

Review

Key innovations in financing nature-based solutions for coastal adaptation

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Supplementary Materials

Table S1. Case study database, section 1.

No.	Case study title	Country	Type of NBS	Project Size ¹	Project status
CS1	Zandmaas and Grensmaas public works projects - Delta Program	Netherlands	Coastal adaptation	Large	2019, Implemented
CS 2	Seychelles Blue bond	Seychelles	Coastal ecosystem conservation	Medium	2018, Implemented
CS 3	Nordic-Baltic Blue Bond	Denmark, Finland, Iceland, Norway, and Sweden	Coastal ecosystems conservation and restoration	Large	2019, Implemented
CS 4	Arkansas Water Utility Green Bond	USA	Watershed management	Large	2020, Implemented
CS 5	DC Water EIB	USA	Stormwater management	Large	2016, Implemented
CS 6	Hampton EIB	USA	Stormwater management	Medium	2020, Implemented
CS 7	Buffalo EIB	USA	Stormwater management	Large	2021, Implemented
CS 8	Atlanta EIB	USA	Stormwater management	Medium	2020, Implemented
CS 9	Louisiana EIB	USA	Coastal adaptation, Coastal ecosystem restoration (Wetlands)	Large	2017, Withdrawn
CS 10	Yuba Forest Resilience Bond	USA	Reforestation	Medium	2018, Implemented
CS 11	Deshkan Ziibi Conservation Impact Bond Project	Canada	Ecosystem conservation	Small	2019, Implemented
CS 12	Rhino Impact Investment Project	South Africa	Ecosystem conservation	Large	2021, Implemented

CS 13	Aotearoa permanent forest bond	New Zealand	Reforestation	Large	Planned
CS 14	Fondo Acción (Fondo para la Acción Ambiental y la Niñez)	Colombia	Ecosystem conservation, sustainable agriculture	Large	2000, Implemented
CS 15	Climate Fund for Madagascar Climate and Conservation Investment Fund	Madagascar	Ecosystem conservation, reforestation	Large	2016, Implemented
CS 16	Sustainable Ocean Fund	Focus areas in Latin America and the Caribbean, Africa and Asia	Coastal ecosystem conservation	Large	2017, Implemented
CS 17	Meloy Fund	Indonesia, Philippines	Coastal ecosystem conservation	Large	2017, Implemented
CS 18	Regen Network	Various	Forest conservation	Not mentioned	2017, Implemented
CS 19	GainForest	Various	Forest conservation	Not mentioned	2019, Implemented
CS 20	FLRChain	Uganda	Reforestation	Not mentioned	2021, Implemented
CS 21	Project Genesis 2.0	Hong Kong	Forest conservation, reforestation	Not mentioned	2022, Planned
CS 22	Papariko Blue Carbon project	Kenya	Coastal Adaptation, coastal ecosystem restoration (Mangroves)	Large	2021, Implemented
CS 23	BioTokens	Australia	Ecosystem Conservation	Not mentioned	2017, Implemented
CS 24	Treecycle	Paraguay	Reforestation	Large	2018, Implemented
CS 25	PPP for sand nourishment in Pevensey Bay	United Kingdom	Coastal adaptation, sand nourishment	Large	2000, Implemented
CS 26	Oxcley Creek green corridor	Australia	Ecosystem restoration	Large	2018, Implemented
CS 27	Tweed Sand Bypass	Australia	Coastal adaptation, sand nourishment	Large	2000, Implemented
CS 28	Zorrotzurre district redevelopment	Spain	Watershed management, Stormwater management	Large	2016, Implemented
CS 29	Hybrid flood management, the Norfolk Broadlands	United Kingdom	Watershed management, Stormwater management	Large	2001, Implemented

CS 30	Mikoko Pamoja	Kenya	Coastal adaptation, coastal ecosystem restoration (Mangroves)	Small	2012, Implemented
CS 31	Vlinder Myanmar Blue Carbon	Myanmar	Coastal Adaptation, coastal ecosystem restoration (Mangroves)	Large	2020, Implemented
CS 32	Markets and Mangroves Project	Vietnam	Coastal Adaptation, coastal ecosystem restoration (Mangroves)	Large	2012, Implemented
CS 33	Blue forests Madagascar	Madagascar	Coastal Adaptation, coastal ecosystem conservation (Mangroves)	Large	2016, Implemented
CS 34	Yokohama Blue Carbon Project	Japan	Coastal Adaptation, coastal ecosystem restoration (Seagrass)	Medium	2015, Implemented
CS 35	Fukuoka Blue Carbon Project	Japan	Coastal Adaptation, coastal ecosystem restoration (Seagrass)	Medium	2015, Implemented
CS 36	J-Blue Project	Japan	Coastal Adaptation, coastal ecosystem restoration (Seagrass)	Medium	2015, Implemented
CS 37	Forested Wetland Assimilation in the Mississippi Delta	USA	Coastal adaptation, coastal ecosystem restoration (Wetlands)	Large	2012, Withdrawn
CS 38	Vida Manglar Blue Carbon Project	Colombia	Coastal adaptation, coastal ecosystem restoration (Mangroves)	Large	2012, Implemented
CS 39	Miro Forestry	Ghana, Sierra Leone	Reforestation	Large	2020, Implemented
CS 40	India Sundarbans Mangrove Restoration Project	India, Bangladesh	Coastal Adaptation, coastal ecosystem restoration (Mangroves)	Large	2010, Implemented
CS 41	Selva Shrimp Kalimantan	Indonesia	Coastal Adaptation, coastal ecosystem restoration and conservation (Mangroves)	Large	2013, Implemented
CS 42	Galapagos National Park user fees	Ecuador	Marine ecosystem conservation	Medium	1998, Implemented
CS 43	Bonaire Marine Park scuba diving fees	Netherlands	Marine ecosystem conservation	Small	1992, Implemented
CS 44	International Visitor Conservation and	New Zealand	Ecosystem conservation	Medium	2019, Implemented

Tourism Levy					
CS 45	Environmental preservation fee in Bombinhas, Santa Catarina	Brazil	Coastal adaptation, coastal ecosystem conservation	Small	2013, Implemented
CS 46	Beach nourishments in North Carolina	USA	Coastal adaptation, sand nourishment	Medium/Large	2005, Implemented
CS 47	Measures against coastal erosion in Sirolo and Numana	Italy	Coastal adaptation, Sand nourishment	Large	2020, Implemented
CS 48	The "Carnes del Pastizal" label	Argentina, Brazil	Ecosystem conservation	Small	2010, Implemented

* Small size: < US\$ 1 million, medium size: < US\$ 20 million, large size: > US\$ 20 million.

Table S2. Case study database, section 2.

No.	Innovative financial solution							Ecotour. user fee	Betterm. levy
	Green bond	EIB	Project bund.	Smart contracts	BC Token	Carbon credit	Eco-label		
CS1	x		x						
CS2	x		x						
CS3	x		x						
CS4	x		x				x		
CS5		x							
CS6		x							
CS7		x							
CS8	x	x	x						
CS9		x							
CS10		x	x						
CS11		x							
CS12		x							
CS13	x	x							
CS14			x						
CS15	x		x						
CS16			x				x		
CS17			x						
CS18				x	x	x			
CS19				x	x				
CS20			x	x					
CS21	x		x	x		x			
CS22			x		x	x			
CS23			x		x				
CS24			x		x				
CS25									
CS26									
CS27									
CS28			x					x	
CS29			x						
CS30						x			

CS 31	x	x	x
CS 32			x
CS 33		x	
CS 34		x	
CS 35		x	x
CS 36		x	
CS 37		x	
CS 38		x	x
CS 39		x	x
CS 40	x	x	
CS 41	x		x
CS 42			x
CS 43			x
CS 44			x
CS 45			x
CS 46			x
CS 47			x
CS 48		x	

Table S3. Case study database, section 3.

No.	Financial Barrier addressed						
	FB 1: High performance risks	FB 2: Low measurability	FB 3: Site specificity	FB 4: Long lead time	FB 5: Insufficient project size	FB 6: Jointness	FB 7: Low revenues
CS1	x	x			x		
CS 2	x	x			x		
CS 3	x	x			x		
CS 4	x	x			x		
CS 5	x						
CS 6	x						
CS 7	x						
CS 8	x	x					
CS 9	x	x					
CS 10	x	x		x			
CS 11	x						
CS 12	x						
CS 13	x						
CS 14	x				x		
CS 15	x				x		
CS 16	x				x		
CS 17	x				x		
CS 18			x		x		
CS 19		x			x		
CS 20		x	x		x		
CS 21	x	x					
CS 22					x		x
CS 23					x		x
CS 24					x		x
CS 25	x					x	
CS 26							
CS 27	x					x	
CS 28					x	x	x
CS 29	x				x	x	
CS 30							x
CS 31							
CS 32							x
CS 33							x
CS 34						x	x
CS 35						x	x
CS 36							x
CS 37							x
CS 38							x
CS 39							x
CS 40	x				x		x
CS 41							
CS 42		x					x

CS 43		x
CS 44	x	x
CS 45	x	x
CS 46	x	x
CS 47	x	x
CS 48		x

Table S4. Case study database, section 4.

No.	Enabling conditions of applicability	Hindering conditions of applicability	Support from Financial service providers/intermediaries	Support from Public/Philanthropic sector	References
CS1	High credit rating; Pipeline of investment-ready eligible projects; Procurement criteria prioritising NBS	Low credit ratings; Insufficient project size	Certification, credit rating, verification	None	Marsters et al. 2021
CS 2	Alignment with government policy agenda Pipeline of investment-ready eligible projects	Low credit rating; need for clear economic benefits; Coordination of multiple parties, high transaction costs	Transaction structuring, credit rating, verification	Credit enhancement	Iyer et al. 2018; Tirumala and Tiwari 2022
CS 3	Not mentioned	Complex product with limited direct replicability	Transaction structuring, credit rating, verification	Not mentioned	Tirumala and Tiwari 2022; NIB 2019
CS 4	High creditworthiness; Credible certifications	Not mentioned	Certification, third-party verification, credit rating	Granting	Marsters et al. 2021
CS 5	Alignment with government policy agenda	Lack of track record	Transaction structuring, financial advisory, third-party verification, performance measurement	Enabling legislation, granting	Brand et al. 2021, Goldman Sachs (2016)
CS 6	High credit rating; regulatory incentives	Lack of pipeline of investment-ready projects; Insufficient project size	Transaction structuring, financial advisory, third-party verification, performance measurement	Granting, regulatory incentives	Quantified Ventures 2023b; CBF 2023a, b.
CS 7	Alignment with government	Not mentioned	Transaction structuring,	Granting	Quantified Ventures 2023a

	policy agenda		financial advisory, third-party verification, performance measurement		
CS 8	Single proxy metric (Volume of stormwater storage) across the different projects	High uncertainty and transaction costs due to lack of track record	Transaction structuring, financial advisory, third-party verification, performance measurement	Granting	Quantified Ventures 2023c, Brand et al. 2021
CS 9	"Polluter pays" funds available through the deepwater horizon oil spill fund	Changes in political preferences resulted in the interruption of the project	Transaction structuring, financial advisory, third-party verification, performance measurement	Granting	EDF 2018
CS 10	Repayment structure matches the time horizon of benefit generation; Focus on measuring ESS with clear economic benefits	Lack of track record; Plurality of paying beneficiaries increase complexity and transaction costs; Trade off between precise measurement and ESS price.	Transaction structuring, financial advisory, third-party verification, performance measurement	Credit enhancement, granting	BFC 2017
CS 11	Community involvement and relationship-building	Misalignment between financing cycle and restoration benefits; Difficulties in stakeholders coordination and standardisation complex systems	Transaction structuring, third-party verification, performance measurement, certification	Granting	Arjaliès, 2021
CS 12	Use of proxy metric	Difficulty in tracking number of individuals	Transaction structuring, performance measurement,	Granting	The Green Finance Institute 2023c

		varies from species to species	third-party verification		
CS 13	Not mentioned	Arrangement complexity is a source of structural risk (risk mitigation and revenue generation tradeoff)	Investment intermediary, transaction structuring, performance measurement, third party verification	Granting	Hall et al., 2017 Hall and Lindsay 2018
CS 14	Track record of social and environmental projects; Program diversification; Expertise in innovative finance mechanisms with private sector engagement	Trade-off between private corporate objectives and the non-profit interests; Building relations and policy change requires long time frames that are incompatible with some investors	Project aggregation, certification, transaction structuring, financial advisory	Granting, credit enhancement	Bath et al. 2020
CS 15	Strong link between conservation and economic development	Country risks; Limited beneficiary payment capacity; Bureaucratic processes distancing stakeholders from project managers	Investment intermediary, transaction structuring, project aggregation	Granting	Gibbon 2017; Michaelowa et al. 2021
CS 16	Not mentioned	Lack of track record; Projects are often early-stage and involve complex, multi-level systems of stakeholders	Project aggregation, transaction structuring	Credit enhancement	Green Finance Institute 2023b
CS 17	Not mentioned	Lack of track record	Project aggregation, transaction structuring, financial advisory,	Granting, credit enhancement	Green Finance Institute 2023a USAID 2021

			certification.		
CS 18	Plurality of monitoring instruments (local and remote)	Not mentioned	Not mentioned	None	Booman et al. 2021, Howson et al. 2019
CS 19	Data-rich transactions; Plurality of monitoring instruments for both auditable and high resolution data.	The integration of data requires specialised skills and instruments such as AI and Internet of Things	Third-party verification	None	GainForest 2023, Kotsialou et al. 2021
CS 20	Smart contract structure is easily tailored to specific project needs	Regulatory gaps; Monitoring and information verification delay rewards. Low stakeholders' digital literacy; long-term, integrated conservation is too complex for smart contracts.	Third-party verification	Granting	Mulley 2021, 2022
CS 21	Not mentioned	Regulatory and policy gaps; lack of market maturity	Third-party verification	None	BIS 2022
CS 22	Prepaid forward model, whereby payments for credits are made in advance and delivery is guaranteed. Integration of indigenous knowledge.	Not mentioned	Standard setting, third-party verification	Granting	Solid World 2023
CS 23	Governmental development offset framework	Not mentioned	Transaction structuring	Regulatory incentive, granting	CommBank 2019
CS 24	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Czura 2022
CS 25	Operating costs	Contracting and	Not	Not	Bisaro and

	represent a significant share of the overall costs.	tendering was time consuming and a learning process for all parties due to lack of experience in PPP.	mentionedProject specification and supervision	mentionedProject specification and supervision	Hinkel 2018 Tanis and Vergeer 2008
CS 26	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Baroni et al. 2019 Brisbane City, 2018
CS 27	Specific enabling legislation enacted; Uncertainty related to new technology	Risks related to the large variability in coastal processes	Financial advisory	Enabling legislation	Ware and Banhalmi-Zakar 2017
CS 28	The relocation and compensation of companies operating on the site was managed with ample preparation time; Broad stakeholders involvement.	The great number of stakeholders involved delayed the realisation of the project. Initial lack of trust in the commitment of private partners to pursue wider co-benefits	Not mentioned	Granting	Climate Adapt 2016, Baroni et al. 2019
CS 29	Broad, periodic and digital public consultations; Integration of wider benefits within the financial limits of the project.	Social resistance to restoration	Not mentioned	Project specification and supervision	Climate Adapt 2020b
CS 30	Long-term research and community engagement background; Community-based model integrating education, employment	Wider-scale co-benefits are not captured yet; Unstable carbon credit prices; Insufficient project size to achieve economies of scale and global	Standard setting, transaction structuring, third-party verification, financial intermediary	Granting	UNDP 2020, Wylie et al. 2016

	and training for carbon credit long-term sustainability	markets; Soil carbon and sea level rise not accounted for.			
CS 31	Community-based model integrating education, employment and training for long-term sustainability	Not mentioned	Standard setting, transaction structuring, third-party verification	None	Vanniarachchy 2020
CS 32	Proven direct economic benefits of certifications. Broad stakeholders involvement	UN-REDD application for carbon credits dropped due to lengthy bureaucracy.	Standard setting, third-party verification	Not mentioned	Wylie et al. 2016
CS 33	Not mentioned	Incoherent policy framework	Standard setting, third-party verification	Enabling legislation	Wylie et al. 2016
CS 34	Development of ad hoc carbon crediting scheme for local offsetting; Alignment with government policy goals; Social acceptance and support; Broad stakeholders participation.	Not mentioned	Not mentioned	Granting	Kuwae et al. 2022; Suehiro et al. 2020
CS 35	Local social acceptance and support; Broad stakeholders participation.	Not mentioned	Not mentioned	Granting	Kuwae et al. 2022
CS 36	Dynamic carbon credit pricing (based on relative co-benefits) and flexible scheme for methodologies. Local social	Not mentioned	Transaction structuring, third-party verification	Granting	Kuwae et al. 2022

	acceptance and support; Broad stakeholders participation.				
CS 37	Inclusion of soil carbon sequestration	The project was withdrawn due to large uncertainties in GHG sequestration estimates	Standard setting, transaction structuring, third-party verification	Granting	Mack et al. 2022, Sapkota and White 2020
CS 38	Community-based model integrating education, employment and training for long-term sustainability	Limited local capacity in environmental governance	Standard setting, transaction structuring, third-party verification	Granting	VERRA 2021, Conservation International 2022
CS 39	Clear revenue streams (forestry sector)	Not mentioned	Certification, standard setting, transaction structuring, third-party verification	None	GPC 2021, MIRO 2022
CS 40	Cheap labour costs. Inclusion of soil carbon sequestration.	Several climate and anthropogenic pressures on restored areas. Sea level rise was not accounted for.	Standard setting, transaction structuring, third-party verification	None	Wylie et al. 2016
CS 41	Investment in marketing of the Selva Shrimp label. Supportive role of Government passing new regulation for certified aquaculture and payments for ecosystem services	Uncertain landscape-level impact. Restoration is measured through proxy which is not descriptive of ecosystem health, and there is no horizontal collaboration among farmers to manage area-level risks.	Certification, third-party verification, financial advisory, financial intermediary	Granting, supervision, enabling legislation	Bottema 2019
CS 42	Revenues used	Anthropogenic	None	Granting,	Benitez et al.

	to reduce pressures on the ecosystems; Presence of Charismatic species; developed tourism sector. Price discrimination.	pressures on the ecosystems. Fees are not based on willingness-to-pay of the users, nor on management costs.		enabling legislation	2001
CS 43	High willingness to pay	Stakeholders' opposition to optimisation of fees.	None	Granting	Brenes Vega 2004
CS 44	High willingness to pay; Growing tourism sector	Not mentioned	Not mentioned	Enabling legislation	Ministry of Business, innovation and employment 2023
CS 45	High willingness to pay; growing tourism sector.	Not mentioned	Not mentioned	Enabling legislation	Prefeita Municipal de Bombinhas, 2013
CS 46	Clear, yet unequally distributed, recreational and risk mitigation values of restoration.	Instances of public resistance to increased taxation for coastal management.	None	Enabling legislation	Mullin et al. 2018
CS 47	Broad stakeholder consultation and cooperation with local communities; Cost-benefit analysis demonstrated tourism revenues as co-benefits.	Tension between future budget uncertainties and need to repeat beach nourishment periodically.	None	Enabling legislation, granting	Climate Adapt 2020a
CS 48	Proof of increase of profit from the sale of certified products (market demand)	Market conditions limiting the promotion of sustainable ecosystem management. Possible trade-offs with other	Certification, third-party verification	Granting	Altmann and Berger Filho 2020

productive
activities carried
out within the
certified farm.

Table S5. Case study database, References.**REFERENCES**

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