Mainstreaming Environment and Equity in Resilient Infrastructure Assessments (*MEERIA*) An alternative valuation framework

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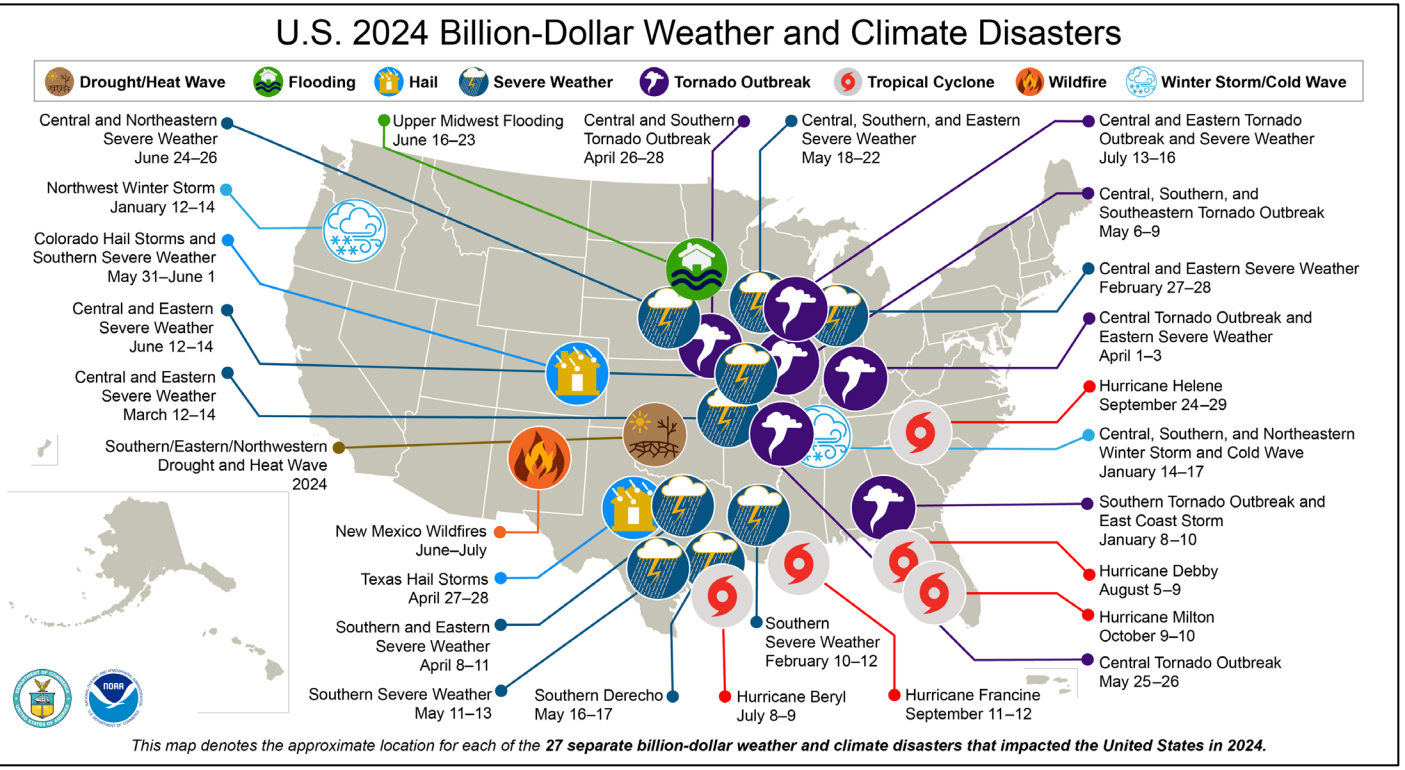
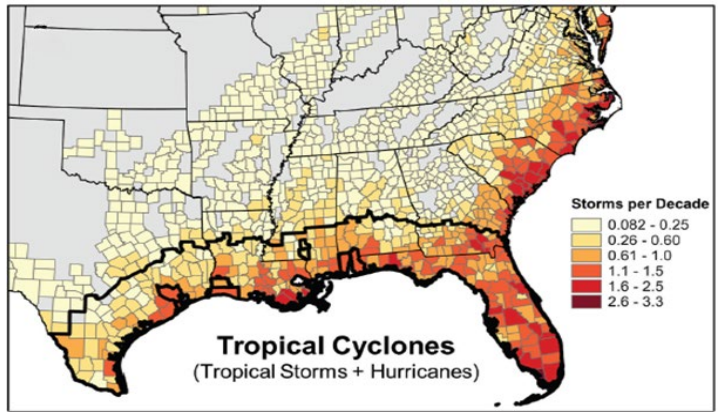
[1]Florida International University, [2]The Everglades Foundation, [3]Collaborators Consulting Group, [4]University of Miami, [5]Independent Consultant

We live in a multi-hazard *and* compounding disaster risk reality



Escalating losses: 27 individual billion-dollar US disasters in 2024 cost **$180.2 billion** (NCEI-NOAA 2024)

Helene 2024
(New York Times)



Frequency of tropical storms and hurricanes since 1900 (Strader 2023)

The disaster-related economic losses do not reflect the costs of environmental degradation and social impacts


Mangrove forests damaged after Hurricane Irma (Earth Observatory, NOAA 2017)


Hurricane Sandy 2012 (nytimes)

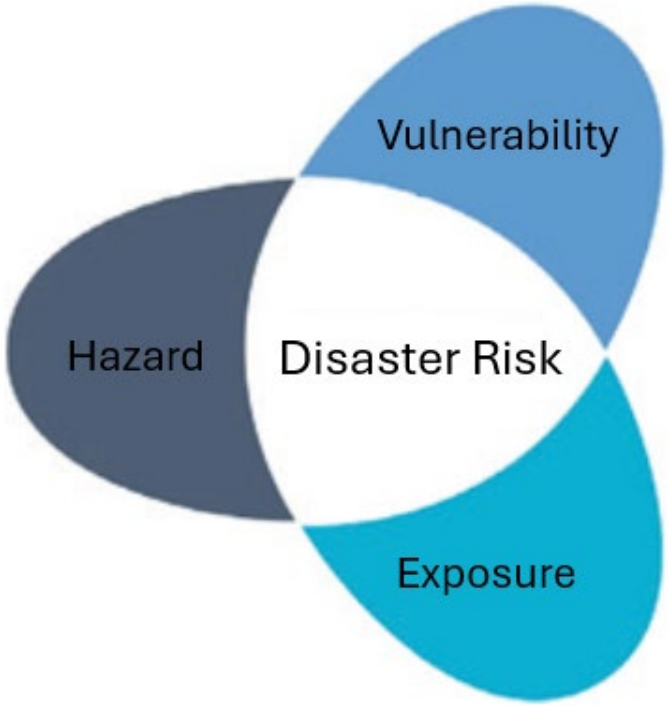

Shoreline erosion post Hurricane Dorian (Cummins Cederberg)


Hurricane Sandy 2012 (nytimes)

Inequitable patterns of US flood risk in the Anthropocene (Wing et al. 2022)

- Current average annual losses of (US$32.1 billion) (borne disproportionately by poorer communities with a proportionally larger White population.
- The future increase in risk will disproportionately impact Black communities, while remaining concentrated on the Atlantic and Gulf coasts.

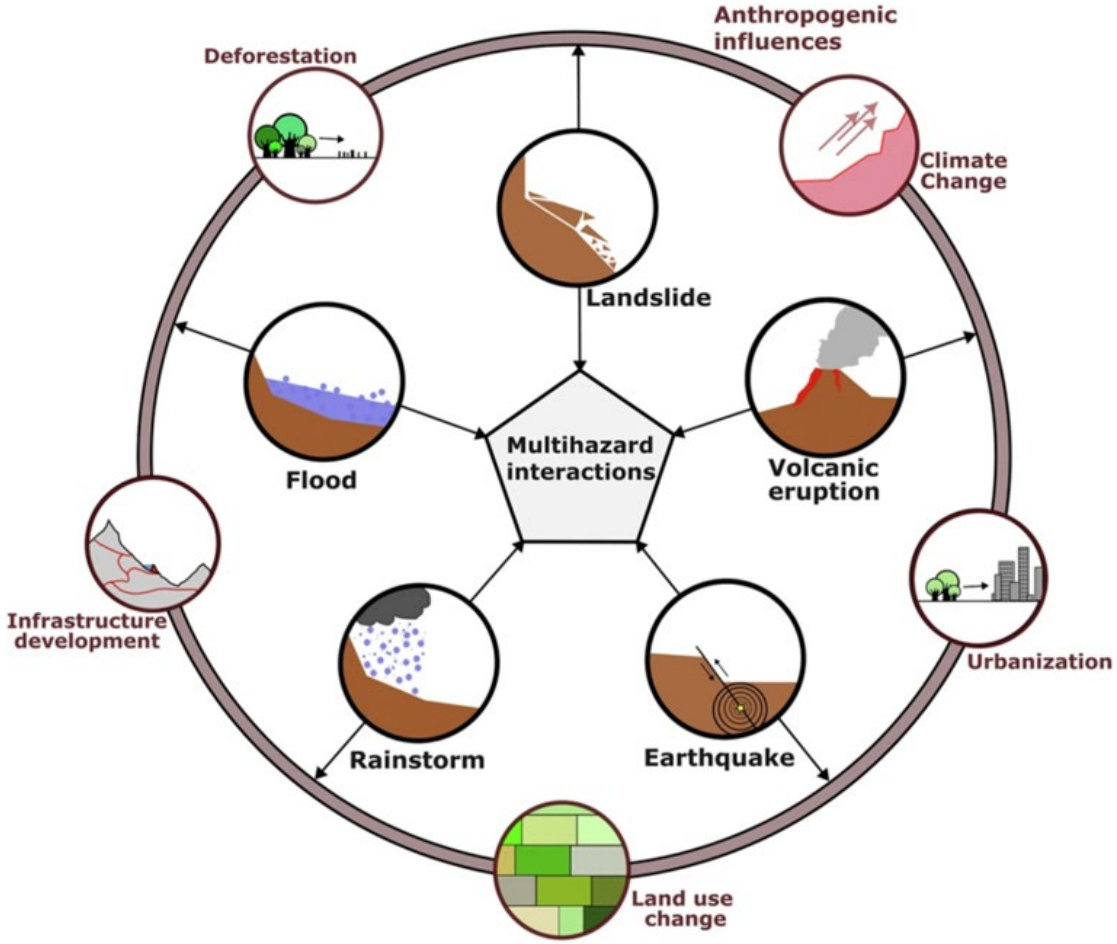
Disaster risk is systemic in nature



Wisner et al. 2003; Oppenheimer et al. 2014

"....**infrastructure design**, planning, governance, and disaster preparedness for compound events are critical for **building resilient systems**."

(Fifth National Climate Assessment 2023)



"*All hazards are multi-hazard, few of them are natural.*"

Potential **anthropogenic influences** and some of the hazards these may apply to

(Van Wyk de Vries 2025)

Traditional risk management, focuses on ‘gray’ engineered infrastructure, and exacerbates environmental and social impacts of disasters

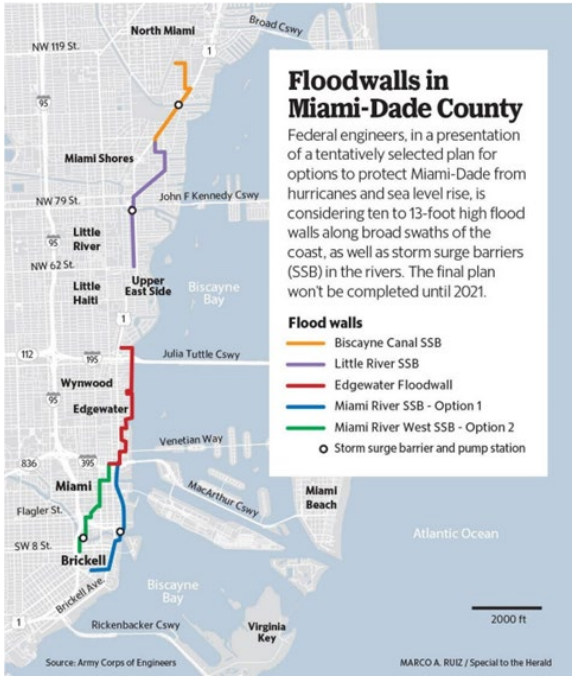
Fox Point Hurricane Barrier 1966, Rhode Island (Rasmussen et al. 2022)

Acre seawall, Israel (Wikipedia)

The Thames Barrier, London (Wikipedia)

Artist rendering of a proposed storm surge barrier (USACE)

The United States Army Corps of Engineers (USACE)

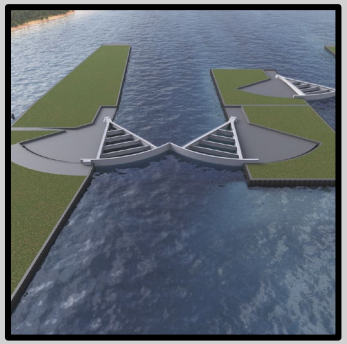


The aftermath of Hurricane Sandy triggered the beginnings of a shift in the US risk management approach

The North Atlantic Coast Comprehensive Study (USACE 2015)

- **Redefined Resilience: Coastal resilience** is the ability of a system to prepare, resist, recover, and adapt to disturbances to achieve successful functioning through time" (Rosati et al. 2015)

- The ***comprehensive approach*** recommended … "holistically incorporate coastal water resource, or engineering features and activities; ecosystem features, both naturally occurring and constructed; and community aspects including the social and economic assets, and critical facilities of coastal systems.



Gray/Hard Infrastructure

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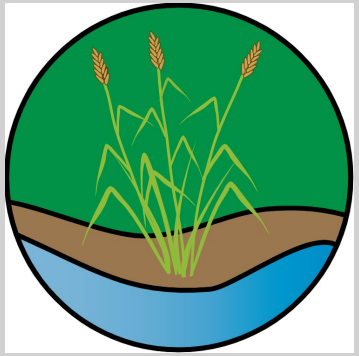

Nature-Based Solutions (NBS)

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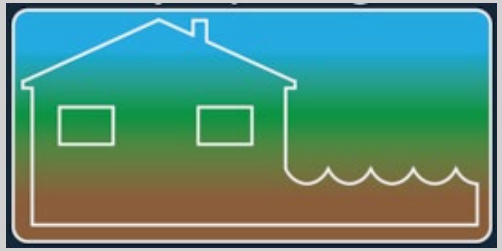


Non-structural solutions like elevating and flood-proofing homes

=

COMPREHENSIVE APPROACH

However, barriers to a comprehensive approach persist.

Reliance on engineered megaprojects

Table 1. An incomplete list of proposed public works coastal flood protection projects in the US

Project	Location	Strategy	Year proposed	Lead agency	Project cost	Status (as of 2020)
Boston Harbor Surge Barrier	Boston	Levee/barrier	2018	UMass Boston	$6.5 to 11.8 billion	Proposed
East Side Coastal Resiliency Project	New York	Levee/nonstructural	2014	NYC/HUD	$1.5 billion	Under construction
Lower Manhattan Climate Resiliency Project	New York	Coastal advance/fill	2019	NYC	$10 billion	Proposed
Embarcadero Seawall	San Francisco	Seawall	2018	City of San Francisco	$5 billion	Proposed
Red Hook Integrated Flood Protection System	New York	To be determined	2013	NYC	$0.1 billion	Undergoing a redesign
Coastal Texas Protection and Restoration Project	Coastal Texas	Levee/barrier/nonstructural	2015	USACE	$23.1 to 31.8 billion	Proposed
Galveston Bay Park	Galveston, Texas	Levee/barrier/nonstructural	2020	SSPEED	$2.3 to 2.8 billion	Proposed
South Shore of Staten Island CSRM Project	New York	Levee/nonstructural	1993	USACE	$0.6 billion	Under construction
Charleston Peninsula: A Coastal Flood Risk Management Project	Charleston, South Carolina	Levee/seawall	2020	USACE	$1.1 billion	Proposed
City of Norfolk CSRM Project	Norfolk, Virginia	Levee/barrier/nonstructural	2015	USACE	$0.9 to 2.3 billion	Authorized
Miami-Dade Back Bay CSRM Project	Miami	Levee/barrier/nonstructural	2020	USACE	$0.9 to 5.2 billion	Proposed
Collier County CSRM Project	Naples, Florida	Levee/barrier/nonstructural	2020	USACE	$2.2 billion	Proposed
Fairfield and New Haven Counties, CT CSRM Project	Fairfield and New Haven, Connecticut	Levee/seawall/pumps	2019	USACE	$0.05 to 0.3 billion	Proposed
New York–New Jersey Harbor and Tributaries Project	New York	Levee/barrier/nonstructural	2019	USACE	$15 to 119 billion	Planning suspended

Note: CSRM = coastal storm risk management; HUD = department of housing and urban development; NYC = New York City; and SSPEED = severe storm prediction, education, and evacuation from disasters center.

Rasmussen et al. 2022

Lack of community engagement

The New York Times

Why Does Disaster Aid Often Favor White People?

JULY 2, 2017 | 4 MIN READ

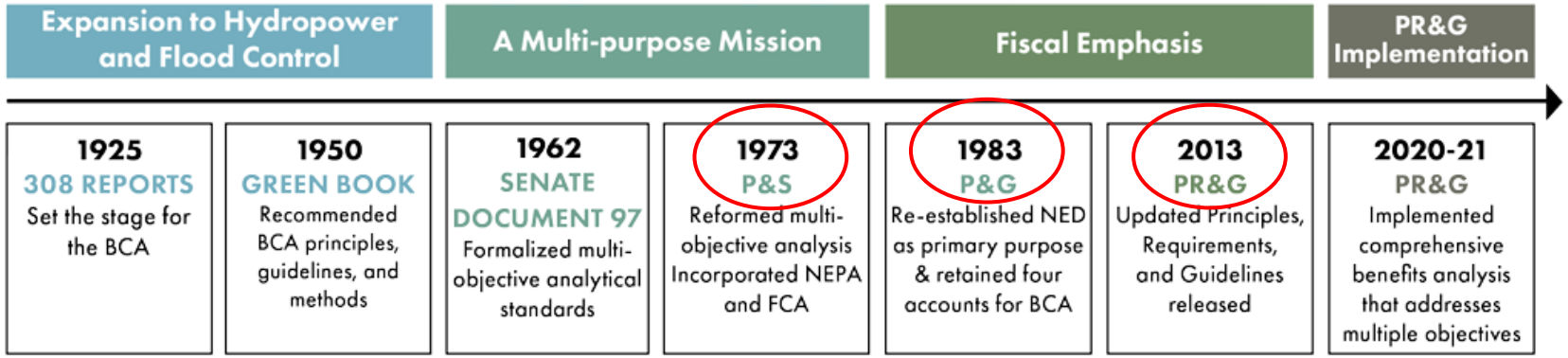
~~Natural~~ Disasters by Location: Rich Leave and Poor Get Poorer

Lack of consensus on NBS effectiveness & viability

Kuwae and Crooks 2021; Fischbach 2022

Federal policy guidelines dictate USACE selects projects solely on the merit of economic benefits (*disregarding environmental and social outcomes*)

The **Benefit Cost Analysis** is the primary decision-making tool for project selection since 1925/1930



Net Economic Development (NED) in the Principles and Guidelines (P&G)

Consistency: Thy Name is OMB

Fox in the Henhouse

Gerald E. Galloway, Jr., University of Maryland

Keep it to Numbers
Higher NED Numbers Win

From Net Economic Development ...to "*Net Public Benefits"* in the **Principles, Requirements, and Guidelines**, April 2025

Section 234.4 (c) "Net public benefits. The Corps shall strive to maximize net public benefits to society. Public benefits encompass economic, environmental, and social goals, include monetized and un-monetized effects, and allow for the consideration of both quantified and unquantified effects."
Section 234.7 (h) "Nonstructural and nature-based solutions. ...shall be considered...and included when appropriate."

The need for a tool that enables sustainable, equitable, and just distribution of 'comprehensive benefits' from infrastructure projects

The need for a tool that enables sustainable, equitable, and just distribution of 'comprehensive benefits' from infrastructure projects

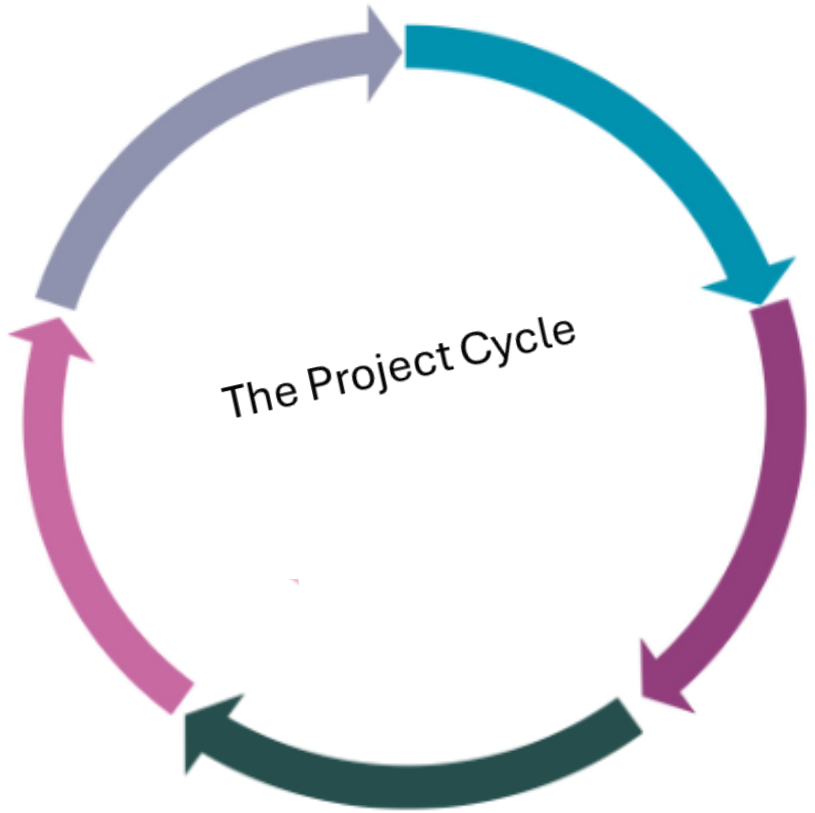
- Developed an alternative valuation framework and rubric: Mainstreaming Environment and Equity in Resilient Infrastructure Assessments *(*MEERIA)
- Analyzed feasibility studies of three US resilient infrastructure projects
- Applied MEERIA rubric for an illustrative analysis of the three USACE coastal resilience projects

Development of the MEERIA framework

To mainstream environment and equity in resilient infrastructure projects

5 | MONITORING

4 | IMPLEMENTATION



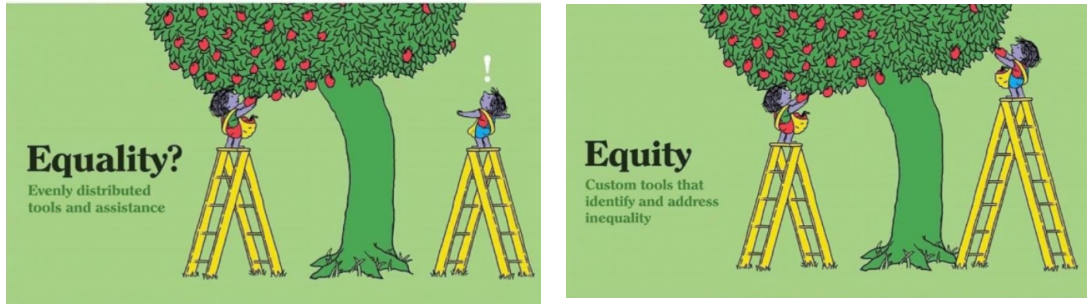
1 | SCOPING

2 | PLANNING & DESIGN

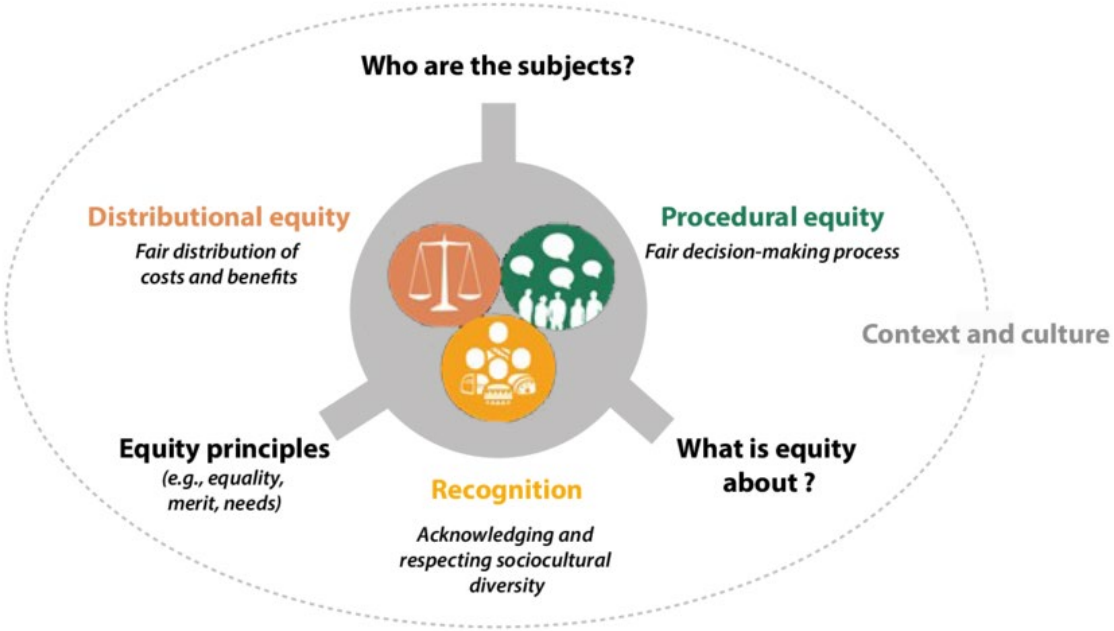
3 | EVALUATION

MEERIA draws resilient infrastructure projects to focus on procedural equity

- **Procedural equity** is the intentionally inclusive decision-making approach to maximize representation, engagement, and participation of community members and stakeholders across diverse socioeconomic groups and structures of political power in the developing, planning, and implementation of public projects to enhance equity outcomes.
  - It involves transparent, fair, respectful, inclusive, and participatory decision-making processes embodied in voice and choice (Prilleltensky, 2012).
  - MEERIA includes **Recognitional equity** which brings to light historical inequities and the social, political, and institutional structures that continue to sustain those inequities. Recognizing these inequities fosters respect across community groups and helps find effective solutions.

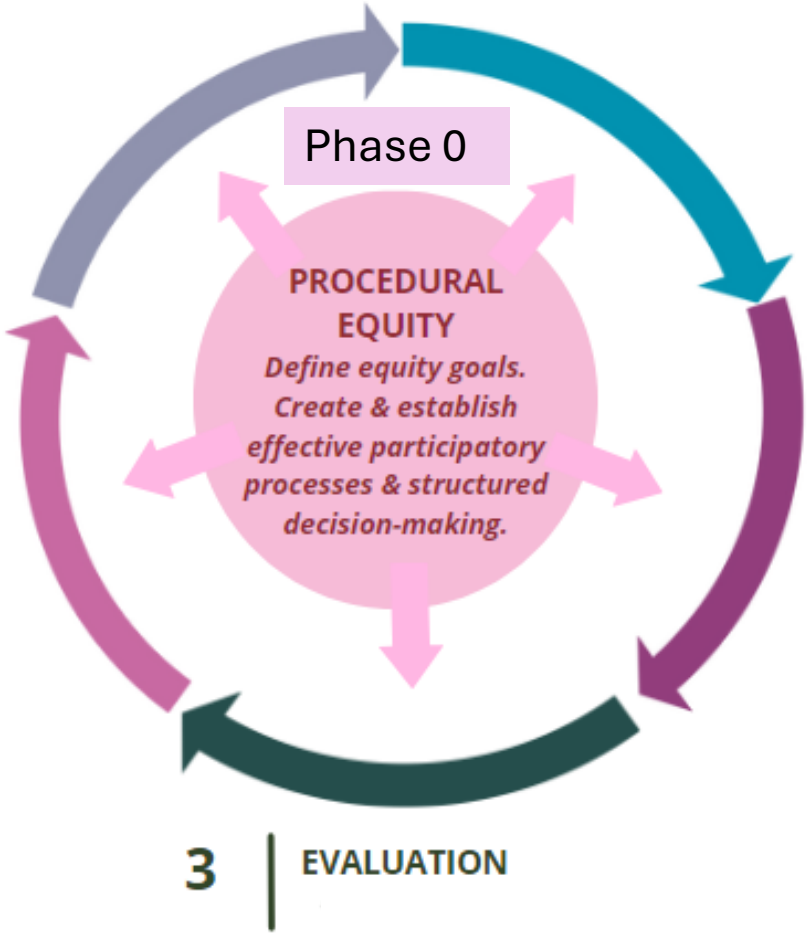


Ruth 2019



Equity framework based on Schlosberg (2007), McDermott et al. (2013), and Sikor et al. (2014). The procedural equity icon is adapted from “Family” by Joanna Woerner, Integration and Application Network (ian.umces.edu/media-library) used under CC BY-SA 4.0, and the recognition icon is from Ruano-Chamorro et al. 2022.

The MEERIA Framework



1 | SCOPING

2 | PLANNING & DESIGN

3 | EVALUATION

4 | IMPLEMENTATION

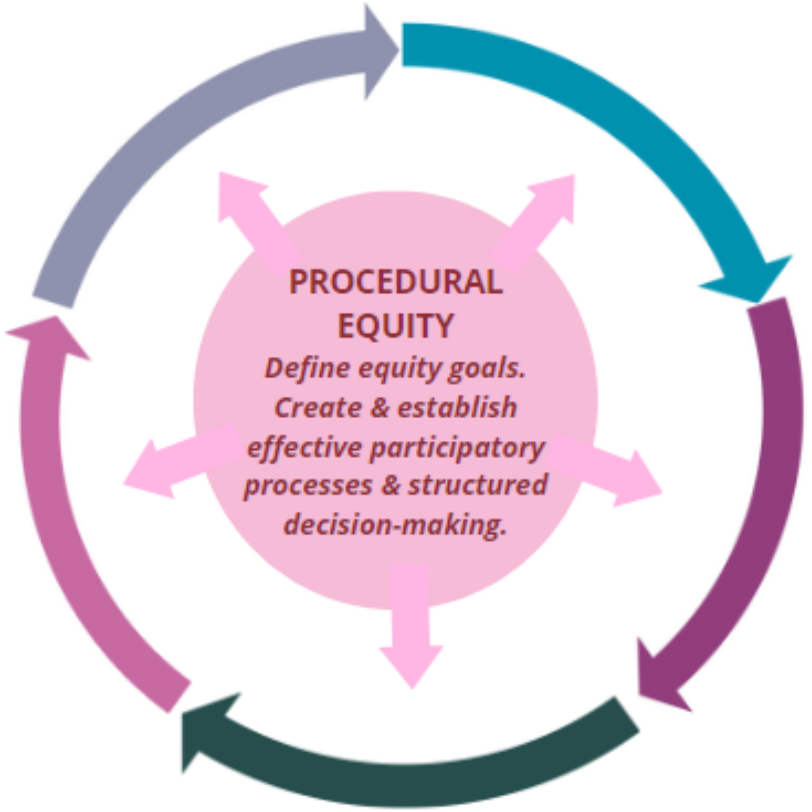
5 | MONITORING

Procedural Equity Criteria in MEERIA:
Equity goals, Acceptance, Process
(Schlosberg 2007)

MEERIA draws resilient infrastructure projects to focus on ecosystem services and distributional equity

- **Ecosystem services** are the direct and indirect contributions of ecosystems to human well-being.
  - Ecosystem services approach enhance positive environmental outcomes (Millennium Ecosystem Assessment 2005, TEEB 2010; Rincon-Ruiz et al. 2019; The Integrated Valuation of Ecosystem Services or IVES approach).
- **Distributional equity** is the fair allocation of goods, services, infrastructure, environmental amenities, risk reduction benefits, and economic opportunities to all, but more expressly to improve the welfare of the underserved (Schlosberg 2007, 2012, 2013; Meerow et al. 2019).
  - Social welfare approach, Welfare economics, Social vulnerability (A. Sen 2987; Pearce and Nash 1981; IPCC 2014; Cutter 2012)

The MEERIA Framework



1 SCOPING
- *Understand relevant ecosystem services & interactions, prevalent disaster and climate risks, potential project impacts.*

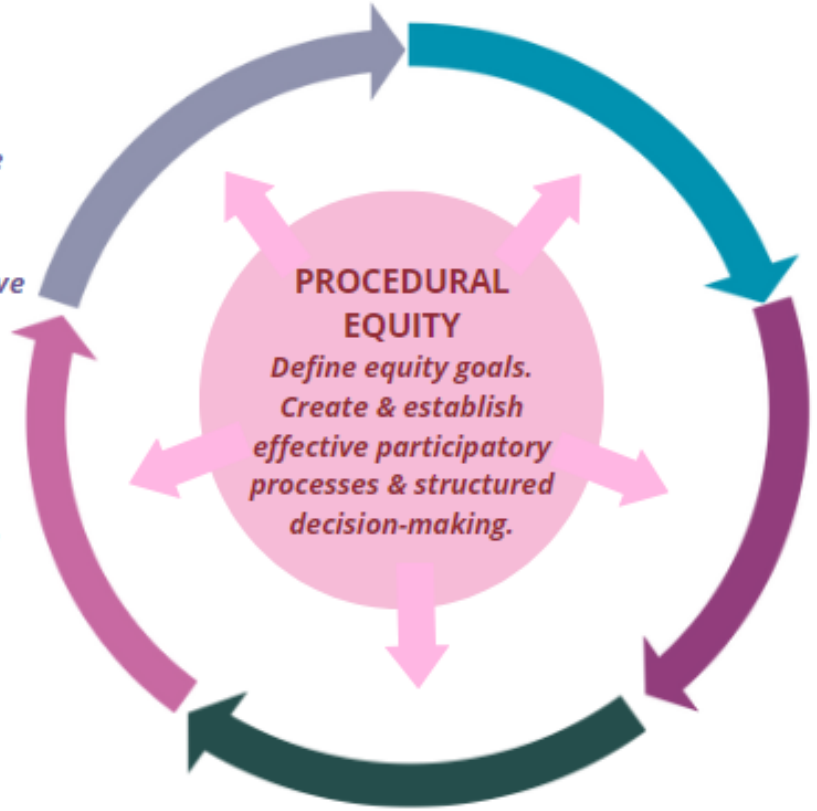
2 PLANNING & DESIGN
- *Adopt an integrated approach to ecosystem valuation & purposefully include /prioritize nature-based solutions.*

3 EVALUATION
- *Integrate comprehensive ecological assessments.*

4 IMPLEMENTATION
- *Ensure project is faithful to ecosystem integration goals*

5 MONITORING
- *Measure project performance and impacts regularly & mitigate adverse ecosystem impacts.*

The MEERIA Framework



1 SCOPING

- *Understand relevant ecosystem services & interactions, prevalent disaster and climate risks, potential project impacts.*
- *Conceptualize diverse project alternatives & equitable allocation of benefits, burdens, and responsibilities.*

2 PLANNING & DESIGN

- *Adopt an integrated approach to ecosystem valuation & purposefully include /prioritize nature-based solutions.*
- *Build foundations of equitable decision-making structures & processes.*

3 EVALUATION

- *Integrate comprehensive ecological assessments.*
- *Use appropriate and diverse tools to estimate equity, reversibility, and distribution of project impacts.*

4 IMPLEMENTATION

- *Ensure project is faithful to ecosystem integration goals*
- *Apply appropriate mechanisms to actively promote equitable project outcomes.*

5 MONITORING

- *Measure project performance and impacts regularly & mitigate adverse ecosystem impacts.*
- *Ensure sustainability of equitable project results and institute corrective measures where needed.*

Normative

The MEERIA Framework and Rubric

Technical guideline

Evaluative

Project Phase	Focus area	Focus area objective	Criteria	Determination Examples *(see Applendix A)*	Assessment Score
0. Procedural Equity Phase *The process necessitating the involvement of communities and stakeholders and the establishment of mechanisms to facilitate their participation at each stage of the project.*	**Equity Goals**	*Defining objectives for an equitable project*	Equity goals		
	Acceptance	*Creating effective participatory procedures to increase the likelihood of public acceptance*	Representativeness; Independence; Early involvement; Transparency; Influence.		
	Process	*Fostering the quality of the participatory process itself*	Resource accessibility; task definition; Structured decision-making; cost-effectiveness.		
1. Scoping Phase *The preliminary process of gathering information on project demands and opportunities, stakeholders' needs, and potential environmental and community impacts.*	**Ecosystem Services**	*Forming an understanding of the region of interest and the project's potential ecological interactions*	Ecosystem identification; Ecosystem impacts; climate change impacts; Ecosystem interactions.		
	Distributional Equity	*Conceptualizing a project that provides an equitable allocation of benefits, burdens, obligations, and responsibilities*	Stakeholder identification; Scoping objectives; Alternatives development; Community impact.		
2. Planning and Design Phase *The process of developing project alternatives based on a variety of decision-making approaches, valuation techniques, and considerations made toward the distribution of project impacts.*	**Ecosystem Services**	*Establishing an integrated approach to ecosystem service valuation and the incorporation of nature-based solutions into project design*	Ecosystem prioritization; Ecosystem valuation; Natural and hybrid alternatives.		
	Distributional Equity	*Forming the foundational decision-making structures and processes necessary to provide an equitable allocation of benefits, burdens, obligations, and responsibilities*	Plannning and design objectives; Feedback integration; Decision-making approach; Valuation techniques; Intragenerational equity; Intergenerational equity; Constraints; Assumptions.		
3. Evaluation Phase *The process of estimating, integrating, and assessing project impacts, both positive and negative, across all alternatives and stakeholders, within a final project analysis.*	**Ecosystem Services**	*Integrating a comprehensive ecological assessment into the project analysis*	Ecosystem analysis; Sensitivity analysis.		
	Distributional Equity	*Utilizing appropriate decision-making tools to estimate the equity, reversibility, and distribution of project impacts*	Evaluation objectives; Alternatives analysis; Stakeholder analysis; Distributional/Risk Weighting; Risk and uncertainty; Decision-making criteria; Exclusions; Communication of decisions.		
4. Implementation Phase *The period of time during project implementation within which the monitoring, compensation, and/or mitigation of project impacts is executed.*	**Ecosystem Services**	*Ensuring the project's fidelity to environmental considerations*	Environmental Implementation Monitoring; Environmental mitigation		
	Distributional Equity	*Applying appropriate mechanisms to promote equitable project outcomes*	Implementation objectives; Implementation methodology; Mitigation of stakeholder impacts; Dispute resolution mechanisms; Transferability plan.		
5. Monitoring Phase *The period of time post-project implementation and over the project lifecycle within which the real project results are observed and corrected, as necessary.*	**Ecosystem Services**	*Measuring and mitigating the project's ecological impacts*	Environmental post-implementation methodology		
	Distributional Equity	*Sustaining the equitable distribution of real project results*	Monitoring objectives; Stakeholder engagement; Corrective measures for inequity.		

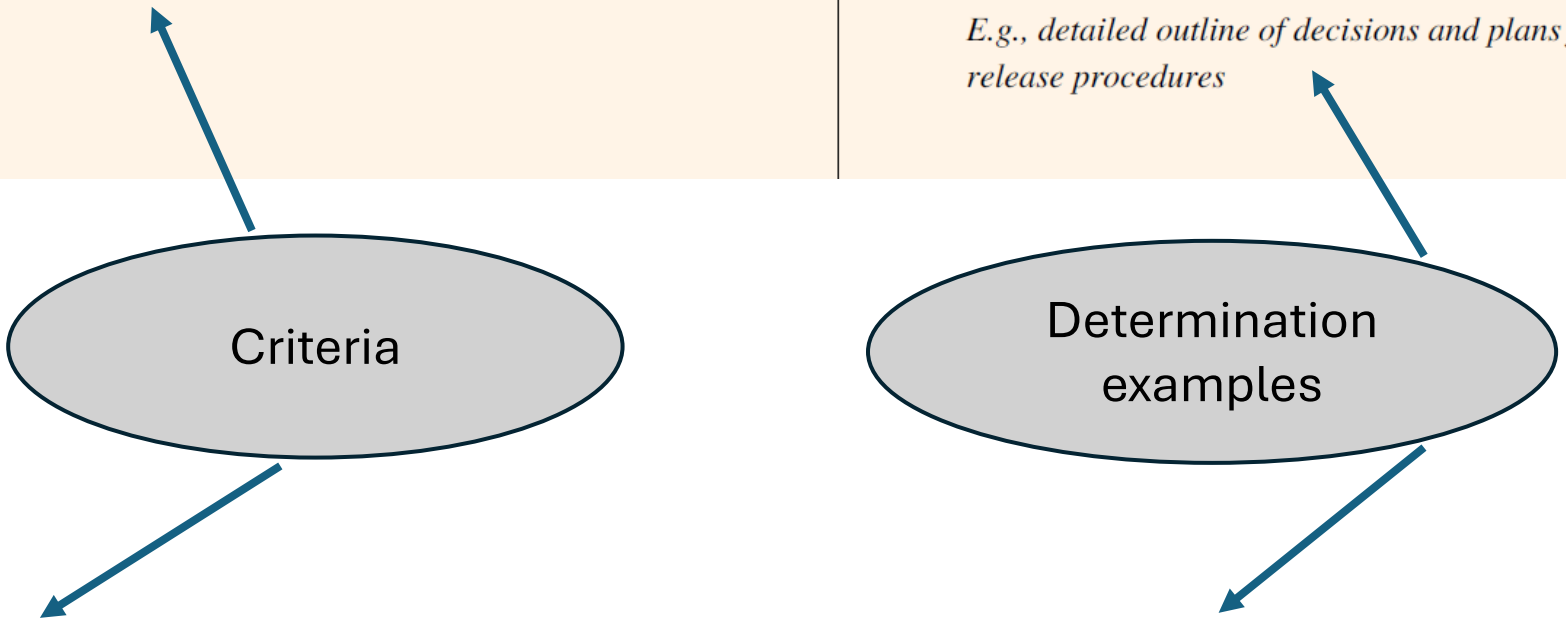
Procedural equity

0.2d. Transparency

"The process should be transparent so that the public can see what is going on and how decisions are being made." (p.15)

- Project establishes a Communication Plan to guide the transparent and efficient communication of information between the public and project leads/authorities/sponsors.

  E.g., detailed outline of decisions and plans for public involvement, information release procedures



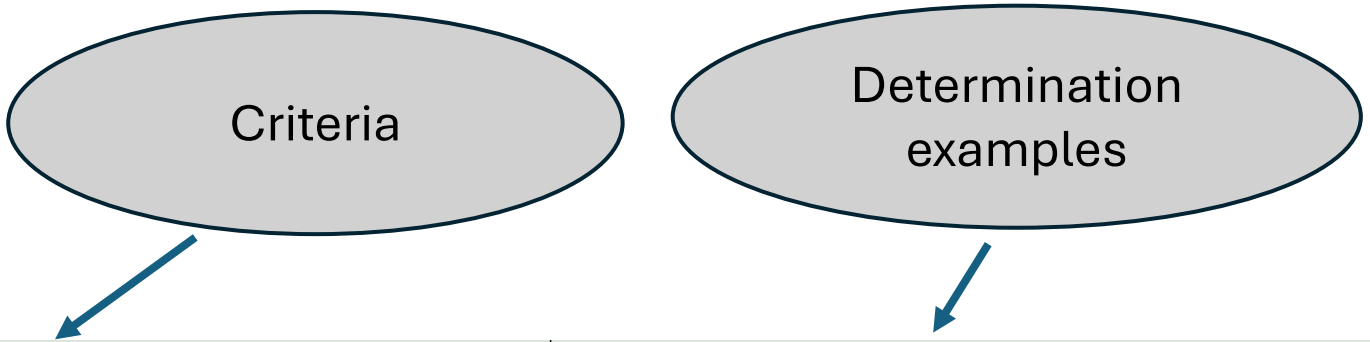
0.2c. Early Involvement

"The public should be involved as early as possible in the process as soon as value judgements become salient." (p.14)

- The public is involved during the earliest stages of the project *(i.e., scoping of the project, during identification and valuation of resources.)*

  E.g., Utilizing surveys, focus groups, meetings

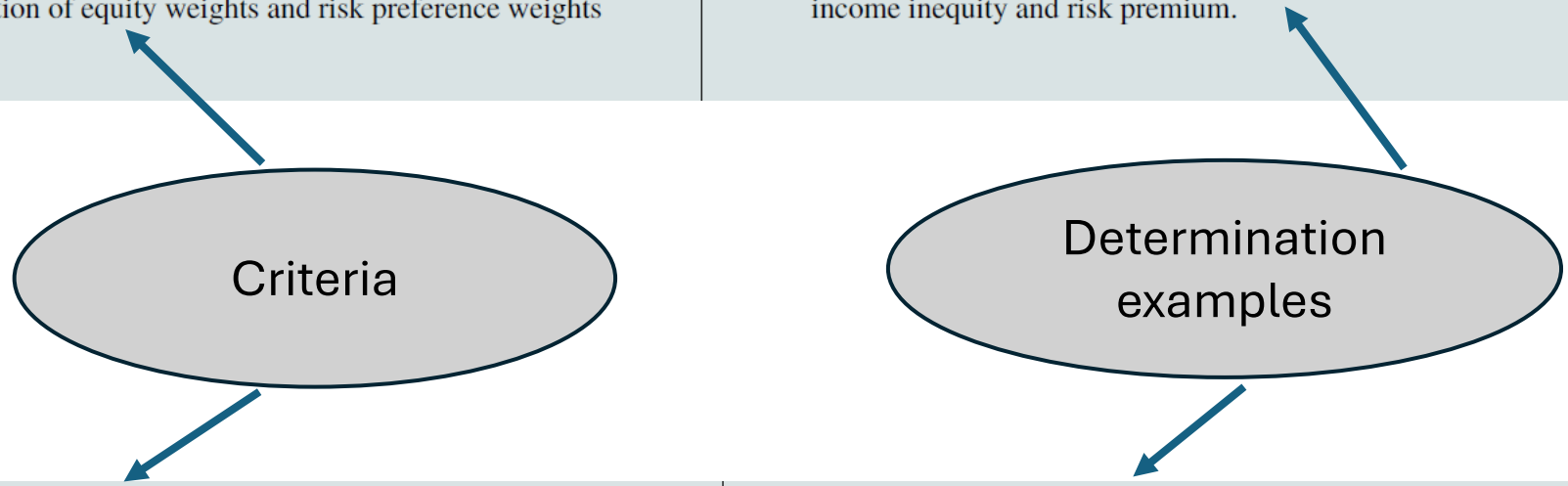
Ecosystem services



2.1c. Natural and Hybrid Alternatives Consideration of relevant and competitive Natural/Nature-Based and hybrid project alternatives	• Explicit consideration of a range of solutions. *Does the project consider the feasibility of technological, nature-based, and/or social solutions?* • Inclusion of relevant and viable Nature/Nature-Based Features (NNBFs) and hybrid alternatives, along with conventional measures, that can reasonably be expected to meet project objectives. *Can these NNBF/hybrid measures compete fairly in the rigorous qualitative and/or quantitative analysis during project evaluation?* *Can these alternatives strive to exceed basic policy requirements for inclusion in project plans?* • An evidence-based, expert-informed justification is provided for the presence of/absence of natural/nature-based project measures.

Distributional equity

3.2d. Distributional/Risk Weighting Consideration of equity weights and risk preference weights	• Application of social welfare approach, including appropriate adjustments of income inequity and risk premium.
3.2e. Risk and Uncertainty Address project risk and uncertainty	• Assessment of the degree of irreversibility involved in the project. *E.g., If/when the initial investment is sunk, if/when the damage to the natural environment cannot be repaired* • *Consider whether risk is distributed equally or disproportionately within the community.* • *Conduct appropriate sensitivity, scenario, and probabilistic benefit-cost analyses, when feasible.* • *Propose appropriate mechanisms to minimize risk to the community and natural resources.*



The MEERIA Rubric

	Subtotal	Assessment Score
	1 out of 1	100 %
	1 out of 3	33 %
	0 out of 4	0 %
	4 out of 12	33 %
	5 out of 12	42 %
	3 out of 9	33 %
	8 out of 24	33 %
	1 out of 6	17 %
	8 out of 24	33 %
	N/A	N/A
	N/A	N/A
	1 out of 3	33 %
	0 out of 3	0 %

Analysis of three resilience infrastructure projects

EAST SIDE COASTAL RESILIENCY PROJECT

New York:
ESCR, 2019

Miami-Dade Back Bay Coastal Storm Risk Management Draft Integrated Feasibility Report and Programmatic Environmental Impact Statement

Draft Feasibility Study

May 29, 2020

Miami-Dade
MDBB, 2020

Mississippi Valley Division,
Regional Planning and Environment Division South

South Central Coast Louisiana

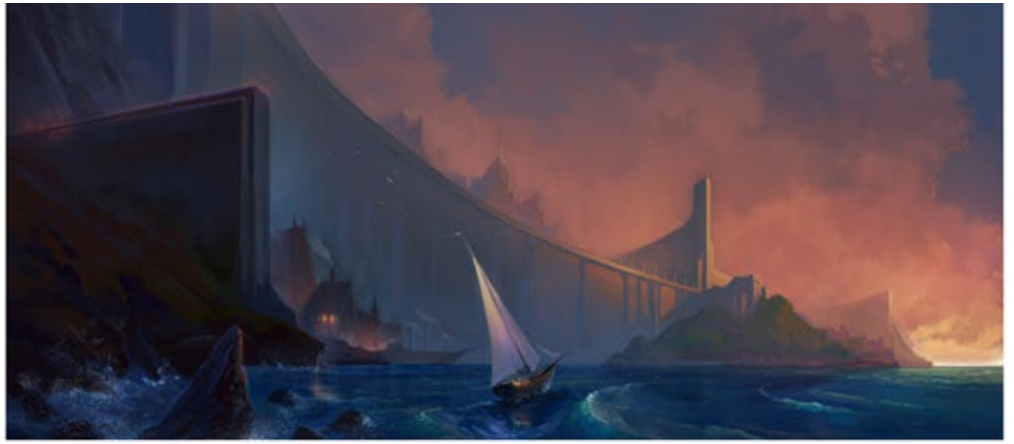
Hurricane Ike flooding in Delcambre, Louisiana 2008.

Final Integrated Feasibility Study with Environmental Impact Statement

June 2021

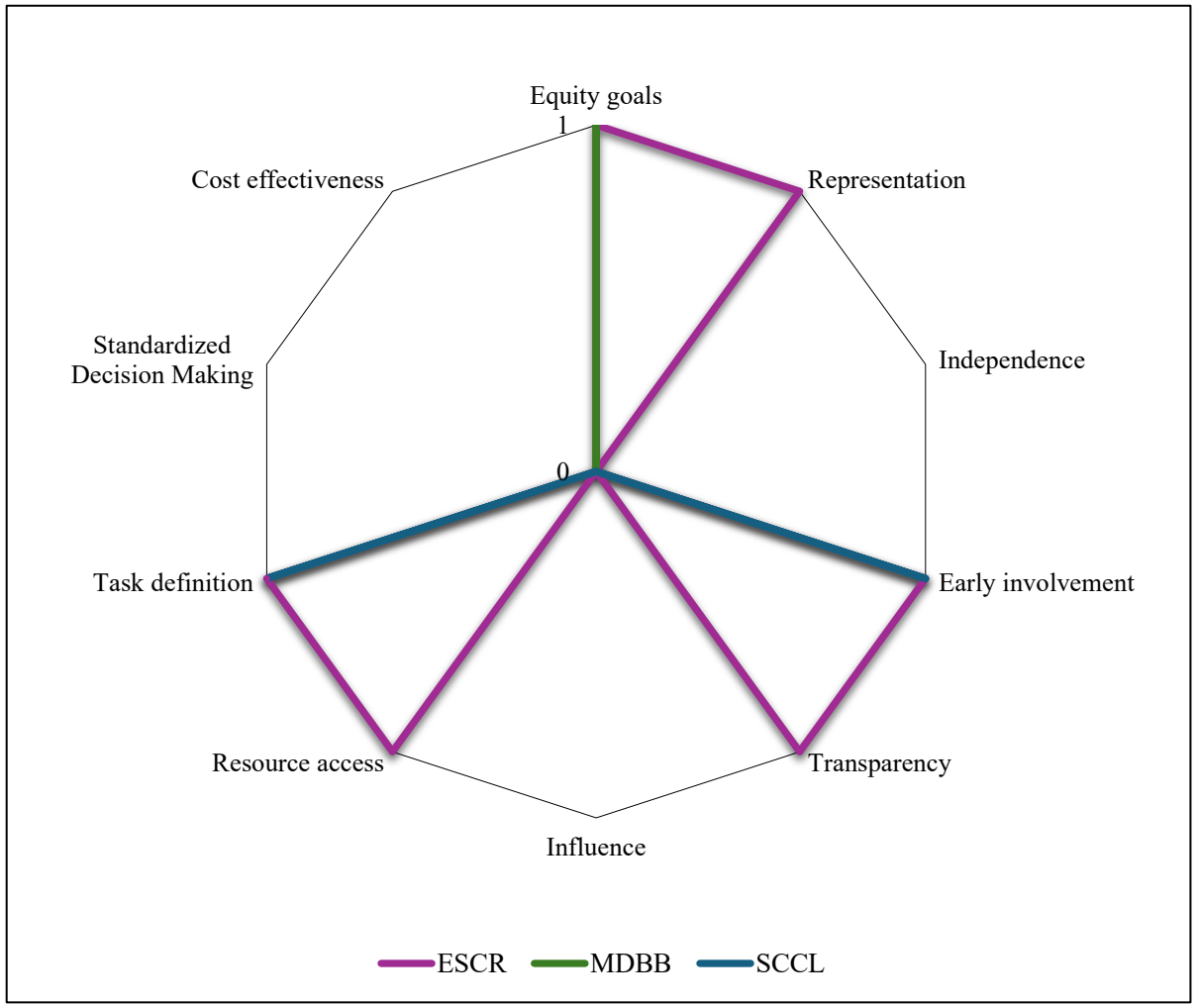
Controlled by: USACE MVD
CUI Category(ies): USACE MVN
LDC or Distribution Statement: FEDCON
POC: Karla Sparks, [redacted]

South Central Louisiana
SCCL, 2021



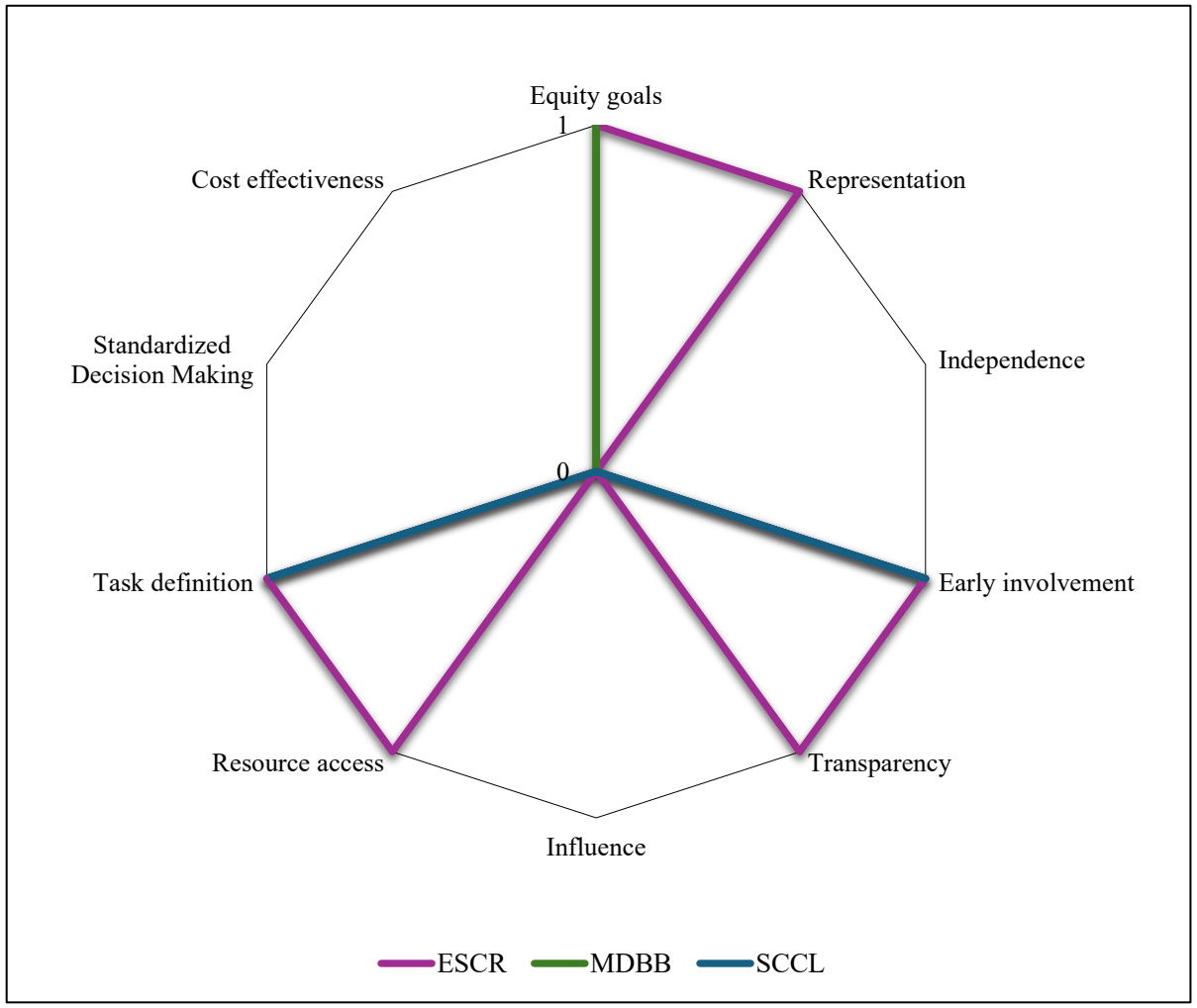
Findings

Procedural equity



- Recognitional equity absent
- Including goals for equity is not a requirement
- Neither is diverse stakeholder participation
- With the exception of ESCR, New York, documentation of public engagement was perfunctory
- Budget allocation for participatory processes limited or non-existent
- Low evidence of influence of public participation on final decision-making
- Robust communication does not guarantee inclusion of people's views and voices.

Procedural equity: *An effective participatory process relies on robust intentions, meaningful representation, candid communication, and carrying the good work to the finish line*



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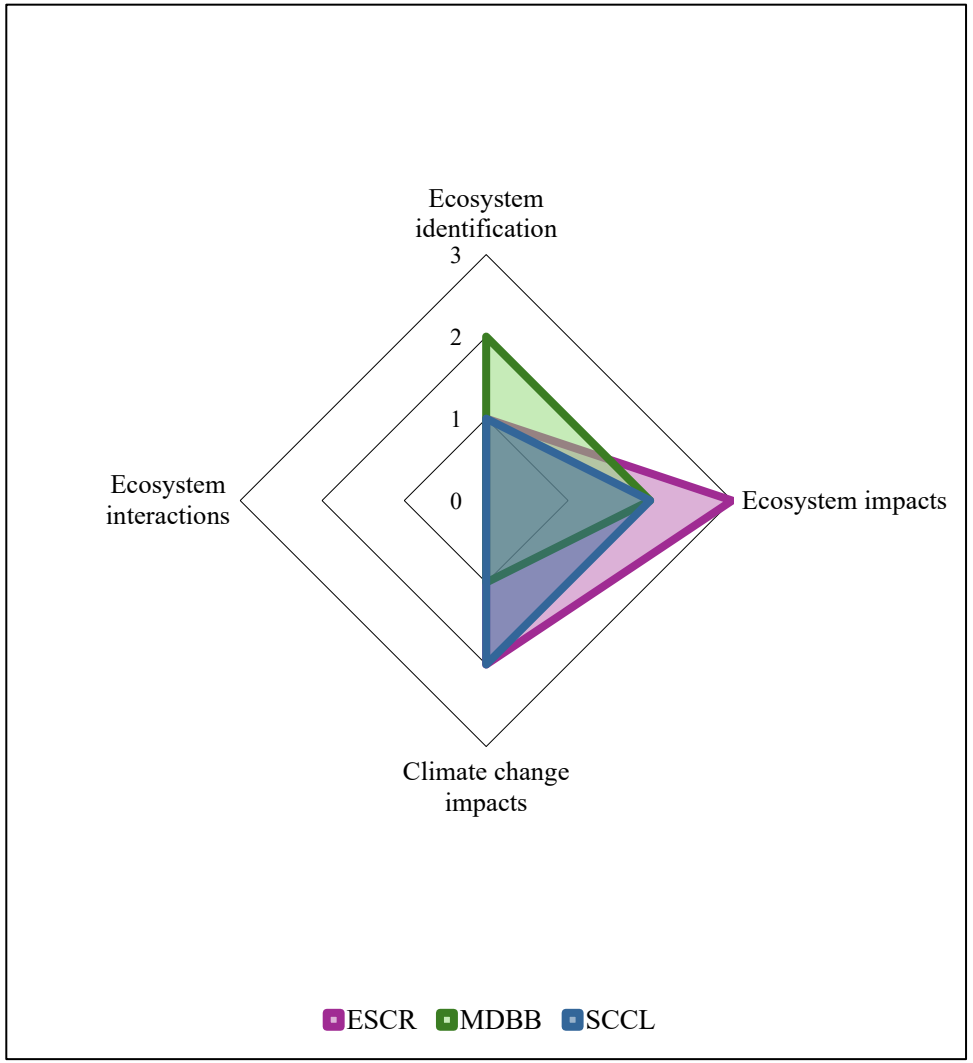
Ecosystem services

- Robust cataloguing of ecosystems of concern
- Interactions with climate change impacts limited
- Meaningful engagement with stakeholder to determine their values, preferences absent
- Project impacts on ecosystems, feedback effects, and dependence on ecosystem functionality ignored.
- Limited use of multidisciplinary methodologies to appropriately value ecosystem services
- None of the studies included nature-based solutions or hybrid solutions as significant elements to reduce disaster risk



Scoping phase

Ecosystem services

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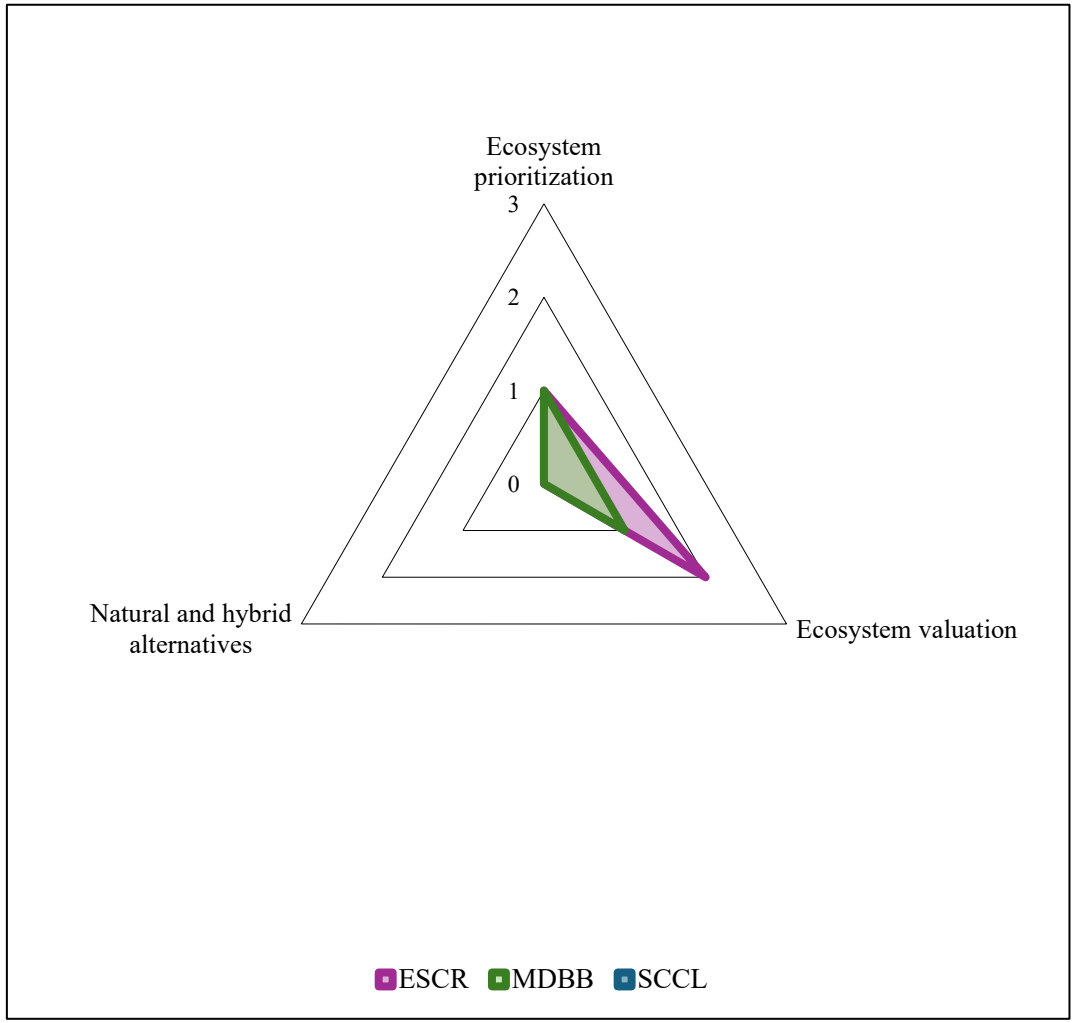

Planning and Design Phase

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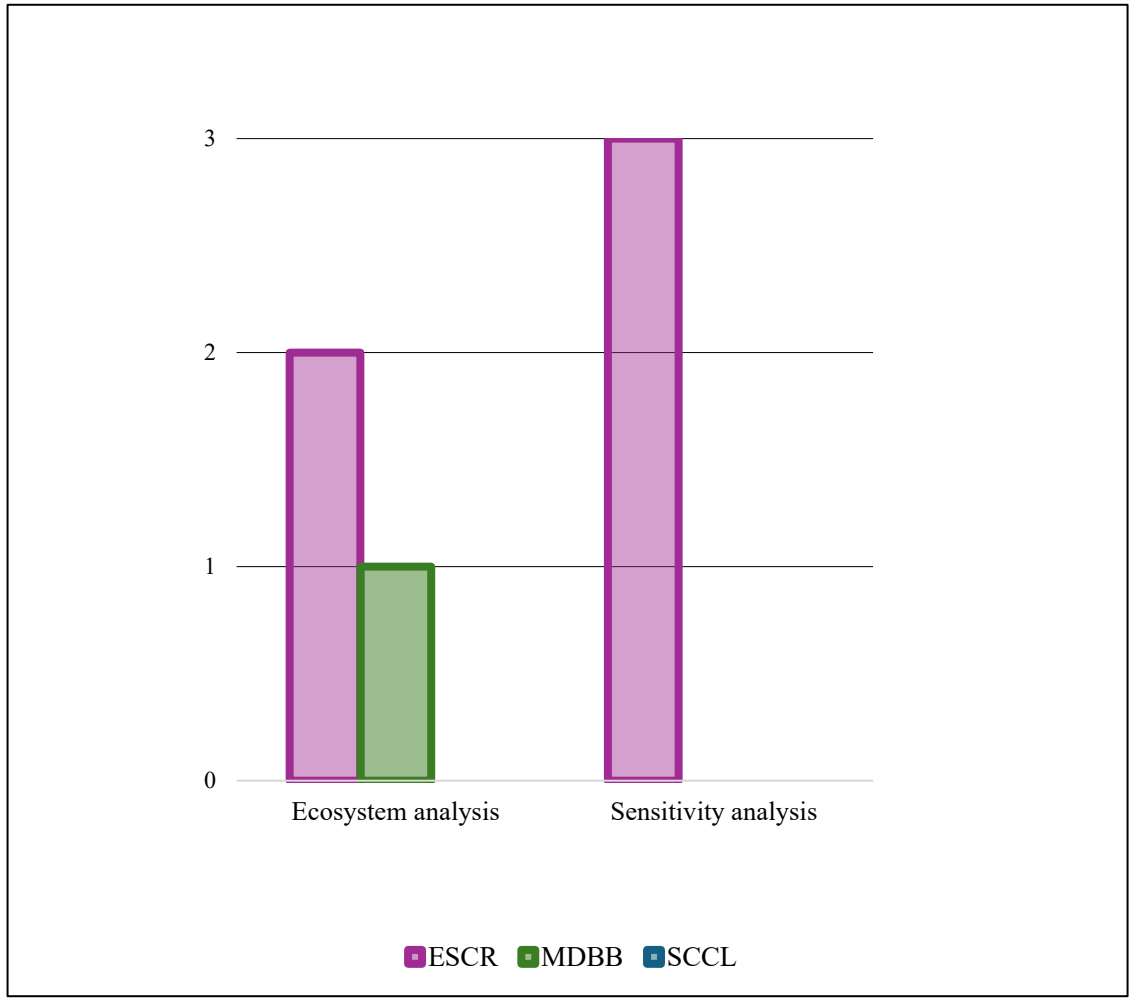
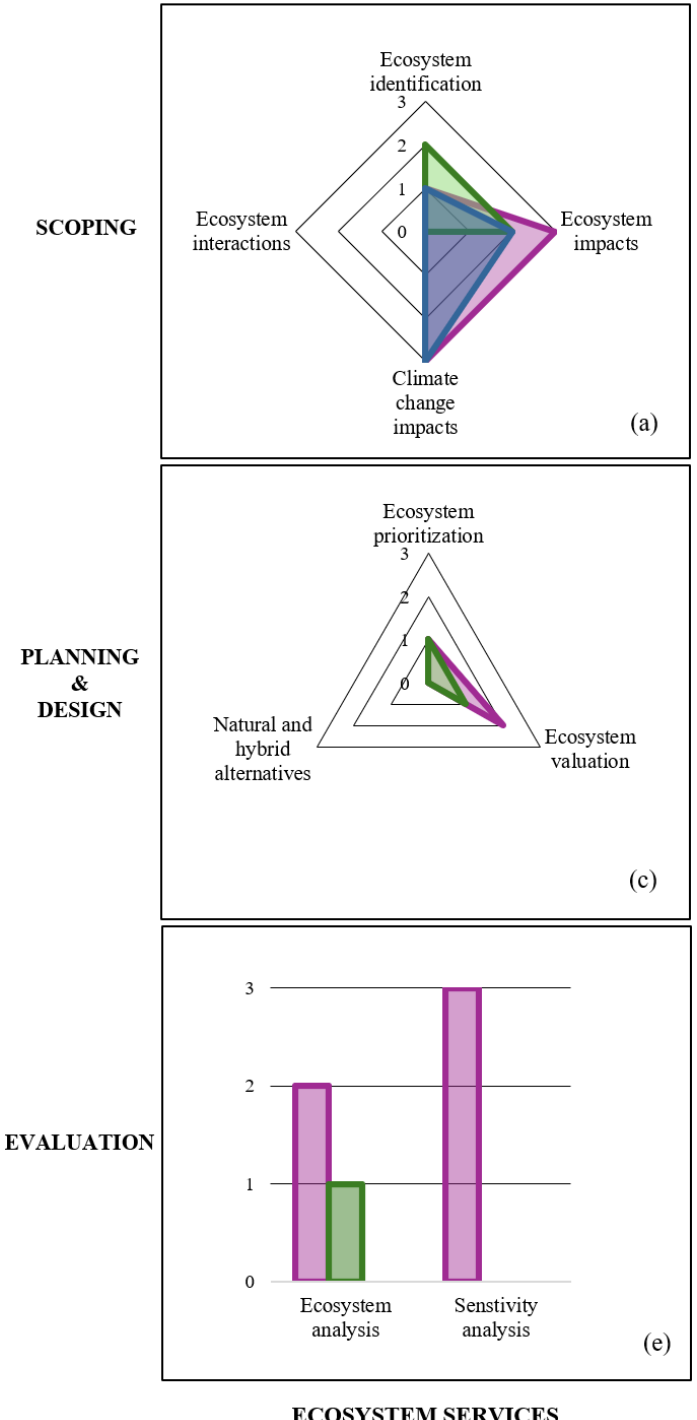


Evaluation phase

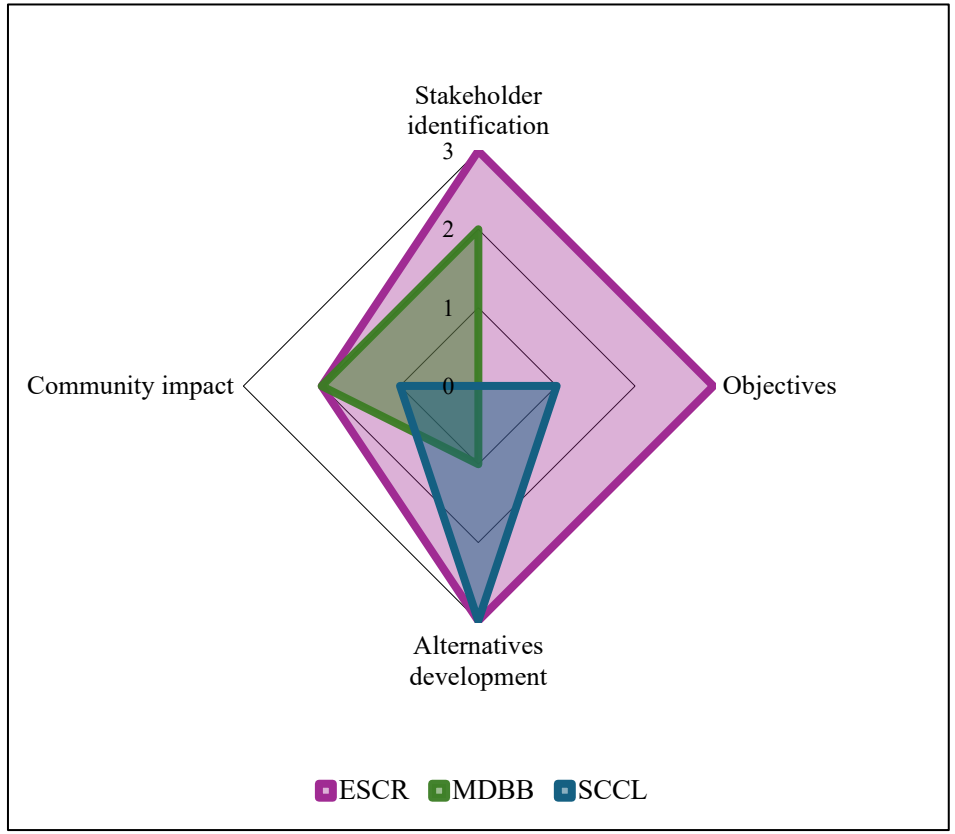
Ecosystem services: *Acknowledged but undervalued*

- Robust cataloguing of ecosystems of concern
- Interactions with climate change impacts limited
- Meaningful engagement with stakeholder to determine their values, preferences
- Limited use of multidisciplinary methodologies to appropriately value ecosystem services
- As a consequence, none of the studies included nature-based solutions or hybrid solutions as significant elements to reduce disaster risk



Distributional equity

- Complexity of hazards not addressed
- Unidimensional solutions
- Focus on NED ~ National Economic Development
- Nonstructural solution without considering implementation hurdles
- Who suffers? Who benefits?
- Lost opportunity for non-monetary evaluation and social welfare benefits



Scoping phase

Distributional equity

- Complexity of hazards not addressed
- Unidimensional solutions
- Focus on NED ~ National Economic Development
- Nonstructural solution without considering implementation hurdles
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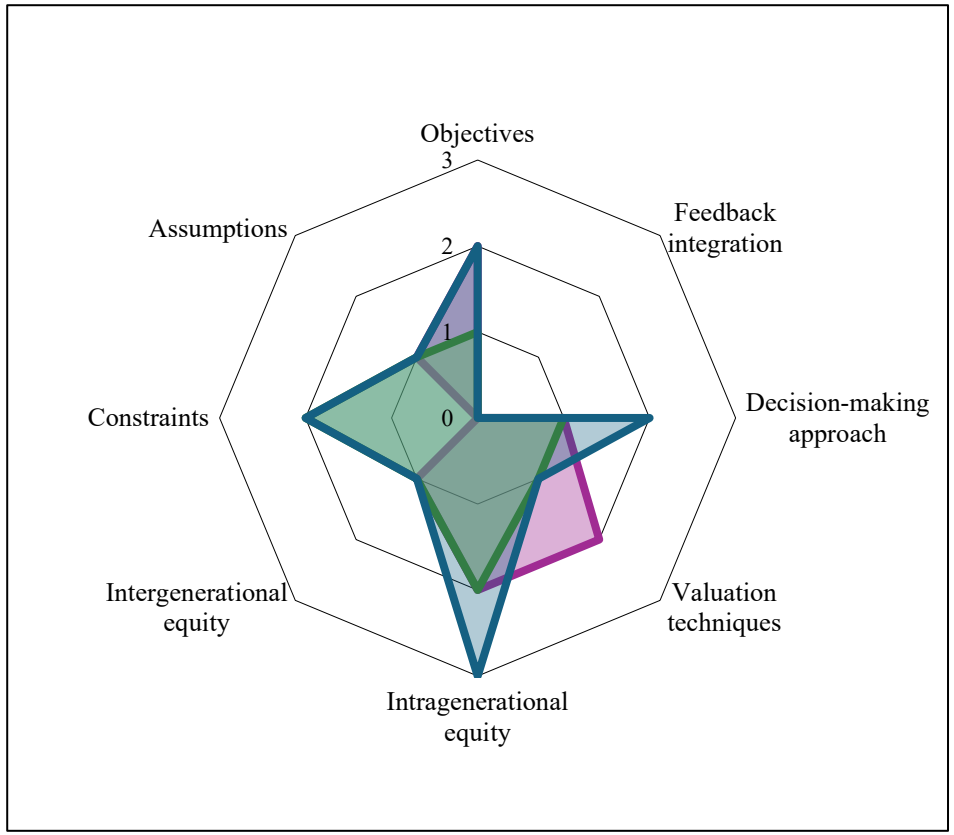
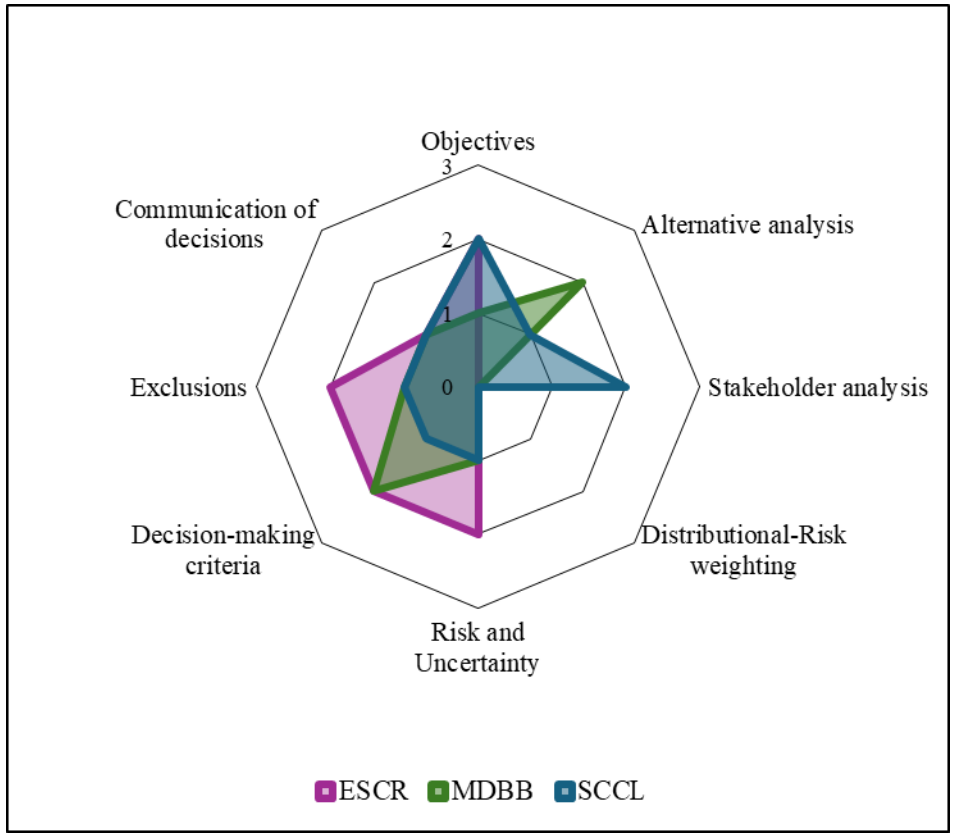


Planning & Design phase

Distributional equity

- Complexity of hazards not addressed
- Unidimensional solutions
- Focus on NED ~ National Economic Development
- Nonstructural solution without considering implementation hurdles
- Who suffers? Who benefits?
- Lost opportunity for non-monetary evaluation and social welfare benefits

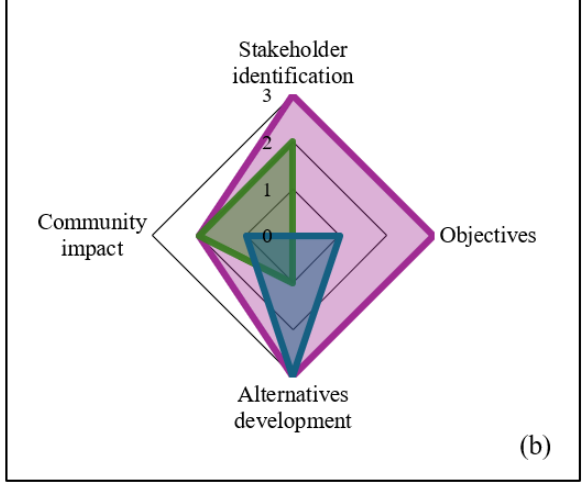


Evaluation Phase

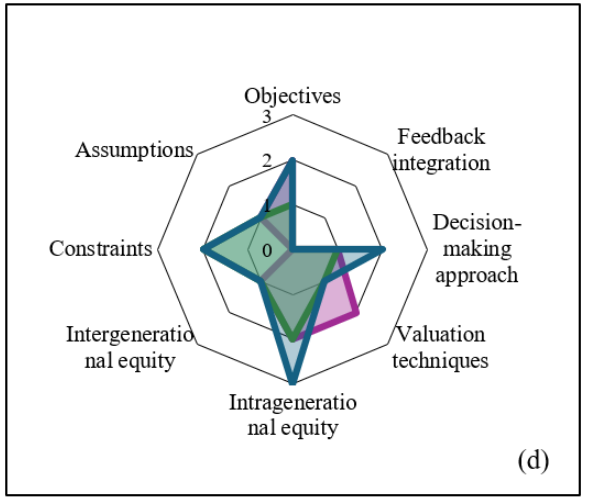
Distributional equity *or Diversity exclusion--of objectives, alternatives, nature, people, and benefits*

- Complexity of hazards not addressed
- Unidimensional solutions
- Focus on NED ~ National Economic Development
- Nonstructural solution without considering implementation hurdles
- Who suffers? Who benefits?
- Lost opportunity for non-monetary evaluation and social welfare benefits

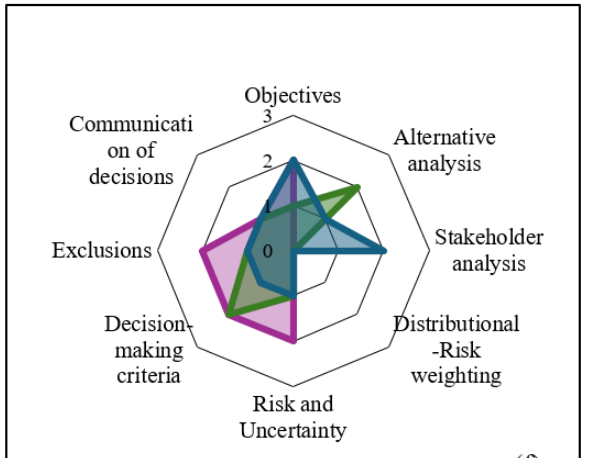
SCOPING



PLANNING & DESIGN



EVALUATION



In conclusion

Resilience infrastructure has the potential to deliver holistic, sustainable, and equitable resilience…

- … but environment and equity are neglected in the project life cycle and throughout the planning processes.

- Our analyses revealed several barriers limiting comprehensive benefits of resilience infrastructure projects . These include
  - ❑ lack of democratic participatory processes involving informed community members, affected stakeholders, and unbiased subject matter experts to account for and support positive environmental outcomes through more innovative risk reduction measures like NBS or socially equitable measures
  - ❑ lack of equity-oriented mechanisms to address power asymmetries, conflict, and equity-oriented mechanisms.
  - ❑ exclusion of improved and diverse economic tools to effectively quantify environmental and social values
  - ❑ exclusion of intangible and non-market costs and benefits which may have substantive implications for the welfare of stakeholders

- MEERIA framework aims to mitigate the common pitfalls of a traditional analysis such as the BCA and offers a holistic and integrative approach enabling equitable and just distribution of comprehensive benefits from resilience projects.

Mainstreaming Environment and Equity in Resilient Infrastructure Assessments (*MEERIA*)

An alternative valuation methodology

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