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A system dynamics approach to investigate the benefits of invasive alien clearing restoration practices 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.

In South Africa, restoration success is advocated as a state of ecosystem which maximizes ecosystem benefits by the removal of certain invasive alien plant (IAP) species. A large effort has been made to remove IAPs in South Africa as a means of reducing further degradation as well as minimizing the direct loss of ecosystem goods and services valued at over 100 billion rand per annum. The cost and benefits associated with this type of restoration varies by location, IAP composition and extent of invasion. Many restoration projects clear an area of IAP types and then return for a series of follow up clearing to remove regrowth until seedbanks are depleted.

Given the context provided above, the purpose of the development of this short term interactive model is to understand how investment into restoration projects as well as the process of invasive alien plant clearings effects the cost and benefits of restoration clearing over a fixed time frame (5 years). With the help of this model users will be able to simulate changes based on various restoration projects and be provided with some insight into the potential benefits and cost of that specific restoration project.

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 Contract parameters

Contract parameters covers the general parameters that are considered when a restoration project involved in clearing of invasive alien plants are drawn-up or awarded. This includes the length of the project, the budget awarded for the project from public and private sectors for both initial IAP clearings as well as follow-up clearings (if the project includes follow-up clearing). It also considers the delays in the project, either delays from when the contract was initialized to actual clearings being carried out or delays considering how long after the initial clearing, follow-up clearings are done.

Contract related parameters	Description	Units
Initial project length	The number of years a restoration project is contracted for	year
Initial contract delay	The time between contractual project start time and actual restoration clearing project start.	year
Initial restoration clearing: public budget	The total budget allocated for initial restoration IAP clearing from the public sector.	Rand
Initial restoration clearing: private budget	The total budget allocated for initial restoration IAP clearing from the private sector.	Rand
Number of follow-up restoration cycles	Frequency of follow-ups over a 5 years 20 interval period	Number of follow-ups (dmnl)
Follow-up restoration clearing delays	Length of delay for (all) follow-up clearing completion	year
Follow-up restoration clearing: public budget	The total budget allocated for all follow-up restoration IAP clearing from the public sector.	Rand
Follow-up restoration clearing: private budget	The total budget allocated for all follow-up restoration IAP clearing from the private sector.	Rand

3.2 Initial ecosystem state parameters

Initial ecosystem state parameters include information pertaining to the extent and condition of the degraded land that a restoration project will be addressing. This includes identifying the specific type of invasive species that would be cleared from the area as well as restoration exit threshold.

Initial ecosystem state parameters	Description	Units
Initial degradation extent	The extent of degraded land prior to any IAP clearing	Hectares
Initial degradation condition	The % of area that is considered degraded	% (dmnl)
Dominant invasive species	The dominant invasive species that would be removed during restoration clearing	species
Restoration exit threshold	The replacement value of the improvements at the affected area	% (dmnl)

3.3 Economic parameters

Information required to complete this section are related to all the economic variables considered for restoration clearing projects. This includes the unit opportunity cost, unit benefit, unit cost per species and discount rate.

Economic parameters	Description	Units
Unit opportunity cost of degradation	Monetary potential loss from a missed opportunity by not attending to degraded land	Rand/hectare
Unit benefit of restoration	Monetary potential benefit gained by addressing degraded land	Rand/hectare
Initial restoration: jobs required	The total labour required for the initial restoration phase	Job/ hectare
Follow-up restoration phase: jobs required	The total labour required for all the follow-up restoration phases	Job/ hectare
Discount rate	The rate of return that investors investing in restoration clearing projects can expect	% (fraction/year)
Initial restoration: unit cost of *Acacia mearnsii*	Unit cost to remove one hectare of *Acacia mearnsii* in the initial restoration clearing phase	Rand/hectare
Follow-up restoration: unit cost of *Acacia mearnsii*	Unit cost to remove one hectare of *Acacia mearnsii* in the follow-up restoration clearing phase	Rand/hectare
Initial restoration: unit cost of *Acacia cyclops*	Unit cost to remove one hectare of *Acacia cyclops* in the initial restoration clearing phase	Rand/hectare
Follow-up restoration: unit cost of *Acacia cyclops*	Unit cost to remove one hectare of *Acacia cyclops* in the follow-up restoration clearing phase	Rand/hectare
Initial restoration: unit cost of *Acacia longifolia*	Unit cost to remove one hectare of *Acacia longifolia* in the initial restoration clearing phase	Rand/hectare
Follow-up restoration: unit cost of *Acacia longifolia*	Unit cost to remove one hectare of *Acacia longifolia* in the follow-up restoration clearing phase	Rand/hectare
Initial restoration: unit cost of *Pinus spp*	Unit cost to remove one hectare of *Pinus spp* in the initial restoration clearing phase	Rand/hectare
Follow-up restoration: unit cost of *Pinus spp*	Unit cost to remove one hectare of *Pinus spp* in the follow-up restoration clearing phase	Rand/hectare
Initial restoration: unit cost of *Opuntia aurantiaca*	Unit cost to remove one hectare of *Opuntia aurantiaca* in the initial restoration clearing phase	Rand/hectare
Follow-up restoration: unit cost of *Opuntia aurantiaca*	Unit cost to remove one hectare of *Opuntia aurantiaca* in the follow-up restoration clearing phase	Rand/hectare

4 Interpreting the results

The results from different management strategies and most important environmental indicators on the farm can be viewed on the “Main results” page and the “Results details” page. The total contribution to GHG emissions from the farm will be illustrated on these pages. The baseline carbon footprint for the farm stems from the initial assessment based on the current practices and available data. The baseline evaluation can be used to identify primary drivers for GHG emissions on the farm. This may result in emission reduction opportunities and assist in the identification of efficiency drivers as well as associated financial and economic costs and benefits. The impact of management changes and progress can be monitored over time through annual assessments. More information on how to interoperate and understand the results graphs is given below.

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 under initial restoration is expressed in hectares and represents the amount of land that is at each a specific time undergoing the initial clearing of the inputted dominant invasive species.
2. The initial restored area is expressed in hectares and is shows the amount of land that has successfully initially been cleared from the IAP, however, has not undergone any further follow-up clearing and has a high potential for IAP regrowth.
3. The area under follow-up restoration is expressed in hectares and represents the amount of land that is at each a specific time undergoing follow-up clearing of the inputted dominant invasive species
4. The degraded area is expressed in hectares and show the total area considered to be degraded and not being cleared (in either initial or follow-up phases) or re-degraded land after regrowth of IAP. A successful project should see degraded land decreasing over time.
5. The restoration success is expressed in hectares and shows the total area considered to be fully or as closely restored to its original state. An area of land is only conceded restored is the potential for regrowth of IAP is very low or if 85% of that area is at its original state.

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 economic restoration benefits is expressed in rand/year and represents the monetary potential gain of the restoration project.

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