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A Case for "Green Water" Projects
In Distributed Green Nature-Based Infrastructure Policies

The following is a brief discussion of four landscape related concepts that G3 believes should be considered in the descriptions of distributed "green" infrastructure projects with multiple benefits.

1) Watershed Approach to landscaping and the Soil Sponge
2) "Green" Water Zone
3) Precipitation and Green Water
4) Metrics for evaluating landscaping projects

Watershed Approach (WA) to Landscaping

This whole-systems approach to landscaping converts areas that generally are considered "***ornamental***" into multi-benefit environmental solutions by emphasizing the function of the design, installation and management of the land over the aesthetics. The WA focuses on ***soil health*** and ***rainwater capture*** in addition to plants and irrigation, while the ornamental-only approach to landscaping focuses on plants and irrigation systems with little consideration for soil health and rainwater. Through the WA, landscapes become a vital resilience-building tool for both water cycle and carbon cycle management.

The WA is so-called because the principles of watershed management, well understood by all water policy managers, are scaled to become relevant to every land parcel, regardless of size or land use (*epa.gov/nps/watershed-approach*). Defined by the EPA, a watershed is:

> ***An area of land that drains to a common waterway, such as a stream, lake, estuary, wetland, aquifer, or even the ocean.***

With this definition, any area of land, every property (every front or back yard, every roof top), can be described and regenerated as a "***mini-watershed***" using agreed upon best management practices. When aggregated, landscapes utilizing the WA restore urban environments. The following WA to landscaping standards are applicable on public or private property and enable the harnessing of private investment that ordinarily is spent on ornamental gardens.

1) Creating a healthy living soil "sponge"
2) Contouring for rainwater retention
3) Selecting climate-appropriate plants
4) Using highly efficient irrigation only as needed

The way water is regulated in the plant/soil system is described through the concept of "***Plant Available Water***." This is the key concept in irrigation management. Plant Available Water (PAW) is the soil water reservoir held within the root zone of plants. The greater the root zone area, the greater is the soil water reservoir (*cimis.water.ca.gov/Resources/aspx*).

PAW is depleted through Evapotranspiration (ET), a leafy plant's transfer of water vapor and oxygen into the atmosphere as a response to solar radiation (photosynthesis). When water is applied to the soil, it refills the PAW, and maintains the soil oxygen/water balance. Maintaining the oxygen/water balance is critical for healthy plant root growth and for supporting the microbial community that sequesters carbon in the soil and maintains good "spongey" soil structure. This is the justification for irrigation, but the water might just as easily be applied by precipitation.

Soil microbes require great amounts of organic carbon to grow large and diverse communities in order to perform nutrient exchange and other functions with the plants' root systems. Through photosynthesis, plants convert atmospheric carbon into organic carbon to build biomass and to feed these soil microbes. Urban soils are generally degraded and compacted. Therefore, additional organic carbon (organic matter) must be added to urban soil to sustain the microbial community in the root zone and create or maintain the soil sponginess (*NRCS, 2005, Urban Soil Primer, Chap. 2&3;* M*arinCarbonProject.org/marin-carbon-project-science).*

Studies have shown that PAW approaches 30% as soil organic matter approaches 5%. As soil organic carbon increases by a factor of four, the PAW increases by about 2.5 times (*Hudson, B.D. 1994, Soil organic matter and available water capacity, Journal of Soil and Water Conservation, 49, 189-194*). In a review of more than 100 studies analyzing the effectiveness of compost and mulch in water conservation , the average water savings from compost was 26% to 34% and from mulch was 19% to 39%, with the average water savings between 20% and 46% (*Compost and Mulch Water Conservation & Green House Gas Literature Review, January 2015, CalRecycle and Assoc. of Compost Producers*).

The California Healthy Soils Initiative and AB 1826 set high standards for the rapid reduction of organic waste diverted to landfills by 2020, and California municipalities are scrambling to comply with these standards. Greenwaste reduction at the source combined with re-direction of compost back into landscapes are two solutions for which there is funding.

Healthy, living, spongey soil has good soil structure, and can be created from any soil type, be it sand, silt, or clay. When soil structure is improved, both the water holding capacity of the soil (PAW), and the soil infiltration rate are improved. Thus, spongey soil produces both water conservation and stormwater (water quality, aquifer recharge) benefits (*The Biology of Soil Compaction, Crops & Soils, July-august 2011, American Society of Agronomy*).

When climate-appropriate plants are introduced into spongey soil, additional water conservation and stormwater benefits may be garnered. Dry climate-appropriate plants have adaptations that reduce the demand on the PAW. Los Angeles' dry native plants have evolved to demand water in sync with the seasonal rain patterns, and therefore require less water during the seasonal drought months, but more water during the typically wet months. If rainwater is not forthcoming in those typically wet months, irrigation must be applied to maintain the soil oxygen/water balance. If rainwater is forthcoming in those months, the native plants and their symbiot soil microbes utilize as much as possible, and store excess in the root zone and in carbon-rich soils created by microbes just below the root zone.

Climate-appropriate plants growing in a microbially diverse, healthy living soil sponge, require little or no fertilizer or pesticide inputs. The reduction or elimination of these inputs further enhances water quality and sets up a positive feedback loop for the proliferation of healthy soil organisms. Additionally, local native plants provide habitat benefits to local native fauna.

Green Water Zone

Irrigation professionals call soil root zone water the PAW, but ecohydrologists refer to the soil root zone as the Green Water Zone (GWZ). "***Green Water***" is the precipitation that is held in the root zone and shallow ground water for the benefit of plant evapotranspiration rather than flowing as either runoff or infiltration into the aquifer. All water that is not held in the GWZ is called "***Blue Water***" (*Falkenmark and Rockstrom, 2004, Balancing Water for Humans and Nature, p. 5-7*)

Blue water supports groundwater, aquatic ecosystems, and is the water resource directly available to, and "harvested" by humans. Green water incorporates the water in forests, grasslands, croplands, and urban landscapes; it sustains terrestrial ecosystems. Groundwater and soil moisture represent the largest wealth of water on land (0.685%), exceeding the volume of water in all rivers and lakes of the world many times over (*Kravcik, Pokorny, Kohutair, Kovac, Totth, 2007, Water for the Recovery of the Climate – A New Water Paradigm, p. 12)* .

Defining the GWZ allows us to "see" the invisible water held in soil and in plant biomass. The GWZ is a buffer between the soil surface and groundwater, helping to regulate flooding and aquifer recharge. A healthy GWZ is the soil sponge that improves infiltration rates and soil water holding capacity. In urban settings, the GWZ is enhanced and maintained by the WA to landscaping.

With a robust GWZ and healthy, leafy, climate-appropriate plant material, evapotranspiration circulates water vapor back into the atmosphere. This water vapor supports the formation of rainfall over the landscape, creating an essential moisture feedback loop, especially in a dry climate like Los Angeles. On a global scale, approximately 40% of terrestrial rainfall is driven by oceanic moisture that is transported inland, while 60% of rainfall results from water vapor produced from the land surface itself (*Falkenmark, et al, p. 10-12; Kravcik, et al, p. 17*). This is very important information that could have tremendous impact on our approach to the management of all water in the LA regional river basins. If we want to have stable precipitation over Los Angeles, it is very important to ensure evapotranspiration from Los Angeles, especially inland.

Precipitation and Green Water

The water in the GWZ, which sustains all terrestrial biomass growth, actually represents a flow of water through the ecosystem, and is directly linked to the sustainability of Blue Water.

Blue water is directly influenced by soil surface conditions; if the soil surface is hard, sealed, or crusted, water will runoff directly. If the soil is vegetated and spongey, the precipitation will be allowed to infiltrate and turn into green water for future evapotranspiration. Once the GWZ is filled to capacity, the timing of which depends largely upon the soil type and root depths, blue water is generated to recharge the aquifer, flow as surface runoff, or flow sub-surface to join rivers, creeks, and the ocean (*Falkenmark, et al, p. 29-31)*.

Cisterns and other rainwater storage devices temporarily interrupt the blue water flow, redirecting stored water for beneficial indoor use or turning it into green water by releasing it into the landscape. Thus, cisterns may change the timing of or otherwise reduce the green water flow. As a result, green water flow should be considered in the implementation of cisterns.

For example, the first flush (the most polluted first portion of a rain event) usually is not permitted to enter the cistern. Considerations should be made for directing the first flush into the landscaped area. Additionally, when the cisterns are full, the overflow should be directed into the landscaped area for the benefit of the GWZ. With first flush and overflow directed into adjacent landscaped area, the cistern becomes a GWZ regulating device.

When the sun comes out, green water is transferred into the atmosphere. The volume of water in the atmosphere is approximately ten times greater than the volume of all the water in all rivers. While the *global* thermoregulatory function for our planet is dependent upon the seas and oceans, atmospheric water has a key role to play in *local* thermoregulation (*Kravcik, et al, p. 12)*.

Water vapor is the most widespread greenhouse gas in the atmosphere. The more water there is in the atmosphere, the stronger its moderating effect on temperatures and the fewer the deviations in the weather. The less water there is in the atmosphere, the weaker its moderating effect on temperatures and the more extreme the deviations in the weather (*Climatic Effects of Water Vapour, Physics World, May 2003).* Where water is lacking in the soil and in the atmosphere, extreme thermal conditions usually predominate. The extreme of GWZ degradation is desertification. All seasonally and semi-arid land areas are at risk for desertification, the only remedy for which is GWZ enhancement (*Kravcik, et al, p. 51-52, 68-69)*.

When evapotranspiration is not enhanced, precipitation is reduced. But, if the GWZ is enhanced by capturing rainfall and reducing runoff, evapotranspiration is enhanced, and precipitation can be increased. When soil surface temperatures are moderated by the presence of healthy vegetation and mulch, the precipitation that is created is not the same energy-filled, torrential rain that occurs in overheated, dehydrated landscapes.

The prospect of more frequent and more gentle precipitation is at the heart of the case for the WA to landscaping in the seasonally dry climate of Los Angeles.

Metrics For Evaluating Landscape Projects

Converting urban landscapes into highly productive GWZs depends upon a few relatively simple inputs:

- Building soil organic carbon by adding organic matter to the soil (*MarinCarbonProject.org/marin-carbon-project-science*)
- Building soil organic carbon by planting climate-appropriate, leafy plants
- Planting climate-appropriate plants with strong, deep root zone potential (chaparral, trees, perennial grasses)
- De-compacting landscaped areas (adding organic matter is the best way to do this)
- Directing rainwater into vegetated, carbon-rich soil sponges
- Directing first flush and overflow from cisterns into vegetated, carbon-rich soil sponges
- Reducing surface temperatures with leafy vegetation and decomposable mulch
- Reducing dependence upon irrigation by increasing efficiency, and utilizing rainwater first

Some possible metrics for these inputs are:

1) Measuring enhanced soil organic carbon
2) Prescribing enhanced surface cover with vegetation and decomposable mulch
3) Setting soil compaction reduction or elimination standards
4) Capturing rainfall from roof surfaces, especially first flush, in landscaped areas
5) Designing first flush and overflow from cisterns into landscaped areas

Some Conclusions

Every ornamental landscape, regardless of size or soil type, can be converted into a functioning Green Water Zone (GWZ) through the Watershed Approach (WA) to landscaping. A healthy GWZ is developed and maintained by (i) building healthy living soil through the addition of organic matter, eliminating compaction, and planting deeply rooted, climate-appropriate, leafy plants, (ii) directing rainwater in wet times and managing irrigation in dry times, if necessary. The GWZ functions as both ***the reservoir*** for evapotranspiration that cools our city and helps to regulate precipitation, and ***the buffer*** between precipitation at the surface of the soil and infiltration to groundwater or runoff to other water bodies.

Healthy living soil is best built through de-compaction of soil and the addition of organic matter in the form of compost and mulch. California municipalities are currently addressing a landfill reduction mandate that will result in funding for keeping organic matter on properties and recycling compost back into urban environments; incorporating these practices into programs funded by a stormwater fee leverages existing investment. Healthy living soil has sponge-like properties that provide water conservation, water quality, groundwater supply, and flood attenuation benefits.

Cisterns are excellent regulators of the flow of water to the GWZ. Therefore, projects that promote water catchment devices (such as cisterns or rain barrels) should include design provisions for integrating the devices into the WA landscape, particularly with regard to first flush and overflow.

Planting deep-rooted, leafy climate-appropriate plant material improves the GWZ, provides Los Angelenos with a "sense of place," and creates much-needed local habitat for native fauna. The combination of climate-appropriate plants growing in a healthy GWZ, filled with beneficial and symbiotic soil microorganisms, reduces or eliminates the need for fertilizers and pesticides, further improving water quality.

With regard to long-term urban resilience in a dry climate like Los Angeles, building GWZ capacity through the WA to landscaping and increasing evapotranspiration may bring more frequent and more gentle rainstorms further inland during the seasonally wet months. The resulting potential reduction of flooding alone should make an investment in this element of green infrastructure worthwhile.

Including metrics, standards, and incentives for the WA to landscaping and building GWZ enhancements into all projects supported by a stormwater fee ensures that distributed "green" infrastructure is truly both green and multi-benefit.