UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into New SUB Rooftop Garden Irrigations Systems

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An Investigation Into Rooftop Garden Irrigation Systems

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Abstract

In this report, the researchers investigated three different solutions for the rooftop garden irrigation system in the new SUB at UBC. They included drip tape, soaker hose and sprinkler irrigation. The soaker hose was recommended. There are a few requirements that are to be met with the solutions. The goal of the new SUB is to have the LEED Platinum Plus Certification so in order to do that, 90% water efficiency should be achieved. The area of irrigation is 1866 m^2 or 20085 sqft. Some constraints include

After performing a triple bottom line analysis, the sprinklers were found to be the least expensive in the initial and maintenance costs. The costs of soaker hose and drip tape were close in long term period and since the SUB is designed to last 100 years, that will be the comparison that is focused on. Sprinkler irrigation was found to have the highest impact to the environment in the sense that its maximum water efficiency was 51.56%. This eliminated the choice of using sprinklers because it would not come close to the LEED Certification. Carbon footprint was then examined and the soaker hose was found to have the least footprint. In terms of the social impact, there was very little difference between the three solutions.

After careful consideration, the soaker hose was selected because of its low carbon footprint. In terms of its economical impact, it was similar to that of drip tape in long periods of time. The sprinkler was very inexpensive; however, its water efficiency was too low to be considered.

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Glossary

Carbon Footprint: Total amount of Carbon Dioxide produced for manufacturing a certain material. It is usually represented in kg CO_2/kg material

Flow Regulator: A device which regulate the flow rate of a fluid passing through

Mulch: A protective covering which is usually consist of plant residues

Percolation: Seepage of water through a porous material

Triple Bottom Line Analysis: Analysis based on the economic, environment, and social values of a product

List of Abbbreviation

SUB: Student Union Building

LEED: Leadership in Energy and Environmental Design

PE: Polyethylene

1.0 Introduction

In this report, the researchers will outline three solutions for the rooftop garden irrigation at the new SUB. They include drip tape, soaker hose and sprinkler irrigation. Throughout this report, the researchers will give a detailed description of the three solutions, including the economical, environmental, and social aspects of each product. The researchers will then use a triple bottom line analysis to compare and contrast the solutions, thereby recommending one solution.

2.0 Requirements

2.0.1 LEED Certification

In the new SUB building, we are trying to achieve the LEED Platinum Plus Certification. It is the highest possible grade for a building designed to be environmentally friendly. Therefore, in proposing a solution to the rooftop irrigation, we can earn a possible ten points in the LEED Certification. In the WE Credit 1: Water Efficient Landscaping, we can earn a possible 4 points for using only captured rainwater, recycled wastewater, recycled graywater or water treated and conveyed by a public agency specifically for nonpotable uses. Since we have already decided to use captured rainwater, we need to most efficiently use the limited rainwater. However, the building project has not progressed to a point where we know how much rainwater we have for irrigation; therefore we will attempt to achieve a 90% efficiency for the rooftop irrigation.

WE Credit 2 deals with wastewater generation so it does not relate to the rooftop irrigation. The intent of WE Credit 3 is to further increase water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems. This credit specifically says that it does not pertain to irrigation so it also does not apply.

2.0.1 Area Of Irrigation

Figure 1 below shoes the areas that need to be irrigated. The total area is 1866 m^2 or 20085 sqft. One note is that the areas are oddly shaped so irrigation efficiency may be sacrificed.

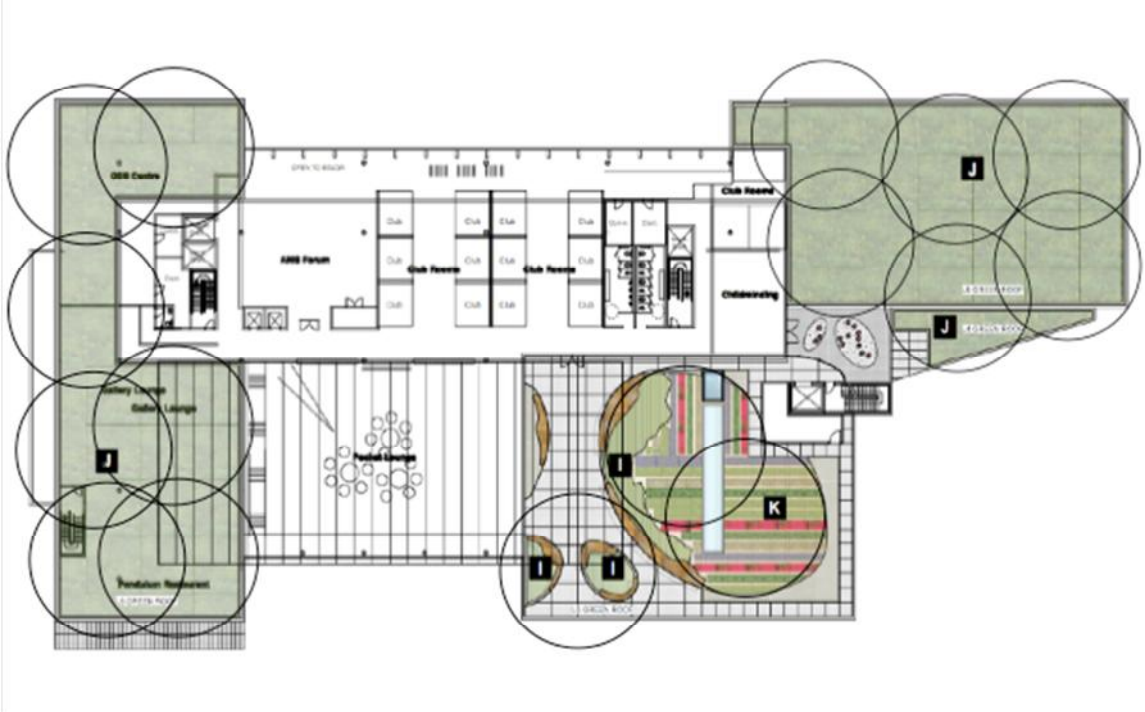

Figure 1: Area of Irrigation

2.0 Solutions

2.0.1 Drip Tape Irrigation

Drip-tape is a thin-wall hose, usually made of polythene (PE) that has been widely used for irrigation system in the last few decades. Essentially, drip-tape irrigation system uses a flexible tubing to deliver water effectively to the root area of the plant with great flexibility. Emitters are placed along the drip-tape tubing. The plants receive a precisely controlled amount of water, drop by drop, depending on the rate of the flow and the choice of emitter size. This attribute of drip-tape irrigation offers the highest efficiency among other commonly available systems on the market.

It has been reported that typical drip-tape irrigation system can achieve an irrigation efficiency of above 90% [1] [2] [3]. Other mechanisms causing the large

difference in watering efficiency between conventional sprinkler and drip-tape irrigation are surface runoff, evaporation. Surface runoff and evaporation occur simultaneously when the humidity of soil is over-saturated over a large surface area. The additional water is wasted to the drainage system via surface runoff and to the air via evaporation before it has a chance to penetrate the soil over one to two inches, i.e. lack of deep percolation. This results in unbalanced irrigation along the roots. Unlike sprinkler's planar irrigation pattern, drip-tape irrigation creates precisely defined wetting zone at the designated locations and a teardrop shaped wetting pattern deeply down the plant roots through capillary and gravitational force, as reported by Haman and Izuno [4]. This precise wetting at the plant roots avoids watering the foliage and reduces the risk of diseases [5]. The limited wetting zone also helps in removing and preventing weeds as only the designated plants are irrigated. Moreover, the ability of deep percolation allows effective irrigation at the end of the plant roots without any issues arise from over-watering, e.g. formation of puddles that submerge a major portion of plant roots, leading to displacement of air in the soil and, thus, drowning the plants. This deep percolation feature provides a better alternative to sprinkler-based system as the new SUB's rooftop garden has a specified extensive green roof and raised planting area with 150mm-/600mm-depth growth medium [6].

All of these properties make drip-tape system a superior irrigation efficiency that places such system as a lower cost in operation and a more sustainable choice as opposed other irrigation systems. The irrigation efficiency of drip-tape system can be more beneficial in the case of chemigation and integrated fertilization requirement where a large percentage of the total agricultural chemicals or fertilizers are conserved in contrast to sprinkler-based system. Another key advantage of drip-tape system is its ability to be highly customized to adopt a wide range of different layouts and irregular terrains and leads to a lower implementation cost and simplified planning process. In addition, drip-tape system can be operated under a relatively low pressure (5-30 psi) in contrast to sprinkler-based system that generally requires a higher pressure to pump the water into the air [4]. This would also make drip-tape systems more economically and environmentally beneficial than sprinkler system due to the energy conserved for the pumping process.

Besides these operational features of drip-tape system, the system has a few advantages over sprinkler system. One of the economical advantages of drip-tape system is the implementation cost. Typical drip tape costs about $.15 to $0.30CAD per foot (15 mil drip-tapes) and it can last up to 3 years for 15 mil drip tapes [7-8]. Depending on the types of plants in the rooftop garden, the inter-dripline spacing can vary from tens of centimeter to a few meters, which can lead to a drastic variation in the cost over the entire projected lifetime of the new SUB, i.e. 100 years. The environmental aspect of the trip-tape system's operation is tightly coupled to its economical advantages. The conservation of water and energy(consumed by the pump) not only reduces the operation cost, but also helps in reducing the carbon footprint of the entire system. As PE drip-tape is most commonly used, the carbon footprint of PE must be taken into consideration for environmental assessment. Due to the limited lifespan of drip-tap, it might have a substantial impact on the

environment at the end of the product life cycle. Unfortunately, it has been reported that plastic (e.g. PE) recycling is not readily available in Point Grey, Vancouver, B.C. by Timothy Carter from UBC Farm. Thus, drip-tape system may potentially cause serious environmental issues if the reusability and end-of-life treatment of drip-tape have not been carefully addressed.

In terms of commercial availability, drip-tape system is commonly implemented around the globe and is readily available in North America. A wide range of drip-tapes with different emitter spacing and diameters, and tube-wall thickness (we use 15 mil rather than 8 mil as the standard drip-tape configuration used for later calculation, as it has a longer lifespan of 3 years) can be easily obtained from various suppliers in North America, e.g. Irrigation Direct© (http://www.irrigationdirect.com/), The Drip Store© (http://www.dripirrigation.com/), and Drip Works© (http://www.dripworksusa.com/).

2.0.2 Soaker Hose Irrigation

Soaker hose is a type of low- volume irrigation system which works similarly to drip tape. However, instead of having equally spaced emitters to allow water out, such as in drip tape, soaker hose utilizes its porous material to "allow water to seep out the entire length of the hose" [9]. Mainly made out of recycled old tires, soaker hoses are considerably tougher and more environmentally friendly than drip tape. As a result, "it [soaker hose] is tough enough to survive being buried in the soil or under a layer of mulch, and is less likely than a drip line to be nibbled by rodents" [13].
In terms of water efficiency, soaker hoses can save between 70% to 90% water consumption. Compared to the other irrigation systems studied in this research project, the performance of soaker hose lies in between the sprinkler and drip tape irrigation.

Figure 2: Soaker Hose

According to a study conducted by University of Rhode Island, soaker hoses require less equipment and are generally easier to set up than drip tapes [10]. A typical automated soaker hose irrigation system simply consist of a programmable timer, a flow regulator (whenever it is required, considering that soaker hose works better under low pressure), hoses, pipes fittings and end caps.
Another economical advantage of soaker hose is its relatively long lifespan. There are several ways to increase the life span of soaker hose, hence reducing its maintenance cost significantly, such as the following steps which are suggested by the City of Bellevue[11]:

- Unscrewing the end caps and flushing out any accumulated sediment once or twice a year; otherwise, it may clog the system and affect the water distribution rate
- Covering the system with mulch to protect it from the sun. If left under the sun, soaker hose will deteriorate after 2 to 3 years
- Replacing small cuts and nicks with connectors and hose clamps which are available from garden centres

Under thorough care, soaker hose system will only need to be replaced after 6 to 7 years.

Despite its advantages in maintenance cost and ease of installation, soaker hose system has a high initial cost. A soaker hose with 90% efficiency cost $27.99 for 50 ft length or approximately $1.85 per meter (refer to Commercially Available Product section). Furthermore, soaker hose has certain limitations which need to be considered during installation. In order to get a uniform water delivery throughout its length, each run should be kept short, never longer than 50-75 feet, and the grounds must be reasonably levelled as well [10].

Commercially Available Products

ColorStorm™ Premium Soaker Hose

- Conveniently water gardens and beds
- Evenly waters from beginning to end
- Thoroughly water using 90% less water than conventional watering
- 50% thicker wall than other soaker hoses eliminating wasteful water that sprays out of the hose. Compare Hoses [PDF]
- Designed with crush proof nickel-plated brass couplings
- Made in the U.S.A. from recycled materials
- Available in 25' or 50' lengths, 5/8" dia

Figure 3: Soaker Hose

Retail Price: 27.99 for 50' length from Amazon.com

Soaker Hose	
Stock Number	**Description**
SNUER025	5/8" x 25'
SNUER050	5/8" x 50'
SNUER075	5/8" x 75'
SNUERA050	Convenience Pack with 6' hose

- Save up to 70% water usage
- Patented water restrictor to control water flow
- 7 Year warranty

Figure 4: Soaker Hose

Retail Price: $14.99 for 50' length from Garden.com

2.0.3 Sprinkler Irrigation

2.0.3.0 Physical Description

Below shows typical components of the sprinkler system.

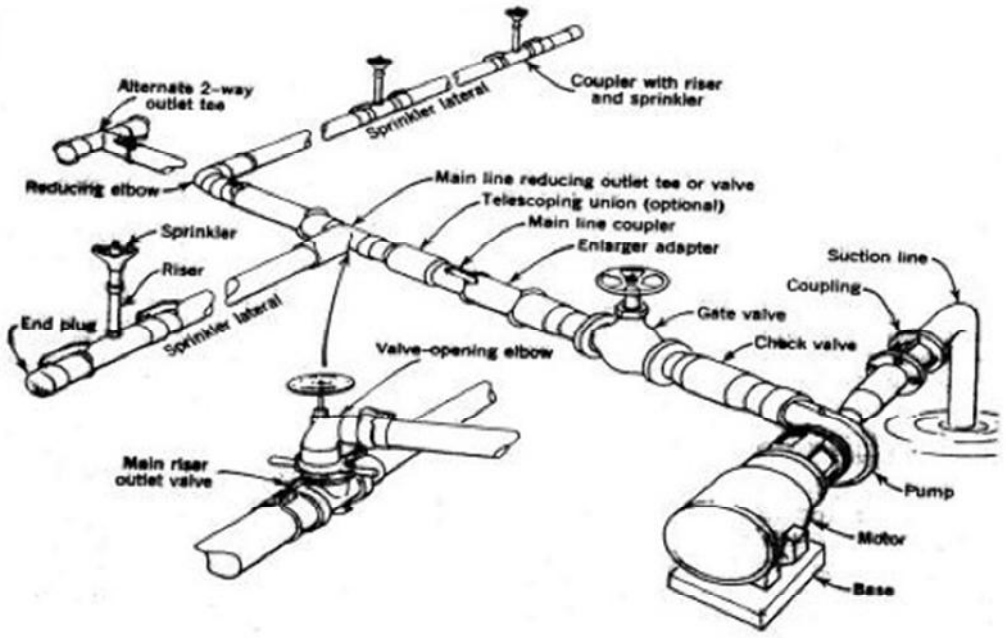

Figure 5: Components of sprinkler irrigation system

This figure shows the typical components of a sprinkler system

(i) A pump unit
(ii) Tubings- main/submains and laterals
(iii) Couplers
(iv) Sprinker head
(v) Other accessories such as valves, bends, plugs and risers.

The rotating head sprinkler system has certain characteristics. The lateral pipes are usually placed on the ground. The riser pipes are attached to these lateral pipes. On the riser pipes are the nozzles placed evenly. The sprinkler heads will then be rotated.

Figure 6: Sprinklers

2.0.3.1 Cost

Initial Costs

The Social Garden is 242m^2 or 2605 sqft whereas the Production Garden is to be 1040 m^2 or 11194 sqft. The typical water efficient sprinklers can have a radius of 25 feet [14]. This means that we will need two sprinklers for the Social Garden and six sprinklers for the Production Garden. From sprinkler.com, one sprinkler cost $8.45 so the eight total sprinklers will cost $67.6.

The total green roof area that needs to be irrigated is 1866 m^2 or 20085 sqft. The sprinklers have been laid out, needing 16 sprinklers according to figure 8.

Product	Price per item ($)	Quantity	Price of Quantity ($)
Sprinkler	8.45	16	135.2
¾'' x 25' Steel Piping	20.90 [15]	25	522.5
¾'' Female Tee Fitting	2.30 [16]	16	36.8
¾'' Couplers	0.56 [17]	13	7.28
¾'' Threaded Cap	0.53 [18]	6	3.18
¾'' Male to Female Riser Pipe	1.04 [19]	16	16.64
Sprinkler System Controller	72.93 [20]	3	218.79
Pump unit	582.92 [21]	3	1748.76
		Total	2689.15

Table 1: Initial Cost of Sprinkler System

The initial installation costs are estimated to be around $4000 dollars [22]. This brings the total initial costs up to $5542.86.

Maintenance Costs

The pipes and fittings do not requirement much maintenance; however, the washers on the sprinkler heads could be worn out easily. This should be checked once a season or every 6 months. In general, check all equipment at the end of a season to make repairs and adjustments [23]. This takes approximately 2 to 5 hours. At $25 dollars per hour, this ranges from $50 dollars to $125.

The sprinklers are warranted for two years [24]so they may be replaced every two years. In the worst-case scenario, all 16 sprinklers could be replaced, costing another $135.20.

2.0.3.2 Efficiency

The efficiency of the sprinkler is at the maximum 75% [25]. This accounts for the water evaporated. The sprinklers have a circle of wetted area so for square gardens, there will be some overlap, hence, a decrease in efficiency of water usage. Looking at Figure 8, the layout for the garden, there is quite a bit of overlap. If there were no overlap, only 11 sprinkler heads would be needed; hence a further 68.75% efficiency would be multiplied to the evaporated water efficiency. This is also assuming that all the water goes to the soil; however, as it can be seen from Figure 8, the layout of the garden, this is not true. Therefore, the maximum efficiency at this layout is 51.56%. On a hot summer day, 50% of the water can be evaporated from the sprinkler [26]. This would bring the total efficiency down to 34.375%.

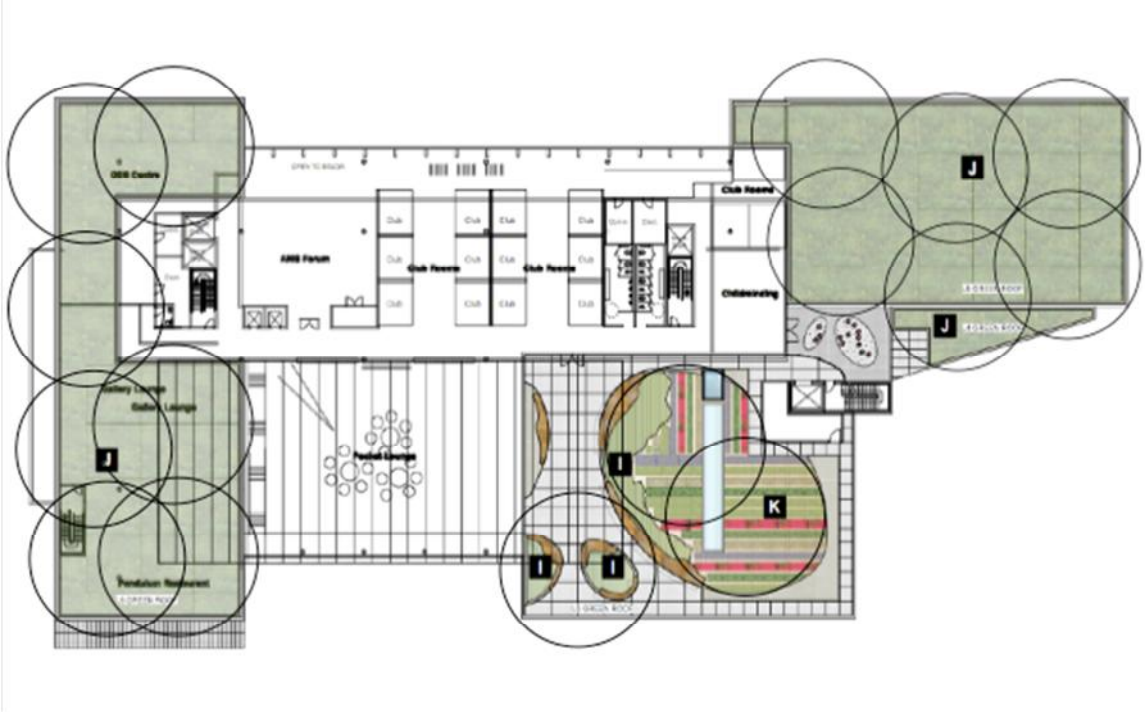

Figure 7: Layout of Sprinklers
Note: Circles are the wetted area of each sprinkler.

3.0 Triple Bottom Line Analysis

3.1 Economical Impact

In order to compare the economics of the three systems (sprinkler, drip-tape and soaker hose), we must derive a comprehensive analysis covering a wide range of costs including operation, maintenance and initial installation expenses. The cost of sprinkler system is a flat-rate with respect to the layout of the plants while the cost of drip-tape and soaker hose systems rely heavily on the inter-dripline spacing as it determines the required tubing length that takes the major portion of the system cost. First, we determined the required length of the tubing required for specific spacing which will depend on how far apart the plants are placed:

_____ — _____

, where is the inter-dripline spacing, is the number of rows (thus, would be the width) and is the area of the entire rooftop garden. We did not take into account of the edge placement due to the high flexibility of the two systems. Next, we formulated the cost for drip-tape and soaker hose:

, where $Cost_{material}$ is the material cost ($0.656 per meter for drip tape and $1.85 per meter for soaker hose). To calculate the labour cost for replacement over a specific period, we derived the following equation:

$$COST_{labour} = L_{required}/L_{length-per-hour} \times COST_{hourly}$$

, where $Cost_{labour}$ is the total labour cost and $L_{length-per-hour}$ is the length of tubing that can be replaced per hour of work at an hourly wage of $COST_{hourly}$. Thus, we obtained the following expense plot over different spacing based on the assumption that the labour cost is at $10 per hour and that 1400 meter of drip-tape/soaker-hose can be replaced within 1 hour of labour, and sprinkler can be replaced at a rate of 15 minutes per sprinkler head. The lifespan for the sprinkler, drip-tape and soaker hose are 3, 7, and 2 years, respectively. The cost of sprinkler is calculated with the assumption that the metal pipe lasts longer than the lifespan of the SUB project, i.e. a flat rate of $805 is used in the calculation for the installation of pipe. We have not taken into account of the cost of pump, filters, sensors and controllers, as these expenses do not deviate too much between different systems. In addition, we have not included the water expenses as it depends primarily on the type of plants and the local weather. Figure 1 depicts the costs associated to different inter-dripline spacing for initial implementation cost, and total expense for 20 years and 100 years.

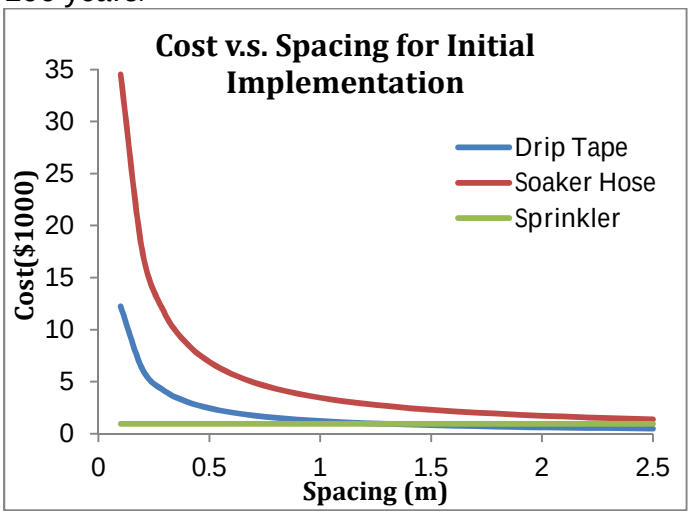

Figure 8: Cost Vs. Spacing for Initial Implementation

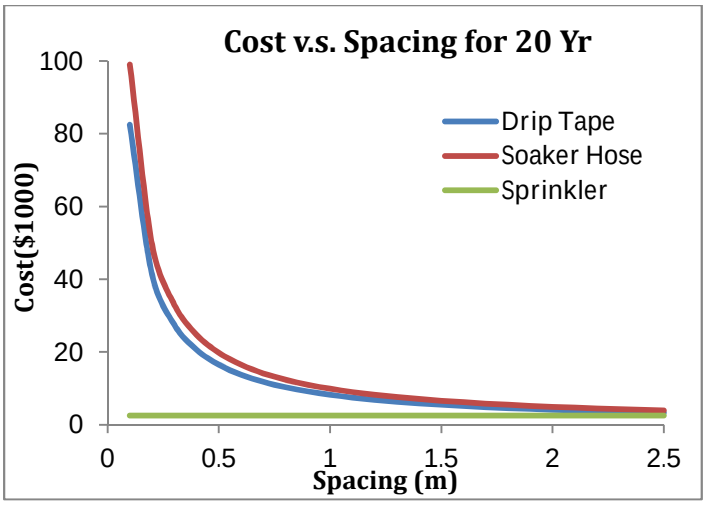

Figure 9: Cost Vs. Spacing for 20 Years

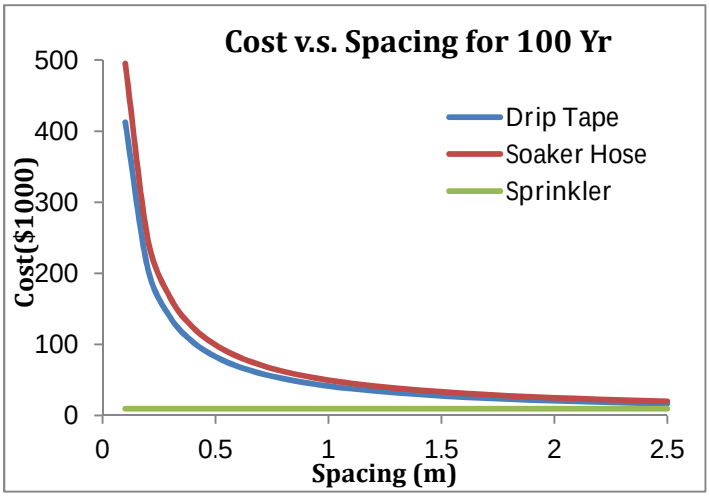

Figure 10: Cost Vs. Spacing for 100 Years

Note. Total cost comparison between drip-tape, soaker hose and sprinkler systems over different excluding the cost of filter, pump and controller for (a) one year, (b) 20 years, and (c) 100 years.

In summary, the cost of the different systems depends heavily on the spacing between the plants. The best approach in selecting the most economical irrigation system is to use a hybrid system that utilizes the advantages of drip-tape and soaker hose for areas with irregular shapes or edges.

3.2 Environmental Impact

In conducting the environmental analysis, booth material carbon footprints and water efficiency of the irrigation systems are evaluated and compared.

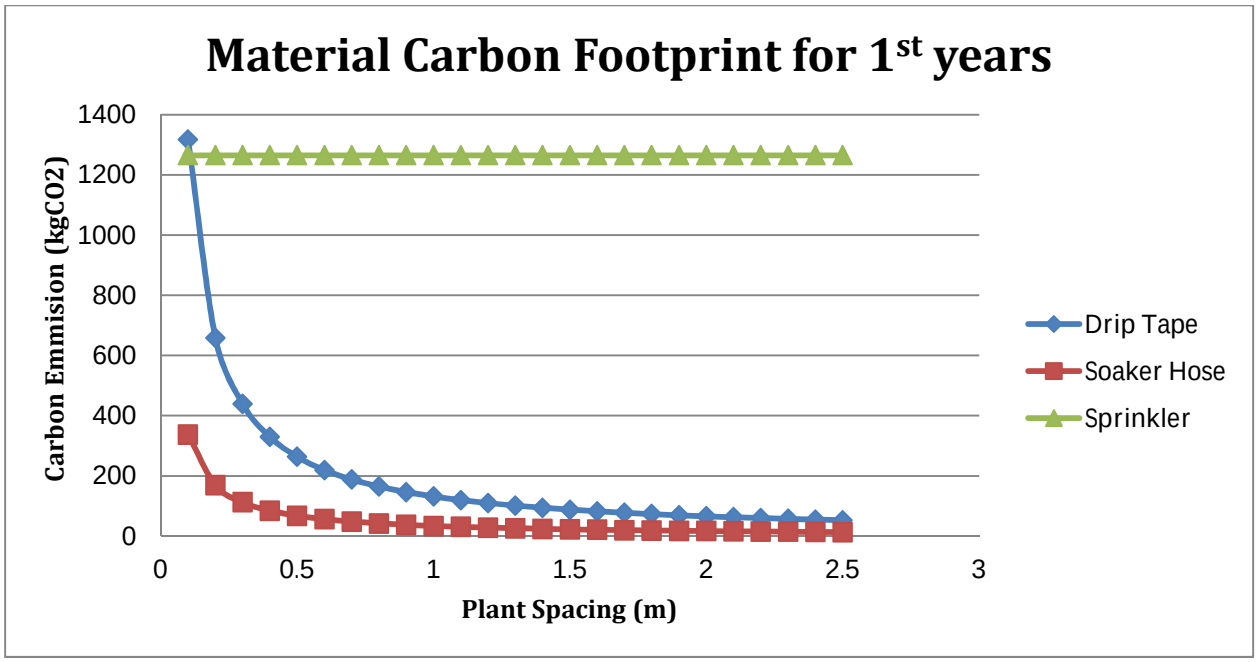

Figure 11. Material Carbon Footprint for the Initial Setup

*Note: *Carbon footprint of drip tape and sprinkler material (polyethylene) is considered to be 2kgCO2/kg material [25]*

** Carbon footprint of soaker hose material (recycled rubber) is considered to be 0.124kgCO2/kg material [26]*

** Carbon footprint of steel pipe material is considered to be 1.987kgCO2/kg material [27]*

From figure 12, it could be seen that total carbon footprints of sprinkler in the initial installation is the highest compared to the other two alternatives. More than 1200kg of CO_2 needs to be produced to manufacture the materials used in the sprinkler system. The high carbon footprint mainly comes from the steel pipes which are used to supply water to the sprinklers. It should be noted that this value is even higher if we take into account the fabrication process and the long distance shipping of the materials as most steel are currently produced in China.

The carbon footprints for the entire project duration of 100 years, however, shows different trend than the previous graph. In figure 12, we can see that for plant spacing less than 0.8m, sprinkler system has lower carbon footprints than drip tape system. However, the soaker hoses are still leading as the system with lowest carbon footprint. The slight change in the trend of the two graphs is caused by the different lifespan of each product. In conducting our analysis, we compare the maximum lifespan of drip tape, soaker hose, and sprinkler irrigation system. The maximum lifespan of drip tape is 3 years, 7 years for soaker hose, 2 years for the sprinkler itself, and approximately 25 years for steel pipes.

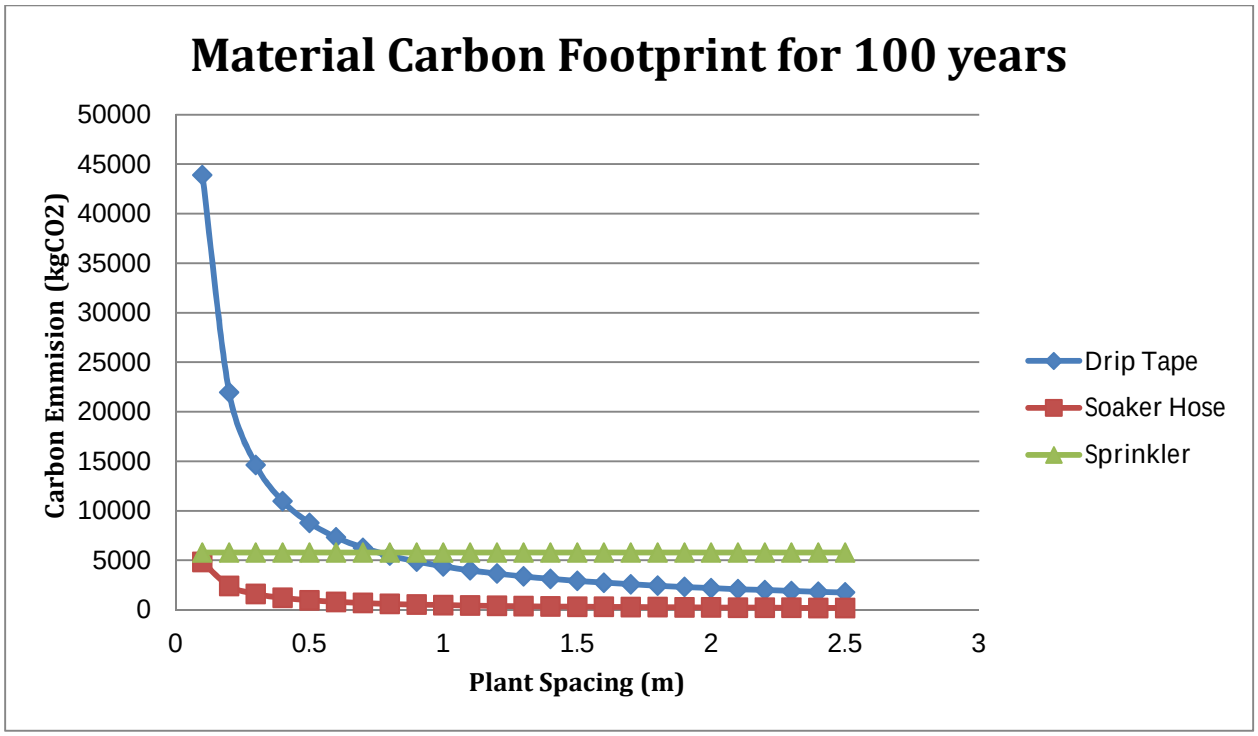

Figure 12. Material Carbon Footprint for 100 years

In addition to carbon footprint calculation, water efficiency is also one of our deciding factors in evaluating the environmental benefit of the three irrigation systems. Water efficiency of each product is summarized in the following table:

Table 2. Water Efficiency of Drip Tape, Soaker Hose, and Sprinkler

Irrigation System	Water Efficiency	Water Efficiency of the Specific Product
Drip Tape	90% and above	90%
Soaker Hose	70% to 90%	90% (Dramm Soaker Hose)
Sprinkler	34.4% to 51.56%	51.56%

Note: Water efficiency accounts amount of water evaporated

Based on both carbon footprint and water efficiency analysis, soaker hose has the best performance among the three irrigation systems.

Social Impact

For this particular problem, there are not many social impacts. One main one is the fact that we must look at where the product that we are buying comes from. If bought locally, we can create jobs inside the country. All three products that we have chosen are made in the US. The pipes that are needed mostly come from China. We must then look if the products are made by employees who are underpaid or mistreated.

Another social impact that we can look at is the comfort level in maintaining the systems. The sprinkler system requires seasonal checkups while the soaker hose and drip tape requires leveling the soil for each replacement. There is no advantage here because it can be argued both ways: frequent smaller jobs or infrequent large jobs.

Conclusion

After the triple bottom line analysis, the soaker hose was recommended for a few reasons. Compared to the drip tape, the long-term costs were very similar although a little higher than the drip tape. At 20 years, if the spacing of the plants were 0.3m, cost for drip tape was $20,000 whereas for soaker hose, it was $23,000. In the 100 years category, it is even closer. In terms of the carbon footprint, the impact of the soaker hose is much less than that of drip tapes. If the spacing were again, 0.3m, at 100 years, the carbon footprint for the soaker hose is 1608 kg CO_2 whereas for drip tape, it is 14635 kg CO_2. In order to achieve the LEED Platinum Plus Certification, we need to use environmentally friendly materials. The sprinkler system was eliminated because of its low water efficiency of 51.56% at maximum.

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