Note: *Green facts below, are incorporated into the microworld.*

A forest of only coniferous trees is less biodiverse than a forest of only deciduous tree. (Trial Issue , 2005)

On average conifer trees are more long lived than deciduous ones. (F. Biondi et. al., 2023)

Deciduous trees grow faster than conifers. (S. Strieby, 2013) Greenmax J. Marsh, 2022

Deciduous trees reach maturity earlier than conifers. Greenmax

Conifers grow quicker than deciduous trees. (Trial Issue , 2005) (K. W. Tomlinson et al., 2014)

In one year, a tree absorbs approximately 10 Kgs of CO2. (R. Bernet, 2023)

CO2 Levels
(A. Moseman, 2021)

- CO_2 levels during human evolution $\approx 200 \text{ to } 300 \text{ ppm}$.
- Pre-industrial CO_2 levels $\approx 280 \text{ ppm}$.
- 20^{th} century levels $\approx 300 \text{ to } 350 \text{ ppm}$.
- Level of CO_2 which would push the world past its target for avoiding dangerous climate change $\approx 430 \text{ ppm}$.
  (Z. Hausfather, 2019)
- One of our best estimates of a CO2 level that would be a tipping point beyond which global temperatures would rise by 8 to 10 $^{\circ}C \approx 1200 \text{ ppm}$.
  (Daily CO2, 2024)
- As of May 16 2024, CO_2 levels in the atmosphere $\approx 426.95 \text{ ppm}$.
  CO2.earth, (Lüthi et al, 2008)
- Lowest known CO_2 level ever, based on findings from ice cores $\approx 172 \text{ ppm}$ (650,000 to 800,000 years ago).
  (Farm Carbon Toolkit, Carbon Cycle), (Farm Carbon Toolkit, Soil Carbon)
- Of all the CO2 locked in the earth, around 5 to 10000 Gt is present as fossil fuels.
- Soil carbon content is roughly 30 to 90 tC / ha of which cultivated soil can lose approximately 3 tC / ha / year.
  (H. Ritchie and M. Roser, 2024)
- In 2022 37.15 GtCO2 was added into the atmosphere year by humans.
  (T.A. Ontl et al., 2012)
- Carbon inputs from photosynthesis by terrestrial vegetation fixes more carbon than carbon loss through soil respiration, resulting in a soil storage rate of about 3 GTC per year.

(Quora, 2024)

- A tree typically absorbs the most amount of carbon dioxide from the air during its rapid growth stage, which is usually in the early years of its life. As the tree matures, its rate of carbon dioxide absorption may decrease, but it continues to sequester carbon throughout its life.
  (World Economic Forum)
- Of all stored carbon in deadwood, around 15% is released into the atmosphere and soil every year.

Temperature Associated with CO_2

- Global temperature in 2022 was around $14.76^{\circ}C$. (NCEI NOAA, 2022)
- Amount of CO_2 in the atmosphere in 2022 ≈ 421.72 ppm. (CO2.earth)
- Global warming calculator.
- A general estimate is that every time CO2 concentrations rise by 10 ppm, the mean global temperature increases by 0.1 °C. (Fakta o klimatu, 2022)

Based on CO_2 and temperature related data above, an environment condition scale has been developed for the microworld as follows.

CO2 Atmospheric Concentration (PPM) →	< 200	200 to 430	430 to 700	700 to 1200	1200 to 1800	>= 1800
Change in CO2 Concentration PPM →	< -219.30	-104.30	145.70	530.70	1080.70	>= 1380.70
Approx. Avg. Global Temp. Change (°C) →	< -2.19	-1.04	1.46	5.31	10.81	>= 13.81
Approx. Avg. Global Temp. (°C) →	< 12.79	13.94	16.44	20.29	25.79	>= 28.79
Approx. Avg. Temperature Ireland (°C) →	< 9.01	10.16	12.66	16.51	22.01	>= 25.01
Approx. Max Temperature Ireland (°C) →	< 26.91	28.06	30.56	34.41	39.91	>= 42.91
Photosynthesis Efficiency →						
Human Life →		> 350			*1200 = Point of no return.*	

Color Scale (Increasing Optimality) →	*Impossible*	*Very Bad*	*Bad*	*Just Ok*	*Good*	*Best*

CO_2 Concentration

$$CO_2 \text{ ppm} = \frac{V_c}{V_t} \times 10^6$$

Here, $V_c =$ volume of CO_2 (m^3) and $V_t =$ volume of air (m^2).

The total volume of Earth's atmosphere is approximately 4.2 billion cubic kilometres or 4.2×10^{18} m^3. (Quora, 2024)

The total carbon on earth is at least $\approx 650,002,700$ GtC where $GtC \Rightarrow$ Gigatonnes of Carbon such that 1 GtC $= 10^{12}$ kg, of which $650,000,000$ GtC is locked away in the earth's surface (glacial deposits, minerals, fossil fuels, oceans), 1400 GtC is present in the soil, 550 GtC may be found within plants and 750 GtC is free, in the atmosphere. (S. Rackley, Science Direct, 2023)

Given weight of carbon in the air and the volume of the atmosphere, the concentration of CO_2 in PPM can be computed as in CO2 PPM from Weight & Volume.

Photosynthesis is more effective at CO2 concentrations ranging from 700 to 1800 with around 1000 being max efficiency. Beyond 1800, conditions may start to become toxic for plants. (M. Poudel and B. Dunn, 2023)

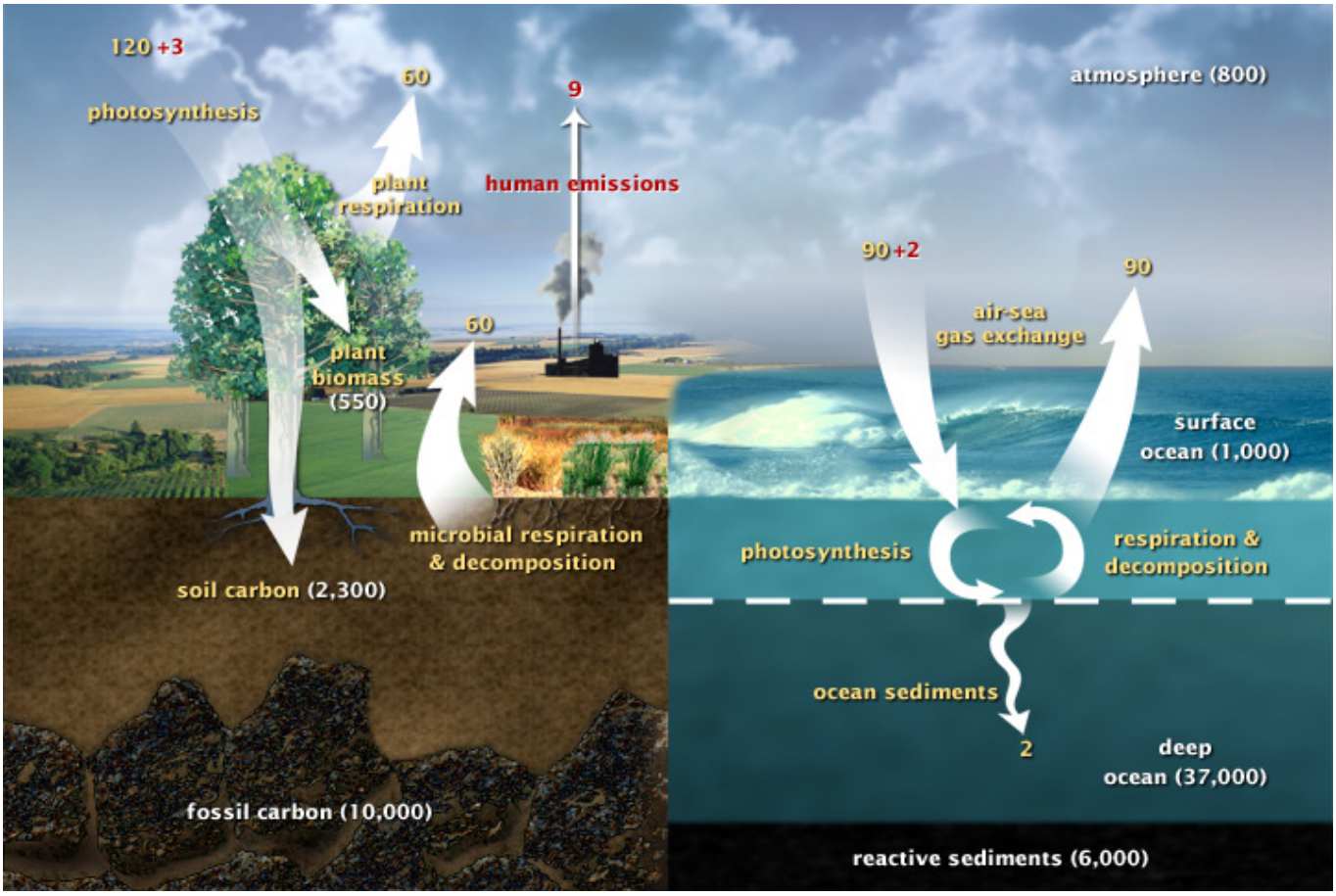
Below about 200 ppm concentration of CO2, photosynthesis is extremely difficult with it being impossible less than or equal to 150 ppm. (Manitoba Govt.)

By weight, dried tree material is about 50 % carbon. (US Department of Agriculture)

Following is an example computation of how much CO_2 a tree absorbs. (Ecotree)

- Let weight of a tree be 1000 kg with 100% humidity.
- Then, this tree is around 500 kg dry mass and 500 kg water.
- Approximately 47.5% of that dry mass is carbon. So, weight of carbon in this tree = 237.5 kg.
- Based on molar masses of carbon (12), oxygen (16), and consequently CO_2 (44) it can be arrived at that it takes 3.67 kg of CO_2 to create 1 kg of C.
- Thus, this tree has absorbed $237.5 \times 3.67 = 871.63 \text{ kg}$ of CO_2.
- Let the age of this tree be 35 years. Then, the amount of CO_2 it as absorbed per year ≈ 25 kg.

Carbon Cycle (H. Riebeek, NASA, 2011)



Reservoir	Amount (GtC)	Pulled (GtC)	Released (GtC)	Fixed (GtC)
Vegetation	550	123	60	63
Soil	2300	0	60	?
Fossil Fuels	10000	0	12	0

Tree Growth

The relationship between diameter growth and height growth of a tree, in nature, is non-linear because either growth rates seems to depend on different variables and non-linear models capture trends better than linear ones (A. Sumida, 2015).

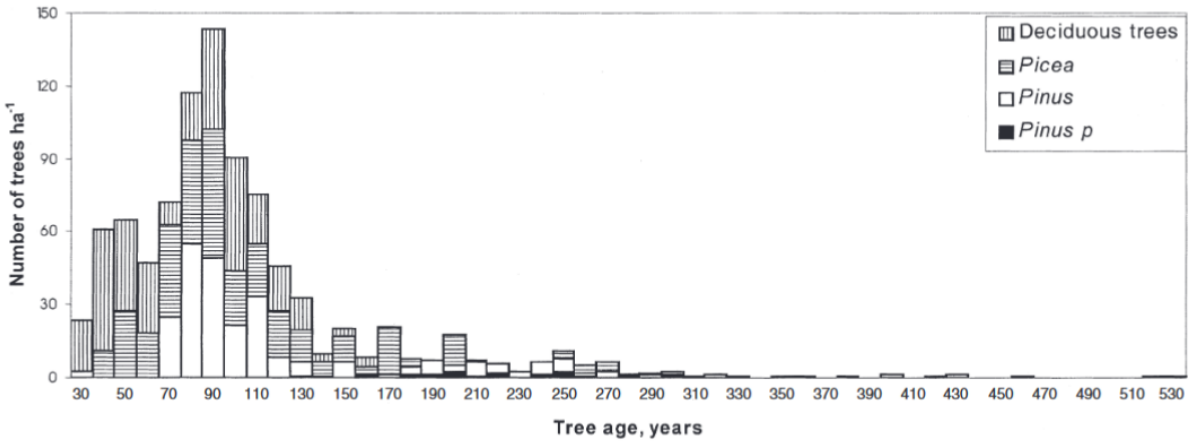
Although subject to significant variability, a good estimate of a relationship between Height and Diameter of a tree is $H \propto D^{2/3}$. (X. Chen and D. Brockway, 2017) (D. Brockway, 2017) Accounting for a proportionality constant, this may be written as $H = kD^{2/3}$. For simplicity, k may be set to 1, implying a direct relationship without any scaling effect due to the environment, species of tree, etc. Thus, in this microworld the relationship between tree height and diameter is, $H_t = D_t^{2/3} \Rightarrow D_t = H_t^{3/2}$.

Forest Composition

(Department of Agriculture, Food and the Marine, Ireland)
Forests in Ireland as per NFI, 2022, is composed of 61.2% conifers and 27.0% broad leaves.

(T. Kuuluvainen et al., 2002)

- Distribution of age and type of trees in an old growth forest in Vienansalo Wilderness, Eastern Fennoscandia is as follows.



- Total no. of trees = 725.
- 450 Coniferous + 155 Deciduous = 605 trees.
- Max age of trees in the real old growth forest is different from that in the microworld. In the real world, the oldest coniferous tree was 525 years old while the oldest deciduous tree was 162 years old. In the microworld, the oldest coniferous tree would be 100 years old and the oldest deciduous tree would be 80 years old. So, to be able to map the composition of the real forest to the microworld, there is a need for Conversion Of Scale.|

For every 1 pound of wet, living wood, about 55 to 60 percent is dry wood (that is, cells) and 40 to 45 percent is water. (E. M. Wengert, 1998)

Height to Diameter Ratio (HDR)

- $\text{coniferous} = 600 : 6 \text{ to } 3700 : 57 \text{ cm} \Rightarrow 2150 : 31.5 \approx 68 : 1 \approx 1 : 0.015$ (T. Nord-Larsen and A. T. Nielsen, 2015)
- $\text{deciduous} = 300 : 4.456 \text{ to } 1000 : 22.28 \text{ cm} \Rightarrow 650 : 13 = 50 : 1 = 1 : 0.02$ (Deepdale)

Temperature Starting Value $\approx 10.0^{\circ}C$ (Irelands Blue Book)

Research ecologists have used the term “old growth” to describe forests dominated by trees greater than 150 years old. (C. Neff, 2021)

The cultivation and drainage of organic soil causes significant CO2 emissions. For 2019, EU Member States reported a loss of carbon from 17.8Mha of land with organic soil (**4.2% of the**

total land area), corresponding to emissions of 108Mt CO2, while 387.6Mha of mineral soil secured net removals of 44Mt CO2. (European Environment Agency, 2022)

Many fungi are ‘saprophytic’, meaning that they live on dead or dying wood, leaf litter or animal bones/faeces. (Heart of England Forest, 2020)

Ecosystem Services

- In Ireland, PES 4 Environmental Enhancement grants worth €150/ha/yr applies where a high ecological priority has been identified. (Teagasc)
- Ireland Forestry Programme 2023-2027 (Irish Farmers Association)

Forest Recreation

- (Department of Agriculture and Food Ireland, 2006) (K. Mayor et. al., 2007)
- There are multiple funds available for construction and maintenance of infrastructure to enable forest recreational activities. A good approximation of no. of visitors to a forest per year = 147340 (Coillte, 2022)