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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 of a region 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 project system dynamics interactive model is to understand how investment into a restoration project and 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 “Short-term restoration model” button.
3. Background information is provided on the “Introduction” page, at the bottom of the page will be a “Get started” button which will navigate to the “Decisions” page.
4. Complete the parameters on each of the three tabs on the “Decisions” page. The three tabs are “1. Ecosystem state parameters”, “2. Project contract parameters” and “3. Economic parameters”, be sure to complete the parameters of all these three tabs. Use the information buttons when unsure about the exact information needed.
5. Once all the relevant parameters are completed, navigate to the bottom of the page where you can insert a name of the ‘scenario run’ of these parameters and “Save & Simulate” the run. You will automatically be navigated to the “Results” page.
6. The “Results” page includes biophysical results of the simulated project ‘run’ as well as the economic results of the ‘run’.
7. The parameters can be changed to run a different scenario which can be compared to the first by completing step 4 & 5 again with a different ‘scenario run’ name. This can be done multiple times in order to evaluate the outcomes of changing different parameters.

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 icon at each variable provides more detail about the data that needs to be entered and the units that it is in. It is important to complete this entire section as accurately as possible to obtain the most value from this tool. The “Decisions” page is separated into three tabs which can be navigated but clicking it on top of the page. The first contains the “Ecosystem state parameters”, the second accounts for the “Project contract parameters” and the last concerns the “Economic parameters”.

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 Ecosystem state parameters

Ecosystem state parameters include the initial 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 growth form of the invasive alien plant that would be cleared from the area as well as restoration exit threshold.

Initial ecosystem state parameters	Description	Units
Total area	Total area of land inclusive of degraded and pristine land.	Hectares
Initial degradation extent	The extent of degraded land prior to any IAP clearing	Hectares
Initial degradation condition	The % of area that is considered degraded	%
Restoration exit threshold	The replacement value of the improvements at the affected area	%
Dominant invasive growth form	The growth form of the dominant invasive alien plant that would be removed during restoration clearing	Growth form
Regrowth rate of invasive growth form	The rate that the dominant invasive alien plant that would be removed grows back after being cleared	%/year
Thicket area of restoration area	The proportion of the total area that would be classified as being a part of the Thicket ecosystem	%
Fynbos area of restoration area	The proportion of the total area that would be classified as being a part of the Fynbos ecosystem	%
Savanna area of restoration area	The proportion of the total area that would be classified as being a part of the Savanna ecosystem	%
Succulent Karoo area of restoration area	The proportion of the total area that would be classified as being a part of the Succulent Karoo ecosystem	%
Grassland area of restoration area	The proportion of the total area that would be classified as being a part of the Grassland ecosystem	%
Desert area of restoration area	The proportion of the total area that would be classified as being a part of the Desert ecosystem	%

3.2 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
Budget: initial clearing	The total budget allocated for initial restoration clearing of invasive alien plants.	Rand
Number of follow-up clearings conducted	Frequency of follow-ups over a 5 years 20 interval period	Number of follow-ups
Budget: follow-up clearing	The total budget allocated for all follow-up restoration clearing of invasive alien plants.	Rand
Follow-up restoration clearing delays	Length of delay for (all) follow-up clearing completion	year

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 benefit of IAP clearing per ecosystem type, unit cost of clearing per invasive alien growth form and the discount rate. These parameters are pre-populated with data based on research conducted by ASSET research however it can be changed to suit the specific context of the project scenario you are running.

Economic parameters	Description	Units
Non-sprouting: initial clearing cost	The unit cost to clear one hectare of non-sprouting invasive alien growth forms during the initial phase of clearing.	Rand/hectare
Non-sprouting: initial clearing personday requirement	The number of person-days required to clear one hectare of non-sprouting invasive alien growth forms during the initial phase of clearing.	Person-day/hectare
Non-sprouting: follow-up clearing cost	The unit cost to clear one hectare of non-sprouting invasive alien growth forms during the follow-up phases of clearing.	Rand/hectare
Non-sprouting: follow-up personday requirement	The number of person-days required to clear one hectare of non-sprouting invasive alien growth forms during the follow-up phases of clearing.	Person-day/hectare
Sprouting: initial clearing cost	The unit cost to clear one hectare of sprouting invasive alien growth forms during the initial phase of clearing.	Rand/hectare
Sprouting: initial clearing personday requirement	The number of person-days required to clear one hectare of sprouting invasive alien growth forms during the initial phase of clearing.	Person-day/hectare
Sprouting: follow-up clearing cost	The unit cost to clear one hectare of sprouting invasive alien growth forms during the follow-up phases of clearing.	Rand/hectare
Sprouting: follow-up personday requirement	The number of person-days required to clear one hectare of sprouting invasive alien growth forms during the follow-up phases of clearing.	Person-day/hectare
Climber: initial clearing cost	The unit cost to clear one hectare of climber invasive alien growth forms during the initial phase of clearing.	Rand/hectare
Climber: initial clearing personday requirement	The number of person-days required to clear one hectare of climber invasive alien growth forms during the initial phase of clearing.	Person-day/hectare

Climber: follow-up clearing cost	The unit cost to clear one hectare of climber invasive alien growth forms during the follow-up phases of clearing.	Rand/hectare
Climber: follow-up personday requirement	The number of person-days required to clear one hectare of climber invasive alien growth forms during the follow-up phases of clearing.	Person-day/hectare
Shrub: initial clearing cost	The unit cost to clear one hectare of shrub invasive alien growth forms during the initial phase of clearing.	Rand/hectare
Shrub: initial clearing personday requirement	The number of person-days required to clear one hectare of shrub invasive alien growth forms during the initial phase of clearing.	Person-day/hectare
Shrub: follow-up clearing cost	The unit cost to clear one hectare of shrub invasive alien growth forms during the follow-up phases of clearing.	Rand/hectare
Shrub: follow-up personday requirement	The number of person-days required to clear one hectare of shrub invasive alien growth forms during the follow-up phases of clearing.	Person-day/hectare
Succulent: initial clearing cost	The unit cost to clear one hectare of succulent invasive alien growth forms during the initial phase of clearing.	Rand/hectare
Succulent: initial clearing personday requirement	The number of person-days required to clear one hectare of succulent invasive alien growth forms during the initial phase of clearing.	Person-day/hectare
Succulent: follow-up clearing cost	The unit cost to clear one hectare of succulent invasive alien growth forms during the follow-up phases of clearing.	Rand/hectare
Succulent: follow-up personday requirement	The number of person-days required to clear one hectare of succulent invasive alien growth forms during the follow-up phases of clearing.	Person-day/hectare
Grass: initial clearing cost	The unit cost to clear one hectare of grass invasive alien growth forms during the initial phase of clearing.	Rand/hectare
Grass: initial clearing personday requirement	The number of person-days required to clear one hectare of grass invasive alien growth forms during the initial phase of clearing.	Person-day/hectare
Grass: follow-up clearing cost	The unit cost to clear one hectare of grass invasive alien growth forms during the follow-up phases of clearing.	Rand/hectare

Grass: follow-up personday requirement	The number of person-days required to clear one hectare of grass invasive alien growth forms during the follow-up phases of clearing.	Person-day/hectare
Thicket restored: Unit benefit	Monetary potential benefit gained by addressing degraded land within a Thicket ecosystem	Rand/hectare
Fynbos restored: Unit benefit	Monetary potential benefit gained by addressing degraded land within a Fynbos ecosystem	Rand/hectare
Savanna restored: Unit benefit	Monetary potential benefit gained by addressing degraded land within a Savanna ecosystem	Rand/hectare
Succulent Karoo restored: Unit benefit	Monetary potential benefit gained by addressing degraded land within a Succulent Karoo ecosystem	Rand/hectare
Grassland restored: Unit benefit	Monetary potential benefit gained by addressing degraded land within a Grassland ecosystem	Rand/hectare
Desert restored: Unit benefit	Monetary potential benefit gained by addressing degraded land within a Desert ecosystem	Rand/hectare
Discount rate	The rate of return that investors investing in restoration clearing projects can expect	% (fraction/year)

4 Interpreting the results

The results from different management strategies of restoration projects can be viewed on the “Results” page. The results are separated into the “Biophysical results” and “Economic results” which can either be navigated on the pages strip on top of the buttons on the bottom of the results pages. 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 project area over time based on the inputted decision parameters.

1. Maintenance phase area
    - This area 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.

2. Degraded area
    - 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.

3. Area under initial restoration
    - 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.

4. The area under follow-up restoration
    - This area 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

4.2 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. Economic restoration benefits
    - This expressed in rand/year and represents the monetary potential gain of the restoration project.

2. Total jobs benefits
    - The total job benefits is expressed in person-days and represents the opportunity of potential employment that the restoration project would create.

3. Opportunity cost of degradation
    - 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.

4. Net present value of benefits
    - 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.