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A system dynamics model to facilitate long run restoration planning in South Africa:
User manual for the online system dynamics model

Herein ASSET Research documents the process to access and operate the online system dynamics model, available at https://assetresearch.org.za/econrestoration/ , to estimate benefits of a restoration projects over a 5 year period.

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1 Introduction

Ecological restoration is the process of repairing damaged ecosystems with the intention of bringing it back to a state that is self-sustainable and healthy. The need to restore degraded ecosystems now more vital than ever. Ecosystems are important not only for the natural beauty but for all the ecosystem services that provide services such as biodiversity conservation and water and food security.

One of the main challenges effecting the restoration of ecosystems are accessibility to knowledge and lack of financing. Even after entering the decade of ecological restoration, underinvestment in restoration still occurs due to difficulty in quantifying the cost and benefits of restoration as well as providing estimates of the risk of restoration failure or likelihood of restoration success. Restoration success is difficult to quantify due to non-linearity and unpredictability of ecosystems as well as the required length of observation required to establish success often outstripping most restoration project funding horizons. Interpretations of restoration success lie on a spectrum ranging from the extent to which an ecosystem is reset along its pre-disturbance ecological trajectory to the quantity of desirable socio-economic consequences, like ecosystem goods and benefits, produced as a result of restoration effort. To spite a variety of interpretations, there are relatively few quantifications of restoration success but it is usually calculated as increases in biodiversity and relative abundance measures.

The ASSET Research Economics of Restoration project has identified a need to provide assistance to resource managers whereby the cost and benefits of restoration projects can be estimated easily and using the best available data. There are at least two scales at which such information is necessary: restoration projects are managed on a case by case basis each with its own successes and challenges however funding for these projects are typically issued at a national level. On the ground a specific restoration project might only receive 5 years of funding while at a national level ecological restoration has been at least a century long ongoing investment by government. The benefits of restoration begin to accrue annually as soon as the land is brought back to a functional state and the stream of annual benefits persist for as long as the land remains in a functional state while the cost of restoration are large at the onset of restoration activity and fall until restoration is determined to be successful after which a small maintained costs might be spent to ensure the restored land parcel remains intact. During short restoration projects, NPV are typically negative due to the nature of costs and the delay in benefit production.

During stakeholder engagement, the need for a short and a long term model have been established. To this end two system dynamics models were built using data from the ASSET Research cost and benefit database (https://assetresearch.org.za/media-resources/). The

first of these models focusses on providing NPVs of restoration and estimation of person days created and hectare restored at a project level (https://assetresearch.org.za/econrestoration/). The second of these models, for which this document is written, focusses at proving such estimates at a national scale.

This long run national restoration model takes into account the political, economic and social drivers of restoration investment as well as the institutional, ecological and skill-base factors driving restoration success.

2 How to use the systems dynamics tool

Follow the instructions below to access and operate the model:

1. Visit the website: https://assetresearch.org.za/interactive-restoration-models/
2. Click the "System dynamics model for short term economics of restoration" button.
3. Complete the parameters on the "Decisions" page. (Use the information buttons when unsure about the exact information needed.)
4. Simulate the model.
5. Evaluate the results.

3 Completing the "Decisions" page

The "Decisions" page covers all the information that are needed for the economics of restoration based on the developed dynamic hypothesis. The information tab at each variable provides more detail about the data that needs to be entered and the units it has to be in. It is important to complete this entire section as accurately as possible to obtain the most value from this tool. When this section is completed for the first time, some data may be missing or unavailable. For these variables, data must be estimated as close as possible to the area average and start being collected for the years to follow. Data accuracy is crucial when improved sustainability, are considered.

3.1 Bio-physical parameters

This model can be run for a variety of restoration intervention types. The user must specify how fast degradation spreads, what the extent of degradation is in the initial period and what the expected growth in degraded area will be if no restoration occurs. The parameters used for this are in Table 1.

Table 1 - bio-physical parameters

Parameter	Description	Units
Initial intact area	The ha value for land that is currently regarded as being	Ha

	"intact" that can potentially be degraded	
land severely degraded	Ha land regarded as being severely degraded	Dimensionless
land moderately degraded	Ha land regarded as being moderately degraded	Dimensionless
Climate change impact on degradation rates	This is the impact of climate change on the rate of all degradation rates (intact to light, light to moderate and moderate to severe). The value can range between (-1;1).	Dimensionless
land lightly degraded	Ha of land regarded as being lightly degraded land	ha
Initial intact to light rate	The initial rate at which intact land degrades to the point where it is classified as lightly degraded land.	Dimensionless /year
Initial light to moderate rate	The initial rate at which lightly degraded land degrades to the point where it is classified as moderately degraded land.	Dimensionless /year
Initial moderate to severe rate	The initial rate at which moderately degraded land degrades to the point where it is classified as severely degraded land.	Dimensionless /year

3.2 Cost and benefit parameters

The model differentiates between severely, moderately and lightly degraded land as well as for 9 ecosystem types. The user must specify: 1) what proportion of degraded land upon which restoration is done belongs to each ecosystem type; 2) what the average benefit of restoring a hectare of an ecosystem is; and 3) what the cost of restoring each ecosystem type is for the three types of degradation severity. These parameter values are seen in Table 2.

Table 2 - Cost and benefit parameters

Parameter	Description	Units
Initial public budget	The state restoration budget in the first year of simulation	R/year
Initial private budget	The private sector restoration expenditure in the first year of simulation	R/year
Average benefit of fynbos restoration	The rand per hectare average benefit of restoration for land restored in the fynbos ecosystem	R/ha
Average benefit of grassland restoration	The rand per hectare average benefit of restoration for land restored in the grasslands ecosystem	R/ha

Average benefit of savanna restoration	The rand per hectare average benefit of restoration for land restored in the savanna ecosystem	R/ha
Average benefit of Rivers, lake and water body restoration	The rand per hectare average benefit of restoration for land restored in the rivers lake and water body ecosystem	R/ha
Average benefit of forest restoration	The rand per hectare average benefit of restoration for land restored in the forest ecosystem	R/ha
Average benefit of desert restoration	The rand per hectare average benefit of restoration for land restored in the desert ecosystem	R/ha
Average benefit of succulent karoo restoration	The rand per hectare average benefit of restoration for land restored in the succulent karoo ecosystem	R/ha
Average benefit of nama karoo restoration	The rand per hectare average benefit of restoration for land restored in the nama karoo ecosystem	R/ha
Average benefit of thicket restoration	The rand per hectare average benefit of restoration for land restored in the thicket ecosystem	R/ha
% of restoration done in fynbos ecosystem	The rand per hectare average benefit of restoration for land restored in the fynbos ecosystem	%
% of restoration done in grassland ecosystem	The rand per hectare average benefit of restoration for land restored in the grassland ecosystem	%
% of restoration done in thicket ecosystem	The rand per hectare average benefit of restoration for land restored in the thicket ecosystem	%
% of restoration done in savanna ecosystem	The rand per hectare average benefit of restoration for land restored in the savanna ecosystem	%
% of restoration done in nama karoo ecosystem	The rand per hectare average benefit of restoration for land restored in the nama karoo ecosystem	%
% of restoration done in succulent karoo ecosystem	The rand per hectare average benefit of restoration for land	%

	restored in the succulent karoo ecosystem	
% of restoration done in desert ecosystem	The rand per hectare average benefit of restoration for land restored in the desert ecosystem	%
% of restoration done in forest ecosystem	The rand per hectare average benefit of restoration for land restored in the forest ecosystem	%
% of restoration done in river lakes and water body ecosystems	The rand per hectare average benefit of restoration for land restored in the rivers lakes and water bodies ecosystem	%
Severely degraded Savanna restoration cost	Cost of restoring severely degraded savanna	R/ha
Severely degraded Grassland restoration cost	Cost of restoring severely degraded Grassland	R/ha
Severely degraded Forest restoration cost	Cost of restoring severely degraded forest	R/ha
Severely degraded Nama Karoo restoration cost	Cost of restoring severely degraded nama karoo	R/ha
Severely degraded Succulent Karoo restoration cost	Cost of restoring severely degraded succulent karoo	R/ha
Severely degraded Desert restoration cost	Cost of restoring severely degraded desert	R/ha
Severely degraded Rivers, lakes and water body restoration cost	Cost of restoring severely degraded Rivers, lakes and water bodies	R/ha
Severely degraded Thicket restoration cost	Cost of restoring severely degraded thicket	R/ha
Severely degraded Fynbos restoration cost	Cost of restoring severely degraded fynbos	R/ha
Moderately degraded Savanna restoration cost	Cost of restoring Moderately degraded savanna	R/ha
Moderately degraded Grassland restoration cost	Cost of restoring Moderately degraded Grassland	R/ha
Moderately degraded Forest restoration cost	Cost of restoring Moderately degraded forest	R/ha
Moderately degraded Nama Karoo restoration cost	Cost of restoring Moderately degraded nama karoo	R/ha
Moderately degraded Succulent Karoo restoration cost	Cost of restoring Moderately degraded succulent karoo	R/ha
Moderately degraded Desert restoration cost	Cost of restoring Moderately degraded desert	R/ha
Moderately degraded Rivers, lakes and water body restoration cost	Cost of restoring Moderately degraded Rivers, lakes and water bodies	R/ha
Moderately degraded Thicket restoration cost	Cost of restoring Moderately degraded thicket	R/ha

Moderately degraded Fynbos restoration cost	Cost of restoring Moderately degraded fynbos	R/ha
Lightly degraded Savanna restoration cost	Cost of restoring Lightly degraded savanna	R/ha
Lightly degraded Grassland restoration cost	Cost of restoring Lightly degraded Grassland	R/ha
Lightly degraded Forest restoration cost	Cost of restoring Lightly degraded forest	R/ha
Lightly degraded Nama Karoo restoration cost	Cost of restoring Lightly degraded nama karoo	R/ha
Lightly degraded Succulent Karoo restoration cost	Cost of restoring Lightly degraded succulent karoo	R/ha
Lightly degraded Desert restoration cost	Cost of restoring Lightly degraded desert	R/ha
Lightly degraded Rivers, lakes and water body restoration cost	Cost of restoring Lightly degraded Rivers, lakes and water bodies	R/ha
Lightly degraded Thicket restoration cost	Cost of restoring Lightly degraded thicket	R/ha
Lightly degraded Fynbos restoration cost	Cost of restoring Lightly degraded fynbos	R/ha

3.2 Institutional paramaters

The user can also specify what climate change is likely to do to the degradation spread rates. The user can affect changes in how budget is spent by varying the proportion of budget spent on training and the proportion of budget that is spent on raising awareness of the cost of degradation. The user can also change the rate at which the expected benefits of restoration inflate over time. The user can additionally change the initial level of skill of restoration labourers and the initial percentage of landowners aware of the costs of degradation. These parameters are described in Table 3.

Table 3 - scenario parameters

Parameter	Description	Units
Inflation	This it the average inflation rate in effect over the scenario	Dimensionless/ year
Initial value of restoration learning	How well is are people employed to restore land trained (0-1)	Dimensionless
Initial awareness factor	This is the percentage of land owners that are aware of the cost of degradation and act to prevent degradation on their land or to lobby private and public sector to act to restore or conserve land	DImensionless
Annual awareness budget proportion	The proportion of the annual restoration budget used to raise awareness among land owners of the cost of degradation	%/year

Proportion of budget allocated to training	The proportion of the annual restoration budget used to train people employed to restore land	%/year

4. Interpreting the results

The results from different restoration efforts can be viewed on the "Main results" page and the "Results details" page. The total restoration budget (private and public), the calculated NPV, the opportunity cost of degradation, the total hectare restored per year, the total person days created per year as well as the land under the four classifications (intact, lightly degraded, moderately degraded and severely degraded) can be viewed here on graphs relative to some baseline scenario. The baseline scenario was generated by calibrating the model for the working for water project and projecting forward from 2020-2050.

4.1 Biophysical results

These results presented are related to the physical state of the area of land that the restoration project attended to. The results provide insights into the state of the area over time based on the inputted decision parameters.

1. The area considered intact includes land that has been restored successfully. This land has a degradation metric density of <0.1. That is less than 10% of the land is invaded, eroded etc.
2. The area considered lightly degraded is land that has a degradation metric density of 0.01-0.3 that is, 1% to 30% of the land is invaded, eroded etc.
3. The area considered lightly degraded is land that has a degradation metric density of 0.3-0.6 that is, 30% to 60% of the land is invaded, eroded etc.
4. The area considered lightly degraded is land that has a degradation metric density of 0.6-1 that is, 60% to 100 % of the land is invaded, eroded etc.
5. Ha restored is the annual ha restored (summed across the three degradation classes)

4.2 Economic results

These results presented are the economics results related to the area of land that the restoration project attended to. The results provide insights into the economic costs and benefits of the restoration project over time based on the inputted decision parameters.

1. Net present value of benefits is expressed in Rands and is the difference between the present value of cash inflows and the present value of cash outflows over the

period of time. Due to the short time frame of the simulated results, it is unlikely that the net present value would be positive or increase over time for the simulated results.

2. The opportunity cost of degradation is expressed in rand/year and represents the monetary potential loss of missed opportunity of degraded land not being attended to.

3. The total job benefits is expressed in jobs and represents the opportunity of potential employment that the restoration project would create.