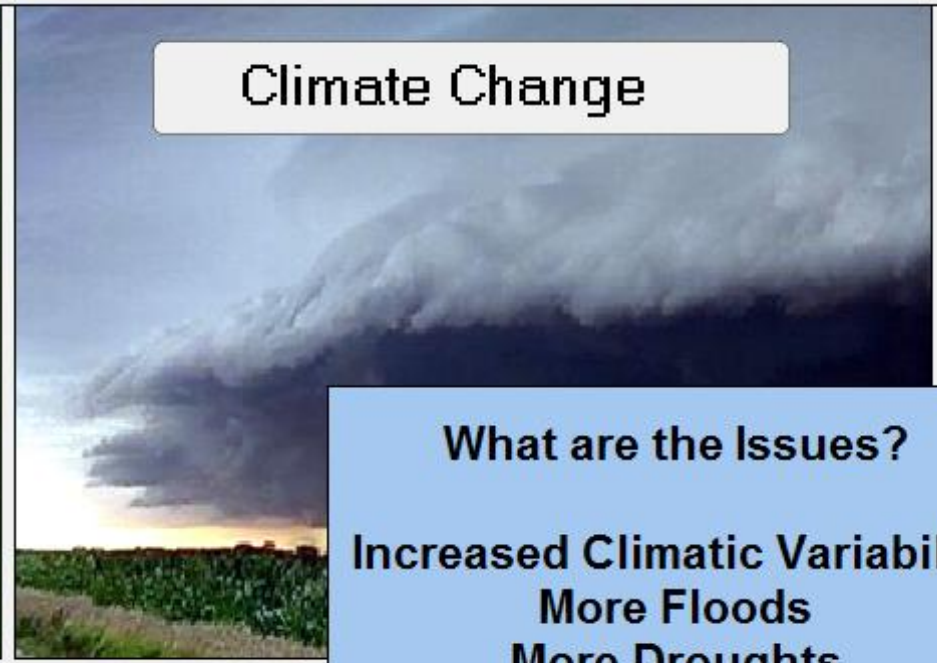
The Combined Effects of Climate & Land Use Change

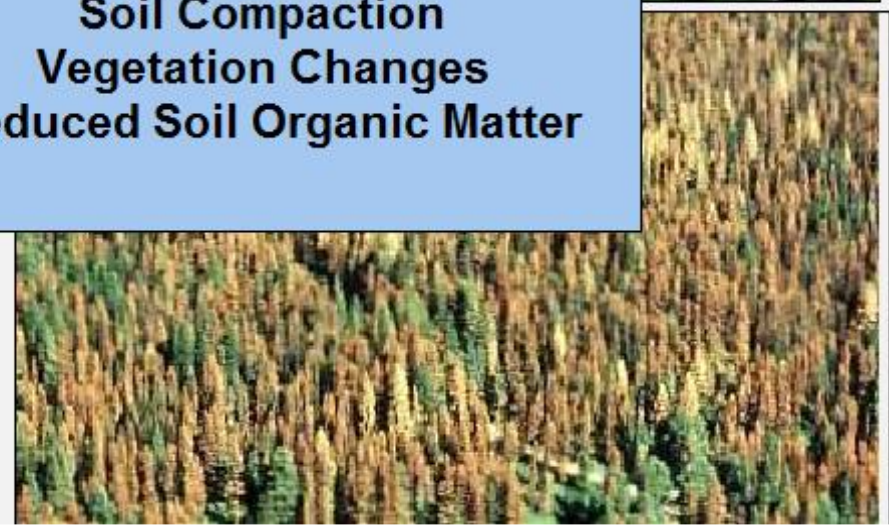


What are the Issues?

Land Use Intensification
Impervious Surfaces
Soil Compaction
Vegetation Changes
Reduced Soil Organic Matter

What are the Issues?

Increased Climatic Variability
More Floods
More Droughts
More Wildfires
Water Supply Problems



Adaptation
Combined Effect of Climate & Land Use Change

Agriculture | Forestry | Urban | Mining | Recreation

Integration

Adaptation
Combined Effect of Climate & Land Use Change

Agriculture | Forestry | Urban | Mining | Recreation

Crops	Heat Tolerant Species Crop Rotation Agro-Bio-Diversity Crop Water Requirement
Irrigation	Sprinklers Drip Cover Channels Night Irrigation
Drainage	Improve Soil Structure Tile Drain Plants with High ET
Grasses	Drought Resistance Diversity of Grasses Rotational Grazing
Livestock	Heat Tolerant Animals Provide Shade & Shelter

Adaptation
Combined Effect of Climate & Land Use Change

Agriculture | Forestry | Urban | Mining | Recreation

Trees	Heat Tolerant Species Species Diversity Crop Water Requirement Minimize Mono-Culture
Fire	Fuel Load Reduction Fire Resistant Species Fire Breaks
Management	Tree Spacing > Snow Road Maintenance Reduce Even Age Conserve Forest < CO_2

Adaptation
Combined Effect of Climate & Land Use Change

Agriculture | Forestry | **Urban** | Mining | Recreation

Heat Islands	Green Belts (Trees) Water Conservation Water Pricing (Block Rate) Public Education
Precipitation	> Infiltration, Swales Minimize Imperviousness Water Detention, Wetlands Water Storage
Wastewater	Improved Treatment Nutrient Recycling
Water Use	Efficient Use (Saving Dev) Water Harvesting Leak Reduction Smart Meters

Adaptation
Combined Effect of Climate & Land Use Change

Agriculture | Forestry | Urban | Mining | Recreation

AMD	Minimize Oxidation Soil Cover Lime Treatment Wetlands, Reduction
Sediments	Sedimentation Ponds Plant Cover (Rehab)
Chemicals	Collection & Treatment Minimize it Use

Adaptation
Combined Effect of Climate & Land Use Change

Agriculture | Forestry | Urban | Mining | Recreation

Winter

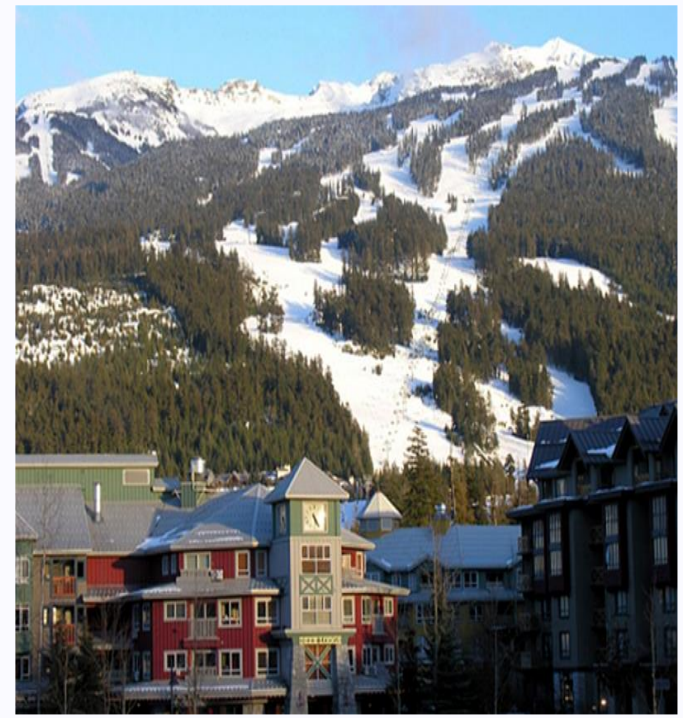
- Snow Making (Short Term)
- Snow Farming
- Move in Elevation
- Micro-Climate (Aspect)

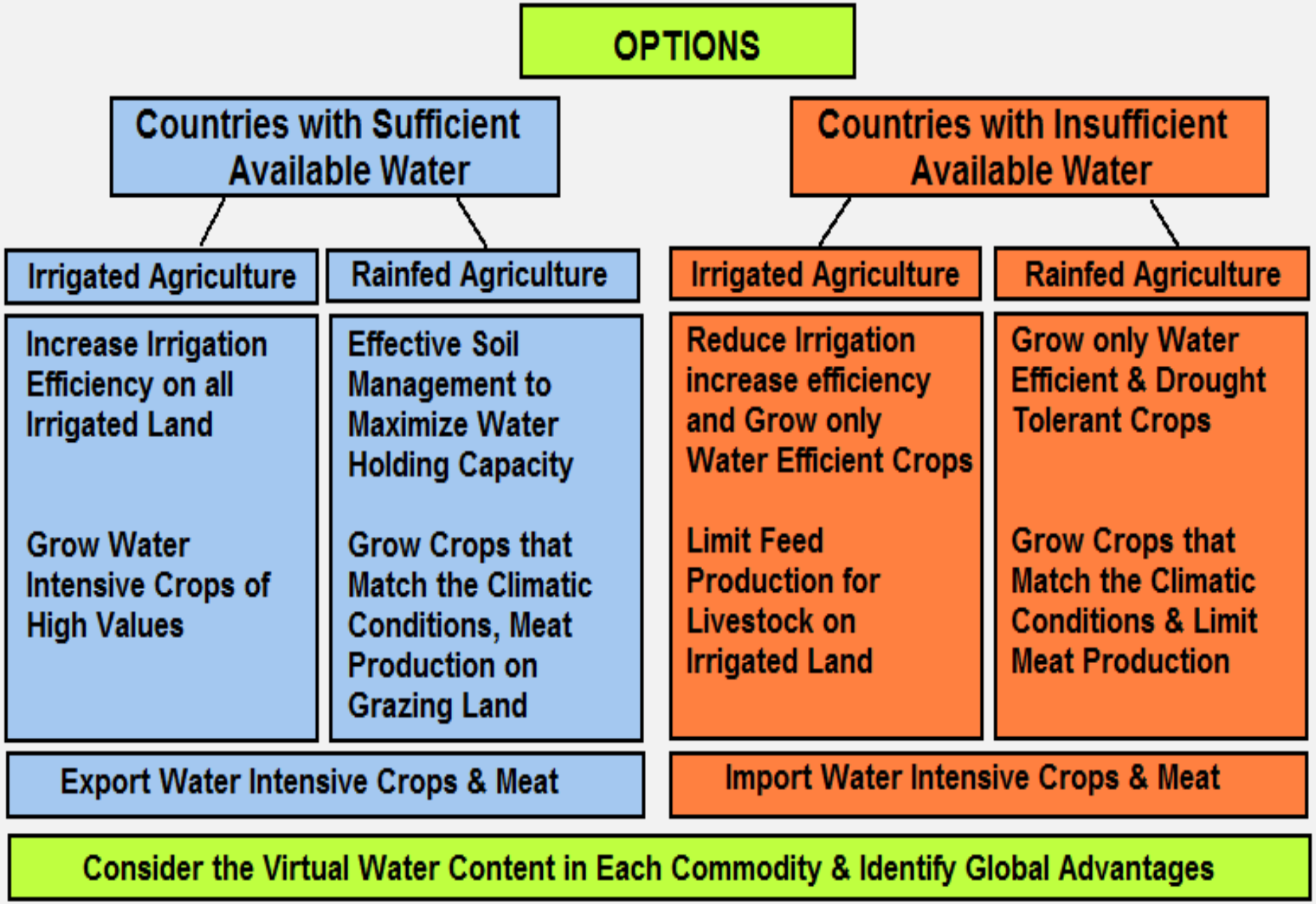
Summer

- Water Conservation
- Source Protection
- GW-SW Interactions
- Fire Protection

Hazards

- Permafrost Risk ID
- Avalance Avoidance
- Flood Protection
- Landslide ID




OPTIONS
Countries with Sufficient Available Water
Countries with Insufficient Available Water
Irrigated Agriculture
Rainfed Agriculture
Irrigated Agriculture
Rainfed Agriculture
Increase Irrigation Efficiency on all Irrigated Land
Grow Water Intensive Crops of High Values
Effective Soil Management to Maximize Water Holding Capacity
Grow Crops that Match the Climatic Conditions, Meat Production on Grazing Land
Reduce Irrigation increase efficiency and Grow only Water Efficient Crops
Limit Feed Production for Livestock on Irrigated Land
Grow only Water Efficient & Drought Tolerant Crops
Grow Crops that Match the Climatic Conditions & Limit Meat Production
Export Water Intensive Crops & Meat
Import Water Intensive Crops & Meat
Consider the Virtual Water Content in Each Commodity & Identify Global Advantages

Agricultural Option in Mountains (CROPS)

Climatic Advantages:

Longer Growing Season
Less Frost
Higher Temperatures
Improved Moisture

Growing Options & Constraints

Select Crops of High Value
Low Input Requirements
Adopted to Poor Soil Conditions
Climate Tolerant Species

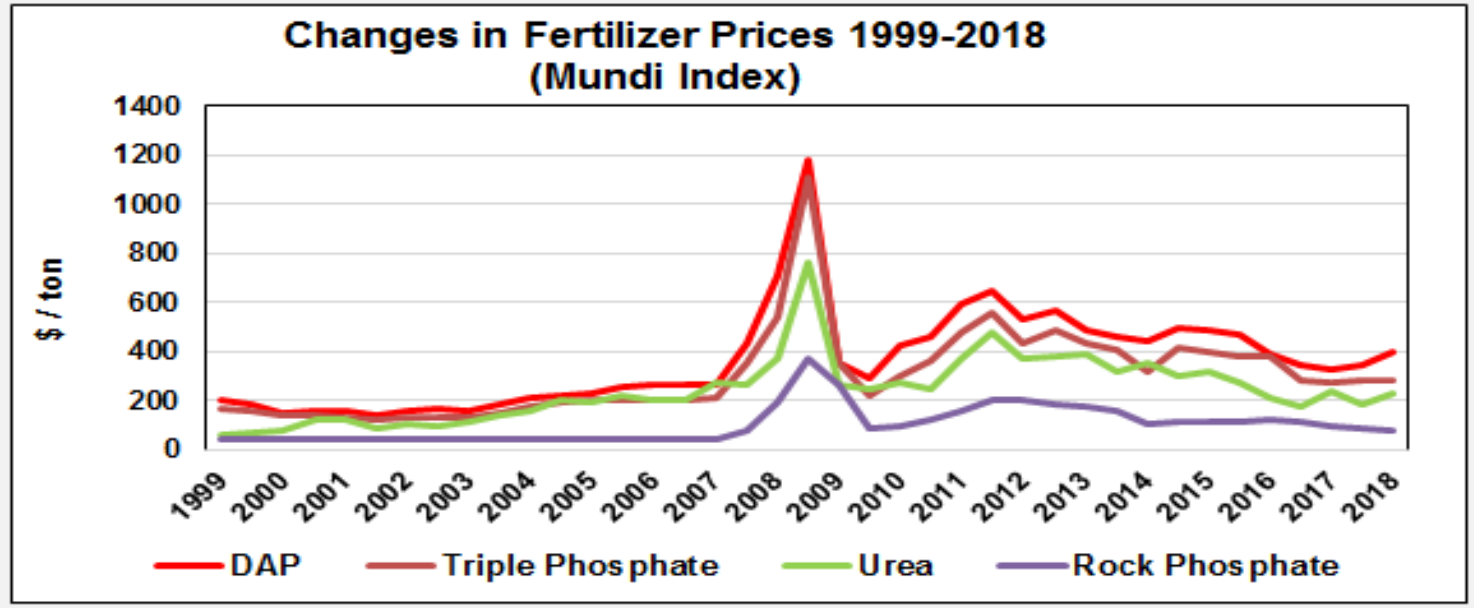
Examples of Appropriate Crops

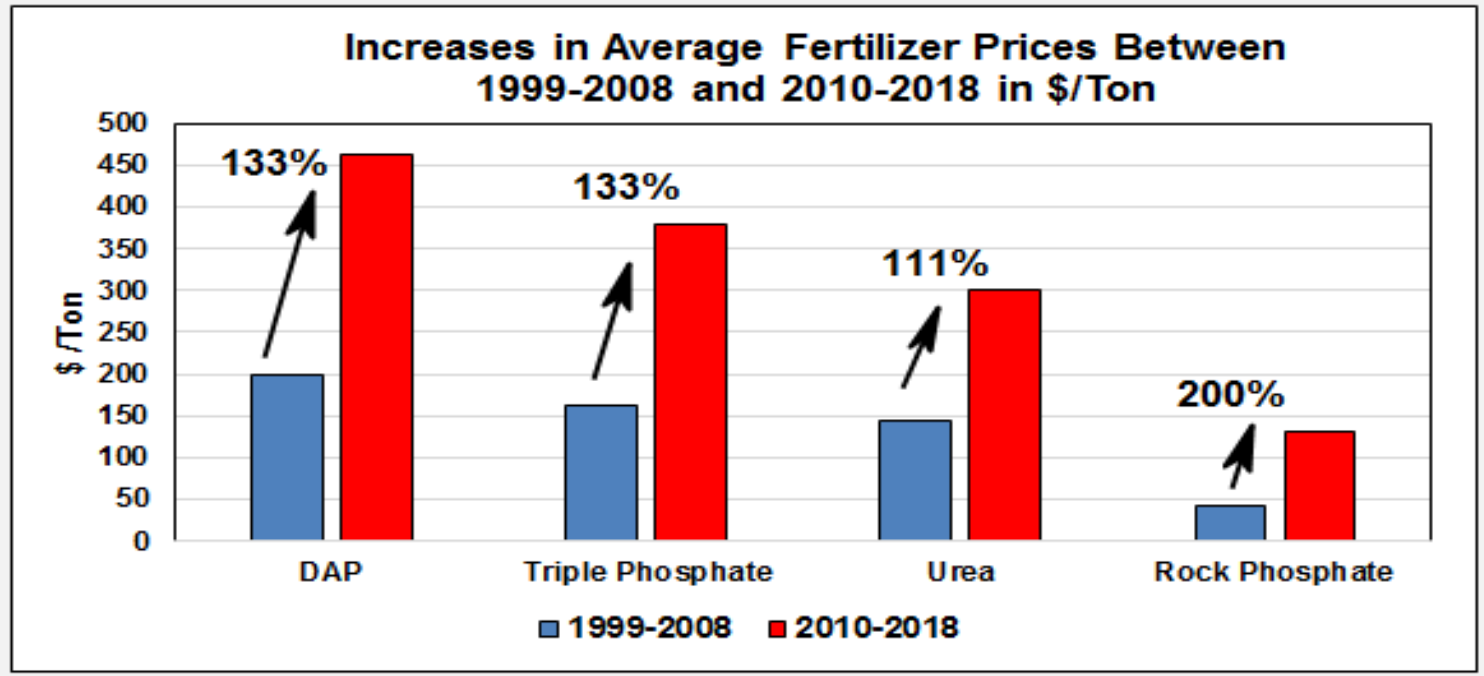
Quinoa
Grapes
Hops
Apples
Lavender (Oil)

Factors to Consider

Tardive Frost
Chill Hours
Insect Pests
Extreme Heat
Late Summer Moisture Stress

Changes in Fertilizer Prices $/Ton 1999-2018





Agricultural Option in Mountains (Livestock Grazing)

Climatic Advantages:

Longer Growing Season
Less Frost
Higher Temperatures
Improved Moisture

Constraints

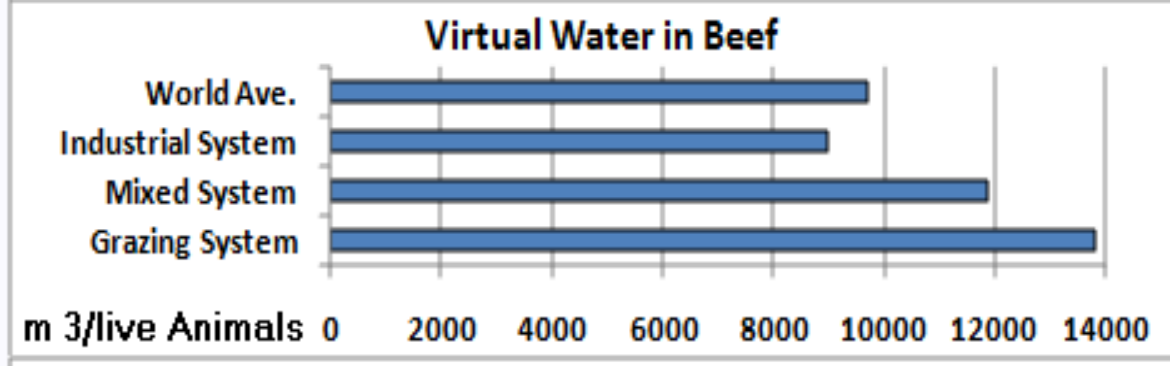
Sensitive to Hear (Some Cattle)
Lactation is Impacted by Heat
Feed & Water Shortages (Late Summer)
More Wildfire

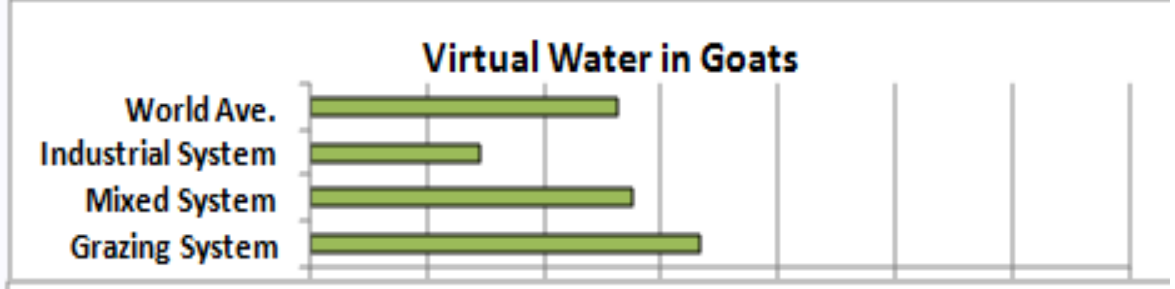
Adaptation Options

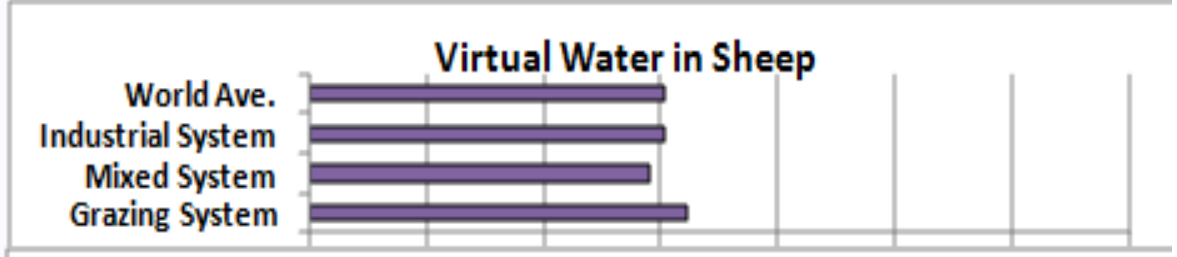
Dynamic Grazing
Provide Shading Structures
Change timing of Grazing & Mowing
Upgrade Water Systems
Lower Herd Size

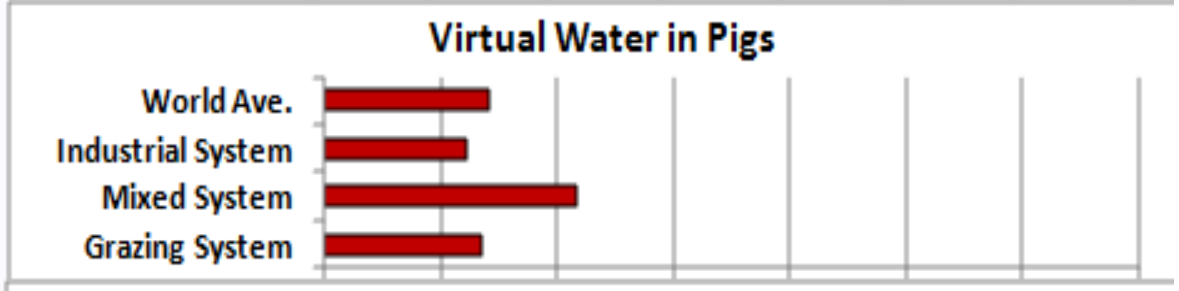
Average Global Virtual Water Content in Live Animals in Different Production Systems
(m3 / Live Animals)

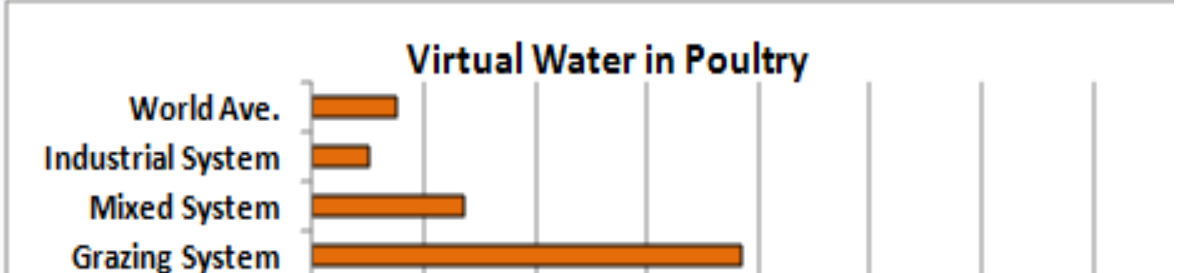
Industrial Systems
Mixed Systems
Grazing Systems











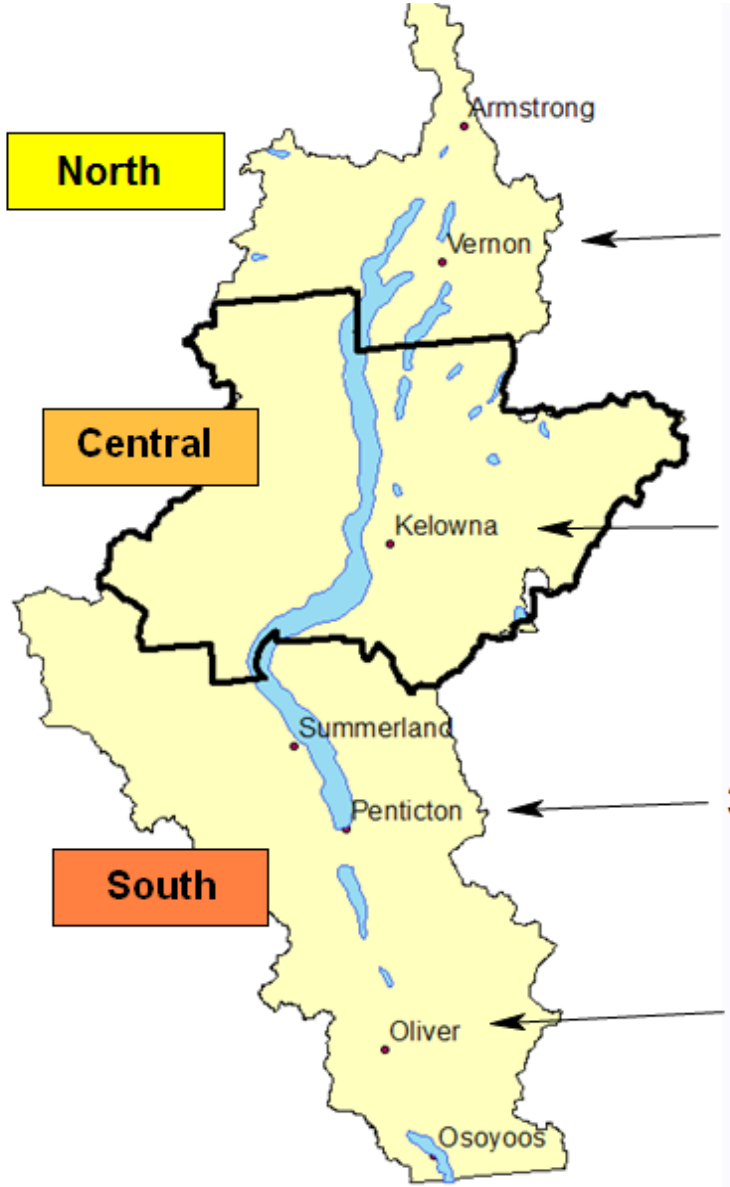
The Okanagan Basin; The Driest Watershed in Canada

Water Requirement for Different Crops in the Okanagan

70% of of all Water is Used for Agricultural Productiuon

The Okanagan Watershed Project

The Driest Watershed in Canada



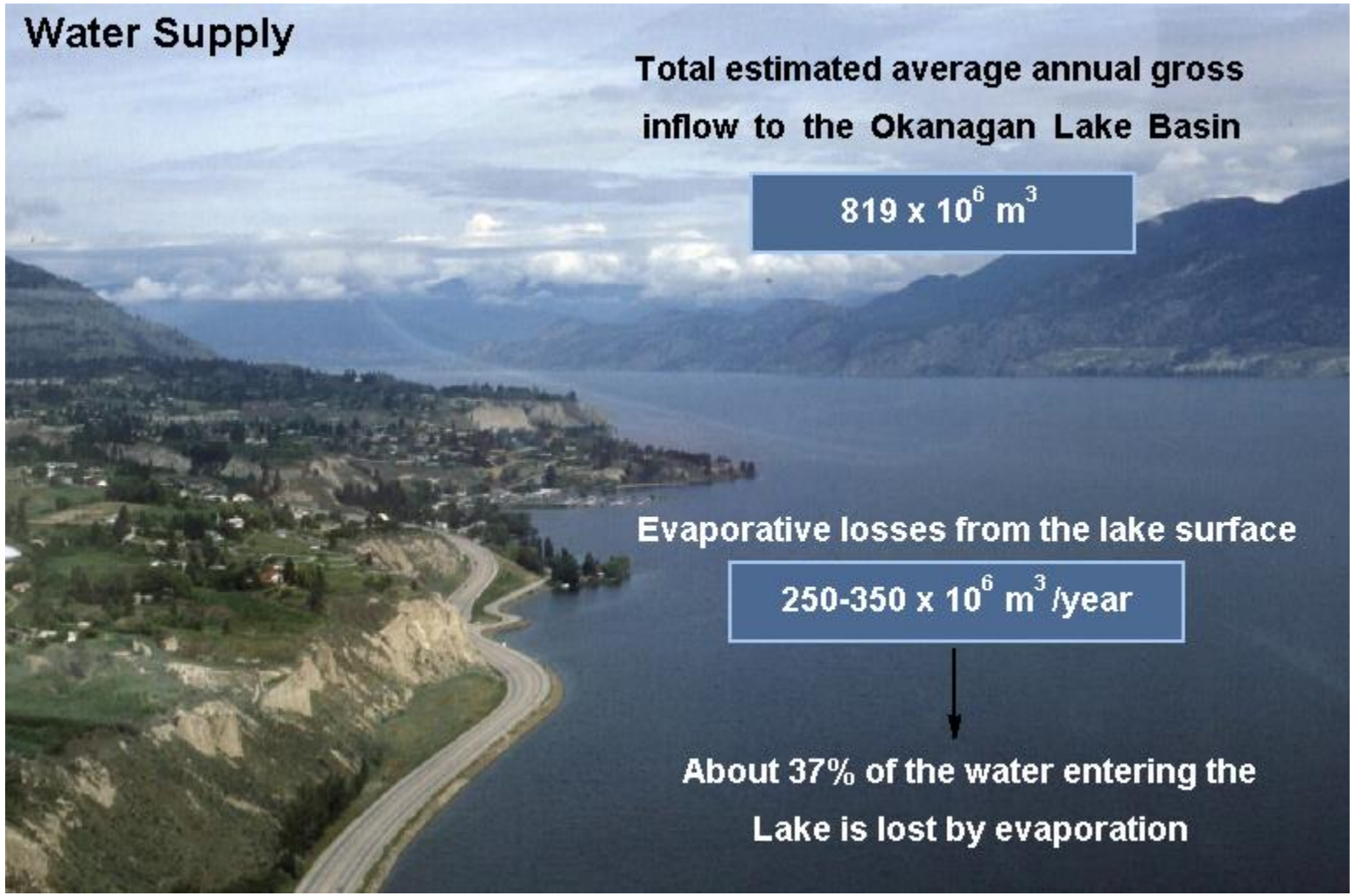
Precipitation Gradient

410 mm/Year

380 mm/Year

333 mm/Year

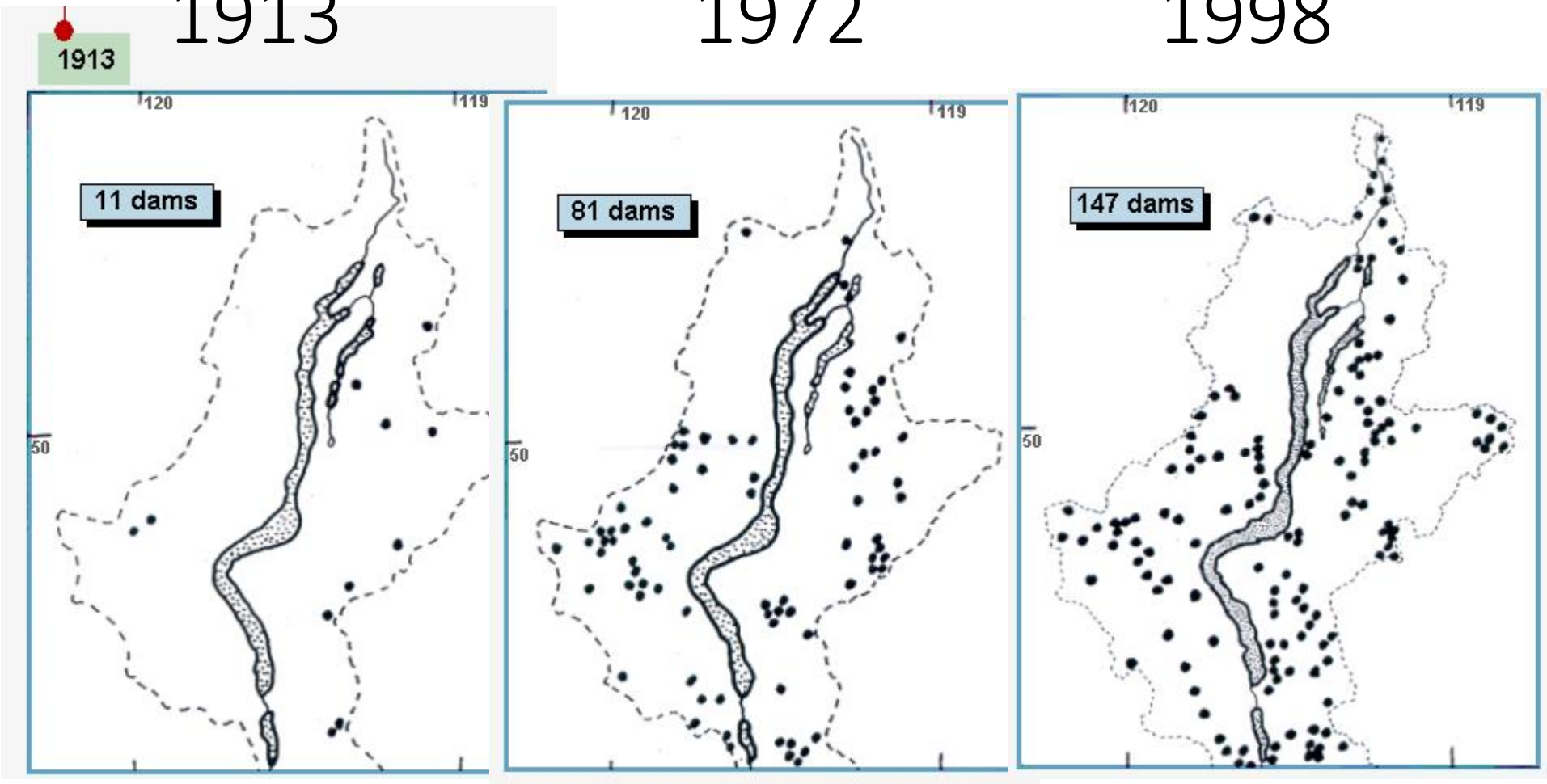
318 mm/Year


Water Supply
Total estimated average annual gross inflow to the Okanagan Lake Basin
819 x 10^6 m^3
Evaporative losses from the lake surface
250-350 x 10^6 m^3 /year
About 37% of the water entering the Lake is lost by evaporation

Development Changes in the Okanagan Watershed 1970-2016

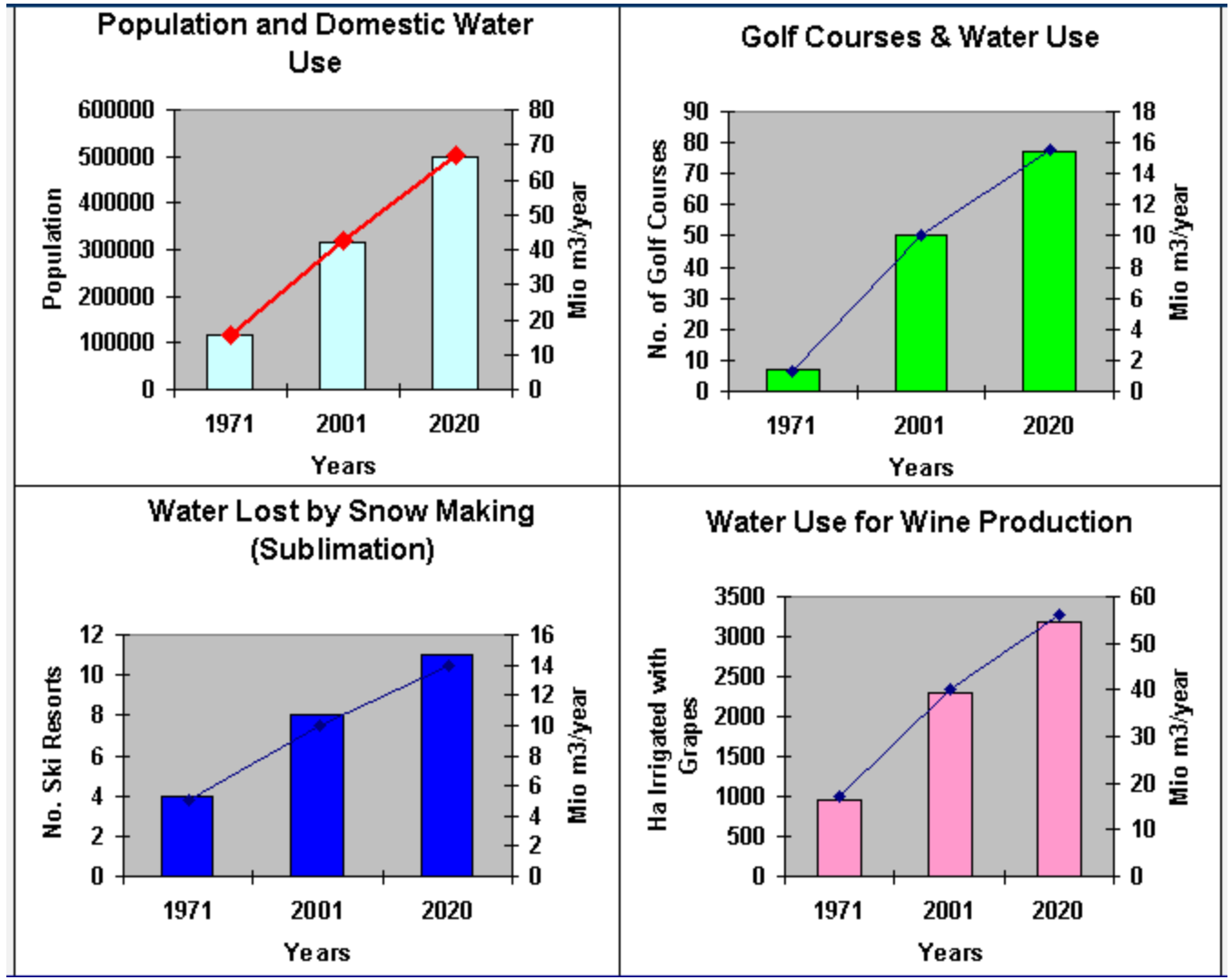
Growth Indicators	1971	2001	2016
Population	115000	317000	350000
Water Storage Systems	12	147	154
Agricultural Area (ha)	198000	173500	140000
Grape Area (ha)	955	2286	2486
Wineries	12	82	179

1913



1972

1998


Population and Domestic Water Use
Population
Mio m3/year
600000
500000
400000
300000
200000
100000
0
80
70
60
50
40
30
20
10
0
1971
2001
2020
Years
Golf Courses & Water Use
No. of Golf Courses
Mio m3/year
90
80
70
60
50
40
30
20
10
0
18
16
14
12
10
8
6
4
2
0
1971
2001
2020
Years
Water Lost by Snow Making (Sublimation)
No. Ski Resorts
Mio m3/year
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
1971
2001
2020
Years
Water Use for Wine Production
Ha Irrigated with Grapes
Mio m3/year
3500
3000
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
1971
2001
2020
Years

Water Consumption

	No. of Water Connections	Consumption Connection	Total Annual Consumption
North	30581	723 m3 Year	22.1 Mil. m3 Year
Central	58322	1281 m3 Year	71.2 Mil. m3 Year
South	22780	2201 m3 Year	50.1Mil. m3 Year

	Agricultural Consumption	Residential Consumption	Other Consumption
North	46 %	36 %	19 %
Central	48 %	34 %	17 %
South	69 %	29 %	2 %

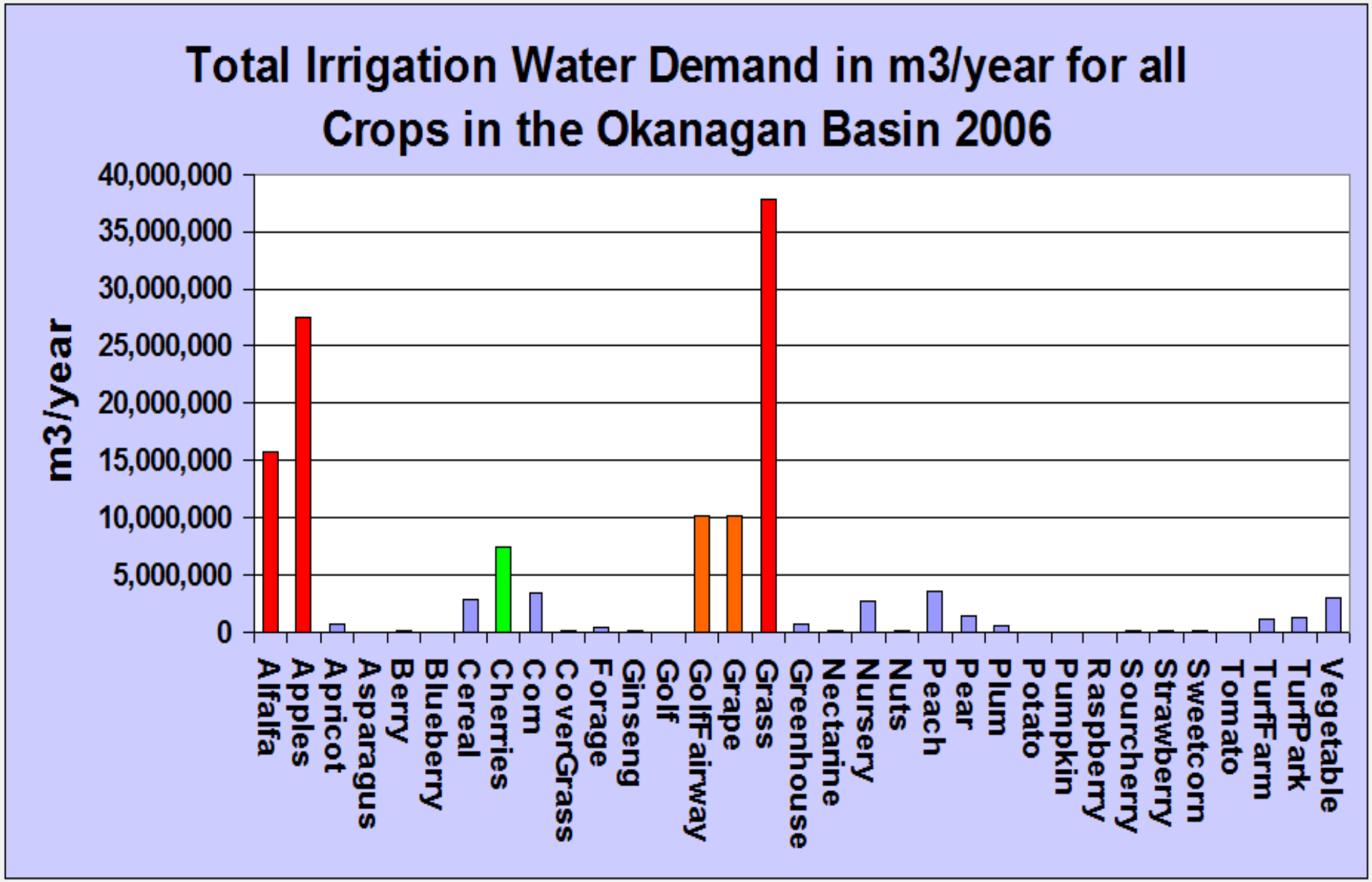
	Agricultural Receipts 2011	Agricultural Receipts 2016
North	$ 111 Million	$ 126 Million
Central	$ 81 Million	$ 96 Million
South	$ 95 Million	$ 104 Million

	GHG Emissions
North	30581
Central	58322
South	22780

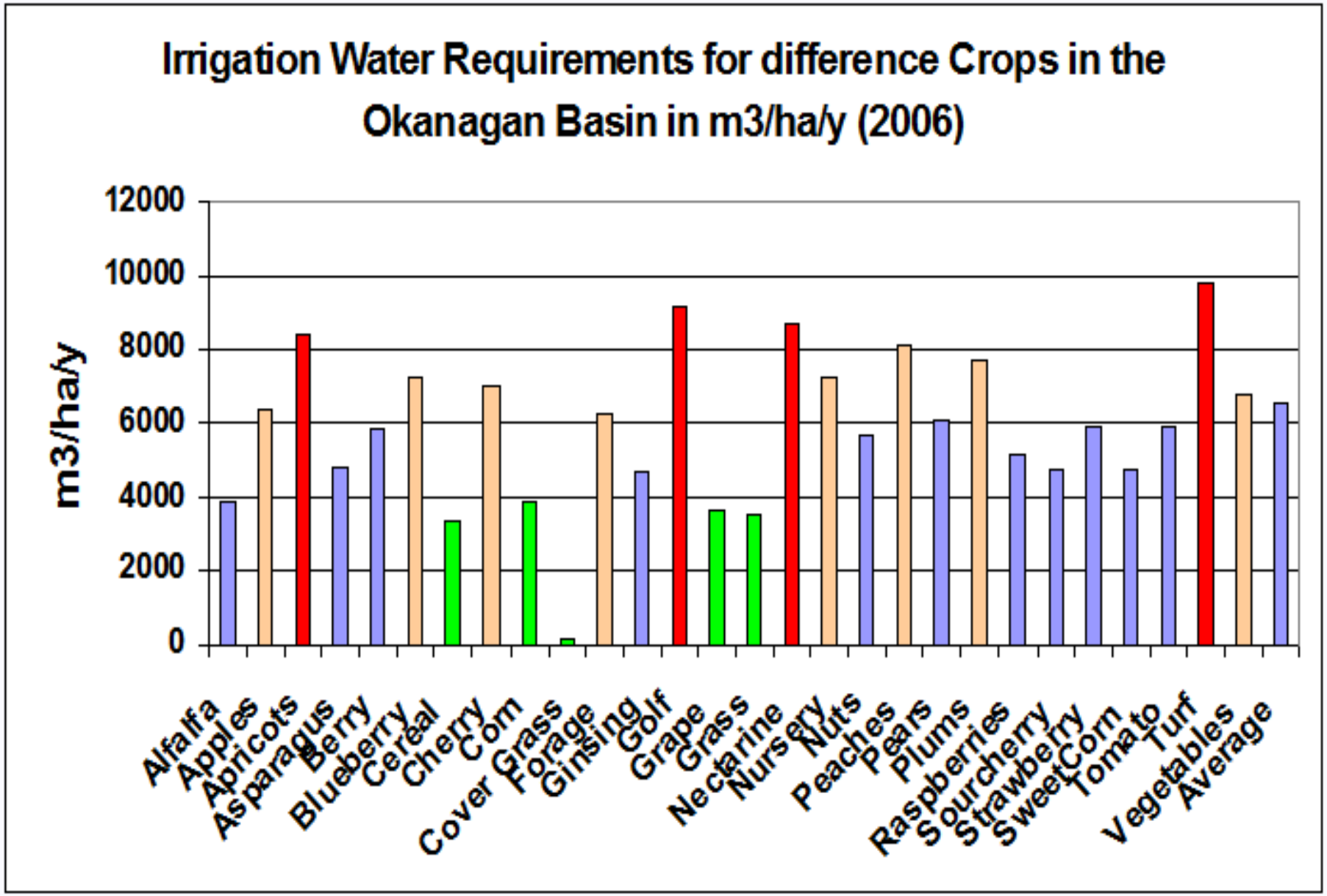
Water Balance for the Okanagan Watershed

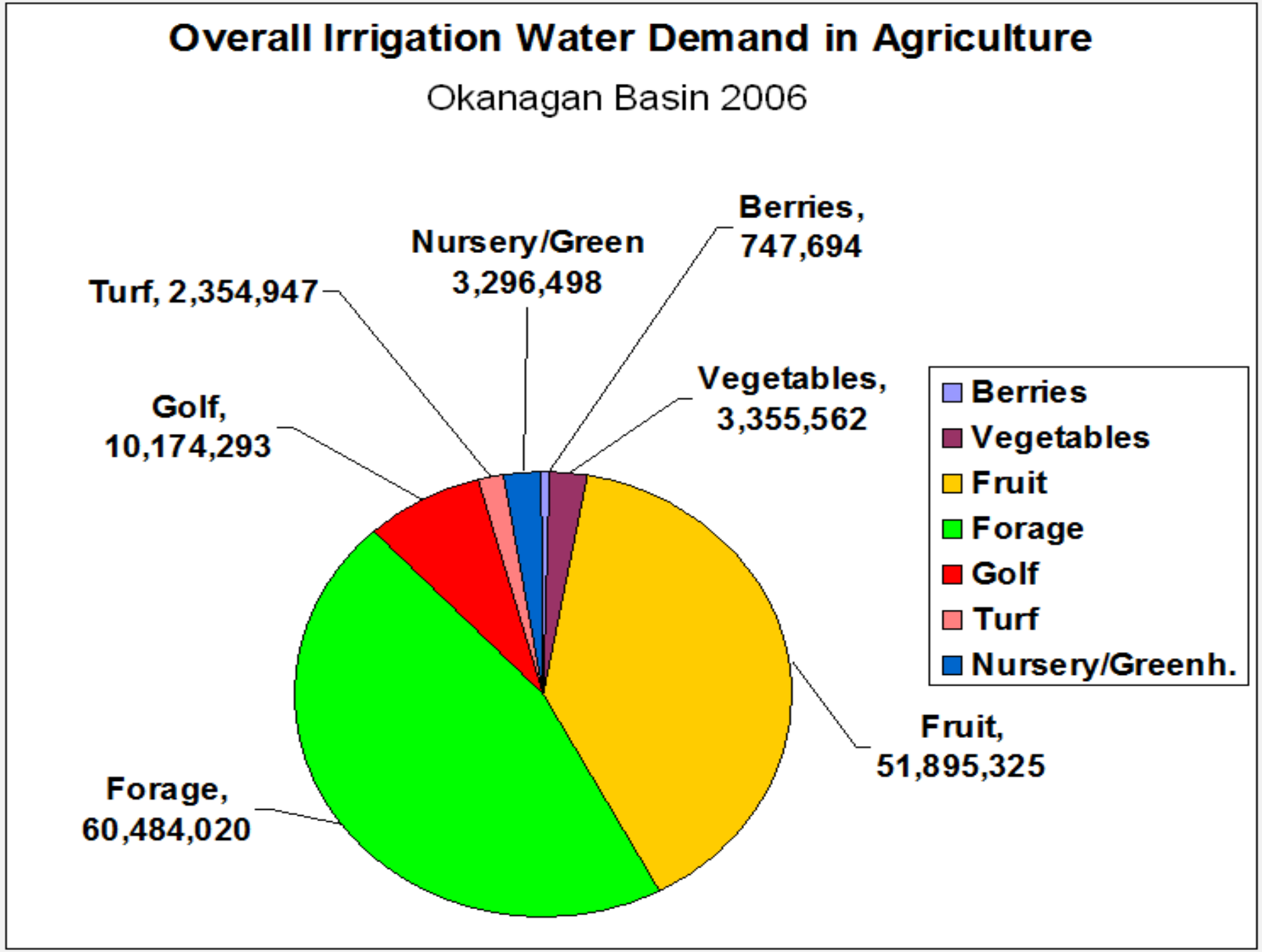
	Million m3/Year	% of Total Water Use			% of Residential Water Use
Agricultural	50.9	47.7		Indoor	53%
Residential	68.5	35.5		Outdoor	47%
Industrial/Others	14.1	9.8			
Unaccounted	10	7.0			

Total Irrigation Water Demand for all Agricultural Products in the Okanagan Basin, 2006



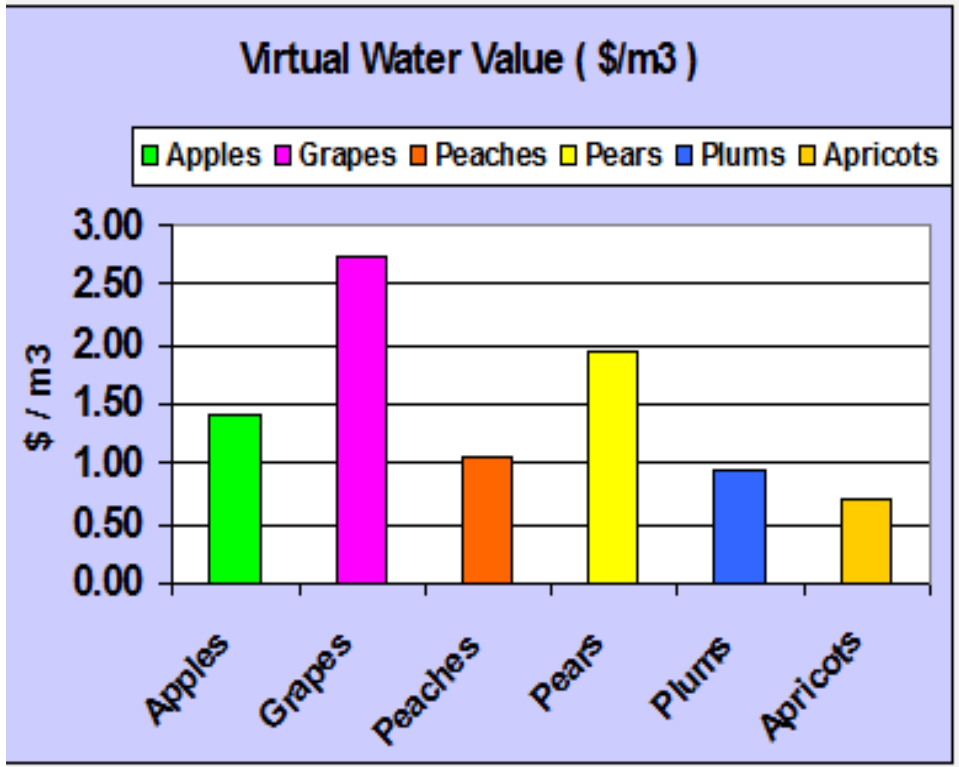
Variation in Irrigation Water Demands for different Crops in m3 / ha / Year

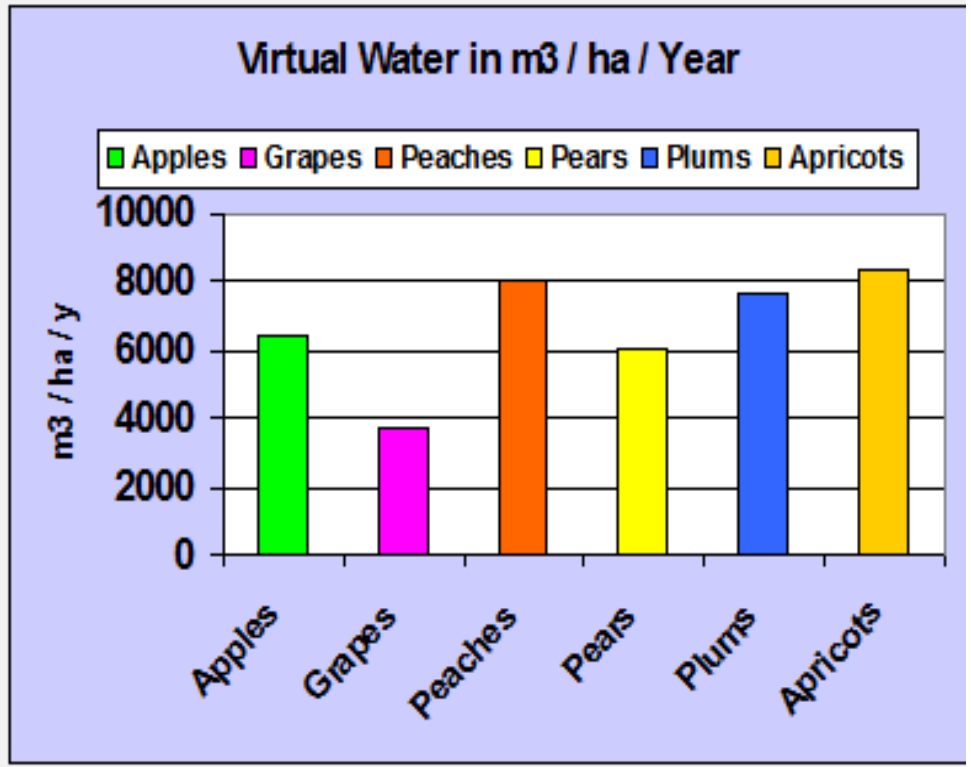


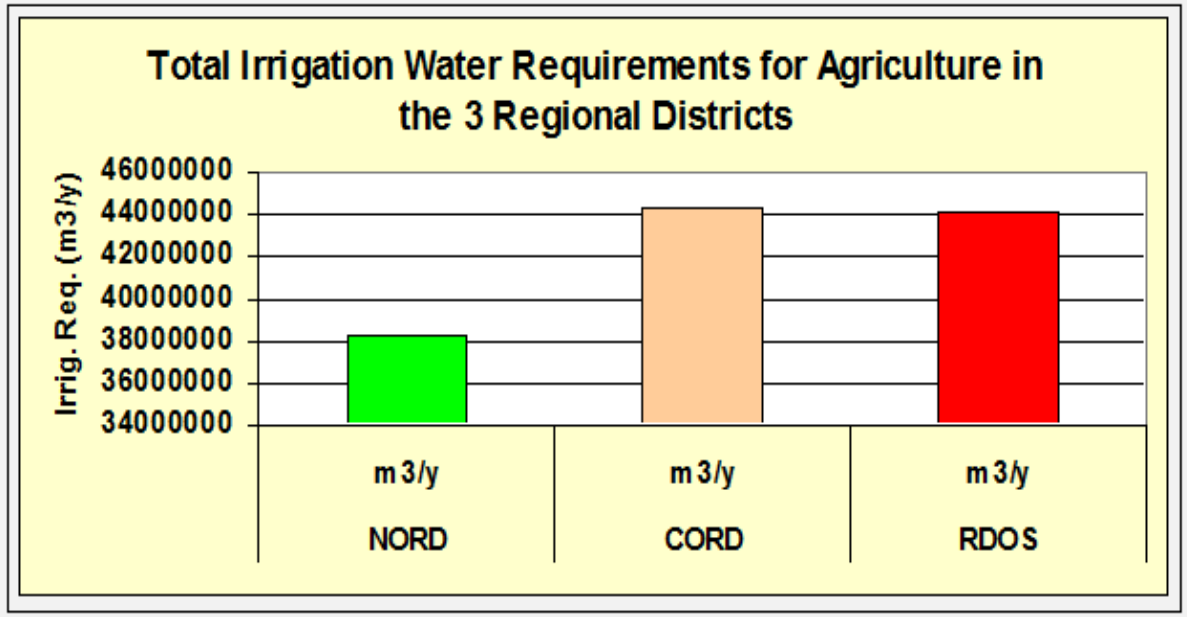

Overall Irrigation Water Demand in Agriculture
Okanagan Basin 2006
Berries, 747,694
Nursery/Green 3,296,498
Turf, 2,354,947
Vegetables, 3,355,562
Golf, 10,174,293
Fruit, 51,895,325
Forage, 60,484,020
Berries
Vegetables
Fruit
Forage
Golf
Turf
Nursery/Greenh.

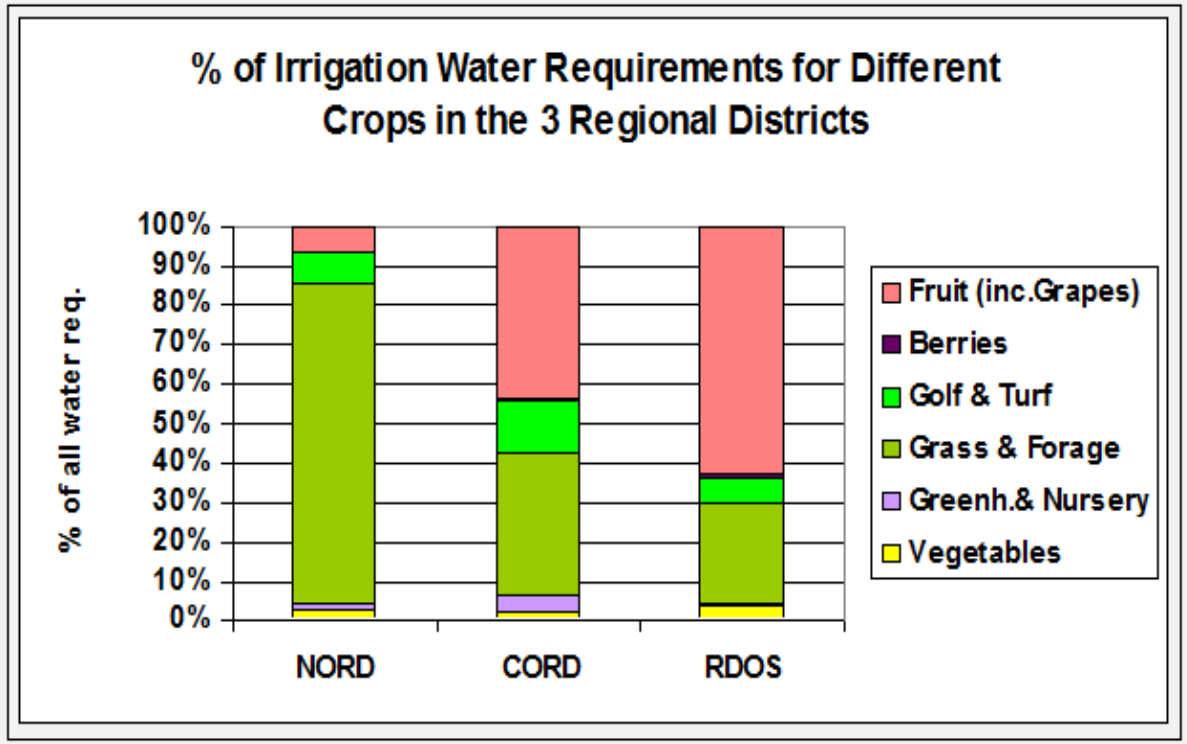
Determining the Value of Virtual Water

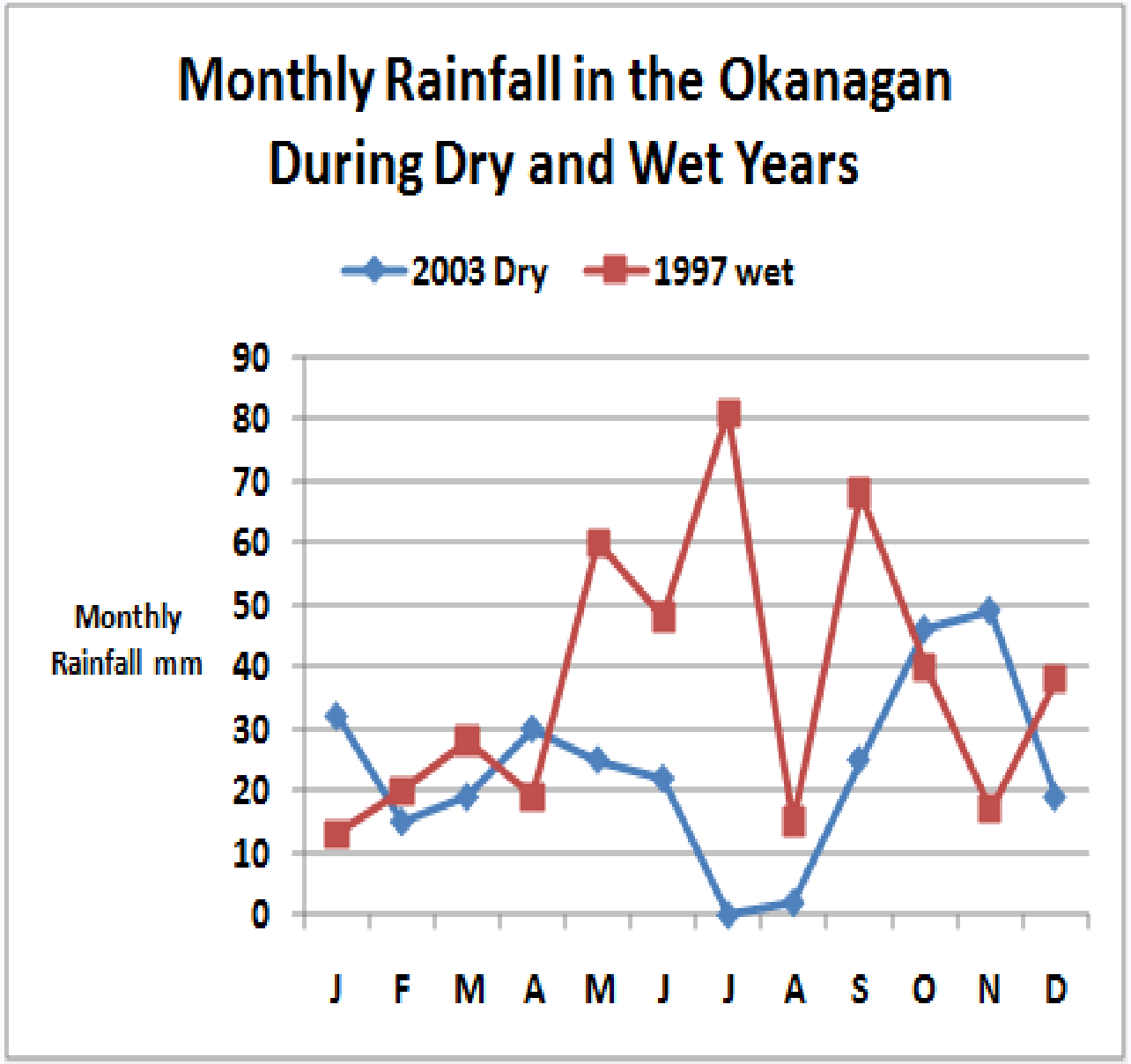
Crop	Area	Yield	Production	Farm Gate	Value	Value	VW	Value VW	VW / ha
	ha	tons/ha	tons	Value Mio $	$ / kg	$ / ha	Mio m3	$/m3	m3/ha/y
Apples	4297	26.3	113,011	38.50	0.34	8960	27.465	1.40	6392
Grapes	2737	6.4	17,517	27.73	1.58	10132	10.116	2.74	3696
Peaches	447	11.3	5,051	3.77	0.75	8434	3.608	1.04	8072
Pears	236	19.3	4,555	2.80	0.61	11864	1.440	1.94	6102
Plums	71	6.6	469	0.52	1.11	7310	0.547	0.95	7704
Apricots	90	7.2	648	0.53	0.81	5856	0.752	0.70	8356






Total Irrigation Water Requirements for Agriculture in the 3 Regional Districts
Irrig. Req. (m3/y)
46000000
44000000
42000000
40000000
38000000
36000000
34000000
m3/y
NORD
m3/y
CORD
m3/y
RDOS


% of Irrigation Water Requirements for Different Crops in the 3 Regional Districts
% of all water req.
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
NORD
CORD
RDOS
Fruit (inc.Grapes)
Berries
Golf & Turf
Grass & Forage
Greenh.& Nursery
Vegetables



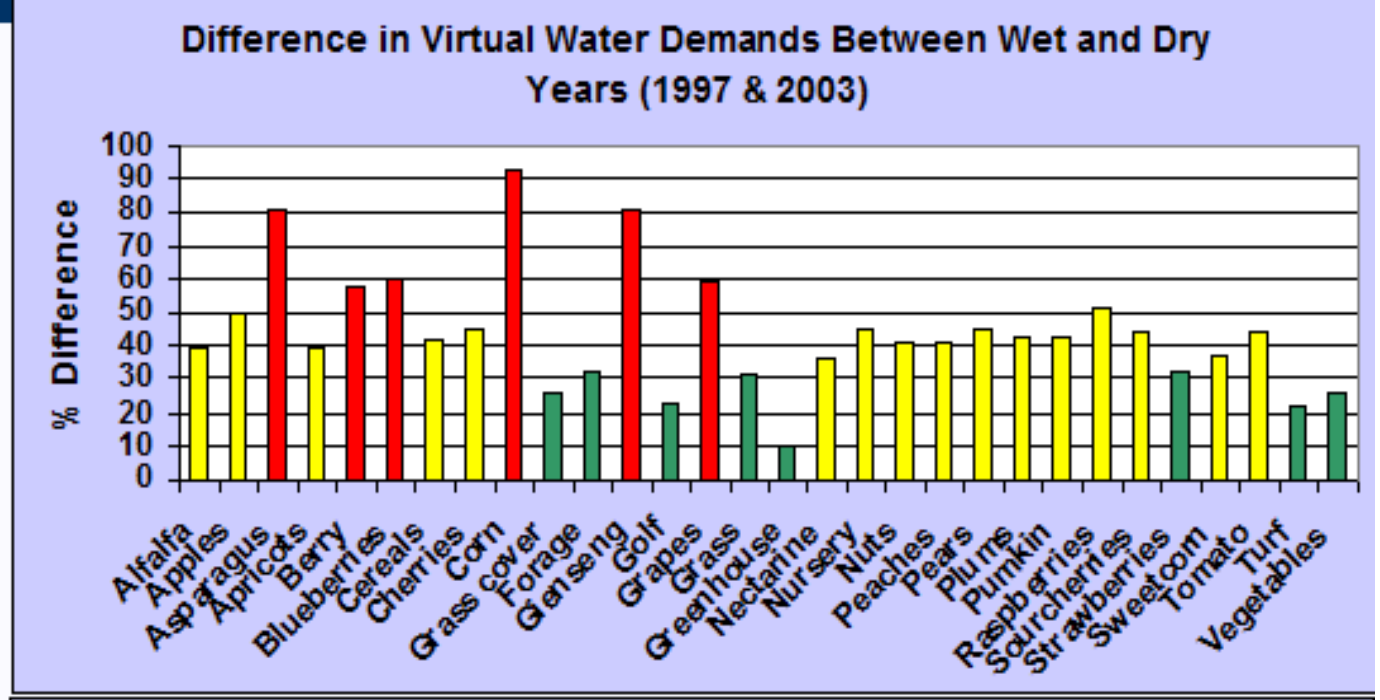
Total Annual Rainfall: Dry Year 2003 = 285 mm
Wet Year 1997 = 447 mm

Difference in Water Demand between Wet and Dry Years

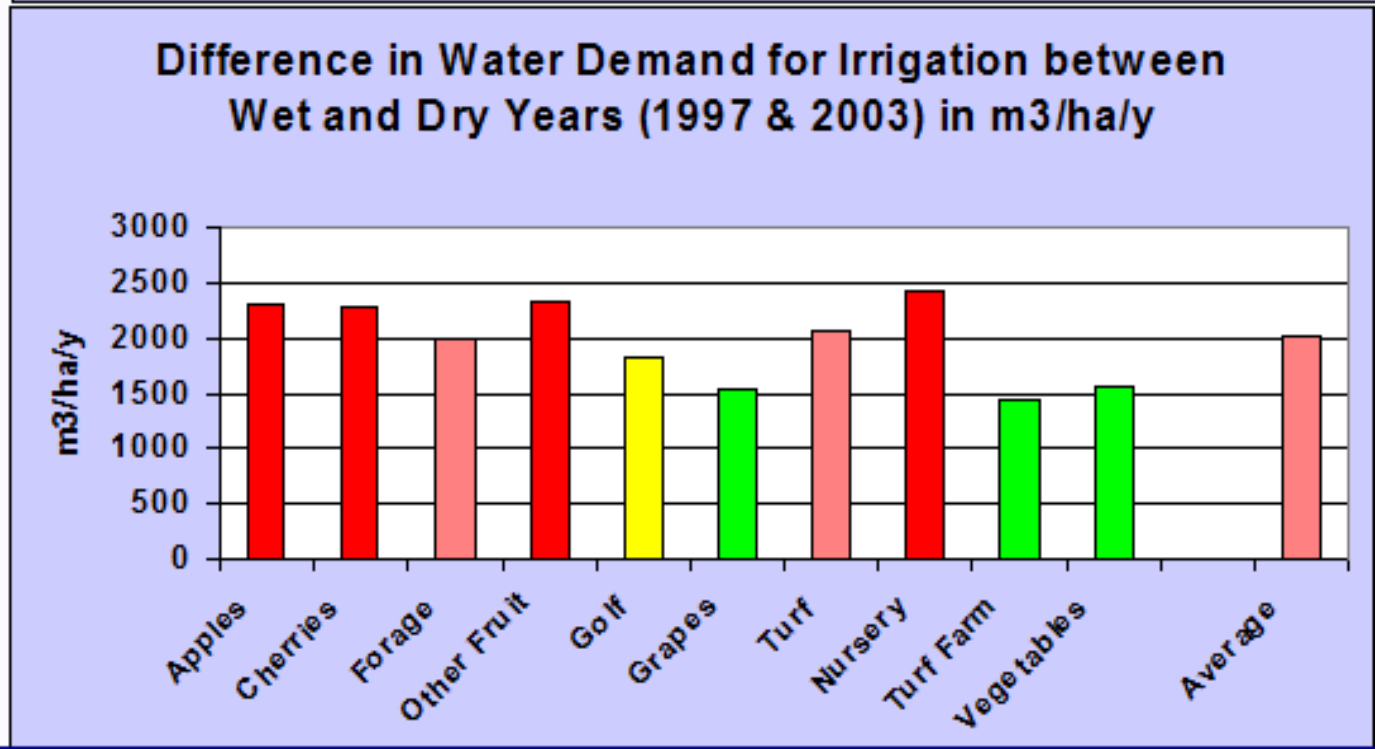
40,073,734 m3/Year
or 33% Variability

Average Yearly Water Demand for Irrigation:

124 Million m3/Year



Fruit, Nurseries & Forage are most sensitive to Wet- Dry Cycles on a per ha basis



Livestock Water Requirements in Million m3/Year

330 Million m3

15 Million m3

83 Million m3

Livestock	Number of Animals				WATER Req.	Water in Million m3/Year Live Anima			
	OK-S	OK-C	OK-N	OK-Total	m3/Live Animal	OK-S	OK-C	OK-N	OK-Total
Calves	15482	2786	22634	40002	2000	31.0	5.6	45.3	**80.0**
Beef Cows	8981	1630	11458	22969	5252	47.2	8.6	60.2	**120.6**
Dairy Cows	102	0	5541	5643	39259	4.0	0.0	217.5	**221.5**
Total Cattle + Calves	24565	4416	39633	68614		82.1	14.1	323.0	**422.2**
Broilers	5649	76964	1E+06	1124135	3	0.0	0.2	3.1	**3.4**
Laying Hens	7091	5982	67168	80241	19	0.1	0.1	1.3	**1.5**
Total Poultry	12740	82946	1E+06	1204376		0.2	0.3	4.4	**4.9**
Pigs	202	204	2736	3142	387	0.1	0.1	1.1	**1.2**
Sheep	1396	813	4478	6687	301	0.4	0.2	1.3	**2.0**
Total Pigs & Sheep	1598	1017	7214	9829		0.5	0.3	2.4	**3.2**
						Total Livestock Water Mio. m3/Year			
						82.8	**14.7**	**329.8**	**420.3**

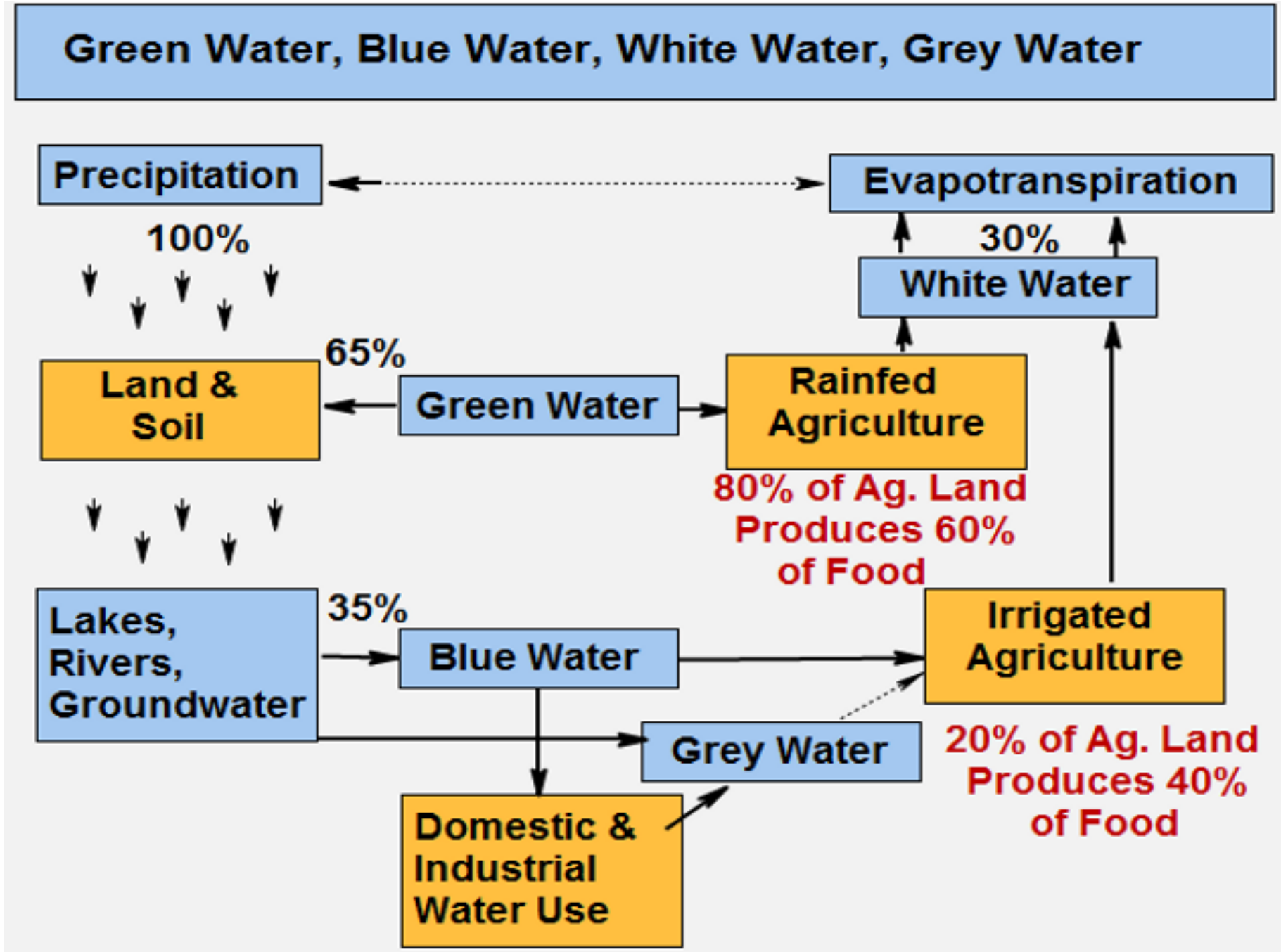
Water Management Constraints & Options for The Okanagan Watershed

Problems

All Water Resources are Fully Allocated
Climate Projections: Hotter and Drier
Snow Dominated System: Earlier Snow Melt, Longer Summer Drought when Demand is High
Limited Options for Inter-Basin Water Transfer

Options

Improve Irrigation Efficiency
Shift from Water Intensive Crops to Water Efficient Crops
Consider Reducing Virtual Water Export (Limit Crops Grown for Export)
Reduce irrigated Agricultural Areas
Minimize Livestock Production in the Basin
Initiate Water Conservation in the Urban Areas
(Water Saving devices, Outdoor Use Restrictions, Rainwater Harvesting etc.)


Green Water, Blue Water, White Water, Grey Water
Precipitation
Evapotranspiration
100%
30%
White Water
65%
Land & Soil
Green Water
Rainfed Agriculture
80% of Ag. Land Produces 60% of Food
Lakes, Rivers, Groundwater
35%
Blue Water
Irrigated Agriculture
Grey Water
20% of Ag. Land Produces 40% of Food
Domestic & Industrial Water Use

Agriculture uses 70% of all Water Globally
20% of the Agricultural Land is irrigated but Produces 40% of all Food


Central pivot.
Photo courtesy USDA


Low Cost Drip System

Types of irrigation

- Sprinkler irrigation
- Drip irrigation
- Sub-surface
- Flood irrigation
- Furrow irrigation
- Border irrigation


Laser controlled
Photo courtesy USDA


Border/Furrow

Precision irrigation :

Increased efficiencies at the field level can be obtained by:

- Reducing the amount of irrigation water lost to evaporation
- reducing the amount of irrigation water lost to runoff
- reducing the amount of water lost to weed transpiration
- reducing the amount of water lost to deep percolation

Underground Cisterns to Store Surface Water Runoff in the Sahara Desert

Underground Cistern in Limestone along the NW-Coast of Egypt. They are designed collect and store rainwater during winter (annual rainfall 250 mm, between November & February) for people and animal use during the dry summer.

Water Harvesting

Surface water runoff collection system with sediment trap. Monsoon rain is stored for drip irrigation during dry season (Nepal)

Roofwater storage system for drinking water use and for low cost drip irrigation during dry season. For cash crop production (Nepal)