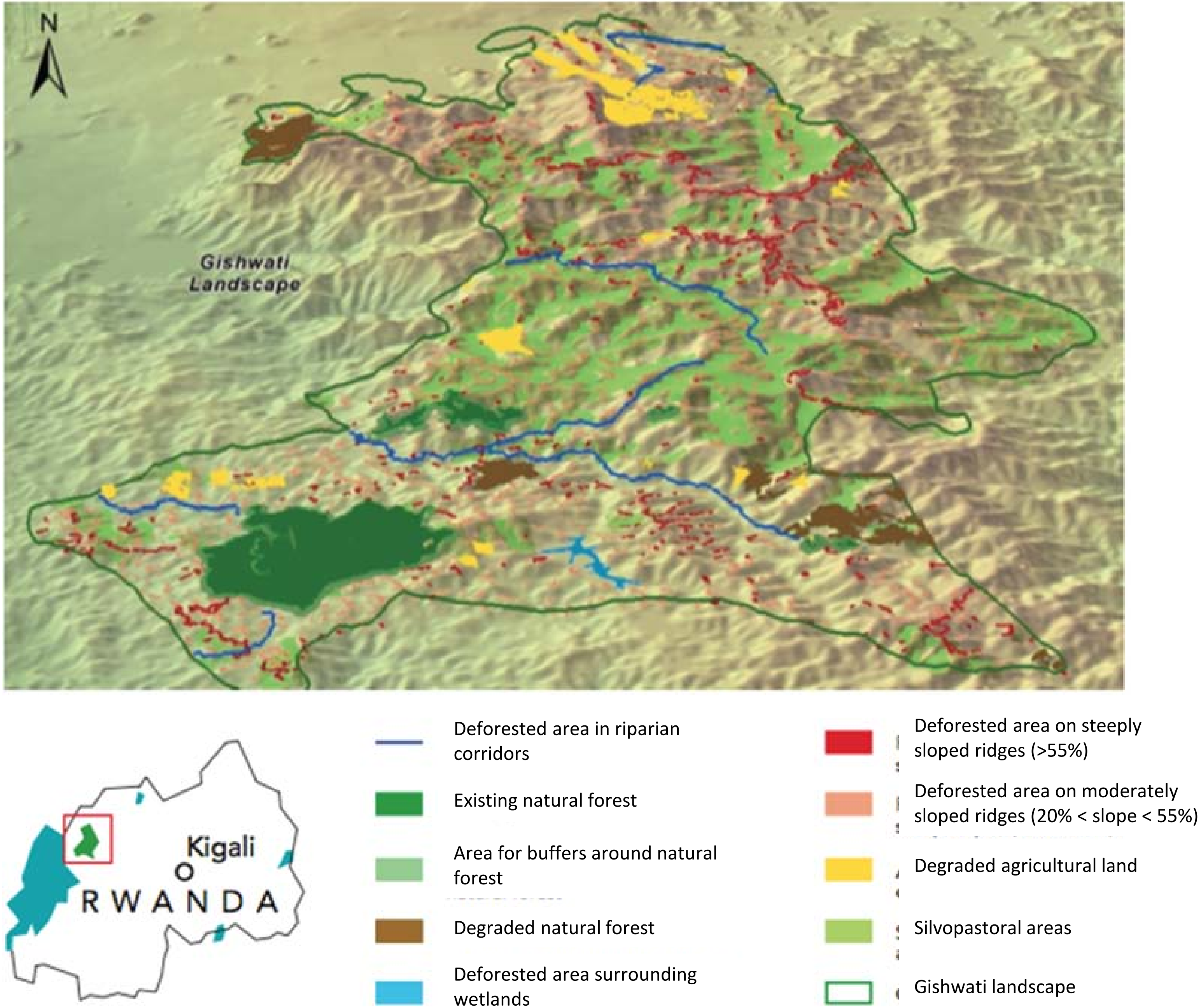
Restoration Economic Valuation & Restoration Carbon ACCRUAL

Assessing the net economic benefits and
carbon mitigation potential
of Forest Landscape Restoration

Restoration Economic Valuation

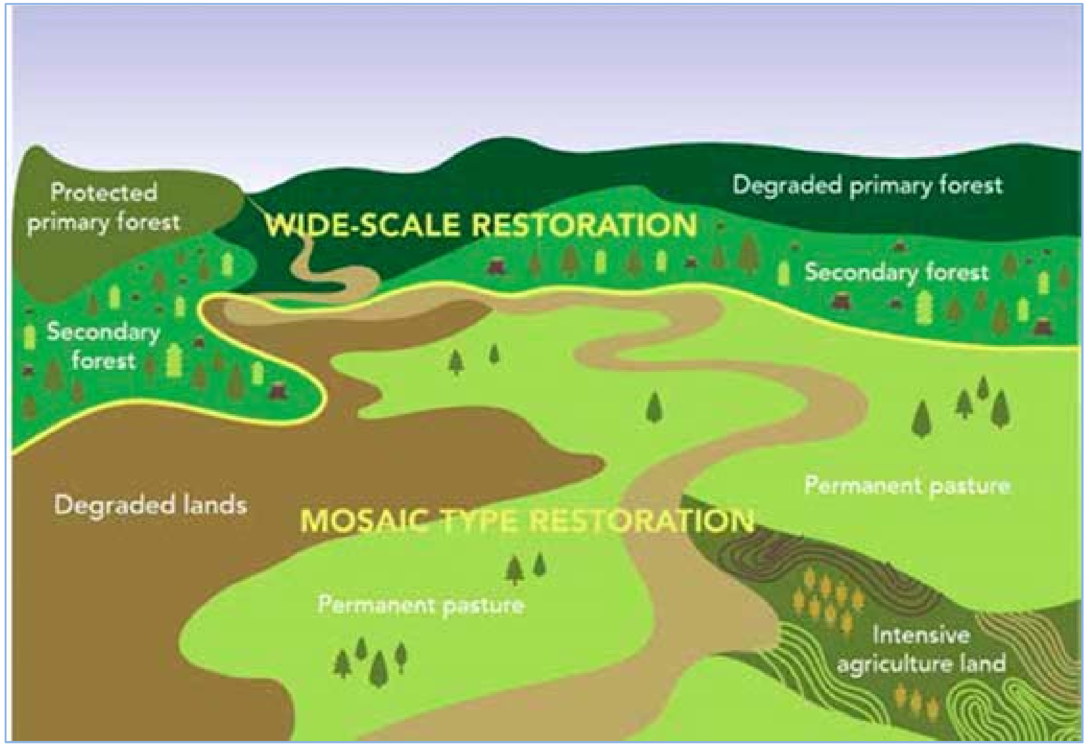
- This valuation tool lets you model the costs, revenue, and ecological benefits of restoration transitions
  - Costs = annual budget needed for management activities and inputs;
  - Revenue = monetary value generated by the sale of fuelwood, timber, crops, carbon;
  - Also considered: the amount of erosion associated with each land use / other values (like water supply);
- Final models are based on data representing a range of ecological outcomes reflecting real-world variation (derived from repeated random in-country sampling).

1. Conducting digital spatial analysis

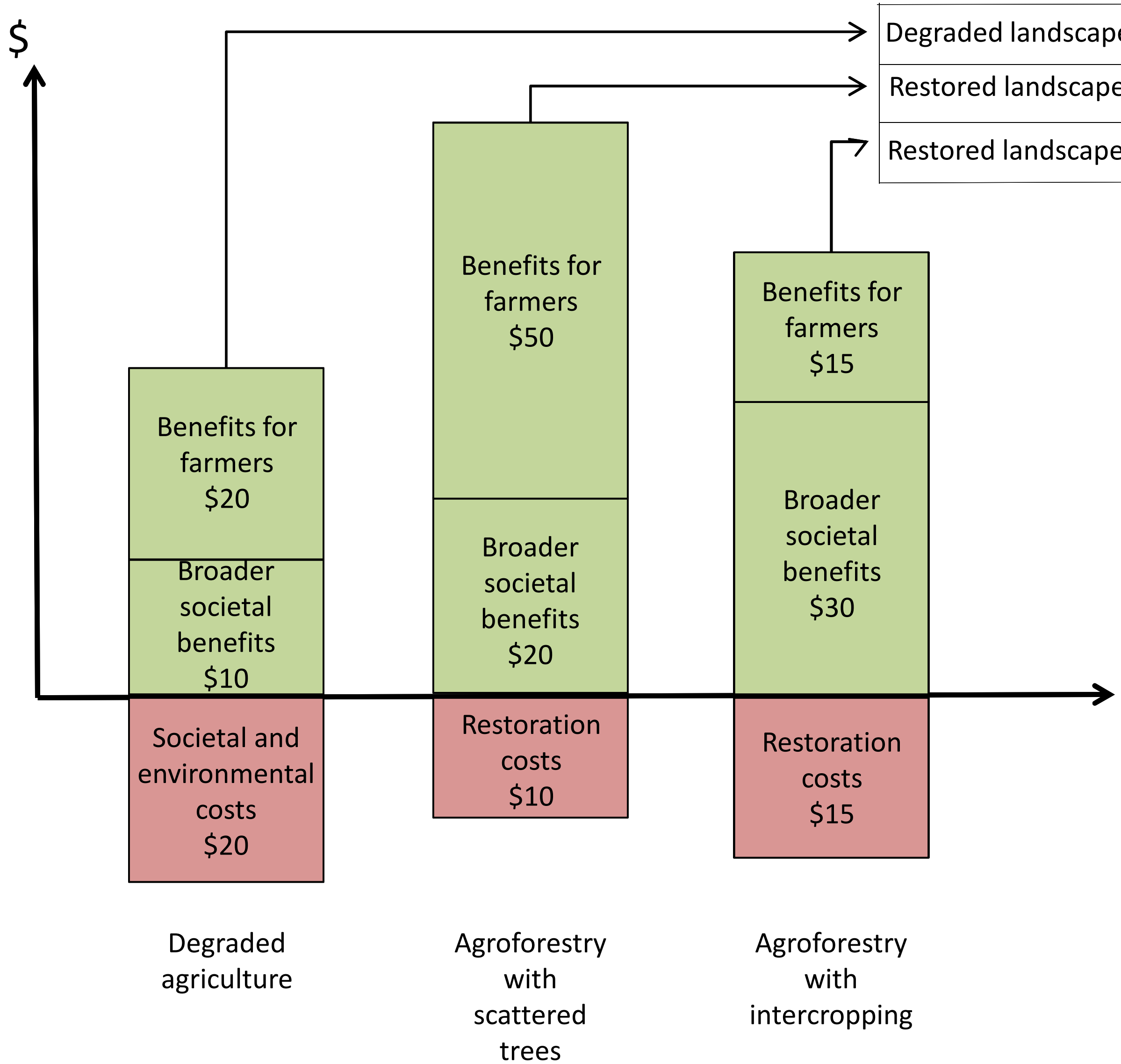


2. Considering Restoration Transitions

- We consider degraded land uses in the project area:
  - E.g., degraded agriculture, poorly managed woodlots and plantations, deforested land, etc.



3. Clarifying societal and individual costs and benefits of transitions



	Benefits - costs	Net benefit	Marginal benefit
Degraded landscape	\$30 - \$20	\$10	-
Restored landscape I	\$70 - \$10	\$60	\$50
Restored landscape II	\$45 - \$15	\$30	\$20

This involves modeling of many values

- Ecosystems services such as:
  - Timber produced
  - Carbon sequestered
  - Erosion controlled
  - Crop yields improved or sustained
  - Other context dependent services, like water supply (varies by country)

- Revenues and costs estimated with market data and budgeting approach
- With repeated random sampling accounting for uncertainty

Modeling timber value

- Each land use is assigned a stocking density (trees per hectare) and management actions are defined:
  - Rotation interval
  - Thinning schedule
  - Seedling survival
- Stocking density is multiplied by growth predictions for each species to estimate above-ground biomass

Species	Mean annual increment (Cubic meters)				
	Single tree	300 trees per hectare	1100 trees per hectare	1600 trees per hectare	Source
Gevillea robusta	0.0048 (0.002)	1.44 (0.6)			Kalinganire, 1996
Eucalyptus tereticornis	0.0065 (0.001)		7.15 (1.1)	10.4 (1.6)	Belgian Development Agency , 2012
Pinus petula	0.003 (0.0005)			4.8 (0.8)	Africa Forest Forum, 2011

Notes: Standard errors are in parenthesis. Grevillea robusta was only considered in an agroforestry context with a density of 300 trees per hectare. Pinus petula was only considered for planting densities of 1600 trees per hectare.

Timber Methodology

- To estimate the mean annual increment of timber growth for 1-hectare of agroforestry, woodlot, or protective forests we used data on the distribution of mean annual increments for:
- *Grevillea robusta, Eucalyptus tereticornis, Pinus petula*,
- Modeled timber and fuelwood production of agroforestry with *Grevillea robusta* as it is the most popular species grown on farms (Kalinganire, 1996).
- Eucalyptus species are the most commonly grown species on fuelwood plantations and on-farm woodlots
- *Pinus petula* is commonly grown in planted forests as well as the bigger zones surrounding indigenous forest reserves (Ndayambaje & Mohren , 2011).

Modeling carbon

- IPCC Tier 1 methodology is used to estimate carbon sequestration considering carbon stocks in:
  - Above ground biomass
  - Below ground biomass
- Carbon sequestration is calculated as follows:

Above ground biomassi(ABG)=M3*BCEFsi [1]

Below-ground biomass (RBDM) =e(-1.805+0.9256*ln(AGBi)) [2]

C(tonnes)=[AGB+RBDM]*0.49 [3]

0.49 is the conversation factor for tons of dry matter to carbon (IPCC, 2003)

Modeling erosion

We model erosion benefits by estimating reduced erosion

- Using the Universal Soil Loss Equation (USLE):
- Erosion = R*K*LS*C
- R = Rainfall intensity, K = Soil erodibility factor, LS = plot length and slope , P= Management factor

Land Use	Universal Soil Loss Equation Variable				Average annual erosion (t/ha)
	R	K	LS	C	
AG	332	0.12	1.5	0.3	17.928
AF	332	0.12	1.5	0.1	5.98
PME	431	0.15	1.5	0.15	14.55
IME	431	0.15	1.5	0.1	9.70
DF	428	0.16	1.5	0.1	10.27
NR	428	0.16	1.5	0.01	1.03
PF	428	0.16	1.5	0.01	1.03

Modeling crop yields

- We use data on baseline crop production

Crop yield regression data means		
Variable	**Maize**	**Beans**
Average yield (t/ha)	3.63 (8.22)	0.91 (0.22)
Land area (ha's)	2,669 (1681)	590 (175)
Precipitation (mm)	591 (175)	590 (175)
Observations	115	114
Notes: Standard errors in parenthesis.		

- And estimate the crop increase/decrease of agroforestry using estimates from literature and data from our partners (e.g. ICRAF).

Estimating costs

- Model the costs of management actions and inputs
- Costs can include planting, monitoring, thinning, seeds, fertilizer, etc…

Annual Legume budget for Rwanda

ITEMS	UNIT	QUANTITY	UNIT PRICE	MONETARY VALUE (Frw)
PRODUCTION				
-Legume	Kg	1,080	93	100440
(1)Gross revenue				100440
Monetary variable input costs				
Hired labor	M.D	22	300	6600
(2) Total M.V.I.C				6600
Non-monet. variable input costs				
Seeds	Kg	40	93	3720
Organic fertilizer	Kg	3,000	2	6000
Household labor	M.D	199	240	47760
Capital cost				660
(3) Total N.V.I.C				58140
Fixed costs				
Small agr. equipment	-			1317
(4) Total F.C				1317
(5)Total variable input cost (2+3)				64740
(6)Total costs (2 + 3 + 4)				66057
(7)Gross Margin[Monetary] (1- 2)				93840
(8)Total Gross Margin (1 – 5)				35700
(9)Net Margin (1– 6)				34383
Returns to family labor per day[(a)]				413
Remuneration rate (8/5 * 100)				55%

Assessing economic impacts of restoration and building a carbon abatement curve

What does economics have to do with restoration?

- Globally, there are more than 2 billion hectares of degraded land.
- With this tremendous opportunity – where? when? and how? landscapes should be restored
- The answers to these questions must be formed on the basis of restoration's expected impacts on ecosystem goods and services.

How can economics help?

- An Return On Investment (ROI) framework is appropriate for serving the decision making processes at the country, regional, or local level.
- Framework assesses the ecosystem service and economic impacts of forest landscape restoration to help decision makers understand trade-offs.
- Carbon abatement curves show how much carbon each transition could capture and helps decision makers offset emissions by restoring landscapes as efficiently as possible.

Four steps in applying the ROI framework

1. *Identify degraded forest landscapes and their land uses:* Map landscapes in need of restoration as well as the characteristics of the landscapes.

2. *Identify restoration transitions:* Determine which restoration interventions could be used to restore each type of degraded land use.

3. *Model and value the change in ecosystem goods and service production for each restoration transition*: Calculate the net change in ecosystem goods and service production.

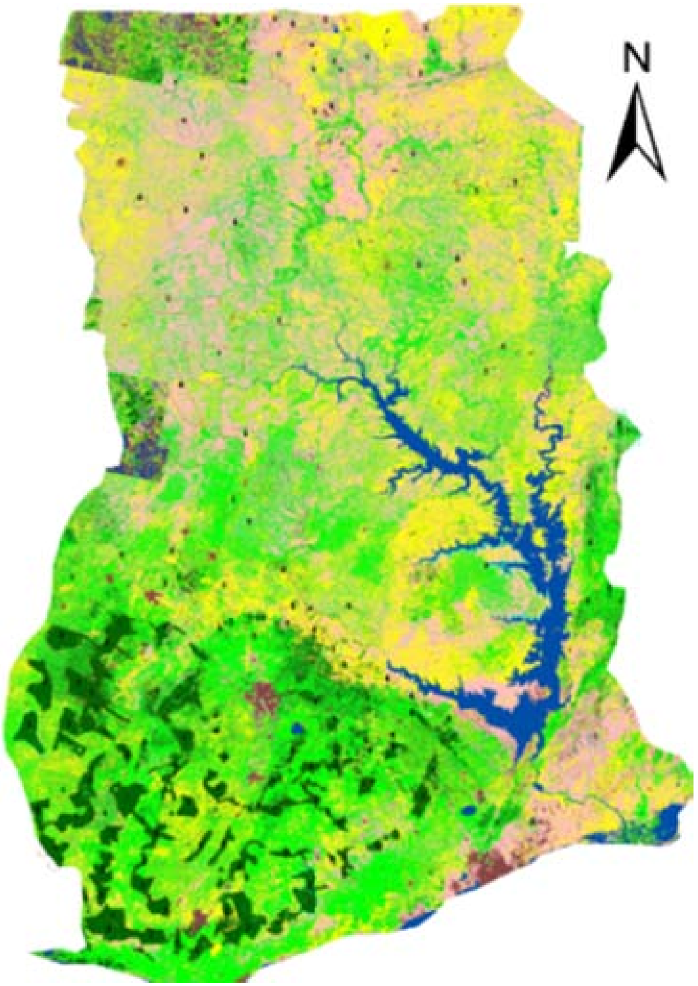
4. *Conduct sensitivity and uncertainty analysis:* See how sensitive the cost-benefit results are to changes in key variables like prices, interest rates, and biological assumptions.

Analysis Process

Step 1: Identify degraded forest landscapes and their land uses

- Map landscapes in need of restoration as well as the characteristics of the landscapes. Degraded landscapes should be characterized in terms of current land uses and land cover, weather, socio-economic conditions, and other contextual information.

Geospatial analysis



- Geospatial analysis used to quantify areas of degraded land use that are also opportunity areas for forest and landscape restoration.
- Analysis based on geospatial datasets including elevation, slope, land cover, forest cover, water bodies, parks and reserves, and administrative areas.
- Data put into a geographic information system (GIS), criteria associated with each type of potential restoration intervention are used to identify opportunity areas.

Step 1: Degraded land uses

1. Deforested land – Previously forested land where the forests have been cleared without being regrown.

2. Degraded natural forest – Forests that have lost the structure, function, species composition and/or productivity normally associated with the natural forest type at the site.

3. Degraded forest plantation – Forest plantations that are producing fewer ecosystem goods and services than they're capable of due to current management practices.

4. Degraded agriculture – Agricultural lands that are producing fewer ecosystem goods and services than they're capable of due to current management practices.

5. Poor farm fallow – Fallowed lands that do not incorporate woody biomass production into the fallow and are shorter than the recommended fallow length.

Step 2: Restoration interventions

1. Tree planting – Using tree planting to restore forest cover on deforested landscapes.

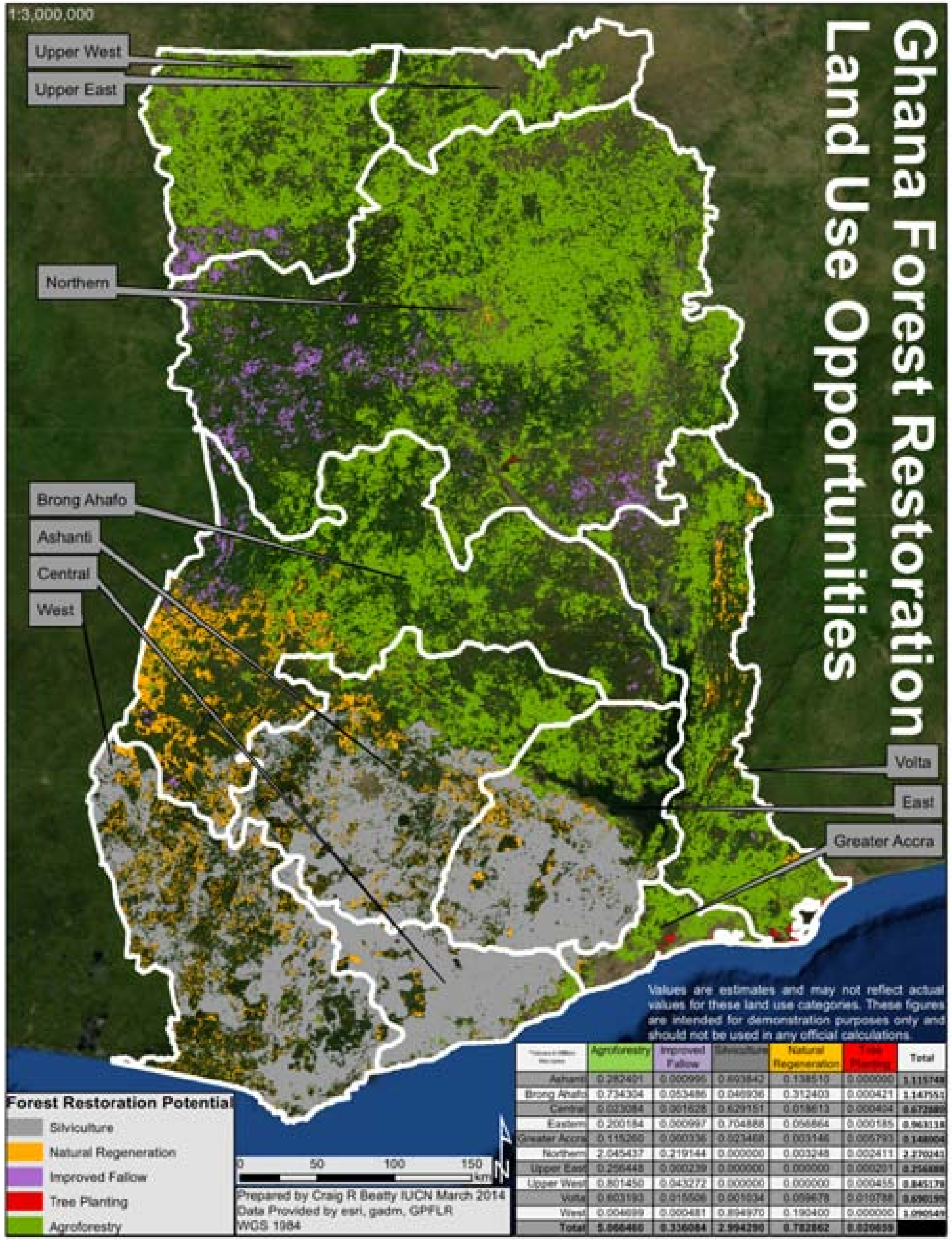
2. Natural regeneration – allowing forest cover in degraded forests to naturally restore itself by removing drivers of degradation.

3. Silviculture– Improving the management of plantations through changes in spacing, thinning, and harvesting regimes.

4. Agroforestry – Incorporating trees into agricultural landscapes to improve crop and timber yields, decrease erosion, and sequester carbon.

5. Improved farm fallow – Introduces leguminous trees into fallow systems to rapidly restore soil nutrient levels and provide a source of fuelwood and timber.

Geospatial analysis



Step 2: Identify restoration transitions

- Determine which restoration interventions could be used to restore each type of degraded land use. For example, degraded agricultural land could be restored with agroforestry and deforested land could be restored with natural regeneration of secondary forests.

Step 2: Restoration transitions

1. Deforested land to tree planting
2. Degraded natural forest to naturally regenerated forest
3. Degraded forest plantation to silviculture
4. Degraded agriculture to agroforestry
5. Poor farm fallow to improved farm fallow

Step 3: Value change in ecosystem services

- The quantity of ecosystem services and their value can be estimated using a number of methods depending on how available biological and market data are.

- In data rich situations more accurate and advanced methods can be used, such as biological production functions.

- In data poor situations benefit-transfer techniques can be used to construct look-up tables of land-use values.

- Here we use a look-up table approach using stylized data.

Step 3: Value change in ecosystem services

- Our goal: estimate economic returns of each restoration transition and identify areas where restoration would have a large, positive impact.
- To do this: compare the value of ecosystem services gained through restoration with the costs of restoration.
- Columns [1a-1c; 2a-2c] in the look-up table are the physical units of ecosystem goods and service that can be measured in the field.
- Columns [1d-1h; 2d-2h] are the values of the ecosystem goods and services, which may be estimated from the information in [1a-1c; 2a-2c] or filled in from estimates in the peer-reviewed literature.
- Column [1i; 2i] is cost of operating each land use.

Step 3: Value change in ecosystem services – calculate ROI with the Look-up Table and ROI Worksheet

Restoration Opportunity Assessment Look-up Table											
	Ecosystem goods and services			Monetized benefit estimates							
Land uses	Timber (M3/ha)	Carbon (tons/ha)	Crop Production (tonnes)	Timber revenue	Carbon revenue	Crop revenue	Value of erosion prevention	NTFPs value	Cost/ha	NPV
Degraded land uses	[1a]	[1b]	[1c]	[1d]	[1e]	[1f]	[1g]	[1h]	[1i]	
1. Deforested land	0	0	0	$0	$0	$0	$0	$0	$50	-$50
2. Degraded natural forest	200	100	0	$0	$2,569	$0	$1,000	$1,000	$100	$4,469
3. Degraded forest plantation	180	90	0	$2,700	$2,312	$0	$750	$500	$4,000	$2,262
4. Degraded agriculture	0	0	18	$0	$0	$3,600	$500	$300	$5,000	-$600
5.Poor farm fallow	0	0	10	$0	$0	$2,000	$250	$200	$2,200	$250
Restoration interventions	[2a]	[2b]	[2c]	[2d]	[2e]	[2f]	[2g]	[2h]	[2i]	
1. Silviculture	300	150	0	$4,500	$3,854	$0	$1,500	$500	$7,000	$3,354
2. Natural regeneration to establish blocks of forest	400	200	0	$0	$5,138	$0	$2,000	$1,000	$1,000	$7,138
3. Improved plantation management	300	150	0	$4,500	$3,854	$0	$1,500	$500	$7,000	$3,354
4. Agroforestry	160	80	24	$2,400	$2,055	$4,800	$1,000	$300	$7,500	$3,055
5. Improved fallow	40	20	16	$600	$514	$3,200	$500	$200	$4,500	$514

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Restoration Opportunity Assessment Look-up Table										
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Land uses	Timber (M3/ha)	Carbon (tons/ha)	Crop Production (tonnes)	Timber revenue	Carbon revenue	Crop revenue	Value of erosion prevention	NTFPs value	Cost/ha	NPV
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	Timber (M3/ha)	Carbon (tons/ha)	Crop Production (tonnes)	Timber revenue	Carbon revenue	Crop revenue	Value of erosion prevention	NTFPs value	Cost/ha	NPV	ROI
Restoration transition	[2a-1a]	[2b-1b]	[2c-1c]	[2d-1d]	[2e-1e]	[2f-1f]	[2g-1g]	[2h-1h]	[2i-1i]	[(Rev -cost)/cost]	[(Rev - cost)/cost]
1. Deforested land to Tree planting	300	150	0	$4,500	$3,854	$0	$1,500	$500	$6,950	$3,404	0.49
2. Degraded natural forest to Naturally regenerated forests	200	100	0	$0	$2,569	$0	$1,000	$0	$900	$2,669	2.97
3. Degraded forest plantation to Silviculture	120	60	0	$1,800	$1,541	$0	$750	$0	$3,000	$1,091	0.36
4. Degraded agriculture to Agroforestry	160	80	6	$2,400	$2,055	$1,200	$500	$0	$2,500	$3,655	1.46
5.Poor farm fallow to Improved farm fallow	40	20	6	$600	$514	$1,200	$250	$0	$2,300	$264	0.11

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1 Michael Verdone, 3/14/2014

Restoration Opportunity Assessment ROI Table											
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Restoration Opportunity Assessment Geospatial Worksheet						
	Cost/ha	NPV	Area	Total cost	Total revenue	Landscape roi
Restoration transition	[1]	[2]	[3]	[1*3]	[2*3]	
1. Deforested land to Tree planting	$6,950	$3,404	4,000	$27,800,000	$13,614,000	1.09
2. Degraded natural forest to Naturally regenerated forests	$900	$2,669	2,000	$1,800,000	$5,338,000	
3. Degraded forest plantation to Silviculture	$3,000	$1,091	10,000	$30,000,000	$10,914,000	
4. Degraded agriculture to Agroforestry	$2,500	$3,655	40,000	$100,000,000	$146,208,000	
5.Poor farm fallow to Improved farm fallow	$2,300	$264	1,000	$2,300,000	$263,800	

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Restoration Opportunity Assessment ROI Table											
	Ecosystem goods and services			Monetized benefit estimates							
	Timber (M3/ha)	Carbon (tons/ha)	Crop Production (tonnes)	Timber revenue	Carbon revenue	Crop revenue	Value of erosion prevention	NTFPs value	Cost/ha	NPV	ROI
Restoration transition	[2a-1a]	[2b-1b]	[2c-1c]	[2d-1d]	[2e-1e]	[2f-1f]	[2g-1g]	[2h-1h]	[2i-1i]	[(Rev -cost)/cost]	[(Rev - cost)/cost]
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Net Present Value

Net Present Value (NPV) concept allows various sums of money to be compared over time by discounting values that occur in the future so they are comparable with the values of today.

e.g. $10 received a year from now would have a NPV of $9 assuming the discount rate is 10%

The NPV of degraded land uses is calculated by adding all of the revenue together and subtracting the cost. If NPV is greater than 0 restoring produces benefits.

Step 3: Value change in ecosystem services – Interpret the results

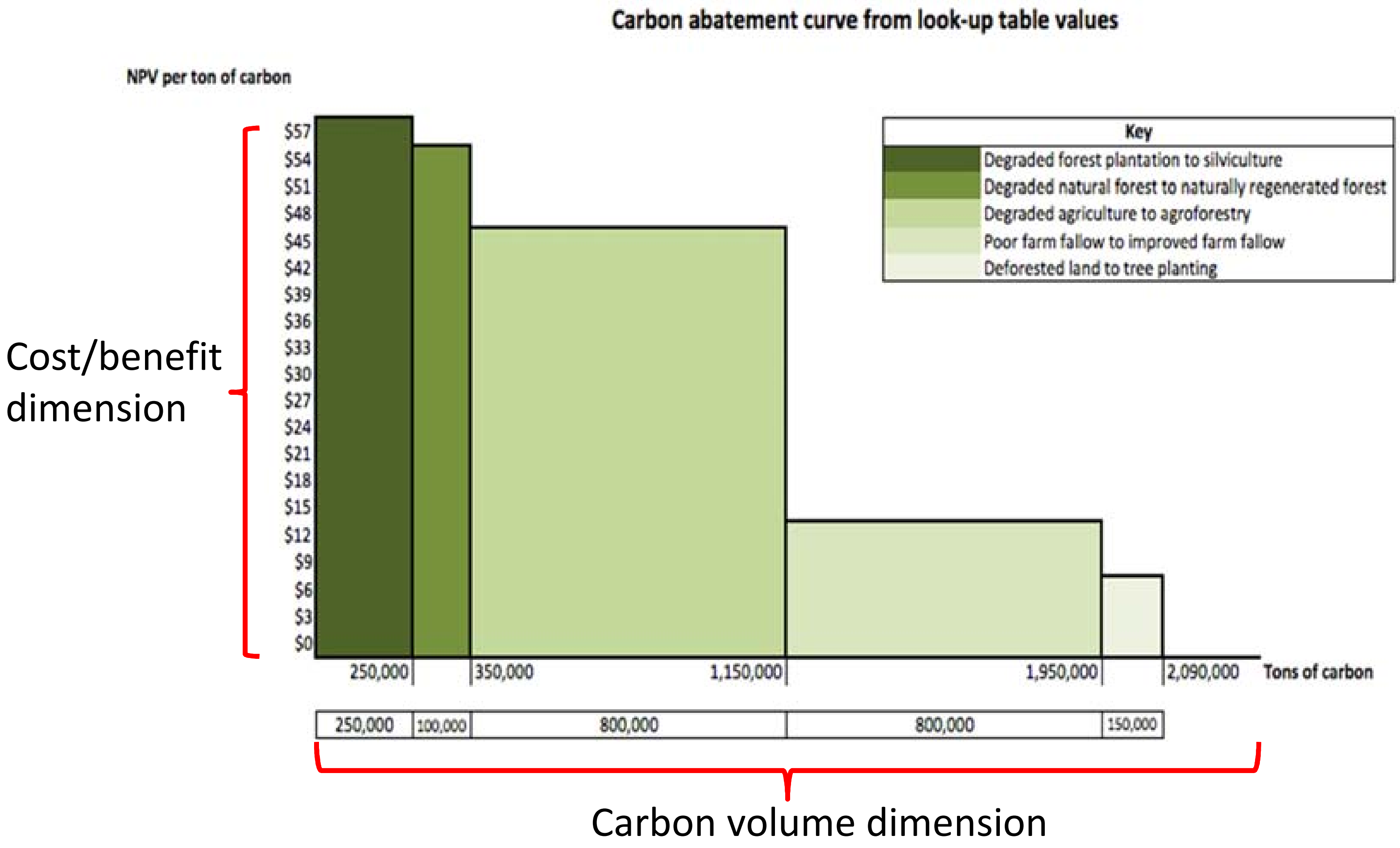
- How much financing would be required to restore the landscape?
- How much revenue would be expected?
- For every dollar invested in the restoration of this landscape how many additional dollars of benefits are created?

Constructing a carbon abatement curve

- Countries who use restoration to offset emissions want to find the least costly/most beneficial way to do so.
- Carbon abatement curves use information on the costs and benefits to estimate the costs/benefits of sequestering carbon under each restoration transition.
- The curves show how much carbon each transition could capture if all of the restoration opportunities were taken.

Two dimensions of a carbon abatement curve

- Cost (benefit) dimension: Height of curves show which restoration transitions sequester carbon for the least cost or most benefit.
- Volume dimension: The width of each bar represents the total amount of carbon that could be sequestered if all opportunity areas were restored.



Constructing a carbon abatement curve

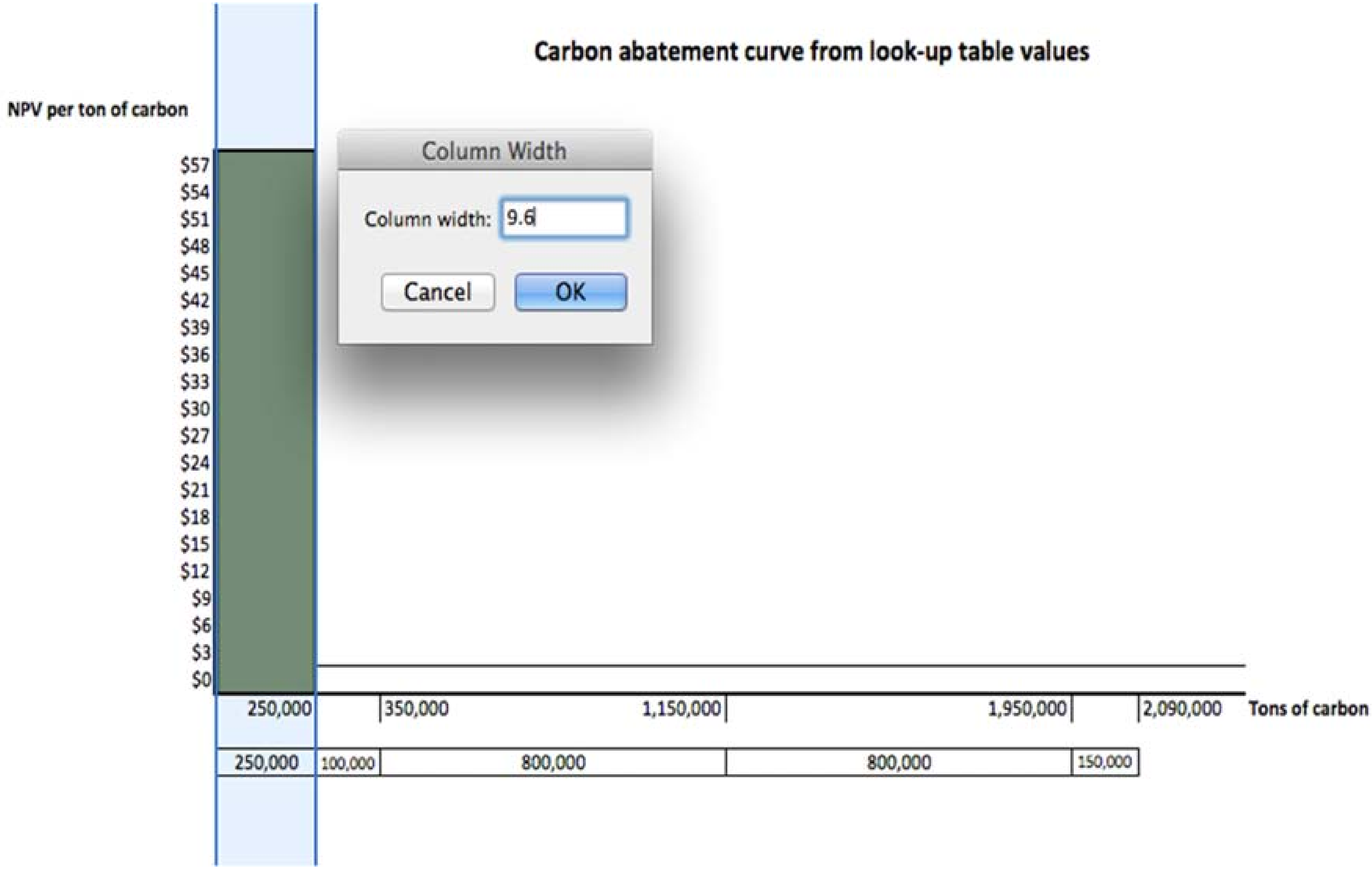
- To construct a carbon abatement curve we need to define the height and width of each restoration transition.
- Begin by creating a table that shows the amount of carbon, total area of opportunity, and the NPV for each restoration transition

Restoration Opportunity Assessment Look-up Table					
Restoration transition	Tons of carbon (Ha)	Area of intervention (Ha's)	Total Carbon	NPV of transition	NPV/TC
Degraded forest plantation to Silviculture	60	4,000	240,000	$3,404	$57
Degraded natural forest to Naturally regenerated forests	50	2,000	100,000	$2,669	$53
Degraded agriculture to Agroforestry	80	10,000	800,000	$3,655	$46
Poor farm fallow to Improved farm fallow	20	40,000	800,000	$264	$13
Deforested land to Tree planting	150	1,000	150,000	$1,091	$7

- The total amount of carbon that can be stored (i.e. the width of each column) by each transition is found by multiplying the carbon sequestered by each hectare with the total number of hectares that could be restored.
- The cost (benefit) of carbon (i.e. the height of each column) is found by dividing the NPV of each transition by the tons of carbon stored by that transition on a single hectare.

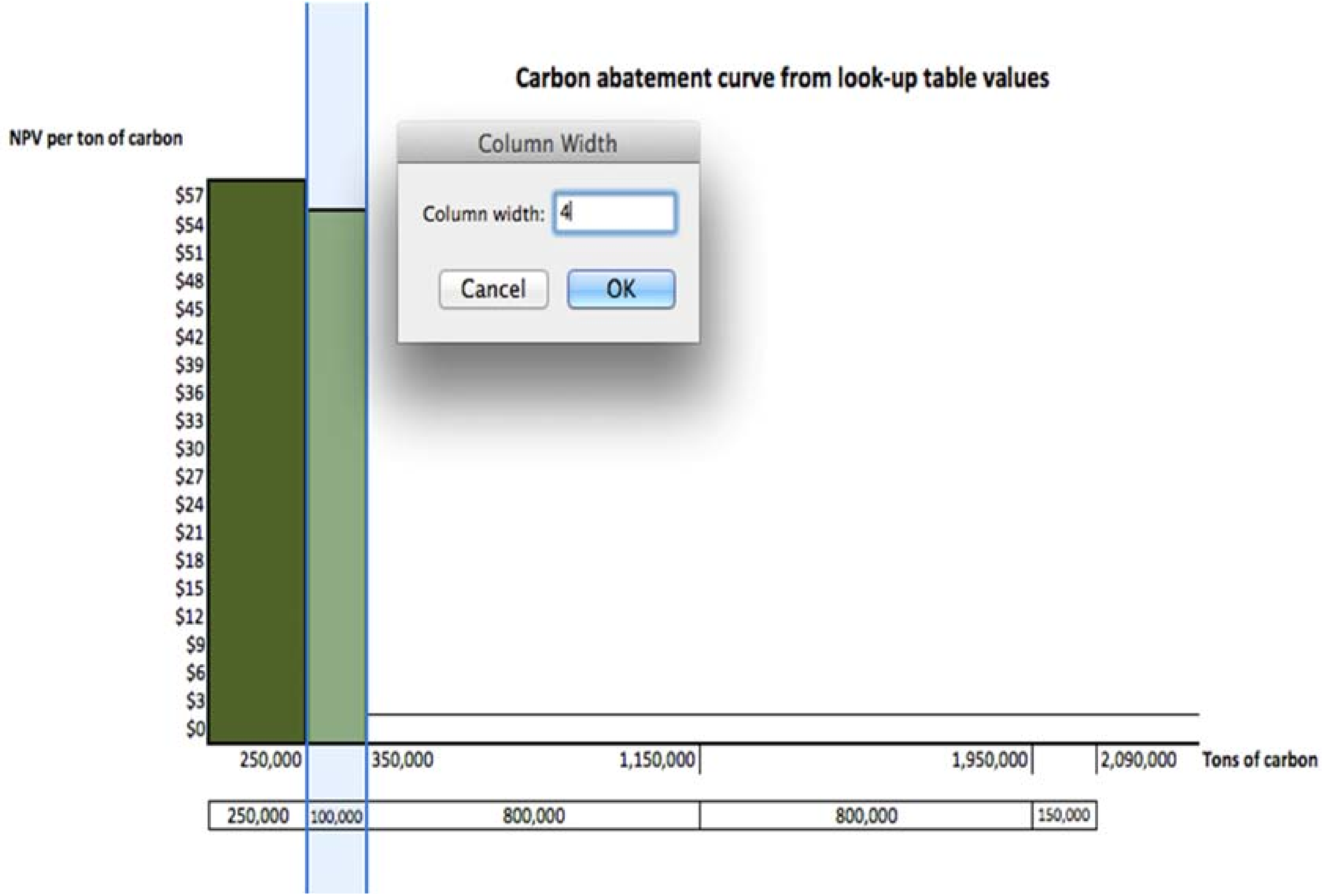
Constructing a carbon abatement curve

Starting with the first transition, draw a rectangle in Excel that is approximately 57 units tall on the vertical axis and 0.00004*240,000 = 9.6 units wide



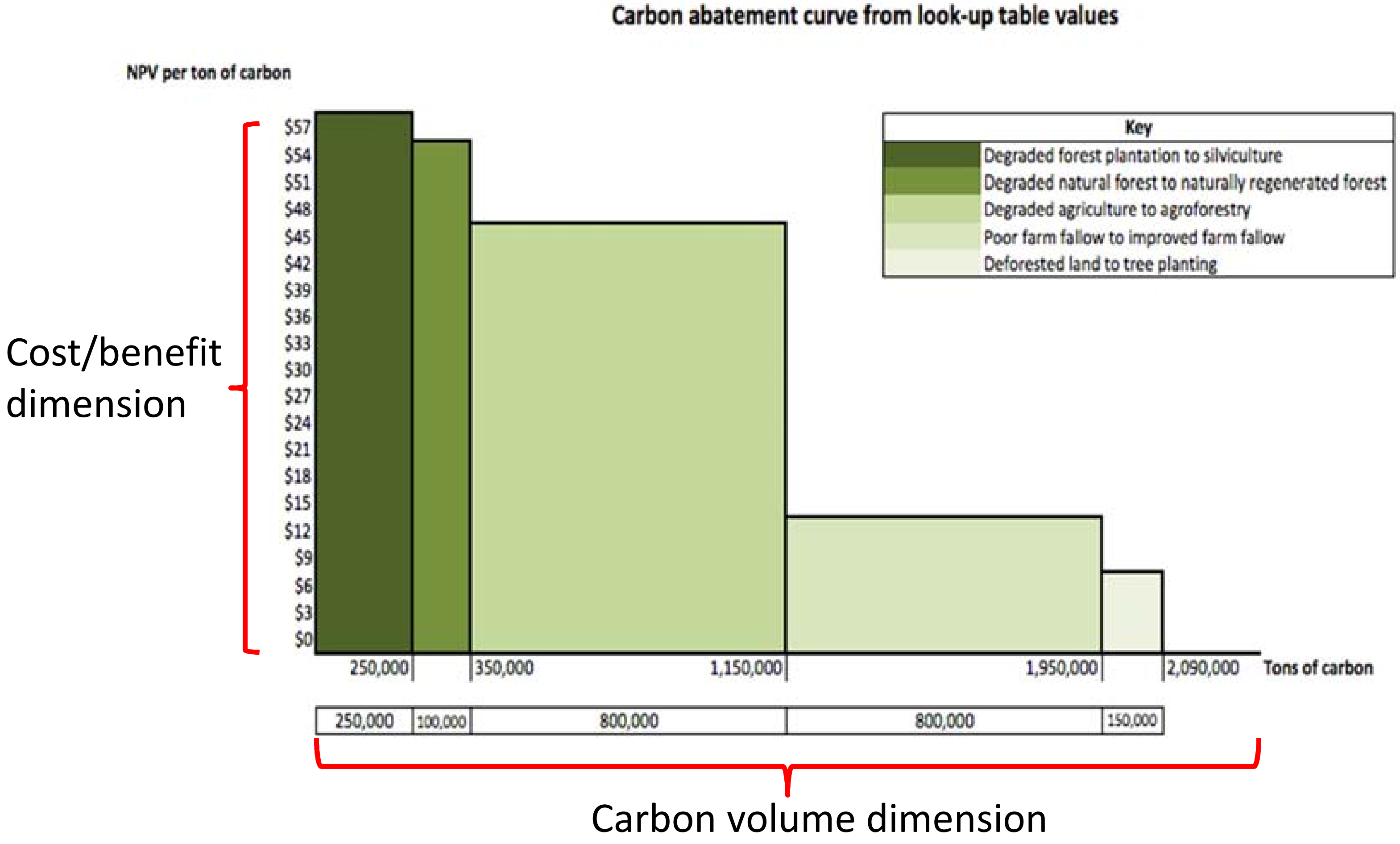
Constructing a carbon abatement curve

The next transition of 'Degraded natural forest to naturally regenerated forest' generates $53 of NPV/ ton of carbon. The height of this bar is 53 and the bar width is 0.00004*100,000 = 4. This same process is repeated for each restoration transition.

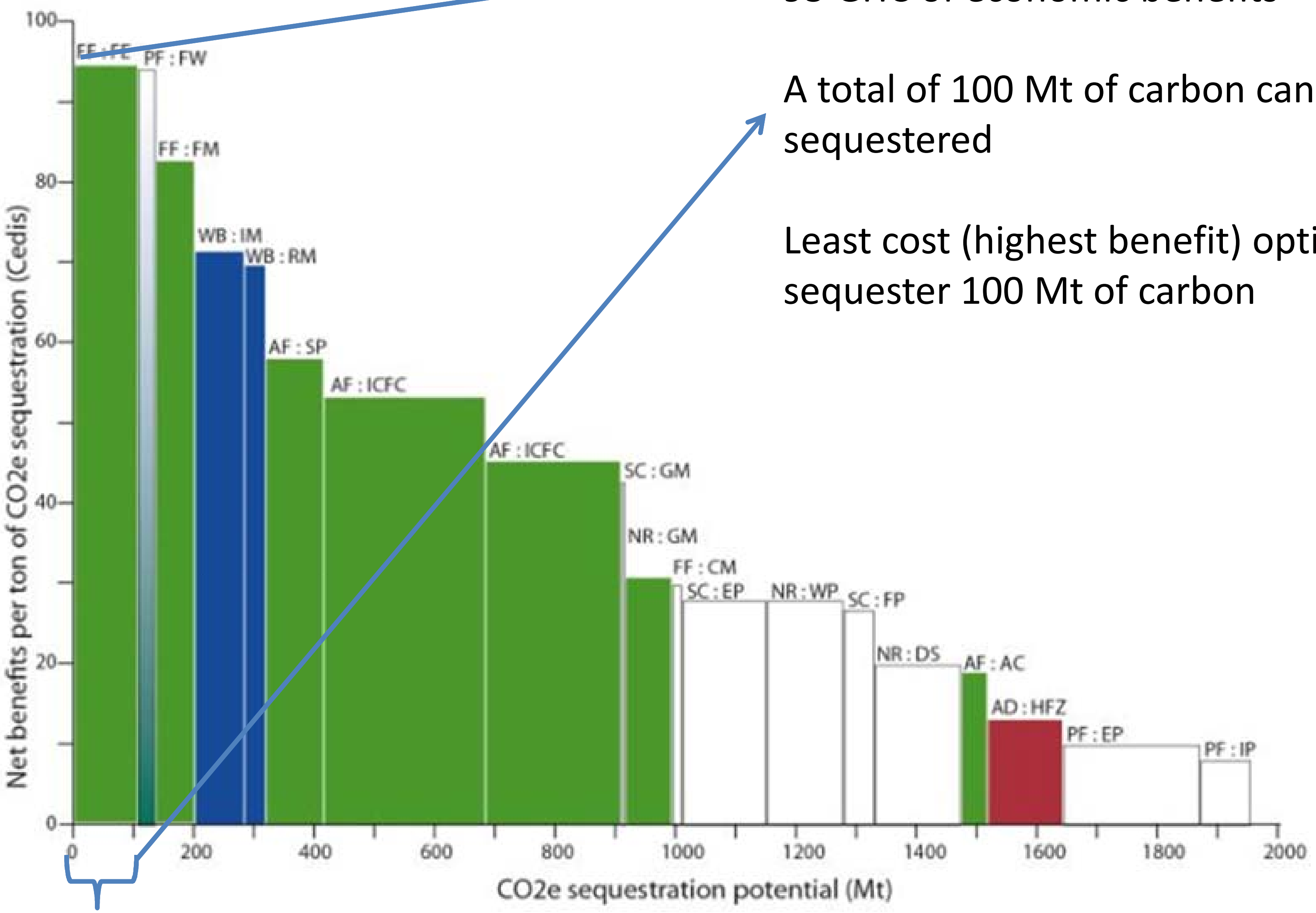


Interpreting a carbon abatement curve

- Which restoration transitions have the potential to sequester the most carbon? Is that what you would have expected?
- If you were a social investor looking for a source of carbon offsets and community impact which restoration transition would you invest in?



Analysis of carbon abatement potential



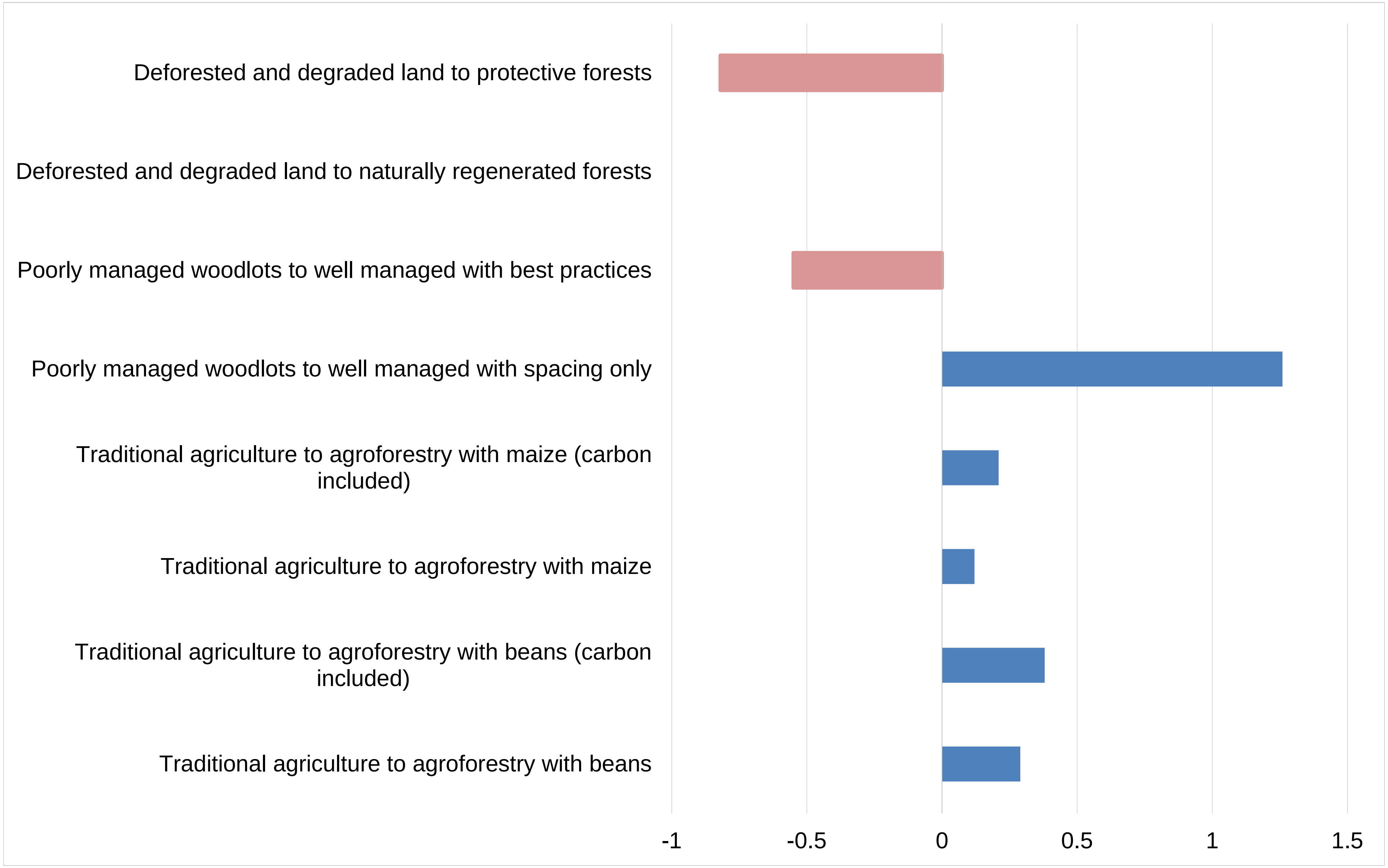
Each ton of carbon sequestered generates 95 GHC of economic benefits

A total of 100 Mt of carbon can be sequestered

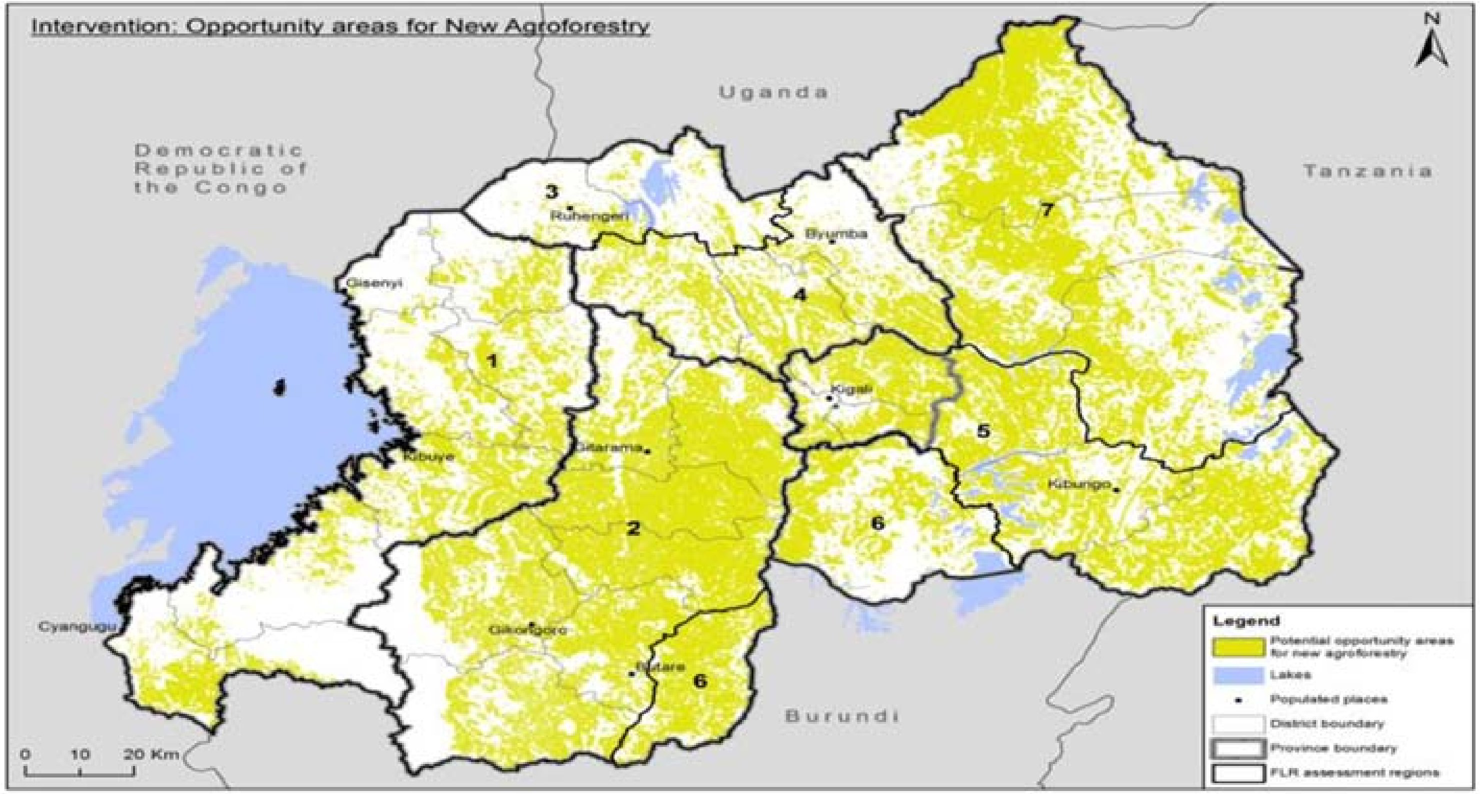
Least cost (highest benefit) option to sequester 100 Mt of carbon

A ”Carbon Cost Abatement” curve of sequestration potential by land use intervention

Calculation of Return On Investments



Identification of benefits from different restoration interventions



Annual crop value (Rwf/ha)	Annual woody biomass value (Rwf/ha)	Annual reduced erosion (t/ha)	Additional carbon (t/ha)	Average Return on Investment
Benefits to farmers	Benefits to farmers	Benefits to farmers / Benefits to society	Benefits to society	
-99,000 to 189,000	75,665 to 132,980	22 to 27	251 to 449	28%

Conclusions

- Given the amount of degraded land across the world, the ability to identify the most beneficial landscapes to restore is an important objective.
- An integrated approach that accounts for both the costs and benefits of restoration provides decision makers with more actionable information.
- Assessing the costs and benefits is useful for prioritizing investments in restoration across a variety of criteria including NPV, ROI, and multi-criteria decision-making.
- Restoration is most successful when planning is based on multiple factors, in addition to economic ones.
- Other factors (e.g. secure land-tenure) will also be key to restoration success. Restoration is most likely to succeed.

Contact Us To Learn More

We are producing Digital Restoration Economic Valuation tools to allow anyone to use the economic valuation framework for forest landscape restoration quickly and easily.

For updates on the software, or to learn more about the economic framework:

Contact us at
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THE GLOBAL PARTNERSHIP ON FOREST LANDSCAPE RESTORATION

WORLD RESOURCES INSTITUTE

- Estimates of biomass, especially in forests, are often reported in terms of standing volume (cubic meters), but since carbon is reported as a weight (tonnes) the standing volume estimates have to be converted. First, standing timber volume (cubic meters) is converted to weight (Kg) using a biomass conversion expansion factor (BCEF) appropriate for the climate zone and forest type (Equation 1):
- $$Above\ ground\ biomass_i(AGB) = M^3 * BCEF_s^i \qquad [1]$$
- Where i indexes the growing stock level and BCEF is the Biomass Conversation Expansion Factor.
- Belowground biomass, or Root Biomass Dry Matter (RBDM), is calculated using an equation that converts aboveground biomass to RBDM:
- $$RBDM = e^{(-1.805+0.9256*\ln(AGB_i))} \qquad [2]$$
- Where AGB is aboveground biomass for growing stock level i. Once the standing volume of timber biomass has been converted to a weight, the weight of carbon is estimated by assuming biomass is 49% carbon by weight (IPCC, 2003). The total carbon sequestered per hectare is found by:
- $$C\ (tonnes) = (AGB + RBDM) * 0.49 \qquad [3]$$
- Where 0.49 is the conversation factor for tons of dry matter to carbon (IPCC, 2003). The estimate could be converted to units of CO_2e by multiplying it by 3.67, which is the ratio of the atomic mass of CO_2e and C, respectively.