Green Roof Adoption: Private vs. Social Optimal

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Poster prepared for presentation at the Agricultural & Applied Economics Association's 2012 AAEA Annual Meeting, Seattle, Washington, August 12-14, 2012

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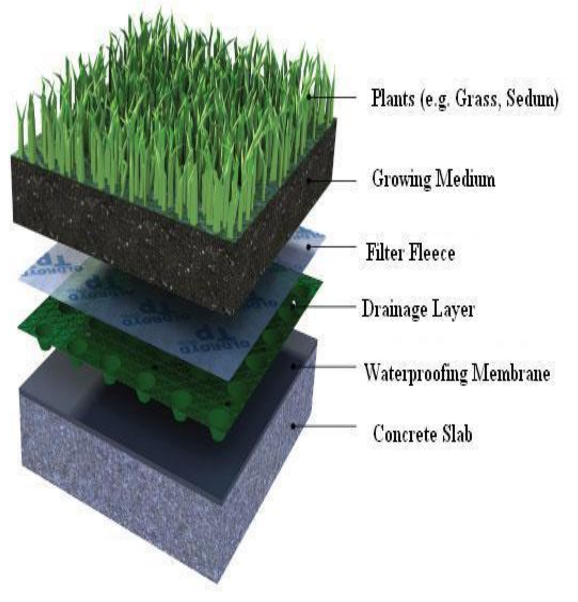
Introduction

Around the globe, green roofs – vegetated coverings in a growing medium – have been proposed as a tool to mitigate adverse effects of urbanization: urban heat island effect (UHIE), excessive stormwater runoff, and air quality degradation.



Over the last 3 decades, Atlanta, Georgia has undergone rapid urbanization, much of which has come in the form of impervious surfaces. This has led to water quality impairments, adverse human health impacts, and additional costs for energy to cool buildings and development and management of stormwater infrastructure.

Figure 1: Section of Green Roof

This study analyzes the economics of adopting green roof technology to offset effects of urbanization within a section of downtown Atlanta (Fulton County, Zip code 30303, GA).

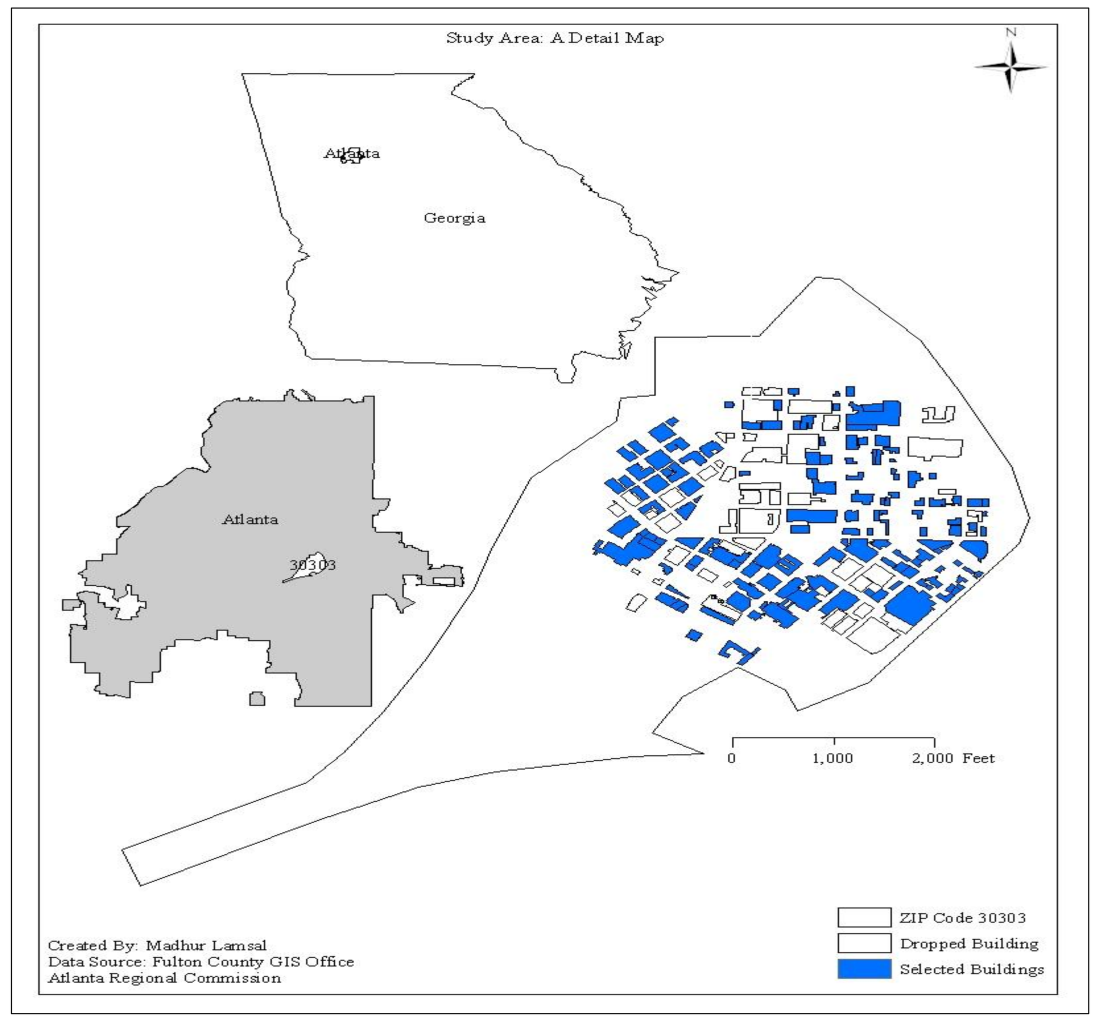


Figure 2: Study Area

Research Objectives

This study attempts to fulfill the following objectives:

- Estimate, from a private perspective, the costs and benefits associated with installing and maintaining an extensive green roof in the city of Atlanta.
- Estimate, from a social perspective, the costs and benefits associated with installing and maintaining an extensive green roof in the city of Atlanta.
- Identify specific buildings for which public incentives for green roof adoption should be considered, i.e., buildings for which it is socially optimal but not privately to install a green roof.

Data & Methods

The analysis includes both private and public costs associated with conventional roofs and green roofs. Private costs include installation, maintenance, energy and stormwater fees. Public costs include stormwater infrastructure costs, and pollutant-related health care costs from nitrogen oxide (NO_x), sulfur dioxide (SO_2) and carbon dioxide (CO_2) emitted during usage of electrical appliances in each building as well as emissions from regional coal fired power plants.

138 buildings in downtown Atlanta were selected for the study. Building-level Impervious surface area was obtained from Fulton county GIS office. Other physical characteristics of the building, such as, number of floors were calculated with the help of Arc GIS v.10 software, Google Earth v. Professional and through on-site inspection.

Installation Costs: Three rates were examined from recent literature.

Table 1: Conventional & Green Roof Rate

Methods	CR (Rate/m^2)	GR Rate/m^2
[1]Carter et al., 2008	$83.78	$155.41
[2]Clark et al., 2008	$167.00	$232.00
[3]Nui et al., 2010	$242.00	$309.00

Energy and Pollution Costs:

Energy consumption data were generated by Energy Plus V.6, a simulator software developed by Department of Energy (DOE). Energy Plus also provides estimates of the emission of pollutants from the each building due to the usage of electrical equipment and other human activities. We use the marginal healthcare cost associated with different pollutants such as (NO_x), (SO_2) & (CO_2) developed by Muller & Mendelsohn (2007).

Stormwater Costs:

The City of Atlanta does not currently charge a stormwater fee. In fact, a referendum for initiating a fee to cover necessary stormwater infrastructure upgrades was recently defeated. We use the proposed fee as a proxy for the stormwater costs associated with a specific building.

Green Roof Benefits:

Benefits associated with green roof were calculated relying on previous studies.

Table 2: Estimates of Green Roof Benefits Relative to a Conventional Roof

Benefits	Method 1	Method 2	Method 3
Energy	28% Energy Saving (Kingsbury and Dunnett, 2008; Peck et al., 1999)	51% Energy saving (Clark, et al.,2008)	10% of Energy saving (Nui et al.,2010)
Stormwater	65% of stormwater fee can be saved. (Moran et al 2004)	65% of stormwater fee can be saved. (Moran et al 2004; etc)	65% of stormwater fee can be saved. (Moran et al 2004; etc)
Health Care	Mean of low ($890/yr) and high ($3390/yr) benefit estimate (Clark et al.,2008)	Mean of low ($890/yr) and high ($3390/yr) benefit estimate (Clark et al.,2008)	Mean of low ($890/yr) and high ($3390/yr) benefit estimate (Clark et al.,2008)

Urban Heat Island Mitigation:

In addition to the above benefits, green roofing a significant area may offset part of t UHI (Lipton, 2003). Based on Akbari et al. (1992) and Lipton (2003) we examine the effect of a green roof-induced reduction of 3^{0}F in ambient air temperature on the net private and social benefits of green roof adoption for the 139 buildings in our study area. The effect on energy use and the concomitant reduction in pollution emissions are considered.

Pollution Emissions:

E-Grid (Emissions & Generation Resource Integrated Database), Energy Star Profile Manager, & Clean Energy Power Profiler tools, developed by USEPA, are used to track emission levels back to the coal fired power plants to determine the study area's energy consumption. In conjunction with E-Grid and Arc GIS, plant level contribution to cost and benefit are computed for conventional and green roof set-up due to usage of energy and reduction in energy use respectively.

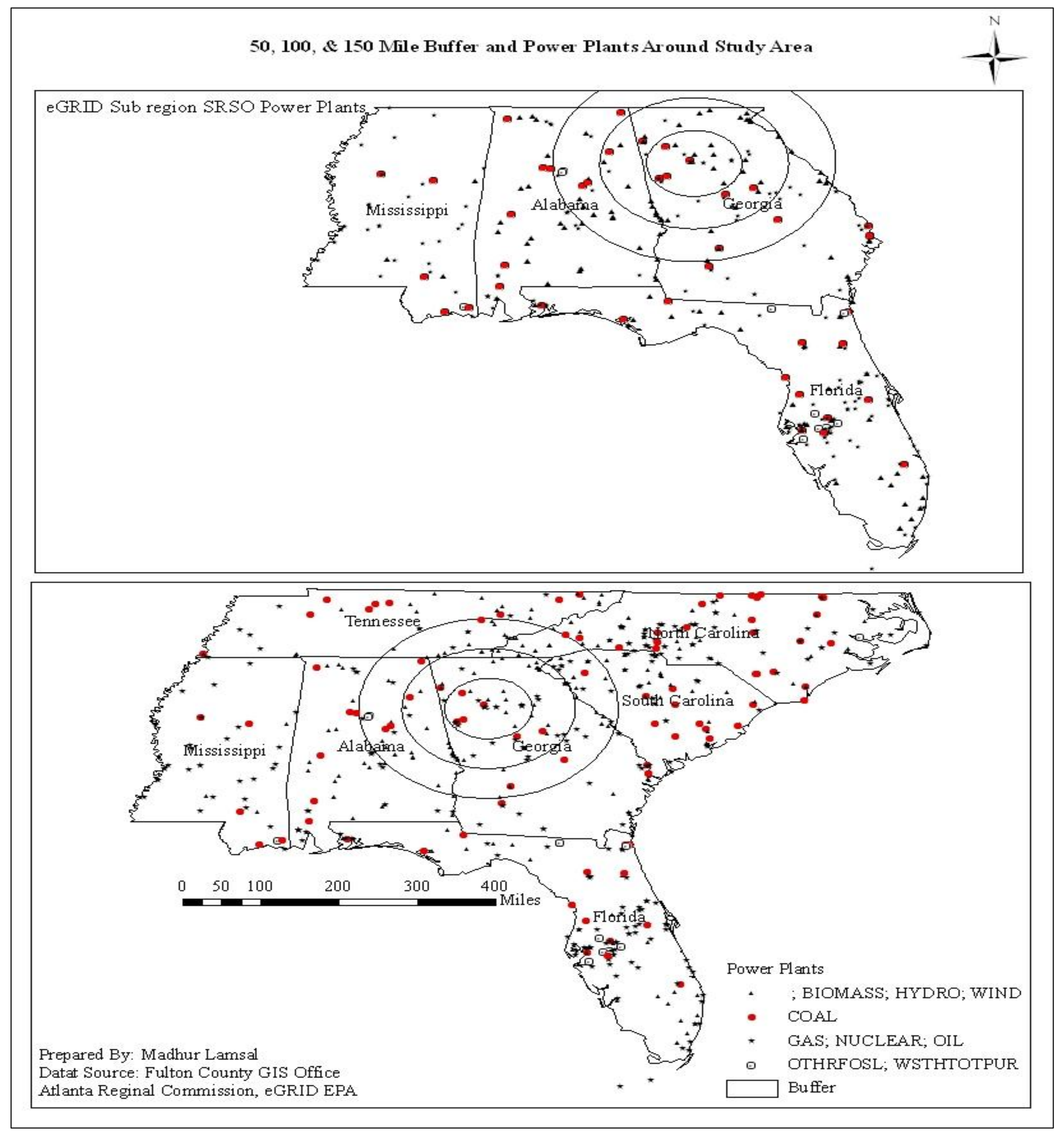


Figure 4: Sub Region Power Plant Location

Comparative Analysis:

The costs and benefits are calculated for three different rates and methods used by previous studies for one 40-year green roof cycle. A discount rate of 4 % for all calculations was used.

Results

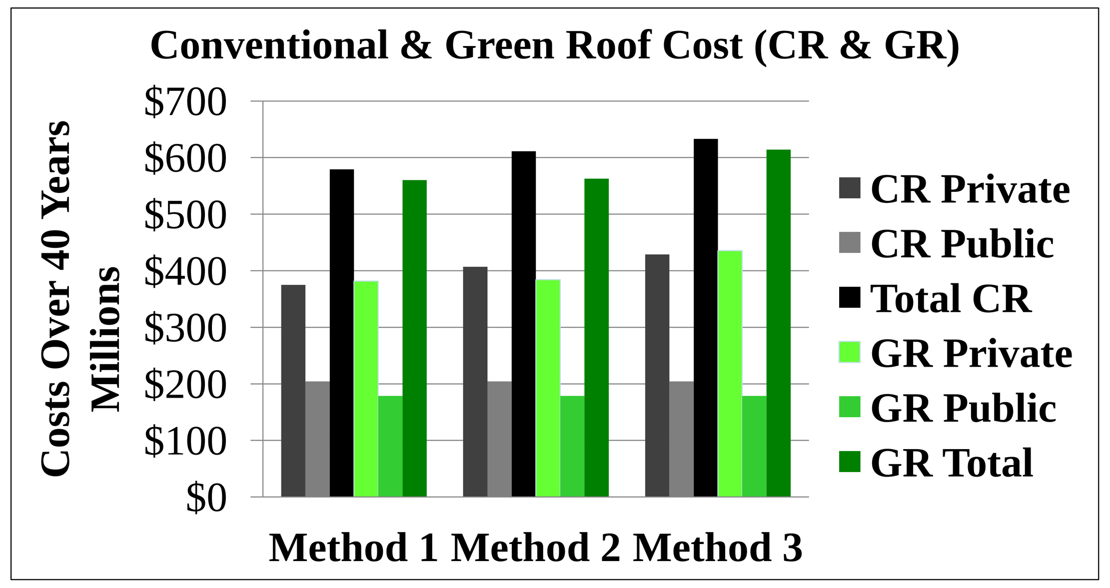


Figure 5: Private & Public Cost of 139 building over 40 years.

Additional GIS analysis is performed to find exact location of private & social optimal buildings for green roof adoption scenarios. The following map is extracted from GIS Analysis.

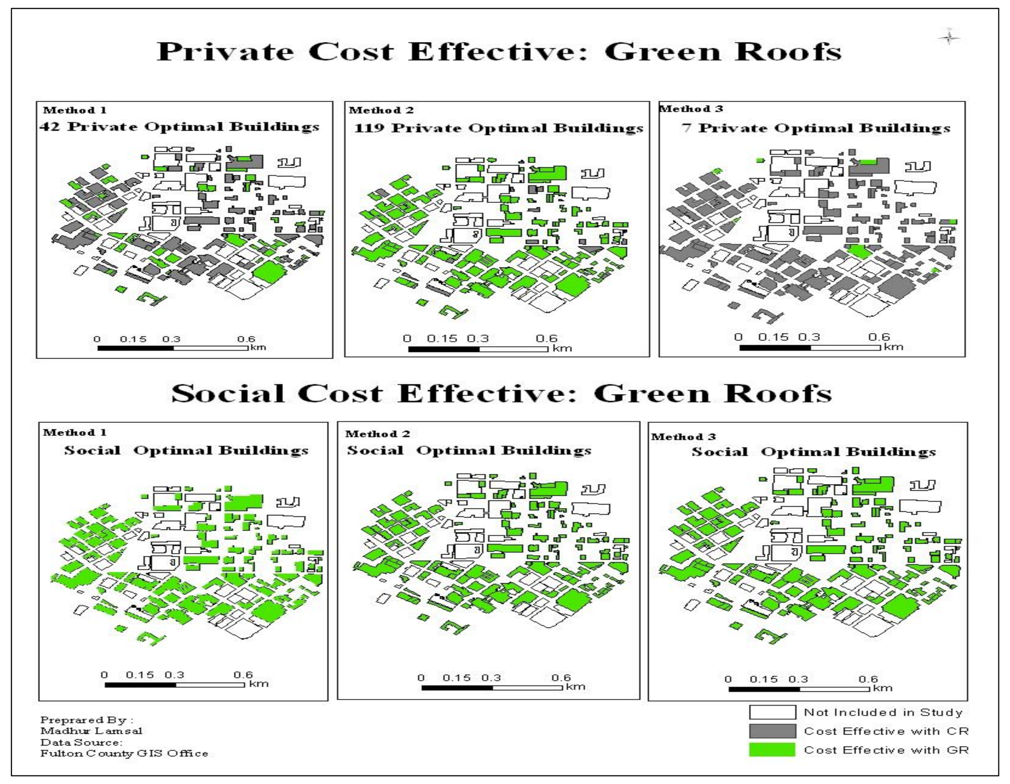


Figure 6: Optimal Building Location

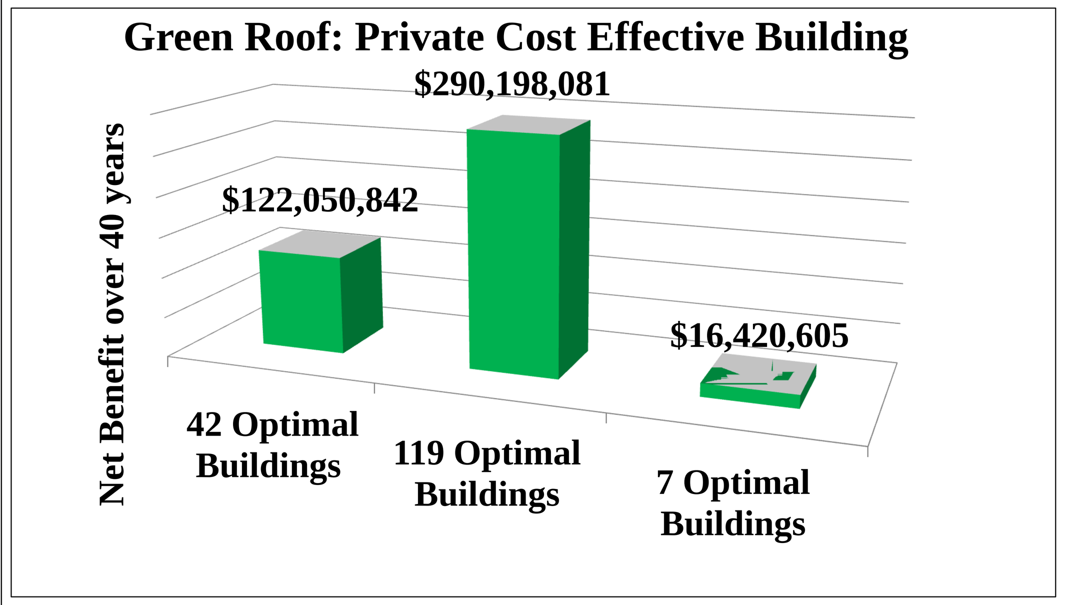


Figure 7: Green Roof Net Benefit

Conclusions

The cost-benefit analysis associated with installing and maintaining green roofs suggest the following:

- Under method 1 there are 42 buildings for which a green roof is both privately and socially optimal; under method 2 there are 119 buildings; under method 3 there are only 7 buildings.
- From a social perspective, green roofing is cost effective under all the three methods.
- A financial incentive or cost-sharing program for green roof adoption for all buildings should be considered. However, an information campaign may be able to coax those buildings for which a green roof is privately optimal into adopting without a direct financial incentive.

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