

Improving the design of contour ridges for water conservation

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Abstract

Contour ridges, sometimes referred to as contour bunds, have been used in many parts of the world for soil conservation. Recently interest has shifted to their use as water conservation structures in low rainfall areas. The use of contour ridges for water conservation requires design approaches that offer appropriate structures for the adopted environment so that the effectiveness of the ridges is reliable. This paper looks at the past and current design approaches for contour ridges and discusses the suitability of these methods on designing contour ridges for water conservation purposes. The information analyzed has been obtained from literature and design manuals. The scientific principles behind the design guidelines are discussed together with the constraints of data availability and the resulting assumptions made in the various design models.

Key words: contour ridge design, water conservation, dead level contours, soil conservation, runoff.

Introduction

Contour ridges have been used in many parts of the world as a soil conservation technology. In some cases, where farmers did not see the need, there has been forceful adoption of the technology through legislation. In recent years more and more emphasis is being placed on the use of contour ridges as a water conservation technology. However literature on how water conservation can be achieved through contour ridges is not available. Further design manuals have no mention or provision of water conservation.

Contour ridges are small earth structures constructed across the slopes on cultivated land. The main objective for their construction is to reduce the erosive power of runoff flowing through the cultivated land resulting in reduction in soil erosion. This is achieved through interception of runoff which is then directed into grassed waterways where it drains to natural streams. The water conservation capacity of soil depends on the soil depth. Thus when a soil profile in a cultivated field is conserved by minimizing erosion its depth remains large and with it water holding capacity. Thus soil conservation indirectly implies water conservation. However while contour ridges reduces soil erosion then also reduces the amount of water added to the soil by draining the water away from the field. Thus the current focus is now on retaining that

water so as to increase the amount of water added to the soil profile without compromising the soil storage potential.

Adoption of contour ridges in many parts of the world has been done without studying the suitability of the practice on local conditions and without identification of modifications necessary to make them work. Elwell (1981) emphasized the need for continued improved techniques in the design of contour ridges in order for them to remain relevant to the developments in agriculture. The focus however has largely been on soil erosion and not on water conservation through retention of water. As a result there are cases where water has been drained away from the field when it should have been retained resulting in negative impacts. MacFarlane (1995) discussed a typical case in which Dambos were drained resulting in serious gulley formation in the commercial farming areas of Zimbabwe. Legislation was then formulated to outlaw cultivation in dambos despite a long history of successful farming in these areas by African people. The African people used to grow rice in the dambos during the rain season and vegetables using water obtained from shallow wells during the dry season. Thus the decision to drain dambos had a negative effect on the food security of the African people who were now forced to grow maize as a staple food under conditions where the risk of failure is high.

A number of authors do refer to contour ridges as a water conservation technology but they do not explicitly show how they achieve this. It is understood that by reducing soil erosion the soils water retaining capacity is improved and therefore contour ridges are a water conservation technology. Attempts have been made though to focus on the actual water harvesting potential of contour ridges by preventing the runoff harvested from leaving the field (Practical Action) through development of dead level contours. Dead level contours are contour ridges that do not have a gradient thereby minimizing drainage of water from the field. The effectiveness of this practice is however not established (Mupangwa et al, 2006). It is therefore not well documented how design of contour ridges incorporate or do not incorporate water conservation. This study is carried out to analyze the existing design criteria for contour ridges and identify how water conservation has been incorporated in the design. Data on design parameters has been collected from literature and design manuals.

Results and Discussion

Several parameters are considered in the design of contour ridges throughout the world. A standard design for a given region or district is normally done as opposed to a specific design for a particular field.

Table 1: Design Parameters for Contour Ridges

Design Parameter	Criteria	Objective
Gradient	Velocity of flow	To encourage drainage, To prevent scour of the channel of the ridge
Length	Discharge rate	To prevent overflow of the contour ridge
Spacing	Runoff volume, land slope	To prevent erosion due to increased runoff volume

Cross Section Dimensions	Discharge volume	
Channel Depth	Velocity of flow	

The results show that water conservation can be presented and discussed in three design principles. These are spillage, overtopping and temporal storage.

Spillage from Contour Ridges

Contour ridges are designed to drain water away from the field. This is achieved through constructing contour ridges at a gradient (Design Manual for Queensland, 2004; Elwell, 1981). Design Manual for Queensland recommends an increase in gradient with the increase in land slope. For steeper slopes the contour ridge gradient increases towards the contour outlet. This encourages faster discharge of water from the field. The practical action approach though does not recommend a gradient for contour ridges in areas where rainfall is low. Most design manuals pay no regard to retention of water when gradient slope is recommended. The Queensland manual in fact discourages ponding of water in the contour ridges.

Overtopping

Contour ridge channels are designed to prevent failure through overtopping. The recommended design capacity of the ridges is to carry a runoff event with a 10 year return period. This implies all the runoff does not overflow into the field. The focus again is to remove water from the field. However this contradicts the observation of farmer Nkomo in Zhulube Catchment of Limpopo Basin in Zimbabwe (personal interview with Mhizha, 2008) who observed that if during the rain season his contour ridge overflows three times he knows he will harvest that year. The overflowing water helps improve the soil moisture in the field as it becomes a form of runoff farming (Prinz and Malik, 2002). Thus it can be argued that preventing overtopping reduces water availability to the crop although the nature and conditions of overtopping may be a risk to soil erosion. Therefore contour ridges are designed without consideration for improving water conservation through allowing overtopping. Circumstances under which overtopping should be allowed need to be established through research.

Temporal Storage

Contour ridges themselves provide a temporal storage even though there is drainage of water to grassed waterways. They can therefore be compared to surcharge storage in dam reservoirs with the drainage rate related to spillage of water in a dam. However little is known of the impact of the temporal storage capacity of the contour ridges on the drainage rate and there has been recommendations for research in this area (Queensland Design Manual, 2004). The recommendation however focuses on drainage rather than water retention. The research should encompass water retention and conditions under which it should be drained away. While in surcharge storage of dam reservoirs spillage will be the main water flow from the reservoir, in contour ridges there are other flow pathways that may be significant depending on prevailing conditions. For example when a heavy storm occurs on a dry field infiltration excess

runoff will be generated. As soon as the storm ceases infiltration continues because the soil will not have reached saturation level. Therefore drainage will continue to compete with infiltration until the water in the channel is finished.

Probable Improvements to the Design

Given the fact that reducing soil erosion improves water availability by increasing the storage capacity of the soil and also that adding water to the soil improves water availability there are two conflicting objectives that need to be met. Reducing soil erosion requires that water be drained away from the field through spillage, preventing overtopping and minimizing storage in the channel. On the other hand adding water to the soil requires that water be retained in the field through minimizing spillage, allowing overtopping of the ridges and maximizing storage in the channel. Therefore design of contour ridges should focus on optimizing benefits from these two conflicting objectives.

Conclusions

From the discussion it can be seen that a contour ridge provides a temporal storage. The residence time of water in temporal storage is determined by the discharge rate (spillage), evaporation and seepage (including infiltration). There is no knowledge on the models that describe these interactions. While the contours are designed to minimize erosion due to accumulated runoff the impact of allowing some overtopping of the contour ridges are not fully understood. Erosion on the land downstream of the contour ridge is likely but the overtopping water may be a form of runoff farming as the water may result in improved soil moisture.

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