Food at Trinity

A Pilot Roof Garden Proposal for Trinity College

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ENV461H1: U of T Campus as a Living Lab
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Introduction

A consistent goal of Trinity College has been to improve environmental and human well-being on campus. Trinity is exploring the possibility of establishing a food-producing green roof (roof garden) on one of their future buildings to expand their sustainable initiatives. Our client, Assistant Provost Dr. Jonathan Steels, approached the ENV461 class for research on the feasible implementation of a green roof, overall community benefits of a roof garden, and specifically, a proposal for a roof garden on a new student residence building at Trinity. Dr. Steels defined three criteria of the project: 1) to foster student wellbeing and engagement with food production; 2) to address food insecurity in Toronto; and 3) to integrate the food produced into Trinity College food services. To explore these goals, we developed three key questions to guide our research process:

1. What are the functional and structural considerations for building a roof garden in Toronto?
2. Which community engagement program is ideal for Trinity's roof garden and what are the wellness impacts of the roof garden?
3. What would be the best practices to build and maintain a roof garden at Trinity College?

After an initial review of the literature, the need to narrow the scope of Dr. Steels's request was identified, and following a consultation with him, we focused our research on two main deliverables: 1) Provide extensive research on urban roof garden projects from two angles: student engagement and operational feasibility, and 2) Develop a comprehensive proposal for a pilot roof garden at Trinity College. This pilot project will include details on the structural and physical requirements, a preliminary budget, discuss the governance and engagement strategies, and identify short- and long-term operation and growth models. Furthermore, this would serve as a trial to inform the creation of a permanent roof garden operation at Trinity College's new residence building.

Methodology

In order to develop a preliminary understanding of our topic and industry trends, a literature review was conducted using primarily academic sources to provide comprehensive research on the technical aspects of green roofs, notably identifying the difference between green roofs and rooftop gardens.

To deepen our understanding of green roofs and roof gardens a number of case examples and experts were selected from within University of Toronto and the greater City of Toronto. Nine semi-structured interviews were conducted with employees at Trinity College, current staff of rooftop gardens in Toronto, and leaders of a variety of gardens at the University of Toronto.

Interviews with students from Trinity College were used in order to understand the demand and interest for green spaces within the college and inform our proposals. 100 students were surveyed within a one month period using both in person interviews in the buttery, shaw cafeteria and online using google forms disseminated using facebook groups. The data collected from these surveys were not to be statistically analyzed, but to offer preliminary information on student awareness and interest in green spaces on campus.

Lastly, we conducted structured observations of green roofs at SkyGarden, St. Hilda's, DigIn! and other maintained gardens at the University of Toronto, as well as the Ryerson roof farm and the Centre of Social Innovation green roof(CSI). These observations included analysis of the physical requirements, governance models, accessibility, maintenance requirements and production yields of each site.

Findings: Literature Review

The academic literature review provided the technical and structural information regarding roof garden and green roof installation and maintenance, as well as the benefits of their presence. It should be noted that all rooftop gardens are green roofs, however, not all green roofs are rooftop gardens. The benefits and tradeoffs of rooftop gardens identified from the literature review are drawn from sources about green roofs, rooftop gardens, and urban agriculture.

Technical Information

A green roof is an extension of an existing roof, involving modifications such as waterproofing and drainage, and includes the growing vegetation directly on a roof. Additionally, green roofs require the addition of the soil substrate, a filter cloth to prevent the loss of these soil particles, and the vegetation itself (Berndtsson, 2010 and Green Roofs for Healthy Cities [GRHC], 2017). Through our analysis of the literature we developed descriptions and classifications for different green roof models and technologies (see Appendix, Table 1).

Green roofs are typically divided into two main engineering categories: intensive and extensive (Berndtsson, 2010), however, there are also semi-intensive and potted models. Intensive green roofs are have unique soil layers that can support larger vegetation, such as crops and bushes (GRHC, 2013), and often require additional maintenance and inputs such as weeding, harvesting and irrigation systems (Berndtsson, 2010). Furthermore, intensive green roofs may be conditionally accessible to the general public and can be suitable for a variety of functions (GRHC, 2013). On the other hand, extensive roofs are have soil layers of less than six inches (GRHC, 2013) suitable for smaller plants and grasses that provide full coverage of the soil

(Berndtsson, 2010). Extensive roofs are common in retrofit projects to improve a building's energy efficiency and stormwater management (GRHC, 2013). The semi-intensive model is less common and often has full-coverage planting with higher plant diversity and provides greater accessibility to the general public (GRHC, 2013). The potted model is often used to grow edible crops in pots, meaning it does not require roof modifications; although this model does not follow the definition of a green roof, it does provide the same functions.

Ecosystem Health and Urban Environment

The environmental benefits vary depending on the type of green roof, however, key environmental benefits include habitat restoration and protection, natural filtration of airborne pollutants, such as particulate matter and noxious gases, resulting in improvement of air quality in the immediate area (GRHC, 2017), and reducing stormwater runoff and pressures on sewage systems (GRHC, 2017). In urban areas, generally 55% of the rainwater becomes runoff, while in non-urbanized/rural areas with high vegetation, only 10% becomes runoff (Environmental Protection Agency, 2003). Green roofs can retain anywhere between 25%-90% of the precipitation that falls over the them, depending on factors such as season, type of plants, and soil type (GRHC, 2017). A heavily vegetated green roof with a 20-40 cm thick growing medium can retain 10-15 cm of water (Peck & Kuhn, 2003). A three-year study evaluating the quantity and quality of runoff from a 14-cm extensive green roof on a multistory York University-building revealed that the green roof discharged 63% less runoff than the neighbouring conventional modified bitumen roof (Van Seters et al., 2009). The study showed that phosphorus concentration is the only variable posing a potential threat to receiving waters (Van Seters et al., 2009).

Impact on buildings

Green roofs also have a positive impact on buildings. It acts as an insulator, which reduces energy usage, in fact, according to a 2003 study published by the National Research Council of Canada, an extensive green roof reduced the daily demand for air conditioning in the summer by 75% (GRHC, 2017). However, the energy savings vary on what level of the building you are evaluating (Green Roof Alliance, 2013). Aside from energy saving benefits, the insulation can also reduce maintenance costs by increasing the lifespan of the roof membrane, and the heating, ventilation and air conditioning systems (GRHC, 2017).

As well, green roofs have an impact on the "comfort management" of the host building, which involves aspects like improving physiological and natural conditions (safety, hygiene, etc.), psychological demands (microclimate of the building, aesthetics, etc.), improving energy efficiency, increasing thermal comfort to reduce inward heat flux, reducing noise pollution in urban cities (Connelly & Hodgson, 2010), and improving visual aesthetics (Loder, 2014). Furthermore, green roofs have economic opportunities, such as increased property values and investment opportunities, because of the growing interest in environmental responsibility (GRHC, 2017).

Personal Wellness

Green roofs also contribute to the physical and mental health of those that engage with it because it provides the opportunity for a meaningful engagement with nature, which is commonly linked to reduced stress and increased satisfaction with society (Banting et al., 2005). Green roofs can also provide the opportunity for socialization and relaxation, which can contribute to illness prevention and healing (Bellows, 2003). Overall, the physical benefits of green spaces include: “reduced mortality, obesity, depression, anxiety, cardiovascular disease…stress reduction, mental restoration and social interactions” (City of Toronto, 2015).

Furthermore, mental health and addiction patients are often prescribed by health-care professionals to participate in urban agriculture and gardening projects (Hanc, 2014; Ngabo, 2017) because they can have healing properties and provide an aesthetic appeal (Loder, 2014). For example, many patients of the Centre for Addiction and Mental Health who work/volunteer at the half-acre “therapeutic oasis” Sunshine Garden report on the healing properties of the garden (Ngabo, 2017).

Community Engagement

Green roofs can be a great tool for community engagement because they can create a safe space for intergenerational and diverse interaction through the collective contribution to food production. Furthermore, the collective effort provides a sense of accomplishment and pride to the community (Payne & Fryman, 2001). Depending on the design, these spaces can also serve as education centres and event spaces, such as the rooftop garden at Eastdale Collegiate Institute in Toronto (FoodShare TO, 2013).

Limitations and other considerations

The literature review reveals that green roofs have a *potential* for environmental, building-specific, personal wellness, and community benefits. These benefits vary depending on the capacity and model of the roof. More insight into the practical application of these findings is required, as it is challenging to accurately assess the quality of each roof model and the benefits each would yield. The literature on the water retention potential focuses on studies of extensive green roofs only, and exact retention potential varies greatly depending on type of roof, slope, plants, rainfall, etc. The Toronto green roof bylaw is another consideration: it requires green roofs to be 80% covered three years after planting, and in the case of roof gardens, harvesting of crops would leave the roof periodically naked — an infraction of the bylaw (Oved, 2015).

Findings: Interviews

Technical Information Interviews

Six of the nine interviews we conducted focused on obtaining technical information about the construction and maintenance of a roof garden. We first interviewed Holly Horne and Jake Hudson from Urban Garden, a Toronto-based landscaping company, who have considerable design and maintenance experience. They drew attention to the structural constraints, specifically the loading capacity of the roof, and the cost limitations of implementing a green roof. They emphasized the importance of having a full time staff maintaining the garden, getting an engineer to conduct a structural assessment of the roof, and conducting sunlight and wind uplift analysis. Holly and Jake also emphasized the benefits of having hybrid green roof model that combines social spaces with a garden atmosphere. The Urban Garden team also echoed the City of Toronto Green Roof Bylaw and supported the retrofitting of old roofs.

Our second interview that focused on the technical information was with the manager of the College's maintenance team: Tim Connelly, Director of Facilities Services at Trinity College. While touring two potential pilot locations, the St. Hilda's Green Roof and the Munk North Roof, Tim highlighted the specific challenges with the two sites, specifically the limited access to water and accessibility issues of the Munk North Roof. Although the St. Hilda's Green Roof was designed to minimize staff maintenance, he emphasized the need for full-time staff at the proposed new roof garden.

Next, we reached out to Ileea Larente, part-time garden manager at Skygarden, which is an intensive green roof on the Civil Engineering building at the University of Toronto.

Skygarden uses “Biotope” planters (plastic pots with an internal water reservoir) and “Dosatron” (an automatic fertilizer injector), which are combined into a single closed-loop irrigation system. She elaborated on the potential plants we could use, the varying growing season, and the success of the biotope planters. From her experience managing the space, she emphasized importance of a full time staff member and the potential challenges of excess food production.

Béatrice Lego, coordinator of the Huron-Sussex Community Garden, also emphasized the need for staffing during our interview by highlighting the unreliability of the volunteer-basis maintenance due to seasonal availability. She recommends collaborative programs with school groups and the community to maintain the roof, and having a designated staff position to oversee campus agriculture projects.

Our fourth interview was with Liat Margolis, the Director of the Faculty's Master of Landscape Architecture program and the Director of the Daniels Faculty's Green Roof Innovation Testing Laboratory (GRIT Labs). Margolis’s academic work informs debates within the literature regarding environmental benefits, specifically around the tradeoffs between green roofs and roof gardens in terms of water retention. She asserted that the primary purpose of the City of Toronto Green Roof bylaws is to increase the number of water retention sites, which aids the City’s stormwater management infrastructure. She added that food-producing roof gardens retain less stormwater than extensive green roofs, and touched upon debate regarding the use of fertilizer. Although some researchers argue that fertilized roof gardens perpetuate the eutrophication of Lake Ontario, a key contributor to algae blooms, Liat disagreed by asserting that roofs can be designed as closed-loop systems, which would ensure containment of the runoff.

Lastly, we interviewed Arlene Thorness, the manager of the Ryerson Urban Farm. Dr. Steels hope to draw inspiration from Ryerson's approach and incorporate it into the pilot project. Arlene described their crop rotation schedule, plant distribution, and irrigation methods, notably, their use of rainwater as the major source of watering. Contrary to Liat, Arlene argued that food production roofs can retain similar quantities of water as extensive green roofs. Most importantly, Arlene's interview provided insight on incentivizing staff to contribute to roof maintenance through the sale of produce at local markets: initially the staff did not receive sufficient pay, and part of their salary included sales revenues.

Community Engagement Interviews

Through our interviews with Marcus Hugh, a Community Animator at the CSI, Kevin Ribeiro, Trinity's Food Services director, and Ileea Larente, we identified that controlling the access to the green roof is important for the safety of the visitors, staff, and the plants. Risks include theft of equipment, food contamination, and safety-related risks due to open accessibility on a roof. Ramata Tarawally, the Associate Director of Community Wellness at Trinity College, suggested incorporating work-study positions and programs wherein students can "take something away". Furthermore, Ramata was open to assigning her work-study students to help with the garden's programming due to her excitement about the project's potential for diverse psychological benefits. Alongside the intrinsic benefits of proximity to nature, a roof garden has the potential to fulfill the three criteria she asserts are necessary for wellbeing: socializing, nutrition and exercise. Program collaboration with the University of Toronto's Multifaith Center was also suggested by Ramata. Our interviews revealed that the benefits of the project can reach well beyond the Trinity community.

Skygarden's primary produce distribution strategy is charitable donations, and they often donate excess produce to The Scott Mission. Ileea noted that the mission does not require third-party quality assessments prior to donation. Ryerson provides two additional methods: a farmers market and a Community Supported Agriculture (CSA) program. These models can mitigate food deserts and set the precedent for direct crop-producer/ crop-consumer relationships. It is important to revisit Kevin's interview to frame the relevance of the alternative distribution models identified above. The Compass Canada Local Food procurement policy mandates that the garden managers become "Good Agricultural Practices"-certified in addition to certifying the garden itself, which would need to undergo two rounds of quality assessment: one conducted by Compass Group Canada, the second by a third part. Additionally, rain water may not be used for irrigation; a handwashing station must be present; and all food must be packaged and stored the day of harvest. Integration clearly involved significant financial barriers and the additional material inputs increase the overall carbon footprint of the project. As outlined in the proposal section, these factors represent significant barriers at the pilot scale; therefore, engaging with diverse means of produce distribution beyond food services integration provides additional options for Trinity College.

Findings: Surveys

A key criteria of the pilot project is to facilitate student engagement with the roof garden; that being said, we conducted a survey of 100 Trinity College students to better gauge their interest in the potential project. The results indicated that the students were largely aware of the St. Hilda's green roof, and expressed an interest in volunteering, growing and using the garden as a study space; students also expressed an interest in work-study opportunities. Some of the concerns voiced by students revolved around equal access, especially for commuter students, and weather considerations. See Figure 1 in the Appendix for the complete results.

Findings: Structured Observations

St. Hilda's

The preexisting extensive green roof at Trinity's St. Hilda's residence. The roof consists of small flowers, bushes and a seating area for socializing, and is accessible during daylight hours from April to October. The design includes compost facilitation, but beyond this, minimal maintenance is required.

DigIn!

DigIn! manages gardens at Sidney Smith, UTSU, and the Anthropology building at the University of Toronto. These are all small spaces featuring a variety of vegetables, herbs, and fruit; they are publicly accessible year round, however, maintenance is limited to the summer growing season.

Skygarden

Skygarden is a high yield, intensive potted garden that can produce 700 pounds of produce annually (see Appendix, Figure 2). Ileea attributes the high yield to the reservoir system contained in Biotop planters, effective fertilizers control via a "Dosatron" and automatic irrigation. There were no clear safety railings on this roof, but there was limited access to the space without a staff present and a waiver signed. Skygarden attempted a student based model but eventually had to hire two project managers to keep the space functional.

Ryerson

Ryerson's Urban Farm is the most intensive model of the ones listed in this paper, in terms of size, crop diversity and crop yield. The garden beds were made with pre-existing organic matter from the original green roof that was built before the creation of the farm (see Appendix, Figure 3). Volunteers were required to sign waivers and staff were trained with roof safety certifications. The roof was made inaccessible in the absence of staff.

CSI

The CSI garden combines an enclosed social space with high railings overlooking an extensive, drip irrigated green roof. However, the social space is the only accessible aspect of this roof (see Appendix, Figure 4).

Findings: Tradeoffs

Dr. Steels's interest in an intensive green roof because it will reduce Trinity College's carbon footprint through the local production of food, and engage Trinity students in gardening programs, improve mental health and wellness, and contribute to organizations like the Scott Mission. However, our research identifies significant trade-offs associated with the project goals.

Tradeoff #1: Environmental Benefits vs Food Production/Wellness

As high food production roof gardens often require vast resources, such as water for irrigation, fertilizers, and full time maintenance, the overall environmental benefits are forgone because of emphasis on high yields. There is often less focus placed on water conservation and rainwater retention, and this can lead to more nutrient runoff from organic soil and fertilizers. Additionally, food producing models, such as the biotope model, does not contribute to reducing energy usage for the building.

Tradeoff #2: Student Management vs Intensive Food Production

Due to unreliable volunteer hours, lack of skilled labour, and student scheduling conflicting with the growing season, there is often a trade-off incorporating student engagement and having a high food yield. Having one person responsible for managing the space full time brings accountability and a vested interest in the success of the project.

Tradeoff #3: Student Accessibility vs Security, Safety, and Protection of Plants

Generally, publicly accessible roof gardens are unsuccessful due to damage to equipment and plants. For a roof garden to be successful, they need to be maintained and monitored by trained staff. Being located on a roof also brings with it a number of safety concerns for public access. Many safety requirements including the addition of balconies and roof safety training must be incorporated into the design and management of a roof if it is to have open access to the public.

Tradeoff #4: Environmental Benefits vs Integration with Food Services

Due to stringent food safety standards, the integration with food services requires foregoing some environmental benefits of a green roof. More resources are required to meet these food safety standards, such as a sink, food packaging, and more intensive irrigation, rather than using rainwater. Additionally, because the scale of food production on the pilot is unconfirmed, we do not know the capacity to which we can contribute to food services.

Proposals & Recommendations

The general process of roof garden implementation entails three parts: the design, the construction, and the maintenance of the space. In this section, we will describe our recommendations for the Trinity College pilot project. This section will describe two potential proposal options, one on the Munk North roof and the other on the pre-existing green roof at the St. Hilda's residence. We will describe the differences between the two proposals and compare the potential projects using a matrix based on the goals of the projects (see Appendix, Table 2). We will also include a cost breakdown of each proposal. First, we will describe the general recommendations for the pilot project and the common costs for both proposals (see Appendix, Table 3). Furthermore, a breakdown of additional costs associated with each proposal will be included (see Appendix, Table 4) as well as the costs associated with the integration with food services (see Appendix, Table 5).

Informed from our findings and through addressing the tradeoffs, the pilot would need to be inaccessible to the general public, involve formalized student engagement, and lack environmental benefits (likely to have significant environmental costs). But the purpose of the pilot will be to gain insight and research important factors that could be of use for the new Trinity College building. The pilot will provide more information on integrating food into Food Services at Trinity and/or other models for food distribution; research into environmental costs of food production (especially stormwater retention); and integrating the garden into the governance and maintenance structure of the College. The following is a description of our main recommendations for the pilot project:

1) A full-time staff member to coordinate work-study students, student groups and volunteers in addition to maintaining the roof and ensure quality food production.
2) Continued research on the inputs and outputs management and environmental costs of food production, as well as research on ways to integrate the food into Food Services.
3) A funding partnership with alumni (similar to the donation that created the Health and Wellness Center at Trinity College) to ensure the longevity and sustainability of this project.

4) Conduction of further and ongoing research to better inform integration of food into Food Services (figuring out food production levels, food calendar, food quality and amount); no integration for the time being. We recommend the food from the pilot gets sold, donated and given to volunteers and employees. The food from the pilot will likely be not enough to change the purchasing protocol at the Food Services, leading to food wastage; additionally, the requirements to integrate into Food Services are too expensive and will take a long time to meet.

Munk North Roof

For the Munk North roof proposal, we suggest having potted plants with stepping stones around the pots (see Appendix, Figure 5). The river rocks currently lining the roof will need to be removed and replaced by a roof membrane-protecting substance. A structural assessment is required before construction to assess the loading capacity of the roof. Due to the lack of readily available running water, plumbing will need to be installed from the washroom down the hall to the roof. There are a series of specific advantages to the Munk North roof; it will be an additional green space at Trinity; can be adapted into a research garden after the pilot is completed; it has better sunlight exposure than the St. Hilda's green roof; and is wheelchair accessible. There are also specific disadvantages to the Munk North roof: it is much more expensive, is close to the offices and presents considerable difficulty in terms of cost and installation of a plumbing and irrigation system; the space is also completely inaccessible to the general public/students (non-social space).

St. Hilda's Green Roof

For a roof garden at St. Hilda's, we recommend planters on top of the pre-existing plant beds, and rows of plants growing from the pre-existing extensive garden bed (see

Appendix, Figure 6). There are no additional plumbing costs, as running water already reaches the roof. The roof does not need to be retrofitted, although a structural assessment would be required to ensure the roof's load-bearing capacity. Building a pilot on this roof is advantageous because it is less expensive (than the Munk North roof), is already a multi-use spaces accessible to most; because it is a pre-existing extensive roof, water/plumbing infrastructure is already in place. The pilot would also present research opportunities and could remain a social space after implementation of the roof garden. The disadvantages of the St. Hilda's green roof proposals are manifest through less daily sunlight exposure, lack of wheelchair access, and vulnerability to plants through easier public access.

Proposal Recommendation: St. Hilda's

For the scope of this research project, we recommend the St. Hilda's roof proposal for the pilot, as it is easier to implement, cheaper, and more accessible to the Trinity College community. If the College acquires more money, a retrofit of the Munk North roof model would be beneficial so that the College has a series of different green spaces on campus.

Looking forward

After a retrofit, the Munk North building would function positively as a Trinity green space, which would bring physical and mental wellness benefits and contribute to a sense of community (Banting et al., 2005). Also, this space can be utilized beyond the limits of the pilot project for research purposes and act as a living lab to inform and further our knowledge of roof gardens.

Limitations

Our proposals are limited by the lack of knowledge and research on factors such as bylaws and restrictions, the general size of the space, roof barriers, and sunlight exposure.

Furthermore, a larger sample can be surveyed to discern the views of the broader Trinity community and better inform our understanding of student interest in engagement. Additionally, the budget for the project greatly influenced the feasibility of the two proposed sites, and ultimately, led to the choice of the St. Hilda's roof. Lastly, the variation in roof garden models, growing techniques, and city bylaws made it challenging to evaluate the success of different roof gardens, identify the best practices and correct plant selection (Fioretti, Patta, Lanza & Principi, 2010; Wong et al., 2003). While many of the findings from these studies can be useful in developing background information, they are case-specific.

Conclusion

Our team's academic research, semi-structured interviews, structured observations, and student surveys were able to successfully inform the three objectives laid out by our client. After limiting the scope of the project to a pilot roof garden proposal -as informed by research on operational feasibility and student engagement- our team asserts that making minor amendments to the St. Hilda's roof garden is the most cost effective and accessible model. In pursuing this proposal, Trinity College would strike the ideal balance between student engagement, food production, and financial feasibility while ensuring minimal environmental detriments. Integration with food services can also be tested which, along with the other knowledge gained, through the pilot's implementation, will inform the design of the roof garden intended for Trinity's future resident building.

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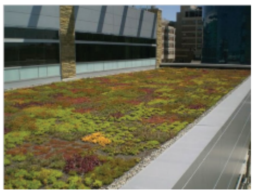
Appendix

Supplementary Material

Table 1. Comparison of green roof and roof garden models in terms of structural, functional, environmental and social considerations.

Type	**Extensive** *green roof*	**Semi-Intensive** *green roof*	**Intensive** green roof/roof garden	**Potted** *roof garden*
				
Suitability	Suitable for large area retrofits	Hybrid of intensive and extensive	Suitable for recreational applications, human use and projects with specific objectives	Low-cost project to produce food and have community involvement
Description	6" or less depth Usually Inaccessible	Around 6" depth, may be 25% of roof area partially accessible	Over 6" depth Usually Accessible	Potted vegetation
Planting	Low plant diversity Low growing plants and mosses with stress-tolerance qualities	Medium plant diversity Potential for basic garden	High biodiversity Agricultural/Functional Plants as well as native vegetation	Medium-high biodiversity Agricultural/Functional Plants and some native vegetation
Weight	Low Weight 10-35 lb/sq. ft.	Variable Weight 35-50lb./sq.ft.	High Weight 35-300lb/sq. ft.	Low Weight
Irrigation	Little to no irrigation	Some irrigation may be required weather and plant dependent	High irrigation May depend on weather but must be watered at least once per week through growing season	High Irrigation
Maintenance	Low maintenance with little accessibility Does not require full time staff	Variable Some irrigation and planting may be required May require part time staff	High ongoing irrigation and upkeep Will require full time staff and maintenance year round	High maintenance May be lower if using auto-irrigation system Requires full- time staff for extended growing season

Environmental Benefits	Reduction of Urban Heat Island Effect Improved air quality Improved stormwater management Improvement in air quality through absorption of carbon dioxide and release of oxygen Habitat for wildlife Increased Biodiversity and also helps to optimize comfort management/indoor conditions (thermal, acoustic, etc.)	Reduction of Urban Heat Island Effect Improved air quality Use of roof area as additional space Improved stormwater management Heating and Cooling Building Efficiency Improvement in air quality through absorption of carbon dioxide and release of oxygen Habitat for wildlife Increased Biodiversity	Reduction of Urban Heat Island Effect Improved Air Quality Use of roof area as additional space Highest stormwater management among all models Highest Heating and Cooling Building Efficiency among all models Improvement in air quality through absorption of carbon dioxide and release of oxygen Habitat for wildlife Reduces Waste in Landfill Through Composting Reduces Food Kms and CO2 by growing food locally Increased Biodiversity	Improved air quality Improvement in air quality through absorption of carbon dioxide and release of oxygen Pollination Potential Habitat? Reduces Waste in Landfill Through Composting Reduces Food Kms and CO2 by growing food locally
Social Benefits	No Engagement Only indirect benefits through improved building quality and urban ecology	Multiple Uses Aesthetic Design Options Wildlife observations Urban Access to Nature Education Visually attractive; aesthetic appeal and greenery of green roofs in cities linked to psychological well-being (based on a study of office workers in Chicago and Toronto).	Variety of Human Uses Community Development Improved Well-being Reduced Crime Reconnecting People with Food Wildlife observations Urban Access to Nature Education Visually attractive and also helps many with mental health issues (more to do with urban agriculture rather than roof garden exactly, but it fits)	Community Development Improved Well-being Reduced Crime Education Reconnecting People with Food Wildlife observations Semi-visually attractive
Advantages	Lightweight Low Maintenance Lower Cost Easily Replaced No Irrigation	Utilizes areas with greater loading capacity with high coverage and low cost Includes environmental benefits as well as some human access and social benefits	Revenue Centre Reduces Food Insecurity Social and Environmental Benefits Education	Low Cost, high productivity for human use

Disadvantages	No Public Access	Requires some irrigation and with human access requires safety and security considerations and maintenance	High maintenance and cost ongoing. Must accommodate human access, safety. Requires significant planning and full time staffing. Potential leaching of nutrients into drainage system, research not conclusive	Loss of several environmental benefits
Cost	Low	Medium	High	Medium-Low

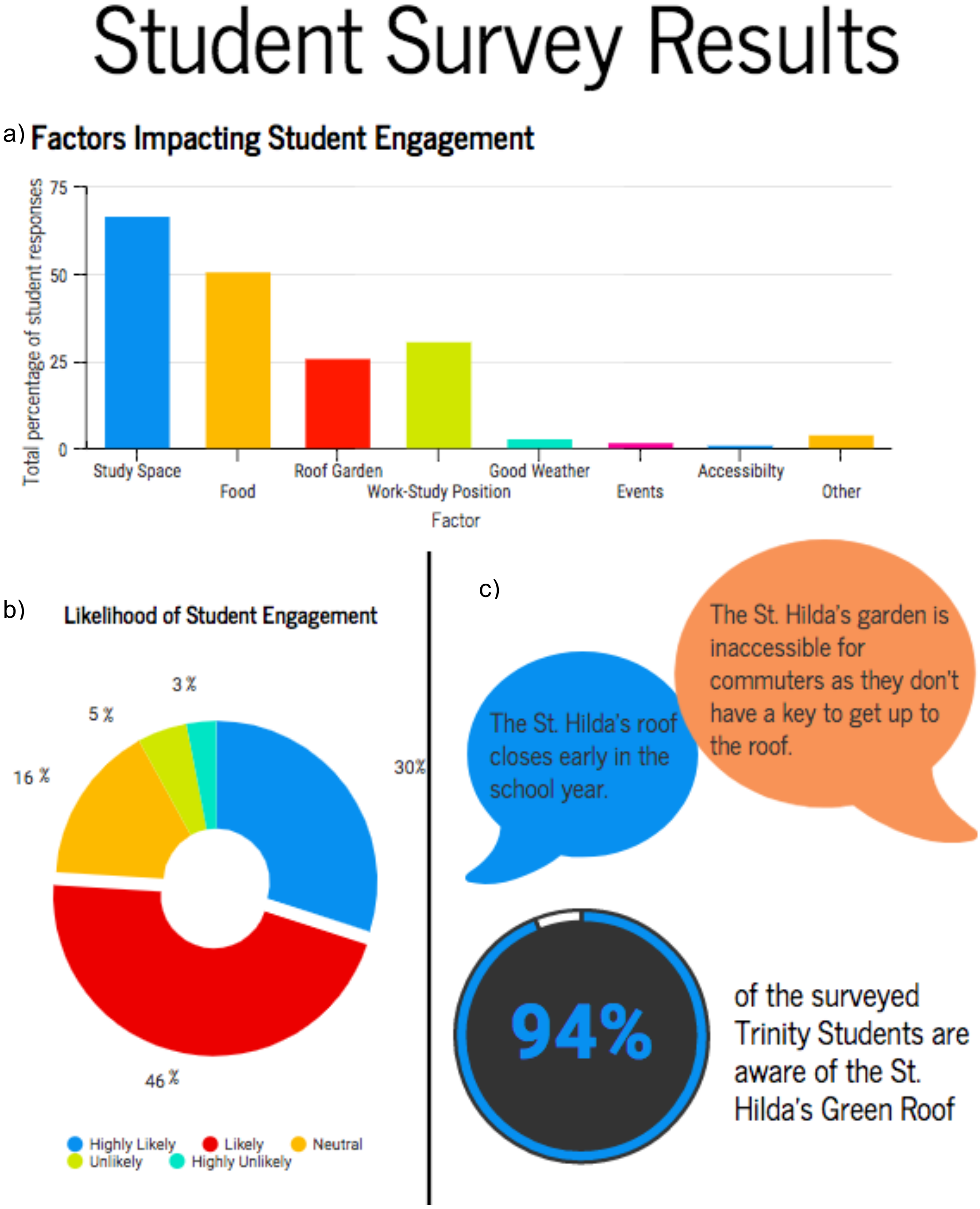


Figure 1. Summary of student survey results conducted at Trinity College during November 2017. 100 Students were surveyed using a combination of in-person and online responses. Figure 1a) displays the interests students showed in potential ways of engaging with a green space on campus. Figure 1b) represents the likelihood that students would engage with a new green space on campus if it were available to them. Figure 1c) is a small sampling of feedback received from students when asked to comment.

Figure 2. Photos taken at SkyGarden at the University of Toronto. Figure 2a) and 2b) show the potted model being used for a variety of plants including tomatoes and basil. Figure 2c) shows the closed system used for irrigation and fertilizer application.

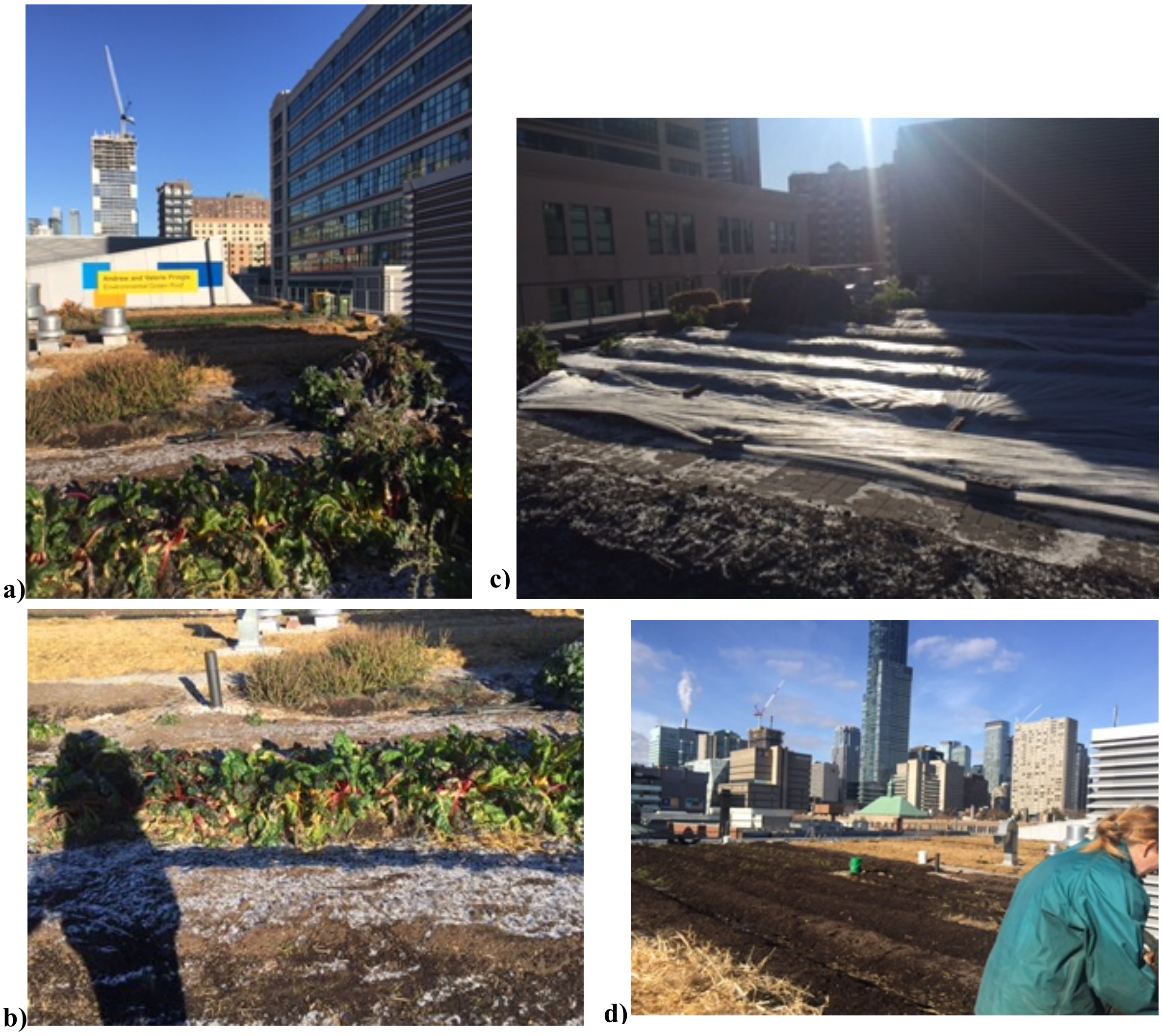


Figure 3. Photos taken at Ryerson roof farm in November 2017.


a)

b)

Figure 4. Photos taken at the Center for Social Innovation (CSI) in October 2017.

Table 2. Roof garden proposal matrix

Criteria	Factor	Munk Roof Summary model	St Hilda's Summary of model
Implementation	Building Time- start to finish	~1 month	~1 month
	Start Date	April 2018	April 2018
	Common Capital Costs	$8,500	$8, 500
	Common Labour Costs	$15,000	$15,000
	Extra Costs	$8,600- $13,600	N/A
	Total Costs	$32,100-$37,100	$23,500
Growing Suitability	Sunlight	~7/8 hours in the summer (10am- 6pm)	8+ hours in the summer (~9am-7pm)
	Types of vegetation	List of potential plants*	
	Irrigation	Need to bring plumping from the washroom to the roof, timed water systems to the biotop pots	Pre-existing watering access, connect it to the timed water systems to the biotop pots
	Roof Size	~1900 square feet	~2200 square feet
Long Term Operation/Management	Number of staff required to maintain the roof	At least 1 full-time	
	Labour costs per staff	$15,000 (five months of work)	

	Volunteer opportunities	As many as possible (maximum 10)	
Benefits	Ecosystem health	Very beneficial for urban biodiversity	
	Personal Wellness	Very beneficial for wellness	
Community Engagement and Accessibility	Site Accessibility-wheelchair	Purchasing a STOP GAP would allow wheelchair access.	Not wheelchair accessible
	Alumni Engagement opportunities	Potential alumni volunteer opportunities and funding partnerships	Already an alumni partnership space, potential alumni volunteer opportunities and funding partnerships
	Student Engagement opportunities	-Work study opportunities, student group engagement, formal volunteering opportunities -The Munk Roof would be locked whenever staff were not present -Both roofs lack engagement opportunities during summer term	
	Faculty Engagement opportunities	-Both roofs can be open to faculty to use during breaks and can take food, only while staff are working -Used for class tours	
Food Services Options	Integration with food services at Trinity College	-Must follow the food services requirements and process -Costly implementation, need to research into feasibility	
	Collaboration with City food banks, Scott Mission	-Easy to implement, good use for extra food -No cost implementation -Addresses food insecurity in Toronto	

	Farmers markets, Community Supported Agriculture programs	-Need Research into regulations and program, but fairly easy to implement -Creates a beneficial incentive structure for employees similar to the program at Ryerson's Urban Farm

*List of potential plants

- Tomatoes (a wide range of different types)
- Eggplant (a range of different types)
- Peppers
- Carrots
- Broccoli
- Herbs
- Flowers (Wild Flowers/Pollinator gardens)
- Onions
- Potatoes
- Lettuce
- Rhubarb (can survive over winter)
- Spinach
- Squash
- Melons

→ Skygarden regularly experiments with different plants and determines what grows the best
→ Should plant the plants together according to family. Additionally different plants should be planted at different times of the year (important for crop cycles and soil quality)

Table 3. Common general capital and labour costs for the pilot proposals

Item	Cost
"Biotop" Food grade planters connected with timed irrigation system (x20 planters)	$1,500
"Dosatron" Fertilizer Dispenser	$500
Plants, seeds, fertilizer, light-weight agricultural soil	$1,000
Plant supports (wind/frost barriers)	$500
Miscellaneous supplies	$1,000

Structural Assessment	$4,000
Staff Position(s) for Pilot Duration	$15,000
	Total: $23,500

Table 4. Munk North roof proposal additional costs

Item	**Cost**
Roof Preparation- remove rocks and water-absorbent membrane	$5,000-$10,000
Plumbing	$2000
Concrete step stones (60 x $10)	$600
*Potential stormwater recapture	$1000
	Total: $8,600-$13,600

Table 5. Food services integration additional costs

Item	**Cost**
Cleaning food and hand washing station	$1150
Containers	$150
Signage/Marketing/Labels	$350
Quality Assurance (QA) third party assessment	$150-$1200
Good Agricultural Practices (GAP) training program	$325-$625 per person
	Total: $2,125-$3,475 (1 person)

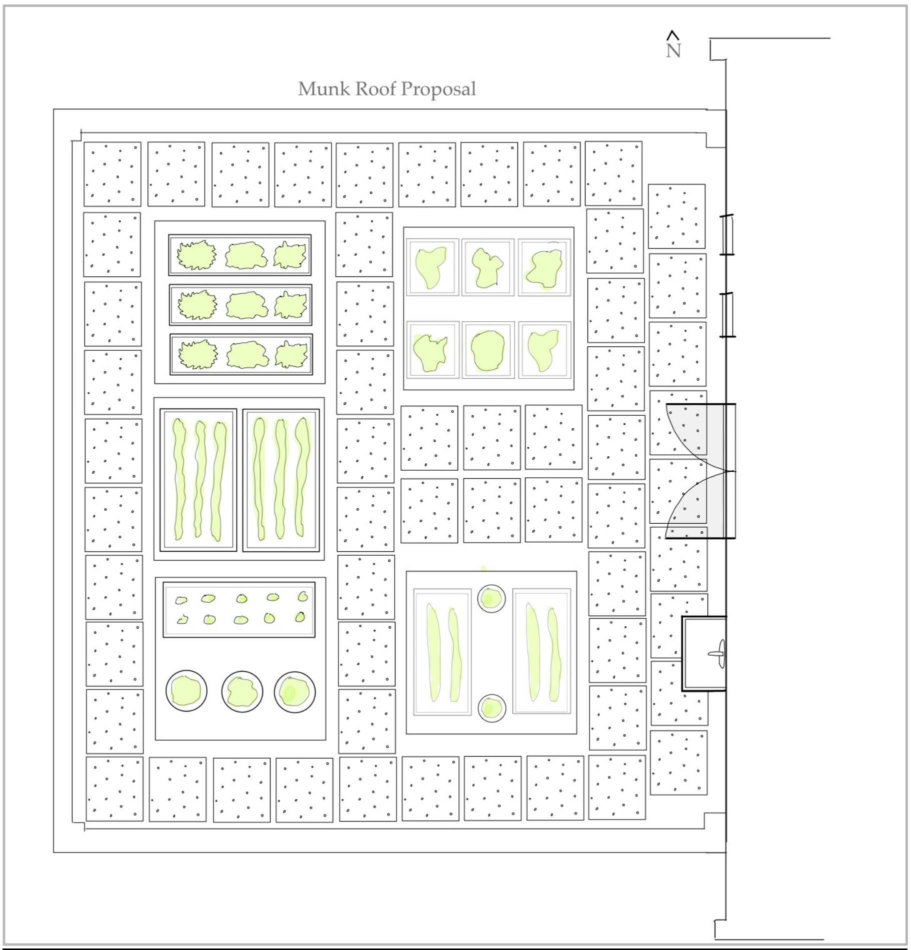


Figure 5. Munk North roof proposal design.

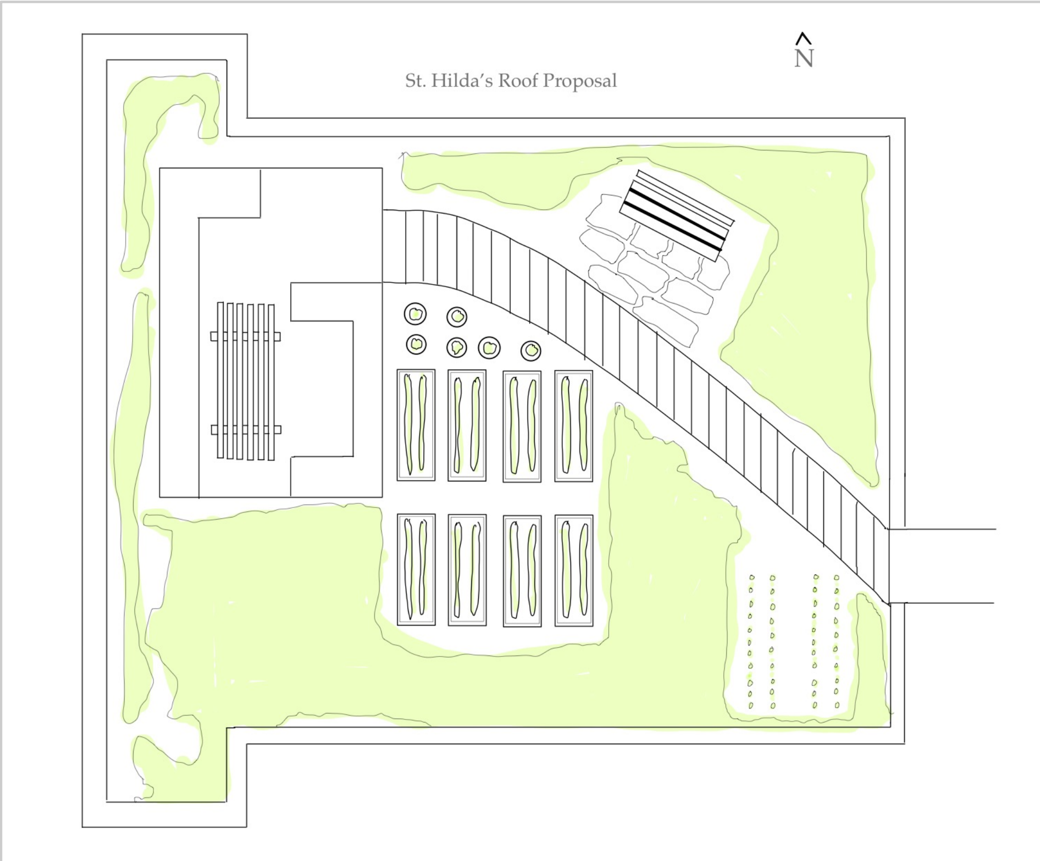


Figure 6. St. Hilda's roof proposal design.