Water Conservation Through Improved Practices

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I. INTRODUCTION

The planet Earth is unique among the planets in our solar system. It is neither too close to the sun nor too far from the sun and it rotates so as to produce day and night in close succession. Life is possible on the surface of the earth because it is protected from the extreme cold of outer space and from the ionizing radiations of the sun by a blanket of atmosphere. Life is sustained by a unique combination of chemical and physical checks and balances that permit cycling of life's essential ingredients. Water, one of these essentials, can be considered the life blood of the earth. Its mobility, energy transformations and chemical and physical behavior impinge on every facet of organic life. Our lives are influenced by the unending flux of water known as the hydrologic cycle. This complex series of phase changes and interconnected flows are shown in the schematic diagram in Fig. 1.

Agricultural enterprises have initial access to much of the world's fresh water supplies. This situation places a tremendous burden on agriculture to be a wise custodian of the water in its portion of the hydrologic cycle. A logical question follows: Can water be used more efficiently by agriculture? This discussion is limited to that portion of the hydrologic cycle involving the soil, the plant, and the thin layer of the atmosphere in which plants and animals live.

In the hydrologic cycle, a portion of the total precipitation that reaches the ground is returned to the oceans as runoff. The remainder is returned to the atmosphere by evaporation, either directly from the earth's surface or through plant transpiration. The soil acts as a reservoir; water is always in transitory storage in the soil. Considerable time may elapse before this stored water flows underground to the streams or is returned to the atmosphere by evaporation. Eventually, however, all water temporarily stored in the soil must enter the transitory part of the hydrologic cycle

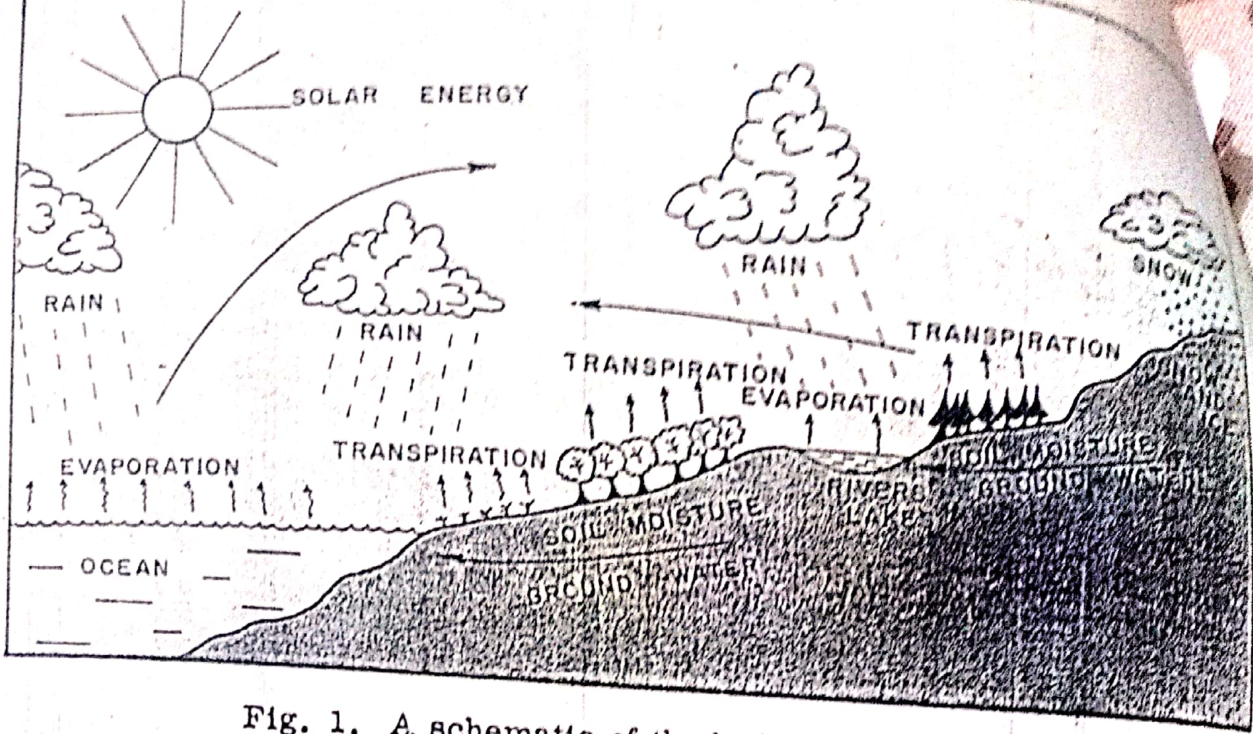

Fig. 1. A schematic of the hydrologic cycle.

by percolating to underground streams or by evaporating. Discussions by Russell (1957) show that there are many opportunities to influence the cycle and effect water conservation in agriculture.

The hydrologic cycle is not always punctual in delivering precipitation to the earth's surface, and drought is one of the major deterrents to adequate food production and a full life for the world's growing population. An evaluation of the water budget of any area of the country leads to the conclusion that water can be used more efficiently than at present. For example, the average precipitation in the Great Plains is approximately 20 inches. Of this 20 inches about 60%, or 12 inches, is lost directly from the soil by evaporation; about 20%, or 4 inches, is used by the crop; about 14%, or 2.8 inches, is used by weeds; about 5% or 1 inch, appears as streamflow; and about 1%, or 0.2 inch, percolates down into the soil. Of the 20% absorbed by the plants, less than 5%, or about 0.2 inch, is actually used in plant metabolism. The remainder passes through the plant into the air and serves only to cool the plant.

According to Hedrickson et al. (1963) the average annual precipitation in the humid Southern Piedmont area is about 50 inches. Of this 50 inches, approximately 11 inches, or 22%, runs off into streams and lakes. The remaining 39 inches, or 78%, is lost through deep percolation and evapotranspiration. According to Harold et al. (1959), Peters (1960), Koslowski (1964), and Tanner (1960) only about 6 to 8.5 inches of water are required to produce a crop such as corn under usual conditions; therefore, a major portion of the water remaining after runoff is lost without producing economic benefit on the land where it falls.

An examination of the water budget for other areas of this country will show that if water conservation is to be effected, we must find ways to control evaporation, transpiration, and runoff.

Because water is a dynamic component of the ecosystem, its conservation is difficult. It moves through the system at rates that vary widely in time and space in response to the general transport law which is simply stated as:

Flux = transmission coefficient × driving force

When used to describe the flow of water in a soil-plant-atmosphere system, the flux is expressed in quantity of water transported in a given time through a unit area perpendicular to the flow direction. The driving force is expressed as the negative of the gradient of the water potential. The transmission coefficient is the proportionality between the flux and the driving force. Solar radiation provides the energy to create the dominant driving force for moving water in soil-plant-atmosphere systems. Under conditions approaching ideal, about 75 to 85% of the net radiation absorbed during daytime is used to evaporate water, 5 to 10% goes into sensible heat storage in the soil, 5 to 10% goes into sensible heat exchange with the atmosphere by convective processes, and about 5% goes into photosynthesis. The transmission coefficient is not a constant, but rather a function of the transmitting medium and the material being transmitted--in this case, water.

Big changes in water-use efficiency are not likely because this world requires a feedback system where the overall climate-soil-plant relationships change. Agricultural endeavors are not large enough to affect the overall hydrologic cycle of a region, but land managers can alter the speed with which hydrologic phenomena occur on specific small land areas and thereby, through management, alter the fate of water delivered to the land.

II. SURFACE WATER MANAGEMENT

A. Runoff control

Present research has shown that the best possibilities of moisture conservation are in controlling that portion of the precipitation that normally runs off the land. In the continental United States runoff is estimated to be about 9 inches per year. All of this water does not appear in streams and lakes; some disappears in transit to the streams.

Control of surface water to prolong detention of water on the surface and increase the amount entering the soil has been a goal of agriculturists for centuries. Contour cultivation--one of the oldest conservation methods--effectively conserves moisture by creating ridges and trenches which temporarily retain water, thus allowing more time for infiltration. The degree of effectiveness of contour cultivation in conserving moisture, reducing runoff, and increasing crop yields depends on soil type, rainfall intensity,

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distribution and amount and land slope, length, and steepness. Contour cultivation is especially valuable in semiarid areas where all precipitation is needed where it falls; however, contouring can be equally important in humid regions where it aids in conveying excess water off cultivated fields in an orderly manner during periods of excess rainfall, and retains surface water on the land during periods with less rainfall.

Strip-cropping in which alternate strips of close-growing crops and intertilled crops are grown with rows at right angle to the direction of slope is also a well-established water conservation practice. Strip-cropping is effective because the close-growing crop tends to slow down the water, filter out the silt, and permit greater time for infiltration.

Terraces are ridges of soil, usually with shallow channels, laid out nearly on the contour of sloping land. The interval along the slope depends on the soil type, the degree of slope, and prevailing climate. In humid areas, terraces are usually graded to permit orderly removal of surplus water from the land. In semiarid areas, terraces are frequently level and sometimes have the ends turned up hill to develop catchment basins. Although terraces have conserved water and resulted in yield increases, the water storage capacity of the narrow channel area of level, closed-end terraces is limited. Runoff water is not distributed over a large enough area to be of much consequence. Sometimes water percolates below the root zone and other times it remains impounded long enough to cause crop damage in the terrace channel.

To overcome the disadvantages of level terraces, A. W. Zingg (1959) developed the conservation bench terrace. Phillips (1965) and Buchta et al.[1] modified Zingg's ideas slightly to fit special situations. This is one of the most promising water conservation systems available today. This system (Fig. 2) employs level contour benches and terrace ridges to control erosion and spread runoff water over a leveled bench where it may be stored in the soil for crop use. The effectiveness of this water conservation measure is shown by the data in Table 1. In this study at Bushland, Texas, the leveled benches had continuous grain sorghum while the other system and the watersheds for the leveled benches had a wheat-sorghum-fallow rotation. The average yields on the conservation bench system were almost 1.5 times those obtained on the level terrace and graded terrace systems.

The 3-year (1958-1960) average annual runoff from watersheds into the leveled benches at Bushland, Texas, was 0.89 inch from wheat, 2.84 inches from sorghum, and 3.27 inches from fallow. The average annual runoff of 2.3 inches was 9.4% of annual

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[1]Buchta, H. G., D. E. Broberg, and F. E. Liggett. 1965. Flat channel terraces for erosion control and water conservation. Presented at Amer. Soc. Agr. Eng. meeting, Athens, Ga. June 1965. Paper No: 65-231.

Runoff can be reduced if infiltration rate of soil is increased or water can be held on soil for longer time. A good granular soil structure is helpful for it.

Effect of

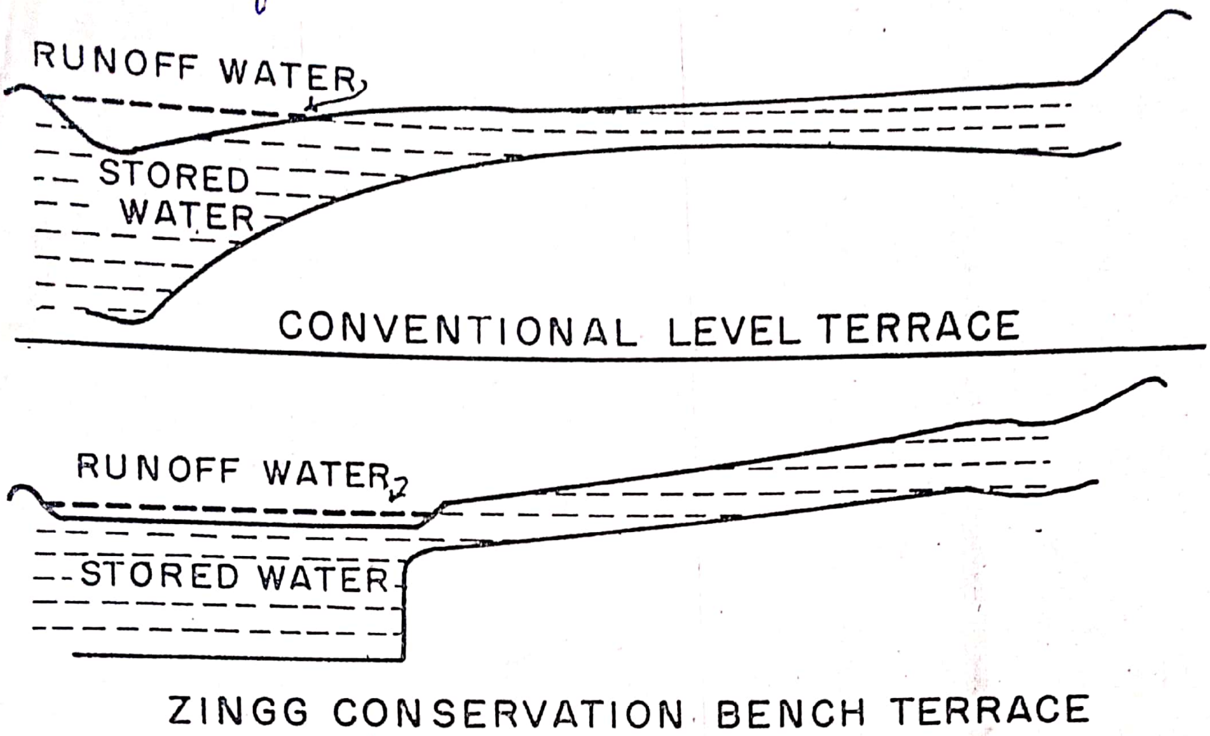

Fig. 2. Cross section of conventional level terrace and Zingg conservation bench terrace showing available soil moisture stored in the summer of 1957, Bushland, Texas (from Hauser and Cox, 1962).

Table 1. Average grain production from 1957-1960 with each of three terrace systems at Bushland, Texas*

	Average production, cwt/100 acres		
	Wheat	Grain sorghum	Total
Zingg conservation benches	204	1284	1488
Level terraces	309	709	1018
Graded terraces	311	664	975

* Data by Houser, V. L., and M. B. Cox (1962)

precipitation. Since this system interrupted the runoff and spread it to another part of the watershed for crop use, runoff was effectively prevented and water was conserved.

In a field study at Hays, Kansas, Houser and Cox (1962) found that level-benched land yielded 17% more grain sorghum than adjacent sloping land. The benched land received 1.7 inches of runoff water. This was a saving of 5% of average annual precipitation.

Mickelson[2] found that at Akron, Colorado, the average annual yields on benches with sorghum watersheds averaged 2.7 times greater than the contributing slopes. Benches with fallow contributing watersheds yielded 1.7 times those of the cropped watersheds. Runoff during the growing season averaged 14.7% for fallow and about 19.8% for sorghum watersheds. During the same period,

[2] Mickelson, R. H. 1962 Annual report of the US Dep. Agr. Central Great Plains Field Station, Akron, Colo.

Table 2. Crop yields and moisture use by several crops grown on the level pan system at Akron, Colorado, 1962.*

Crop	Watershed acreage /pan acreage	Runoff water received, in. 5-16 to 8-13	Yields, lb/A	Water-use efficiency, lb/in
Grain sorghum	356/6.27	2.12	Grain 2,454 Forage 6,274	163 417
	Check	0	Grain 0 Forage 2,600	0 259
Forage sorghum	62/2.5	1.47	12,756	925
	Check	0	5,162	486

* Data by Mickelson, R. H., M. B. Cox, and Jack Musick (1965).

runoff from buffalograss was only 2% of the precipitation. Hanks[3] reported that level benches with contributing areas were used at Mandan, North Dakota, in 1960-62. Wheat yields averaged 8 bushels higher on leveled benches than on contributing slopes. The contributing slopes, also planted to wheat, yielded 0.7 inch of water to leveled areas below.

Water spreading, another method for conserving water normally lost in runoff, has evolved from research conducted during the past 30 years. Water spreading involves the collection and diversion of runoff water from higher land for spreading and storage on leveled cropland in another field or area.

Water spreading has been studied extensively by the Agricultural Research Service at Spur, Texas, Akron, Colorado, and Mandan, North Dakota. Results by Mickelson et al. (1965) from Akron, Colorado show striking increases in moisture conservation. Table 2 shows results obtained in 1962. Similar results were also reported for 1963 and 1964. The yields of sorghum on the level areas receiving extra water were more than twice those on the adjacent check plots. Pounds of grain or forage produced per inch of water were also nearly doubled by the extra water. Supplemental water is especially effective in an area such as the Central Great Plains where about 10 inches of water are necessary before any significant yields can be harvested. In general, water-use efficiency increases as water availability increases above the essential base amount.

B. Water harvesting

Another area of moisture conservation research involves the concept of "water harvesting." This is based on the assumption that a given area of land is more valuable for the water that can be harvested than for any other use.

The potential value of water harvesting is demonstrated by the fact that 1 inch of rain produces 5.6 gallons of water per square

[3] Hanks, R. J. 1963. Research in moisture conservation. Unpublished report given at SCS-ARS Workshop.

yard. The national average rainfall is about 30 inches or 170 gal/square yard of land surface per year. The dry stream beds in many parts of the nation are testimony to the fact that we are losing a lot of water some place. Less than 10% of the precipitation in the Colorado River basin appears as runoff in the river. More than 90% is retained essentially where it falls. Part of the retained precipitation is used by useful vegetation and part percolates to underground aquifers, but most of it evaporates directly from the soil or from nonbeneficial vegetation. Myers (1963a, 1963b) investigated the use of various materials for waterproofing the soil as well as other aspects of the problem.

Initial research with standard anionic asphalt emulsions showed that they did not bond to the soil. Later research with cationic emulsions has been more successful. Other studies have involved such treatments as land smoothing and removal of rocks, spraying the soil surface with water-resistant repellent and covering the soil with sheets of aluminum foil, butyl rubber, and polyethylene plastic. The most promising treatments combine anionic asphalt emulsions with ground covers of aluminum foil, butyl rubber, or plastic film. One hundred percent recovery of rainfall is common 2 years after application of the asphalt emulsion with aluminum, butyl, or plastic film treatments; however, these sheet materials are easily damaged by livestock and wild animals. In 1964, over 50% runoff was secured from a bare plot sprayed with a single application of a commercial water repellent.[4]

Another method of water harvesting with resulting water conservation and increased crop production was studied by Kemper (1964). Two rows of corn or sorghum are planted in a strip 2 feet wide and spaced 10 feet apart. The 10-foot intervals are ridged like miniature watersheds and are compacted or covered with concrete or plastic to increase runoff of water to the crop. For small grains, planted strips the width of a grain drill alternate with compacted ridges of equal width and 6 to 8 inches high. This cropping system is potentially more efficient than fallowing to conserve moisture. If ridges are placed on the contour, runoff is virtually eliminated.

By contour ridging to prevent runoff and by covering the ridges between 42-inch rows with a black plastic film, Willis (1962) and Willis et al. (1963) harvested moisture and used it to raise the average corn yield from 25 to 50 bushels per acre at Mandan, North Dakota. The effectiveness of this system results from: (i) more efficient use of light rains, (ii) better utilization of the increased soil moisture in corn rows, and (iii) increased soil temperature, which stimulated germination and seedling growth.

[4] Personal communication from L. E. Myers, USDA Water Conservation Laboratory, Tempe, Arizona.

WATER CONSERVATION THROUGH IMPROVED PRACTICES

Surface water management

A. **Runoff Control**
B. **Water Harvesting**
C. **Land Forming**
D. **Increasing Infiltration**
E. **Tillage**
F. **Soil sealants and water repellents**
G. **Lining for water conveyance**
H. **Application of irrigation water**

C. Land Forming

Land forming rearranges the earth's surface permitting improved water management. It has been proved through experiments that through adjustment of microrelief positive surface drainage may be achieved. By grading to selected slopes, uniform irrigation may be applied with a minimum of ponding. It is not uncommon for runoff to occur when only the top few centimeters of soil have been wetted. Runoff water will often collect in shallow surface depression and may cause crop damage and rest of it will be frequently evaporating without any useful purpose. Land forming will effectively prevent this condition by spreading water uniformly over fields and increasing the time for infiltration.

If surface irrigation is to be used or rainfall patterns are such that drainage is necessary, then fields are graded to permit optimum water management. Although the basic designs and techniques for land forming are widely recognized, there are still many critical problems that challenge the soil scientists and engineers.

On more steeply sloping land in humid regions, runoff control has traditionally been affected by contour tillage and ridge terraces. These practices have been designed to convey surface water from fields with minimum erosion. These were not designed to retain water on the land to affect profile recharge.

It can be said that runoff can be effectively controlled and more water recharged into soil profile by land forming. Another advantage of this system is that the graded rows facilitate efficient surface irrigation.

Disadvantages are:

I. High cost of earthmoving to precisely graded large fields

II. Lot of fertility problems created by deep cuts and fills.

A system which combines parallel terraces with graded rows and underground tile outlets for water impounded in waterways above terraces has been developed. This system appears to combine the desirable water management features to control erosion, provide maximum time for infiltration, release excess water for use in low lying areas and facilitate the use of large farm machinery.

D. Increasing Infiltration

Research aimed at decreasing runoff by maintaining a surface soil structure which enhances infiltration is underway at many locations in the world. Infiltration is influenced by host soil factors. In general, results show that the most effective method to increase or maintain high infiltration rates is to provide protection for the soil surface. Mulch also influences infiltration.

i. Infiltration increases and runoff decreases as the amount of mulch increases.
ii. Infiltration is enhanced and runoff reduced by maintenance of high levels of organic matter in the soil.
iii. It has been proved that organic matter content is more important than soil texture in this regard.

E. Tillage

Tillage practices designed to maintain optimum surface conditions for high infiltration and minimum runoff have been developed for specifics soil and cropping conditions. Systems of tillage to create and maintain the desired surface structures are known by various terms such as:

i. Minimum tillage
ii. Reduced tillage
iii. Plough plant tillage
iv. Wheel track planting
v. Lister planting
vi. Strip tillage

Reduced tillage is an effective water conservation measure not only because of less compaction by farm machinery but also because the rough surface can store more quantities of water in the micro depression and prolong opportunity for infiltration of water into the soil. This potential storage capacity in the micro depressions has been termed as depression or detention storage. It has been proved from experiments that water loss from minimum tilled watershed was a very small fraction of that from conventionally tilled areas. It is also well known that a rough surface reduces runoff and increases infiltration, thus providing more water in the soil for plant use.

F. Soil sealants and water repellents

Control of evaporation and seepage losses from storage and conveyance facilities is a goal of all water conservationists. According to US department of Agriculture reports deflocculating agents such as sodium hexametaphosphate, sodium carbonate or tetrasodium superphosphate have been successfully used to reduce seepage in many water reservoirs. Commercially available compounds containing resinous polymers that react with soil to form lattice which restrict water movement in the soil are under study and preliminary results are encouraging. Other current studies involve the use of water repellents including silicones, various combinations of salts and sugars and other similar materials which react with soil particles and present a hydrophobic exterior.

G. Lining for water conveyance

Most of the research on canal lining materials has been conducted in USA. Most of the materials used cannot be classified as new but the specific way in which these materials were used is new one. Results indicated that complete water tightness is seldom achieved. Among all the lining materials, butyl sheeting, plastic films and prefabricated asphaltic liners are most water tight materials. Site conditions and other factors, including canal and reservoir management practices and cost, determine the type of lining that should be used. Butyl and plastic materials appear to have great potential as liners, but extensive research on materials handling and canal maintenance is prerequisite to extensive use of canal linings.

Tubing or pipes are frequently used to convey water without suffering the losses inherent in open canals. Application and use of various types of flexible tubing ranging in diameter from 2 to 36 inches proves effective. Results indicate extensive future use of low-pressure flexible tubing to convey water in irrigation.

H. Application of irrigation water

The three general methods of applying water to croplands are:

a. Surface irrigation

b. Sprinkler or overhead irrigation
c. Subsurface irrigation

The aim of every method is to:

i. Apply water uniformly
ii. Without any harm to the crops
iii. At least cost
iv. With minimum water available

Water application efficiencies of these methods range from 30-90 %, with an average value of less than 50 %. Improvements in this regard can be made by:

a) Better management practices
b) Proper land preparation
c) Proper length of rum
d) Proper scheduling of irrigation according to time and quantity of distribution
e) Use of systems designed to fit individual field needs so as to supply water in the time required as indicated by infiltration rate.

Irrigation water can be conserved by applying the right amount of water at the right place in the proper amount of time. The amount to apply at a given time is governed by the infiltration characteristics of the soil and by the needs and rooting characteristics of the crop.