Green Roof Research Models and the Landscape Architect

Malmö, Genova, Brussels

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ABSTRACT Green roof research has been conducted utilizing numerous research typologies which each yield distinct results. Differences in results may be linked to the varying methods employed by autonomous research stations. Inconsistent results stemming from variations in research methodology can lead to difficulties for landscape architects who are charged with converting data produced by first hand research into practical solutions. The use of green roofs to address the problem of urban storm water management is one such example. This paper applies case studies of research stations in three European locations: Augustenborg in Malmö Sweden, the University of Genova in Italy, and the city of Brussels Belgium. These sites were chosen because they represent distinct research approaches which need to be understood in order to be applied by design professionals seeking more effective modes of designing for living roofs.

INTRODUCTION

Landscape architecture is a discipline that has long struggled with the expansion of its professional boundaries. The vast scale range that landscape architects are charged with managing presents distinct challenges in standardizing how data is collected and applied in the discipline. Research conducted under the banner of landscape architecture tends to use a plethora of methodologies leaving gaps and tension between what the research points to as fact.

Green roof research in particular offers a unique challenge to the landscape architect in that the data produced is almost entirely quantitative. Traditionally, landscape architecture has been largely concerned with qualitative factors such as experience and sense of place, so adapting to increasingly quantitative endeavors such as the application of green roof research presents an extra level of sophistication. In attempt to tackle this challenge, this paper explores a number of research methodologies from three distinct European research stations dealing with quantitative green roof data. These will be categorized into research models aimed at bridging the divide between quantitative data generation and qualitative design solutions.

The first case study is from the Augustenborg district of Malmö, Sweden and is an example of what will be called the "laboratory model". This study was a highly controlled scientific examination of an extensive sedum-moss green roof and it offers raw quantitative data from which a landscape architect must draw his or her own conclusions. The second case study is focused on an experiment conducted at the University of Genoa in Genoa, Italy. This will be categorized as a "practical model" as it is an example of study carried out in real-world conditions and accounts for variables landscape architects may encounter when designing for green roofs. The third case centers on a "theoretical model" that was developed for the city of Brussels, Belgium. This study "analyz[ed] the original measurements reported in 18 publications" and applied first-hand green roof research to the city of Brussels. This model is the most useful of the three to landscape architects as it is an example of the conversion of first-hand research data into a practical solution.

Figure #1. Case Study Locations
Adapted from http://www.worldatlasbook.com

THE LABRATORY MODEL

This case study was based on research reports generated by Lars Bengtsson at al. that describe an experiment conducted in the Augustenborg district, which "is a residential area located in the central part of Malmö city in southern Sweden" (Bengtsson et al. 260). As is the case in Portland, Oregon, Augustenborg has opted to disconnect its combined sewer system in favour of alternate soft infrastructure systems such as green roofs that can help manage stormwater on site. The challenge to reduce pressure on the combined sewer system provided the motivation for the green roof study in Augustenborg.

A retrofit was carried out in the area and a large portion of "low industrial buildings were provided with green roofs" (Bengtsson 270) and "some of the roofs [were] reserved for research purposes" (Bengtsson 270). Runoff from natural events as well as from simulated events was assessed through this experiment. As this was a laboratory model, all variables had to be accounted for in the experiment. As "only 6 events producing more than 1mm runoff over 10min" (Bengtsson 270) occurred, artificial rain events were necessary in order to arrive at scientifically conclusive results. For further experimental control, artificial plots were constructed which made it "possible to investigate the influence of the slope and length of the roof on runoff distribution" (Bengtsson 274) which would not be possible with the roof plots on actual buildings.

The plots on the roofs of the buildings at the Augustenborg test site measured 4m long with a fixed slope of 2.6% (Bengston 270). Runoff was collected using a flume and hose and was measured in a barrel beneath. Runoff intensity was then measured. The artificial roofs were similar in design (Fig # 3), although the slope of the roof could be adjusted between 2.6 -23% (Bengston 276). The Augustenborg study offers a high degree of experimental control and scientific rigour. Although it was focused on generating quantitative data, the process reveals some excellent practical concepts applicable to green roof design. It was concluded that "rain on dry green roofs hardly produces any runoff at all"(Bengtsson 279) and that the "runoff produced by rain on wet roofs is delayed and the runoff peak reduced compared to the rain intensity peak"(Bengtsson 279). This is supported by research conducted by Roehr and Kong who state: "increasing vegetated areas helps mitigate the effects of increased urban runoff volume" (Roehr and Kong 125). In simple terms, green roofs increase urban infiltration of runoff by providing impervious surface and are most effective before they become saturated.

While the conclusion that green roofs are most effective when dry is important, it can be misleading. In climates, such as Vancouver's where heavy precipitation occurs in the winter and is followed by a dry summer, green roofs will have limited effectiveness in both seasons. Roofs will quickly become saturated in the winter, and the "green roof growing medium [must] store enough water for plants to survive in the summer" (Roehr and Kong 60). Therefore, designers dealing with sites bearing extreme climatic variation, such as in Vancouver, need to apply these results with caution, recognizing an important climatic difference between the study conditions and those found on Vancouver's roofs.

Bengtsson also concludes "runoff response to rainfall shows no dependence on slope and very little dependence on the roof length" (Bengtsson 277). Caution by the landscape architect is again advised, as because this is a controlled, quantitative study, it does not consider crucial practical concerns landscape architects must acknowledge. For instance, despite Bengtsson's conclusion, "structural anti-shear/slip protection measures [should] be installed for roof pitch greater than 20[degrees] (36.4%)" (Fassman et al. 140), and slope therefore is a significant practical constraint in green roof design.

Experimental research models such as Bengtsson's study of Augustenborg are a source of useful quantitative data for Landscape architects. As designers, the ability to draw on rigorous scientific studies is critical to understanding the capabilities of green roofs. It must be understood, however, that these studies are concerned with numerical data and may not consider potential design constraints such as those identified by Roehr and Kong as well as Fassman et al. Quantitative data from experimental research models must therefore be treated as supplemental, and practical design constraints should not be neglected.

Figure #2. Augustenborg, Malmö, Sweden
Adapted from Google Earth Image

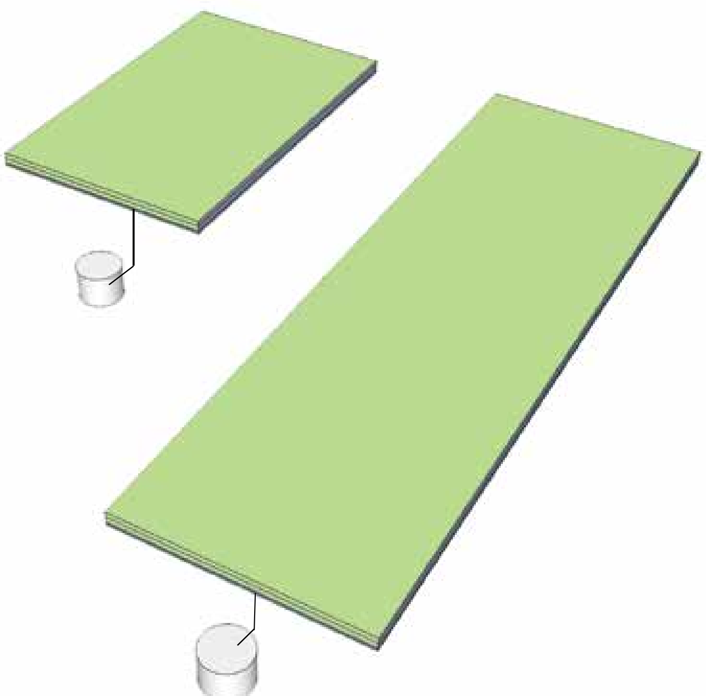
storm lab

adjustable size
2m or 1m long

adjustable slopes
2.6% to 23%

water intensity
controlled

vegetation less
developed (time)



augustenborg

4m long

non-adjustable slope

exposed to natural
rain events

Figure #3. Malmö Labratory Plots

THE PRACTICAL MODEL

While the data produced from the University of Genoa study is similarly quantitative to that which was produced in Augustenborg, the research done at the University of Genoa holds important differences. Only natural events were recorded as they fell on a real-world green roof in Genoa meaning nothing was staged. This renders the study a "practical model" for conducting research.

Fioretti et al. have prepared a report documenting a three-phase study commencing in May 2007 "during retrofitting works for [a] new green roof " (Fioretti et al. 1900). The first phase was aimed at collecting data from the impervious roof surface; the second phase examined the entire newly installed green roof; the third phase focused on a smaller area within the roof. For the research study, the central roof plot was divided into equal portions containing different growing mediums (Fig # 4): "In one half the growing medium is 70% lapillus, 30% pumice and peat and in the other half the composition is 70% lapillus, 20% pumice, 10% zeolite and peat" (Fioretti et al. 1898). While these variables were manipulated to measure the effects of substrate mix on subsurface flow, intensity was not measured through artificial means as it was in Bengtsson's study. The method used to measure stormwater, however, was very similar to that utilized in study at Augustenborg.

Of critical importance is the fact that this study utilized only natural rainfall events, and unlike the work conducted in Augustenborg, it did not apply artificial rains at controlled intensities. During a period of thirteen months, nineteen events occurred and "in all events the rainfall volume was completely infiltrated (no surface runoff occurred) and only partially exfiltrated" (Fioretti et al. 1902). Unlike at Augustenborg, green roof performance was not measured under fully saturated field capacity conditions.

The University of Genoa study does provide an excellent opportunity to the landscape architect that a laboratory study does not. Because this study was carried out during the construction of a real-world green roof, it is an excellent example of the power of adaptive management as a tool for the landscape architect. Adaptive management "is a rigorous approach for learning through deliberately designing and carrying out management actions as experiments" (Murray and Marmorak 1), and this is precisely what occurred at the University of Genoa. By monitoring green roof projects, both during and after installation, the landscape architect is able to evaluate the performance of a green roof and adjust a project during its construction or take lessons learned and apply them to the next project.

Figure #4. University of Genoa, Italy
Adapted from Google Earth Image

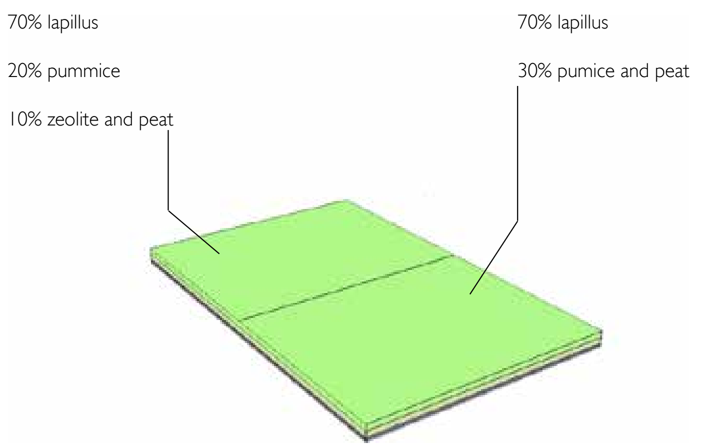


Figure #5. University of Genoa Central Roof Plot

THE THEORETICAL MODEL

The ability to synthesize and apply quantitative research collected from multiple sources is arguably the most useful of the three methods to the landscape architect. This allows the designer to extrapolate data from rigorous first hand studies and use it to project potential effects green roofs may have on a site. Mentens et al. have taken "measurements reported in 18 publications" (Mentens et al. 217) and have generated a "theoretical model" to apply to Brussels. This research approach is not unprecedented in landscape architecture. Roehr and Kong have utilized first-hand research data to assess the effectiveness of green roofs in different regions (see "Runoff Reduction Effects of Green Roofs in Vancouver, BC, Kelowna, BC, and Shanghai, P.R. China").

A comprehensive literature review was necessary to generate the first hand data required to produce a theoretical model for Brussels. A limitation, however, is that "most of the [green roof] research has been done in Germany, so the core of the literature data comes from Germany" (Mentens et al. 219). While the climates of Belgium and Germany may not be drastically different, landscape architects from other areas of the globe may have more difficulty than Mentens et al. in assuming "comparable climatic conditions" (Mentens et al. 219) between research station locations and their own regions. When conducting literature review, landscape architects must therefore strongly consider the regional climatic context that produced the data they are utilizing when generating theoretical models for green roof application.

From their extensive literature review, Mentens et al. determined that 'the runoff is mainly determined by the roof type and may be as high as 91% for a traditional non-greened roof and as low as 15% for an intensive green roof " (Mentens et al. 220). As a general rule, it was therefore concluded that on roofs without greening, precipitation is the sole factor in runoff production, while in greened roofs substrate depth is an important additional factor. Literature review made it "clear that rainfall –retention capability on a yearly basis may range from 75% for intensive green roofs (median substrate depth: 150mm) to 45 % for extensive roofs (medium substrate depth: 100mm)" (Mentens et al. 224).

From the collection of such data through the review of first-had research literature, a model specific to Brussels was developed (Fig #6 and 7): "Under a modest scenario of 10% of Brussels' roofs to be greened with and extensive green roof (100mm substrate depth), the runoff reduction can easily be 2.7%" (Mentens et al. 224). The viability of green roofs in solving the problem of storm water mitigation in Brussels may now be determined using this conclusion produced by the application of a theoretical model.

Figure #6. Existing Roof Conditions
Brussels, Belgium
Adapted from Google Earth Image

Figure #7. Artist's Depiction of Brussels
after Green Roof Application
Adapted from Google Earth Image

CONCLUSIONS

As a discipline with expanding professional boundaries, landscape architectural practice is developing increasingly quantitative means of determining design guidelines. This is particularly evident in the case of storm water mitigation and the use of green roof systems as a potential solution. Green roof research centers provide complex quantitative data that is often far removed from practical design solutions, and landscape architects face the problem of bridging the data-design divide. Categorizing the research methodologies employed by green roof research stations is a valuable step in understanding how this quantitative data applies to design.

The three cases explored in this paper have been chosen because each utilizes a distinct research model regarding the effectiveness of green roof systems. The Augustenborg study is an example of a laboratory model that provides the landscape architect with reliable scientific data, however, it does not consider practical limitations of this data. Research conducted at the University of Genoa, Italy is an example of a practical model of green roof research that lends well to adaptive management of projects carried out by landscape architects. As this research was not conducted through a controlled experiment, limitations exist in the conclusiveness of the data collected.

Lastly, a theoretical model was developed in Brussels, Belgium through a comprehensive literature review of first-hand green roof research. This allowed Mentens et al. to apply the quantitative data collected and assess the viability of green roofs as a solution to storm water runoff challenges in Brussels. This is a useful model in that it is directly employable by landscape architects when conducting site analysis for a site that may benefit from green roofs. All three of these models offer distinct opportunities and constraints. With this in mind, the categorization of these unique research models allows the landscape architect to bridge the gap between research and design and apply green roofs more effectively.

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