STUDY ON SEDIMENT YIELD OF ALLUVIAL TERRACES USING RAINFALL SIMULATOR

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ABSTRACT

Soil erosion has been considered as an environmental concern that can lead to a decline in the quality of life. One of the effective factors in soil erosion is geological formations of the drainage basin from the view point of amount of runoff and sediment yield. Quaternary Formations are one of the widespread geological materials on the earth surface. Due to the fact that many human activities such as development of natural resources and agriculture occur on Quaternary Formations, the investigation of these formations is very essential. This research studies sediment yield on Quaternary formations consisting of alluvial terraces and the relationship between some physical and chemical factors with sediment yield. Therefore a part of Segzi- Kouhpayeh subdrainage located in Zayandeh-Roud Drainage Basin was chosen. A field rainfall simulator was used and runoff and sediment were collected from the plots and sediment yield factor was obtained. Soil samples were taken adjacent to each microplot for laboratory analyses and the data were analyzed statistically. The obtained regression models show that among the measured factors related to the sediment yield of alluvial terraces, the amount of sand and relative wetness have had important and significant roles.

Key Words : Alluvial terraces, Sediment yield, Physicochemical characteristics, Rainfall simulator, Iran

INTRODUCTION

Gathering reliable information about the amount of soil erosion and the improvement of conservational methods and management strategies, need activities based on real and exact information about the quantity and intensity of erosion. The geological and geomorphological characteristics of Quaternary Deposits are considered as the basic criteria for the structures of natural geography and geomorphology in human environment and should be studied in-detail in all of the economic plans and in the selection of habitants, industrial and agricultural poles, infrastructural and basic installations, extension of civic societies and land use.

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But unfortunately, due to the loss of knowledge about these lands and unsystematic exploitation of them, a great part of these lands in Iran are lost as a result of soil erosion. The susceptibility of Quaternary Formations to erosion depends on the nature of the formations and their surroundings. The area, relief, climate and lithology are the main controlling factors of sediment yield and measuring sediment yield is the main key to understand the effect of land control in past and present climatic conditions.

To avoid the expensive and time-consuming measurements of erosion in field plots, many workers have tried to predict sediment yield ratings from the results of more simple laboratory and field tests. These tests range from the physical, chemical and mineralogical analyses of the soil\textsuperscript{2,3}, through determination of certain aspects of physical reaction of the topsoil material\textsuperscript{4}, to measurements of the infiltration rate, runoff and soil loss with infiltrometers and rainfall simulators\textsuperscript{5}. Theoretically using simulated rainfall method has the advantage that the recorded runoff and soil loss reflect the integrated effects of all the processes occurring during sheet erosion, i.e., splash, swelling, slaking, crusting and sealing, infiltration and runoff, particle detachment and sediment transport. Using rainfall simulator has limitations since they can never explain the natural conditions completely. But despite the existing challenges the application of rainfall simulators are used worldwide for research on different aspects of erosion and sediment yield. In this study, a sprinkling rainfall simulator (made in Netherlands) was used to generate precipitation. The rainfall simulator covered an area of 0.0625 m\textsuperscript{2} (25 cm x 25 cm), with an intensity of 2.88 mm/min. The rainfall used by this simulator is almost the same as a 15 minutes rainfall with a 100 years return period in the synoptic weather station of Isfahan.

Different methods were used to measure the erosion in Quaternary formations. Sowers et al.\textsuperscript{6} measured the rate of erodibility of different Quaternary units in Silver Creek basin in California, depending on the behavior of geological materials. Mather et al.\textsuperscript{7} made use of mapped valley profiles and reconstructing form of valleys before erosion in order to study amount of erosion Quaternary deposits in Southeast Spain. Liua et al.\textsuperscript{8} utilized mineralogical analysis as an index for the amount of physical degradation and chemical weathering in a study on the climatic control on erosion and weathering of Quaternary deposits in eastern Tibet plateau and Mekong Basin. In Iran, Karimkhani\textsuperscript{9} studied the erosion of Quaternary terraces of Taleghan region with PSIAC method. Sheklabadi\textsuperscript{10} performed a study on the relative soil erodibility of some geological formations and its relation to several physical and chemical characteristics of soil in Golabad basin, by using a field rainfall simulator and laboratory studies on soil samples. Feiznia et al.\textsuperscript{11} studied the effects of physical, chemical and climatic factors on the production of sediment caused by surface erosion in loess soils, by using a rainfall simulator. Simple laboratory determination can provide data significantly correlated with those resulting from more expensive or time-consuming field investigations. The aim of this study was to determine the effective factors in the alluvial terraces sediment yield and to provide useful models for sediment assessment based on laboratory data in the studied area.
MATERIAL AND METHODS

This study was carried out in Esfahan province in central Iran. The studied area is a part of Segzi- Kouhpayeh subbasin located in Zayandeh-Roud Drainage Basin which is limited from the south to Zayandeh-Roud river. In this region the average of annual temperature is 16.3°C and the average of annual precipitation is over 116 mm. The maximum precipitation is in December and the minimum precipitation is in September. The region climate is cold arid by Emberger PG. The case study is performed on types of Quaternary Deposits that are named Alluvial terraces (Qt). These terraces are located in a lower level compared with other geological units and are made of rubble interlinked sediments in the clay matrix which are deposited by torrential and overflowing rivers. Alluvial terraces are surfaces with slight slope which are formed parallel to the direction of the river valley and in higher levels of the current riverbed and then are appeared in the course of rivers as a result of an erosion cycle (Detachment, Transition, Sedimentation).

In April 2007, soil samples were collected adjacent to alluvial terraces. The experiments have been carried out using a portable rainfall simulator similar to that described by Kamphorst. For the sake of performing experiments related to simulator in this geological unit, rainfall simulators were used in places which were the same from the aspects of topography and vegetation. Therefore in each point, the quantity and intensity of rainfall, slope and the surface conditions of each plot have been constant and similar. The rainfall simulator experiments were done in dry-run conditions. The runoff and sediment produced in each test of simulator were gathered in bottles. Undisturbed 0–20 cm soil samples were collected close to each microplot.

The volume of the gathered runoff at the end of each simulation test was measured with a Graduated Cylinder and filtered sediment was dried and weighed by oven in 105°C and thereby the sediment concentration was obtained. By multiplying the produced runoff by the sediment concentration, the amount of dry material was gained per gram. The physical and chemical variables studied here are: Texture, the percentage of very fine sand, relative wetness, acidity, organic matter, electrical conductivity and calcium carbonate. Particle size distribution was determined using disturbed soil samples sieved through a 2 mm by the hydrometer method. The percentage of very fine sand, was measured by the sieve. Determination of soil organic carbon (SOC) content was carried out by wet oxidation (K2Cr2O7), pH was measured in CaCl2 extract of soil (1:2.5 solution). Electrical conductivity on saturated extract was measured by EC meter. The percentage of calcium carbonate also, was obtained by applying the calcimetric method. The soil wetness was determined from the weight difference of soil after and before being dried in 105°C. For the analysis of information and to study the relationship between different factors and sediment yield, variance analysis test and Duncan’s Multiple Range Test were used. For performing the entire statistical analysis, the SPSS software was utilized. In order to access accurate models
to estimate sediment yield, regression models were developed. Selection of regression models was carried out to estimate the amount of sediment by using the coefficient of determination, considering the significance of the model’s coefficients of correlation in the levels of 1 percent and 5 percent. Estimation errors were used to define validity and to evaluate the model.

RESULTS AND DISCUSSION

The measured physical and chemical variables in this Quaternary unit are: Sand, silt, clay, fine sand, relative wetness, calcium carbonate, electrical conductivity, organic matter, acidity, sediment yield, sediment concentration and the coefficients of runoff. The results are shown in Table 1.

Table 1: Average runoff coefficient, soil loss, sediment concentration, ... on alluvial terraces

<table>
<thead>
<tr>
<th>Quaternary unit</th>
<th>Clay (%)</th>
<th>Silt (%)</th>
<th>Sand (%)</th>
<th>Fine sand (%)</th>
<th>Soil moisture (%)</th>
<th>Caco₃ (%)</th>
<th>EC (millimhos cm⁻¹)</th>
<th>Organic matter (%)</th>
<th>PH (KCl)</th>
<th>Soil loss (g)</th>
<th>Sediment concentration (g/l)</th>
<th>Runoff coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial terraces</td>
<td>14.7</td>
<td>52.3</td>
<td>33</td>
<td>17</td>
<td>6</td>
<td>24.7</td>
<td>4.76</td>
<td>0.86</td>
<td>7.84</td>
<td>3.11</td>
<td>8.64</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Table 2: Pearson-Rho correlation coefficient between soil characteristics and sediment productivity

<table>
<thead>
<tr>
<th>Soil characteristics</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>-0.600*</td>
</tr>
<tr>
<td>Silt</td>
<td>-0.169</td>
</tr>
<tr>
<td>Clay</td>
<td>-0.197</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.138</td>
</tr>
<tr>
<td>Silt+Fine sand</td>
<td>0.303</td>
</tr>
<tr>
<td>EC</td>
<td>0.246</td>
</tr>
<tr>
<td>Moisture</td>
<td>-0.703**</td>
</tr>
<tr>
<td>Om</td>
<td>0.236</td>
</tr>
<tr>
<td>Caco₃</td>
<td>0.386</td>
</tr>
<tr>
<td>PH</td>
<td>0.286</td>
</tr>
</tbody>
</table>

** Significant at the level of 1% , * Significant at the level of 5%
The results obtained from the study of the matrix of correlation between the studied physical and chemical variables and the sediment yield rate of alluvial terraces, are shown in Table 2. Very fine sand is a significant factor to compute interrill erodibility in WEPP (Water Erosion Prediction Project) model, so it is used as one of the important factors for evaluation. Silt + very fine sand factor is an important factor to compute erodibility in USLE (Universal Soil Loss Equation) model, therefore this factor was considered to study the relations between independent and dependent varieties.

In order to identify the most important factors effective in the sediment yield of the studied deposits from the soil factors, the results of regression analysis and the study of the correlation matrix were used. Different relationships were then established between measured and estimated sediment productivity when regression models were used. The best-fit models between predicted and observed sediment values that were selected based on maximum determination coefficient (R²) and minimum prediction error (RE) criteria have been summarized in Table 3.

<table>
<thead>
<tr>
<th>Quaternary unit</th>
<th>Regression model</th>
<th>$R^2$</th>
<th>RE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial terraces</td>
<td>$Y=-0.088\ \text{sa}+4.834$</td>
<td>0.40*</td>
<td>42.18</td>
</tr>
<tr>
<td></td>
<td>$Y=-0.401\ \text{mst}+5.741$</td>
<td>0.51**</td>
<td>21.48</td>
</tr>
</tbody>
</table>

$R^2$ is coefficient of determination, RE is the relative error, ** Significant at 0.01-level, * Significant at 0.05-level, (Mst: Moisture, sa: Sand, y: sediment productivity)

Alluvial terraces are loose, unconsolidated, uncemented and contain little clay, thus are considered highly erodible. In this research, the obtained significant negative correlation between the amount of sand and sediment yield in alluvial terraces is different from the point of view of Verhaegen\textsuperscript{16} and Martz\textsuperscript{17}. This case occurs due to presence of high amount of sand texture of deposits and therefore high penetrability of the unit. Sediment yield in alluvial terraces have a significant negative correlation with soil moisture, because the gain of soil relative moisture causes increase of soil adherence and finally lead to decrease of erosion. Sediment loss in rainfall simulations depends on soil moisture\textsuperscript{18}.

Sediment productivity which has positive correlation with electrical conductivity has been proved by Merzouk and Blake\textsuperscript{19} and Rienks et al.\textsuperscript{20} Particles limestone with the same size of silt cause to make crust and fill soil porosity and resulting instability of large aggregates\textsuperscript{19}, therefore positive correlation with calcium carbonate reasonable in this investigate. The positive correlation of acidity with sediment yield is the same as results of Donsheng and et al.\textsuperscript{15}
CONCLUSION

Considering the coefficients of correlation between the sediment yield of alluvial terraces and physicochemical factors measured in this research it is shown that the parameters of relative wetness and sand amount in this unit, have had the most important effect on sediment production. On the basis of these parameters, significant regression models with high coefficients of determination and low relative error for assessing sediment yield in these formations were obtained. Regarding land uses in the studied area, due to high values of sediment yield of the alluvial terraces which usually have fallow and agriculture land uses and also integrated management activities more research on erodibility of these units are emphasized. It is recommended to do similar researches in other places with different conditions of slope and climate, on sediment yield and susceptibility to the erosion of alluvial terraces, in order to compare the results and to obtain practical relationships and comprehensive methods and policies.

REFERENCES


Marine Sciences, Tarbiat Modares University, 120, (1997)

10. Sheklabadi M., Investigation of soil relative erodibility in some geology formations and relation with numbers soil physical and chemical characteristics in Golabad Basin, MSc Thesis in pedology, College of Agriculture, Isfahan University Technology, (2000)


