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Analysis of Selecting a Sustainable Irrigation System

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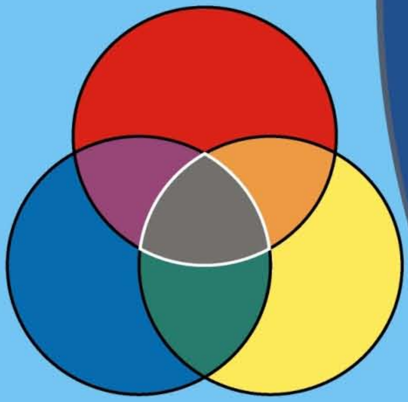
Introduction

Numerical Analysis is my Passion

- as an Engineer
- for Modeling and Design
- for Decision-Making

Sustainability is my Profession

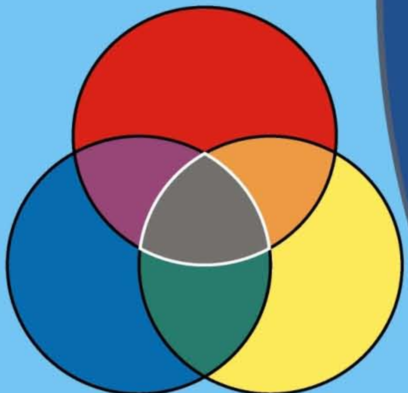
- as a Consultant
- for Water Acquisition
- as an Educator



Introduction

There are Many Concepts as to What is "Sustainability"?

- Is it purely "Green"?
- Is it worth pursuing?
- Can it be measured?
- Can comparisons be made?



Introduction

Sustainable Irrigation Analysis is:

- Defining Sustainability
- Fitting Irrigation to Definition
- Applying a Numerical Model
- Comparing Results

Disclaimer

Please be Open-Minded!

- This Presentation is an Initial Formulation of Ideas
- Sustainability is a Grand Concept: Irrigation is “Simplified Enough”

Disclaimer

Please be Open-Minded!

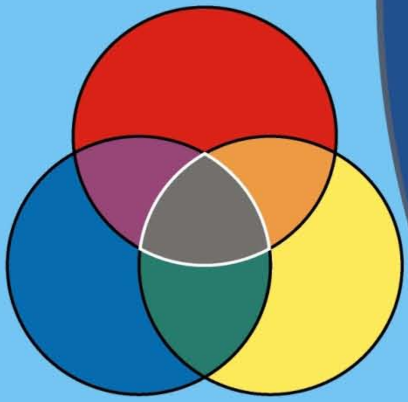
- Attempt to Quantify "Non-Numerical" Qualities for Analysis in Water Resource Decisions

- Theory of Heat:
  - •Quantity (Energy)
  - •Quality (Hot or Cold)
  - •Quantify Hot or Cold by Temperature

Defining Sustainability

World Commission on
Environment and Development
1987 Brundtland Commission

Definition of Sustainable Development:
"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

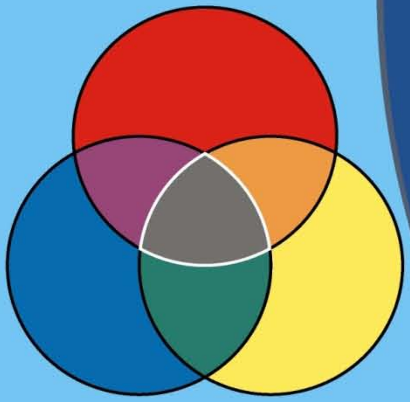


Defining Sustainability

2007 United Nations
Adopts the "Triple Bottom Line" (TBL)

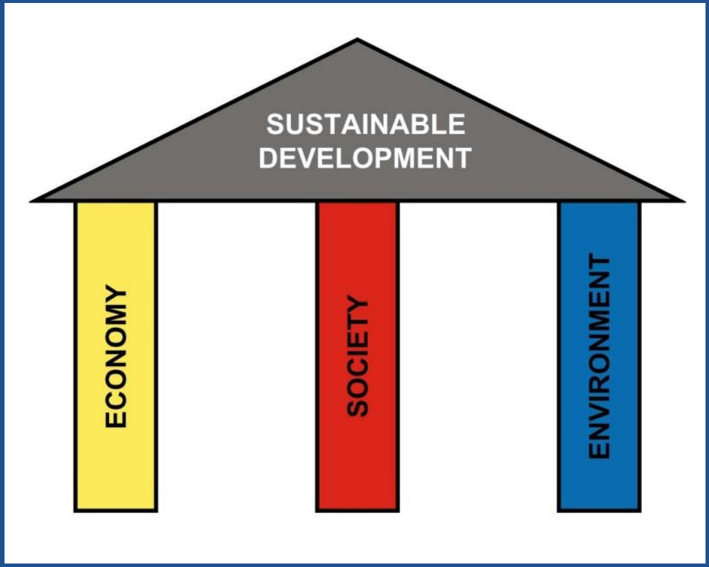
Three Dimensions of Sustainability

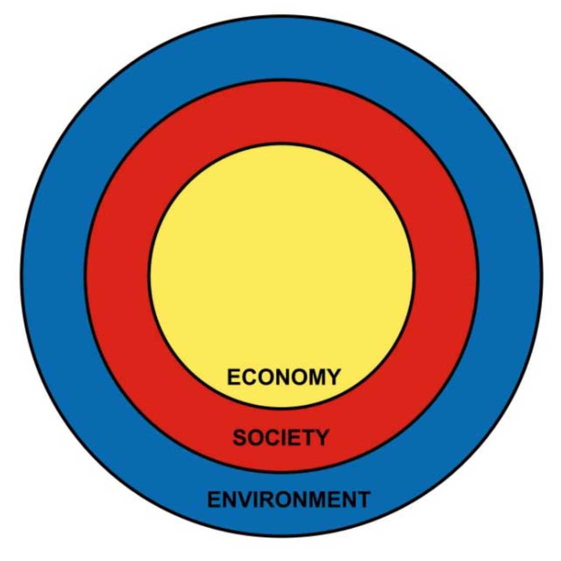
- Economy
- Society
- Environment



Defining Sustainability

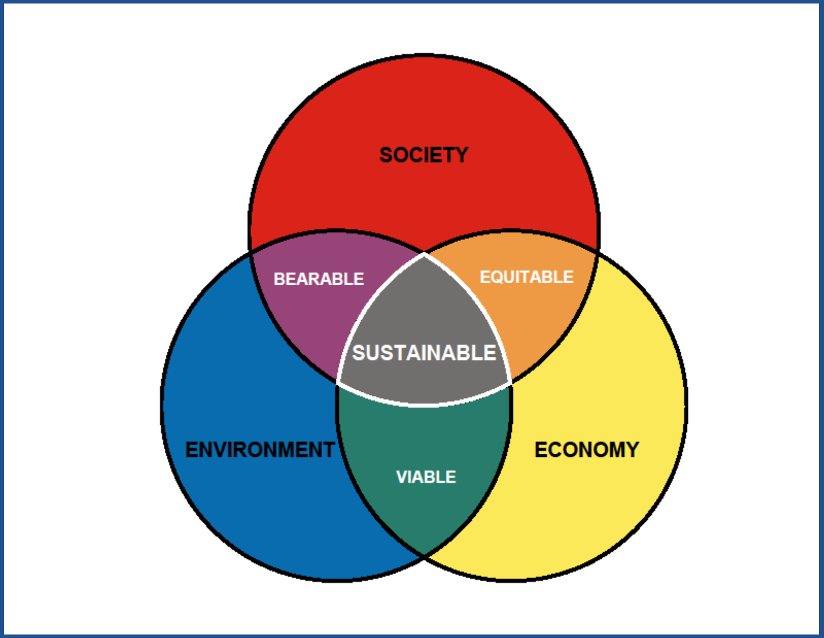
Alternative Models





Defining Sustainability

Overlapping Circle TBL Model
Definition for this Discussion
Dimensions are Not
"Mutually Exclusive"



Defining Sustainability

In years past, economic decision involved non-monetary outcomes as “Externalities” not included in the cost

TBL strives for “full-cost accounting” to encompass non-monetary effects from development

Sustainable Irrigation

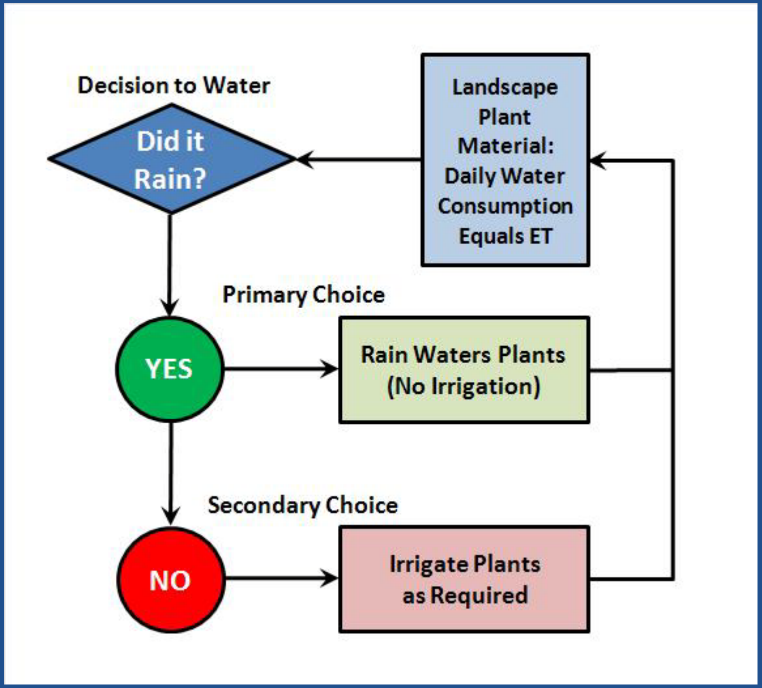
If Irrigation is to meet this Definition of Sustainability, it must address the Three Dimensions:

- Economy
- Society
- Environment

Role of Irrigation

Consider That:

- Irrigation Supplements Rainfall—It does not *Replace* it. (Temperate)



Role of Irrigation

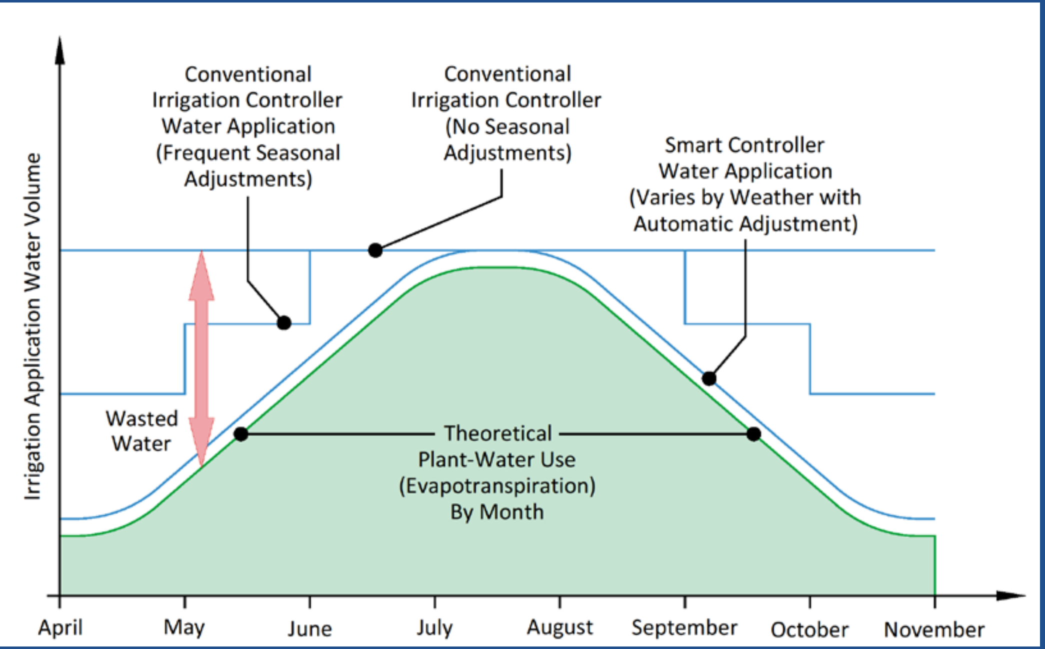
Consider That:

- Irrigation Design Changes to Suit Landscape—Not Vice Versa

Role of Irrigation

Consider That:

- Irrigation Systems are only as Smart as their Managers



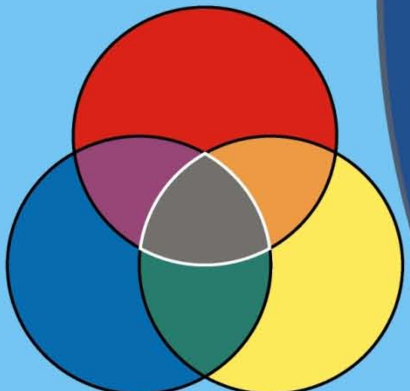
ANALYSIS OF SELECTING A SUSTAINABLE IRRIGATION SYSTEM

Economy

An Irrigation System must be Economically Viable NOW and in the FUTURE

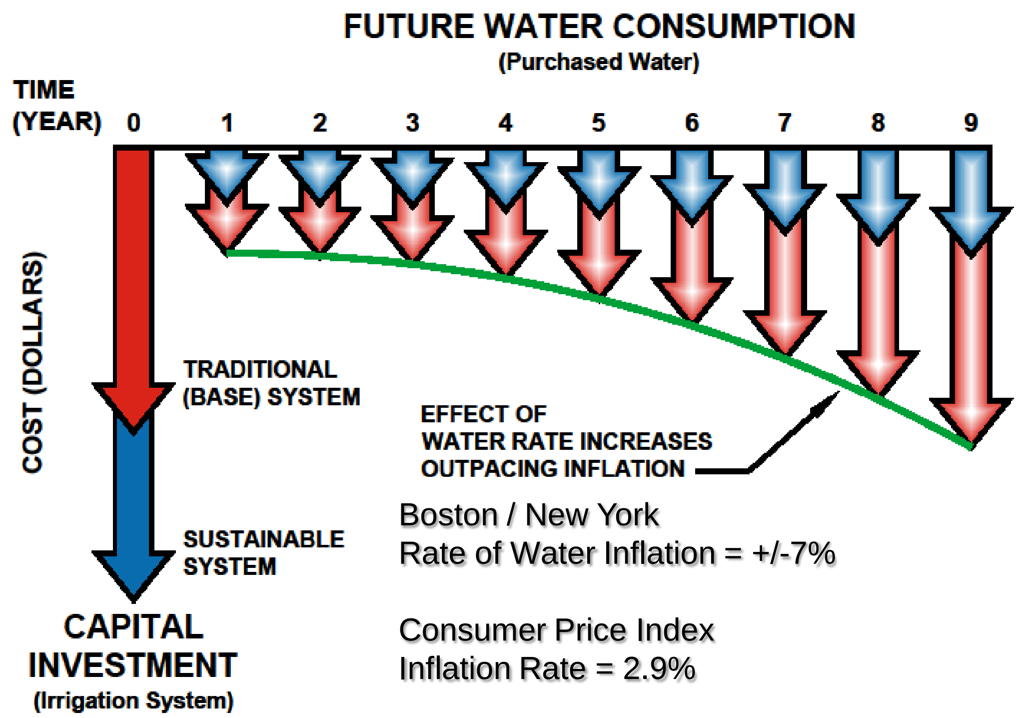
Cannot Simply Select Cheapest System—We Must Consider

- Future Potable Water Costs
- Future Electricity Costs
- Future Maintenance Costs
- RISK of LOSS



Economy

Sum of Arrows is “Present Value”



Boston / New York
Rate of Water Inflation = +/-7%

Consumer Price Index
Inflation Rate = 2.9%

Over 30 Year Period

Society

In order for Landscapes to fulfill their design intentions, they must be healthy now and in the future

While irrigation does not impact Society directly in the traditional sense, it does so through Landscape Efficacy

Society

Architects and Designers decide and argue how their Landscapes are used by Society (Parks, Offices, Campuses, Retail Stores)

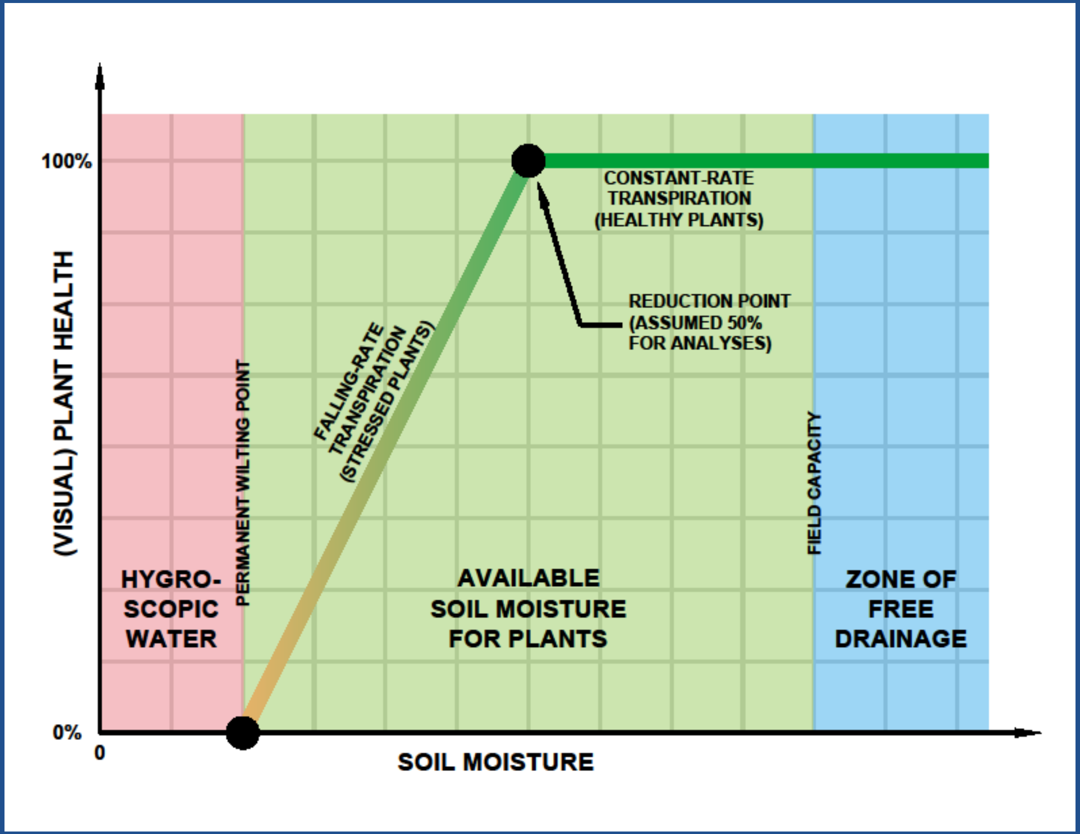
Irrigation affects Society by the

<u>Level of Landscape Plant Health</u>

- Attractiveness
- Usefulness
- Hazard Prevention (Fires)

Society

Plant-Dependent "Vulnerability Curve"



ANALYSIS OF SELECTING A SUSTAINABLE IRRIGATION SYSTEM

Environment

"Green" Projects are conscious of many Site-Specific Environmental Issues:

- Stormwater
- Erosion
- Open Space
- Heat-Island Effect

INTENT: Think Globally—Act Locally

Environment

Irrigation Directly Influences Regional Environment by Drawing from Area Water Supplies and Levels Critical to Humans and Wildlife

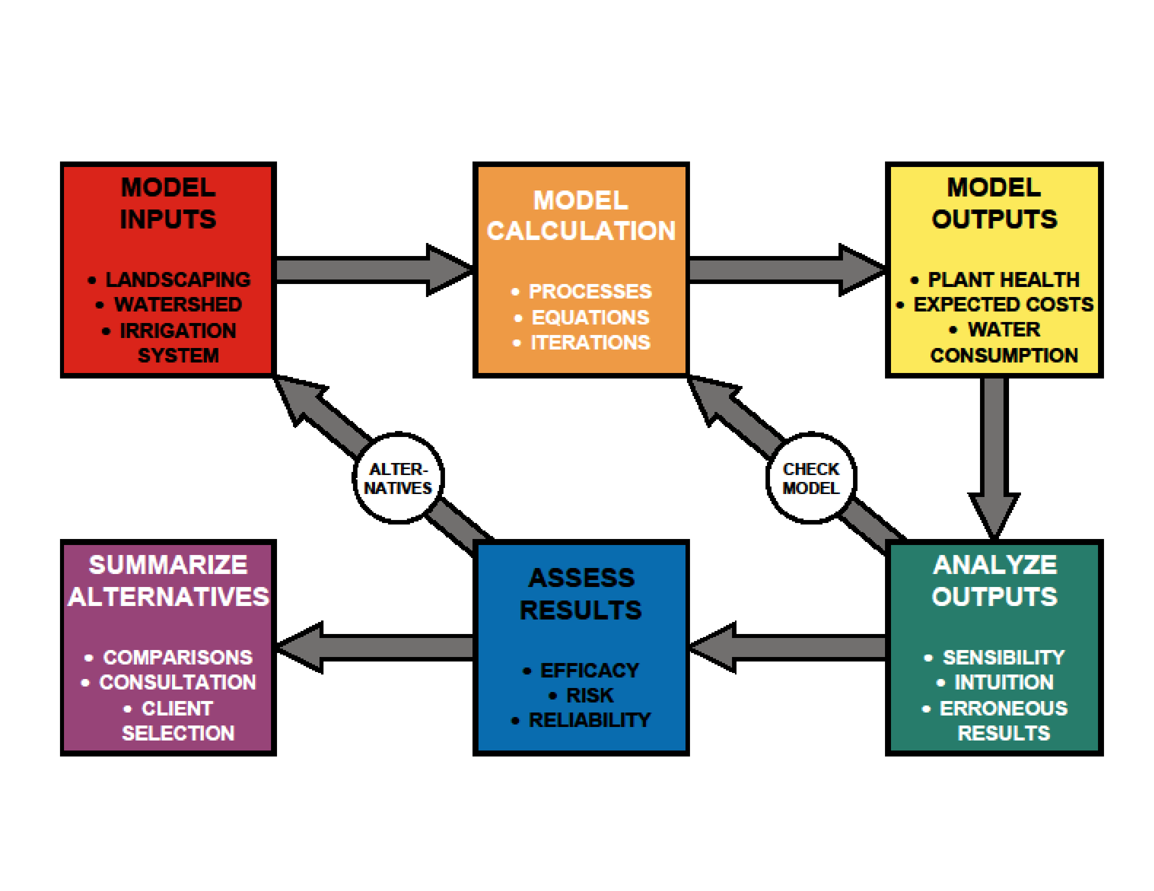
Excessive Potable Use = Bad for Environment

Numerical Modeling

We Can Create a Computer Model using Long-Term Climate Records to Simulate Irrigation Performance to Obtain:

- Economy = Present Value
- Society = Plant Health (Soil Water)
- Environment = Potable Consumed

Numerical Modeling



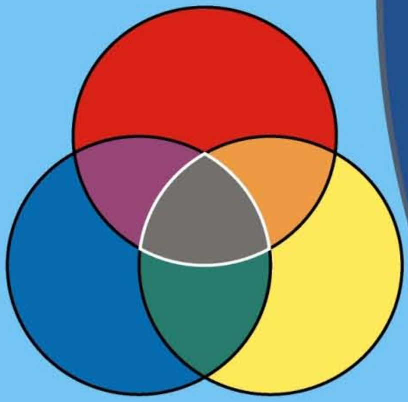
ANALYSIS OF SELECTING A SUSTAINABLE IRRIGATION SYSTEM

Numerical Modeling

25-Year Climate Data		Site Adjustments		Soil Moisture Accounting					
P (in)	PET (in)	Eff. P (in)	ET_0 (in)	Initial Moisture	+ Rain (in)	- Plants (in)	= Sub-total	+ Irrig. (in)	= Final Moisture
0.100	0.020	0.067	0.016	0.846	0.067	0.016	0.846	0.000	0.846
0.000	0.040	0.000	0.032	0.846	0.000	0.032	0.814	0.000	0.814
0.000	0.030	0.000	0.024	0.814	0.000	0.024	0.790	0.056	0.846
0.000	0.050	0.000	0.040	0.846	0.000	0.040	0.806	0.000	0.806
0.000	0.050	0.000	0.040	0.806	0.000	0.040	0.766	0.080	0.846
0.150	0.040	0.101	0.032	0.846	0.101	0.032	0.846	0.000	0.846

Total = Consumption
(Economy & Environment)

Average = Plant Health (Society)



ANALYSIS OF SELECTING A SUSTAINABLE IRRIGATION SYSTEM

Numerical Modeling

We Have Numbers for Each Dimension

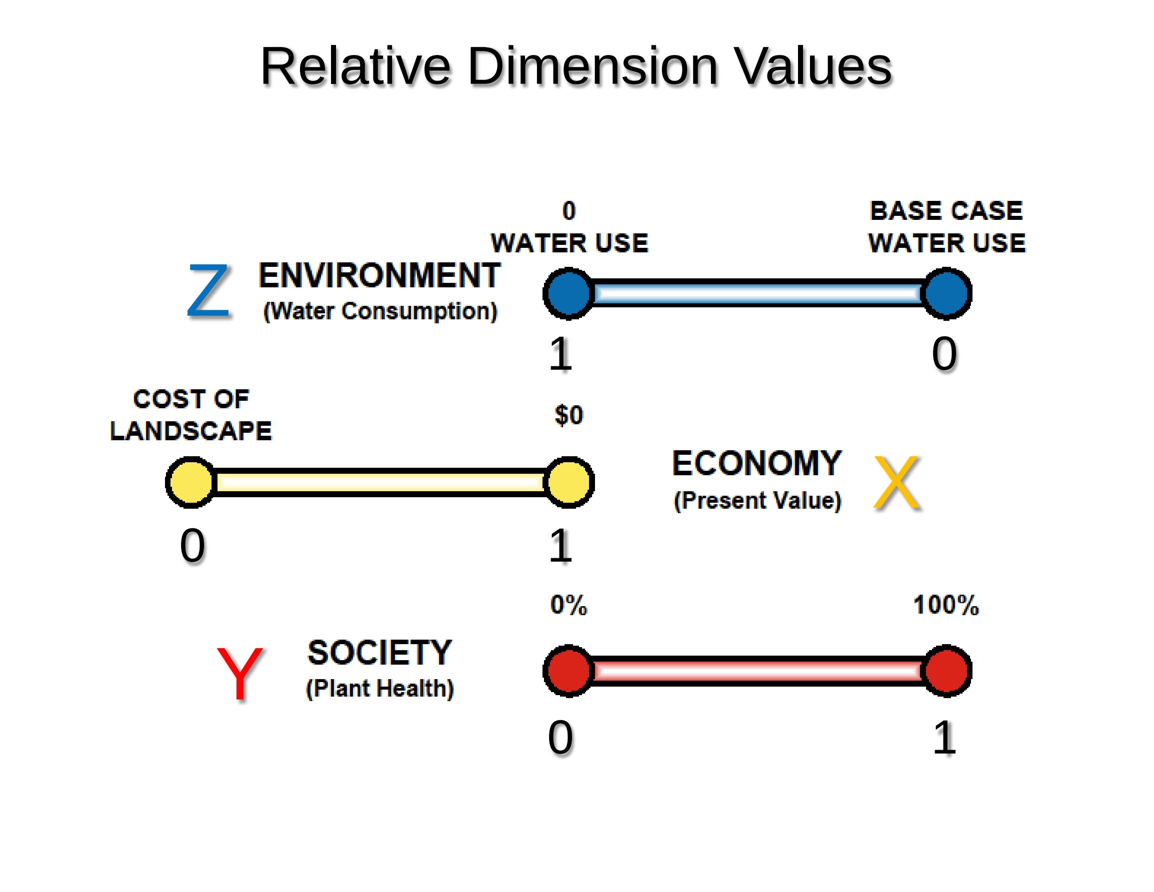
Dimension Comparisons

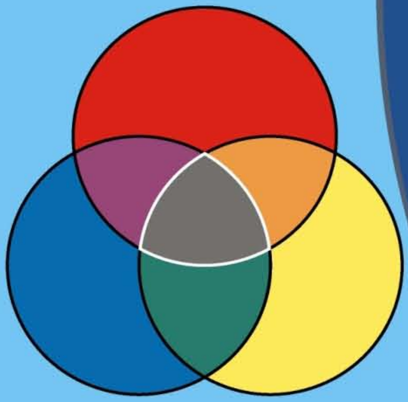
- How does X dollars compare to Z gallons of water consumed?

Comparison Between Designs 1 and 2

- How does X_1 compare to X_2 from Sustainability Definition?

Numerical Modeling





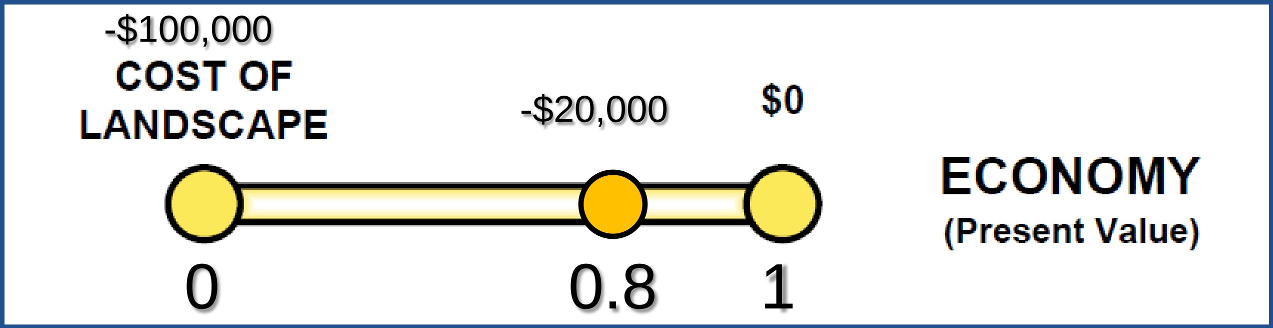
ANALYSIS OF SELECTING A SUSTAINABLE IRRIGATION SYSTEM

Numerical Modeling

Example:

Landscape Value: -$100,000 (Worst)
Ideal Present Value: $0 (Best)

Calculated Present Value = -$20,000
X Value = 0.80



Numerical Modeling

Irrigation Consulting, Inc.
Providing innovative design solutions for irrigation worldwide.

Propose a Sustainability Index, S

$$S = X + Y + Z$$

Maximum S = 3 (Certainly Sustainable)
Minimum S = 0 (Certainly Not Sustainable)

Example

Economy

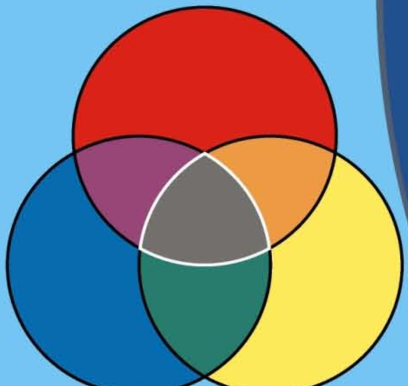
Landscape Cost = -$300,000
20-Year PV = -$100,000
X = 0.67

Society

Average Plant Health = 95%
Y = 0.95

Environment

Base Consumption = 1.0 MGY
Design Consumption = 0.2 MGY
Z = 0.80



Example

Sustainability Index

$S = X + Y + Z$

$S = 0.67 + 0.95 + 0.80$

$S = 2.42$

I Propose this Design is "More Sustainable" than Ones with $S < 2.42$

This is True By Definition because All Dimensions Must Be Considered Equally (Additive)

Example

In Comparing Design Alternatives, Might Have to Give Back with a Dimension to Gain in Another

Case 1:

$S_1 = X_1 + Y_1 + Z_1$

$S_1 = 0.67 + 0.95 + 0.80$

$S_1 = 2.42$

Case 2:

$S_2 = X_2 + Y_2 + Z_2$

$S_2 = 0.60 + 1.00 + 0.95$

$S_2 = 2.55$

Example

What About 0 Values?

These Designs Should Not Be Selected by Definition

Base Irrigation Design Case:

Water Consumption is Max: Z = 0

<u>No Dimension is Mutually Exclusive</u>

If Water Consumption is Max, then Cost will Greatly Increase, i.e., $Z \Rightarrow 0$, then $X \Rightarrow 0$

(Excessive Water Costs)

A Step Further…

To Now, I Have Presented
Average Sustainability Index

What About Potential Risks?
System Failure
Plant Material Disease, etc.

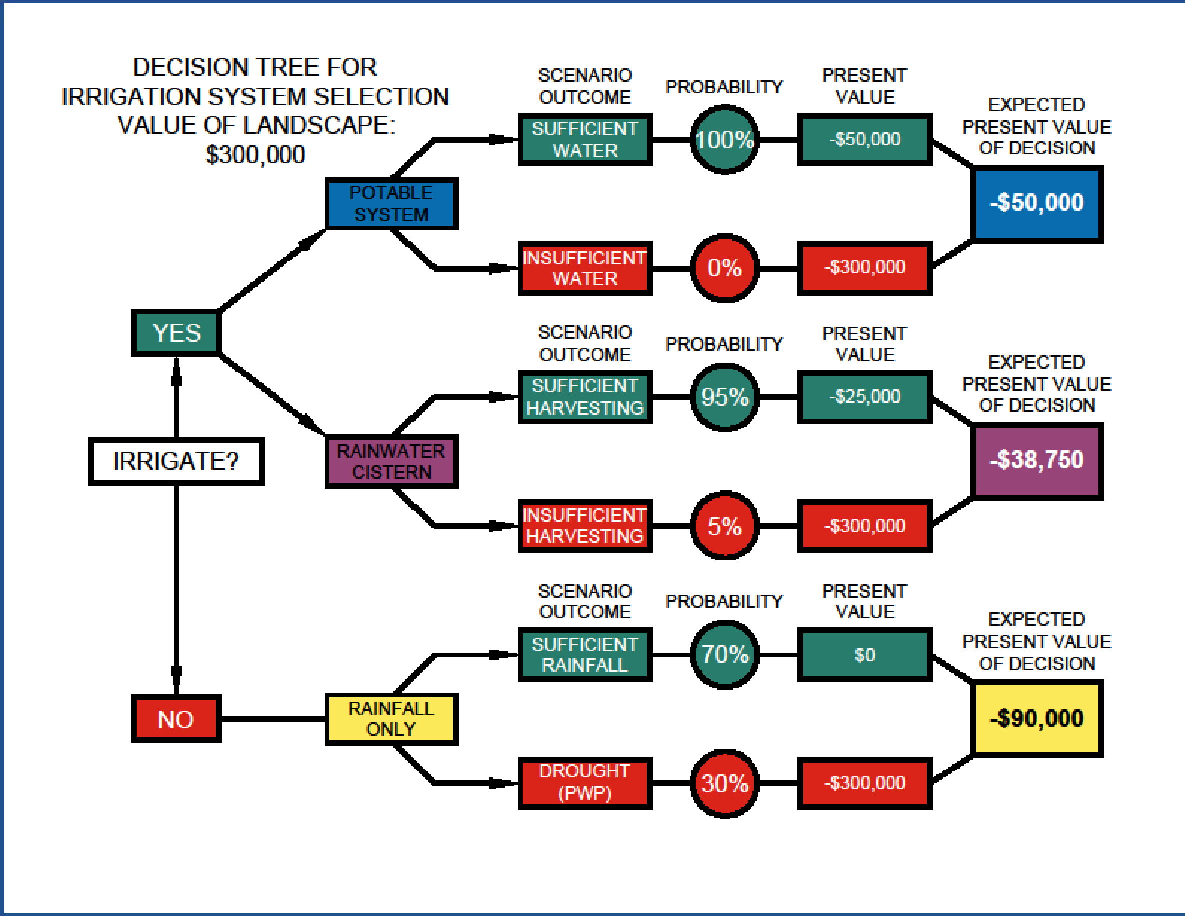
When Using Harvested Rainwater
Resources We Must Consider
DROUGHT RISK

A Step Further…

Instead of Average Sustainability, We Could Consider:
Expected Sustainability Index

Expected Values May Account for Foreseen Potential Risks

A Step Further…



ANALYSIS OF SELECTING A SUSTAINABLE IRRIGATION SYSTEM

A Step Further…

Average Values (No Risk):

$S_1 = X_1 + Y_1 + Z_1$

$S_1 = 0.67 + 0.95 + 0.80$

$S_1 = 2.42$

Expected Values (With Risk):

$S_{EXP} = X_{EXP} + Y_{EXP} + Z_{EXP}$

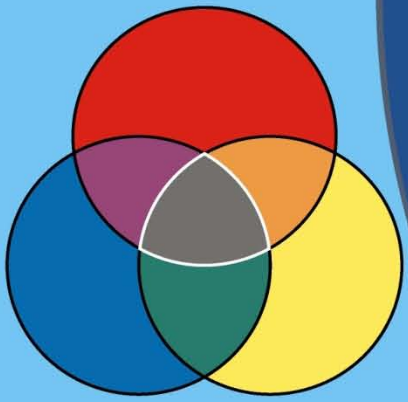
$S_{EXP} = 0.30 + 0.50 + 0.75$

$S_{EXP} = 1.55$

Summary

Accepted Definitions of Sustainability Include Equal Consideration of Economy, Society, and Environment for the Present and Future

Attempts Can Be Made to Quantify Sustainability for Comparisons When the Examples are Simple. Irrigation can provide this Example (Simple Enough).



Summary

Other Design Elements of Development Could Apply This Method if the Processes and Risks are Understood

More Research and Statistical Analysis is Required for More Complex Processes (Statistics of Dependent Variables)

Questions

?

ANALYSIS OF SELECTING A SUSTAINABLE IRRIGATION SYSTEM