GREEN INFRASTRUCTURE ASSESSMENT TOOLS FOR VARYING SCALES IN COASTAL SOUTH CAROLINA

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Abstract. Potential impacts from changing coastal landscapes, specifically the conversion of forested and agricultural lands to residential and commercial development, can be reduced by more informed decision-making related to green infrastructure if the appropriate tools are available. An assessment of existing natural resources and their benefits in terms of ecosystem services can allow for better guidance for their protection and preservation. In contrast, some highly impervious urban landscapes could benefit from restoration strategies based on green infrastructure principles as sustainable solutions that mimic natural hydrology and ecology. The effectiveness of sustainable land use strategies, whether in developed or developing areas, becomes an exercise in optimization at varying spatial and temporal scales: whether at the watershed level; within geopolitical boundaries; in developed neighborhoods, rural communities or preserved tracts of land, or within an individual practice or series of practices (i.e. treatment train). This work introduces tools for the assessment and feasibility of green infrastructure strategies between different scales as related to sustainable land use decision-making in coastal South Carolina - from individual best management practices (BMPs) to the whole watershed. Specific hydrological and ecological parameters can be associated with each spatial and temporal scale. The question is: can these parameters be summed, compounded, and/or prioritized, and if so, what are the implications, if any, to coastal land use decision-making based on green infrastructure principles?

INTRODUCTION

Green infrastructure has been defined as “an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife”. (Benedict and McMahon, 2006). Recent focus on green infrastructure by the U.S. EPA as a measure of “managing wet weather” includes a subset of technologies known as Low Impact Development (LID). EPA-recommended site-scale practices include rainwater harvesting, downspout disconnection, rain gardens, permeable pavements, vegetated swales, green roofs, and brownfield and infill redevelopment. Neighborhood-scale approaches include “green” parking, streets, and highways; pocket wetlands, and urban forestry strategies. Watershed scale strategies include riparian buffers (U.S. EPA, 2010a). Many of these strategies are further explored in a sustainable design and green building toolkit for local governments (U.S. EPA, 2010b). From a stormwater regulatory standpoint, anticipated changes to the NPDES permit requirements both nationwide and within South Carolina are moving toward volume- and infiltration-based strategies in contrast to the current requirements where post-development peak flows must at least equal those of pre-development. As these mandates move forward, local and regional decision-makers and land use practitioners need science-based tools to inform the design process. From a larger conceptual view of green infrastructure, we can summarize landscape design goals as follows:

- ✓ Retain the natural landscape and hydrology
- ✓ Promote open space, corridor, and habitat preservation
- ✓ Encourage riparian and floodplain protection
- ✓ Reduce and disconnect impervious surfaces
- ✓ Provide on-site stormwater management and water re-use

Potential short- and long-term impacts from coastal land use change can be reduced by informed decision-making at various scales, especially if targets for sustainable solutions are well-defined. Whether the effort is one of preservation or of restoration (or both within a given land area), the system components of hydrology, soils, and

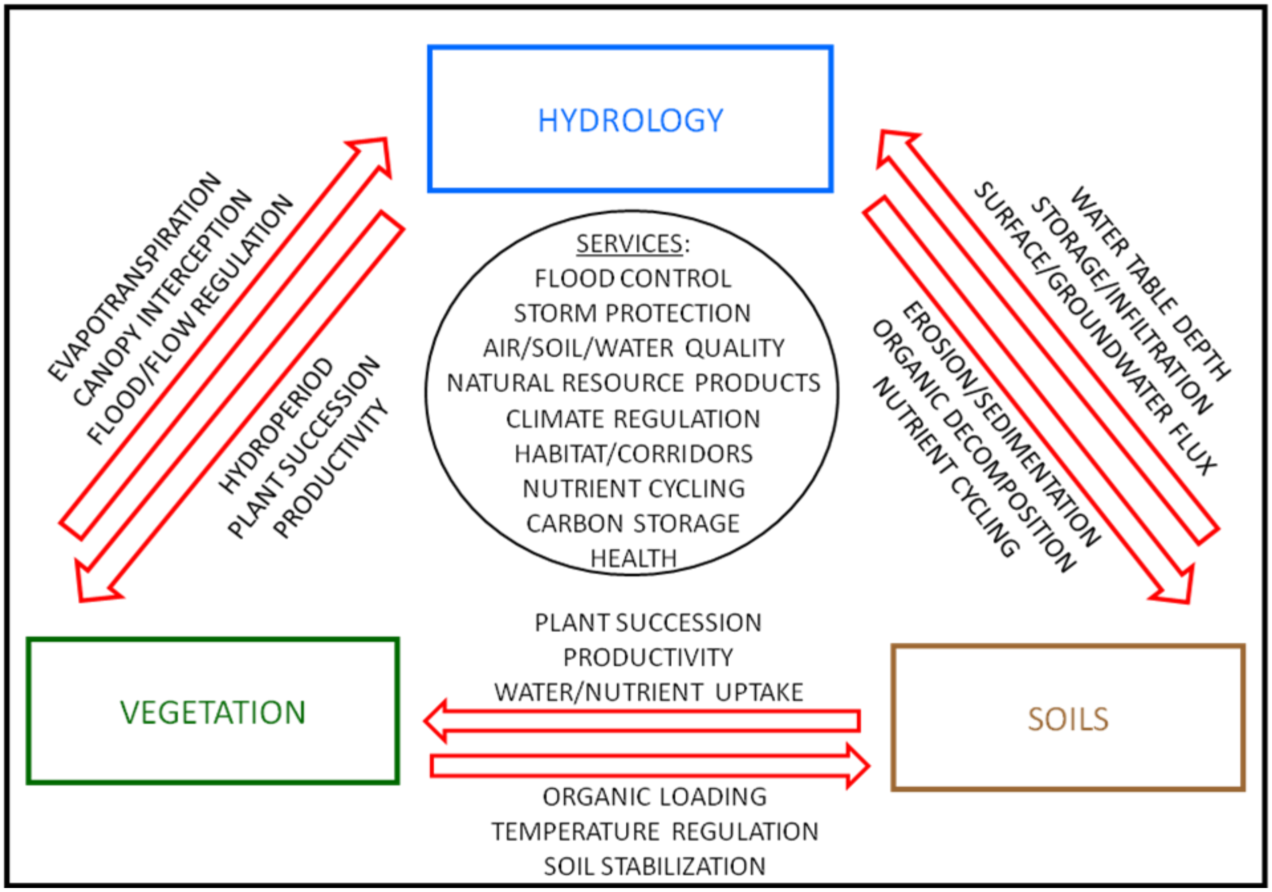

Figure 1. A conceptual model for a multi-scale system of landscape parameters, their interactive complex processes, and related ecosystem services. (Modified from Ge Sun, Southern Global Climate Program, USDA Forest Service)

vegetation and their various elements must be incorporated into the strategy. A conceptual model of processes and their relationships within the coastal landscape fabric in terms of the system components and elements is given in Figure 1. Goals for sustainability, along with associated relevant criteria and metrics for achieving an optimal set of land use decisions, must be clearly defined at any scale. Ecosystem services defined in the figure may serve as goals for optimizing sustainable land use strategies. The conceptual model can be applied at various spatial and temporal scales, while some elements and processes may take priority depending on the given scale within which decisions are to be made, along with any initial and/or critical conditions, allowing for hierarchy and subsequent goal definition at that scale. Can what we learn from the local level be applied to the watershed scale, and vice versa? And if so, can we identify sustainable land use practices and natural resource preservation strategies given available landscape information? Further, can we develop science-based tools to inform the decision-making process related to green infrastructure? Toward this aim, we will consider both the landscape design goals listed above and the conceptual model for landscape parameters in our assessment tool development.

METHODS

Integrated research and extension programs designed to provide science-based information related to South Carolina's natural resources, while representing various spatial scales, are being conducted and delivered, including: (a) evaluating individual LID practices for water budgets and pollutant removal; (b) monitoring hydrological and ecological parameters in forested watersheds prior to residential and commercial development; (c) evaluating green infrastructure design and practices in urbanizing and urbanized watersheds; (d) refining remote data acquisition tools in association with Clemson's Intelligent River© project, and (e) developing web-based mapping tools for natural resource-based land use decision-making. As an example, we focus on the Waccamaw Neck in eastern Georgetown County, SC, where integrated programs include the online Community Resource Inventory (CRI), the Bannockburn Plantation site (originally part of the

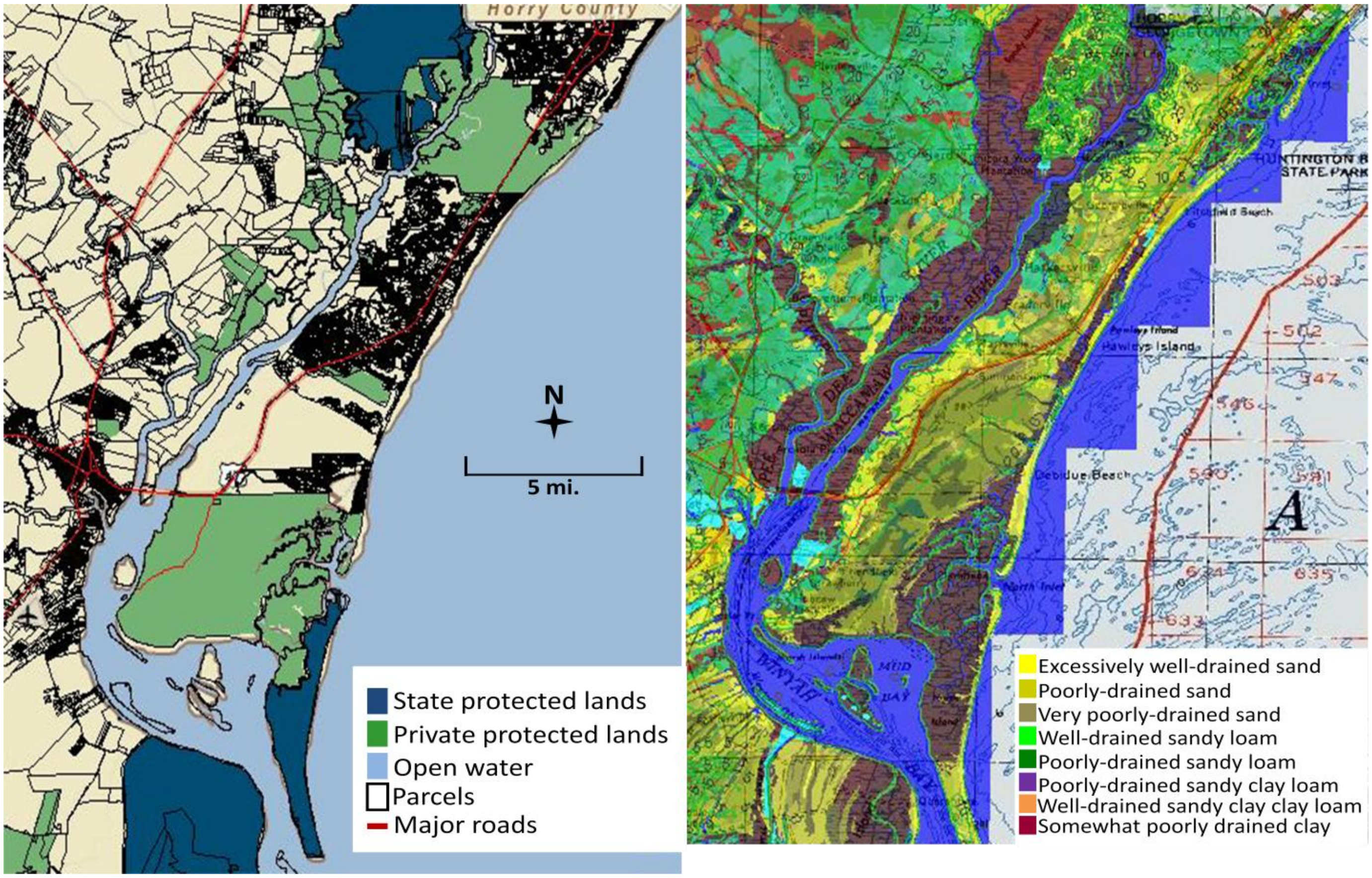

Figure 2. Map outputs from the Online Community Resource Inventory (CRI) for Georgetown County, SC, focusing on the Waccamaw Neck. Property ownership (parcels and protected lands) overlays a street map for natural resource planning and zoning (left) and soil drainage classes overlays a USGS topo map for stormwater management plan reviews and decision-making (right).

Intelligent River© monitoring project), and a rain garden monitoring and demonstration project.

Online Community Resource Inventory (CRI). An interactive web-based mapping tool has been developed for Georgetown County, SC. Available geographic data include parcels, protected lands, roads, soils, land use/land cover, habitat, flood zones, and water resources, and these can be displayed over topographic maps, satellite imagery, or a street map. Selected data overlays can depict specific resources relevant for a land use decision, such as those related to property ownership and the connection of open or green spaces, or to the recommendation and prioritization of stormwater management strategies based on soils and topography (Figure 2), among other information. A user can configure the map for specific views, while pre-configured maps are being developed to assist new users. Near real-time data as RSS feeds, including stream gage data from USGS, have been incorporated into the tool. This information can be incorporated in the conceptual model (Fig. 1) for hydrology (e.g. streamflow, flood zones), soils (e.g. drainage class), and vegetation (e.g. land cover, habitat type) with a goal of quantifying these relationships and linking them to specific ecosystem services (e.g. storm protection, habitat/corridors). Visit www.cri-sc.org for more information.

Bannockburn Plantation. Headwater streams in undeveloped coastal forests with shallow water tables function as natural storage and conveyance mechanisms for surface flows and groundwater discharge. Groundwater position often controls stream flow and evapotranspiration plays the most significant role in surface and subsurface flows seasonally. Toward the determination of baseline ecohydrologic parameters for an undeveloped coastal tract of land, a monitoring project has been conducted at Bannockburn Plantation, where

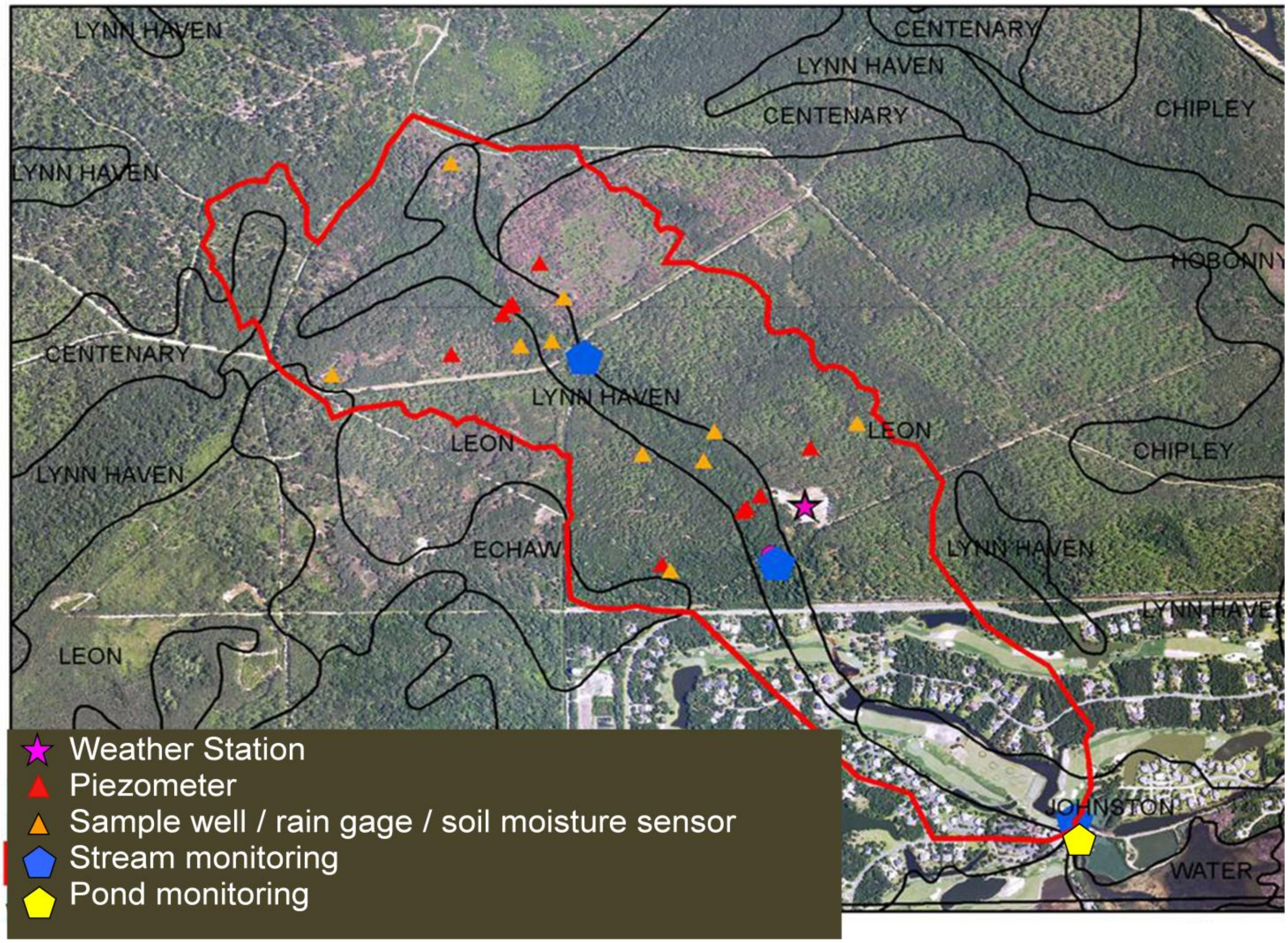

Figure 3. Monitoring stations for Upper Debidue Creek on the Bannockburn Plantation property and in DeBordieu Colony located upstream from North Inlet. The area in typified by low gradient topography and a shallow water table. Runoff: rainfall ratios and factors related to stream flow generation (rainfall, evapotranspiration, and water table position) are being investigated on Bannockburn Plantation as a benchmark for pre-development hydrology for coastal forested headwater streams.

future development has been proposed (Hitchcock et al., 2008). One of the original sites for the larger statewide Intelligent River© project, the primary monitoring strategy for the land tract has included parameters for: (1) meteorological data; (2) surface hydrology and water quality; (3) groundwater hydrology; and (4) vegetative ecology. Two years of monitoring data from the Upper Debidue Creek watershed (approx. 400 acres) have been collected. This information can be incorporated in the conceptual model (Fig. 1) for hydrology (e.g. streamflow and water quality), soils (e.g. water table position), and vegetation (e.g. water/nutrient uptake, organic contribution) with a goal of quantifying these relationships and linking them to specific ecosystem services (e.g. flood control, water quality, habitat, nutrient cycling, carbon storage). Visit www.intelligentriver.org for more information.

Rain Garden Monitoring. At the site design scale, bioretention (rain garden) practices are being monitored for both hydrology and treatment performance. Two newly constructed bioretention cells (rain gardens) at the Clemson – Baruch Institute near Georgetown, SC, have been instrumented to measure water table position and soil moisture changes and, with an onsite weather station, response to rain events. Subsurface water samples can be collected at various depths. The site has an excessively well-drained sandy soil which has been amended with local compost and topped with hardwood mulch. These practices serve as a demonstration site for the infiltration technology where the water table is shallow - a challenge for soil water storage and infiltration limitations as well as the potential risk of contaminating groundwater. This information can be incorporated in the conceptual model (Fig. 1) for hydrology (e.g. storage/infiltration, surface/groundwater interaction), soils (e.g. water table position, nutrient cycling, organic decomposition), and vegetation (e.g. water/nutrient uptake, plant succession, productivity) with a goal of quantifying these relationships and linking them to specific ecosystem services (e.g. flood control, water/soil quality, nutrient cycling, habitat). As a pilot system for the Intelligent River© monitoring network, the Baruch rain garden is being developed as a prototype toward the expansion of the monitoring network to other similar types of systems along the South Carolina coast.

Visit www.clemson.edu/baruch/rain_gardens for more information.

ANTICIPATED OUTPUTS AND OUTCOMES

The multi-scale approach to green infrastructure assessment and the feasibility of sustainable land use solutions is complex. The scale at which a planning/zoning or stormwater management decision is to be made will determine how these tools operate within and between scales as related to the conceptual model. The tools may be useful for creating a watershed-based plan, developing county-wide ordinances, assessing a plan review for a proposed development tract, selecting areas for conservation efforts, or determining the appropriate types of stormwater management practices for an area. Such resources will provide local and regional geographical information for coastal South Carolina, and these may be useful for implementing strategies as defined in EPA's Sustainable Design Toolkit (U.S. EPA, 2010b) or any other green infrastructure or LID guidance materials. We envision that the tools will become accessible and useful to those communities as they revise ordinances and comprehensive plans, and these resources can be integrated at multiple scales for development plan reviews and decisions.

Understanding the hydrologic and ecological dynamics related to natural resources protection (including water quality), flood prevention in coastal landscapes, and critical habitat protection is imperative for science-based land use decision-making. The assessment of baseline hydrology and vegetative ecology, as well as their interactions, provides benchmarks over the course of land use change while defining potential short- and long-responses to this change. Through this work, we demonstrate tools for green infrastructure while aligning hydrological and ecological processes at given spatial scales. Identification of linkages between system components, their specific elements, and ecosystem services requires further investigation, but the tools presented here demonstrate a framework by which we can direct future studies.

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