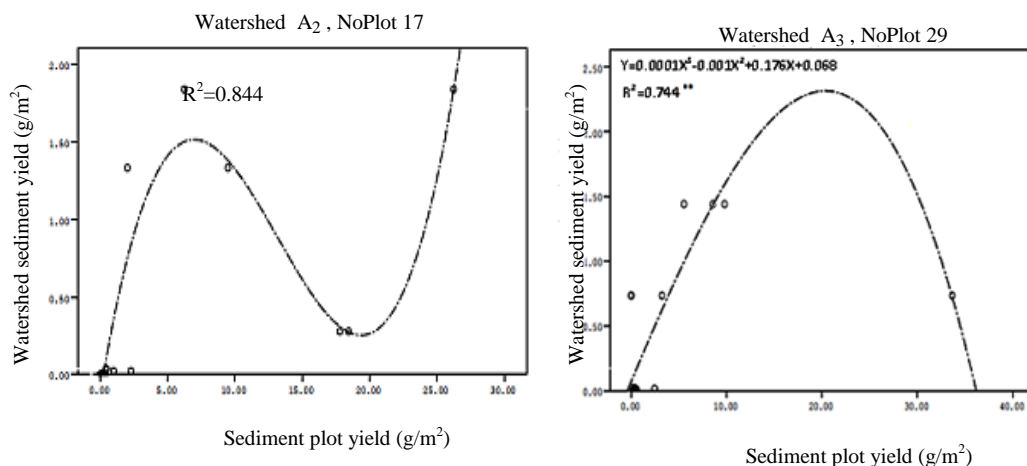
Discussion and conclusion:

Studies acknowledge the application of experimental plots of different proportions for various purposes such as determining the role of slope length, percentage, direction, vegetation cover and soil characteristics in soil erosion but there hasn't been much effort put into identifying the most suitable plot surface area which can be representative of watersheds' condition. The present study aims to investigate the role of plots' surface area in the accuracy of soil erosion assessments. For this purpose, the soil loss of five small watersheds, with varying conditions, and 24 experimental plots inside them were analyzed during 22 rainfall events of different intensities in Kalat Research Site which is representative of semi-arid climate.

Table 3: ANOVA of the correlation between the special sedimentation of the watershed and its plots using a third degree function

| Watershed code | Plot number | Plot area(m ²) | Standard error | Sum of squares | Df | Mean square | F | significant level |
|----------------|-------------|----------------------------|----------------|----------------|----|-------------|---------|-------------------|
| A ₁ | 69 | 10 | 0.067 | 0.002 | 3 | 0.001 | 0.145 | 0.932 |
| | 70 | 20 | 5.551 | 646.081 | 3 | 215.360 | 6.989 | 0.003 |
| | 71 | 30 | 0.556 | 0.731 | 3 | 0.244 | 0.789 | 0.516 |
| | 72 | 40 | 0.990 | 22.827 | 3 | 7.609 | 7.764 | 0.002 |
| A ₂ | 16 | 20 | 0.100 | 0.244 | 2 | 0.122 | 12.132 | 0.000 |
| | 17 | 10 | 0.268 | 6.957 | 3 | 2.319 | 32.369 | 0.000 |
| A ₃ | 26 | 10 | 0.093 | 0.033 | 3 | 0.011 | 1.256 | 0.319 |
| | 27 | 20 | 4.467 | 824.676 | 3 | 274.892 | 13.777 | 0.000 |
| | 28 | 40 | 1.646 | 112.399 | 3 | 37.466 | 13.829 | 0.000 |
| | 29 | 20 | 0.295 | 4.306 | 3 | 1.435 | 16.486 | 0.000 |
| A ₄ | 31 | 40 | 0.185 | 0.045 | 3 | 0.015 | 0.437 | 0.729 |
| | 32 | 10 | 0.001 | 0.001 | 3 | 0.000 | 244.397 | 0.000 |
| | 33 | 10 | 0.004 | 0.000 | 3 | 0.000 | 3.431 | 0.039 |
| | 34 | 20 | 0.838 | 2.521 | 3 | 0.840 | 1.197 | 0.339 |
| | 35 | 30 | 0.196 | 0.163 | 2 | 0.081 | 2.110 | 0.149 |
| | 36 | 40 | 3.300 | 144.813 | 3 | 48.271 | 4.434 | 0.017 |
| | 37 | 20 | 0.414 | 1.001 | 3 | 0.334 | 1.948 | 0.158 |
| | 38 | 30 | 2.305 | 17.922 | 3 | 5.974 | 1.124 | 0.367 |
| A ₅ | 6 | 30 | 0.001 | 0.000 | 3 | 0.000 | 0.849 | 0.485 |
| | 7 | 20 | 0.000 | 0.000 | 3 | 0.000 | 0.849 | 0.485 |
| | 8 | 10 | 0.001 | 0.000 | 3 | 0.000 | 1.507 | 0.247 |
| | 9 | 30 | 0.007 | 0.077 | 3 | 0.026 | 477.565 | 0.000 |
| | 10 | 20 | 0.034 | 0.021 | 1 | 0.021 | 18.198 | 0.000 |
| | 11 | 10 | 0.014 | 0.013 | 3 | 0.004 | 21.202 | 0.000 |

The result of the comparison of the special sedimentation of plots and their surrounding watersheds indicated that the special sedimentation of some plots matches that of their surrounding watersheds i.e. was no significant difference between them. For example, there was a high correlation between the special sedimentation of the 10sqm plots and special sedimentation of the watershed A₄ ($P < 0.001$ and $R^2 = 0.976$) and special sedimentation of the 30m² plot and special sedimentation of watershed A₅ ($P < 0.001$ and $R^2 = 0.998$), (Figure 5). In other words, these plots yield a similar amount of sedimentation to their surround watersheds. This is in agreement with the studies conducted by Sharply and Cleanman (2003), Sarda *et al.* (2009) and Bargalo *et al.* (2011) on the changes of soil loss with respect to plot size.



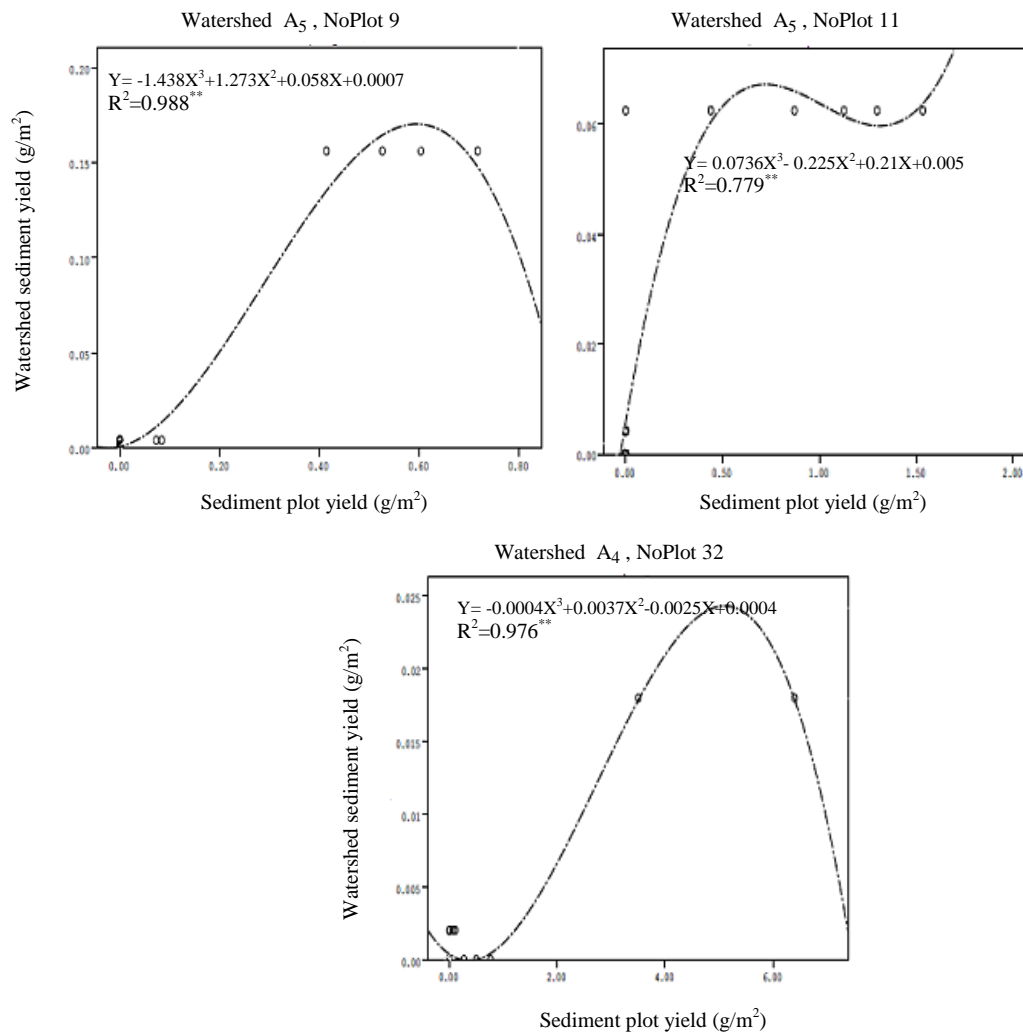


Fig. 5: correlation between the special sedimentation of the plots and special sedimentation of their surround watersheds

Table 4 shows the plots which match the special sedimentation of their surrounding watersheds and can represent them. For example, in the case of watershed A₁, the 20sqm and 40sqm plots have a similar sedimentation yield as the special sedimentation of their watershed. Therefore, utilizing 20sqm plots can save time and money in future studies. Similarly, watersheds A₂, A₃, A₄ and A₅ can respectively use 10, 20, 10 and 10sqm (minimum surface area) plots.

Comparison of the special sedimentation of each plot with the special sedimentation of their surrounding watersheds reveals that the special sedimentation of the plots is more than their watersheds. This is in agreement with the studies conducted by Bulten and Dandy (1976), Rao (1981), Dabni (1999), Puliakef (2002), Biox-fayos *et al.* (2006).

Table 4: characteristics of study watersheds and their representative plots

| Watershed code | Watershed characteristics | | | | | | | | | | | | | Optimum plot area to estimate precipitation (m ²) |
|----------------|---------------------------------|----------|----------------|----------------------|-----------------------------------|-----------------|---------------|------------|--------------|-------------------------|----------|----------|----------|---|
| | Watershed area(m ²) | Shape | Mean slope (%) | Vegetation cover (%) | Dominant type of Vegetation cover | Mean litter (%) | Bare soil (%) | Gravel (%) | Soil texture | Mean of soil depth (cm) | Sand (%) | Silt (%) | Clay (%) | |
| A ₁ | 4308 | Round | 40.5 | 27 | Artemisia-Carex | 1.5 | 31.5 | 40 | Loam | 5-30 | 42 | 46 | 12 | 20 |
| A ₂ | 1189.5 | Round | 63.53 | 20 | Bromus-Atriplex | 1 | 47 | 5 | Silty loam | 10-30 | 21.68 | 64.41 | 13.91 | 10 |
| A ₃ | 1467.5 | Elongate | 47.13 | 18 | Bromus-Artemisia | 1 | 87 | 3 | Silty loam | 10-30 | 29.72 | 61.82 | 8.46 | 20 |
| A ₄ | 11995.5 | Elongate | 31.2 | 30 | Bromus-Artemisia | 1 | 67 | 2 | Silty loam | 5-30 | 34.65 | 54.72 | 10.63 | 10 |
| A ₅ | 16916.5 | Elongate | 30 | 35 | Bromus-Atriplex | 1 | 58 | 6 | Silty loam | >120 | 16.09 | 67.43 | 16.48 | 10 |

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