Ecosystems

Introduction to the unit

Duncan Golicher

What is an ecosystem?

- Concept developed in the early twentieth century by ecologists such as Tansley (1934)
- Ecosystem theory developed in the 1970s by ecologists such as Hutchinson and the Odums
- Text book definition - “An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment, interacting as a system” (Chapin 2002).

Key ecosystem concepts

- Interactions between biotic and non biotic components
- Nutrient cycles and energy flows
- Feedback loops and cycles.
- Homeostasis / tipping points
- Dynamic equilibrium
- Food chains, food webs, trophic cascades
- Keystone species

How big is an ecosystem?

- Ecosystems rarely have clear boundaries
- Is an ecosystem really “uniform regarding the biological turnover, and contains all the fluxes above and below the ground area under consideration?” (Shultze et al 2005)
- Limnology (study of lakes) influential in the development of ecosystem theory as lakes are relatively well defined (Lindeman’s early studies).
- In reality most (all?) ecosystems interact with other ecosystems (I.e they are open systems)
- Ecosystems are in practice defined by the researcher
- The whole world can be thought of as a single ecosystem (Gaia hypothesis)
- Gaia is arguably the only truly closed ecosystem

How do we study ecosystems?

- Empirical experimentation on whole ecosystems (e.g. watershed monitoring)
- Empirical studies on components of ecosystems (e.g. population monitoring)
- Conceptual modelling of ecosystems: Identifying structure and function.
- Mathematical modelling of ecosystems or parts of ecosystems.

System dynamics

Ecosystems often modelled using the system dynamics paradigm

Jay W Forrester (MIT) formalised many of the concepts

Feedback loops

Compartment – flow modelling

Dynamic equilibrium

External and internal forcing

Complex system dynamics models

Club of Rome "World Model" (Meadows et al 1972)

First attempt to use system dynamics to model a virtual world

Modelled the human-biological-resource-pollution system as a system of equations

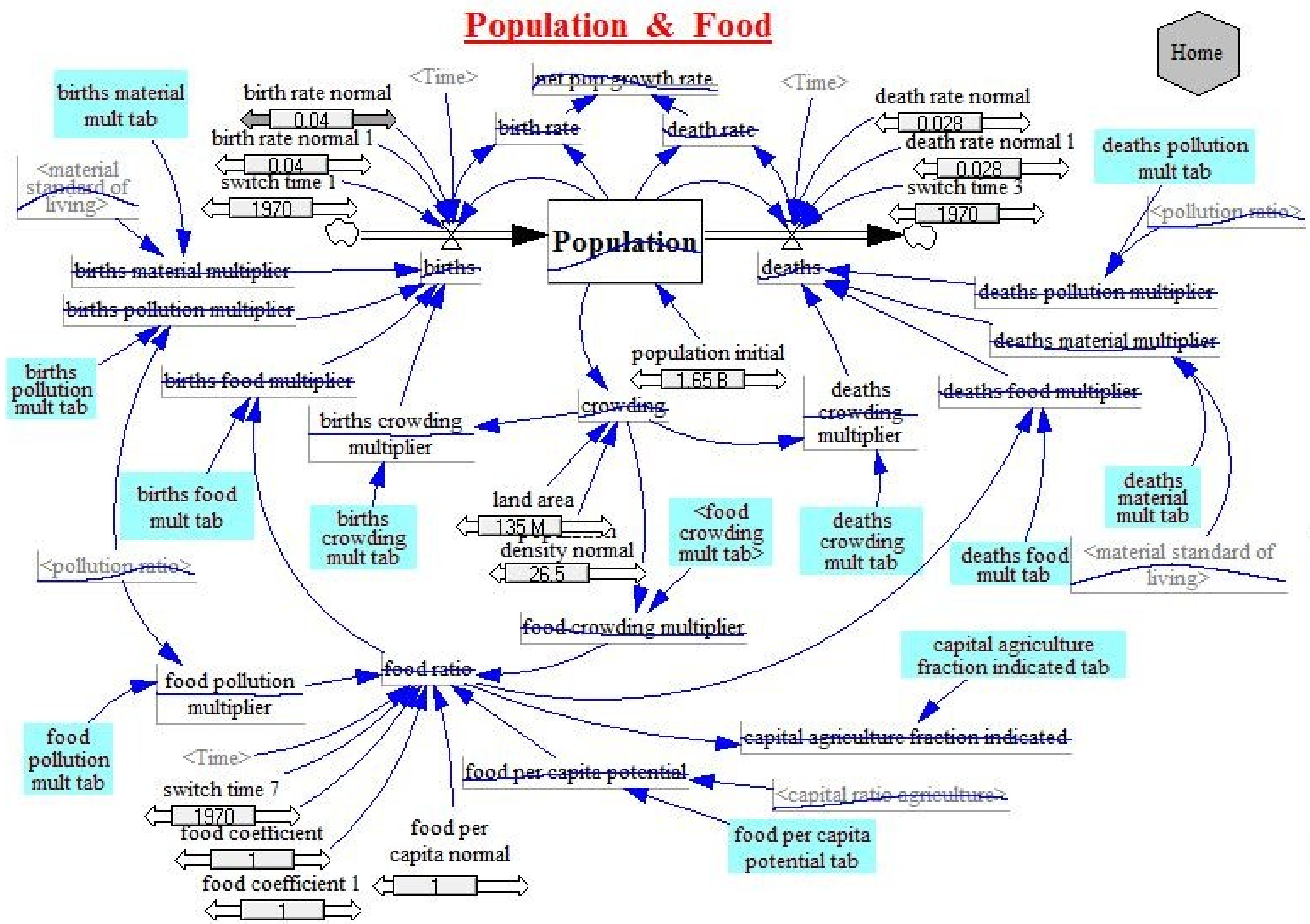
Used in the "Limits to growth" report (1972)

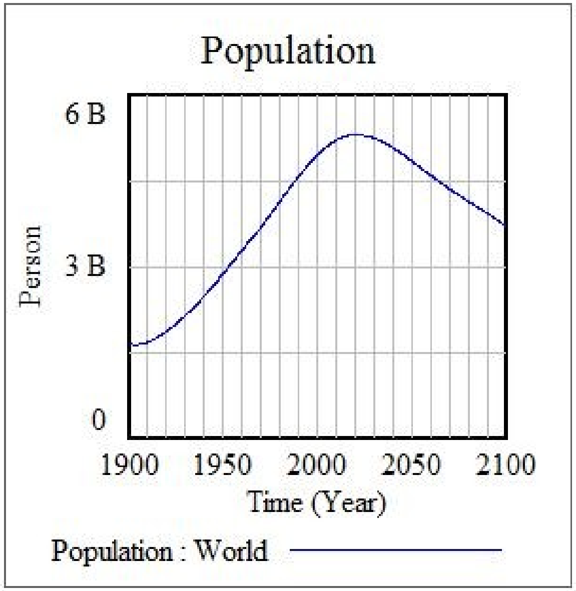
Influenced policy makers to take more of a "whole system" approach to global issues

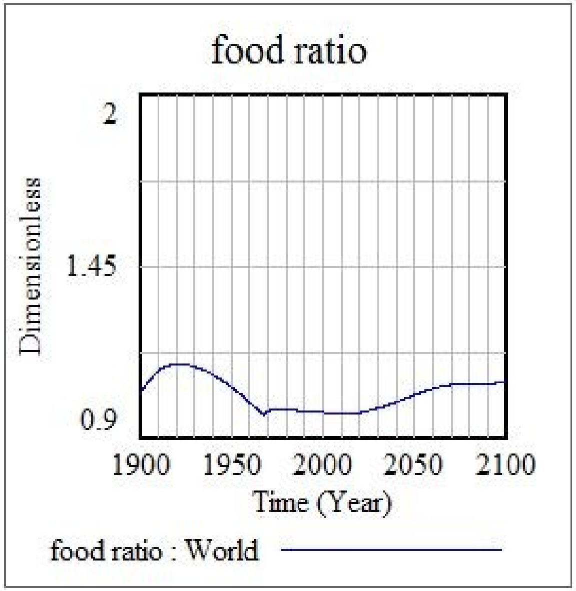
Software for modelling

- System dynamic models can be programmed in any computer language
- Specialised software includes Stella, Vensim, Model maker etc.
- Vensim PLE can be installed on a laptop
- Insight maker runs through a web browser
- https://vensim.com/free-download/
- https://insightmaker.com/

World model in Vensim



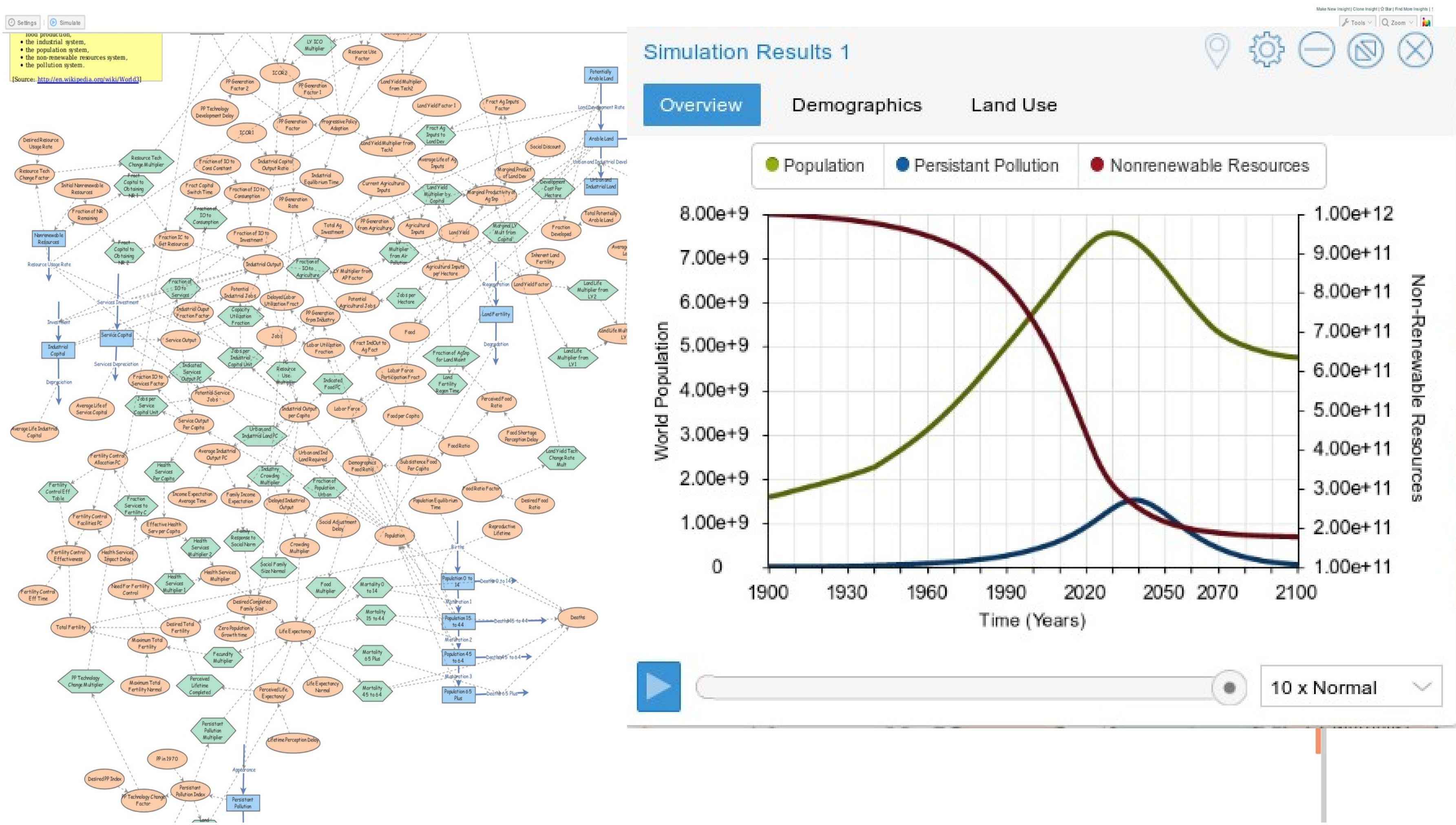




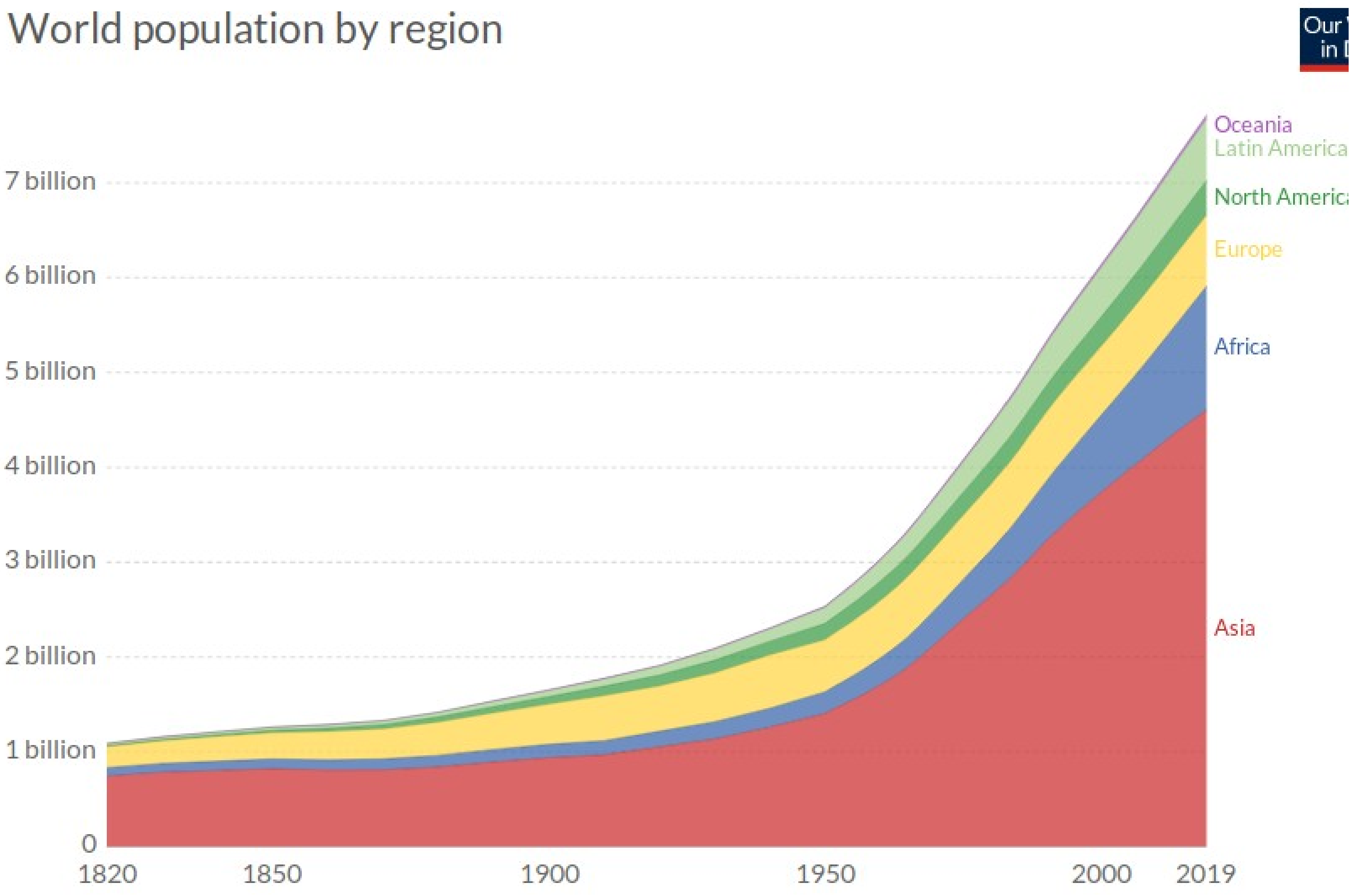
Run the model yourself!

- The model is included as example with VensimPLE (free Personal Learning Edition)
- An analysis of the model is available as a video on this page
- https://vensim.com/model-analysis-world-dynamics/
- https://insightmaker.com/insight/1954/The-World3-Model-A-Detailed-World-Forecaster
- Multiple positive feedback loops that may lead to undesirable and unsustainable pressure on global system
- Has been criticised by many economists as unrealistic, however it still influences conservation thinking.

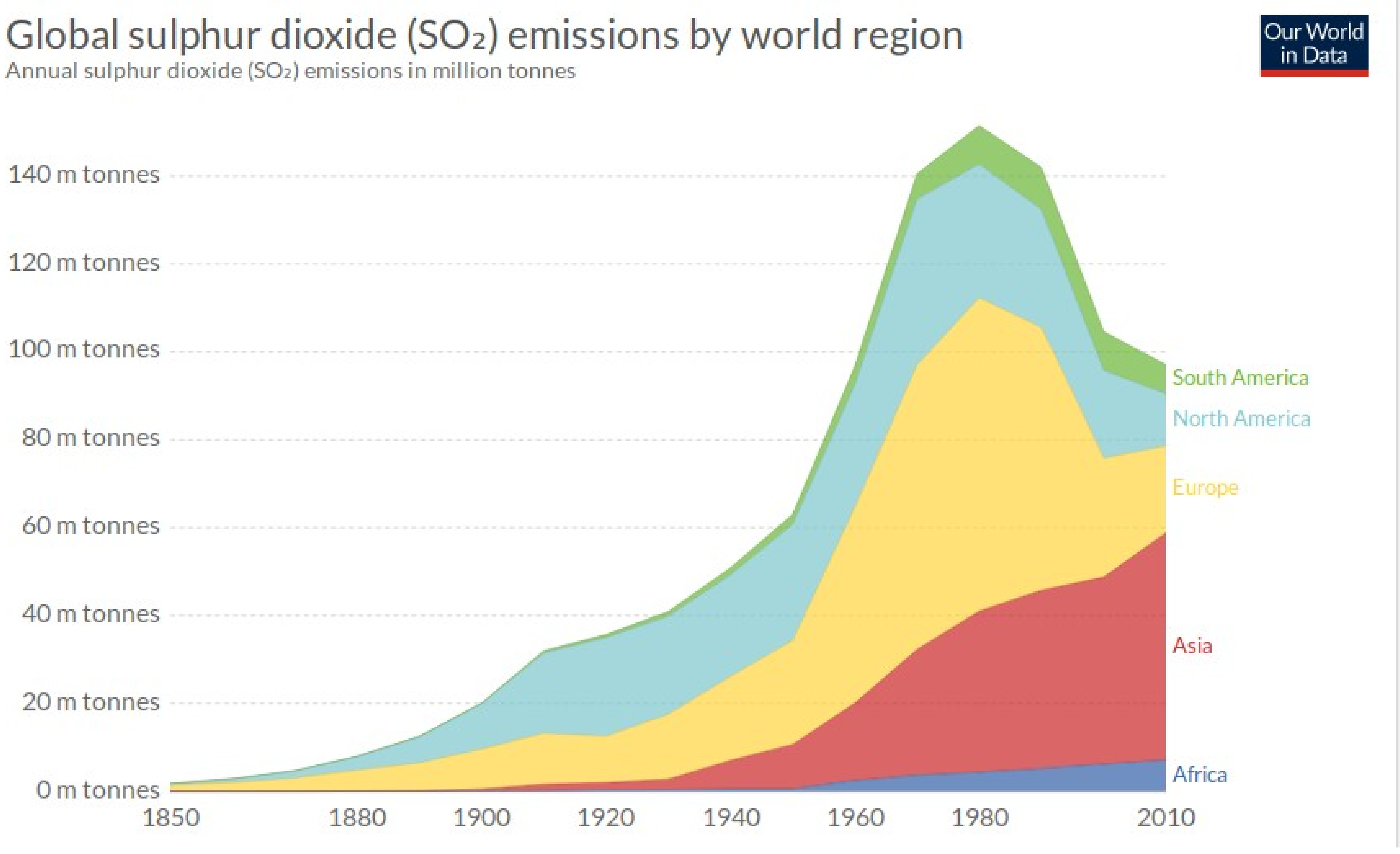
World 3 model
Insight maker



Global population



Sulphur dioxide pollution



The Gaia hypothesis

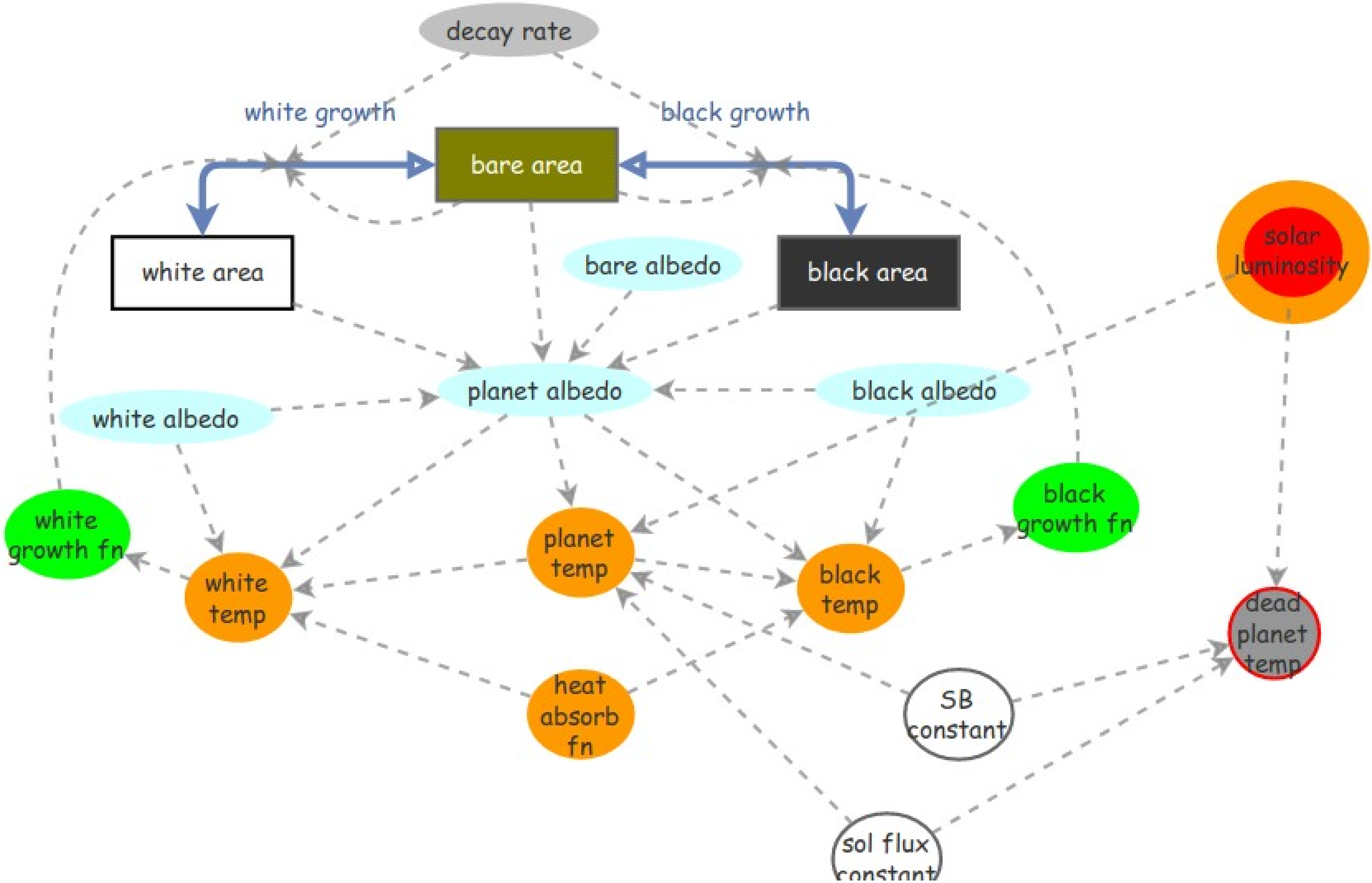
- Developed by Lovelock and Margulis in 70’s
- Based on Ecosystem thinking
- The earth as a self regulating system
- Feedback loops
- Modification of abiotic environment by biotic factors
- Human modification of ecosystems may lead to an alteration in the equilibrium condition

Homeostasis

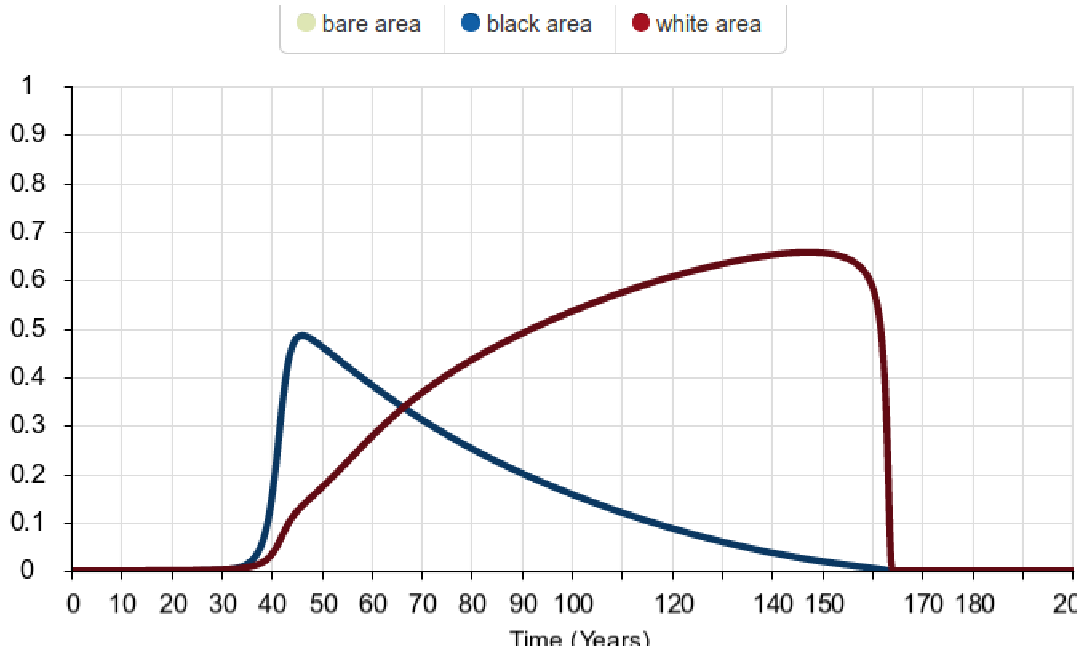
The tendency of a system to return to some particular state

- Simple example. A room with a thermostat controlling the central heating.
- Daisy world more complex (but still much simpler than the real world)
- Ecosystems may have **many** feedback loops
- Some are positive others are negative

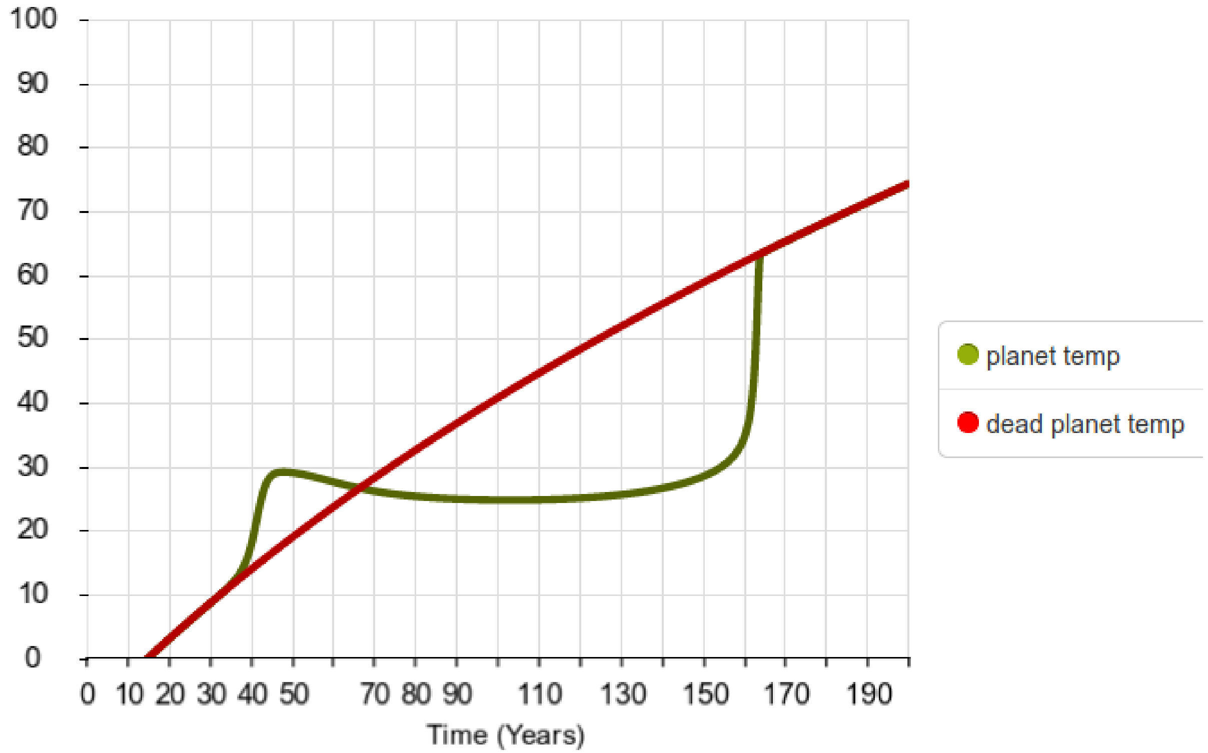
Daisy world



decay rate
white growth
black growth
bare area
white area
bare albedo
black area
solar luminosity
planet albedo
black albedo
white albedo
black growth fn
white growth fn
planet temp
white temp
black temp
dead planet temp
heat absorb fn
SB constant
sol flux constant



bare area
black area
white area
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100 120 140 150 170 180
Time (Years)

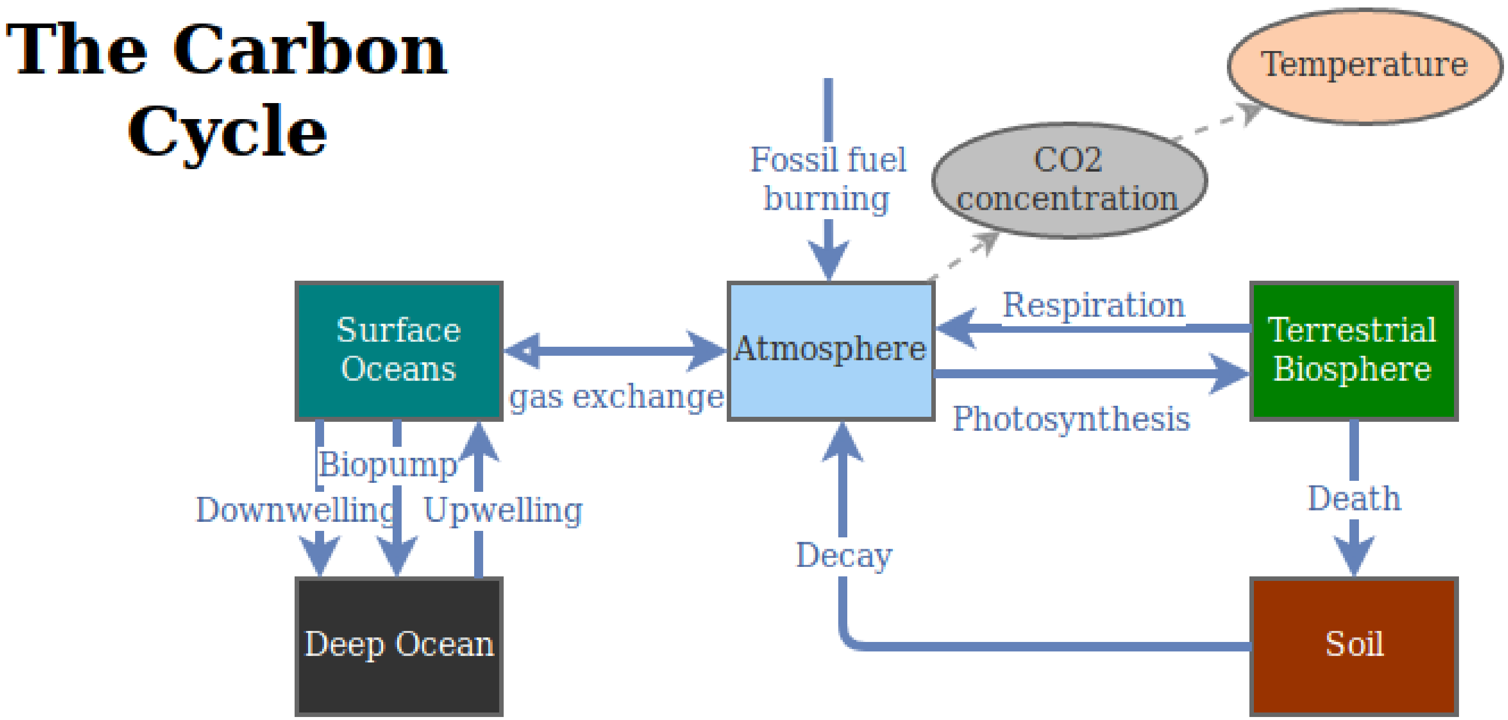


100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 70 80 90 110 130 150 170 190
Time (Years)
planet temp
dead planet temp

Daisy world

- Simple example of self regulating system
- Netlogo model
- http://r.bournemouth.ac.uk:82/Ecosystems/Daisyworld.html
- Also, see video link on Brightspace

Human impacts on Gaia



Simple model of world carbon fluxes

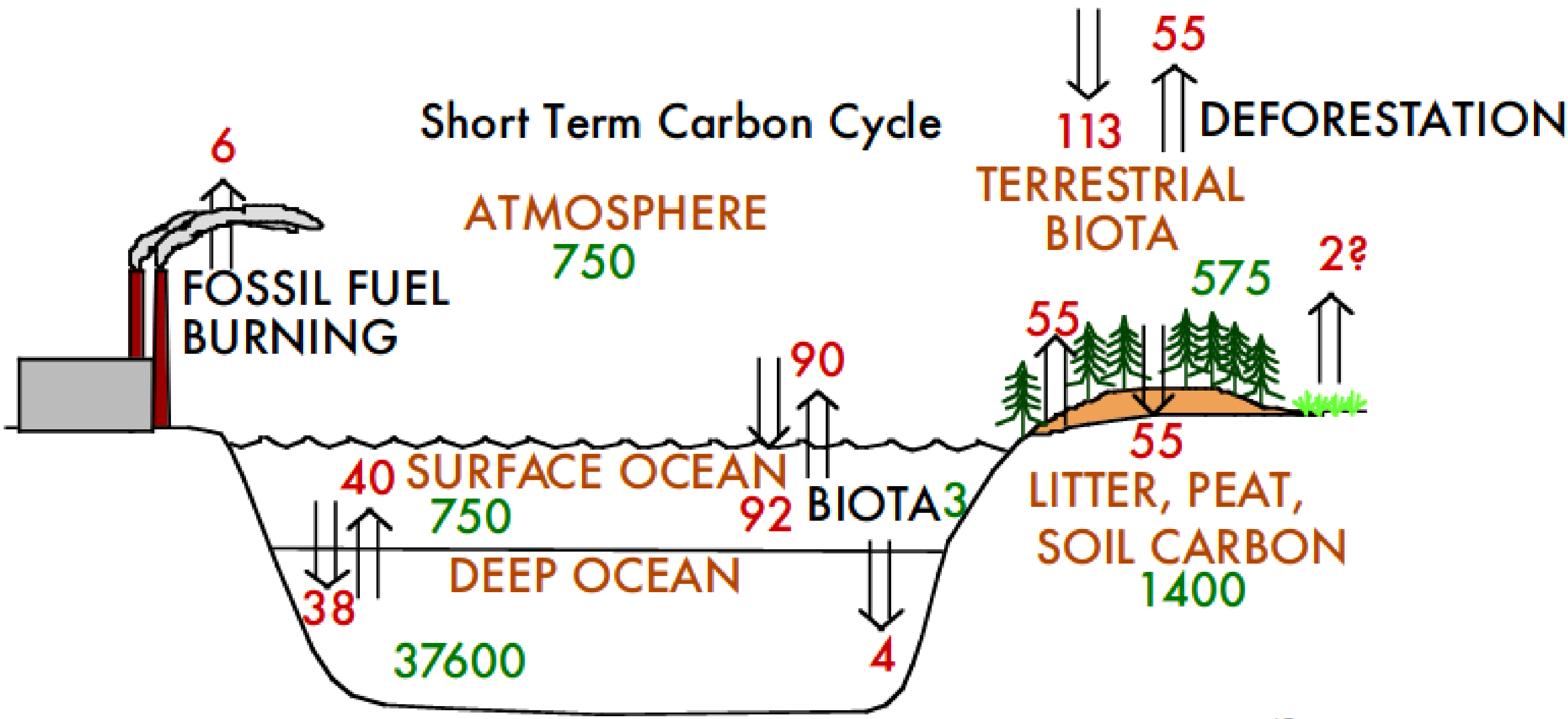


Figure 1. The Carbon Cycle. Numbers in green show the amount of carbon (in 10^{15} grams or gigatons, Gt.) in the atmosphere, oceans, terrestrial biosphere, and soil (including litter, debris, etc.). Fluxes (red) between these reservoirs (arrows) are in Gt./yr. Also shown in the approximate isotopic composition of each reservoir. Magnitudes of reservoirs and fluxes are from Schlesinger (1991).

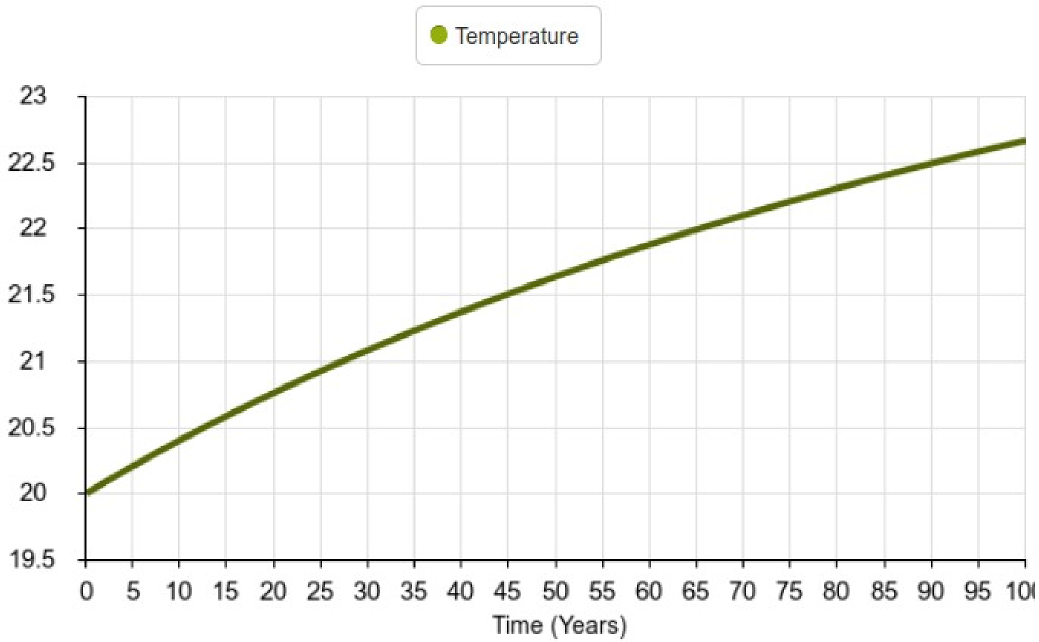
Simple model of atmospheric forcing

- https://insightmaker.com/insight/79473/Global-Carbon-Cycle

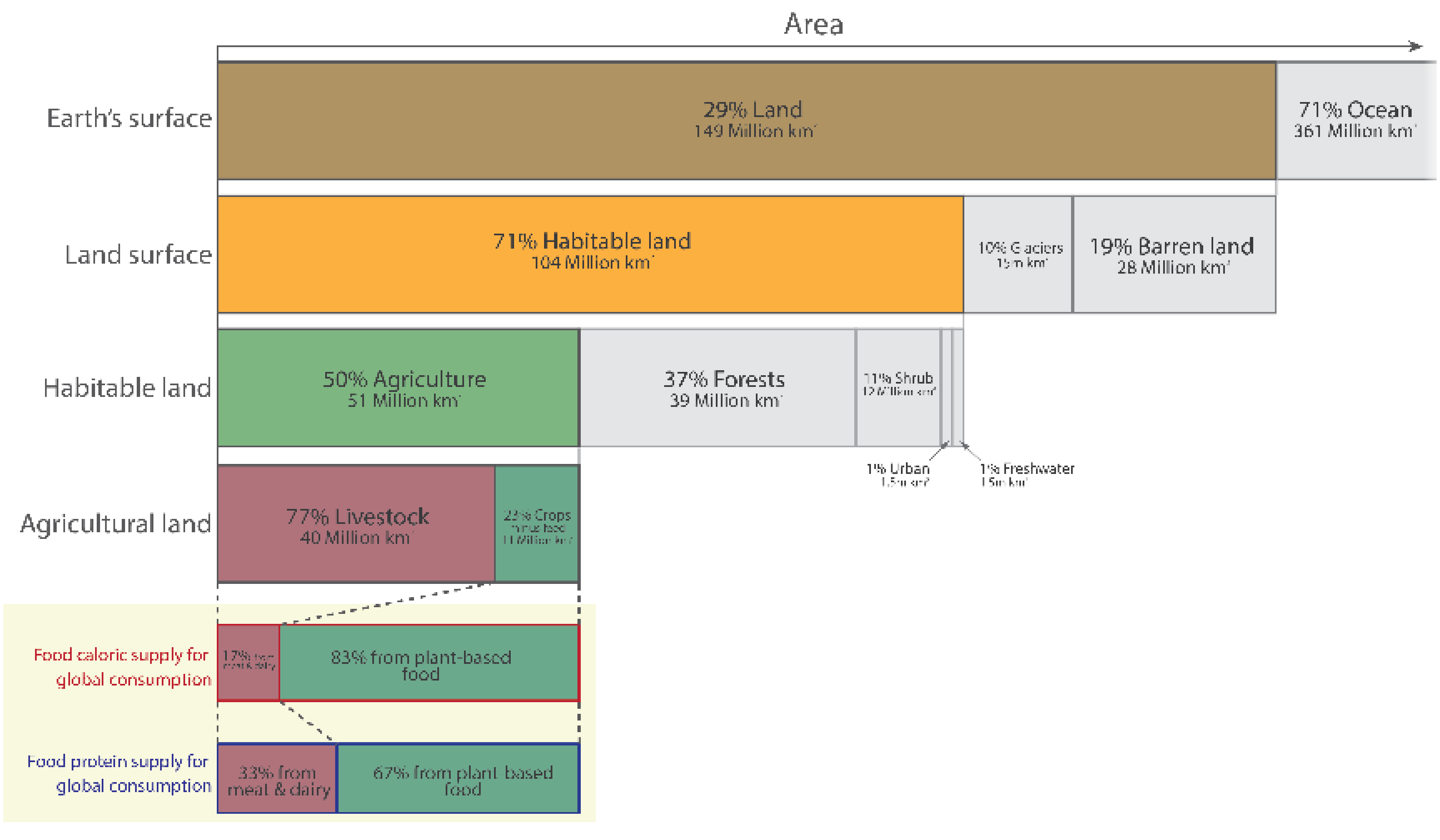
Variable Equation: Temperature

The variable will take on the value calculated from this equation progresses.

```
= 20+([CO2 concentration]-354)*0.01
```



Land area used by humans
FAO data

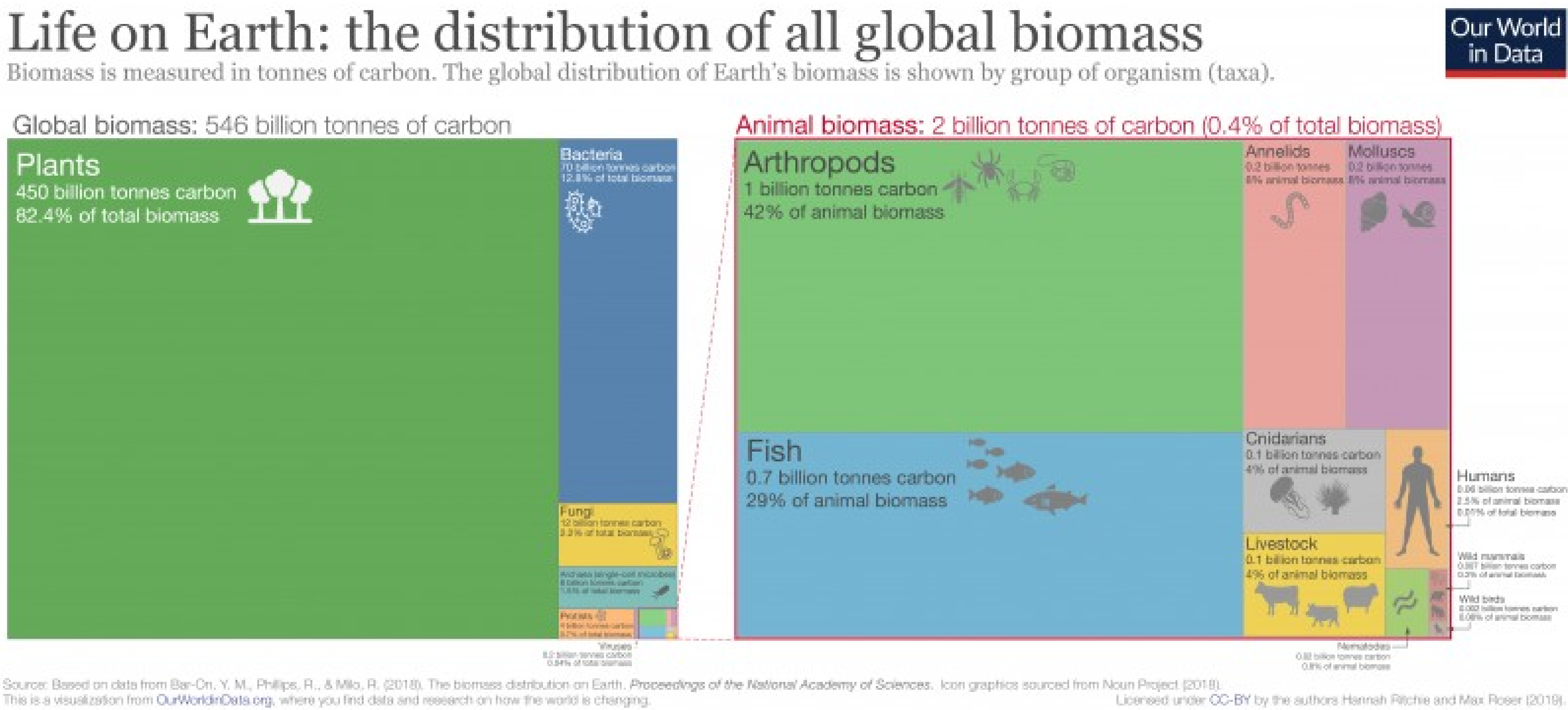


Quantification of life using the metric of biomass

- Humans = 0.01% of the total biomass, or 2% of total animal biomass (marine + terrestrial)
- Livestock = 4% of animal biomass (twice as much as humans
- Human biomass = 10 x biomass of all wild mammals

Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. Proceedings of the National Academy of Sciences (link on Brightspace).

Global biomass



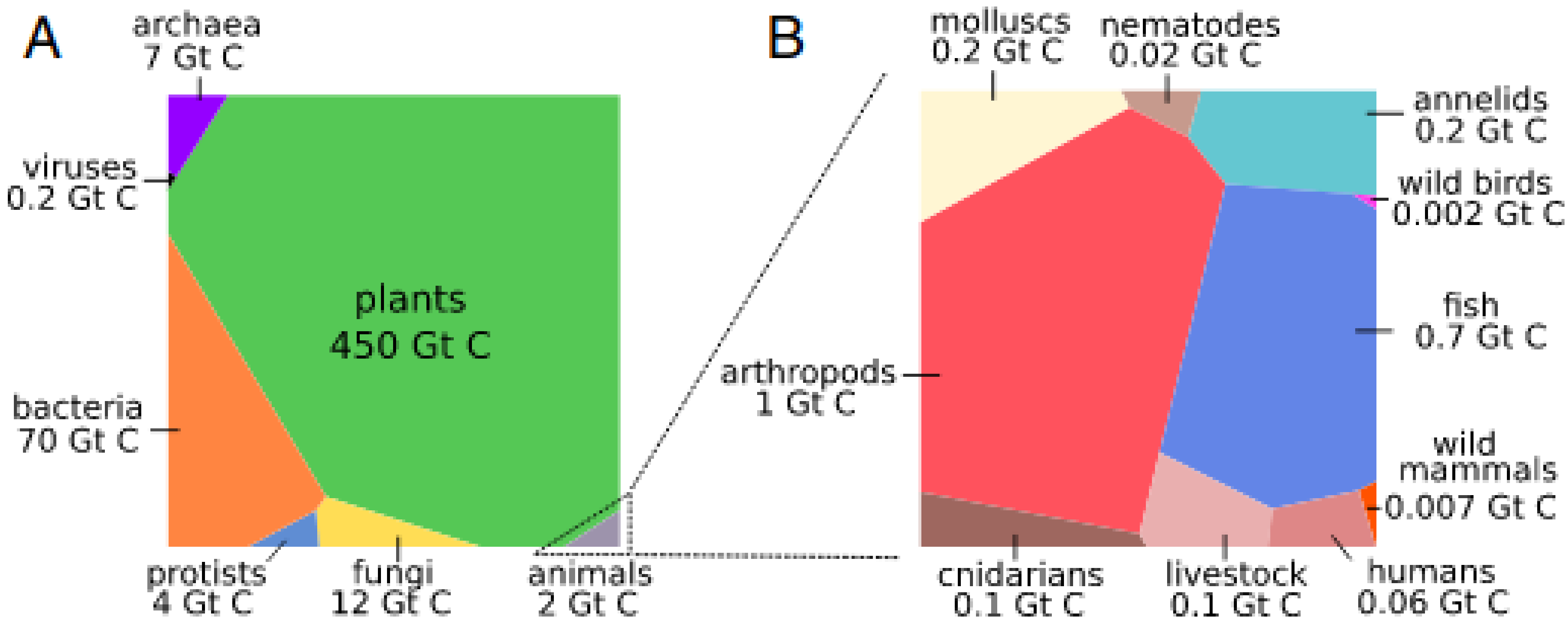
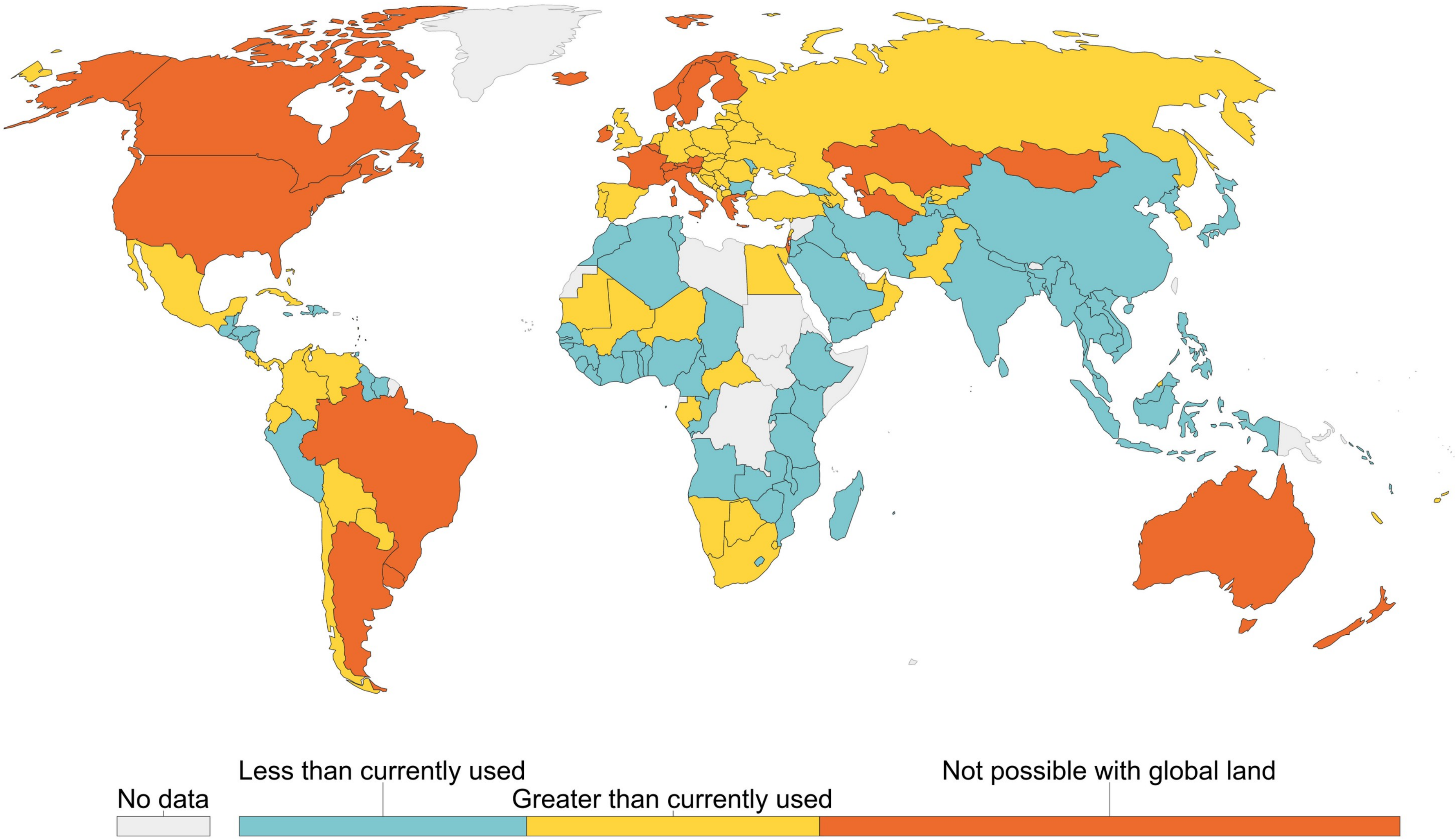

A
archaea
7 Gt C
viruses
0.2 Gt C
plants
450 Gt C
bacteria
70 Gt C
protists
4 Gt C
fungi
12 Gt C
animals
2 Gt C
B
molluscs
0.2 Gt C
nematodes
0.02 Gt C
annelids
0.2 Gt C
wild birds
0.002 Gt C
fish
0.7 Gt C
arthropods
1 Gt C
wild
mammals
0.007 Gt C
cnidarians
0.1 Gt C
livestock
0.1 Gt C
humans
0.06 Gt C

Table 1. Summary of estimated total biomass for abundant taxonomic groups

Taxon		Mass (Gt C)	Uncertainty (-fold)
Plants		450	1.2
Bacteria		70	10
Fungi		12	3
Archaea		7	13
Protists		4	4
Animals		2	5
Arthropods, terrestrial	0.2		
Arthropods, marine	1		
Chordates, fish	0.7		
Chordates, livestock	0.1		
Chordates, humans	0.06		
Chordates, wild mammals	0.007		
Chordates, wild birds	0.002		
Annelids	0.2		
Molluscs	0.2		
Cnidarians	0.1		
Nematodes	0.02		
Viruses		0.2	20
Total		550	1.7

Share of global habitable land needed for agriculture if everyone had the diet of...

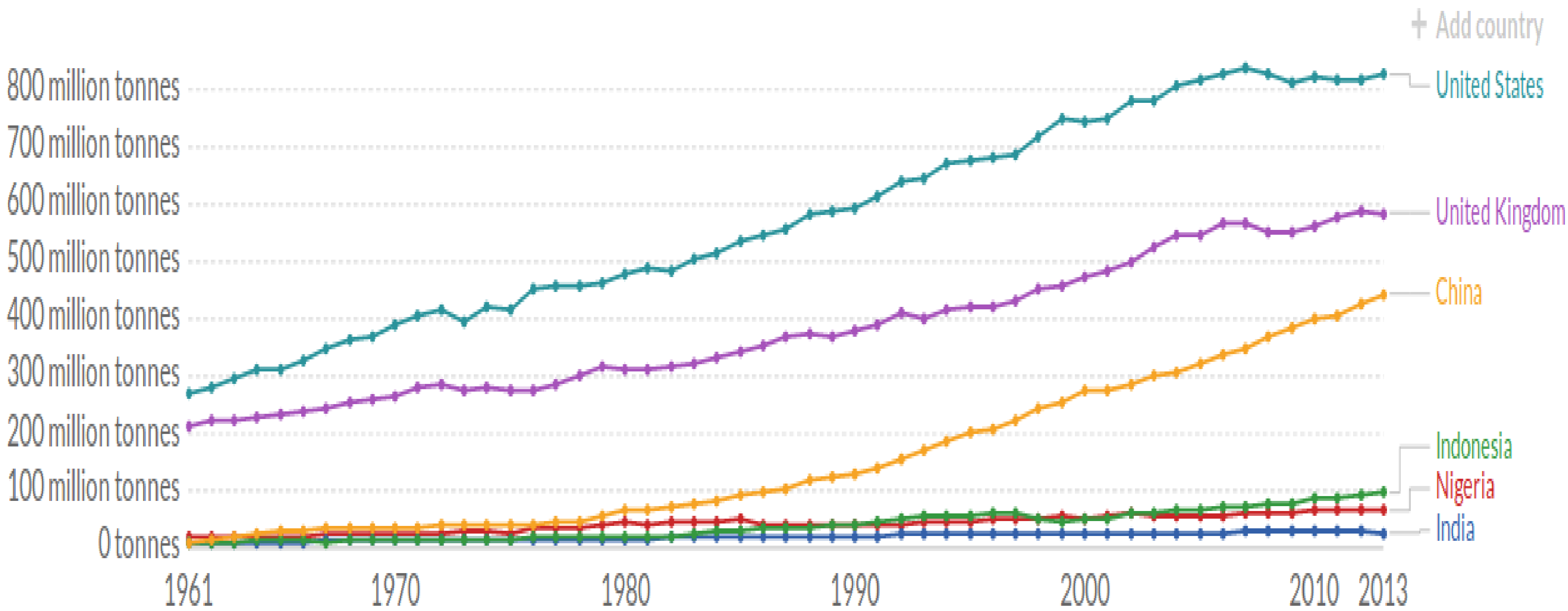
The percentage of global habitable land area needed for agriculture if the total world population was to adopt the average diet of any given country, in 2011. The actual proportion of habitable land used for agriculture was 50 percent. Values greater than 100% are not possible within global land constraints.



Source: Alexander et al. (2016)

Global meat demand if everyone ate like the average citizen of...

Hypothetical global meat demand if everyone in the world ate the same quantity as the average citizen of a given country, e.g. data for the USA in 1990 hypothesises global meat demand if everyone in the world consumed the same amount of meat as the average US citizen in 1990. Actual global meat production in 2013 was 310 million tonnes.



Source: OWID based on FAO & UN