TECHNICAL REPORT

Rainfall Catchments Improve Survival of Container Transplants at Mojave Desert Site

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Simple structures, used by ancient farmers, increased transplant survival by almost 20 percent on this difficult site.

Deserts of the southwestern United States experience infrequent thunderstorms that bring large quantities of rainfall. This limits soil moisture, with favorable conditions for plant establishment typically occurring in only one out of five years (Cox and others, 1982). Lack of water is usually a limiting factor for restoration efforts in these areas and irrigation costs may more than double project costs. Ancient desert civilizations often did not have the resources to transport water over long distances, but they did develop systems for utilizing local water supplies (Shanan, 1979). Over 2,000 years ago, the Nabateans used dams and diversion channels to guide runoff from flash floods to irrigate crops (Evenari and others, 1982). Similar techniques were also used by other peoples in ancient Arabia, North Africa and pre-Columbian America. The rainfall catchment, using soil and stone berms to channel water into a simple basin, is one of the most useful techniques developed by these ancient farmers. These systems provide many advantages over other irrigation techniques. They are simple, inexpensive to construct, and can be built rapidly using local materials and manpower. Runoff water has a low salt content and, because it does not have to be transported or pumped, is relatively inexpensive. It was with this in mind that we set up an experiment to determine whether rainfall catchments could be adapted to a restoration setting, whether they increased survival rates for container out-plantings of native species, and which native species were best suited for the technique.

Site, Catchments and Plantings

We initiated the experiment on a restoration site at the United States Army National Training Center and Fort Irwin in the Mojave Desert approximately 30 miles northeast of Barstow, California. The site had recently been used as a temporary encampment during training activities in October 1997 which resulted in moderate soil compaction and severe crushing of the creosote (*Larrea tridentata*) and bursage (*Ambrosia dumosa*) vegetation. The soil was a sandy loam with very little organic matter (less than one percent), low bicarbonate-extractable phosphorous (< 10 ppm) and low TKN soil nitrogen (< 5 ppm NO_3). The site was approximately 12 acres in size on a gentle (less than 3 percent) slope with a southern aspect at 3,120 ft (950 meters) elevation.

Because bare ground and soil compaction accelerate surface runoff and erosion, a primary concern and objective for the project was to re-establish vegetation while reducing topsoil loss and preventing the formation of erosion gullies that could interfere with training activities. To accomplish this we installed 128 V-shaped catchment basin systems perpendicular to the drainage patterns on the site in February 1998. To determine the most effective size for shrub establishment, we constructed 32 replicate catchments of four different sizes ($4m^2$, $9m^2$, $16m^2$ and $25m^2$) using a combination of hand tools and a small tractor. We adjusted the size of our V-shaped catchments by extending the two soil berms used to funnel water into the roughly 90 degree vertex. In this way, the $4m^2$ size catchment was made from two 2m-long berms, and the $25m^2$ size catchment was made out of two 5m-long berms.

To compare survival inside and outside the catchments we planted 520 seedlings outside the catchments in groupings of five (with at least one meter spacing between plants). These clusters were randomly interspersed with the catchments but not immediately down-slope from any catchment. Inside the catchments we planted a total of 508 plants with each catchment containing four shrubs spaced one meter apart and planted in the vertex. The plant species and planting positions were chosen at random from the container stock available. The species used on the site were native to the region and, where possible, were grown from seed collected at Fort Irwin. Species used included: bursage (*Ambrosia dumosa*), shadscale (*Atriplex polycarpa*), brittlebush (*Encelia farinosa*), Mormon tea (*Ephedra nevadensis*), cheesebush (*Hymenoclea salsola*), bladderpod (*Isomeris arborea*), creosote bush (*Larrea tridentata*) and mesquite (*Prosopis glandulosa*). The seedlings were grown at our own greenhouse and in the Plant Propagation Nursery at Joshua Tree National Park. As a result, the age and sizes of the transplant stock used were variable, ranging from two to six months old; however, random selection of planting position and locations during the February planting minimized this potential bias. All plants received supplemental water during planting and at approximately one-month intervals during the summer months of June, July and August. Survivorship was recorded twice, at four months and one year after planting. We compared overall survivorship inside and outside the catchments and by catchment size using a Chi square test of independence. Chi square contingency tables were calculated for each species to determine species survivorship differences in the catchments.

Berm and basin catchment system for the desert. The view from downslope at Fort Irwin, California during construction of catchments the authors designed to funnel surface-runoff water into planting areas. In these trials, catchments increased survival of some species planted inside collection areas, but results depended on size and design of the simple berm structures, which must be adapted to rainfall, slope, soil permeability and other factors. *Photos by authors*

Survivorship Increased

Survivorship, both four months and one year after planting, was significantly higher inside the catchments (p-value $\leq$ 0.0001) than outside, with survival inside the catchments after one year at 83 percent as contrasted with 64 percent outside (Table 1). Catchment size did not significantly affect survival at either the four-month or the one-year sampling. One year after planting, we found the highest survival (87 percent) in the 4 m^2 catchments. The next highest was in the 25 m^2 catchments (86 percent), and the lowest survivorship (80 percent) was on the 9 m^2 and 16 m^2 catchments. Out of the eight species planted, three species (creosote, brittlebush and bladderpod) survived nearly as well outside the catchments as inside them. The other five species (mormon tea, bursage, cheesebush, shadscale and mesquite) had significantly higher survival rates inside the catchments (Table 2).

Use of Catchments

Using rainfall catchments in arid environments is not a new concept. The results of this study suggest that modern adaptation of this ancient technology to habitat restoration in arid and semi-arid environments is a low-cost and low-tech method for improving transplant survival. Site selection, however, is important. The gradient on the site should be between one and seven percent (Evenari and others, 1982). Square or rectangular catchments, like the ones used in this experiment, are the easiest shapes to stake

Table 1: **Percent survival all species, at four months and one year after planting.**

	Inside Catchments		Outside Catchments		Chi Sq p-value
	# alive	% alive	# alive	% alive	
4 months after planting	474	93.3	427	82.0	0.0001
1 year after planting	426	83.8	334	64.1	0.0001

Native species were planted on a one-meter grid inside catchments, with shrub species set in the apex of the v-shaped catchments where most water collects and percolates into soil. Survival rates were higher inside than outside the catchments for five of eight species planted.

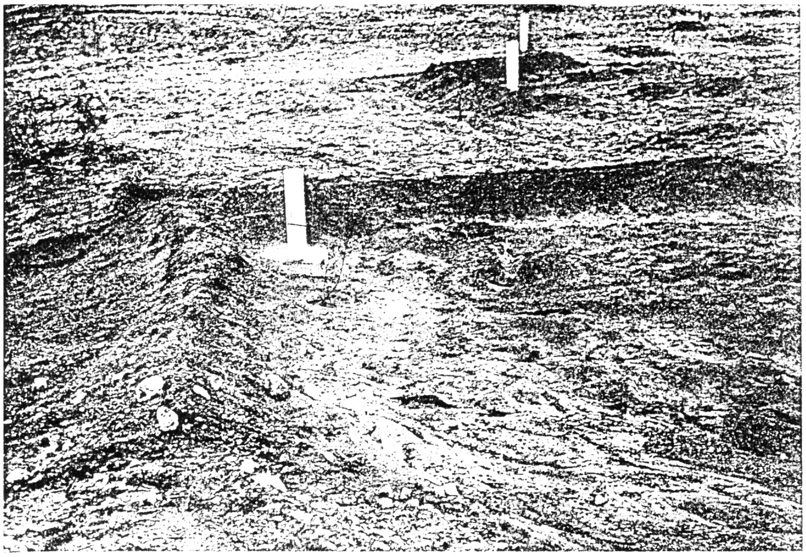
out, and are the most common. However, catchment shapes can also be tailored to suit the topography of the site in order to minimize disturbance while maintaining a more natural appearance. Catchment basins are susceptible to siltation, and the berms may be damaged by erosion and washout if they receive too much runoff. On our site, washouts occurred in several unreinforced catchments that we positioned in natural gullies. In areas and positions that receive too much runoff protective diversion ditches should be constructed up-slope to reduce water flow into the catchment, or suitable erosion control materials, including rocks, should be incorporated into the catchment berms. When properly placed, the catchments should perform for a number of seasons until natural erosion and siltation blur their outline. On this and several other restorations sites we have observed that removal is not necessary or desirable because the relatively loose soil in the catchment berms often becomes riddled with lizard and insect burrows, while the catchment basin continues to trap organic matter and seeds.

Traditionally, the tree or shrub is planted in the basin near the lowest point of the catchment, where the water would be deepest and the dike highest; however, for many desert species this is not desirable and the benefits of additional water collected in the catchment may be offset by problems caused by short periods of inundation (Orev, 1988). After an intense rainstorm, catchments fill with water and may remain flooded for several days. During this time, the roots and lower stem may suffer from lack of aeration and damping off (Orev, 1988). In our study, we planted seedlings one meter apart in the deepest corner of the catchment, and on several occasions we saw standing water in the catchments following rainstorms. Excessively wet soil may actually have been a problem in some catchments. We noticed that some creosote bush transplants inside the catchments did not green up as rapidly as those planted outside. Knowing the infiltration rate of the soil prior to planting may be useful in determining the best planting spot in the rainfall catchment itself. On heavy, slow draining soils, it may be best to plant sensitive species slightly higher on the catchment berm. In sandy, fast draining soils, seedlings planted on the floor of the catchment will receive the most moisture. Planting in this position can also provide an advantage for species that are less drought tolerant.

The results of this experiment were inconclusive with respect to the best catchment size. On the basis of survivorship, it appears that catchments larger than 4 m^2, or 2x2 meters, did not improve survival; however, the supplemental waterings during the summer may have served to equalize survivorship and obscure differences resulting from catchment size. The sizes used here may not be appropriate on other sites. Shanan (1979) suggests that potential water yields should be estimated before decisions regarding catchment size and design are made. The appropriate size for catchments will vary depending on four main physiographic factors: (1) the runoff-producing potential of the local microclimate (annual rainfall, peak rainfall intensity, and the minimum expected annual precipitation); (2) the soil surface condition and permeability (cover, vegetation, crust, stoniness); (3) the gradient and evenness of the slope; and (4) the water-retaining capacity of the soil in the root zone. Calculating the runoff threshold

Table 2. **Percent survival, by species, inside and outside the catchments one year after planting.**

	Inside Catchments		Outside Catchments		Chi SQ
Plant Species	# Planted	% Survival	# Planted	% Survival	p-value
mesquite	45	83.1	21	31.9	0.0059
shadscale	90	66.3	52	44.2	0.011
Mormon tea	53	96.2	100	82.0	0.013
cheesebush	45	83.3	33	63.6	0.0515
bursage	83	90.5	167	82.1	0.0814
brittlebush	56	85.5	82	78.0	0.2785
bladderpod	43	81.0	31	74.2	0.4902
creosote bush	93	92.3	35	88.6	0.5057



Puddles, persisting the day following an early spring thundershower, attest to the effectiveness of catchments in concentrating water at planting sites.

coefficient is one way to synthesize these variables, and can be useful in determining appropriate catchment size. Howell (1989) describes how to calculate and apply this coefficient. The addition of catchments on a site does change hydrologic relations, but because rainfall catchments operate best during intense thundershowers where there are large amounts of water in short periods of time they do not do so by depriving down-slope or existing vegetation. Instead catchments increase water infiltration and allow it to be stored in the soil, where it is available for both existing and transplanted vegetation.

Catchment construction is simple and adaptable to local conditions. In order to better control catchment size we built most of our catchments by hand using soil scraped out of the catchment basin by a small tractor. In general we have found that where existing vegetation needs to be accommodated, more hand labor is required to avoid damage by heavy equipment. On a nearby restoration site, where existing vegetation was absent, we found that scraping the ground in four passes using a small tractor with a bucket (about one meter in length), followed by a final shaping using a shovel was the fastest and best way to produce catchments roughly two meters in length. Also during construction, soil surface treatments can be incorporated either in the catchment itself or the adjacent watershed to alter runoff patterns. In the catchment, water resistant chemicals such as paraffin can be applied over a portion of the catchment floor to reduce soil permeability and direct water to the lowest point where a shrub can be planted. On the watershed above the catchments, rocks can be cleared (increasing surface runoff) or added (decreasing runoff) (Evenari and others, 1982).

Desert thunderstorms can produce large quantities of rainfall in very short periods of time providing more rainfall than can be absorbed into the soil. On disturbed sites, with compacted soils and reduced vegetation cover, less water is absorbed and surface runoff is accelerated. Rainfall catchments harvest this lost water and put it to work. Because catchments are easy to build, improve survival, and take advantage of this otherwise lost resource, we highly recommended them for restoration projects undertaken in deserts, including the arid southwestern United States.

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