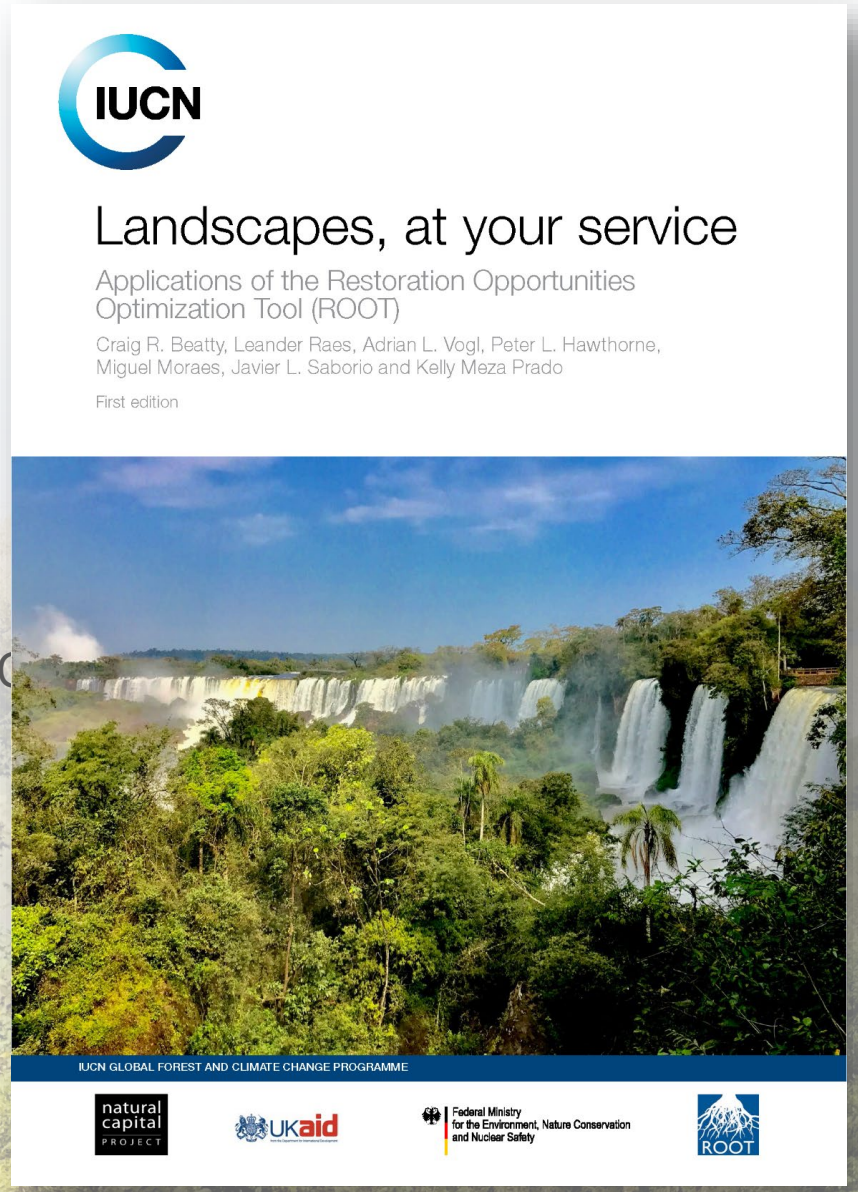


The Restoration Opportunities Optimization Tool (ROOT)

Optimizing ecosystem services for decision-making in forest landscape restoration

Craig R. Beatty

Programme Officer – Forest Landscape Restoration
International Union for Conservation of Nature (IUCN) Global Forest and Climate Change Programme

December 4, 2018

2018 ACES A Community on Ecosystem Services
Natural Resources Benefitting People
Celebrating 10 years of ACES!
In partnership with ECOSYSTEM MARKETS Making Them Work
ESP

- Ecosystem services and their impacts on livelihoods can be helpful in justifying large-scale investments in landscape restoration
- ROOT provides and assessment of ecosystem service trade-offs and facilitates the effective communication of this information to decision-makers
- Knowing where restoration can have the greatest impact on multiple ecosystem services for multiple beneficiaries can help make restoration more cost-effective and increase its success
- ROOT builds support for forest landscape restoration and facilitates the mobilization and direction of funding; it helps people visualise potential landscape benefits and define recommendations
- Investments in restoration have the potential to be optimised such that relatively small interventions can have large and compounding benefits across landscapes
- ROOT can demonstrate how restoration generates multiple benefits beyond the biophysical realm– it connects those services and their provision to people and restoration processes in specific places

	Main ecosystem services	Identified area of restoration opportunity or priority	Beneficiary objectives	Constraints
Espirito Santo, Brazil	Sediment retention and water yield	120,000 ha FLR opportunity area	Groundwater recharge, payments for environmental services, income generation, watershed risk management	Land use type (pasture/ macega), 80,000 Bonn Challenge Pledge
Malawi	Sediment retention, actual evapotranspiration, carbon sequestration	100,000 ha highly degraded land	Hydropower generation, poverty alleviation, gender responsive restoration	Malawi 50,000 ha to begin restoration project
Myanmar	Sediment export	713,400 ha of forest loss	Flood mitigation, job creation, reduction in reliance on unsustainable natural resources	25,000 ha to begin restoration
Colombia	Sediment delivery ratio model ('sediment'), nutrient delivery ratio model ('nutrient'), forest carbon edge effect ('carbon'), seasonal water yield	88,000 ha restoration potential surrounding six urban areas	Watershed protection for urban area water sources	Monetary/budget constraints
Costa Rica	Sediment export, nitrogen export, phosphorus export	1 million ha of degraded and deforested land	Increased agricultural production and carbon sequestration, potable water, wetlands, hydroelectricity, biodiversity corridors	25,000 ha for coffee restoration. 70,000 ha for plantations outside livestock areas

Drought and coffee: planning restoration in Espirito Santo, Brazil

Craig R. Beatty (IUCN) and Miguel Moraes (IUCN)

Maize, power and gender: balancing restoration decisions in Malawi

Craig R. Beatty (IUCN)

A landscape approach to reducing disaster risk and improving livelihoods in Myanmar

Craig R. Beatty (IUCN) and Adrial L. Vogl (Natural Capital Project/Stanford University)

Water for cities: optimising the delivery of water resources based on forest landscape restoration in Colombia

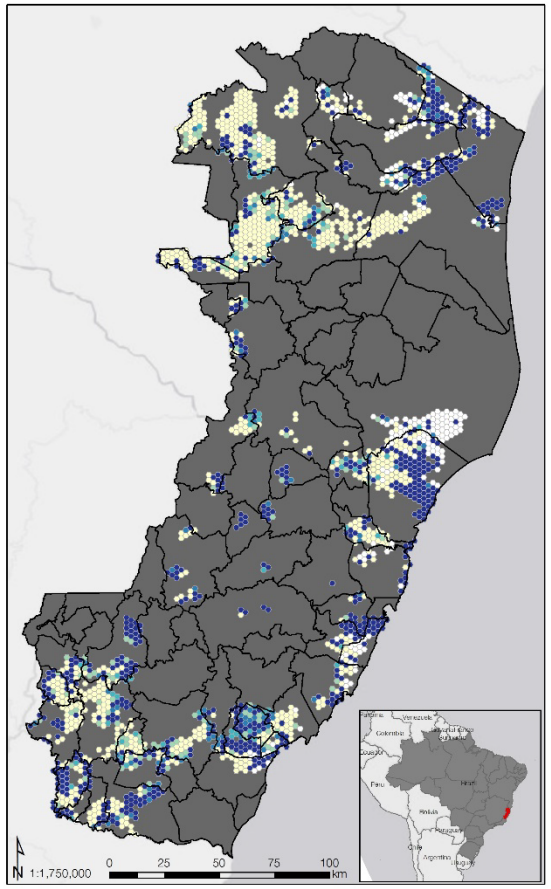
Adrial L. Vogl (Stanford University)

Restoration of coffee and pasture for optimised social, climate and ecological results in Costa Rica

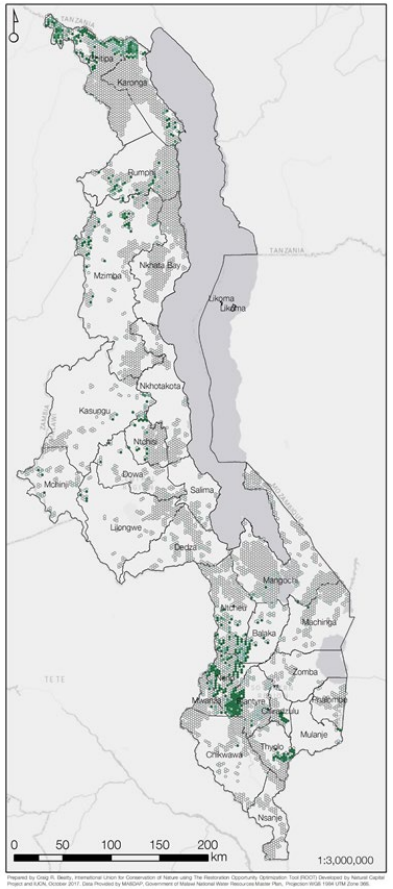
Leander Raes (IUCN), Kelly Meza Prado (Natural Capital Project/University of Minnesota), Peter Hawthorne (Natural Capital Project/University of Minnesota), Javeir Leon Saborio (CATIE)

Some examples of ROOT results from *Landscapes, at your service*

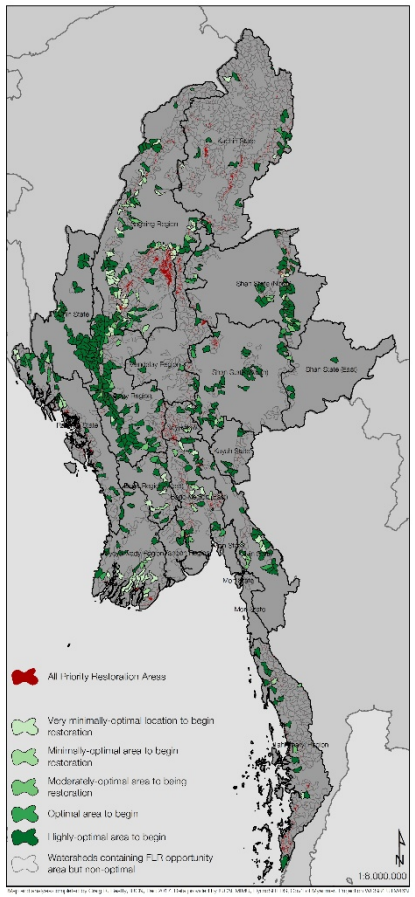
Brazil



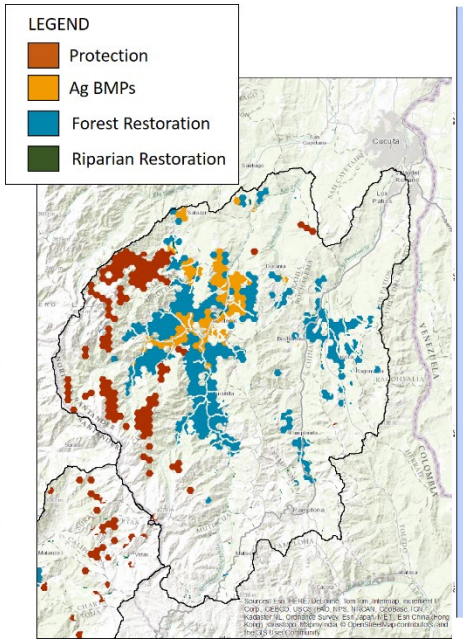
Malawi



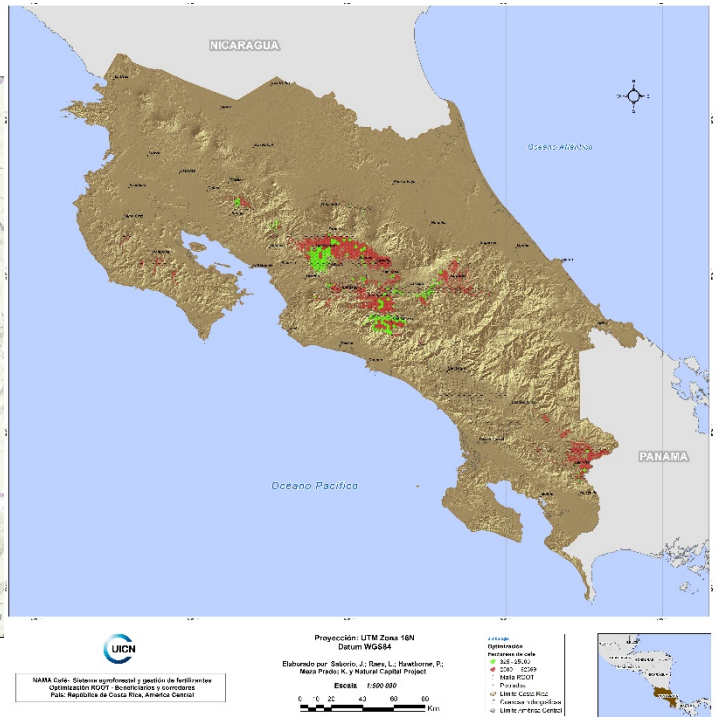
Myanmar



Colombia



Costa Rica



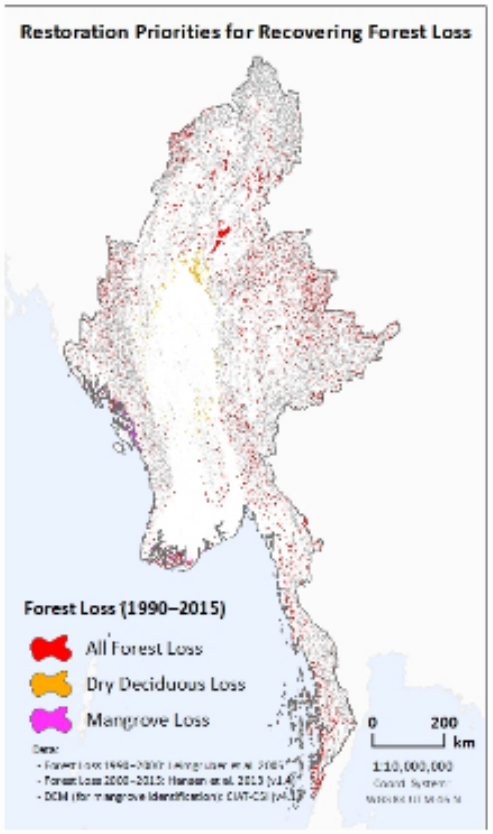
A landscape approach to reducing disaster risk and improving livelihoods in Myanmar

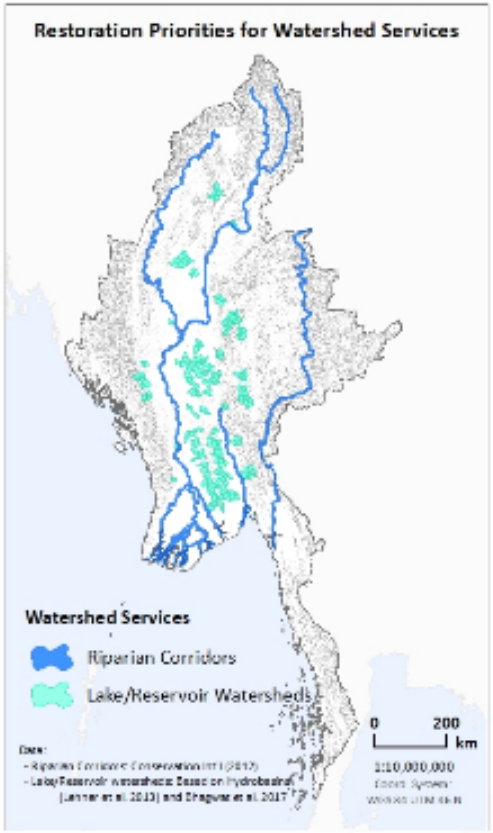
Craig R. Beatty (IUCN) and Adrial L. Vogl (Natural Capital Project/Stanford University)

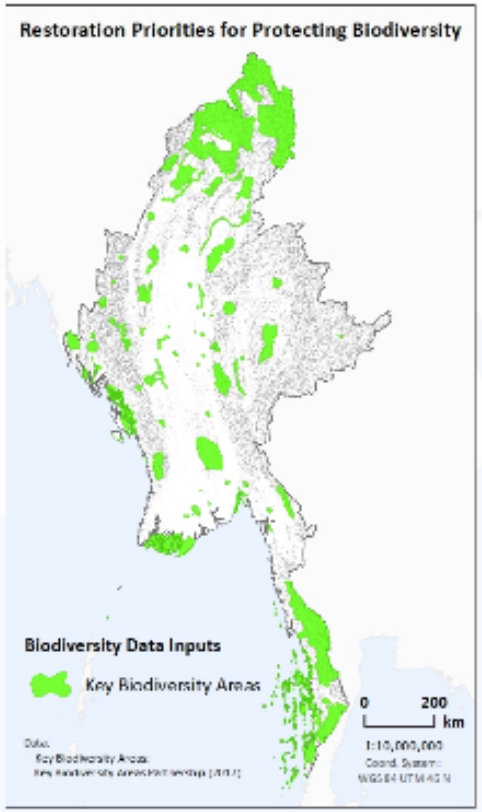
The ROOT analysis for Myanmar used the results from a national forest landscape opportunities assessment map, developed in collaboration among IUCN, The Myanmar Ministry of Natural Resources and Environmental Conservation - Forest Department, and The Nature Conservancy. The objective of ROOT was to maximize the ecosystem service of sediment retention in municipalities most affected by the 2015 flooding, in areas with high unemployment, and areas with a heavily reliance on wood as fuel.

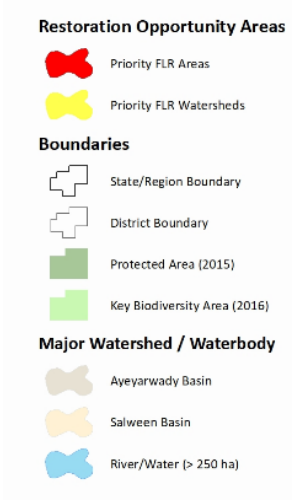
ROOT input categories	Myanmar details
Impact potential maps (marginal values of ecosystem services resulting from restoration activities)	Sediment Retention (Mg/ha/year)
Servicesheds	Floods: flood-impacted villages (number of villages within township heavily affected by floods), Fuel: households heavily reliant on fuelwood for energy (percentage of households per district that rely on firewood for fuel), Employment: individuals per township seeking work, not seeking work, or not paid for work (percentage of population unemployed or not paid for employment)
Composite factors	Sediment retention (floods, fuel, employment)
Activity mask	Myanmar forest landscape restoration opportunity assessment. Opportunity area for forest restoration 1,214,767 ha
Objectives (must account for positive or negative input values since objectives are multiplied in the analysis)	Maximize composite factor of [sediment retention *(floods, fuel, employment)]
Targets	50,000 ha

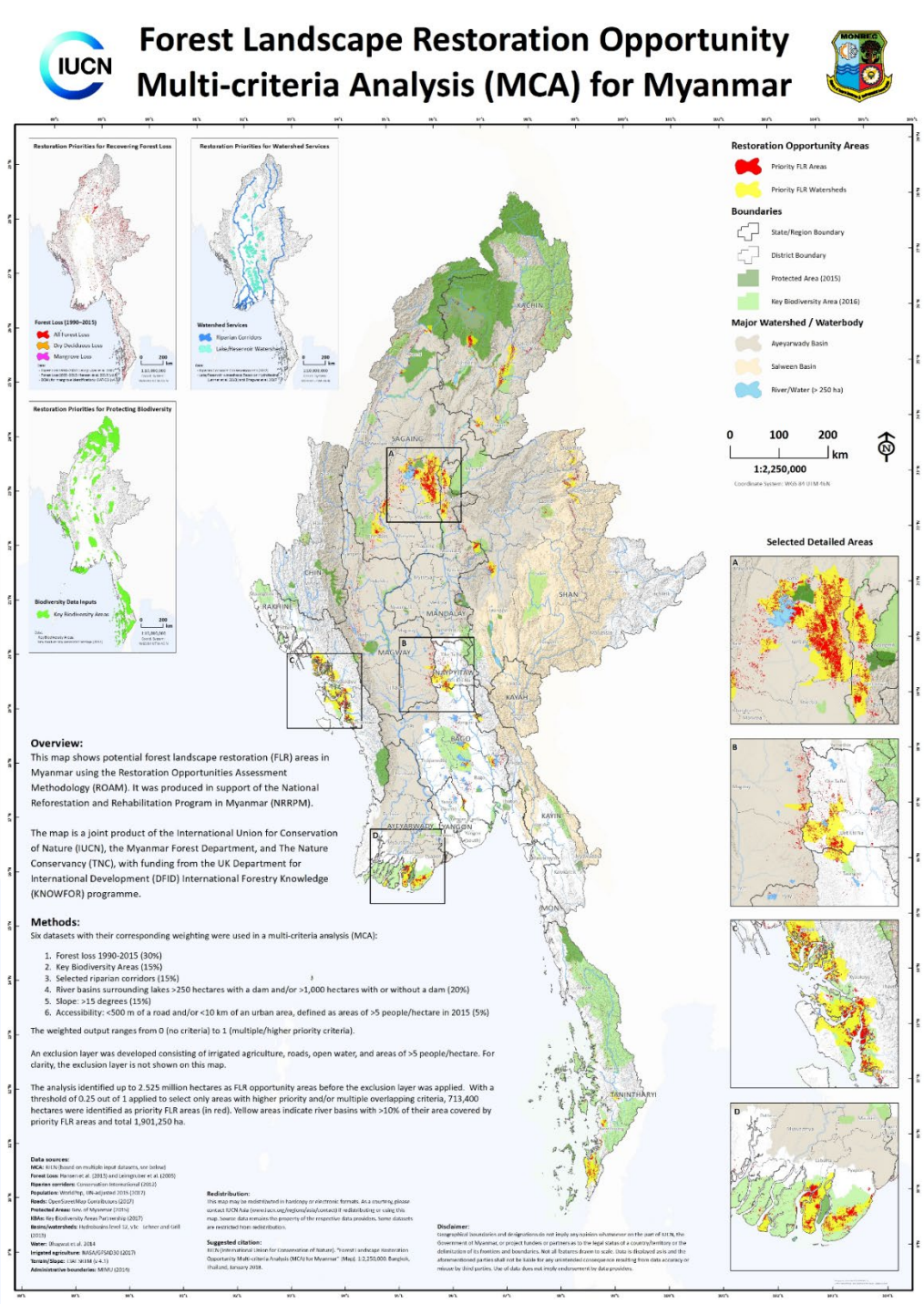
Myanmar National Forest Landscape Restoration Assessment



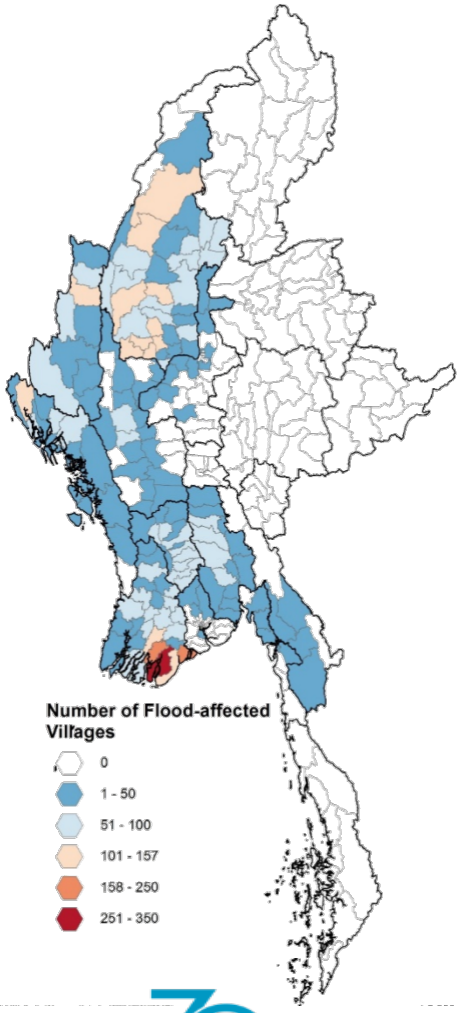




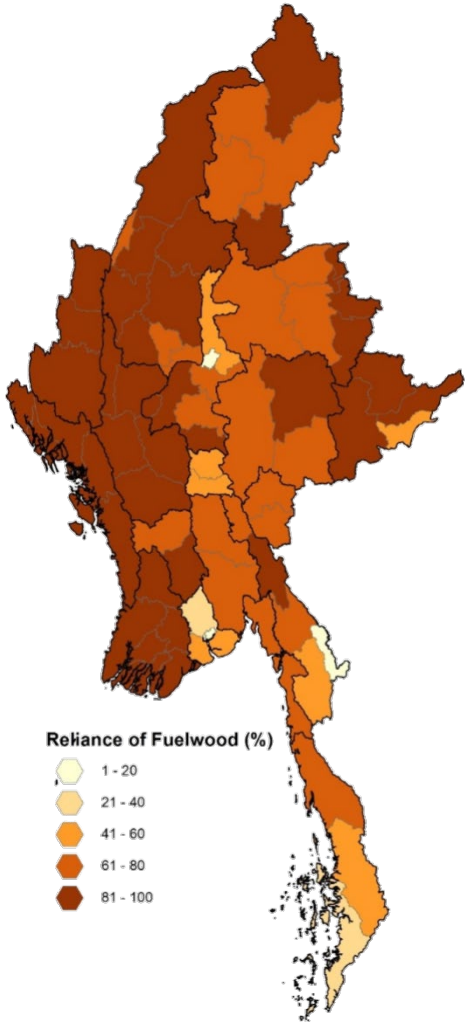




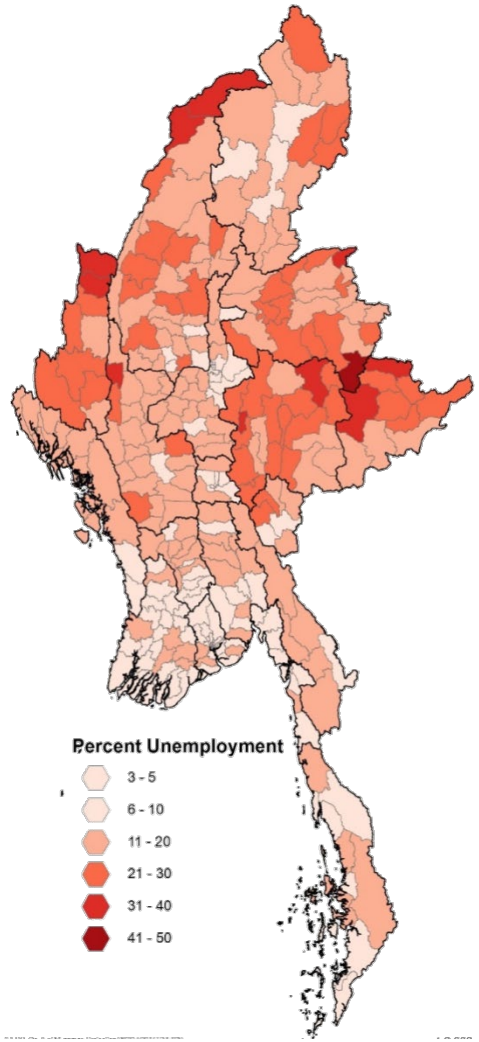
Beneficiary	Calculation
Flood impacted villages	(number of villages within township heavily affected by floods)

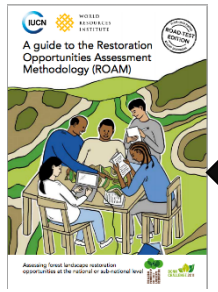


Beneficiary	Calculation
Households heavily reliant on fuelwood for energy	Percentage of households per district that rely on firewood for fuel.



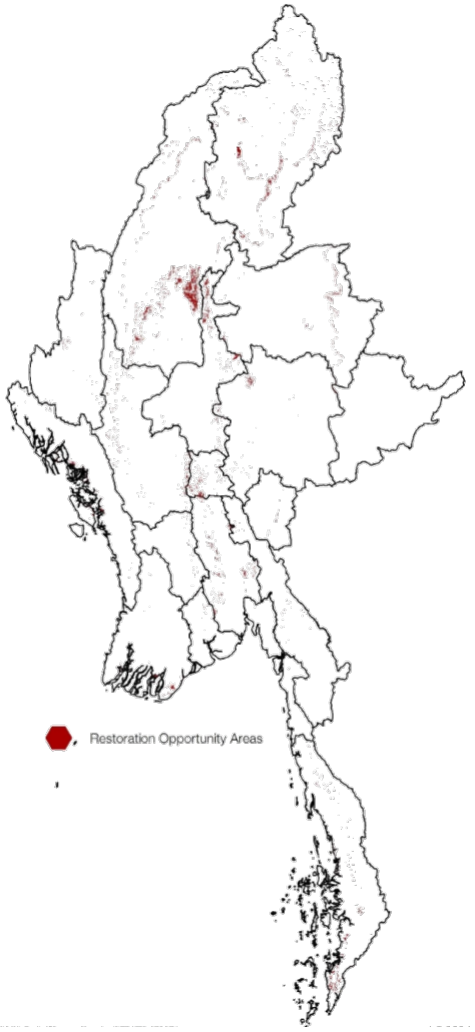
Beneficiary	Calculation
Individuals per township seeking work, not seeking work, or not paid for work	percentage of population unemployed or not paid for employment.





InVEST integrated valuation of environmental services and tradeoffs

Sediment Delivery Ratio Model



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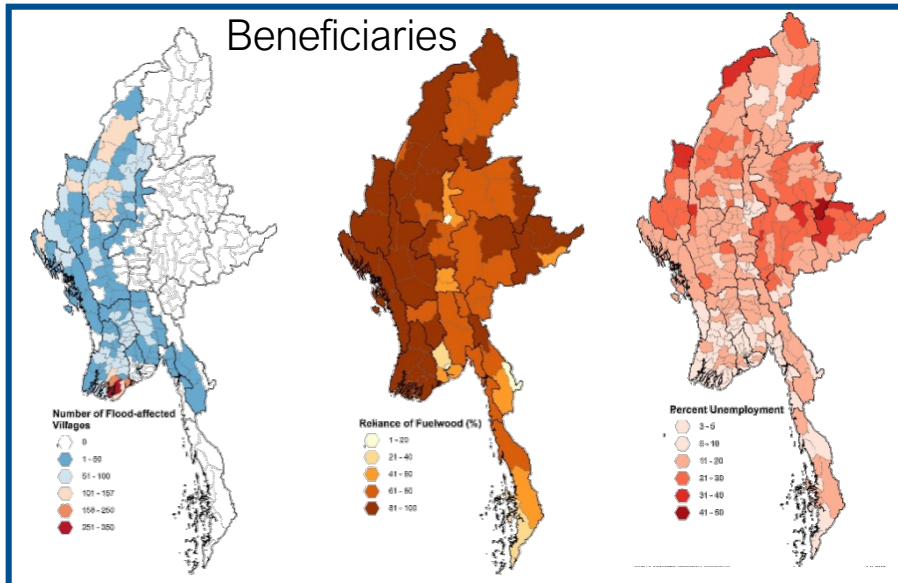
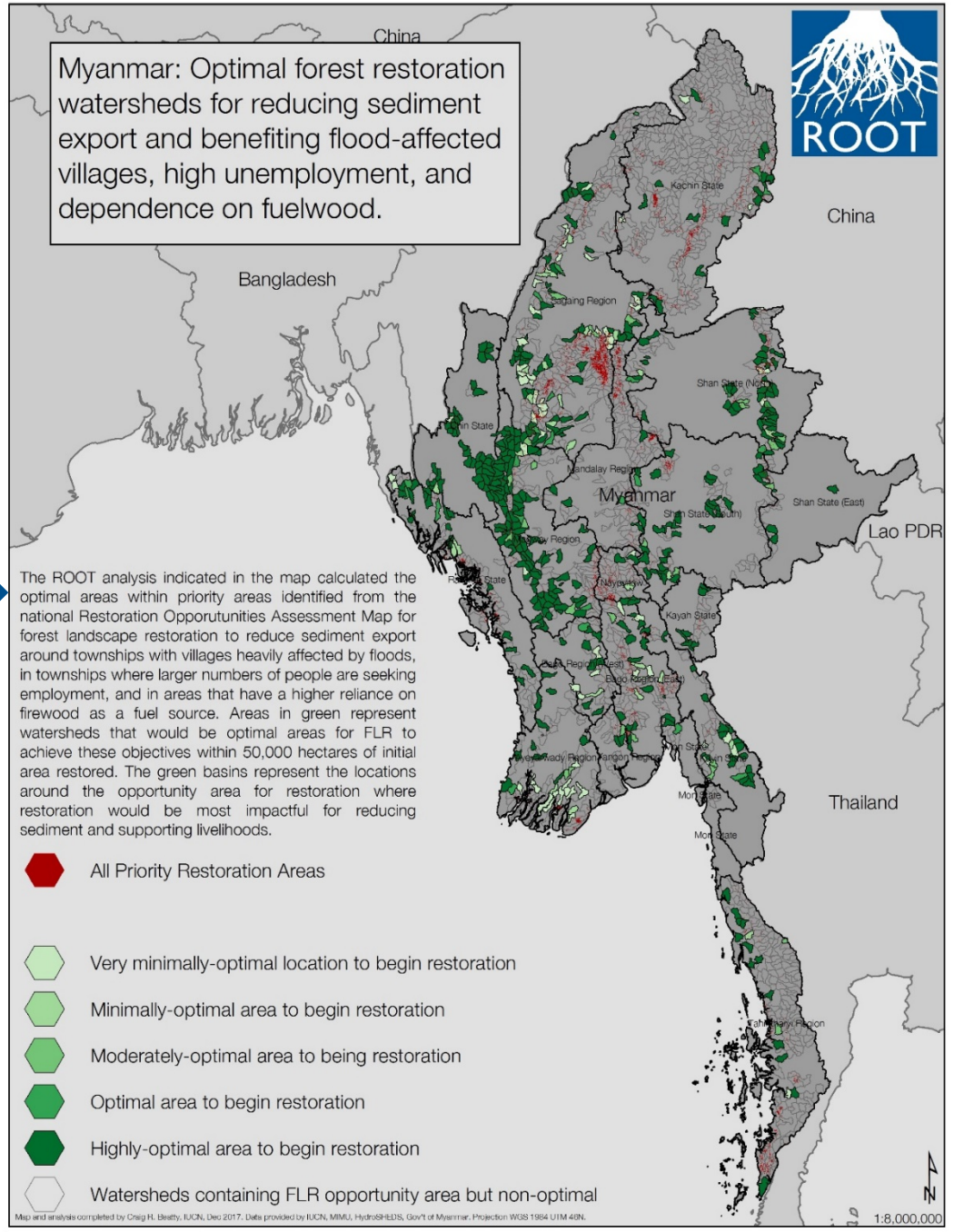
Beneficiaries

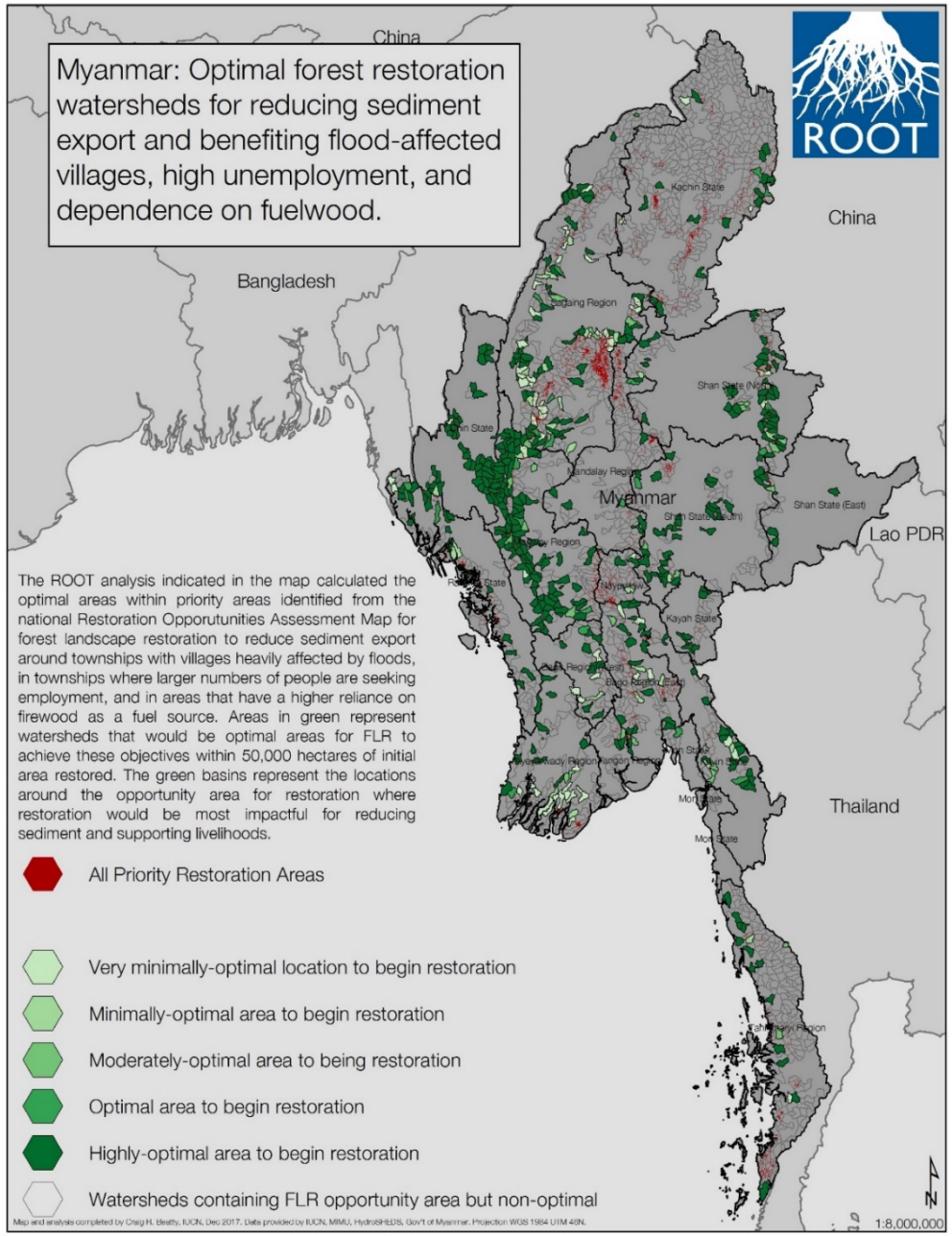


Opportunity Areas

Ecosystem Service Change

ROOT




Myanmar: Optimal forest restoration watersheds for reducing sediment export and benefiting flood-affected villages, high unemployment, and dependence on fuelwood.
ROOT
China
Bangladesh
Myanmar
Lao PDR
Thailand
The ROOT analysis indicated in the map calculated the optimal areas within priority areas identified from the national Restoration Opporutunities Assessment Map for forest landscape restoration to reduce sediment export around townships with villages heavily affected by floods, in townships where larger numbers of people are seeking employment, and in areas that have a higher reliance on firewood as a fuel source. Areas in green represent watersheds that would be optimal areas for FLR to achieve these objectives within 50,000 hectares of initial area restored. The green basins represent the locations around the opportunity area for restoration where restoration would be most impactful for reducing sediment and supporting livelihoods.
All Priority Restoration Areas
Very minimally-optimal location to begin restoration
Minimally-optimal area to begin restoration
Moderately-optimal area to being restoration
Optimal area to begin restoration
Highly-optimal area to begin restoration
Watersheds containing FLR opportunity area but non-optimal
Map and analysis completed by Craig H. Beatty, IUCN, Dec 2017. Data provided by IUCN, MIMU, HydroSHEDS, Gov't of Myanmar. Projection WGS 1984 UTM 46N.
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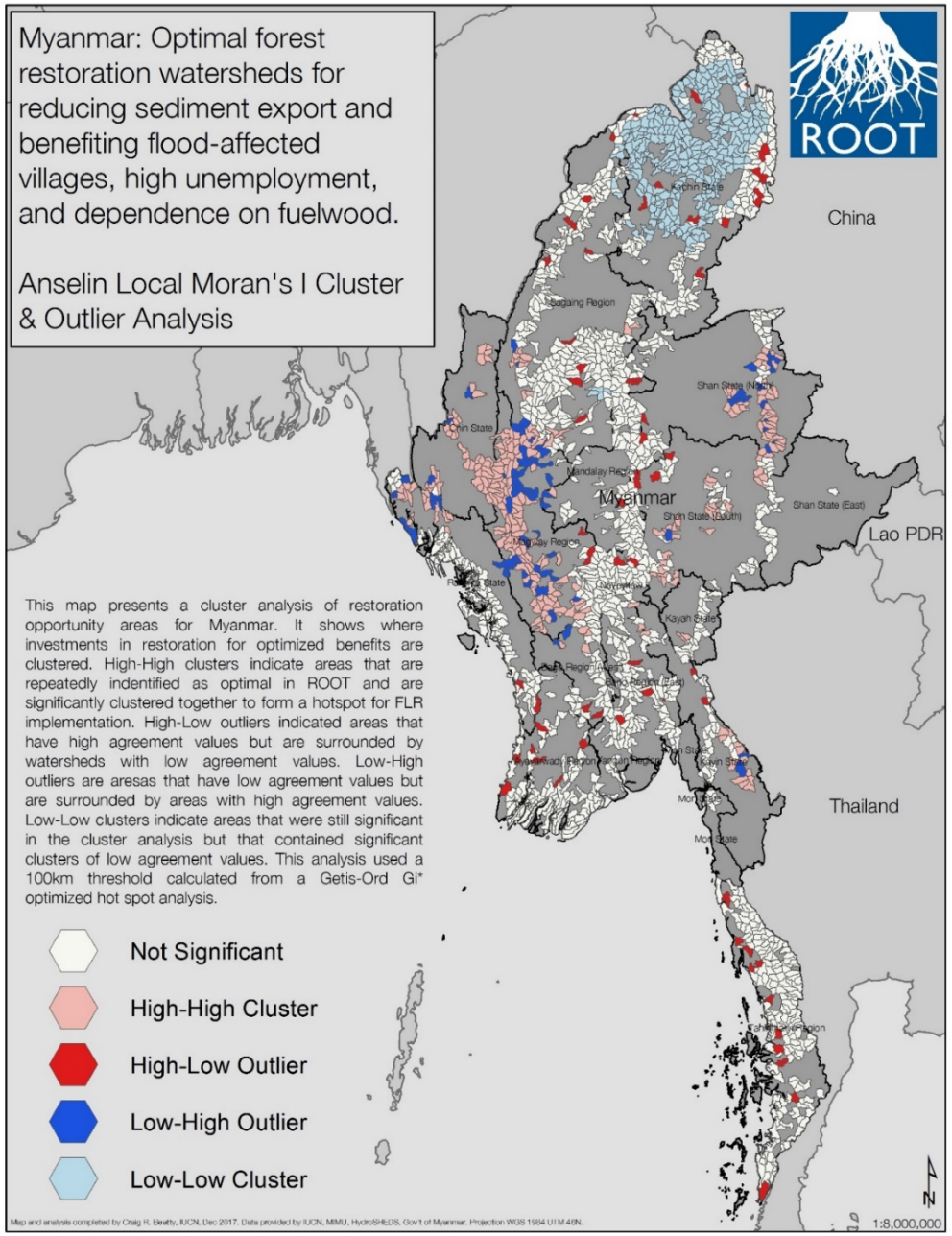
Myanmar: Optimal forest restoration watersheds for reducing sediment export and benefiting flood-affected villages, high unemployment, and dependence on fuelwood.
Anselin Local Moran's I Cluster & Outlier Analysis
ROOT
China
Myanmar
Lao PDR
Thailand
This map presents a cluster analysis of restoration opportunity areas for Myanmar. It shows where investments in restoration for optimized benefits are clustered. High-High clusters indicate areas that are repeatedly indentified as optimal in ROOT and are significantly clustered together to form a hotspot for FLR implementation. High-Low outliers indicated areas that have high agreement values but are surrounded by watersheds with low agreement values. Low-High outliers are aresas that have low agreement values but are surrounded by areas with high agreement values. Low-Low clusters indicate areas that were still significant in the cluster analysis but that contained significant clusters of low agreement values. This analysis used a 100km threshold calculated from a Getis-Ord Gi* optimized hot spot analysis.
Not Significant
High-High Cluster
High-Low Outlier
Low-High Outlier
Low-Low Cluster
Map and analysis completed by Craig H. Beatty, IUCN, Dec 2017. Data provided by IUCN, MIMU, HydroSHEDS, Gov't of Myanmar. Projection WGS 1984 UTM 46N.
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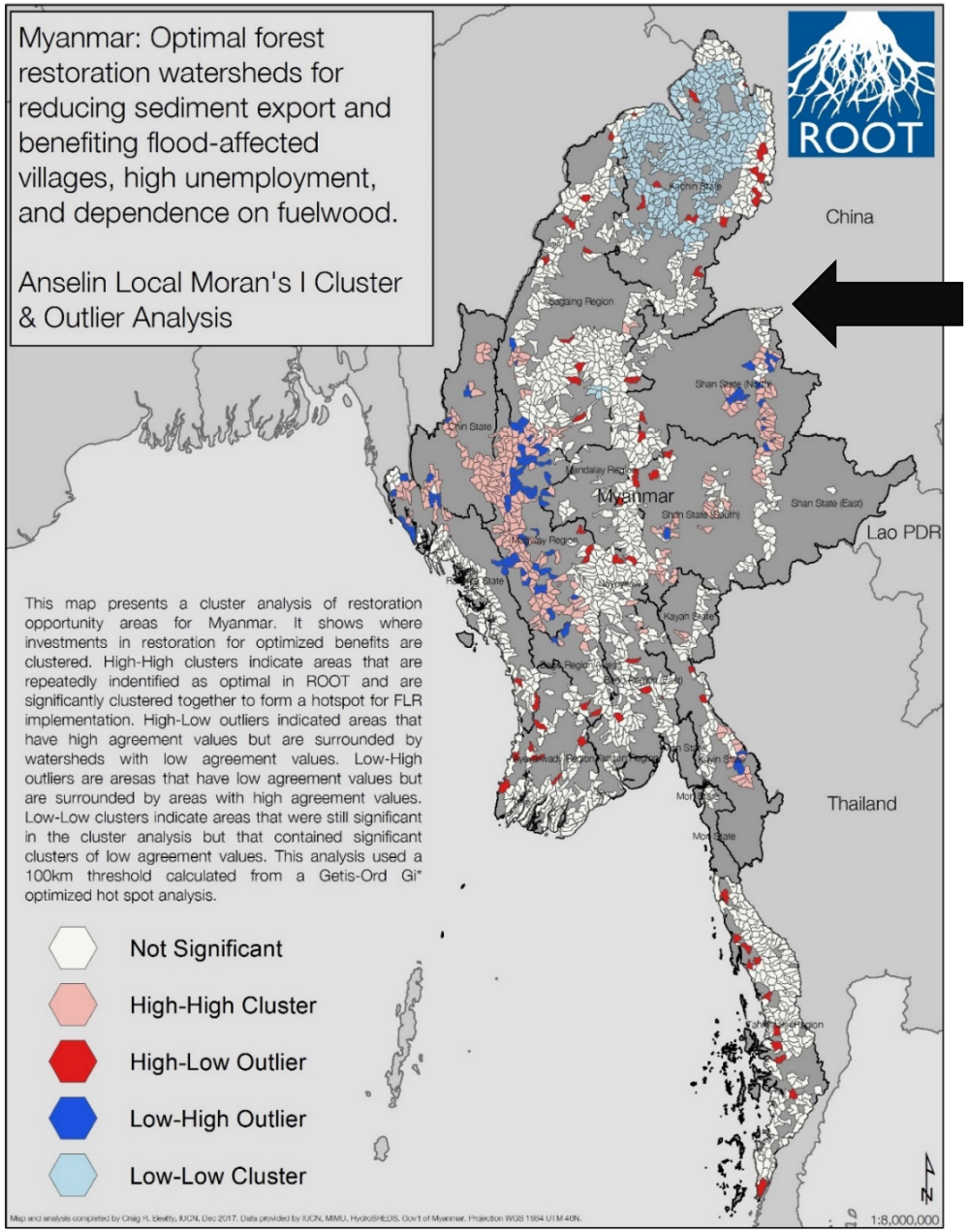
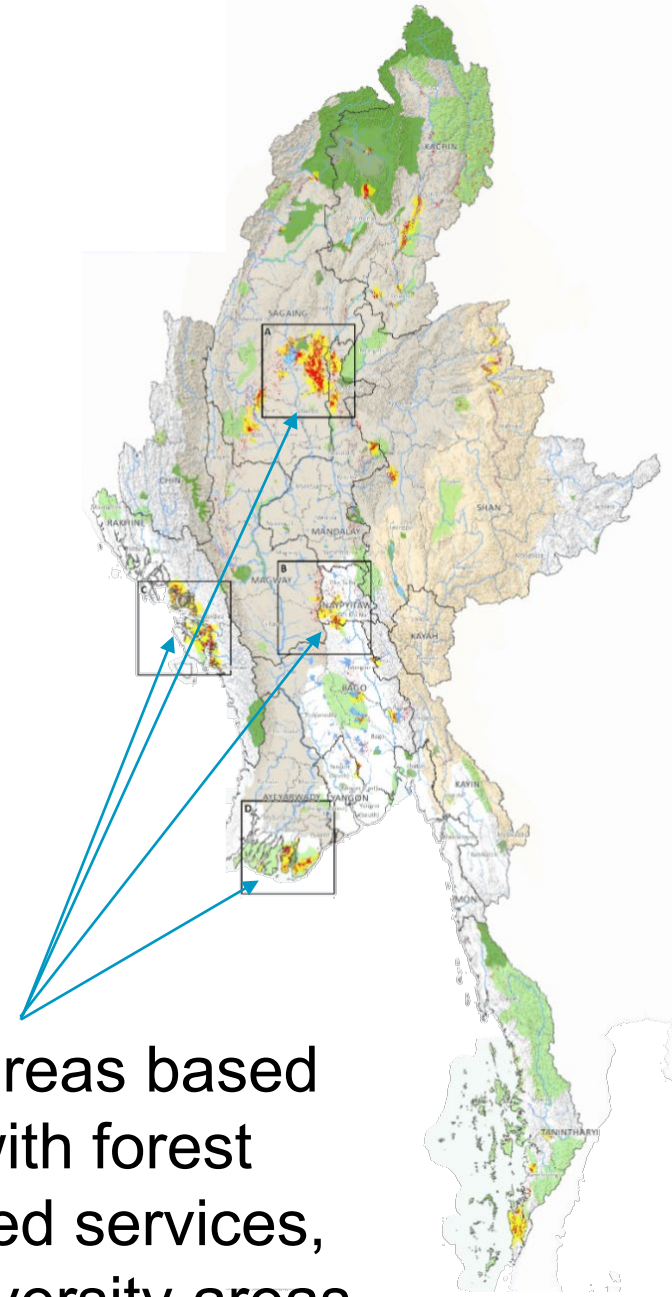
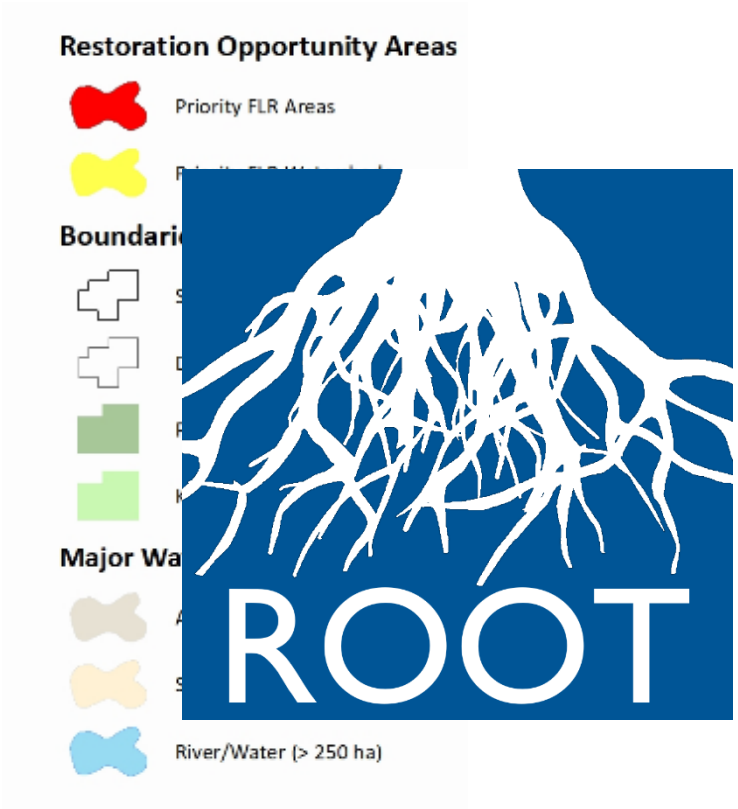


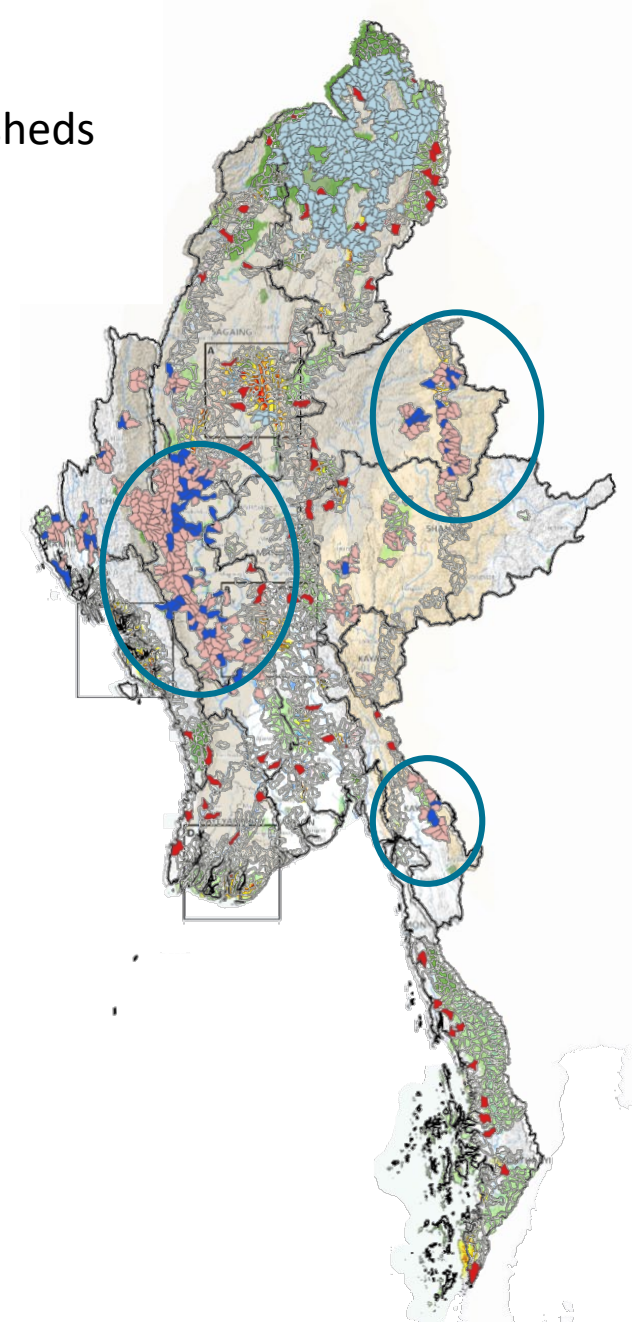
Priority FLR watersheds based on optimized retention of sediment from forest restoration in townships affected by flooding, high unemployment, and dependence on fuelwood. These opportunities are a priority sub-set of the full FLR opportunities map



Priority FLR areas based on overlaps with forest loss, watershed services, and key biodiversity areas

National FLR Opportunity Areas and Watersheds





Priority Watershed clusters for Sediment Reduction from Forest Restoration to support ecosystem service beneficiaries.

These areas are different because they specifically target the restoration of an ecosystem service and optimize based on the benefits that restoration may provide to selected beneficiaries.

Myanmar Conclusions

- The identification of opportunity areas for FLR can generate large areas of potential for landscape restoration activities.
- Within these areas, ROOT can help to further refine priorities based on the restoration and provision of ecosystem services for selected beneficiaries.
- 21,889 ha of forest restoration could have ecosystem and livelihood impacts across 3.8 million ha of watersheds in Myanmar

Region	Area of 100% Optimal Watersheds (ha)
Mandalay Region	45,206
Naypyitaw	4,932
Ayeyarwady Region	119,180
Bago Region (East)	180,003
Bago Region (West)	86,303
Chin State	627,135
Kachin State	30,412
Kayah State	43,562
Kayin State	201,374
Magway Region	958,374
Mon State	8,219
Rakhine State	200,552
Sagaing Region	563,024
Shan State (East)	27,124
Shan State (North)	259,731
Shan State (South)	253,977
Tanintharyi Region	162,743
Yangon Region	33,699
Total Potential Area "Under Restoration"	**3,805,549**
FLR "opportunity" hectares within 100% optimal watersheds	**21,889**

What are the implications of ROOT?

- Provides decision makers and stakeholders with information on where to implement programs and restoration actions to achieve the highest positive impact on the provision of ecosystem services

- Allows for the identification of smaller areas that should be prioritized to start program implementation based on maximized benefits for multiple objectives. ROOT can provide decision-makers with the best places to start restoration activities.

- Can identify priority areas within opportunities assessments, illustrating the importance of including beneficiaries to assure restoration actions are implemented where benefits are maximized.

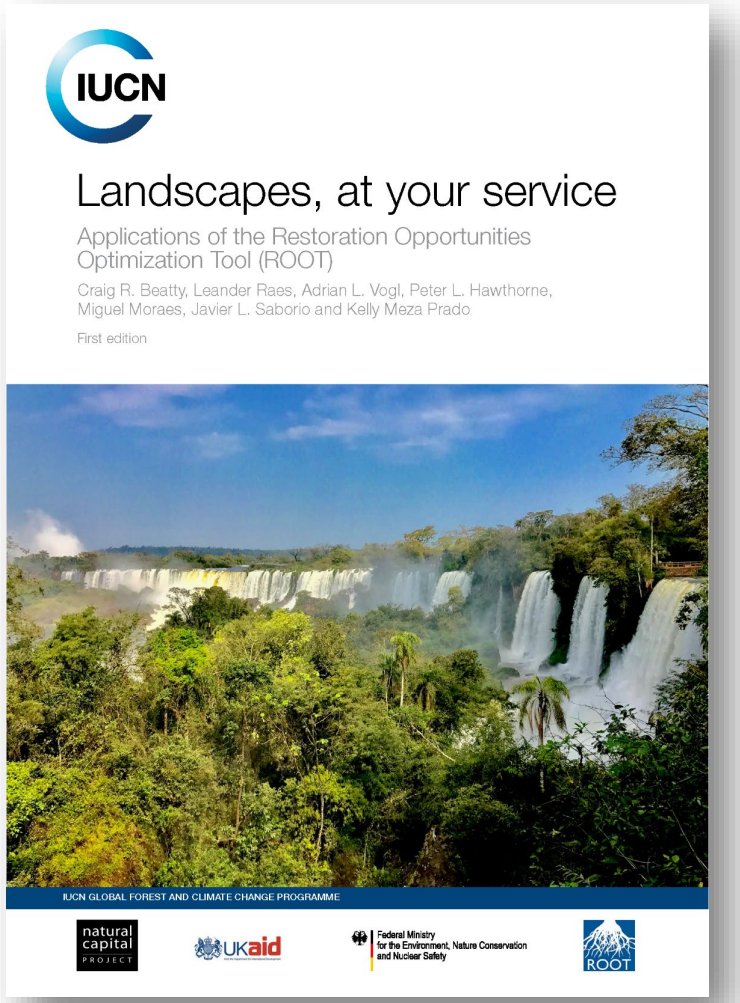
- Creates social support for the implementation of restoration actions, and it may facilitate increased funding for restoration actions, for example when they decrease production costs for the production of hydroelectricity.

ROOT Limitations

- ROOT is very new, and may still have small software bugs – ongoing support from The Natural Capital Project community is key
- ROOT requires previous ecosystem services analysis and restoration scenarios
- Large datasets can be computationally difficult – hence decision units
- Validation that restoration has produced optimal ecosystem service benefits will require coordination and long-term monitoring
- Specific attribution of FLR to improving combined social and biophysical landscape features may be difficult
- Landscape decisions are often (always) political decisions and optimization models may not gain traction in lieu of more traditional decision pathways

Summary

The Need:	ROOT provides decision-makers with a tool to optimize restoration decisions for concurrent social and ecosystem service objectives.
How ROOT works:	Using an integrated linear optimization algorithm, ROOT goes beyond prioritization and helps optimize landscape decisions, hopefully leading to better restoration outcomes.
Results:	ROOT provides clearly communicable results in maps and can distil many livelihood or ecosystem service objectives into clear suggestions.
Implications of Results:	ROOT will lead to better decision-making and better ecosystem service and livelihood results from forest landscape restoration investments.



Beatty, C.R., Raes, L., Vogl, A.L., Hawthorne, P.L., Moraes, M., Saborio, J.L. and Meza Prado, K. (2018). *Landscapes, at your service: Applications of the Restoration Opportunities Optimization Tool (ROOT)*. Gland, Switzerland: IUCN, vi + 74pp. https://doi.org/10.2305/IUCN.CH.2018.17.en

Download ROOT and user guide here: www.naturalcapitalproject.org/ROOT

For questions or support email me Craig.Beatty@iucn.org or Peter Hawthorne hawt0010@umn.edu

Attend Remediation to Restoration session (62) on Thursday at 10:45am in Grand Ballroom Salon H. Leander Raes, author of the ROOT case study from Costa Rica, will speak in more detail about how ecosystem services support landscape restoration policies.

IUCN United for life and livelihoods

Special Thanks to Ukaid, without whom ROOT would not exist and The Natural Capital Project
In particular: Peter Hawthorne, Jesse Gourevitch, Bonnie Keeler, Adrian Vogl, Michael Verdone, Kelly Meza Prado, Orli Handmaker, Leander Reas, Mirjam Kuzee, Chetan Kumar, Marcelo Matsumoto, Miguel Moraes, Miguel Calmon, and Carole Saint-Laurent.


IUCN
United for
life and
livelihoods

Vision and mission

Our vision

A just world that values and conserves nature

Our mission

Influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable

IUCN Members include:

- States and government agencies
- Non-governmental organisations
- Indigenous Peoples' organisations

IUCN Commissions:

SSC Species Survival Commission

CEC Commission on Education and Communication

World Commission on Environmental Law

CEESP

WCPA World Commission on Protected Areas

CEM

Key IUCN Knowledge Products:

RED LIST Guiding Conservation for 50 Years

WDPA

KBA Key Biodiversity Areas

IBAT

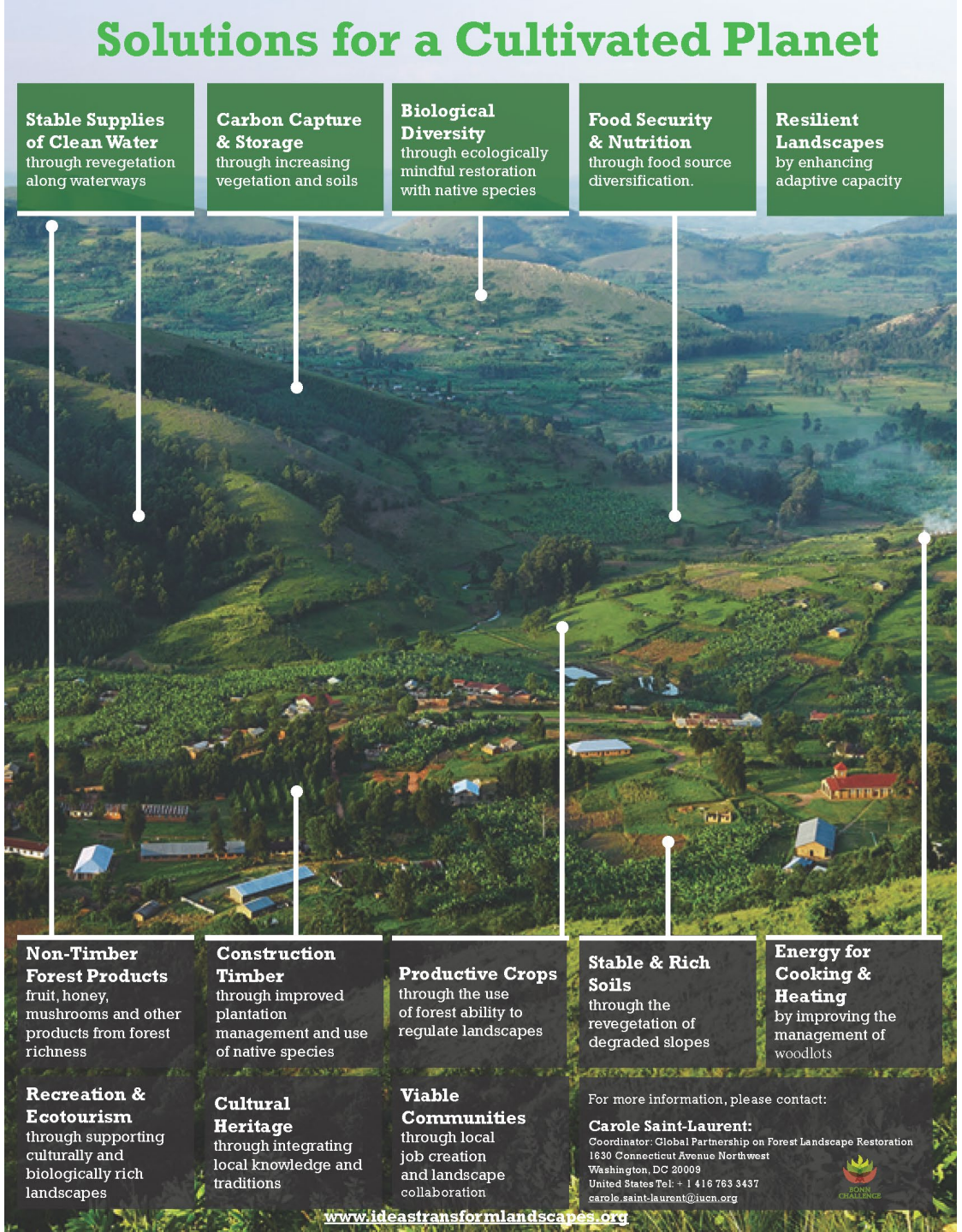
Green List Protected | Conserved Areas

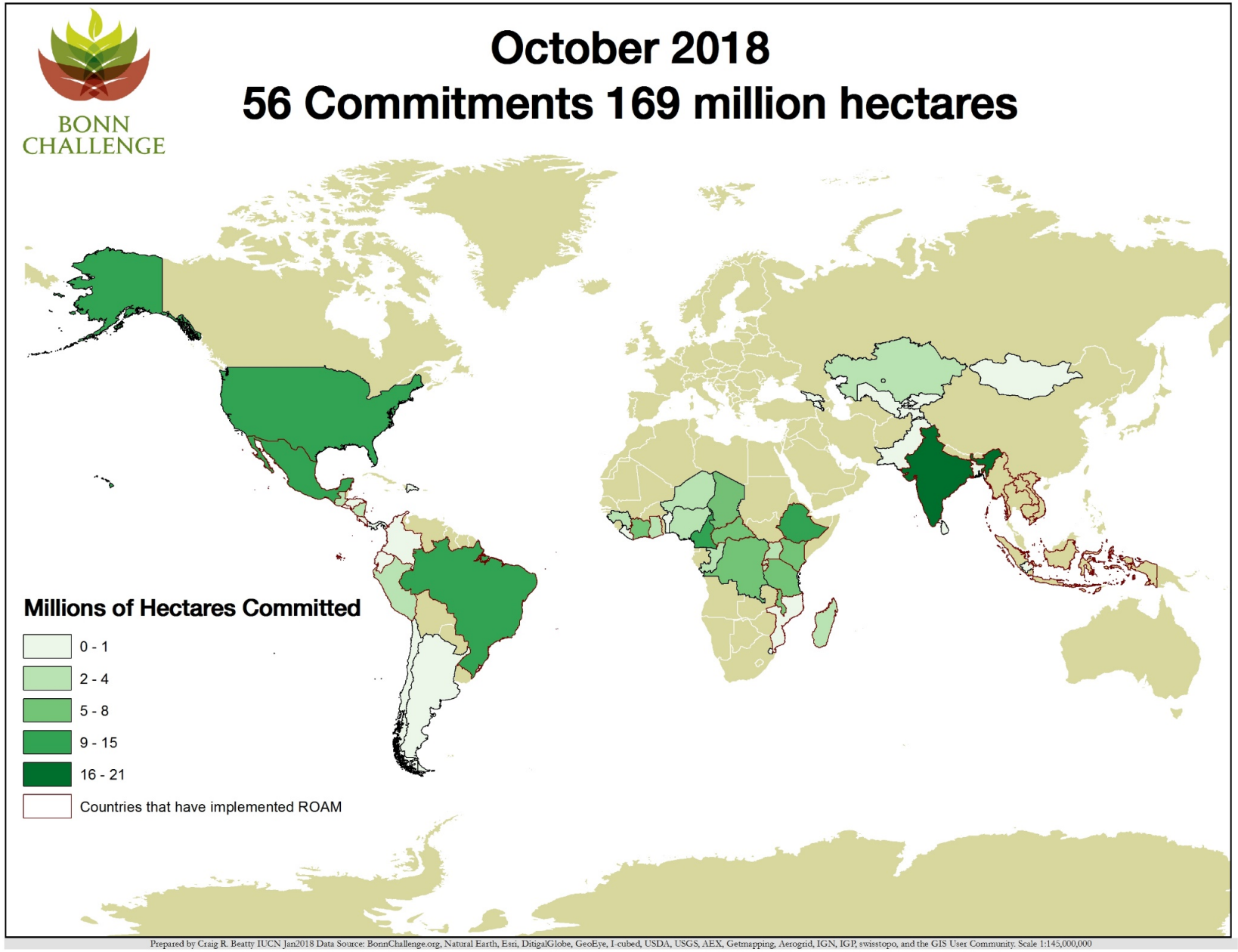
IUCN CEM IUCN Red List of Ecosystems

ECOLEX

What is “Forest Landscape Restoration”?

- Ecological integrity + human well-being
- Restoring ”forward” to meet current and future uses:
  - Thinking long-term over large areas
  - Learning and adapting
- Restoring multiple functions and productivity, not ”original” forest
- Balancing local needs with national and global priorities
- Using a package of diverse restoration strategies





BONN CHALLENGE

A global goal to bring **150 million hectares** of degraded and deforested lands into restoration by 2020 and **350 million hectares** by 2030.

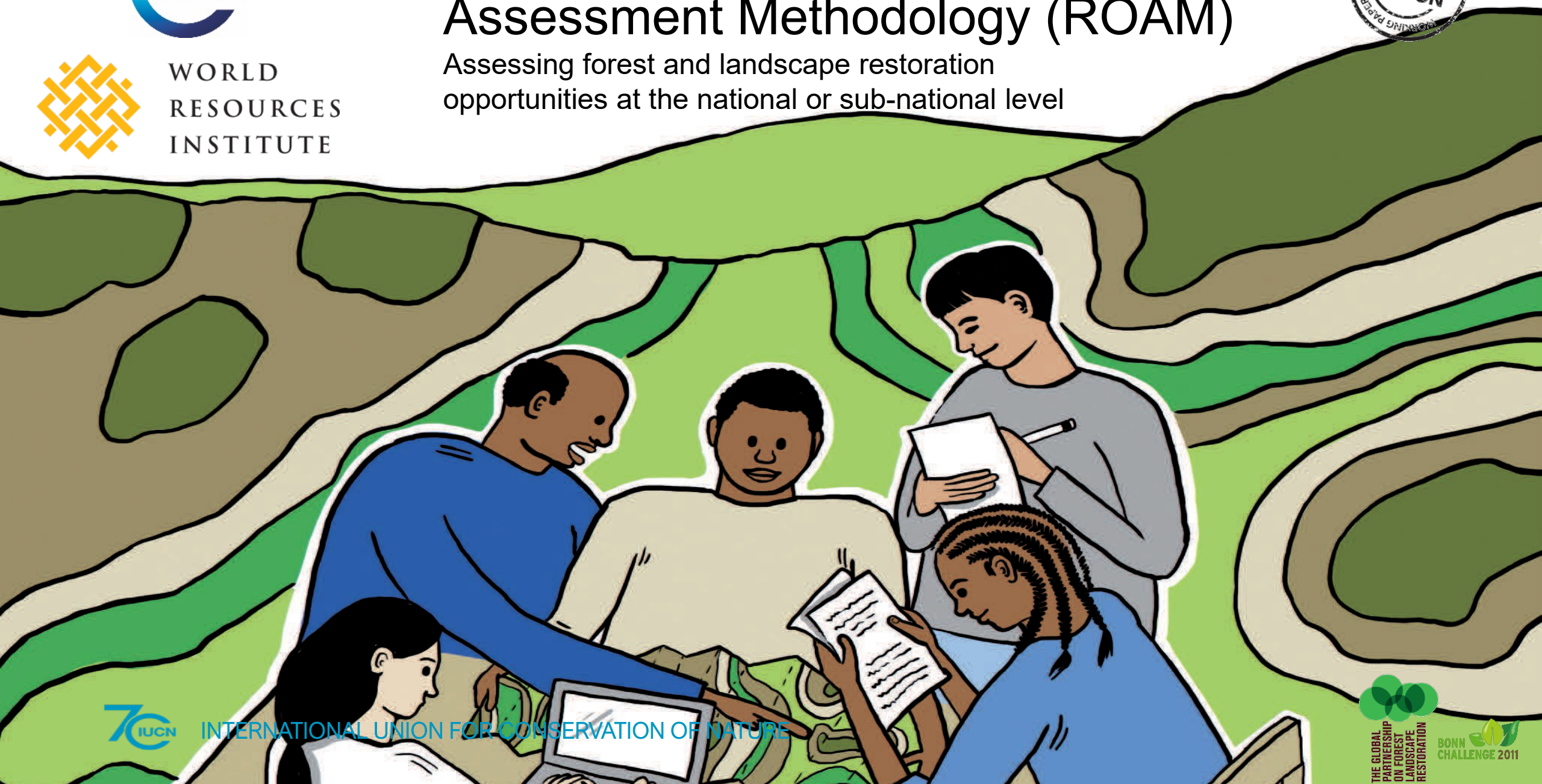
IUCN

WORLD RESOURCES INSTITUTE

A guide to the Restoration Opportunities Assessment Methodology (ROAM)

WORKING PAPER ROAD-TEST EDITION

Assessing forest and landscape restoration opportunities at the national or sub-national level



INTERNATIONAL UNION FOR CONSERVATION OF NATURE

THE GLOBAL PARTNERSHIP ON FOREST LANDSCAPE RESTORATION

BONN CHALLENGE 2011

Key components of ROAM

Scoping drivers of degradation and objectives of FLR

Stakeholder mapping

Stocktaking of past successes and challenges

FLR opportunities, priorities and transitions identified

Economics, ecosystem services, and finance analysis

Social/Cultural aspects of FLR

Data collection and spatial analysis

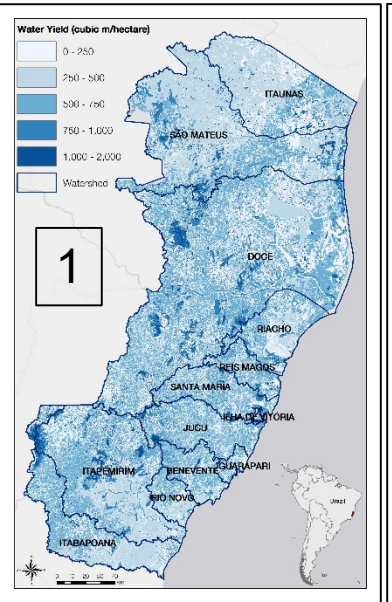
Development of FLR action plan and finance strategy

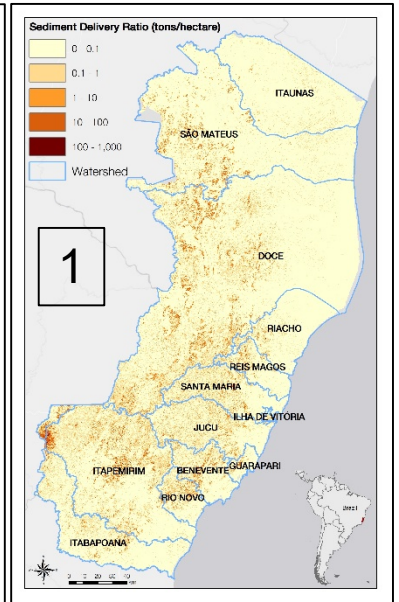
Stakeholder ownership and validation

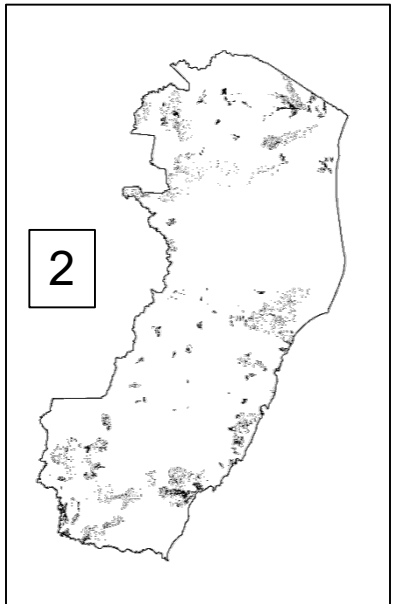
How does ROOT work?

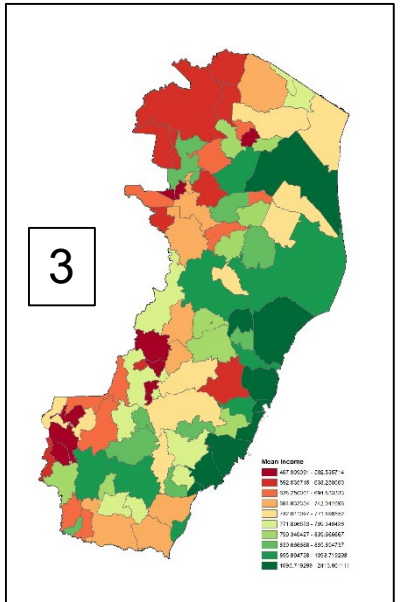
ROOT prerequisites:

1. Spatial data on ecosystem services
2. An area of restoration opportunities
3. Spatial data on who or what you'd like restoration to benefit
4. Some actual or projected geographic or monetary constraints
5. An interest in optimization or trade-offs and a GIS analyst









4

BONN CHALLENGE

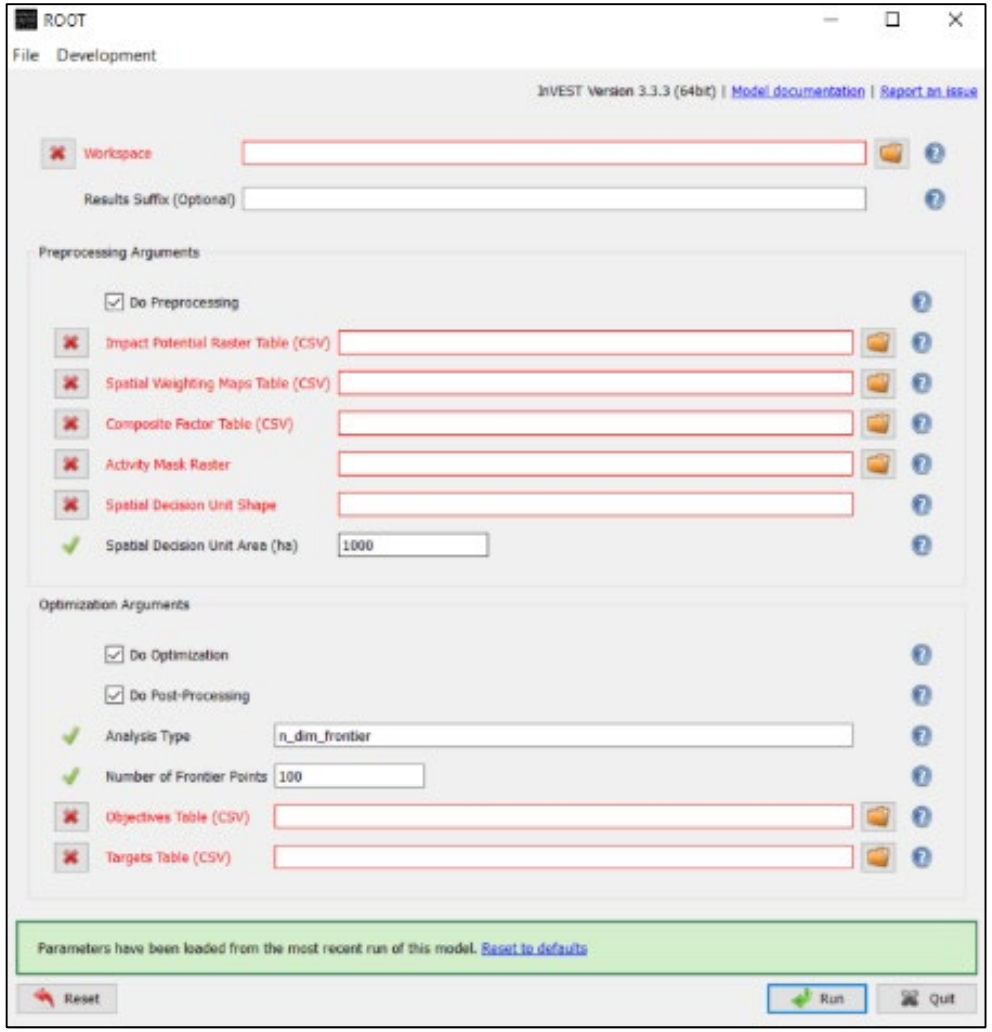
5

How does ROOT work?

Technically: ROOT applies an integrated linear programming algorithm which optimises and displays the location of the expected ecosystem services generated through restoration.

ROOT requires six main inputs

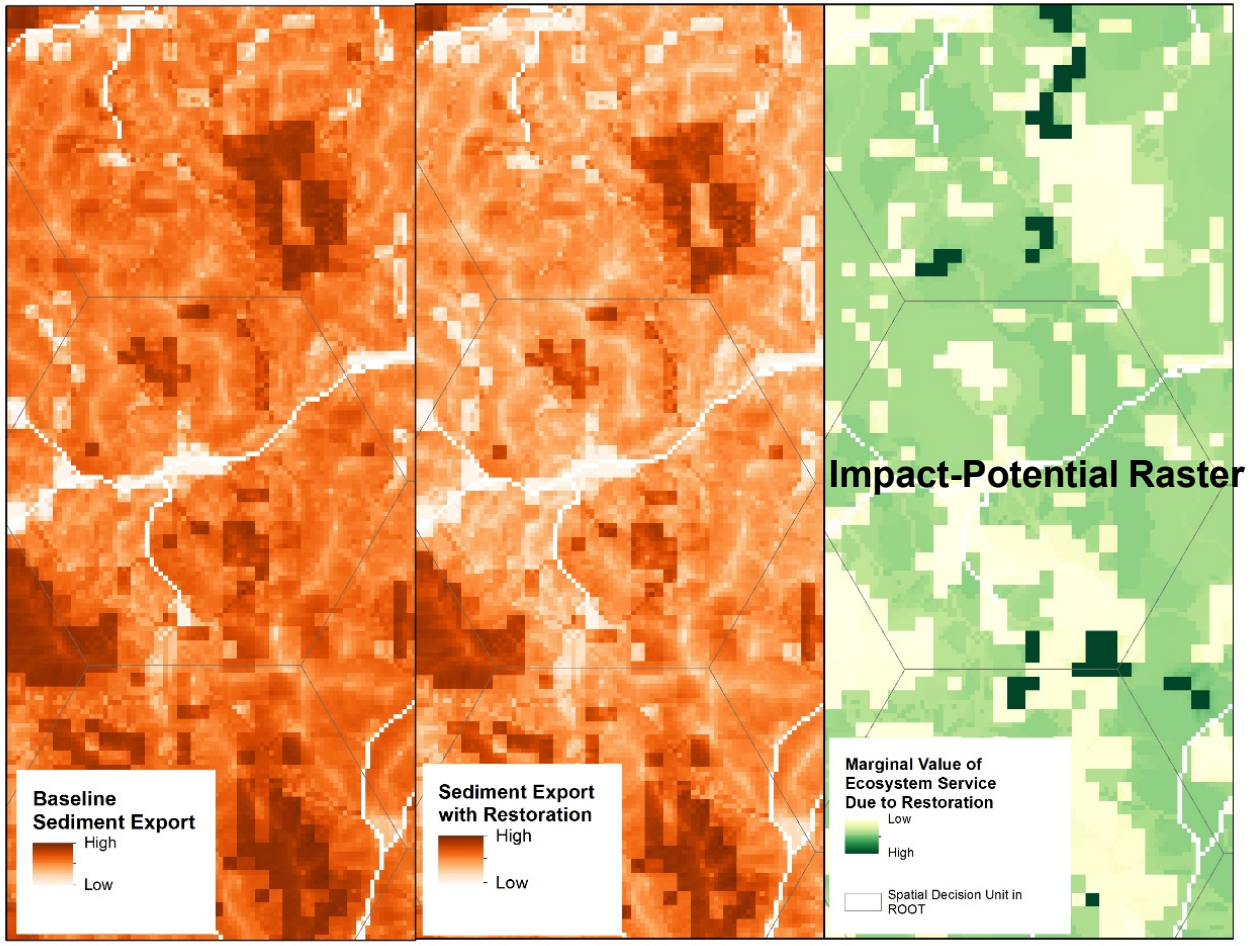
1) Impact Potential Map(s) with Marginal Values
2) Activity Area Map
3) Serviceshed(s) for beneficiaries
4) Composite Factors
5) Ecosystem Service Objectives
6) Area Targets or Constraints



Ecosystem Services Impact-Potential Rasters

A restoration scenario based on the outputs of a restoration opportunities assessment is applied within an ecosystem service modeling tool, such as the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), to determine the potential impacts of restoration on ecosystem services.

These **Marginal Values** indicate the increase or decrease in ecosystem services that can be expected based on proposed restoration interventions including land use changes (e.g. ecosystem restoration) and/or management actions within existing land uses (e.g. woodlot management).



Baseline		
15	4	15
34	25	6
10	11	1

Restored		
13	2	14
31	41	9
6	11	1

[Restored – Baseline]		
2	2	1
3	5	0
4	3	0

Marginal Values

Area Targets or Constraints

Espirito Santo State Brazil: 120,000 ha of restoration opportunity identified (in black); 80,000 ha Bonn Challenge Commitment used as optimization constraint

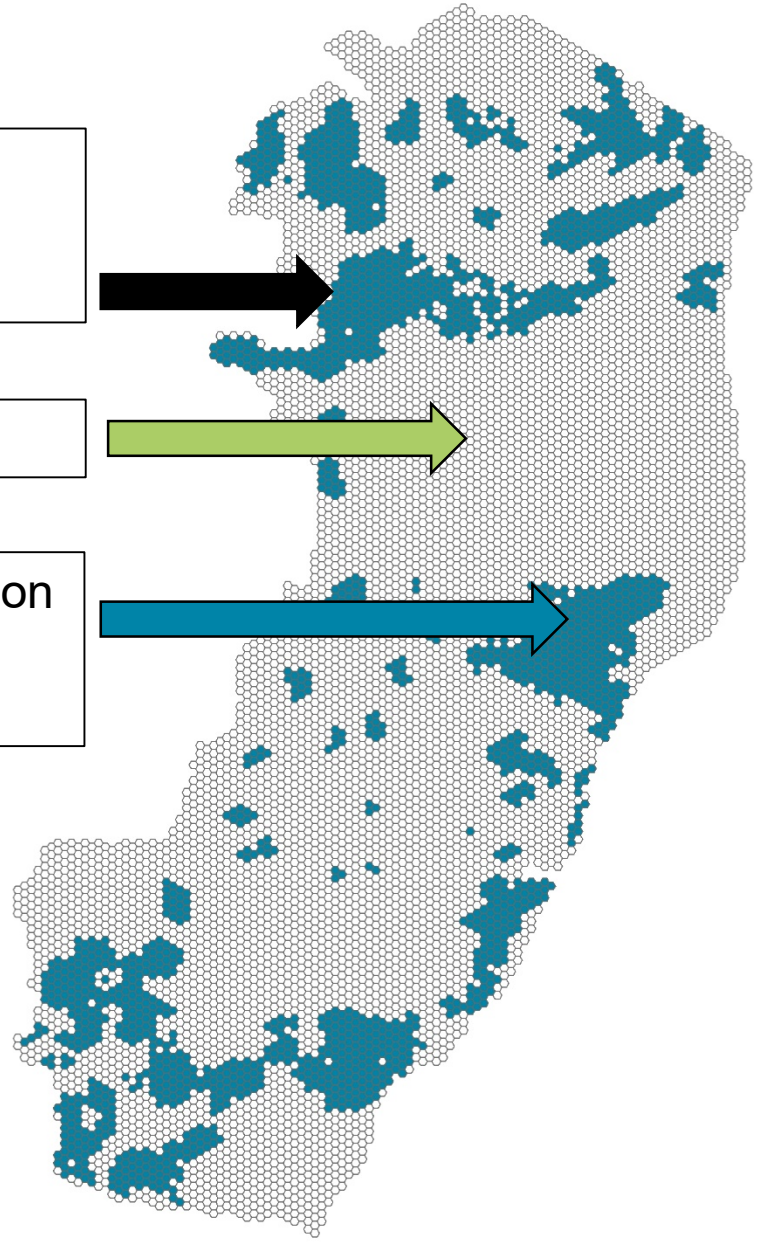
BONN CHALLENGE

Activity Area

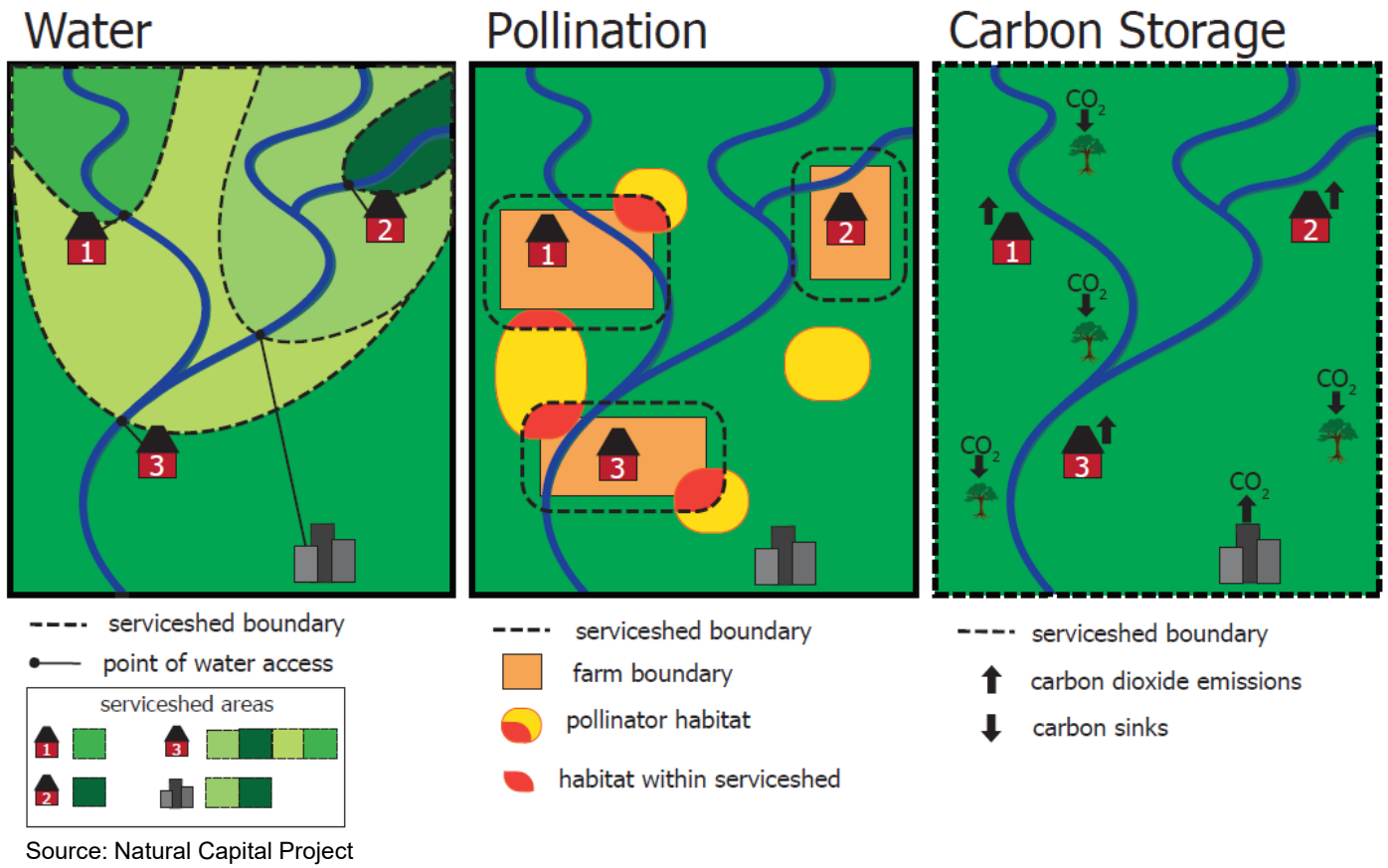
Priority areas identified (e.g. through Restoration Opportunities Assessment Methodology (ROAM))

Spatial Decision Unit Size Defined (hectares)

Spatial Decision Units Selected for inclusion in optimization based on overlaps with “Activity Area”

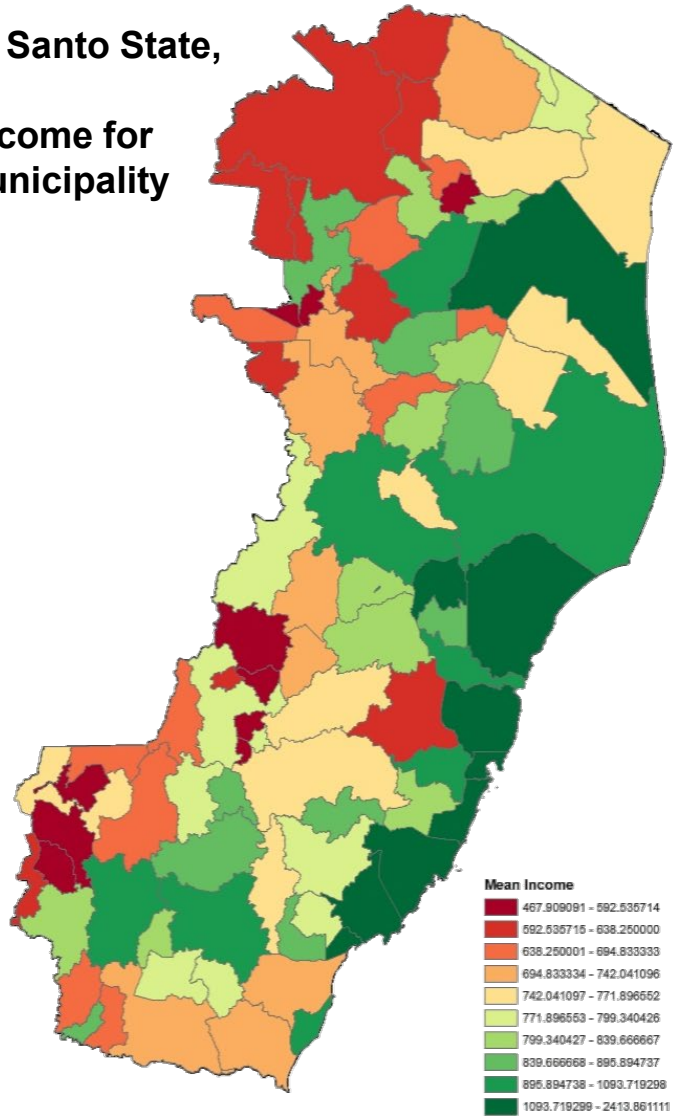


Identifying Servicesheds for Beneficiaries of Interest



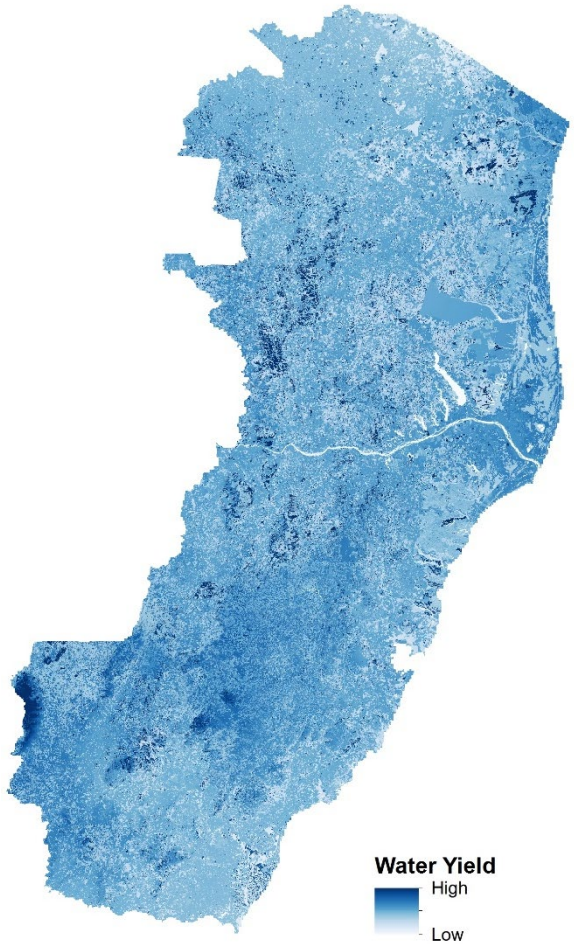
Source: Natural Capital Project

Espirito Santo State, Brazil: Mean income for each municipality



Ecosystem Service Objectives

Minimize or Maximize?



Ecosystem Service Objectives

Minimize or Maximize?

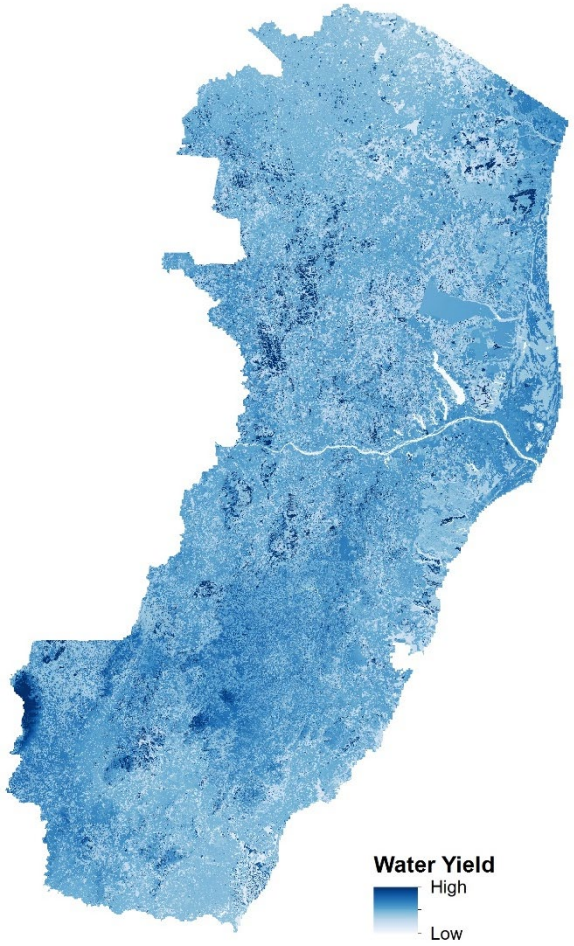
Probably Maximize sediment retention in most cases

Ecosystem Service Objectives

Minimize or Maximize?

Probably
Minimize
sediment export
in most cases

Ecosystem Service Objectives

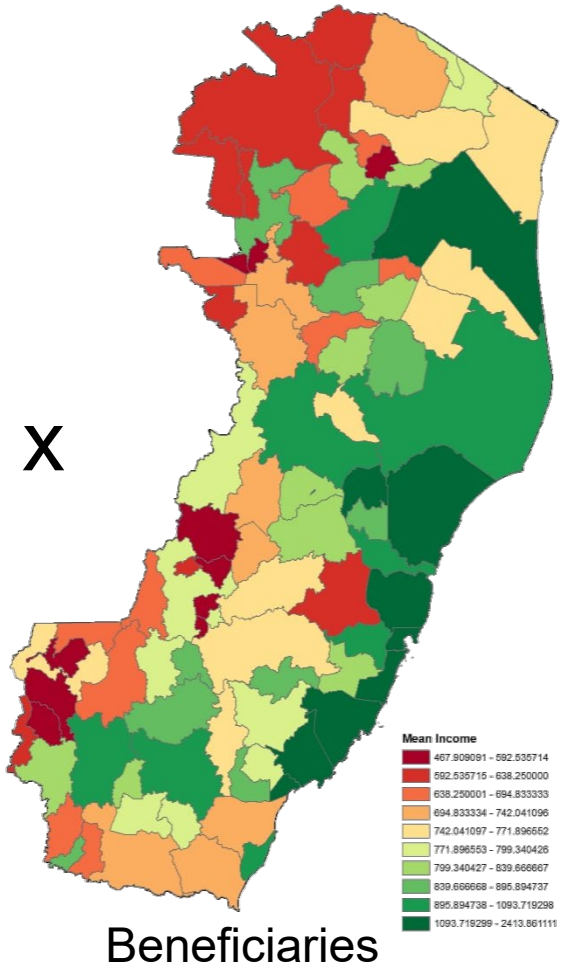


Consult objectives. Water yield shows the volume of water that flows out of a pixel. In this case one of the objectives was ground-water recharge, so in this case we wanted to minimize water yield.

Ecosystem Service Objectives and Composite Factors

Marginal Values

x



Beneficiaries

=

Composite Factor = [Sediment Retention * Income]

Sediment Retention		
-3	-3	-6
-7	-1	-1
-4	-3	0

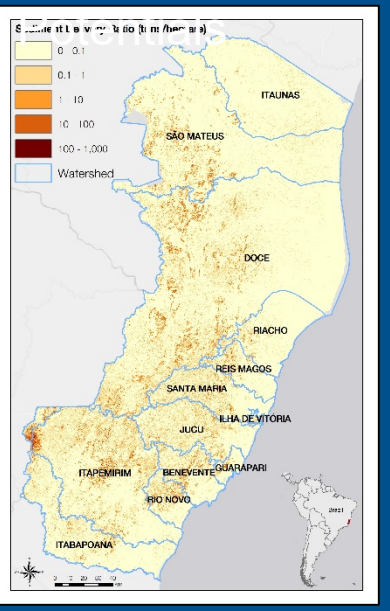
Serviceshed Weight: Income Average		
-5	-7	-1
-7	-1	-6
-5	0	0

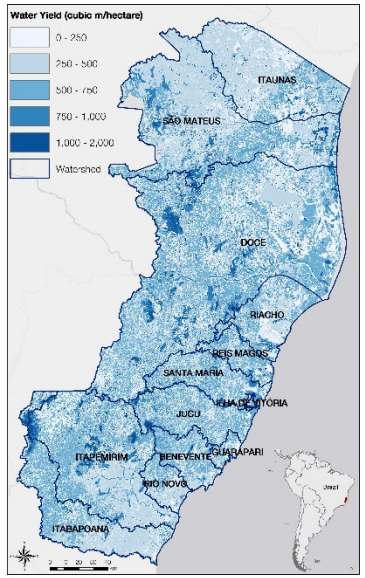
Composite Factor 2		
15	21	6
49	1	6
20	0	0

sed_ret_Income	min	(-)sed ret*(-)income = (+ values) Higher negatives in SDR mean less retention. Higher negatives in income mean richer people. Therefore, more positive values mean lower SDR and richer people.

What are the outputs of ROOT?

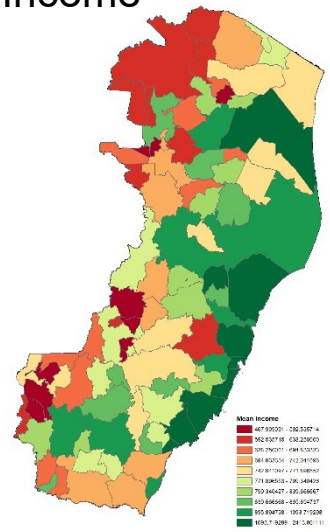
Impact



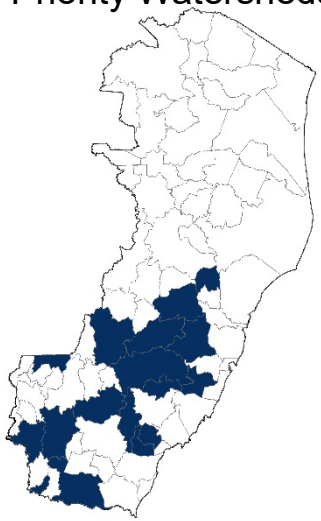


Beneficiaries

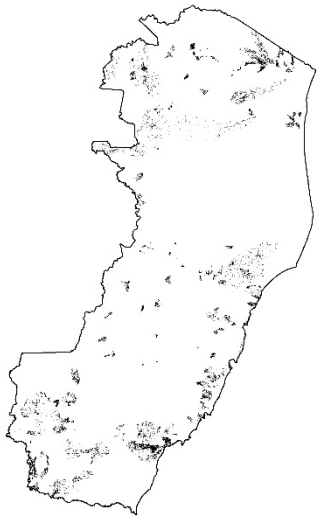
Income



Priority Watersheds



Activity Area

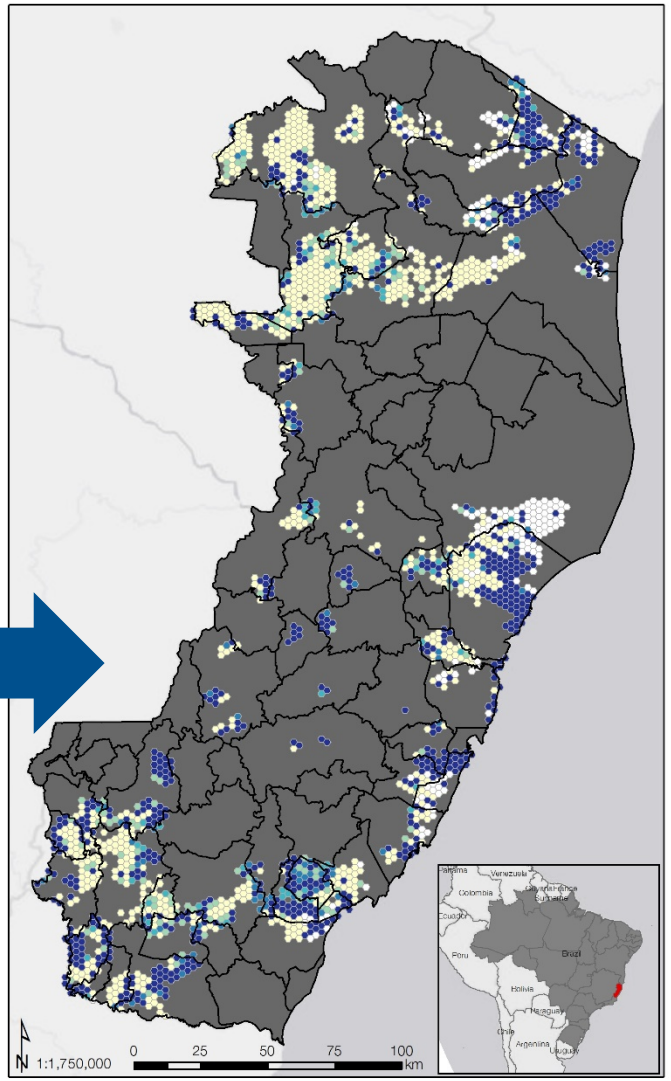


Targets

BONN CHALLENGE

80,000 Hectare Commitment

ROOT



IUCN natural capital PROJECT

Restoration Opportunity Optimization of Ecosystem Services for Landscape Restoration

ESPIRITO SANTO STATE BRAZIL

Ecosystem Services:
Sediment Retention
Water Yield

Beneficiaries:
Priority Watersheds
Low Income

This map shows where investments in restoration could be made where the gains in multiple ecoysystem services would be optimized throughout 80,000 hectares of potential opportunity area in Espirito Santo State, Brazil. These opportunity areas were identified as a part of the statewide forest landscape restoration assessment using the Restoration Opportunities Assessment Methodology (ROAM)(IUCN and WRI, 2014) and meet Espirito Santo's commitment to the Bonn Challenge.

Areas identified in dark blue indicate a high agreement among 50 unique iterations of the optimization model. They indicate that restoration in these areas will have optimal benefits for achieving benefits in both sediment retention and water yield while also considering the optimal locations for restoration where these services may postively impact priority watersheds and in municipalities where incomes are lowest. Hexagons are 1000 hectares large.

UKaid from the Department for International Development

Prepared by Craig R. Beatty, International Union for Conservation of Nature (IUCN) August 2017. Data Provided by State of Espirito Santo, World Resource Institue Brazil, and IUCN Brazil. Model prepared using the Restoration Opportunity Optimization Tool (ROOT) co-developed by IUCN and University of Minnesota Natural Capital Project. Projection: WGS 1984 UTM 24S.

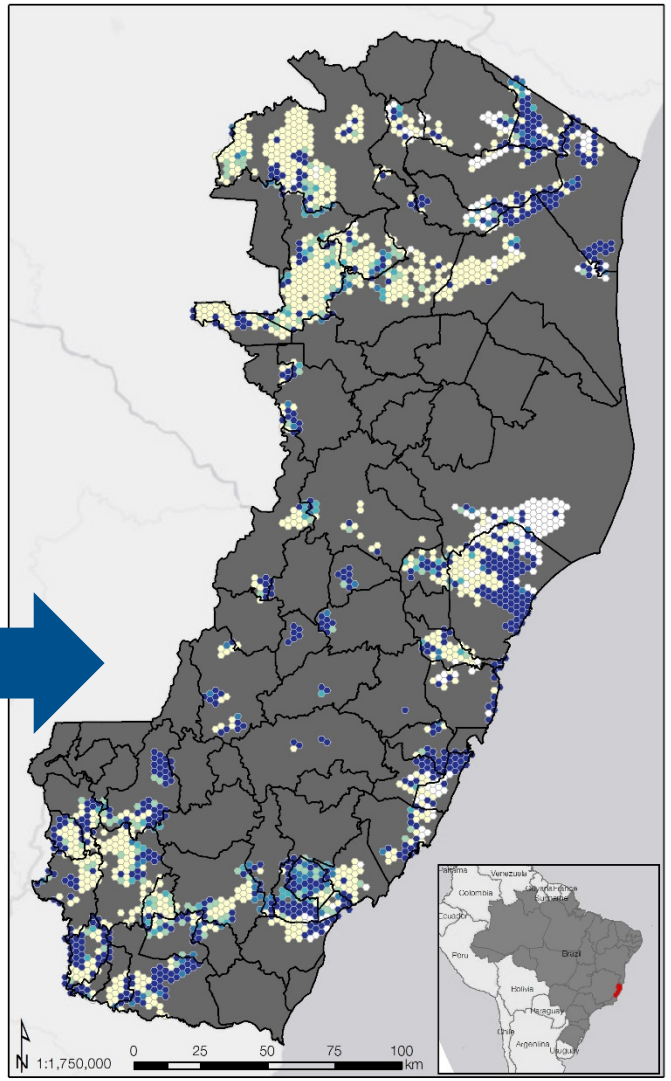
What are the outputs of ROOT?

ROOT results demonstrate where the optimal locations are to increase multiple ecosystem services, especially in areas where identified beneficiaries can receive the benefits of these increases in ecosystem services.

This map shows the aggregated results of 50 individual iterations of ROOT where the beneficiaries' weights have been randomly generated within the range of values to add confidence to the optimization.

Areas in dark blue indicate that the area was selected as an optimal choice in 45-50 of the individual iterations of the model. This indicates a high agreement that these areas will, if restored, produce optimized increases in sediment retention and water yield and will do so most to benefit people within low income municipalities and priority watersheds.

ROOT



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