Application of Coral Reef Decision Models in Guánica Bay, Puerto Rico

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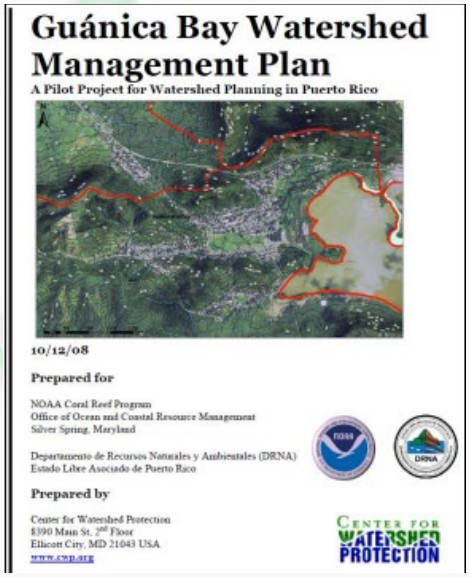
U.S. Environmental Protection Agency
Office of Research and Development

National Academy of Science Committee on Interventions to Increase the Resilience of Coral Reefs—Meeting 4
October 30, 2018

Guánica Bay

US Coral Reef Task Force Initiative

- Concern over effects of watershed stressors on corals led to designation of Guánica Bay as a US Coral Reef Task Force Watershed Initiative
- This led to development of a Guánica Bay Watershed Management Plan


Guánica Bay Watershed Management Plan

A Pilot Project for Watershed Planning in Puerto Rico

10/12/08

Prepared for

NOAA Coral Reef Program
Office of Ocean and Coastal Resource Management
Silver Spring, Maryland

Departamento de Recursos Naturales y Ambientales (DRNA)
Estado Libre Asociado de Puerto Rico

Prepared by

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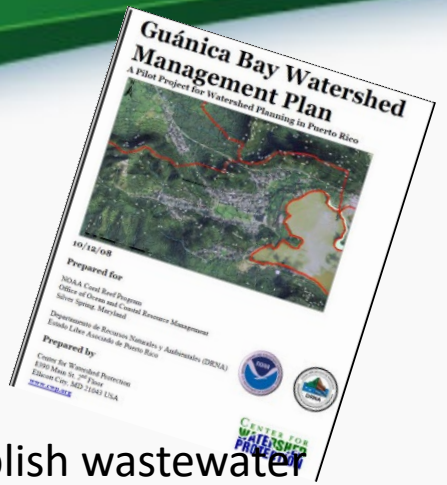
CENTER FOR WATERSHED PROTECTION

Decision Tools

- Structured decision process
- Systems framework
- Alternatives formulation
- Consequence tables
- Scenario testing

Recommended Actions



GB Watershed Management Plan

Maximize planting of cleared home sites & dirt roadways

Dredge reservoirs

Restore lagoon marshes

Sustain and slow reservoir releases

Create incentives for shade grown coffee

Remove relic irrigation structures

Treat stormwater outflows

Treat sewage effluent

Enhance riparian planting

Enforce sediment erosion regulations

Establish wastewater treatment wetlands

Minimize pet waste

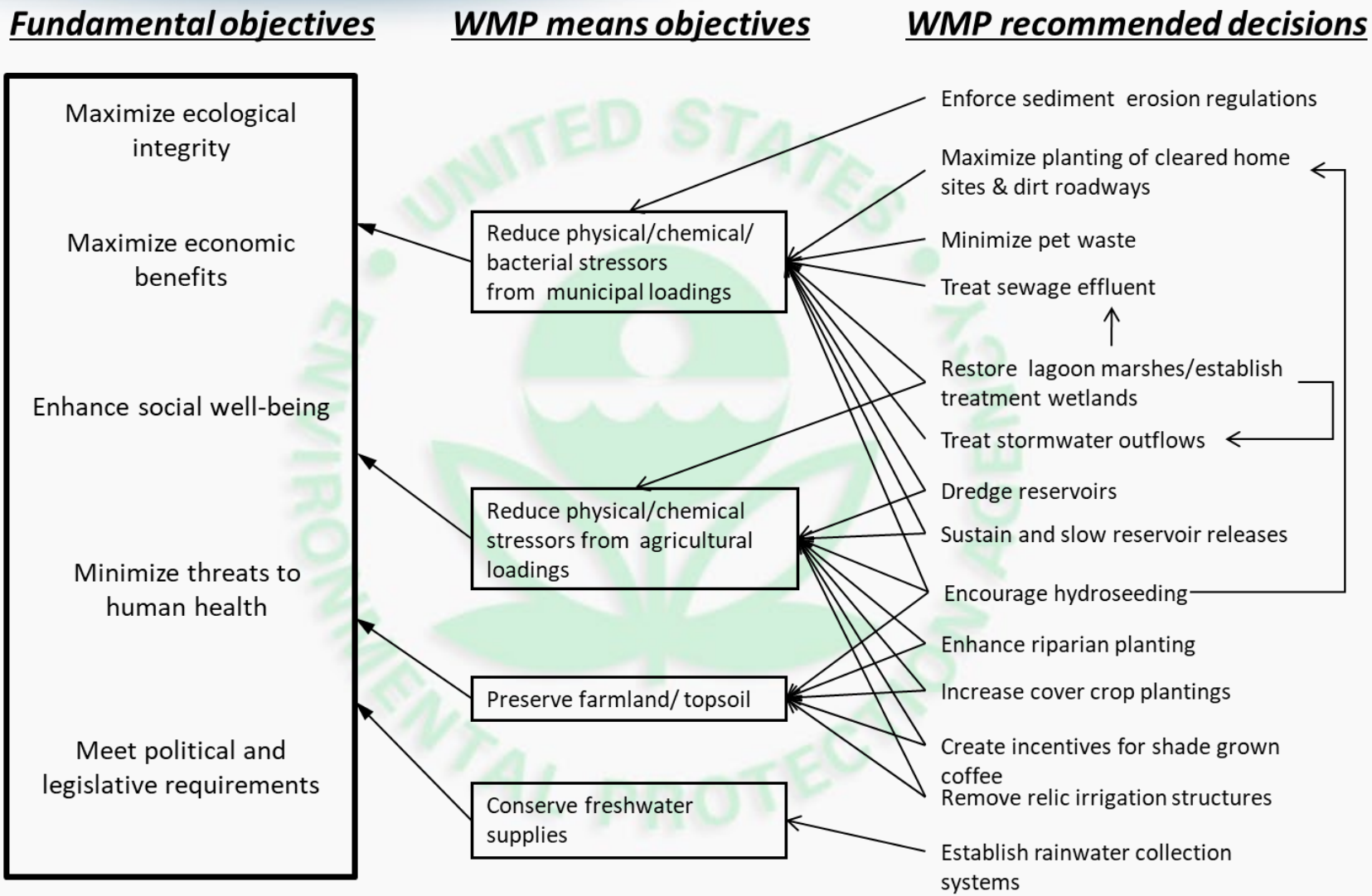
Encourage hydroseeding

Upgrade sewage treatment facility

Increase cover crop plantings

Establish rainwater collection systems

Means-Ends Network



Carriger et al. 2013

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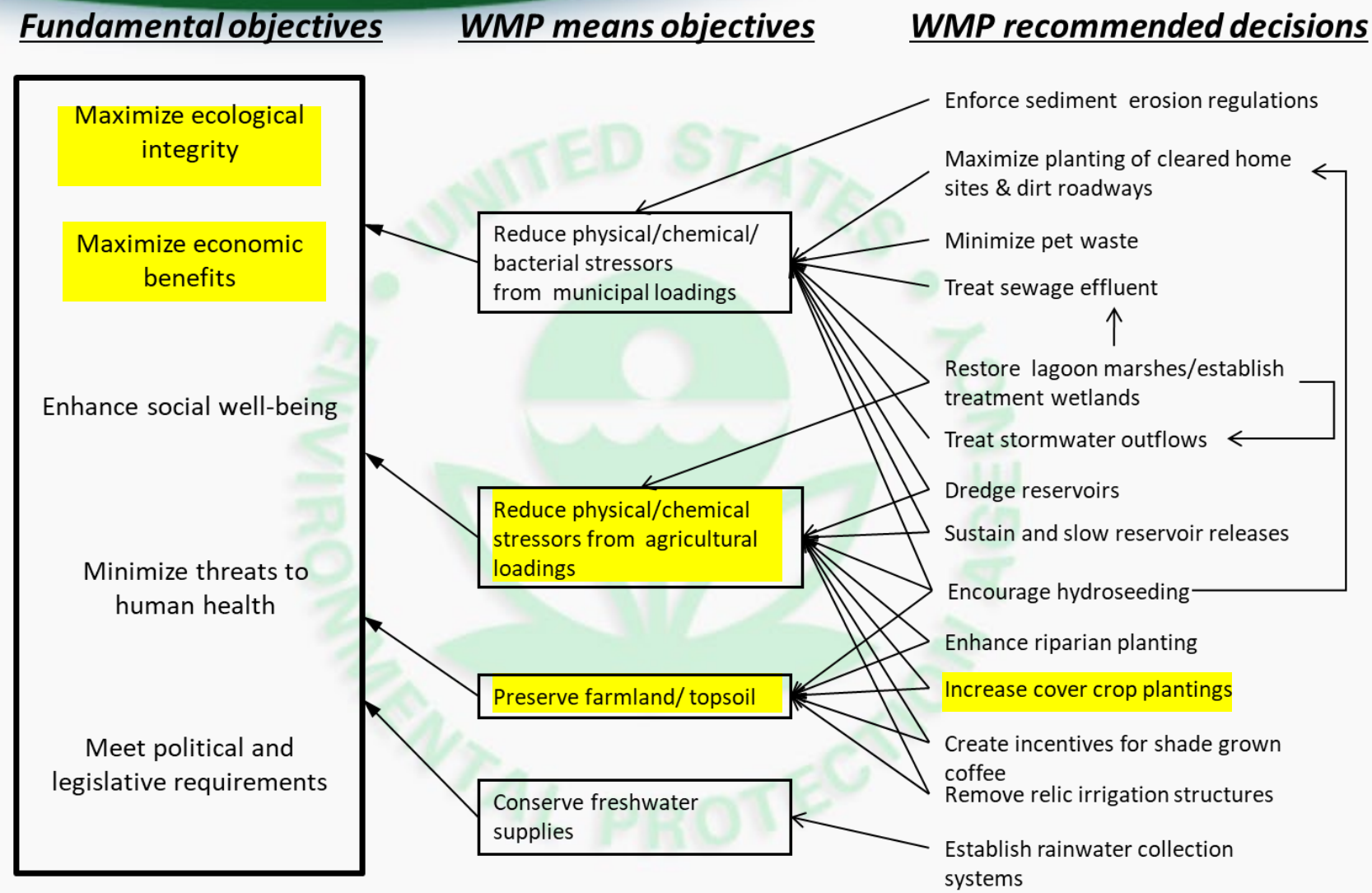

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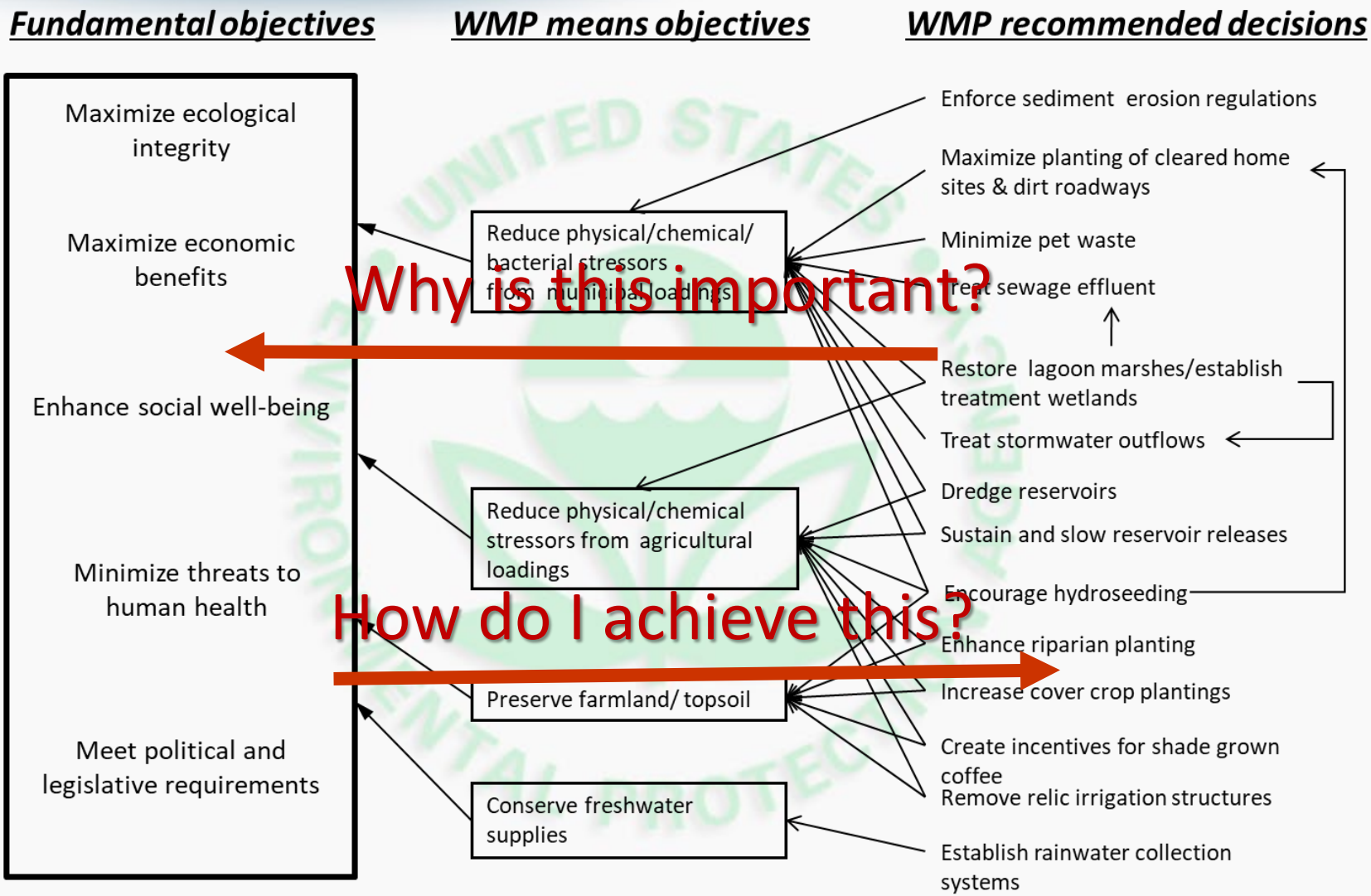
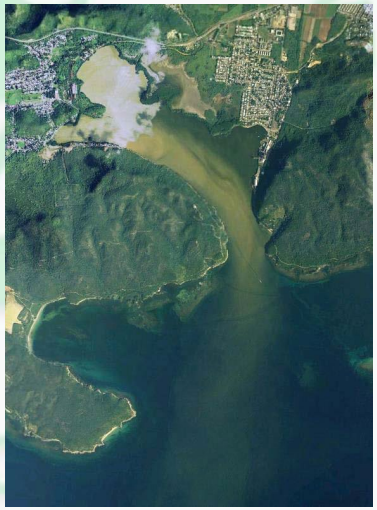


Carriger et al. 2013

Watershed Sediment

- The Guánica watershed has gone through many changes resulting from agricultural and municipal growth
- These changes have altered the quantity and quality of water flowing from the watershed into Guánica Bay and coastal coral reefs, particularly in terms of sediment discharge






Proposed Actions

Actions* to Reduce Sediment Discharge

Shade-grown coffee

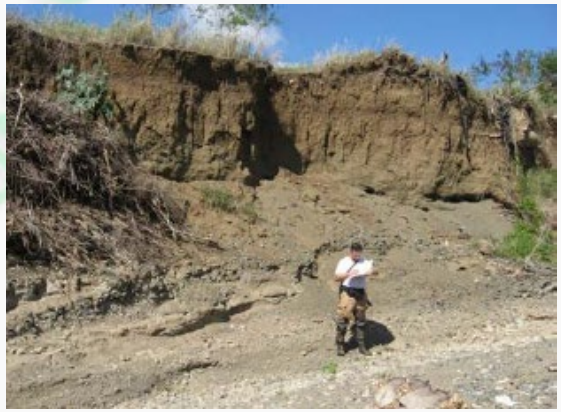
Dredging reservoirs

Lagoon restoration

Hydro-seeding

Riparian planting

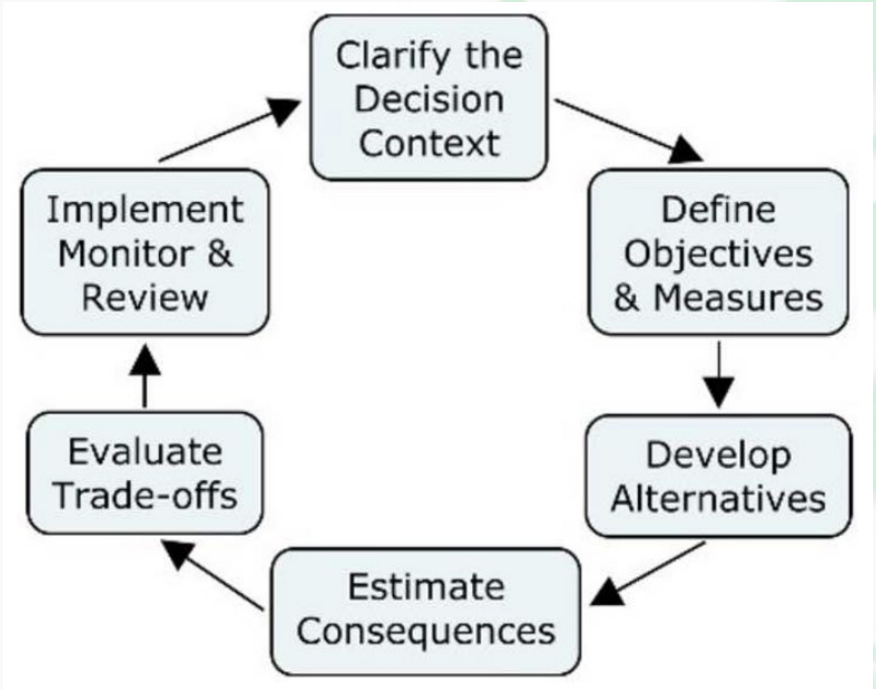
Remove relic irrigation



*Guánica Bay Watershed Management Plan

Structured Decision Making

A process to elicit and organize key ***stakeholder values*** and relevant ***scientific knowledge*** for making decisions



Strengths of SDM

- Facts and values
- Multiple perspectives
- Holistic
- Democratic
- Flexible
- Multiple knowledge sources

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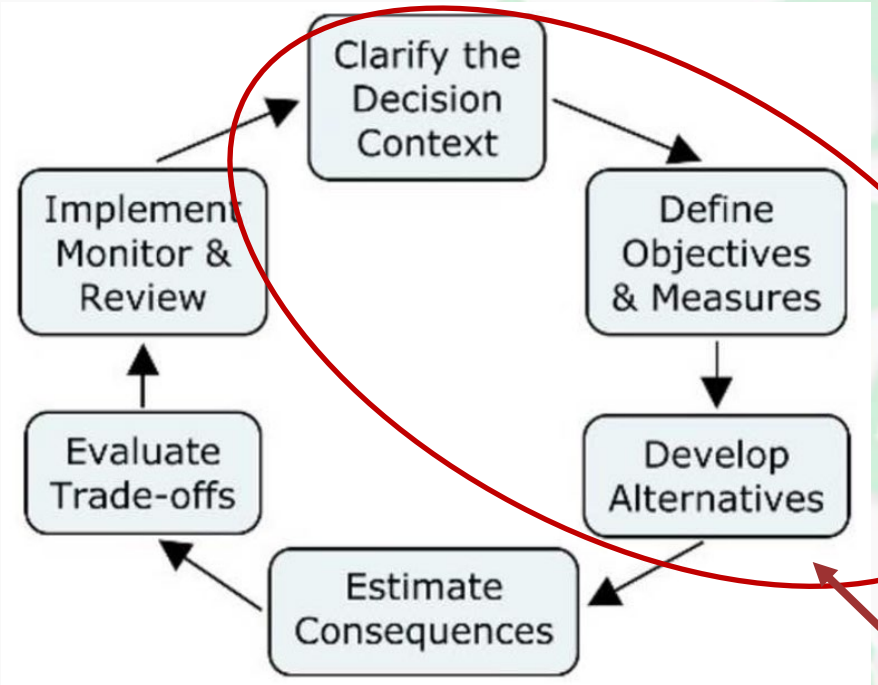

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Stakeholder engagement

Stakeholder Workshops

-- Informing the SDM process

Decision Workshop on Watershed Mgmt Plan 2010	Proposed management options Systems (DPSIR) framework Ecosystem goods and services
Historic Decisions Workshop 2012	Decisions made outside of communities Desire for local empowerment Desire for equitable opportunities Better enforcement of regulations
Coral Reef Condition Workshop 2012	Objectives for management and regulatory protection of coral reefs Attributes and measurements for reef protection
Public Values Forum 2013	Identify broader stakeholder objectives Examine tradeoffs and consequences of decisions Prioritize actions for achieving multiple values Translate decision tools for community application

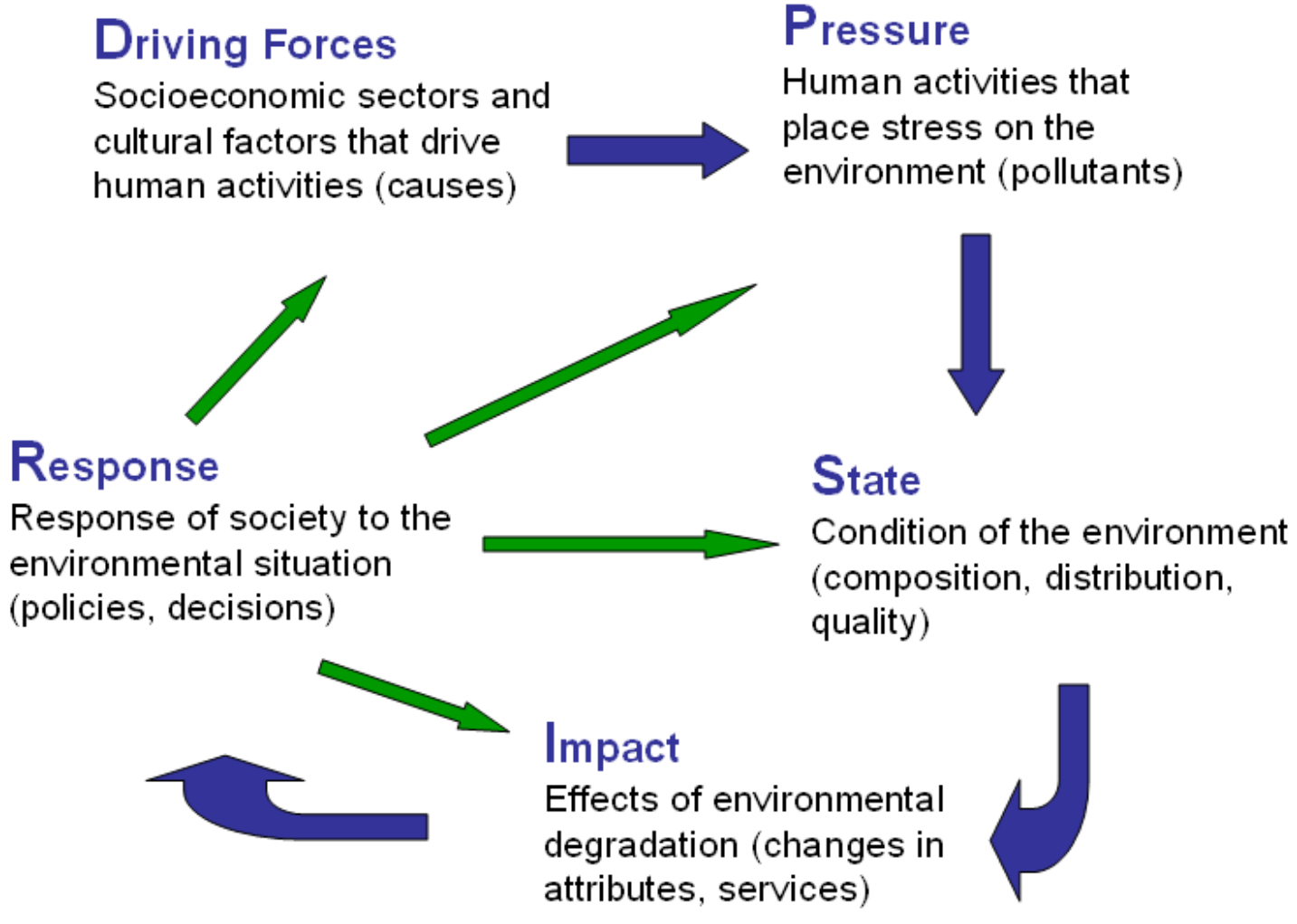
Bradley et al. 2013; Gregory and Gonzalez 2013

Coral Reef Protection

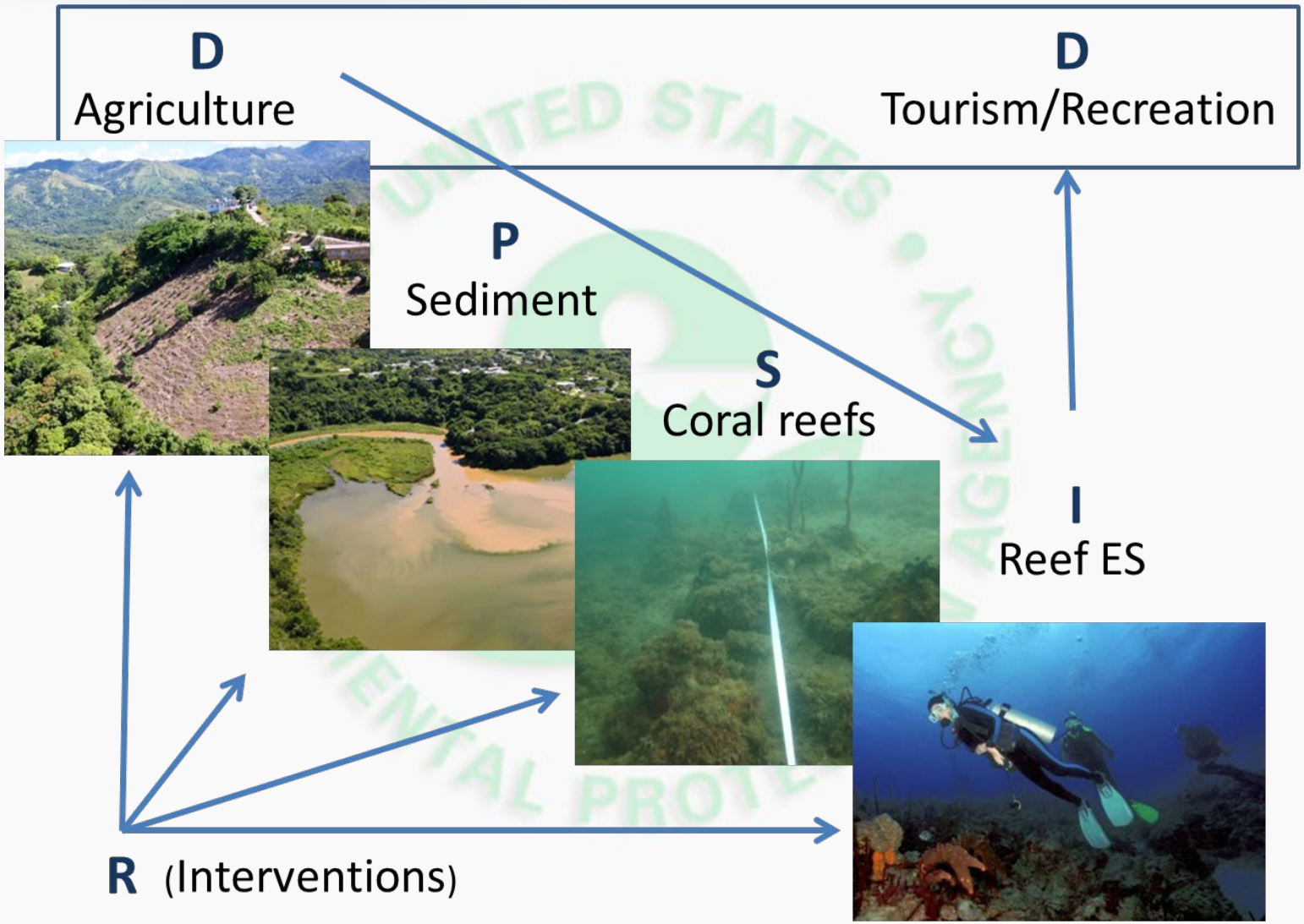
—A plethora of issues

DPSIR Systems Framework

Essential for understanding relationships and assessing tradeoffs



Coral Reef DPSIR



Coral reef systems model

R

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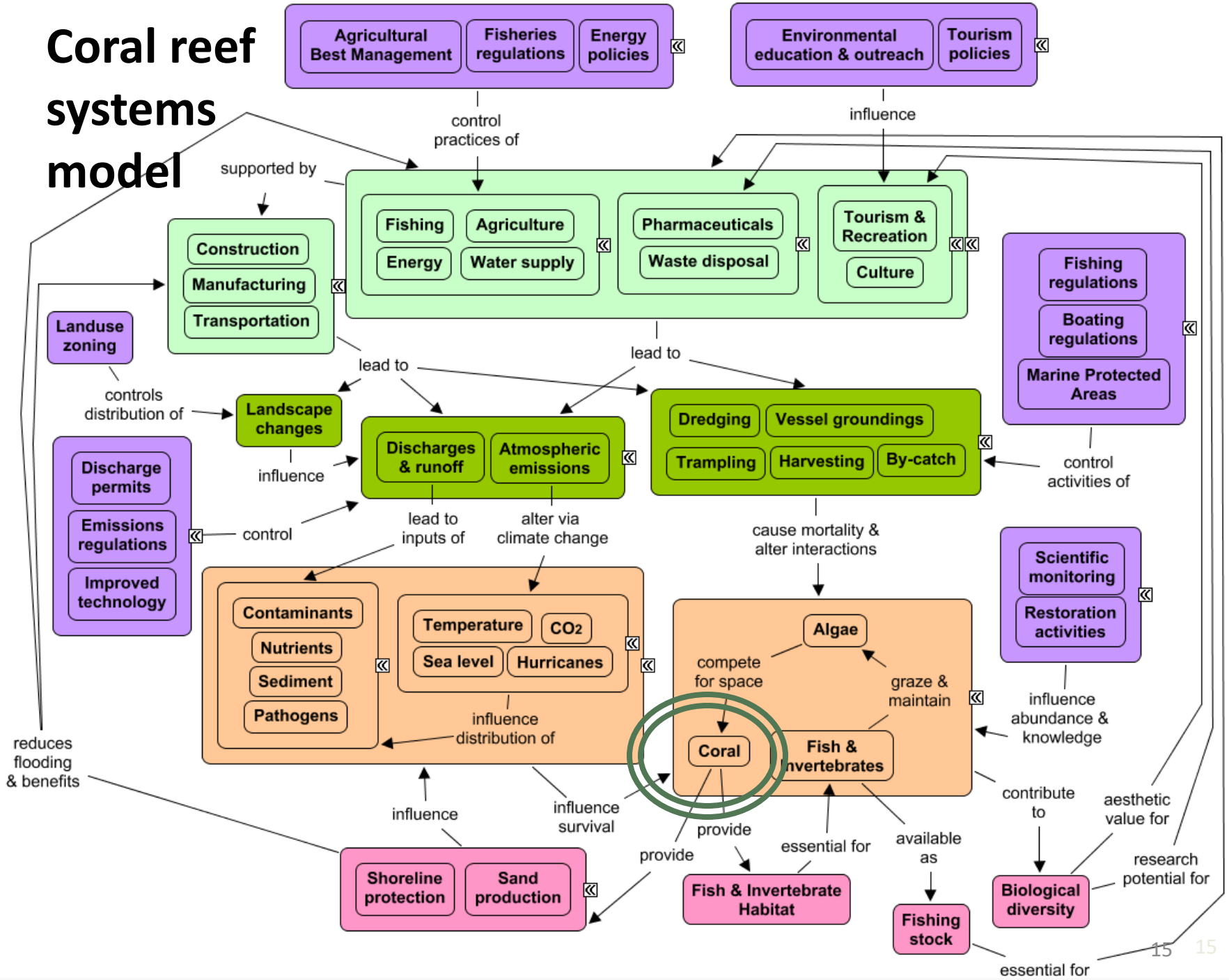

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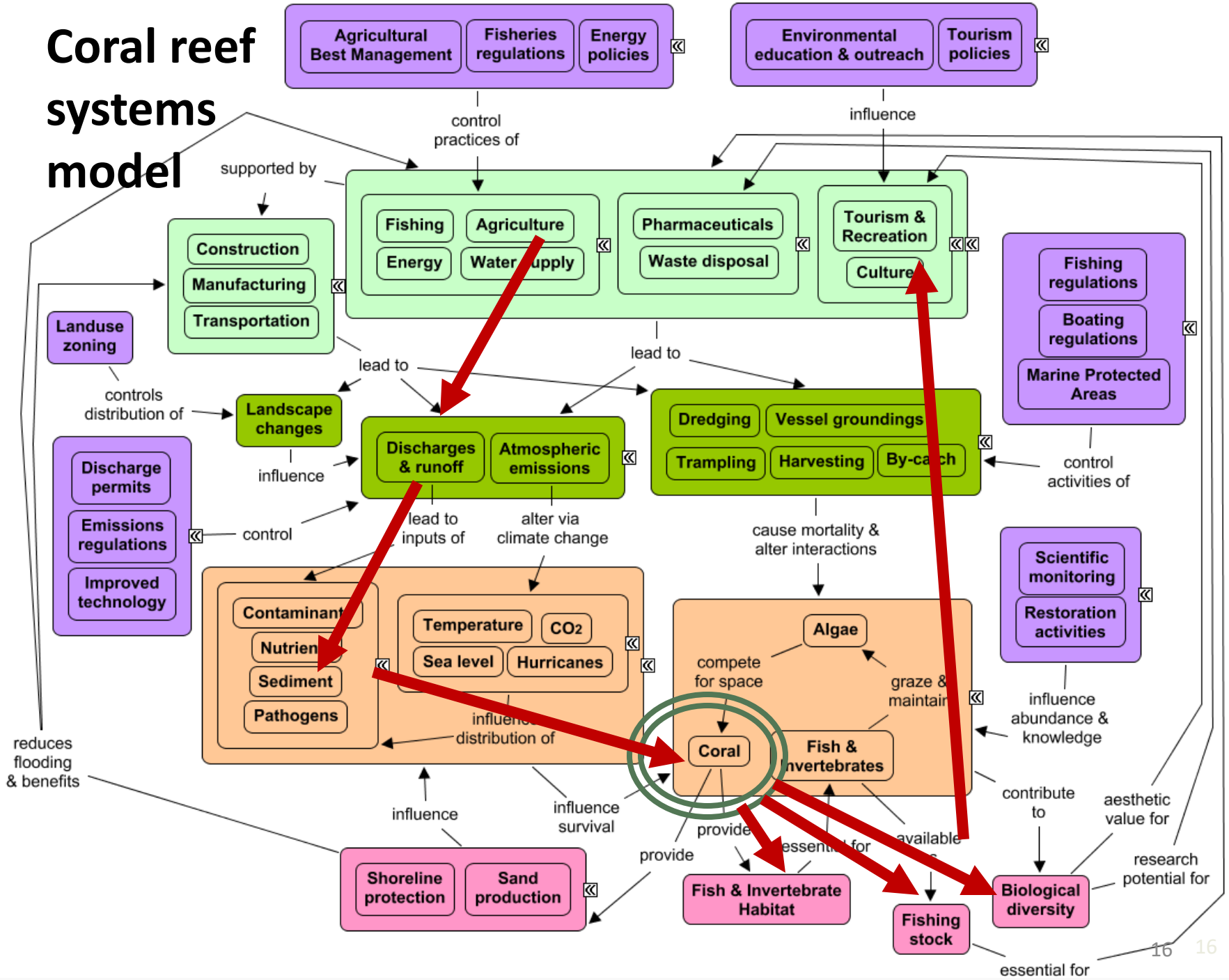

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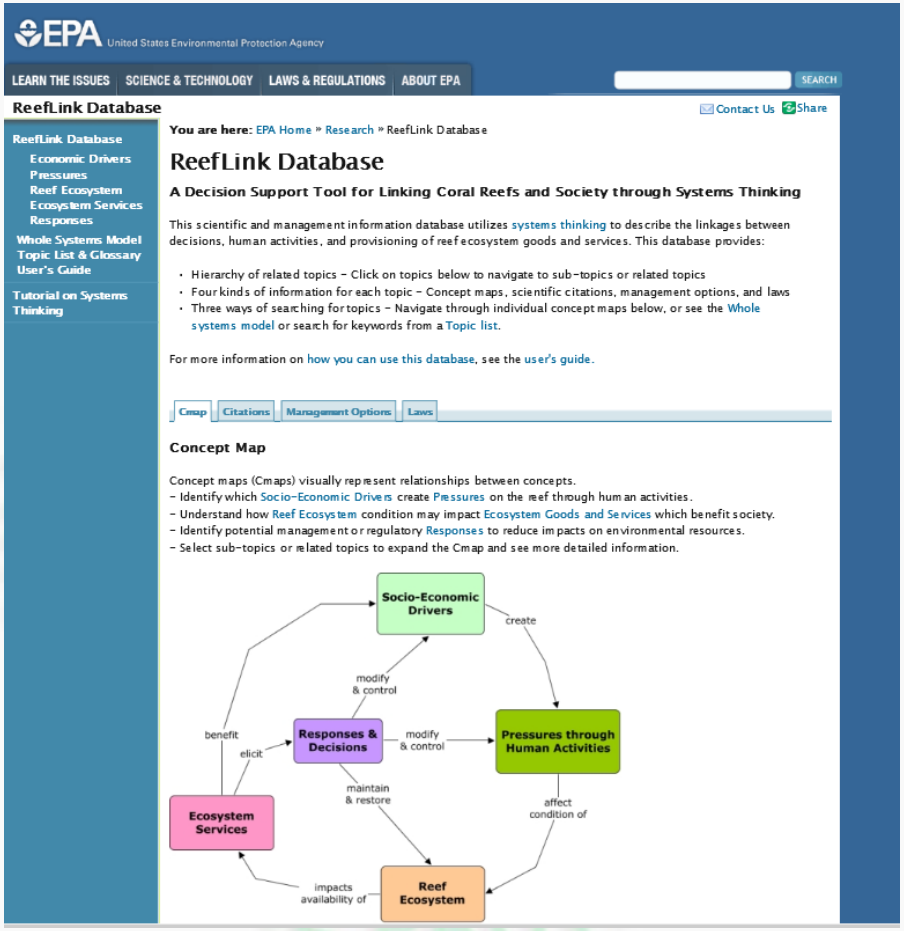
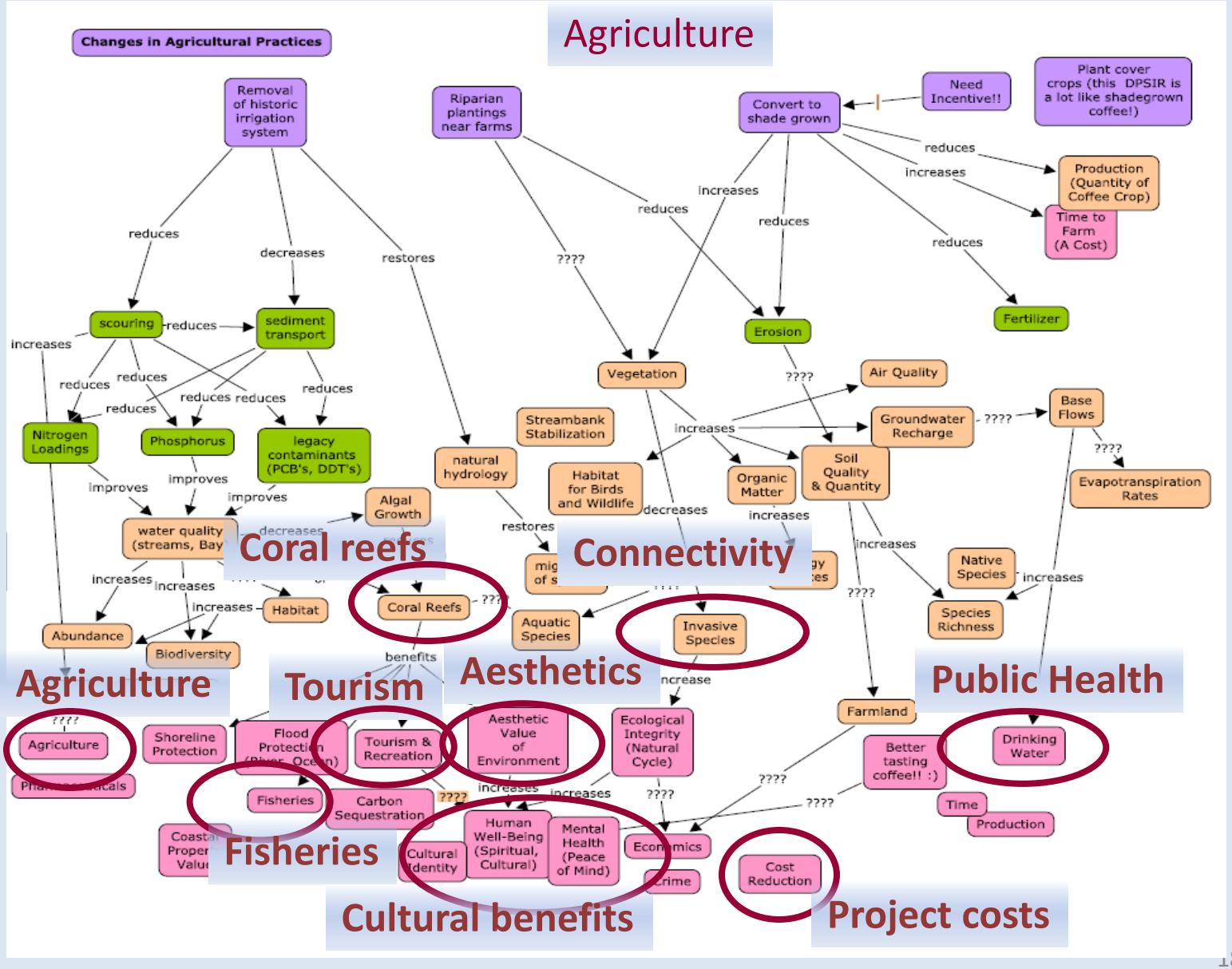
ReefLink Database

— Coral Reef DPSIR Model

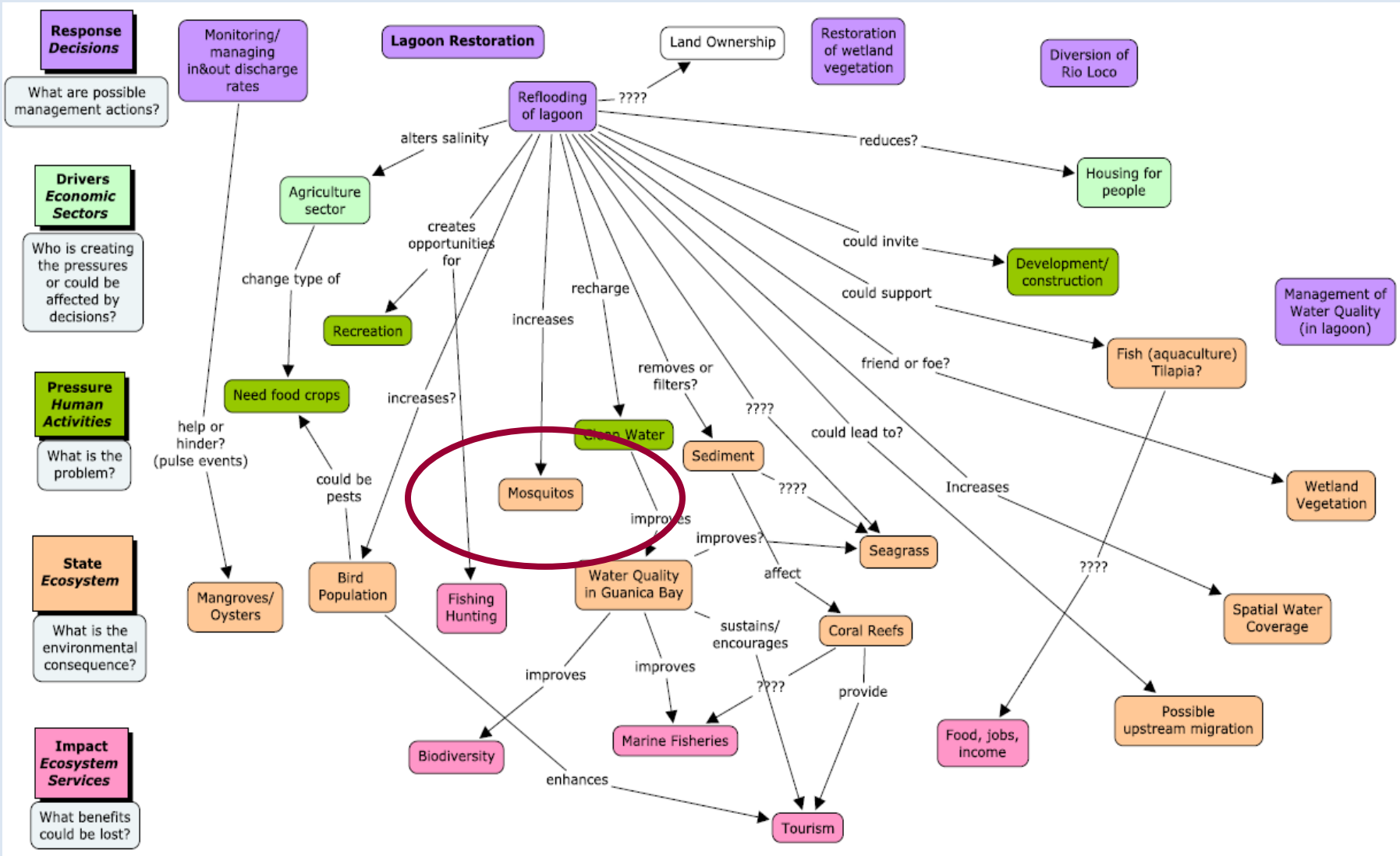


https://archive.epa.gov/ged/coralreef/web/html/index.html

On-the-fly stakeholder input to DPSIR model-Agriculture



On-the-fly stakeholder input to DPSIR model-Lagoon restoration



System Connectivity

How do mosquitos influence coral reef protection?

Restoration of Guánica Lagoon

- Town of Fuig has grown out to edge of the lagoon footprint
- Waterbody so close to town will likely result in an increase of mosquitoes

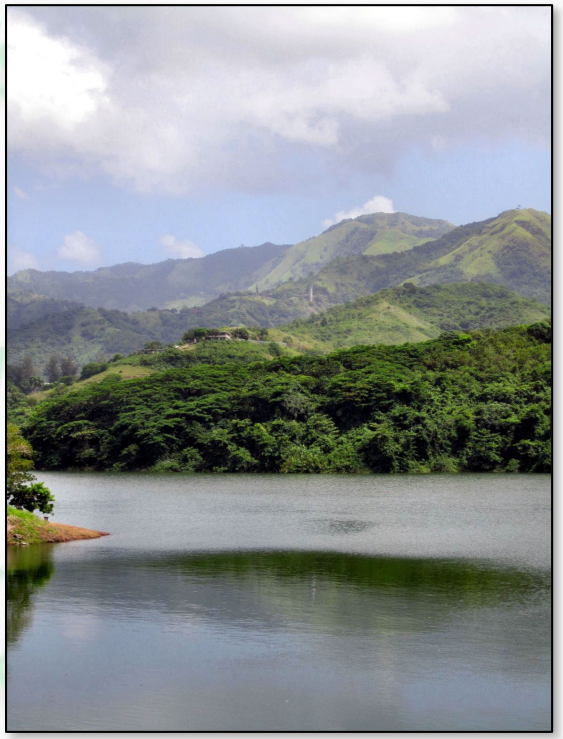
Tradeoffs to consider for town inhabitants

Recreation and aesthetics *vs.* dengue, chikungunya and pesticides

Public Values Forum

Goals:

- Identify stakeholder objectives across the Guánica Bay watershed (not just for corals)
- Develop alternatives for achieving those objectives
- Examine tradeoffs and intended/unintended consequences
- Explore possible management actions for achieving multiple values
- Translate decision tools for future application



Guánica Bay Watershed

Stakeholder Alternatives

Area	Values	Performance Measures	Actions
Economic	Protect agricultural land (Fully utilize potential?)	• Reduce % fallow land • Diversify crops • Promote BMP • $/Ha of production (by type of crop) • Salinity of soil • $ farm production loss due to land under water	•Implement development plans (?) • Ensure continuity of plans • Implement BMP incentives plan • Ensure no net loss of agricultural land • Avoid practices that increase soil salinity • Improve mechanism for water drainage (clean channels to increase water flow)
	Ensure availability of good quality water supply (for agriculture?)	• Percentage of full capacity for reservoir • $ avoiding costs for building new water infrastructure • Percentage of catchment area with vegetated cover (?)	• Dredge sediment from water reservoirs • Schedule maintenance of water reservoirs • Reforest catchment areas
	Create more job opportunities	• Number indirect and direct jobs created • Average $ level of pay • $ value added in local industry	• Prioritize hiring needs •Assess private business investment opportunities • Develop re-training plans for workers
Aquatic ecology	Improve water quality (in rivers and ocean?)	•Turbidity •Solids in suspension • Nutrients • Coliforms	• Restore lagoon • Monitor water quality before, during and after lagoon restoration • Educate community about (?) • Convert Guánica WWTP to tertiary • Restore marshes ability to filter sediments (?) • Consistent enforcement of regulations
	Foster healthy native aquatic community	• Size • Diversity • Health	• Create and improve habitat (where?)
	Improve quality of life related to water resources use	• Aesthetics: reduce visible waste • Reduce turbidity of water • Number of people involved in ecological improvements of the watershed • Ha (cuerdas) forested • Number of recreation activities • Number of recreationists	• Reforestation • Eliminate invasive aquatic species • Conserve soil • Program to educate citizens and industry on reduction and recycling of waste •Educate population about importance of lagoon and marsh ecological services
Land ecology	Restore fauna and habitat	• Index of species biodiversity • Kilometers of ecological corridors • Ha habitat suitable for trust species	• Convert sun grown to shade grown coffee • Establish riparian buffers • Reforestation • Forest enhancement • Restore Guánica lagoon • Land acquisition for conservation purposes • Promote enhanced habitat for trust species • Consistent enforcement of regulations • Continue implementation of 2008 GBWMP
	Conserve soil productivity	• Percentage reduction in erosion • Crop production in tons per ha.	• Promote sustainable agricultural practices • Promote best management practices • Continue hydro-seeding • Create state and private land management plans
	Reduce point and non-point source of contamination in watershed	• Sediments and nutrient levels mg/L/M² • Concentration of hydrocarbons	• Identify point sources of pollution • Create green infrastructure to treat runoff waters
Social	Promote education	• Environmental attitude survey • Number of community members acting in projects	• Promote pro-environmental attitudes via formal and informal education • Implement adopt a beach program •Promote capacity building and in schools and communities
	Improve health	• Percentage people connected to PR Aqueduct and Sewer Authority (PRASA) • Census statistics	• Increase participation in PRASA • Conduct epidemiological studies on key health issues • Survey of home owners to determine status of septic tanks
	Promote sustainable communities	• Number demonstration projects • Number of community based enterprises • Number of community networks • Number of conferences and seminars in communities	• Conduct capacity building workshops • Create community coalitions • Provide citizens access to information • Create opportunities for enhanced public involvement • Promote efficiency through better inter-agency communication

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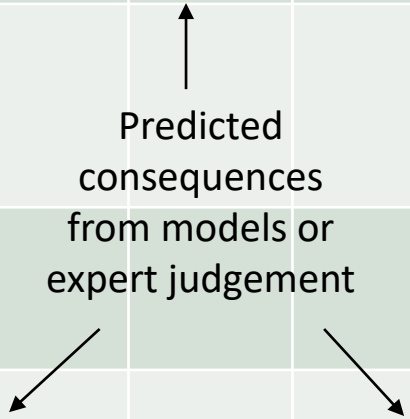
Consequence Table

-- Stakeholder discussion for restoration of Guánica Lagoon

		Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Objectives	Performance Measure	Current status	Full lagoon restoration	2008 mgmt. plan	Adaptive mgmt. plan	Other plan
Protect and create economic opportunities	$/hectare of crop production $ of jobs created Cost of water infrastructure					
Restore and conserve the land environment	Index of species biodiversity % reduction in soil erosion					
Restore and conserve the aquatic environment	Water turbidity Diversity of aquatic life # of recreation activities Hectares forested					
Promote social & cultural opportunities	Environmental attitude % people connected to wastewater treatment plants					

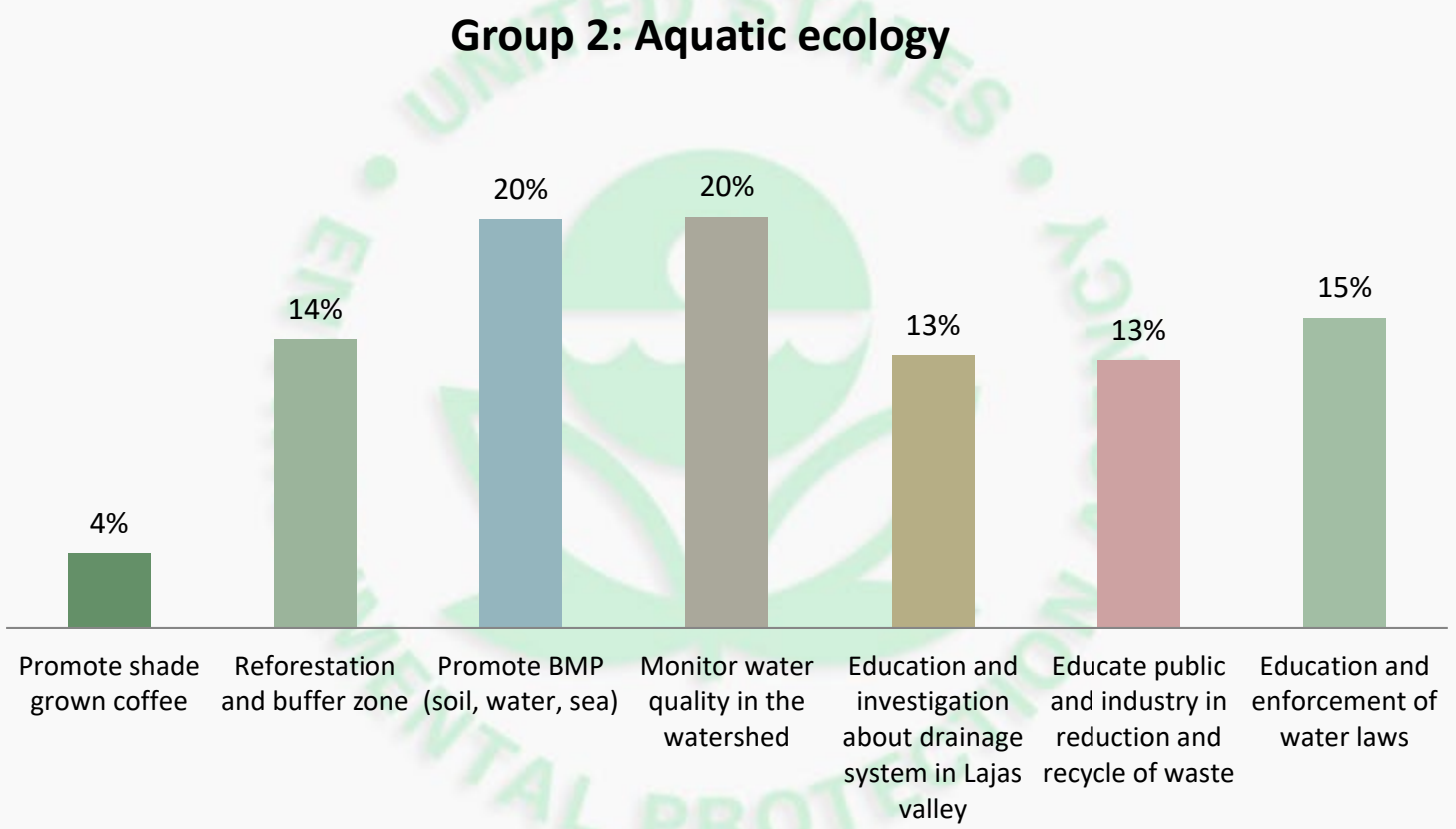


Priority Actions of Stakeholders

Land Ecology	Aquatic Ecology	Economics	Social
1. Research opportunities	1. Promote shade grown coffee	1. Encourage more shade-grown coffee and reforestation	1. Best management and conservation practices
2. Improve river quality	2. Reforestation and buffer zone	2. Establish riparian buffers	2. Measure effectiveness of BMPs
3. Educate people near the river	3. Promote BMP (soil, water, sea)	3. Restoration of lagoon	3. Identify sources of pollution
4. Monitor water quality	4. Monitor water quality in the watershed	4. Dredge reservoirs and dist channels	4. Law enforcement
5. Diversify economic opportunities	5. Education and investigation about drainage system in Lajas valley	5. Restore drainage system	5. No agricultural land loss
6. Improve infrastructure	6. Educate public and industry in reduction and recycle of waste	6. Promote citizens access to information	6. Tertiary treatment of sewage plant
7. Restore ecosystems	7. Education and enforcement of water laws	7. Education programs to promote sustainability	7. Green infrastructure
8. Recreation opportunities in the watershed		8. Continue implementation of GBWMP 2008	8. Reduce sewage from septic tanks
9. Agricultural incentives		9. Create and implement management plan for marine areas of Guánica Reserve	9. Human capital profile
10. Co-management of protected areas in watershed		10. Promote land management plans for private landowners	10. Reefs economic analysis

Scenario Preferences

Anonymous nonbinding voting by watershed stakeholders



Gregory and Gonzalez 2013

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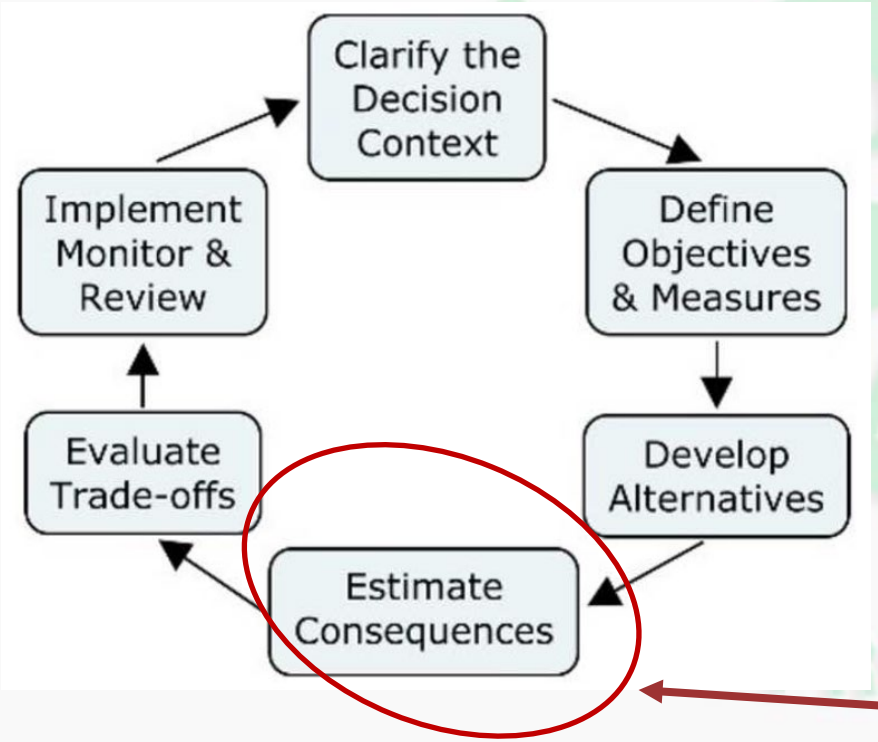

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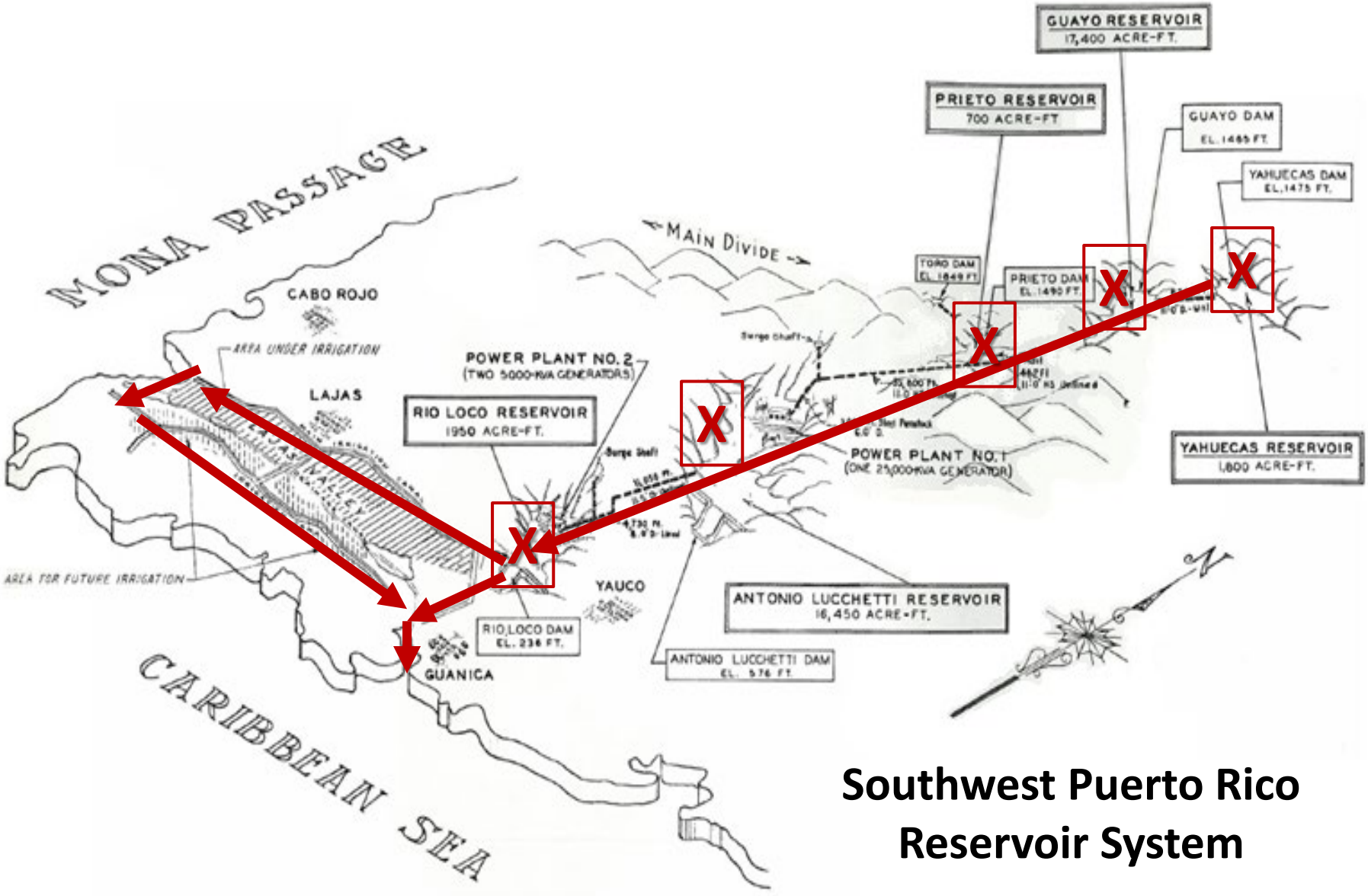
Value added scientific research



Southwest Puerto Rico Reservoir System

Benefits of a Reservoir System

– **A high priority stakeholder objective**

- Irrigation
- Flood protection
- Hydroelectric power
- Drinking water
- Aesthetics
- Recreation
- Fishing
- Sediment trapping

Decline of 60 yr-old reservoir system

- Reservoirs are nearly 50% filled with sediment
  - Reduced water storage capacity
  - Reduced sediment capture capacity
- Increase in sediment discharge to downstream habitats, including coral reefs

Decision Alternatives

Can we extend the longevity of reservoirs?

Alternative 1: Conversion of sun grown to shade grown coffee

Photos: USFWS

Advantages

- Reduces topsoil loss
- Reduces water quality impairment
- Reduces downstream effects on fish and wildlife habitat

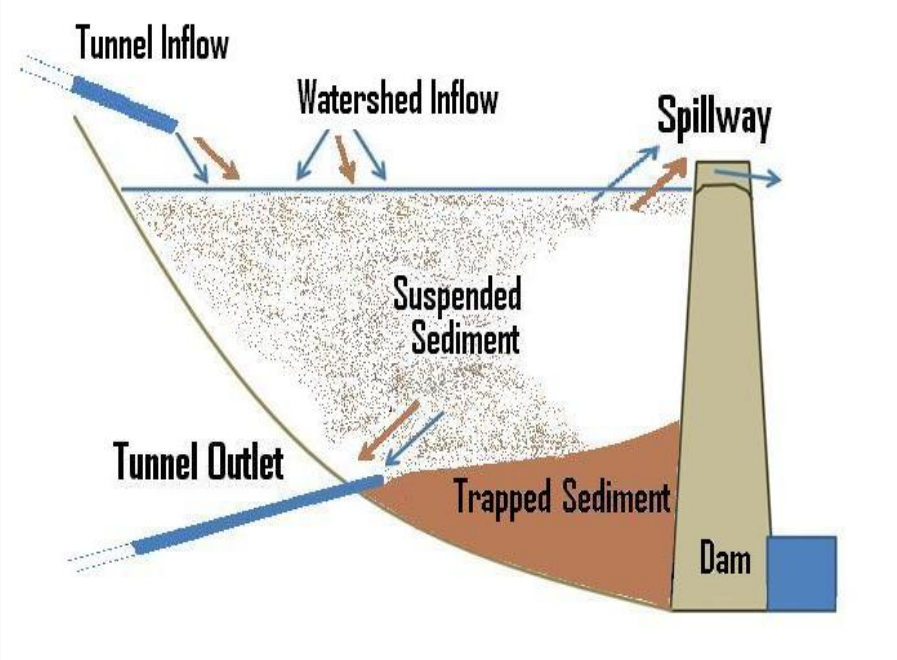
Disadvantages

- Cost in time and money to replant with shade-grown varieties
- Marketing a new coffee that may or may not be accepted

Decision Alternatives

Can we extend the longevity of reservoirs?

Alternative 2: Dredging sediment from reservoirs



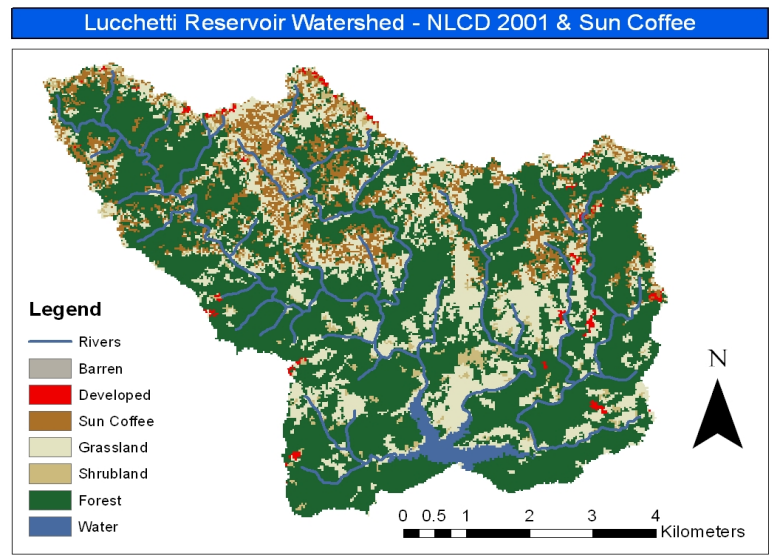
Advantages

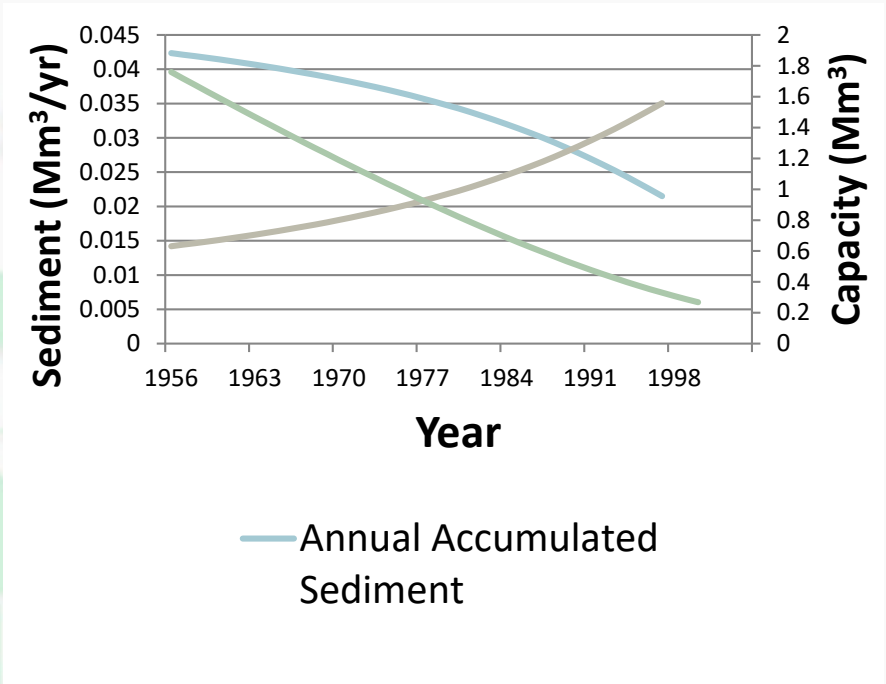
- Increase drinking water availability
- Improve water quality, aesthetics and recreation
- Increase flood protection and hydroelectric capacity
- Increase sediment trapping capacity, which protects downstream habitats

Disadvantages

- Expensive
- Environmental damage
- Sediment disposal

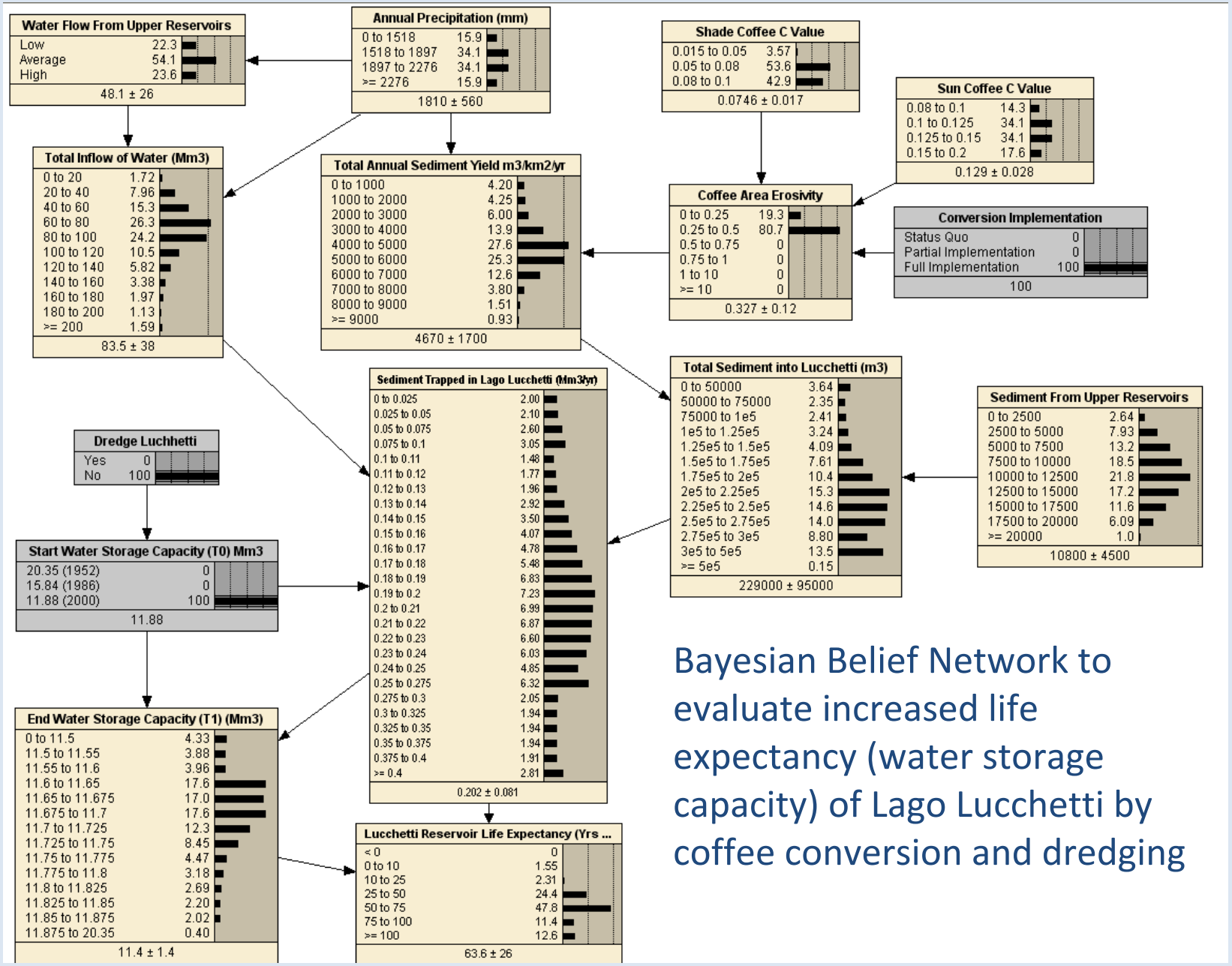
Science Challenges





Assessing the sediment contribution from coffee farm erosion and the reduction in sediment if farms were converted from sun-grown to shade-grown coffee

Estimating the loss of trapping efficiency and the increase of sediment discharge to downstream ecosystems as the reservoir fills with sediment



Bayesian Belief Network to evaluate increased life expectancy (water storage capacity) of Lago Lucchetti by coffee conversion and dredging

Bousquin et al. 2014

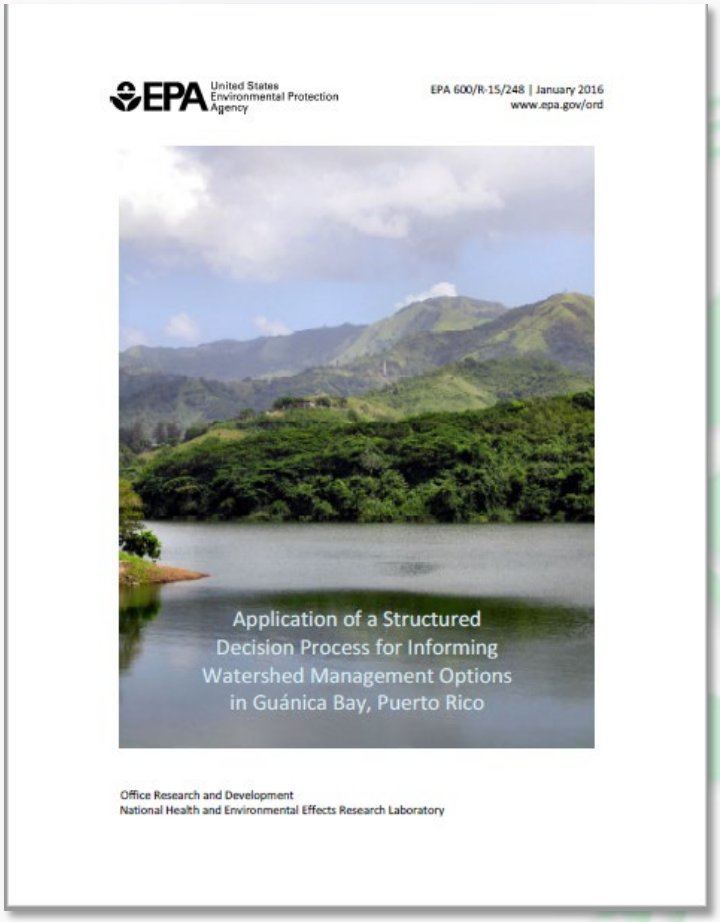
Results of Bayes Analysis

-- Estimated life expectancy* for Lago Lucchetti under two decision scenarios

Scenarios	Life Expectancy* (years)
Coffee conversion	
No conversion	48 ± 16
Partial Implementation	52 ± 17
Full Implementation	56 ± 18
Dredging	
No dredging	48 ± 16
50% of sediment	75 ± 18
100% of sediment	81 ± 19
Combined	
Partial Implementation/50% dredge	79 ± 19
Partial Implementation/100% dredge	85 ± 18
Full Implementation/50% dredge	83 ± 19
Full Implementation/100% dredge	89 ± 18

*Life Expectancy=time until there is no water storage capacity remaining

Reference



Application of a Structured Decision Process for Informing Watershed Management Options in Guánica Bay, Puerto Rico

(EPA 600/R-15/248, January 2016); EPA Science Inventory
https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NHEERL&dirEntryId=324903

Useful Tools and Approaches

- **Stakeholder engagement** early and often to understand objectives, alternatives and the changing decision landscape
- **Structured Decision Approach** to accommodate both stakeholder objectives and scientific knowledge
- **Systems Framework** to provide transparency and to identify unintended consequences
- **Consequence comparisons** to characterize tradeoffs across multiple objectives
- ***Value added* scientific research** to provide information that directly influences a decision

The views expressed in this presentation are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

Thank you

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