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Effects of Contour Farming on Runoff and Soil Erosion Reduction: A Review Study

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ABSTRACT

The purpose of contour farming is to reduce runoff and soil erosion on mild slopes. This practice can also increase crop yield through the soil moisture retention in arid and semi-arid regions. Results showed contour cultivation reduced the annual runoff as 10% in compared with cultivation perpendicular to the slope. Also cultivation and planting along contour lines in comparison with cultivation and planting downwards the slop reduced soil losses and water losses as 49.5 and 32%, respectively. Although contour farming reduces runoff and soil erosion largely, but when it's combined with other conservation tillage such as no-tillage or minimum tillage can be more effective. Contour farming on permanent raised beds combined with residue retained on the soil surface is suggested according the results of previous studies as the best practice on mild slopes.

Introduction

Water erosion of agricultural soils has for many years been recognized as a global environmental problem. In areas that soils are light in texture and readily erodible, this problem can be serious with rates of erosion typically between 0.5 and 200 Mg $ha^{-1}yr^{-1}$ [4]. Tillage is a dynamic process that alters the nature of the soil surface, detaches and displaces soil aggregates and clods, and moves or translocates soil to lower elevations. Water, tillage, wind and soil creep are most forces that affect soil erosion on slope areas. Contour farming is an effective tillage practice for controlling soil erosion and increasing crop yield. Contour farming is the practice of tillage, planting and other farming operation performed on the contour of the field slope. This method is effective on moderate slope. Tillage and planting operations follow the contour line to promote positive row drainage and reduce ponding. Also, by increasing the soil surface roughness, contour ridging results in rainwater ponding in the furrow area, which reduces runoff velocity, increases infiltration, and reduces soil erosion (Liu et al., 2014). In addition, nutrients (e.g., nitrogen and phosphorus) in runoff are retained better in contour ridge tillage compared with up and downslope tillage (Ma et al., 2010; Liu et al., 2014). In dried areas, contour farming increases crop yield by increasing infiltration and retaining water. However, there are some main problems for implementation of contour farming that prevent to develop this practice. The aim of this study was introduction of different aspects of contour farming, its implementation problems, and review some previous studies and interpret differences between their results. There isn't any review study about contour farming and its results and because of that, this study could be useful for people who would like to know this practice and the results were obtained from previous studies.

Conditions where practice applies

Contour farming is most effective on slopes between 2 and 10 percent (Anonymous, 2008).

This practice will be less effective in achieving the purposes on slope exceeding 10 percent and single storm erosion index greater than 140. In other conditions, the crop grown along contours must always be associated with other practices of conservation (Rìo Grande do Sul, 1985). The practice is not well suited to rolling topography having a high degree of slope irregularity because of the difficulty meeting row grade criteria. Several factors influence the effectiveness of contour farming to reduce soil erosion. These factors included (Anonymous, 2008):

- Row grade
- Ridge height
- Cover and roughness
- Slope length
- Slope steepness
- Soil hydrologic group

The crop rows shall have a sufficient grade to ensure that runoff does not pond and cause unacceptable crop damage. Soils with very slow infiltration rates (hydrologic group C and D) will have a minimum absolute row grade of 0.2 percent on slopes where ponding could be a problem. The maximum grade of rows shall not exceed 2 percent or one half of the up and down hill slope percent used for erosion prediction, whichever is less. Up to a 3 percent row grade is permitted within 150 feet of a stable outlet such as a grassed waterway, field border, or other stable outlet. The minimum ridge height shall be 2 inches during the period of the rotation that is most vulnerable to sheet and rill erosion prediction technology (Anonymous, 2008). The minimum ridge height criteria are not required when residue and tillage management, no-till/strip till/direct seed (Anonymous, 2008) is used for the contour and at least 50 percent surface residue cover is present between the rows after planting. A contour farming layout shall not occur on a hill slope length that is longer than the maximum slope length identified in Table 1.

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Table 1. Maximum slope length limitations (Anonymous, 2008).

Land slope percent	Maximum length (m)
1 to 2	125
3 to 5	100
6 to 8	60
9 to 12	40
13 to 16	25
17 to 20	20
21 to 25	15

Before implementation of contour farming, some considerations should be considered:

- Increasing residue and roughness decrease overland flow velocities, thus increasing the maximum acceptable slope length. But increasing residue and roughness alone is not sufficient to produce this effect.
- Before designing and layout contour lines, obstruction removal and changes in field boundaries or shape should be considered.
- Where contour row curvature become too sharp to keep machinery aligned in rows during field operations, consider the establishment of sod turn strips on sharp ridge points or other odd areas as needed.
- When the intersection of crop rows with the field edge is not perpendicular, a field border (Anonymous, 2008) may be needed to allow farm implements room to turn.
- If using residue and tillage management, ridge till (Anonymous, 2008) on the contour, avoid crossing over ridged rows the effectiveness of the ridges. Sod turning strips may be established if correction areas are unavoidable.

Operation and maintenance

All tillage and planting operations perform parallel to contour baseline. Farming operations should begin on the contour baseline and proceed both up and down the slope in a parallel pattern. Where field operations begin to converge between two non-parallel contour baseline, establish a correction area that is either permanently in sod, in cover management. Where contour row curvature becomes too sharp to keep machinery aligned with rows during field operations, establish sod turn strips on sharp ridge points or other odd areas as needed. Maintenance needed for this practice includes protecting the permanent guide rows, periodic inspection and repairs to water outlets, and protecting up and downhill farm roads from erosion.

The main constraints of contour farming

Some of the main constraints to practicing contour farming are as follows:

- Overturning tractors and self-propelled vehicles, especially in wet conditions is one of the main constraints of contour farming.
- The trends in the agricultural sector are not conducive to soil conservation practices. With increasing off-farm employment of young people, its mostly old farmers that stay behind in rural. Both trends decrease the likelihood of using contour cultivation.
- Difficulties of drawing contour lines and lack of knowledge about contour farming are other constraints.

Review of the contour farming studies

Steven et al (2009) conducted a research in a farm with clay soil and slope of 2 to 6 degrees in which the minimum tillage was applied using disk implements with 15 cm deep in the half of the farm and conventional tillage was applied using a moldboard plow with a maximum depth of 18 cm in the other half. Each of these two parts included three different planting systems, so split plot design with two main factors and three secondary factors in three replications was used for analyzing the results. The treatments included: minimum tillage, minimum tillage with contour plowing, minimum tillage up and down slope and after that contour plowing, minimum tillage with contour plowing and beetle bank, conventional system, conventional system with contour plowing, conventional system with tillage up and down slope and after that contour plowing, conventional system with contour plowing and beetle bank. The runoff was collected at the end of each plot in some ponds with the depth of 3 m below. Around these ponds, clay soil had been compacted to preventing the water infiltration. Collected water and its deposits were transmitted to related tanker through separated pipes for each plot. Data were analyzed with SPSS and R software. Results showed contour cultivation did not affect in a significant reduction in surface runoff when compared to up and down cultivation in either the plough or minimum tillage plots. However, there was quite a large difference between the treatments, with a mean reduction of 72.2%, although this ranged from 9 to 98%. Sediment losses followed a very similar pattern to runoff.

In another study that was conducted in Mali by Traore et al (2004), permanent ridge on contour lines were drawn using animal's draught in the farms with the slope between 1 to 3% with the total annual rainfall of 800 to 1000 mm. The farm with contour ridges is shown in Figure 1.

Figure 1. The farm with contour ridges (Traore et al., 2004).

In order to reduce the runoff, a ditch was constructed perpendicular to the slope in upper boundaries of fields, in which runoff was driven to the permanent waterway in the field margins. The soil moisture content in soil profile was measured in different samples and dried under 105. 3 Samples were collected to a depth of 200 cm in three following dates: 1- July – with occurring the early rain. 2- End of August – rainfall stands maximum in this month. 3- End of September. Hence, moisture regime was obtained on both plots with counter cultivation and with ridges perpendicular to the slope. Runoff was collected through the end of the field and one-tenth of that was transported to a 200 l tanker, so that, runoff was measured for each rainfall. Authors reported that the ridges on contour lines reduced the annual runoff as 10%. Traore et al. (2004) also reported that the maintenance of rain water in deep soil layers is higher by ridges on contour lines compared to conventional tillage. The impact of contour lines on moisture regime is shown in Figure 2 (Traore, et al., 2004).

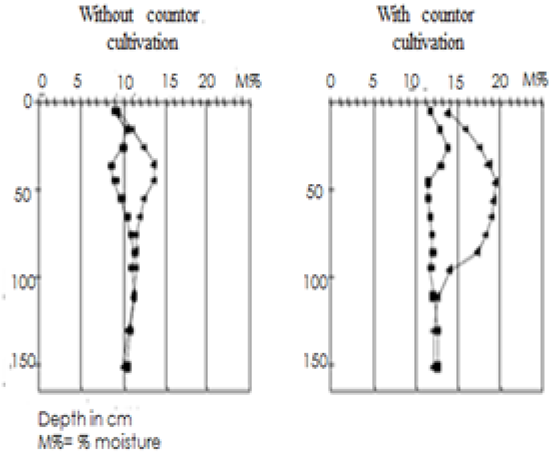

Figure 2. Soil moisture at the beginning and at the end of the rains (Traore, et al., 2004).

A study was conducted by Gebreegziabher et al (2009) in northern Ethiopia. The length of growing period varied between 45 to 120 days. The average annual rainfall was 519 mm that 85% of total rainfall was concentrated in July and August. Study was conducted under rain-fed conditions and soil erosion was determined in different tillage systems and cultivation on contour lines. The Randomized Complete Block Design (RCBD) with plots and two replicates of each treatment was used for analyzing data. Experimental systems included: 1- Permanent raised bed on contour lines (PRBCL): contour furrows were created at 60 to 70 cm interval. 2- Conventional ploughing (CP): plots were ploughed three times, twice before planting (before the onset of rain and after the onset of rain) and after that a superficial tillage was applied after planting to cover the seeds with soil. 3- Terwah ploughing (TP): system was applied in the way that described for conventional system, but contour furrows were made at 1.5 to 2 m interval. Contour lines, Terwah system and conventional tillage system in the aspect of runoff and soil erosion were compared. Runoff of PRBCL, CP and TP were determined as 255, 653, 381 per hectare, respectively. It showed significant difference between permanent raised bed cultivation on contour lines and Terwah system compared with conventional tillage system at the 95% level of probability.

In a research that was conducted by McIsaac et al (1991) in the north west of Illinois, United States, runoff was measured through creating the artificial rain. Artificial rain was created by a rotating boom and the runoff was measured in three-minute intervals. Slope varied between 6 to 13% with 9% as average. The plot was ploughed by disc-plough and was prepared for maize planting after soybean cultivation for two years. Four systems were applied in that year: 1- ploughing with moldboard plough, 2- chisel ploughing, 3- Strip tillage, 4- No-tillage. There were two replicates perpendicular to the slope and two replicates on contour lines for each individual system. Difference between means was investigated with student's t-test. Scheffe test was used for comparing more than two means at the 95% level of probability. Linear regression and covariance analyzing were applied for identifying the significant linear relations between residue and runoff (SAS Institute, 1985). Authors reported that the impact of contour lines on reduction of runoff and soil erosion was nonsignificant. It is probably due to the high degree of slope and the heavy artificial rain produced in the experiment.

These results once again prove that contour farming doesn't work properly in situations which have a high degree of slope and rain.

In a study that was conducted by Quinton et al (2004) in England, data were collected from eight plots. Soil texture was sandy loam and the slope varied between 7 to 13%. Two main treatments in the study were: 1- Tillage system: a) minimum tillage, b) conventional system, 2- cultivation direction: a) across the slope, b) perpendicular to the slope and on contour lines. Multi-factorial design in randomized complete block design with two levels and two replicates was applied. Runoff was collected in some waterways at the end of each plot and separately transported to 2000 L tankers through some pipes. Runoff was measured in 48-hour intervals. Data related to the runoff and sediments were statistically analyzed by Statistical software. Results showed runoff on contour lines in comparison with conventional tillage was significant ($P < 0.01$). Although soil erosion was non-significant, but it was considerably reduced.

A study undertaken at the Campinas Institute of Agronomy (Bertoni et al., 1972) showed a major increase in maize yields for the crop planted along the contours compared with down the slope (Figure 3). A smaller increment in yield was achieved by also preparing and tilling the land along the contours.

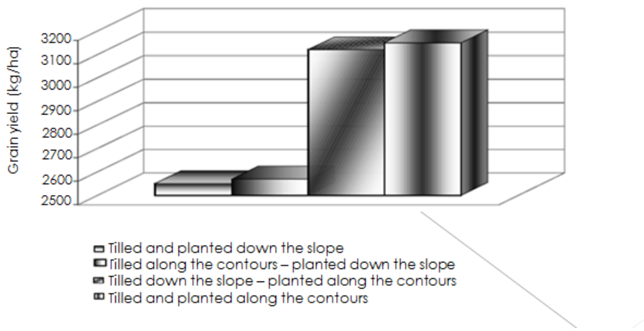

Figure 3. Effect of the direction of planting and the soil preparation method on maize grain yield (Bertoni et al., 1972).

When the soil preparation and the planting were both done downwards the slope, the furrows and the crop rows directed the flow of the runoff downwards, dragging the soil, the nutrients and the organic matter with it. When the crop is planted along the contours, this corrects the negative effect of the furrows left after preparing the land downwards the slope. By combining both the land preparation and the planting along the contours, small contour ridges are shaped. These, together with the planted crop, serve as obstacles, causing slight flooding and will thus increase the infiltration of the water into the soil and reduce the erosion (Table 2). As it is shown in Table 2, when cultivation and planting were done along contour lines, soil loss and water loss were reduced 49.5 and 32 percent in comparison with cultivation and planting downwards the slop, respectively.

Table 2. Effect of management and conservation practices on erosion losses under annual crops (Bertoni et al., 1972).

Cultivation and planting practices	Soil loss (t/ha)	Water loss (% of rainfall)
Down slope	26.1	6.9
Along contours	13.2	4.7
Contours + alternation with pasture	9.8	4.8
Contours + bands of sugarcane	2.5	1.8

The use of contour farming combined with conservation tillage such as no-tillage could help improving the effects on runoff and soil erosion reduction. No-tillage system improves the water infiltration rates, because this system does not distribute the soil repeatedly. Because of that, it reduces the runoff after each rainfall. This feature appears better by vegetation over the next few years (Govaerts, et al., 2007). De Alba (2006) reported that runoff reduced by 40% for no-tillage system compared to conventional tillage. Both minimum tillage and no-tillage cause to less separation of soil particles due to splash the rain drops, hence, transferring the soil would be lower. The process of increasing the soil fertility and improving the soil structure is time-consuming and will be occurred after a few years (Gebreegziabher, et al., 2009). Retained residue is another factor which improves water infiltration rates and reduce runoff. Safari et al (2013) in a research showed that retention 90 percent residue increased moisture content compared to no residue treatment. There are some other factors in which involved with effectiveness of no-till system and contour lines cultivation on erosion reduction. Evans (2002) reported that the lands under fallow and winter cereals cultivation are less susceptible to soil erosion compared to other crops cultivation.

In order to prevent the failure risk during the early stages of growth, farmers usually wait for considerable rainfall for cultivation. This delay cause to insufficient access of moisture for plant during flowering, consequently the lowest yield would be achieved. Water can be delivered to plant at the end of the growth season for two or three more weeks by contour lines cultivation in the form of bed (De Alba, et al., 2006).

It was reported that many farmers are reluctant to contour lines cultivation, because spraying and weeding are difficult to do (Stevens, et al., 2009). A report in China showed that the probability of using contour lines cultivation is higher in families with large-scale farms and more fertile soil in which young men are decision-makers (Liu, et al., 2013). Many farmers are reluctant to adopt contour cultivation because of difficulties with cultivation and spraying operations (Quinton and Catt, 2004). Chambers et al (2000) reported that contour cultivation has not been widely taken up in the UK due to concerns that machinery will overturn in wet conditions. Liu et al (2014) reported that lack of labor and knowledge limit farmer capability to adopt conservation practices such as contour farming. Using permanent raised bed can reduce the difficulties to drawing contour lines. The authors suggest where contour farming can be used, the government organize training course for farmers. Where the use of contour farming is limited because of the difficulties of spraying and weeding, practice such as terwah cultivation, beetle banks or stone banks can be used at 1.5 to 2 m interval on contour lines. However, these practices are not as proper as using contour farming across the field, but still can be useful for reducing runoff and soil erosion.

Conclusions

The use of contour farming systems is one of the most important management approaches to reduce runoff and soil erosion on a mild slope. Results showed contour cultivation reduced the annual runoff as 10% in compared with cultivation perpendicular to the slope. Also cultivation and planting along contour lines in comparison with cultivation and planting downwards the slop reduced soil losses and water losses as 49.5 and 32%, respectively. However, contour farming in conjunction with other conservation tillage such as no-tillage or minimum tillage is more effective. This practice can also improve crops yield through the soil moisture retention in arid and semi-arid regions. Where the use of contour farming is limited based on the conditions, beetle banks or stone banks can be used at 1.5 to 2 m interval on contour lines. Although these practices are not as proper as using contour farming across the field, but these still can be useful for reducing runoff and soil erosion. These practices can also reduce difficulties of cultivation and spraying operations, which are limitations to using contour farming.

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