UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into New SUB Rooftop Garden Irrigations Systems

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APSC 262

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Rooftop Garden Irrigation Systems

A Triple-Bottom-Analysis of Irrigation Systems for the New SUB

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Abstract

The students within Applied Science 262 were given several choices for their projects relating to the new SUB building. We were tasked with further researching irrigation systems that can be used for the rooftop gardens. We were to conduct a triple bottom-line analysis for the different irrigation systems that could be used and compare the results and determine what would be the best choice to use for the rooftop garden for the new SUB. With the idea of attaining LEED platinum in mind our decisions were based more off of the environmental and social aspects of our triple bottom line analysis. It is our recommendation that Sub-surface Drip Irrigation (SDI) be used for the crop area of the new SUB roof top garden. Container gardening and the Greenhouse due to their smaller size should be watered by hand or through the use of high efficiency sprinkler systems. We also that further analysis of using multiple types of irrigation systems for the garden be done. Within the limited time frame of the course we were unable to fully investigate the possibility of multiple systems.

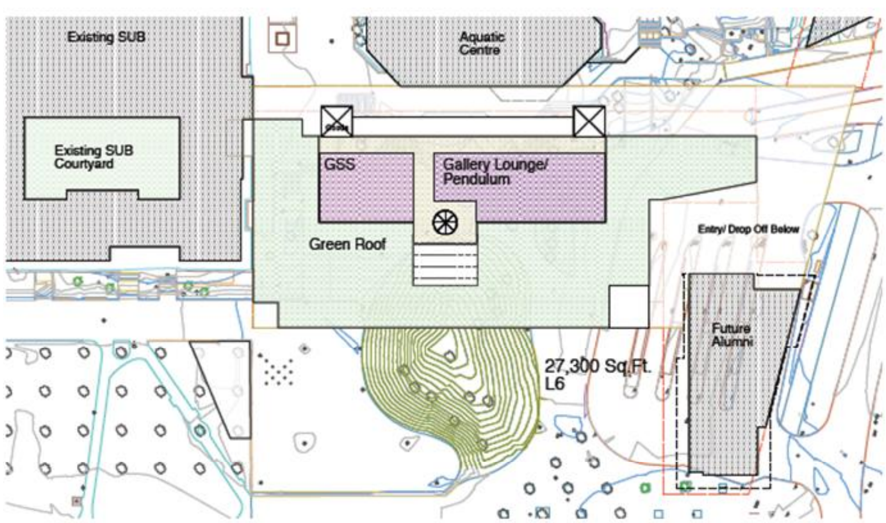
1.0 Introduction

The UBC campus has made it a goal to implement more sustainable designs into new and existing buildings. The students have voiced their ideas on sustainability issue, and their ideas are being incorporated into the design of the new student union building. Within the APSC 262 course we were tasked to complete a triple bottom line analysis of irrigation systems that could be used in the rooftop garden. We conducted research into water efficiency and cost for three different irrigation systems. The three systems included sub-surface drip irrigation (SDI), Low altitude drip irrigation, and overhead sprinklers. We then based our recommendations off of our findings highlighting certain areas of importance over one another.

This report covers the research we have conducted, our recommendations and what potential steps should be made in the future for this section of the SUB project.

1.1 Problem Definition

The new SUB building is to include a rooftop garden covering a total of 22000 square feet. 6500 square feet has been allocated for crop growth and approximately half of the crop production will be grown in containers. We were tasked to determine a suitable method for irrigating the rooftop garden. The current goal for the new SUB is to reach LEED platinum standard, with this in mind we kept environmental and social aspects higher on our choice criteria. In an economic sense the project is smaller scale that what is found in industry so estimated capital costs were lower for SDI and low altitude drip irrigations. This will be outlined further in the economic analysis.



DIALOG+BH **SUB DESIGN STUDY** Oct. 13 / 2010 1:500 OPTION 5 **Level 6** El. +52'

2.0 Over Head Irrigation Systems

2.1 Environmental

One of the larger issues with the overhead irrigation is the water loss that involved with the system. Leaks are prone to develop over the lifetime of the system and the distribution of water to the plants tends to be irregular. Optimal distribution of water to the crops due to sprinkler placement is discussed in depth in *Irrigation Management for Improved Efficiency(1997)* and was considered when comparing the three systems. The water loss from the overhead system was about (find value in paper discussing irrigation system comparison) less efficient than the sprinkler system (Sprinkler system shown as MESA). As seen below:

Table 1. Basic assumptions for six irrigation distribution systems.

Irrigation System	Operating Pressure (psi)*	Application Efficiency (%)	Efficiency Index	Acres Irrigated
Conventional furrow (CF)	10	60	1.47	160
Surge flow furrow (SF)	10	75	1.17	160
Mid-elevation spray application (MESA)	25	78	1.13	125
Low elevation spray application (LESA)	15	88	1.00	125
Low energy precision application (LEPA)	15	95	0.93	125
Subsurface drip irrigation (SDI)	15	97	0.91	160

*PSI = Pounds of pressure per square inch of water.

2.2 Social

With the use of overhead irrigation systems for the roof top garden there would be a few issues that should be addressed. The high powered overhead irrigation systems would be unreasonable to use for the roof top as the watering method as the distribution of the spray is hard to control and tends to be localized. In addition there is the issue of it being on the SUB rooftop if the water were to spray over the edge of the roof and soak students below. However, if considered on a smaller scale it would potentially be possible to have more accurate methods of irrigation. Currently smaller systems are being used in green houses as the greenhouses provide the structural support necessary to allow for this method. Therefore if we were to include sprinkler irrigation in the greenhouses this would be a viable option. Examples of this method can be found in the on campus greenhouses.

The sprinkler systems also tend to be fairly loud and might cause some disturbances to students trying to study. There is also a large amount of man power required to set up and take down the systems. This system would not work for the winter conditions as the temperature in the Vancouver drops below zero.

2.3 Economic

In an economic sense these are the cheapest of the three systems analyzed. A more detailed breakdown of costs will be provided further in the report. The maintenance costs for this system in comparison to the drip tape systems is much higher as connections need to be check regularly. It is comparable to the maintenance costs for the in-ground systems. However, due to easy access in comparison to the in-ground system the maintenance would be easier to complete.

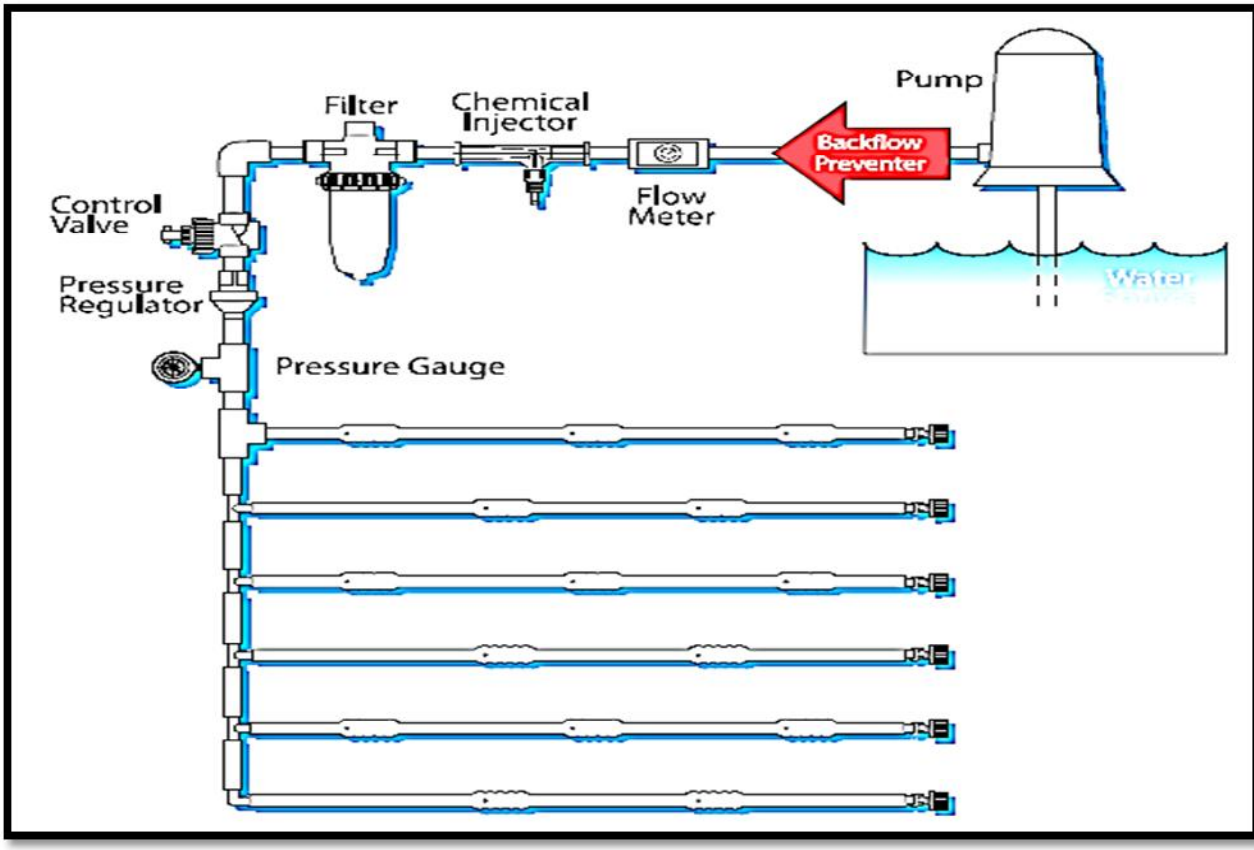
Where:

Table 2. Investment costs of alternative irrigation systems.

Distribution System	Gross Investment ($/acre)	Net Investment[1] ($/acre)	Net Investment[2] ($/acre)
Conventional furrow (CF)	165.32	152.63	141.65
Surge flow (SF)	185.32	171.11	158.79
Mid-elevation spray application (MESA)	341.68	252.37	234.21
Low elevation spray application (LESA)	366.90	268.05	252.18
Low energy precision application (LEPA)	376.00	277.73	257.73
Mid-elevation spray application (MESA)*	234.56	173.26	160.78
Low elevation spray application (LESA)*	245.91	181.64	168.56
Low energy precision application (LEPA)*	250.00	184.66	171.37
Subsurface drip irrigation (SDI)	832.23	614.71	570.46

3.0 Low Altitude Drip Irrigation

This technology came into existence decades ago and since then has been used all over the world in nurseries, greenhouses and a variety of industrial applications, for this technology helps to conserve water [4].



A Typical Drip Irrigation System

Drip irrigation helps to use water efficiently. A well-designed drip irrigation system loses practically no water to runoff, deep percolation, or evaporation. Irrigation scheduling can be managed precisely to meet crop demands, holding the promise of increased yield and quality.

3.1 Environmental

Advantages

The leaves remain dry, thus lowering the risk of disease. Water is evenly distributed to the root zone; soil is well aired.
The plant uses less energy to absorb water from soil; this boosts plant growth.
The land between the plant rows remain dry and weed growth is prevented .

The plant shadows the water zone; consequently, evaporation is reduced and water consumption is lowered.
Drip irrigation is suited for heavy as well as light soils .
There is no soil erosion; moreover, preparation of levelled bed, bund and channels is avoided, land smoothening is sufficient.
Variances in soil moisture are completely eliminated which results in better growth and yield. Drip irrigation has proven to increase yield from 10 to 230%.

Disadvantages

The leaves aren't watered; consequently, there is certain degree of salting. If the salt isn't washed additional other watering methods must be used.
Drip irrigation reduces the buffering capacity of the root zone. Failure of the system in a critical period may have ill effects on vegetation\plants.

In an experiment, drip irrigation yielded a significant higher yield over other methods. The superior yield advantage displayed in drip irrigation over furrow irrigation is fairly expanded by the application of fertilizers through drip irrigation water; fertigation treatments resulted in higher fruit yield and yield parameters over drip irrigation.

Treatments	Number of fruits per plant	Mean fruit weight (g)	Fruit yield (kg / plant)	Total fruit yield (t / ha)
Furrow	12.4	86	1.07	34.38
Drip irrigation	14.5	103	1.37	43.87
½ soil ½ Fertigation	15.3	109	1.51	48.18
¼ soil ¾ Fertigation	15.6	113	1.69	54.16
100 % Fertigation	16.8	117	1.84	58.76
LSD (P = 0.05)	1.6	9	0.14	4.15

Table 1 : Yield and yield components of tomato as affected by fertilizer method and fertigation rate

A comparison of pattern of moisture availability to crops under different irrigation methods is graphically shown in Figure 2. As can be observed, the soil moisture contents remained much closer to the *field capacity* (optimum growth) level in drip & sprinkler systems as compared to other traditional surface irrigation methods.

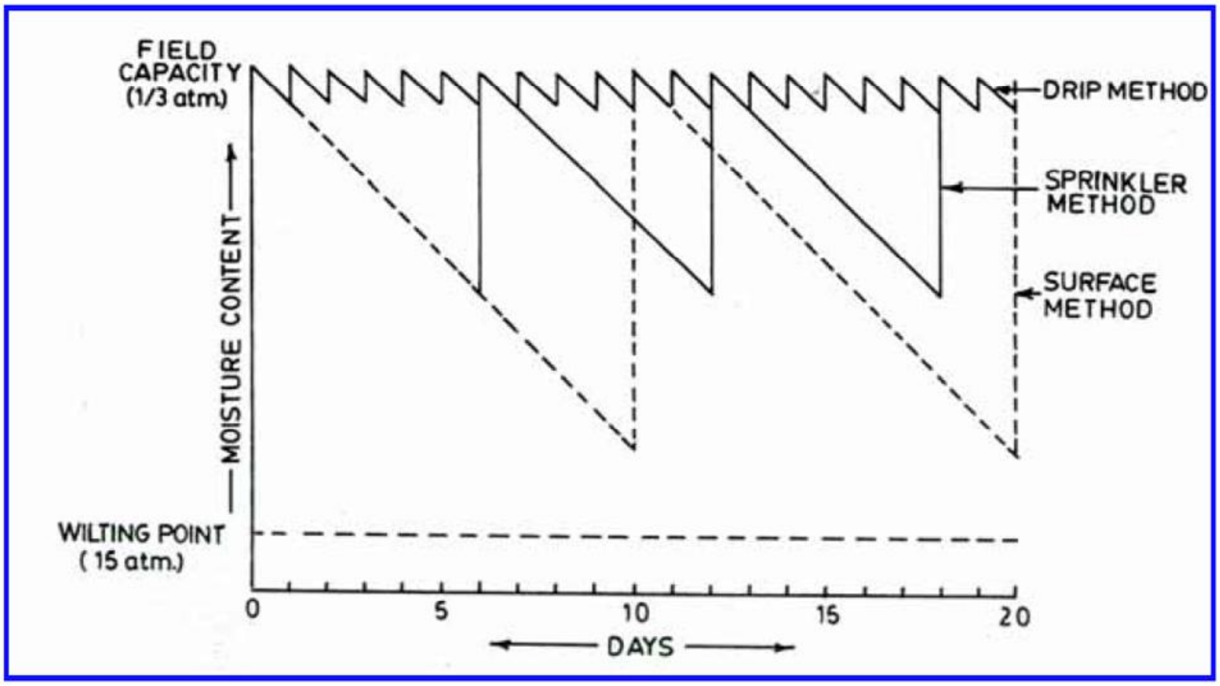


Figure 2: Soil Moisture Availability to Plants under Various Irrigation

3.2 Economic

Farmers and landscapers converting to drip irrigation have realized quick payback and substantially improved profits with drip systems. The following report is based on a drip system which was installed by farmer in Nebraska.

Drip Irrigation Payback in Years Based on Actual Results*

	Drip Scenario 1:	Drip Scenario 2:	Drip Scenario 3:	
Drip Irrigation System Investment	$1,200	$1,200	$1,100	per acre
EQIP Cost Share	$0.0	$0.0	$330.0	30% of cost
Grower Investment	**$1,200.0**	**$1,200.0**	**$770.0**	per acre
Potential Yield Increase with Drip (assuming 175 bu/ac with Gravity)	50	50	100	bushels/acre
Corn Price	$3.50	$2.50	$3.50	per bushel
Potential Additional Revenue	**$175.00**	**$125.00**	**$350.00**	per acre
Potential Savings				
Fuel Savings	$25.00	$25.00	$25.00	per/acre
Labor Savings	$26.62	$26.62	$26.62	per/acre
Chemical/Fungicide Savings	$27.50	$27.50	$27.50	per/acre
Fertilizer Savings	$43.88	$43.88	$43.88	per/acre
Culitvation Savings	$37.50	$37.50	$37.50	per/acre
Potential Cost Savings	**$160.50**	**$160.50**	**$160.50**	per/acre
Payback Calculation †	**3.6**	**4.2**	**1.5**	**Years**

*Results based on specific conditions - variations may apply.
† Grower Investment divided by sum of Potential Additional Revenue and Potential Cost Savings.
Drip Scenario 1: No Subsidy; 50 bu/ac yield increase; $3.50/bu
Drip Scenario 2: No Subsidy; 50 bu/ac yield increase; $2.50/bu
Drip Scenario 3: EQIP Subsidy; 100 bu/ac yield increase; $3.50/bu

Table 2: Payback of drip irrigation

Advantages

Drip systems allow precise supply of nutrients to vegetation; moreover, fertilizer and nitrate losses are reduced.
There are savings in labour, for a well-designed system only needs an individual to start and stop the system.
Due to high efficiency, the required area is irrigated within the required time frame; thus energy is saved.
The efficiency of operations like spraying, weeding, harvesting is increased .Hence; the operational costs can be reduced to up to 50%.
Research studies have indicated that the water saving is about 40-70% and the yield is increased by 10-100% for various crops.

Disadvantages

Emitters are easily clogged due to silt/sand and replacing them could be expensive. Clogging can affects the rate and uniformity of water distribution; this results in increased maintenance costs.
Due to extensive equipment requirements, high initial investment and annual costs are observed. Drip irrigation systems cost nearly $500 to $1,200 or more per acre

The comparison of drip to other irrigation systems is shown below.

Comparing Drip/Micro to Sprinkler and Flood Irrigation			
	Drip/Micro	Sprinklers	Gravity
Emission device flow rate	GPH	GPM	N/A
Operating pressure	4-60 psi	30-90 psi	Low
Duration of irrigation	seconds, minutes, or hours	minutes	hours, days
Frequency of irrigation	daily	weekly	monthly
Filtration	150-200 mesh	none	none
Quantity of devices	More	Less	N/A
Size/cost of each device	Less	More	N/A
Wetting patterns	.5-40 feet	5-100 feet	Broadcast
Wetting plants	Typically no	Typically yes	Typically no
Wetting non-targeted areas	Typically no	Typically yes	Typically yes
Runoff on slopes	Typically no	Typically yes	Typically yes

Table 3: Comparison of various irrigation systems

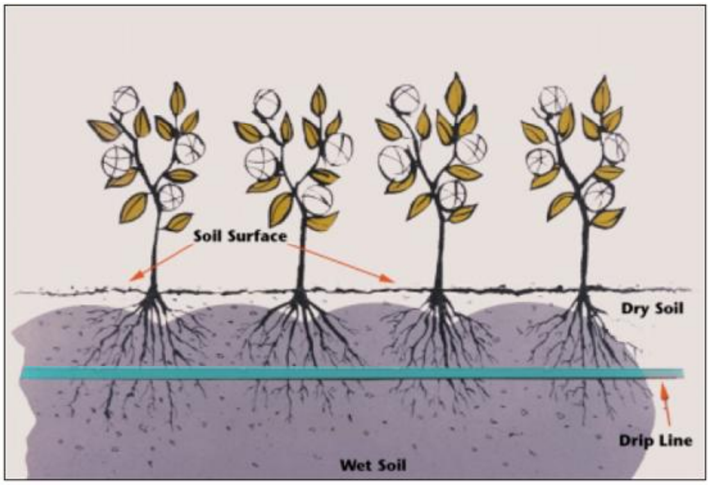
3.3 Social

Factors such as high initial cost, non-availability of parts and technicalities involved and regular maintenance of the system are making drip irrigation unpopular. Individuals operating the system need to be trained to repair faults if they occur.

“Moreover, drip irrigation allows for targeted, intelligent water applications, where runoff, leaching and the wetting of non-targeted areas such as roads, plant leaves, tree trunks, sidewalks, cars, windows and buildings are avoided or completely eliminated.”

4.0 Subsurface Irrigation Systems

Subsurface drip irrigation (SDIs) systems are a variation to drip irrigation (DI) systems, the variation being SDIs are installed under the surface of the soil. Efficient installations are of 4 to 30 inches beneath the surface.



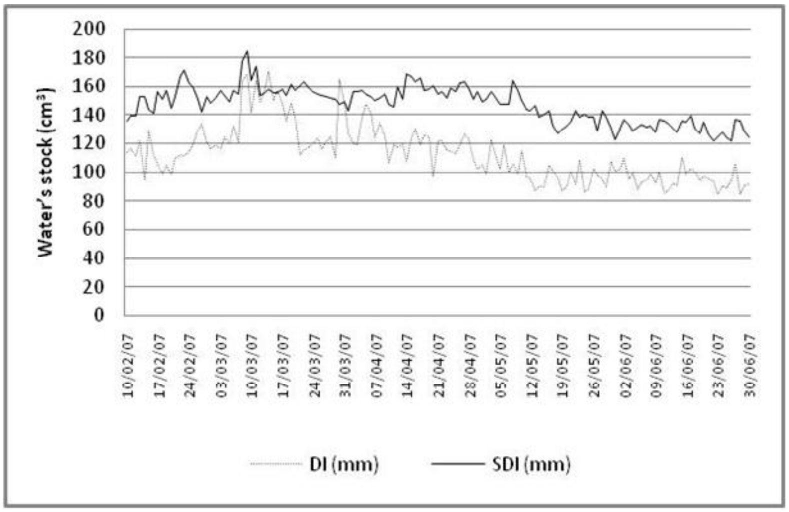
Artist Rendition of SDIs

4.1 Environmental

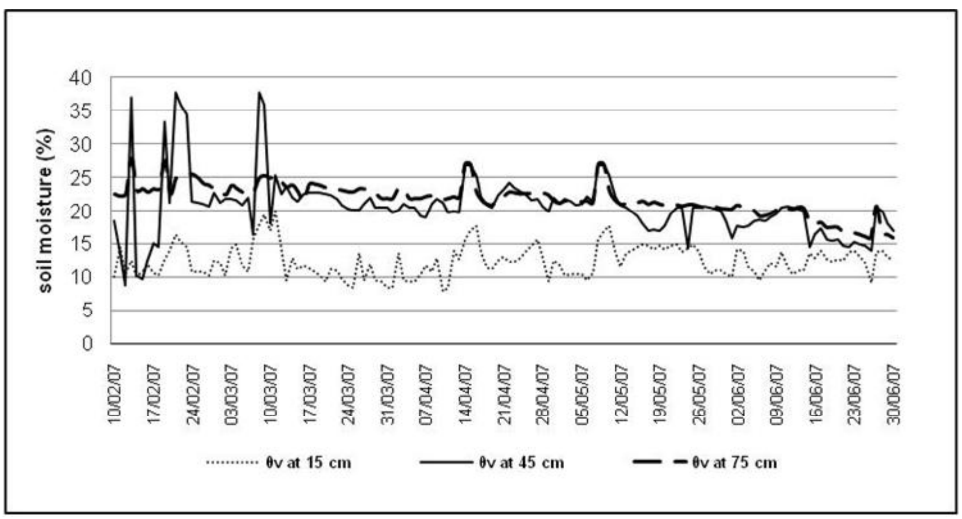
SDIs are very environmentally friendly and sustainable. Most SDIs are made out of drip tape, which is made of polyethylene, the most widely used plastic. The production of polyethylene is derived from modifying natural gas, such as methane, ethane, or propane, and generates waste; however, this waste can be recycled back into plastic pellets for reuse. Although plastics have many environmental issues in itself due to its durability and resistance to degradation, drip tape is a recyclable material which can be reused in both the plastics industry and drip tape industry. According to a drip tape recycling program in New Jersey, there are measures one must be aware of when recycling drip tape. Only a low-density polyethylene drip irrigation tape is accepted, and they must be cleaned of all contaminants such as soil, plant material, mulch plastic, and twine. It must also not be tied with any other materials other than the drip tape itself as the recycling plant will reject any other materials. In addition, the drip tape should be stored in a place that is not exposed to sunlight or moisture and should be cleaned as thoroughly as possible.

SDIs are the most efficient method of irrigation if maintained properly. Due to the fact the drip tape system is beneath the surface and it applies water directly to the roots, it minimizes losses of water from evaporation, wind, and runoff; this can bring the water application efficiency up to 97%.

In a controlled case study in Chott Mariem High Agronomic Institute, Sousse, Tunisia, for four months they observed growth parameter, soil moisture content and yield of crop at three different depths of soil, 15, 45, and 75cm. They concluded SDIs save 23.2% (up to 30%) more water compared to DI, which is a huge environmental benefit. The figures below depict graphs taken from the website of this case study to emphasize water efficiency.



DI vs SDI Water Stock



Soil Moisture Distribution at Different Depths

Therefore, SDIs are the most water efficient and sustainable irrigation system/technology used to date, which will leave the smallest environmental footprint in our society.

4.2 Social

As stated earlier, the material used to make drip take is made of polyethylene, the most common plastic material. Almost all polyethylene is manufactured in large production facilities everywhere, so there are most likely no health/well-being or ethical/human rights implications with the production of our drip tape material.

One of the main disadvantages of SDIs is the maintenance that is incorporated with operating such a system. It requires regimented maintenance and regular flushing to avoid any issues, such as impure water quality, clogging, and unbalanced chlorination. However, almost all of these larger issues with SDIs can be prevented with regular maintenance. This demand for maintenance will likely be solved by employing UBC staff and/or students, which will be required year-round.

Fortunately, maintenance around the SDIs will generally be safe for both health and physical well-being. There is virtually no threat of vandalism, theft, injuries, or unpleasant visual presentation.

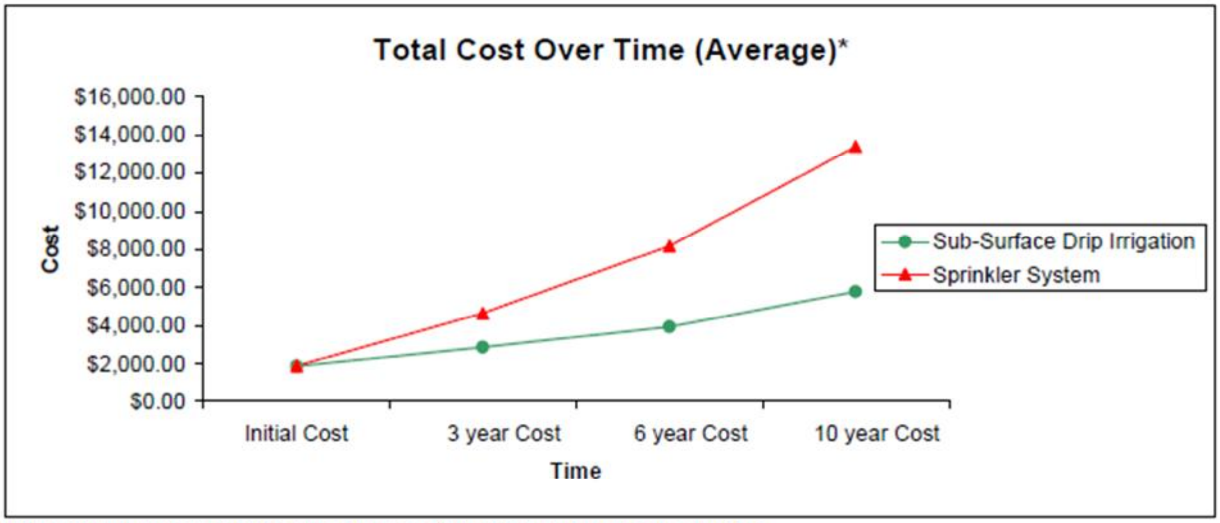
Therefore, we can conclude that the social aspect of SDIs have no overly important social disadvantages and will aid our community at UBC with employment.

4.3 Economical

One of the main disadvantages of SDIs is the high capital costs of buying the materials and installing it. Installation costs can cost anywhere between $8,000 - $12,000/ha, the main variable being tape spacing (the smaller the spacing the more expensive). Other things to consider are buying the drip tape, pumps, and valves.

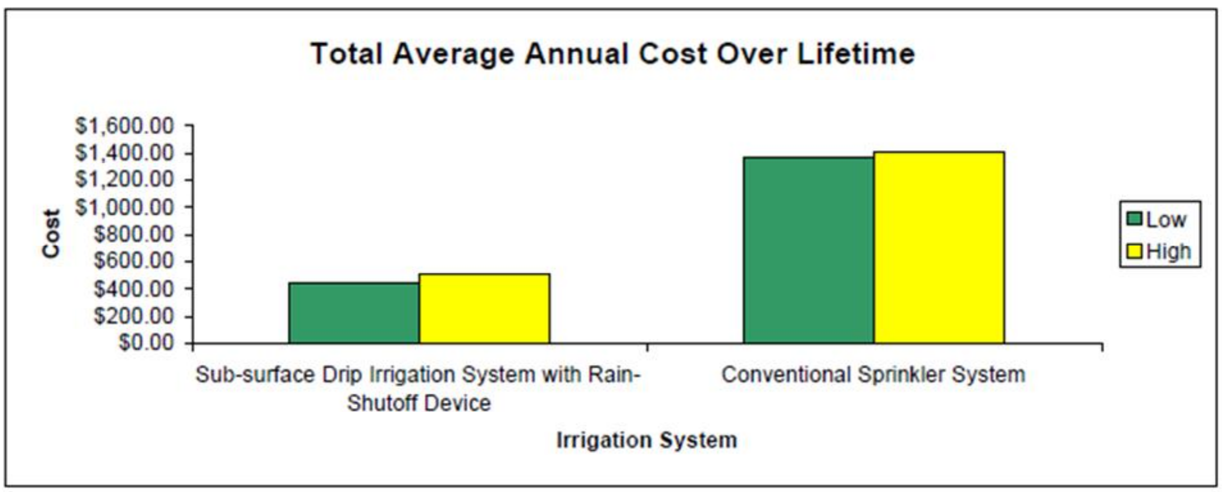
As with any system, maintenance is required to ensure proper functionality of SDIs. The system must be flushed regularly with acid and chlorine injections. Acid injections treat chemical deposits and chlorination kills algae and organic matter; both are done to prevent any clogging within the system.

Below are some images of graphs, taken from a SDI Cost Calculator, which compare an SDI system to a conventional sprinkler system.



*This graph is generated using the average of the high and low cost estimates.

Total Cost vs Time (SDI vs Sprinklers)



Average Annual Cost (SDI vs Sprinkler)

We can conclude from these graphs that initial capital and installation costs are approximately equal, but over the lifecycle of both systems, the cost to maintain SDIs is much lower.

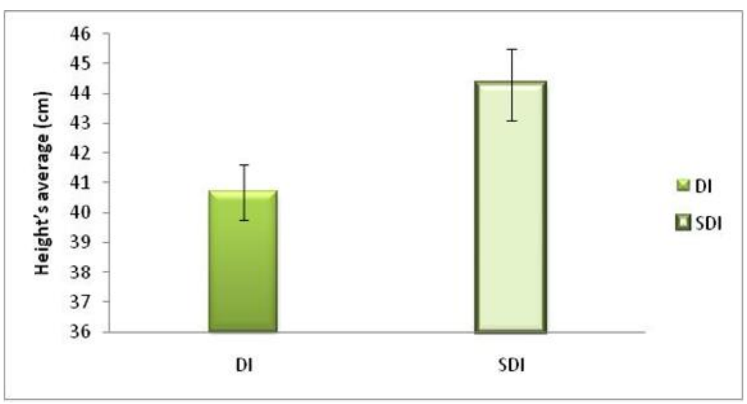
Using the cost calculator for SDIs, the results were as follows:

Sub-surface Drip Irrigation System with Rain-Shutoff Device	Low Cost Estimate	High Cost Estimate
Rain Sensor	$27.00	$69.99
Sub-surface Drip Irrigation Materials and Installation Cost	$1,680.00	$1,960.00
Initial Cost	$1,707.00	$2,029.99
Number of Irrigations Per Year Without Rain-Shutoff Device	45.00	45.00
Gallons of Water Used Annually Without Rain-Shutoff Device Per Year	128,898	154,184
Average Number of Irrigations Saved by Rain-Shutoff Device Per Year	8.40	8.40
Gallons of Water Used Annually With Rain-Shutoff Device Per Year	104,837	119,133
Water Cost (annual)	$209.67	$238.27
Annual Maintenance and Repair Cost (average over lifetime)	$168.00	$165.00
Average Annual Maintenance and Water Cost over Lifetime	$377.67	$403.27
Lifespan (years)	25	20
3 year Cost	*$2,661.02*	*$3,069.79*
6 year Cost	*$3,690.04*	*$4,184.59*
10 year Cost	*$5,478.74*	*$6,087.65*
Total Average Annual Cost over Lifetime	*$445.95*	*$504.77*

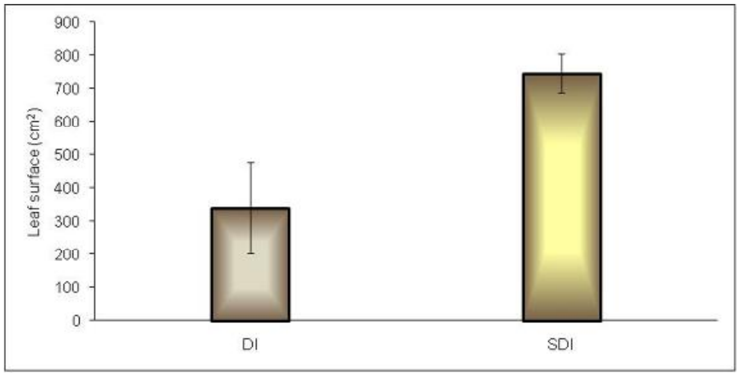
SDI Cost Calculator

We can see that the estimated costs for 10 years will be approximately $5,478.74, and therefore the entire 100 year lifetime should be around $50 – 60,000.

Moreover, there are additional benefits: there is a direct correlation between water efficiency and plant yield. Due to the fact SDIs have a 97% water efficiency rate, we see the average plant height as well as average leaf surface area of plants are much higher when compared to an above surface DI system. This is portrayed in the graphs below taken from the case study from Sousse, Tunisia.



DI vs SDI Plant Height



DI vs SDI Leaf Surface Area

Additional funds could be saved by UBC by utilizing rainwater. Vancouver receives about 1200mm per year in rainwater, and this water could be used to irrigate our plants. One of the highest maintenance costs in SDIs is purchasing water, so utilizing a runoff system on the roof could potentially pay for itself.

To sum up, although installation costs of SDIs are higher than DIs, the low maintenance costs, long lifetime, excellent water efficiency and high yield make SDIs the most logical and practical choice for a new SUB rooftop garden.

5.0 Recommendations

Based on the research done whilst comparing and contrasting the different irrigation systems using the triple-bottom-line assessment, we concluded that using subsurface drip irrigation system as a start would be the most beneficial for the new SUBs rooftop garden. We base our recommendations due to the fact that SDIs are the most water efficient system (97%), have the lowest lifecycle costs ($50-60k/100 years; approx 10-15 years at a time), and can be easily maintained by UBC staff or students. SDIs are also the most sustainable solution with proper recycling of the wasted materials (drip line tape), minimal losses in water and energy, and maintenance requirements (chlorination and acid injections). Our group hopes that with these recommendations for implementing a subsurface drip irrigation system, the new SUB for UBC will be recognized a sustainable building with a green rooftop garden.

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