Assessment of Water Dynamics with Changing Land Use in the Lower Fraser Valley, B.C.

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Introduction

Thesis statement: Changing agricultural land use has impacted field water dynamics, as different crops and management practices have different water requirements. Thus, information is required to assess these changes in field water dynamics and develop strategies to manage water resources more efficiently, including assessment of alternative irrigation systems.

Issue: Water stress in the Lower Fraser Valley (LFV): the conflict between growing agricultural water consumption demand and limited water resources.

How we manage land and water resources is critical for food security, particularly with the increasing pressure from population growth and climate change[1]. Globally, agriculture consumes 70% of fresh water, much more than industrial (19%) and municipal (11%) water use[2]. Also, irrigation induces changes in evapotranspiration and groundwater recharge processes in the water cycle[3].

The LFV is one of the most densely populated and intensively farmed areas in BC. The unequal temporal distribution of rainfall makes irrigation demand even higher during the crop growing season. Agricultural development in the LFV relies on water resources, but climate change is likely to cause drier and warmer summers and wetter winters[4]. This tends to increase water stress due to the higher demand for irrigation.

Literature Review

1. The importance of irrigation in LFV

The Fraser Valley contains 3% of BC's total Agriculture Land Reserve (ALR) but gains 50% of provincial farm gate value. The total ALR area in Fraser Valley is 137,746 Hectares and most of the ALR is located in the lower part of Fraser Valley (Figure 1).

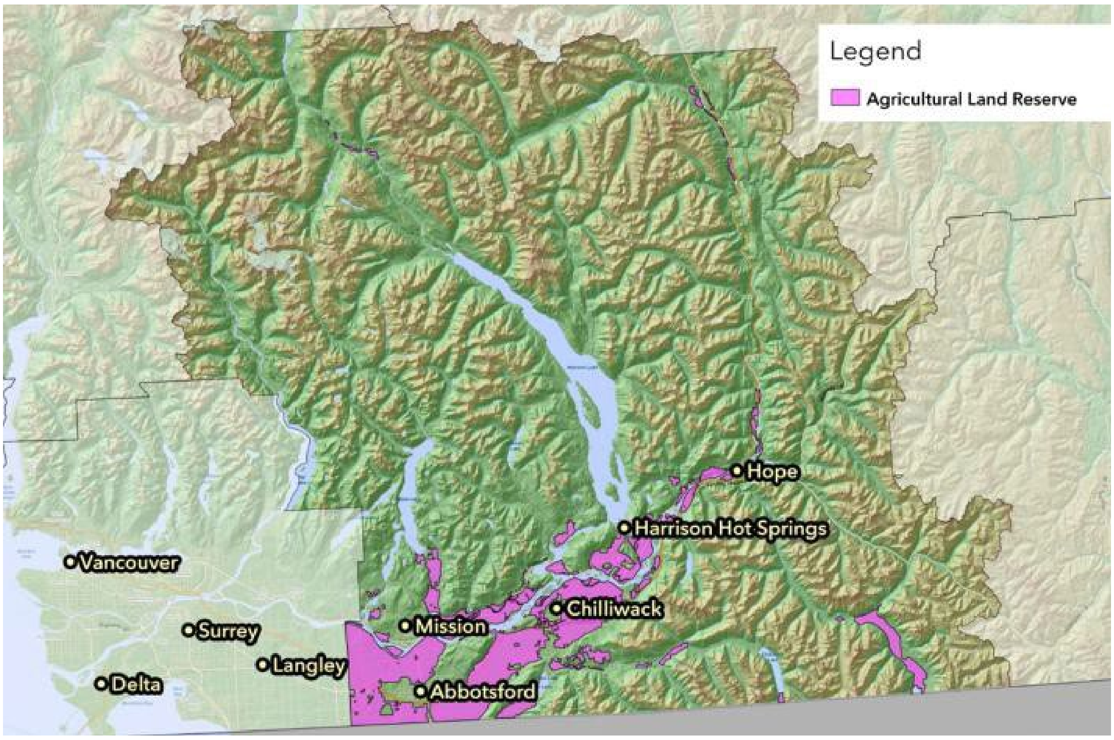

Figure 1. ALR areas in Fraser Valley [5]

The Fraser River and groundwater are the two main sources of irrigation water supply. However, because most crops, such as berries and corn, are not tolerant of salinity (as indicated in Table 1) when the Electrical Conductivity (EC) value exceeds 0.4 ms/cm, irrigation intake from Fraser will be shut down[6].

Table 1. Crop tolerance to irrigation water salinity[6]

Crop	Electrical Conductivty of Irrigation Water Ecw - ms/cm	Crop Tolerance
Cranberries	< 0.7	not tolerant
Strawberries, Raspberries	< 0.7	not tolerant
Beans Carrots	< 0.7	not tolerant
onion, lettuce, celery	< 1.2	slightly tolerant
peas, potatos	< 1.2	slightly tolerant
sweet corn, forage corn	< 1.2	slightly tolerant
cucumber, tomato, alfalfa	< 2.2	moderately tolerant
beets, oats, clover	< 3.5	tolerant
soybean, wheat, barley	< 5.0	very tolerant

For better management of groundwater use, the Water Sustainability Act (WSA) requires farmers who use groundwater for agricultural production to apply for a water license and pay for water rental fee from February 29th, 2016[7]. Reducing irrigation water use also means saving money for farmers.

2. Concerns of water scarcity in LFV

Climate change will increase the irrigation demands drastically in the drier and hotter summers, which is very likely to happen based on experience in 2015 and 2017. In 2015, the BC government raised the drought level to the highest category level 4 in Fraser Valley (Figure 2), which caused the water shortage for municipal, industrial and agricultural water uses[8].

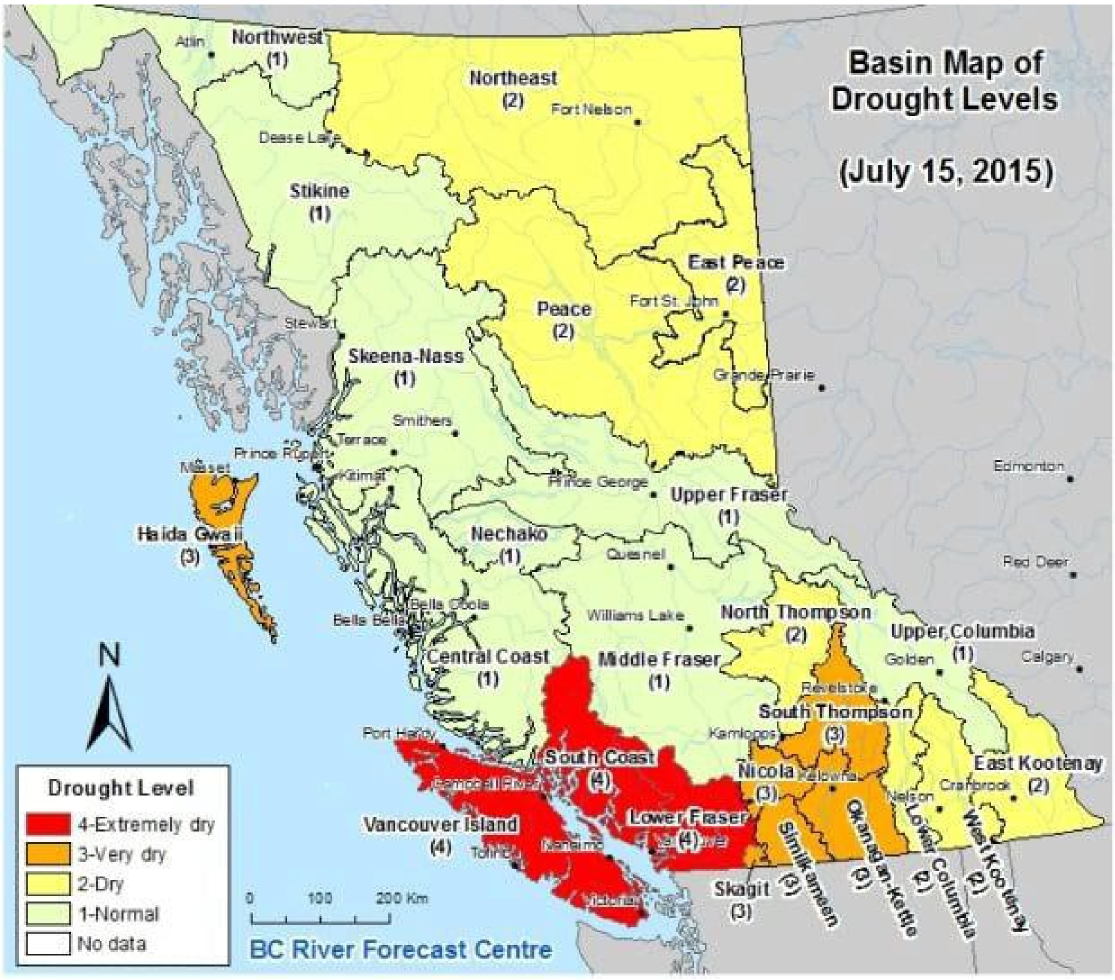

Figure 2. Drought level in 2015 [8]

This increased part of irrigation demands need to be made up by higher efficiency irrigation systems, better management practice and could potentially change the land use, which will help achieve the final goal of growing more with less water.

3. The BC Agriculture Water Demand Model (AWDM)

The AWDM was developed in the Okanagan Watershed to help to understand the current water use, it expanded to various watersheds in BC, including the Fraser Valley[9]. The model is based on a Geographic Information System (GIS) and data required for the calculation by the model includes crop type, irrigation system type, soil texture, and climate data.

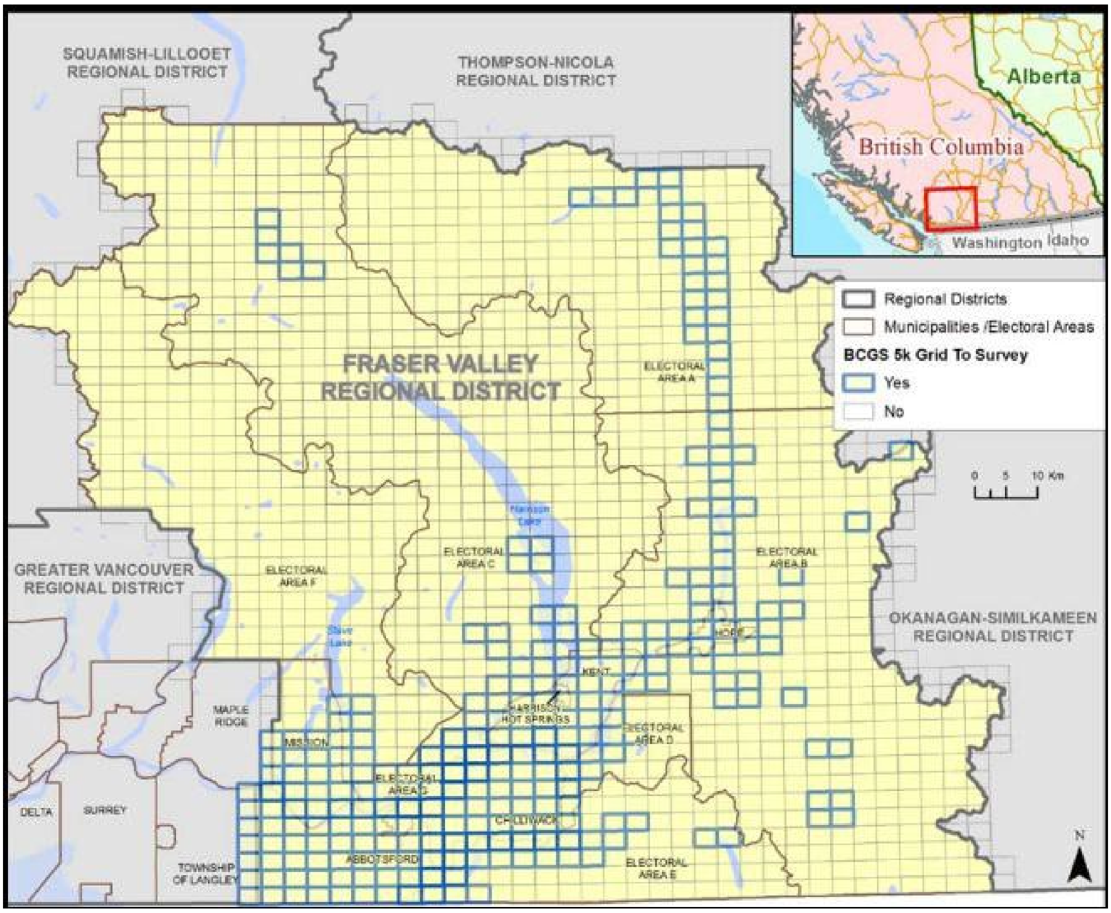

Figure 3. Overlaid Survey Map sheets, Fraser Valley [9]

The existing 1961-2003 climate dataset from climate stations in Fraser Valley was used in this model. The soil texture is determined as the most predominant texture within the crop rooting depth.

The AWDM Equations listed in Table 1 show the process of how the AWDM calculates step by step in each polygon basis. Then, the polygons are added to calculate the water demand for each cadastre.

Table 2. The AWDM Equations/Process for calculation[9]

	Equation/Explanation
(1) Pre-Season Soil Moisture Content	Soil stored moisture before the start of each crop's growing season.
(2) In-Season Precipitation	Dry Climate $EP = (Precip - 5) \times 0.75$ Wet Climate $EP = Precip \times 0.75$
(3) Crop Coefficient (Kc)	Kc values represent the crop type and ground coverage, Figure 4 shows Kc changes with the development of blueberry plants
(4) Crop Evapotranspiration (ETc)	$ET_c = ET_o \times K_c$
(5) Climate Moisture Deficit (CMD)	$CMD = ET_c - EP$ $CMD_a = CMD - storedMoisture$
(6) Crop Water Requirement (CWR)	$CWR = CMD_a \times swFactor \times stressFactor$
(7) Irrigation Requirement (IR)	$IR = CWR \times \frac{D_f}{I_e}$ Each irrigation system type has its Ie value, inefficient irrigation system uses more water to satisfy the same crop demand.
(8) Irrigation Water Demand	$IWD_{perc} = IR \times soilPercFactor$ $IWD = IR + IWD_{perc}$
(9) Frost Protection	Water used to protect some crops(like cranberries) from frost damage.

(10) Annual Soil Moisture Deficit	Only for dry areas, water added to prevent the soil from freezing in a dry/cold climate.
(11) Flood Harvesting	Water used for flood harvesting techniques(like cranberries)

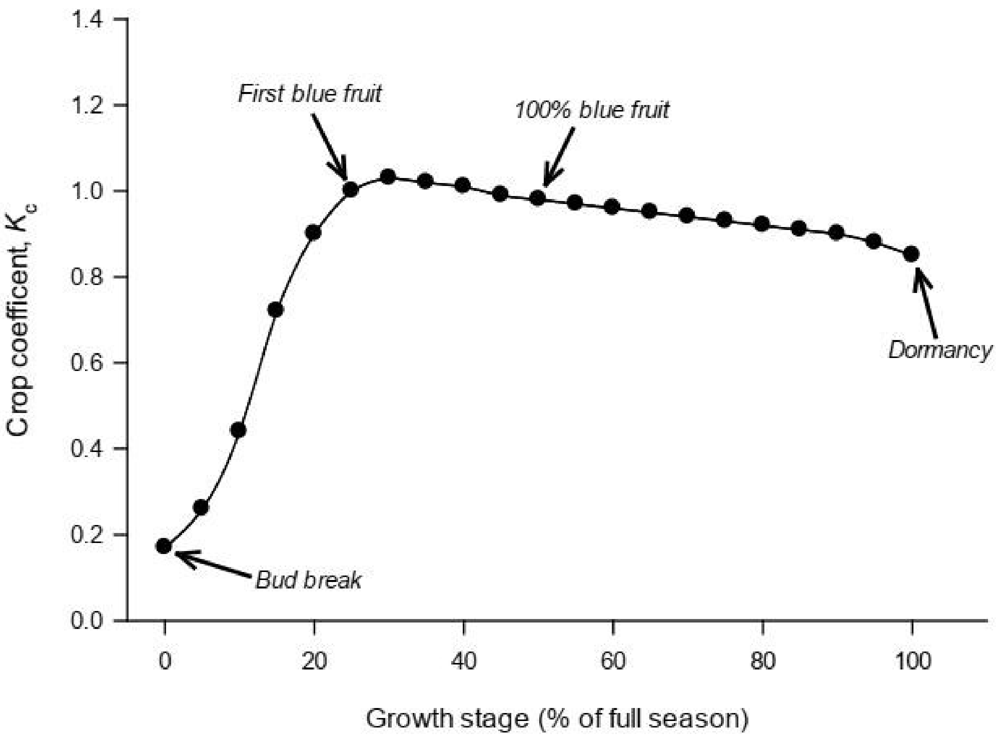

Figure 4. Temporal variation of blueberry Kc over the growing season (obtained from AgriMet)

One of the limitations for the model's accuracy in the Fraser Valley is that the water table is not considered in the equation. Therefore, high water tables in many low-lying areas in the Fraser Valley may receive higher results than actual uses.

Project Objectives

1. To compare the irrigation demand of different land uses (pasture, corn, raspberries, and blueberries) and determine the effect of changing land use from pastures, corn, and raspberries to blueberries on the water dynamics in the LFV.

2. To compare the irrigation water efficiency of different irrigation systems (sprinkler and drip) and explore alternative irrigation methods.

Methods

1. The BC Agriculture Water Calculator tool in the BC Agriculture Water Demand Model (AWDM) (http://bcwatercalculator.ca/agriculture/irrigation) will be used to calculate and compare the irrigation demand of different soils, crop types, and irrigation systems.

Soils and location (Figure 5)**:** Abbotsford soil (in Abbotsford), Monroe soil (in Northern Chilliwack), Cloverdale soil (in Cloverdale), and Whatcom soil (in Maple Ridge).

Land Uses: forage, corn, raspberries, and blueberries

Irrigation Systems: sprinkler and drip

2. Determine the irrigation demand change if land use switches from forage, corn, or raspberries to blueberries.

The assumption is that within a given area, soil, irrigation system and climate conditions are the same, but the land use is different compared to the water demand.

3. Determine which irrigation technique, sprinkler or drip, is more efficient for crop

production.

The assumption is that within a given area, soil, crop and climate conditions are similar, but the irrigation system is different compared to the water demand.

Results and Discussion

1. Results on irrigation demand for four different soils, four different land uses and two irrigation systems.

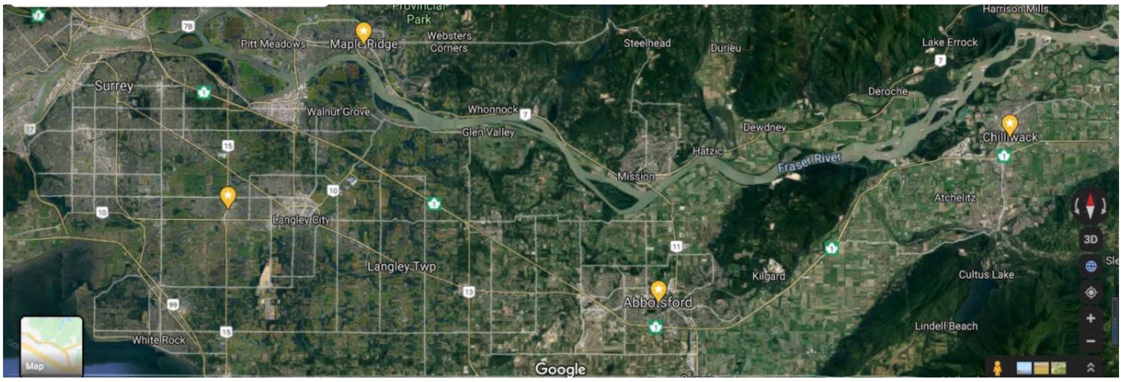

Figure 5. Locations of four different soils

From West to East: Cloverdale, Whatcom, Abbotsford, Monroe

(https://www.google.com/maps)

1.1 Abbotsford

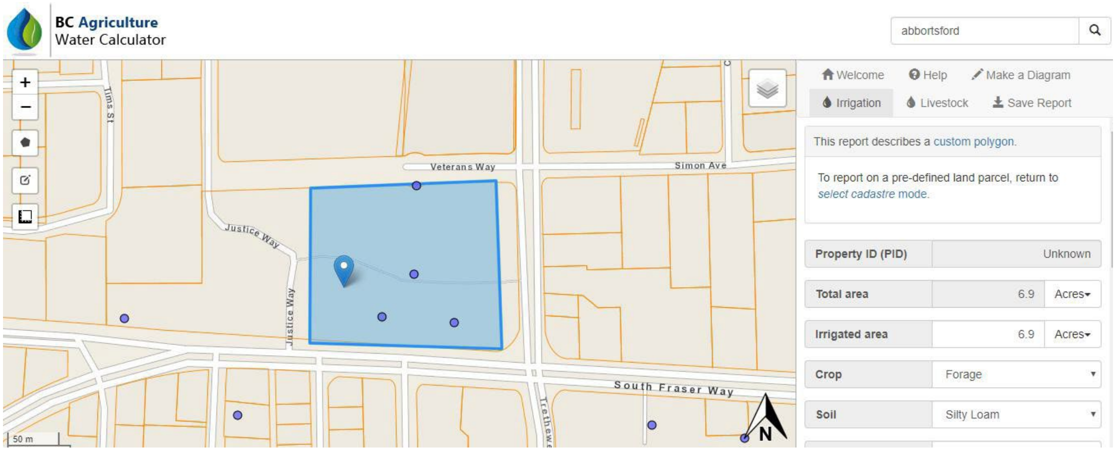

Figure 6. Locations of Abbotsford soils

Table 3. Total annual water demand (m^3) per hectare in Abbotsford

	Sprinkler (m^3/hectare)	Drip (m^3/hectare)
Forage	3463	2710
Corn	2494	1953
Raspberries	1906	1492
Blueberries	2667	2086

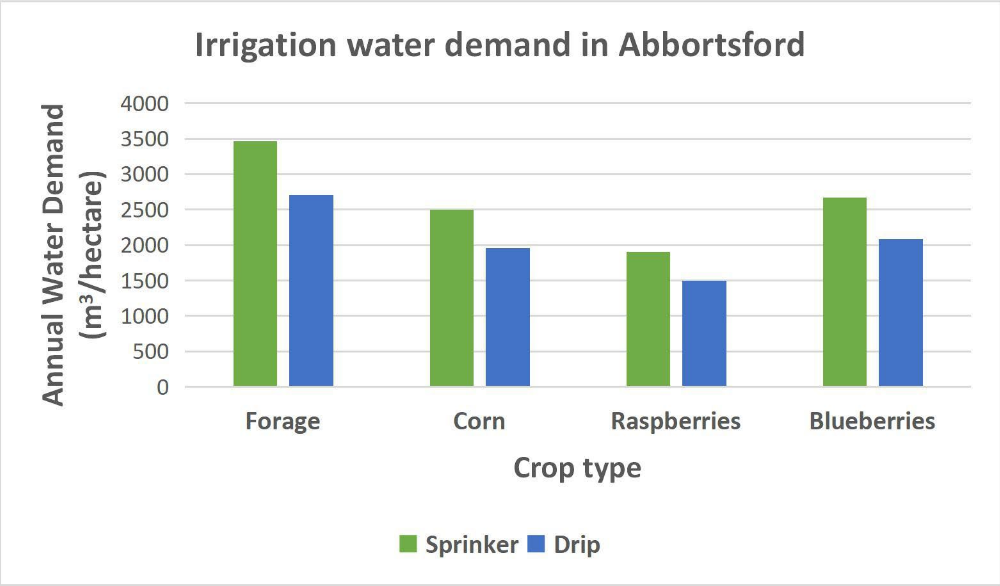

Figure 7. Total annual water demand (m^3) per hectare in Abbotsford

1.2 Cloverdale

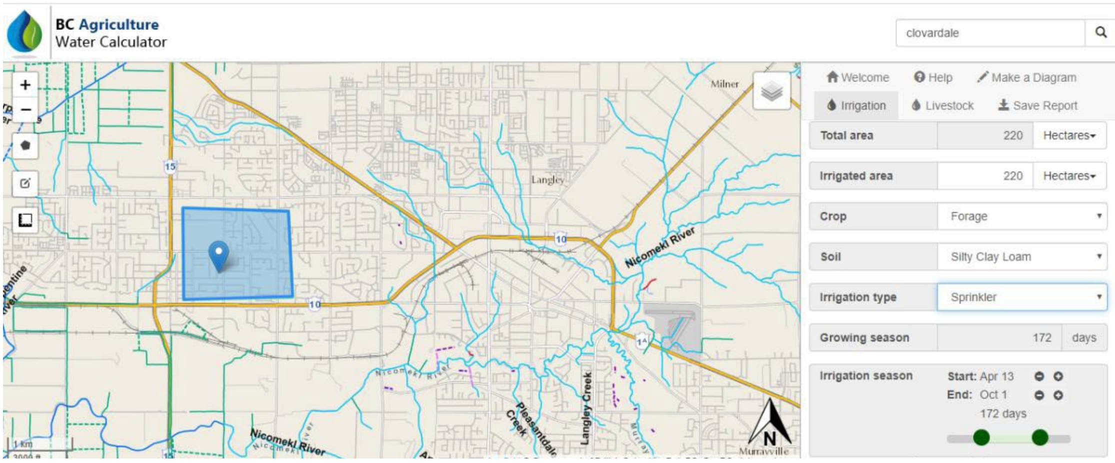

Figure 8. Locations of Cloverdale soils

Table 4. Total annual water demand (m^3) per hectare in Cloverdale

	Sprinkler (m^3/hectare)	Drip (m^3/hectare)
Forage	3397	2658
Corn	2446	1914
Raspberries	1869	1462
Blueberries	2616	2047

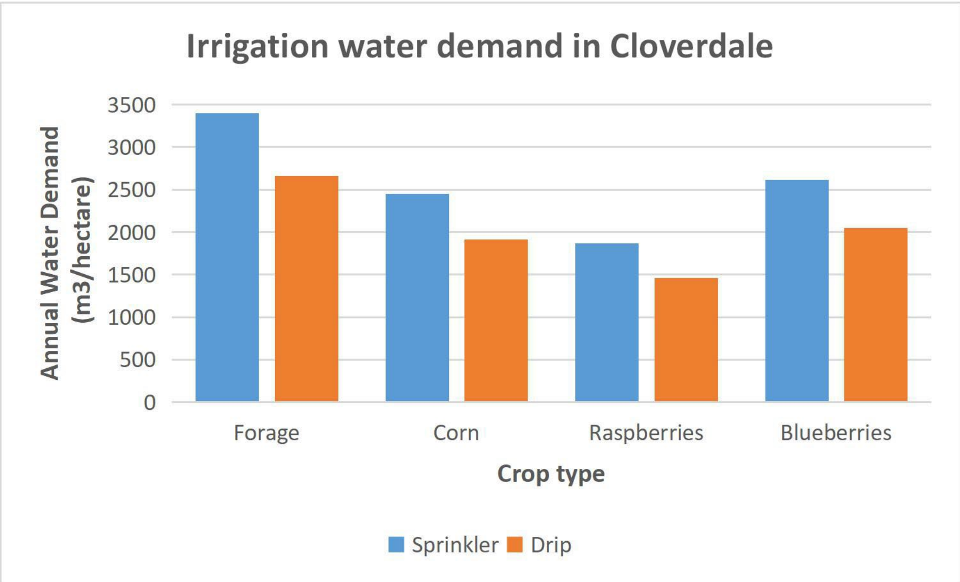

Figure 9. Total annual water demand (m^3) per hectare in Cloverdale

1.3 Monroe

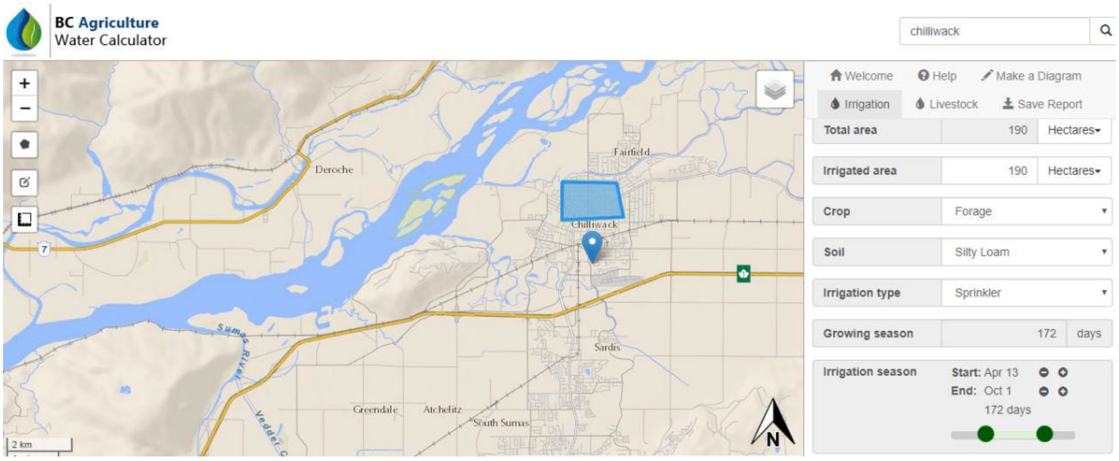

Figure 10. Locations of Monroe soils

Table 5. Total annual water demand (m^3) per hectare in Monroe

	Sprinkler (m^3/hectare)	Drip (m^3/hectare)
Forage	3626	2837
Corn	2611	2043
Raspberries	1994	1560
Blueberries	2792	2184

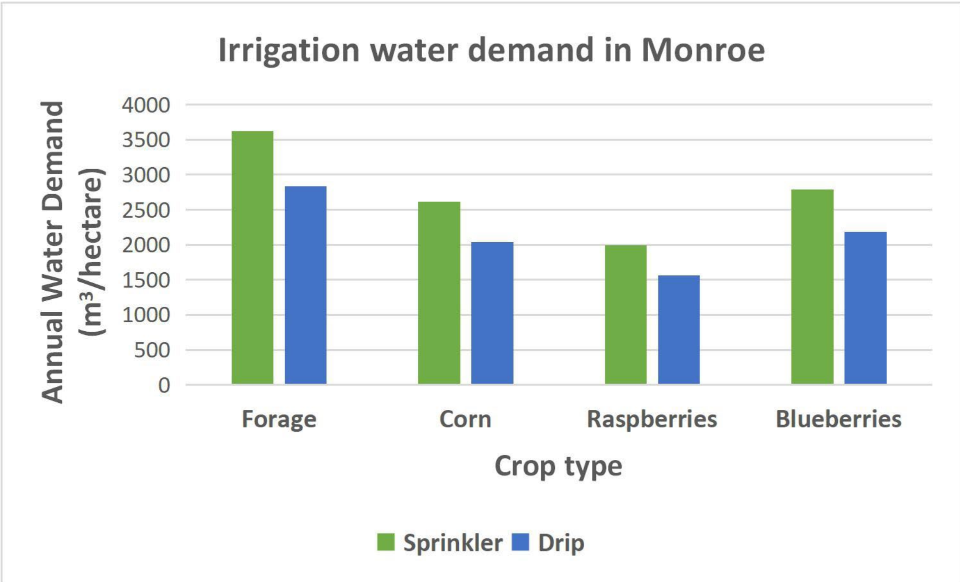

Figure 11. Total annual water demand (m^3) per hectare in Monroe

1.4 Whatcom

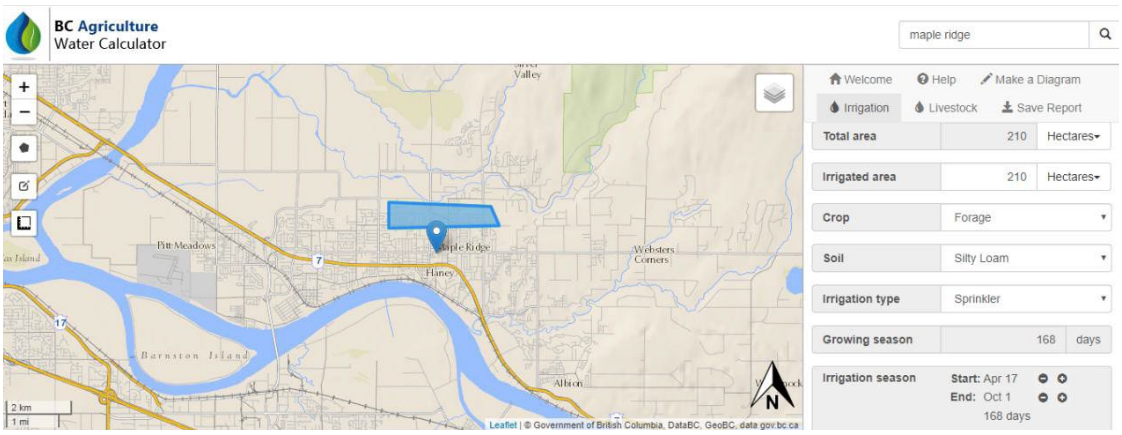

Figure 12. Locations of Abbotsford soils

Table 6. Total annual water demand (m^3) per hectare in Whatcom

	Sprinkler (m^3/hectare)	Drip (m^3/hectare)
Forage	3512	2748
Corn	2529	1979
Raspberries	1932	1511
Blueberries	2704	2116

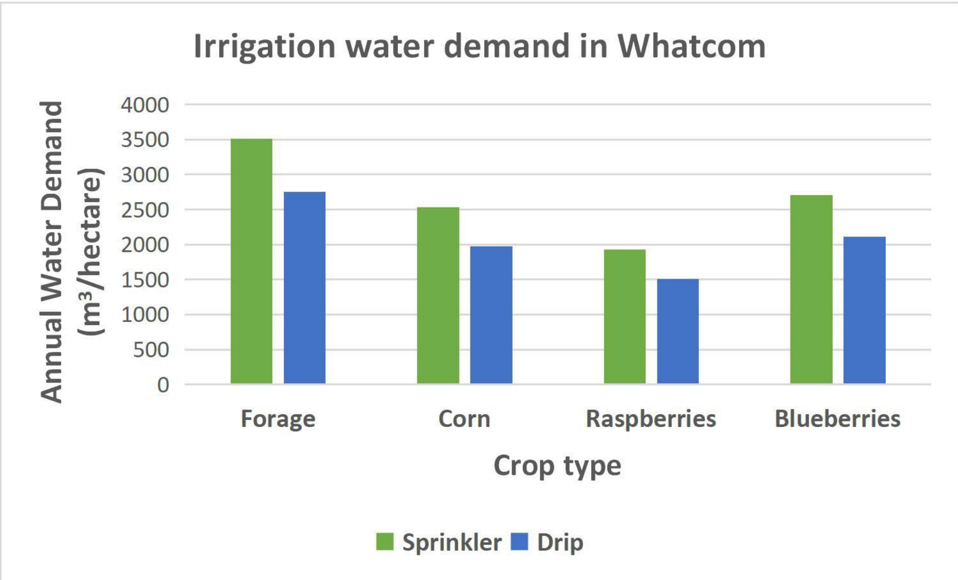

Figure 13. Total annual water demand (m^3) per hectare in Whatcom

1.5 Comparison of water demand of 4 soils, 4 crops and 2 irrigation systems

Irrigation demand varies between soils, crops and irrigation systems(Table 7). Based on these crop comparison results, the annual water demand is highest for forage followed by blueberries, corn and raspberries(forage>blueberries>corn>raspberries), The most potential reason is that forage rooting depth is shallower and needs several harvests during the growing season, so the cumulative Kc is higher.

In all soils and crops, a drip irrigation system is more efficient than a sprinkler(sprinkler>drip).

Table 7. Total annual water demand (m^3) of 100 hectares

A-Abbotsford, C-Cloverdale, M-Monroe, W-Whatcom

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	A-Sprinker	**A-Drip**	**C-Sprinkler**	**C-Drip**	**M-Sprinkler**	**M-Drip**	**W-Sprinkler**	**W-Drip**
Forage	**346308**	**271004**	**339732**	**265832**	**362558**	**283700**	**351200**	**274795**
Corn	**249355**	**195305**	**244609**	**191405**	**261053**	**204258**	**252862**	**197857**
Raspberries	**190645**	**149176**	**186855**	**146209**	**199405**	**156037**	**193167**	**151143**
Blueberries	**266667**	**208638**	**261595**	**204691**	**279174**	**218447**	**270424**	**211595**

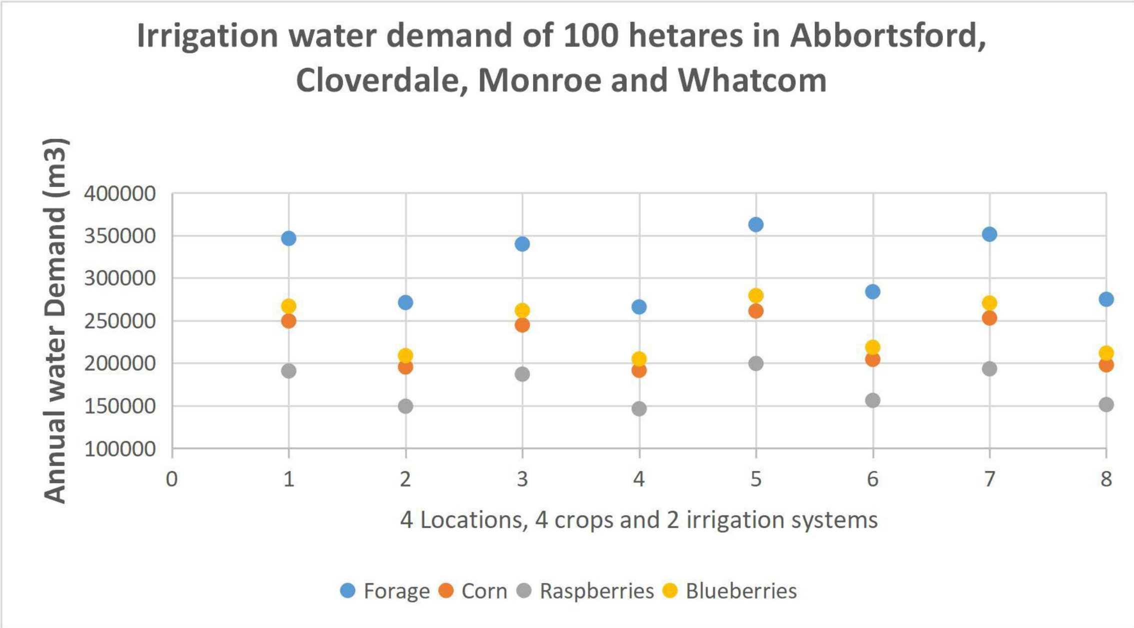

Figure 14. Total annual water demand (m^3) of 100 hectares

In general, Cloverdale soil uses the least amount of water (Monroe>Whatcom>Abbortsford>Cloverdale). The reason is most likely the soil texture is different (Table 8), silty clay loam soil in Cloverdale has finer particles than silt loam soils (Figure 15).

Table 8. Soil characteristics comparison

	Abbotsford soil	Cloverdale soil	Monroe soil	Whatcom soil
Soil texture	Silty loam	Silty clay loam	Silty loam	Silty loam
Drainage	Well to rapidly drained	Poorly to moderately poorly drained	Moderately well to well drained	moderately well to well drained

Water holding capacity	high	high	high	high
Main Location	Abbotsford	Cloverdale	Northern Chilliwack	Matsqui, Landley, Maple Ridge

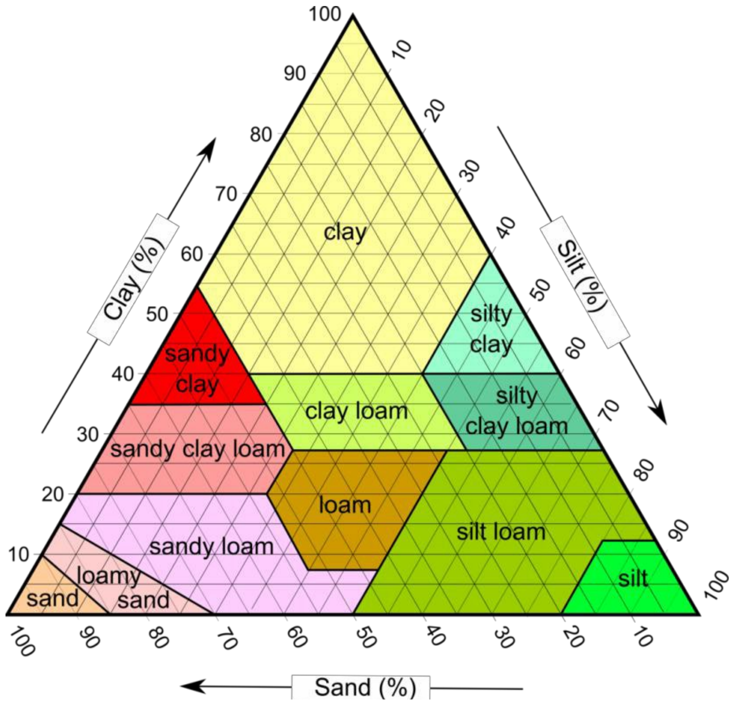

Figure 15. Soil Texture

(https://images.app.goo.gl/dJZigJqPhU72YWpR8)

2. Compare the Water demand change due to land use change

There has been a large increase in production in BC from 2013 due to the higher profit of blueberry production. Most of the blueberry fields are transformed from raspberry, forage or cornfields.

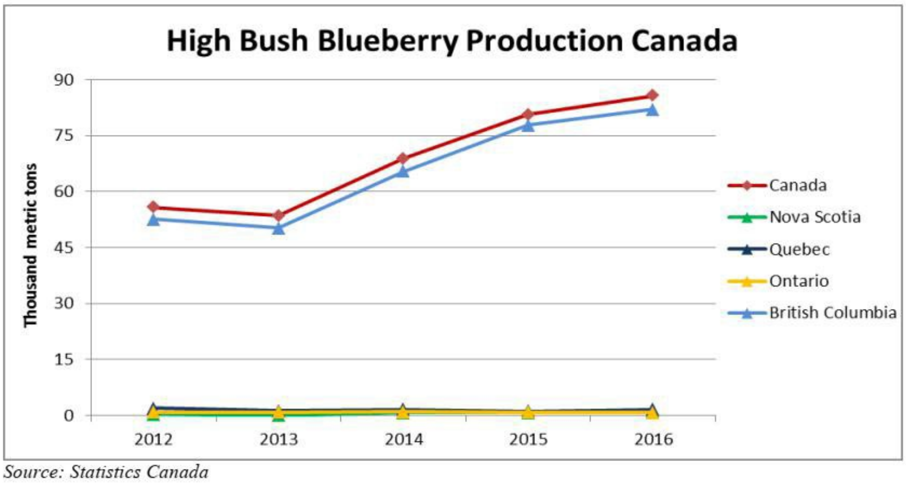

Figure 16. High bush blueberry production in Canada[10]

2.1 Water demand change from Raspberries to blueberries on a hectare basis

Starting from the 1990s, large areas of raspberry fields were transformed into blueberry fields. So we compared the water demand to see how water demand changes due to this land use change in Abbotsford.

Table 9. Water demand(m^3/hectare) change from Raspberries to blueberries

	Sprinkler (m^3/hectare)	Drip (m^3/hectare)
Raspberries	1906	1492
Blueberries	2667	2086
Water demand change (Raspberries to blueberries)	761↑	594↑
	39.9%↑	39.8%↑

Based on the results (Table 9), if raspberry fields are transformed into blueberry fields, the water demand will increase by nearly 40% per hectare. Because both raspberry and blueberry fields are using a drip irrigation system, a 39.8% increase in water demand is likely to increase water stress and bring a big difference to water balance in such areas.

2.2 Water demand change from Forage to blueberries on a hectare basis

Based on the result (Table 10), 23-30% less irrigation water will be used if land use changes from forage to blueberries. However, because drip irrigation is mostly used in crops planted in rows, so it's not commonly used in forage fields. However, most of the BC blueberry fields has switched to drip from sprinkler, we also compared forage by sprinkler to blueberry by drip, around 40% less water will be used.

	Sprinkler (m^3/hectare)	Drip (m^3/hectare)	
Forage	3463	2710	3463 (Sprinkler)
Blueberries	2667	2086	2086 (Drip)
Water demand change (Forage to blueberries)	796↓	624↓	1377↓
	30.0%↓	23.0%↓	39.8%↓

Table 10. Water demand (m^3/hectare) change from Forage to blueberries

2.3 Water demand change from Corn to blueberries on a hectare basis

Based on the result (Table 11), 7% more irrigation water will be used if land use change from corn to blueberries.

Table 11. Water demand (m^3/hectare) change from Corn to blueberries

	Sprinkler (m^3/hectare)	Drip (m^3/hectare)
Corn	1906	1492
Blueberries	2667	2086
Water demand change (Corn to blueberries)	173↑	133↑
	6.9%↑	6.8%↑

3. Compare the blueberry water demand of different irrigation systems on a hectare basis.

The majority of Canadian high bush (cultivated) blueberry production is concentrated in BC, which exports more than 95 percent of Canadian fresh cultivated blueberries. According to Statistics Canada, the total area of high bush blueberry planted in 2016 was 10,523 hectares[10].

Table 12. Total annual water demand (m^3) of Sprinkler and Drip

	Sprinkler	Drip
Blueberries	2667 (m^3/hectare)	2086 (m^3/hectare)
10,523 hectares Blueberries	28064841 (m^3)	21950978 (m^3)

For blueberry production, drip irrigation is also more efficient than a sprinkler and only uses 78.2% of the water used in the sprinkler system. If all the high bush blueberry areas switch to a drip irrigation system from a sprinkler, 613863 m^3 of water will be saved annually.

To grow more with less water and secure local food security, a more efficient irrigation system like drip is highly recommended to growers and municipal governing bodies to take on the challenges of accelerated climate change and the growing population in the long-term.

Conclusion and Recommendation

1. Forage has the highest irrigation demand, followed by blueberries, corn, and raspberries (forage>blueberries>corn>raspberries). The most significant impact of land use could come from the following two types of transition (Table 12): forage to blueberry and raspberry to blueberry.

Table 12. Land use change impact AWD

Land use change	AWD change (m^3/hectare)	AWD change (percentage)
forage in sprinkler → blueberry in drip	1377↓	39.8%↓
blueberry in drip → raspberry in drip	594↑	39.8%↑

2. From the perspective of saving water, the land use change from forage to blueberry is recommended, since it's difficult to apply drip irrigation technique in forage production. Also, blueberry water demand is lower so 39.8% less water will be saved for the possibility of potential irrigation area expansion and threaten of water scarcity due to climate change.

3. However, even though both raspberry and blueberry production are using drip irrigation nowadays in LFV, but still blueberry use 39.8% more water than raspberry, considering the big transition from raspberry to blueberry production is happening now in large areas of LFV, so not only the farm gate value and local economics is important, but also the long-term water use sustainability is also the key to maintain high productivity in LFV, also adaptation strategies should be initiated due to higher water demand brought by land use change and climate change.

4. Drip irrigation systems use less water in different soils and crops. Therefore, higher efficiency irrigation systems are highly recommended to save water.

Audience

The target audience is municipal policymakers and local growers.

Based on crop type and irrigation methods, irrigation demand is estimated to provide theoretical support for water management policy implementation.

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9. AGRICULTURE WATER DEMAND MODEL Report for Fraser Valley(2015) https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/water/agriculture-water-demand-model/500300-14_agric_water_demand_model_fvrd_report_feb13_2015.pdf

10. High Bush Blueberry Production in Canada (2017)

https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=High%20Bush%20Blueberry%20Production%20in%20Canada_Ottawa_Canada_12-29-2017.pdf

Appendix

Agriculture Water Demand Report

Generated by: www.bcagriculturewatercalculator.ca (v2.0.2)

Date: Aug. 23, 2020

Property

Property ID (PID): 1 unknown

Total Area: 190 hectares

Irrigation

Irrigated Area: 190 hectares

Crop: Forage

Soil: Silty Loam

Irrigation Type: Sprinkler

Climate ID: 25562102

Peak Evapotranspiration (ET): 5.6 mm/day

Peak Flow Rate: 170 l/s

Irrigation season: Apr 13 - Oct 1 (172 days)

Irrigation water demand by month:

January	-
February	-
March	-
April	3,040 m3
May	32,830 m3
June	134,400 m3
July	250,350 m3
August	205,110 m3
September	60,980 m3
October	2,150 m3
November	-
December	-

Annual irrigation water demand: 688,860 m3

Livestock

No Livestock

Total annual water demand: 688,860 m3

Agriculture Water Demand Report

Generated by: www.bcagriculturewatercalculator.ca (v2.0.2)

Date: Aug. 23, 2020

Property

Property ID (PID): 1 unknown

Total Area: 210 hectares

Irrigation

Irrigated Area: 210 hectares

Crop: Forage

Soil: Silty Loam

Irrigation Type: Sprinkler

Climate ID: 25492007

Peak Evapotranspiration (ET): 5.3 mm/day

Peak Flow Rate: 170 l/s

Irrigation season: Apr 17 - Oct 1 (168 days)

Irrigation water demand by month:

January	-
February	-
March	-
April	2,520 m3
May	36,090 m3
June	153,420 m3
July	273,910 m3
August	209,940 m3
September	59,920 m3
October	1,720 m3
November	-
December	-

Annual irrigation water demand: 737,520 m3

Livestock

No Livestock

Total annual water demand: 737,520 m3

Agriculture Water Demand Report

Generated by: www.bcagriculturewatercalculator.ca (v2.0.2)

Date: Aug. 23, 2020

Property

Property ID (PID): 1 unknown

Total Area: 220 hectares

Irrigation

Irrigated Area: 220 hectares

Crop: Forage

Soil: Silty Clay Loam

Irrigation Type: Sprinkler

Climate ID: 25761990

Peak Evapotranspiration (ET): 4.9 mm/day

Peak Flow Rate: 170 l/s

Irrigation season: Apr 13 - Oct 1 (172 days)

Annual irrigation water demand: 747,410 m3

Livestock

No Livestock

Total annual water demand: 747,410 m3