UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into New SUB Rooftop Garden Irrigations Systems

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APSC 262 SUSTAINABILITY REPORT:

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Abstract

Garden irrigation is a critic component for the new SUB rooftop garden. Contrary to popular belief, it's entirely untrue that plants in Vancouver do not have to be watered despite heavy rainfall over the course of a year in British Columbia. Using the triple bottom line analysis, a new recommendation for an irrigation system is made. Sprinklers, drip irrigation and sub irrigation are the three systems that are discussed in this sustainability report.

Sprinkler irrigation systems consist of a system of pipes that are used to bring water to the ground. It makes for one of the most natural methods of irrigation, almost identical to conventional home sprinklers, where water falls right on top of the plants like raindrops. There are many different factors that affect the usage of the sprinkler irrigation system, such as Suitable Slopes, Suitable crops, Suitable Soils, Suitable irrigation water. Drip irrigation done through a system of valves, tubing, pipes, and emitters. This method uses less water as opposed to sprinklers because of its low pressure output and its ability to reduce water contact with leaves. This system allows for increased yield and quality. Drip systems are especially good for onions, cauliflower, broccoli, lettuce, melons, and tomatoes. Only negatives about this system are the fact that the material it is made up of is not recyclable. Also, it is extremely tedious to maintain when there are problems with clogging, and punctures in the tubing. Sub irrigation is the last of the three systems that will be talked about. There are very similar in terms of drip irrigation, with its high maintenance costs. They are very environmental friendly for its ability to reuse recycled water. This allows for high uniformity.

All three systems are all possible options for the new SUB roof. When it comes to sustainability, having the building be as green as possible is of the utmost importance. Maintenance costs, life spans, and water waste are all factors that account into sustainability. The amount of water saved within the 100 year life span of the new SUB building is crucial because these savings will outweigh the costs

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Glossary

Application Rate	The amount of water the system applies over a specified period of time.
Distribution Uniformity	A measure of spatial variation in precipitation.
Emitter-	An emitter, also called a dripper, is a product used in drip irrigation to regulate the flow from the mainline or branch line tubing to the area to be irrigated.
Evaporation	Process by which water is converted from its liquid form to its vapour form.
Fertilizers	Substances that supply plant nutrients or amend soil fertility
Filter	A filter is used to remove particles from the water that might otherwise plug up your emitters.
Greenhouse	Building where plants are grown
Infiltration Rate	Amount of water absorbed by the soil in a given amount of time
Inflation Rate	The percentage rate of change in price level over time
Irrigation	Artificial application of water to the soil
Low Flow Rate	Emission device flow rates are typically measured in gallons per hour (GPH), resulting in low application rates.
Low Pressure	Operating pressures typically range between 10-30 psi, rarely exceeding 60 psi, for most emission devices.
Molding	A process of manufacturing by shaping pliable raw material using a rigid frame
pH	Measure of acidity or basicity of an aqueous solution

Pressure	Pressure is the force pushing the water flow. Pressure is expressed in pounds per square inch or PSI.
Subsoil	The layer or bed of earth beneath the topsoil.
Soil -	With drip irrigation the density of the soil affects how far the water flows from the emitter.
Sprinkler	A device for irrigation of lawns or crops.
Uniformity	A state or condition in which everything is regular, homogenous or unvarying
Water Pressure	Water pressure describes the force behind the water in a line and is expressed in Pounds per Square Inch (PSI).

List of Abbreviations

CFD – Computational Fluid Dynamics

SDI – Subsurface drip irrigation

DU – Distribution Uniformity

DU: Distribution Uniformity

% : Percentage

etc. : et cetera

USD: United States Dollar

CAD: Canadian Dollar

ft: Feet

m/sec: meter per seconds

mm: millimetre

in: inches

hr: hour

SUB: Student Union Building

1.0 INTRODUCTION

The new sub project is being designed to be a new interactive and dynamic student union building budgeted at $103 million. As leaders in sustainability, UBC puts a lot of effort and money to insure that it has the least amount of environmental impact possible. There are many expectations for the new sub; one major expectation is LEED Platinum+. LEED Platinum+ is the highest rank a building can get in North America. LEED ranks the environmental impact of buildings, therefore the higher the rank the greener the building is.

Among many rigorous conditions, LEED Platinum+ exergues that the storm water runoff are minimized. One such way to minimize water run off is to insert some kind of vegetation on the roof of the building as to hold most of the rain/storm water. The decision was made to construct a rooftop farm. One of the major reasons a farm was picked over a garden was the profit that can be made from selling the produce. Although its main goal is to decrease water runoff, the rooftop farm still needs an irrigation system to survive

There are many irrigation systems available; however a rooftop irrigation system has many requirements. Such requirements consist of: minimize the use of machinery, minimize the amount of runoff water, and minimize the pollutants from fertilizers. In addition to numerous requirements presented by a farm being on the roof, we used the triple bottom line analysis to compare the various irrigation types. Through much research, we concluded that there were only two promising irrigation types, Drip Irrigation and Sprinkler Irrigation. We also included sub irrigation as a viable irrigation system.

2.0 SPRINKLER IRRIGATION

2.1 Introduction

[1A] Among different types of irrigation methods we have looked into, Sprinkler irrigation System is one of the best irrigation* methods suitable for watering rooftop garden in Vancouver. Sprinkler* Irrigation is the method of spraying water into the air, which is then allowed to fall on the ground in somewhat familiar manner as the raindrops, making one of the most natural method irrigation. A system of pipes is used to distribute water to the sprinkler where it is broken down into smaller drops before they fall on the ground. There are many different factors that affect the usage of the sprinkler irrigation system, such as Suitable Slopes, Suitable crops, Suitable Soils, Suitable irrigation water.

2.2 Dependent Factors

Factors that affect the efficiency of the sprinkler irrigation systems are:

- **Suitable Slopes**

The Sprinkler Irrigation System can be used in any slope given that the pipes supplying water to the sprinklers are laid along the land contour in order to minimize the pressure* changes at the sprinklers. This will provide a uniform irrigation without depending on the slope (uniform or undulating). This is one of the positive reasons for using sprinkler method than the other methods as most of the other methods are to use in the area of slope.

- **Suitable Crops**

The types of crops used limit the possibility of using sprinkler irrigation method. This method is suitable mostly for the row, field and tree crops in which the water can be sprayed over or under the crop canopy. In case of small, delicate crops, such as lettuce, it's always better option to avoid using large sprinklers as the large water drops can easily damage the crops.

- **Suitable Soils**

Sprinklers can be used for most soils, but they are best choice for sandy soils with high infiltration rates*. On the other hand, sprinklers shouldn't be used for the soils which easily form a crust.

- **Suitable Irrigation water**

In order to avoid nozzle blockage, clean water, without suspended sediments, sprinkler systems should be used. This also prevents the crop for being spoiled by the coating of the sediment.

Reference:

[1A] Chapter 5. sprinkler irrigation. (n.d.). Retrieved from http://www.fao.org/docrep/s8684e/s8684e06.htm#chapter

2.3 Advantages and Disadvantages

It is always necessary to consider the best type of irrigation system based on its advantages and disadvantages. Similarly, sprinkler irrigation system has several advantages which make it a better option to use as compared to other irrigation systems. Some of the advantages include more available area for growing crops as there are no bound, hence increasing the yield. [1B].Another use is that it is more economical as it saves money through precise watering by using right amount of water in the needed areas [1B]. To add to the advantages, sprinklers can also be used to for applying fertilizers* and pesticides by placing them at the splits. This may cost slightly more, but on the other hand, it saves the overall labor cost. [2]. Another way of reducing cost is that fewer sprinklers can be used due to the mobility of the sprinklers as the same sprinkler can be moved from one place to another [1B]. One of the biggest economical advantages is no requirement of expensive land levelling.

At the same time, the disadvantages of sprinkler systems exist. One of them is the high installation cost which is primarily at the beginning. It also requires high operation expenses due to energy needed for pumping, and relatively large investments in equipment: sprinklers and pipes [4]. These systems have a huge negative effect on watering which is basically due to the wind strength and temperature. With the increase in wind strength and temperature, the water application efficiency decreases. [3,4]. The limit of the wind strength it can hold is around 2m/sec. It is always better to use a different type of irrigation system in the areas where the wind strength is more than this limit, unless there are some ways to control this wind strength. During high temperatures, there is a great loss of water due to evaporation*. Along with these disadvantages, it is also not a really good idea to use this system during moist environments as there is a chance of plants getting diseased.

References:

[1B] Sprinkler irrigation. (n.d.). Retrieved from http://agritech.tnau.ac.in/agricultural_engineering/spring_irrigation.pdf

[2] Sprinkler irrigation system. (n.d.). Retrieved from http://www.share4dev.info/kb/documents/2637.pdf

[3] Main advantages & disadvantages of sprinkler irrigation . (n.d.). Retrieved from http://nawazagriengineering.blogspot.com/2009/10/main-advantages-disadvantages-of.html

2.4 Types of Sprinkler Irrigation Systems

2.4.1 Center Pivot

This is a sprinkler system type that uses water source. [4]The water source is located at the center and is connected to the pipes or hoses to supply water throughout the field. The source of water could be a water tank, well, canal, or any other big storage tank. It is the most used type of sprinkler due to the most number of advantages it has in comparison to the other types of sprinkler irrigation systems. [5] Some of the advantages include the requirement of low pressure* which results in low costs. It is also one of the most uniform systems. At the same time, it also has a high efficiency varying from 75% to 90%.

In contrast, it also has some disadvantages. The disadvantages include high capital cost and higher instantaneous application rate.

References:

[4] Benefits of pivot irrigation. (n.d.). Retrieved from http://pivotirrigation.blogspot.com

[5] Energy efficient irrigation . (n.d.). Retrieved from http://www.auroraenergy.com.au/save_energy/pdf/AUAGF1021_irrigation_FS.pdf

2.4.2 Solid Set Sprinkler

[6] This is a sprinkler system in which sprinkler is permanently installed at different spots. Some of the advantages include requirement of high pressure which results in less energy being used. These types of sprinklers have a high application rate* if it is properly designed with appropriate sprinkler spaces.

The reason of these sprinklers being not used on a widespread scale is basically due to lower efficiency which varies from 75% to 85%.

References:

[6] Energy efficient irrigation . (n.d.). Retrieved from http://www.auroraenergy.com.au/save_energy/pdf/AUAGF1021_irrigation_FS.pdf

2.4.3 Traveling Gun

[7] These sprinklers are large sized which are used to spray water to greater heights and greater area. It is very flexible and easily portable. It doesn't have a lot of advantages as compared to other types, but contains many disadvantages such as it requires high pressure, thereby increasing the operational cost. It also has a low uniformity*, making it less efficient, where the efficiency ranges from 65% to 75%.

References:

[7] Energy efficient irrigation . (n.d.). Retrieved from http://www.auroraenergy.com.au/save_energy/pdf/AUAGF1021_irrigation_FS.pdf

Table 2.1 compares the efficiency of the three types of sprinkler systems.

Center pivot & linear move	75–90%
Solid set or permanent	75–85%
Traveling gun	65–75%

Table 2.1: Compares the efficiencies of Sprinkler Types (taken from Chapter 4: Performance Evaluation of Irrigation Projects)

[8] References: M.H. Ali, *Practices of Irrigation & On-farm Water Management: Volume 2*, 111

Taking into account the advantages, disadvantages and efficiency, Center Pivot comes up to the best Sprinkler Irrigation System.

2.5 Center Pivot Details

[9] As described in the New SUB rooftop garden description, the SUB will have the following layout:

Root Depth = 12 inches

Maximum rainfall annually = 1224 mm

Additional rainfall required for complete irrigation = 717mm

Total Rainfall Required=1224mm + 717mm = 1941mm

Allowable Water Deficit = 717/1941)

Taking these into account, it is possible to decide which is the best soil to use for Center Pivot is. The following tables compares the sprinkler system for different soils based on infiltration factors.

	Coarse Sand				Fine Sand			
Root Depth (inches)	12		12		12	12	12	
Allowable Water Deficit (%)	36		36		36	36	36	
Soil Type	Coarse Sand				Fine Sand			
Subsoil	Uniform	Uniform	Compact	Compact	Uniform	Uniform	Compact	Compact
Surface	Bare	Covered	Bare	Covered	Bare	Covered	Bare	Covered
Slope (%)	0.5	0.5	0.5	0.5	0.5			
Results								
Soil Infiltration rate (inches/hr)	2	2	1.5	1.75	2	2	1.5	1.75
Root Zone available water capacity (inches)	0.5	0.5	0.5	0.5	0.87	0.87	0.87	0.87
Irrigation required (inches)	0.18	0.18	0.18	0.18	0.31	0.31	0.31	0.31

Table 2.2: Compares Sprinkler Irrigation Using Types of Sandy Soil

	Silty Clay				Clay			
Root Depth (inches)	12		12		12		12	
Allowable Water Deficit (%)	36		36		36		36	
Soil Type								
Subsoil	Uniform	Uniform	Compact	Compact	Uniform	Uniform	Compact	Compact
Surface	Bare	Covered	Bare	Covered	Bare	Covered	Bare	Covered
Slope (%)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Results								
Soil Infiltration rate (inches/hr)	0.15	0.2	0.15	0.2	0.15	0.2	0.15	0.2
Root Zone available water capacity (inches)	1.6	1.6	1.6	1.6	1.35	1.35	1.35	1.35
Irrigation required (inches)	0.58	0.58	0.58	0.58	0.49	0.49	0.49	0.49

Table 2.3: Compares Irrigation Using Types of Clay Soil

Reference:

[9] Organic land care - irrigation calculator. (n.d.). Retrieved from http://www.auroraenergy.com.au/save_energy/pdf/AUAGF1021_irrigation_FS.pdf

The above table includes calculations done through the online calculator. The above tables compares the different types of soils based on several factors, such as Soil Infiltration Rate*, Root Zone available Water Capacity, Irrigation required, etc. Higher the Soil Infiltration Rate, better it is for the plants and crops as the soil absorbs more water in a given time. As it is clearly seen from the tables, sandy soils have the highest Infiltration Rate, especially the coarse sand type with uniform subsoil*. Another piece of information from these tables is that sandy soils are a lot better when compared to any other soil type, like Clay, etc. Along with this, we can also conclude that sprinkler system is a better option to use during the sandy soil condition.

2.6 Calculating Watering Time Based on Application Rate

Application Rate plays a great role in deciding when to use the center pivot sprinkler system. The average application rate for the sprinkler varies from 0.1 in/hr to 3 in/hr.

Zone	Water Requirement	divided by	Application Rate	multiplied by	Conversion Factor	equals	Watering Time (adj. for uniform.)
1	1 inch	/	0.5 in/hr	*	60	=	120 minutes
2	1 inch	/	2.0 in.hr	*	60	=	30 minutes

Table1.2.4: illustrates the importance of precipitation rate in determining how many minutes each zone should be watered

(Source: Sprinkler systems . (n.d.). Retrieved from http://www.conservewater.utah.gov/OutdoorUse/SprinklerSystem/)

As it can be seen, the higher the application rate is, the lower the watering time becomes. This is due to the rain water as it plays a great role in reducing the watering required.

2.7 Center Pivot Based on Triple Bottom Line Analysis

The Triple Bottom Analysis is one of the best ways to evaluate an irrigation system. It consists of three factors: Environmental, Economic and Social. These are described in more detail as following:

2.7.1 Environmental Factors

Some of the dependent factors that farmers should be aware of when it comes to a certain type of irrigation are the discharge rates and irrigation duration. The environmental conditions are more favourable for sprinkler systems so the famers can have a better control of the dependent factors. In case of the sprinkler systems, farmers are totally in control of these factors. [10]

The term used for determining the amount of water to be applied to the field or a garden and the accurate timing of application is called Irrigation Scheduling. The advantages of the irrigation scheduling are to save as much as water and energy an individual can. It can also help in increasing the efficiency of an irrigation system. [11]

The following are the different types of sprinkler systems that can be considered in relation to the irrigation scheduling:

- **Set/Fixed Sprinkler Systems:** As the name suggests, these systems operate being in a fixed position. The usage of these systems to apply depths having a smaller size and requires frequent watering sessions. These systems would not be useful for systems with low application rates. [10]
- **Travelling gun sprinklers:** The irrigation use of these systems lies in the depth range of 15-40 mm. Due to limitations in system capacity, these systems are not appropriate for applying either small or large depths. [10]

Disadvantages of Irrigation Scheduling Techniques

The main reason for not adopting the irrigation scheduling techniques is that the implements of these techniques lack skill and they don’t also produce the required outputs, unless the application of water practices are done in a proper manner. [10]

Center-Pivot Irrigation Systems

The use of these systems is widespread. One of the uses is the possible rice irrigation with the help of these irrigation systems.

These systems are more useful than the other forms of sprinkler irrigation systems such as the flood irrigation. These systems irrigate fields with water uniformly as compared to the flood or furrow irrigation systems. This results in the reduced outflow of water which saves water. It also requires less pumping which saves energy. The use of “accurate metered fertilizers and chemicals “is done through these type of irrigation systems with the resultant efficiency equal to the efficiency of irrigation water. Due to leaching and runoff, the loss of chemicals and fertilizers is minimized. The overall outcome of these aspects is that it results in the increase of the input efficiencies and the reduction of possible environmental impacts. [12]

References:

[10] Inter-relationships between irrigation scheduling methods and on-farm irrigation systems. (n.d.). Retrieved from http://www.fao.org/docrep/w4367e/w4367e0c.htm

[11] Irrigation scheduling. (n.d.). Retrieved from http://www.ext.colostate.edu/pubs/crops/04708.html

[12] Irrigating rice with center pivot sprinkler systems. (n.d.). Retrieved from http://irrigationadvances.com/2010/10/irrigating-rice-with-center-pivot-sprinkler-systems/

2.7.2 Economic Factors

[13] The economic analysis of Center Pivot irrigation systems involves looking at factors like calculating annual capital cost and distribution uniformity*. The term Distribution Uniformity is “a measure of spatial variation in precipitation”

Reference**:**

[13] Factors affecting the economic benefits of sprinkler uniformity and their implications for irrigation water use, Introduction,

DU is used to check if the system has the acceptable efficiency. Figure 2.1A shows the how the total capital cost per hectare of different sprinklers varies with the change in mean DU of the associated sprinklers. When considered this, the life time of the sprinkler used is assumed to be 5 years, while the lifetime of the components is assumed to be 15 years. As we can see from the graph, for the range of higher costs, DU is also higher for systems. On the other hand, for the lower cost range, there is a lot of variation of DU, as we can find some systems with higher DU having a lower total capital cost. [13]

Figure 2.1 B shows how the water use and gross capital cost varies with DU for different sprinkler systems. It can be clearly seen that the water usage is inversely dependent on the Distribution Uniformity, as with the increase in DU, the water usage decreases. On the other hand, DU increases with the increase in gross capital making them directly proportional. Therefore, it can be seen that it is always a best option to choose the sprinkler system with higher DU(close to 70% as seen from the graph) even though it has higher capital cost, but the lower water usage compensates for that. This is the point when the mean water usage level and the mean gross capital cost intersect. [13]

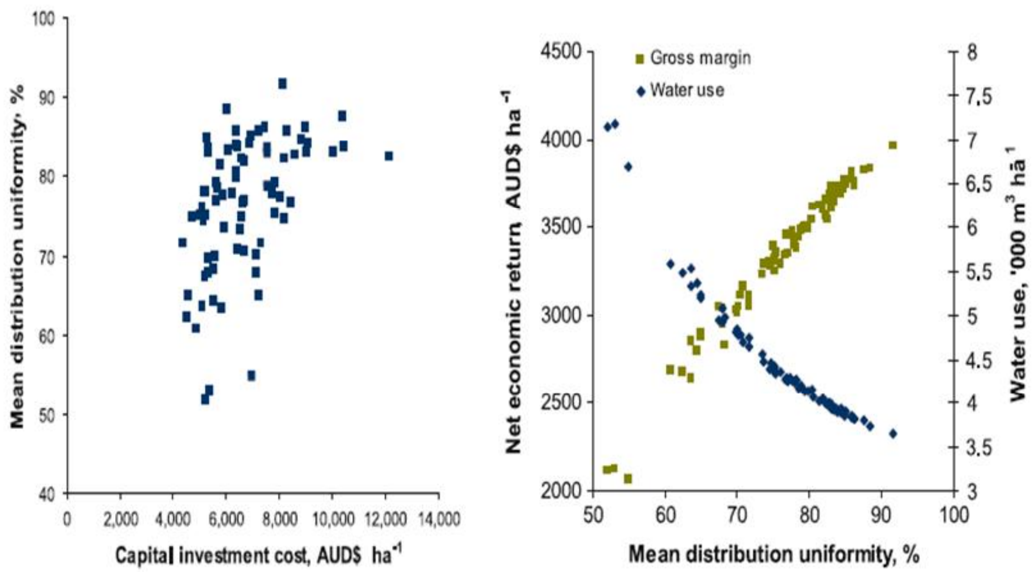

Figure 2.1 A: Estimated total capital costs against sprinkler uniformity

Figure 2.2 B: Water use and gross margin for different sprinkler systems, according to mean distribution uniformity

Figures taken from Paper Factors affecting the economic benefits of sprinkler uniformity and their implications for irrigation water use, by Donna Brennan Received: 31 October 2006 / Accepted: 23 March 2007 / Published online: 13 June 2007_ Springer-Verlag 2007

CASE STUDY: 60 Acre Pivot Irrigation Cost Analysis

[14] This Case Study estimates the annual cost of Center Pivot Sprinkler System that was used as an irrigation system in Alabama. The cost evaluation is based on the capital cost of the sprinkler along with the component cost. In this case, the pivot is placed at a center and is used to irrigate the area of approximately 60 acres. The following table gives the total annual cost of the sprinklers in USD.

COST ANALYSIS OF IRRIGATION SYSTEM
CENTER PIVOT SYSTEM

60 Acre Coverage 1 Pivot Point	Initial Cost	Years Useful Life	Yearly Depreciation
A. Basic System – Investment Cost			
1. System - Electric Drive	$ 35,154	20	$1,758
Length – 837 feet plus			
end gun coverage = 100 feet			
Systems Options (including):			
End Gun & Automatic End Gun Control			
Running Lights – Automatic Stop -			
Booster Pump – Sprinkler Package -			
Low Pressure Shut-off			
2. Freight, Installation	$10,000	20	500
3. Power Unit and Pump	$ 4,439	20	222
15 Horsepower 3PH Electric Motor			
"Across-the-line" Starter			
Centrifugal Pump 450 GPM @ 107' TDH			
4. Generator for Pivot (NOT REQUIRED)			
1200' feet, PIVOT power and safety wire	$ 6,000	15	400
5. PVC Pipe (Installed) -	$ 9,720	20	486
6 inch x 1200 feet @ $8.10 per foot			
6. Pipe Valves, Fittings, Concrete	$ 4,888	20	244
7. Miscellaneous	$ 3,204	---	---
TOTAL COST	$73,405		3610
TOTAL COST PER ACRE	$ 1,223		60

Table 2.5: Shows the cost of the Center Pivot Sprinkler System

1 USD = 0.9714CAD

Therefore, Total Cost Per Acre = $1223 USD * 0.9714

= $1188.02 CAD

Reference:

[14] This table is taken from article - 60 Acre Pivot Irrigation Cost Analysis Department of Biosystems Engineering, Auburn University, AL 36849-5626 BSEN-IRR-08-01 OCTOBER, 2008

2.7.3 Social Factors

The major social impacts of sprinklers include making the better irrigation systems will increase more farmers to migrate from rural to urban areas to purchase commercial properties. [15] The use of sprinklers will help in employing more people to irrigate the rooftop garden or any farm. The use of the sprinklers is becoming more popular worldwide because of its high efficiency and low water usage. The scope of this technology is higher in developing countries like India, China, etc. where the emergence of new technologies is not seen often on a regular basis.

Reference:

[15] Sprinkler irrigation system market: global water scarcity driving growth. (n.d.). Retrieved from http://marketpublishers.com/report/industry/agriculture/sprinkler_irrigation_system_market_global_water_scarcity_driving_growth.html

3.0 DRIP IRRIGATION

3.1 Introduction

Drip irrigation is a method that allows water and fertilizer to drip slowly to the root of plants. It can either go directly onto the surface or onto the inner roots of the plants. This is done through a system of valves, tubing, pipes, and emitters. This irrigation technique reduces water contact with leaves, stems and fruit allowing for increased yield and quality. Drip irrigation provides consistent doses of water to the entire root area on a continuous basis so chances of dry-outs are highly reduced. With this consistent soil moisture, the ability for growth at early stages is maximized. There is the option of having this system installed above or under the soil. When buried below the surface, the tape is less vulnerable to damage and natural wear and tear. This is often referred to this as “subsurface drip irrigation” (SDI for short). As a result of directly watering the root, the plant is much healthier at the fruiting stage, while also adding greater resistance to disease and pests. Drip irrigation can also reduce fungus and mold problems. Experiments have shown proven yield and quality responses to drip irrigation in vegetables and fruits such as onions, cauliflower, broccoli, lettuce, melons, and tomatoes. Many of these crops will be grown on the new roof garden. The system can be put on a timer allowing for automatic dosing of fertilizer, saving water consumption and man-power.

3.2 System Components

Drip irrigation systems are made up of water distribution networks. There are automatic valves at the water source. From here, water is controlled giving out nutrients and chemicals, which depending on the plants, will be filtered and regulated accordingly. PVC and PE pipes are where the water is delivered through; it delivers water and nutrients directly to the plant roots. Drip irrigation systems are very strong and durable and are built to withstand outdoor conditions. With that said, extra caution must be taken to avoid damage by wildlife, foot traffic, or field equipment.

3.3 Main Advantages and Disadvantages

There are many advantages to drip irrigation. With this system, there is minimized fertilizer loss attributable to localizer application and reduced leaching. The energy needed to run drip systems in also very small, because the operation generally requires only low-pressure systems. There is minimized soil erosion since the moisture within in the root is well maintained. Generally, drip systems have a lifetime of 5-7 years. Its service life is usually dependant on UV radiation from the sun and its natural degradation of the drip material. Deposits may be permanently marked in the system causing leaks.

On the other side of the equation, these systems do have its disadvantages. They are expensive to install and maintain. The tubes generally have a short lifespan because they need to be constantly repaired for leaks and kinks, and drip irrigation material is not environmentally friendly. Unlike some other types of irrigation systems, the materials used in the system are not recyclable, resulting in an accumulation of plastic waste. The drip irrigation material is not decomposable, adding to extra clean up costs post-harvest. Clogging is the biggest problem with these systems. Algae, silt or mineral deposits can enter the pipeline and cause insufficient filtration. This is especially common if there is a dirty water source being used. Due to clogging, the drip systems will have to be maintained. These costs significantly add up over time

3.4 Drip Emitter Study

In a study done by the Huazhong University of Science and Technology, three types of emitters*, including orifice eddy driparrows, long-path pre-depositing drippers and long-path round-flowdrip-tape were used in an analysis of emitter clogging. Moving traces of suspended solids in emitter channels were obtained through computational fluid dynamics (CFD) based on visual and direct results.

Emitter Type	Technical parameters			
	Operating water, P (mH2O)	Nominal flow rate, qv (L/h)	Flow exponent, *x*	Manufacturing variation, CV (%)
Eddy drip-arrow	10	6.59	0.45	3.5
Pre-depositing dripper	10	5.5	0.55	6-8
Round-flow drip tape	10	4.3	0.52	<5

Table 3.1: Technical Parameters or Emitter Types

[16] From experimental tests, it was found that the eddy channel was the best of the three designs. From test stages 1 to 8, there was only a drop of 100 in discharge rate (the values of γ_q) for the simulations and experiment tests, whereas the others two emitter types dropped immensely in terms of performance. The simulation and experiment curves for the pre-depositing dripper shows that the emitter discharge decreases gradually as particle size increases and the concentration of sands added.

Comparing the eddy channel results with those of the round-flow drip tape, γ_q variations from simulations and experiments were higher for the latter. In the first four stages, the emitter discharge decreases slowly but once it hits stage 4, the declination is rapid. At the last stage, it is only about 50% of its initial discharge. With this being said, it is very expensive to clean clogged emitters. Doing so requires the entire drip system to be removed from the soil. These filters* require frequent cleaning which further contribute to the increasing equipment costs. This means that drip tape is not an optimal solution when the water quality is poor.

Figure 3.1: Flow Drip Tape experiments and simulations

[16] Liu, H., Huang, G., Wang, P., & Bai, Z. (2009). Effect of drip irrigation with reclaimed water on emitter clogging. *Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering, 25*(9), 15-2

3.5 Economic Factors

Unlike most other irrigation systems, drip irrigations rated in gallons per minute (GPH) and not in gallons per hour because of its low flow rate*. Drip emitters are usually rated at 1-4 GPH (gallon per hour) whereas a micro-sprinkler might be rated at 15-45 GPH (gallons per hour). Drip emitters use 10-15 times less water compared to micro-sprinklers.

With drip systems, water is not lost through run off or evaporation unlike conventional watering systems. Instead, water is slowly absorbed into the soil at a constant rate, directly into the root zone, and absolutely no water is wasted on non-growth areas. This method causes the water to be pushed deeper into the soil and helps to promote the plants' roots to grow downward and not just laterally, as they would with shallower watering, such as sprinklers. In the long run, a lot of money will be saved through drip irrigation systems.

3.6 Social Factors

With drip irrigation, more jobs will be available. Not only will there be jobs to install the system on the roof garden, but also jobs to maintain and retain it, ensuring everything is working smoothly. Because the new sub aims to be LEED Platinum, having drip irrigation as the installed irrigation system on the rooftop garden might further encourage other buildings to choose drip irrigation systems as well.

3.7 Environmental Factors

Drip irrigation materials are generally not recyclable unlike other types of systems. The plastic build up accumulates in landfills. In Vancouver, this type of waste is not managed by the City of Vancouver thus accumulation of the used drip material will have to be thrown away and won't be recyclable. This is definitely not good for the environment.

4.0 SUB IRRIGATION

4.1 Introduction

[17] Apart from the drip Irrigation and the sprinkler irrigation systems, **sub irrigation** is another useful irrigation method. This method involves water being supplied "to the plant from underneath the soil* surface."

[17] Reference: What is sub-irrigation?. (n.d.). Retrieved from http://www.wisegeek.com/what-is-sub-irrigation.htm

4.2 Advantages and Disadvantages

[18] There are several advantages and disadvantages that could be useful for choosing the best irrigation method.

- **Advantages**

Some of the advantages of the sub-irrigation systems are as follows:

1) Since it requires less labour, it reduces the labour cost, thereby making it more economical.
2) They have high uniformity.
3) There is less chance of getting plants diseased.
4) They are beneficial for plants as the water reaches the root level directly without going through a lot of interruptions.
5) They don't make use of drinking water. The water is recycled over and over, reducing the amount of water being wasted. Therefore, it is more beneficial for environment.

- **Disadvantages:**

Following are the disadvantage of the sub-irrigation systems:

1) They have high installation cost.

2) It is important for the farmers to check the pH* balance of the soil on a regular basis.
3) When these systems are used in the field, it requires the usage of pipes which have a great chance of cracking.

[18] Reference: Subirrigation in field crops and usage in greenhouses. (n.d.). Retrieved from http://www.agricultureguide.org/subirrigation-in-field-crops-and-usage-in-greenhouses/

4.3 Types of Sub-Irrigation Systems

There are [19] four main types of Sub-irrigation systems: ebb-and-flow benches system, dutch movable trays, trough benches system, and flooded floor systems. These are closed and recirculating systems and are described in more detail as following:

1) **Ebb-and-Flow Benches**: This is one of the most common sub-irrigation systems and is made up of a molded* plastic bench being flooded in water. The water from the bench is drained into a storage tank after the irrigation is complete and is later reused. There are several advantages of ebb-and-flow benches system, such as it is very versatile as the bench has a great capacity to accommodate different pot sizes, etc. It also has a higher efficiency of 80%-90% as compared to the remaining three types.

2) **Dutch movable trays**: This system is a mechanized version of Ebb-and-Flow Benches. In this system, trays serve different functions, such as growing benches, containers to move crops from one place to another. It has higher initial costs along with higher maintenance and repair cost. They have efficiency of 81% to 89%.

3) **Troughs**: This type is a perfect example of closed and recirculating system. In this system, water is distributed to plants through an inclined and shallow trough which holds the plants. This trough ends up in a return path used for recirculating the irrigation solution. One of the major advantages of this type is that any size of trough can be used depending on the plant pot and bench size providing higher variability. It has a slightly lower efficiency of 70% to 80% as compared to ebb-and-flow method.

4) **Flooded Floor**: This type is mostly used in greenhouses*. In this system, concrete is used to cover the whole floor which is specially designed to "pitch towards the openings present in the floor. Through these openings, irrigation solutions enter and flood the floor."

After the flooding, any remaining solution is drained back into the storage for reuse. It has a highest efficiency of 85% to 95%.

[19] Reference: Greenhouse management / engineering. (n.d.). Retrieved from http://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/ghsubirr.html

The initial costs of installing the system vary from type to type. Table 4.1 compares the initial costs and efficiencies of all the four types of sub-irrigation

Sub-Irrigation System Type	Initial Cost Range (USD/ft^2)	Efficiency Range
Ebb-and-Flow Benches	$4 to $6	80% to 90%
Dutch Movable Trays	$5 to $6	81% to 89%
Troughs	$2 to $6	70% to 80%
Flooded Floor	$3 to $5	85% to 95%

Table 4.1: Compares the initial cost and efficiency of Sub-Irrigation types. (Source: http://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/ghsubirr.html)

4.4 Environmental Analysis

- **Water Supply Requirements for Sub irrigation**

The water to be used for sub-irrigation should be clean to the maximum extent. It should not contain chemicals and sediments. [20] The water supply should be enough to fulfill the water requirements for different crops or plants to be irrigated. The water supply should also be enough to handle the water that is going to be lost due to seepage.

- **Soil Requirements**

“The soil profile should be uniform and relatively deep with a good hydraulic conductivity”

The pre-requisite for using sub irrigation systems at a certain site is to have the control drainage.

- **Irrigation Scheduling**

The most important requirement for implementing sub irrigation systems is to provide sufficient amount of water needed for the roots to absorb. At the same time, the amount of water supplied to the roots should not hinder the plant root development. One of the other factors to keep in mind is to have the level of the water table to be adjusted in the range of 0.75-1m below the soil surface**.**

[20] Reference: Controlled drainage / subirrigation. (n.d.). Retrieved from http://www.agf.gov.bc.ca/resmgmt/publist/500Series/564000-1.pdf

It is very important to minimize the use of water and fertilizers as this is becoming a major financial concern for the greenhouse growers. The zero runoff sub irrigation system can be used a tool to increase the efficiency of the fertilizer input. This will increase the overall efficiency of the greenhouse production.

4.5 Economic Analysis

Case Study: Comparing the profitability of using the 4 zero runoff sub irrigation systems to produce 3 crop categories

In this case study [21], the profits of four different types of sub-irrigation are compared based on the cost. The detailed specifications are as following:

Categories of crops used:

1) **Small potted plants (< 5" pot) 4 1/2" Geranium: an 8-week crop**
2) **Large potted plants (> 5" pot) 6" Poinsettia: a 17-week crop**
3) **Bedding plant plugs and flats 1204 size Impatiens flats: a 10-week crop**

Area: A 20,000 sq. ft. model greenhouse facility

- **Inflation Rate*: 3%**
- **Average space use efficiency:**

Efficiency of the System:

1) **Ebb&flow benches: 87%**
2) **Dutch movable trays: 85%**
3) **Flood floors: 90%**
4) **Trough benches: 77%**

[21] Reference: Wen-fei , Initials. (2002, 06). *Selecting zero runoff subirrigation*. Retrieved from http://aged.ces.uga.edu/browseable_folders/power_points/Horticulture/Greenhouse_Operation_Management/Selecting_Zero_Runoff_Subirrigation_WL_Uva.ppt

The following table shows the cost comparison (in USD) of the four types of sub-irrigation system.

	Ebb/flow rolling benches	**Dutch movable trays**	**Flood floors**	**Trough benches**
Investment item		($)		
Greenhouse structure	$185,000	$185,000	$185,000	$185,000
Thermo curtain	25,000	25,000	25,000	25,000
Heating system	70,000	70,000	70,000	70,000
Irrigation system[a]	**150,000**	**170,000**	**140,000**	**95,000**
Computer[b]	20,000	20,000	20,000	20,000
Electrical service	40,000	40,000	40,000	40,000
Pest management equipment	4,500	4,500	4,500	4,500
Crop movement system	8,000	N/A[c]	8,600	8,000
Total capital investment cost	**$502,500**	**$514,500**	**$493,100**	**$447,500**
Cost per Square Foot	**25.13**	**25.73**	**24.66**	**22.38**
Adjusted for tax saving from depreciation (30% tax)				
Annual equivalent cost adjusted for the tax saving				
Adjusted for space efficiency (%)				
Cost per SFW in production	**0.037**	**0.039**	**0.034**	**0.037**

Table 4.2: Compares the cost of four types of Sub-Irrigation system

As these costs are in USD, converting them into CAD gives

1 USD = 0.9718 CAD

Cost per Square Foot	24.42	25.00	23.96	21.74

Therefore, comparing the types of systems based on cost, we suggest that Trough Bench is the best option as they have the lowest capital cost.

4.5 Social Analysis

The designing of the new irrigation system not only brings the implementation of a new technology into play but also the equity of the members living in the society. It is very important that the members of the society are adaptable to the changes the new technology being implemented will bring about. The importance of water is huge in every individual's life. The type of irrigation method plays a key role in gaining success in the field of agriculture. The sub irrigation is one of the irrigation methods that help in providing the social benefits.

5.0 CONCLUSION

In Conclusion, the three options are all viable irrigation systems. However because there is such a strong focus on making the building as green as possible, we believe the drip tape is the best option because it will have the least amount of water runoff and water waste. Although it has a bit higher maintenance and starting cost, the life span of this building is meant to be 100 years and we believe the amount saved in water will outweigh those costs. Realistically, the drip tape really only works for certain types of vegetation. Certain vegetables that can be very close together cannot be irrigated through drip tape because of the physical dimensions. Therefore we believe that a combination of sprinklers and drip tape would be the best solution.

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Appendices

Case Studies:

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