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# Tillage Management on Sustainable Rainfed Agricultural Resources

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**Abstract:** The aim of this study is to investigate the effects of plowing treatments on the volume of surface runoff, soil loss and crop yield, a research plan was implemented on hillslopes of the Sohrain Gharacharian floodwater spreading station in Zanjan province, Iran. Rainfall, surface runoff, sediment and crop yields were monitored in 1.8 wide ×22.1 m long erosion plots. Two plowing treatments of contour and up and down the slope were compared on three slope classes of 0-12, 12-20 and 20-40% in triple replication and randomized complete block design in a regional wheat cropping experiment. Results demonstrated that contour plowing significantly reduced the volume of surface runoff and sediment yield in all slope classes. The amounts of reduction in all three slope classes were 83, 88 and 57% for runoff and 92, 97 and 95% for sediment, respectively. The volume of surface runoff and sediment yield from contour plowing of the 12-20 and 20-40% slopes were significantly lower compared to up and down the slope plowing of 0-12%. Similar results were obtained when comparing volume of surface runoff and sediment yield from contour plowing of 20-40% slope to up and down the slope plowing of 12-20%. Contour plowing resulted in soil loss that was 6.11, 7.73 and 7.73 times less than the soil loss threshold in 0-12, 12-20 and 20-40% slopes, respectively. The quantity and quality of crop yield did not change by plowing treatments. But, contour plowing increased the crop yield by 19, 21 and 9% on 0-12, 12-20 and 20-40% slopes, respectively.

**Key words:** Conservation practices, crop yield, plow direction, rainfed, runoff, soil erosion

## INTRODUCTION

Degradation and mismanagement of resources pose a great tragedy in recent times, these resources should be conserved and utilized to the maximum possible extent. The prevention of soil erosion, which means reducing the rate of soil erosion to approximately that which would occur under natural conditions, relies on selecting appropriate strategies for soil conservation. Although it is impossible to stop soil erosion completely under natural conditions, there is a great need to control erosion for proper land and water use planning. A practical measure of soil resistance to erosion used by pedologists is the Soil Loss Tolerance (SLT). The term SLT denotes the maximum rate of soil erosion that can occur and still permit crop productivity to be sustained economically. Bhattacharyya *et al*. (2008) computed SLT minimum limits of 2.5 t ha$^{-1}$ for Shivalik-Himalayan region in India. Regarding the time needed for soil formation under different climatic, topographic and biological conditions, Bybordi (2001) concluded that 100-300 years required developing 2.5 cm of soil and 1.16 t ha$^{-1}$ annual SLT.

Shrestha (1997) evaluated the magnitude of soil erosion in a middle mountain region of Nepalese, Himalaya. Results showed that the highest and the lowest rates of soil loss of 56 and 1 t ha$^{-1}$, belong to rainfed cultivation areas and dense forest, respectively.

Although irrigation is relatively more important in cereal production in developing countries, with nearly 60% of cereal productions coming from irrigated areas, Rosegrant *et al*. (2002) contend that globally, 69% of all cereal area is rainfed including 66% of wheat. Based on National Statistical Calendar (2006), from 17.6 million ha of agricultural lands in Iran, 53% are rainfed, from which 69% are under cultivation of annual crops, 29% fallow and 2% under orchards. Inadequate moisture and periodic droughts reduce the periods when growing plants provide good soil cover and limit the quantities of plant residue produced. Erosive rainstorms are not uncommon and they are usually concentrated within the season when cropland is least protected. Water, as rainfall and runoff, is the active agent for the basic process of water erosion. Water erosion is a serious problem in sub-humid, semiarid and arid regions and the need for conservation has become critical in many countries. Soil erosion resulting from improper management of landuse activities has environmental and economical impacts (Nikkami *et al*., 2002). The eroded soil covers bottom lands and man-made

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structures as sediment. Gullies, sand dunes and other obvious signs of erosion are examples of improper land management. Deterioration in the quality of cropping and grazing lands as a result of erosion, reduces productivity and increases expenditure on fertilizers. In extreme cases yields become so poor that land has to be taken out of cultivation (Morgan, 1986). Many researchers have observed declining crop yields with decreasing topsoil depth. For example, more than half of India's cropland is losing productivity because topsoil is being washed or blown away faster than natural forces can replace it.

Perhaps the single most important factor contributing to erosion of sloping cropland is tillage. Clearing the land exposes the soil to the effects of weather. The amount of soil erosion that occurs depends on the kind, the amount and the direction of tillage operations in relation to the slope of the land and the timing of tillage. The maximum rate of soil erosion was recorded in the plots with the variant of conventional up and down the slope tillage and it was much smaller in the no-tillage variant and in all variants with tillage across the slope (Basic *et al*., 2000). Moldboard plow on different slope gradients resulted in down slope translocation and dispersion. Both translocation and dispersion are strongly affected by slope gradient (Oosta *et al*., 2000). Surface residue and surface clod mass were consistently reduced by 45% or more in conventional tillage compared with minimum tillage and delayed minimum tillage (Schillinger *et al*., 2001). Soil condition, opening angle and tillage velocity were also critical factors affecting the translocation coefficient for the harrow disk in a research conducted in Portugal (Marques Da Silva *et al*., 2004). Subsoiling resulted in the highest increase in moisture storage and lowest evaporation during the fallow period when four soil tillage practices of conventional tillage, no tillage, subsoiling and reduced tillage were compared by Cornelis *et al*. (2002). Alberts and Neibling (1994) found that surface runoff and soil loss exponentially decrease with increasing vegetal residue and reducing soil preparation practices. They indicate the role of canopy cover on reducing destructive effect of rain drops on soil and reducing surface runoff.

Considering rainfed farm slope in many areas, which is usually much more than FAO recommendations, applying improved agricultural practices prevents soil erosion and conserves natural moisture of rainfall at dropping points. Many developing countries located in arid or semi-arid regions experience significant problems in securing adequate amounts of water for rainfed crop production. Water scarcity problems in arid regions result simply from the lack of sufficient rainfall (Rosegrant *et al*., 2002). Rockstrom and Falkenmark (2000) note that due to high rainfall variation in semi-arid regions, a decrease of one standard deviation from the mean annual rainfall often leads to the complete loss of the crop. *In situ* soil moisture conservation practices like ridges and furrows, compartmental bounding, tied ridges and mulching as useful moisture conservation practices in rainfed agriculture were compared by Ramesh and Devasenapathy (2007). Results showed that moisture conservation through tied ridges along with mulching recorded significantly higher soil moisture and improved grain yield of pigeon pea in Tamil Nadu, India. Keeping these views, a field experiment was planned to investigate the effect of different tillage directions on the volume of surface runoff, soil erosion and crop yield.

## MATERIALS AND METHODS

The research plan was implemented on steep lands of Sohrain Gharacharian floodwater spreading research station located in northwest, 30 km from Zanjan city in Iran during September 2003 to August 2005. Covering an area of 15,000 ha the station lies on quaternary sediments beside the Gharacharian River with maximum and minimum elevations of 1900 and 1500 m from sea level. Most of the lands in this area are under wheat rainfed farming. Annual precipitation is between 350 and 400 mm in lower and upper lands, respectively with Mediterranean to cold semiarid climate.

Two treatments of up and down the slope and contour plowing on three slope classes of 0-12, 12-20 and 20-40% with three replications and randomized complete block design were studied under regional wheat planting (first year) and fallow conditions (second year) in 18 erosion plots of 1.8 wide ×22.1 meter long. Plowing treatments in the plots were simulated manually by shovel and measured plow depth (25-30 cm) and furrow space (35-40 cm) in the actual field that was prepared by conventional tractor-drawn moldboard plow. For enrichment, ammonium phosphate at the rate of 50 kg ha$^{-1}$ were added at the time of preparation in the first year and conventional amount of 100 kg ha$^{-1}$ wheat seeds were used for planting. Soil fractions and characteristics such as sand, silt and clay percentage, organic carbon and saturation percentage were extracted from soil samples of 0-5, 5-20 and 20-40 cm depth of a soil profile in each slope class at the first year.

During September 2003 to August 2005, 22 rainfall events which produced surface runoff were monitored by a recording rain gauge in the station. After each rainfall the volume of surface runoff and the amount of its sediment content were measured in the tanks located at the lower end of each plot. Using a pipe, two

Fig. 1: Runoff and sediment sampling from collecting tank

220 L collection tanks were connected to each other to ensure having enough space to collect all produced runoff in each rainfall. Using a tube, these tanks were connected to the plots to carry surface runoff and sediment. A 10 L bucket was installed under the carrying tube, within the main collection tank, to trap coarse materials. Using these buckets and a cylindrical sampler (Fig. 1) increases the computational accuracy of sediment concentration by sampling from collection tanks (Nikkami *et al*., 2004). Quantity and quality of produced wheat seeds during first year were also measured.

## RESULTS AND DISCUSSION

Physicochemical analysis of soil samples from 0-5, 5-20 and 20-40 cm depth of each profile on 0-12, 12-20 and 20-40% slope classes are indicated in Table 1. The volume of surface runoff and the amount of sediment yield resulting from 22 rainfalls during September 2003 to August 2005 were calculated. Table 2 show the amount of surface runoff and sediment yield from 0-12, 12-20 and 20-40% slope plots, respectively. The quantity and quality of produced wheat crop are also shown in Table 3 and 4. Analyzing the results by Least Significant Difference (LSD) method demonstrated that the contour plowing significantly reduced the volume of surface runoff and the amount of soil loss in all slope classes compared to up and down the slope plowing. The amount of reduction with 99% confidence in 0-12, 12-20 and 20-40% slopes were 83, 88 and 57% for runoff and 92, 97 and 95% for sediment, respectively. The volume of surface runoff and sediment produced from contour plowing of 12-20 and 20-40% was significantly lower compared to the results of up and down the slope plowing of 0-12%. The same result was noted when comparing volume of surface runoff and sediment yield from contour plowing of 20-40% to the results of up and down the slope plowing of 12-20%. The quantity and quality of crop yield did not change significantly by plow treatments. But, contour plowing increased the crop yield by 19, 21 and 9% on 0-12, 12-20 and 20-40% slopes, respectively.

The contour plowing significantly reduces surface runoff and sediment yield compared to the up and down the slope plowing. The average reduction on surface runoff and sediment yield was 76.5 and 91.9%, respectively and shows the effectiveness of plowing direction on steep lands. The amount of reduction on sediment yield was 91.16, 92.31 and 92.31% and the amount of reduction on surface runoff was 83.28, 89.24 and 56.84% in 0-12, 12-20 and 20-40% slopes, respectively. The volume of surface runoff and sediment yield produced from contour plowing of 12-20 and 20-40% were significantly lower compared to up and down the slope plowing of 0-12%. The volume of surface runoff and sediment yield produced from contour plowing of 20-40% was significantly lower compared to up and down the slope plowing of 12-20%. Compared to annual SLT of 1.16 t $ha^{-1}$ (Bybordi, 2001), up and down the slope

Table 1: Physicochemical analysis of soil samples

| Slope (%) | Depth (cm) | Sand (%) | Silt (%) | Clay (%) | SP[1] (%) | $CaSO_4$ (%) | TNV[2] (%) | N[3] (%) | P[4] (ppm) | K[5] (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-12 | 0-5 | 51 | 24 | 25 | 43.14 | 0.009 | 14.99 | 0.025 | 13.6 | 172.0 |
| | 5-20 | 53 | 22 | 25 | 52.57 | 0.004 | 23.63 | 0.014 | 11.0 | 112.0 |
| | 20-40 | 51 | 26 | 23 | 43.23 | 0.006 | 16.67 | 0.014 | 20.6 | 246.0 |
| 12-20 | 0-5 | 50 | 36 | 14 | 44.15 | 0.009 | 32.03 | 0.008 | 7.8 | 92.0 |
| | 5-20 | 38 | 38 | 24 | 43.86 | 0.012 | 15.86 | 0.006 | 12.8 | 168.0 |
| | 20-40 | 50 | 24 | 26 | 47.32 | 0.013 | 27.13 | 0.007 | 8.4 | 94.0 |
| 20-40 | 0-5 | 53 | 34 | 13 | 48.46 | 0.004 | 21.47 | 0.017 | 11.4 | 112.0 |
| | 5-20 | 49 | 28 | 23 | 40.33 | 0.004 | 14.99 | 0.014 | 15.4 | 184.0 |
| | 20-40 | 47 | 28 | 25 | 43.52 | 0.003 | 14.99 | 0.014 | 12.2 | 246.0 |

[1]Saturation percentage, [2]Total neutralizing value, [3]Nitrogen, [4]Phosphorus, [5]Potassium

Table 2: Surface runoff and sediment yield of 0-12, 12-20 and 20-40% slope plots

| | | Plowing treatments, volume of surface runoff (L) and sediment yield (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st replication | | | | 2nd replication | | | | 3rd replication | | | |
| | | Up and down | | Contour | | Up and down | | Contour | | Up and down | | Contour | |
| No. | Rain (mm) | Runoff | Sediment | Runoff | Sediment | Runoff | Sediment | Runoff | Sediment | Runoff | Sediment | Runoff | Sediment |
| **Slope 0-12%** | | | | | | | | | | | | | |
| 1 | 11.5 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 2 | 15.5 | 0.00 | 0.0 | 0.35 | 14.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.49 | 12.0 | 0.81 | 9.0 |
| 3 | 3.5 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.13 | 0.8 | 0.07 | 490.0 |
| 4 | 19.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 5 | 7.0 | 0.26 | 1.5 | 0.00 | 0.0 | 4.16 | 15.0 | 0.42 | 0.5 | 36.00 | 180.0 | 0.00 | 0.0 |
| 6 | 19.0 | 21.60 | 560.0 | 1.73 | 20.0 | 27.60 | 640.0 | 3.08 | 3.0 | 31.20 | 530.0 | 0.00 | 0.0 |
| 7 | 18.5 | 158.40 | 2290.0 | 38.40 | 199.0 | 204.00 | 8620.0 | 13.20 | 40.0 | 192.00 | 10940.0 | 0.00 | 0.0 |
| 8 | 5.5 | 79.20 | 1590.0 | 33.60 | 1120.0 | 93.60 | 1680.0 | 9.60 | 110.0 | 88.80 | 1880.0 | 9.60 | 230.0 |
| 9 | 3.0 | 96.00 | 690.0 | 62.40 | 290.0 | 135.60 | 1100.0 | 14.40 | 50.0 | 135.60 | 870.0 | 21.60 | 10.0 |
| 10 | 19.5 | 30.00 | 370.0 | 31.20 | 10.0 | 108.00 | 1000.0 | 8.40 | 20.0 | 88.80 | 760.0 | 0.38 | 3.0 |
| 11 | 15.0 | 74.40 | 4640.0 | 69.60 | 1980.0 | 122.40 | 5510.0 | 15.60 | 40.0 | 153.60 | 4500.0 | 2.28 | 5.0 |
| 12 | 6.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 1.28 | 4.0 | 1.30 | 0.4 | 0.00 | 0.0 |
| 13 | 5.5 | 0.13 | 0.6 | 0.16 | 0.4 | 0.00 | 0.0 | 0.06 | 0.04 | 0.35 | 1.3 | 0.00 | 0.0 |
| 14 | 4.0 | 0.42 | 4.0 | 1.20 | 4.0 | 0.40 | 2.0 | 0.65 | 3.0 | 0.63 | 0.1 | 0.44 | 0.5 |
| 15 | 5.5 | 2.43 | 24.0 | 0.00 | 0.0 | 0.46 | 3.0 | 0.00 | 0.0 | 1.36 | 13.0 | 0.00 | 0.0 |
| 16 | 6.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.26 | 1.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 17 | 7.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 18 | 11.5 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 19 | 3.5 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 20 | 14.5 | 23.00 | 380.0 | 0.61 | 4.0 | 10.30 | 320.0 | 0.00 | 0.0 | 48.00 | 2020.0 | 0.00 | 0.0 |
| 21 | 6.0 | 12.00 | 56.0 | 0.82 | 5.0 | 2.30 | 27.0 | 0.00 | 0.0 | 23.10 | 85.0 | 0.00 | 0.0 |
| 22 | 3.5 | 12.80 | 27.0 | 0.88 | 3.0 | 6.80 | 15.0 | 0.00 | 0.0 | 22.20 | 54.0 | 0.00 | 0.0 |
| **Slope 12-20%** | | | | | | | | | | | | | |
| 1 | 11.5 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 |
| 2 | 15.5 | 3.04 | 14.0 | 0.54 | 9.00 | 0.38 | 15.0 | 0.68 | 13.0 | 0.94 | 14.0 | 0.24 | 5.0 |
| 3 | 3.5 | 0.15 | 4.0 | 0.00 | 0.00 | 0.15 | 4.0 | 0.15 | 3.0 | 0.06 | 2.0 | 0.00 | 0.0 |
| 4 | 19.0 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 5 | 7.0 | 12.70 | 97.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 6 | 19.0 | 48.00 | 840.0 | 0.00 | 0.00 | 9.60 | 340.0 | 0.00 | 0.0 | 26.40 | 400.0 | 1.43 | 17.0 |
| 7 | 18.5 | 189.60 | 3450.0 | 0.00 | 0.00 | 172.80 | 2390.0 | 27.60 | 109.0 | 196.80 | 5170.0 | 6.72 | 18.0 |
| 8 | 5.5 | 81.60 | 6150.0 | 0.00 | 4.00 | 55.20 | 1060.0 | 12.00 | 160.0 | 16.80 | 350.0 | 7.20 | 112.0 |
| 9 | 3.0 | 145.20 | 1810.0 | 6.00 | 71.00 | 100.80 | 760.0 | 25.20 | 150.0 | 130.80 | 1020.0 | 25.20 | 150.0 |
| 10 | 19.5 | 52.80 | 599.0 | 1.10 | 2470.00 | 79.20 | 1420.0 | 26.60 | 270.0 | 88.80 | 1260.0 | 13.10 | 50.0 |
| 11 | 15.0 | 158.20 | 7260.0 | 1.23 | 0.002 | 93.60 | 3530.0 | 27.63 | 48.0 | 164.40 | 4320.0 | 19.50 | 27.0 |
| 12 | 6.0 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 1.24 | 0.4 | 3.013 | 1.0 | 0.00 | 0.0 |
| 13 | 5.5 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.36 | 0.4 | 0.00 | 0.0 | 0.00 | 0.0 |
| 14 | 4.0 | 0.00 | 0.0 | 0.00 | 0.00 | 0.66 | 1.7 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 15 | 5.5 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 16 | 6.0 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 17 | 7.0 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 18 | 11.5 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 19 | 3.5 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 |
| 20 | 14.5 | 43.20 | 970.0 | 0.42 | 1.00 | 43.20 | 2920.0 | 0.00 | 0.0 | 24.80 | 160.0 | 0.00 | 0.0 |
| 21 | 6.0 | 12.00 | 44.0 | 1.26 | 3.00 | 18.80 | 65.0 | 0.00 | 0.0 | 6.00 | 28.0 | 0.00 | 0.0 |
| 22 | 3.5 | 8.50 | 14.0 | 0.00 | 0.00 | 12.80 | 24.0 | 0.00 | 0.0 | 2.35 | 14.0 | 0.00 | 0.0 |

Table 2: Continued

| No. | Rain (mm) | 1st replication, Up and down, Runoff | 1st replication, Up and down, Sediment | 1st replication, Contour, Runoff | 1st replication, Contour, Sediment | 2nd replication, Up and down, Runoff | 2nd replication, Up and down, Sediment | 2nd replication, Contour, Runoff | 2nd replication, Contour, Sediment | 3rd replication, Up and down, Runoff | 3rd replication, Up and down, Sediment | 3rd replication, Contour, Runoff | 3rd replication, Contour, Sediment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Slope 20-40%** | | | | | | | | | | | | | |
| 1 | 11.5 | 0.95 | 1.0 | 2.03 | 3.0 | 2.76 | 5.0 | 2.98 | 4.00 | 2.08 | 7.0 | 2.86 | 5.00 |
| 2 | 15.5 | 1.81 | 2.0 | 2.77 | 5.0 | 0.25 | 17.0 | 3.80 | 13.00 | 0.78 | 4.0 | 2.94 | 5.00 |
| 3 | 3.5 | 0.46 | 0.6 | 1.23 | 0.5 | 0.97 | 0.5 | 1.45 | 2.00 | 0.66 | 0.5 | 1.20 | 0.97 |
| 4 | 19.0 | 0.00 | 0.0 | 3.40 | 10.0 | 2.10 | 0.9 | 3.03 | 0.07 | 0.00 | 0.0 | 0.00 | 0.00 |
| 5 | 7.0 | 22.80 | 77.0 | 0.29 | 2.0 | 1.13 | 0.7 | 0.36 | 0.00 | 12.00 | 8.0 | 1.31 | 2.00 |
| 6 | 19.0 | 69.60 | 1740.0 | 57.60 | 103.0 | 56.40 | 247.0 | 45.60 | 196.00 | 40.80 | 102.0 | 48.00 | 151.00 |
| 7 | 18.5 | 127.20 | 3230.0 | 69.60 | 830.0 | 141.60 | 1320.0 | 79.20 | 22.00 | 112.80 | 4550.0 | 64.80 | 2.90 |
| 8 | 5.5 | 110.00 | 157.0 | 67.00 | 71.0 | 54.00 | 42.0 | 72.00 | 132.00 | 44.00 | 47.0 | 24.00 | 19.00 |
| 9 | 3.0 | 116.40 | 2090.0 | 36.00 | 119.0 | 49.20 | 212.0 | 30.00 | 4.00 | 68.40 | 715.0 | 49.90 | 3.00 |
| 10 | 19.5 | 96.00 | 3200.0 | 94.80 | 731.0 | 37.20 | 320.0 | 12.00 | 7.00 | 30.00 | 245.0 | 1.89 | 1.50 |
| 11 | 15.0 | 139.20 | 8150.0 | 37.20 | 438.0 | 42.00 | 2280.0 | 20.37 | 19.00 | 33.18 | 549.0 | 0.98 | 1.00 |
| 12 | 6.0 | 1.33 | 2.0 | 1.36 | 0.6 | 0.00 | 0.0 | 1.28 | 0.06 | 0.00 | 0.0 | 0.00 | 0.00 |
| 13 | 5.5 | 0.53 | 2.0 | 1.14 | 0.8 | 1.17 | 0.6 | 1.01 | 0.50 | 0.00 | 0.0 | 0.00 | 0.00 |
| 14 | 4.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 |
| 15 | 5.5 | 1.01 | 6.0 | 0.19 | 1.0 | 0.15 | 0.1 | 8.50 | 169.00 | 0.00 | 0.0 | 0.00 | 0.00 |
| 16 | 6.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.0 | 0.00 | 0.00 | 0.79 | 7.0 | 0.00 | 0.00 |
| 17 | 7.0 | 19.70 | 49.0 | 1.23 | 0.2 | 16.30 | 41.0 | 3.18 | 0.30 | 60.00 | 397.0 | 1.70 | 1.00 |
| 18 | 11.5 | 6.00 | 97.0 | 1.03 | 3.0 | 33.60 | 134.0 | 4.70 | 179.00 | 22.70 | 363.0 | 2.68 | 34.00 |
| 19 | 3.5 | 5.50 | 10.0 | 0.00 | 0.0 | 4.70 | 12.0 | 0.00 | 0.00 | 22.70 | 106.0 | 0.00 | 0.00 |
| 20 | 14.5 | 40.80 | 3009.0 | 0.77 | 2.9 | 30.80 | 1290.0 | 1.75 | 12.00 | 88.80 | 7250.0 | 0.00 | 0.00 |
| 21 | 6.0 | 43.20 | 760.0 | 2.93 | 14.0 | 43.20 | 1840.0 | 3.15 | 180.00 | 86.40 | 1540.0 | 0.22 | 0.70 |
| 22 | 3.5 | 15.40 | 0.029 | 0.77 | 0.002 | 20.50 | 0.088 | 0.00 | 0.00 | 52.60 | 0.318 | 0.00 | 0.00 |

Plowing treatments, volume of surface runoff (L) and sediment yield (g)

Table 3: The quantity of produced wheat seeds

| Replication | 0-12, Up and down | 0-12, Contour | 12-20, Up and down | 12-20, Contour | 20-40, Up and down | 20-40, Contour |
|---|---|---|---|---|---|---|
| 1 | 4.64 | 4.33 | 1.88 | 4.94 | 1.81 | 2.21 |
| 2 | 4.07 | 5.03 | 3.26 | 2.88 | 2.41 | 2.47 |
| 3 | 2.50 | 4.43 | 2.72 | 2.14 | 2.58 | 2.76 |
| Average yield/plot | 3.74 | 4.60 | 2.62 | 3.32 | 2.27 | 2.48 |
| Average yield/ha | 923.68 | 1136.08 | 647.07 | 819.96 | 560.63 | 612.50 |

Slope (%), plowing treatments and wheat production (kg)

Table 4: Wheat seed quality analysis

| Factor name | 0-12, Up and down | 0-12, Contour | 12-20, Up and down | 12-20, Contour | 20-40, Up and down | 20-40, Contour |
|---|---|---|---|---|---|---|
| 1000 kernel weight (g) | 48.0 | 49.0 | 47.0 | 48.0 | 41.0 | 41.0 |
| Suni bug damaged kernels (%) | 1.0 | 2.0 | 2.5 | 2.0 | 3.0 | 2.5 |
| Protein (%) | 9.4 | 9.1 | 9.3 | 9.1 | 9.1 | 9.2 |
| Sedimentation test (No.) | 22.0 | 21.0 | 21.0 | 17.0 | 20.0 | 21.0 |
| Bread volume (mL) | 278.0 | 251.0 | 307.0 | 280.0 | 266.0 | 289.0 |
| Moisture content (%) | 12.3 | 12.5 | 12.3 | 12.3 | 11.9 | 12.0 |
| Hardness index (No.) | 37.0 | 35.0 | 36.0 | 36.0 | 36.0 | 36.0 |
| Water absorption (%) | 62.0 | 62.1 | 61.9 | 61.8 | 62.5 | 62.4 |
| Falling number (No.) | 441.0 | 443.0 | 422.0 | 471.0 | 413.0 | 436.0 |
| Wet gluten (%) | 23.0 | 22.0 | 24.0 | 19.0 | 21.0 | 21.0 |
| Gluten index (No.) | 17.0 | 27.0 | 36.0 | 23.0 | 16.0 | 33.0 |
| Dry gluten (%) | 8.0 | 7.0 | 8.0 | 6.0 | 7.0 | 6.0 |

Slope (%) and plowing treatments

plowing of 0-12, 12-20 and 20-40%, increased the soil loss 1.85, 1.68 and 1.68 times, respectively. Contour plowing of the slopes of 0-12, 12-20 and 20-40% decreased the soil loss 6.11, 7.73 and 7.73 times less than the amount of soil loss tolerance. The quantity and quality of wheat crop yield did not show significant difference among different treatments. But, contour plowing increased the yield by 19, 21 and 9% on 0-12, 12-20 and 20-40% slopes, respectively. The average wheat production of rainfed croplands in Iran was 1069 kg $ha^{-1}$ in 2005 (National Statistical Calendar, 2006). The results of this research showed 1136, 820 and 612 kg $ha^{-1}$ for contour plowing and 924, 647 and 561 kg $ha^{-1}$ for up and down the slope plowing of 0-12, 12-20 and 20-40%, respectively. This means 15.7% increase in wheat production on lands with 0-12% slopes compared to the country's average wheat production.

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