Environmental Analysis and Ecology
HSLU, Semester 4

Matteo Frongillo

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Week 1

1 TODO

Carrying capacity in general systems:
The maximum level of output or performance that a system can sustain over time without experiencing degradation or failure.

Carrying capacity in population:
Maximum population size of a species that an environment can sustain indefinitely, given the available resources and environmental conditions.

Week 2

2 Systems

2.1 Characteristics

- Input and Output
- Set of components
- Rules and relationships between components
- System's boundaries

2.2 System's loops

2.2.1 Feedback loops

Feedback loops are the system's response to changes
Two types of loops:

- Positive feedback loops (Reinforcing):
  Causes systems to change further in same direction
- Negative feedback loops (Balancing):
  Causes systems to change in opposite direction from which it is moving

2.2.2 System's responses

Time delays Complex systems often show time delays between input of a feedback stimulus and the response to it **(oscillating graph)**
Ex: Population growth or global climate change

Synergistic interaction System effects can be amplified through synergistic interaction

2.3 Casual loop diagram (CLDs)

CLDs are maps showing casual links with arrows from a cause to an effect and it allows the identification of polarity of feedback loops (positive or negative)

2.4 Reference Behavior Pattern (RBP)

Example If A increases, B will increase (↑↑)

- Arrows show same direction → assign (-)
- Variables can also be decreasing in the same direction (↓↓) → also assign (-)

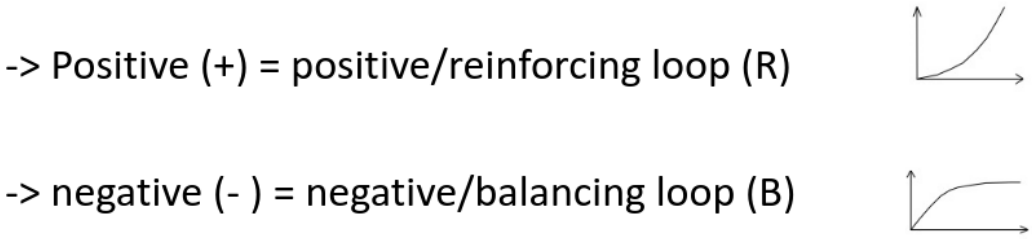


Figure 1: Reference Behavior Pattern

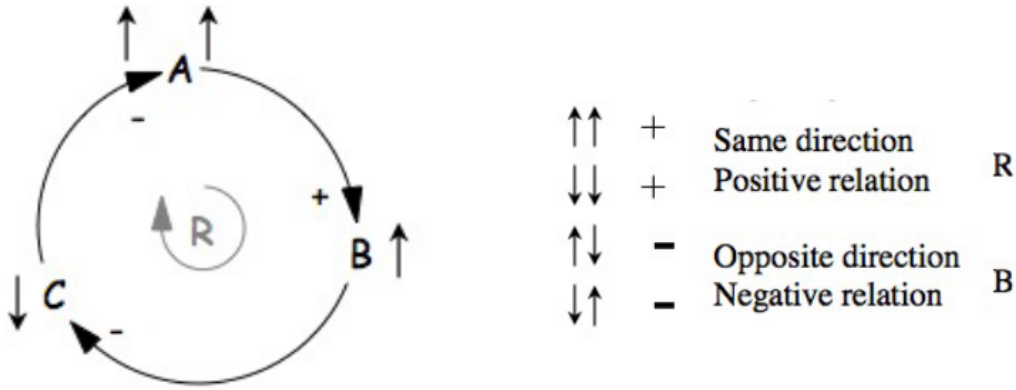


Figure 2: RBP Example

If B increases, C decreases (↑↓)

- Arrows show opposite directions → assign (-)

If C decreases, A increases (↓↑)

- Arrows show opposite directions → assign (-)

So:
A↑ → B↑ → C↓ → A↑↑ (Reinforcing Loop)
A↓ → B↓ → C↑ → A↓↓ (Reinforcing Loop)

3 Ecosystems

3.1 Energy flow in ecosystems

Robustness in ecosystems is the capacity of an ecosystem to withstand disturbances (e.g., drought, fire, pollution) while maintaining its structure and key functions.

It is important because it helps prevent collapse into degraded states and preserves ecosystem services like nutrient cycling, productivity, and biodiversity support.

3.2 Cycles in the biosphere

3.2.1 Nutrient cycle

TODO

3.2.2 Hydrologic cycle

TODO

3.2.3 Nitrogen cycle

- Major reservoir for the nitrogen is the atmosphere (78%)
- Nitrogen cannot be directly absorbed and used as a nutrient by plants or animals

Human alteration

- Humans add large amounts of nitric oxide (NO) into the atmosphere by burning any fuel at high temperatures (e.g. car, jet engines) → acid rain
- Nitrous oxide (N_2O) in atmosphere through commercial inorganic fertilizers → N_2O is a GHG and depletes stratospheric ozone
- Large quantities of nitrogen stored in soils and plants through destruction of forests, grasslands, and wetlands
- Humans alter nitrogen cycle in aquatic ecosystems through agricultural runoff and discharges from municipal sewage systems

3.2.4 Phosphorus cycle

- Phosphorus circulates in the soil mainly, also through water, the earth's crust, and living organisms
- As water runs over exposed phosphorus-containing rocks and dissolves phosphate
- Phosphate is mainly absorbed by plants roots

Human alteration

- Removal of large amounts of phosphate from the earth to make fertilizers
- Soil from fertilized crop fields carries large quantities of phosphates into streams, lakes and the ocean, where it stimulates the growth of algae
- Phosphate runoff from sewage water and mining waste

3.2.5 Sulphur cycle

- Most of the earths sulphur is stored underground in rocks and minerals, including sulphate salts buried under ocean sediments
- Sulphur also enters the atmosphere from several natural sources (e.g. active volcanoes, organic matter, which is broken down by anaerobic decomposers) → Deposited as acid rain

Human alteration

- Release of large amounts of sulphur dioxide into the atmosphere → Acid rain
  - Burning of coal and oil to produce electric power
  - Refining of sulphur-containing fossil fuels to make gasoline and heating oil
  - Conversion (smelting) sulphur-containing metallic mineral ores into free metals such as copper, lead, and zinc

3.2.6 Carbon cycle

- Carbon cycle is based on carbon dioxide (CO_2)
- 0.038% of the atmosphere consists of CO_2
- CO_2 is a key component of natures thermostat:
  - If too much CO_2 is removed from the atmosphere → atmosphere gets cooler
  - If too much CO_2 is added to the atmosphere → atmosphere gets warmer
- Plants and animals exchange CO_2 with the atmosphere through photosynthesis and respiration
- Carbon stored more permanently in plants returns to atmosphere as CO_2 through decomposition
- Oceans absorb and emit carbon to the atmosphere, and some of this carbon ends up accumulated at the bottom of the ocean
- Humans heavily contribute carbon to the atmosphere:
  - Extraction of fossil fuels → CO_2 emissions due to combustion

Week 3

4 Biodiversity

4.1 Definition

Biodiversity is the variety of earths species, the genes they contain, the ecosystems in which they live and the ecosystem processes (energy flow and nutrient cycling).

TODO

5 Species diversity

5.1 Population dynamics

5.1.1 Population

Group of individuals of the same species that live in the same place at the same time

5.1.2 Population factors

- Distribution
- Size
- Age structure
- Density

5.1.3 Population dynamics

Study of how population characteristics change in response to changes in environmental conditions.

Four factors that determine population size:

- Births
- Deaths
- Immigration
- Emigration

Population change is defined as:

$$\boxed{\text{population change} = (\text{births} + \text{immigration}) - (\text{deaths} + \text{emigration})}$$

Age structure can have a strong effect on how rapidly a population size increases or decreases:

- Pre-reproductive age (not mature enough to reproduce)
- Reproductive stage (capable of reproduction)
- Post-reproductive stage (too old to reproduce)

5.1.4 Growth functions

Species vary in their capacity for population growth under ideal conditions

5.1.5 Intrinsic rate of increase

Rate at which the population of a species would grow if it had unlimited resources.

Populations with high intrinsic rate of growth typically reproduce early in life, have short generation times (time between successive generations), can reproduce many times, and have many offspring each time they reproduce.

5.1.6 Carrying capacity

Intrinsic rate of increase and environmental resistance = carrying capacity.

Definition:
Maximum population of a given species that a particular habitat/area can sustain indefinitely without being degraded

- Carrying capacity of an area is not fixed
- A population with few (or no) limitations can grow exponentially
- Environmental resistance slows down growth rate as population size gets closer to carrying capacity:
  → logistic growth curve or S-shaped growth curve

5.2 Human influence

Extinction rate caused by human influence will increase to 10,000 times the background extinction within this century.

Annual extinction rate of 1% per year (currently between 0.01 - 0.1%)

New species eventually evolve to take the places of the lost one.

Week 4

6 Stock and flow diagrams (SFD)

6.1 Translating CLDs into SFDs

- CLDs represent conceptual models, which depict causal mechanisms based on underlying reference behaviour patterns (RBPs)
- First step in computational modelling of CLDs is the translation of CLDs into SFDs

6.2 Stock and flow diagrams (SFDs)

- SFDs provide a richer visual language than CLDs
- Six basic elements exist in SFDs: **Stocks, Flows, Converters, Connectors, Sources, and Sinks**

6.3 Components of SFDs

6.3.1 Stocks

A stock is a "part of a system whose value at any given instant in time depends on the systems past behavior".

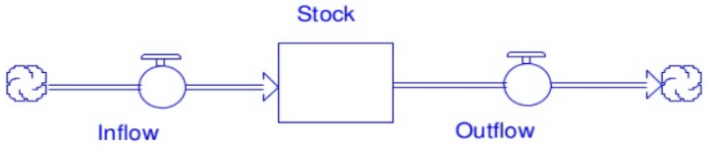
A stock is defided as:

$$\boxed{\text{Stock} = \int_{t_0}^{t_1} (\text{inflow - outflow})\, dt + \text{initial value}}$$

- Stocks represent anything that accumulates (normally in both directions)
- **Stocks are only affected by input and output flows**
- Stocks are normally tangible, countable and physical
  - But can also be non-physical (e.g. level of fear, aggression)
  - Non-tangible stocks require special attention, since differences in numerical translation might cause different system behaviours
- Stocks are usually presented by nouns

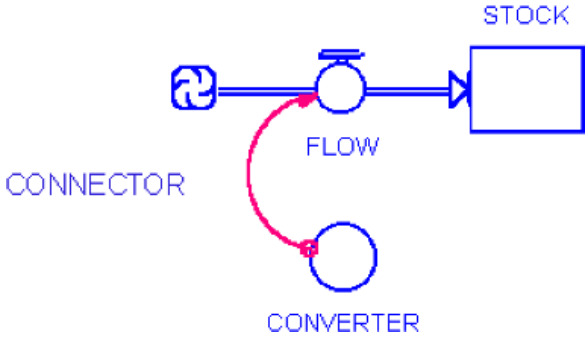
6.3.2 Flows

- Represent activities that lead to inflows and outflows to stocks (e.g. births, migration)
- Inflows cause the stock to increase
- Outflows decrease the stock
- Flows are usually presented by verbs or nouns describing an action



6.3.3 Converter

- Contain equations that generate an output value during each time interval of a simulation (e.g. birth rate, migration rate)
- Can also be used for storing constant values (e.g. initial population size)

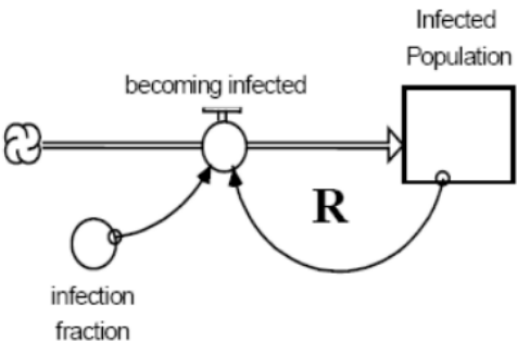


6.3.4 Connectors

- Transmit information to regulate flows
- Connectors can connect into flows or converters but never into stocks

6.3.5 Source and Sink

- Stocks that lie outside the system boundary
- Are used to show that a certain stock inflow is coming from another source (e.g. migration)
- Or that an outflow ends up in another stock outside the system (e.g. emigration)



Week 5

7 Climate

7.1 Weather vs. climate

Weather:

- Weather is a local, short term phenomenon
- Weather is mainly expressed by temperature, humidity, precipitation, wind speed, cloud cover
- Measured over hours or days

Climate:

- Areas general pattern of atmospheric or weather conditions
- Measured over long periods of time (ranging from decades to thousands of years)

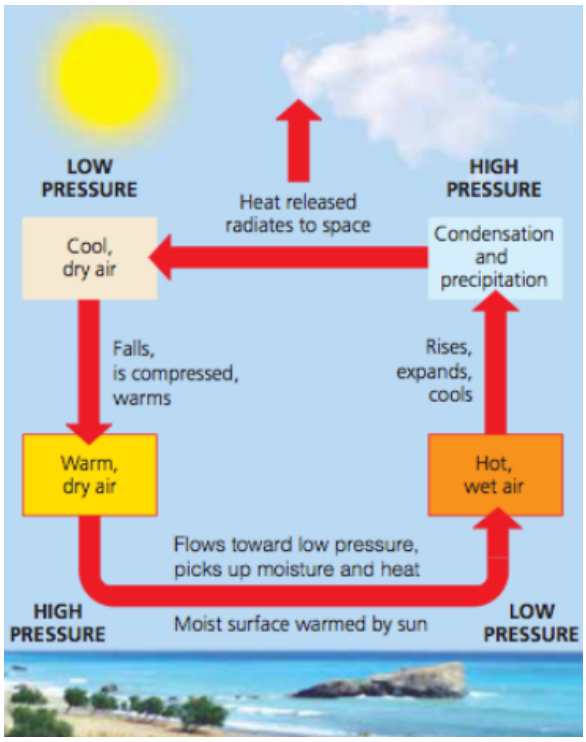
7.2 Climate factors

7.2.1 Climate zones

- Important component of earth's natural capital
- Climate variations caused by patterns of global air circulation and ocean currents

7.2.2 Factors of air circulation in lower atmosphere

- Uneven heating of earth's surface → Air is heated more at the equator
- Rotation of the earth around its axis:
  - Heated air masses rise above equator and move north and south
  - Atmosphere divided in cells, distinguished by direction of air movement
  - Differing directions of air movement are called **prevailing winds** (major surface winds that blow almost continuously and distribute air, heat, moisture and dust)
  - Prevailing winds also produce mass movements of surface water (currents)
- Properties of air, water and land:
  - Heat from the sun evaporates ocean water and transfers heat from the oceans to the atmosphere, especially near the equator
  - Evaporation of water creates cells (low and high pressure) which circulate air, heat, and moisture



7.2.3 Ocean conveyer belt (thermohaline circulation)

- Heat is also distributed when ocean water mixes vertically in shallow and deep ocean currents
- Result of differences in the seawater density
- Colder seawater (higher density) sinks and flows beneath warmer and less dense seawater
- Connected loop of deep and shallow ocean currents

- Acts like giant conveyer belt that moves heat to and from the deep sea
- Transfers warm and cold water between tropics and poles

7.2.4 Link between ocean and atmosphere

- Ocean currents are affected by winds in the atmosphere
- Heat from the ocean affects atmospheric circulation

7.2.5 Earth's surface features

- Heat is absorbed and released more slowly by water than by land:
  → Difference creates land and sea breezes → oceans and large lakes moderate weather and climates of nearby lands
- Topographic features of earths surface can create local and regional weather and climatic conditions that differ from the general climate of a region (e.g. mountains)

7.2.6 Greenhouse effect warms lower atmosphere

- Greenhouse gases allow visible light (and some infrared radiation and UV radiation) from the sun to pass through the atmosphere
- Earths surface absorbs much of this solar energy and transforms it to heat, which then rises into the lower atmosphere
- Some of this heat escapes into space, but some is absorbed by molecules of greenhouse gases → Warms the lower atmosphere and the earths surface (greenhouse effect)

8 Climate change - natural cycles

8.1 Characteristics of climate change

8.1.1 Natural variations

- Changes of earths climate are neither new nor unusual
- Atmosphere has experienced prolonged periods of global cooling and global warming
- Alternating cycles of cooling and warming are called glacial and interglacial periods

9 Natural forces

9.1 Milankovitch cycle

9.1.1 Variations

Earth's orbit
Earths orbit changes from being nearly circular to slightly elliptical (termed eccentricity)

→ Cycle has a period of around 100.000 years

→ The more elliptic the orbit becomes, the less time the earth spends near the sun

→ Less solar energy leads to cooling effect

Angle of tilt
Angle of tilt of the earths axis changes from 22,1ř (22,5) to 24,5ř (term obliquity)

→ Cycle has a period of 41.000 years

→ Land mass of the northern hemisphere face more/less towards the sun

→ Leads to cooling/warming effects

Direction of tilt
Direction of tilt of the axis changes (termed precession)

→ Cycle has a period of 26.000 years

→ Causes winters and summers to be warmer or colder depending on the amount of land surface being more or less exposed to the sun