TEQIP-III Short Course on Systems Analysis of Biofuels and Bioproducts

Module 1: Systems analysis and overview

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Goals of this Course

Provide a working knowledge of tools to perform technical feasibility analysis, economic viability analysis, environmental risk assessment, resource sustainability assessment and life cycle assessment (LCA).

Learning Objectives

By the end of this course, you must be able to:

1. Describe various aspects of sustainability.
2. Evaluate technical feasibility.
3. Assess economic viability.
4. Evaluate the environmental impacts of a given product/process using the life cycle impact assessment method.

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Course Schedule

1. Module 1: Systems analysis and overview (7th Dec)
2. Module 2: Technical Feasibility and Resource Sustainability (8th Dec)
3. Module 3: Techno-economic Analysis (9th Dec)
4. Module 4: Life Cycle Assessment (10 and 11th Dec)
5. Practice Session: (12th Dec. ***2:00-7:00 pm***)
6. Module 5: Policy and Social aspects (14th Dec)
7. Module 6: Expert lectures (15, 16 and 17th Dec)
8. Module 7: Resilience thinking, Conclusion (18th Dec)

Class Timings:
- 5:00-7:30 pm (IST) everyday Except 12th Dec. (Saturday)
- No class on 13th Dec (Sunday)

Exam on 16th Dec. Completely online, take home open book exam.
- Scoring a minimum of 60% in the exam is necessary for obtaining **completion certificate**. There will be no other types of certificates.

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Motivation to Teach this Course

Where are biofuels produced in the world?

Source: The International Renewable Energy Agency (IRENA)
https://energypost.eu/biofuels-slump-in-investment-and-innovations-must-be-reversed/

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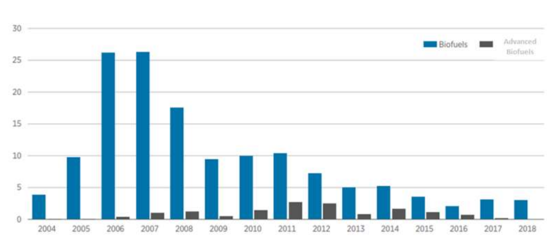
Motivation to Teach this Course

Investments into the Biofuels industry



Source: The International Renewable Energy Agency (IRENA)
https://energypost.eu/biofuels-slump-in-investment-and-innovations-must-be-reversed/

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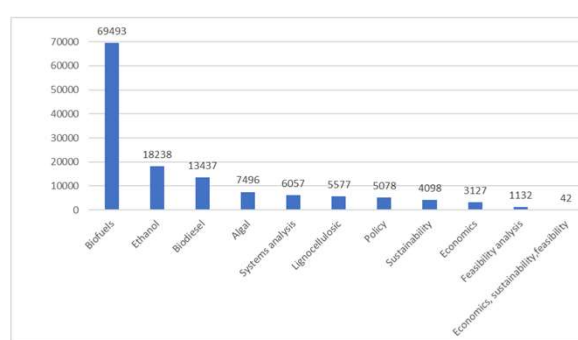
Motivation to Teach this Course

Publications related to biofuels (2000-2020) in Scopus



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Motivation to Teach this Course

Glen kertz grows algae in bags suspended in a greenhouse. Oil is extracted and turned into biofuel. The yield, according to Kertz, is 100,000 gallons of algae fuel per acre per year. Corn, Kertz says, yields 20 to 30 gallons.

BIOFUELS

8,571,428 Gallons of Algae Oil Per Acre!

BARD Algae says it can squeeze thousands of times more oil out of an acre of algae than others. Competitors and scientists are skeptical.

ERIC WESOFF | NOVEMBER 09, 2009

8,571,428 Gallons of Algae Oil Per Acre!

Biofuel from algae

It is reported that algae yield 30 times more energy per acre than land crops such as soybeans and some estimate even higher yields up to 15000 gallons per acre. It keeps the earth clean and free from pollution as these algal biodiesel fuels

than 60 per cent of their own biomass) of lipids. Microalgae have the highest oil yield among various oil plants. It can produce up to 100,000 lts oil per hectare per year, whereas palm, coconut, castor and sunflower produce up to 5950, 2689, 1413 and 9521 per hectare per year, respectively.

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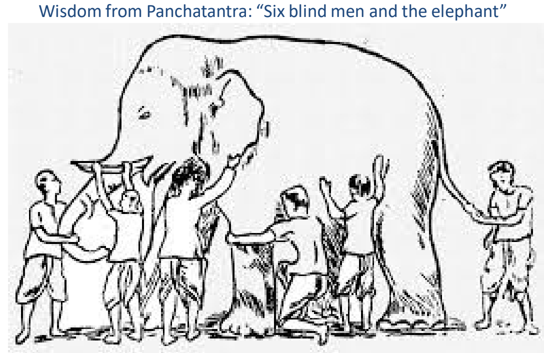
Motivation to Teach this Course

Wisdom from Panchatantra: "Six blind men and the elephant"



Source: https://jainworld.com/education/jain-education-material/jain-stories/elephant-and-the-blind-men/

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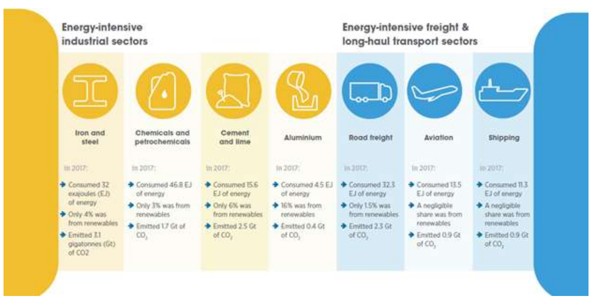
Motivation to Teach this Course

"Seven energy-intensive industry and transport sectors will account for 38% of emissions and 43% of final energy use by 2050"



Source: IRENA (2020), Reaching zero with renewables: Eliminating CO2 emissions in industry and transport
https://energypost.eu/decarbonising-end-use-sectors-buildings-transport-industry-which-strategies-are-bes

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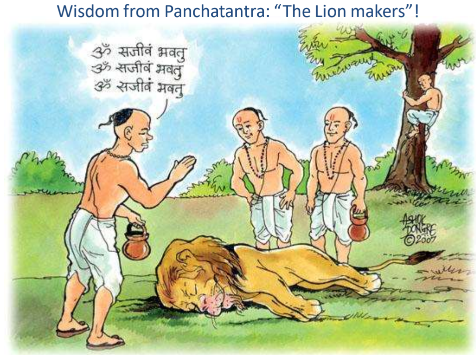
Motivation to Teach this Course

Wisdom from Panchatantra: "The Lion makers"!



Source: epanchatantra.com

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Goals of this Lecture

Understand the importance of Systems Approach

Learning Objectives

By the end of this lecture, you must be able to:

1. Describe what is systems approach
2. Explain why we need Systems Approach to study biofuels and bioproducts.

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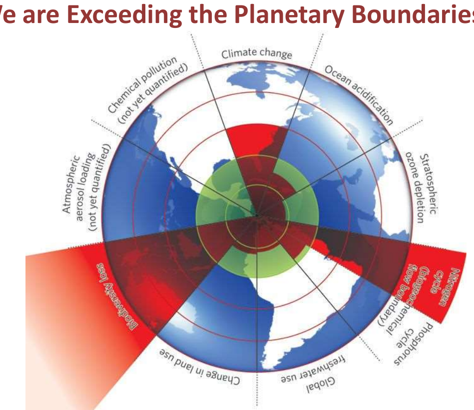
We are Exceeding the Planetary Boundaries



https://www.nature.com/articles/461472a

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Why do we need a Systems Approach?

- A resource constrained world
- Human activities have significant impact on earth processes
- Earth is a complex system
- Linear, simplistic solutions lead to unforeseen problems
- Nexus perspective helps in developing strategies to address complex problems in an uncertain, information deficient and multi-objective scenarios

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Why do we need Systems Analysis?

Goals → Problem → Decision → Results
Situation → Problem

"Systems Thinking is the art and science of linking structure to performance, and performance to structure—often for purposes of changing structure (relationships) so as to improve performance" – Richmond (1994)

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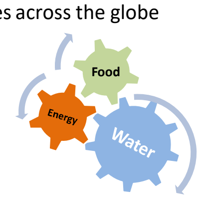
Food-Energy-Water Nexus

- Emerging (Re)recognition of Food-energy-water nexus
  - Has a long history going back to the first UN conference on water in Mar del Plata in 1977.
  - Needs to be understood from a wider perspective of resource and social inequalities across the globe
  - Irrigated agriculture, energy production and urban fresh water usage are three major contributors to overall water usage.



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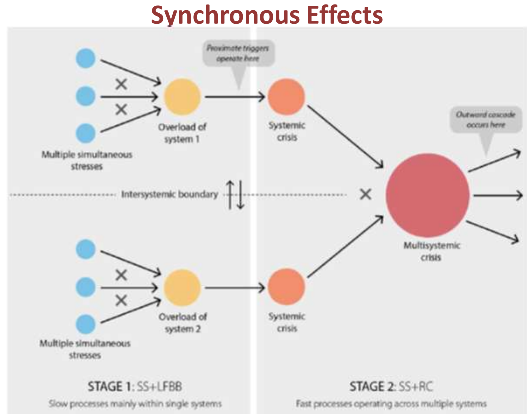
Synchronous Effects



Ref: Homer-Dixon et al. 2015

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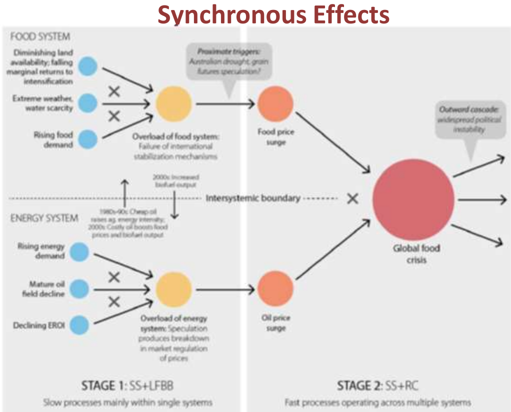
Synchronous Effects



Ref: Homer-Dixon et al. 2015

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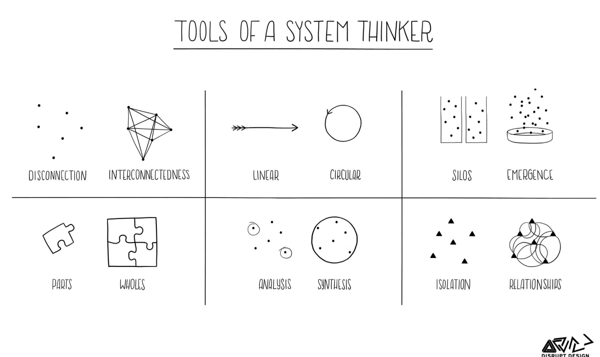
Systems Thinking



Source: https://medium.com/@leyla_Acaroglu

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Why do we need Systems Analysis for Sustainability?

The Behavior Analyst 2011, 34, 245–266 No. 2 (Fall)

In Response

Can We Consume Our Way Out of Climate Change?
A Call for Analysis

Lyle K. Grant
Athabasca University

Four classes of solutions based on:
- Consumption
- Culture
- Regulatory
- Dissemination

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The End of Sustainability??

Society and Natural Resources, 27:777–782
Copyright © 2014 Taylor & Francis Group, LLC
ISSN: 0894-1920 print/1521-0723 online
DOI: 10.1080/08941920.2014.901467

Routledge
Taylor & Francis Group

Policy Review

The End of Sustainability

MELINDA HARM BENSON
Department of Geography & Environmental Studies, University of New Mexico, Albuquerque, New Mexico, USA

ROBIN KUNDIS CRAIG
S. J. Quinney College of Law, University of Utah, Salt Lake City, Utah, USA

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Aspects of Sustainability

- Sustainability: Many definitions
- Definition of sustainability
- Various aspects of sustainability
- Sustainability metrics
- Systems analysis for assessing sustainability
- Different sustainability indicators.
- Precautionary Principle

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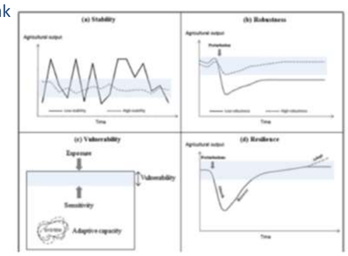
Some Terminology

- Sustainability:
  Latin *sub* (from below) *tenere* (to hold)→ *sustinere*: hold/support
- Stability: From Latin *stabilis*: to stand firm or steady
- Robustness: Latin *robustus*: strong
- Resilience: Latin *resilio*: rebound
- Vulnerability: Latin *vulnus*: injury
- Fragility: Latin *fragilis*: to break



Ref: Urruty et al. 2016. Stability, robustness, vulnerability, and resilience of agricultural systems. A review.

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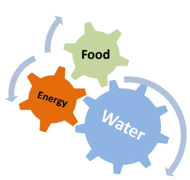
What is Systems Analysis for Sustainability?

Systems Perspective
- Techno-Economic
- Environmental impacts
- Resource sustainability
- Policy
- Social-political



It is challenging and requires an integration of multidisciplinary approaches at its core.

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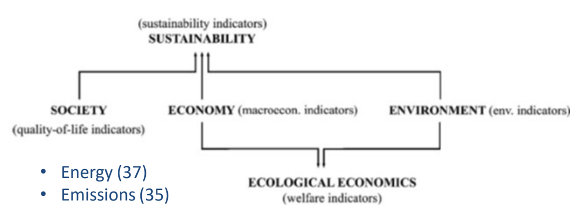
Aspects of Sustainability

- Sustainability: Metrics



- Energy (37)
- Emissions (35)
- Disclosure(30)
- Water (24)
- Materials (23)
- Effluent and Waste (19)
- Biodiversity(10)

Ref: Cohen et al. 2014. The Growth of Sustainability Metrics

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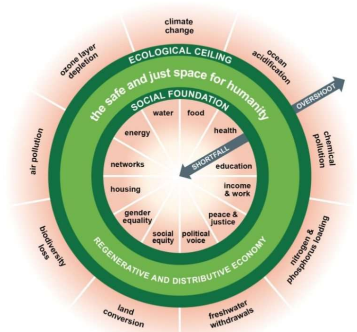
Aspects of Sustainability

- Sustainability: Doughnut Economics (Dr. Kate Raworth)



https://www.kateraworth.com/doughnut/

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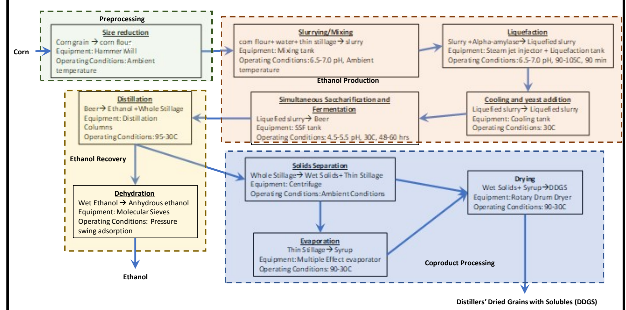
Dry Grind Corn Ethanol Process



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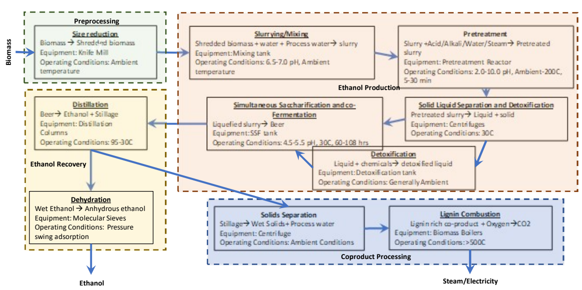
Generic Cellulosic Ethanol Process



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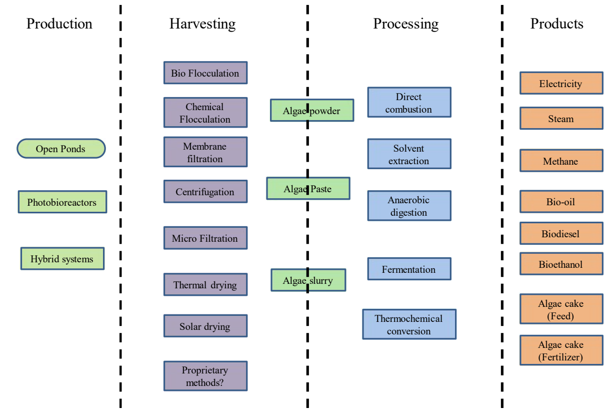
Overview of Algae Biofuel and Bioproduct Pathways



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Goals of this Lecture

Understand the importance of Systems Approach

Learning Objectives

By the end of this lecture, you must be able to:

1. Describe what is systems approach
2. Explain why we need Systems Approach to study biofuels and bioproducts.

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What will we do differently in this course?

- Quantitative analysis
  - Technical Feasibility
  - Economic Viability
  - Environmental impacts Assessment using LCA
  - Resource Assessment
- (Semi) Qualitative Analysis
  - Policy and social aspects
  - Risk Analysis framework

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TEQIP-II Short Course on
Systems Analysis of Biofuels and Bioproducts

Module 1: Systems analysis and overview

THANK YOU

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TEQIP-III Short Course on
Systems Analysis of Biofuels and Bioproducts

Module 1: Environmental Risk Assessment

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Goals of this Lecture

Introduce the Environmental Risk Assessment methods.

Learning Objectives

By the end of this lecture, you must be able to:

1. Describe what is ERA.
2. Understand how risk is computed.
3. Understand the difference between various qualitative and quantitative risk assessment methods.

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Risk Analysis

- What is Risk Analysis and why do we need it?
  - “who fears what from where and why?”
- What leads to risk?
  - Macro Level
    - Increasing complexity
    - Global economy
    - Increasing rate of change
  - Micro level
    - Uncertainty (epistemic and aleatory)
    - Natural variability

Risk assessment (more/less likely) ≠ safety assessment (yes/no)

Ref: C. Yeo. 2013. Introduction to Risk Assessment. Corps risk analysis online training modules.

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Risk Analysis

- What are different types of risks?
  - Type: Existing, future, historical, new, transferred, transformed risks, risk reduction, and residual risk.
  - Source: Life/health, regulatory, financial/investment, political social, strategic risks
- Goal of risk analysis for a decision or problem:
  - Identify and describe the risks
  - Manage the risks
  - Communicate the risk

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. p9

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Risk Analysis

- Components of risk analysis
  - “Risk assessment: defining the nature of the risk, its probability (qualitatively, quantitatively or a combination).
  - Risk management: the actions taken to accept, assume and manage risk
  - Risk communication: the multi-directional exchange of information to allow better understanding of the risk.”

Risk= Probability x Consequence

Risk= Likelihood x Severity

Caution: Risk is multidimensional and cannot be indicated by a single number!!

Ref: C. Yeo. 2017. Introduction to Risk Assessment. Corps risk analysis online training modules.

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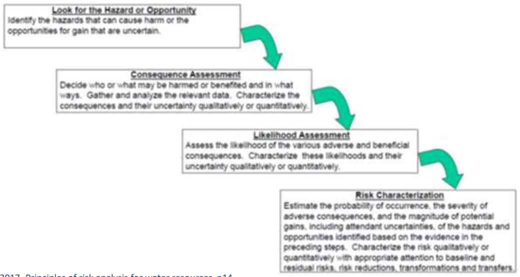
Risk Assessment

- What can go wrong?
- How can it happen?
- How likely is it?
- What are the consequences?



Ref: C. Yeo. 2017. Principles of risk analysis for water resources. p14

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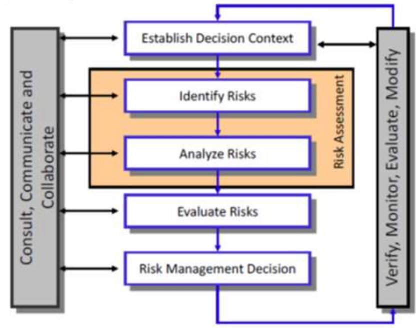
Risk Informed Decision Making Model



Ref: C. Yeo. 2017. Principles of risk analysis for water resources. p45

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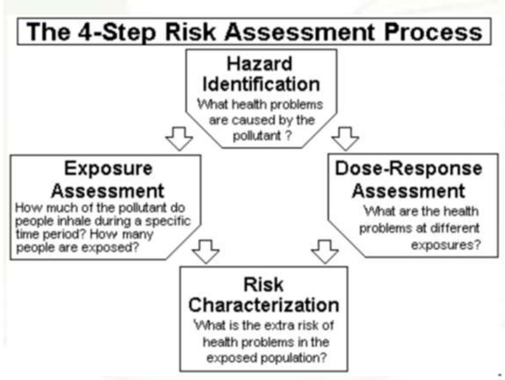
EPA Risk Assessment



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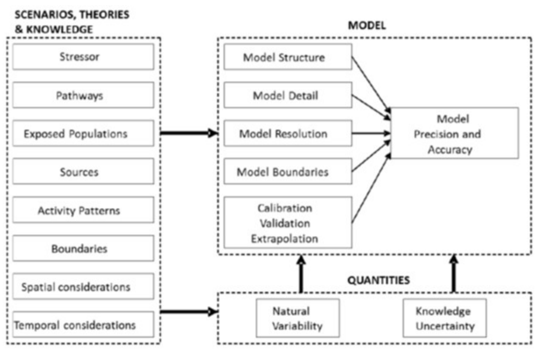
Risk Assessment

- Ecosystem Restoration Risk Assessment schema



Ref: C. Yeo. 2017. Principles of risk analysis for water resources. p30

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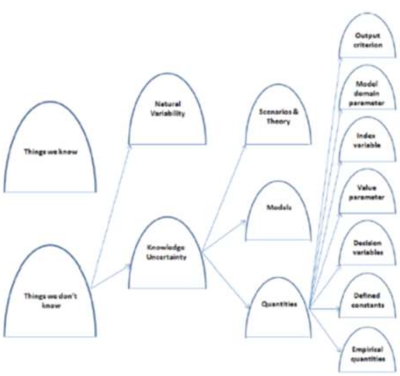
Risk Assessment



Ref: C. Yeo. 2017. Principles of risk analysis for water resources. p25

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Risk Assessment

- Qualitative risk assessment
  - Brainstorming
  - Interviews
  - Checklists
  - Expert Elicitation
  - Increase or decrease risk
  - Risk narratives
  - Screening
  - Ratings
  - Rankings
  - Risk Matrix
  - Hazard Analysis and Critical Control Points (HACCP)
  - Preliminary Hazard Analysis (PHA)
  - Hazard Operatbility Study (HAZOP)
  - Structured What-if(SWIFT)

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. Chapter 7

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Risk Assessment

- Quantitative risk assessment
  - Event tree
  - Fault tree
  - MCDA
  - Monte Carlo
  - Sensitivity analysis
  - Scenario analysis
  - Uncertainty decision rules
  - Subjective probability function
  - Safety assessment
  - Fragility curves
  - Root Cause analysis
  - Environmental risk assessment

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. Chapter 8

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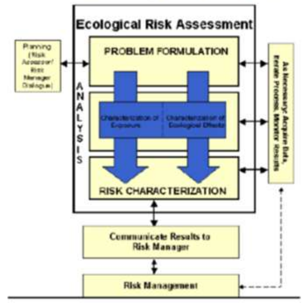
Risk Assessment

- Environmental risk assessment

Framework for Ecological Risk Assessment



Ref: C. Yeo. 2017. Principles of risk analysis for water resources. Chapter 8

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Risk Management

- What is the problem?
- What information do we need to solve the problem (Assessment)?
- What can be done to reduce the impact of the risk described?
- What can be done to reduce the likelihood of the risk described?
- What are the tradeoffs of the available options?
- What is the best way to address the described risk?
- (Once implemented) Is it working?

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P 10

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Risk Management

Risk reduction strategies	Risk taking strategies
Avoidance: this strategy emphasizes the elimination of the probability of a negative consequence event or reducing the impact of the negative consequence event to eliminate the risk.	Creation: strategies that increase the probability of a positive consequence from 0 to a positive value
Prevention: this strategy emphasizes the reducing the probability of a negative consequence event.	Enhancement: strategies that increase the probability from an existing nonzero value to a higher nonzero value.
Mitigation: this strategy reduces risk by reducing the impact of negative consequences through management actions.	Exploitation: this strategy involves increasing the impact of the consequence of the event but does not increase the probability of the event
Transfer: this strategy involves transfer of the risk to a different stakeholder willing to bear the risk.	Sharing: this strategy maximizes both the probability and the desirable consequences.
Retention: when no means for reducing the probability or the consequence of the negative event exists, and the residual risk is still unacceptable even after all mitigation efforts, the only viable strategy is to accept the risk and actively monitor the risks.	Ignoring: this strategy involves taking no action to either increase the probability or strengthen the consequences of the desirable event.

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. p14

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Risk Communication

- What are we communicating?
- Who are our audiences?
- What do our audiences want to know?
- How will we communicate?
- Who will carry our plans? Why?
- What problems or barriers have we planned for?
- How will we listen?
- How will we respond?
- Have we succeeded?

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P16, 70

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Six Mistakes of Executives in Risk Management

- Manage risk by predicting extreme events.
- Studying past will help us manage risk.
- Do not listen to advice about what we shouldn't do.
- Assume risk can be measured by standard deviation.
- Do not appreciate that what is mathematically equivalent is not psychologically equivalent.
- Do not realize that optimization makes the systems fragile.

Ref: Taleb et al. 2009. The six mistakes executives make in risk management. Harvard Business review. October 2009 issue.

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Environmental Risk Assessment

- Developed by EPA: https://www.epa.gov/risk
- Sometime called Ecological Risk Assessment "evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors"
- Depends on pathway analysis.
- EPAs ERA Technical Overview: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/ecological-risk-assessment-pesticides-technical
- Overview of the ERA process: https://www.epa.gov/sites/production/files/2014-11/documents/ecorisk-overview.pdf

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P168

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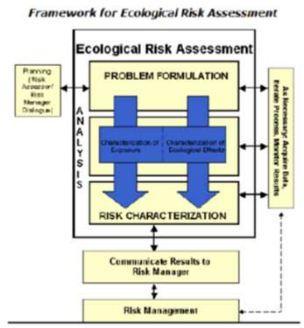
Environmental Risk Assessment: Process



Ref: C. Yeo. 2017. Principles of risk analysis for water resources. Chapter 8

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Environmental Risk Assessment: Process

- Problem Formulation Phase
  - Assessment endpoints that reflect management goals and the ecosystem they represent
  - Conceptual model(s) that represents predicted key relationships between stressor(s) and assessment endpoint(s)
  - Plan for analyzing the risk

Risk= Probability x Consequence

- Analysis Phase
  - Exposure characterization (exposure profile based on Environmental fate and transport data)
  - Ecological effects characterization (stressor-response profile)
  - Uncertainty analysis is also performed here.
  - Risk assessors and risk managers communicate extensively during this phase.
- Risk Characterization Phase
  - The integrated risk characterization includes the assumptions, uncertainties, and strengths and limitations of the analyses. It makes a judgment about the nature of and existence of risks.
  - Guidelines:
    - Transparency, Clarity, Consistency and Reasonableness (TCCR)
    - EPA Risk Characterization handbook (https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=40000006.txt)

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P168

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Environmental Risk Assessment

- Strengths:
  - Detailed understanding and presentation of the nature of the problem and the factors that contribute to environmental risk(s)
  - Pathway analysis can identify critical points in the chain of risk events that show how and where it may be possible to improve risk controls or introduce new ones
- Weaknesses:
  - Relatively extensive data requirements
  - Without extensive data, ERA can have a high level of uncertainty associated with it

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P168

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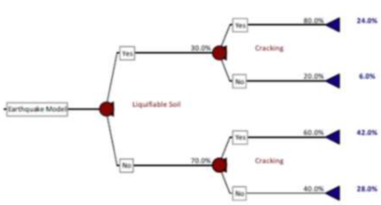
Event Tree

- Qualitative or quantitative analysis
- All nodes are assumed to be determined by chance. (no decisions on any pathways)
- Assess frequencies of various possible outcomes.
- Requires explicit understanding of the process.
- New tree for each distinct initiating event.



Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P140

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Event Tree

- Strengths:
  - Able to display potential scenarios following an initiating event
  - Can account for timing, dependence, and domino effects that are cumbersome to handle in verbal descriptions and other models
- Weaknesses:
  - Require analysts to be able to identify all relevant initiating events
  - May require a separate model
  - Difficult to represent delayed success or recovery events when nodes are constructed with dichotomous branches
  - Any path is conditional on the events that occurred at previous branch points along the path
  - Models can quickly grow very large

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P140

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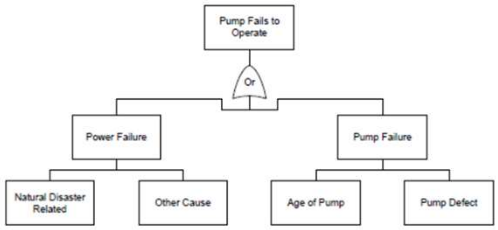
Fault Tree

- Qualitative or quantitative analysis
- Opposite of an Event Tree (uses Backward Logic)
- Assess frequencies of various possible outcomes.



Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P140

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Fault Tree

- Strengths:
  - Can analyze a wide variety of factors including physical phenomena, human responses and interactions of all these factors
  - Top down approach focuses attention on those causes of failure that are directly related to the top event
  - A good model for water and infrastructure systems with many interfaces and Interactions
  - System behavior can be readily understood by the visual depiction of failure modes
  - Can identify combinations of events that could lead to failure
  - Often useful in decomposing events so probabilities can be estimated
  - May not be possible to estimate the probability of a dam failure all at once; but after the chain of necessary and sufficient events is identified it may be feasible to estimate the probabilities of these events
- Weaknesses:
  - Can become quite large for complex systems
  - Usually a high level of uncertainty in the calculated probability of the top event
  - For some situations causal events are not bounded and it is hard to know if all important pathways to the top event are included

Ref: C. Yeo. 2017. Principles of risk analysis for water resources. P140

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Goals of this Lecture

Introduce the Environmental Risk Assessment methods.

Learning Objectives

By the end of this lecture, you must be able to:

1. Describe what is ERA.
2. Understand how risk is computed.
3. Understand the difference between various qualitative and quantitative risk assessment methods.

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TEQIP-III Short Course on Systems Analysis of Biofuels and Bioproducts

Module 1: Environmental Risk Assessment

THANK YOU

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