



Thematic week: Water and Land

Thematic axis: Land Use Planning, Forest Cover and Afforestation

Title of the presentation: More efficient irrigation systems for desert and dryland restoration

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Abstract:

One of the great challenges for agriculture, agroforestry, forestry, and restoration is establishing plants and growing crops on sites that are seasonally dry or dry all year. This is becoming increasingly important as global change creates new areas of drought and more erratic rainfall patterns. Although vast areas of the world are still managed by resource limited owners, low cost simple irrigation methods that would help them increase yields have been ignored by scientific research and international development programs. Drip systems are well known, but more efficient traditional methods of irrigation that could be of great help have not been well studied or publicized. These include: deep pipes, buried clay pots, porous capsules, wicks, porous hose, and subirrigation with perforated pipe. These require much less water and work well on slopes. They also reduce weed growth dramatically and ensure that water is used to grow the crop, not weeds.

Key words: Irrigation, efficiency, deep pipe, buried clay pot, wick, porous capsule, porous hose, perforated pipe, remote site, slopes, drought

Abstract: (Spanish)

Uno de los desafíos más grandes para la agricultura, agroforestería, recursos forestales, y restauración en general, consiste en establecer plantas y cultivos en zonas estacionalmente o permanentemente secas. Este hecho esta aumentando la importancia de este desafio, a medida que el cambio climático crea nuevas zonas áridas y provoca mas episodios de lluvia esporádicos. Aunque muchas zonas amplias del mundo siguen siendo manejadas por un número pequeño de dueños con limitados recursos, estos métodos de bajo coste que pueden ayudarles a disminuir pérdidas han sido olvidados por estudios científicos y por programas internacionales de desarrollo. Los sistemas de riego por goteo son bien conocidos, pero otros métodos alternativos de riego que podrían funcionar a la perfección no han sido suficientemente estudiados o publicados. Entre estos se incluyen: tubos profundos, macetas de arcilla enterradas, cápsulas porosas, mechas, mangueras porosas e irrigación subterránea con tubos perforados. Estos métodos requieren mucha menos agua y además funcionan bien en zonas de gran pendiente. Además, reducen dramáticamente el crecimiento de malas hierbas debido a que el agua llega exclusivamente al cultivo.

Palabras clave: Irrigación, eficiencia, tubo profundo, maceta de arcilla enterrada, mecha, cápsula porosa, manguera porosa, tubo perforado, lugar remoto, pendientes, sequía

1. Introduction

Over the years we have worked with and tested many irrigation systems from traditional cultures around the world and developed several new methods. The following systems are those that have proved most effective. All use much less water than the best conventional techniques and are suitable for both remote sites and landscaping. The actual water requirements for the small seedlings we prefer to plant are often only 1-2 liters per month (rather than 1-2 l per hour); but more water is better and will improve survival and growth. For crops water demands are higher, but on a per hectare basis may only be a few cm per month.

Water is heavy, awkward to handle, and quickly becomes expensive at remote sites. For example, an acre inch of rain weighs more than 100 tons and would represent 200-400 pickup truck loads. Over the years we have developed methods that use as little water as possible, but water is still needed when transplanting and usually must be transported to the planting site from some distance. A water truck, water trailer, collapse-a-tank, or saddle tank for a pickup can be used to carry water for watering.

Plant shelters and plant protection can help reduce plant water demand and improve survival (Bainbridge, 1994). Plants with roots in moist soil can often maintain water content in the shelter air at levels higher than open field air. This may help reduce plant water demand in the desert where very low humidity and high winds are common. The shelters also protect the plant from drying winds and sandblast. These factors enhance survival and growth in tree shelters (Bainbridge, 1991; Bainbridge and MacAller, 1996).

2. The most promising alternative irrigation systems

Tests in the Colorado, Mojave and Sonoran deserts have proved the value of deep pipe, buried clay pot, wick, porous capsule, porous hose, perforated pipe irrigation systems (Bainbridge, 2007). These are described below.

2.1. Deep pipe irrigation

Deep pipe irrigation uses an open vertical or near vertical pipe to concentrate irrigation water in the deep root zone (Mathew, 1987; Bainbridge and Virginia, 1990). Experiments in Africa demonstrated that the deep pipe drip system is much more efficient than surface drip or conventional surface irrigation (Sawaf, 1980). Grape vine weight on a deep pipe drip system was more than double the weight found with surface drip and more than six times the vine weight of conventional surface irrigation. Root spread reached 100 cm horizontally with conventional surface irrigation, only 60 cm with surface drip, but 178 cm with deep pipe irrigation.

Deep pipe irrigation develops a much larger root volume than other forms of irrigation and helps develop a plant that is better adapted to survive after watering is terminated following establishment. Plants started on deep pipes also responded better to rare summer rains.

Deep pipe irrigation is commonly done with 1-3 cm diameter pipe placed vertically in the soil 30-50 cm deep near the seedling or tree with a screen cover (1 mm hardware cloth) to keep out lizards and animals. The top of the pipe may be set close to the ground to minimize visual impact, or may extend above ground 20-40 cm. Screen fabricators can make these at low cost and they can be glued on with silicone caulk. A series of 1-2 mm holes should be spaced about 5-7.5 cm apart down the side of the pipe nearest the plant to facilitate root growth in the early stages of development. If shallow rooted plants from containers are planted next to a deep pipe the roots may not make contact with the wetted soil unless these holes are drilled and the pipes are filled with water. If a drip just wets the soil in the bottom of the pipe the young seedling can be left high and dry. Several pipes may be used for older trees. These may be filled from a water truck or hose, hand watering cans or fitted with a drip emitter (Bainbridge, 2007). This has been a very effective system and can be combined easily with a drip emitter.

Deep pipe irrigation can be used with low quality water. It is possible to set up with simple materials and unskilled labor without extensive support systems (pressurized filtered water is not needed). The deep pipes provide better water use efficiency (due to reduced evaporation) and weed

control. They also enable water to be applied quickly and efficiently with no runoff waste even on steep slopes.

2.2 Buried clay pot

Buried clay pot irrigation uses a buried, unglazed clay pot filled with water to provide a steady supply of water to plants growing nearby (Bainbridge, 2001; Stein, 1998). The water seeps out through the walls of the buried clay pot at a rate that is in part determined by the water used by the plant. This leads to very high irrigation efficiency.

The controlled water delivery from buried clay pot irrigation provides young seedlings with a steady water supply even during periods with very high temperatures, low humidity, and desiccating winds. This controlled water delivery is of special value in coarse sand or gravel soils that drain quickly. This steady delivery makes buried clay pot irrigation a good method for use with direct seeding. Germination rates were 78-100 percent for Palo Verde seeds on buried clay pots but germination of mesquite seeds has not been as good (Bainbridge et al., 1990).

Researchers in Pakistan used buried clay pot irrigation to establish acacia and eucalyptus trees in an area with 200 mm annual precipitation (Shiek'h and Shah, 1983). The trees irrigated with buried clay pots grew 20% taller than trees receiving hand watering at the same rate and survival increased from 62% to 96.5%. Buried clay pot irrigation has also been used with mesquite trees (Kurian et al., 1983). Air-layer vegetatively reproduced mesquite trees were outplanted using 5 liter buried clay pots. Trees irrigated with buried clay pots were more than 3 times taller than rainfed trees and 70% taller than surface irrigated trees. Areas affected by salinity or where only saline water is available for irrigation have also demonstrated the value of buried clay pot irrigation (Mondal, 1983; 1984).

Most standard red clay garden pots are suitable for irrigation if the bottom hole is plugged. Silicone caulk works better than rubber stoppers or corks. Masking tape is placed across the bottom of the pot, then the pot is turned over and the hole is filled with silicone caulk from a caulking gun. The buried clay pots can be filled by hand or connected to a pipe network or reservoir. A tight fitting lid with drain holes to allow rain into the pot should be used or animals may knock loose lids off to drink the water. Clay or metal lids can be used (a standard 8" pot is matched to a common aluminum pie tin size). Rocks should be glued to lightweight lids to keep them from blowing away.

Buried clay pot irrigation is also very effective for irrigating cuttings, in the nursery or in the field. In the nursery a sealed pot is placed within a larger pot with the drain left open, with sand between them. The interior pot is filled with water and maintains moisture in the sand (Bainbridge, 2007).

2.3 Wick irrigation

Wick systems were first used in India in conjunction with buried clay pot irrigation (Mari Gowda, 1974). A hole or holes was punched in the buried clay pot and a porous wick made of cotton is inserted in the hole. The material wicks the water from the container into the soil and provides a slow steady source of water to encourage root development and plant growth. Wicks can be set up as capillary or gravity fed irrigation systems. The capillary systems use a wick in a tube that rises above water level, water movement is limited but steady. A gravity wick is below water level and the water flows through the wick.

A capillary wick system set up in a hot dry greenhouse at U.C. Riverside using a Palo Verde (*Cercidium floridum*) seedling in a bucket of 16 grit silica sand used only 20-30 ml/day. After one month the plant was still growing and exhibited no sign of water stress. Nylon wicks made with woven (not braided), washed and weathered nylon rope worked better than cotton on subsequent tests. Current tests using larger diameter nylon wicks (1.2 cm) and a 20 liter reservoir have been very successful. Woven nylon rope should be washed in hot water and detergent before use to remove oils.

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2.4 Porous capsules

Porous capsule irrigation is an efficient modern adaptation of buried clay pot irrigation (Silva et al., 1981a,b; 1985a,b). Porous capsules are made with porous low fired clay and can be more easily tied into a piped network than buried clay pots. They can also be made by gluing clay pots together. We have found them to be effective, but more costly to make and install than buried clay pots or deep pipes. Two tubes must be run to each capsule to allow air to escape when water is introduced.

Porous capsules are not as sensitive to clogging as drip emitters, but harder to clean as buried clay pots and they may eventually clog from sediment or bacterial, fungal, or algal growth. Capsules can be set up with relatively large diameter connectors that require less filtration and lower pressure than the small tubing used with many drip emitters. An excellent opportunity for commercial development, either with ceramic or microporous plastics.

2.5 Porous hose

This method uses a vertically placed section of porous hose to wet a vertical soil column. The porous hose can be installed before the plant is planted, using a drill to almost any depth desired (depending on soil conditions and rockiness). The porous hose can also be placed in the soil when the plant is planted. This can be connected to a water bottle or a tank and distributing system. Only the high volume leakers may work at low pressure.

Porous hose water delivery should be fairly consistent through the soil column providing excellent conditions for deep root growth. Early trials of vertically placed 12" long 3/8 inch diameter porous hose have been very encouraging. A series of porous hoses could be used to develop wind firmness in very windy areas, being placed in a tri-slotted planting hole. These could be left in place after the plants are established and the surface pipes are removed because the porous pipe breaks down fairly quickly.

2.6 Perforated pipe

Buried perforated drainage pipe was fairly successful for irrigation at an initial trial along highway 86 in the Sonoran Desert. This led to a very successful installation of more than a half mile of buried slotted drainage pipe to water a windbreak at Fort Irwin in the Mojave Desert. Vertical standpipes with screen covers at about 30 m intervals are used to fill the pipe and water the plants. Similar success has been realized with additional plantings. Pipe can be installed very economically in some soils with a specialized plow and pipe roll installer.

Perforated pipe can be installed easily if tractors or graders can be used. A sloping ditch is dug and the pipe is laid at the bottom, with filling risers tied to posts at intervals based on slope and flow direction. The pipe is then covered with another pass, and then side bars are placed by hand.

3. Conclusions

The most appropriate system for a given site and application should be chosen after reviewing survival and growth goals and water availability, plant species water demand, labor skill and availability and budget. The cost of all of these systems is modest compared to the total cost of installing a plant at a remote site. Plants generally should receive a tree shelter to reduce the risk of herbivory and water loss, figure 7. These irrigation systems can be even more effective if they are installed within a microcatchment rainwater harvesting system that will provide water for the plant if it rains.

Deep pipes remain the most common first choice. Buried clay pot systems can be very effective but are more costly. They may be appropriate where direct seeding or live cuttings are used or where seeds in the soil seed bank are expected to germinate and grow. Buried clay pots with treeshelters may provide good plant growth from seed at a cost below container planting. The clay pots can also be recycled. Porous tubes work well. Porous capsules require more labor for construction than other systems but could probably be commercially produced at competitive costs, they have been used in conjunction with fog capturing systems in Latin America. For linear

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plantings the buried slotted drainage pipe irrigation systems have been very effective. The pipe must be left in the ground however and this may not be suitable in some cases.

Even with the best preparation and planting techniques few seedlings will survive transplanting to drylands or deserts without supplemental irrigation. In our early trials survival with only one supplemental watering was about 2%, in contrast, the deep pipe, perforated pipe, buried clay pot, porous capsule, porous tube and wick have worked well, with survival often near 100%

These alternative and little known irrigation systems can dramatically increase survival and improve plant growth even in severe desert conditions, figure 8 (Bainbridge, 2007). Supplemental irrigation should be provided for as long as possible, perhaps once every two weeks the first three months and then once a month for two summers. These effective and efficient irrigation systems should also be considered for much wider use in restoration, forestry, agroforestry, agriculture, gardening, landscaping and revegetation because they work well and save water.

Suppliers:

Screen disks for deep pipes

TWP Inc.

www.twpinc.com/index.html

Porous tubes (soaker hose)

High rate soaker tube from Lee Valley Garden Supply. www.leevalley.com

(Drip Master, AquaPore, Moisture Master)

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5. Figures

Figure 1. Deep pipe with treeshelter (double wall treeshelters have worked best).



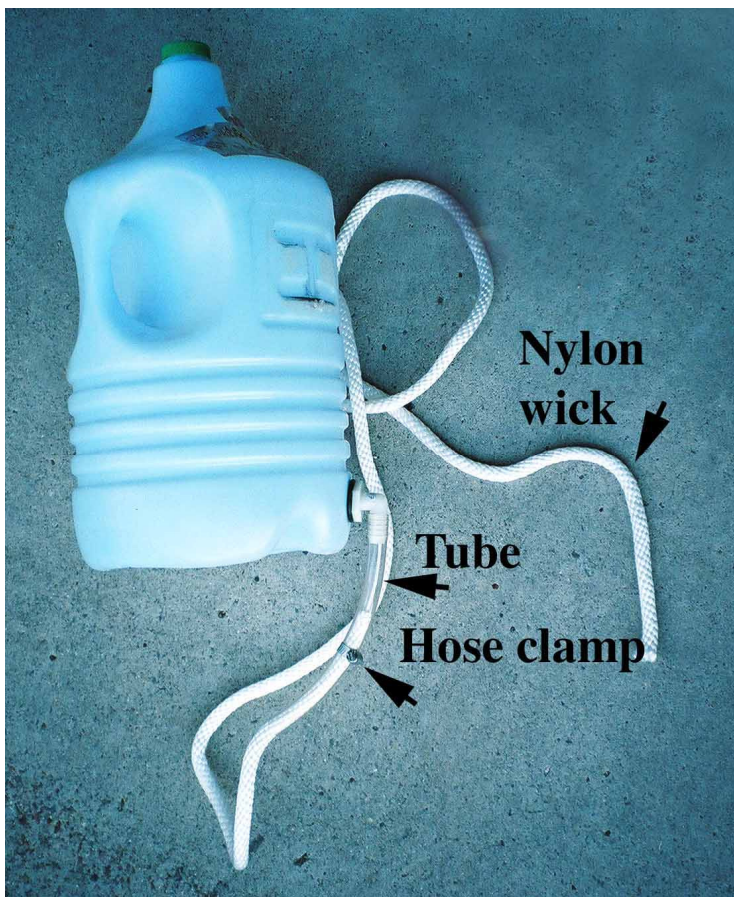
Figure 2. Buried clay pot irrigation, shown without lid. Rim painted white to reduce water loss and improve visibility.



Figure 3. Wicks



Capillary wick with Palo verde seedling



Gravity wick with 12 liter reservoir

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Figure 4. Porous capsule made with clay pots with 20 liter reservoir



Figure 5. Porous hose on 1 liter bottle, will be inserted vertically in soil, can also be attached to drill system as a super-emitter. Much less likely to clog.



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Figure 6. Perforated pipe, will be back filled and planted. Water truck fills standpipes periodically



Figure 7. Tree shelter, gravity wick, 20 liter reservoir, cage and growing tree



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Figure 8. Success in a climate with rainfall of only 7.5 cm year
Mesquite (*Prosopis glandulosa*) a multi-purpose tree crop

