This presentation premiered at WaterSmart Innovations

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A Sustainability Index for Landscape Irrigation

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A Design Team Conversation…

As the Irrigation Engineer for a Green project in Boston, I explain that ICI's Irrigation Design:

- Has Enough Non-Potable Water to Supply Irrigation Entirely
- Irrigation Assures Perfect Plant Health
- Smart Irrigation Controls will Minimize Water Waste
- Savings in Purchased Water Results in 5-Year Payback

To me: <u>This Irrigation System is Sustainable</u>

A Design Team Conversation…

A "Sustainability Consultant" at a Large Firm is involved with this conversation. After hearing my explanation, her automatic response was:

- The Certification Process strives for No Irrigation
- Should we even be considering irrigation at all when Boston receives 45 inches of rain per year? (Obviously, it is +/- 45 inches of *precipitation* for 12 months—snow included)

A Design Team Conversation…

I took home a few things about Sustainability

- Sustainability Means Different Things to Different People
- Even Providing a Strong <u>Verbal</u> Argument for Irrigation, Pre-Conceived Notions Affect Design
- Prescriptive Measures (like Rating Systems) Weigh Heavily on Decision Making Due to Precedence and Popularity

What is Sustainability Today?

Sustainable Development is Driven by Rating Systems

Rating Systems are "Prescriptive Methods" that are promoted by their creators as methods to be "Green" or "Sustainable"

Examples:

- LEED - US Green Building Council
- Sustainable Sites Initiative
- EPA WaterSense Program
- Some Ordinances use Rating Systems as Standard

What is Sustainability Today?

These are effective programs with great Environmental Benefit, however, some developers believe, or are led to believe (by popularity or law) that:

1. By Prescription, partaking in the rating system means they ARE SUSTAINABLE and
2. By not partaking they ARE NOT SUSTAINABLE

What is Sustainability Today?

In Other Words, Sustainability is Promoted as Deterministic: Either a Project Is Sustainable or Is Not

This is Impossible to Know at the Design Phase!

The Proper Question to Ask is:

How Likely is the Project to be Sustained?

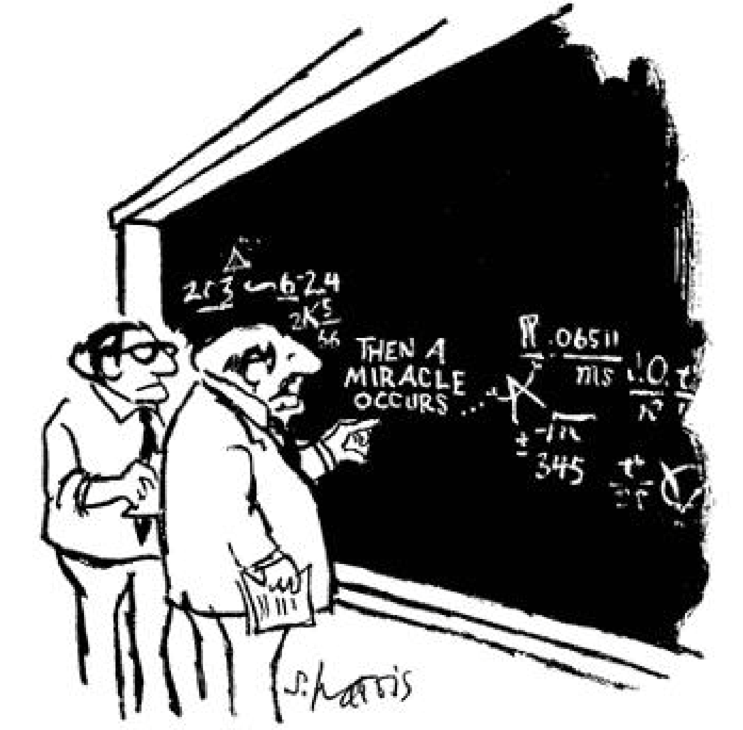
Therefore, Sustainability would be a

Probabilistic Trait

What is Sustainability Today?

Obviously, there are Communication Gaps and Differing Concepts in defining Sustainability

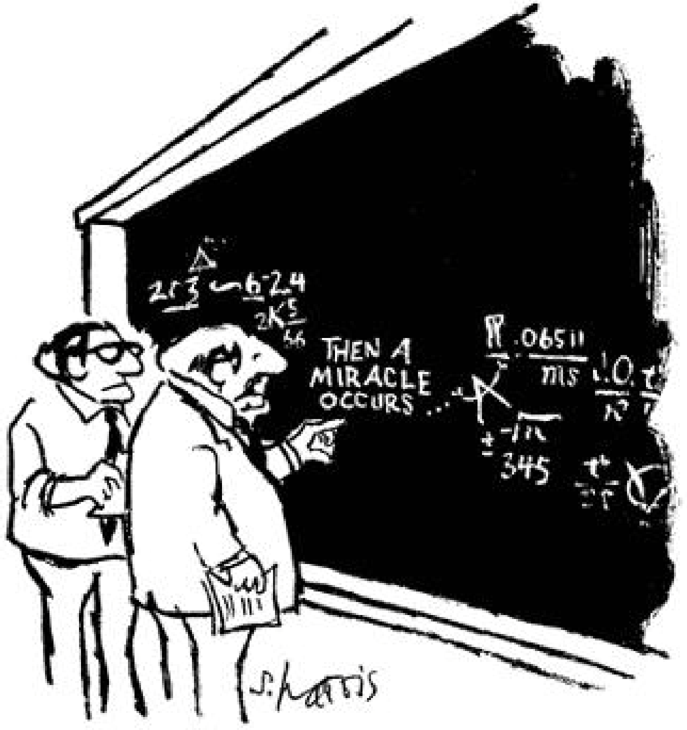
But, I feel my argument for landscape irrigation is justified, so how do I win the debate? I need PROOF! (This Presentation, Hopefully)



"I think you should be more explicit here in step two."

What is Sustainability Today?

A Sustainability Index can Compare Design Alternatives from which the best will be the Most Likely Sustained Over Time



"I think you should be more explicit here in step two."

What is Sustainability Today?

Sustainable Development is a concept that has an evolving definition over the last 50 years

1987 Brundtland Commission of the United Nations:
"The Standard"

- Sustainable Development:

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

What is Sustainability Today?

2006 International Union for Conservation of Nature (IUCN) Report "The Future of Sustainability"

- "The core of mainstream sustainability thinking" involves Three Dimensions to consider:

Economy
Society
Environment

=

Triple Bottom Line Method for Full Cost Accounting of Resources

Resources

Resources Come in a Wide Variety of Forms for Use
(Used for Landscape Irrigation Sustainability Index)

Economy
Society
Environment

Air

Water

Wildlife
Habitat
(Ecological
Balance)

Resources

Resources Come in a Wide Variety of Forms for Use
(Used for Landscape Irrigation Sustainability Index)

Production

Appearance

Economy
Society
Environment

People
(Assembly)

Resources

Resources Come in a Wide Variety of Forms for Use
(Used for Landscape Irrigation Sustainability Index)

Land

Money

Economy
Society
Environment

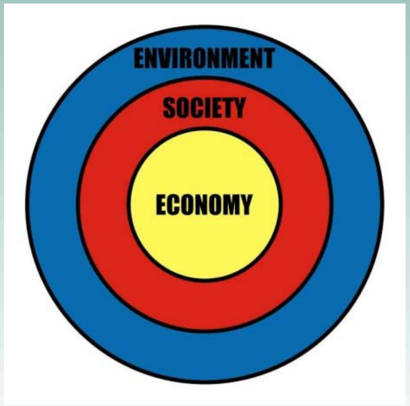
Commodities

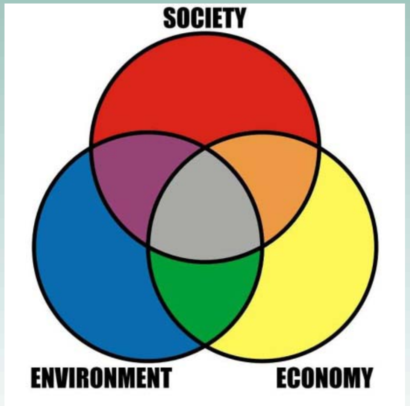
What is Sustainability Today?

Proper Management of TBL Resources leads to Sustainable Development (Conceptual Modeling)

From IUCN 2006:

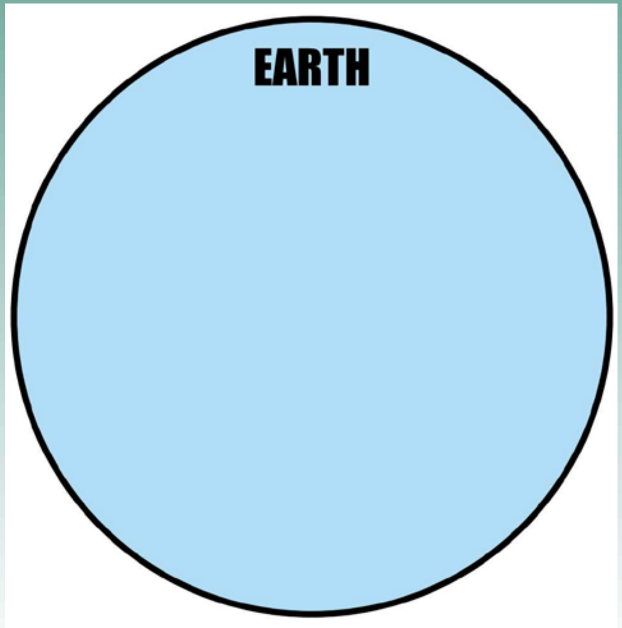
- How does one describe this management?
- How does one describe the interaction of dimensions?





New Sustainability Model

Model Life as a "Living Organism" that Uses Earth's Resources for its Survival Needs. Its functions evolve over time, driven by our Preferences to arrive at the full TBL Resources of today.



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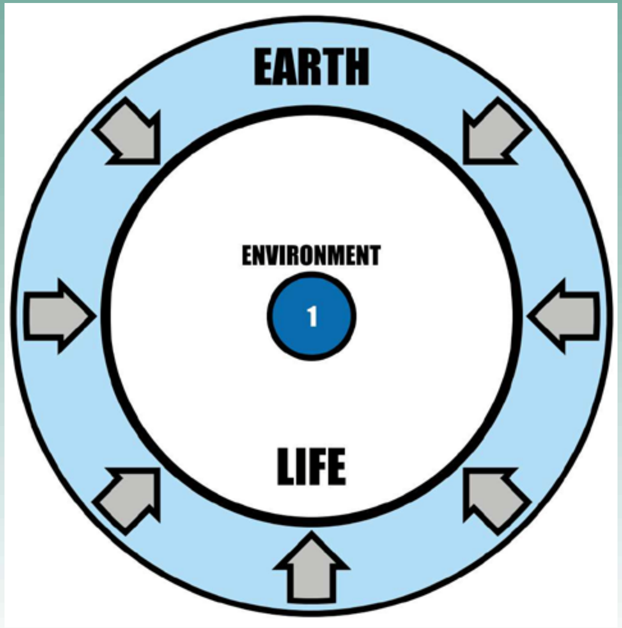

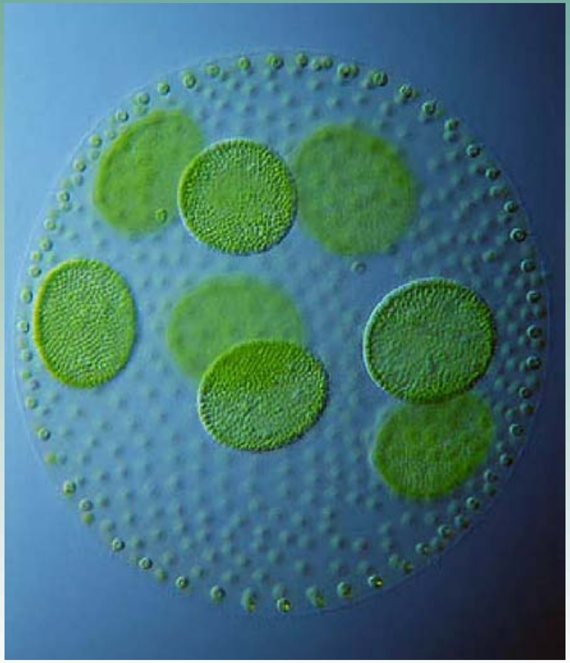

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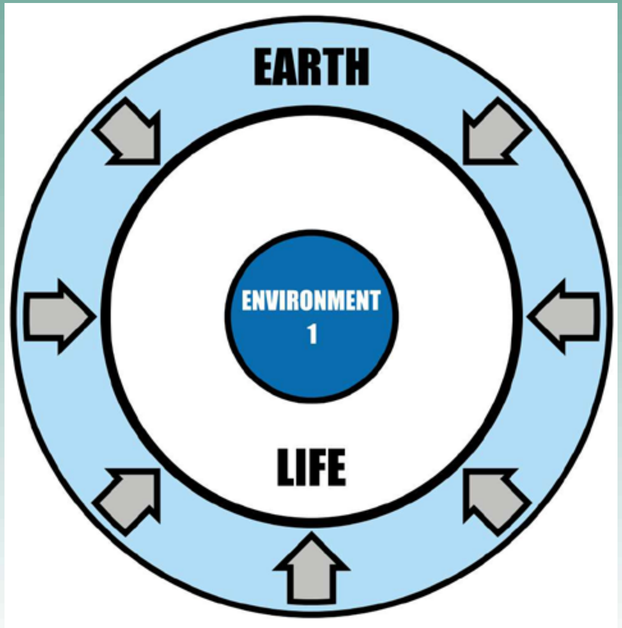

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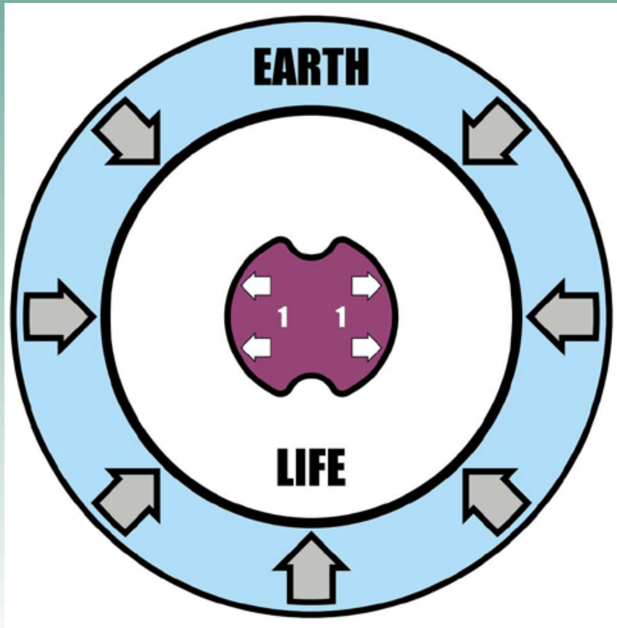

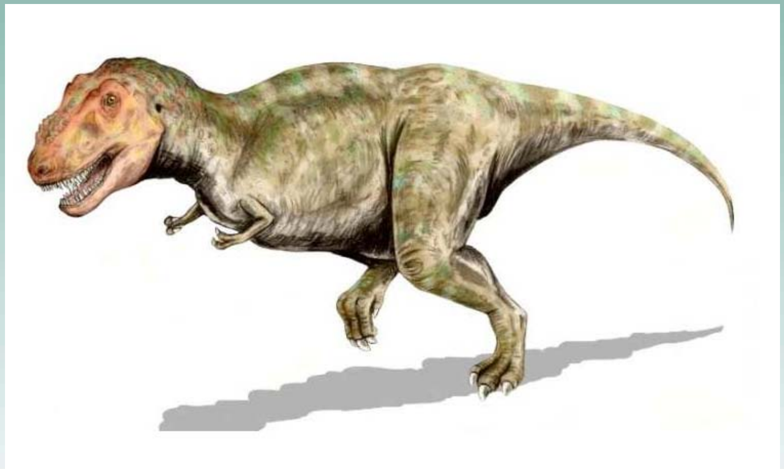

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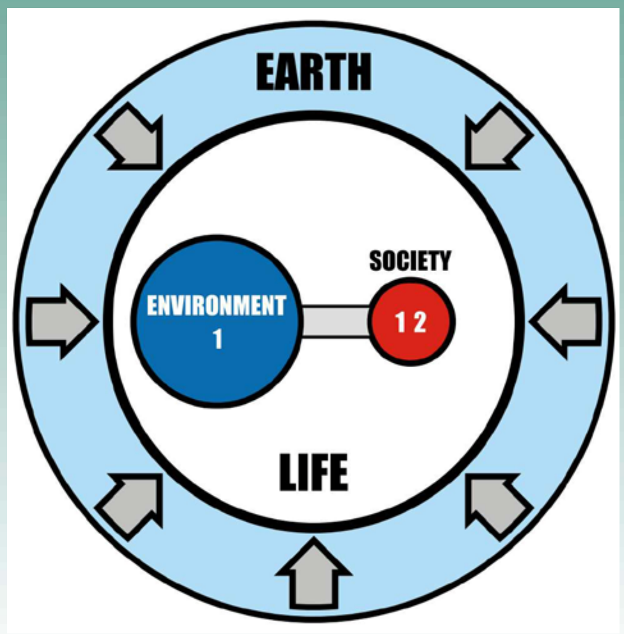

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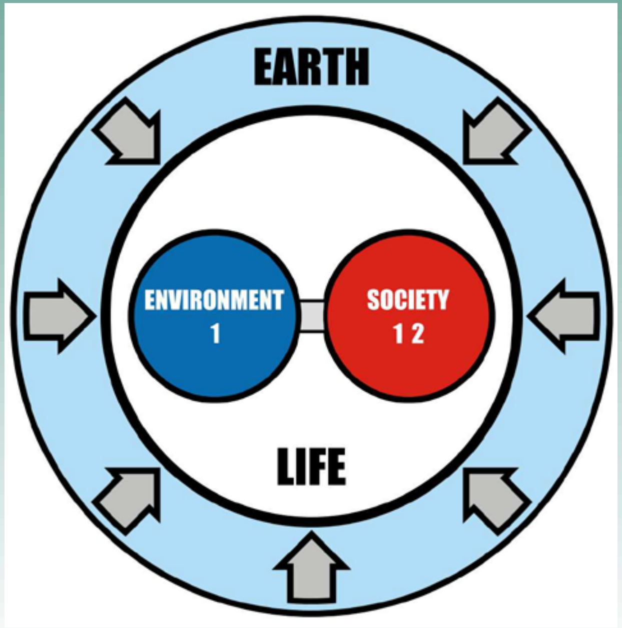

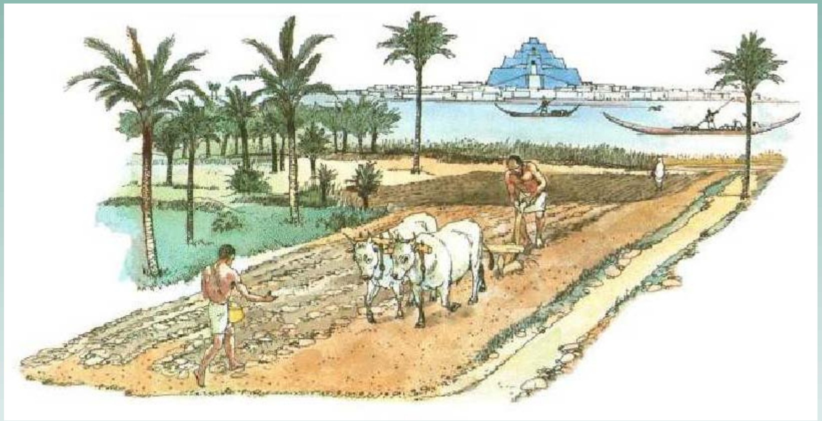

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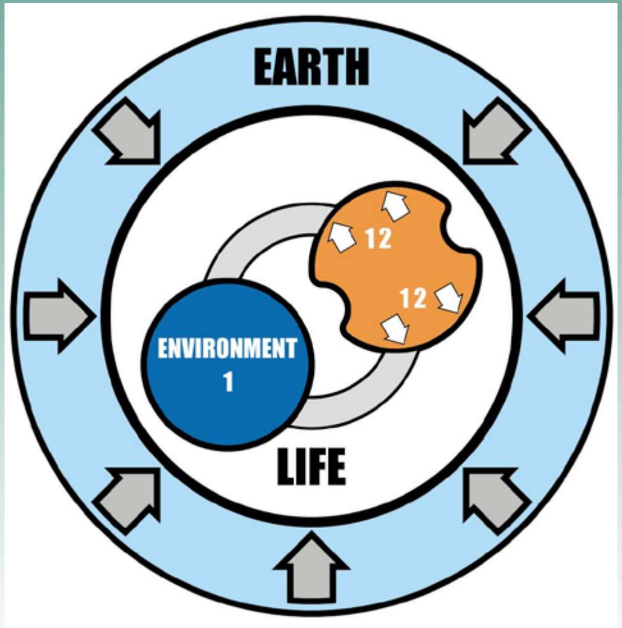

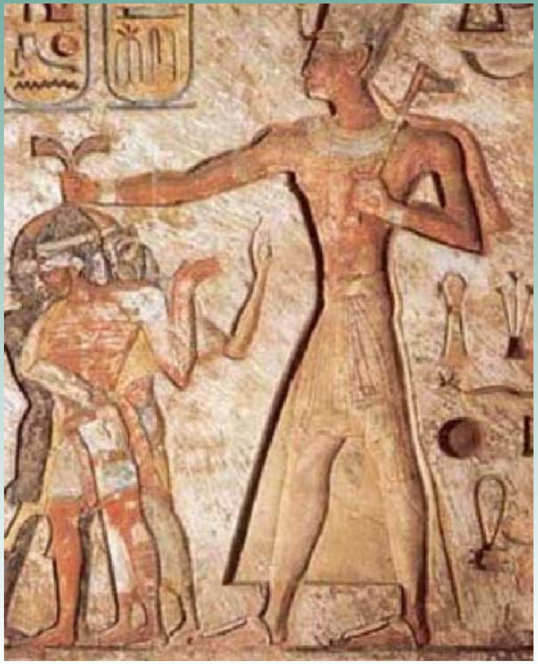

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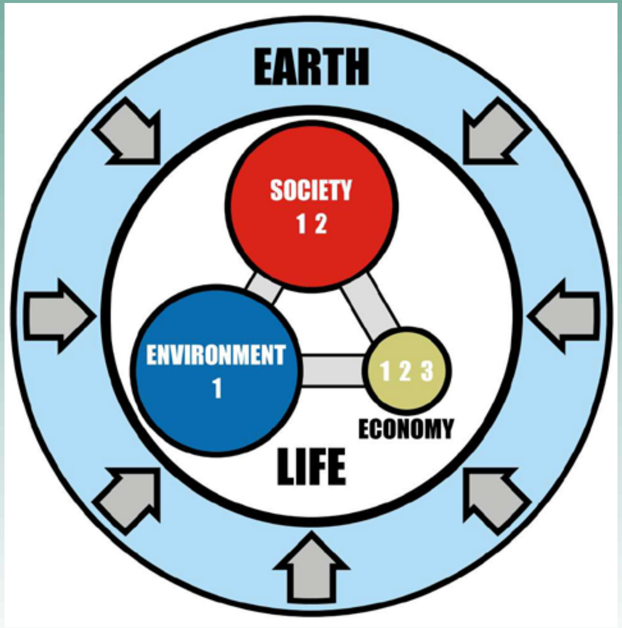

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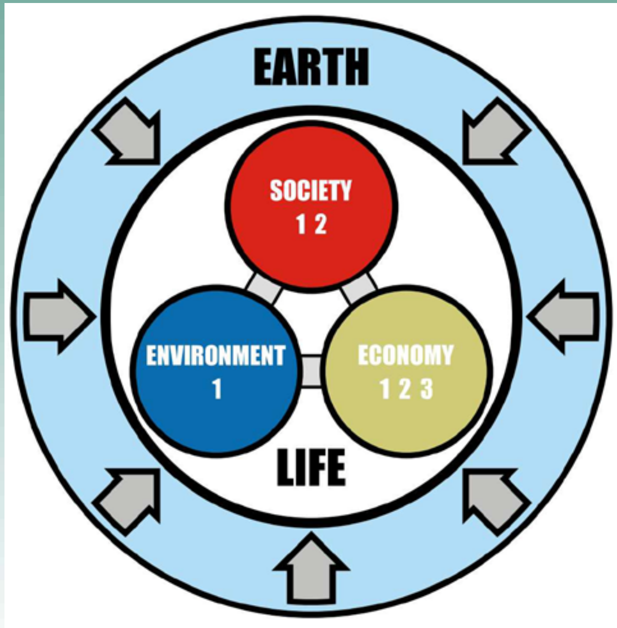

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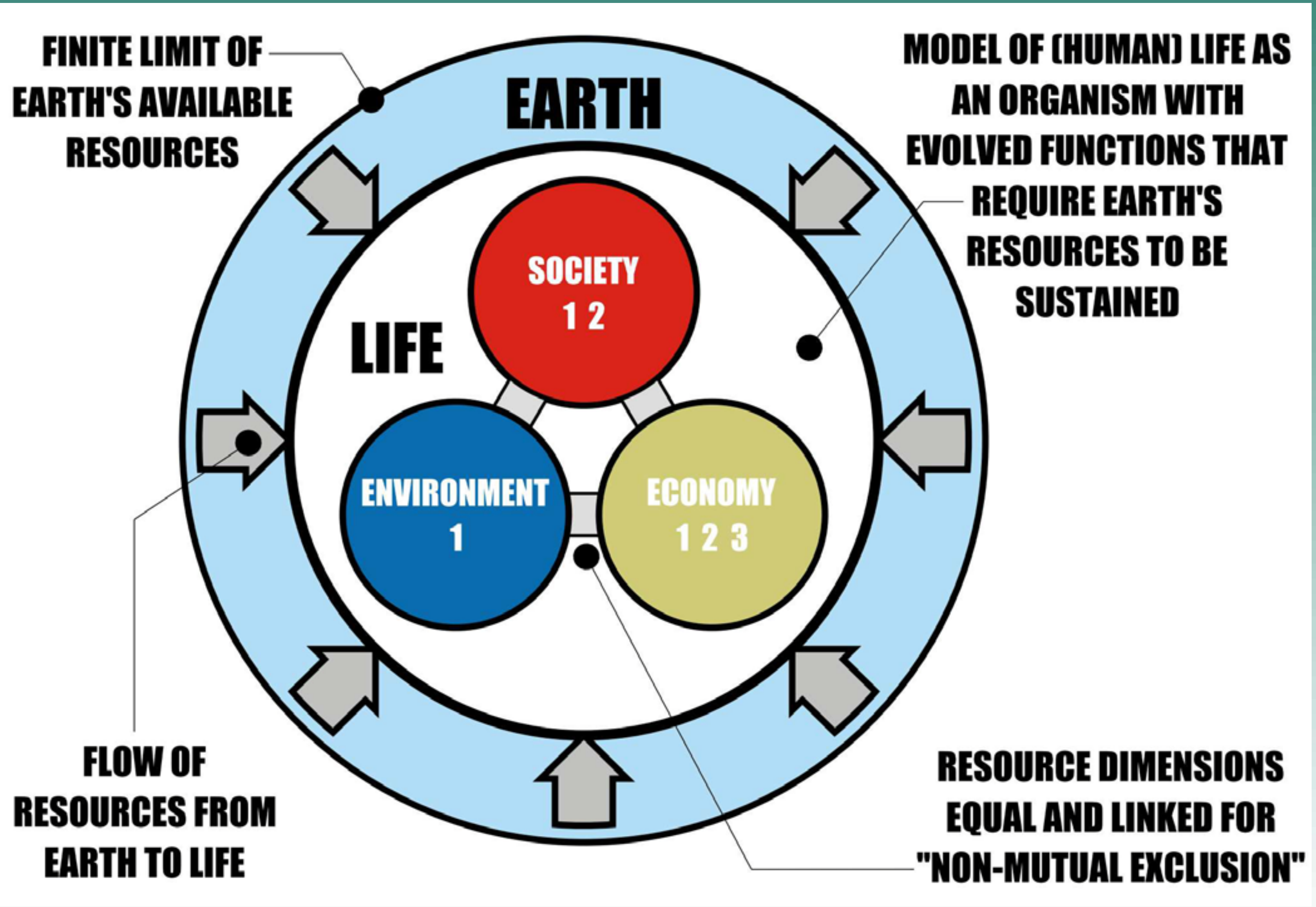

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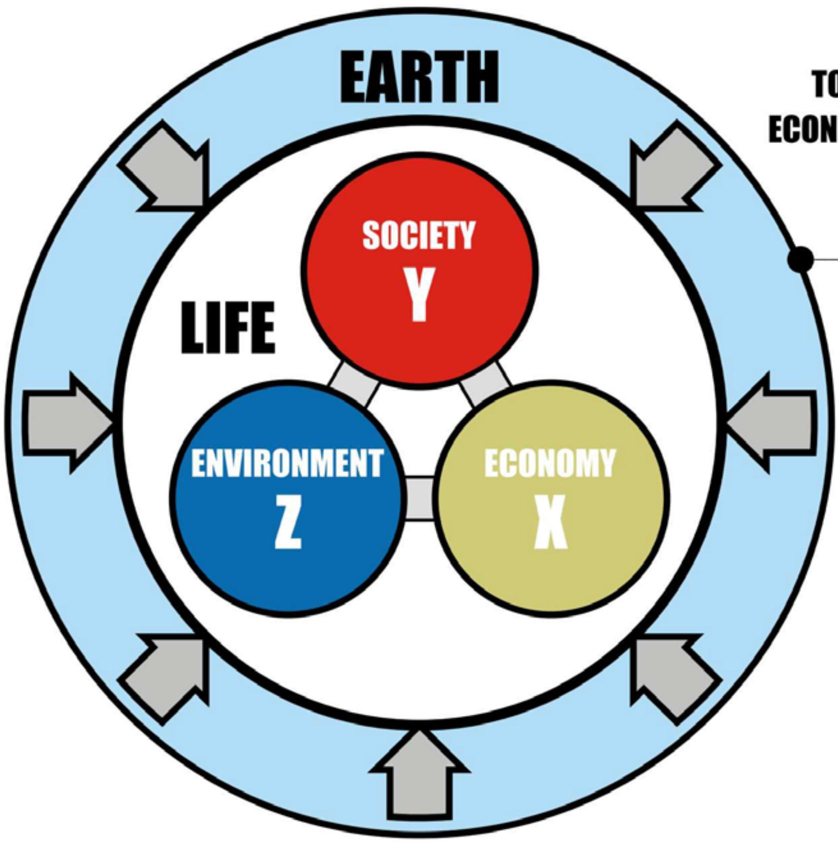


MATHEMATICALLY,
TOTAL RESOURCE CONSUMPTION =
ECONOMY + SOCIETY + ENVIRONMENT, OR
X + Y + Z

HOWEVER THERE IS A FINITE POOL OF RESOURCES TO DRAW FROM

THEREFORE:

THE GOAL OF "SUSTAINABILITY" IS TO MAXIMIZE THE EFFICIENCY OF USING THESE RESOURCES SO THAT OUR RESOURCE POOL (EARTH) CAN BE SUSTAINED OVER TIME.

Why Be Sustainable?

Much of this Numerical Analysis Derives from Game Theory

Consider LIFE and EARTH Engaged in a Non-Zero Sum Game

No Outright Winner/Loser

Both May Score High through Negotiation or Cooperation

- If EARTH "Loses" or "Scores Low", Then LIFE "Loses" or "Scores Low"
  - Our Chance at Survival is Low
- If EARTH "Wins" or "Scores High", Then LIFE "Wins" or "Scores High"
  - Our Chance at Survival is High

Why Be Sustainable?

In Other Words:

Mother Earth

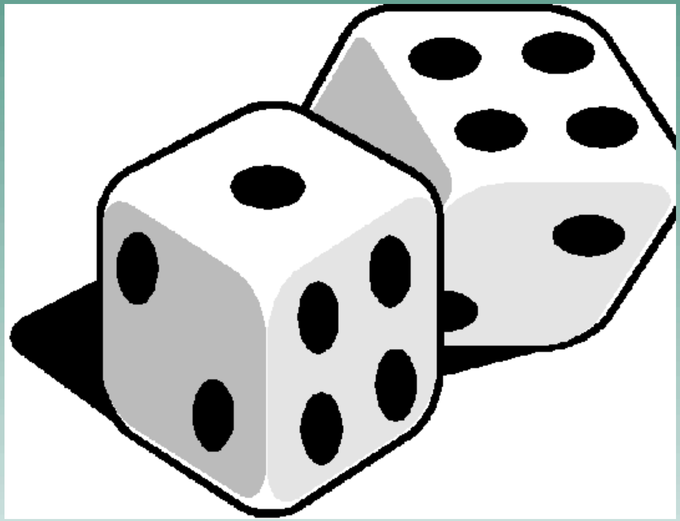
Human Development

We Must put ourselves in a Position with Earth for a “Win-Win” Situation

Mathematically, this is an Optimization Problem

Assessing Risk

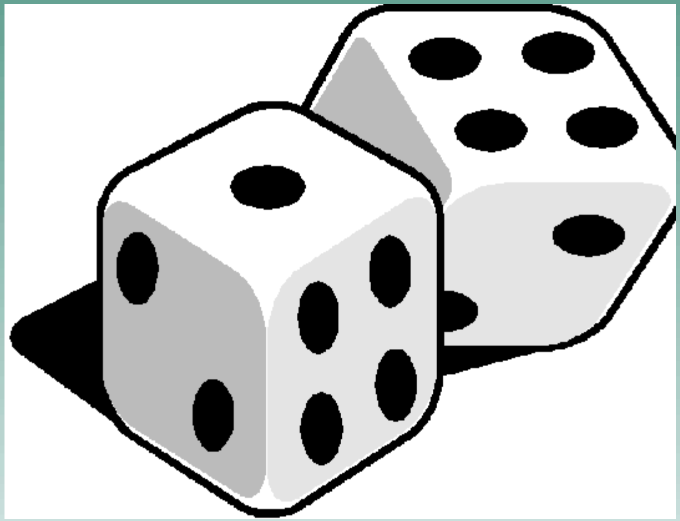
Prescriptive Methods do not account for the Developer's Risk (Idealized or Average Designs)



In Equating Sustainability as a "Game", we note that Games have Elements of Risk

Assessing Risk

Generally, People are Risk Averse, i.e., they avoid it



People shed risk by opting for Insurance Products

- Car
- Home
- Life

Assessing Risk

We Always Hear about Irrigation as "Insurance" for our Landscaping against Risk of Drought

It is Preferred by Developers as a means of Protecting their Landscape Investment

However, the Insurance Analogy is Not Quite Accurate as We Assume

Assessing Risk

In Order to Model a Win-Win Scenario using the Insurance Analogy, we:

Model EARTH as a "Real-World" Insurance Company
- A Big Company like New York Life, etc.

Model Landscape Owners as the Insured

Model Irrigation Systems as Policies

Earth as Insurance Company

People PREFER Full Insurance or Full Coverage

But, Real World Insurers (Almost) NEVER offer Full Coverage

- Deductibles
- Tight Rules for Coverage
- Denied Coverage after Investigation

Earth as Insurance Company

Why do Insurers offer INCOMPLETE coverage?
Two Reasons by Autor (2004) can relate to Irrigation

1. CREDIT CONSTRAINTS

Even if offered and People Prefer them,
People Simply Cannot Afford Full Insurance
(Costs Too Much)

Earth as Insurance Company

Why do Insurers offer INCOMPLETE coverage?
Two Reasons by Autor (2004) can relate to Irrigation

2. NON-DIVERSIFIABLE RISK CANNOT BE INSURED

Insurance Policies for Earth Exploding or Ice Caps Melting Cannot be Insured since everyone incurs same loss simultaneously

Earth as Insurance Company

Consider an Irrigation Example for New Landscaping

Scenario 1: Traditional System

- 20 Sprinkler Heads (Low DU)
- No Smart Controls (Irrigates Every Day)
- Uses 20,000 gal/year
- Risk of Plant Death = 0% (Full Insurance)
- Installation Cost: $2,500 (Is This a Premium?)

Earth as Insurance Company

Consider an Irrigation Example for New Landscaping

Scenario 2: Water Conserving Irrigation System

30 Sprinkler Heads (High DU)

Smart Controls (Irrigates As Needed)

Uses 9,000 gal/year On Average

Risk of Plant Death = 0% (Full Insurance)

Installation Cost: $5,000 (Is This a Premium?)

Earth as Insurance Company

Consider an Irrigation Example for New Landscaping

Scenario 3: No Irrigation

Relies on Natural Rainfall Patterns Only

Risk of Plant Death = 40% in a Given Year

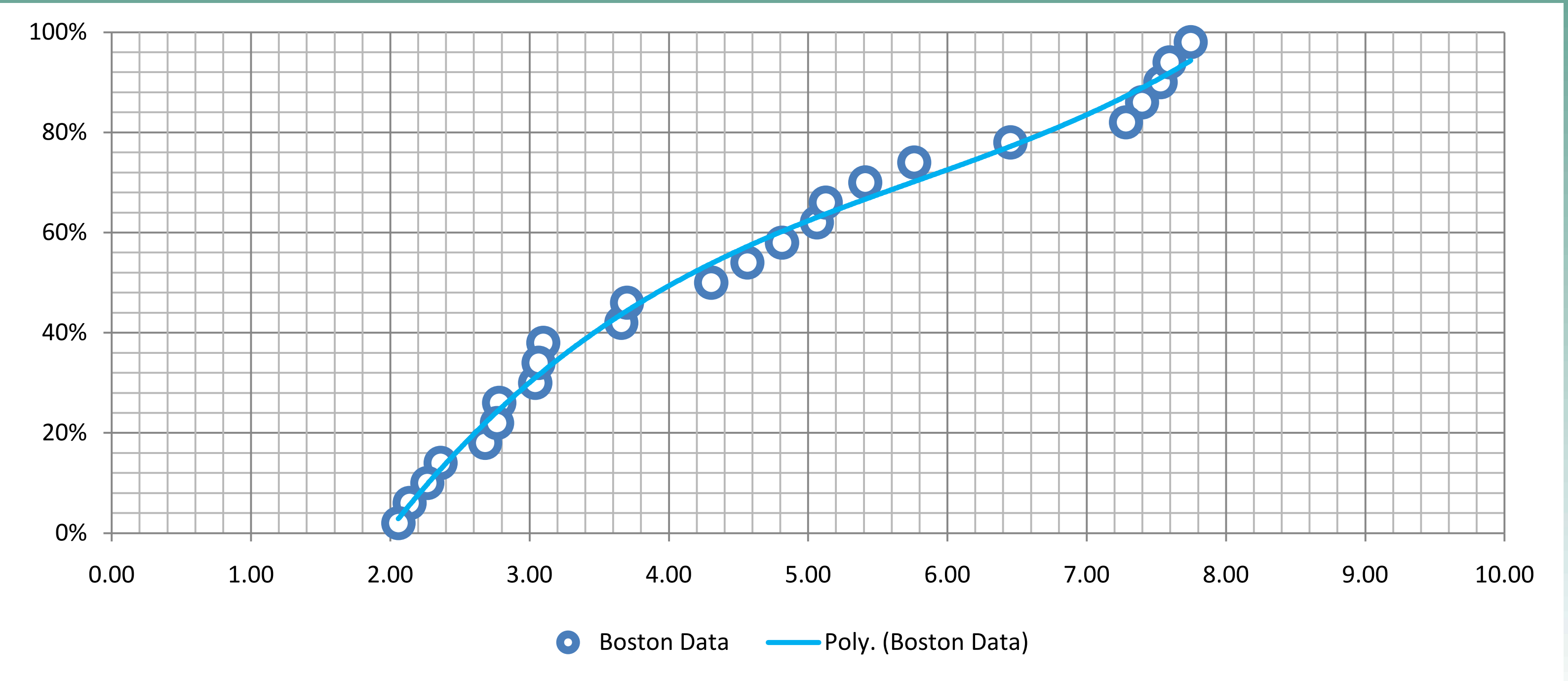
Installation Cost: $0

Note that LEED Automatically Awards Maximum Points to Developers for this Scenario

Earth as Insurance Company

How do I know the Risk of Plant Death is 40%?

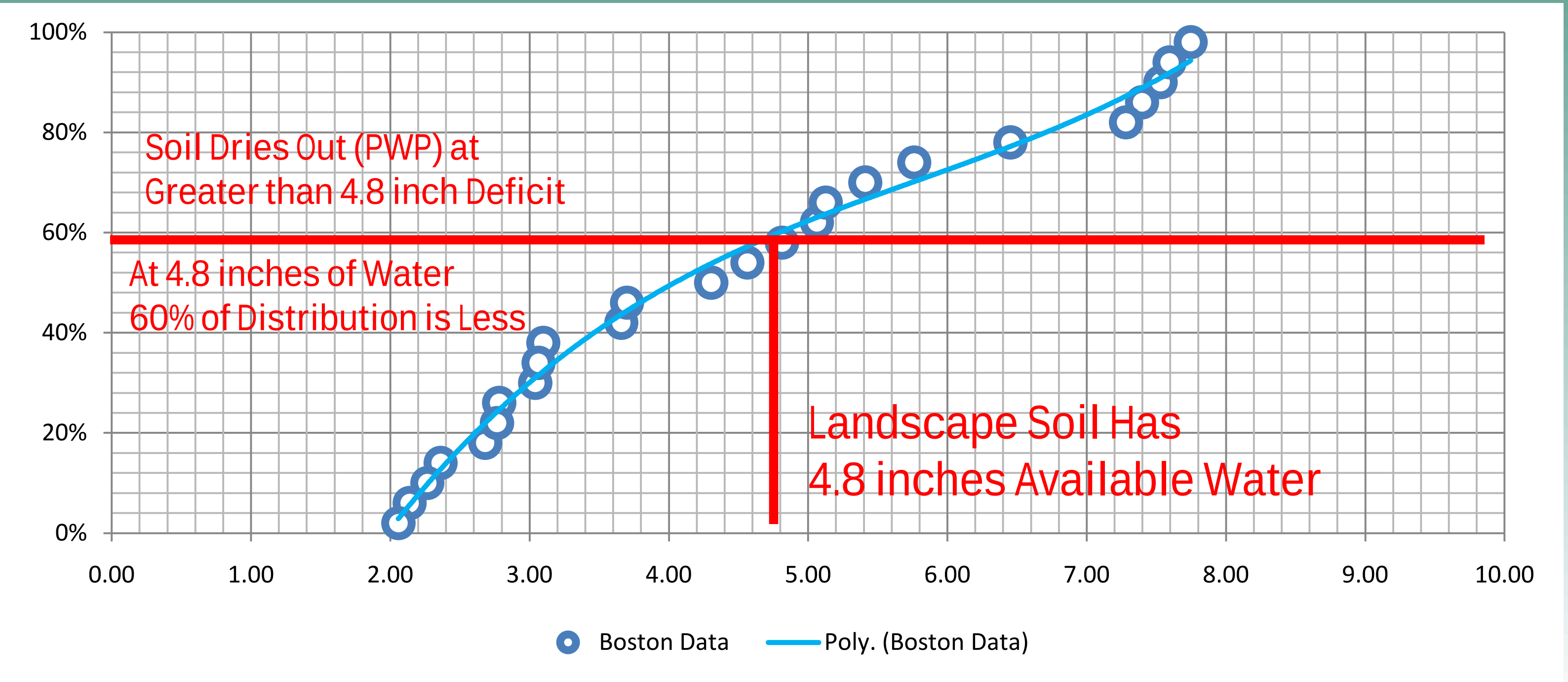
Existing Climate Data Distribution



Earth as Insurance Company

How do I know the Risk of Plant Death is 40%?

Existing Climate Data Distribution

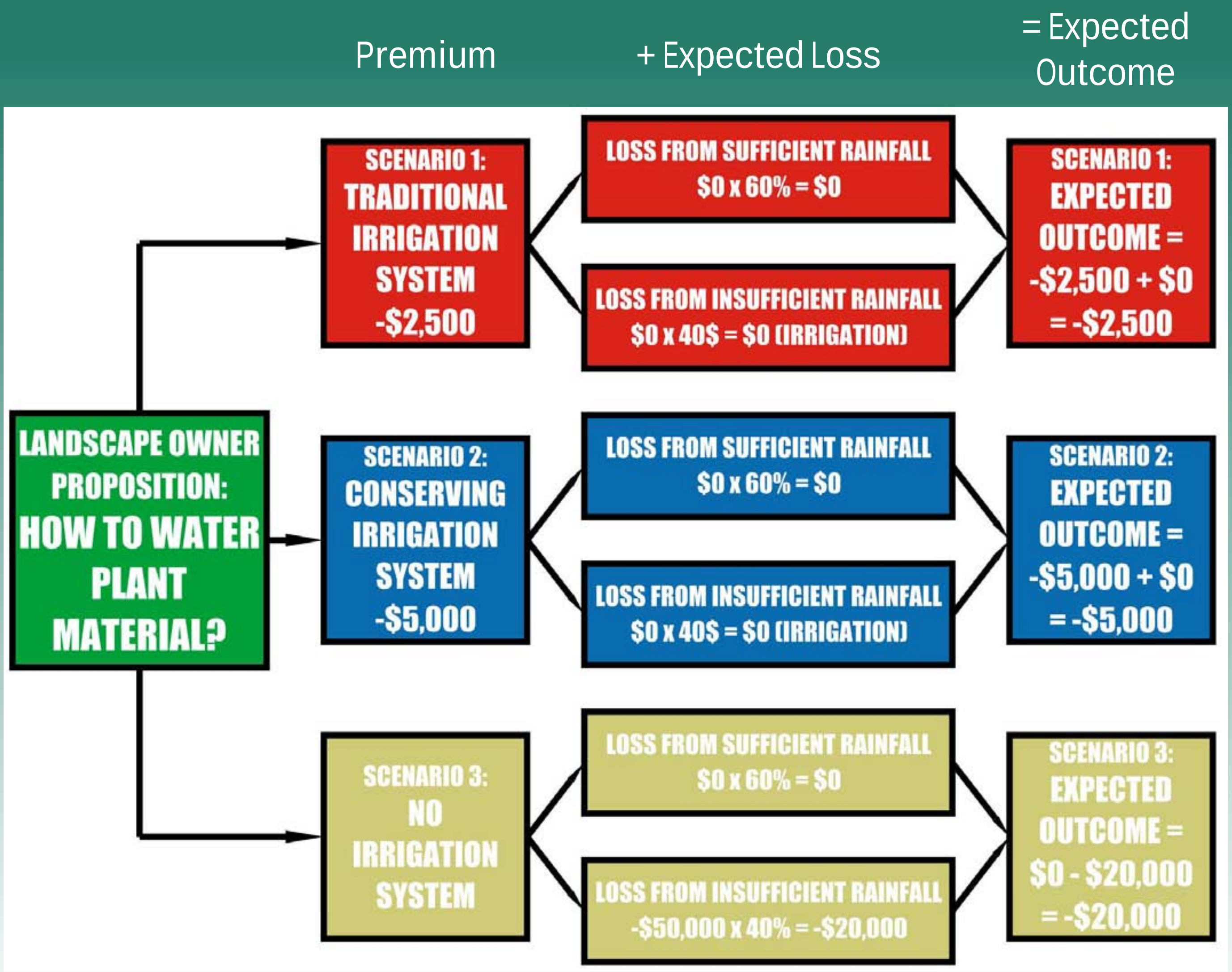


Earth as Insurance Company

Examine the Landscape Owner's "Decision Tree" of Which "Policy" (Irrigation System) to Buy

Value of Landscape to "Insure" = $50,000
$50,000 = "Total Loss"

Traditional Decision Making:
Based Only on Current Costs Using Decision Tree


Premium
+ Expected Loss
= Expected Outcome
LANDSCAPE OWNER PROPOSITION: HOW TO WATER PLANT MATERIAL?
SCENARIO 1: TRADITIONAL IRRIGATION SYSTEM -$2,500
LOSS FROM SUFFICIENT RAINFALL $0 x 60% = $0
LOSS FROM INSUFFICIENT RAINFALL $0 x 40$ = $0 (IRRIGATION)
SCENARIO 1: EXPECTED OUTCOME = -$2,500 + $0 = -$2,500
SCENARIO 2: CONSERVING IRRIGATION SYSTEM -$5,000
LOSS FROM SUFFICIENT RAINFALL $0 x 60% = $0
LOSS FROM INSUFFICIENT RAINFALL $0 x 40$ = $0 (IRRIGATION)
SCENARIO 2: EXPECTED OUTCOME = -$5,000 + $0 = -$5,000
SCENARIO 3: NO IRRIGATION SYSTEM
LOSS FROM SUFFICIENT RAINFALL $0 x 60% = $0
LOSS FROM INSUFFICIENT RAINFALL -$50,000 x 40% = -$20,000
SCENARIO 3: EXPECTED OUTCOME = $0 - $20,000 = -$20,000

Earth as Insurance Company

2 Things to Point Out (Strictly Monetarily)

1. An Irrigation System Should Be Installed (Eliminate Scenario 3: High Expected Loss)
2. If Scenario 1 and 2 BOTH offer Full Insurance, Why Pick Scenario 2 which costs more?
   i.e., Why Pay a Higher Policy Premium?

Earth as Insurance Company

Let's Clarify the Insurance Model Entities Involved: Perceived Model

Insured Policyholder

Insurer

Premium

Policy

Payout

Earth as Insurance Company

Let's Clarify the Insurance Model Entities Involved: Perceived Model

Insured Policyholder

Insurer

Premium: Irrigation Cost

Policy: Irrigation System

Payout: Fresh Water

Landscape Owner

Mother Earth

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Earth as Insurance Company

Perceived Model is Incorrect!
Premium is in $, Payout is in Water

Insured
Policyholder

Insurer

Premium: Irrigation Cost

Policy: Irrigation System

Payout: Fresh Water

Landscape Owner

Mother Earth

Earth as Insurance Company

The Correct Insurance Model:
Insurer Receives No Premiums (Not Sustainable)

Policyholder

$

Insurer

Contractor

???

Landscape Owner

Payout: Fresh Water

Mother Earth

Earth as Insurance Company

From a strict economic sense, there is no incentive to pay more for a policy when one exists that costs less and provides same coverage

Moreover, the WATER COST to the insurer is *zero*. If the cost is zero, then there are no credit constraints for the insured

Violates Theoretical Insurance Model

Mother Earth would go BANKRUPT as an Insurance Company in this example very quickly since no "Revenues" (Water) are taken in

Recall, if EARTH Loses, then LIFE Loses (Must Have Win-Win)

Earth as Insurance Company

There is a Reason Why Some Insurance Companies Like New York Life Have *Sustained* Business for over 100 Years:

An Insurance Company ONLY Offers Policies
Where They EXPECT To Not Lose Money
Expected Outcome of an Offered Policy will be > or = 0

Free Competition Amongst Firms Assures:
Expected Value of Legitimately Offered Policy = 0

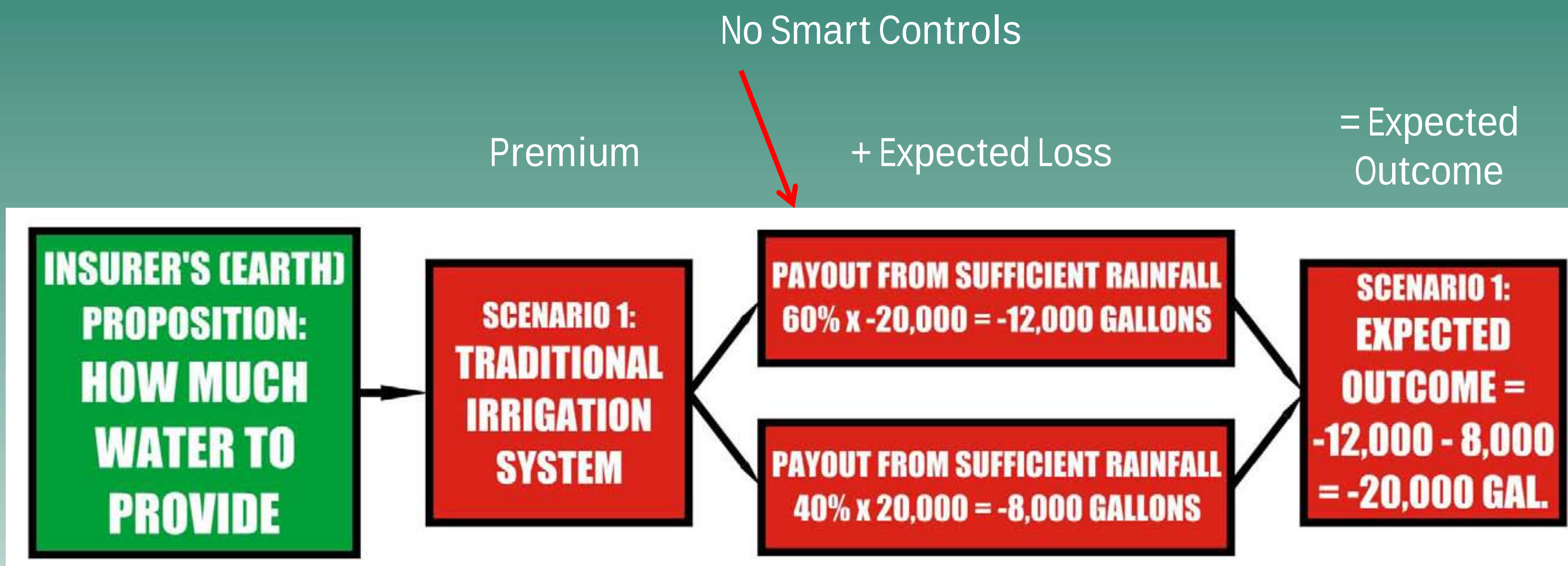
Earth as Insurance Company

Let's Say Landscape Owner Picks Scenario 1:
Traditional Irrigation System = 20,000 gal/year
(Lowest Cost)

Now Examine Earth's (Insurer's) Decision Tree to Offer This Policy

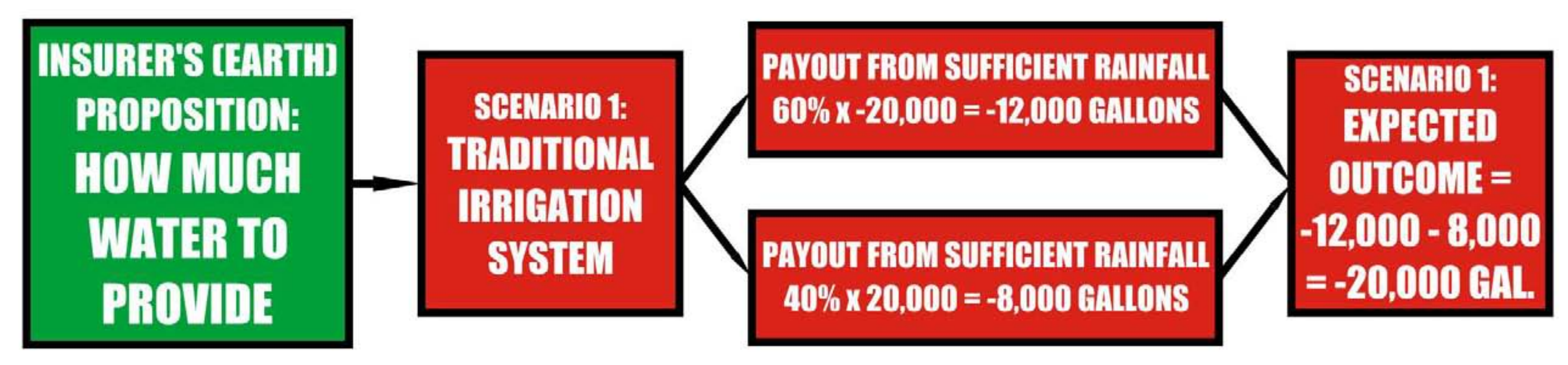
Values are in Gallons of Fresh Water, either:

- Domestic Water (Refined Natural Water)
- Aquifer or Ponds (Raw Natural Water)


No Smart Controls
Premium
+ Expected Loss
= Expected Outcome
INSURER'S (EARTH) PROPOSITION: HOW MUCH WATER TO PROVIDE
SCENARIO 1: TRADITIONAL IRRIGATION SYSTEM
PAYOUT FROM SUFFICIENT RAINFALL
60% x -20,000 = -12,000 GALLONS
PAYOUT FROM SUFFICIENT RAINFALL
40% x 20,000 = -8,000 GALLONS
SCENARIO 1: EXPECTED OUTCOME = -12,000 - 8,000 = -20,000 GAL.

Sustainable Insurance Companies Will <u>NEVER</u> Offer This Policy (Expected Value < 0 at -20,000 Gallons)

Premium | + Expected Loss | = Expected Outcome



Yet, This Scenario Happens More Often than Not

Earth as Insurance Company

Moreover, if 1,000 Traditional Systems are used in a Community, that's 20,000,000 gallons/year!

If Recharge < 20 MG/Year,
Earth Loses & We Lose

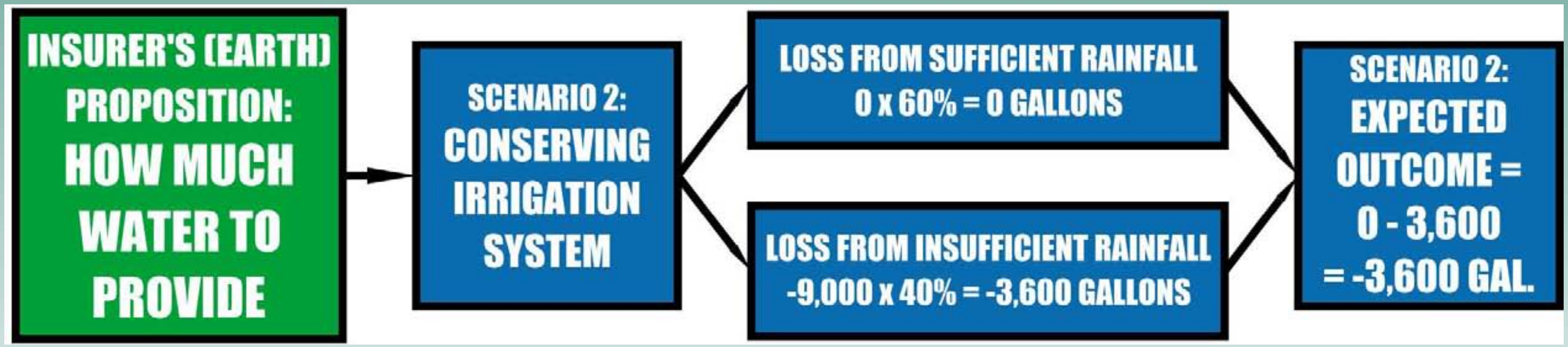
DROUGHT is a Non-Diversifiable Risk That Cannot Be Insured…at least with Full Insurance

Earth as Insurance Company

We Need to Fix the Earth Insurance Model

Examine Scenario 2: Water Conserving System

Using Smart Controls



Still Unacceptable as Expected Outcome < 0

Earth as Insurance Company

What if Earth Required a "Premium" for Irrigation Up to Certain Need? (i.e. Bring Water to the Table)

Premium =
3,600 Gallons of
On-Site Stored Water
Safe for Recharge

Earth as Insurance Company

What if Earth Required a “Premium” for Irrigation Up to Certain Need? (Premium = 3,600 Gal Harvested)

This is a Plausible Full Insurance Policy

Earth as Insurance Company

What if Landscape Owners Also Paid “Deductibles” Covering Smaller Needs Before a Payout by Earth?

Deductible =
1,000 Gallons of
Alternative Water
(On or Off-Site Water)
Before Natural Water Used

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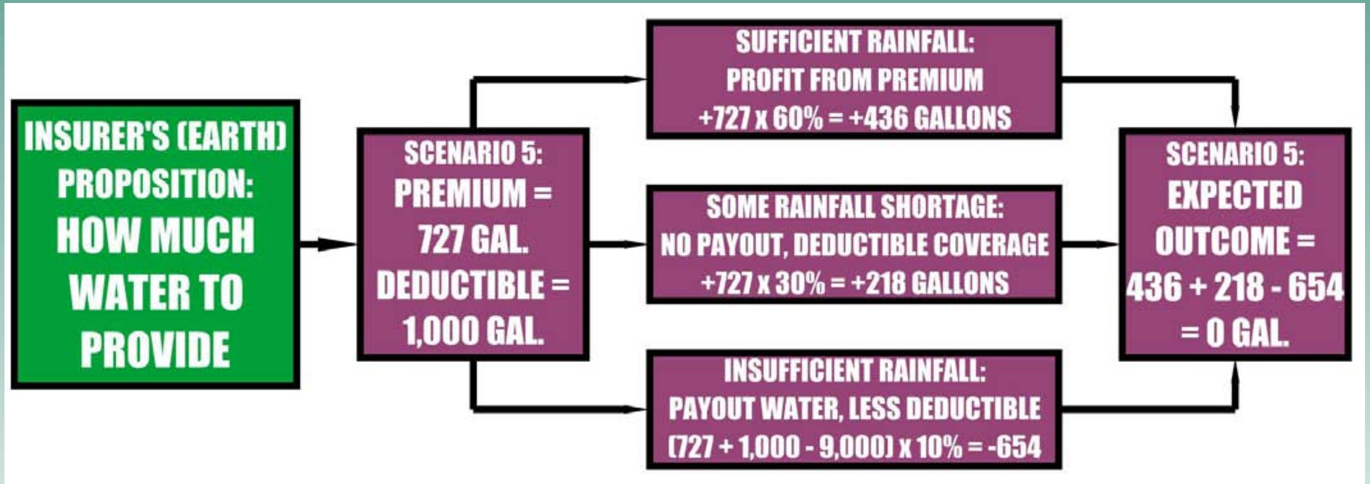
Earth as Insurance Company

What if Landscape Owners Also Paid "Deductibles" Covering Smaller Needs Before a Payout by Earth?



This is a Plausible Incomplete Insurance Policy

(Notice that the Premium is Reduced!)

Earth as Insurance Company

Re-examine the Landscape Owner's Decisions under Correct Insurance Model

Value of Landscape to "Insure" = $50,000
$50,000 = "Total Loss"

Sustainable Economic Decision Making:
Based Only "Total Life Cycle Costs"

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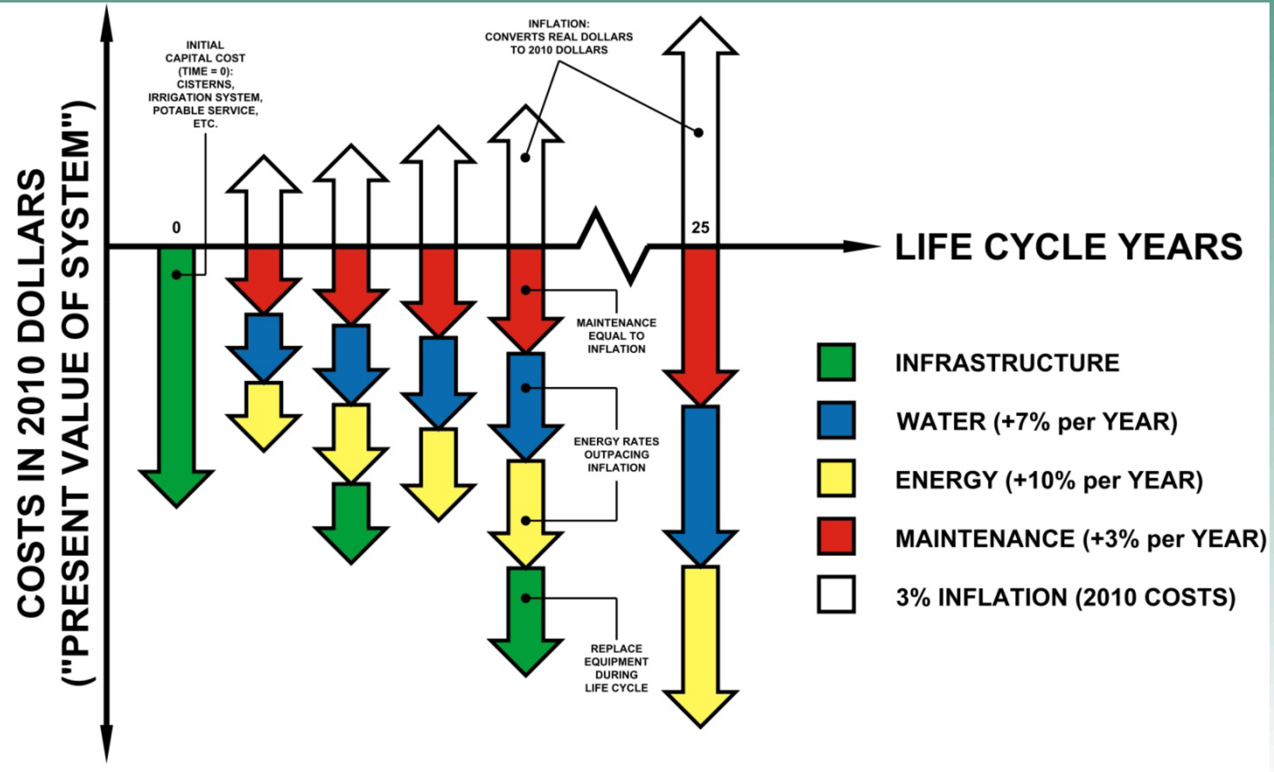
Earth as Insurance Company

Life Cycle Costs Derived from Cash Flow Diagram



Compare Results (Tradeoffs)

Irrigation System Results Comparison	Expected Dollar Cost, $	Expected Water Cost, Gal.
No System	$20,000	0
Greywater System, Full Insurance	$15,000	0
Greywater System, Deductible Paid	$10,000	0
Water Conserving System	$10,000	9,000
Traditional System	$15,000	20,000

Compare Results

Tradeoffs are the Heart of Sustainability and the Reason for a Sustainability Index!

How Do We Compare $ and Gallons?

If We Give Up Something ($ or Gallons),
We Can Maximize Combined Benefits
and Achieve a Win-Win with Earth

Society Dimension

Until Now, we've only considered the Economic and Environmental Dimensions

$ and Gallons of Water

Also Until Now, we've only considered Scenarios that Provide Perfect Plant Health at All Times

Society Dimension

Architects Design and Estimate How Society will USE Landscapes

Designs Must Be Made within Society's Framework

- Laws
- Zoning
- Prescriptive Methods
- Preferences!

Society Dimension

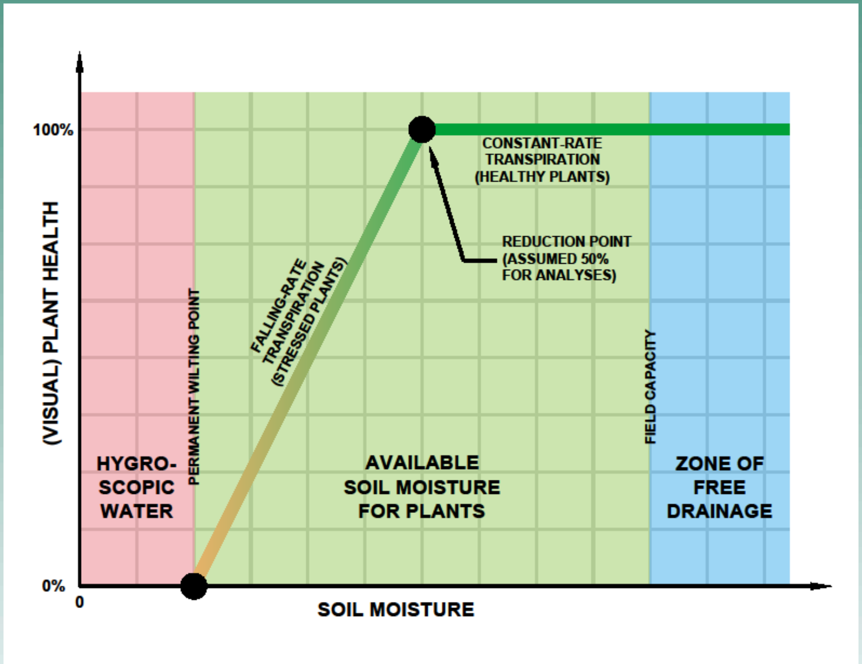
Irrigation Provides a Means for Maintaining Landscape Efficacy within Society (Design Intention)

We Can Measure a Project's Society Dimension through Plant Health & Appearance

Presuming: Social Use drops with Worsening Appearance

Society Dimension

Plant Health is Related to Available Soil Moisture
(Measurable Quantity)

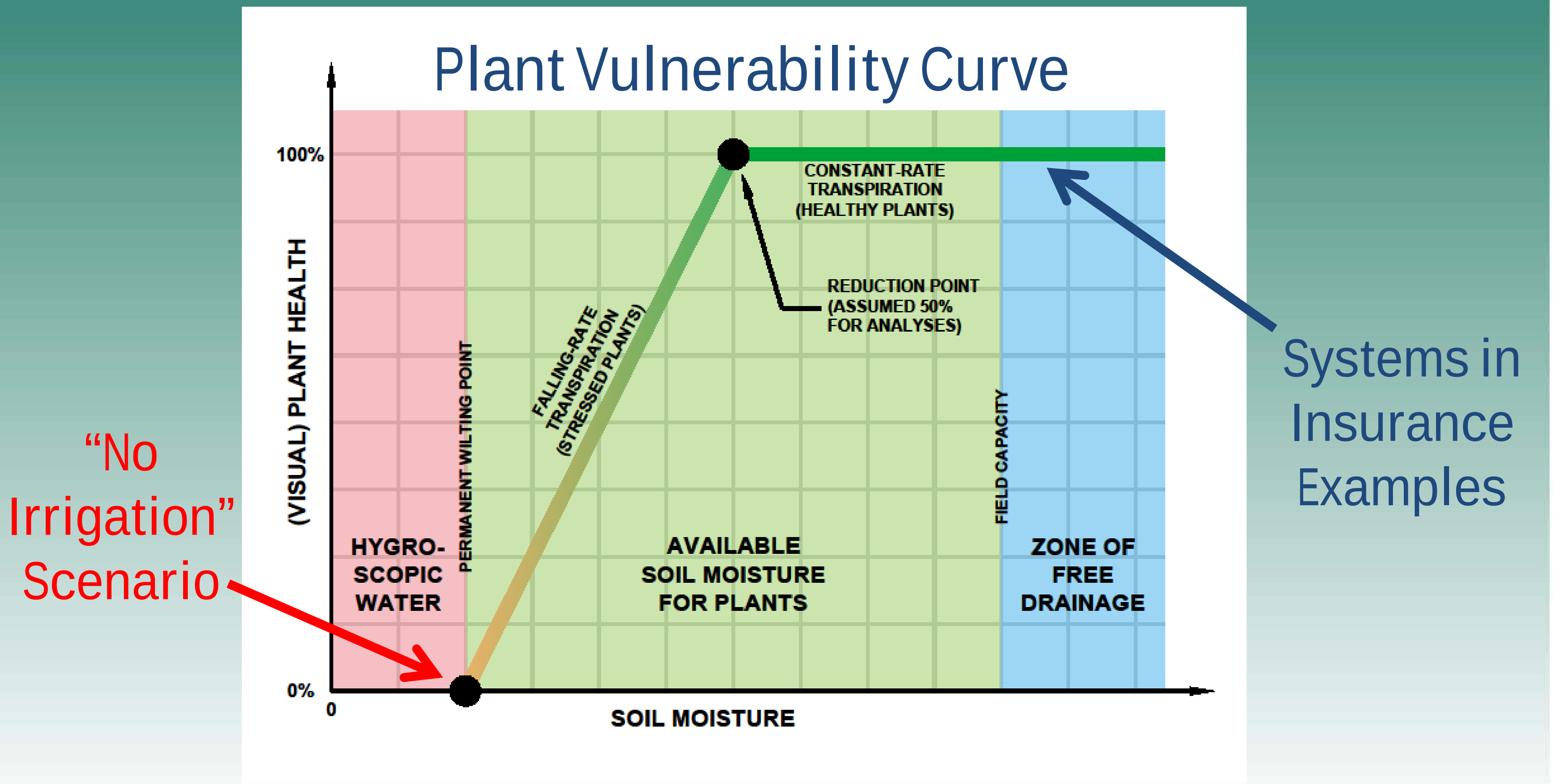


If we know Soil Moisture
(Irrigation Design),
Then we know Plant Health

We Can Estimate:

Plant Health % = Effectiveness = Society Dimension (%)

Society Dimension



Compare Results (Tradeoffs)

Irrigation System Results Comparison	Expected Dollar Cost, $	Expected Water Cost, Gal.	Expected Social Value, %
No System	$20,000	0	60%
Greywater System, Full Insurance	$15,000	0	100%
Greywater System, Deductible Paid	$10,000	0	100%
Water Conserving System	$10,000	9,000	100%
Traditional System	$15,000	20,000	100%

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Standardization

We Have 3 Dimensions in 3 Different Units:

- Economy = Dollars
- Society = Percent of Plant Appearance
- Environment = Gallons of Water

To Have 1 Sustainability Index, We Need to Combine These Expected Outcomes Somehow (Standardization Process)

Standardization

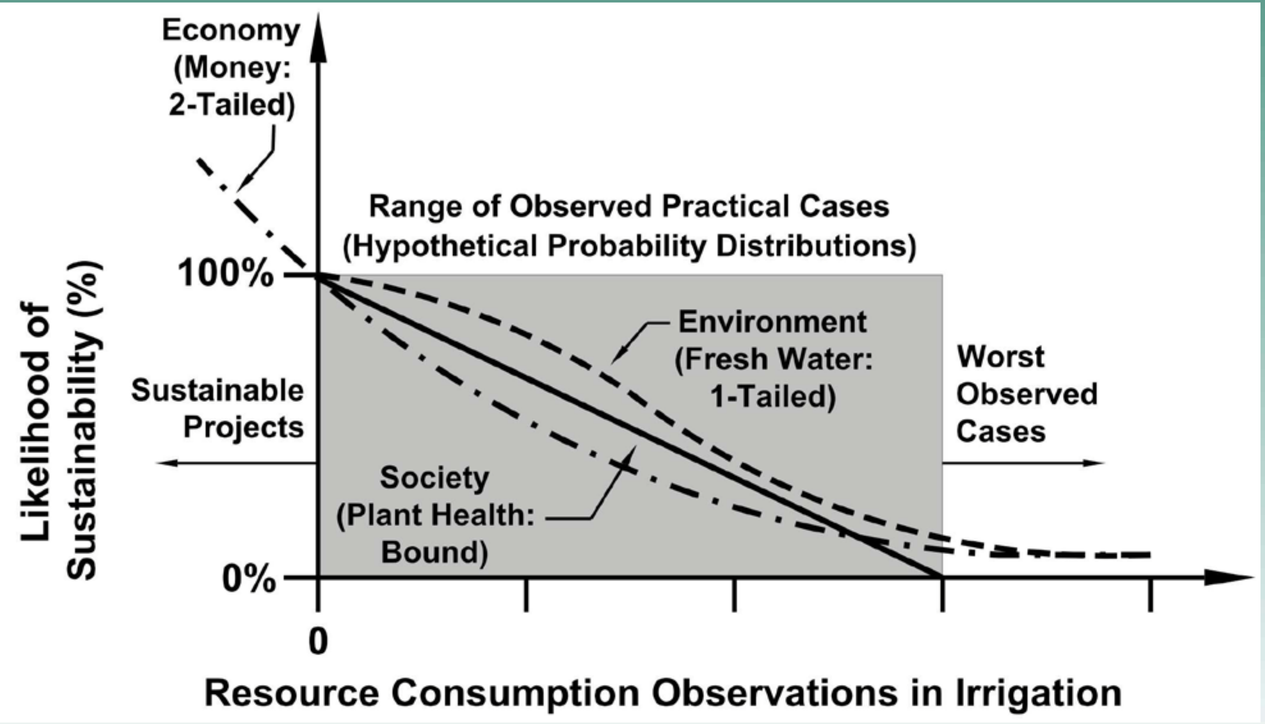
Examine the Range of Observed Practical Cases

BEST CASE SCENARIOS:

Economy:
Positive Return on Investment ($0 Cost)

Society:
100% Plant Health

Environment
No Fresh Water Used



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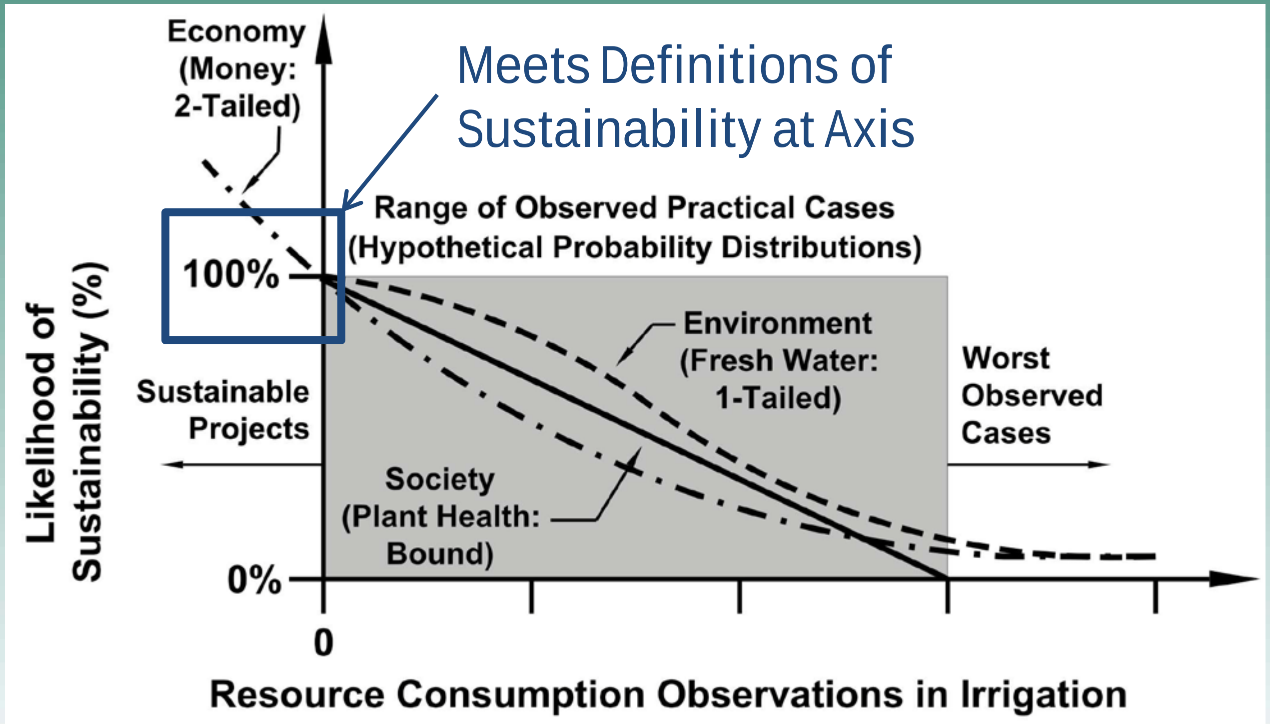
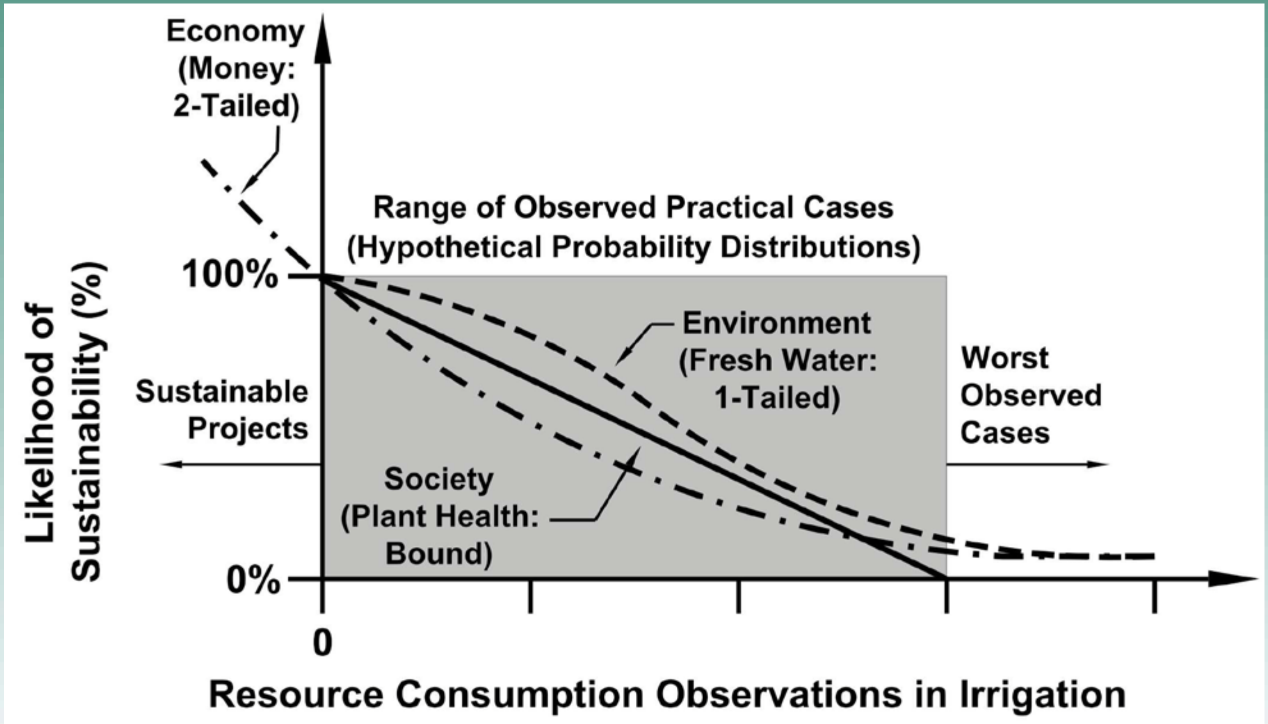


Standardization

Examine the Range of Observed Practical Cases



WORST OBSERVED CASE SCENARIOS:

Economy: Total Loss of Landscape Value

Society: 0% Health, i.e., Dead Plants

Environment: Extreme Waste of Water (No Smart Controls or Uniformity Considered)

Standardization

Standardization of Possible Outcomes from 0 to 1

BEST OBSERVED CASE SCENARIOS = 0
Zero Resource Consumption:
CERTAINLY SUSTAINABLE (Deterministic Outcome)

WORST OBSERVED CASE SCENARIOS = 1
Maximum (100% Possible) Resource Consumption:
CERTAINLY NOT SUSTAINABLE (Deterministic Outcome)

Standardization

Raw Data

Irrigation System Results Comparison	Expected Dollar Cost, $	Expected Water Cost, Gal.	Expected Social Value, %
Worst Case Scenarios	$50,000	20,000	0%
No System	$20,000	0	60%
Greywater System, Full Insurance	$15,000	0	100%
Greywater System, Deductible Paid	$10,000	0	100%
Water Conserving System	$10,000	9,000	100%
Traditional System	$15,000	20,000	100%
Best Case Scenarios	$0	0	100%

Standardization

Standardized Data

Irrigation System Results Comparison	Expected Dollar Cost, $	Expected Water Cost, Gal.	Expected Social Value, %
Worst Case Scenarios	1.00	1.00	1.00
No System	0.40	0.00	0.40
Greywater System, Full Insurance	0.30	0.00	0.00
Greywater System, Deductible Paid	0.20	0.00	0.00
Water Conserving Domestic System	0.20	0.45	0.00
Traditional Domestic System	0.30	1.00	0.00
Best Case Scenarios	0.00	0.00	0.00

Aggregation (Combining Values)

Aggregate Data of Similar Bases

Irrigation System Results Comparison	Expected Dollar Cost, $	Expected Water Cost, Gal.	Expected Social Value, %	Aggregate Values
Worst Case Scenarios	1.00	1.00	1.00	3.00
No System	0.40	0.00	0.40	0.80
Greywater System, Full Insurance	0.30	0.00	0.00	0.30
Greywater System, Deductible Paid	0.20	0.00	0.00	0.20
Water Conserving Domestic System	0.20	0.45	0.00	0.65
Traditional Domestic System	0.30	1.00	0.00	1.30
Best Case Scenarios	0.00	0.00	0.00	0.00

Simplified Analysis

BEST OBSERVED CASE SCENARIO AGGREGATE SCORE = 0
Zero Resource Consumption:
CERTAINLY SUSTAINABLE (Deterministic Outcome)

WORST OBSERVED CASE SCENARIO AGGREGATRE SCORE = 3
Maximum Resource Consumption:
CERTAINLY NOT SUSTAINABLE (Deterministic Outcome)

Simplified Analysis

TYPICAL CASE SCENARIOS AGGREATES BETWEEN 0 AND 3
Between Definitely Yes and No on Sustainability
(Probabilistic Outcome based on Expectation)

If Scenario A Index < Scenario B Index
Then Scenario A is MORE LIKELY to be Sustainable
Compared to Scenario B because
Overall Resource Consumption is Less

Simplified Analysis

CASE SCENARIOS AGGREGATES BETWEEN 0 AND 3
Between Definitely Yes and No on Sustainability
(Probabilistic Outcome based on Expectation)

Irrigation System Results Comparison	Expected Dollar Cost, $	Expected Water Cost, Gal.	Expected Social Value, %	Aggregate Values
Worst Case Scenarios	1.00	1.00	1.00	3.00
No System	0.40	0.00	0.40	0.80
Greywater System, Full Insurance	0.30	0.00	0.00	0.30
Greywater System, Deductible Paid	0.20	0.00	0.00	0.20
Water Conserving Domestic System	0.20	0.45	0.00	0.65
Traditional Domestic System	0.30	1.00	0.00	1.30
Best Case Scenarios	0.00	0.00	0.00	0.00

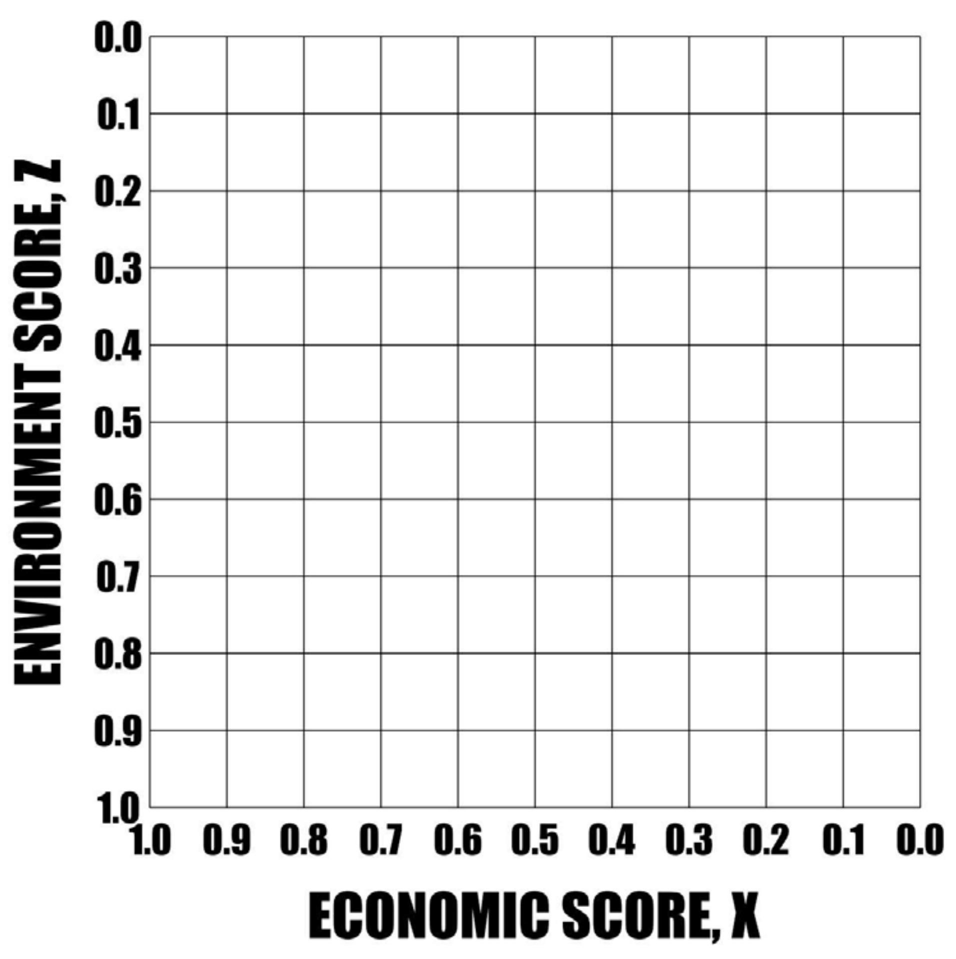
Simplified Analysis

Aggregate Value = Sustainability Index, S

$$S = X + Y + Z$$

Irrigation System Results Comparison	X: Expected Dollar Cost, $	Y: Expected Water Cost, Gal.	Z: Expected Social Value, %	S: Aggregate Values
Worst Case Scenarios	1.00	1.00	1.00	3.00
No System	0.40	0.00	0.40	0.80
Greywater System, Full Insurance	0.30	0.00	0.00	0.30
Greywater System, Deductible Paid	0.20	0.00	0.00	0.20
Water Conserving Domestic System	0.20	0.45	0.00	0.65
Traditional Domestic System	0.30	1.00	0.00	1.30
Best Case Scenarios	0.00	0.00	0.00	0.00

Selecting a System



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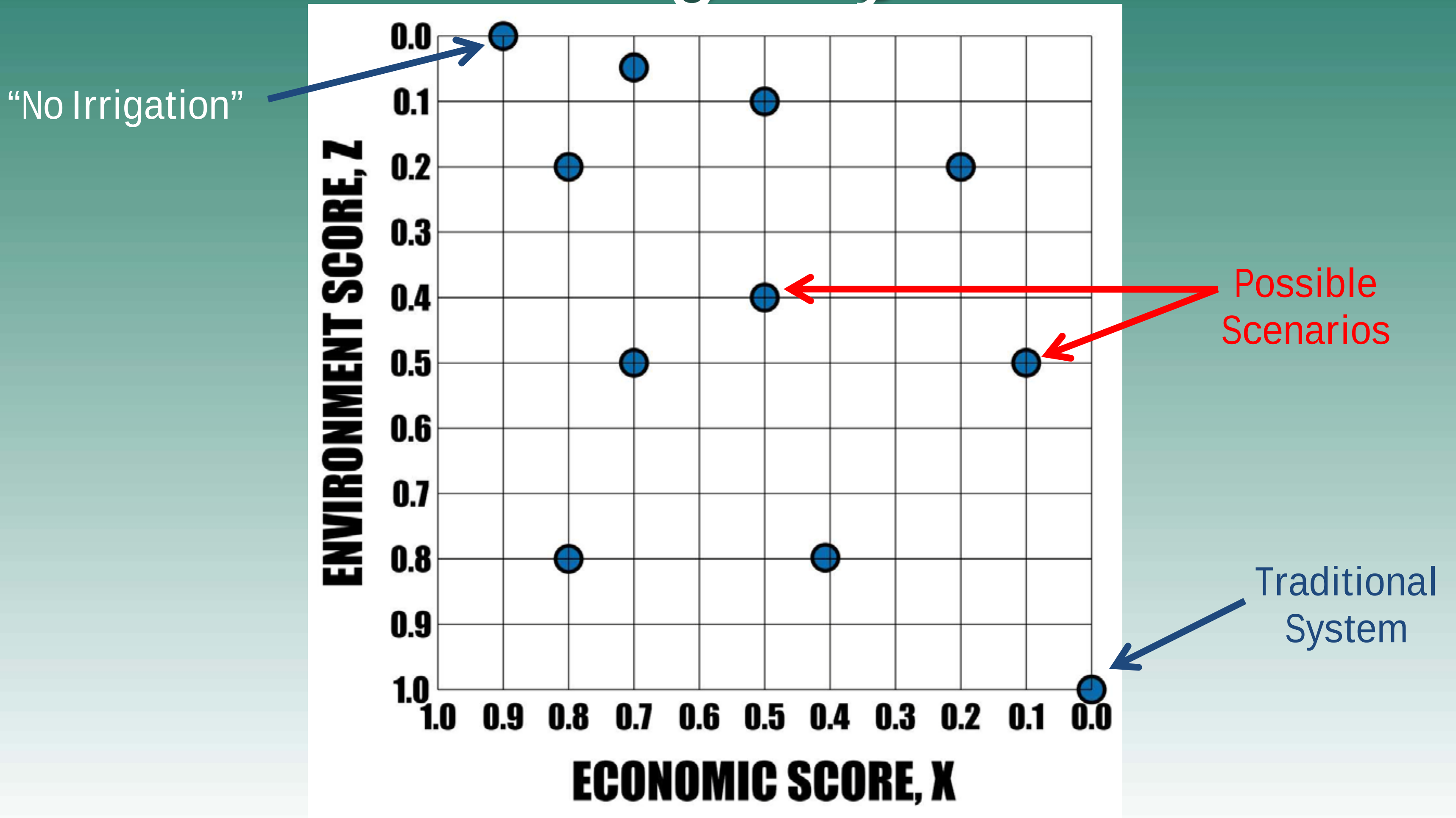

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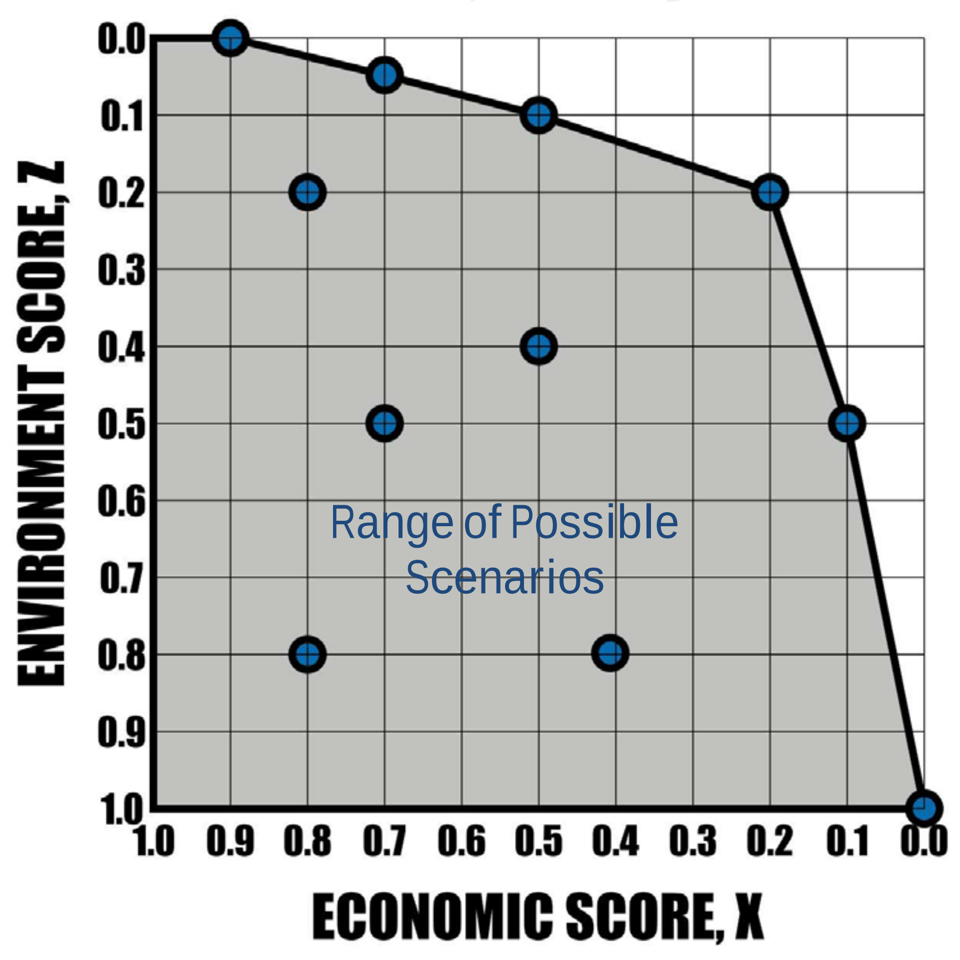

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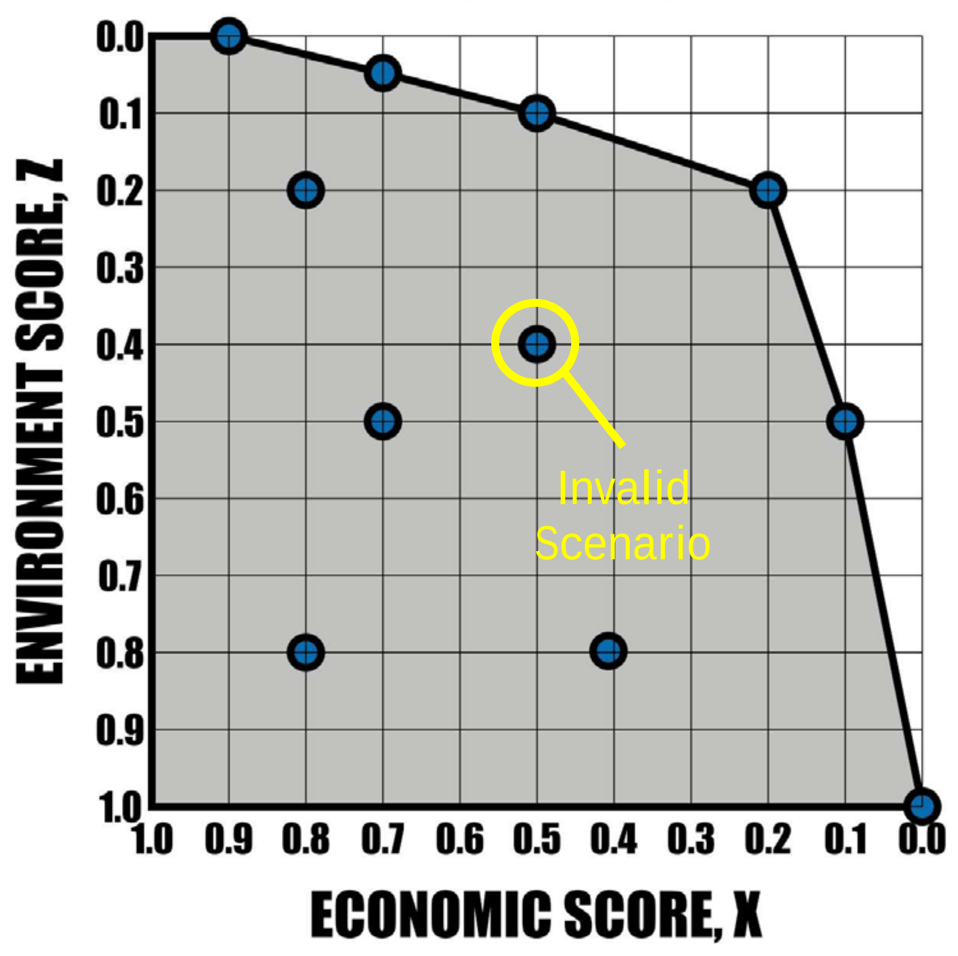

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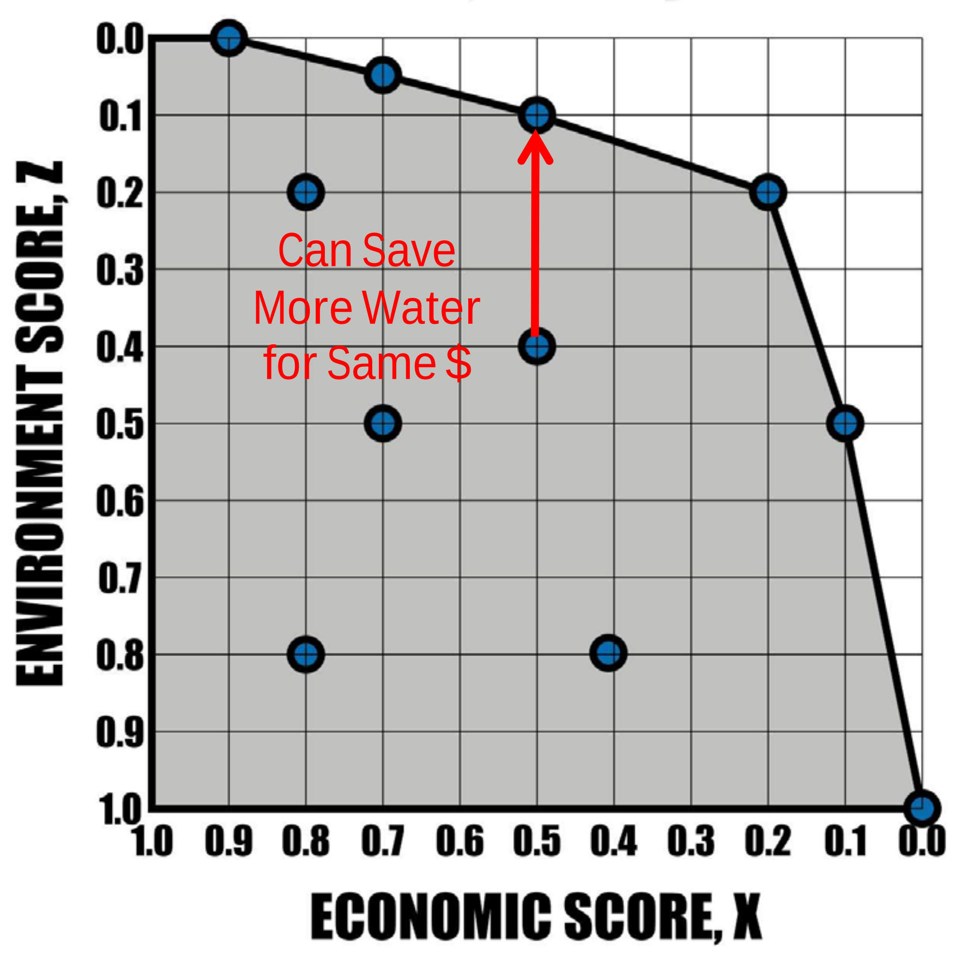

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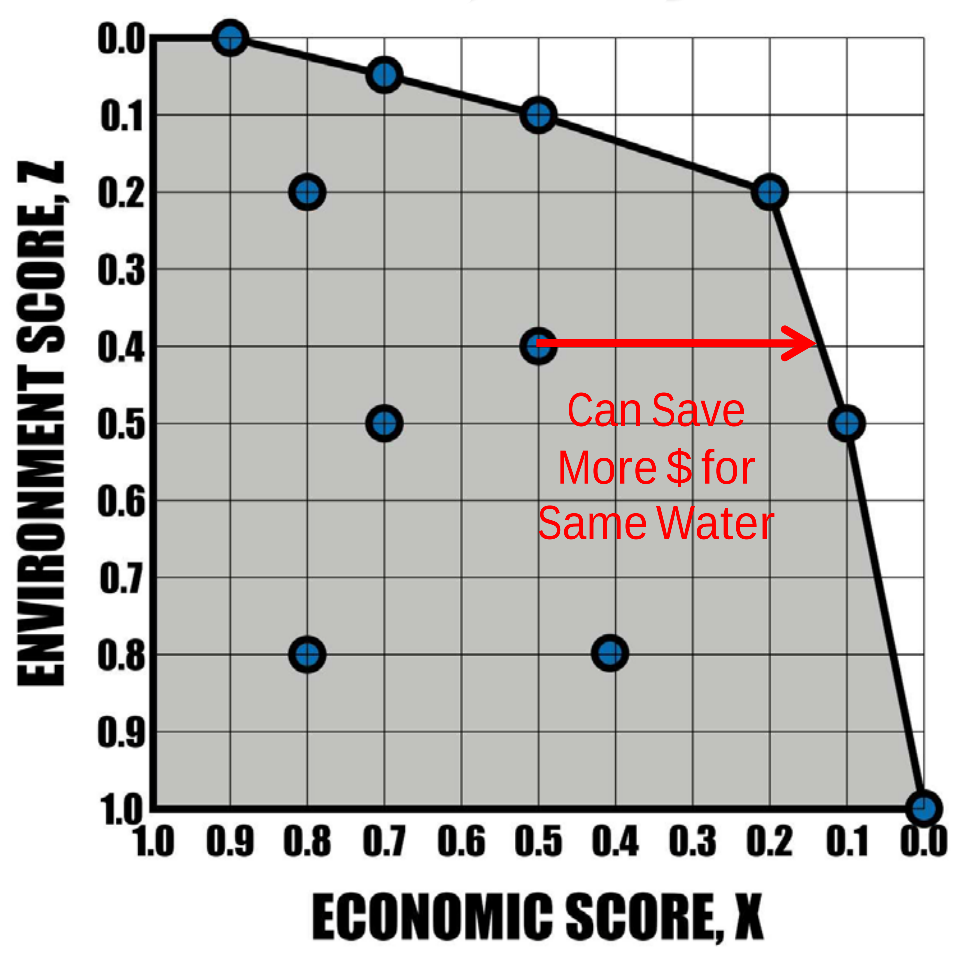

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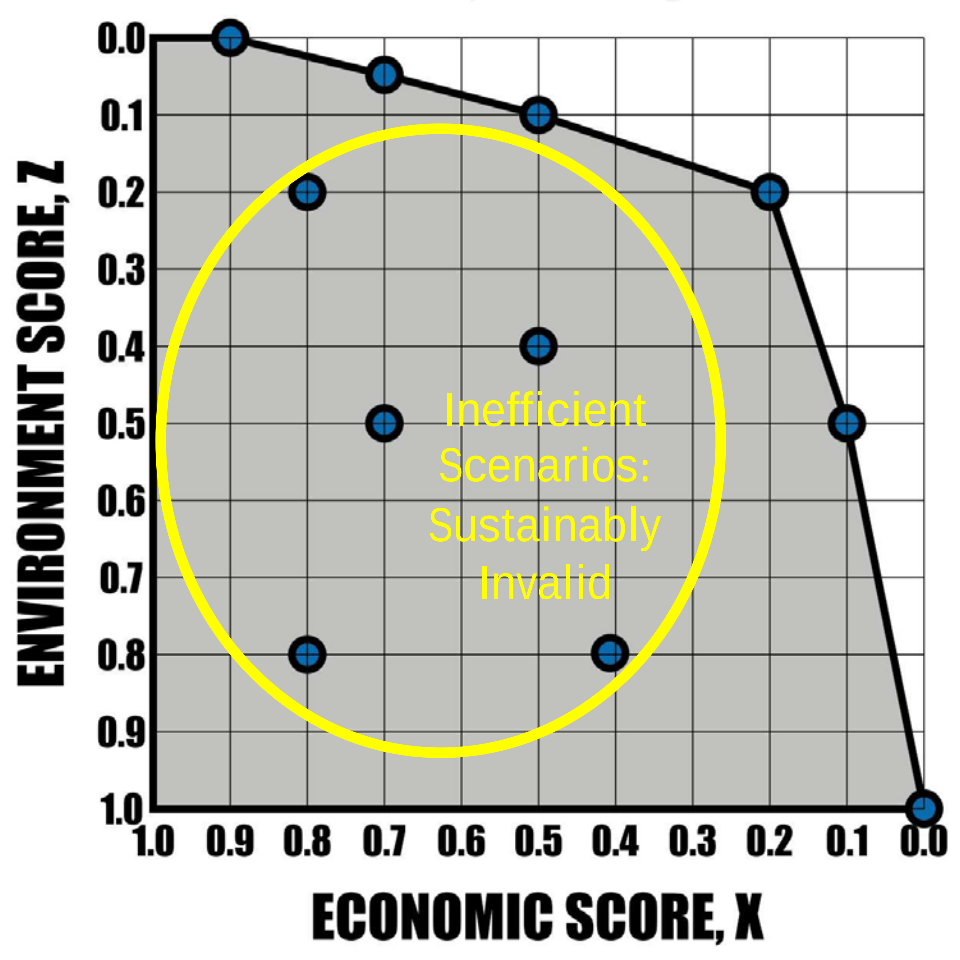

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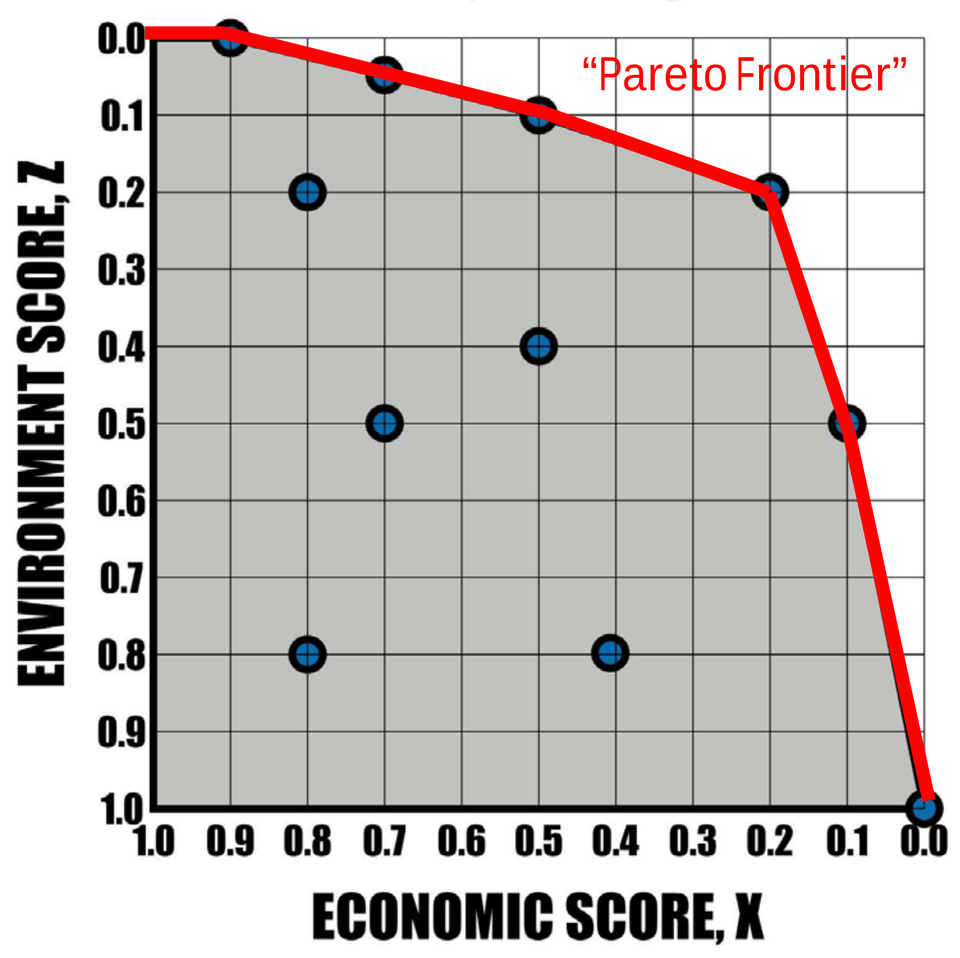
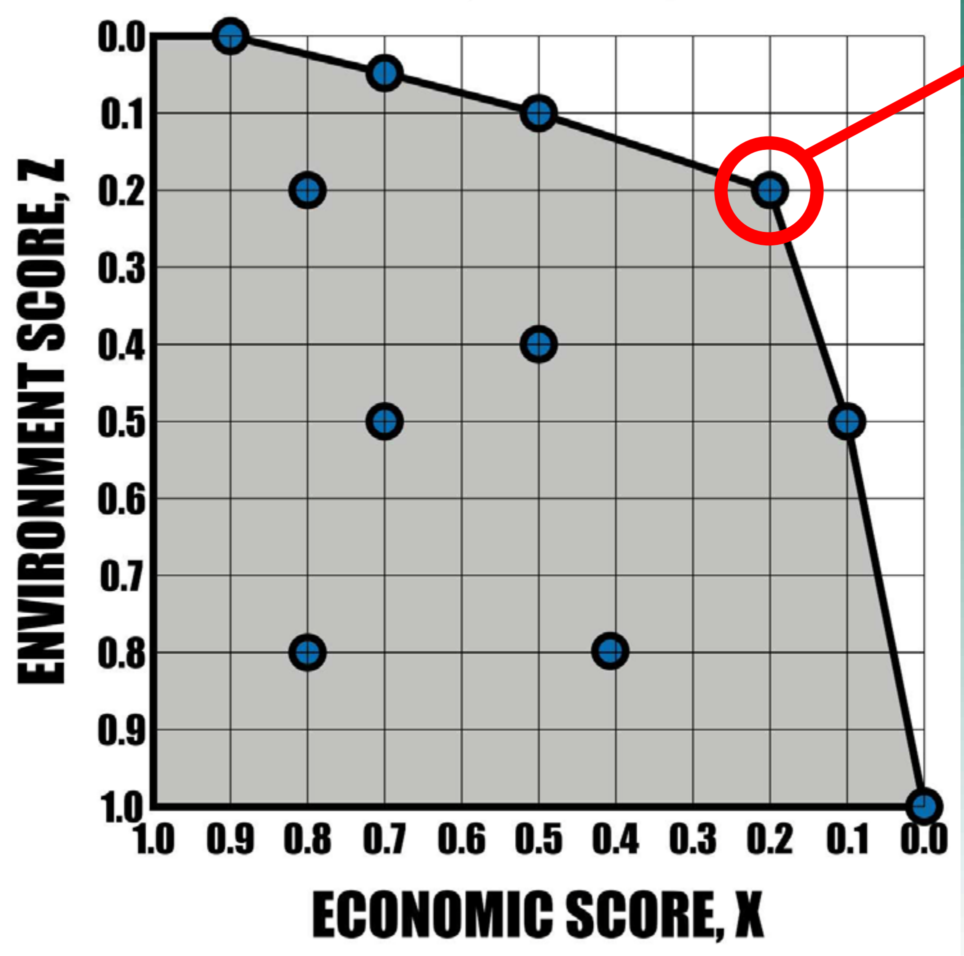


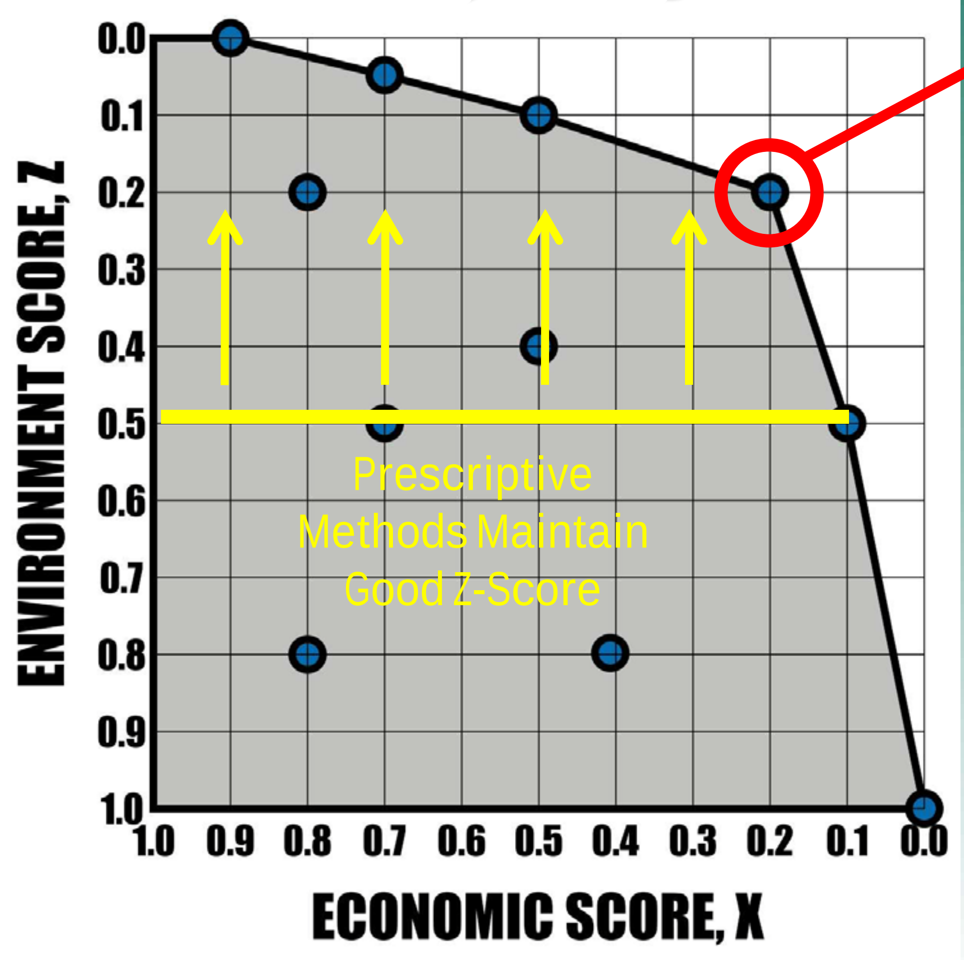
"Pareto Efficient" Scenarios Exhibit REAL TRADEOFFS

Selecting a System



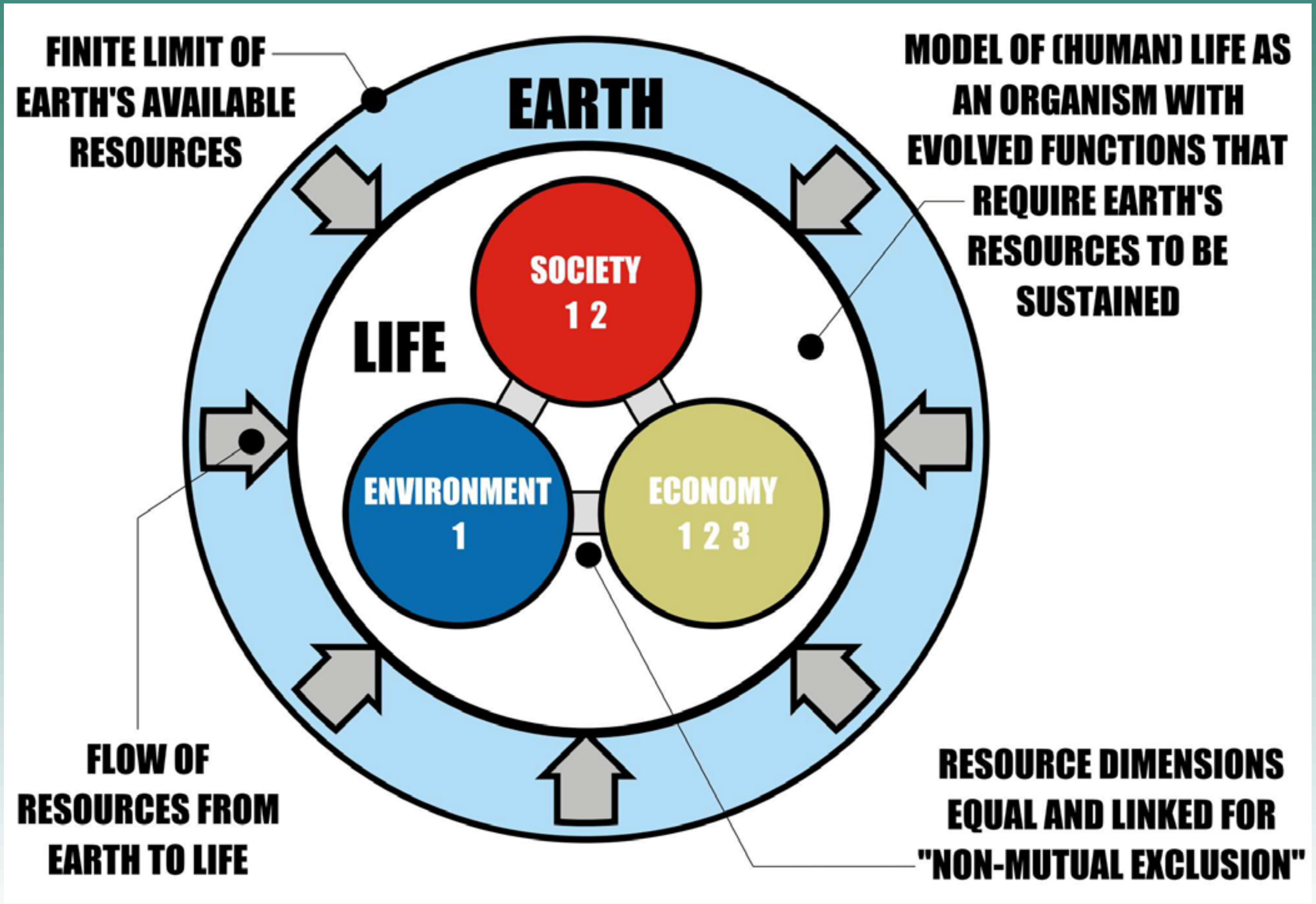
Select the System with Highest TOTAL Benefit (Score) on Pareto Frontier

Selecting a System

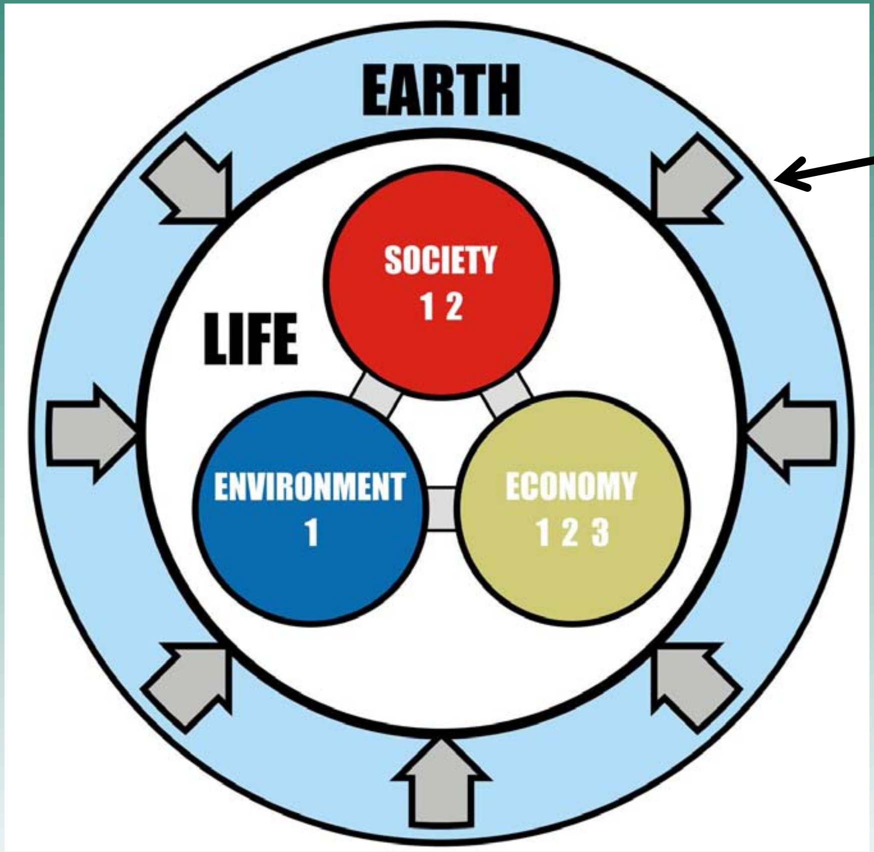


Select the System with Highest TOTAL Benefit (Score) on Pareto Frontier

Conceptualizing Index to Model

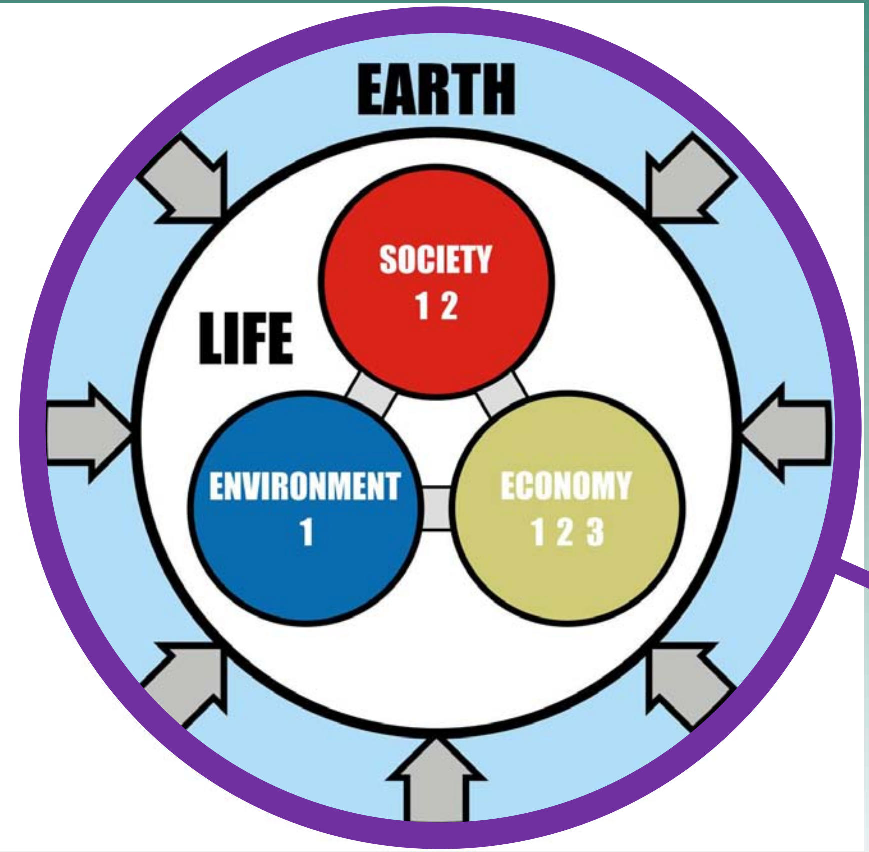


Conceptualizing Index to Model



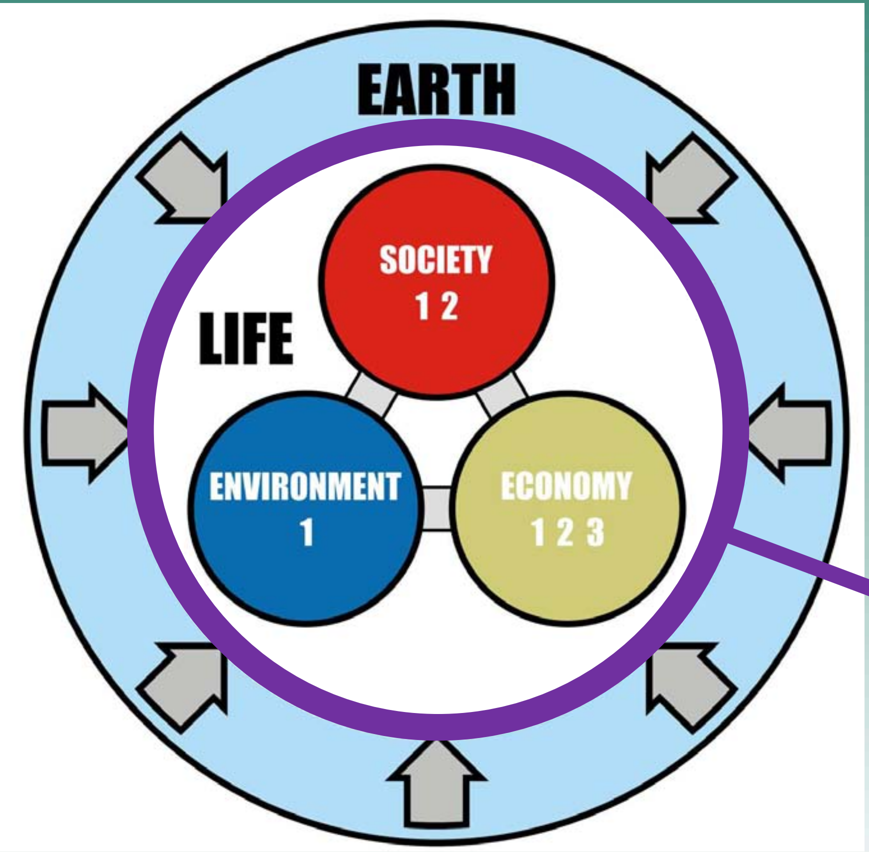
Earth's Available Resources are Finite and Decreasing over Time

Conceptualizing Index to Model



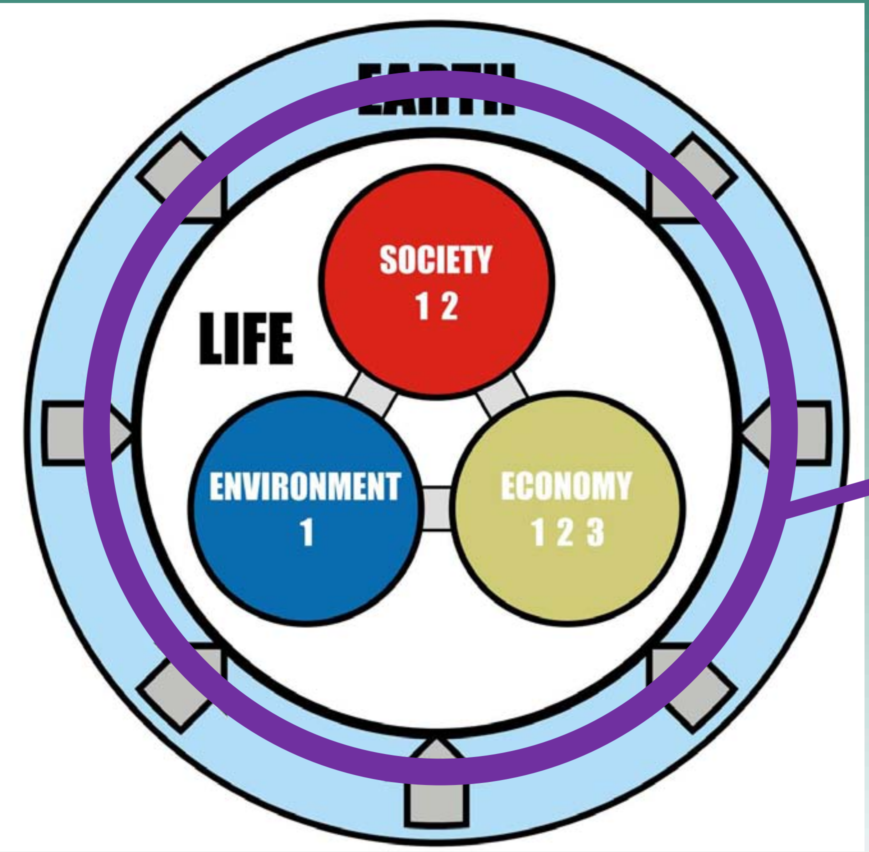
S = 3 (Worst Case)
Is a Maximum Radius
Requiring All
Available Resources
for LIFE (Project) to be
Sustained

Conceptualizing Index to Model



S = 0 (Best Case)
Is a Minimum Radius
Requiring
No Available Resources
for LIFE (Project) to be
Sustained

Conceptualizing Index to Model



S between 0 and 3 = Requires Some Resources to be Sustained: Pick the Smallest Score, Radius, and/or Need for Resources

THE SMALLER THE RADUIS, THE HIGHER THE PROBABILITY OF A PROJECT'S SUSTAINABILITY

Summary

This Presentation is ONE METHOD or ATTEMPT for Measuring the Likelihood of Sustainability

Mathematics is the Universal Language:
It may be possible to Overcome Communication Gaps in Sustainability by taking a More Rigorous Approach (through Standardization and Aggregation)

Summary

In Deterministic Systems (Prescriptive Methods), there are OUTRIGHT Winners and Losers:

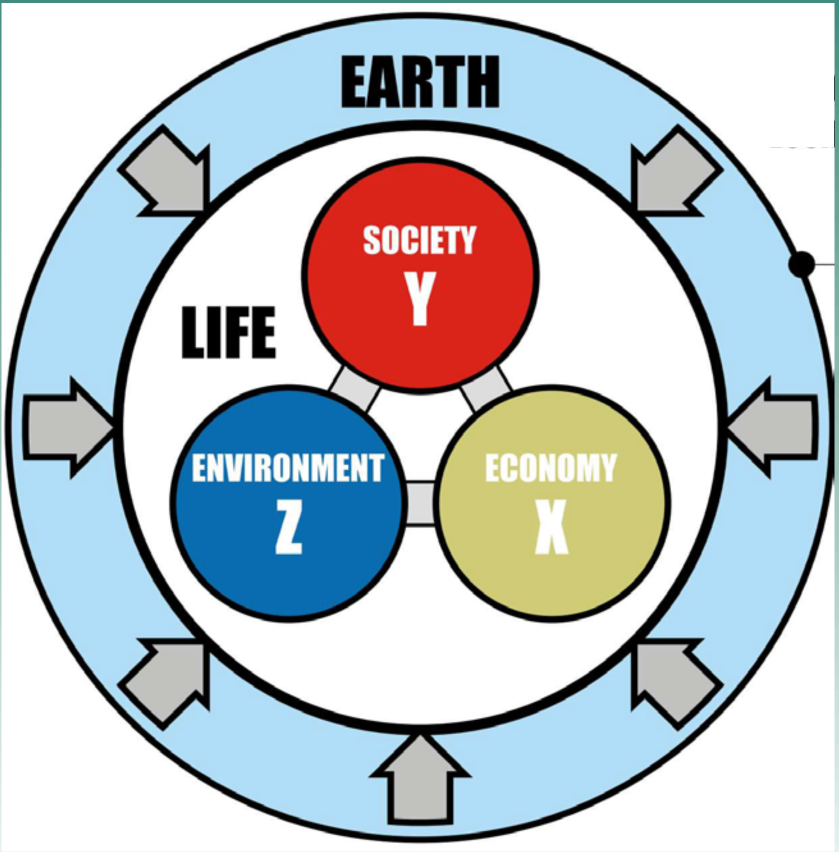
WHY Does it Have to Be This Way?

There are Existing Non-Zero Sum Game Systems (such as Insurance) to Model Sustainability After so that we can:

Achieve a WIN-WIN Scenario

Questions ?

S = X + Y + Z



Thank You!

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