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The State of Sustainable Bioretention: Bridging Disciplines in Academia and Practice

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Abstract: Rain gardens are an effective Best Management Practice that reduce stormwater runoff, improve water quality, and contribute aesthetic value to urban settings. The more engineered a rain garden is, the less it replicates natural processes, and the less sustainable it is. Unfortunately, this design approach is common. In a time where solutions to environmental problems demand collaboration between disciplines, where are the horticulturalists, the plant scientists, in policy making? How can landscape designers address the aesthetics of ecology in urban areas?

Keywords: rain gardens, bioretention, experiential learning, research applied design, stormwater management

1. Introduction

Rain gardens (also called bioretention areas) are an effective Best Management Practice (BMP) in reducing stormwater runoff and filtering non-point source pollution of stormwater. Simply put, rain gardens are slightly sunken gardens that are sited to capture and filter storm water. The filter bed and plants both play parts in cleaning the water. A rain garden is typically comprised of four main elements: excavated bed (1), filter bed (2), plantings (3), and mulch (4). Rockery (5) might be included to reduce the velocity of stormwater entering the garden. A berm along the backside or low side (6) might also be incorporated to help retain stormwater if the garden is located on a slope (Kraus *et al* 2009).

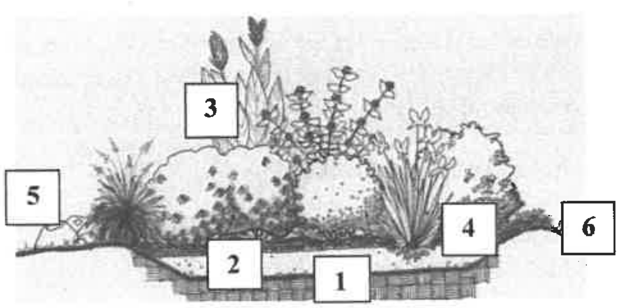

Fig. 1 Section Through a Rain Garden (drawn by author)

Rain gardens should be about five to ten percent of the total impervious square footage of a site to capture sufficient stormwater runoff. They can either be fairly shallow and cover more surface area, or have a smaller footprint with a deeper filter bed to collect greater volume. The term 'rain garden' is a bit of a misnomer. They are neither wetland gardens, nor dry gardens. Instead, they must survive, once established, on natural rainfall patterns. For many, this is often periodic deluges, followed by long periods of drought (Kraus *et al* 2009). Rain gardens are constructed in a variety of ways depending on the discipline – from the components of the filter bed, to the inclusion/exclusion of subsurface drainage systems, to the type of plants and planting design of the garden. Engineers tend to be more filter-bed oriented and concerned most with rapid infiltration, while horticulturalists are focused more on slower infiltration and the impact of plants.

1.1 Filter Bed

The most engineered method includes a filter bed constructed of 85% sand, 10-12% clay or silt, and 3-5% organic matter (Perrin et *al* 2009). This creates a very high infiltration rate, but most commonly an underdrain is installed at the base of the filter bed. The underdrain is connected to the storm drain system. Due to this set up, stormwater runs through the filter bed rapidly, into the storm drain and outlets into the nearest creek or stream. This filter bed has low Cation Exchange Capacity (CEC) which means that pollutants do not bind as readily to the particles. Hand in hand with this is the fact that plants need water in the soil long enough to uptake it and redeposit it to solubilize nutrients in the filter bed. If water moves through the filter bed too fast, plants might not be able to perform this function. It is also more expensive to build (often existing soil is hauled away and all new filter bed materials are brought in to site). Because of all of these factors, this type of filter bed does not support plant life over long run, and is less sustainable.

Horticulturalists, champions for plants, often prefer a filter bed made of part native/extant soil and part compost or Permatill™ (expanded shale). Both amendments improve infiltration, but compost allows the water to infiltrate slowly, giving plants an opportunity to absorb the water and nutrients/pollutants. Compost and Permatill™ have higher CEC than sand, allowing more nutrients to bind to soil particles. Compost also provides nutrients for plants and incorporates microbial activity into the filter bed. Microbes are key players in breaking down pollutants in soil. Detractors of this method are concerned about the use of organic matter leaching into the storm drain as well as its short-lasting nature.

1.2 Plant Material

Countless resources and guides specify that native plants should be used in rain gardens because they are adapted for a given area. The problem with this is that a rain garden in an urban setting is not at all natural. Additionally, in the case of engineered rain gardens made of mainly sand, specifying native plants for a region (which might require soils other than sand) sets up an unsustainable model. While many extension publications state that a horticulturalist should be consulted for plant selection, it is doubtful that occurs regularly.

Planting amounts and style are quite varied. Engineers will plant sparingly, partly to retain as much sunlight as possible reaching the rain garden to help kill off bacteria (Hunt et *al* 2009), and partly because they do not know the growth characteristics of the plants (Woodward 2010). Landscape designers and architects will plant more heavily based on principles of good design and horticultural practices.

1.3 Aesthetics

Despite the profession's interest in ecological design and using native plants, there is another hotly contested issue—the issue of aesthetics. While professionals are bending over backwards recreating natural systems in urban areas, public reception is luke warm. Research has shown that the majority of the general population does not find native landscapes/ecological landscapes aesthetically pleasing (Nassauer 1988). When people choose to spend time in natural settings, they anticipate and expect nature. In an urban center of daily life, however, people want/need landscapes to look as if they have been built by humans—orderly, neat, controlled. When informally polled about landscapes they found attractive, the majority of students responded not with the qualifiers one might expect such as "beautiful" and "colorful". Instead, most students were drawn to landscapes they described as "neat" and "clean". Additionally, most rain garden images available show designs predominantly of perennials plantings, taken (of course) in summer, when they look their most attractive. What is rarely shown (if at all) is what these gardens look like in winter (typically barren). Planting designers understand that for gardens to be attractive year-round, there must either be a mix of plant types (deciduous, evergreen, and perennial) or substantial amounts of perennials that still retain their structure in winter (e.g. ornamental grasses, where the foliage goes dormant, but the size, habit, some color, and movement remain intact). In fact, this is why I was first brought on my current collaborative team: a local municipality realized the importance of rain gardens, but did not like the aesthetics of what they had seen so far: "If this type of BMP is weedy looking, then we don't want them." they said (Beggs 2010).

At some point rain garden aesthetics and function overlap. Perennial root systems grow during the summer months, taking up nutrients and pollutants; woody plants put out root growth in the fall and winter. Here in North Carolina we receive approximately 42" of rain a year, fairly evenly distributed between the seasons, so it is important to have plants working to uptake nutrients and pollutants year round.

In my opinion, the best rain gardens currently being designed and built in the United States are in Portland, Oregon. They are city-funded projects, headed up by plant-savvy landscape architects. They are exemplary because they function well (in terms of capturing large amounts of runoff and reducing the amount entering the underground storm drain system), they are gorgeous year round (due to diversity of plant types), require little management, and they still look attractive, even years after installation (Perry et *al* 2012).

2. Challenge Tackled

A major problem is still the lack of collaboration between disciplines, both in the private sector as well as academic sector. It is very common for horticultural academics and engineer academics to rely only on their respective professional journals, resulting in the left hand not talking to the right.

One area where design professionals have always excelled is identifying a given problem, determining the best people needed to solve problems, and bringing those people together as a collaborative team.

The biggest issue is education. More specifically, *how* we educate, and *who* we educate—students, professionals in other disciplines, policy makers, municipalities, and homeowners all need this information. Students often learn greater lessons, and longer lasting lessons from experiential learning projects--hands on learning, learning by doing. Additionally, service-learning projects, those projects were lessons are learned through projects involving a real client and/or community outreach are extremely valuable for students. It allows them to apply lessons they've learned in the classroom to a real project.

In the university setting, we are able to utilize the latest (and even on-going) research in our teaching. In design classes we can take this one step further and teach students the importance of applied research to design. The incorporation a design/build opportunity for students allows them to experience firsthand the entire the design process--from site visit and client meeting to design development to design installation.

Outreach projects can show students real world challenges that they might not otherwise be prepared for when they enter the profession. Students not only apply design skills, but are often in a position where they need to educate others. Students gain an invaluable foundation in the classroom, utilize research to strengthen their designs, practice communication and education skills, and then evaluate the whole process. These are skills which they will utilize their entire careers.

3. Approach Applied

To tackle the challenge of greater collaboration, idea sharing, problem solving and education of a wide audience, I cast a wide net and looked to bring together and overlap all the groups – professionals, communities, and students – that I work with.

3.1 Professional Design Collaboration

We are fortunate on our campus to have a unique office called Watershed Education for Communities and Officials (WECO). Their job is to partner appropriate university faculty with the community and facilitate outreach projects. For the past several years WECO has been targeting one community within the Black Creek watershed. They began by working with biological and agricultural engineers, then added me (a landscape designer/architect) for the aesthetic component and planting expertise. Since 2010 we have designed and built several projects on public greenways, private yards, and public school grounds. The biggest area of contention was the engineer and I finding some middle ground on the best way to construct the filter bed. This engineer was not at all concerned about the plants in one rain garden we built at a grade school: "Of the entire project, the plants were the smallest expense. If they die, it's no big deal." But it is: a rain garden functions better with plants. It is more attractive with plants. Plus, the garden was installed with external grant money. The school has no funds to replant. Not to mention the principal, teachers and students at the school were so excited about the garden project. If it died, they would have been devastated. If the plants died the city would be less and less inclined to support rain gardens as a way of managing runoff. So to have the attitude that plants aren't that important does not promote sustainability. We finally came to an agreement that we would layer filter bed media - the standard bioretention mix on the bottom, more existing soil and compost in the top where it's available for plants. In some cases the rain garden is not large enough (deep enough) for layering media for the engineer to feel comfortable, so we use the standard bioretention mix with a modest amount of compost when we plant each plant in the garden. Regardless of the filter bed, the gardens are always mulched, which will provide a slow, but steady stream of organic matter for the plants. The collaborative groups have held many workshops focusing on ways to reduce storm water runoff at the residential scale for homeowners. Most recently, we have published a series of fact sheets about rainscaping techniques that are geared specifically for homeowners.

3.2 Teaching

This past semester I incorporated a current WECO project to my class as a learning vehicle. Horticulture and Landscape Architecture students in an upper level planting design course in the Department of Horticultural Sciences at North Carolina State University learned about rain gardens in a variety of methods this semester.

3.2.1 The Introduction

Students were given an overview of rain gardens in a classroom lecture. The importance of rain gardens was discussed as was properly locating and relating the garden to the larger landscape. Different construction methodologies were covered as were appropriate plant choices. The lecture was also used to show good and bad examples of built rain gardens in the United States, as well as stimulate a discussion about the different approaches to construction and planting and the students' role/responsibility to bringing their expertise to the table when they enter the professional arena.

3.2.2 In-Class Research

To focus just on the plant palette and needed research, the students were then given a hypothetical site project. Half of the class was told the site had wet or consistently moist soils; the other half was told the site had dry soils. All other environmental factors were the same. The students then had to research appropriate plants for their sites. The lists they developed were then cross-checked and the species that appeared on both lists (that were suitable for dry as well as wet soils) were compiled as potentially appropriate species for rain gardens.

3.2.3 Observation

Although images of rain gardens were shown in the lecture, there is no substitute for seeing gardens first hand. Students were taken to several rain gardens in the area to practice their critical thinking skills by assessing garden placement, analyze storm water entry into the garden, study planting design of the garden, identify and critique plant species used, assess apparent functionality/effectiveness and rate overall aesthetics.

3.2.4 Application

With a solid foundation in rain garden design, students were then given a real rain garden design/build project at a local elementary school. This was part of the WECO Black Creek Watershed Collaborative Project, so an engineer had already done the calculations for storm water catchment and underdrain system, placement, and garden shape. Regardless, students were instructed to study the site on their own, and double check garden placement and shape. They could either incorporate the engineer's garden layout, or design a new shape, as long as it captured the same amount of runoff. Each student developed their own design and presented to the clients (members of WECO group and the Northwoods Elementary Parent/Teacher Association). The students took the feedback they received and collaborated as a design team to combine the best ideas into one final design for the client as shown below in figure 2.

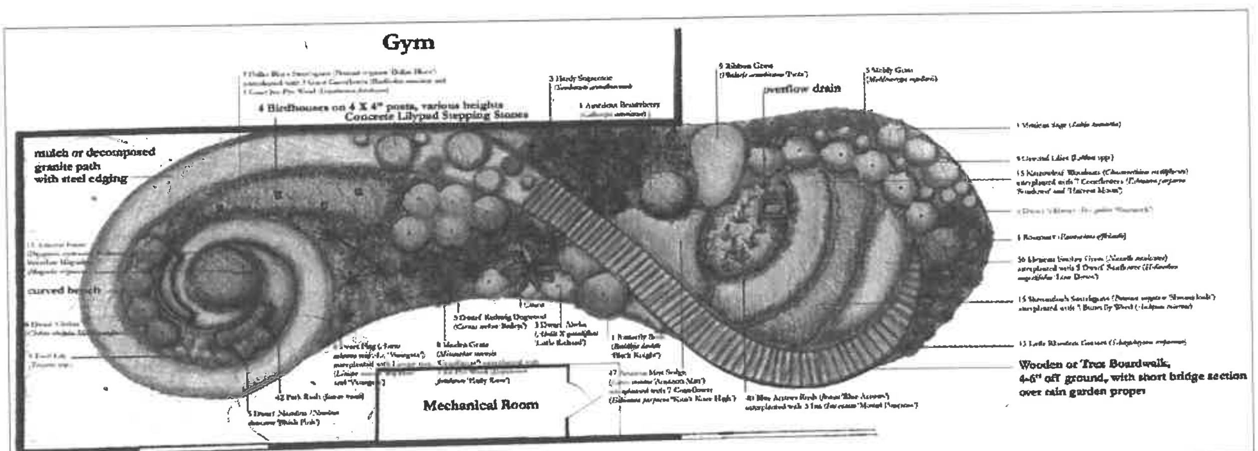

Fig. 2 Northwoods Elementary School Rain Garden and surrounding planting, designed by horticulture and landscape architecture students at North Carolina State University, Department of Horticultural Sciences, Fall 2012.

3.2.5 Culmination

Students saw their ideas come to life during the installation of the garden a few weeks later. Installation was made possible with grant monies from the Environmental Protection Agency (EPA), a donation from an ornamental grass nursery, and hardscape material donations from parents of the elementary school children. After the excavation, installation of the underdrain, and building of the filter bed by the engineer and contractor, the garden proper was built by my students, myself, and a small group of volunteers from WECO and the elementary school (parents, teachers, and even some young students).

Some students have spent their entire design education in a classroom, so to see how their ideas grow from a mental idea, to developed design on paper, to actual installation was the best learning experience they had ever had, and they got to see how people reacted to their design ideas, which was incredibly rewarding.

3.3 Innovative Research

In addition to undergraduate teaching, I also supervise graduate research. Rain garden research to date has typically been conducted within individual disciplines. In 2009, however, a multidisciplinary research committee formed to help a master's student in the Department of Horticultural Sciences at NC State University with a rain garden project. The student's committee was comprised of four horticulturalists (a soil scientist, 2 nursery management and media specialists, and a landscape designer) and one biological and agricultural engineer. The student successfully conducted an ambitious study comparing three different filter bed mediums (standard bioretention mix, soil and compost mix, and Permatill™) for infiltration rates, nutrient leaching, etc. She also tested the performance of several native plant species and cultivars of those species (technically non-native) in the different filter beds (Pledger 2012).

Just as important as the research findings was the collaborative process experienced by everyone involved. That one project (and subsequent publications) will undoubtedly lay the groundwork for future interdisciplinary collaborations.

4. Conclusion

This paper focused on rain gardens, but the lessons of collaboration and education of wide ranging audiences can be applied to almost any environmental design challenge requiring creative problem solving skills.

Major lessons learned include the fact that individual disciplines are not well-equipped to solve environmental problems. Every team should be collaborative for the greatest depth and breadth of creative problem solving. Collaboration is a necessary skill that should be part of any teaching curriculum. Even contentious discussions can become teachable moments. Faculty who have roles in both the professional realm as well as academic setting should strongly consider overlapping the two as doing so provides the greatest opportunity for education.

In summary, environmental problems are solved best by collaborating disciplines. Students should be exposed to research-driven design, critical thinking skills, and the art of collaboration early.

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This book is about imagination, quite simply because responsible management of the ensemble of natural and cultural phenomena surrounding us, which we call landscape, requires imagination. Landscape – unlike land – cannot be owned, unless it is by all of us commonly. This requires us to come to terms with each other for its proper management. Landscape, however, is not just a physical object that can be described and measured; landscape exists because we experience it, we participate in it. In fact, we shape the landscape with our hands and in our minds. To communicate about this landscape we need imagination, both in everyday life and in education.

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