Development Engineering

TD 463

Lecture 4

Sustainability

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What is Sustainability?

- The ability of a *closed* composite system to continue till perpetuity.
- But what is a system?
  - It has several internal interacting subsystems.
  - Each has several *time-varying* state variables.
  - Each variable has a governing simple differential equation in terms of itself and other state variables. Dynamics
- Sustainability : Repeating states, with natural periods.
- Marine Ecological Sustainability.
  - Ocean water, Species.
  - Physical properties - salinity, dissolved oxygen, organic and inorganic concentration. Species populations.
  - Biological inter-dependence biological processes.
- Human Systems: many state variables and dynamics in our control.

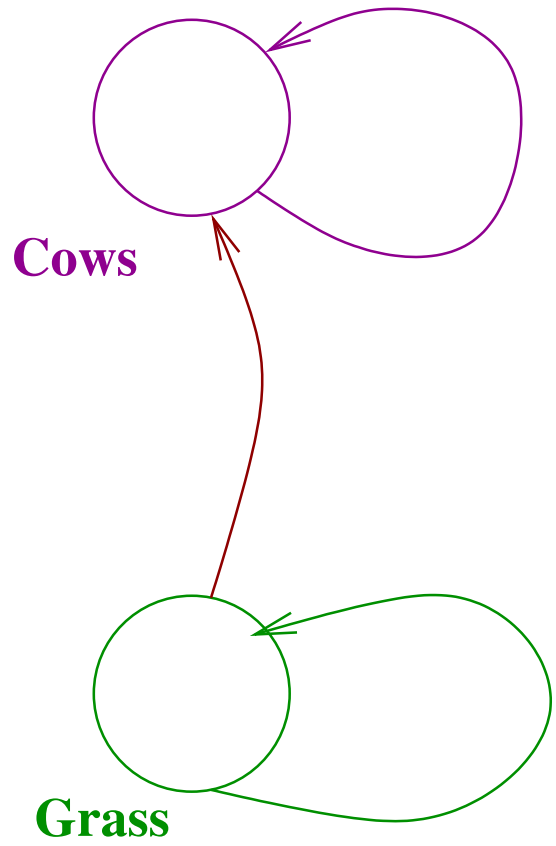
Key Questions

- How do I know whether the current values and dynamics lead to stable/periodic systems?
- Can we have $s_1 > 2$ and $s_2 < 3$ and yet have a sustainable system?
- How do the parameters of the system determine the steady states?

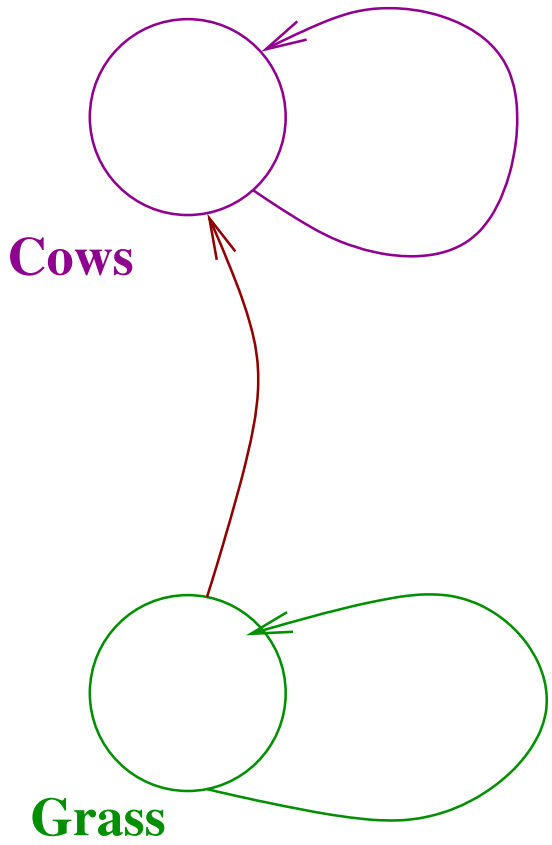
Simple Stock-and-Flow systems

- System $\mathcal{S} = (S, E)$consists of k *stocks,* $S = \{s_1(t), \ldots, s_k(t)\}$, and some r environment conditions $E = \{e_1(t), \ldots, e_r(t)\}$.
- $ds_i/dt = f_i(S, E)$

- An island has area A and has only grass growing on it.
- The grass $g(t)$ on the island (in total kgs) grows at a constant rate $\alpha \cdot g(t)$ provided it does not exceed a constant G. At G it does not grow at all till it drops below G.
- There are $c(t)$ cows on the island as well. They eat grass at the rate $d(t) = \beta \cdot c(t)$ kgs/day, if $g(t) \geq 0$, or else, it is zero.



- The grass $g(t)$ on the island (in total kgs) grows at a constant rate $\alpha \cdot g(t)$ provided it does not exceed a constant G. At G it does not grow at all till it drops below G.
- There are $c(t)$ cows on the island as well. They eat grass at the rate $d(t) = \beta \cdot c(t)$ kgs/day, if $g(t) \geq 0$, or else, it is zero.
- The population grows at the rate $\mu \cdot (d(t) - d_0 \cdot c(t))$.



Solution

For what values of α, β, μ and G, d_0 is there a steady state where $c(t) \geq C$?

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- $dc/dt = 0 \Rightarrow \beta = d_0$. This implies $\alpha g(t) = \beta c(t)$.
- Thus there is a range of choices with $g(t) = K < G$ and $c(t) = \alpha \cdot K/d_0$.

Steel

- Steel in a society is stored as Useful steel $U(n)$ and as Scrap $S(n)$.
- Every year, a constant $d \cdot U(n)$ becomes scrap. This d is called the depreciation factor.
- It manufactures upto e cu.m. of steel from ore extraction every year.
- It can recycle upto $r \cdot S(n)$ cu.m. steel every year. This r is called the recycle rate.
- If it wants to have K cu.m. of useful steel as assets for its population, what should be its steel production/recycle regime?
- How many years will it take to achieve zero extraction?

Solution

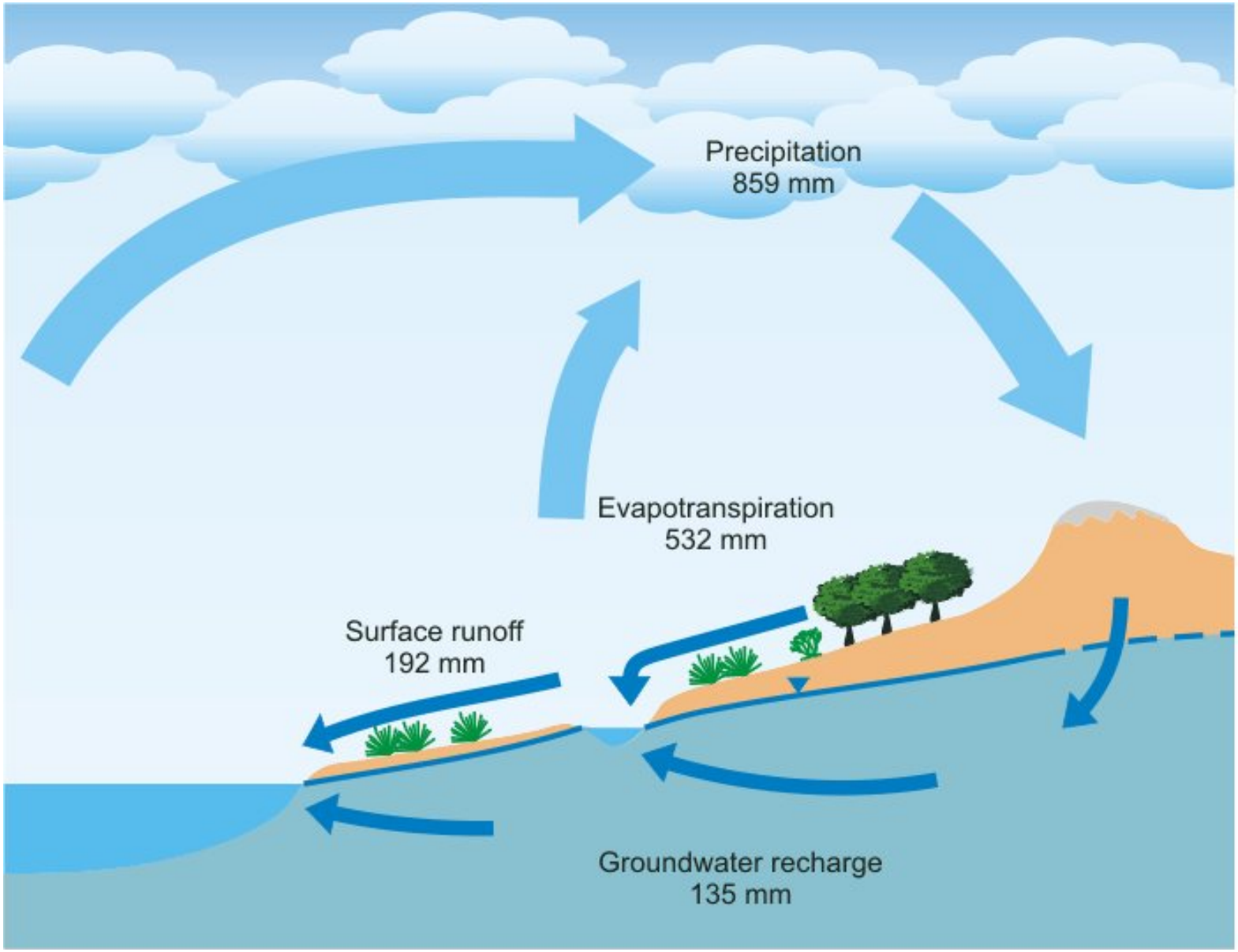
- For zero extraction, we have $S \cdot r = U \cdot d$. Thus, if $d = 2\%$ and $r = 6\%$, then $U/S = 3$. Thus, if $U = K$, then the total steel in the system is $4K/3$.
- It will take $n = 4K/(3e)$ years to achieve zero extraction. For all these years, the rate of recycle must be r.

In real life

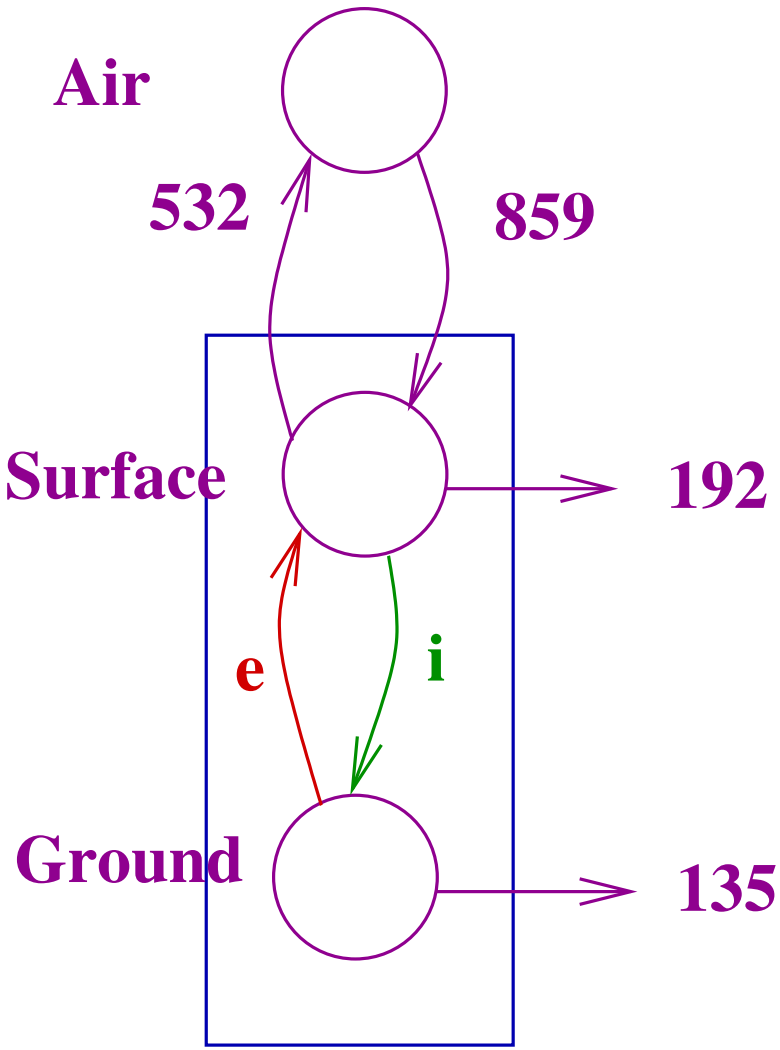
- There is a stock $O(n)$, the amount of ore available, and $D(n)$ the depth at which ore is available. As the ore depletes, the cost $P_1(n)$ (in Rs./cu.m.) of extraction increases.
- Recycling cost $P_2(n)$, reduces with increased volume.
- Research $\Rightarrow$ Recycle rate $\uparrow$ and Depreciation rate $\downarrow$.

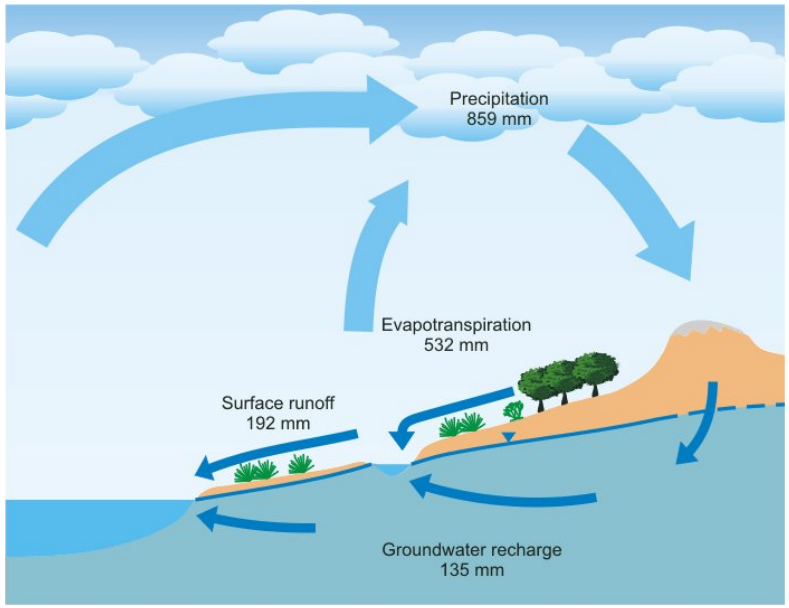
Alas, number of jobs in the sector depend on $r \cdot S$ and e!

Water in Germany



Water

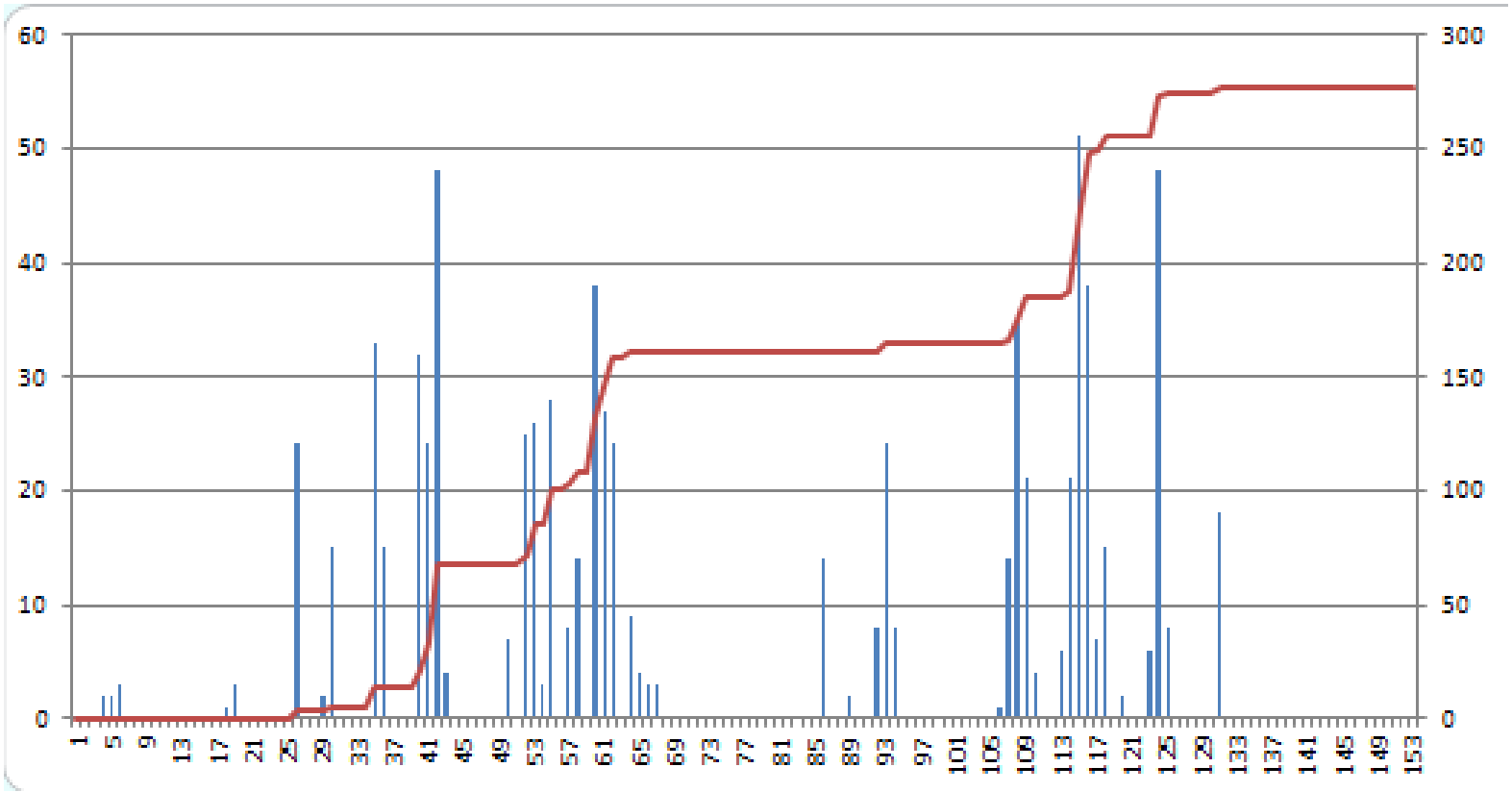




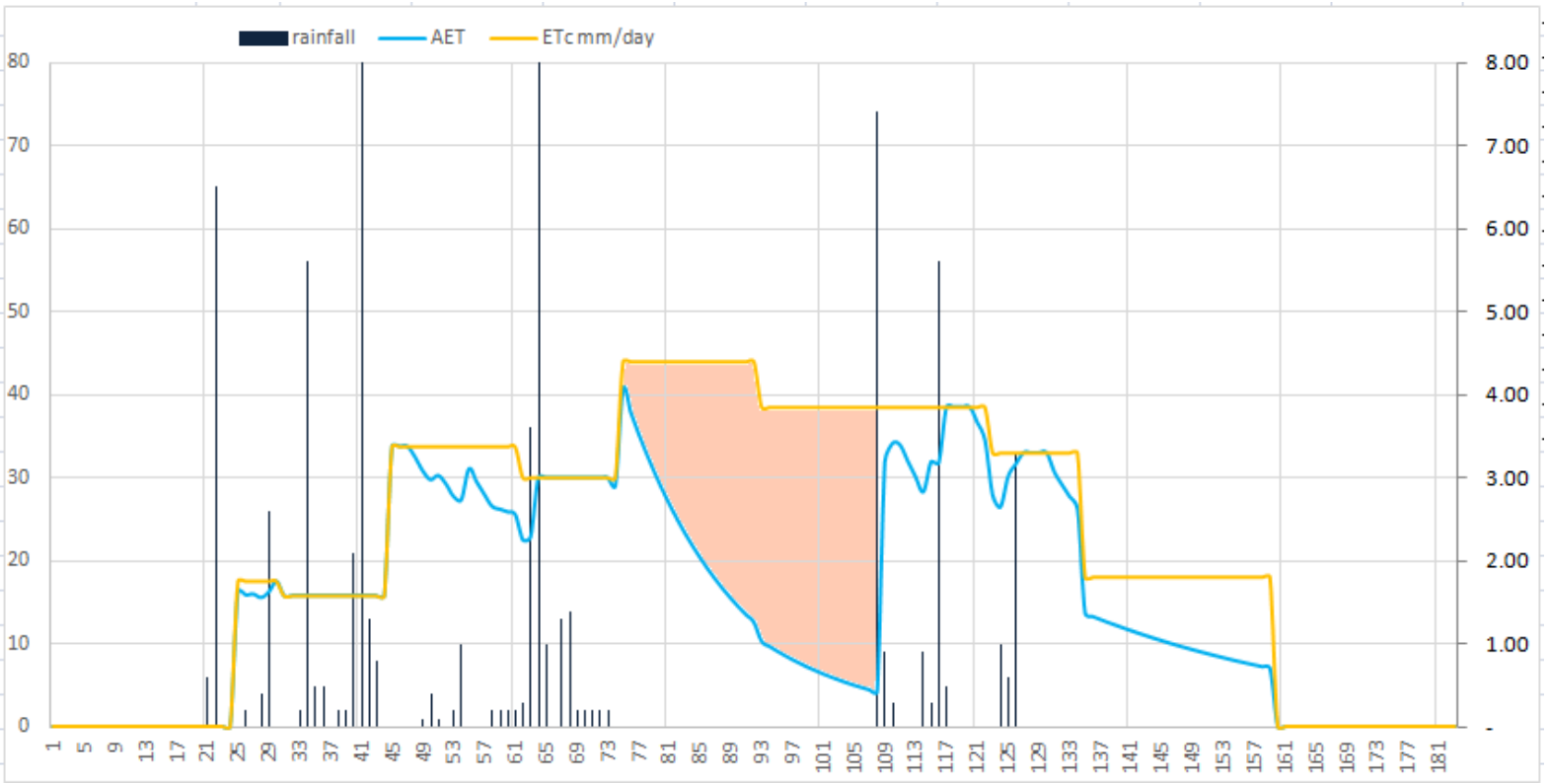
rainfall	835	
run-off	192-x	$\downarrow$
gw flow	135-y	$\downarrow$
ET	532+z	$\uparrow$

What are i and e? How are they to be implemented?

Climate Change



Crop Stress

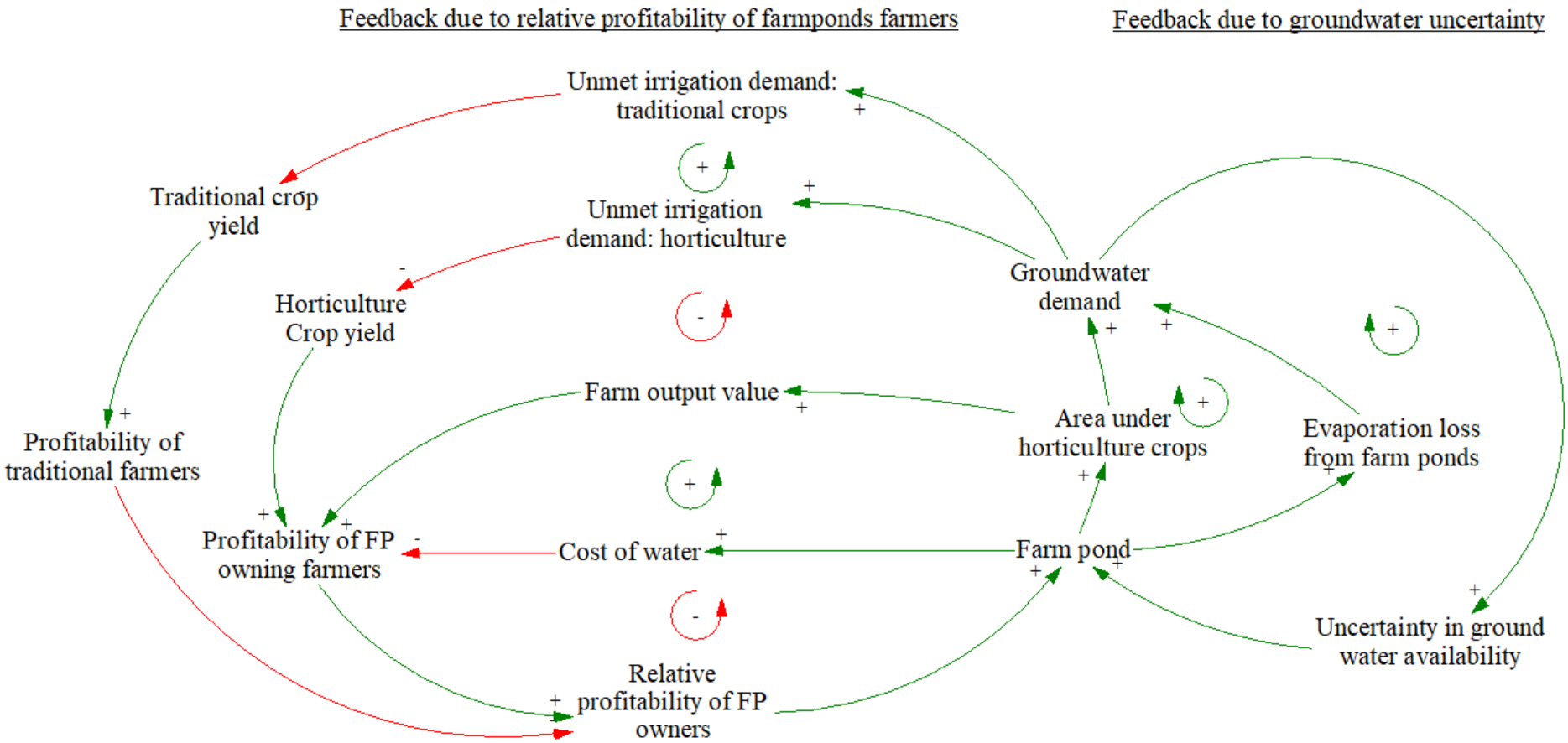

rainfall
AET
ETc mm/day
80
70
60
50
40
30
20
10
0
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
-
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105 109 113 117 121 125 129 133 137 141 145 149 153 157 161 165 169 173 177 181

Farm Ponds

- A farm-pond is large tank built on a farm, *with lining*.
- Filled up in monsoon through stream water or wells.
- Used in Rabi or Summer.
- Costs roughly Rs 2 lakh for a storage of 2TCM.
  Depreciation 20%. Water loss by evaporation 20-40%.
- Used largely for Mosambi, Pomegranate, Grapes or some expensive Rabi vegetable.

Is this viable? Is this sustainable?

Farm Ponds - Sustainability (Pooja)



Viability

- Generally different from sustainability. *Financial, Cultural, Political, Economic* viability.
- About a particular project or a profession.
  - The profession of a regional singer, or *tamasha*. Rock band?
  - Dismantling caste-based job reservations/promotions.
  - Allowing longer hours of internet in hostels. Or curfew time for girls hostel. *Cultural issue, academic, safety, social* issues.
  - The Bullet-Train project. Panvel Airport.
  - Agriculture as a profession.
- Analysis within a particular man-made socio-economic-cultural framework.
- An economic system, a political system. **Sustainable?**

A Multinational Company - personal health, food, etc.

Heading	2017-18 in Rs. cr.	in 2016-17
Revenues	35,787	35,013
Profit before Tax	5,237	4,490
Fees and Royalty	993	1,044
Wages	1,745	1,620
Raw Material	10,047	8,999
Packaging Material	2,444	2,364
Purchase of Stock-in-Trade	3,812	4,166
Advertising and Promotion	4,105	3,470
Depreciation	468	384
Carriage and Freight	1,492	1,457
SME payable (var. heads)	6,872	5,764
R&D	23	28
Tax	2018	1906

Wages

- 18,000 employees, around 5,800 *permanent*.
- CEO, MD 170 times median employee.
- Other ED, 40-50 times median employee. Top management, Rs. 37 crores.
- Median wage increase 4.7%. Average (non-top management) 9.4%.
- Total Wage Bill: Rs. 1745 crores.

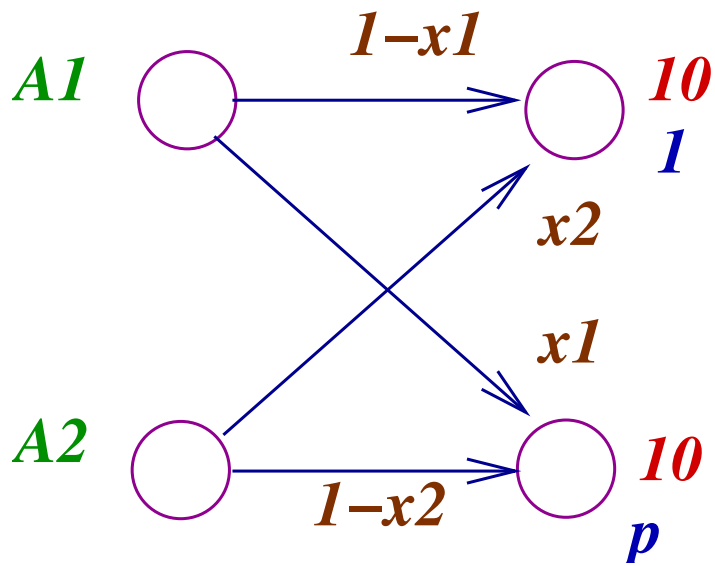
The Big Question

The system seems viable! But is it really so? And is such a system sustainable? Lets do a small model.

The model

Two classes A_1 and A_2 producing identical goods G_1 and G_1.
Consumption preferences.

	A_1/G_1	A_2/G_2
Pop.	1	10
Prod.	10	1
Pref. A1	$1-x_1$	x_1
Pref. A2	x_2	$1-x_2$



$$\begin{aligned} 10 &= 10 \cdot (1 - x_1) + 10p \cdot x_2 \\ 10p &= 10p \cdot (1 - x_2) + 10 \cdot x_1 \\ p &= x_1/x_2 \end{aligned}$$

What are the wages?

Model this...

- What if α_i is the unit pollution for the production of good G_i?
- Should we move one member of A_2 to A_1?

Thanks