Ecosystem-Based Approaches in Managing Risks Associated with Climate Change

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Outline of Presentation

- What is EBA?
- EBA and Climate Risk Management
- Some Related Concepts from Environment and Engineering
- Examples of EBA in Various Sectors
- What Do We Know About the Effectiveness of EBA in Various Settings?
- Summary and Concluding Remarks

1. Ecosystem-based Adaptation (EBA):

"the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change"*

- *the use of biodiversity and ecosystem services*
- *part of an overall adaptation strategy*
- *help people*
- *adapt to the adverse effects of climate change*

Diverse Agro-ecology. Photo Roger Leakey 2013

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* Convention on Biodiversity, 2009

Forest Conservation, Sustainable Forest Management

Adaptation functions:

- Maintenance of nutrient and water flow, water quality
- prevention of landslides
- regulation of floods

Co-benefits:

Social, cultural: Recreation, culture, shelter

Economic: Ecotourism, provisioning, sustainable logging

Biodiversity: Conservation of habitat for forest-dependent species

Mitigation: Carbon storage

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Mangrove Conservation

Adaptation functions:

- Protection against storm surges, coastal erosion associated with sea-level rise and related risks

Co-benefits:

Social, cultural: Fisheries and prawn cultivation – local employment and food security

Economic: Income generated through mangrove products

Biodiversity: Conservation of Mangrove-dependent species

Mitigation: Conservation of carbon stocks (above and below ground)

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Diverse Agroforestry

Adaptation function:

- **Diversification of agricultural production to cope with changed climate**

Co-benefits:

Social, cultural: Contribution to food and fuel wood security

Economic: Generation of income from sale of timber, firewood, other forest products

Biodiversity: Conservation of biodiversity in agricultural landscapes

Mitigation: Carbon storage (above and below ground biomass)

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2. EBA and Climate Risk Management

Options for Managing Risk

Understanding of risk helps us to identify generic risk management strategies:

- Reduce the hazard (the role of mitigation)
- Reduce exposure to the hazard
- Reduce sensitivity (susceptibility to harm)
- Increase adaptive capacity

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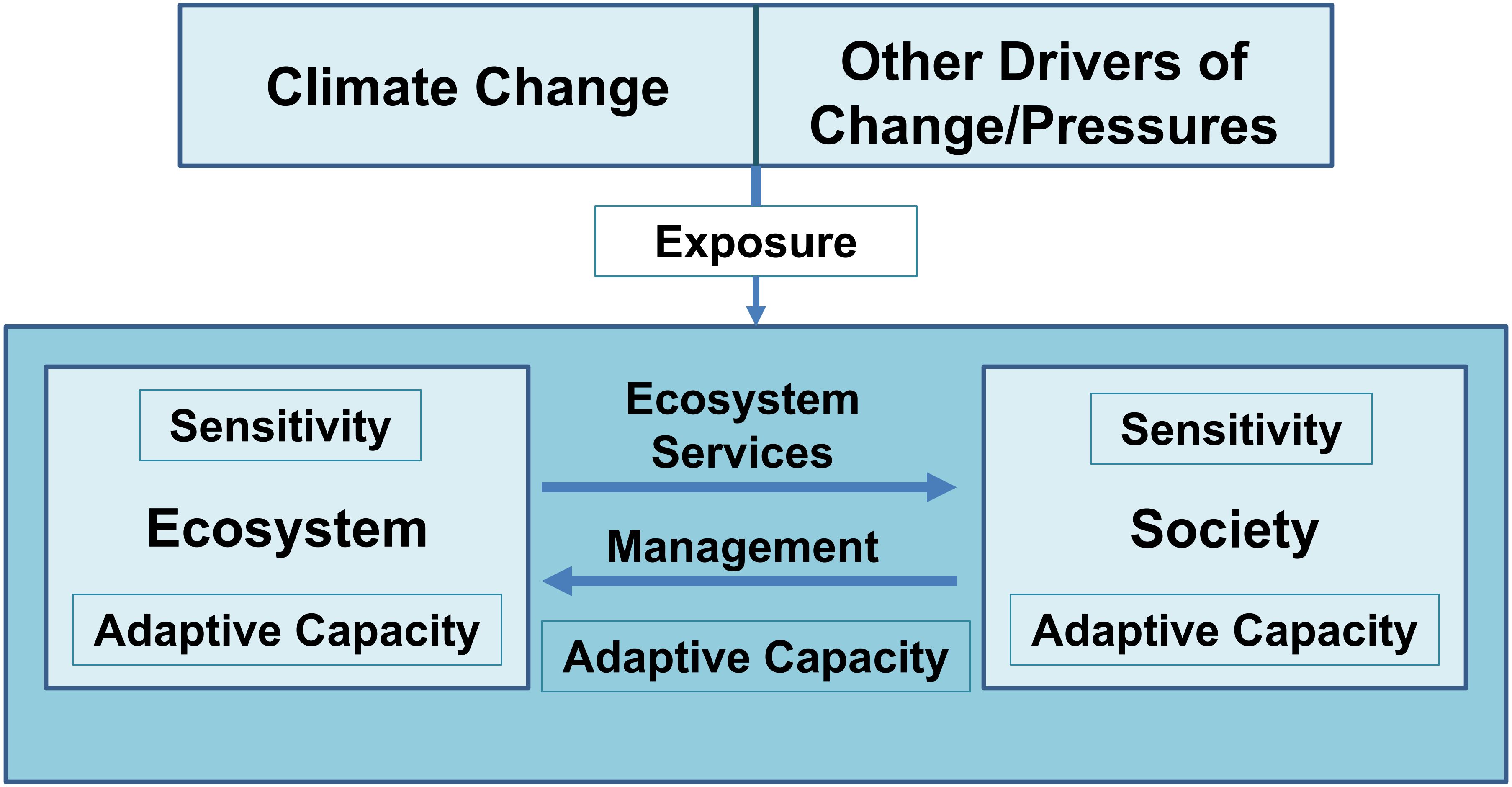
EBA: Risk Management in Coupled Human-Environmental Systems



Based on Locatelli and co-authors, 2008

3. Related Concepts from Environment and Engineering

EBA: Related Concepts from Engineering

EBA also utilizes a range of approaches found increasingly in the engineering literature and practice :

- Green Infrastructure
- Bio-engineering
- Ecological Engineering

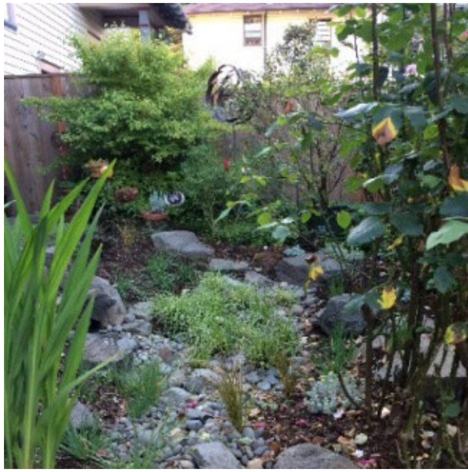
Green Infrastructure

Using nature to provide important services for communities, e.g.,

- **Stormwater management**
- **Flood control**
- **Urban heat management**
- **Air/soil/water quality improvement**

Green Roofs

Infiltration Gardens



Rainwater Harvesting

Bio-engineering

"Using tools that nature provides as components of infrastructure or construction, and capitalizing on their structural properties …"

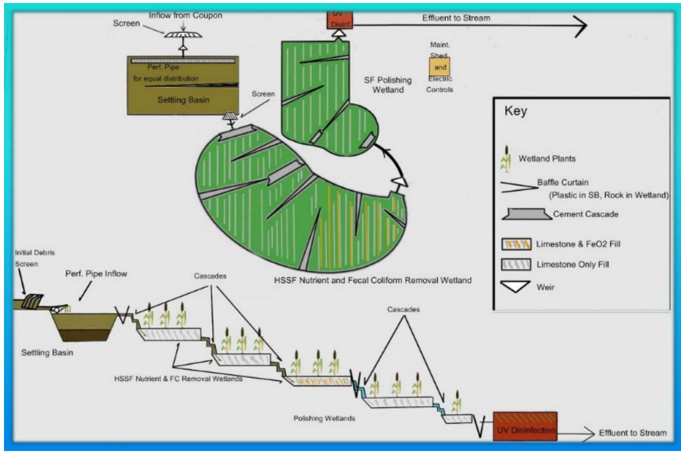
- **Slope stabilization**
- **River embankment stabilization**
- **…..**

Quote from Jonathan Ho, Field Engineer ICEM

Ecological Engineering

“An emerging study of integrating ecology and engineering, concerned with the design, monitoring, and construction of ecosystems.”

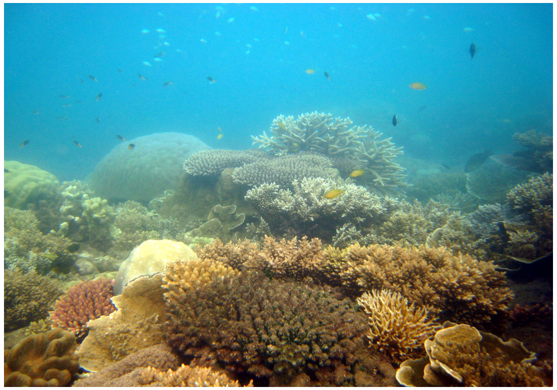
- **Constructed wetlands for water treatment**
- **Constructed habitat for desirable species**



4. Some Examples of EBA in Various Sectors

Spectrum of EBA

Environment, Development & NRM ↔ **Infrastructure Complement** ↔ **Infrastructure Substitute**



Coral Triangle

Multiple Lines of Defense

Living Weir

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EBA in NRM: Coral Reef Rehabilitation and Management Program (CTI)

Coral Reefs:

- Indonesia contains 18% of the world's coral reefs
- 70% of Indonesia's coral reef ecosystem is currently degraded.

Climate Change:

- Climate change-induced ocean temperature increase, sea level rise, and ocean acidification are having adverse impacts on coral reef ecosystems and biodiversity.
- Coral reefs, mangroves, and sea grasses act as carbon sinks, protect human assets and livelihoods.

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COREMAP-CTI

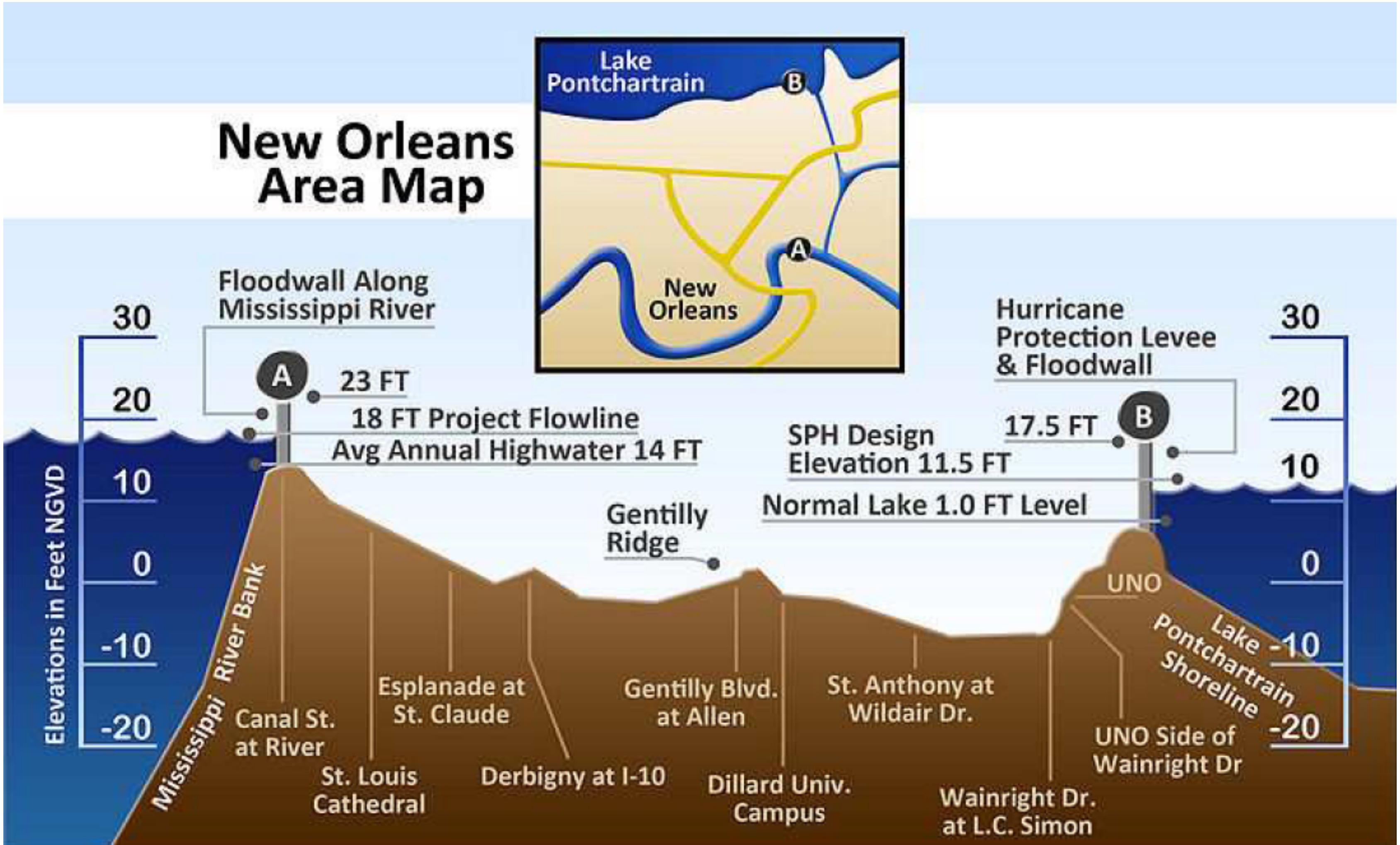
Objectives:

- Enhance resilience of coral reef ecosystems
- Contribute to adaptive capacity of target coastal communities to climate change impacts

Project outputs:

- Effective coral reef management (marine protected areas)
- Ecosystem-based resource management (ICZM)
- Sustainable marine-based livelihoods

EBA in Coastal Protection: New Orleans



City below river, sea level; highly vulnerable to flooding (e.g., Hurricane Katrina 2005)

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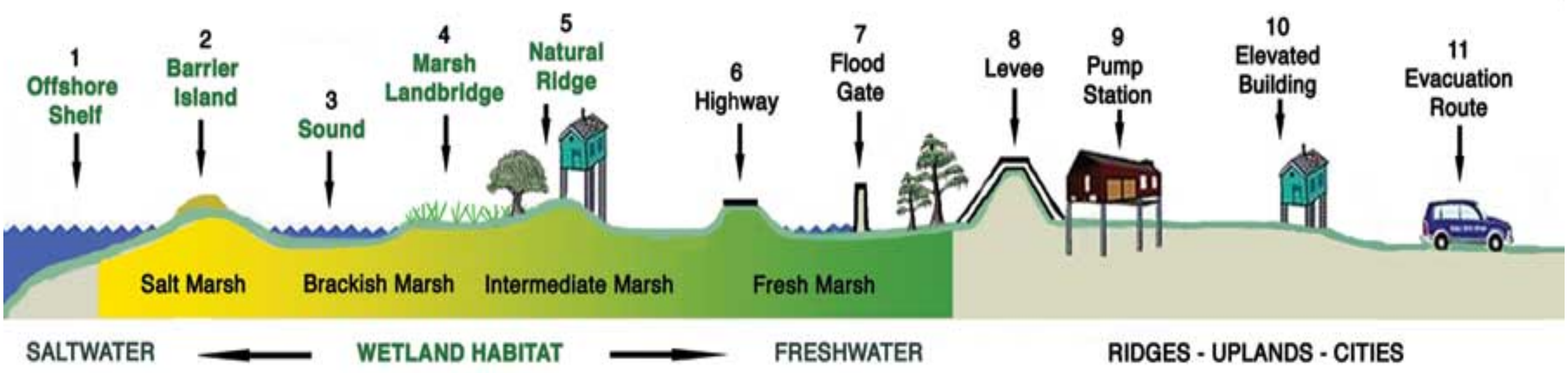
EBA in Coastal Protection: New Orleans

- **Hurricane Katrina (2005): 1,245 deaths, $108 billion in damages**
- **The "Multiple Lines of Defense" Strategy to Sustain Coastal Louisiana**



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EBA in Coastal Protection: New Orleans

Landscape Features

- Existing Wetland
- New or Restored Wetland 50-year projection
- Agricultural, Upland Forest or Open Land
- Open Water

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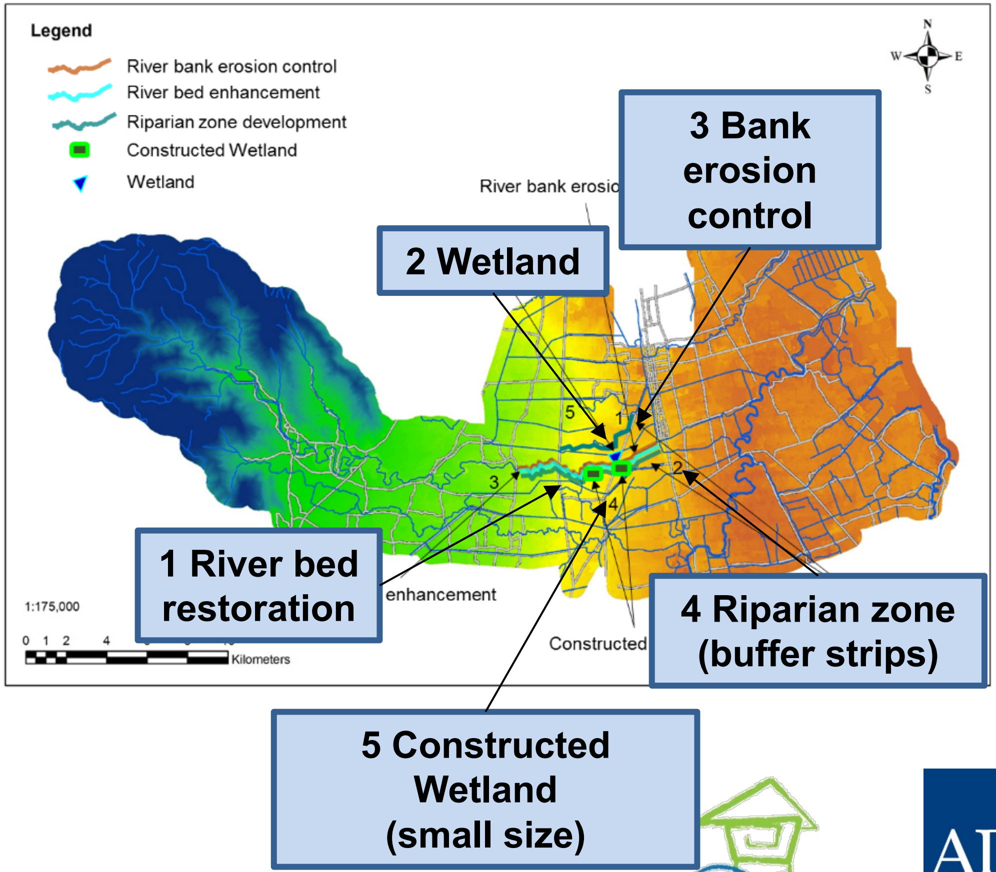
EBA to Address Environmental Degradation in Thailand (GIZ)

Projects Objective: The responsible authorities desire to prevent increased flood and drought damage through the implementation of ecosystem adaptation measures in the catchment areas of Thailand

Tha Di River Basin

- **Flood (Land use planning) (1, 2)**
- **Erosion (deforestation)**
- **Discharge of wastewater (5)**
- **Discharge of nutrients (3, 4)**
- **Erosion (river bank erosion) (3)**
- …



Courtesy Roland Treitler, GIZ

"Living Weirs" in the Tha Di Watershed

Benefits:

- Low cost weir structure based on tree roots
- Ground water recharge leads to higher production yield

Drawbacks:

- Longer construction period
- No research on impacts so far

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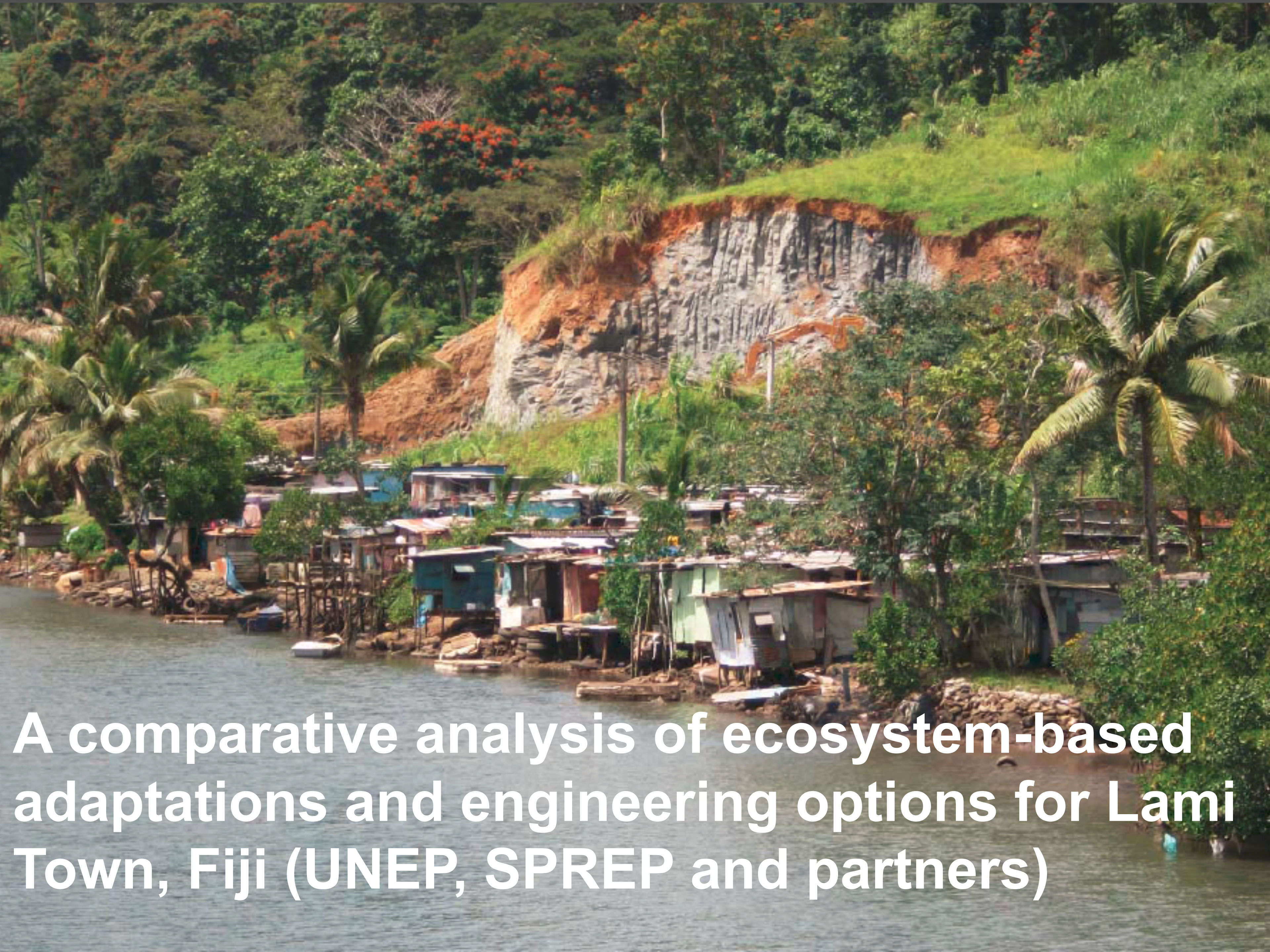
Courtesy Roland Treitler, GIZ



A comparative analysis of ecosystem-based adaptations and engineering options for Lami Town, Fiji (UNEP, SPREP and partners)

Context of Vulnerability, Lami Town

Vulnerability to Flooding:

- coastal flooding from storm surges or large waves from Suva Harbour
- flash flooding from rapidly rising rivers where hillslopes have been cleared of vegetation
- surface flooding where high rainfall pools in low lying areas

Vulnerability to Erosion:

- Shoreline erosion during storms from surge, waves, or longshore drift of sediment
- Riverbank erosion risk where rivers flow rapidly through the hills and where the river has been constrained by engineering
- Upslope or inland erosion occurring on hill-slopes, especially after forest clearing.

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Source: Lami Town Synthesis Report

Lami Town: Adaptation Options to Reduce Coastal Vulnerability

Ecosystem-based options:

- Re-plant mangroves
- Re-plant stream buffers
- Reduce upland logging
- Reduce coral extraction

Policy and social options:

- Regulating land tenure & informal settlements
- Re-zoning land use
- Re-location of highly vulnerable households
- Flood warning system and mapping

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Source: Lami Town Synthesis Report

Lami Town: Engineering Options to Reduce Coastal Vulnerability

Reinforce Rivers:

- Protect river banks
- Dredge rivers
- River re-alignment

Build sea walls

Increase drainage

Improve bridges

Land reclamation

Storm surge barriers

Beach replenishment

Sea dikes

Elevation of infrastructure

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Source: Lami Town Synthesis Report

Lami Town: Analysis of Options

Adaptation Options	Ecosystem-based option	Emphasis on ecosystem-based options	Emphasis on engineering options	Engineering options
Re-plant mangroves	100%	75%	25%	0%
Re-plant stream buffer	100%	75%	25%	0%
Monitoring & enforcement	100%	40%	20%	0%
Reduce upland logging	100%	50%	20%	0%
Reduce coral extraction	100%	50%	20%	0%
Build sea walls	0%	25%	75%	100%
Reinforce rivers	0%	25%	75%	100%
Increase drainage	0%	25%	75%	100%

***Percentages are relative to full implementation**

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Source: Lami Town Synthesis Report

Lami Town: Benefit-Cost Analysis

Scenario	Benefit-to-cost Ratio	Assumed Damage Avoidance
Ecosystem-based options	19.5	10% - 25%
Emphasis on ecosystem-based options	15.0	25%
Emphasis on engineering options	8.0	25%
Engineering options	9.0	50%

- Ecosystem-based interventions were assumed to be less effective than engineering options
- Implied trade-off between physical and cost effectiveness

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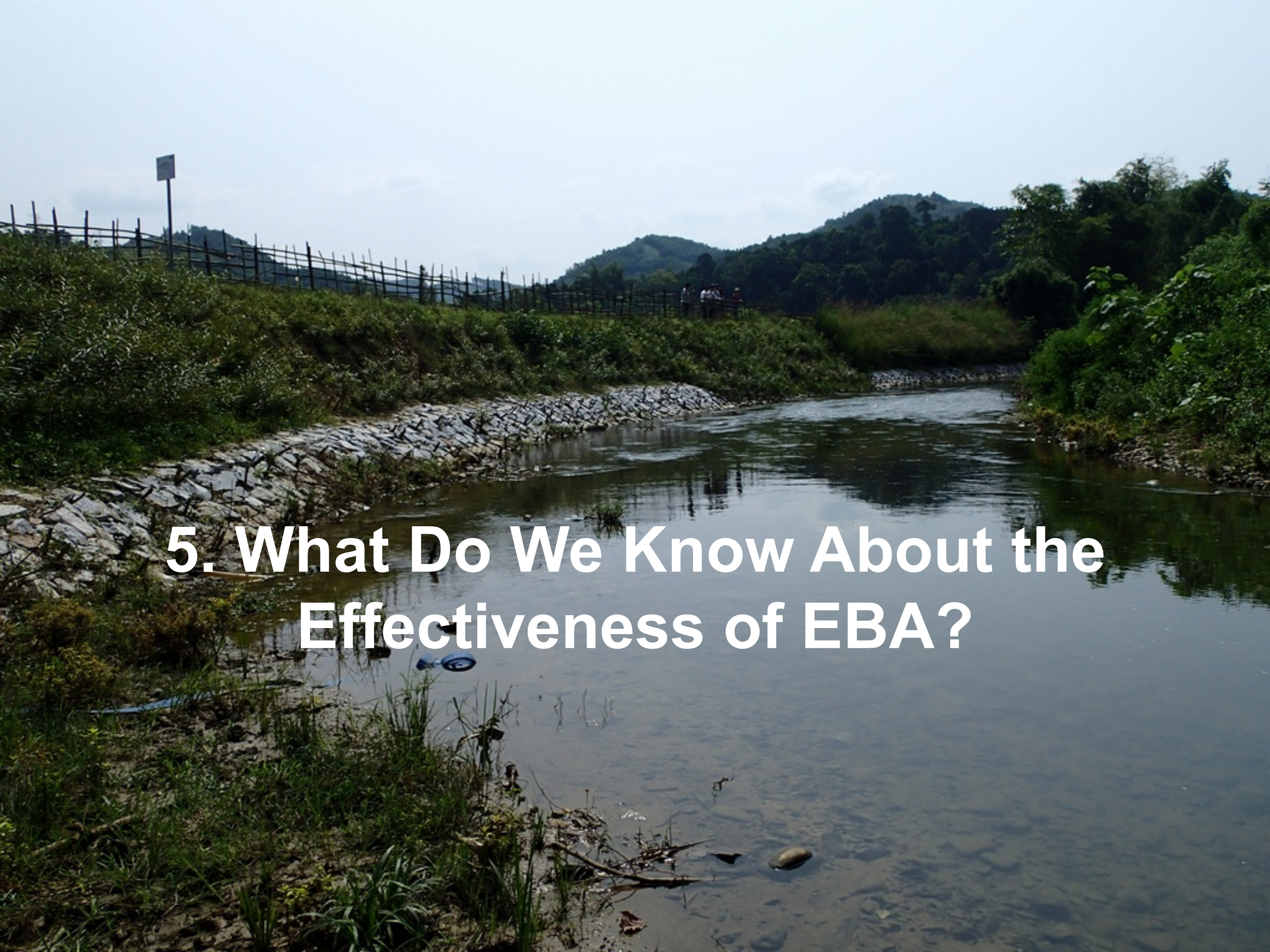
Source: Lami Town Synthesis Report


5. What Do We Know About the
Effectiveness of EBA?

Forests and Flood Mitigation Mechanisms

1. ***Sponge Effect***

- **The ability of forest and understory vegetation to act as a sponge in absorbing water from rainfall and gradually releasing it.**

2. ***Evapotranspiration – soil water deficit***

- **Trees can mitigate peak discharge flow under intense rainfall by maintaining soil moisture deficit.**

3. ***Canopy interception capacity***

- **Trees also capture rainwater in their canopy delaying or preventing some of the water from reaching the ground.**

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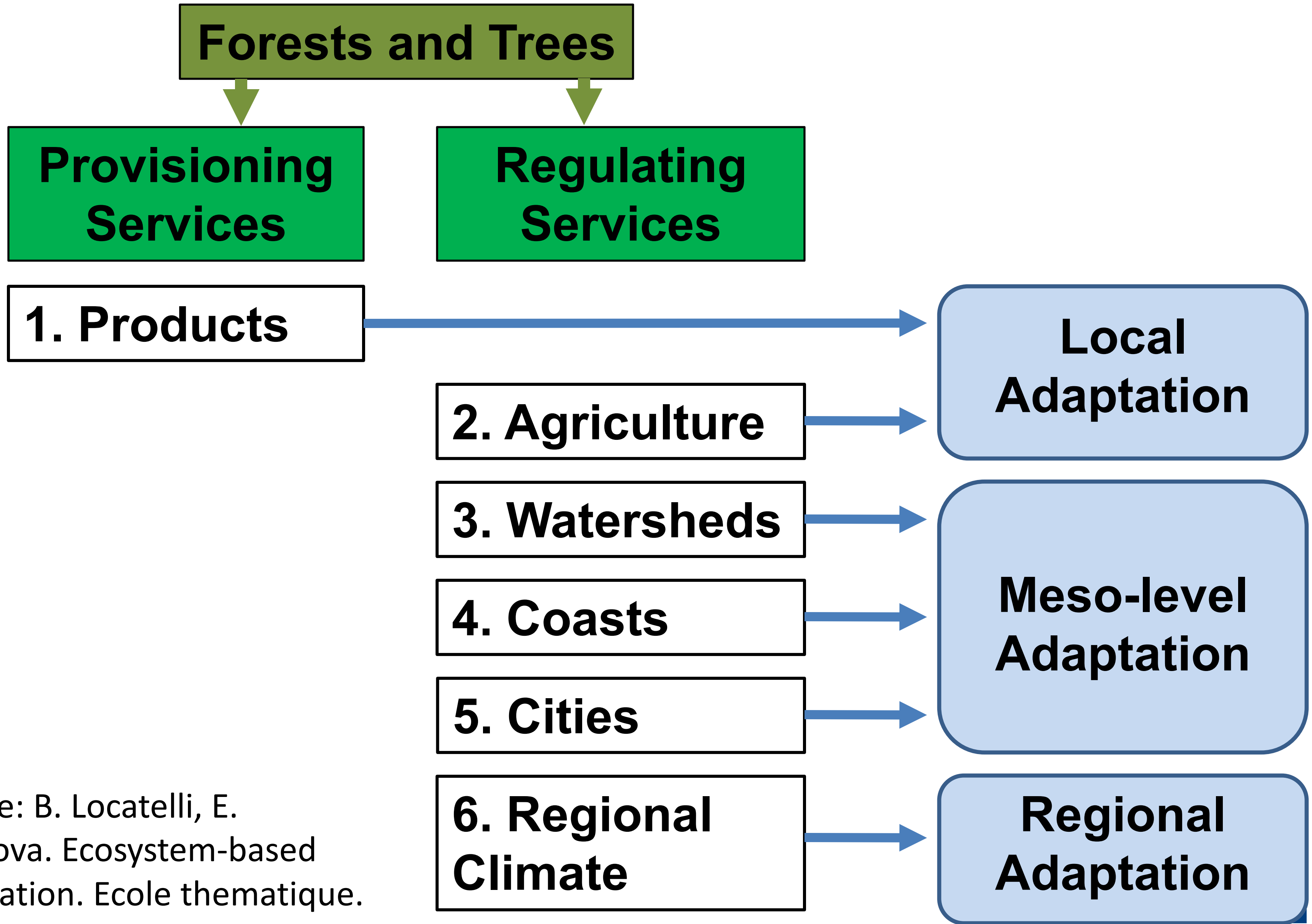
Evidence: Forests and Trees



Source: B. Locatelli, E. Pramova. Ecosystem-based adaptation. Ecole thematique. Indonesia. 2015.

Evidence: Forests and Trees

Theme	Benefits of Forests, Trees	Issues
Products	• Safety nets for local communities coping with climate shocks • Livelihood diversification	• Poverty trap? • Sustainability of natural resources for adaptation • Property rights and access
Agri-culture	• Maintain production under climate variability and protect crops against extremes • Local shade cover, soil fertility and moisture, wind breaks, water infiltration	• Trade-offs: Production vs. resilience
Water-sheds	• Regulate base flows (dry seasons), peak flows (intense rainfall) • Stabilize soil (landslide risks)	• Trade-offs between services (more regularity, less total water) • Not enough evidence, many studies based on common • wisdom, controversies (e.g. floods and forests)

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Evidence: Forests and Trees

Theme	Benefits of Forests, Trees	Issues
Coasts	• Absorb and dissipate wave energy and stabilize coastal land • Protection from tropical storms, sea level rise, floods and coastal erosion	• What level of protection from extremes do they provide?
Cities	• Regulate temperature and water for resilient urban settlements • Services: Shading, evaporative cooling, rainwater interception, storage and infiltration	• Opportunity costs • Studies almost only in developed countries
Regional Climate	• Cooling effect through increased evaporation and cloud cover • Influence on precipitation: water pumping and rainfall recycling	• Controversies • Multiple scales involved (local, regional, global) • How policies could address this role of forests?

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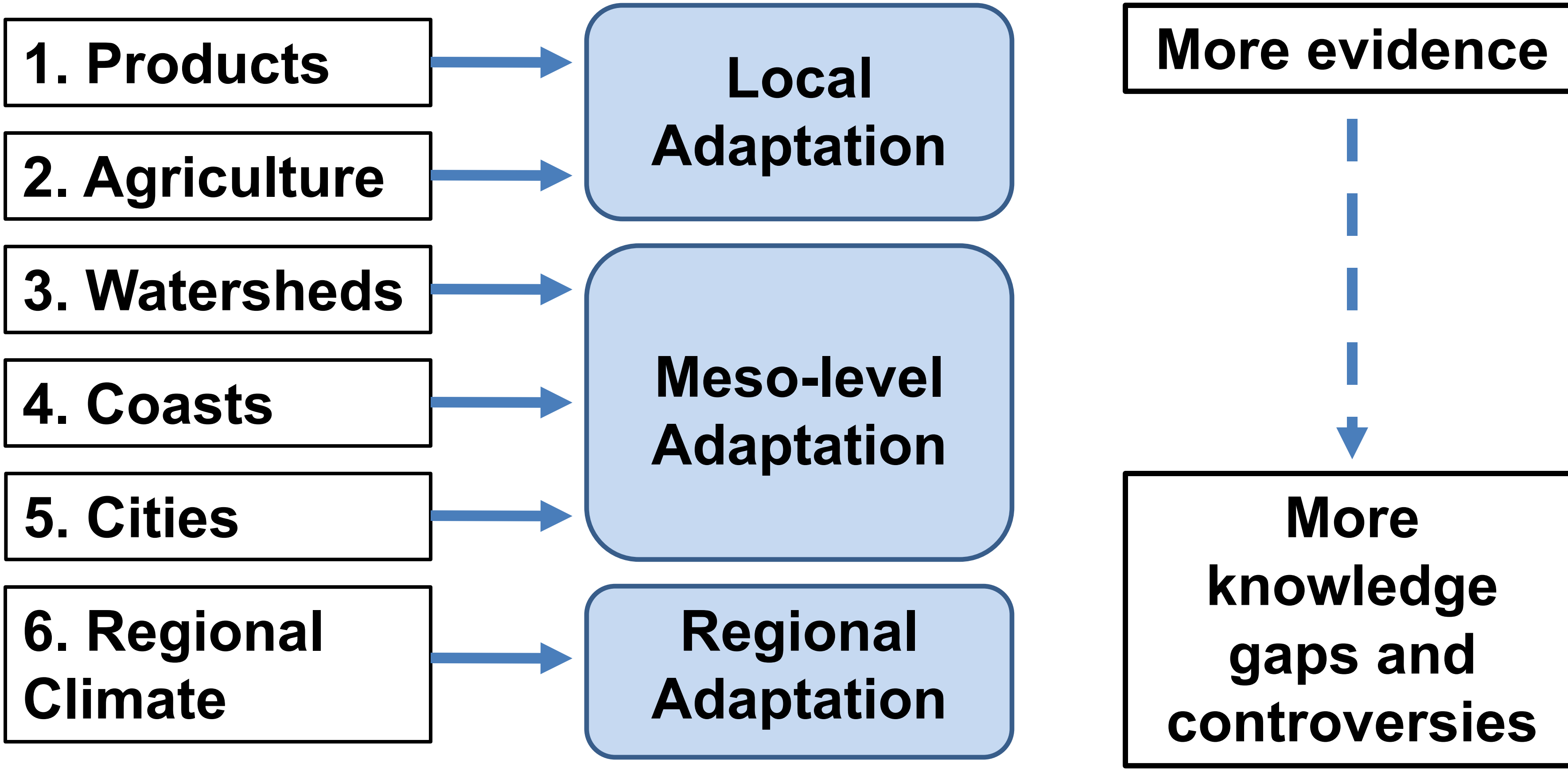
Forests and Trees: Scales and Evidence



- "The knowledge (e.g. on forest hydrology) should be revisited with a climate change adaptation lens"
- "Uncertainties on some benefits of EBA to adaptation but need to consider co-benefits (biodiversity, climate change mitigation)"

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Wetlands and Coastal Ecosystems

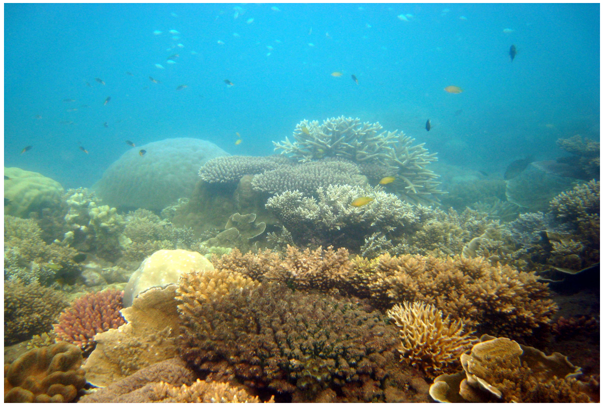
Intermediate Ecosystem Service	Final Service	Hazard Reduction; Adaptation	Sector Relevance	Co-Benefits
Soil formation and primary productivity (forests and inland wetlands)	Water absorption, flow regulation, soil erosion prevention	Flood regulation, erosion control, water availability under drier conditions, slope stability	Hydropower, Agriculture, Irrigation, Transport, Water	e.g. Tropical forests provide 26-9384 USD/ha/year in raw materials, food, genetic resources, and other uses.
Coastal ecosystems (mangroves, salt marshes, barrier reefs, dunes, etc.) productivity	Wave energy attenuation, sediment accretion, reduced storm surges	Flood risk mitigation from higher storm surges due to sea level rise and extreme storms	Coastal Infrastructure (property, roads, industry),	Coastal systems can provide up to 50,000 USD/ha/ year in provisioning and cultural services

Adapted from ecosystem services' classification system, Fisher and Kerry Turner, 2008

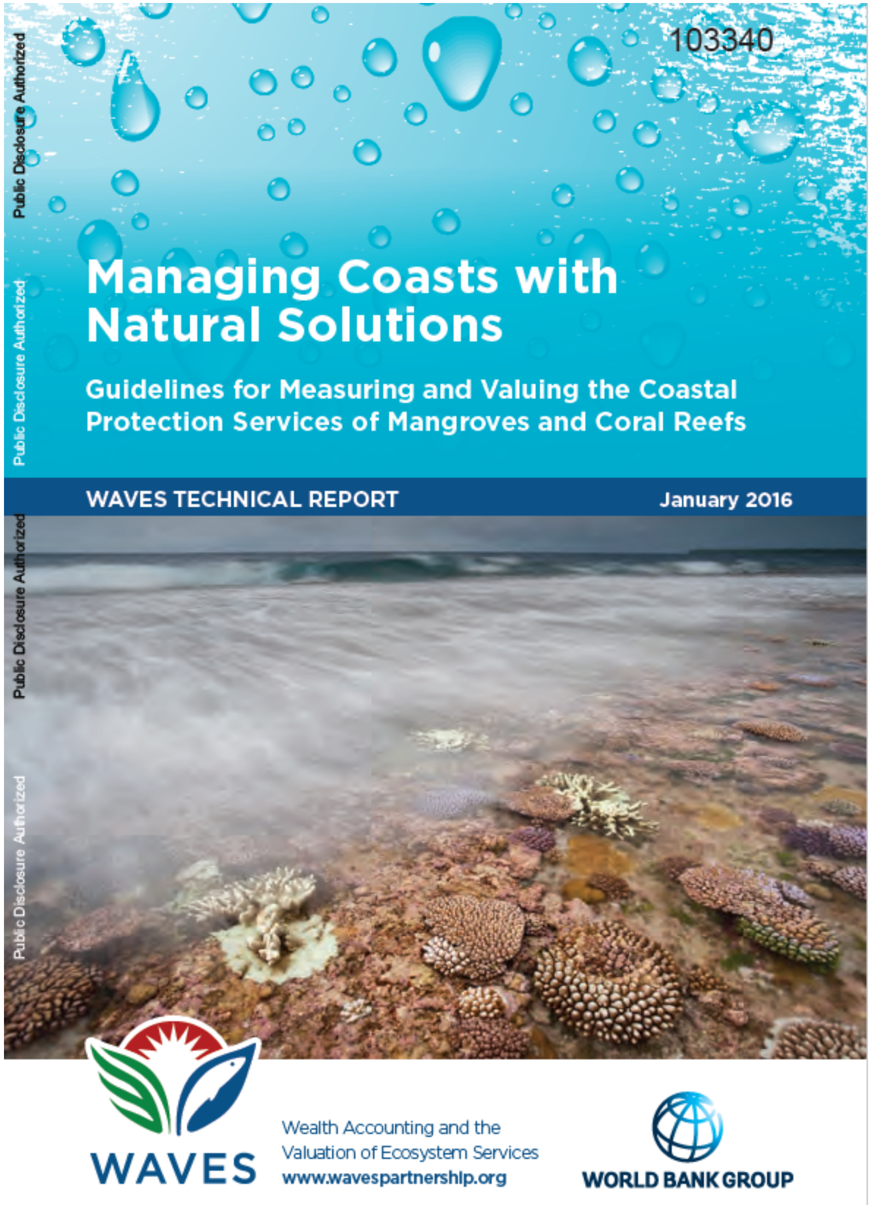
Coastal ecosystems: protection mechanisms

Mangroves, coral reefs, salt marshes:

1. Reduction in wave energy/strength, velocity of water flow and sheer stress over the sea bed => reduced exposure of inland communities and property to storm surges, reduced storm surge intensity.
2. Natural sediments and deposition leads to accretion and reduces the depth of the water level.
3. Coral reef structure (degree of roughness) can reduce wave energy in many cases.



WAVES Report: Coastal Protection



Review of evidence:

- **Effectiveness of mangroves for coastal protection**
- **Coastal defense services from coral reefs**

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WAVES Report: Mangroves

- “Mangrove forests reduce risk from coastal hazards, such as waves, storm surges, and tsunamis.
- “The level of risk reduction depends on the type of hazard, as well as mangrove characteristics.
- “For wind and swell waves, wave height can be reduced by 50 to 100 percent over 500 meters of mangrove forest
- “Mangrove species with dense vegetation are most effective at reducing wave height
- “One kilometer wide mangrove forest can reduce storm surge peak water levels by 5 to 50 centimeters
- “Mangroves can also be damaged or destroyed by tsunamis and hurricanes, cyclones, typhoons and their associated storm surges”

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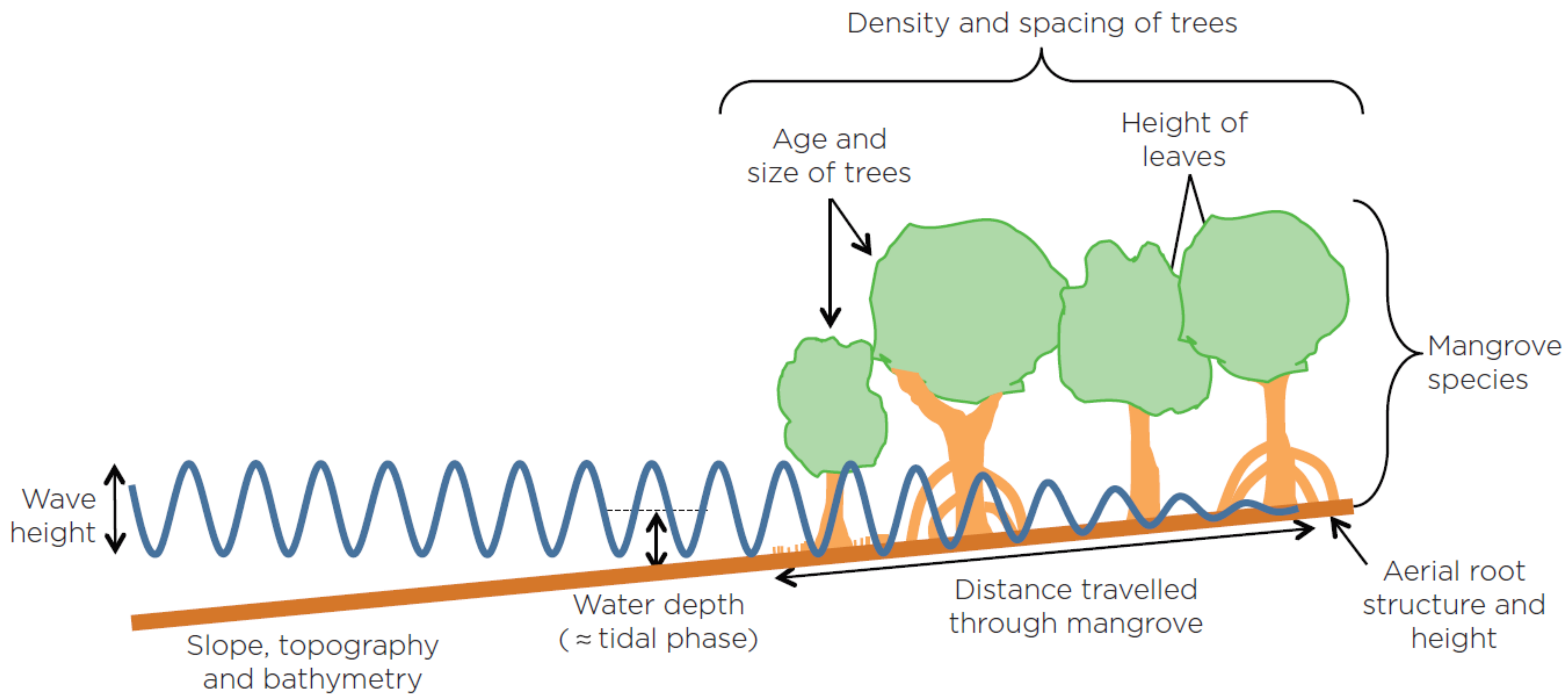
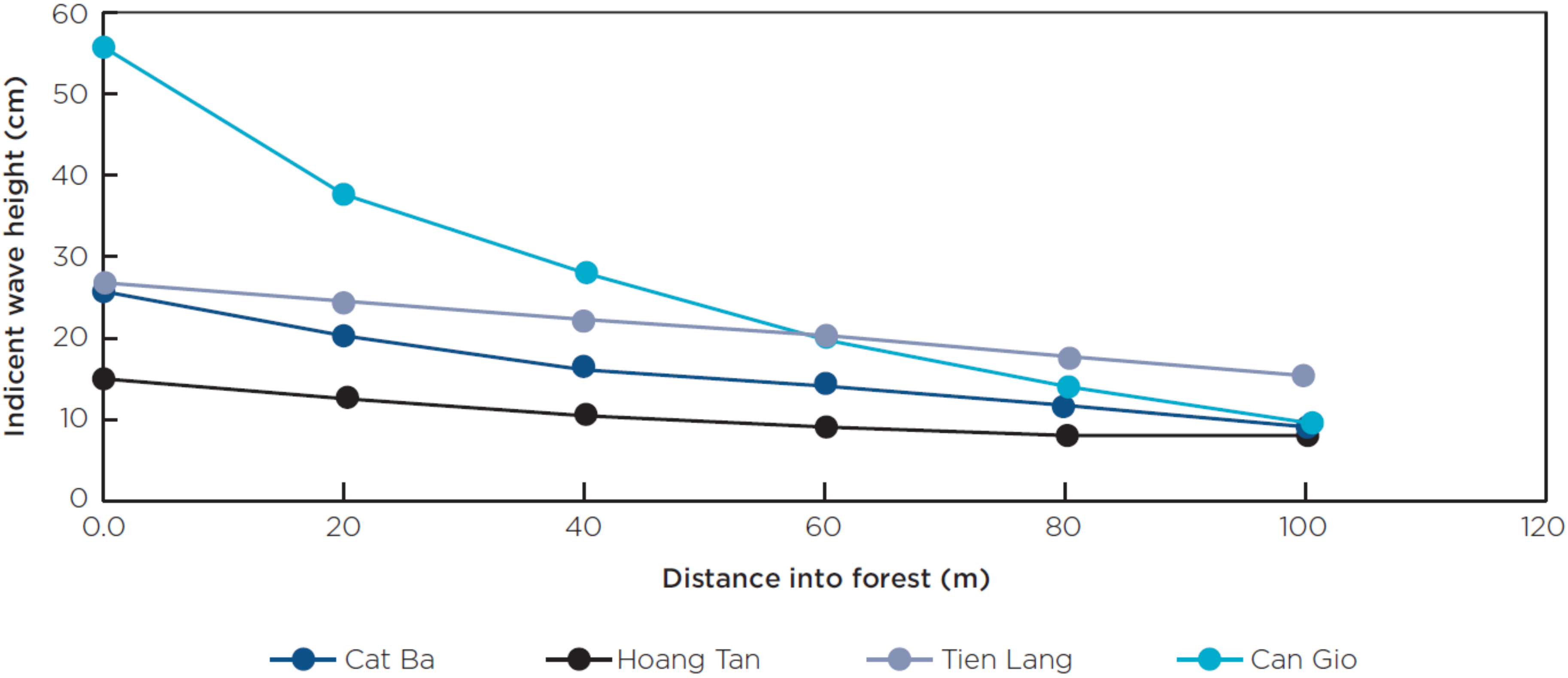
WAVES Report: Mangroves

Figure 2.1: Factors Affecting Wave Attenuation through Mangroves



WAVES Report: Mangroves

Figure 2.2: Variation in Wave Height with Distance Travelled through Mangrove Forests in Four Sample Locations in Vietnam (adapted from Bao 2011)



WAVES Report: Coral Reefs

- Coral reefs provide protection to coastal communities from natural hazards such as flooding, coastal storms, and sea-level rise
- naturally protect coasts from erosion and flooding by absorbing wave energy and supplying and trapping sediment
- Reefs function similar to low-crested breakwaters, reduce wave energy by up to 97 percent
- Coral reefs … generate massive amounts of carbonate structure, which allows them to keep pace with sea level
- Healthy reefs can provide a significant part of coastal protection even during cyclones under strong wave conditions
- Potential impacts of climate change, including SLR and coral mortality under warmer and more acidic waters may reduce the protection they offer

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Review: What the Evidence Tells Us About EBA

- Much of what we know (or assume) about physical effectiveness of EBA comes from the scientific and engineering literature outside of the context of EBA:
  - Watershed hydrology
  - Coastal engineering
  - Environmental quality
  - Ecological science
  - (many others)
- While the upstream science gives us confidence in many EBA approaches, they need to be re-visited in the context of EBA
- Effectiveness of EBA will be context-specific, so that the context must be well understood

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Summary and Concluding Remarks

Strengths of EBA as Adaptation Strategy

- Ecosystems evolve and change over time; are naturally resilient and adaptable up to some rate of change
- EBA promotes decentralized, participatory decision-making that is flexible and adaptive; ownership
- EBA promotes learning and skill acquisition
- "No-regret" – likely to generate benefits even in the absence of climate change
- Low costs relative to many structural alternatives
- Increase resilience – not simply adaptive
- Low risk of maladaptation
- Extensive co-benefits

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Challenges to EBA Implementation*

- Lack of financial sufficiency and predictability (co-finance)
- Lack of quantitative data on benefits
- Limits to technical expertise
- Organizational and institutional complexity arising out of the number and diversity of partners that must be engaged in projects
- Antecedent regulatory or legislative decisions that inhibit landscape-scale decision-making and the creative provision of funds, material and expertise
- Limited public awareness about the multiple benefits associated with ecosystem-based approaches

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* S. Naumann, ecologic.eu, 2013

EBA: Unresolved Issues

- *Ecosystem Sensitivity to Climate Change:* ecosystems are themselves vulnerable to many impacts of climate change, and failures may occur; monitoring and evaluation costs may be high
- *Uncertainty in Performance:* limited empirical evidence exists for the effectiveness of many EBA interventions over a range of settings
- *Residual Risk:* EBA may provide only incomplete risk management (e.g., flood protection) – additional structural measures may still be required
- *Context Specific:* Effectiveness of EBA interventions can be highly context-specific; difficult to generalize or transfer to other settings

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Questions welcome, looking forward to the discussion

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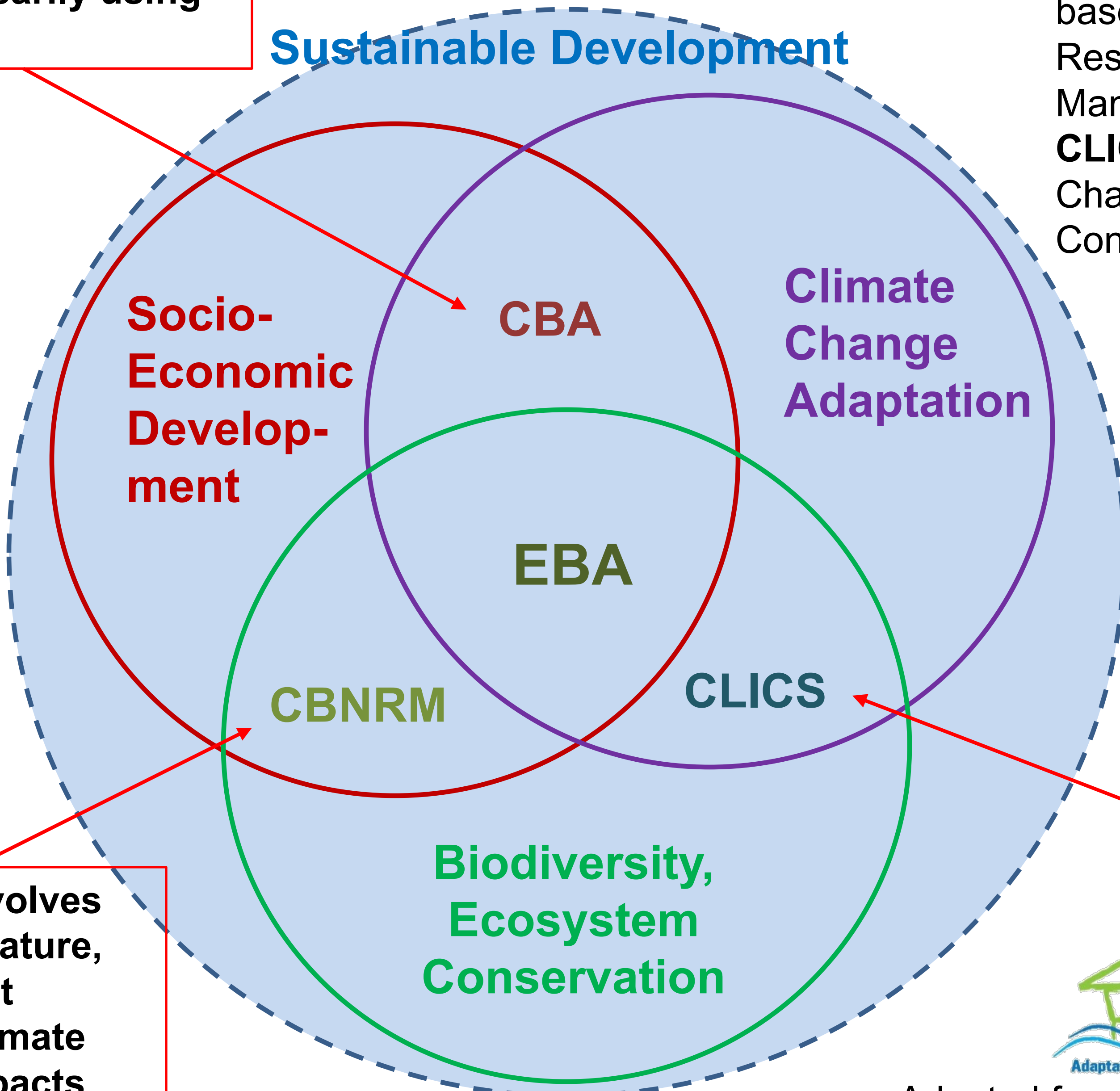
Links Between EBA, Related Fields of Practice

CBA: Community-based Adaptation
CBNRM: Community-based Natural Resources Management
CLICS: Climate Change- Integrated Conservation Strategies

CBA addresses human vulnerability to CC, but not necessarily using nature



CBNRM involves people in nature, but may not address climate change impacts

CLICS protect nature from climate change but may not involve people

Adapted from Midgley et al., 2013