COMMONWEALTH AGRICULTURAL BUREAUX

Rainfall Collection for Agriculture in Arid and Semiarid Regions

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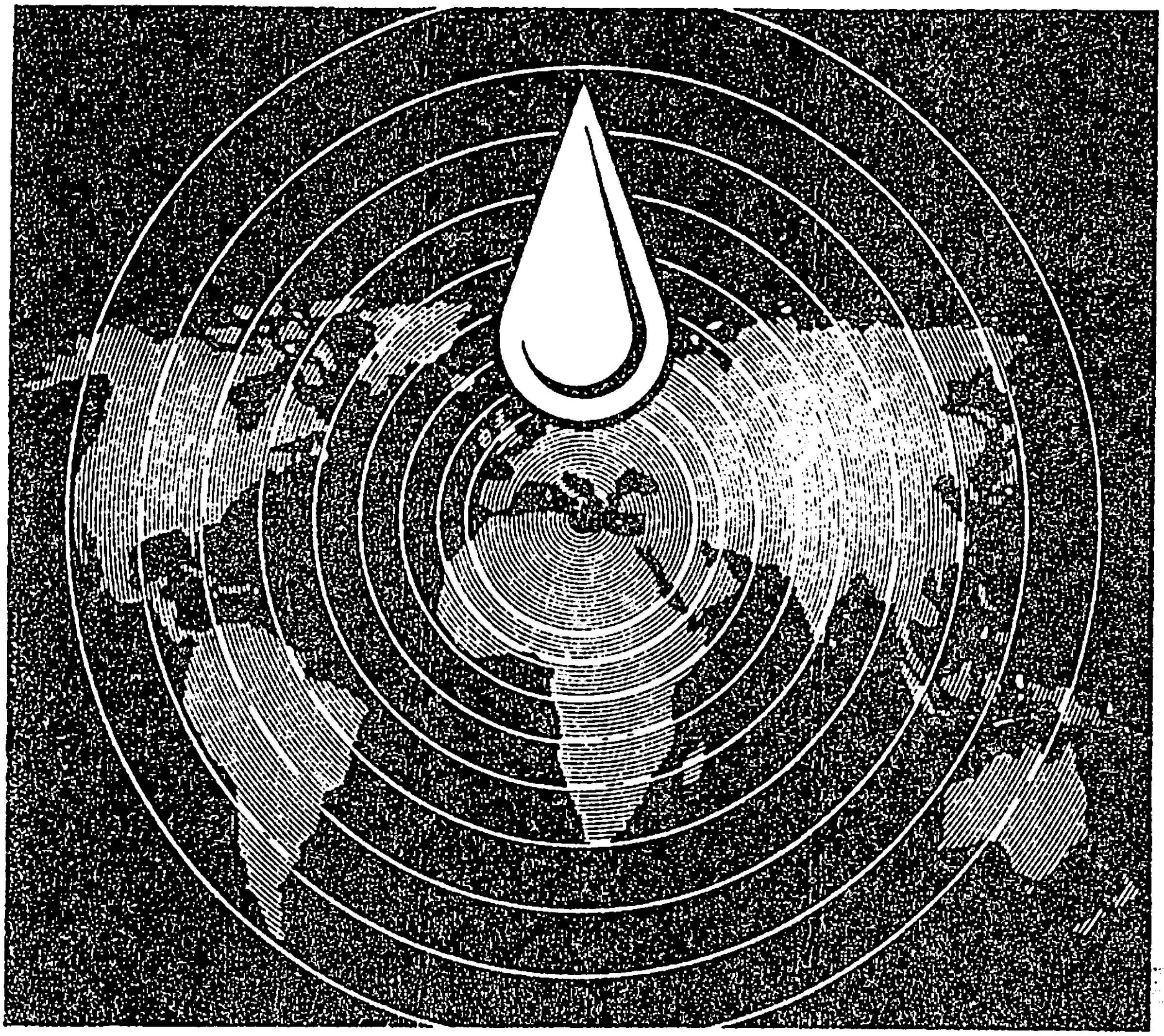
Edited by G. R. DUTT, C. F. HUTCHINSON and M. ANAYA GARDUNO



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WATER FOR ANIMALS, MAN, AND AGRICULTURE BY WATER-HARVESTING[1]

Gary W. Frasier[2]

Abstract--Many methods and materials are available for constructing water-harvesting systems for supplying drinking water. There is not a single method or material that is universally the best treatment. Runoff-farming applications of water harvesting are technically capable of supplying many of our future needs of food and fiber.

INTRODUCTION

There is an increasing public awareness that many parts of our arid and semiarid lands can be more effectively utilized to meet the world demands for increased food and fiber production if sufficient, economical water supplies can be found or developed. Water-harvesting is a technique that can provide onsite water when needed for a variety of uses. Water harvesting is being used with increasing frequency for providing livestock, wildlife, and domestic drinking water supplies. Water-harvesting runoff-farming techniques are slowly being revitalized as a method of food production. While major progress is being made in the development of methods and materials for water-harvesting applications, many details still need to be worked out. Finally, before water harvesting is universally used as a means of water supply, there must be a technology transfer of research results and design information from the researcher to the user.

DRINKING WATER FOR LIVESTOCK, WILDLIFE, AND DOMESTIC USES

All water-harvesting systems for supplying drinking water have two major components, a semipermeable or impermeable soil treatment or covering for the catchment apron, and a water storage facility for holding the collected water. Both of these components must be matched to the site conditions, i.e., soils, climate, topography, and water requirements, and must perform to specifications unattended without failure for long, periods. Many treatments are potentially suitable for the catchment surface, and a variety of methods can be used for water storage. For maximum effective performance, each system must be individually designed considering as many of the factors as are feasible (Frasier, 1975).

Catchment Treatments

During the past 20-30 years, various researchers and users have tried almost every conceivable method of soil treatment or membrane covering for water-proofing catchment aprons (Frasier, 1975; Cluff, 1975; Cooley et al., 1975). Unfortunately, many of these installations were failures. As a result, many potential users of water-harvesting developed doubts concerning the effectiveness of this method of water supply. These failures were a result of poor weathering performance of the treatments, improper installation techniques, or inadequate preventive maintenance (Chiarella and Beck, 1975). Many of these installations would be successful if installed and maintained using presently known criteria.

Table 1 lists some of the types of catchment treatments that have been used or are potentially suitable when properly installed and maintained. There are other treatments, such as salt dispersion, which are potentially suitable for some installations. Some of these treatments are discussed in other papers in this workshop. The precipitation runoff efficiency, estimated life, and initial costs of the treatments are based on the results of over 15 years of study at the U.S. Water Conservation Laboratory's Granite Reef test site near Phoenix, Arizona (Fink et al., 1979) and the field installation or performance evaluation of over 50 operational units constructed in cooperation with and/or by private ranchers and Governmental agencies (Frasier et al., 1979). The costs shown, adjusted to 1980 prices, represent only the initial expense of the materials used on the catchment apron and do not include any allowance for site preparation, installation, water storage, maintenance or interest.

Smoothing and Clearing

The smoothing and clearing treatment is probably the oldest water-harvesting treatment, dating back over 4,000 years (Evanari et al., 1961)

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[2]Research hydraulic engineer, USDA-SEA-AR, Southwest Rangeland Watershed Research Center, 442 East Seventh Street, Tucson, Arizona 85705.

Table 1.--Potential water harvesting catchment treatments.

Treatment	Runoff Efficiency	Estimated Life	Initial Cost
	(%)	(Years)	($/m²)
Land smoothing and clearing	20-35	5-10	0.01-0.06
Water repellents	60-85	5-8	0.15-0.20
Paraffin wax	60-95	5-8	0.30-0.50
Gravel-covered sheeting	75-95	10-20	0.40-0.60
Asphalt-fabric membranes	85-95	10-20	1.25-1.75
Concrete, sheet metal artificial rubber	60-95	10-20	3.00-5.00

consisting only of grading, smoothing, and some compaction of the soil surface. The effectiveness of the treatment for increasing precipitation runoff is highly dependent upon the soil type. Coarse, sandy soils with high permeabilities are, generally, unsuited for the treatment because of relatively low precipitation runoff efficiencies. Finer soils with significant quantities of a nonexpanding type clay can be smoothed and compacted sufficiently to yield significant quantities of runoff. Care must be used with this treatment in designing the lengths, angles, and uniformity of catchment slopes to minimize soil erosion (Frith, 1975; Hollick, 1975). Yearly maintenance is required to control weed growth and to repair any areas of potential soil erosion. Smoothing and clearing has been extensively used in Australia in the form of roaded catchments (Burdass, 1975), but has not been widely used in the United States.

Water Repellents

Many chemical compounds can induce a water repellency in soils. Most of these chemicals have not been studied enough to determine their potential as water-harvesting catchment treatments (Fink and Frasier, 1975). One material, a water-based silicone commercially used to waterproof concrete, has been evaluated as a catchment treatment. This treatment has been successful on soils containing up to 15% clay. The silicone was diluted with water and sprayed onto the prepared catchment surface at a rate of 700-1,000 kg silicone per hectare (2-3 liters of solution/m^2). The silicone reacts with the soil complex, bonding to the soil particles, forming a water repellent layer 1-2 cm deep. Measured runoff efficiencies were initially 85 to 95%, but decreased to 60 to 70% in 3 to 5 years. The decrease in runoff was attributed to both chemical deterioration and a loss of treated soil by erosion (Myers and Frasier, 1969). The treatment does not provide any significant soil stabilization.

Studies are being conducted to evaluate additives to the silicone for stabilizing the treated soil layer. One promising material is a long chain water emulsion latex that is compatible for mixing with the silicone. The latex-silicone mixture, 10% latex by volume (1,500 - 2,000 kg/ha), is sprayed onto the soil surface in a single application at a rate of 2 to 3 liters of solution/m^2. Studies have shown a water repellent depth of 1-2 cm and a stabilized soil depth of 0.2-0.5 cm is achieved. This treatment is undergoing field evaluation on operational water-harvesting systems.

Paraffin Wax

The wax treatment is basically a water repellent soil treatment with many of the characteristics of the silicone treatment. The treatment consists of spraying molten refined paraffin wax (average melting point (AMP) 52-54C) onto the catchment surface at a rate of 1.0 to 1.5 kg/m^2 (Fink et al., 1973). This treatment is best suited for soils containing less than 20% clay in climates where the soil temperature will exceed the AMP of the wax during some part of the year (Frasier, 1980). Measured runoff efficiencies from the treatment are often 80 to 99%. The wax treatment has an advantage of a continual increase in the depth of the water repellent layer with time. The wax gradually penetrates deeper into the soil each time the soil temperature approaches or exceeds the melting point of the wax. Initially, the wax treatment will provide some degree of soil stabilization. With time, as the wax continues to move deeper into the soil, the wax coating around each soil particle becomes thinner with less bonding between soil particles, thus providing less soil stabilization. This treatment is being used for livestock water-harvesting systems.

Gravel Covered Sheeting

The gravel covered sheeting treatment is simply a thin impermeable plastic sheeting (polyethylene) or standard asphalt coated roofing paper covered with a layer of gravel. The gravel holds the membrane in place and provides a protective cover for reducing wind or other mechanical damage. The membrane is placed on the catchment surface and a 1.0- to 2.0-cm layer of pea-sized (0.5 - 1.0 cm gravel is spread over the sheeting. The gravel layer retains approximately the first 2 mm of each precipitation event, which is usually lost to the atmosphere by evaporation. Runoff is essentially 100% of all the precipitation in excess of 2 mm. Minor problems have been encountered with windblown dust trapped in the gravel, providing a seedbed for plants (Cluff, 1975). This treatment is a relatively low cost method for any area which has a readily available source of clean gravel.

Asphalt-Fabric Membranes

There are several types of asphalt-fabric membrane treatments. One of the most widely used treatments consists of a random weave fiberglass matting saturated with asphalt emulsion. The fiberglass matting (90- to - 150-cm wide rolls) is unrolled on the catchment surface and saturated with an asphalt emulsion at a rate of 3 liters/m^2.

After drying for a period of 3 to 10 days, a second coating of roofing-asphalt-clay emulsion is brushed onto the membrane at a rate of 2 liters/m^2 (Myers and Frasier, 1974). This treatment has been successfully used for catchments in the hot, arid deserts to the colder, mountainous regions of Colorado and New Mexico. In recent years, new mattings composed of polyester synthetics have become available. Some of these polyester mattings, which are compatible with the asphalt emulsion and have satisfactory weathering performance, are undergoing evaluation. All the asphaltic-fabric treatments become semirigid with hardening of the asphalt. The hardened membranes are relatively resistant to mechanical and animal damage and weathering processes. With good preventative maintenance and a periodic new sealcoat of asphalt, this treatment has a long, effective life. This treatment is being extensively used for furnishing drinking water for wildlife and livestock in the United States.

Concrete Sheet-Metal Artificial-Rubber

Most conventional construction materials are potentially suited for use on water-harvesting catchments. These materials are usually relatively expensive, but when properly installed, have long life expectancy. Poured slabs or blown (gunite) concrete has been used for various types of catchments. Properly mixed and cured concrete is very durable but will have shrinkage cracks when used to cover large areas. The shrinkage cracks can lose significant water unless they are periodically filled with some type of mastic sealer. Runoff from concrete catchments will usually be 60-90%.

Sheet metal roofs have long been a method of water-harvesting. Recently, many sheet metal catchments have been constructed by placing the framework directly on the ground. This method provides a durable, low maintenance runoff apron (Lauritzen, 1967). Costs of the roof may be prohibitive for some installations.

In the early 1950's, many catchment aprons were installed using artificial rubber (butyl) membranes. Many of these catchments failed because of improper installation techniques. If the artificial rubber sheetings were subjected to local tension stresses from improper placement over rocks or other objects, the weathering properties would often be reduced due to accelerated aging processes (Dedrick and Paterson, 1975). Also, butyl sheetings remained as flexible membranes and were susceptible to mechanical damage from wind and animals (Dedrick, 1973). Only a limited number of artificial rubber catchments are still in use.

Water Storage

Water-storage facilities for a water-harvesting system are the most expensive single item, sometimes representing 50% of the total cost (Cooley et al., 1978). Any basic type of water storage may be used (Dedrick, 1975). Usually, the storage selection is determined by the availability of materials and location access. In remote sites, primary consideration is the durability of the storage.

One commonly used type of storage is constructed from sectionalized bolted steel plates with a bottom of reinforced concrete or an impermeable liner on the inside of the tank. Many liners are sensitive to sunlight deterioration. Their lifespan is greatly extended if the tank is covered.

One relatively low cost storage is a plastered-concrete tank. The tank, approximately 2 m high and 10 cm thick, has two layers of concrete reinforcing wire (20- x 20-cm) filled with concrete. The concrete is held in place by a second layer of small mesh (2 cm x 2 cm) woven wire fencing. The tank is made waterproof by a layer of cement plaster (inside and outside) spread over the wire mesh. The bottom of the tank is wire-reinforced concrete.

Unlined earthen pits are not usually a successful method of water storage for water-harvesting systems. Excessive seepage losses often negate the cost of collecting the water. Most types of plastic and rubber sheetings and various chemical sealants have been tried as potential impermeable liners. One major problem is mechanical damage from wind, animals, and plants when the liners are exposed on the soil surface. Properly installed buried plastic liners have been relatively successful (Dedrick, 1975).

Evaporation Control

Conserving the collected water is one of the most economical methods of maintaining an adequate water supply. Various methods of reducing evaporation have been investigated including changing the color of the water, monomolecular films, shading, and floating covers (Cooley, 1975).

Many older water-harvesting systems had roofs constructed over the storage tank. These roofs effectively reduced evaporation, but construction costs are often relatively expensive, and some installations have been damaged by high winds or excessive snow accumulations.

For vertical-walled storage tanks, the floating cover is one of the most effective means of evaporation control. One type of floating cover is made of a low-density synthetic foam rubber. Only minor problems have been reported such as birds pecking the cover or wind blowing it off when the tank is full (Dedrick et al, 1973). Other materials used as floating covers include rafts of polystyrene sheeting and a continuous layer of paraffin wax. Neither of these methods is presently used on operational water-harvesting systems.

Evaporation control from sloping-side storages is more difficult because of the changing surface area with depth. As the water leval drops, floating covers become stranded upon the sides and are susceptible to mechanical damage.

RUNOFF FARMING APPLICATIONS

In a runoff farming system, a small runoff area collects water that is directed toward the plants and stored in the soil profile. Any type of catchment area treatment is potentially feasible. The cost of the materials usually determines the type of treatment selected. Design factors for a runoff farming application must include the water holding capacity and the infiltration rate of the soil as well as the temporal and quantity water demands of the plants.

A study in southern Arizona showed that by clearing and treating strips of land to increase precipitation runoff and by concentrating that runoff on adjacent strips of cropped land, the average forage yield (based on total land area) of blue panicgrass (Panicum antidotale Retz) could be increased by a factor of two over yields on plots with a solid planting of grass. With less than 125 mm of precipitation during the growing season, some plots produced average forage yields greater than 2,500 kg/ha (850 kg/ha runoff area included) compared to yields of less than 450 kg/ha on control plots (Frasier and Schreiber, 1978). While the potential increase in forage yields in the studies was significant, the costs of the treatments on the runoff area were relatively high compared with current returns from grass in the form of increased meat production.

FUTURE NEEDS OF WATER HARVESTING RESEARCH

The following are areas in which further research is needed to maximize the effective returns from water-harvesting/runoff-farming installations:

Information is needed concerning the water requirements and timing of the many crops and plants which may be potentially suited for runoff farming applications in arid and semiarid climates. Studies are needed to determine the potential increase in yield when these crops are supplied with additional quantities of water.

The relative expense of presently used methods of storing the collected water is a major factor in optimizing the relative sizes of catchment and storages. New, effective durable materials are needed for lining excavated pits. New types of above ground storages are needed for use in remote, poorly accessible sites.

The control of evaporation from the water storage facility is an often overlooked but critical factor. For the quantity of water saved, the method of evaporation control can often be the most effective cost item. Effective evaporation control for use on water storages with sloping sides is not presently available.

Other areas needing additional studies are (1) developing criteria or guidelines concerning the types of soils and climate where chemical treatments, i.e., waxes and water repellents, are suited, (2) development of low cost stabilizers for use with chemical treatments to prevent soil erosion, and (3) improved criteria for sizing of catchment and storage based on rainfall probability and relative cost of materials.

SUMMARY

Methods and materials are available for constructing water-harvesting systems for supplying drinking water for wildlife, livestock, and domestic animals. There are various types of catchment treatments and storage facilities which are potentially suitable. There is not a single method or material that is universally the best treatment. Each system must be individually designed to meet the onsite needs and factors.

Runoff-farming applications are potentially capable of providing a significant portion of our future needs of food and fiber. Studies are being conducted to evaluate runoff-farming techniques for increasing forage production on arid and semiarid rangelands. At present, the costs of the treatments are relatively high compared with the potential economic returns that might be expected from increased meat production. The relation of food production to water requirements of many arid and semiarid native plants for maximum effective production is not known in sufficient detail to achieve maximum benefits from the potential of runoff-farming.

LITERATURE CITED

Burdass, W. J. 1975. Water Harvesting for Livestock in Western Australia. In: Proc. Water Harvesting Symposium ARS W-22, U.S. Department of Agriculture, Phoenix, Arizona. pg. 8-25.

Chiarella, J. Y., and W. H. Beck. 1975. Water Harvesting Catchments on Indian Lands in the Southwest. In: Proc. Water Harvesting Symposium ARS W-22, U.S. Department of Agriculture, Phoenix, Arizona. pg. 27-39.

Cluff, C. B. 1975. Engineering Aspects of Water Harvesting Research at the University of Arizona. In: Proc. Water Harvesting Symposium ARS W-22, U.S. Department of Agriculture, Phoenix, Arizona. pg. 27-39.

Cooley, K. R. 1975. Evaporation Suppression for Conserving Water Supplies. In: Proc. Water Harvesting Symposium ARS W-22, U.S. Department of Agriculture, Phoenix, Arizona. pg. 192-200.

Cooley, K. R., A. R. Dedrick, and G. W. Frasier. 1975. Water Harvesting: State-of-the-Art. In: Proc. Watershed Management Symposium, American Society of Civil Engineers, Irrigation and Drainage Division, Logan, Utah. pg. 1-20.

Cooley, K. R., G. W. Frasier, and K. R. Drew. 1978. Water Harvesting: An Aid to Management. In: Proc. First International Rangeland Congress, Society for Range Management, Denver, Colorado. pg. 292-294.

Dedrick, A. R. 1973. Raintrap Performance on the Fishlake National Forest. Journal of Range Management 26(1):9-12.

Dedrick, A. R. 1975. Storage Systems for Harvested Water. In: Proc. Water Harvesting Symposium ARS W-22, U.S. Department of Agriculture, Phoenix, Arizona. pg. 175-191.

Dedrick, A. R., T. D. Hansen, and W. R. Williamson. 1973. Floating Sheets of Foam Rubber for Reducing Stock Tank Evaporation. Journal of Range Management 26(6):404-406.

Dedrick, A. R., and D. A. Paterson. 1975. Accelerated Aging Tests on Elastomeric Sheeting and Inter-Location Correlation. Journal of Elastomers and Plastics 7:315-327.

Evanari, M. L., L. Shanan, N. Tadmor, and Y. Aharoni. 1961. Ancient Agriculture in the Negev. Science 133:979-996.

Fink, D. H., K. R. Cooley, and G. W. Frasier. 1973. Wax-Treated Soils for Harvested Water. Journal of Range Management 26(6):396-398.

Fink, D. H., and G. W. Frasier. 1975. Water Harvesting from Watersheds Treated for Water Repellency. In: Soil Conditioners, Special Publication No. 7, Soil Science Society of America, Madison, Wisconsin. pg. 173-182.

Fink, W. H., G. W. Frasier, and L. E. Myers. 1979. Water Harvesting Treatment Evaluation at Granite Reef. Water Resources Bulletin, American Water Resources Association 15(3):861-873.

Frasier, G. W. 1975. Water Harvesting for Livestock, Wildlife, and Domestic Use. In: Proc. Water Harvesting Symposium ARS W-22, U.S. Department of Agriculture, Phoenix, Arizona. pg. 40-49.

Frasier, G. W. 1980. Harvesting Water for Agricultural, Wildlife, and Domestic Use. Journal of Soil and Water Conservation 35(3):125-128.

Frasier, G. W., K. R. Cooley, and J. R. Griggs. 1979. Performance Evaluation of Water Harvesting Catchments. Journal of Range Management 32 (67):453-456.

Frasier, G. W., and H. A. Schreiber. 1978. Rangeland Forage Rehabilitation by Water Harvesting. In: Proc. First International Rangeland Congress. Society for Range Management, Denver, Colorado. pg. 295-298.

Frith, J. L. 1975. Design and Construction of Roaded Catchments. In: Proc. Water Harvesting Symposium ARS W-22, U.S. Department of Agriculture, Phoenix, Arizona. pg. 122-127.

Hollick, M. 1975. The Design of Roaded Catchments for Maximum Runoff. In: fProc. Water Harvesting Symposium ARS W-22,f U.S. Department of Agriculture, Phoenix,d Arizona. pg. 201-220.

Lauritzen, C. W. 1967. Raintraps of Steel. Utah Science, September. pg. 79-81.

Myers, L. E., and G. W. Frasier. 1969. Creating Hydrophobic Soils for Water Harvesting. Journal of Irrigation and Drainage Division, American Society of Civil Engineers 95(IR1):43-54.

Myers, L. E., and G. W. Frasier. 1974. Asphalt-Fiberglass for Precipitation Catchments. Journal of Range Management 27(1):12-15.