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Dr. Ch. Hemant Solanki
Department of Soil Conservation and Water Management, C S Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Dr. Amar Kant Verma
Department of Soil Conservation and Water Management, C S Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Kushal Sachan
Department of Soil Science and Agricultural Chemistry C S Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Corresponding Author:
Dr. Amar Kant Verma
Department of Soil Conservation and Water Management, C S Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Soil conservation and water management measures for tree based systems

Dr. Ch. Hemant Solanki, Dr. Amar Kant Verma and Kushal Sachan

Abstract
Soil Conservation and Water Management Measures for Tree Based Systems promote the conservation of natural resources particularly water and soil in the land scapes and can change the hydrological balance within the system. Large scale developmental efforts such as MGNREGA, IWMP and Horticulture Missions are being made to convert the wastelands or fallow lands to be brought under different tree based systems such as horticulture, Agroforestry systems etc. In the process, soils with low water holding capacity and shallow depth soils in low to medium rainfall zones located in undulating terrains etc are converted to tree based systems. In order to derive the optimum benefits through tree based systems, it is necessary that land be treated first with soil conservation measures so that even in low rainfall regions these systems might able to survive, though it may take a longer time to derive economical benefits. In the absence of this, the systems may not be in a position to establish themselves leading wastage of funds. There are many time-tested technologies of soil conservation and water management that can be adopted for tree based systems whether it is Horticulture, Agro-horti systems, Agro-forestry, Silvi-pasture system etc. Much of the literature dealing with growing trees in low rainfall areas come from Middle East countries etc. In India, tree plantations have been promoted on a wide scale in watershed development programme along with soil conservation and water management measures such as continuous contour trenches, water absorption trenches etc. These interventions were chosen initially as *shramdan* of watershed beneficiaries and are promoted extensively to bring in the much needed vegetation on denuded hills. The type of soil conservation and water management measure will depend on the size and shape of the areas to be developed for cropping, its location within the watershed of which this area is a part, the kind of plantation being taken up etc. For small farm fields areas, *in-situ* conservation practices such as formation of basins, or micro relief systems and agronomic conservation practices may suffice whereas for large plantations, watershed scale development work may have to be taken up. The following section deals with few soil conservation measures which could be implemented for tree based systems in rainfed areas.

Keywords: Agro-forestry, Soil conservation and water management measures

Soil Conservation and Water Management Systems

Majority of soil conservation and water management measures include some type water harvesting with in the field which is often known as micro catchment water harvesting in which surface runoff is collected from a small catchment area and storing it in the root zone of an adjacent infiltration basin. This infiltration basin may be planted with a single tree, bush or with annual crops (Boers and Ben-Asher, 1982) [1].

The advantages of MC-WH systems are

- Simple design and cheap to install, therefore easily replicable and adaptable.
- Higher runoff efficiency than medium or large scale water harvesting systems; no conveyance losses.
- Erosion control function can be constructed on almost any slope, including almost level plains.

The typical examples of this type of system: Negariam micro-catchments, contour bunds and semi-circular bunds (Critchley and Seeger, 1991) [2], continuous contour trenches, water absorption trenches, staggered trenches, platform and trench type etc.

The general design principle of Micro catchment rainwater harvesting systems involves a catchment area, which collects runoff coming from ground surfaces which receives and concentrates runoff from the catchment area for crop water supply. The relationship between the catchment area and the cultivated area, in terms of size, determines by what factor the rainfall will be multiplied. For a more efficient and effective system, it is necessary to calculate the ratio between the two if the data related to the area of concern in terms of rainfall, runoff and crop water requirements is available (Moges, 2004) [8].

Micro catchment systems provide many advantages over other irrigation schemes. They are simple and inexpensive to construct and can be built rapidly using local materials and manpower. The runoff water has a low salt content and, because it does not have to be transported or pumped, is relatively inexpensive. The system enhances leaching and often reduce soil salinity (Matthew and Bainbridge, 2000) [7] The major techniques include: Pitting (wor105), earth basins, Strip catchment tillage, Semicircular bunds (wor105), earthen bunds, Meskat-type system, Negarim micro catchments (water harvesting, Sudan), contour ridges (swim07) and stone lines (Critchley and Siegert, 1991) [2].

Pitting System

Pitting system consists of small circular pits, with about 30-50 cm in diameter and 20-50 cm deep, dug to break the crusted soil surface, to store water and to build up soil fertility. Organic manure and compost are usually added into the pit to improve fertility. It works by combination of water harvesting and conservation of both moisture and fertility in the pit. The catchment to command area ratio is about 3:1 and is suitable for rainfall of 300-600 mm year^{-1}.

Earth Basins

Earth basins are normally small, circular, square or diamond shaped micro catchments, intended to capture and hold all rainwater that falls on the field for plant use. They are constructed by making low earth ridges on all sides, to keep rainfall and runoff in the mini-basin. Runoff water is then channeled to the lowest point and stored in an infiltration pit. The technique is suitable in dry areas , where annual rainfall amounts are at least 150 mm, slops steepness ranges from flat to about 5 per cent, and soil that is at least 1.5 m deep to ensure enough water holding capacity. Earth basins are especially for growing fruit crops, and the seedling is usually planted in or on the side of the infiltration pit immediately after the beginning of the rains. The size of the basin may vary between 1 to 2 m in width and up to 30 m in length for large external catchments with a deep at about 0.5 m (Mati, 2005) [6].

Earthen Bunds

Earthen bunds various forms earth-shapings, which create run-on structures for pounding runoff water. The most common are within-field runoff harvesting systems, and can be easily done by manual labor and animal drought. The variations of the system include contour bunds, semi-circular bunds and negarims micro catchments. The normal designs for semicircular bunds involve making earth bunds in the shape of a semi-circle with tip of the bunds in the contour. The dimension of the holes and the spacing of the contours are dictated by the type of crop. For common fruits, the holes are made with a radius of at least 0.6 m and a depth of 0.6 m. the sub-soil excavated from the pit is used to construct a semicircular bund with a radius ranging from 3 m to 6 m on the lower side of the pit. The bund height is normally 0.25 m. the pits are mixed with mixture of organic manure and top soil to provide the required fertility and also to help retain the moisture.

Negarims micro catchments are regular square earth bunds, which have been turned 45 degrees from the contour to concentrate surface runoff at the lowest corner of the square where there is an infiltration pit dug. The shape of the infiltration pit can be circular or square, with dimensions varying according to the catchment size. Manure or compost be applied to the pit to improve fertility and soil water holding capacity. The bund height changes with the catchment size and slope of the area. The catchment areas range from 10 to 100 m2 depending on the specie of tree to be planted. The catchment to command area ratio varies between 3:1 to 25:1 and suitable for rainfall regions of less than 600 mm/annum.

Meskat-type system is a type of micro catchment system in which the catchment area diverts runoff water directly onto a cultivated area at the bottom of the slope (Rosegrant *et al.*, 2002) [9]. In this system instead of having catchment area and cultivated area alternating like the previous methods, here the field is divided into two different parts, the catchment area and cultivated area which is placed immediately bellow the catchment area. The catchment area must be compacted and free of weeds. The recommended ratio between the catchment area and cultivated area in Semi-arid areas is 2:1 (Hatibu and Mahoo, 1999) [5]. These types of systems are not normally practiced in India.

Contour Ridges is a micro catchment technique which consists on making ridges following the contour at a spacing of usually 1.5 to 2 meters, which means with a ratio between catchment and cultivated area from 2:1 to 5:1, respectively (Haile and Merga, 2002) [4]. Runoff is collected from the uncultivated strip between ridges and stored in a furrow just above the ridges. The systems can implemented in annual rainfall regions between 350 and 750 mm and on all soils which are suitable for agriculture, slopes from flat up to 5 per cent and smooth areas (Critchley and Siegert, 1991) [2].

Triangular bunds are also similar to contour ridges except that the bund are either formed in semi circular shape or triangle shapes and plating is done at place where runoff is collected within the bund. The catchment to cultivated area ratio is about 4:1 and can be taken up on lands with slopes of 2-20 per cent in annual rainfall regions of less than 600mm.

Inter row water harvesting

The catchment is divided in such way that part of area is considered as donor area and the land below is considered as receiver area. The donor area is kept vacant and sometimes measures are taken to induce runoff from this area so that it could be collected in the receiver area for meeting the water requirement.

Staggered Trenches / Water Absorption Trench / Continuous Contour Trench

At its simplest, contour trench construction is an extension of the practice of plowing fields at a right angle to the slope. Contour trenches are ditches dug along a hillside in such a way that they follow a contour and run perpendicular to the flow of water. The soil excavated from the ditch is used to form a berm on the downhill edge of the ditch. The berm is planted with permanent vegetation (native grasses, legumes) to stabilize the soil and for the roots and foliage in order to trap any sediment that would overflow from the trench in heavy rainfall events.

Water absorption trench (WAT) / CCT / ST treatment are proposed on hills and area where the catchment area and slope are more. Beside the soil and water conservation the main purpose of this treatment is to store and in filter the huge quantity of runoff. It is generally proposed on hills and at bottom of hills from where farms start. Therefore WAT treatment is very important as it increases soil moisture of down side fields. This is low cost treatment and returns are in multiple compare to other drainage line treatments. It is also easy to plan, execute the work, maintenance and has life more than 10 years. It protects fields, which are at foothill side from damage and erosion of fertile soil. It also increases the moisture and simultaneously crop production in downside fields, which are mostly rainfed, and has low soil depth.

An average horizontal interval proposed between two consecutive contour lines is 20 m has been assumed depending upon the slope and given an average length of 100 m to 150 m ha^{-1}. The variation between CCT and WAT is the cross sectional area.

Trenches are not more than 15m length and are generally staggered with a cross of 0.3 *0.3 m or 0.5 *0.5 m with Side slopes of trenches are 1:1 or 0.5:1. The quantity of runoff expected to be collected is estimated by the following formula.

For continuous trenches

Q = w*d/(100*hi)

For staggered trenches

Q = w*d/(100*hi*(1+x/l))

Where-

Q-depth of runoff from area, cm: w-width of trench, cm

d-depth of trench, cm:hi-horizontal interval, m

x-gap between trenches, m: l-length of trench, m

In medium rainfall areas with highly dissected topography, Staggered Contour Trenches (SCT) areadopted. The length of the trenches is kept short around 2-3 m and the spacing between the rows may vary from 3-5 m. The chances of breaches of SCT are less as compared to Continuous Contour Trenches.

30 x 40 Model

The 30 x 40 model is a method of in-situ soil and water conservation. It involves dividing uplands into small plots of 30 x 40 ft (30 ft along the slope and 40 ft across the slope), digging pits at the lowest point in each plot and bunding the plot using the soil dug out of the pits.

Platform and Trench

In hilly areas, with slopes more than 15 per cent, a platform and trench is built around each tree. Platforms around trees are in the shape of a half moon, with a radius of 2 m, and have sloping sides. The platform is constructed with locally available stones or soil clods, or by filling murum. Height of platform varies according to the slope. A trench of 2 x 0.60 x 0.60 m is dug on the upstream side of tree.

Permeable Rock Dikes

Permeable rock dikes are erosion control structures built along the natural contour of the land. They are built between 30 and 50 cm high and twice or three times as wide as they are high. They are made with different-sized stones and rocks, and the crest of the dike is horizontal. There are two main types of permeable rock dike: those without a filter layer, which are suitable for flat land with no gully erosion and those with a filter layer suited to land with heavy runoff. The permeable rock dike differs from the contour stone bund in that it is bigger in size, is constructed with various layers of stones and is designed to control stronger water flow. For this reason, such dikes are often constructed upstream of stone bunds to dissipate the force of the water flowing from the plateau and slopes. Permeable rock dikes are designed for use on cropland, but can also be used on forest/rangeland. They are recommended for ecological units with gravely and sandy-clayey soils and pediments. They can also be used to fill in small rills (Good Practices in soil conservation and water management and soil protection and restoration: An investment in Future Generations, (GIZ, 2012) [3].

Prioritized rainfall based soil conservation and water management measures for land capability classes of greater than 4 which are normally used for tree based systems is given below:

Land Capability Class	Rainfall <500 mm	Rainfall 500-750 mm	Rainfall 750-1000 mm
V	Outward Terraces	Outward Terraces	Outward Terraces
	Semi Circular basins	Semi Circular basins	Semi Circular basins
	Small pits	Small pits	Small pits
	Hillside Ditches	Hillside Ditches	Contour Trenches
	Live Hedges	Live Hedges	Hillside Ditches
	Semi Circular Catchments	Semi Circular Catchments	Live Hedges
	Staggered Trenches	Staggered Trenches	Semi Circular Catchments
	-	-	Trapezoidal Catchments
VI	Outward Terraces	Outward Terraces	Contour Trenches
	Semi Circular basins	Semi Circular basins	Hillside Ditches
	Small pits	Small pits	Inward Terraces
	Hillside Ditches	Hillside Ditches	Semi Circular Catchments
	Live Hedges	Live Hedges	Trapezoidal Catchments
	Semi Circular Catchments	Semi Circular Catchments	Vegetative Buffer Strips
	Staggered Trenches	Staggered Trenches	-
VII	Outward Terraces	Hillside Ditches	Contour Trenches
	Semi Circular basins	Inward Terraces	California type with Mechanical Barrier
	Small pits	Semi Circular Catchments	Graded Terraces
	Hillside Ditches	Staggered Trenches	Trapezoidal Catchments
	Semi Circular Catchments	Trapezoidal Catchments	Vegetative Buffer Strips
	Staggered Trenches	Vegetative Buffer Strips	-
	Vegetative Buffer Strips	-	-
VIII	Hillside Ditches	Contour Trenches	Graded Trenches
	Inward Terraces	California type with Mechanical barrier	Graded Trenches
	Staggered Trenches	Hillside Ditches	California type with Mechanical Barrier
	Trapezoidal Catchments	Inward Terraces	Trapezoidal Catchments
	Vegetative buffer strips	Trapezoidal Catchments	-
	-	Vegetative buffer strips	-

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