CAPTURING RAINWATER TO REPLACE IRRIGATION WATER FOR LANDSCAPES: RAIN HARVESTING AND RAIN GARDENS

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Abstract. Capturing rainwater and using it for landscape watering needs is a reasonable and realistic way to reduce the use of potable water for landscape irrigation. This option has until recently not been given much consideration in humid climates such as Georgia. However, today water conservation is a critical issue for Georgia's growing population.

For many irrigated landscapes, harvesting of rainwater is a valuable alternative. An irrigation system coupled with a rain harvest system provides a source of irrigation water for all but the longest dry periods, and it reduces the amount of stormwater that moves offsite. Capturing stormwater during a storm and holding it on site to be used later for irrigation has many advantages. In Georgia, enough stormwater can be captured to significantly reduce or eliminate the need for potable water use in landscapes.

Harvesting and storing rainwater for irrigation uses is only one method to make better utilization of rainwater for landscapes. Rain gardens and bioretention areas are intentional low areas where runoff water from impervious surfaces is diverted and contained so that the runoff will infiltrate into the soil. Rain gardens are most often a feature in a residential or small landscape. The purpose of a rain garden is to create a more natural flow keeping stormwater on site to infiltrate and reducing the amount of stormwater that runs into streets and storm drains. Bioretention areas serve a similar function to rain gardens but tend to be located in larger commercial landscaped settings. They collect rainwater from roofs of commercial buildings and/or parking lots.

INTRODUCTION

In the US, outdoor water use is about 30 % on average of total residential potable water use (Vickers, 2001). The greatest demand for outdoor water use occurs during the hottest driest months of summer adding significantly to municipal peak water use periods. In Georgia, outdoor water use is a major component of the total demand for urban areas.

In Georgia's efforts to develop a water plan, water for landscape irrigation will most likely be low in priority for potable water supplies. However, landscape irrigation does not require potable water quality. Areas of Georgia get an average of 114-165 cm (45-65 inches) of water per annum. Captured rainwater is of suitable quality to be used for irrigation if the rainwater falls on relatively clean impermeable areas or landscaped areas.

Water captured on site and used for landscape irrigation also reduces the volume of stormwater runoff, a valuable water quality benefit. Utilizing captured rainwater for irrigation results in infiltration which provides a couple of benefits. Nutrients and other pollutants are removed as water moves through the soil, and groundwater is recharged. The water quality and conservation advantages of capturing rainwater for landscape irrigation makes it a viable alternative technology that needs to be considered in better site design.

This paper discusses two methods of utilizing captured rainwater onsite as a substitute for irrigation in urban landscapes. The first method is to capture rainwater in a cistern, tank or pond applied through watering hoses or irrigation systems. The second method is the use of rain gardens or bioretention areas to capture rainwater onsite as a part of a landscape design.

BACKGROUND AND RELATED WORK

Rainwater Harvesting and Storage Systems

An irrigation system coupled with a rain harvest system provides a source of irrigation water for all but the longest dry periods, and it reduces the amount of stormwater that moves offsite. Capturing stormwater during a storm and holding it on site to be used later for irrigation has many advantages. In Georgia, enough stormwater can be captured to significantly reduce or eliminate the need for potable water use in landscapes. Distributing and applying captured rainwater does not require the kind of plumbing code restrictions that graywater use does. Capturing the stormwater and applying it back to the soil is beneficial because it maintains the health of green spaces and the infiltrated irrigation water can provide recharge to groundwater.

The primary components of a rain harvesting system are the collection area, the transport system, filtration, storage, delivery and distribution. The collection area can be primarily impervious or a mix of green spaces and impervious surfaces. Areas with bare soil should not be collection areas because of the sediment that is entrained in the runoff.

Water is transported from the collection areas to storage through a combination of pipes and open channels. Storage can be an open pond or a storage tank of some kind. Storage tanks can be buried or above ground and can be made from many different kinds of materials. The storage tank material is not critical if the water is being used for landscape irrigation. Before entering the irrigation system suspended materials must be removed. Some settling will occur in storage, but further filtration may be needed. The degree of filtration is dependent on the amount of debris in the captured water and the irrigation equipment.

In some locations with enough elevation change, gravity may be sufficient for delivery of water to irrigation applicators, but this is typically not the case for pressurized irrigation systems. Low volume, low pressure microirrigation systems are best suited for many small landscape water distribution systems. Microirrigation systems will require less storage volume for the same area than sprinkler applicators. Harvested rainwater can also be siphoned from a tank and hand applied with hoses or watering cans.

If the surface the rainwater is captured from is fairly inert and clean, the quality of the stormwater will be suitable for irrigation without a lot of treatment to the water. The water does not contain the detergents and chemicals that graywater has.

A rain harvesting system will add some capital and operating costs as compared to using municipal water for irrigation, but if municipal water costs continue to rise and water utilities set up conservation fee structures, the payback period for rainwater harvesting could become minimal. Installing a rain harvest system is less expensive if it is a part of the initial design and construction of a building. Usually retrofit rain harvest systems are more expensive and may not fit in as well with the building design or overall site design.

Previous Research on Rainwater Harvesting

Research has investigated the reuse of stormwater at the neighborhood or community scale and results indicated that this kind of reuse is economically feasible. Mallory and Boland (1970) used a hydrologic and economical optimization model to evaluate the cost effectiveness of reuse of stormwater in communities using large detention ponds for storage. They evaluated untreated stormwater and stormwater treated to be potable for reuse. The untreated stormwater reuse systems required a dual distribution system which made it more expensive than non-reuse potable water systems. However, the untreated stormwater reuse system was comparable in cost to the treated stormwater reuse system. The untreated stormwater reuse system was 23 % more costly on a per dwelling unit basis than a conventional non-reuse water supply system.

Mitchell, Mein and McMahon (1996) evaluated the integrated reuse of stormwater and treated wastewater and found they could half the water supply demand with the installation of an integrated reuse system. Courtney (1997) modeled the operating policy of the University of Colorado's automatic irrigation systems and used the simulation model to estimate the amount of stormwater runoff that could be used for irrigation. The campus is about 60 % impervious. Results showed that much of the stormwater could be infiltrated through irrigation already in use on the campus.

Researchers have looked at less centralized reuse systems. Hermann et al. (1996) determined that rainwater harvesting from residential roofs into storage tanks could provide 30-50 % of the residential water demand while also reducing heavy metals in the stormwater not harvested by 5-25 %. Karpiscak, Foster and Schmidt (1990) give a detailed discussion of graywater reuse and stormwater reuse for a single residence in Tucson, AZ. Todd and Vittori (1997) provide several case studies on successful designs of rainwater harvesting systems.

Heaney, Wright and Sample (2000) developed a model for an individual residential property utilizing harvested rainwater for landscape irrigation. They described a method for evaluating the efficacy of on-site capture of stormwater for landscape irrigation use. They used this model for cities around the US including Atlanta. Using average monthly weather data for Atlanta, for a typical 140 square meter (1500 square foot) home with a garage on a 929 square meter (10,000 square foot) lot, the storage tank size that would use the most stormwater for irrigation was sized at 26.5 cubic meters (936 cubic feet). This study did not do an economic cost benefit analysis of rainwater harvesting versus use of municipal water for irrigation.

Rain Gardens and Bioretention Areas

Another excellent way to use captured rain water for landscape water needs is a rain garden or bioretention area. Rain gardens and bioretention areas are intentional low areas where runoff water from impervious surfaces is diverted and contained so that the runoff will infiltrate into the soil.

Rain gardens are most often a feature in a residential or small landscape. The purpose of a rain garden is to create a more natural flow keeping stormwater on site to infiltrate and reducing the amount of stormwater that runs into streets and storm drains. A rain garden collects stormwater runoff and filters it through soils and plant roots. The plants in the rain garden are designed to be an attractive landscape feature. Bioretention areas serve a similar function to rain gardens but tend to be located in larger commercial landscaped settings. They collect rainwater from roofs of commercial buildings and/or parking lots.

The predominate features of rain gardens are that they are an integral part of the landscape and water infiltrates into the soil. Water should stand in a rain garden no longer than 48 hours after the rain stops. Rain gardens should not increase mosquito populations because mosquitoes cannot complete their breeding cycle in this length of time.

Several states have included specifications for the design of rain gardens or bioretention areas in their stormwater management design manuals (Maryland Department of the Environment, NC Department of Environment and Natural Resources, Atlanta Regional Commission). Hunt and White (2001) provide a thorough discussion of the design process and appropriate uses of bioretention areas and rain gardens. Bannerman and Considine (2003) have developed an outstanding guide for homeowners on do-it-yourself rain gardens. The Clean Water Campaign (2003) published a guide for homeowners on creating rain gardens in Georgia with appropriate plants for Georgia's climate.

Because this is such a new stormwater management practice, the ability of various rain garden and bioretention area designs to remove pollutants has not been verified completely, but studies are on-going. Bioretention areas provide treatment by adsorbing metals and phosphorus in organic matter, biomass and soil, by killing harmful pathogens and by reducing sediments and nitrogen as captured stormwater infiltrates. However, too much sediment load can create a soil crust destroying the infiltration mechanism.

Bioretention areas often do not sufficiently remove nitrate-nitrogen. Hunt, Jarrett and Smith (2003) evaluated a design variation on a typical bioretention area by creating an anaerobic zone in the soil below the surface of the bioretention area. The purpose of the anaerobic zone was to provide conversion of more nitrate-nitrogen to nitrogen gas. Hunt, Jarrett and Smith (2003) did not find that the anaerobic zone had a significant effect on nitrate-nitrogen reduction.

Rain gardens typically do well in natural depression areas of the landscape. If the area is already a natural depression, runoff will tend to move towards it. However, rain gardens are not appropriate where the seasonal high water table is within 60 cm (24 inches) of the soil surface because the high water table will inhibit infiltration. Rain gardens should not be placed over the top of a septic system. While they should not be next to building foundations, rain gardens next to impervious features of the landscape such as driveways, patios and sidewalks are very helpful when they capture the runoff from these. A rain garden should be at least 3 meters (10 feet) from a house or other building foundation. Land that has more than a 12 % slope will likely need additional soil brought in and equipment to move the soil for the rain garden.

There are some other situations in which rain gardens are not suitable. A rain garden capturing runoff with a high sediment load or runoff that might be contaminated with hydrocarbons and other chemicals will not last for very long before toxicity or clogging makes the rain garden ineffective. For example, if a homeowner does a lot of car maintenance in a certain location on the driveway, runoff from the driveway should not be directed to a rain garden. The chemicals may be toxic to the plants as well as contaminating the soil in the rain garden.

Conjunctive Rain Harvesting – Rain Garden Systems

Rain harvesting tanks combined with rain gardens or bioretention areas can be an even better on-site stormwater reduction system than the use of either system independently. Both rainwater harvesting and rain gardens must have some overflow mechanism for larger volume storms or long-term rainfall patterns. Creating a rain garden downstream of a rainwater harvesting overflow can capture much of the overflow and make use of that additional stormwater for infiltration. Landscape and building designs can readily accommodate this combination of stormwater best management practices (BMPs) and be economical if this is a consideration in the initial design. Retrofitting a combination of the two BMPs at an established site may be more difficult and costly, but can still be workable.

CONCLUSIONS

Both rainwater harvesting and rain gardens lead to at least a partial restoration of the pre-development hydrology of an impervious urban area by increasing infiltration of stormwater. At the same time, both of these BMPs replace irrigation water needs that may previously have been met with potable municipal water or well water. These two alternatives for landscape water supply are win-win strategies that can be used in both commercial and residential site design to improve water quality and reduce the need for potable water use in landscape irrigation.

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