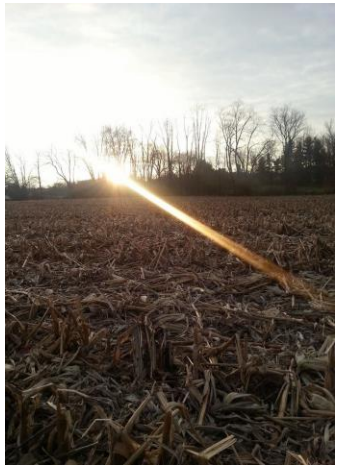
MATH FOR THE INDECISIVE:

USING STATISTICS FOR CLIMATE DECISION-MAKING

Cecina Babich Morrow

WHO AM I?

WHO AM I?



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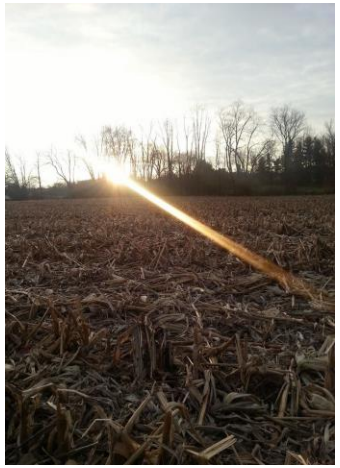
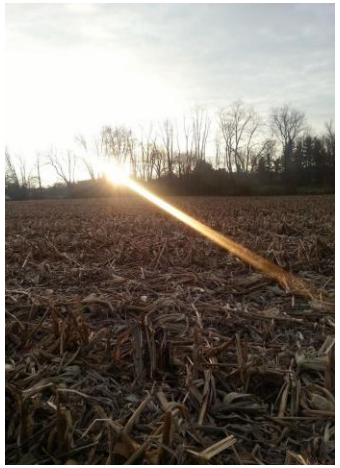
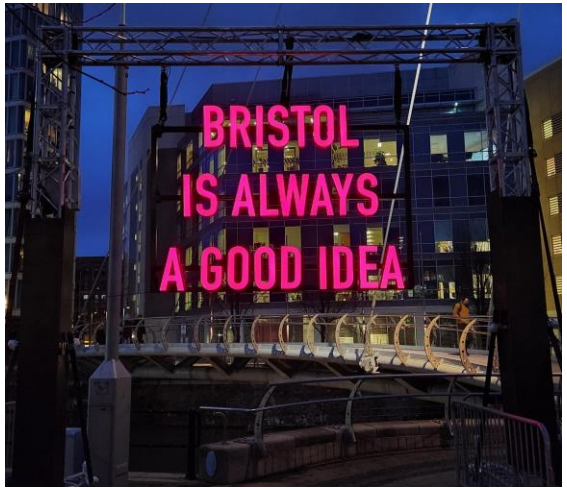


WHO AM I?


TRIXIE'S
CACTUS
GARDEN




MUSEUM
OF THE
CITY
OF NEW YORK


BRISTOL
IS ALWAYS
A GOOD IDEA

WHO AM I?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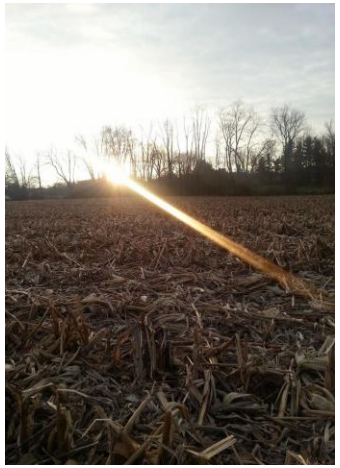


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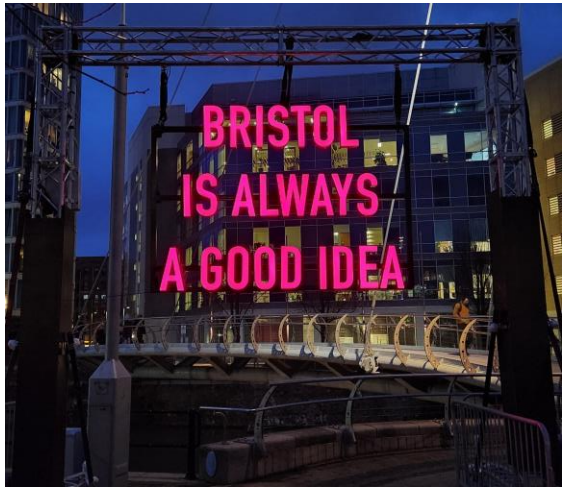
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TYR

WHO AM I?


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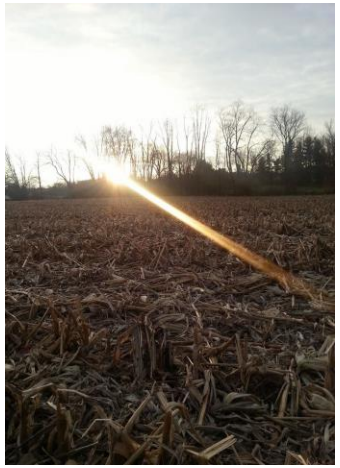


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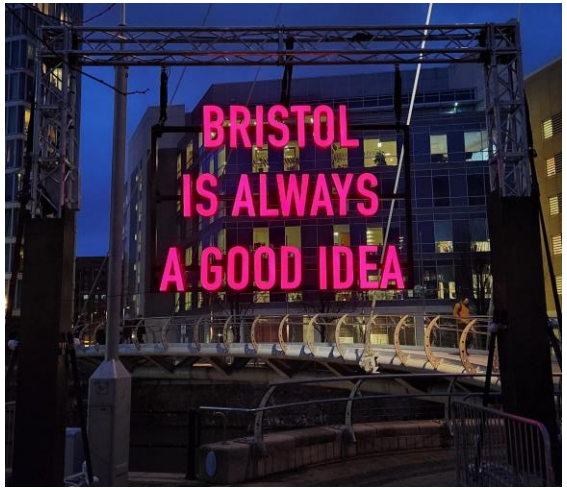
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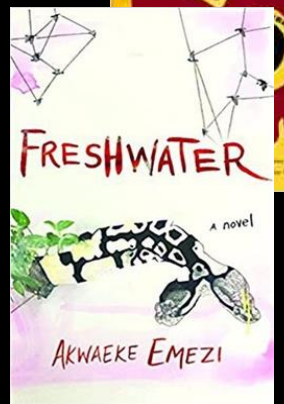
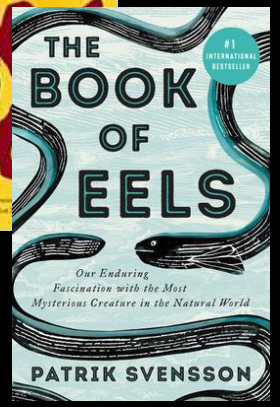
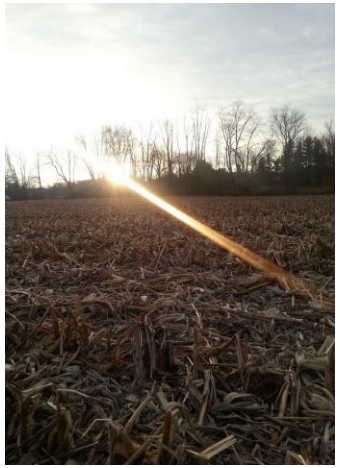
WHO AM I?


NEW YORK TIMES BESTSELLER
BARBARA
KINGSOLVER
WINNER of the ORANGE PRIZE
THE LACUNA


FRESHWATER
A novel
AKWAEKE EMEZI


THE
BOOK
OF
EELS
Our Enduring Fascination with the Most Mysterious Creature in the Natural World
PATRIK SVENSSON


TRIXIE'S
CACTUS
GARDEN

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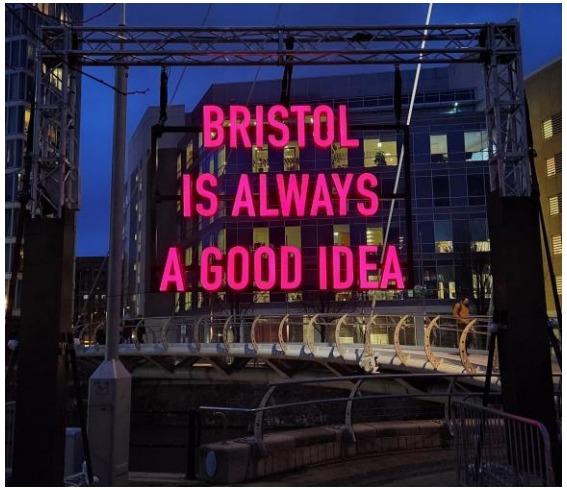
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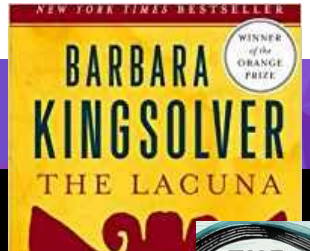
NEW YORK TIMES BESTSELLER
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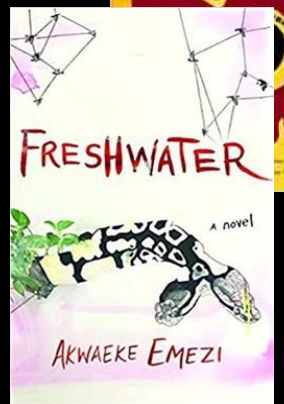
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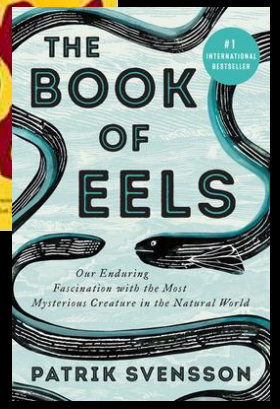
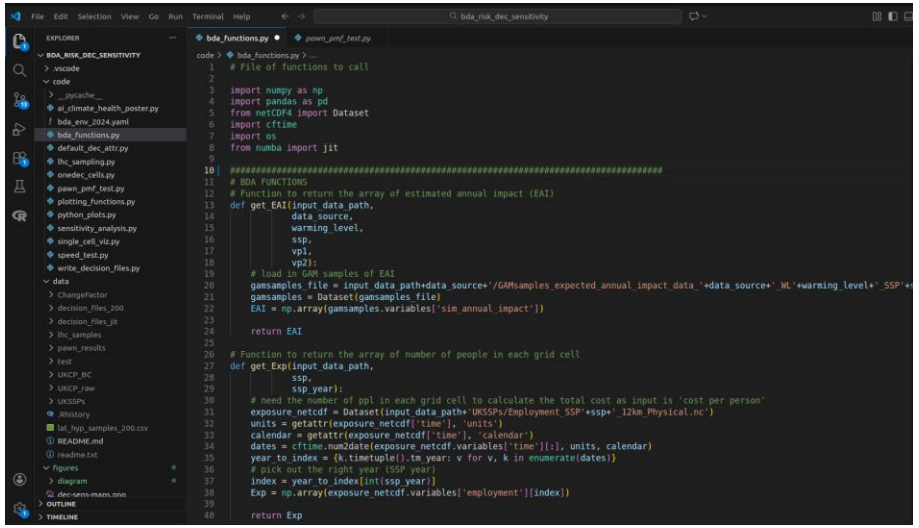
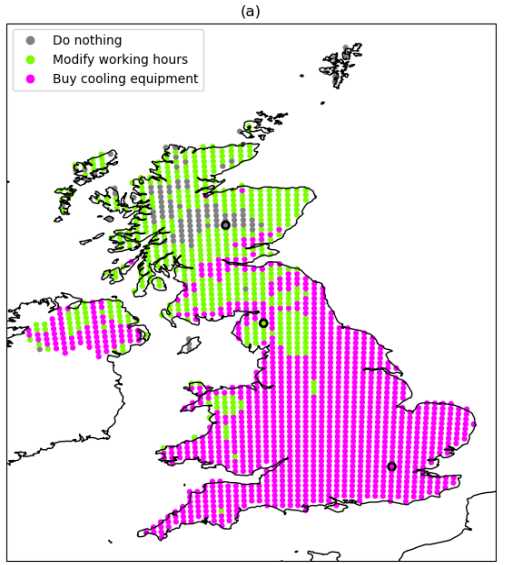
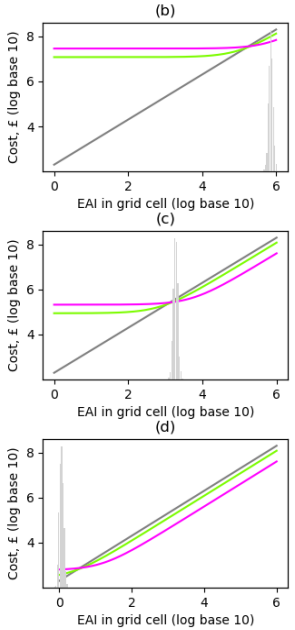

THE
BOOK
OF
EELS
#1 INTERNATIONAL BESTSELLER
Our Enduring Fascination with the Most Mysterious Creature in the Natural World
PATRIK SVENSSON

WHAT DO I DO?

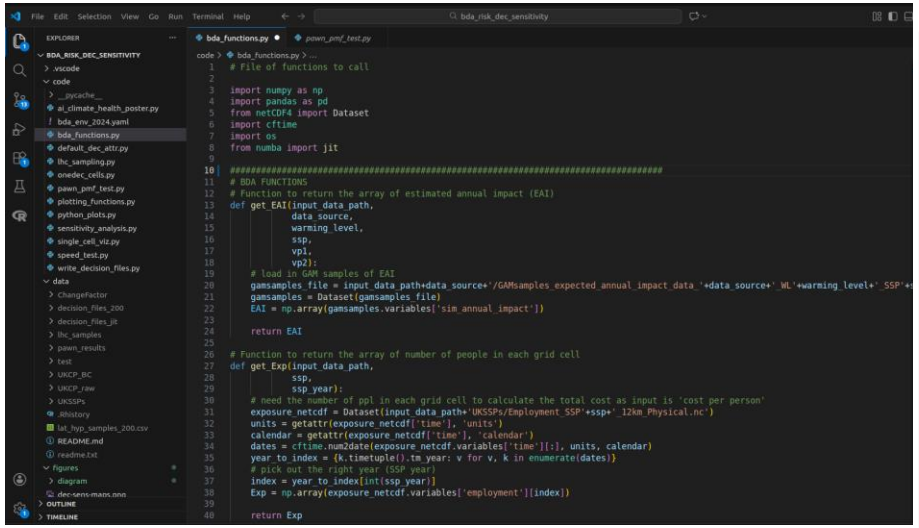

LAPTOP
SCIENTIST
R

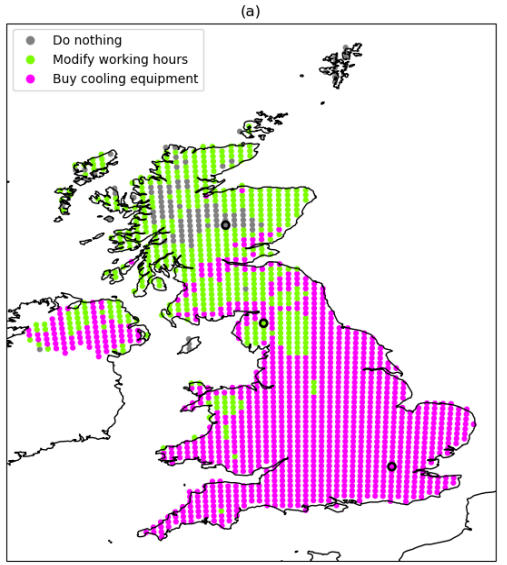

bda_functions.py
# File of functions to call
import numpy as np
import pandas as pd
from netCDF4 import Dataset
import cftime
import os
from numba import jit
# BDA FUNCTIONS
# Function to return the array of estimated annual impact (EAI)
def get_EAI(input_data_path,
data_source,
warming_level,
ssp,
vp1,
vp2):
# load in GAM samples of EAI
gamsamples_file = input_data_path+data_source+'/GAMsamples_expected_annual_impact_data_'+data_source+'_WL'+warming_level+'_SSP'+
gamsamples = Dataset(gamsamples_file)
EAI = np.array(gamsamples.variables['sim_annual_impact'])
return EAI
Function to return the array of number of people in each grid cell
def get_Exp(input_data_path,
ssp,
ssp_year):
# need the number of ppl in each grid cell to calculate the total cost as input is 'cost per person'
exposure_netcdf = Dataset(input_data_path+'UKSSPs/Employment_SSP'+ssp+'_12km_Physical.nc')
units = getattr(exposure_netcdf['time'], 'units')
calendar = getattr(exposure_netcdf['time'], 'calendar')
dates = cftime.num2date(exposure_netcdf.variables['time'][:], units, calendar)
year_to_index = {k.timetuple().tm_year: v for v, k in enumerate(dates)}
# pick out the right year (SSP year)
index = year_to_index[int(ssp_year)]
Exp = np.array(exposure_netcdf.variables['employment'][index])
return Exp

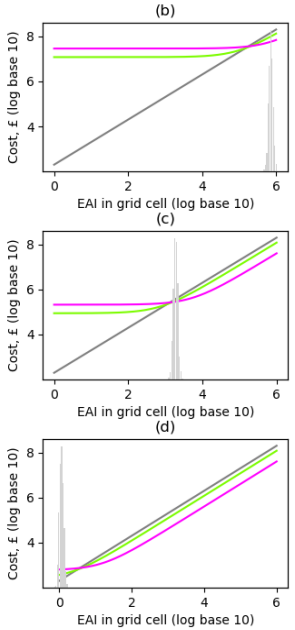

(a)
Do nothing
Modify working hours
Buy cooling equipment


(b)
Cost, £ (log base 10)
EAI in grid cell (log base 10)
(c)
Cost, £ (log base 10)
EAI in grid cell (log base 10)
(d)
Cost, £ (log base 10)
EAI in grid cell (log base 10)

WHAT DO I DO?







WHAT DO I DO?

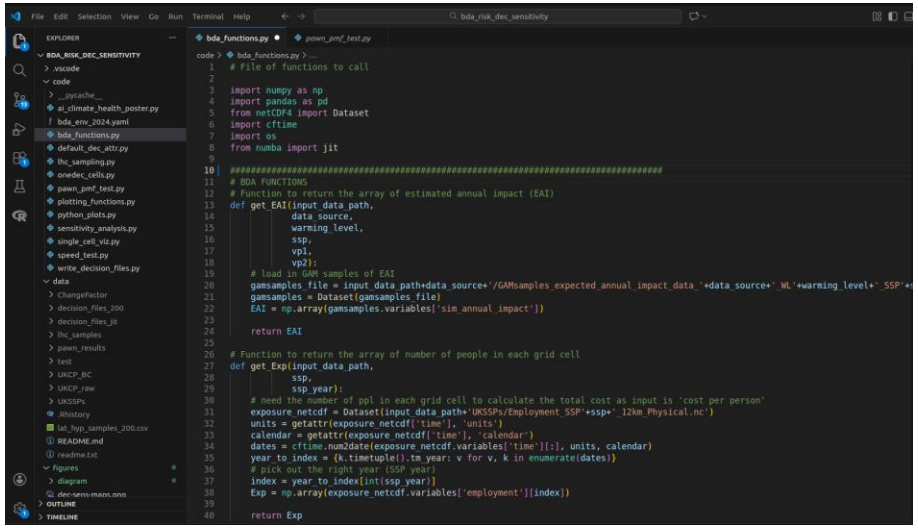
Computing information value

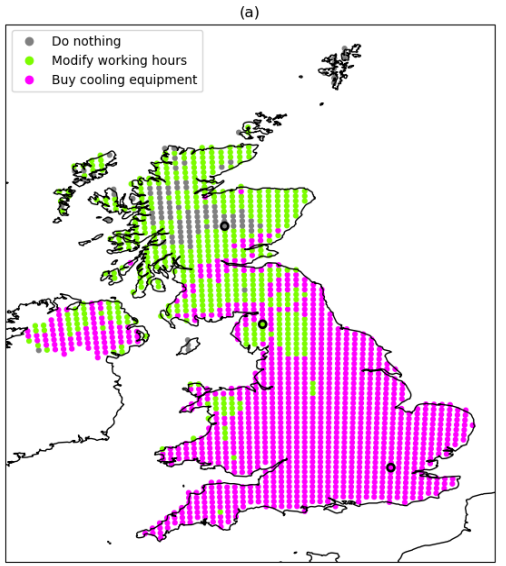
University of BRISTOL

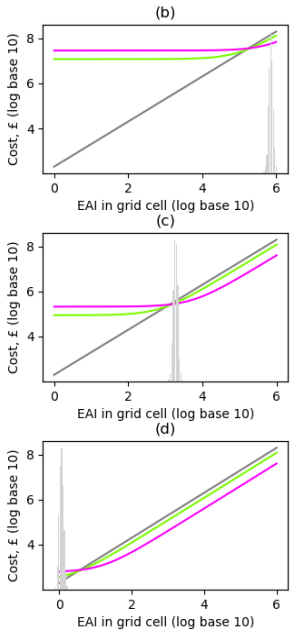
Algorithm Calculate $\mathbb{E}_{\mathbf{X}}[u(\mathbf{X}, a_{opt|M})]$

1: Take N samples of $M \sim \mathcal{N}(7.5, 1)$
2: **for** $m = 1$ to N **do**
3: **for** $a = 1$ to 3 **do**
4: Take n samples of R_a and n samples of C_F.
5: Calculate n values of $Y_e(a)$ using $M = m$ and the samples of R_a and C_F.
6: Calculate $\mathbb{E}_{\mathbf{X}_e|M}[Y_e(a)]$
7: Calculate $\mathbb{E}_{\mathbf{X}_e|M}[u(\mathbf{X}, a)] = -\mathbb{E}_{\mathbf{X}_e|M}[Y_e(a)] - c_a(a)$
8: Find $u(\mathbf{X}, a_{opt|M=m}) = \max_a \mathbb{E}_{\mathbf{X}_e|M} u(\mathbf{X}, a)$
9: Average the $u(\mathbf{X}, a_{opt|M=m})$ over all m values to get $\mathbb{E}_{\mathbf{X}}[u(\mathbf{X}, a_{opt|M})]$

Then $V_M = \mathbb{E}_{\mathbf{X}}[u(\mathbf{X}, a_{opt|M})] - \mathbb{E}_{\mathbf{X}}[u(\mathbf{X}, a_{opt})]$







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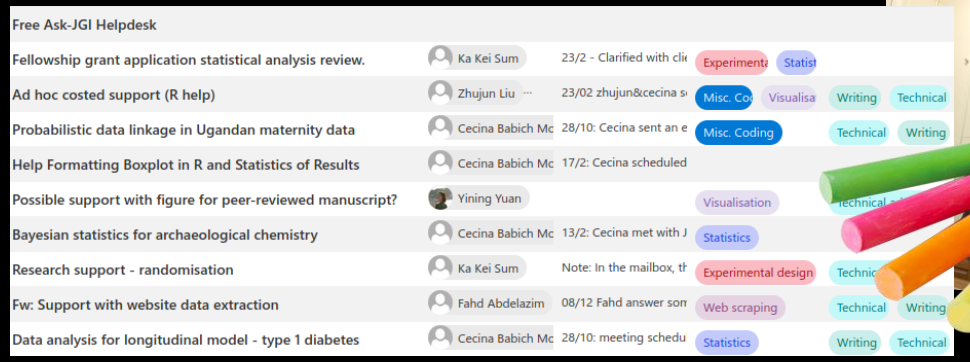

HOW DID I GET HERE?


phoenixzoo
ARIZONA CENTER for NATURE CONSERVATION

NATIONAL
PARK
SERVICE


GAME & FISH

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RMBL
science. OUTSIDE.

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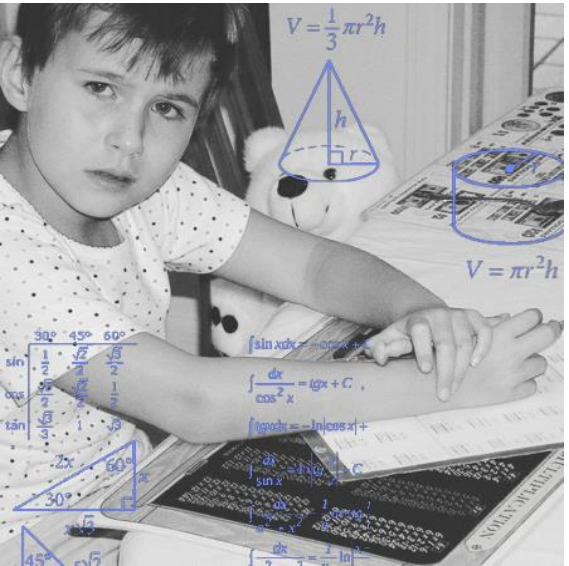

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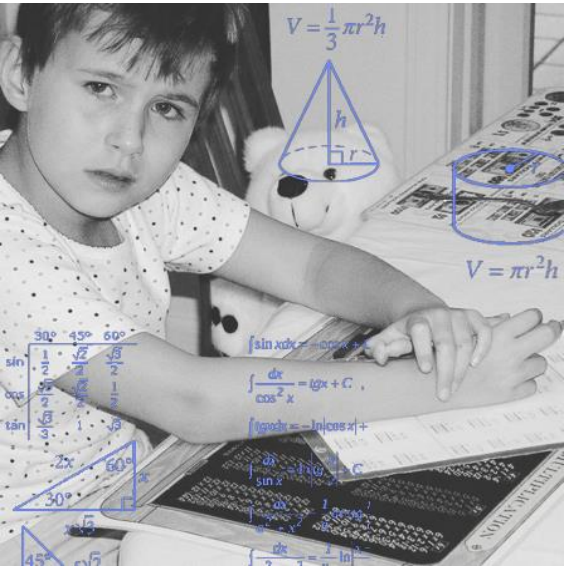

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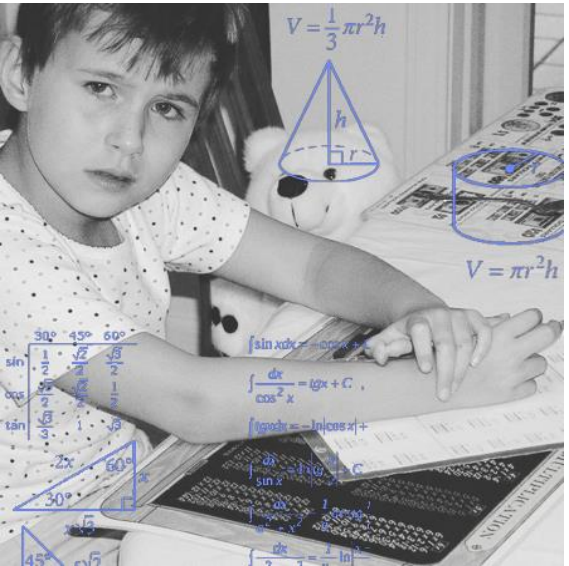

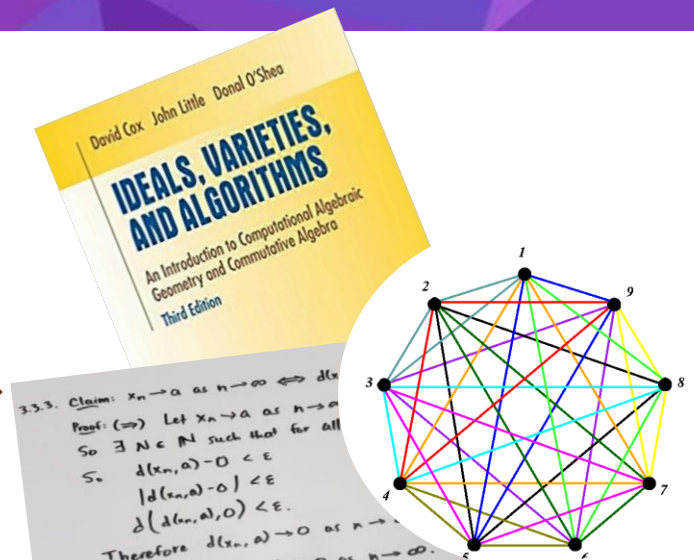

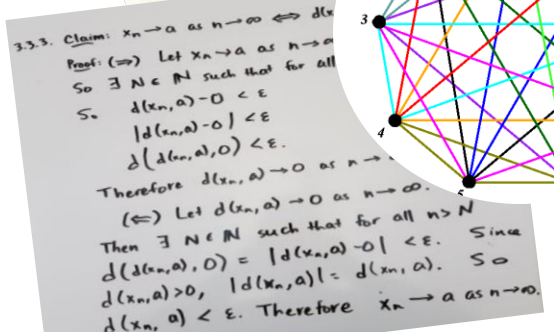

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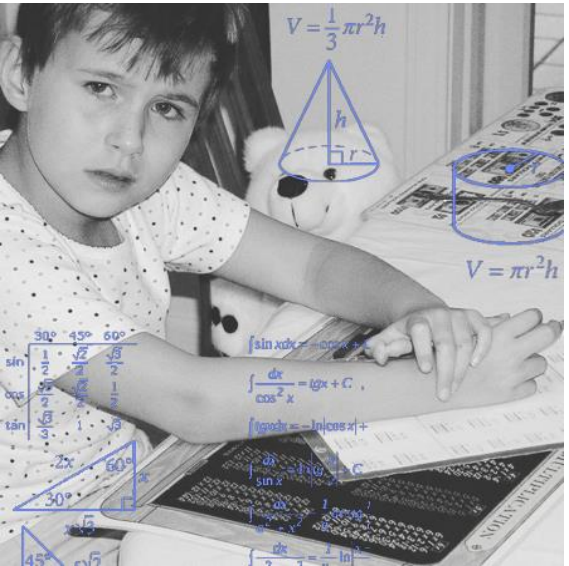
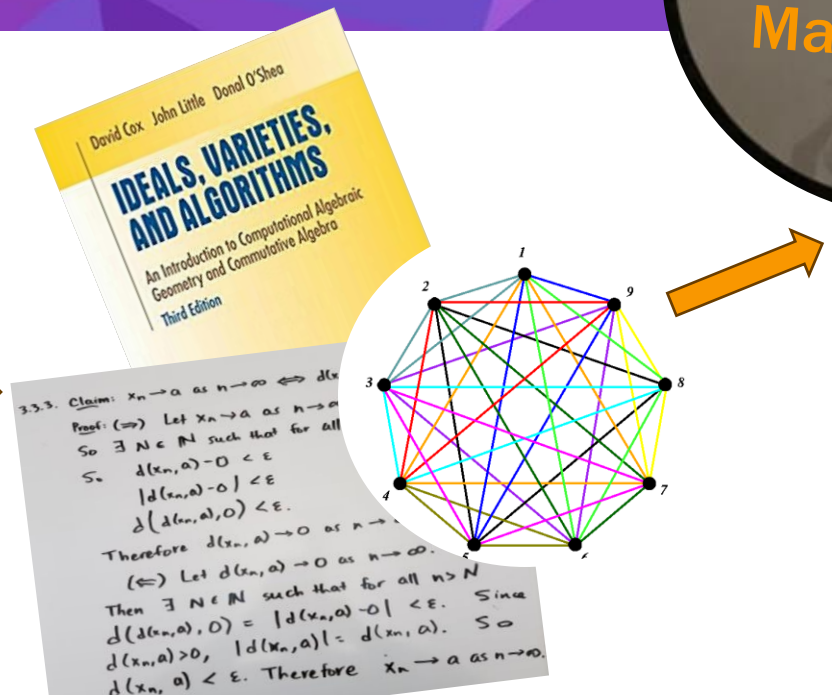
R

I declared my major today!!

Biology & Mathematics



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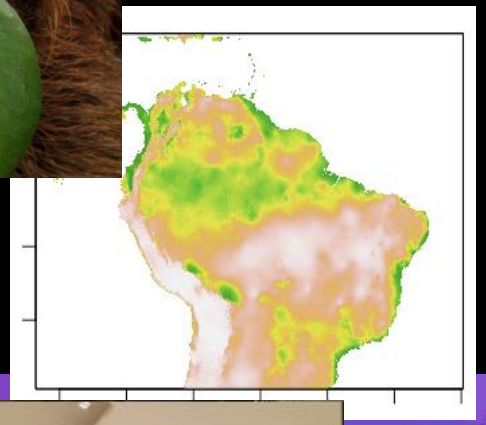
Biology &
Mathematics



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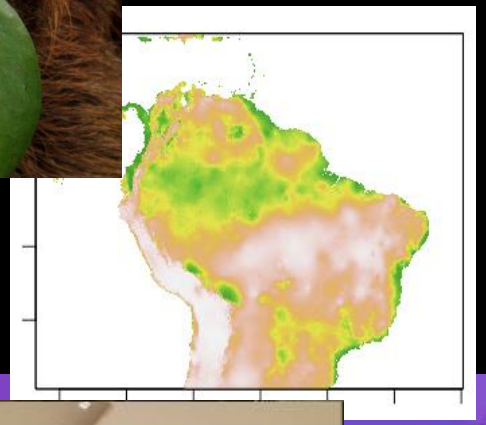
Biology & Mathematics

Spring Health



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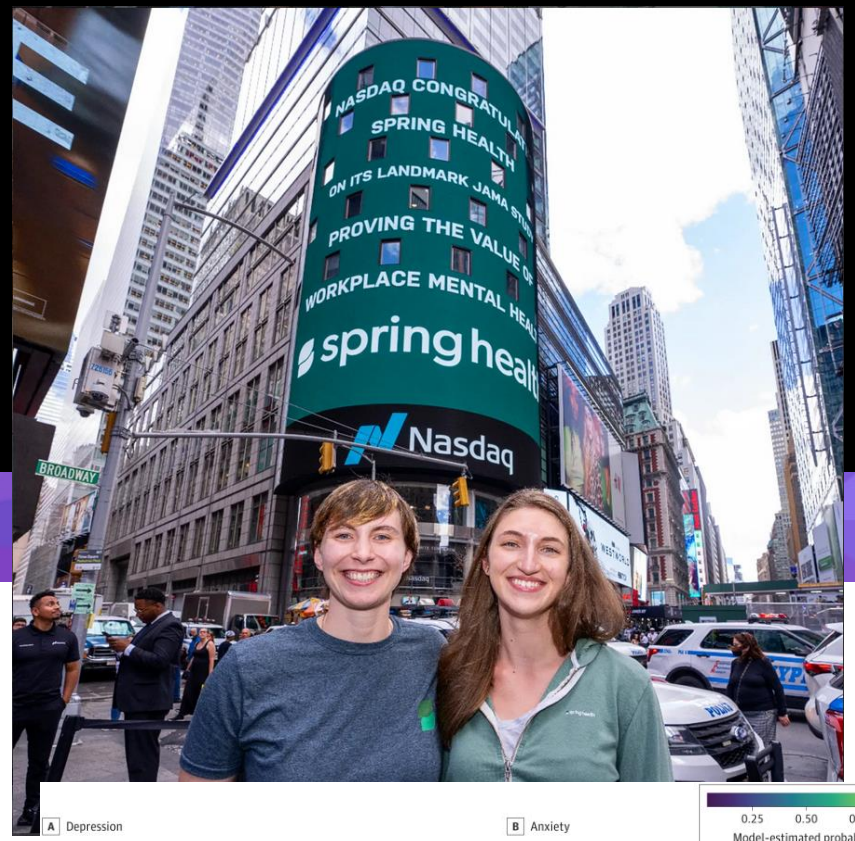

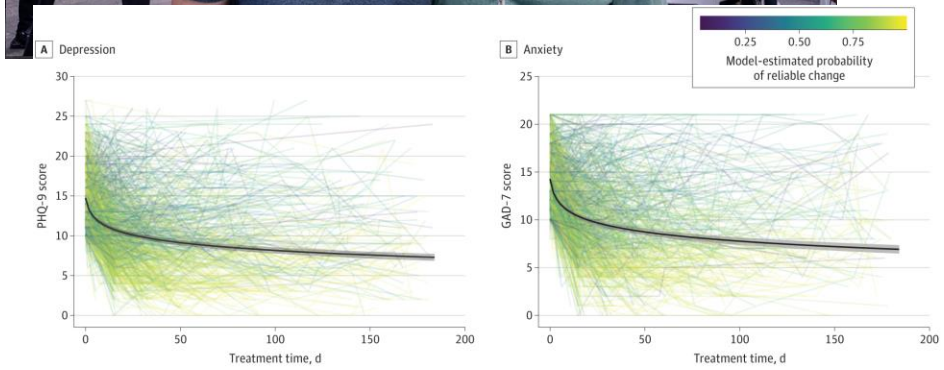

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NATIONAL PARK SERVICE

ARIZONA GAME & FISH

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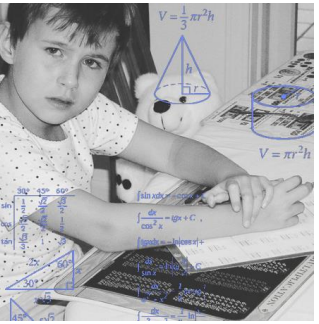
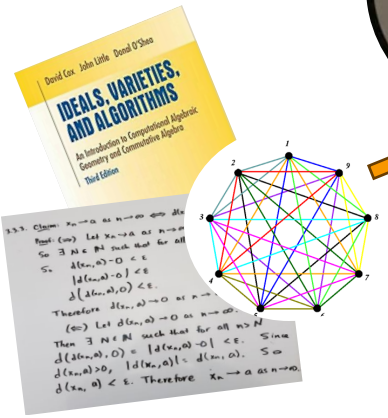
science. OUTSIDE.





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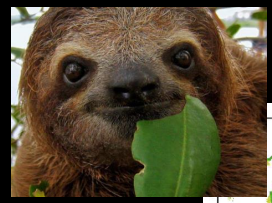
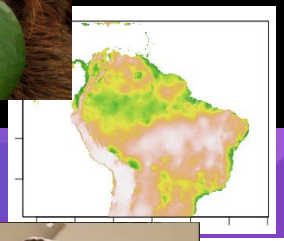
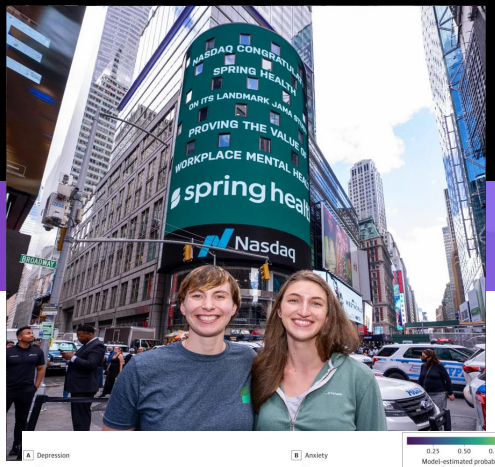
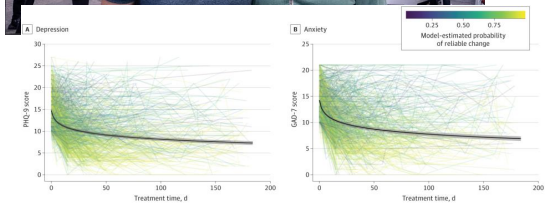
Biology & Mathematics





Spring Health





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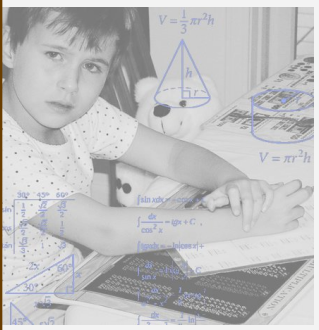
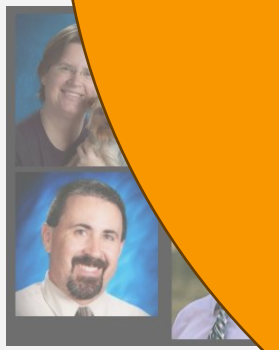
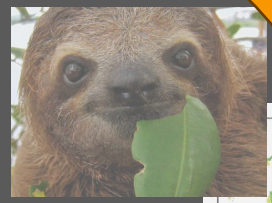
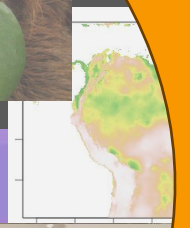
scien

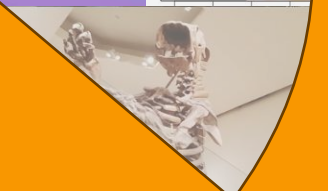
Spring Health

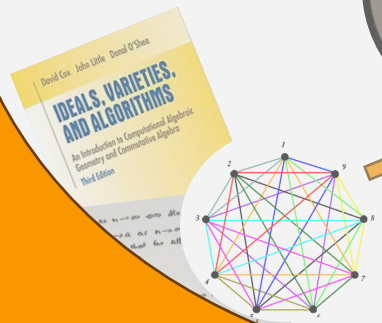


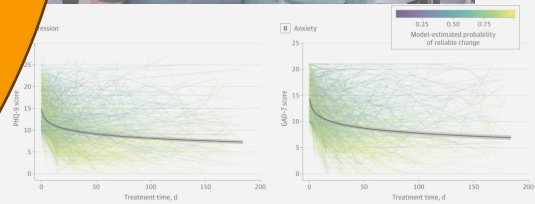












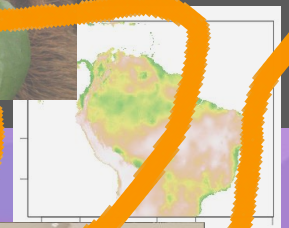
phoenixzoo
ARIZONA CENTER for NATURE CONSERVATION

NATIONAL PARK SERVICE

ARIZONA GAME & FISH

RMBL
science. OUTSIDE.

R



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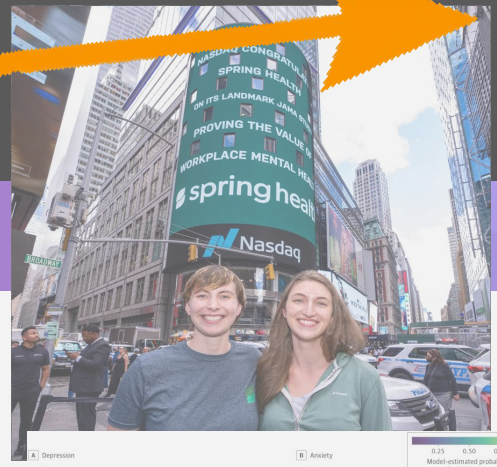

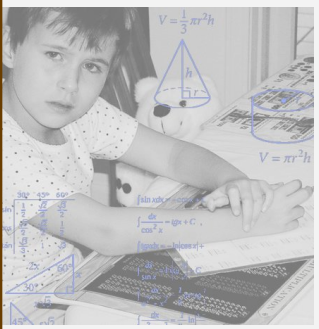

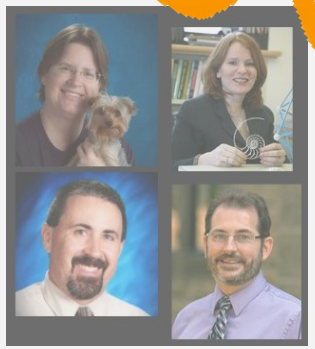

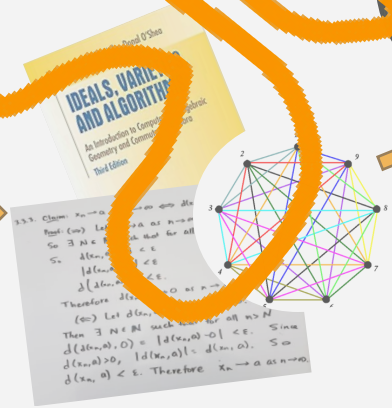

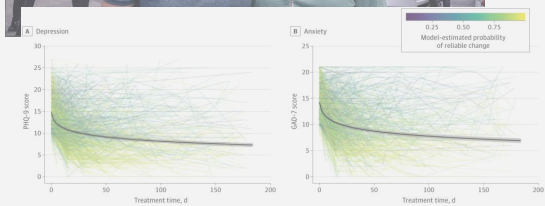

WHAT DO I RESEARCH?

CLIMATE ADAPTATION DECISION-MAKING

England enters fourth heatwave as temperatures reach 33.4C

EEA report 01/2026

Overheated and underprepared: Europeans' experience of living with climate change

Report (PDF) | Published 04 Feb 2026

"Every fraction of a degree of warming will cause more hospital admissions and heat deaths, putting more strain on the NHS."

Professor Antonio Gasparrini
Lead of the EHM Lab, LSHTM

CLIMATE ADAPTATION DECISION-MAKING

11 December 2025

UK social homes are unprepared for rising heat as policy fails to keep pace, new research warns

CLIMATE ACTION AND WASTE REDUCTION

What is climate change adaptation and why is it a priority at COP27?

Oct 28, 2022

Women and Extreme Heat: Simple Adaptations Make a Big Difference

CEO of World Neighbours Dr. Kate Schecter explains how extreme heat undermines women's livelihoods and what can be done to adapt

by **Kate Schecter - CEO of World Neighbors** — December 23, 2025 in **Climate Change, Health, Society**

Europe, Physical Risk, UK

July 14, 2025

Employers told to invest in climate adaptations as workers feel the heat

By Florence Jones

Comment | Published: 29 January 2026

Climate change adaptation must consider older people

Liming Yao, Shiqi Tan, Chengwei Lv, Nan Wang, Yoshikuni Yoshida & Yin Long

Nature Human Behaviour (2026) | Cite this article

177 Accesses | **2** Altmetric | Metrics

Older adults face higher risks from climate change. We propose an age-sensitive climate adaptation framework, which emphasizes non-digital communication, financial assistance and community-based strategies for older populations.

BAYESIAN DECISION ANALYSIS

How can we make decisions ***under uncertainty***?

BAYESIAN DECISION ANALYSIS

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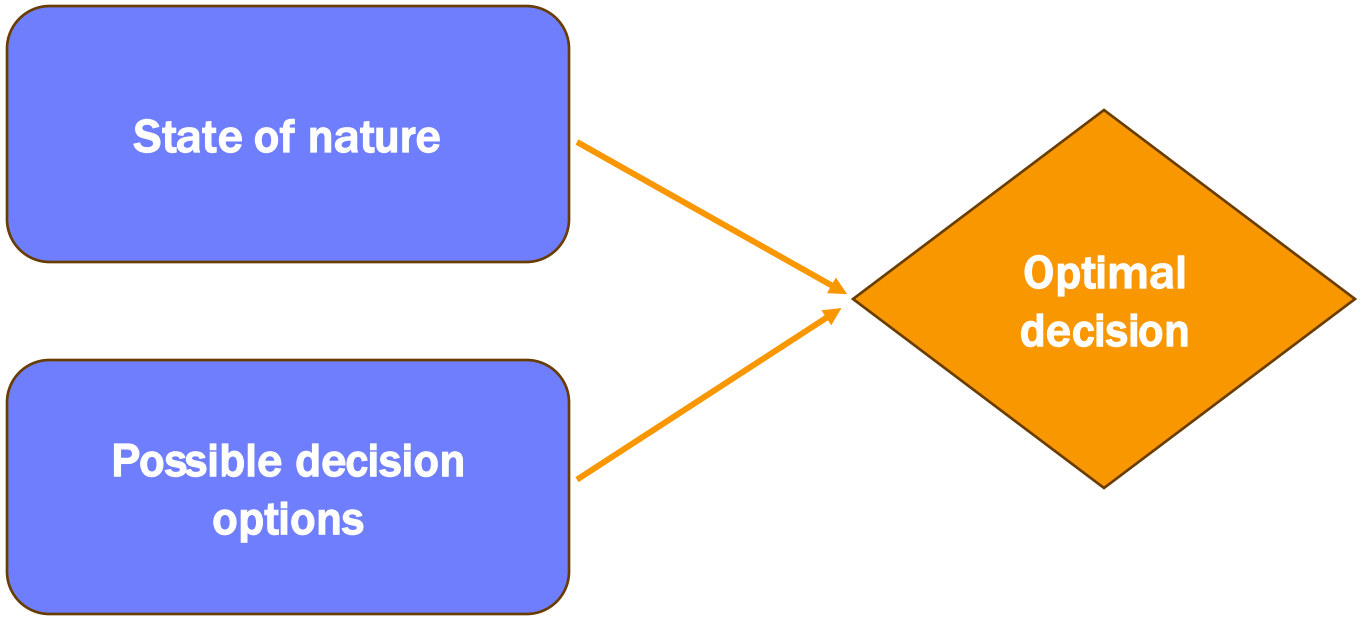

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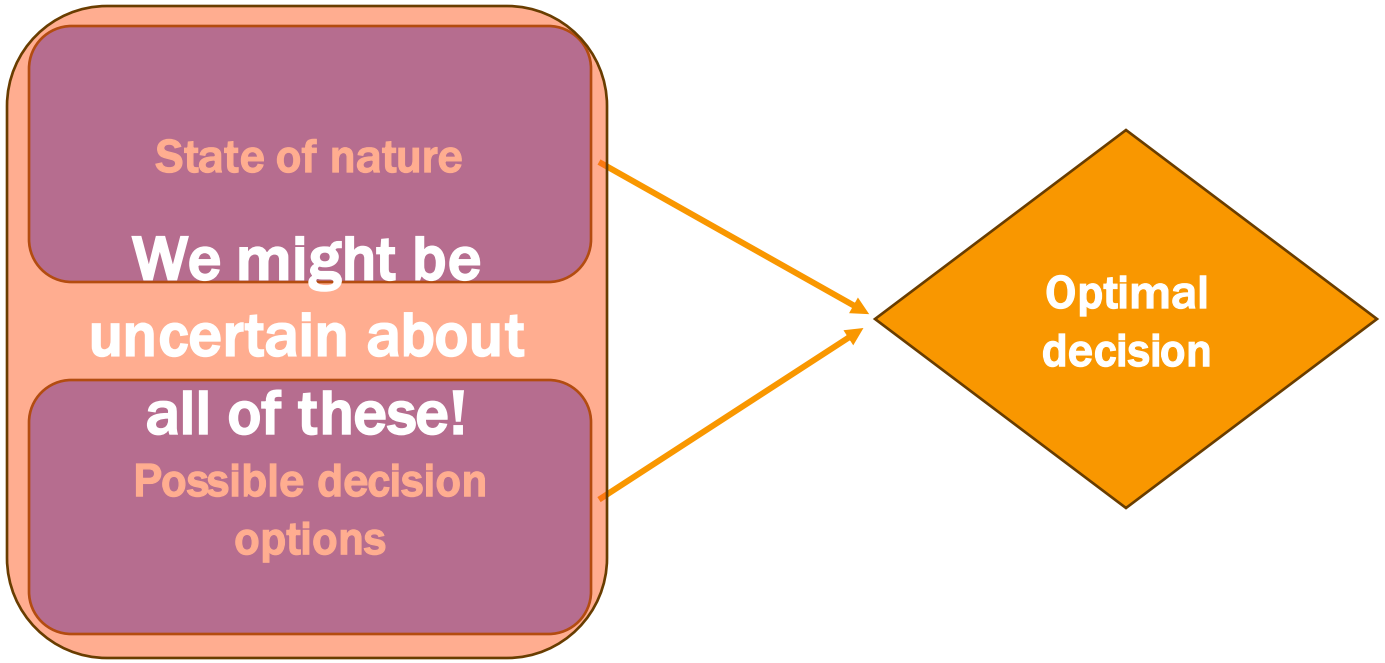

A BRITISH DECISION

State of nature: will it rain tomorrow?

Decision options: wear a raincoat OR don't wear a raincoat

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Weather forecast: 67% chance of rain tomorrow

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What do you want to do?

A BRITISH DECISION

	It rains tomorrow	It doesn't rain tomorrow
Wear a raincoat	+ 5 (stay dry!)	-2 (too hot)
Don't wear a raincoat	-10 (got rained on)	+10 (comfortable)

Pick your decision

Roll your dice:

1, 2, 3, or 4: it rains

5 or 6: it doesn't rain

What is your utility?

THE BAYES OPTIMAL BRITISH DECISION

Bayes optimal decision

Select the decision that maximises expected utility:

Bayes decision under utility U

Select the decision d^* such that

$$d^* = \arg\max_d \sum_{\theta \in \Theta} U(\theta, d) p(\theta) = \arg\max_d \bar{U}(d)$$

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Weather possibilities

Utility of a particular decision given a particular weather

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Raincoat: E[U(raincoat)] =

U(rain, raincoat) × P(rain) +

U(no rain, raincoat) × P(no rain)

=

No raincoat: E[U(no raincoat)] =

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A MORE COMPLICATED BRITISH DECISION

But what if the parameters of our decision change?

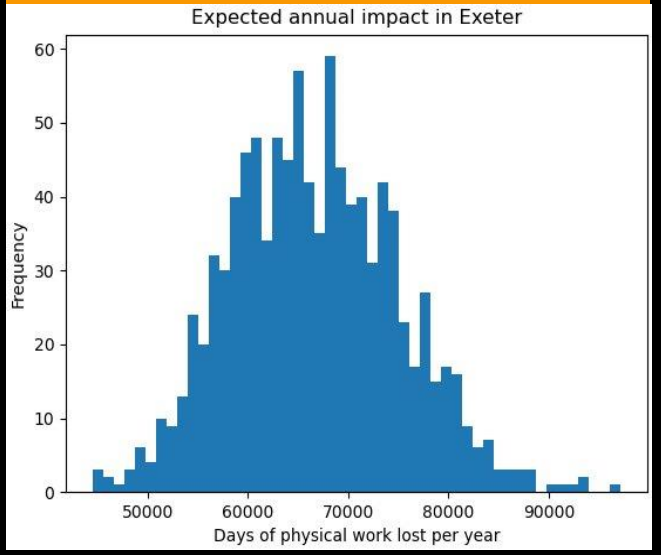
- What if the probability of rain is only 50%? 30%?
- What if our utilities are different?
- What if we are deciding between multiple jacket options?
- …

MY RESEARCH

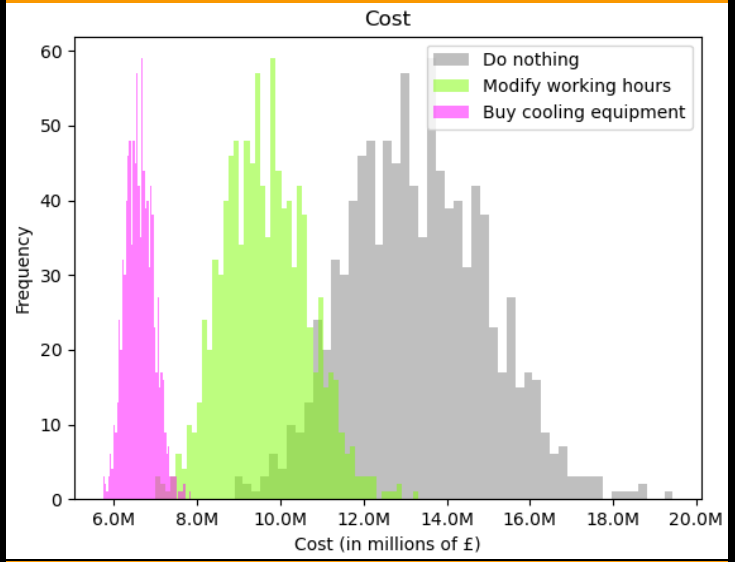
- How do we make climate adaptation decisions?
- How can we account for uncertainty in climate information?
- How can we account for uncertainty in decision information?
- What makes a decision robust?
- How can we make decisions over time?

AN EXAMPLE DECISION

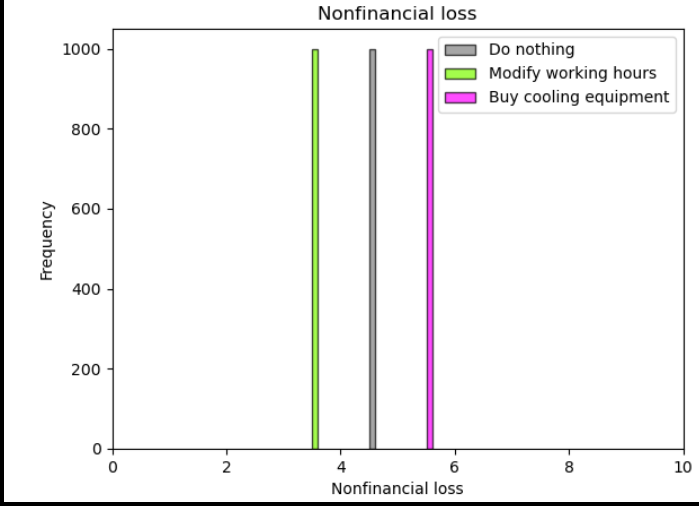
Risk



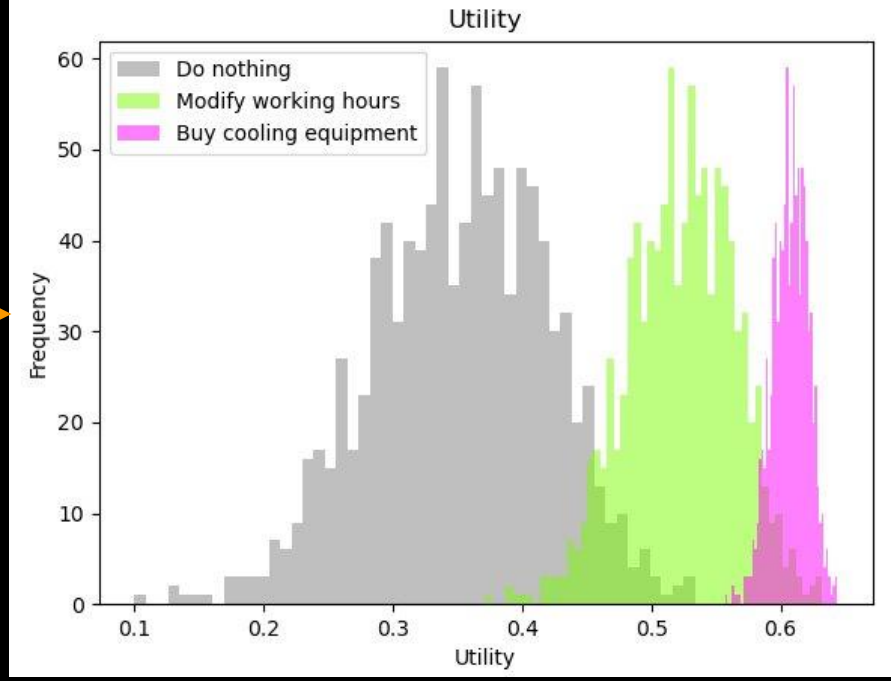
Financial loss



Non-financial loss



Utility



$\mathcal{D}$: decisions

- d_1 : do nothing
- d_2: modify working hours
- d_3: buy cooling equipment

DECISION UNCERTAINTY