A Framework for Analyzing Forest Landscape Restoration Decisions

CBD Training

1. Introduction

Landscape restoration is an opportunity for communities to restore the ecosystem goods and services once provided by deforested and degraded landscapes. Globally, there are more than 2 billion hectares of such land that could be restored. With this tremendous opportunity for restoration, deciding which landscapes to restore right away and how to restore them will be necessary and difficult.

Landscape restoration benefits communities and society alike. Restoring degraded and deforested land to provide more provisioning services like food, fuel and timber can improve the livelihoods of poor and vulnerable people who rely acutely on the land. More broadly, restoration can reduce dangerous greenhouse emissions from land-use change and fossil fuel use. In other cases, restoration can be used to produce critical ecosystem services, like clean water, at a fraction of the cost of traditional, built infrastructure.

Getting the most out of restoration requires making difficult decisions about where, when, and how landscapes should be restored. For the practitioner the question arises: where to start and how to proceed? For the policy maker: who will pay for it? The answers to these and other questions must be formed on the basis of restoration's expected impacts on ecosystem goods and services, and the needs of the communities who surround or depend on the land.

This tutorial shows participants how an ROI framework can serve decision making processes at the country, regional, or local level. The framework assesses the ecosystem service and economic impacts of forest landscape restoration to help decision makers understand the economic and ecosystem trade-offs of different restoration scenarios. With some modification it can also address a number of policy issues.

The rest of the tutorial lays out the economic framework and stylized example of how it can be used. The next sections lists the four (4) steps in the framework and the following sections present each step and show how the mechanics of the analysis. The penultimate section presents a carbon abatement curve and discusses how to construct one. The tutorial concludes with some final thoughts.

2. Steps in the economic framework

There are four steps in the application of 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. Degraded landscapes should be characterized in terms of current land uses and land cover, weather, socio-economic

conditions, and other contextual information.

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.

3. *Model and value the change in ecosystem goods and service production for each restoration transition*: Model the production of ecosystem goods and services on degraded and restored land in order to 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.

Step 1: Identifying degraded forest landscapes

The first step of the assessment process is to identify degraded forest landscapes and their characteristics at the desired level of analysis (e.g., national, regional, or local). Stakeholder consultation and GIS analysis can be used to map the boundaries of degraded forest landscapes. When geospatial data is not available stakeholder consultation can be used to identify degraded landscapes.

Step 2: Identify restoration interventions and restoration transitions

Once the degraded land uses are mapped and understood, restoration interventions can be designed to restore them. Here we define five (5) degraded land uses.

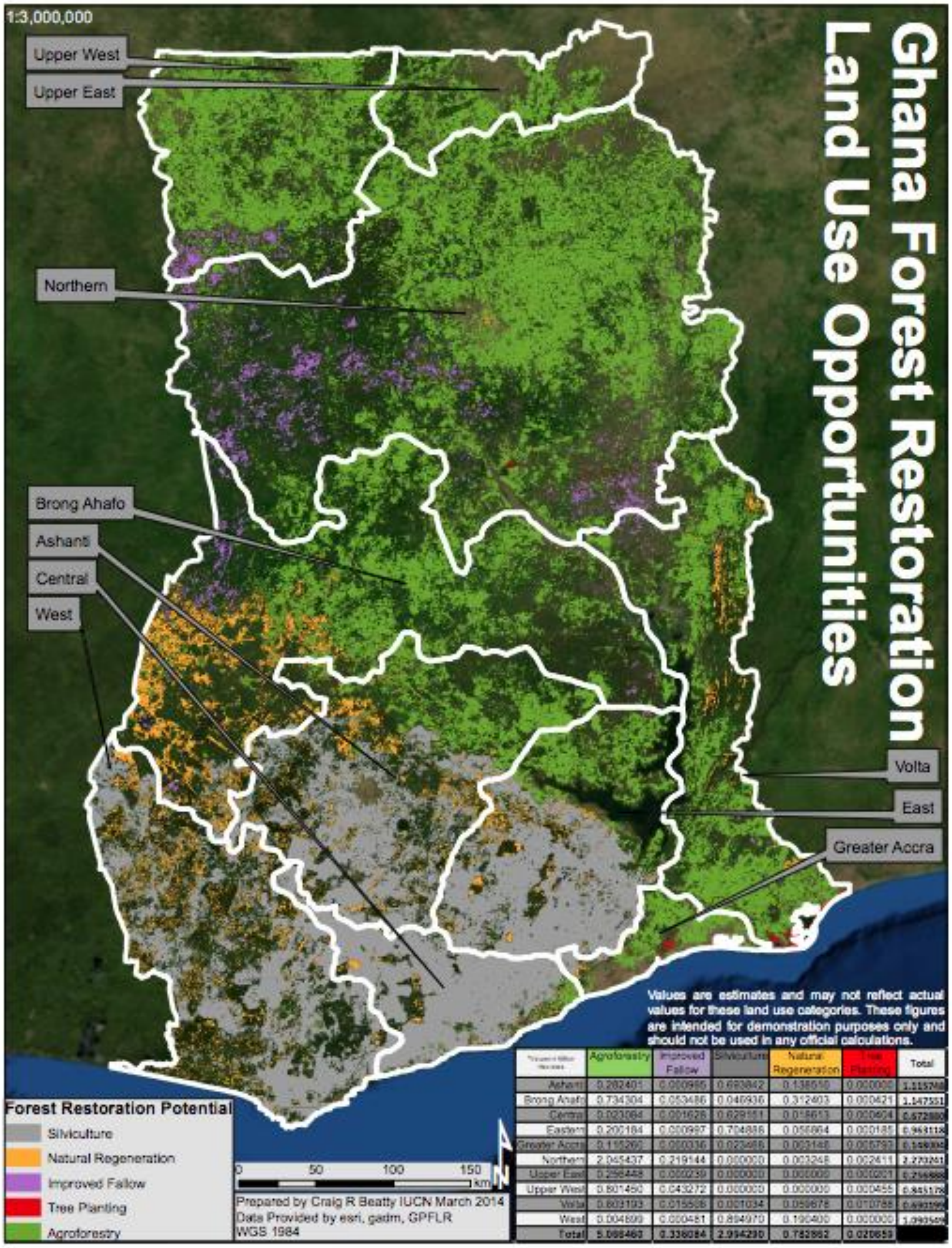
Degraded land uses

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 (ITTO, 2002).
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.

Based on the current land uses we define five (5) restoration interventions to restore them.

Map of restoration opportunities in Ghana



Prepared by Craig R Beatty IUCN March 2014
Data Provided by esri, gadm, GPFLR
WGS 1984

Values are estimates and may not reflect actual values for these land use categories. These figures are intended for demonstration purposes only and should not be used in any official calculations.

[illegible]	Agroforestry	Improved Fallow	Silviculture	Natural Regeneration	Tree Planting	Total
Ashanti	0.282401	0.000985	0.693842	0.138510	0.000000	1.115740
Brong Ahafo	0.734304	0.053486	0.046936	0.312403	0.000421	1.147551
Central	0.023084	0.001626	0.629151	0.018613	0.000404	0.672880
Eastern	0.200184	0.000997	0.704886	0.056864	0.000185	0.963118
Greater Accra	0.115260	0.000336	0.023486	0.003148	0.005797	0.148030
Northern	2.045437	0.219144	0.000000	0.003248	0.002411	2.270201
Upper East	0.256448	0.000239	0.000000	0.000000	0.000201	0.256888
Upper West	0.801450	0.043272	0.000000	0.000000	0.000455	0.845178
Volta	0.603193	0.015506	0.021034	0.059678	0.010788	0.690199
West	0.004899	0.000481	0.894970	0.190400	0.000000	1.090505
Total	5.088460	0.338084	2.994290	0.782862	0.020653	

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.

Based on the current land uses and restoration interventions, we define five (5) restoration transitions, which reflect the degraded land and the restoration intervention that would be used to restore it.

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

Once the restoration transitions have been defined, the financial and non-financial value of each transition can be calculated by modeling the ecosystem services associated with each degraded land use and restoration intervention using information on key ecological variables like mean-annual-increment, carbon sequestration, precipitation, and crop yields.[1]

Step 3: Model and value ecosystem goods and service production for restoration transitions

The primary ecosystem goods and services produced by each degraded land use and restoration intervention can be identified through stakeholder consultation. The quantity of ecosystem services and their value can be estimated using a number of methods depending on the how available biological and market data are. In data rich situations more accurate and advanced methods can be used, such as biological production functions, which are mathematical models of the processes by which ecosystem goods and services are produced. In data poor situations benefit-transfer

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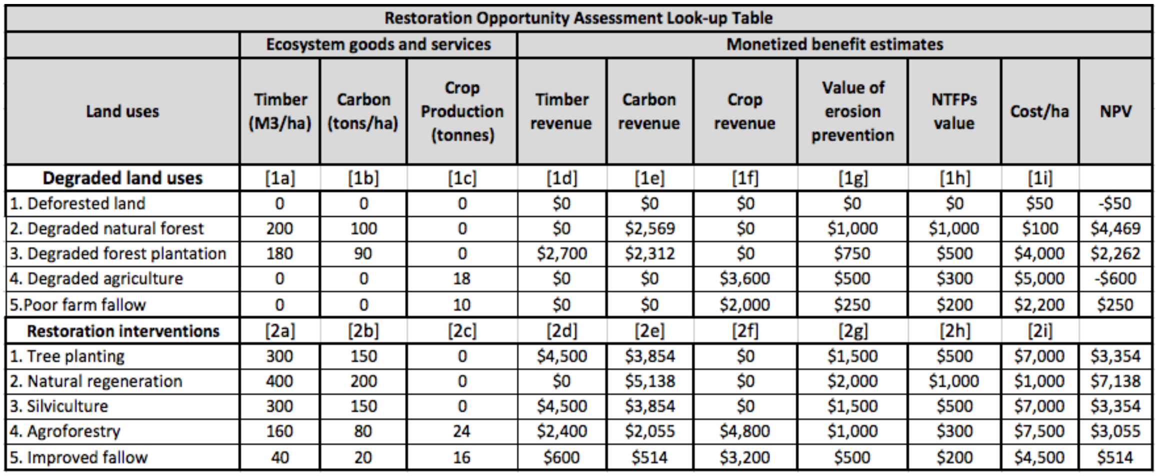
[1] Financial values reflect the revenue earned through the sale of primary production, such as crops, fuelwood, or timber. Non-financial values reflect benefits received

techniques can be used to construct look-up tables of land-use values.

For this exercise we use look-up tables, which are constructed using the relatively simple Benefit Transfer methodology.[2] Below is the look-up table we'll use for this exercise. The table shows the present value of costs and benefits for each degraded land use and restoration intervention. The present value is the sum of future revenue flows that have been discounted to their current value.[3]



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. Tree planting	300	150	0	$4,500	$3,854	$0	$1,500	$500	$7,000	$3,354
2. Natural regeneration	400	200	0	$0	$5,138	$0	$2,000	$1,000	$1,000	$7,138
3. Silviculture	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

Our goal is to estimate the economic returns of each restoration transition and use that information to identify areas where restoration would have a large, positive impact. To do this we want to compare the value of ecosystem services gained through restoration with the costs of restoration. Columns [1a-1c; 2a-2c] are the physical units of ecosystem goods and service that can be measure 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.

The 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 we have today. For example, $10 received a year from now would have a NPV of $9 assuming the future is discounted at a rate of 10%. The NPV concept simply reflects the fact that people prefer things that happen in the present more than events that occur in the future. The NPV of each land use and restoration intervention can be calculated by:

NPV = sum[1d-1h; 2d-2h]– [1i; 2i]

For example, the NPV of degraded land uses is calculated by adding all of the revenue

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[2] The benefit transfer method is uses to estimated economic values for ecosystem services by transferring available information from studies already completed in another location and/or context.

[3] Net Present Values are calculated as $NPV = \sum_{t=0}^{T} \delta^t (R_t - C_t)$ where t is a subscript for time, δ is the discount factor, R is revenue, and C is cost.

together (i.e. [1d]+[1e}+[1f]+[1g]+[1h]) and subtracting the cost [1i] from the revenue.

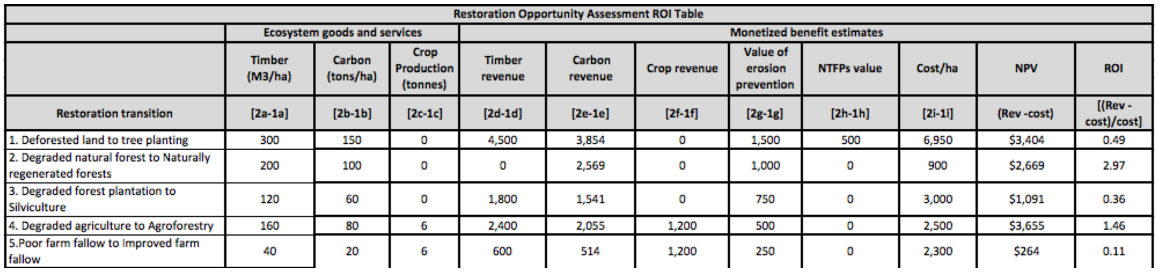
If the NPV of the restoration transition is greater than zero it suggests that restoring the degraded landscape is a worthwhile endeavor. An NPV less than zero suggests that restoring the degraded landscape will generate too few benefits to justify the costs relative to other landscapes. We use the NPV from each restoration transition to calculate the return on investment (ROI) of each restoration transition. Higher ROI's reflect investments that return more benefits per unit of currency invested.

The ROI calculates the amount of value (measured in currency) that would be generated by every dollar invested in the restoration transition. For example, if a restoration had an ROI of 0.2 that would mean for each dollar invested in that transition $1.20 worth of ecosystem goods and services would be created. Generally, private investors and private landowners want to achieve large ROIs through land use transitions and the information provided by this framework can help them understand the trade-offs of their land use decisions.

We calculate ROI as follows:

$$ROI = (NPV_2 - NPV_1)/(C_2 - C_1)$$

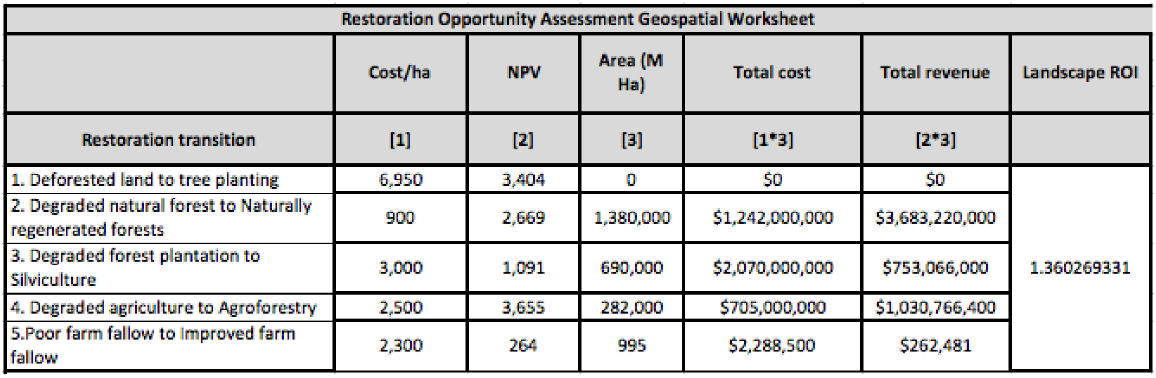
Where NPV_2 is the net present value of the restoration intervention and NPV_1 is the net present value of the degraded land use, respectively. The cost values follow the same convention.



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)	[(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

3. ROI of restoring the landscape: Combining economic and geospatial analyses

Here we combine the information from the ROI worksheet with area information from the map of restoration opportunities in Ghana. In the example below, the areas are from Ashanti Region, Ghana. We see that there were no opportunities to use tree planting to restore deforested land so the area is recorded as 0. There are 1.38 million hectares of degraded natural forest that could be restored with natural regeneration. The total cost of realizing all of the opportunities would be $US 1.24 billion, but over time the transition would create $3.68 billion in benefits. The landscape ROI is the return that would be expected from realizing all of the restoration opportunities in the region. Note that this approach is perhaps more useful for small-scale (<10,000 ha) scenario analysis, as restoration rarely involves regional-scale landscapes.



Restoration Opportunity Assessment Geospatial Worksheet

	Cost/ha	NPV	Area (M Ha)	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	0	$0	$0	1.360269331
2. Degraded natural forest to Naturally regenerated forests	900	2,669	1,380,000	$1,242,000,000	$3,683,220,000	
3. Degraded forest plantation to Silviculture	3,000	1,091	690,000	$2,070,000,000	$753,066,000	
4. Degraded agriculture to Agroforestry	2,500	3,655	282,000	$705,000,000	$1,030,766,400	
5.Poor farm fallow to improved farm fallow	2,300	264	995	$2,288,500	$262,481	

4. Constructing a carbon abatement curve

In some cases restoration is used to offset greenhouse gas emissions. Countries who use restoration to offset emissions want to find the least costly way to do so. Carbon abatement curves use information on the costs and benefits to estimate the costs 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. Combining this information into a single graph helps decision makers offset emissions by restoring landscapes as efficiently as possible.

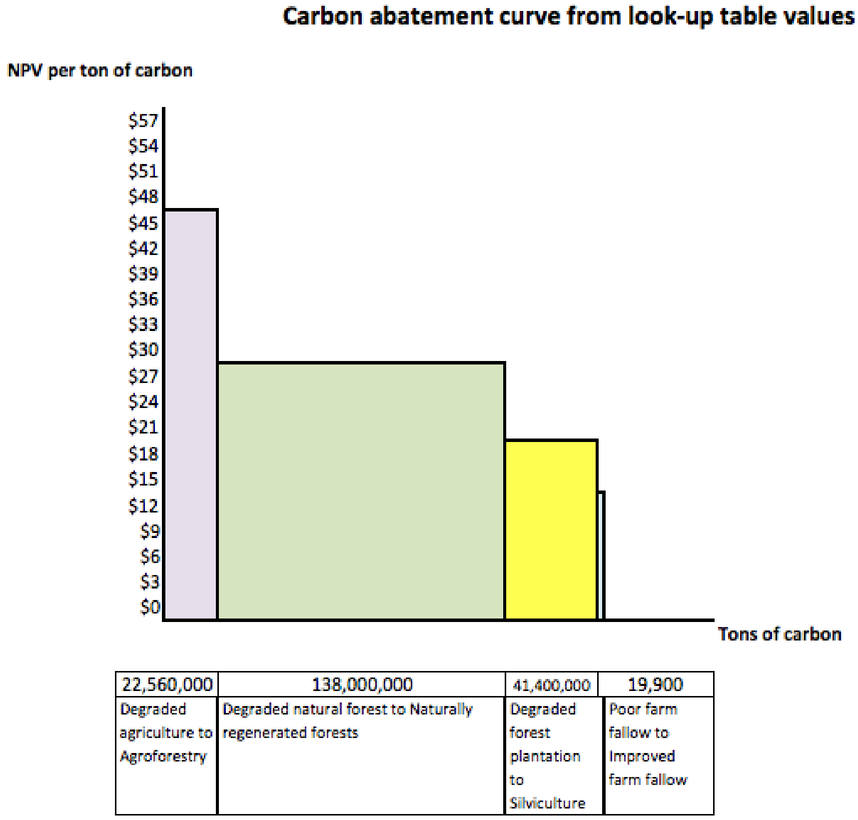
There are two dimensions to a carbon abatement curve:

- Cost (benefit) dimension: Carbon abatement curves show which restoration transitions sequester carbon for the least cost or most benefit. The height of each bar represents the additional costs (benefits) that result from the intervention for each ton of carbon that is sequestered.
- Volume dimension: The width of each bar represents the total amount of carbon that could be sequestered if all opportunity areas were restored.

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. 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.

Carbon Abatement Curve Worksheet					
Restoration transition	Carbon (tons/ha)	Area	Total Carbon	NPV	NPV/TC
	[1]	[2]	[1*2]	[3]	[3/1]
1. Deforested land to tree planting	150	0	0	$3,404	$23
2. Degraded natural forest to Naturally regenerated forests	100	1,380,000	138,000,000	$2,669	$27
3. Degraded forest plantation to Silviculture	60	690,000	41,400,000	$1,091	$18
4. Degraded agriculture to Agroforestry	80	282,000	22,560,000	$3,655	$46
5.Poor farm fallow to Improved farm fallow	20	995	19,900	$264	$13

Once the table has been filled in the carbon abatement curve can be constructed. First, identify the restoration transition with the largest NPV per ton of carbon (or highest cost). This is the first transition we will plot using Excel. First, we plot our vertical axis, which measures the NPV/ton of carbon. Our largest value in this field is $46 and our smallest value is $13. Since we are plotting the highest value first, we make a plot starting at $46. Next, we adjust the size of the horizontal axis, which measures the total tons of carbon that can be sequestered based on the areas reported in the spatial analysis. In total, all of the restoration transitions in this example can store an additional 201,979,900 tons of carbon compared to the status quo. The end result should look like the figure below.



Take aways

The amount of money available for restoration is increasing thanks to commitments like the CBD's Aichi Target 15, which calls for the restoration of 15 percent of all degraded ecosystems. Still, the amount of money available for restoration is far less than what is needed, creating a need to identify landscapes that will provide the most value in ecosystem services per unit of cost. In other words, there is a need to target the landscapes that provide the largest return on investment. In the Rwandan context, our analysis found that landscapes with large areas of poorly managed woodlots are likely to generate the largest returns due to the low costs of restoring productivity and the relatively large amount of timber that could be produced. However, if priority is given to restoration interventions that produce the largest variety of ecosystem goods and services then agricultural landscapes could be prioritized. What is clear is that each landscape has a unique set of costs and revenues, which create different ROIs that must be evaluated and compared.

While restoration decisions can be based on a wide variety of criteria, including ecological priorities and restoration costs, an integrated approach that accounts for both the costs and benefits of restoration is most likely to lead to successful outcomes. This framework shows how ecological and economic information can be combined in order to provide actionable information to decision-makers that allow them to direct limited financial resources to the most promising landscapes. Given the amount of degraded land across the world, the ability to identify the most beneficial landscapes to restore is an important objective.

The framework presented in this report is useful for prioritizing investments in restoration across a variety of criteria including NPV, ROI, and multi-criteria decision-making. This information is useful for policy makers, restoration professionals, and natural resource managers who are interested in understanding more about the economic opportunities and trade-offs of restoring deforested and degraded landscapes. The information provided by the framework can help these professionals to use the limited funds available for restoration as efficiently and effectively as possible.