Microcatchment Rainwater Harvesting

Arid and semiarid zones are characterized by low erratic rainfall of up to 700 mm per annum, periodic droughts, and different associations of vegetative cover and soils. Interannual rainfall varies from 50 to 100% in the arid zones of the world, with averages of up to 350 mm. In the semiarid zones, interannual rainfall varies from 20 to 50% with averages of up to 700 mm (CASL, 2006).

The majority of the population in the arid and semiarid areas depend on agriculture and pastoralism for subsistence. These activities face many constraints due to predominance of erratic rainfall patterns, torrential rainfall that is mainly lost to runoff, high rate of evapotranspiration that further reduces yields, weeds growing more vigorously than cultivated crops, competition for scarce reserves of moisture, low organic matter levels, and highly variable responses to fertilizers (CASL, 2006).

There is a need of more efficient capture and use of scarce water resources in the arid and semiarid areas. An optimization of rainfall management, through water harvesting in sustainable and integrated production systems, can contribute to improvement of small-scale farmers' livelihood by upgrading rainfed agricultural production.

Microcatchment rainwater-harvesting systems have the following characteristics: overland flow harvested from short catchment length, catchment length usually between 1 and 30 cm, runoff stored in soil profile, ratio of catchment: cultivated area usually from 1:1 to 3:1, normally no provision for overflow and even plant growth. These are typical examples of this type of system: Negarim microcatchments, contour bunds, and semicircular bunds (Critchley and Siegert, 1991).

The general design principle of microcatchment rainwater harvesting systems involves a catchment area that collects runoff coming from roofs or ground surfaces and a cultivated area that receives and concentrates runoff from the catchment area for crop water supply. The relationship between catchment area and 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 data related to the area of concern in terms of rainfall, runoff, and crop water requirements are available (Moges, 2004).

Major techniques

The microcatchment rainwater-harvesting system is a method of collecting surface runoff from a small catchment area and storing it in the root zone of an adjacent infiltration area (Cofie *et al.,* 2004). The system is mainly used for growing medium water-demanding crops such as maize, sorghum, groundnut, and millet (Hatibu and Mahoo, 1999). It has also been used to supplement rainfall for native vegetation (Matthew and Bainbridge, 2000).

Microcatchment 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 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). The major techniques include pitting, earth basins, strip catchment tillage, semicircular bunds, earthen bunds, meskat-type system, negarim microcatchments (water harvesting sudan), contour ridges and stone lines (Critchley and Siegert, 1991).

Pitting system

A pitting system consists of small circular pits, about 30 cm in diameter and 20 cm deep, dug to break the crusted soil surface in order to store water and build up soil fertility. Variations of the system include Zai, Tassa, half moon, Katumani pitting, planting pits, chololo pits, and "five by nine" pits. They are used in areas with rainfall between 350 and 600 mm (Hatibu and Mahoo, 1999).

The Zai technique uses shallow, wide pits that are about 30 cm in diameter and 15–20 cm in depth into which four to eight seeds of a cereal crop are planted (Itabari and Wamuongo, 2003). Organic manure and compost are usually added into the pit to improve fertility. It works by a combination of water harvesting and conservation of both moisture and fertility in the pit. In the Njombe district of southern Tanzania, the pits are made bigger and deeper (at least 0.6 m deep), and 20-liter volume of manure is added. Since the area receives an annual rainfall close to 1000 mm, the farmers plant about 15 to 20 seeds of maize per pit and yield is more than double those in conventionally tilled land (Mati, 2005).

The chololo pit technique is a pitting method comprising a series of pits that are about 22 cm in diameter and 30 cm in depth. The pits are spaced 60 cm apart within rows and 90 cm between rows, with rows running along the contour. The soil removed during excavation is used to make a small bund around the hole. Inside the pit, ashes (to expel termites), farmyard manure, and crop residues are added, then covered with the requisite amount of soil while retaining sufficient space in the hole for runoff to the pond. One or two seeds of either maize/millet or sorghum are planted per hole. Crops usually survive even during periods of severe rainfall deficits and yields have been noted to triple. The required labor for digging the holes is low (Mati, 2005).

The "five by nine" is a pitting method for maize crops, which are 60 cm square and 60 cm deep. They are larger than Zai pits but have a square shape. The name is based on the five or nine maize seeds planted at the pit diagonals (five for dry areas and nine for wet areas). This type of pit can hold more manure than a Zai pit. Hence, it is capable of achieving higher yields that have a long-lasting effect. The pit can be reused up to 2 years (Mati, 2005).

Strip catchment tillage

Strip catchment tillage involves tilling strips of land along crop rows and leaving appropriate sections of the interrow space uncultivated so as to release runoff. It is normally used where slopes are gentle and runoff from the uncultivated parts adds water to the cropped strips. The catchment-basin area ratios used are normally less than or equal to 2:1. The system can be used for almost all types of crops and is easy to mechanize. Herbicides are used to control weeds in the catchment area (Hatibu and Mahoo, 1999).

Earth basins

Earth basins are normally small, circular, square or diamond-shaped microcatchments 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, where slope steepness ranges from flat to about 5%, and where soil is at least 1.5 m deep to ensure enough water-holding capacity. Earth basins are especially used for growing fruit crops. The seedling is usually planted in or on the side of the infiltration pit immediately after the rains begin. The size of the basin may vary between 1 m and 2 m in width and up to 30 m in length for large external catchments with a depth at about 0.5 m (Mati, 2005).

Earthen bunds

Earthen bunds are various forms of earth shapings, which create run-on structures for ponding runoff water. The most common are within-field runoff harvesting systems, which require less mechanization, relying more on manual labor and animal draft. The variations of the system include contour bunds, semicircular bunds, and negarim microcatchments. Contour bunds are not suitable for small-scale agriculture; they are most appropriate for large-scale endeavors, especially when mechanized.

The normal design for semicircular bunds involves making earth bunds in the shape of a semi-circle with the tip of the bunds in the contour. In Busia District, Kenya, semi-circular bunds are made by digging out holes along the contours. 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 subsoil excavated from the pit is used to construct a semicircular bund with radius ranging from 3 m to 6 m on the lower side of the pit. Bund height is normally 0.25 m. The pits hold a mixture of organic manure and topsoil to provide the required fertility and to help retain moisture. It is a common practice to plant seasonal crops such as vegetables, including beans and other herbaceous crops in the pits before the tree crops develop a shady canopy (Mati, 2005). The technique is found in areas with annual rainfall ranging from 200 mm to 275 mm, and land slope with less than 2% steepness. The main problems associated with this type of bunds are difficulty in construction with animal draft, high labor requirement, regular maintenance needed, and inability to use machinery (Critchley and Siegert, 1991).

Negarim microcatchments 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. Three seedlings of at least 30 cm should be planted in each infiltration pit after the first rain of the season (Critchley and Siegert, 1991). Manure or compost should be applied to the pit to improve fertility and soil water-holding capacity. The bund height changes with catchment size and slope of the area. The system is used to establish fruit trees and grass in arid and semiarid regions where seasonal rainfall can be as low as 150 mm (Mati, 2005). The catchment areas range from $10m^2$ to $100m^2$, depending on the tree species planted (SCTD, 2001).

Negarim microcatchments are appropriate for small-scale tree planting in any area that has a moisture deficit. Besides harvesting water for trees, they simultaneously conserve soil. The system is efficient, precise, and relatively easy to construct. However, there are limitations on its implementation: not easily mechanized (limited to small scale) and very difficult to cultivate between tree lines (Critchley and Siegert, 1991).

Contour ridges

A contour ridge is a microcatchment technique that involves making ridges following the contour at a spacing of usually 1.5 to 2 m, which means that the ratio between catchment and cultivated area is 2:1 to 3:1, respectively (Haile and Merga, 2002). Runoff is collected from the uncultivated strip between ridges and stored in a furrow just above the ridges. Crops are planted on both sides of the furrow. The system is simple to construct, by hand or by machine, and can be even less labor-intensive than conventional tillage. The following conditions are most suitable for its implementation: annual rainfall between 350 and 750 mm, soils suitable for agriculture, slope steepness from to 5%, and smooth areas (Critchley and Siegert, 1991).

The overall layout of the contour ridge system consists of parallel earth ridges approximately on the contour at a space of between 1 and 2 m. Soil is excavated and placed downslope to form a ridge, and the excavated furrow above the ridge collects runoff from the catchment strip between ridges. Small earth ties 15–20 cm high and 50–75 cm long are provided above the furrow every 4 to 5 m to ensure even storage of runoff. A diversion ditch 50 cm deep and 1–1.5 m wide is usually done before the contour ridges are built to protect the system against runoff from outside (Critchley and Siegert, 1991).

In the contour ridge system, the main crop (usually a cereal) is seeded into the upslope side of the ridge between the top of the ridge and the furrow. An intercrop, usually a legume, can be planted in front of the furrow. It is recommended to use approximately 65% of the plant population for rainfed cultivation, so that the plants can have more moisture available in years of low rainfall. Weeding must be carried out regularly around the plants and within the catchment strip (Critchley and Siegert, 1991).

Broadbed and furrow systems are a modification of contour ridges, with a catchment ahead of the furrow and a within-field microcatchment water-harvesting system. In Ethiopia, Kenya, and Tanzania, the systems are made as small earthen banks with furrows on the higher sides, which collect runoff from the catchment area between the ridges. The catchment area is left uncultivated and clear of vegetation to maximize runoff. Crops can be planted on the sides of the furrows and on the ridges. Plants that need much water, such as beans and peas, are usually planted on the higher side of the furrow, and cereal crops such as maize and millet are usually planted on the ridges. The distance among the ridges varies between 1 m and 2 m, depending on the slope gradient, size of catchment area desired, and amount of rainfall available. The system is most suitable in areas where the annual rainfall is from 350 mm to 700 mm, even topography, gentle slope of about 0.5–3% steepness, and soils fairly light due to high infiltration rates (Mati, 2005).

In-field rainwater-harvesting technique

The in-field rainwater-harvesting technique is a microcatchment technique that combines the advantages of water harvesting, no-till, and basin tillage to stop runoff completely on clay soils (Hensley *et al.*, 2000). The technique consists of a catchment area, which promotes in-field run-off, and a cropped basin, which allows the stoppage of ex-field runoff completely and maximizes infiltration and stores the collected water in the soil layers beneath the evaporation-sensitive zone. Ridges are immediately done after each cropped basin to allow better conservation of water in the soil profile. Mulch is placed in the cropped basin to minimize evaporation losses. The ratio between catchment area and cropped area, based on field experience with crops in the semiarid areas is 2:1 (Rensburg van *et al.*, 2003). Herbicides are used to control weeds in the catchment area.

Meskat-type system

The meskat-type system is a type of microcatchment system in which the catchment area diverts runoff water directly onto a cultivated area at the bottom of the slope (Rosegrant *et al.*, 2002). In this system, instead of having catchment area and cultivated area alternating as in 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 catchment area and cultivated area in semiarid areas is 2:1 (Hatibu and Mahoo, 1999).

Source

Rainwater Harvesting Technologies for Small-Scale Rainfed Agriculture in Arid and Semi-arid Areas by N. Ibraimo and P. Munguambe. February 2007. Department of Rural Engineering, Faculty of Agronomy and Forestry Engineering, University Eduardo Mondlane, Mozambique.

References

CASL (Community Adaptation and Sustainable Livelihoods). 2006. Arid and semi-arid lands: characteristics and importance.

Cofie, O., Barry, B., Bossio, D. 2004. Human resources as a driver of bright spots: the case of rainwater harvesting in West Africa. NEPAD, Conference Paper No 19. Nairobi, Kenya.
Critchley, W., Siegert, K. 1991. A manual for the design and construction of water harvesting schemes for plant production. Food and Agriculture Organization of the United Nations, Rome, Italy.
Haile, M., Merga, S.N. 2002. Workshop on the experiences of water harvesting in the dry lands of Ethiopia: principles and practices. DCG report number 19.
Hatibu, N., Mahoo, H. 1999. Rainwater harvesting technologies for agricultural production: a case for Dodoma, Tanzania. Department of Agricultural Engineering and Land Planning, Sokoine University of Agriculture, Tanzania.
Hensley, M., Botha, J.J., Anderson, J.J., Van Staden, P.P., Du Toit, A. 2000. Optimising rainfall use efficiency for developing farmers with limited access to irrigation water. Water Research Commission Report No. 878/1/00, Pretoria, South Africa.
Itabari, J.K., Wamuongo, J.W. 2003. Water harvesting technologies in Kenya. Technical Note number 16.
Mati, B.M., 2005. Overview of water and soil nutrient management under smallholder rainfed agriculture in East Africa. Working Paper 105. International Water Management Institute, Sri Lanka.
Matthew, W. F., Bainbridge, D.A. 2000. Microcatchment water harvesting for desert revegetation. Soil Ecology and Restoration Group. Bulletin Number 5.
Moges, Y. 2004. Water harvesting techniques: training and construction manual. Consultancy Sub-report Number 2. Tropical Forestry.
SCTD (Schumancher Centre for Technology and Development). 2001. Water harvesting in Sudan. Practical action. SCTD.