Tragedy of the Commons

Outline

Introduction

- The term ‘tragedy of commons’ was coined in 1968 by Garrett Hardin, a biologist at UC Santa Barbara
- Described TOC addressing the human overpopulation and argued technology isn’t enough to support rising populations.
- Models of cooperation: Swiss Alpine pastures, forests in Japan, water irrigation in Spain, meadows in England

Microeconomic Background

Common Public Resource (CPR) vs public good: limited resource and use by one person impacts the availability for the other.

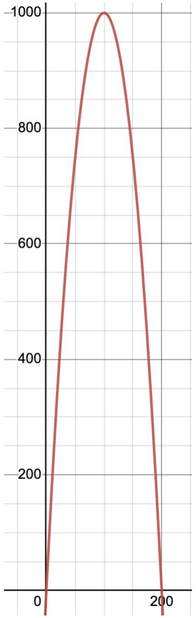
$$\textbf{Utility function} = (P(n_i) - D(N(n_i)) , N(n_i) = \sum(n_i)$$

n_i : number of cows of each owner i, P(): Profit derived from each cow, D(): Degradation of the commons by total number of cows

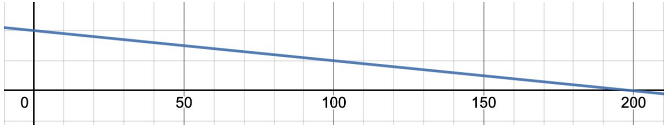
$$\partial D(n_i)/\partial P(n_i) \approx 0$$

$P = -0.1H^2+20H$, p(per cow) = $-0.1H + 20$

Total Profit



Profit per cow



Commoner B's cows		Commoner A's cows		
		50	**60**	**100**
50				
	Size of herd	100	110	150
	Profit per cow (£)	10	9	5
	A's profit (£)	500	540	500
	B's profit (£)	500	450	250
	Total profit (£)	1 000	990	750
60				
	Size of herd	110	120	160
	Profit per cow (£)	9	8	4
	A's profit (£)	450	480	400
	B's profit (£)	540	480	240
	Total profit (£)	990	960	640
100				
	Size of herd	150	160	200
	Profit per cow (£)	5	4	0
	A's profit (£)	250	240	0
	B's profit (£)	500	400	0
	Total profit (£)	750	640	0

The model

Space

- 101x99 grid

Grass patches

- Initially occupies the whole space with max length (=1)
- Grows according to the logistics equation $g_1 = g + r*g*(1-g)$
- A minimum limit is set (=0.1), else it can't regrow.

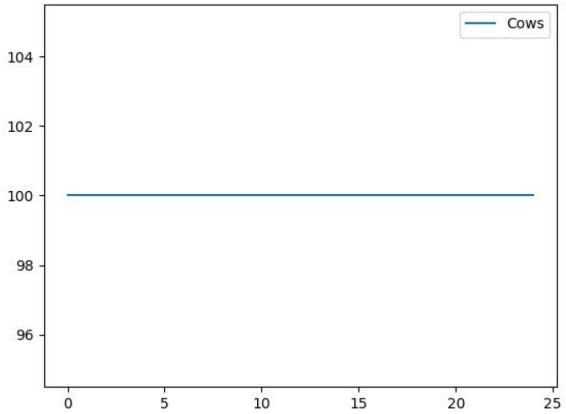
Cow agents

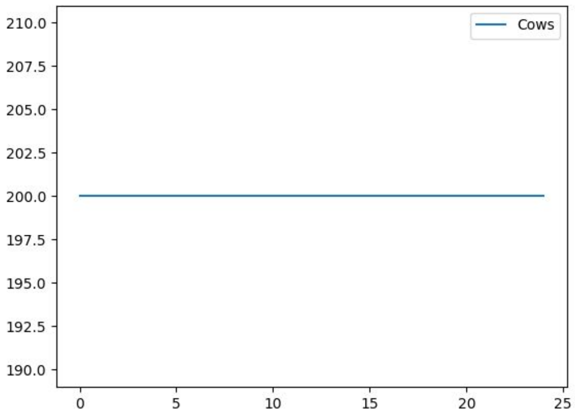
- Moves around, finds the nearest grass patch with grass>0.7 and grazes 0.55 from it.
- If grass<0.7, grazes till grass is 0.1 and dies.

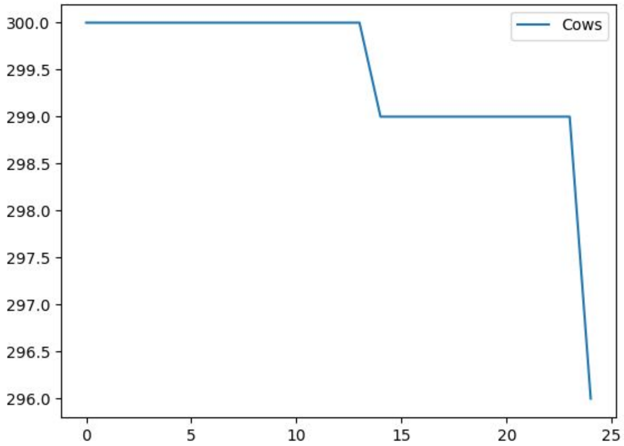
The Carrying Capacity

Based on the grass regrowth rate, the meadow size and the time horizon, there is an optimum number of cows it can handle.

The Carrying Capacity







Introducing Rational Owner Agents

Owner Agents

- Initially each owner agent owns equal number of cows.
- The owners want to maximize the number of cows they have on the meadows. We are assuming the profit of each owner is directly proportional to the number of cows (say each cow produces same amount of milk which he can sell).
- Previously, we looked at a simple model, where according to the profit function, they can cut back on the number of cows when profits decline (iteratively).
- Here, they don't have the knowledge of the total number of cows.
- We now want to arrive at a policy for the owners to arrive at the optimal number of cows.

Introducing Rational Owner Agents

Policy 1

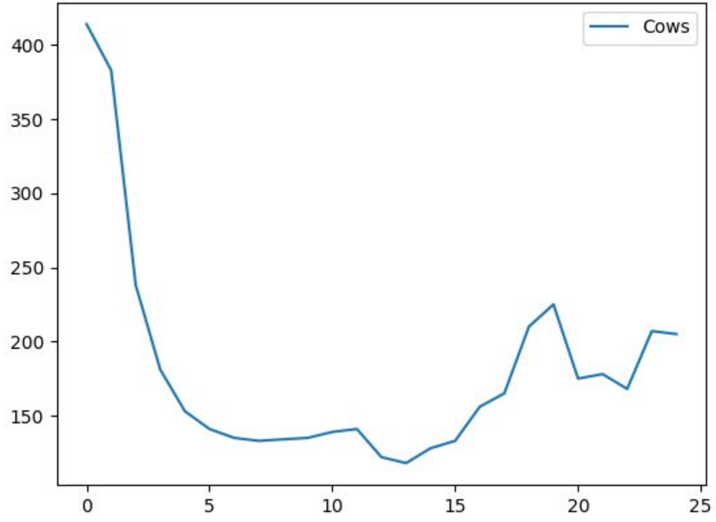
- At the end of each year, the owner looks at the number of cows and if none of his cows have died, he increases the number of cows by an upward increment factor (Normal RV with mean = 0.1, s.d =0.5).
- If some of his cows have died, he decreases the number of cows by a decrement factor (Normal RV with mean = 0.5, s.d =0.5).
- We have assumed D.F > I.F as people generally value risk aversion and avoiding death more than profits.

Introducing Rational Owner Agents

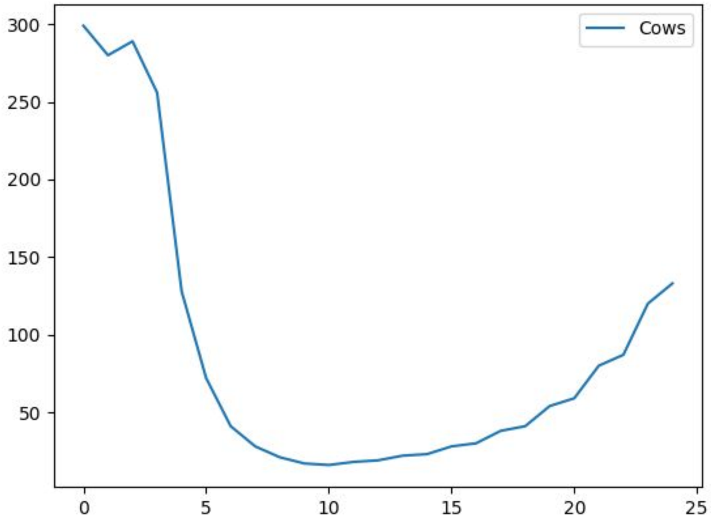
Agent Rationality

	Low	High
Increment Factor	Risk aversion	Greed
Decrement Factor	Risk appetite	Risk aversion

Results



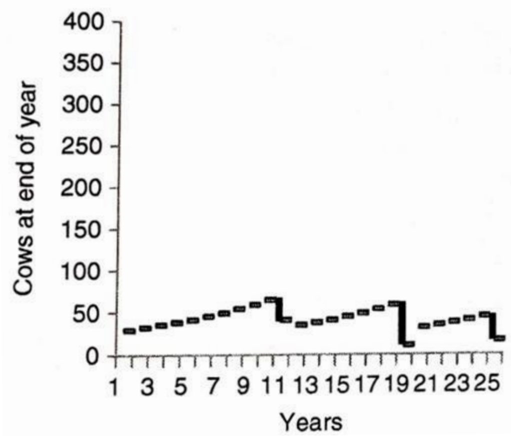
Cows
400
350
300
250
200
150
0
5
10
15
20
25

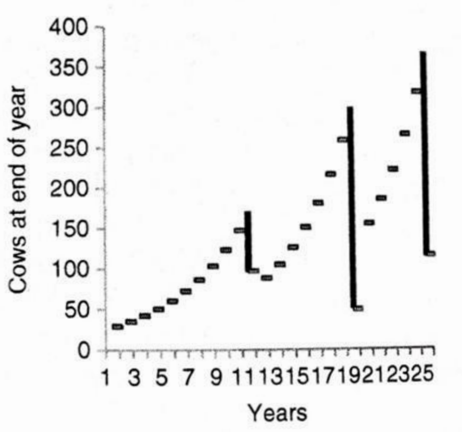


Cows
300
250
200
150
100
50
0
5
10
15
20
25

Policy 1 observations

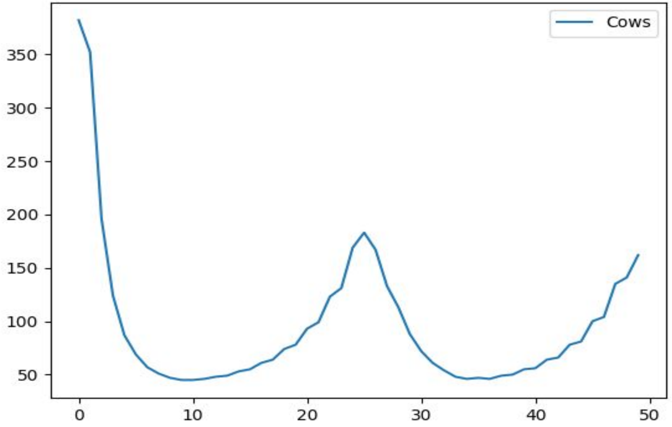
- Sometimes settles to the carrying capacity, can be bistable or even chaotic,
- High inequality in the final number of cows.
- Example: A(0.5,0.1), B(0.5,0.2), greed is rewarded

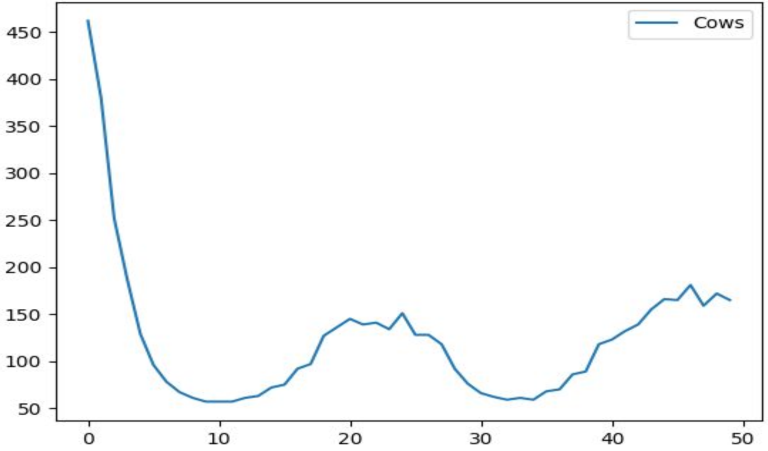




Policy 2 and observations

- There is a set limit on the number of cows
- Even if the limit if relatively high, the chaos is much less and less inequality among owners.
- Downside is that less cows than optimum achieved.

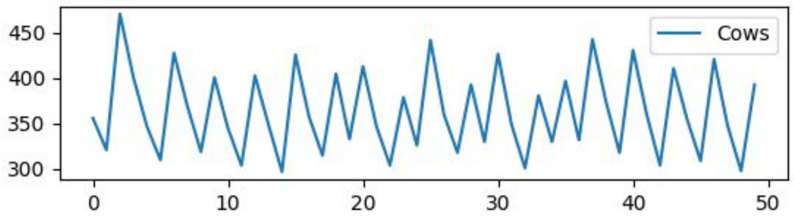


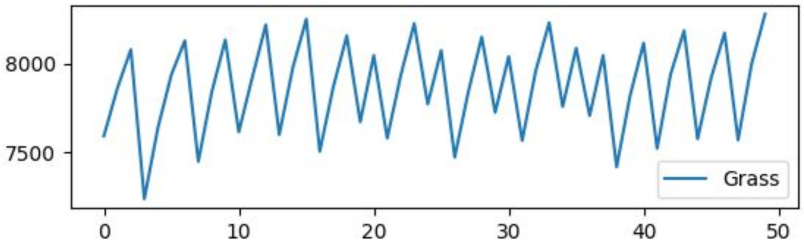


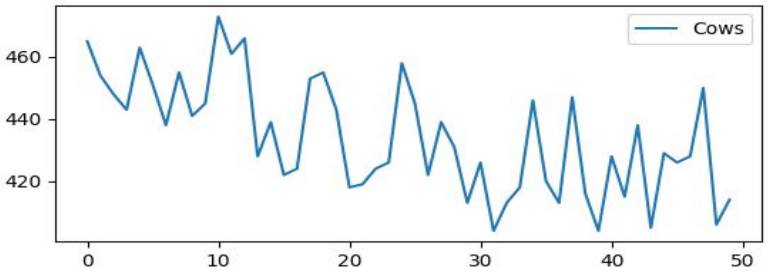
Policy 3

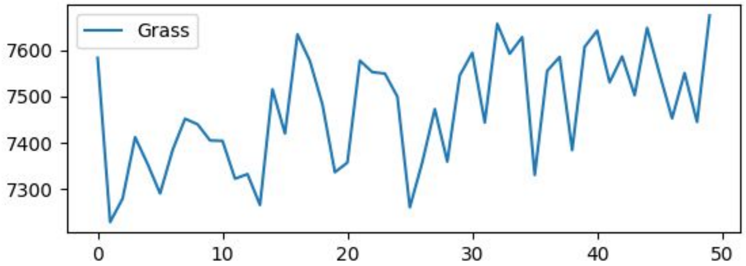
- There is a set lower limit on the grass, i.e at the end of each year everyone looks at the amount of grazable grass patches left. If it is below a limit, everyone decreases their cows by a DF. If not, everyone increases their cows by an IF.

Policy 3 and observations









Policy 3 observations

- Achieves the optimum capacity very soon, least instability.
- Less inequality among the owners.
- We conclude that it is the best policy.

Applications and conclusions

$$U = (P(n_i) - D(N(n_i)) , N(n_i) = \sum(n_i)$$

$$\partial D(n_i)/\partial P(n_i) \approx 0$$

- **Global warming:** the most pressing problem
- **Misinformation** and sensationalism on the internet

The Challenge

- Contradiction with Adam Smith's invisible hand

References

1. Agent-based modelling in economics, Lynne Hamill, Nigel Gilbert
2. Agent-Based Models with Python: An Introduction to Mesa, course by Complexity Explorer, Santa Fe Institute
3. Growing Artificial Societies by By Joshua M. Epstein and Robert L. Axtell
4. Prospect Theory: An Analysis of Decision under Risk, Daniel Kahneman, Amos Tversky

Thank you