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Impact of slope, tillage systems and methods of cultivation on the rate of soil erosion in cultivating rain fed wheat of Khozestan province

Amin Reza Jamshidi*, Ali Afrous

Department of Engineering, Andimeshk Branch, Islamic Azad University, Andimeshk, Iran

Abstract: Soil erosion is a natural and general phenomenon which is considered as one of the most important natural damages for agricultural lands. Erosion of agricultural lands is created as a result of undesirable methods of agriculture. Aquatic erosion is specifically important in humid and rainy regions, especially in sloped and plowed lands. In order to review the impact of slope, tillage systems and methods of cultivation on the rate of soil erosion in cultivating rain fed wheat, an experiment was done in Khozestan province in the year 2013-2014. This experiment was done three times with split plot design in a randomized complete block design, including slope at two levels (6 to 8 and 10 to 12 percent), tillage at three levels (conventional tillage, low tillage and non-tillage) and cultivation method at three levels (manual, cultivation with a drill parallel and perpendicular to the slope). The results of this research showed that non-tillage compared to conventional tillage has respectively 28 and 35% of less sediment and runoff from rainfall, low tillage compared to conventional tillage 5 and 10 percent. And also cultivation with a drill parallel to the slope and cultivation with a drill perpendicular to the slope has respectively reduced sediment for 7 and 20% and runoff for 9 and 40%.

Key words: Slope; Tillage System; Cultivation Methods; Soil Erosion; Runoff

1. Introduction

Soil is one of the most important natural sources of a country that provides for needs of all of its men and animals, which unfortunately is constantly exposed to aggression and changes of the human factors and natural elements (Casasnovas et al., 2002). Erosion is one of the effective factors in soil structure degradation and making the fertile agricultural lands poor and consequently sedimentation of soil in the riverbeds. This not only ruins the surface active soil, which is considered as the base of agriculture, but also the transmission of chemical pollutant materials such as chemical fertilizers and plant pesticides into the rivers and water behind dams leads to pollution of aquatic sources (Mohanty et al., 2007). Due to erosion, nutrition that plants need is destroyed and soil's fertility reduces (Harmel et al., 2006). On one hand, soil erosion is considered as one of the factors of reduction of soil's quality. Reduction of erosion leads to reduction of sedimentation and preparation of a condition for more moisture to be stored in soil. Shortage of stored moisture (due to the deficiency of organic materials) in soil is also an important factor in creation of moisture insufficiency and reduction of product's function in arid and semi-arid regions (Porto et al., 2003). Development of agricultural economy and maintenance of natural sources depends of optimal usage of water. At the peak of water demand, sources are not responsive and collecting, storing or generally adjusting the consumption of stored waters in soil and using them throughout the growth season is essential (Unger, 1994). By applying an accurate protective management pattern, winter cover of row crops or creation of seed texture in soil, can reduce the rate of soil erosion and sediment load. The rate of rainfall for agricultural crops including rain fed wheat is approximately 250mm with normal and wide distribution and for each millimeter of additional water; a function about 5 to 15kg wheat in each hectare is expected in rain fed cultivation (Keller et al., 2007). Adequate capacity of soil surface to store surface runoff fluctuates up to 85% of soil's permeability.

Tillage affects the quality of soil through erosion and also changing physical, chemical and biological characteristics of soil (Zhang et al., 2007). Yield is considerably more in deep tillage (deep plowing) due to more storage of moisture in soil compared to conventional tillage. One of the methods of reducing the rate of soil erosion is making the soil permeable by using proper patterns of tillage. The rate of erosion process depends of the type of tools used in tillage. Selecting proper tools for tillage in sloped lands and doing the operation of tillage perpendicular to the slope increases the storage of moisture in soil. Soil in sloped lands in traditional cultivation is less permeable than mode of cultivation in terrace and perpendicular to the slope. Using improper models of tillage increases soil compaction and it reduces its permeability of water when it is raining and leads to creation of runoff

* Corresponding Author.

Tillage operation makes compacted soils more permeable; therefore, we can reduce the rate of surface runoff through this. Pitting and excavation operations are effective in the reduction of runoff and the produced sediment compared to other operations and on the other hand, this operation costs less and its implementation is also simpler (Park et al., 2002). One of the key factors in reducing the rate of erosion in rainfed prone lands is low slope, in addition to this; the depth of the agricultural land also influences the reduction of the rate of erosion (Terzoudi et al., 2007). Soils with medium to heavy textures reduce the erodibility due to increasing the rate of organic materials (Zhang et al., 2004). Rainfall intensity in a short time is an important factor in how runoff is created and sediment is produced in lands (Adekalu et al., 2007). By increasing the slope of the ground, the rate of runoff and degradation of soil increases up to 15% (Terzoudi et al., 2007). Doing the improper tillage operation leads to soil erosion and, therefore, reduction of the quality and fertility of soil and ultimately, reduction of yield. The rate of soil erosion in 40 to 43 percent of sloped hills, due to the impact of improper tillage, reaches 40 to 151 (Mega gram per hectare) per year.

Studying the impact of types of rain fed proper tillage machines in order to increase storage of soil moisture and yield in the conditions of Khozestan province is necessary and the farmers of the area will benefit from the results of the project in controlling soil erosion and increasing the wheat yield. Given the fact that the annual soil erosion in the world is 75 billion tons, that Iran's share of it has been reported to be more than 2 billion tons and approximately three times more than soil erosion in Asia, economic value of annual damages of soil erosion in the country is about 10000 billion Rials and it is equal to destroying one million hectares of agricultural lands, especially in country's mountainous areas such as Khozestan province which have the potential to be eroded. Any kind of research or study that would be able to present a way to reduce the rate of soil erosion in country is essential and necessary and in fact, it is a step towards maintaining production factors that will ultimately end with increasing agricultural yield.

2. Materials and method

In order to review the impact of tillage systems and cultivation in sloped surfaces on soil bulk density and soil erosion, an experiment was done in rain fed condition of Andimeshk city located in a 155-kilometer distance from Ahvaz province. Experiment's design was split plot design in a randomized complete block design which was done three times in a land with an area of 10000m^2. Treatments that were compared in this design were: conventional tillage (Moldboard plow and then Syngonium), low tillage (chisel plow and then Syngonium) and non-tillage. Each experiment was done in an independent slope of 6 to 8% and 10 to 12%. Main treatments were applied as follows: moldboard plow in a 25-centimeter depth and then Syngonium in a 15-centimeter depth, chisel plow in 25-centimeter and then Syngonium in a 15-centimeter depth and non-tillage and after applying tillage treatments in the land which is the location for implementation, cultivation was done by using a drill in the form of three systems, conventional or manual cultivation (in the direction of slope) and mechanized cultivation (perpendicular to the slope and in the direction of the slope). In order to calculate the aquatic erosion in each plot, soil ridges were used around the plots. In order to collect the surface runoff, throughout each plot a ridge (the ridge at the bottom of each plot) was covered with plastic and the runoff was conducted into the containers, which were prepared before at the bottom of each plot, through polyethylene pipes. The plots are 13-meter long and 4-meter wide and the distance between each plot are 2 meters and the distance between the two experiments is 5 meters.

3. Calculations associated with physical properties of soil:

Before and after applying tillage systems and cultivating 162 samples from the depths of 0-10, 10-20, and 20-30cm by using steel containers with a diameter of 7.5cm, the containers were carefully inserted in soil and they were removed alongside with soil and after weighing, their weight was again calculated after being in a 105 ° C autoclave and then, the soil bulk density was calculated.

Soil bulk density in the surface layer of soil and the depths 0-10, 10-20 and 20-30cm of each treatment and formula (1) were calculated (2).

Formula (1) $$Pb = \frac{M_{od}}{V_t}$$

Pb = bulk density (gr / Cm3)
M_{od} = weight of soil dried in oven (gr)
V_t = volume of the soil sample (Cm^3)

4. Results and discussion

Given the data obtained from measuring runoff and sediment as the results of rainfall showed that in low tillage system compared to conventional tillage, there is respectively 5 and 10% of reduction of sediment and runoff caused by rainfall. Whereas, in a non-tillage system compared to a conventional tillage, 28 and 35% reduction in the rate of sediment and runoff was calculated. Cultivation with a drill parallel to slope has had respectively 7 and 9% reduction of sediment and runoff caused by rainfall as a result and as for cultivation with a drill perpendicular to the slope, it was 20 and 40% compared to conventional cultivation. Soil bulk density of the location of experiment before the application of tillage systems and cultivation in the depths 0-10, 10-20 and 20-30cm was respectively 1.17, 1.24 and 1.35 Mega grams per m^3 and this bulk density was respectively calculated to be 1.01, 1.05

and 1.12 after application of tillage systems and cultivation. The results of analyzing the variance of the impact of tillage systems and cultivation on the soil bulk density in the depths0-10, 10-20 and 20-30cm alongside with the rate of runoff and sediment caused by rainfall has been provided in table (1).

Given the measured means of soil bulk density in 0-10 and 10-20cm depths, there is a significant difference between conventional tillage system with low tillage and non-tillage system but no significant difference was seen between cultivation methods in 0-10cm depth. But in 10-20cm depth, there is a significant difference between the method of conventional cultivation and cultivation with a drill parallel to the slope and cultivation with a drill perpendicular to the slope. In 20-30cm depth, there is a significant difference between the low tillage system and the other two systems, there is the same difference also between the applied cultivation methods and these results are in accordance with the findings of Asoudar et al. (2010) and Charm et al. (2003).

Table 1: Analysis of variance of bulk density, runoff and sediment of soil

Source of changes s.ov	Freedom degrees	Means of squares				
		Soil bulk density			Runoff caused by rainfall	Sediment caused by rainfall
		0-10 cm	10-20 cm	20-30 cm		
Slope	1	0.00119*	0.000312	0.00000185	1815.9	1.32**
Compound error	4	0.000212	0.00094	0.0010963	876179.6	1145.70
Tillage	2	0.00919**	0.01017*	0.031957**	141198**	251592.01**
Slope x tillage	2	0.000119	0.000312	0.00000185	39685	808.3
Tillage error	6	0.000443	0.00174	0.012543	204018	13125.54
Cultivation	2	0.00138	0.019280**	0.012946**	222019**	14146.66
Slope x cultivation	2	0.0000352	0.000112	0.001112	11588	615.036
Tillage x cultivation	4	0.001612	0.00110	0.011174	414496**	81297.48**
Slope x tillage x cultivation	4	0.0000740	0.0001113	0.0001113	151595	681.90
Remained error	27	0.001910	0.002127	0.00089	191374	11182.74
Distribution coefficient (%)	-	31.40	21.70	21.63	113.87	114.94

*, **respectively show significant difference at 5% and 1% level.

Table 2: impact of tillage systems on bulk density, runoff and sediment caused by rainfall

Treatment		Soil bulk density			Runoff caused by rainfall (mm/m^2)	Sediment caused by rainfall (g/m^2)
		0-10 cm	10-20 cm	20-30 cm		
Tillage	Moldboard plow and then Syngonium	0.9168^b	1.013^b	1.019^b	121095.9^a	258.03^a
	Chisel plow and then Syngonium	1.010^a	1.018^a	1.17^a	101871.6^b	245.17^a
	Non-tillage	1.011^a	1.07^b	1.112^b	67150^c	1817.24^b
Cultivation	Conventional or manual cultivation	0.9192^a	1.04^b	1.111^b	12446.8^a	251.83^a
	Cultivation with a drill parallel to the slope	0.986^a	1.50^b	1.14^a	11372.5^a	236.14^b
	Cultivation with a drill perpendicular to the slope	1.00^a	1.018^a	1.113^a	58198.2^b	2102.47^c

*Means or different letters in each column have significant difference at 5% level (Duncan multiple range test)

Table 2 shows the significant difference in terms of the impact of tillage system and cultivation on soil bulk density. This significant difference is between tillage system and method of cultivation on bulk density. There is not a significant difference between the impact of slope and soil bulk density and also between the interaction of slope and tillage systems, slope with the method of cultivation and slope with tillage system and cultivation. By considering Table 2, the obtained means show a significant difference

between the three tillage systems but in the applied cultivation methods, a significant difference is seen between the method of cultivation perpendicular to the slope and the other two methods (conventional cultivation and parallel to the slope). About the rate of sediment caused by rainfall among the applied tillage systems, there is a significant difference between non-tillage system and the other two systems (low tillage and conventional tillage). And there is a significant difference between each of the three methods of cultivation which is in accordance with the findings of Shahrivari et al. (2009). If the rate of runoff and sediment is high in conventional tillage system and conventional cultivation, it is because of doing tillage parallel to the slope and not leaving the plant remains on the surface of soil and creating proper slots which act like small streams when it rains. Also in this factor, in cultivation parallel to the slope, the applied low tillage system is seen with a lower intensity compared to the conventional tillage system, which indicates that despite the presence of plant remains in cultivation parallel to the slope, the runoff is more current between the lines. There is a significant difference between the applied tillage systems, method of cultivation and also the interaction of tillage system and method of cultivation and these findings are in accordance with the reports of Yousefi (2012).

5. Conclusion and recommendations

Applying the proper tillage system which is in accordance with weather conditions of each region has a significant impact on the rate of soil bulk density and erosion, in such way that by applying proper tillage system and cultivation in sloped surfaces, especially in west regions of the country in which most lands are sloped rain fed ones, can have a considerable impact on the reduction of soil erosion. Even by applying a tillage system which is conventional for each region but is perpendicular to the slope, we can reduce the rate of soil erosion and it can be effective in maintaining available natural sources. There is a significant difference between applied tillage systems and methods of cultivation in terms of their influence on the rate of runoff and sediment caused by rainfall. Among the applied tillage systems, the non-tillage system, despite the fact that it is in the first year of implementation, it has a significant difference with other cultivation and tillage systems and it helps maintaining the surface cover of soil. This is an issue that shall be researched about and attention shall be paid to it in terms of implementation.

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