



CIPSEM 2023

# Predictive Ecology:

What is it and why should you care?

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Postdoc Fellow UBC / Guest Scientist at TU Dresden

@PredictiveEcol

Eliot McIntire, Samuel Hache, Dene First Nations, Frances Stewart, Diana Stralberg, Junior Tremblay, Mathieu Leblond, Alex Chubaty, James Hodson, Steve Cumming, Celine Boisvenue, Greg Paradis, Ian Eddy, Ceres Barros ... and many others!



Black Forest, Germany  
by R Boed



# CONTENT & STRUCTURE

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# SYLLABUS

## 1. CONTENT AND STRUCTURE

1.1. Content and Structure

1.2. Rules

1.3. Who am I?

## 2. PART I – Predictive Ecology: what is it?

2.1. Ecology

2.2. Prediction

2.3. Predictive Ecology

## 3. PART II – Predictive Ecology: The basics

3.1. Modelling

3.2. From data to ecological models

3.3. Applying ecological models in a predictive context

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# SYLLABUS

## 4. PART III – Predictive Ecology: how can we do it right?

### 4.1. The PERFECT approach to Predictive Ecology

### 4.2. Important tools: the power of R and version control

### 4.3. SpaDES: the importance of reusability in science

## 5. PART IV – Predictive Ecology: a real example

### 1.1. The Western Boreal Initiative

## 6. Hands-on – Are birds a good umbrella for turtles in a changing world?

### 1.1. Game based exercise

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# RULES – This is a participative discussion

- 1. Ask questions, just raise your hand at any time**
- 2. If a theme that was not planned emerges and is of interest, we go for it**
- 3. Please respect both me and your colleagues when they talk**
- 4. Try your best to engage both in during the theoretical and practical parts**

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# Who am I?



**B.Sc.**  
2002-2007



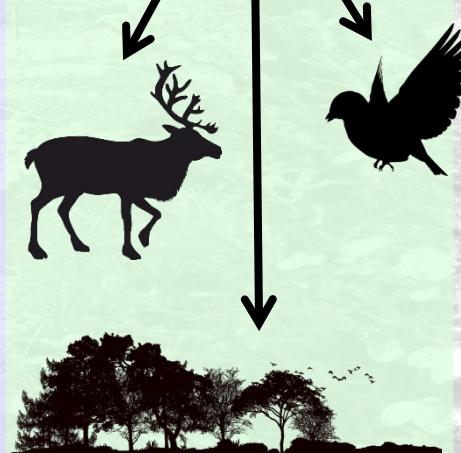
**M.Sc.**  
2008-2010



TECHNISCHE  
UNIVERSITÄT  
DRESDEN



PRIFFYSGOL  
**BANGOR**  
UNIVERSITY



**M.Sc.**  
2009-2011

**Ph.D.**  
2013-2017

**PD**  
2017-Current

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# ANY QUESTIONS?

*"It is not the answer that enlightens, but the question." – Eugene Ionesco*

*"The art and science of asking questions is the source of all knowledge." – Thomas Berger*

*"The man who asks a question may be a fool for a minute; the man who does not ask is a fool for life." – Confucius*

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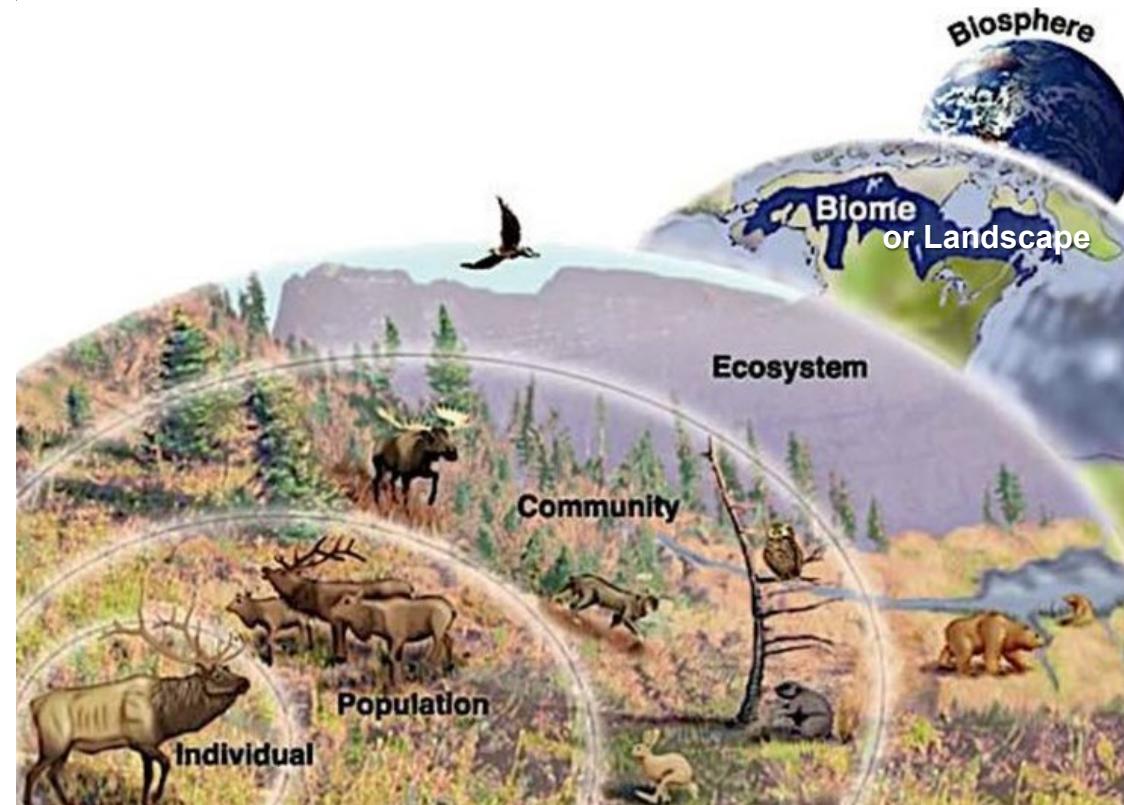
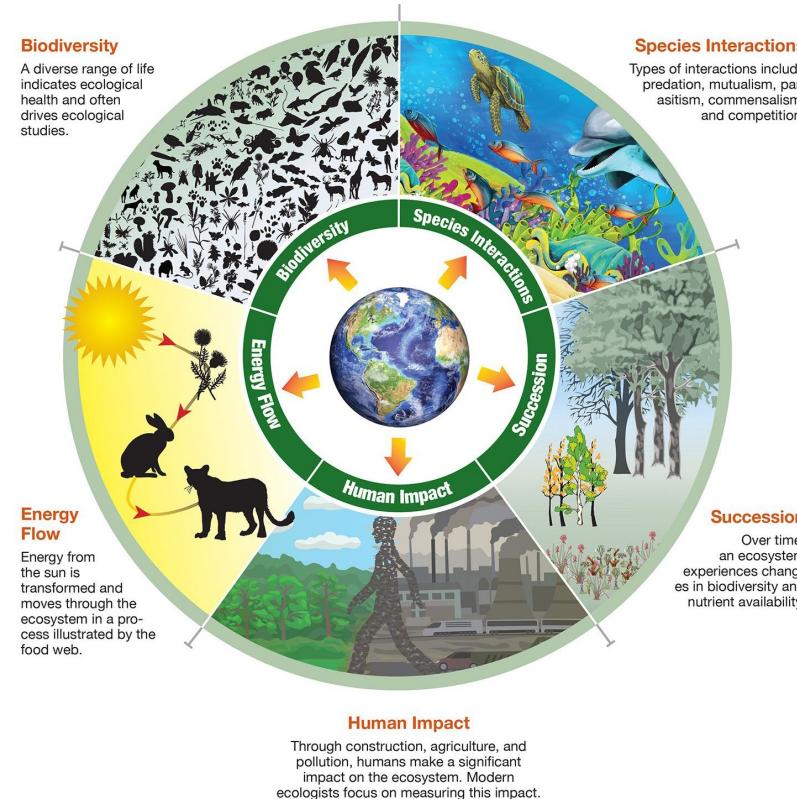
# PART I

## Predictive Ecology: what is it?

# Before we talk about Predictive Ecology...

## What is *ECOLOGY* to you?

*the study of the relationships between living organisms, including humans, and their physical environment, and the balances among these relationships.*



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# Before we talk about Predictive Ecology...

## Why is ECOLOGY important?

*provides information about the benefits of ecosystems and how we can use Earth's resources in ways that leave the environment healthy for future generations.*



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# Before we talk about Predictive Ecology...

## *What is **PREDICTION** to you?*

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### **predict** [ pri-dikt ] [SHOW IPA](#)

See synonyms for: **predict / predicted / predicting / predicts** on  
Thesaurus.com

#### *verb (used with object)*

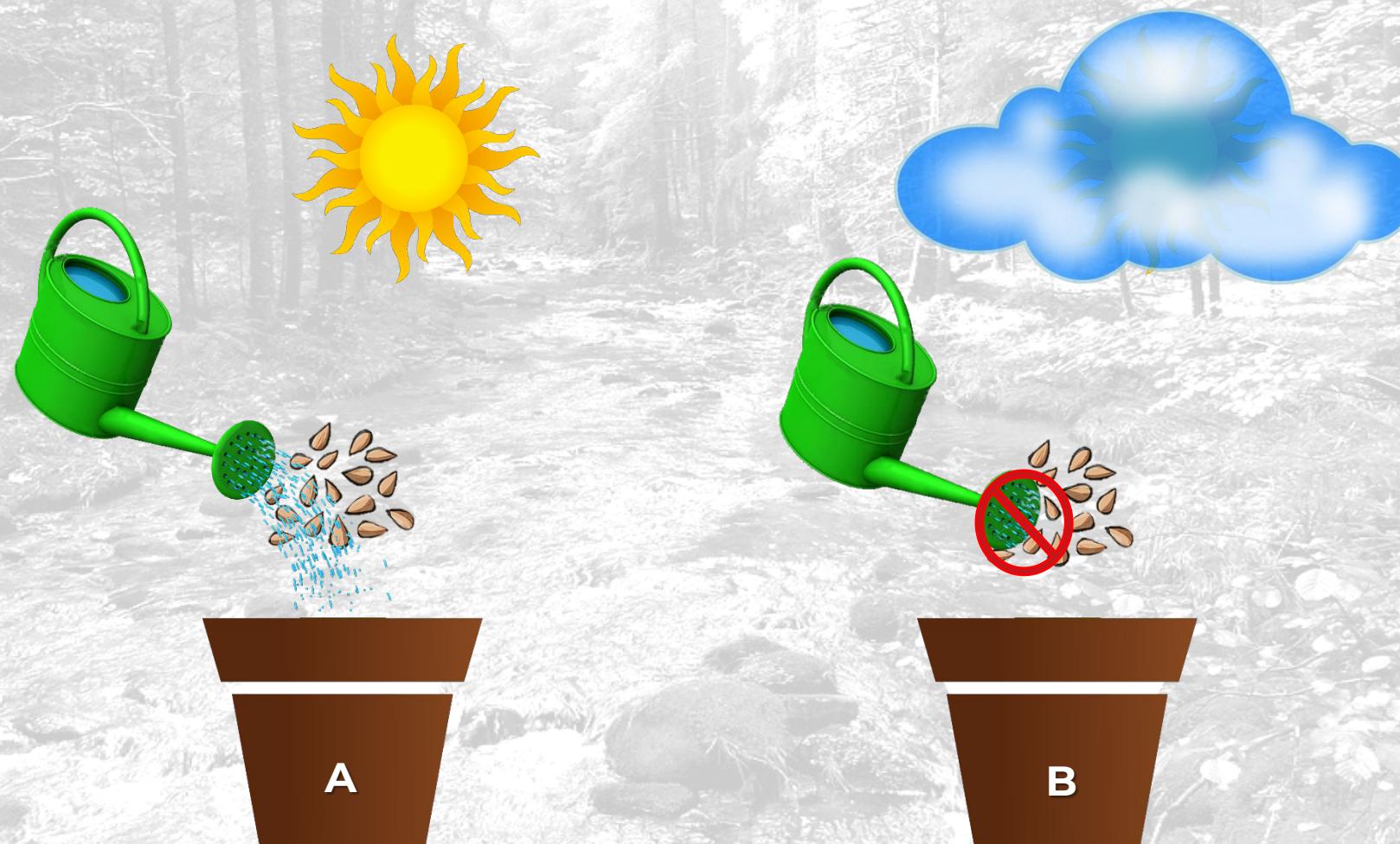
- 1 to declare or tell in advance; prophesy; foretell:  
*to predict the weather; to predict the fall of a civilization.*

#### *verb (used without object)*

- 2 to foretell the future; make a prediction.

# Before we talk about Predictive Ecology...

## *How to make PREDICTIONS?*



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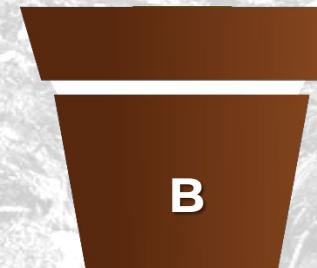
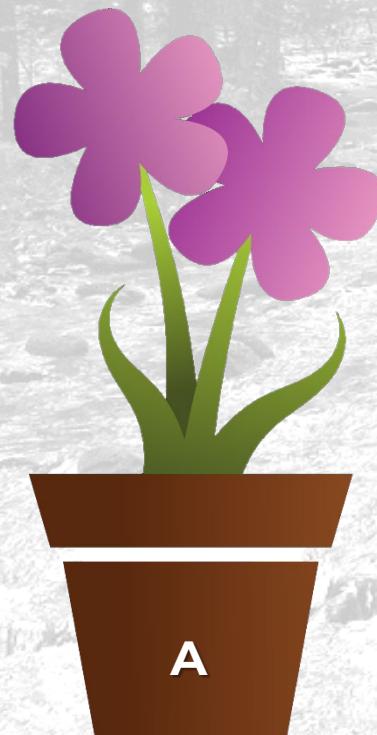
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# Before we talk about Predictive Ecology...

## *How to make PREDICTIONS?*



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# Before we talk about Predictive Ecology...

## *How to make PREDICTIONS?*

- Knowledge about how plants grow
- Knowledge about what plants need
- Knowledge about what happens when plants get what they need
- Knowledge about what happens when plants don't get what they need

**Use the knowledge about relationships  
to guess the future**

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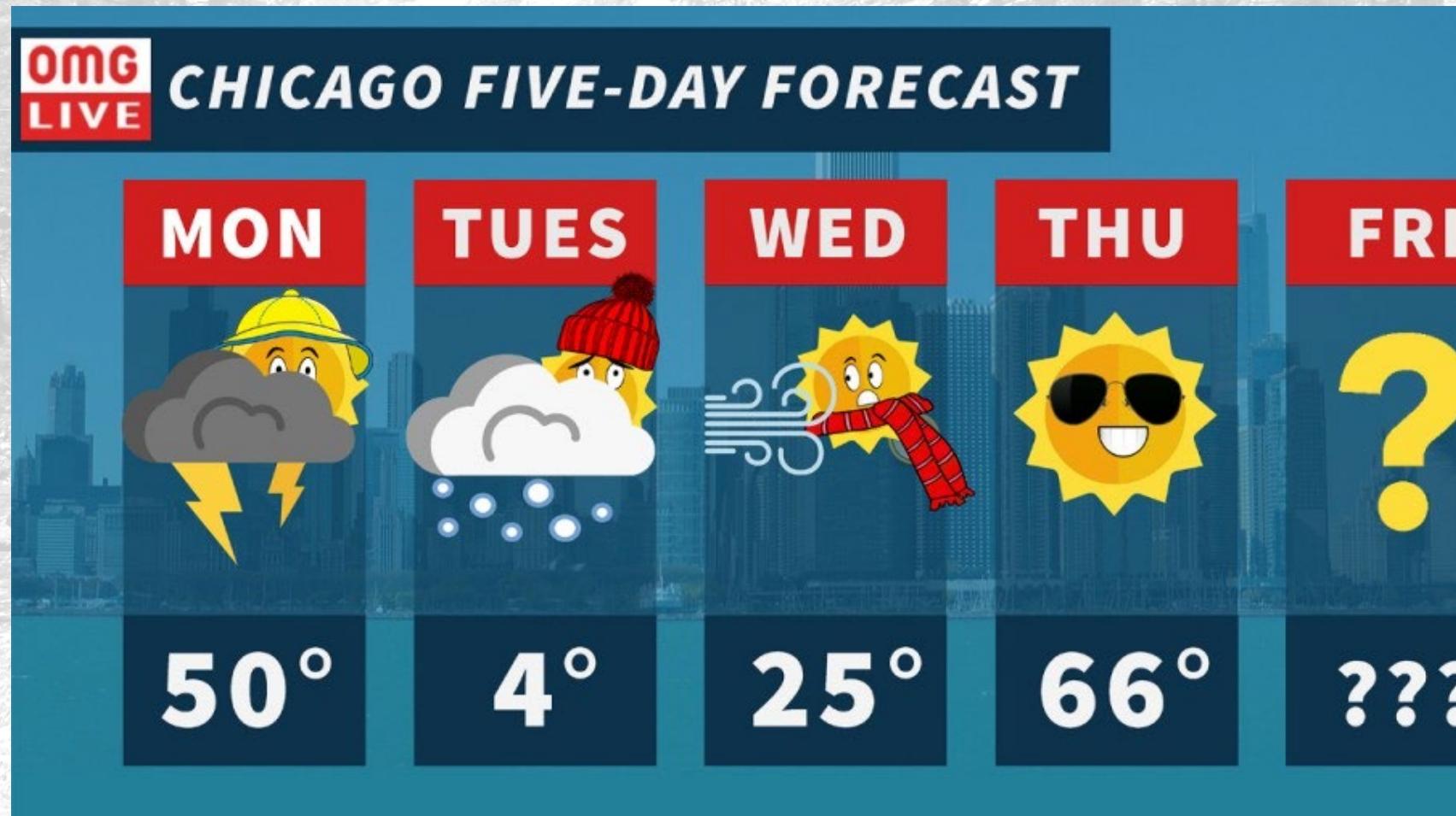
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# Do you care about Predictive Sciences?

*Why do you care about weather forecast?*



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# Do you care about Predictive Sciences?

*Why do you care about weather forecast?*

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# So, what is Predictive Ecology?

*Ecology + Prediction = Predictive Ecology*



Knowledge of a given relationship



Use this understanding to infer what might happen

In other words...

Predictive Ecology is an approach to studying ecological systems that relies on predicting outcomes that have not yet happened. -- Dr. Eliot McIntire



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# So, why should you care about Predictive Ecology?

*Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time.*

IPCC, 2019

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*Predictive Ecology can take ecology one step further and help us solve problems as quickly as possible, monitor the outcomes of our actions, and iteratively improve our actions to keep our goals on sight.*

# ANY QUESTIONS?

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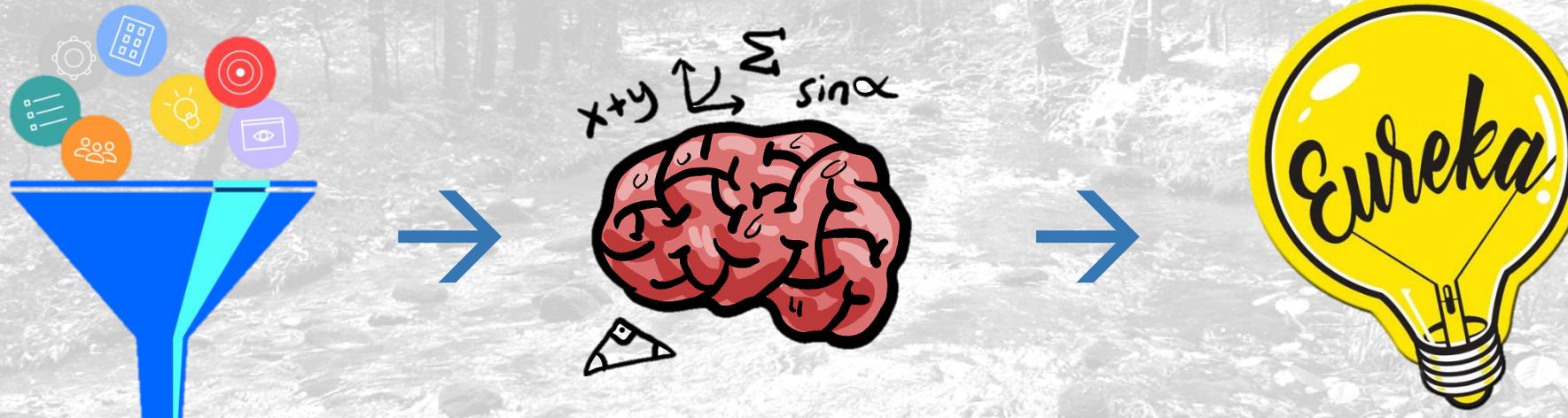
# PART II

## Predictive Ecology: The basics

# Predictive Ecology: The basics

## *What is modelling?*

- A model is a representation of a phenomenon, or of a system. It is a logical way of presenting a process.



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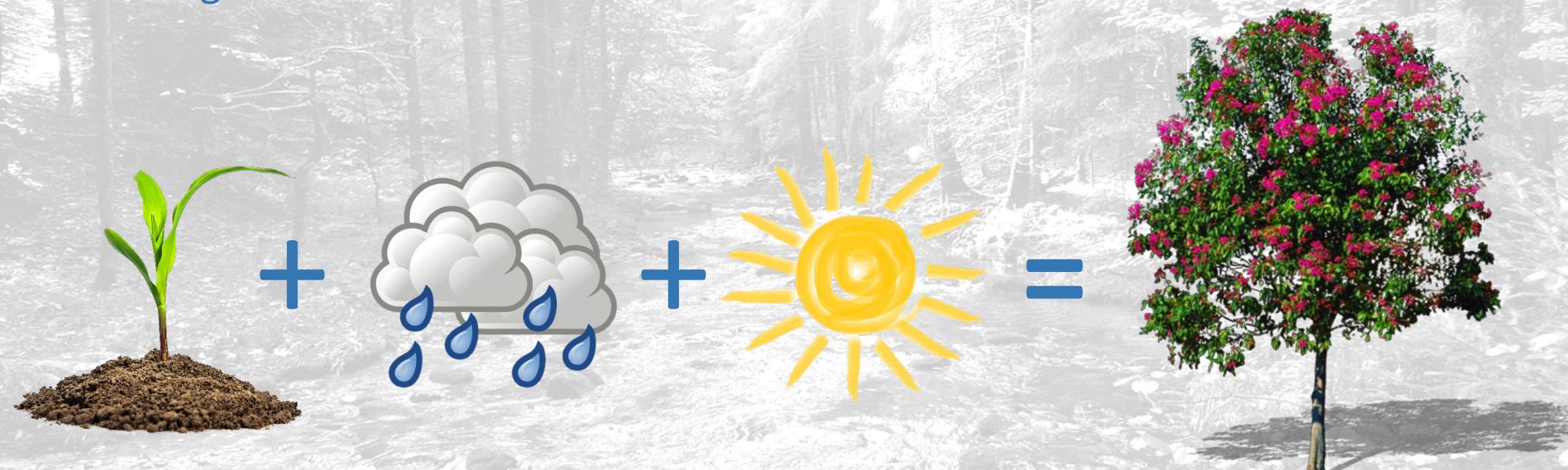
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# Predictive Ecology: The basics

## *What is modelling?*

- Plant growth model:



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# Predictive Ecology: The basics

## *What does ecological modelling mean?*

*the construction and analysis of mathematical models of ecological processes, including both purely biological and combined biophysical models.*

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# Predictive Ecology: The basics

## A more complex example: a community model

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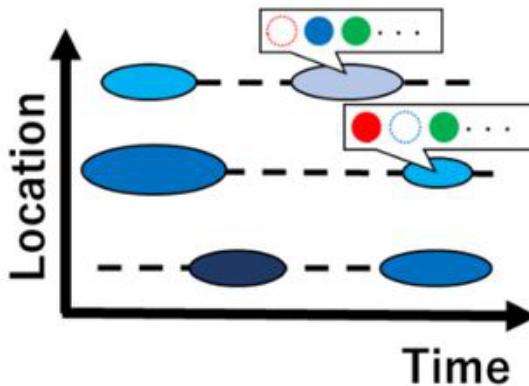
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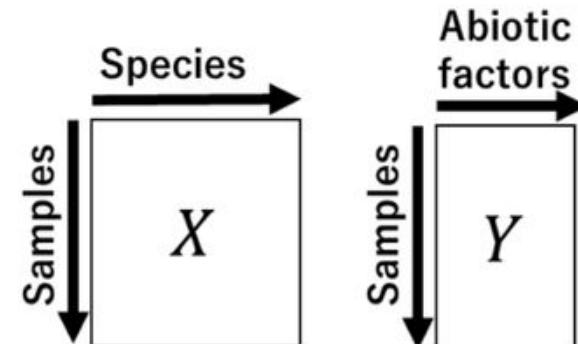
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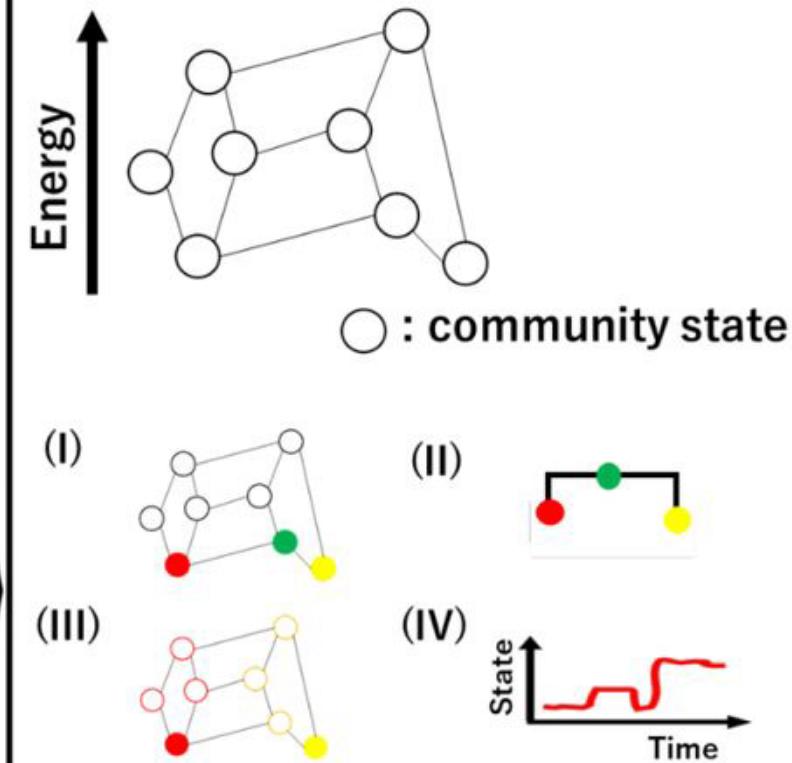
### (A) Ecological communities



### (B) Observational data



### (D) Energy landscape analysis



### (C) Fitting parameters of a pairwise maximum entropy model

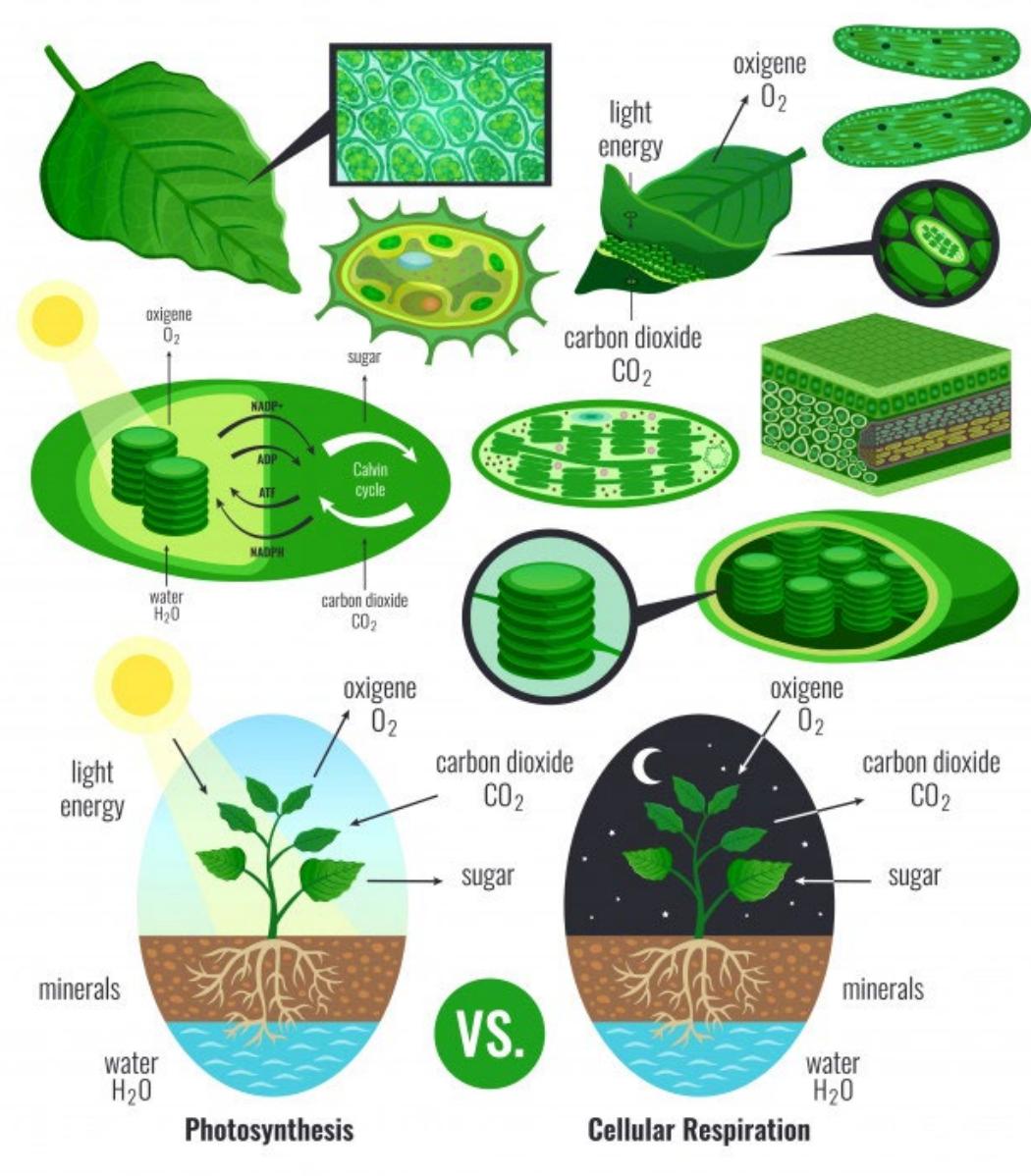
$$P(\sigma^{(k)}) \propto \left[ \begin{matrix} \text{Implicit} \\ \text{Abiotic} \\ \text{factors} \end{matrix} \right] + \left[ \begin{matrix} \text{Explicit} \\ \text{Abiotic} \\ \text{factors} \end{matrix} \right] + \left[ \begin{matrix} \text{Biotic} \\ \text{interactions} \end{matrix} \right].$$

# Predictive Ecology: The basics

*Two types of models:*

## 1. ANALYTICAL:

- Focus on explaining processes, based on inputs and outputs;
- Example: photosynthesis and respiration of a plant



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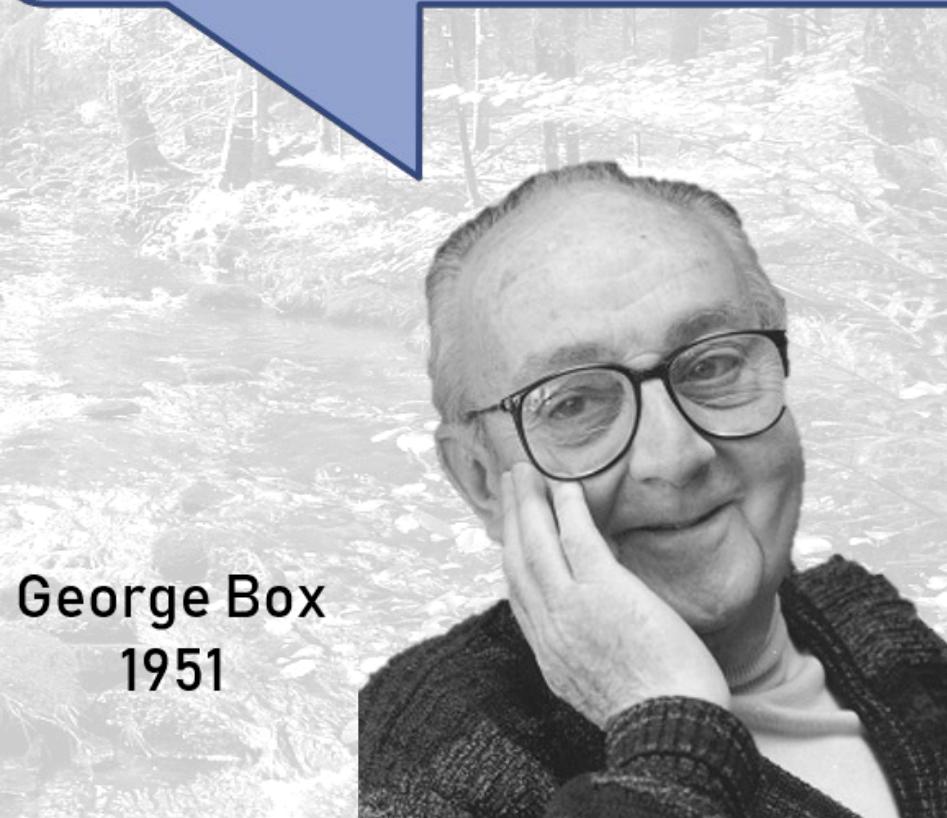
# Predictive Ecology: The basics

*Two types of models:*

## 1. ANALYTICAL:

- Focus on explaining processes, based on inputs and outputs;
- Example: photosynthesis and respiration of a plant

**All models are wrong;  
some are useful**



George Box  
1951

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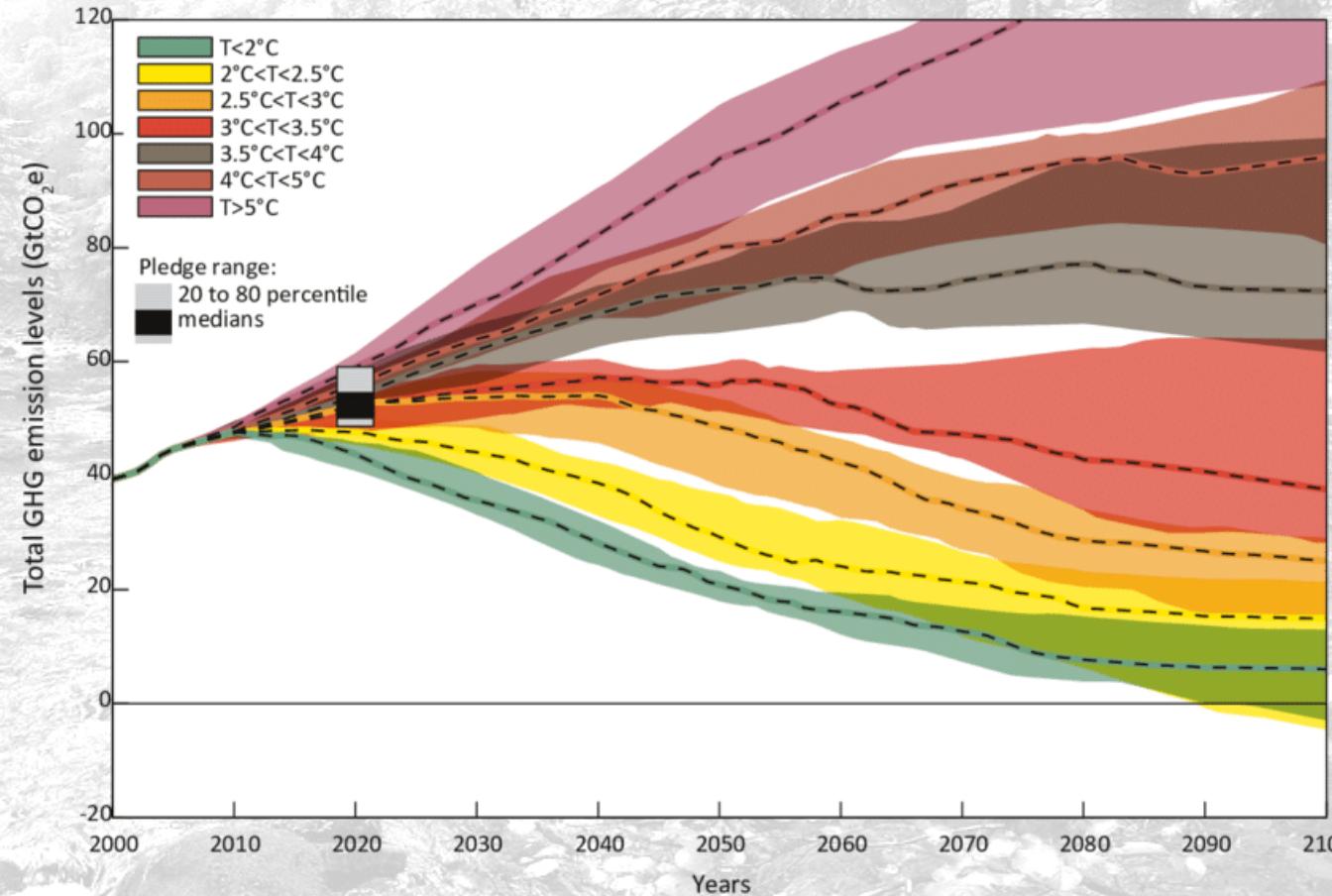
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# Predictive Ecology: The basics

*Two types of models:*

## 2. SIMULATION:

- Focus on predicting results;
- Example: climate models from IPCC



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# Predictive Ecology: The basics

*Two types of models:*

## 2. SIMULATION:

- Focus on predicting results;
- Example: climate models from IPCC

**All models are right;  
most are useless**



Thaddeus Tarpey  
2009

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# Predictive Ecology: The basics

*How can we make  
models more  
useful?*

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# ANY QUESTIONS?

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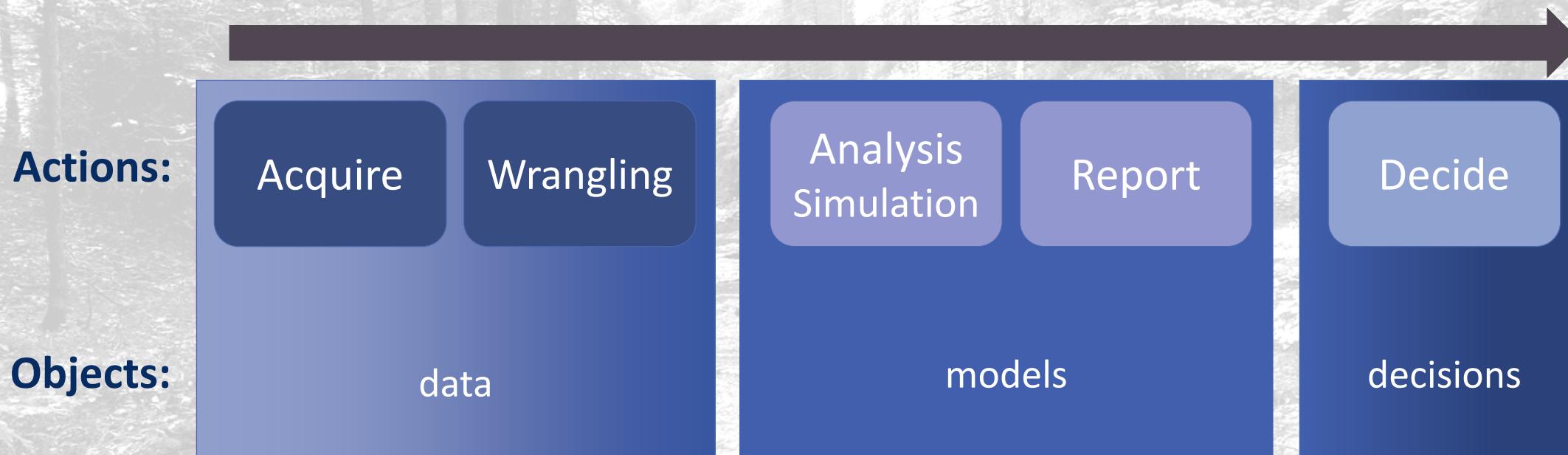
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# PART III

**Predictive Ecology: how can we do it right?**

# We need fast and informed decisions...



disjunct and performed in separate chunks

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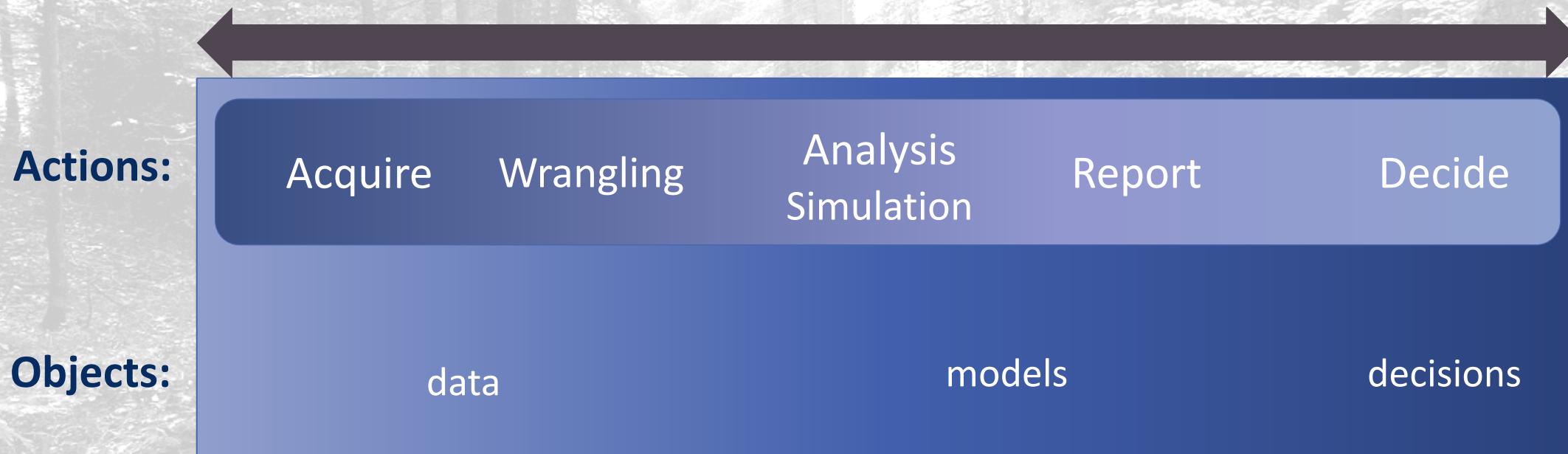
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# We need fast and informed decisions...



disjunct and performed in separate chunks

# For that, we need a better framework!

20 minutes to read...

## ECOLOGY LETTERS

Viewpoint |  Open Access |  

### PERFECT: A Re-imagined foundation for predictive ecology

Eliot J. B. McIntire  Alex M. Chubaty, Steven G. Cumming, Dave Andison, Ceres Barros, Céline Boisvenue, Samuel Haché, Yong Luo, Tatiane Micheletti, Frances E. C. Stewart

First published: 22 March 2022 | <https://doi.org/10.1111/ele.13994>

 SECTIONS

 PDF  COMMENTS  TOOLS  SHARE

### Abstract

Making predictions from ecological models—and comparing them to data—offers a coherent approach to evaluate model quality, regardless of model complexity or modelling paradigm. To date, our ability to use predictions for developing, validating, updating, integrating and applying models across scientific disciplines while influencing management decisions, policies, and the public has been hampered by disparate perspectives on prediction and inadequately integrated approaches. We present an updated foundation for Predictive Ecology based on seven principles applied to ecological modelling: make frequent Predictions, Evaluate models, make models Reusable, Freely accessible and Interoperable, built within Continuous workflows that are routinely Tested (PERFECT). We outline some benefits of working with these principles: accelerating science; linking with data science; and improving science-policy integration.

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# The PERFECT approach to Predictive Ecology

## How can we make predictive models more useful?

- Predict frequently,
- Evaluate models, make models
- Reusable
- Freely accessible and
- Interoperable built within
- Continuous workflows that are routinely
- Tested

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# The PERFECT approach to Predictive Ecology

## What are the benefits of this approach?

### 1. Accelerating science:

- **Occam's razor:** Assessing right model complexity by comparing models;
- **Informative priors:** Bringing results from previous studies to new ones (Northrup & Gerber, 2018);
- **Forecast horizon:** Iterative forecasts with new data and models (Petchey et al., 2015);
- **Community of contributors:** Enables large projects with many contributors and updates(Fer et al., 2021)
- **Predictive validation:** Using future data to test models (Power, 1993)
- **Rewriting models:** Using widely known languages increases access (Thiele & Grimm, 2015)
- **Many eyes:** Understandable and open models more easily allow for fixing bugs and identifying improvements

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# The PERFECT approach to Predictive Ecology

## What are the benefits of this approach?

### 2. Bridging to Data Science:

- **Building on data science tools:** Facilitating cloud computing and repositories, user access control and data caching improves assess to modelling process
- **Data quality and quantity:** Building data-model-validation pipelines from reusable components allowing for assessment of different data sources (White et al., 2019)
- **Linking models to data:** Maintaining linkages between canonical data sources and models for rapid re-parameterization and updating with continuous testing (Micheletti et al., 2021)

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# The PERFECT approach to Predictive Ecology

## What are the benefits of this approach?

### 3. Improving science-policy integration:

- **Cross disciplinarity:** Lessening the technological, data and cultural barriers that make cross-disciplinary work challenging (Chassé et al., 2020)
- **Regular reporting:** Reducing the effort required to produce regular updates for policy reporting
- **IPCC-like process:** Allows lower budget projects to achieve IPCC-like integration (Masson-Delmotte et al., 2021)
- **Different users:** Allows for all types of expertise to interact (Ferraz et al., 2021)
- **Web and decision support applications:** Allows for the development of generic web and decision support tools—“dashboards”—that can be reused widely
- **Coping with contradictions:** Opening the science informed decision-making and policy-making process to shed light on cases where models contradict one another and offering an objective way to resolve those contradictions

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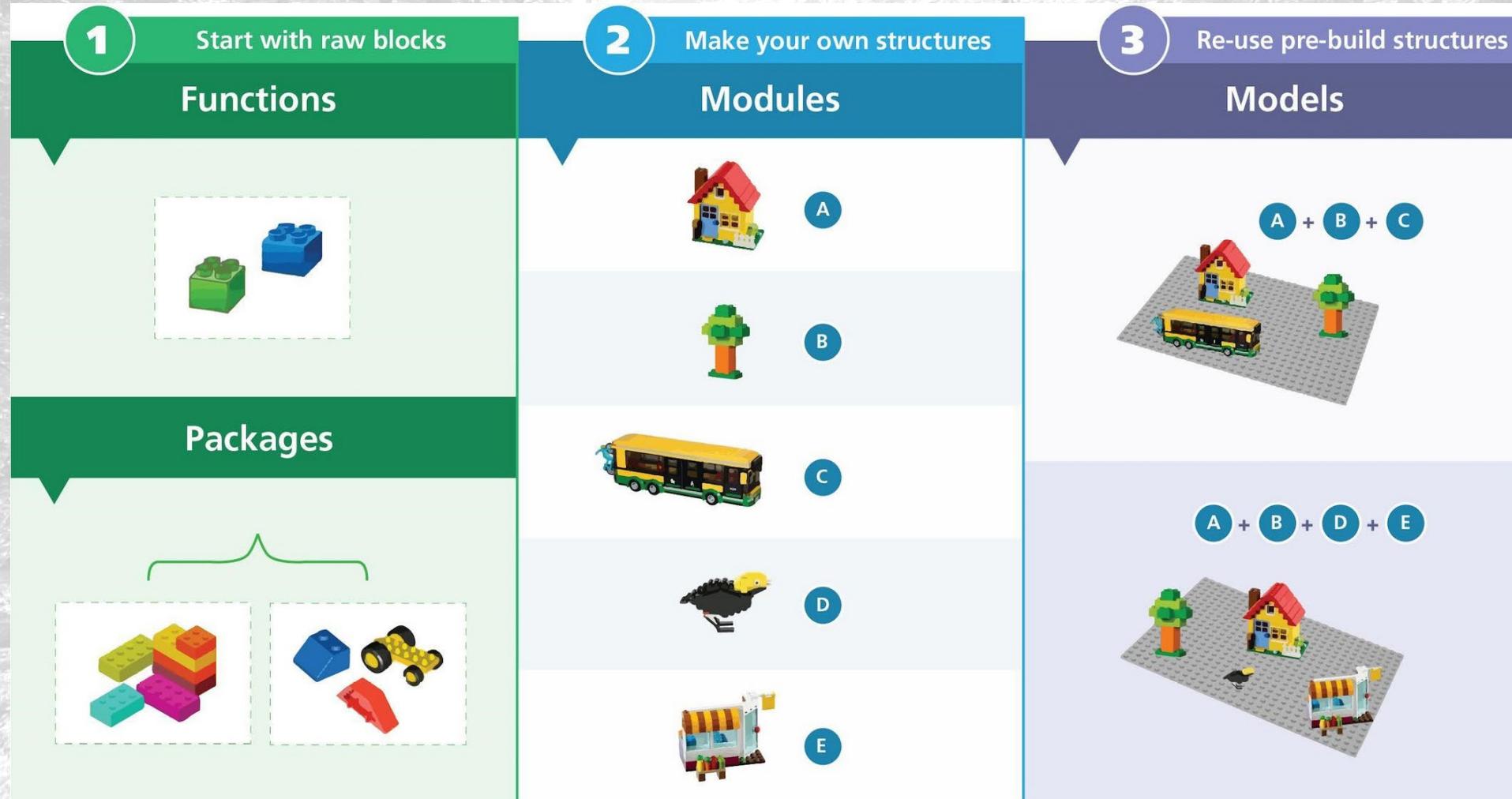
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# The PERFECT approach to Predictive Ecology

## But how can we do this in practice?



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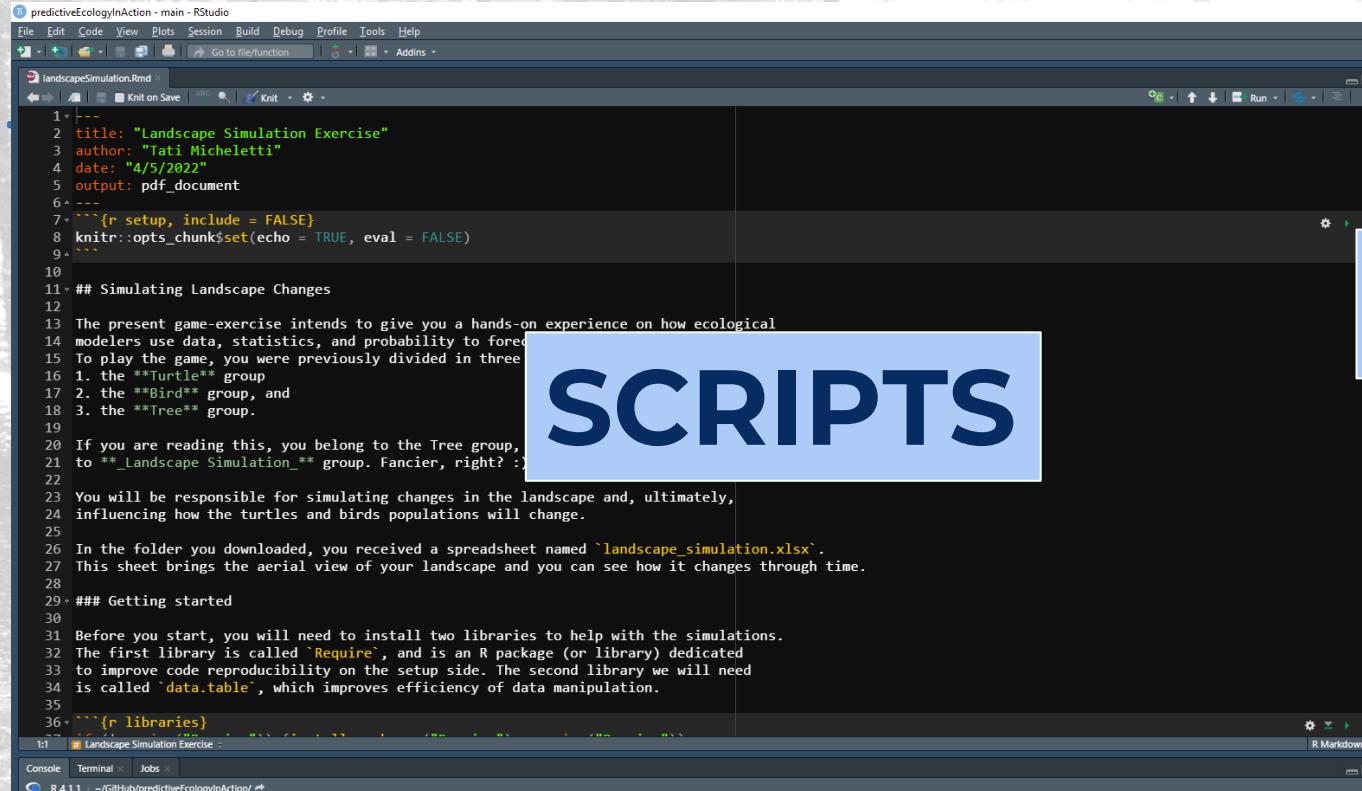
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# Important tools: the power of R and version control



```

1 ---  

2 title: "Landscape Simulation Exercise"  

3 author: "Tati Micheletti"  

4 date: "4/5/2022"  

5 output: pdf_document  

6 ---  

7 ```{r setup, include = FALSE}  

8 knitr::opts_chunk$set(echo = TRUE, eval = FALSE)  

9 ```  

10  

11 ## Simulating Landscape Changes  

12  

13 The present game-exercise intends to give you a hands-on experience on how ecological  

14 modelers use data, statistics, and probability to forecast changes in landscapes.  

15 To play the game, you were previously divided in three groups:  

1. the **Turtle** group  

2. the **Bird** group, and  

3. the **Tree** group.  

16  

17 If you are reading this, you belong to the Tree group,  

18 to **_Landscape Simulation_** group. Fancier, right? :)  

19  

20 You will be responsible for simulating changes in the landscape and, ultimately,  

21 influencing how the turtles and birds populations will change.  

22  

23 In the folder you downloaded, you received a spreadsheet named `landscape_simulation.xlsx`.  

24 This sheet brings the aerial view of your landscape and you can see how it changes through time.  

25  

26 ## Getting started  

27  

28 Before you start, you will need to install two libraries to help with the simulations.  

29 The first library is called 'Require', and is an R package (or library) dedicated  

30 to improve code reproducibility on the setup side. The second library we will need  

31 is called 'data.table', which improves efficiency of data manipulation.  

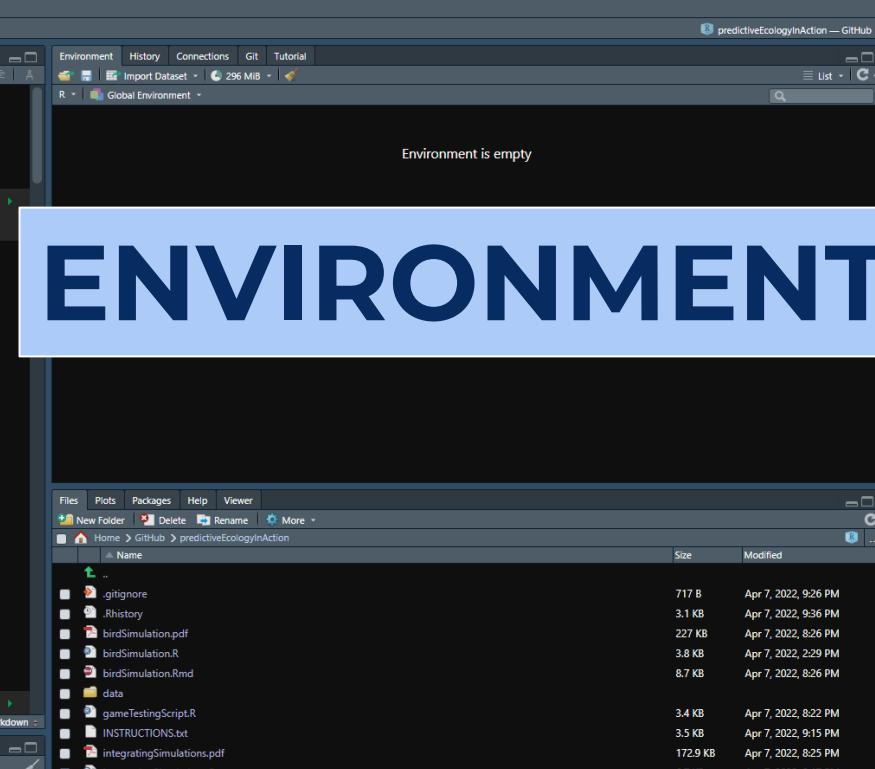
32  

33 ## Libraries  

34

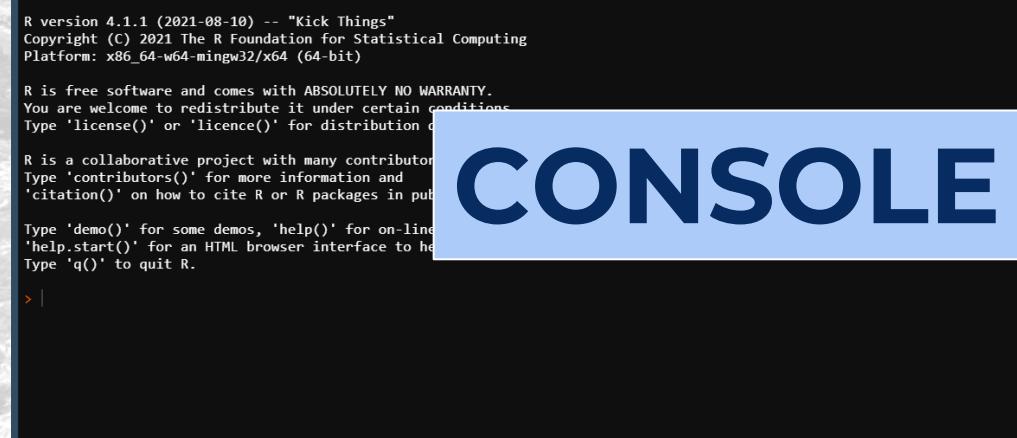
```

SCRIPTS



Environment is empty

ENVIRONMENT



```

R version 4.1.1 (2021-08-10) -- "Kick Things"
Copyright (C) 2021 The R Foundation for Statistical Computing
Platform: x86_64-w64-mingw32/x64 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line
'help.start()' for an HTML browser interface to help
Type 'q()' to quit R.

>

```

CONSOLE



| Name                       | Size     | Modified             |
|----------------------------|----------|----------------------|
| ..                         |          |                      |
| .gitignore                 | 717 B    | Apr 7, 2022, 9:26 PM |
| .Rhistory                  | 3.1 KB   | Apr 7, 2022, 9:36 PM |
| birdSimulation.pdf         | 227 KB   | Apr 7, 2022, 8:26 PM |
| birdSimulation.R           | 3.8 KB   | Apr 7, 2022, 2:29 PM |
| birdSimulation.Rmd         | 8.7 KB   | Apr 7, 2022, 8:26 PM |
| data                       |          |                      |
| gameTestingScript.R        | 3.4 KB   | Apr 7, 2022, 8:22 PM |
| INSTRUCTIONS.txt           | 3.5 KB   | Apr 7, 2022, 9:15 PM |
| integratingSimulations.pdf | 172.9 KB | Apr 7, 2022, 8:25 PM |
| integratingSimulations.R   | 6.7 KB   | Apr 7, 2022, 8:17 PM |

FILES, GRAPHS,  
HELP

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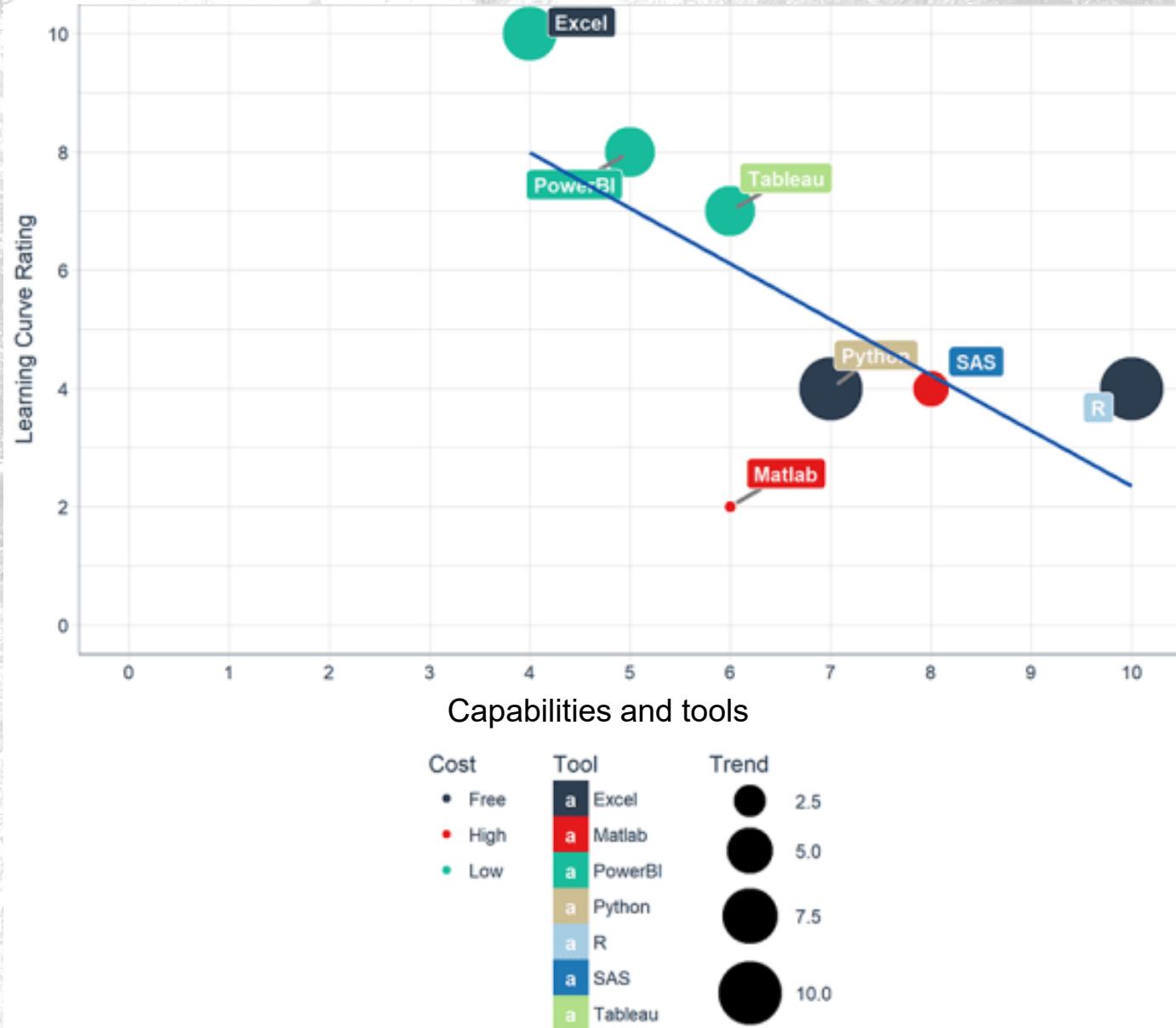
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# Important tools: the power of R and version control

- What is  ?
- Why  ?



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# Important tools: the power of R and version control

- What is  ?

- Why  ?

- Advantages and disadvantages of 

Lots of packages

Huge community

Free and open-source

Handles all sorts of data

Several graphical libraries

Easier automation of tasks

Fast if you know how to code

Logical Language (once you learned it)

Compatible with most other platforms

Powerful with more complex statistical analysis

Handles the full workflow from data to reporting

Security

Some packages' quality

Generally harder to learn than Excel or Tableau



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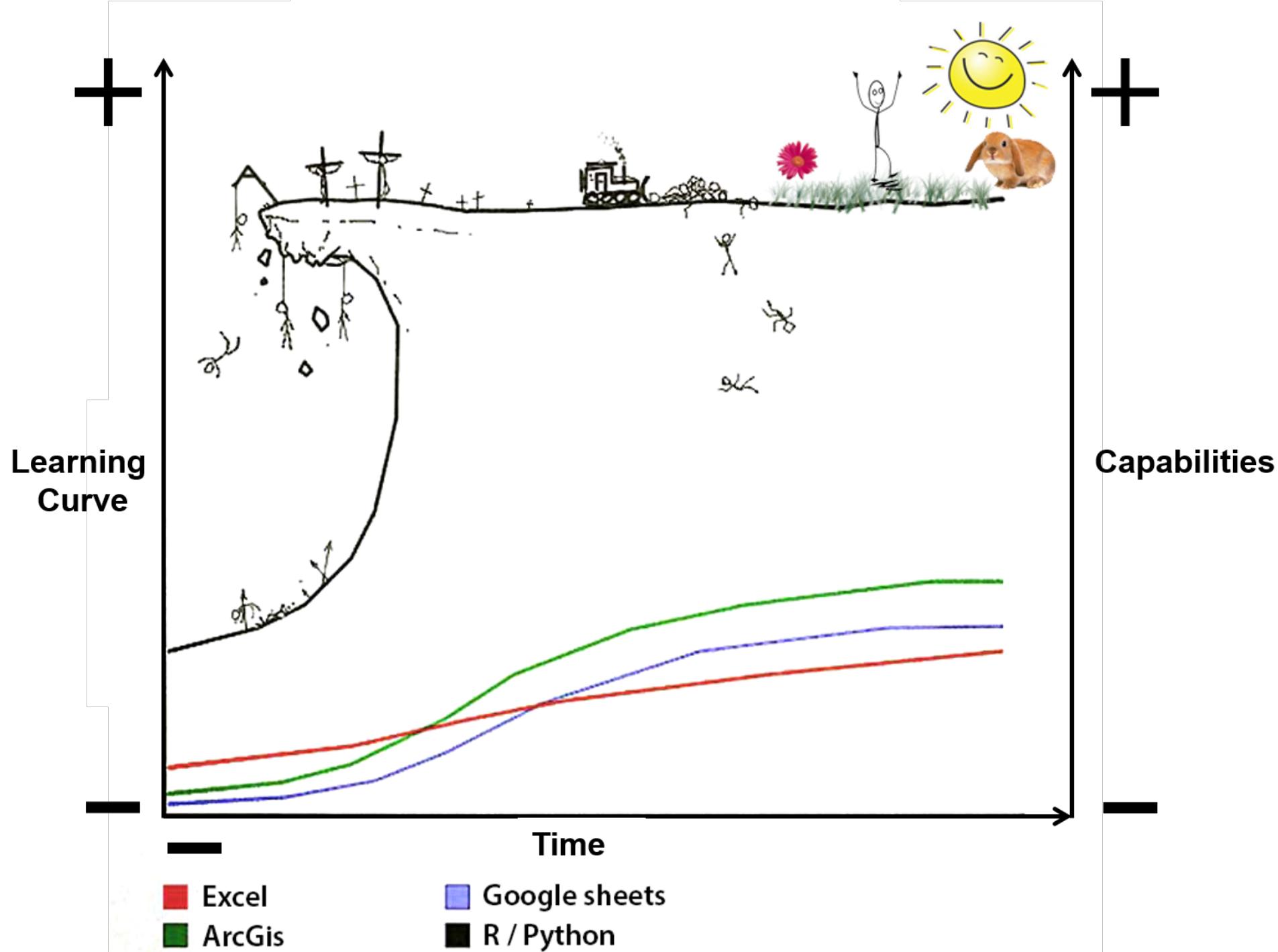
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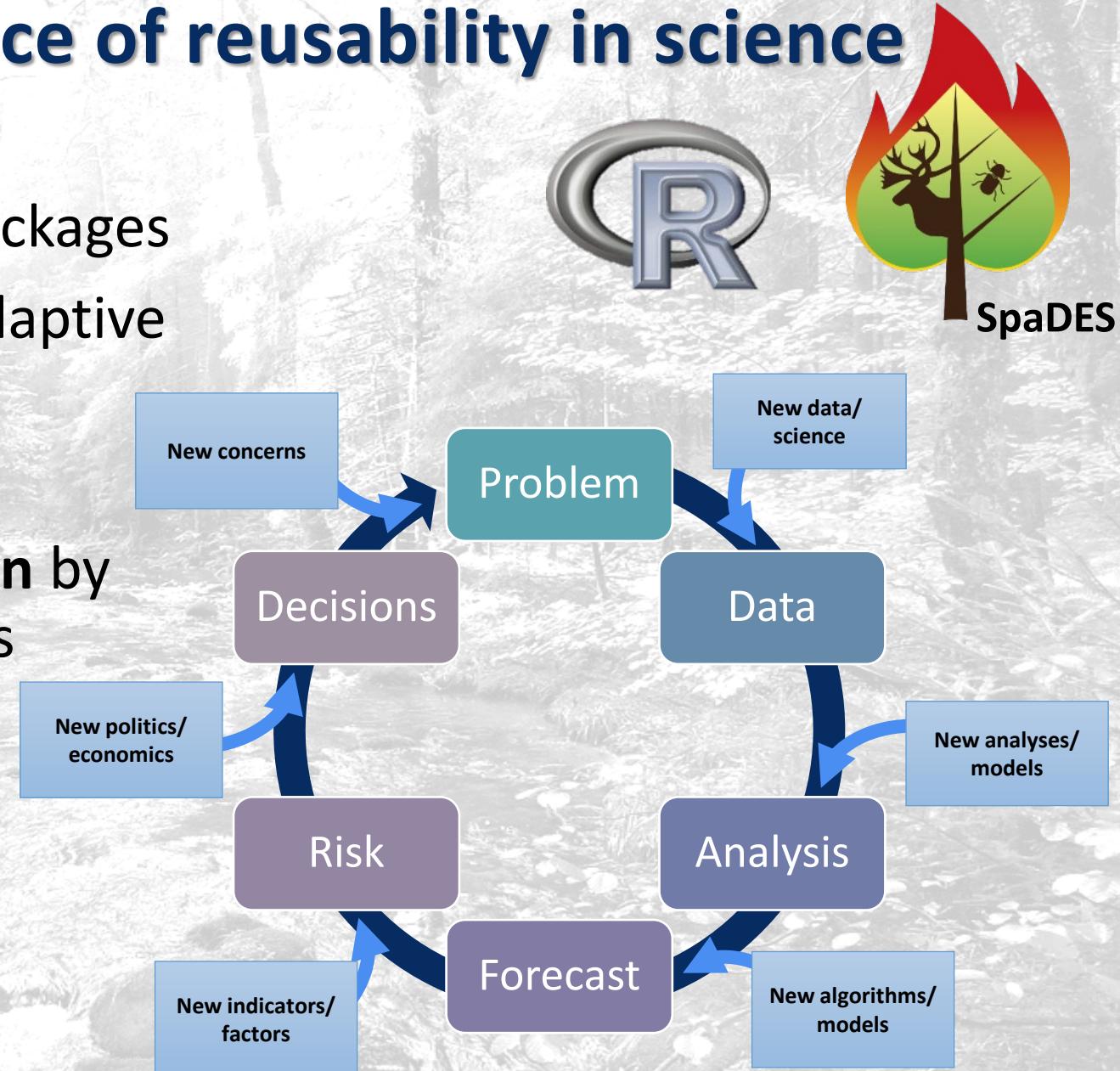
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# SpaDES: the importance of reusability in science

- ♠ **Modelling tool:** set of R Packages
- ♠ **Framework:** continuous adaptive management
- ♠ **Metadata** is mandatory
- ♠ Promotes easier **integration** by declared inputs and outputs



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# Big projects with management focus?

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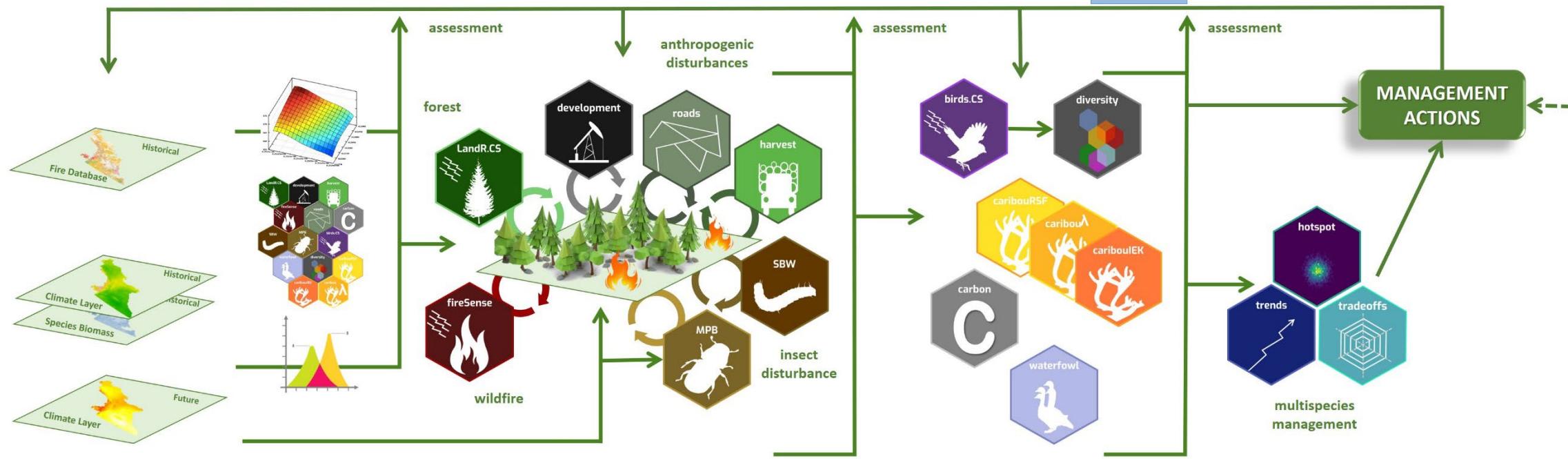
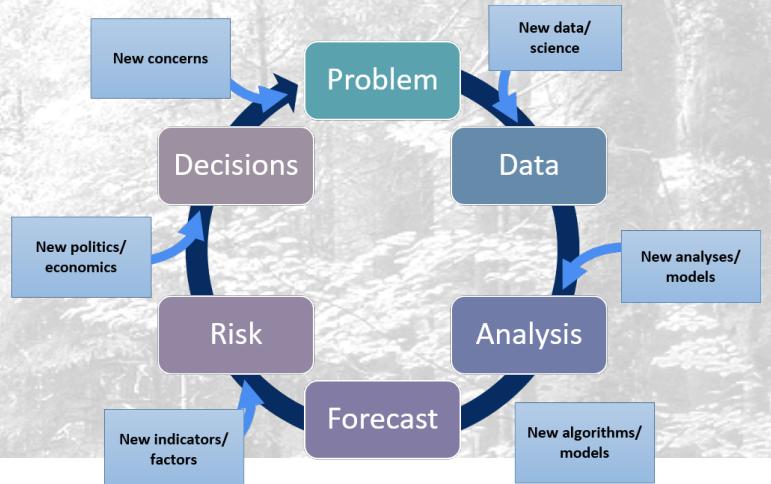
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data processing

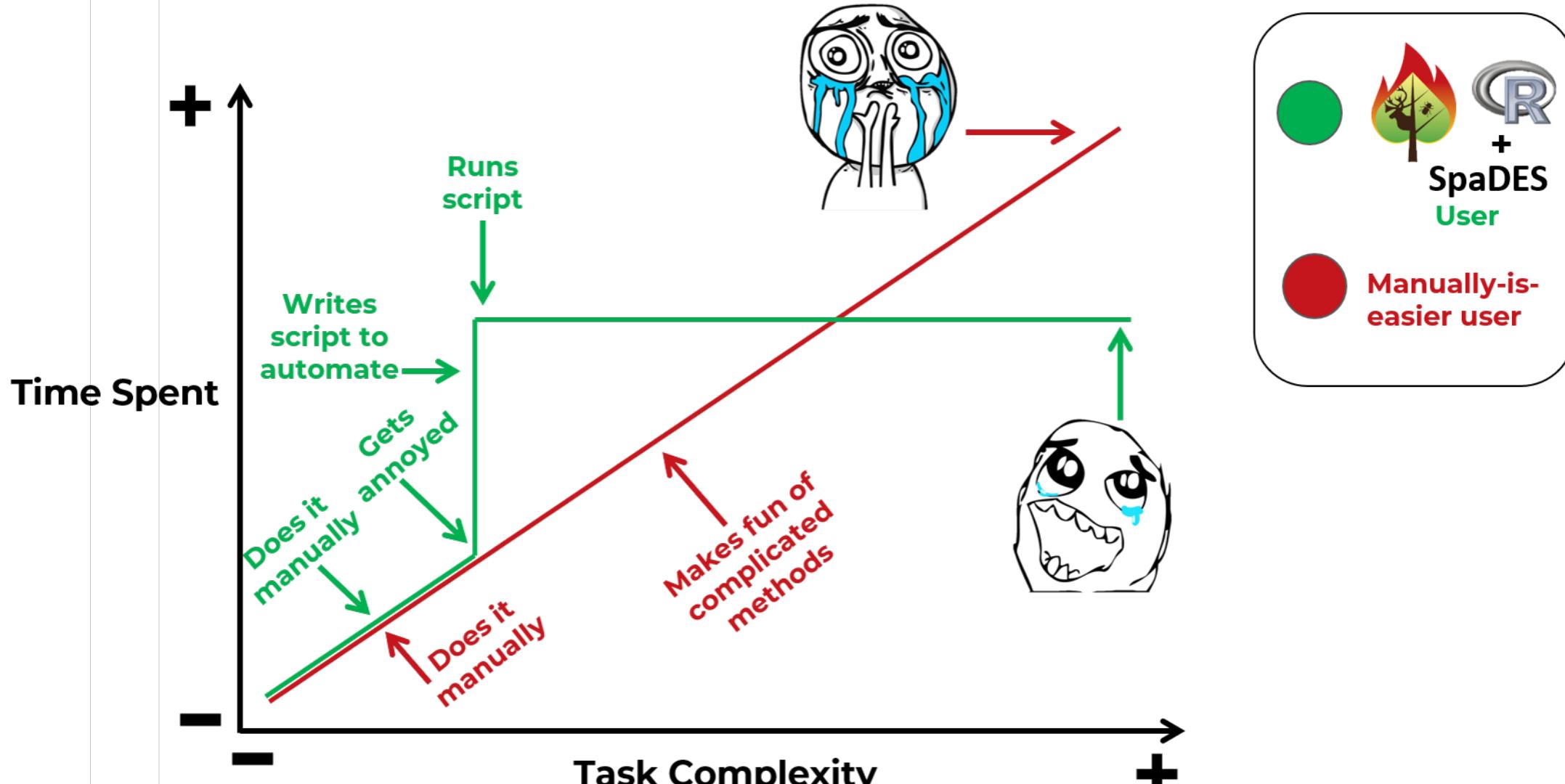
landscape simulation

valued ecosystem components

valued outcomes

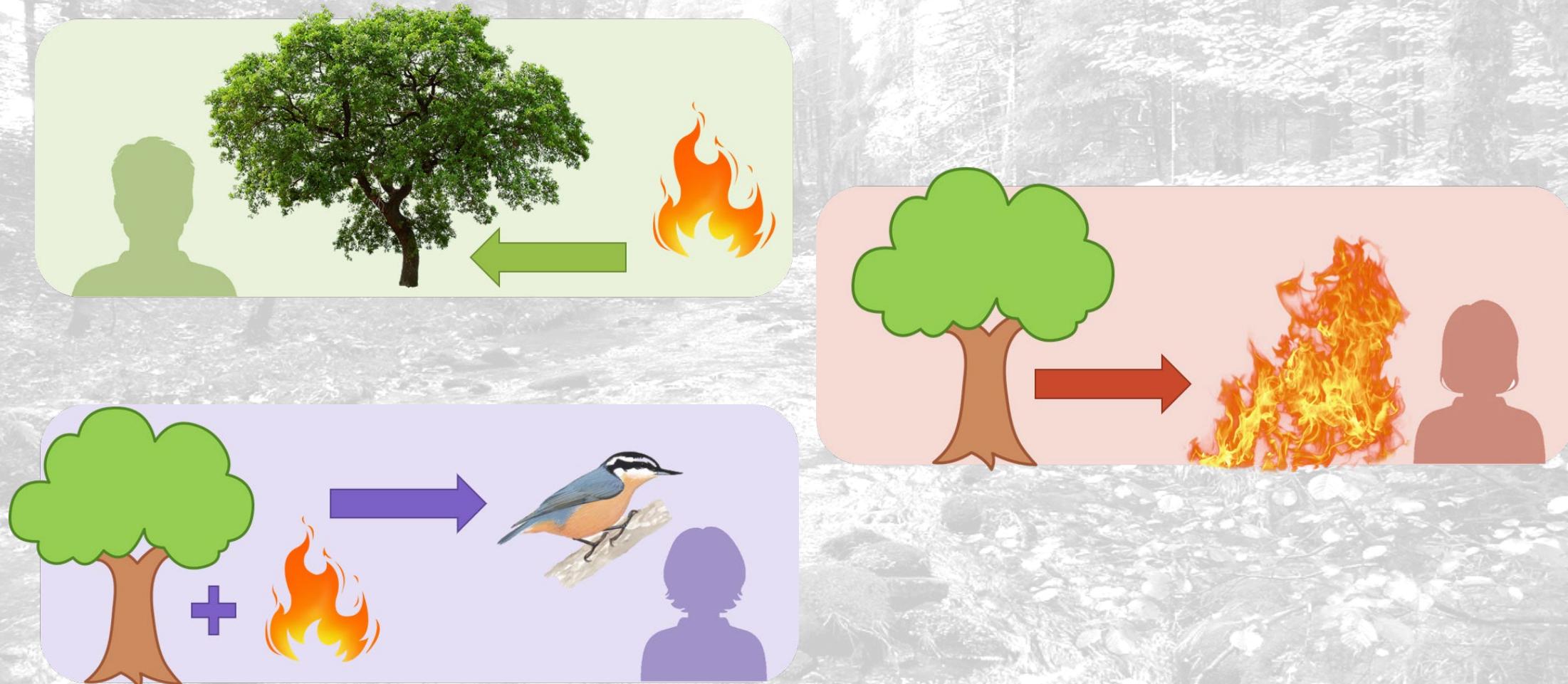
policy

## Iterative Scripting vs Manual Approach



# Bringing these concepts to an example

Nobody is an expert in everything



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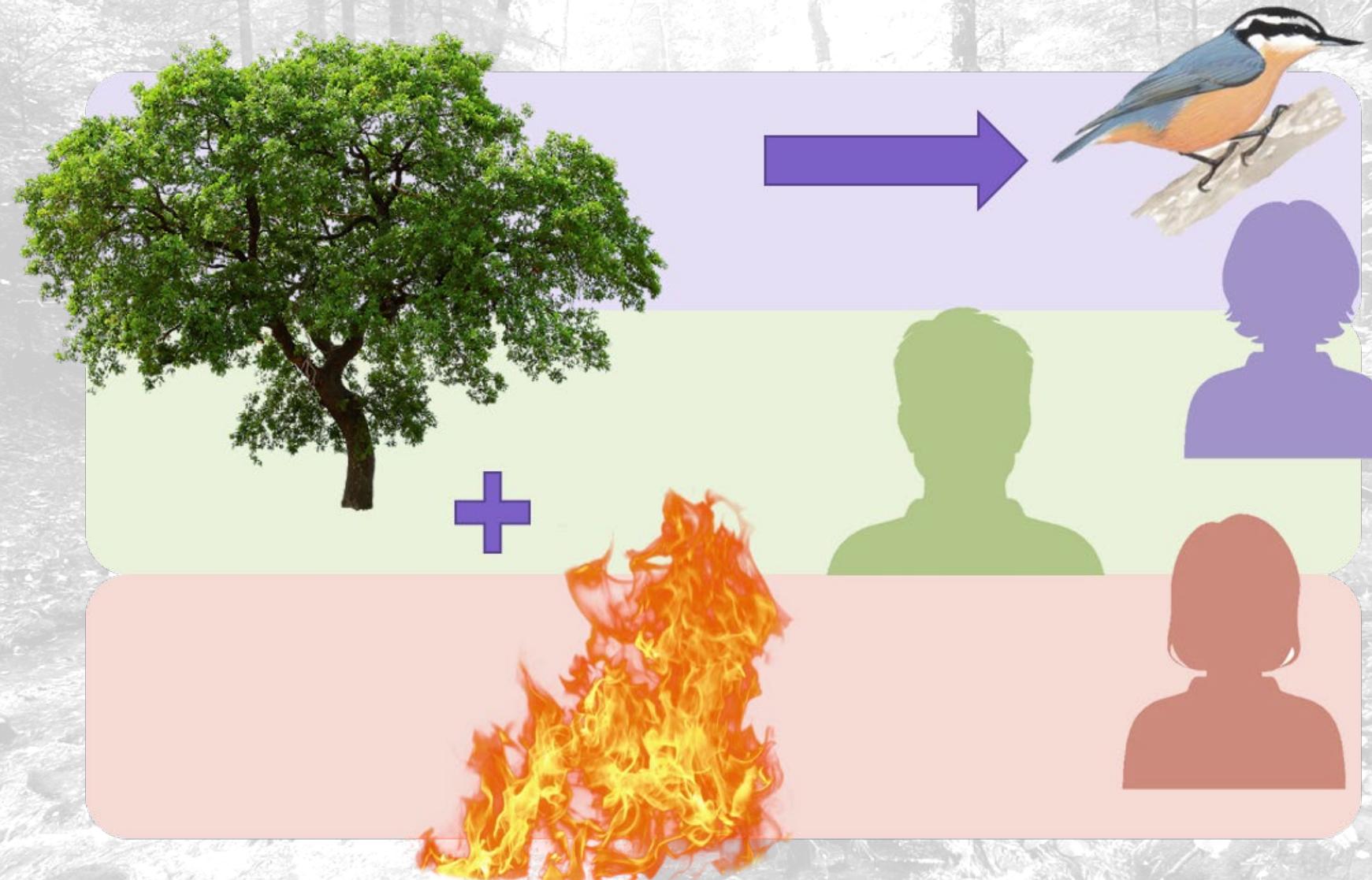
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# Bringing these concepts to an example



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Integrating transdisciplinary efforts is key to improve our power of action in changing the world to a better place!



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# ANY QUESTIONS?

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# PART IV

## Predictive Ecology: a real example

# We are running out of time and need to address several aspects of conservation!



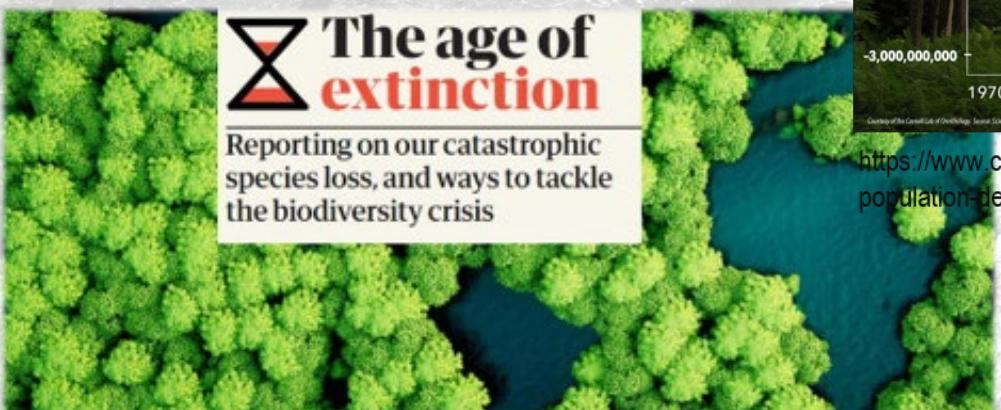
Politics

## Woodland caribou continue to decline as provinces fail to meet protection deadline



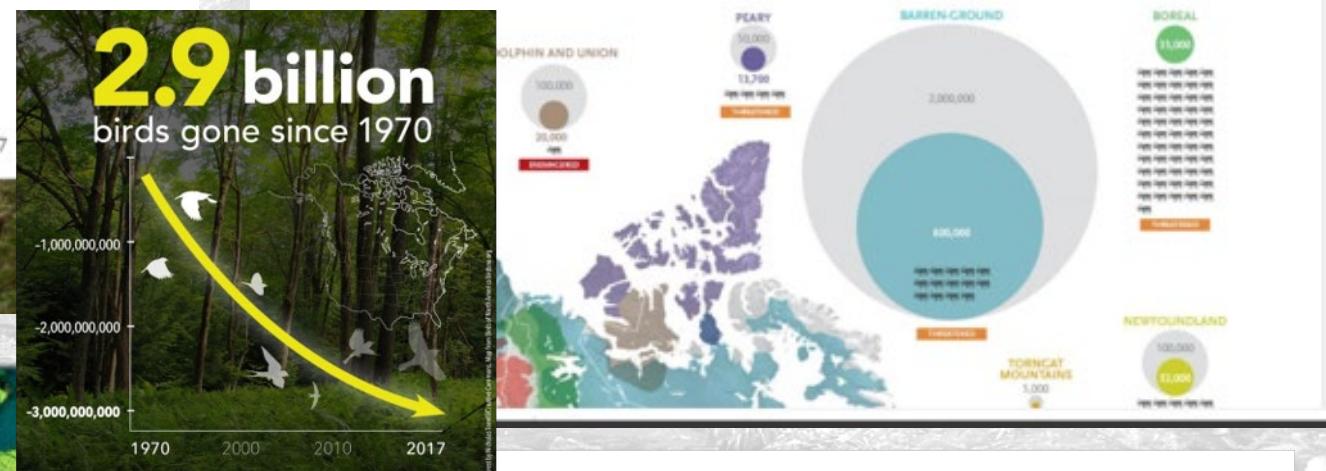
In the meantime, caribou, and their habitat continue to decline

Susan Lunn · CBC News · Posted: Oct 31, 2017 12:01 PM ET | Last Updated: October 31, 2017



## Mapping the decline of Canada's caribou

A snapshot of the country's drastically dwindling caribou herds



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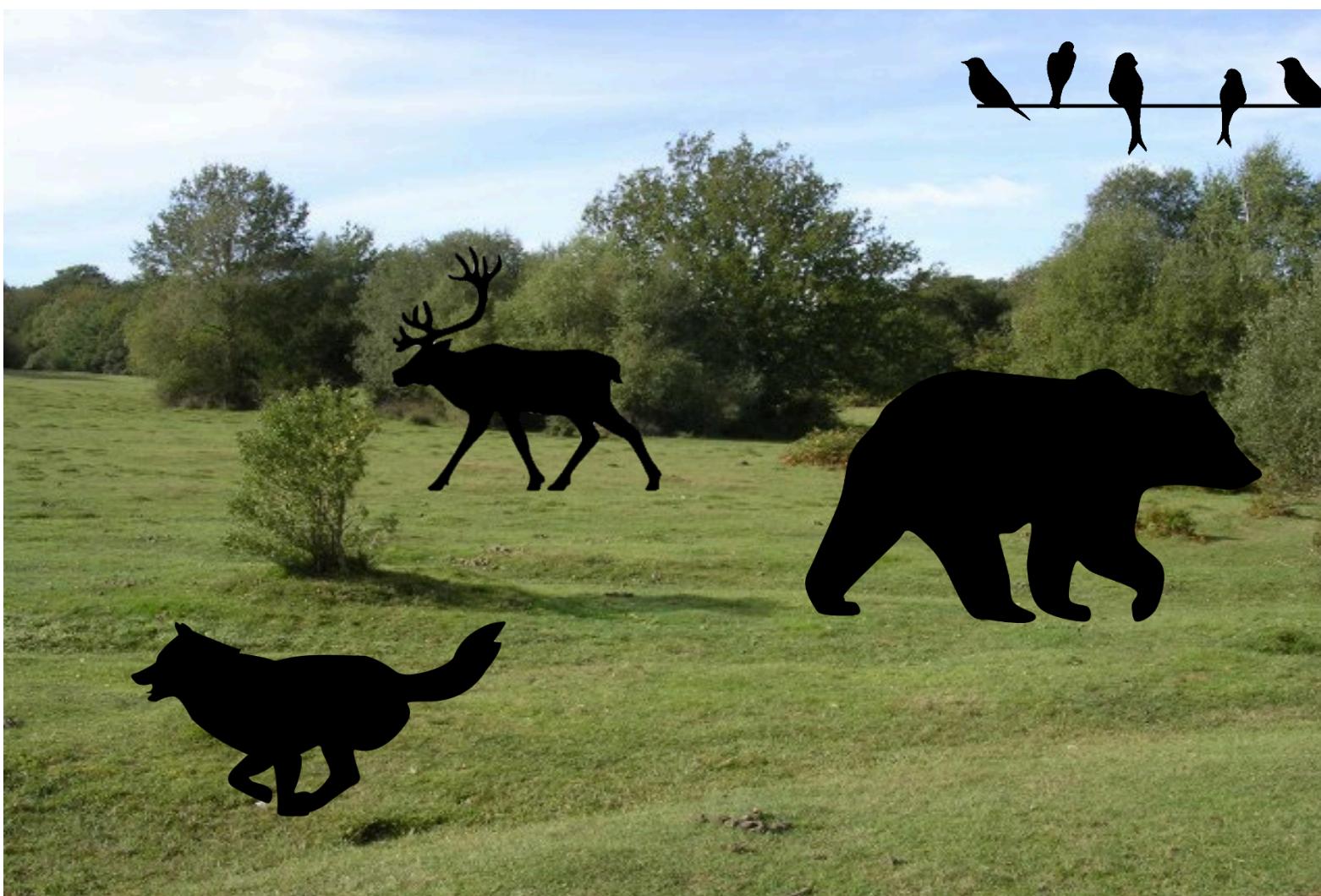
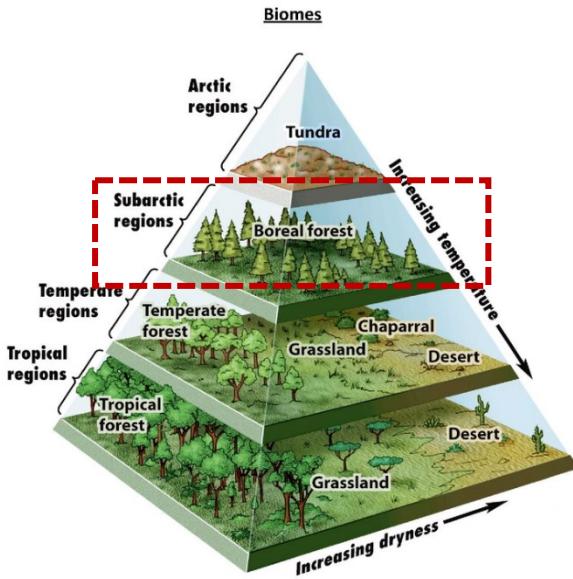
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# Northern Boreal Forests are especially sensitive to changes



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# The Western Boreal Initiative: From the Northwest Territories to West Canada



Western  
Boreal  
Initiative



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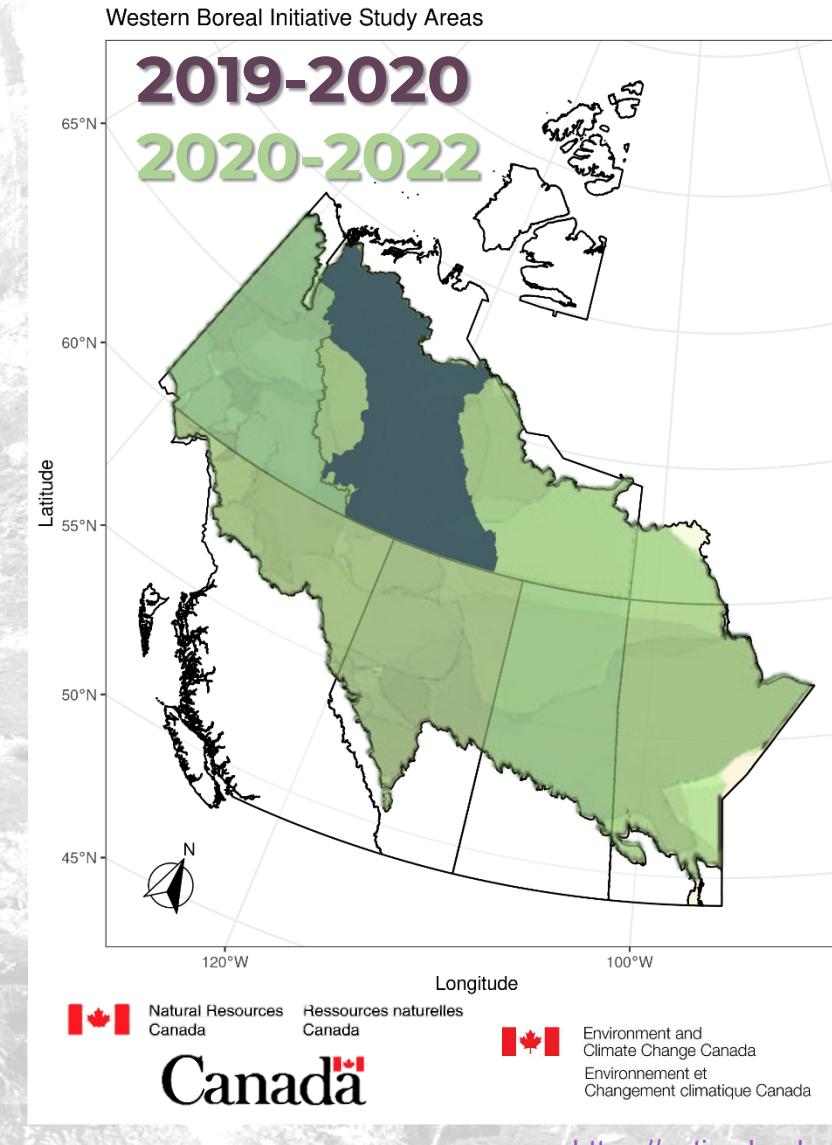
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# Research Team



THE UNIVERSITY  
OF BRITISH COLUMBIA



UNIVERSITÉ  
**LAVAL**



UNIVERSITY OF  
**ALBERTA**



Boreal Avian  
Modelling Project  
  
Project de modélisation  
aviaire boréal

[tati.silva@ubc.ca](mailto:tati.silva@ubc.ca)



@PredictiveEcol



Natural Resources  
Canada

Ressources naturelles  
Canada

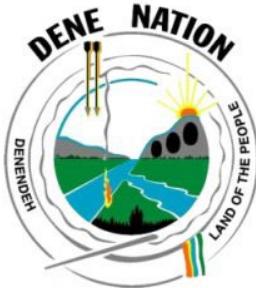
**Canada**



Environment and  
Climate Change Canada

**Canada**

@PredictiveEcol



Eliot McIntire



Western  
Boreal  
Initiative

Samuel Hache

Dene First Nations

Frances Stewart

Diana Stralberg

Junior Tremblay

Mathieu Leblond

Alex Chubaty

James Hodson

Steve Cumming

Celine Boisvenue

Greg Paradis

Ian Eddy

Ceres Barros

... and many others!

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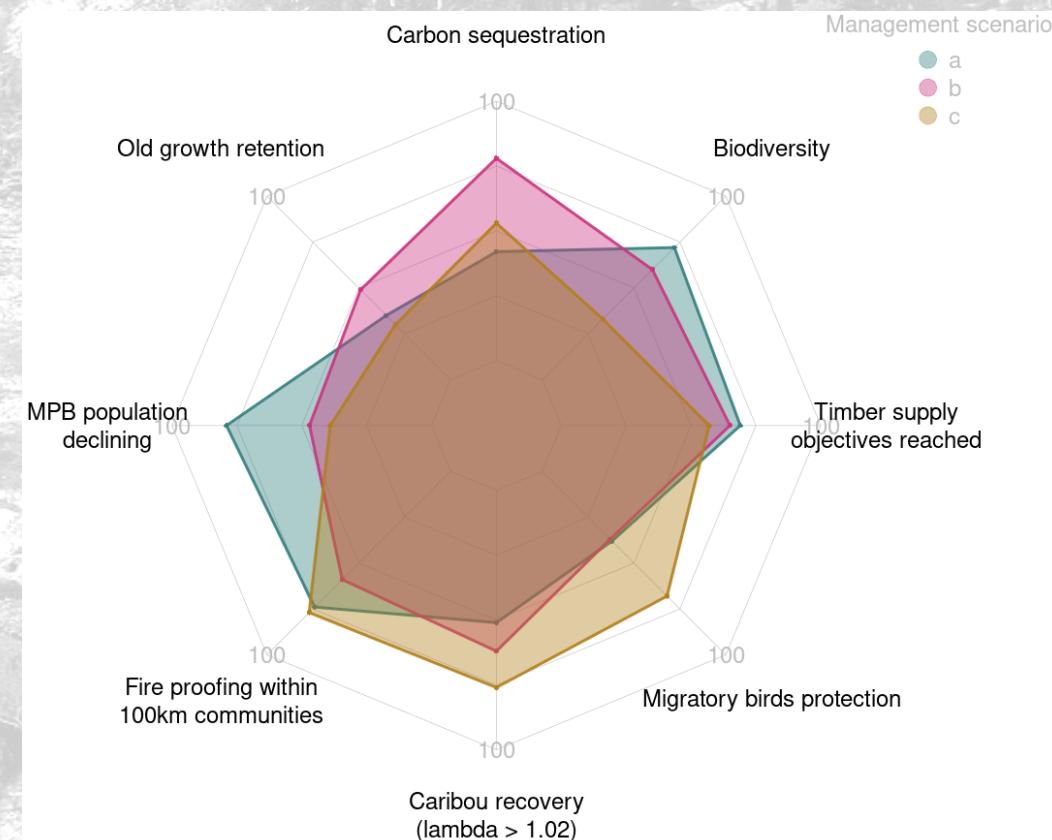
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# Main objectives

- **Assess the cumulative effects of natural and anthropogenic disturbances under climate change in Western Canada**
- ***Identify trade-offs among long-term conservation of priority species and places, carbon sequestration, and land management***



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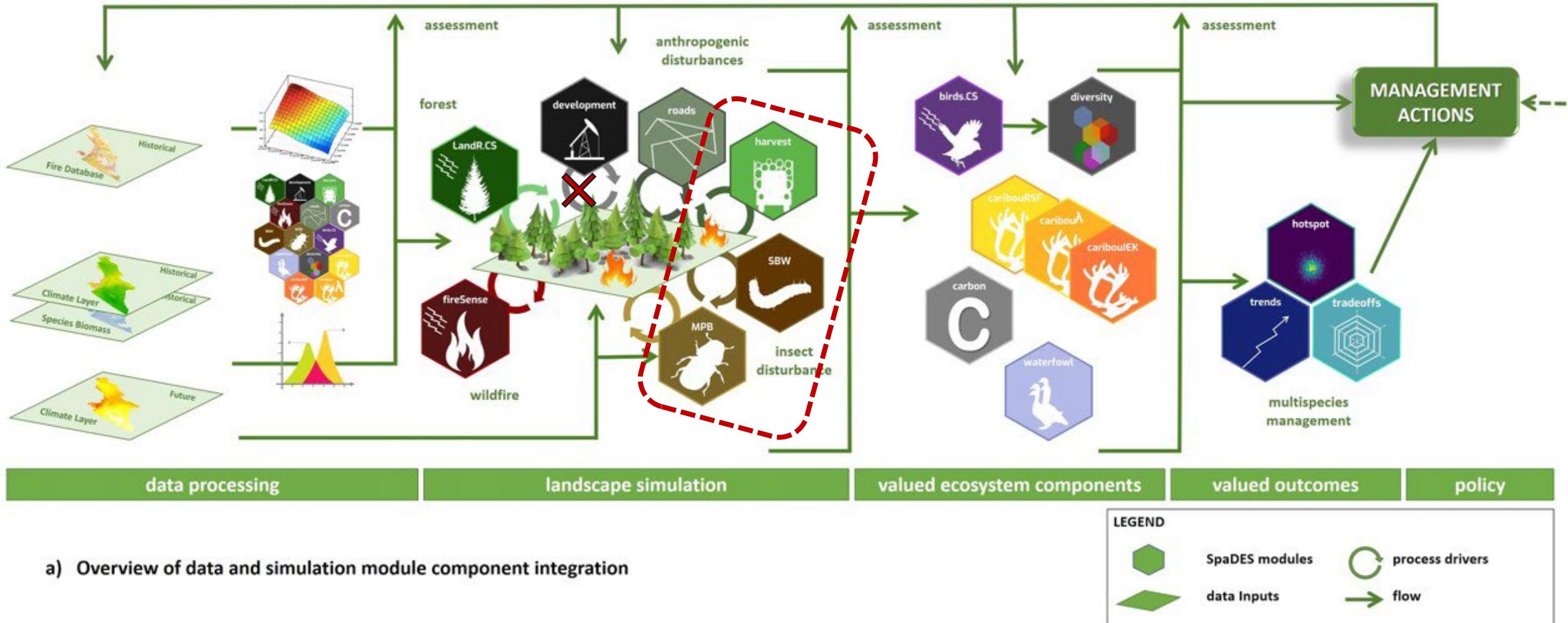
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# Current Framework

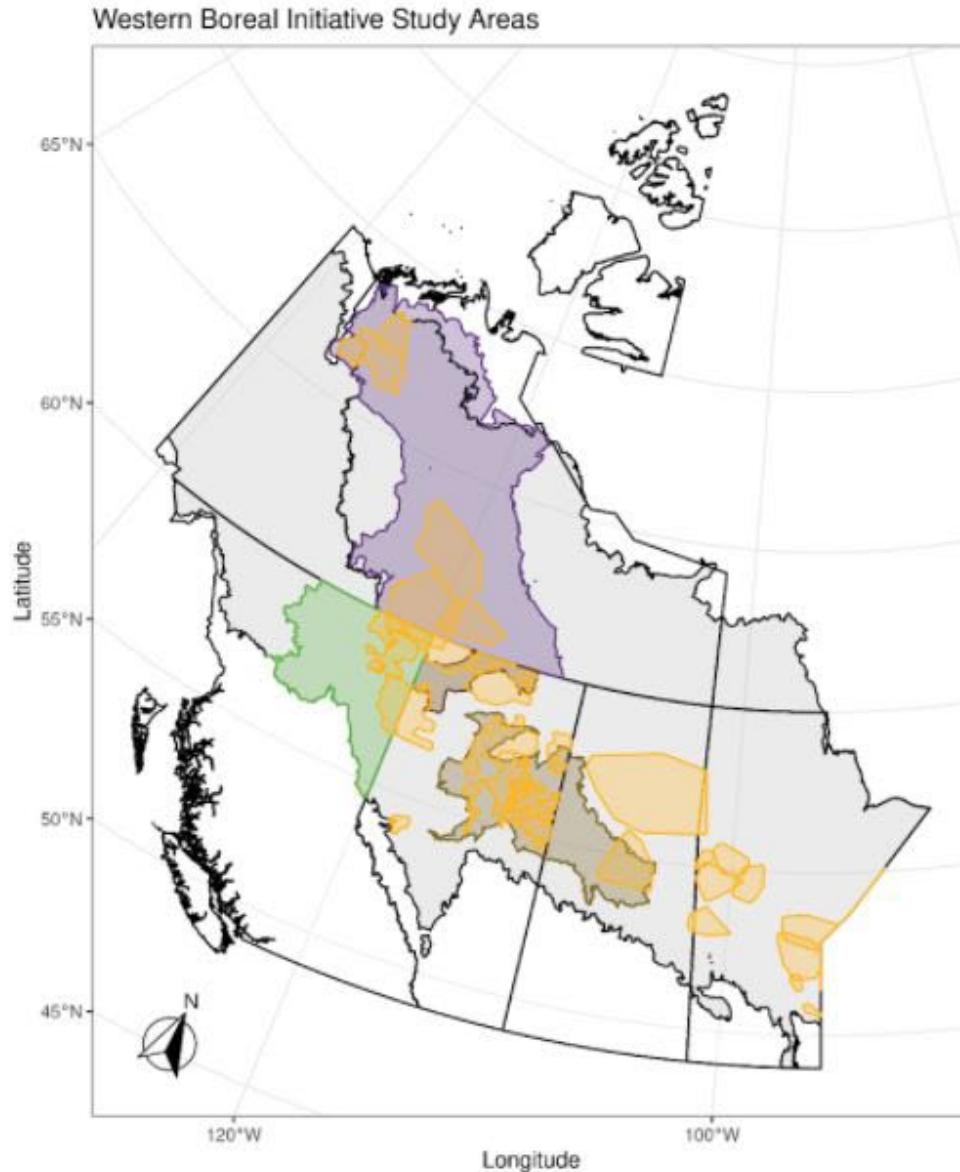


Western  
Boreal  
Initiative





# Study Area of each component



- Harvesting, Carbon Budget Model, Carbon LandR
- Caribou Resource Selection (Caribou IEK\*)
- Caribou Population Growth, Anthropogenic disturbance
- Spruce Budworm
- Mountain Pine Beetle
- Landbirds, Waterfowl, Forest Dynamics, Wildfire, Priority Places\*\*

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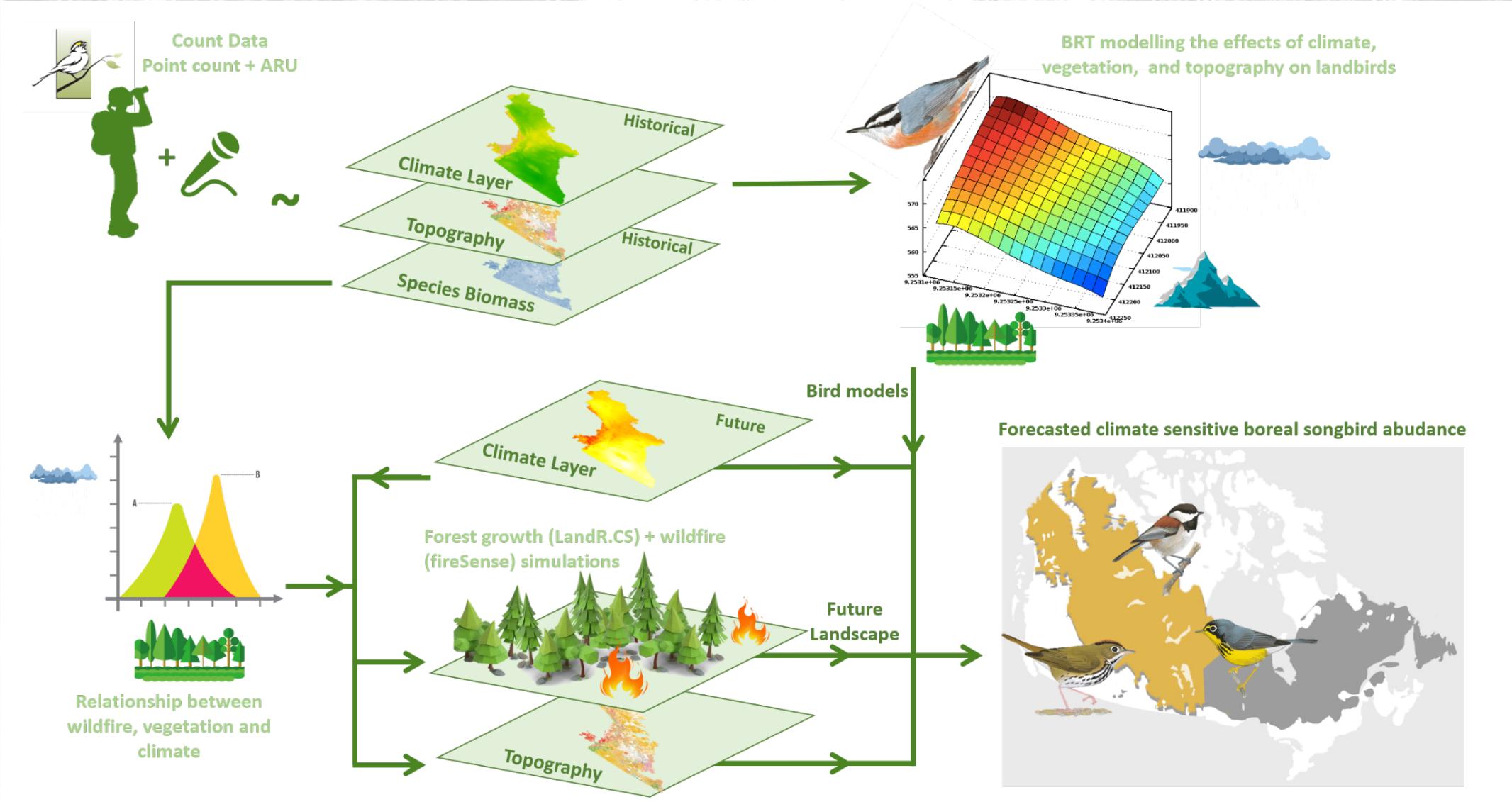
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# Current Framework in more detail: birds example



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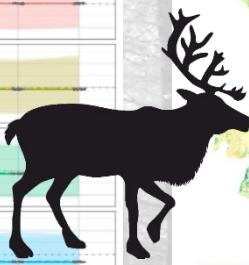
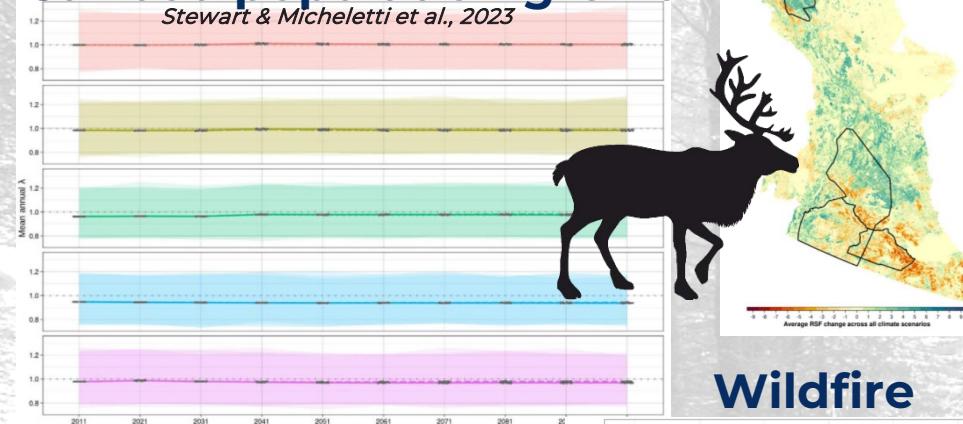
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# Some results

## Caribou population growth

*Stewart & Micheletti et al., 2023*

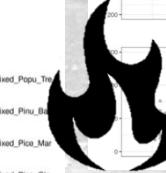


## Wildfire

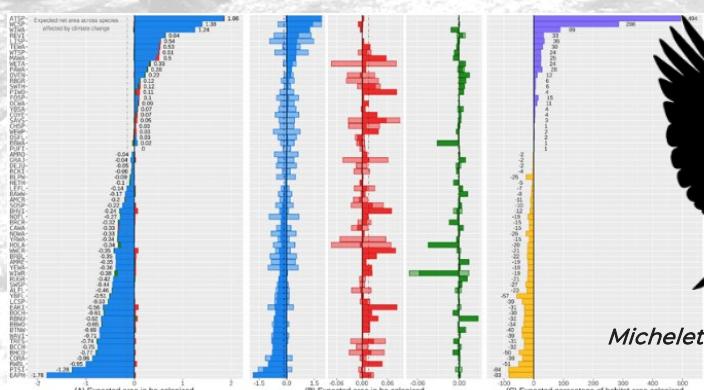
*McIntire et al., in prep*

## Vegetation

*McIntire et al., in prep*



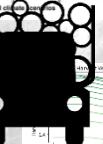
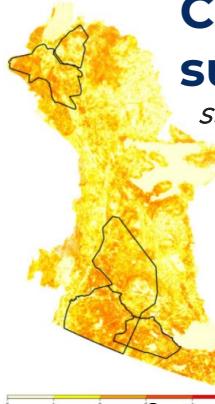
## Climate effects on landbirds



*Micheletti et al., 2021*

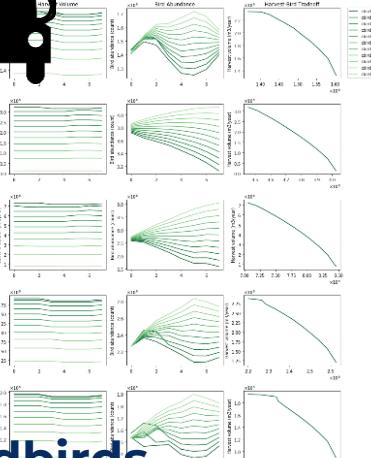
## Caribou habitat suitability

*Stewart & Micheletti et al., 2023*



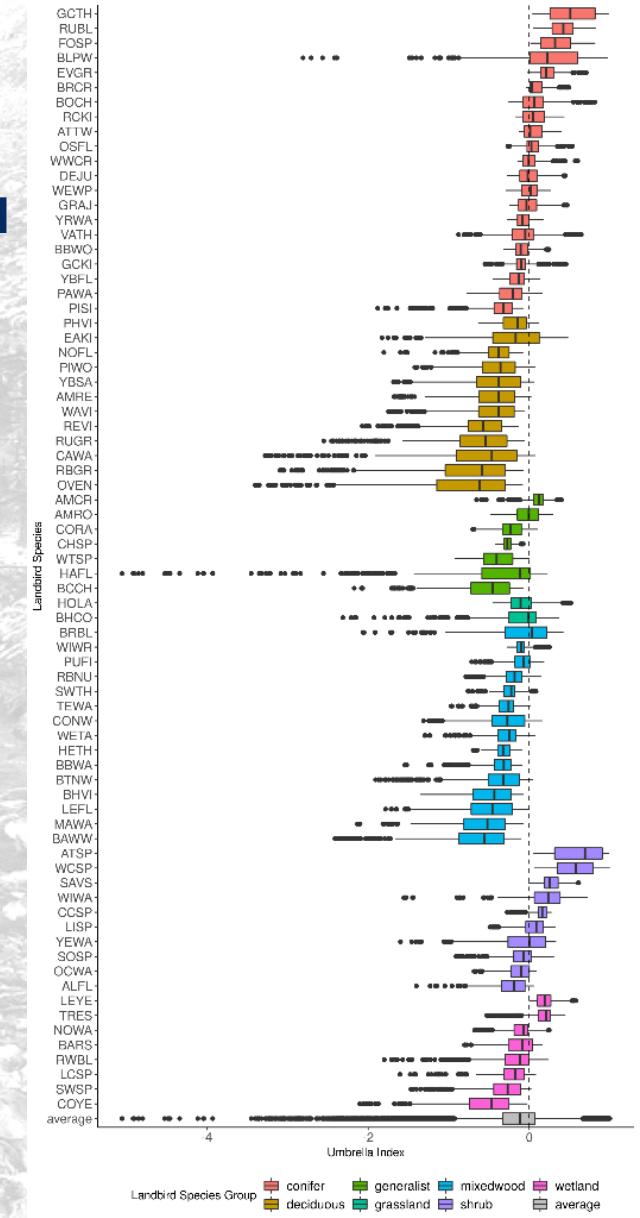
## Forestry and birds

*Paradis et al., in prep*



## Caribou umbrella function for birds

*Micheletti et al., 2023*



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# Hands-on

**Are birds a good umbrella for turtles in a changing world?**

# Are birds a good umbrella for turtles in a changing world?



1. **Form your groups:** You should already have divided yourselves in 3 groups: **TREE**, **BIRDS** and **TURTLE**.
2. **Get your computers (ONLY ONE PER GROUP!):** You should already have installed the software needed: Excel, R and RStudio, and also the libraries requested in advance.
3. **Exercise folder:** You should also already have downloaded the exercise folder (named PredictiveEcologyInAction)
4. **Open RStudio and the project files from the exercise folder:** The name of the file is predictiveEcologyInAction.Rproj
5. **Open the .Rmd file that belongs to your group:** For example, landscapeSimulation.Rmd, birdSimulation.Rmd or turtleSimulation.Rmd
6. **Read the Instructions:** I will come to each group and make sure you understand the game
7. **Duration:** We will have about 1 hour to finish the game so we can integrate all the work from the three groups.

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