

CEADIR DISCUSSION SERIES

**Navigating the
Climate Economy:
Investing for Growth and
Resilience**

**Cost-Benefit Analysis: Mangrove
Conservation versus Shrimp
Aquaculture, Bintuni Bay and Mimika,
Indonesia**

August 20, 2020

**Moderator: Juliann Aukema, USAID
Gordon Smith, CEADIR
Benjamin Brown, Blue Forests**

This presentation was made possible by the support of the American People through the United States Agency for International Development (USAID) and was prepared by Crown Agents-USA and Abt Associates for the Climate Economic Analysis for Development, Investment, and Resilience (CEADIR) Activity. The authors' views do not necessarily reflect the views of the United States Agency for International Development (USAID) or the United States Government.

AGENDA

Welcome to the CEADIR Series and Introduction

Pablo Torres, *Chief of Party* (CEADIR)

Introductory Remarks

Juliann Aukema (USAID)

Uses of Mangroves, Survey Design, and Field Data Collection

Benjamin Brown, *Senior Advisor* (Blue Forests)

Cost-Benefit Analysis and Results

Gordon Smith, *Technical Lead for Sustainable Landscapes* (CEADIR)

Open Forum



COST-BENEFIT ANALYSIS OF MANGROVE CONSERVATION VERSUS SHRIMP AQUACULTURE IN BINTUNI BAY AND MIMIKA, INDONESIA

Climate Economic Analysis for Development,
Investment and Resilience

Contract No.: AID-OAA-I-13-00038, Task Order AID-OAA-TO-14-00007

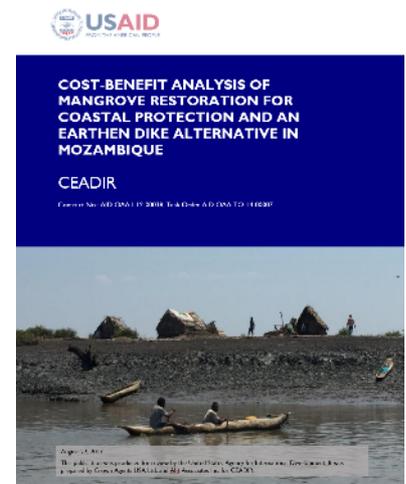


March 12, 2020

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CEADIR'S COST-BENEFIT ANALYSIS OF MANGROVE RESTORATION FOR COASTAL PROTECTION AND AN EARTHEN DIKE ALTERNATIVE IN MOZAMBIQUE (2017)

- Purpose: inform decisions of USAID/Mozambique-funded Coastal City Adaptation Project (CCAP) and Government of Quelimane to protect climate-vulnerable residents in peri-urban areas of this coastal city from sea level rise, cyclones, flooding, and erosion
- Scenarios:
 - Business as usual
 - Mangrove restoration, including replanting mangrove seedlings on 22 hectares (ha) of elevated riverbank and coastal flood plains
 - 5,000-meter earthen dike to protect from flooding after storms



Financial and economic net present values of mangrove restoration were positive and exceeded those of the earthen dike under all scenarios, in base case and all sensitivity analyses

CEADIR'S MANGROVE ECOSYSTEM VALUATION: METHODS AND RESULTS (2018)

- Describes methods for valuing market and extra-market goods and services provided by mangroves
- Analyzed 28 studies (1982-2014) in developing countries that quantified value of mangroves and gave information on study areas
- Regulating services of mangroves had highest adjusted average annual value, followed by cultural services, and then provisioning services
- The few studies that tried to estimate total value of mangroves had adjusted, annual average value of \$7,350 per hectare
- Average annual per hectare value highest for benefit transfer methods, followed by replacement cost and alternative cost methods, travel cost approach, contingent valuation, and market valuations methods
- Few studies valued carbon sequestration benefits of mangroves. CEADIR estimated value of accumulated carbon stock and present value of future mangrove carbon sequestration per hectare of mangroves



MANGROVE ECOSYSTEM VALUATION: METHODS AND RESULTS

CLIMATE ECONOMIC ANALYSIS FOR DEVELOPMENT, INVESTMENT, AND RESILIENCE (CEADIR)

Contract No. AID-OAA-11-33388, Task Order: AID-OAA-TO-14-00007





**Juliann Aukema,
Ph.D.**

- Senior Climate Change & Sustainable Landscapes Advisor, USAID's Global Climate Change Office
- Prior to USAID, worked at the National Center for Ecological Analysis and Synthesis
- Applied research has included climate change risk and adaptation, ecosystem services, forest management, economic costs of invasive forest pests, and issues related to big data
- Ph.D. in ecology and evolutionary biology from the University of Arizona

USAID MANGROVES INVESTMENTS (I)

- **Mangroves cover a small area globally but provide outsized ecosystem services**
- USAID works on mangroves in many countries and in many ways, including:
 - *Sundarbans*: tiger conservation, resource user groups, ecosystem-based adaptation
 - *West Africa*: restoration; empowering women fishers
 - *Philippines*: conservation and management of urban mangroves
 - *Indonesia*: rights and community-based fisheries and ecosystem management in Bintuni Bay

USAID MANGROVES INVESTMENTS (2)

- SWAMP (Sustainable Wetlands Adaptation and Mitigation Program) global research
 - Carbon dynamics; mapping; GHG inventories; country strategies (global)
 - Carbon stocks in Mimika (Indonesia)
 - Decision support tools for restoration (Vietnam)
 - West Indian Ocean Mangrove Restoration Guide (East Africa);
 - Mortality and resilience of mangroves to hurricanes (Caribbean and Mesoamerica)
- **Understanding tradeoffs and accounting for a full suite of economic impacts is crucial for good development and conservation decisions**



Benjamin Brown

- Senior Advisor and co-founder of Blue Forests, an Indonesian non-profit working with local people for sustainable use and restoration of mangroves
- Member of IUCN: International Union for Conservation of Nature – Mangrove Specialist Group
- Pursuing Ph.D. at Charles Darwin University
- Deep expertise in mangrove ecology and restoration, especially Indonesia

GLOBAL LOSS OF MANGROVES

- Globally, 35% of mangroves cleared 1980-2000
- Global rate of loss slower after 2000 but continuing
- 1.5 million ha of Indonesian mangroves have been deforested or degraded from an original total of 3.3 million ha.
- Globally 8.1 million hectares remained as of 2014



Photo credits: Robert Hewatt– Oil palm plantation development in the lowland swamp forest adjacent to Mimika’s mangroves (left); mangrove clearance for development of new government buildings in Fanamo, Mimika (right)

Photo credit: Ben Brown – PT BUMWI operates an 88,000 ha logging concession in Bintuni Bay producing chip for pulp/paper production

MANGROVE CLEARING

- Intentional for aquaculture ponds
 - maximum life span of 10 years
 - many become unproductive after two years
- Unintentional from unsustainable harvesting of wood
- Conversion to oil palm (increasingly common in both state forests and non-state forest areas)
- Built infrastructure



Photo credit: Ben Brown

PURPOSE OF THE STUDY

- Conduct cost-benefit analysis (CBA) of mangrove conservation versus partial conversion for shrimp aquaculture in Indonesia
- Financial and economic analyses and simulation modeling
 1. *Financial analysis*
 - reflected perspective of local communities in Bintuni Bay and Mimika
 - financial revenues and costs faced by firms and individuals, including taxes
 2. *Economic analysis*
 - adopted national and global perspectives
 - financial analysis plus social costs and benefits, including extra-market environmental goods and services; taxes are a transfer

MAJOR MANGROVE VALUES

- Very productive finfish and shellfish fisheries and important nursery and fish refugia role supporting 70% of near-shore fisheries.
- Wood for construction, fuel and other uses
- Storm protection
- Carbon sequestration (wood and soil)
- Water cleaning



Photo credit: Ben Brown – PT BUMWI operates an 88,000 ha logging concession in Bintuni Bay producing chip for pulp/paper production



Photo credits: Robert Hewatt Top – Kamoro youth subsistence fishing, Kamoro fisherman displaying Barramundi

CULTURAL VALUES

- People identify with landscapes they live in
- Some groups venerate ancestors and sacred places
- Not quantified in this analysis

Photo credit: Robert Hewatt. Kamoro man showing a traditional carved shield depicting flora and fauna of the mangroves



INDONESIA: PAPUA AND WEST PAPUA

- Comprise traditional area called Tanah Papua with 250 indigenous ethnic groups
- Special autonomous status under Indonesian law
- Holds half of Indonesia's biodiversity and 38% of Indonesia's primary forest in 2012
- Deforestation increased to 100,000 ha/yr in 2014-15, due to illegal logging, illegal cutting in legal concessions, road construction, resource extraction (oil, gas, mining), conversion to agriculture (especially oil palm), urban and public infrastructure
- 70% of West Papua targeted for natural forest conservation
 - But 64% of land available for agriculture.
 - Governor committed to review 2.6m ha of development permits that overlap conservation and protected areas

GEOGRAPHIC FOCUS OF THE STUDY

- Bintuni Bay: 260,000 ha
- Mimika: 244,000 ha and contiguous with mangroves to east and west to make second largest mangrove area in the world totaling approx. 500,000 ha
- Largely intact; slow loss; sustainable timber harvest in Bintuni



MANGROVES USES QUANTIFIED IN THIS STUDY

- **Extractive uses:**
 - Fisheries (finfish, mollusks, shrimp, crab) local to international markets
 - Wood: fuel (wood and charcoal) construction, chips for paper-making (Bintuni)
 - Hunting and gathering
 - Palm products
- **Non-extractive uses:**
 - Carbon sequestration (biomass and soil)
 - Storm and tsunami protection
 - Water quality and biodiversity not quantified in this study



Photo credit: Robert Hewatt

DATA COLLECTION

- Survey of 120 households, in three villages in each of the two areas
- Information collected: costs and benefits of activities supported by mangroves, and values of buildings
- No damage function for loss of offshore fisheries production as a function of mangrove loss; this cost was not quantified
- Secondary data on numbers of households and buildings, amounts of carbon storage and loss on conversion
 - No history of cyclones or tsunamis in either site, so base case analysis assumed these events would not occur during the study period, but included in sensitivity analysis
 - Cyclones and tsunamis included in the CBA tool, to allow others to model effects in other locations

DATA COLLECTION

Impact of Activities Supported by Mangroves on Household Incomes

Activity	Bintuni Bay			Mimika		
	% of households involved	Average revenues per household	Average costs per household	% of households involved	Average revenues per household	Average costs per household
Fishing	45	447.8	261.8	59	212.5	81.9
Farming	7	72.3	4.7	12	13.7	0.1
Hunting/gathering	4	76.7	0.3	17	316.3	8.2
Mangrove wood harvesting	2	1,248.1	17.9	0	n/a	n/a
Mangrove palm product harvesting	1	2.8	0.0	0	n/a	n/a



**Gordon Smith,
Ph.D.**

- Technical Lead for Sustainable Landscapes, CEADIR
- Principal, Ecofor LLC, focusing on mitigating greenhouse gas emissions by changing land use, especially forestry and agriculture quantification and offset accounting
- Ph.D. in Forestry, University of Washington; Masters in Public Policy, Harvard University

COST-BENEFIT ANALYSIS (CBA) APPROACH

- Real discount rates: 3%, 7%, and 12% (inflation adjusted)
- Time horizon: 50 years for financial and economic analysis
- Financial analysis considered activities supported by the mangroves, including near-shore fishing, farming, hunting and gathering, wood harvesting, and collection of mangrove palm products for roofing materials, food, and beverages
- Economic analysis included social cost of greenhouse gas emissions
- Two scenarios:
 - Business-as-usual
 - Increased conversion to aquaculture
- Sensitivity analysis
 - Conducted with a 100-year time horizon

BUSINESS-AS-USUAL SCENARIO FOR MIMIKA AND BINTUNI BAY

- Assumed very low, existing mangrove conversion rate of 0.05% per year would continue at both sites
- Leading to 2.8% reduction in mangrove area over 50 years
- Most of this mangrove conversion has been for human settlements and infrastructure, not aquaculture



Photo credit: Rio Ahmad: Nayaro Village, Mimika.

ALTERNATIVE SCENARIO: INCREASED CONVERSION TO AQUACULTURE

- Assumed additional 0.75% of the mangrove area would be converted to shrimp aquaculture each year
- 52% reduction in net mangrove area over 100 years (after regrowth of abandoned aquaculture ponds)
- Upon conversion, 89% of biomass and soil carbon emitted as carbon dioxide



Photo credit: Ben Brown

STUDY LIMITATIONS

- CBA did not value other mangrove ecosystem services (such as water quality improvement, biodiversity protection, and option and existence values) due to lack of biophysical and economic data on these complex relationships
 - Inclusion of these additional ecosystem service values would increase economic superiority of mangrove conservation over partial conversion to aquaculture
- Nursery habitat for off-shore fisheries likely undervalued
- Large areas of mangroves have different responses to disturbances vs narrow strips

FINANCIAL ANALYSIS RESULTS

- Over 50 years, at a high 12% discount rate, financial value of partial conversion of mangroves to shrimp aquaculture was only 2-4% higher than conservation, even excluding value of carbon sequestration
- Small difference could be offset by unquantified value of spawning and nursery values for open water fisheries

Location	Financial Net Present Value (Million U.S. \$, 12% discount rate, 50 years)		
	BAU Scenario	Alternative Scenario	Net Value of Conservation
Bintuni Bay	701	731	-30
Mimika	845	861	-17

MORE FINANCIAL ANALYSIS RESULTS

- At 3% and 7% discount rates (used by U.S. Government for domestic cost-benefit analyses), the financial benefits were lower for shrimp aquaculture than mangrove conservation
- Over a 100-year time frame, even at the high 12% discount rate, mangrove conservation gave higher financial return than conversion

ECONOMIC ANALYSIS RESULTS

- At low end (\$5/tCO₂e social cost of carbon and 12% discount rate) mangrove conservation had 5.5% higher value than partial conversion to shrimp ponds. At \$25/tCO₂e social cost of carbon, 3% discount rate, over 100 years) mangrove conservation had 18-22% higher value
- At \$8/tCO₂e, 99% of total value of conservation is carbon sequestration value
- Excludes risk of cyclones or tsunamis, because no history of these events at these sites

Location	Economic Net Present Value (Million U.S. \$, \$5/tCO ₂ e, 12% discount rate, 50 years)		
	BAU Scenario	Alternative Scenario	Net Value of Conservation
Bintuni Bay	56,406	53,455	2,950
Mimika	48,562	46,027	2,534

ECONOMIC ANALYSIS DISCUSSION

- When carbon storage benefits of mangroves were included, economic analysis favored mangrove conservation, with higher values than partial conversion for shrimp ponds
- Economic advantages of mangrove conservation increased with changes in three key assumptions:
 1. Higher social costs of carbon (economic damage from greenhouse gas emissions)
 2. Lower discount rates (annual percent decrease in the value of money over time)
 3. Longer time period for the analysis

ASSUMPTIONS IN THE SENSITIVITY ANALYSIS

Parameter	Base Case	Sensitivity Cases
Time horizon (years)	50	100
Real discount rate (percent)	12%	3% and 7%
Social cost of carbon (\$/tCO ₂ e)	\$5	\$0, \$8, \$15, and \$25

SENSITIVITY ANALYSIS: CARBON SEQUESTRATION DOMINATES



Photo credit: Rio Ahmad: Massive old-growth *Rhizophora apiculata*, some in excess of 40 meters tall.

- At 3% discount rate, conservation was higher value than conversion, even at carbon price of zero
- Total value largely scales with carbon price
- At \$25/tCO₂e social cost of carbon, carbon values were more than 99% of total value, even in partial conversion to shrimp aquaculture, at all discount rates and time horizons

MONTE CARLO ANALYSIS: THE METHOD

- Define probability distribution for each variable
 - Parameters varied in analysis: population growth rate, deceleration in population growth, shrimp pond profitability, shrimp pond life, logging rate, fishing revenue variability, probability of tsunami, probability of cyclone, tsunami death rate, cyclone death rate, number of houses destroyed by tsunami or cyclone
- For each simulation run: randomly select value for each variable from probability distribution for the variable, and calculate NPV using selected values
- Do 10,000 simulation runs and find probability distribution of NPV values

MONTE CARLO ANALYSIS RESULTS (I)

- Even without carbon storage benefits, mangrove conservation was more valuable than partial conversion for shrimp ponds in 23–37% of model runs, at a 12% discount rate
- When carbon storage benefits were counted, mangrove conservation was more valuable than partial conversion for aquaculture in nearly all model runs

MONTE CARLO ANALYSIS RESULTS (2)

- Profitability of shrimp aquaculture caused 82% of variation in financial analysis outcomes
- Economic value of conservation greater than partial shrimp pond conversion in more than 99% of cases

Monte Carlo Analysis Results (Millions of U.S. Dollars)

	Financial NPVs		Economic NPVs	
	BAU	Alternative	BAU	Alternative
Bintuni Bay	708 (581-834)	735 (600-869)	56,413 (56,284-56,658)	53,458 (52,639-54,278)
Mimika	847 (735-959)	861 (742-980)	48,564 (48,450-48,679)	46,028 (45,332-46,724)

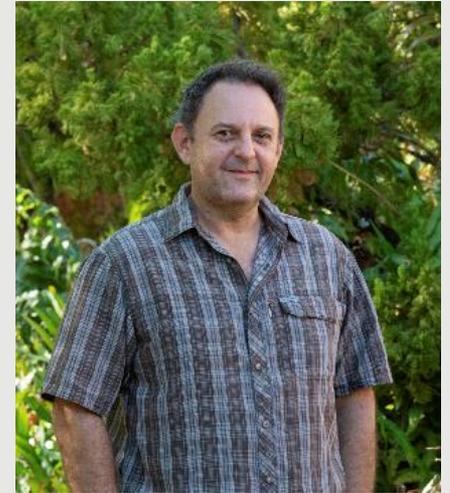
QUESTIONS AND ANSWERS



**Juliann Aukema,
USAID**



**Gordon Smith,
CEADIR and Ecofor**



**Benjamin Brown,
Blue Forests**

FOLLOW UP

- Webinar recording and presentation will be shared with all registrants
- CBA report available at https://pdf.usaid.gov/pdf_docs/PA00WGJS.pdf
- Access previous CEADIR discussions and resources on our [Climatelinks Resource Page](#).
- Additional questions?
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 - Pablo Torres: ptorres@crownagents.com

REFERENCES

- Smith, Gordon; David Cooley; Benjamin Brown; Ria Fritriana; and Eric Hyman. 2020. *Cost-Benefit Analysis of Mangrove Conservation Versus Shrimp Aquaculture in Bintuni Bay and Mimika, Indonesia*. Washington, DC: Crown Agents USA and Abt Associates. Prepared for the United States Agency for International Development, available at https://pdf.usaid.gov/pdf_docs/PA00WGJS.pdf
- Smith, Gordon; Eric Hyman; Lindsay Foley; and Charlotte Mack. 2018. *Mangrove Ecosystem Valuation: Methods and Results*. Washington, DC: Crown Agents USA and Abt Associates. Prepared for the U.S. Agency for International Development, available at https://pdf.usaid.gov/pdf_docs/PA00TC8C.pdf