



STUDENTS ON GREEN ROOFS



Fall 2006

Greetings!

Instead of a newsletter, this quarterly I'd like to circulate a document that was prepared for the May 2006 Green Roof for Healthy Cities Research Committee meeting. It was a task that I'd accepted at the previous year's meeting, namely to summarize all the green roof articles published in English-language journals, as well as proceedings and books (see the 2006 GRHC Bibliography at www.greenroofs.com/forum/bibliography). The idea was to illuminate areas of missing information and loopholes of knowledge.

New research since June 2005 is probably under-represented (see Methods), but the summary provides an overview of published research and, if the timing is right for any students looking for meaningful theses, perhaps it could help to effectively fill gaps. It's far from perfect, but take it for what it's worth.

I'll leave it at that, and would be so glad to hear from you! What are your thoughts on the summary? How is your research or work coming/ going/ being? Linda and I love hearing from you! Remember that we encourage you with absolute gusto to submit something to the Student Forum. Articulation is good practice, the exposure excellent.

Happy autumn and best of luck with your endeavours!

Truly,

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Research Summary based on GRfHC Bibliography

Introduction

This document addresses one of the needs identified by the Green Roofs for Healthy Cities (GRfHC) Research Committee, in the 2005 pre-conference meeting in Washington, D.C. The task of summarizing all the green roof articles published in English-language journals, as well as proceedings and books, is meant to illuminate areas of missing information and knowledge gaps. By providing an overview of published research, whether scientific articles, books or proceedings, loopholes can be deliberately and effectively filled by informed researchers.

Methods

The main research topics established by the Research Committee cover the following five topics: **stormwater management, urban heat island effect, energy efficiency, biodiversity, and living walls**. As a starting point for this task, items listed in the GRfHC Bibliography (version: June 23, 2005) were divided into these five categories, and subdivided into more specific headings when necessary (see Appendix 1).

The Bibliography was divided into two sections: articles published in either journals or in proceedings, books and other reports. Articles published in journals are often peer-reviewed, meaning that the content may be more scientifically rigorous and objective compared to other publications. Of all the articles listed in the Bibliography, then, only a fraction of these discuss statistically analysed data or experimental findings.

Further to summarizing the published information from the Bibliography, research that is currently underway is also mentioned in the discussion. The Student Directory on greenroofs.com lists students who are involved in green roof research. Some entries are clearly detailed, while others are vague. The students whose directory entries suggest that their interests complement those of the RC were contacted by the author to determine the status of their work and whether they intend to publish their findings.

Results

Energy efficiency (building insulation, thermal performance, cooling effects)

This topic has appeared frequently in journals like *Energy and Buildings* and *Building and Environment*. Of the 11 articles included on the Bibliography, the majority of them report results from studies carried out in Asia and Greece. A Canadian report on the engineering performance of rooftop gardens is published in the Journal of Roof Consultants Institute.

An additional four articles focusing on this topic are published in GRfHC Proceedings. Three of these discuss thermal performance of green roofs in Toronto and Singapore, one explains an energy model which compared white and green roofs in NYC (?). One article, published by the American Council for an Energy-Efficient Economy discusses tax credit opportunities for energy efficient and green buildings.

Urban heat island effect (air quality)

Three scientific articles focused on the urban heat island effect discuss how the addition of more vegetation to the urban environment is a strategy for mitigating the microclimatic

effects that cause human suffering. Two of these are based out of the north-eastern America, including NYC, and one is out of Greece.

The eight articles found in the Proceedings section include six reports on climate change and the urban heat island effect in Toronto and Canada. Two articles describe initiatives that employ green roofs as mitigation or adaptation strategies (Canadian National Research Council and U.S. EPA). Four titles are published in GRfHC Proceedings, and the rest are reports.

Stormwater management (runoff quality and -quantity)

Five scientific articles focus on stormwater issues of runoff quality and -quantity. Three of the four articles focused on runoff quality are published in *Environmental Science and Technology*, and one appears in *Water Research*. These appear to be Swiss researchers from the ETH (?). One report discussing green roof stormwater retention, by researchers at Michigan State, is published in the *Journal of Environmental Quality*.

Of the 20 articles listed in the Proceedings list on the topic of stormwater retention, 10 are published in GRfHC Proceedings. The other sources include ASAE and Acta Hort, technical papers, books, or U.S.EPA reports or press releases.

Biodiversity

On its own, this research topic is under-represented in the Bibliography, although the Proceedings section includes 10 papers that focus on urban ecology and green roofs designed for biodiversity. Other papers in this section come from the perspective of landscape architecture and planning, as well as ecology texts.

No scientific articles in the Bibliography are devoted to biodiversity, although a few located in the Proceedings section could be moved there (e.g. Acta Hort, Landscape and Urban Planning, Anthos, The American Naturalist). In any case, biodiversity-related articles in the scientific section are subdivided and categorized into different sections and are based by plant research (-physiology, -ecology, -methods). Overall, the subdivided headings include plant physiology and plant-water relations, plant ecology, species selection, plant propagation and establishment methods, growing media, and ecology and biodiversity.

The twenty-three scientific articles categorized under **plant physiology** focus on plant water relations, mostly discussing life strategies of succulents or reporting findings on specific Crassulacean Acid Metabolism (CAM)-plants. These appear in journals devoted to the studies of photosynthesis, plant biology, plant physiology and experimental botany.

Of the eleven titles on the Proceedings list that are focused on **plant physiology**, seven are books (plant physiology, herbaceous perennials, or succulents). Two articles are published in GRfHC Proceedings, one is published in proceedings from the International Plant Propagation Society, and one is published in Acta Hort.

Five scientific articles discuss issues in **plant ecology**, such as competition, co-existence and succession. Three articles discuss **species selection** for specific environmental conditions, although not green roof conditions. Indeed, none of the articles under the previous three categories mention green roof plants specifically.

Twenty-one items on the Proceedings list focus on **ecology and biodiversity**, and span a variety of titles published in proceedings, books, and as technical papers. Eleven of these 21 titles specify green roof topics, eight of which are published in GRfHC proceedings.

In the Proceedings list, eight articles discuss **species selection**, of which 6 are devoted to green roofs and are published in GRfHC proceedings. These studies were conducted in England, the Pacific Northwest, the American Northeast, Toronto, and Germany. An article from China recommends a particular Sedum species for roof greening, and is published in Acta Agriculturae Shanghai. And an eastern European study discusses plant selection for extreme landscapes, although the author has been unable to access this source.

Three scientific articles discuss **plant propagation and establishment methods** for xerophytic/ succulent/ green roof plants. Two studies focusing specifically on green roof plants were conducted in southern Sweden and in Michigan.

Five articles focus on **growing medium** and its role for plant growth. Two of these articles (published in HortScience and HortTechnology) are green roof studies, one focusing on medium depth and freezing injury, the other observing the influence of watering regime and substrate design on plant growth. The other three articles discuss the influence of soil amendments on water use and plant establishment and growth.

Of the 10 titles in the Proceedings list focused on **growing medium**, four are focused on green roofs and are published in GRfHC proceedings. Another paper focused on green roofs is published in Acta Hort. Two papers in this category are standard technical publications describing substrates which are often used for green roofs. Finally, two sources in this section are books devoted to growing media and soil physics.

Vertical greening

Only one article is included in the Bibliography that focuses on living walls, and it is published in a popular journal, *Alternatives*.

Other topics listed in Bibliography

Five topics, categorized as Methods, Policy, Design, Landscape, and General, do not fall within the GRfHC research topics, but are nonetheless valuable for their scope. These are mostly found in the Proceedings list and are summarized below.

Methods

Eleven scientific articles explain methods for plant research, and two more are included in the Proceedings section (one article, one book). The methods discussed include chlorophyll fluorescence, digital image analysis, estimation of plant transpiration, and others. Uniform methods used by green roof researchers can simplify experimental designs, interpretations and information sharing.

Policy, costs, planning, market

Of the eleven titles in this category, seven are focused on green roofs and are published in GRfHC Proceedings. These papers stem primarily from North America, and include Toronto and Portland (OR) as city examples. One paper discusses the role of green roofs in cost-effective city greening in Singapore (??). The remaining four titles are published as reports or in proceedings from other conferences, and one article is published in *Environmental and Planning B: Planning and Design* (is this the correct title?).

Design (sustainability, urban agriculture, LEED)

Of the nine titles in this category, three are published in GRfHC Proceedings, two are books, and the rest are published in journals like *Acta Hort*, *Environmental Science and Technology*. Topics range from McDonough & Braungart's concepts of "green industrial design" and "Design for life" to the quantification of green roofs in the LEED green building system or as a strategy for local urban food production.

Landscape (-ecology, -management)

Two books listed in this category include the titles, "Principles in landscape architecture and land-use planning", and "Urban landscape management." These books mention green roofs and/ or how green roofs fit into urban- and landscape planning. One article, published in the journal *Economic Geography*, discusses the agro-industrial revolution in the American Midwest.

General

Ten titles fall under this category, and include four beautiful books which focus on urban vegetation and/ or green roofs. The FLL guidelines are also included here, as well as a paper, published in GRfHC proceedings, which summarizes "Green roofs in Germany: yesterday, today, tomorrow." Case studies are described in a GRfHC paper which summarizes "100 extensive green roofs: lessons learned", and one which describes "Green roof installation at the Ford Motor Company." Another article discusses "Grass-roofs movements in landscape architecture."

Discussion

This discussion is meant to elucidate loopholes in the research that currently exists (as listed in the GRfHC Bibliography) such that information gaps can be purposefully closed. The Bibliography that was compiled by members of the GRfHC Research Committee is an excellent start for the information sharing that will advance and promote the application of rooftop greening in the English speaking world. This Bibliography should, without question, be maintained and updated. Titles from the proceedings of the World Green Roof Congresses would be beneficial additions to this Bibliography, as well.

It might be recalled that there does exist a wealth of green roof knowledge in the German-speaking world. Collaboration and/ or information exchange with German-speaking colleagues and the translation of valuable documents may be an interesting avenue for English-speaking researchers to explore. Also, input from the Policy Committee could help steer research efforts, and collaboration with this committee would be beneficial for all parties and for the big picture.

If, for example, the main driver for green roofs in North America is stormwater management, then research efforts might address those elements that will illustrate the benefits provided by green roofs, thereby helping in the permitting of new policies. Since North America covers so many climate zones, cities interested in implementing green roof infrastructure may require data showing how much stormwater green roofs can retain under local conditions. Furthermore, plant- and substrate selection for different areas – influenced by issues like annual and diurnal temperature fluctuations, snow load and precipitation rates, pH of precipitation and surface waters, etc. – may need to be established in new areas.

Following through with this example, the Bibliography includes several publications that focus on **stormwater** runoff quality and quantity. GRfHC proceedings alone include quantitative studies from monitoring sites on the American west coast (Portland, OR) as well the north-east (Rock Springs, PA) and south-east (Raleigh, NC; Athens, GA). An article awaiting publication at the time of writing addresses stormwater retention on green roofs in the mid-West (East Lansing, MI).

According to the Student Directory (greenroofs.com), studies furthering our knowledge of green roof impacts on **stormwater** issues are currently underway at Michigan State University, The Pennsylvania State University, Pace University (New York City), North Carolina State University, The University of Georgia (Athens, GA), The University of Wisconsin-Milwaukee, Southern Illinois University Edwardsville (SUIE) and the British Columbia Institute of Technology (BCIT).

On the topic of **energy efficiency** by green roofs, the majority of publications stem from Asia and Greece. The National Research Council of Canada continues to publish results on thermal performance by green roofs. Still, Ottawa, Toronto and Vancouver have very different climates compared to the rest of the American continent, and so further research in different climatic regions would elaborate our understanding of how green roofs influence building energy efficiency.

According to the Student Directory on greenroofs.com, studies on **thermal performance** of green roofs (R-value of different substrates, cost-benefit analyses) are underway at Carleton College (Minnesota), Polytechnic University of Barcelona (Spain), Texas A&M University, and the Federal University of Sao Carlos (Sao Paulo, Brazil), as well as Iowa State University and York University (Toronto, Canada). A green roof study at Michigan State University includes **energy analyses**, and BCIT has entered Phase II of its research program which includes this parameter.

The “Adaptation and Impacts Research Group” in Toronto (Environment Canada) has published several papers on energy performance, climate change and the urban heat island effect. A student at the Commonwealth Secondary School in Singapore is evaluating green roofs for their capacity countering the **Urban Heat Island Effect**. In the Bibliography, three articles focused on this topic support the concept of rooftop greening as a strategy to improve urban life. A student from the University of Florida is writing a technical research paper which focuses on urban vertical greening.

Studies on **green roofs designed for biodiversity** are on-going in the U.K. and Switzerland, thanks to the UK-CH partnership. A student at the University of London is studying spider populations on green roofs, in particular related to brownfield sites, and a study on ground-nesting birds was recently completed by a student at the FH Wädenswil (Dec. 2005). A student at Portland State University is researching urban green roofs and biodiversity. The Vancouver Convention Centre Expansion Project (VCCEP), due in 2008, includes a 6 acre living roof with plants native to the Pacific Northwest. The plant palette is unprecedented, and the trials being tested in the nursery have entered Phase 3.

Vegetation studies are ongoing in at SLU (Swedish University of Agricultural Sciences) as well as the City of Malmö in southern Sweden, and the University of Sheffield is investigating plant selection for extensive green roofs in the UK. In North America, the testing of **native species** is occurring at St. Mary’s University (Halifax, Canada), Michigan State University,

The University of Michigan, Carleton College (Minnesota), The University of Illinois. A green roof research study at the Lady Bird Johnson Wildflower Center, in collaboration with a Masters student at the University of Texas at Austin, will study native species on roof platforms. VCCEP will be planted with a debut assemblage of native plants.

To the author's knowledge, few studies are exploring **native species** for green roof applications, which would be a valuable and holistic investment into local ecosystems and industries. It would be a positive step to recommend the inclusion of locally native species to researchers interested in plant research for green roofs. Collaborating with local nurseries which specialize in native seeds and stock would be a beneficial association, as such nurserymen have practical knowledge of local plants that could be appropriate for green roof conditions. Collaborating with local ecologists and botanists can help to identify native plant palettes by observing analog communities, ie. plant assemblages which occur naturally in conditions similar to those found on green roofs.

On the topic of **growing media**, or green roof substrates, only a few studies have reported on this fundamental topic. Seven papers (five from GRfHC proceedings) focus on the substrate, and explore how different factors (depth, type, slope, irrigation) influence plant establishment and performance under certain conditions. Two of the conference papers outline the design criteria for green roof media. Studies from MSU and PSU (publication pending) studied plant performance in various depths of commercially popular green roof media.

The study of how medium type and depth influence plant performance and water retention has been exhaustively researched in Germany, however most publications are in German. Penn State has developed testing facilities where green roof growing media may be assessed following the FLL criteria. An important design investment would be to conduct life cycle analyses of the growing media currently available in North America. Since the green roof market in North America is still in its emergence, there is no better time to incorporate sustainability principles into its design, and starting with the growing medium is a logical first step.

In closing

Do the data generated from these studies suffice for the policy-makers in these regions? If not, what else is required for the promotion of green roofs there? Answering such questions - in addition to the fundamental questions of species selection, substrate types and depths for the desired green roof functions, the sustainability of components and systems, the potential for habitat creation and supporting endangered species - could establish guidelines for effectively introducing green roofs to different geographical regions. If the questions that municipalities need answered right at the forefront are satisfactorily and elegantly provided, and green roofs are expertly installed, then the future of the green roof market will advance quickly and with the integrity that will further promote it.

A noticeable point from the Bibliography and this summary is that many studies are published in GRfHC proceedings. This may be restrictive for researchers or students with low budgets, since each conference proceedings comes with a cost comparable to attending the conference itself. This came up at the Research Committee meeting in D.C., and this report substantiates the need for a broader publishing medium. The task of arranging for a "special green roof edition" with a scientific journal was discussed then, as was the establishment a special Green Roof journal for this purpose.