WATER HARVESTING AND WATER-SAVING TECHNIQUES

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Keywords: China, conservation tillage, conventional tillage, rain-fed agriculture, Tunisia, water harvesting, water saving

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Summary

The rainfall regime in drylands is known by its scarcity, unpredictability and torrential character; its water balance is negative during almost the whole year. In order to achieve a reasonable crop production under those conditions and to overcome this drought stress additional water has to be supplied. In this paper, two case studies are presented on the efficient use of rainwater harvesting for the cultivation of trees and crops.

A first case refers to southeast Tunisia, where a *jessr system* is described for collecting runoff water from the slopes of a micro-catchment into a terrace with olive trees. The results of field rainfall simulation tests indicate that large amounts of runoff and sediment can be collected on the terrace. Those amounts depend mainly on the rainfall intensity rather than on the total amount of rainfall of individual events.

A second case deals with the semiarid loess plateau of northeast China, near Luoyang in Henan Province, where the different components of the soil-water balance were analyzed in order to determine the most efficient tillage practice for water saving in winter wheat fields. Subsoiling provided the highest increase in moisture storage and lowest evaporation rates during the fallow period. Because of the presence of a wheat straw mulch, direct sowing resulted in low evaporation and high water storage, particularly at the beginning of the crop-growing season.

The two examples commented in this paper illustrate that water efficiency can still be highly improved in areas where, under natural conditions, water shortage hampers normal crop growth or holds major risks for crop failure.

1. Introduction

Arid and semiarid zones account for approximately one third of the earth's surface and affect some 16% of the population **(**see *Drylands and Desertification*). In these areas the rainfall regime is known for its scarcity, unpredictability and torrential character, and the water balance is negative almost all year round. Increasing population pressure, hard competition for water resources and the consequences of global warming create additional problems of water scarcity. As rain-fed farming is an important component in agricultural production, it should be supported by additional moisture supplied through rainwater harvesting and rainwater saving techniques (see *Management of Drylands and Desert Areas*).

There are many ways to harvest and store water, including traditional water harvesting techniques and conservation-based cropping systems (see *Desert Reclamation and Management of Drylands: Water Aspects*). In this paper, two case studies are presented where the effects of water harvesting and water-saving techniques were investigated on the soil-water balance in semiarid regions. In a first case study, the effect of a jessr water harvesting system in Amrich, Oued Oum Zessar watershed (South Tunisia) is described and evaluated for its impact on soil and water conservation. The second case reports findings of a field study on winter wheat carried out in the semiarid loess plateau of Northern China, near Luoyang (Henan Province) to compare the soil-water balance under different soil tillage practices.

2. Review of Some Widely-adopted Water-harvesting and Water-saving Techniques

2.1. Water-harvesting Techniques

Four main groups of water harvesting techniques can generally be distinguished: micro- and macro-catchments, floodwater harvesting and storage reservoirs. Typical micro-catchment techniques involve the delineation of natural depressions, the construction of contour and stone bunds, systems for inter-row water harvesting, terracing, construction of semicircular (half moon) and triangular (V-shaped) bunds, eyebrow terraces, Vallerani-type micro-catchments, pits, meskats and negarim.

Macro-catchments include large semi-circular and trapezoidal bunds and hillside conduits. Floodwater can be harvested within the stream bed or diverted to the cropping fields. Storage media include underground storage reservoirs such as soil and sediment, and cisterns, and surface storage media like tanks, jars, ponds and reservoirs. An excellent overview of all these techniques can be found in FAO (2003).

The catchment or water-collection area can be a roof top, a small land surface, a slope or a larger catchment area feeding seasonal water courses.

In southern Tunisia e.g. a large variety of classic water harvesting techniques are used and, as described by Boers and Ben-Asher (1982) and Mainguet (1991), these have been

developed since Antiquity. Ouessar *et al.* (2002) describes the following techniques as most common ones in southern Tunisia:
Jessour - This is an old runoff water harvesting technique widely adopted in arid highlands, which occupies the runoff watercourses. The hydraulic unit of a jessour is the *jessr* consisting of three components: the impluvium, the terrace and the dyke. The impluvium or the catchment area is used for collecting (harvesting) the runoff water. The terrace or the cropping zone is the area where crops or trees are grown and where the runoff water is caught. The dyke is a barrier established to block the sediments and runoff water. Its body is made of earth equipped with a central and/or lateral spillway and one or two abutments. This should assure the evacuation of excess water.

Tabias - This is a replica of the jessour system constructed in the foothill and piedmont areas. It is a relative new technique constructed by mountain dwellers.

Meskat - It is a traditional system consisting of two compartments, a catchment area and a downslope cropping area, both delineated by low bunds. Catchment and cropping area are connected by a spillway.

Floodwater harvesting system **-** It is on old technique which diverts the total or a portion of the floodwater carried by wadis - dry riverbeds that only contain water during and immediately after heavy rains - to the neighboring cultivated fields, in the form of natural irrigation. It has three components including a diversion dam, a distribution network and the cropping fields. The diversion dam is generally made of earth acting as a fuse by breaking down in case of very intense floods. Recently, gabions (see below) and reinforced concrete are becoming most popular. The distribution network is made of open trapezoidal canals (primary, secondary, tertiary, ...) with gentle slopes except in partition points to avoid silting up. The cropping fields are generally flat with a rectangular shape and delineated by earthen embankments to retain up to 1 m of water.

Gabion units - These units are made of wire mesh cages filled with rock, and are constructed in wadi beds in order to divert water directly to the neighboring fields, often located within the wadi itself.

Recharge wells - These are casting tubes drilled into the underlying bedrock – when of very low permeability – enhancing the infiltration of runoff water to the ground water table. This technique was adopted only recently in Southeastern Tunisia.

Terraces - This very old technique is constructed on steep slopes and consists of small retaining walls made of rocks to slow down the flow rate of the water and to control erosion.

Cisterns - These were traditionally used to provide drinking water. A unit consists of three components, an impluvium, a sediment settling basin and a storage reservoir. The impluvium is a sloping piece of land delineated by a diversion channel or a paved runoff area. The settling basin ahead of the entrance of the cistern allows sedimentation of runoff loads. The storage compartment or cistern consists of a hole dug in the ground, coated with gypsum or concrete, and which is leading to a stone-faced underground small or large-size tank.

2.2. Water-saving Techniques: Conservation Tillage

Besides implementing water harvesting techniques, water can also be saved by applying conservation tillage practices. These include any tillage or tillage and planting combination which leaves 30% or greater cover of crop residue on the surface. Its purpose is to minimize or reduce loss of soil and water. Garcia-Torres *et al*. (2001) have shown that the rate of adoption of conservation tillage for agricultural sustainability is exponentially growing in many regions of the world for the sake of soil and water conservation. Conventional farming practices with extensive cultivation and little use of crop residue exacerbate soil, water and nutrient losses, causing decreases in water availability, soil fertility and crop productivity.

Below is a summary of the most widely adopted conservation tillage practices. More detailed information can be obtained from UN (1999).

Strip cropping - This is the farming of sloping land in alternate, contoured strips of inter-tilled row crops and close growing grasses or another ground cover crop. The strips are aligned at right angles to the direction of the natural runoff flow. The strips slow down the runoff water and filter out soil washed from the land in the inter-tilled row. As a result, infiltration of runoff water will increase and so will be the moisture in the soil. The strip widths can vary depending on the soil type and slope.

Contour farming - This practice involves aligning plant rows and tillage lines at right angles to the normal flow of runoff. The rate of runoff is slowed down, thus giving the water time to infiltrate into the soil. The contour bunds often consist of earth banks 1.5 to 2.0 m wide, and form buffer strips at 10 to 20 m intervals.

Mulch tillage - It is a practice in which the bare soil is covered with mulch or plant litter to reduce the impact energy of rain drops and to minimize the soil evaporation. The mulch is usually made up of crop residues such as wheat straw, sorghum trash or maize stover. When these are not available, or are used by farmers, gravel can be used as a mulch.

Reduced or minimum tillage - This involves the tilling of the soil to some extent, without inverting it completely. Several tools have been developed for reduced tillage, such as ploughs supplemented with discs or a chisel harrow, and non-turning duck-food erosion plows. As a result, a smaller volume of soil is exposed to erosion and to loss of moisture by evaporation.

Subsoiling - This practice loosens the subsoil by deep plowing, breaks hardpans and facilitates infiltration and aeration of the root zone. Subsoiling allows crop residues to remain on the field without burying it. The residue has the same positive effects as a mulch.

Zero or no tillage - As the word says, land is not tilled at all. Water is conserved in the soil profile since the soil is not tilled and exposed to drying. Weed control is generally done by applying herbicides. The new crop is generally planted directly into the stubble of the previous crop by direct sowing tools.

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Biographical Sketches

Donald Gabriels is professor at the Department of Soil Management and Soil Care of the Faculty of BioScience Engineering of Ghent University, Belgium where he coordinates the Research Group on Soil Erosion and Soil Conservation and the International Center for Eremology (ICE). He is an agricultural engineer of Ghent University and holds a MSc. in agronomy (Soil Physics) of Iowa State University, USA, and a PhD in agricultural engineering of Ghent University. He was a Fulbright postdoctoral scholar at Purdue University, USA.

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