Modern Landscaping: Aesthetically Pleasing Yet Water Conservative

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Abstract

Water is one of the most precious resources on earth, and irrigation is internationally one of the most wasteful uses of water. Traditional methods of irrigation, such as watering by hand or sprinklers, contribute to the waste of water through evaporation and runoff. A recent method of irrigation called drip irrigation involves laying water-emitting tubes on the ground or directly below the soil surface. To test the idea that a drip system is more efficient than hand watering, the researcher simulated a drip-line-watered environment and a hand-watered environment. Both environments had equal amounts of soil, weighed by a triple beam scale; both were exposed to the same temperature and equal sunlight for an hour, and at the end of the hour, the hand-watered environment had allowed more water to evaporate than the drip line environment. Physical landscape features also contributes to water waste by allowing runoff and soil erosion. The researcher built models of a slope and a terrace to test which would allow more soil erosion when equal amounts of water were poured at the top. When the experiment was finished, the researcher was able to conclude that terraces slow the rate of runoff and reduce soil erosion.

The use of mathematics to create visually pleasing proportions in landscaping has existed for centuries. The most famous of proportions in landscaping is the Fibonacci sequence (in which each component is the sum of the previous two components), whose adjacent components create pleasing dimensions and attractive ratios. After researching these ratios and other mathematical ideas that visually enhance a closed space, the researcher designed a blueprint of a 39 x 63 foot formal garden in a way that was both visually pleasing and utilized the water-conserving concepts researched and tested.

Background

Water Conservation in Landscaping

In the current environmental atmosphere, water has quickly risen among the ranks as one of the most precious substances on earth. Yet it is still wasted by the billions of gallons every day, particularly in wealthy countries such as the United States. Approximately 7.8 billion gallons of the 26 billion gallons of water used daily in the U.S. is spent for outdoor purposes, according to the U.S. Geological Survey. The average suburban landscape itself utilizes close to 10,000 gallons of water, excluding rainwater (“Water Efficient Landscaping”, n.d.).

Irrigation is the main source of outdoor water expenditure, and improper or careless irrigation often results in enormous water loss. Depending on the type of soil, state of the plants, recent weather, and the season, a different strategy must be used to irrigate with the least amount of evaporation or runoff, while ensuring that the plants receive the necessary amount of water. Irrigation based on individual circumstances rather than rigid schedule reduces water consumption and increases water-efficiency (“Water Efficient Landscaping”, n.d.).

The U.S. Environmental Protection Agency writes, “According to the AWWA Research Foundation’s outdoor end use study, households that manually water with a hose typically use 33% less water outdoors than the average household.” Households that used in-ground sprinklers, sprinklers with automatic timers, and even drip irrigation systems used more water than those without automatic systems, although those with drip irrigation systems were over the average by a smaller percent than the other two categories. This is attributed to the truth that those households with automatic systems were likely to neglect the individual needs of different plants, which results in water waste since most average plants do not need daily watering.

Systems such as the drip irrigation system are theoretically more efficient than hand watering, but without conscious monitoring and operation, these systems are just as water-consumptive as traditional methods (“Water Efficient Landscaping”, n.d.).

The most efficient way to organize an irrigation system is to divide and conquer – literally. By dividing the landscape into zones of high-water-use, low-water-use, and moderate-water-use plants, several irrigation programs can be designed to water each zone according to individual needs (“A Home Owner’s Guide”, 2006). Established trees only need watering every other month, but in particularly dry situations, watering trees can be allowed when the top 4 to 6 inches of soil are dry. Shrubs need watering once a week, and small plants need watering once every two weeks. Both may be watered when more than 2 to 3 inches of topsoil are dry. Turf grasses are among the most high-maintenance plants since they are sensitive to climatic changes and need five to three days of watering depending on the soil type (“Irrigation Controller”, n.d.). Thus it is advisable to use gravel or mulch to cover ground where turf has no practical or aesthetic purpose. Both help save water by reducing irrigation area, encouraging water retention, and preventing evaporation from the soil beneath (Erler, 2005).

Drip irrigation is one particular method of irrigation that is becoming increasingly popular. This system delivers water at a slower rate than other systems and can be 30 to 50 percent more efficient than traditional sprinkler systems. Pipes with low-flow emitters are laid along the ground near the plants or underground to form a drip irrigation system; these systems are so simple that even industrious homeowners often create and install drip systems. Drip lines reduce runoff and erosion and even prevent plant disease by not overwatering. The drip lines have the advantage of delivering water right at the roots of the plant, while other systems tend to splatter water where it is not needed as well as where it is. Drip systems with automatic irrigation controls can coordinate several watering schedules for different drip lines and are perhaps one of the most water-conservative irrigation plans (“A Home Owner’s Guide”, 2006).

The physical landscape itself can be designed to be water-conscious. Steep hills occurring in the natural landscape can be a serious source of water run-off and soil erosion during watering or rainfall, especially if the hill is void of deep-rooted plants. Terracing a hill can break the long, smooth curve of a hill into a series of shorter, more level steps. This prevents run-off and erosion because the flow of soil and water is interrupted by flat surfaces, which also allows rain to soak more deeply into the soil rather than simply flowing off the surface (“In Your Backyard”, 2010.).

Aesthetics in Landscaping

Mathematics plays a prominent role in aesthetically pleasing forms of landscapes, such as with the use of certain ratios, the most familiar being the Fibonacci sequence. Few realize, however, that landscape architects use these age-old ratios in their plans and designs to this day.

In 1202, Leonardo Fibonacci, otherwise known as Leonardo of Pisa, discovered a truly wondrous series of numbers. In this Fibonacci sequence, every individual component is the sum of the two numbers preceding it. Thus the start of the sequence would be 0,1,1,2,3,5,8,13,21,34, 55, etc. According to this formula, a well-balanced space has dimensions that are adjacent numbers in the sequence, so dimensions such as 8 x 13 or 21 x 34, would be the most aesthetically pleasing. The Fibonacci sequence is even found in nature itself: in natural growth patterns, the distribution of branches and leaves, seed arrangement in pine cones and sunflowers, and even flower petal configurations (Erler, 2005). One important aspect of landscaping is the delicate balance between the height of certain components and the depth of the surrounding components. Catriona Tudor Erler (2005) writes that most landscape architects suggest that the depth of a border be at least two-thirds the height of the structure directly behind it: “According to that rule, a border planted in front of a 6-foot tall fence or hedge should be at least 4 feet deep, measurements close to the proportions in Fibonacci’s number series (4:6 = 2:3)” (pg 35).

Not only must the structural parts of a garden be properly proportioned, but the smaller individual aspects must also be determined with consideration to size and depth. Even with smaller or more confining spaces, it is generally wise to try to use the mass and stature of a single large feature and use it as a reference for the rest of the plantings. By varying plant heights and textures, one can achieve a great sense of depth in a landscape. Planting tall species then adding layers of successively shorter species in front of it, ending with small, low-growing shrubs or edging plants can visually enlarge the space. Even the texture of the leaves of a plant can impact the way a space is perceived; small, fine leaves add the illusion of distance, while large, coarse leaves shorten the distance. Therefore placing fine-leafed shrubs in the forefront will add depth as well. Adding a vertical element such as a trellis or arbor can also help draw the eye away from boundaries and make a confined space look larger (Erler, 2000).

Yet another way to maximize the size of a property is to take advantage of the diagonal. Since the diagonal is the longest dimension in square and rectangular gardens, designs that emphasize this angle by creating a vista, which is an avenue or line of sight that allows a distant view, elongate the area and create the illusion of a longer space (Erler, 2005).

Formal style, which is based on straight lines, geometric forms, symmetry, and a central axis, has a definite sense of structure and order. These gardens create intellectual interest and take advantage of pleasing proportions and elegant lines. This classic style is less dependent on seasonally active plants and easily maintains beauty throughout the year. The informal style of landscape is much less defined; it is an abstract art and is designed with curving lines that attempt to mimic nature. These tend to be more difficult to design since there is no sense of solid structure and the focus is on rhythm and flow rather than sculptural form (Erler, 2000).

Research Question:

How can I use mathematics to further understand and reinforce certain water-conserving ideas as well as create an aesthetically pleasing landscape?

Methods

I first collected a sample of soil from an empty lot in a neighborhood. I chose this location for my samples to ensure that the soil was not imported from elsewhere in the country or supplemented by artificial fertilizers, since I wanted the experiment to measure the effectiveness of two types of irrigation on natural soil, in this case, from the Piedmont of North Carolina. Soil from the Piedmont generally has high clay content, and I could safely conclude that my sample was a clay loam, which also meant that its water absorption rate would be very slow. I thoroughly mixed my sample to keep the soil composition homogenized throughout. I measured soil samples of equal weight and poured one sample into Tub 1, which represented hand-watered soil. Tub 2, representing drip-line-watered soil, would be filled later.

To emulate hand watering evenly, I punctured a small Ziploc bag with six evenly spaced holes to be a “watering can,” which I would use to distribute water evenly over Tub 1. To design a drip irrigation system, I first took a thin plastic tube and stopped one end with modeling clay and covered that with an electric taped stopper. I then punctured holes approximately 4 inches apart in the tube. These holes allowed water to seep out slowly and steadily, imitating the emitters in a real drip irrigation system. I inserted a funnel into the open end of the tube so that I could pour water in without leaks or spills. Then I wound the pipe evenly along the bottom of Tub 2 and taped there using electrical tape.

I then spread one soil sample out on the bottom of Tub 2. I placed both tubs outside in front of the Hawthorn Dormitories at UNCC in full sunlight and recorded the temperature, and allowed for one hour of irrigation and evaporation. The first step was to pour 400 mL into each tub using either the Ziploc-watering can or the funnel-and-pipe drip line. I had begun the timing for one hour at the moment the individual irrigation processes started. When the hour was over, I weighed the dirt from Tub 1 and Tub 2 to find the new weights of the wet soil. Since 1 gram of water is 1 mL of water, I used subtraction to find the volume of water remaining and lost.

The first limitation was that I did not have access to a digital scale, so my measurements had to be done on a triple beam balance using a small measuring cup to hold soil, which severely slowed down the process. When I was re-weighing the wet soil, my measurements would have been more accurate if I could have weighed the entire tubs, wet soil and all, and then subtracted the weights of the emptied and cleaned tubs and/or the drip lines. But although some soil must have been lost in the process, the results were clear enough that the slight mathematical inaccuracies did not affect the final conclusion. The time frame was limited, so I had to design the experiment to finish in quickly, so that during the rest of the class I could measure and calculate the proper figures. If I had had more time to both design and conduct the experiment, I would have used longer periods of time, a more sophisticated drip line, and more soil per tub.

Slopes vs. Terraces: Which Allows More Erosion?

I decided to create a model slope and terrace to test the well-known idea that terraces help prevent soil erosion as a result of causing less runoff. My first step was to wood glue together 4 sheets of Styrofoam to create a block. Then I penciled the dimensions of a terrace with four steps. Each step was 1 inch tall, 1.5 inches deep, and 6 inches across in width. Using a combination of a handsaw and a box cutter, I cut away at the Styrofoam block and created a model terrace. I turned the remaining piece upside down and carved as large a slope as I could. The bottom was 11 inches x 6 inches, and the slope was carved to imitate the angle of the terrace, although I did not attempt to carve precisely, since no slope would follow a single angle from crest to valley.

I decided to test out the slope first, so I measured out two quantities of precisely 325 grams of soil (pebbles included) and spread it out carefully on the Styrofoam slope and terrace. I kept a plastic lid underneath both models to catch the runoff and eroded soil, since the experiment was conducted indoors. After filling two beakers with 200 mL of water each, I poured the water from one beaker slowly on the top of the slope and watched soil and water run down the slope, leaving several large spots void of soil. I videotaped the experiment in order to collect qualitative data afterward. The weight of the remaining soil was drenched, so I could not weigh it and calculate erosion or runoff. After I had cleaned off the slope and the lid, I repeated the process with the terrace. This time however, there were no gaping white spots where the soil had fully washed away, although there was some runoff and erosion.

I experienced the several limitations as the irrigation system experiment went underway. I had similar problems with imprecise measurement, although the triple beam balance was tolerable for this round of experimentation since we only needed one measuring cup full of soil per Styrofoam model. The tools I used to cut the Styrofoam with were also rather imprecise, and I highly doubt that the cuts were straight even though I followed penciled dimensions.

Aesthetically Conservative Landscaping

After I had finished my first two mini-experiments that supported my research, I decided to put my newfound knowledge to the test and create a simple blueprint of a landscape that utilized the mathematical ideas of design as well as the water-conserving techniques that I had learned and tested. I set a few guidelines for myself to ensure that my blueprint would include the ideas and information I researched. I decided to design a blueprint that included the following: trees, shrubs, small plants, and turf; at least one walking path, more than one gravel or mulched area, at least one terraced feature, an efficient watering system, an environmentally-friendly drainage system, at least three uses of the Fibonacci sequence or its ratios, at least two instances of taking advantage of perspective or depth, symmetry, and a central axis. Since symmetry and the use of a central axis appealed to me, I chose to design a formal garden.

Results

Drip Irrigation System vs. Hand Watering: Which is More Water-Conserving?

	Temperature	Original Mass	Original Volume of Water	New Weight of Wet Soil	Volume of Water Remaining	Volume of Water Lost
Tub 1 Soil	36.5°C	2802.3 grams	400 mL	2991 grams	188.7 mL	211.3 mL
Tub 2 Soil	36.5° C	2802.3 grams	400 mL	3020 grams	217.7 mL	182.3 mL

Visually, the difference between the two systems simulated by the two tubs was not astounding; in fact it was rather worrying. Upon examination, the soil in Tub 2 appeared to be drier than that in Tub 1, which appeared to be soaked. Based upon appearances only, I would have inferred incorrectly that Tub 1 retained more water than Tub 2. Clearly, however, Tub 2 did retain more water than Tub 1 did. Tub 2, the drip irrigation system model, retained 54.425% of the original amount of water, while Tub 1, the hand watering method model, retained 47.175% of the original amount of water. The difference between the two was not extreme, yet it was significant enough to prove that one method is at least slightly better than the other.

Slopes vs. Terraces: Which Allows for More Erosion?

When the slopes were tested, I noticed that the downward flow of the water and soil was rather fast. By the time the 200 mL were completely spent, there were large areas that were completely bare of soil altogether, exposing the white Styrofoam slope. However, when the terraces were tested, although some water and soil did flow off the surfaces, no soil-covered areas became exposed in the process. No part of the terrace that had originally been covered with soil became completely void of soil. The water/soil flow over the terraces was visibly slower than the flow of water/soil over the slopes.

Aesthetically Pleasing Landscaping

I designed a plot of land that would be suitable for a neighborhood commons area or a community garden. The plot is elongated like the empty plots located between two houses that are too narrow or unsuitable to build upon. Usually such land is simply wasted or covered with turf grasses, but with my plan, the wasted land can be turned into a beautiful garden. In the Appendix A, the areas labeled 10, 11, and 17 are trees; the areas labeled 3, 12, 14, and 16 are shrubs; areas labeled 4, 5, 13, and 15 are small plants. Area 1 is a walkway and patio; areas numbered 18 are mulched areas; areas labeled 9.1 through 9.4 are the four steps of a terraced area. The watering system for the garden is a drip irrigation system, but there are six different watering schedules: for the trees, hedges, side flower beds, turf area, small plants by the walking path, and the terraces. The back end of the lot is on a slope, as is often the case with plots not suitable for building, and so that whole area is terraced, and the non-terraced corners have two trees planted to keep the soil rooted in place. The lowest point in the entire lot is the pool, so any runoff naturally drains into the pool. During and after rain, if the pool overflows with water, the extra water simply flows over and through the half-foot-wide metal grate border, under which a system of pipes deposits the wasted water in a reservoir tank, which sends the water through the drip irrigation system. The dimensions of the entire plot are adjacent components of the Fibonacci sequence: 13 yds x 21 yds. The depth of the hedges is 4 feet and the height of the fence is 6 feet tall, which forms a 2:3 Fibonacci ratio and follows the rules of balancing height and depth. The dimensions of the oval pool are a Fibonacci sequence: at the widest point of the pool is 9 feet wide, and at the longest point, the length of is 15 feet wide, meaning that the width and length of the pool are at a 3:5 ratio. Depth is created by layering different textures and heights in front of each other. One example of layering different heights and textures would be the way in which areas 16, 15, 14, 13, and 12 become successfully shorter towards the front. The different textures are evident in that the plants by the walking path alternate between fine-leafed shrubs and flowering plants. Side flower beds (area 4) are about 2 feet high, and the height of the green groundcover plants (area 5) is 1 foot tall, fitting the category of layered textures and sizes, and also fitting a 2:1 Fibonacci ratio. I designed the central walking path to be a long rectangle in order to create a vista that would elongate the area and expand the space. The wide patio area at the front of the plot also narrows gently into the path in order to give the whole space a more open feel. The garden is perfectly symmetrical, and the central axis lies 19.5 feet from either side of the garden and runs straight from the front of the garden to the back.

Conclusion

Drip Irrigation System vs. Hand Watering: Which is More Water-Conserving?

This experiment did indeed prove that a drip irrigation system is more water-efficient than hand watering and reduces evaporation and water waste. While the figures were not overwhelming, the difference of 7.25% in the percent of water retained was significant enough to accept that drip lines are more water-efficient than irrigation by hand. The experiment also modeled both methods rather accurately: the drip lines did indeed take much longer to distribute the whole 400 mL than the hand watering did. If time were not an issue, I would have liked to test and compare the efficiencies of different layouts of the drip lines, different emitter hole spacings, different water pressures, etc. If I had had the resources to do so, I would have even attempted to test soil with turf grass versus soil with deeper rooted plants, sprinkler systems versus drip irrigation systems, and underground lines versus above-ground lines.

Slopes vs. Terraces: Which Allows for More Erosion?

This particular experiment was successful, although I only had qualitative observations for data. I was hoping to prove the idea that terraces allow less runoff and erosion, and I achieved that: there was a clear, definite difference between the runoff and erosion of the sloped surface and the terraced surface. The terraced surface clearly slowed down the flow of water, and the slower speed was most definitely the reason less soil was washed away. This must have been because of the four separate, broken horizontal planes. The sloped surface allowed water to flow easily and quickly with nothing to stop it from carrying away plenty of soil. All in all, the experiment supported the common knowledge that terraced areas help prevent erosion and runoff and that slopes provide a surface that allows and encourages erosion and runoff.

The experiment was not realistic in that the soil was only loosely, albeit carefully, set on Styrofoam, whereas in real life the soil would be compacted together and would not have flowed off the surface so easily. I would have preferred to have designed a system that could have allowed me to measure the runoff or eroded soil so that I could have exact figures that would provide a foundation for a solid conclusion. It occurred to me afterwards to collect the washed off wet soil from the lid, weigh it, and bake the soil, after which I could weight it again and calculate the water runoff. Unfortunately, since I did not consider that possibility, microwaves and ovens were not on my supply list. I am also interested in finding out how different root systems and different types of growth would affect the rates of runoff and erosion.

Aesthetically Pleasing Landscaping

I was successfully able to apply theoretical mathematics and practical science to create a visually appealing yet water-wise landscape that took advantage of land that would be wasted. If I had had enough time, I would have liked to have learned how to use software that could create a 3-dimensional model of the landscape, since it is difficult to visualize the slopes and terraces on a blueprint. Having said that, I was truly satisfied that I was able to bring together beauty and practicality to create a feasible landscape design.

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