Effects of Varied Magnesium Supply on Wheat Grown under Ambient and Elevated Carbon Dioxide Conditions

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Outline

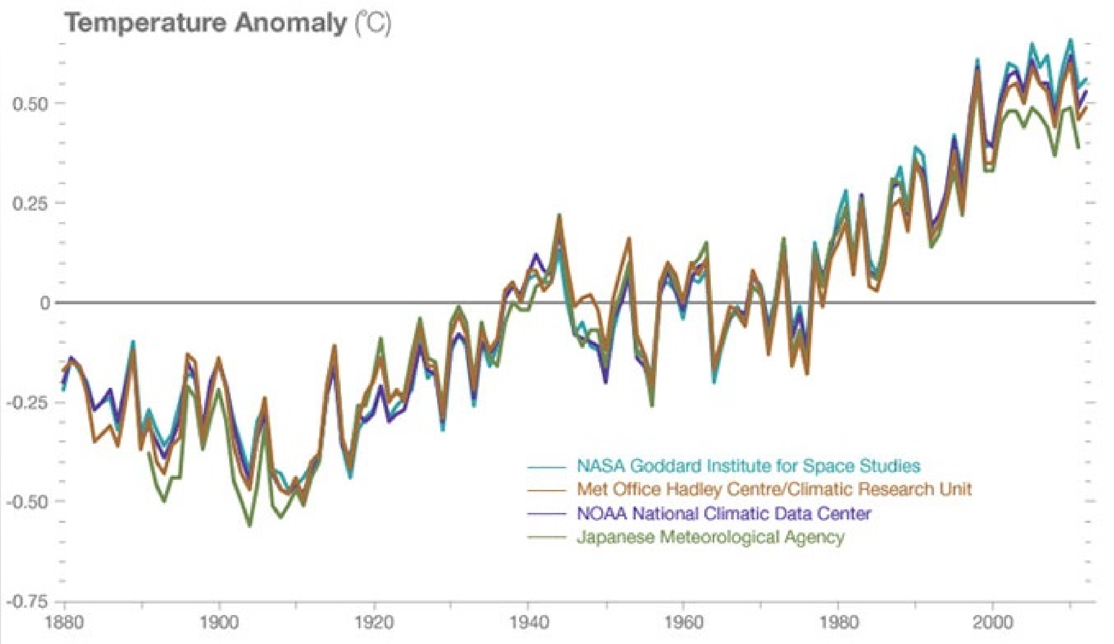
01 Changing climates, elevating [CO_2] and Mg nutrition

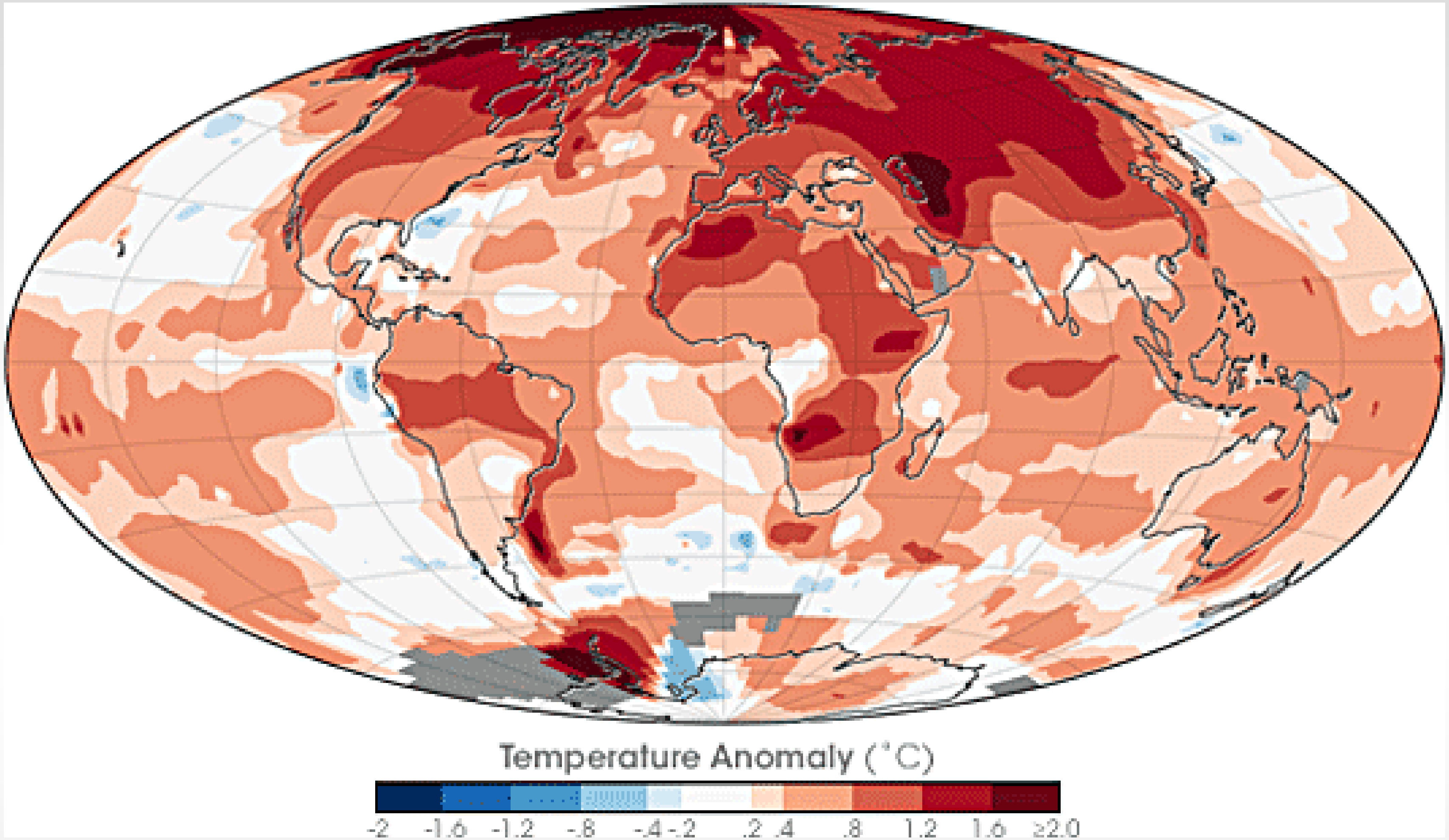
02 Inadequate Mg nutrition cancels out PS gain by elevated [CO_2]

03 Invest on Mg to benefit GCC?

Witnessing a historical warm up!

- Since 1800's 16 warmest years occurred since 1990
- May be the warmest years of the last millennium (according to modeling data)
- Confirming evidence: phenological spring comes 6 days earlier and autumn is delayed 5 days in the northern hemisphere than it did in 1959
- Seal level rise is now 3 cm per decade



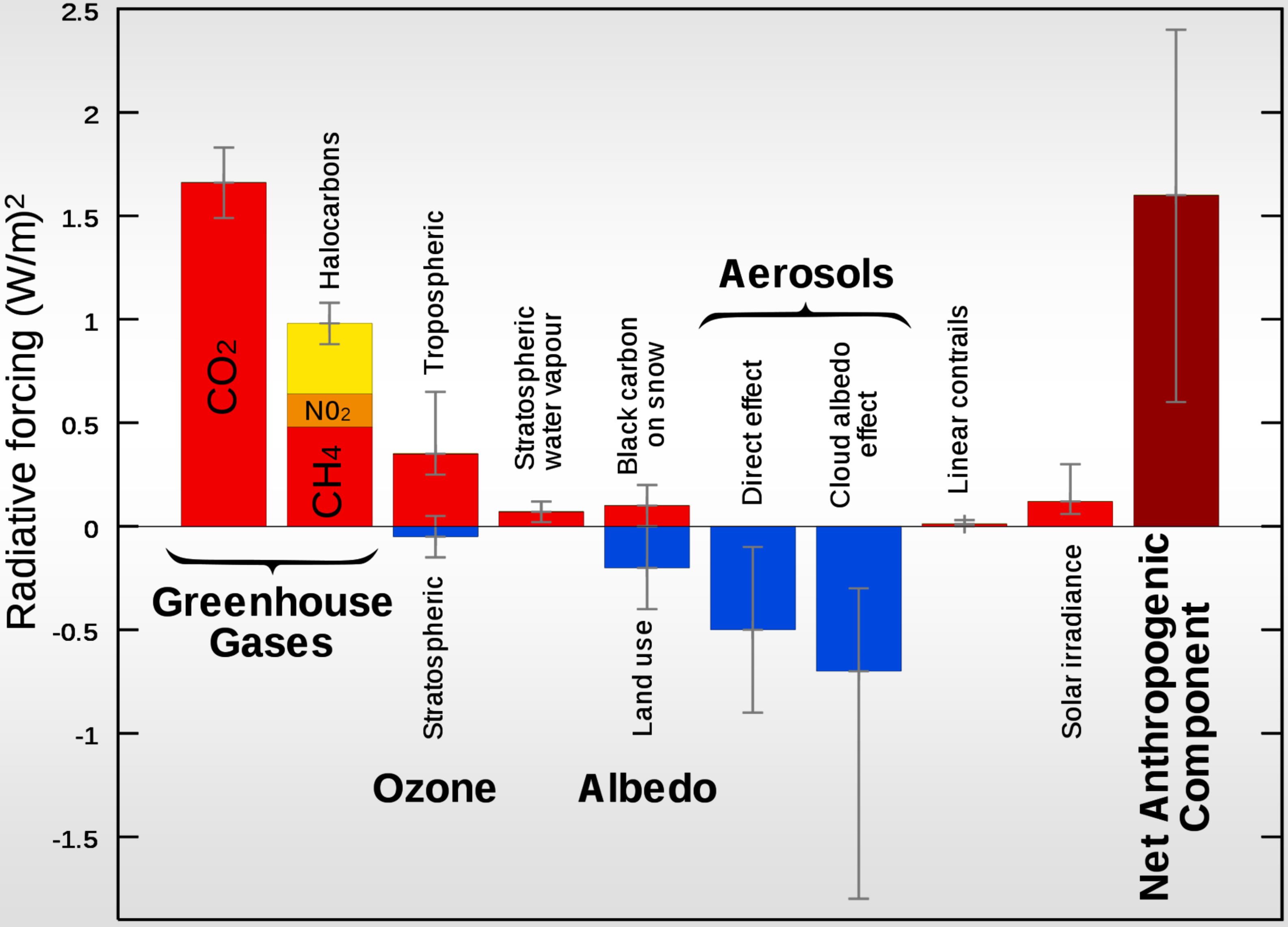


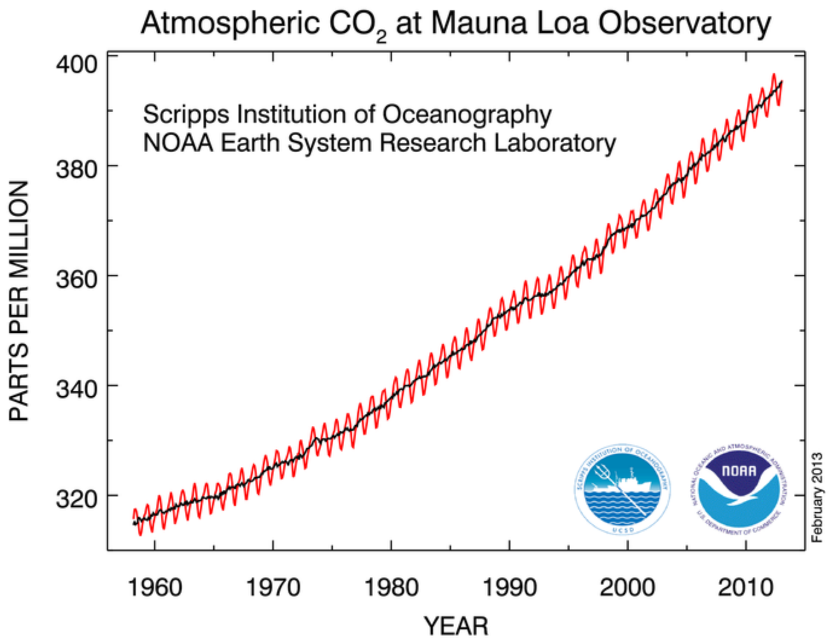
Map showing difference in surface temperature in 2006 compared to 1951-1980 average. Most of the globe is anomalously warm, with the greatest temperature increases in the Arctic Ocean, Antarctic Peninsula, and central Asia.

What is the cause of warm up?

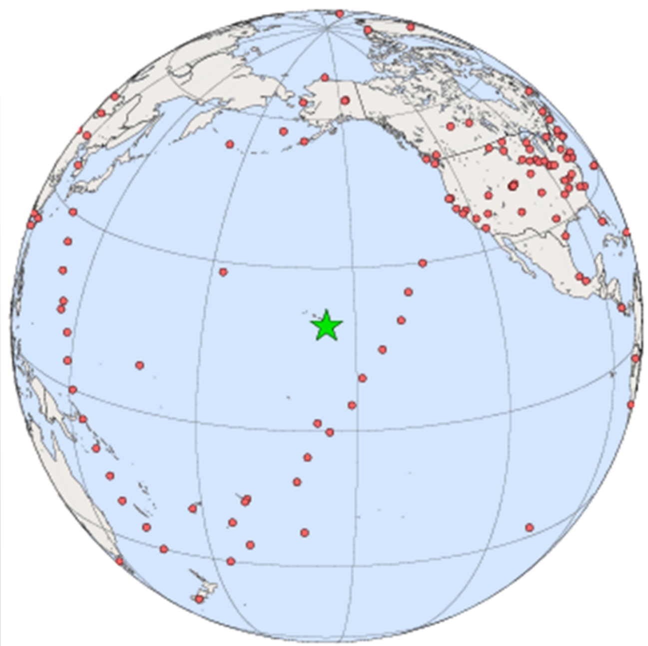
- Natural events unable to explain the cause of global warming
- Most plausible explanation: warming is mainly due to increasing human-made ***greenhouse gases***
- **Greenhouse gasses:** gasses that absorb ***infrared radiation*** (carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, tropospheric ozone)
- **Infrared Radiation:** Radiation with longer wavelengths than visible light, but shorter wavelengths than radio waves. Most of energy absorbed by Earth is radiated as infrared radiation (which greenhouse gasses can absorb)
- **Radiative Forcing:** Capacity of a gas to affect the balance of energy entering and leaving the Earth (measured by W/m^2)

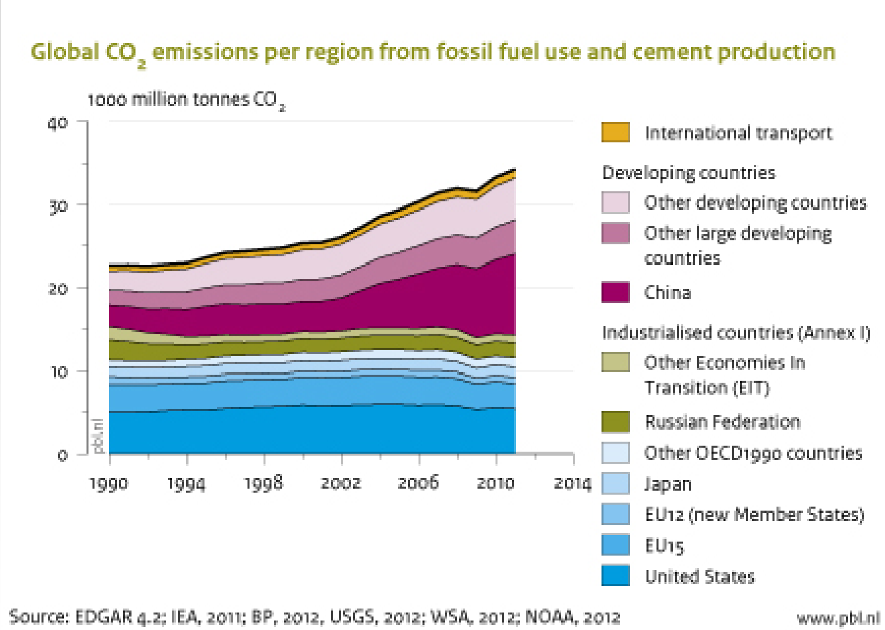
Radiative Forcing Components

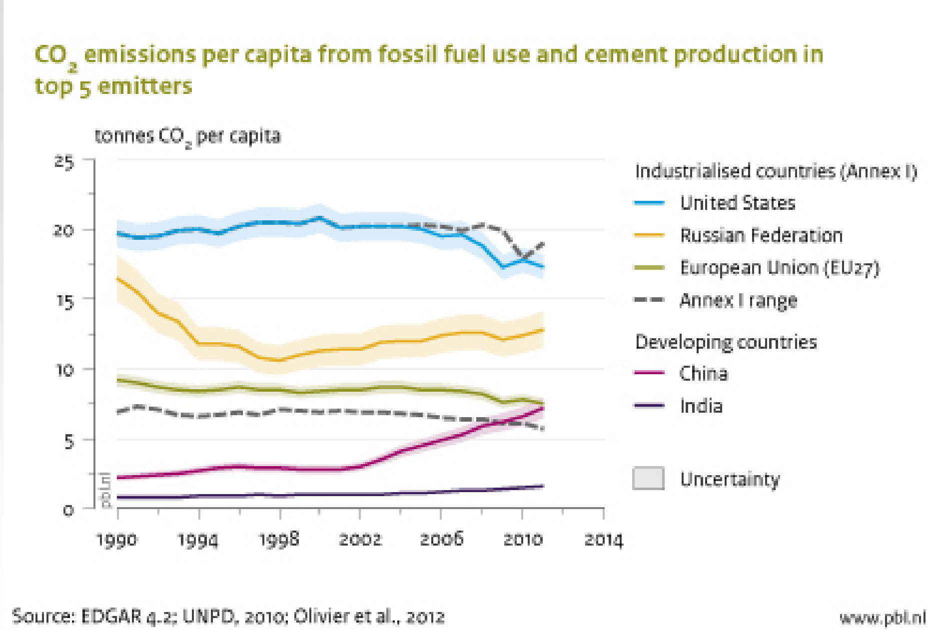




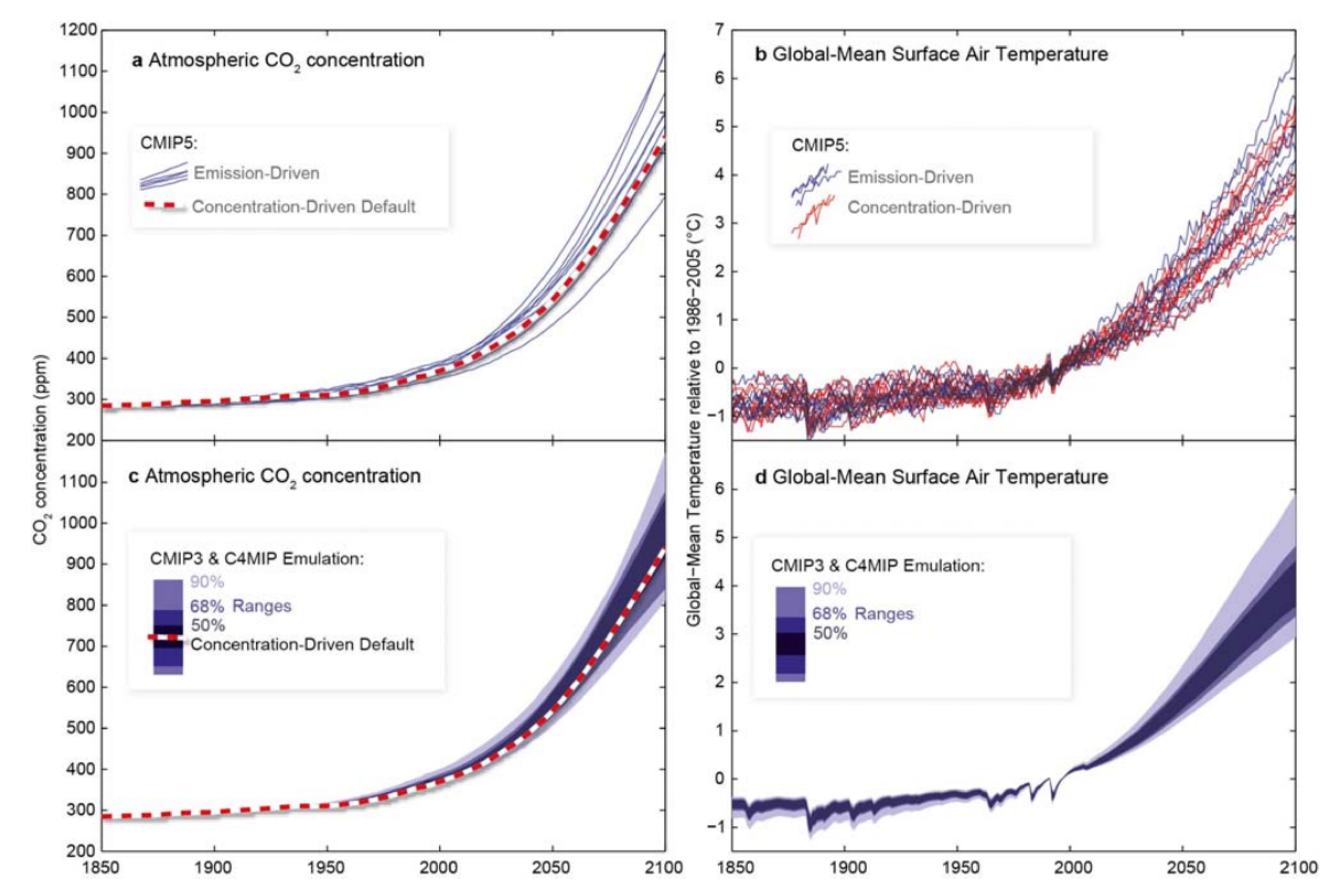
- The Mauna Loa Observatory: atmospheric research facility continuously monitoring atmospheric change since the 1950's.
- The undisturbed air, remote location, and minimal influences of vegetation and human activity are ideal for monitoring constituents in the atmosphere that can cause climate change.







- Global CO_2 emissions increased by 3% in 2011, reaching an all-time high of 34 billion tonnes in 2011
- With a decrease in 2008 and a 5% surge in 2010, the past decade saw an average annual increase of 2.7%
- The top 5 emitters are China (29%), the United States (16%), the European Union (EU27) (11%), India (6%) and the Russian Federation (5%), followed by Japan (4%).
- In 2011, China's average per capita CO_2 emissions increased by 9% to 7.2 tonnes, reaching EU values (EU saw a decrease of 3%)
- United States was still one of the largest CO_2 emitter with 17.3 tonnes per capita after a steep decline by the recession in 2008-2009, high oil prices compared to low fuel taxes and an increased share of natural gas.



Final Draft (7 June 2013) Chapter 12 IPCC WGI Fifth Assessment Report
http://www.climatechange2013.org/

Sources of Increasing Greenhouse Gasses

- Carbon dioxide (CO_2): Burning carbon-containing fossil-fuels (coal, oil, natural gas), land conversion (logging of tropical forests, wild fires)
- Methane (CH_4): Oil and natural gas production, decomposition of carbon-containing material by anaerobic bacteria (cattle production, rice paddies, land-fill)
- Nitrous oxide (N_2O): Industrial processes, land use conversion, N-fertilizer use in agriculture

Sources of CO_2 Emissions

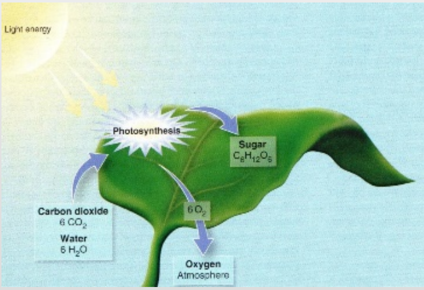
Seven main fossil fuel combustion sources	Contribution (%)
Liquid fuels (e.g., gasoline, fuel oil)	36%
Solid fuels (e.g., coal)	35%
Gaseous fuels (e.g., natural gas)	20%
Cement production	3 %
Flaring gas industrially and at wells	< 1%
Non-fuel hydrocarbons	< 1%
"International bunker fuels" of transport not included in national inventories	4 %

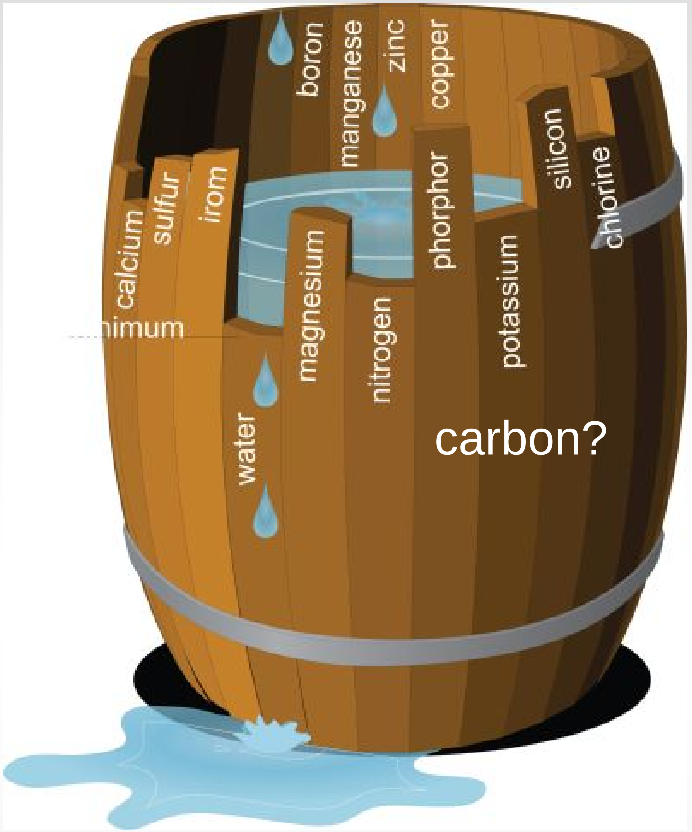
Mass of carbon dioxide emitted per quantity of energy for various fuels[120]

Fuel name	CO_2 emitted (lbs/10^6 Btu)	CO_2 emitted (g/10^6 J)
Coal (anthracite)	227	97.59
Petroleum coke	225	96.73
Coal (lignite)	215	92.43
Coal (sub-bituminous)	213	91.57
Coal (bituminous)	205	88.13
Wood and wood waste	195	83.83
Tires/tire derived fuel	189	81.26
Fuel oil	161	69.22
Kerosene	159	68.36
Automobile gasoline	156	67.07
Aviation gasoline	153	65.78
Liquefied petroleum gas	139	59.76
Propane	139	59.76
Natural gas	117	50.30

Background:

- **Elevating [CO_2] can be advantageous:** PS and growth rate (particularly in C_3 plants) can be positively affected (Ainsworth, 2007; Taiz and Zieger, 2006; Bloom et al., 2010)
- **Long-term studies:** all nutrients should be in ample quantities to get higher yields and quality from crops cultivated under elevated [CO_2] (Leakey, 2012)





Liebig's law of the minimum: "The availability of the most abundant nutrient is only as good as the availability of the least abundant nutrient."

Background:

- Among factors influencing growth rate and yield under elevated [CO_2], efficient transport of photosynthesis products towards growing tissues (**phloem export**) has crucial importance
- The bottle neck in phloem export arises from the **unmatched phloem loading rate** compared to the production rate of carbohydrates (CH) which may exceed plant demand (sink activity) under elevated [CO_2] conditions
- Mg has a key role in phloem loading of carbohydrates (Cakmak et al., 1994)

Hypothesis:

Under an elevated [CO_2] environment…

(i) does inadequate Mg nutrition exacebrate CH accumulation and thus

(ii) cancel out the PS gain?

Experimental:

- Plant species: Durum wheat (*Triticum durum*, cv. Saricanak 98)
- Mg supply: adequate Mg (1000 µM) and low Mg (75 µM)
- Growth conditions: in nutrient solution and under two different atmospheic CO_2 levels (ambient: 400 µmol mol^{-1} and elevated: 700 µmol mol^{-1})
- Measured parameters: gas exchange, chlorophyll, carbohydrate, specific wt. (all measured in 2^{nd} oldest leaves), biomass production and [Mg] in whole plant parts.

Effect of Mg and CO_2 treatments on shoot and root biomass production

Treatment		Shoot Dry Weight		Root Dry Weight	
		(mg plant^{-1})		(mg plant^{-1})	
Ambient CO_2	Adequate Mg	230 ± 5	B	98 ± 4	B
	Low Mg	157 ± 13	C	51 ± 6	C
Elevated CO_2	Adequate Mg	263 ± 38	A	107 ± 8	A
	Low Mg	149 ± 12	C	42 ± 3	D
LSD (0.05)		22		5	
CV(%)		12		7	
F Test		***		***	

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Effect of Mg and CO_2 treatments on shoot and root Mg concentration

Treatment		Shoot Mg conc.		Root Mg conc.	
		($mg\ kg^{-1}$)			
Ambient CO_2	Adequate Mg	1526 ± 54	A	1687 ± 79	B
	Low Mg	459 ± 5	B	851 ± 46	D
Elevated CO_2	Adequate Mg	1559 ± 91	A	1829 ± 24	A
	Low Mg	480 ± 18	B	1009 ± 51	C
LSD (0.05)		51		56	
CV(%)		5		4	
F Test		***		***	

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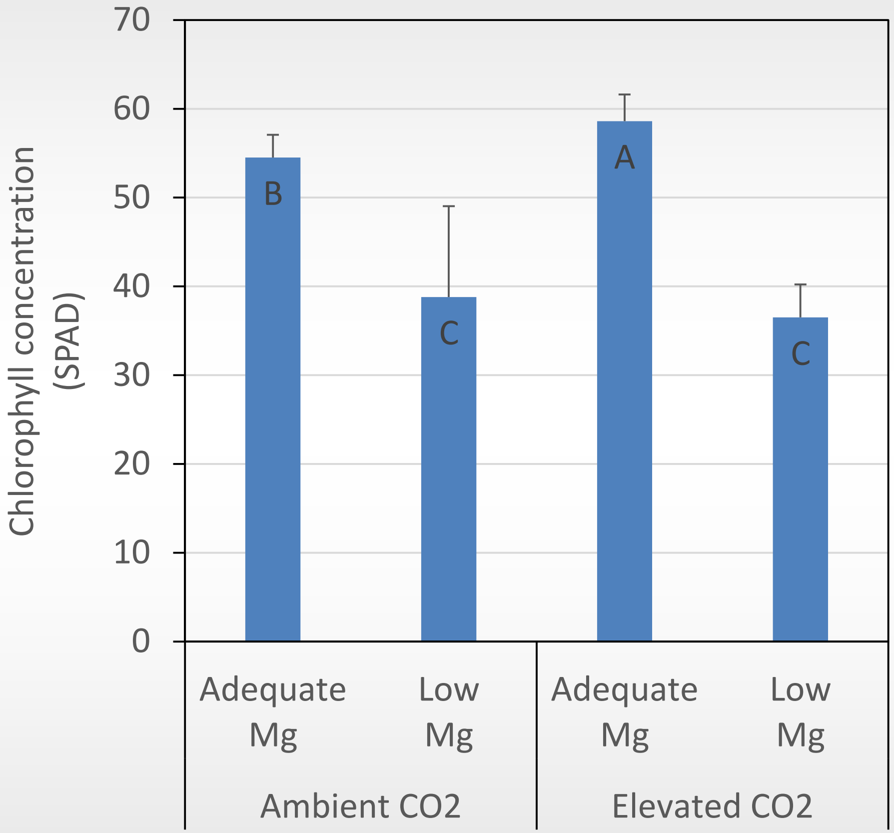
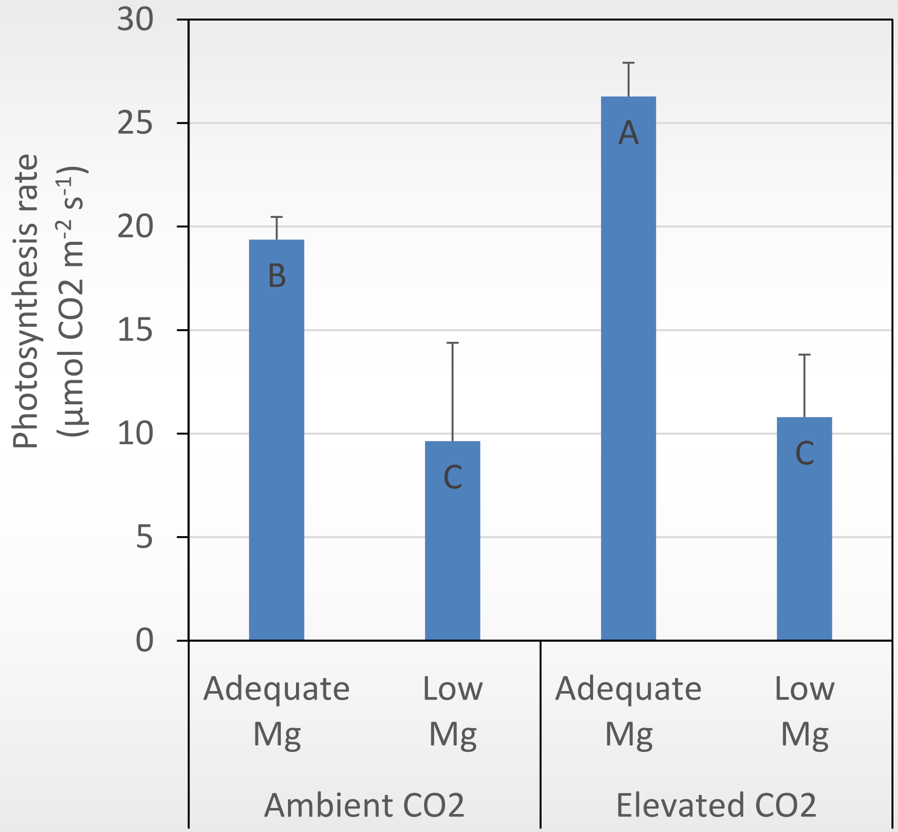
Changes in chlorophyll concentration and photosynthesis rate as affect by Mg and CO_2 treatments





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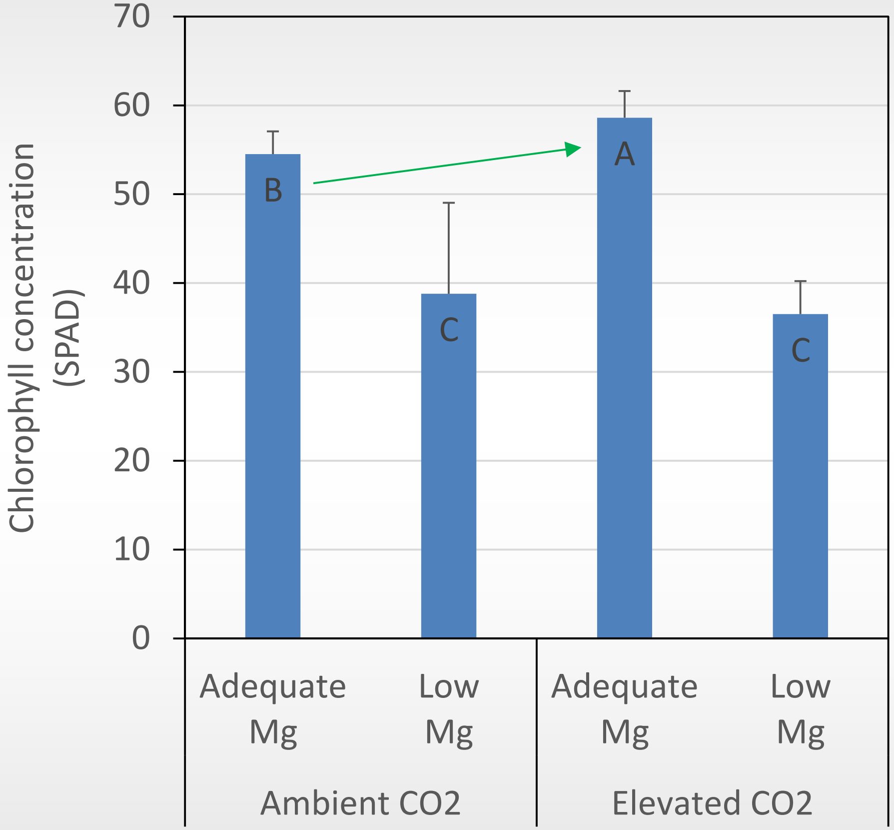

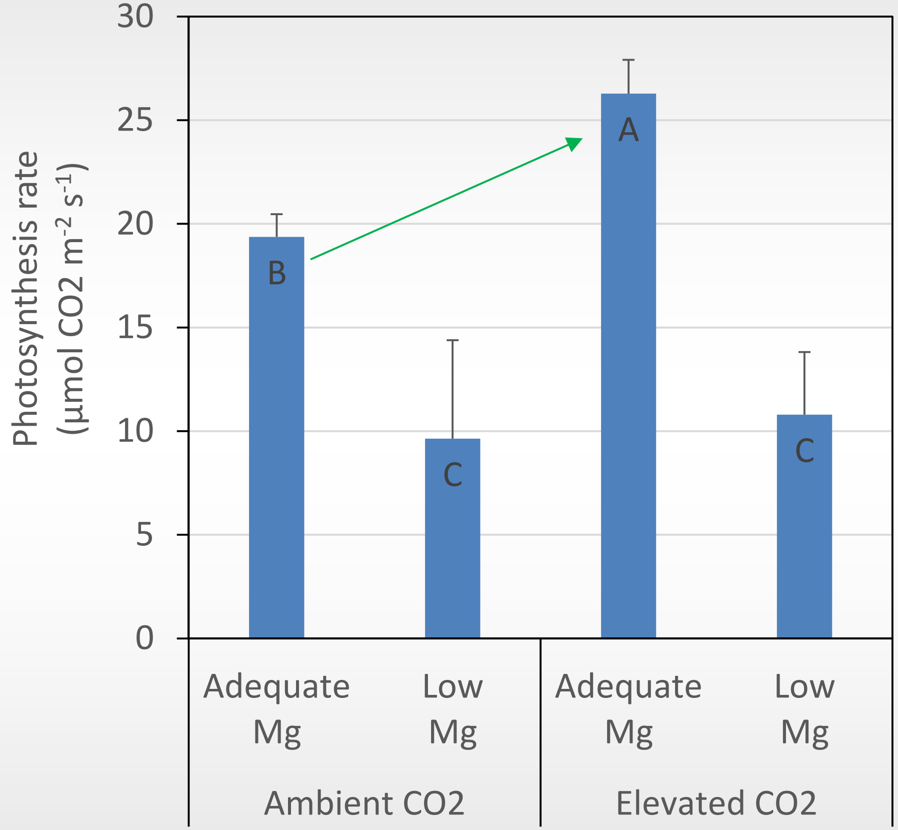

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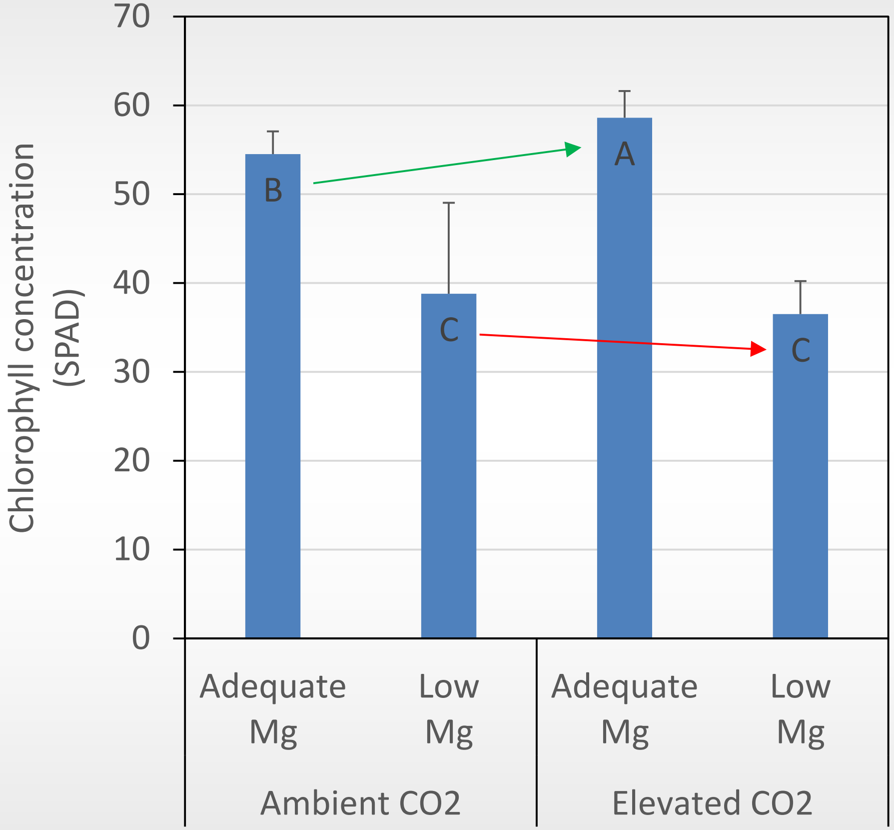
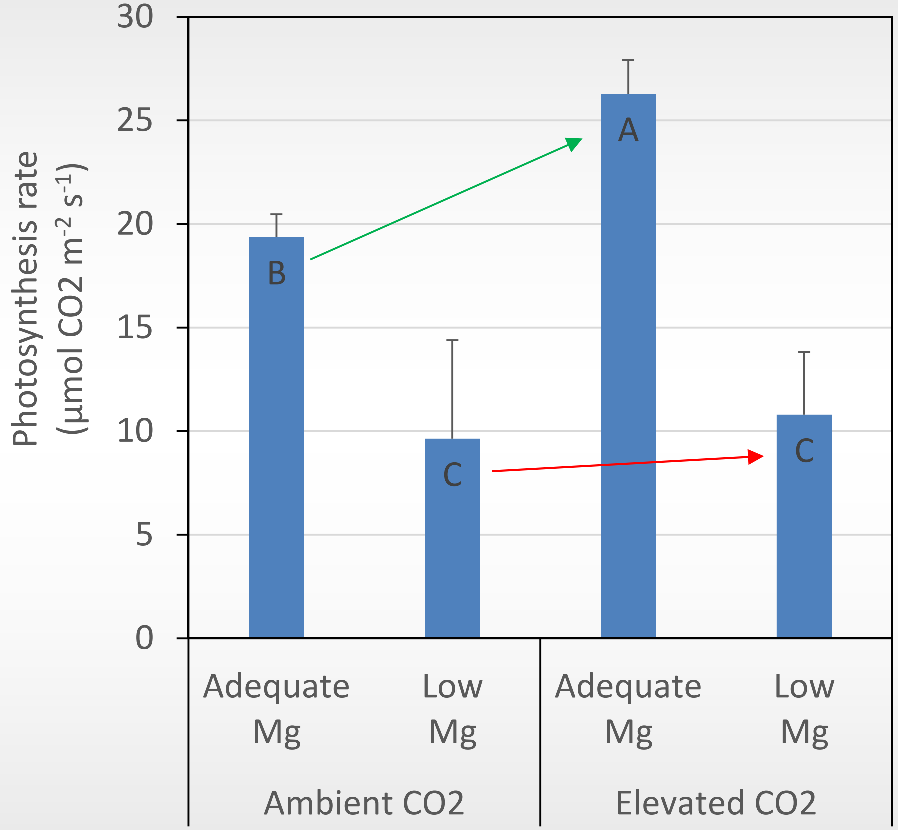
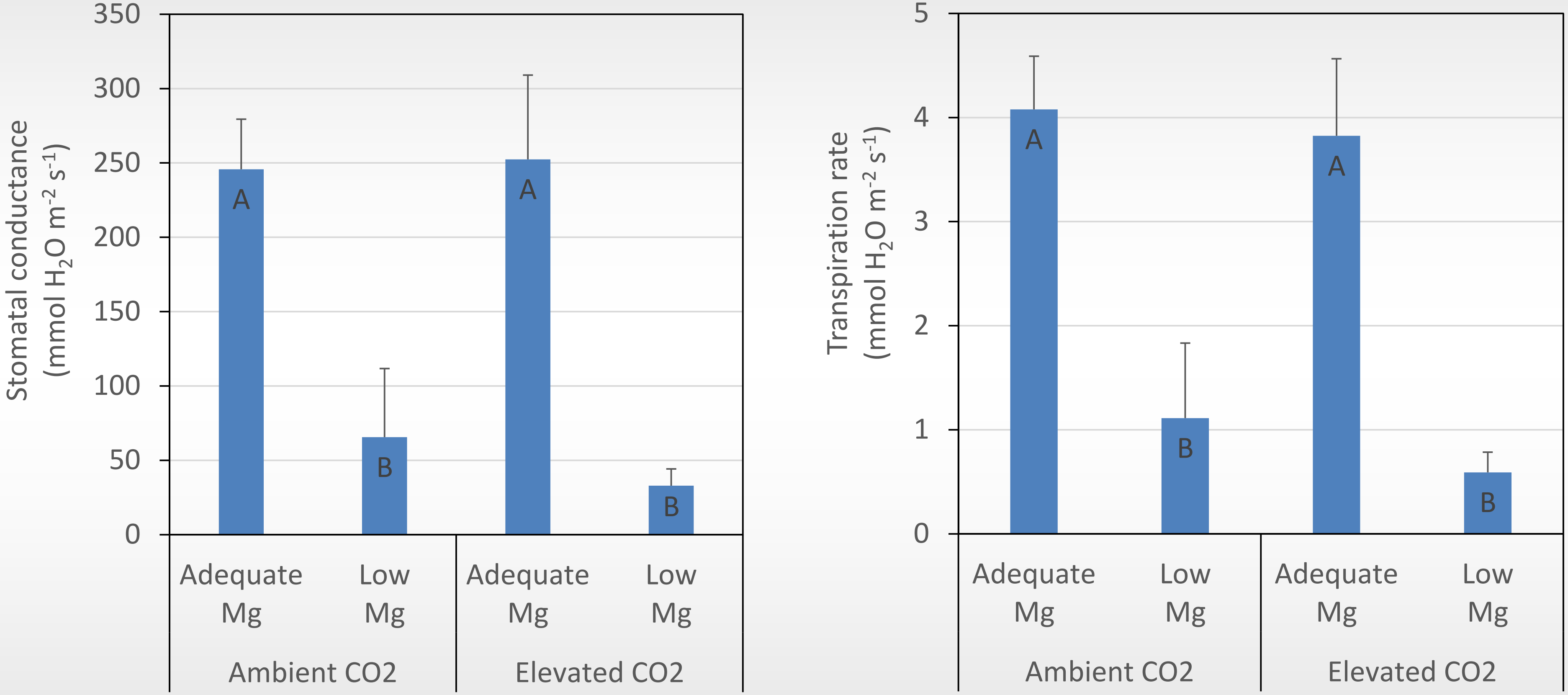
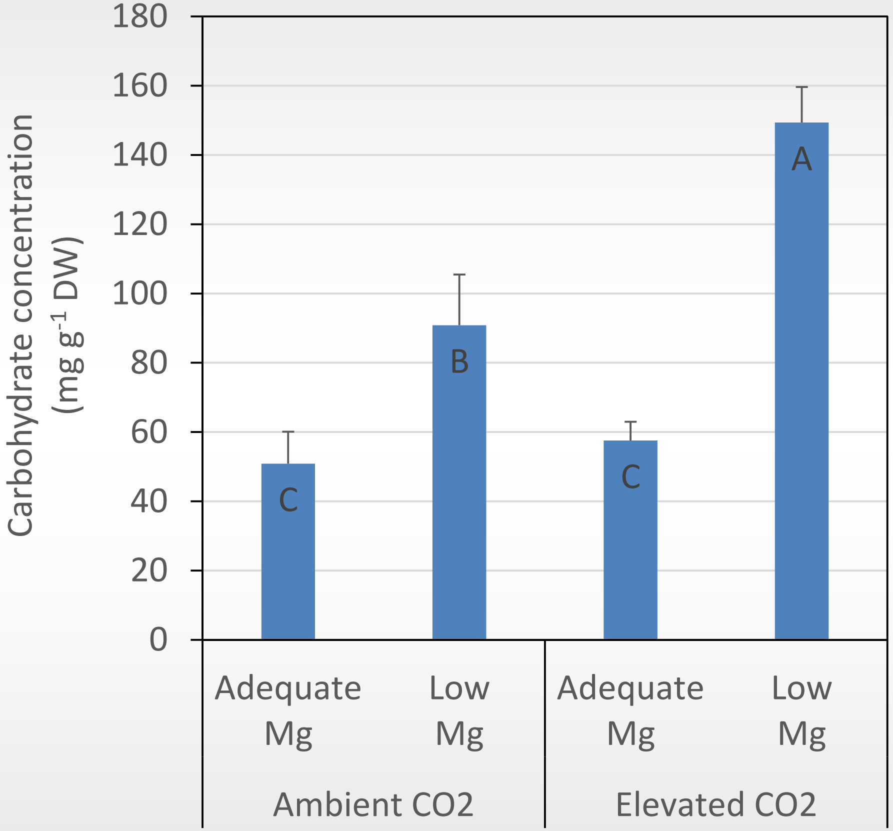


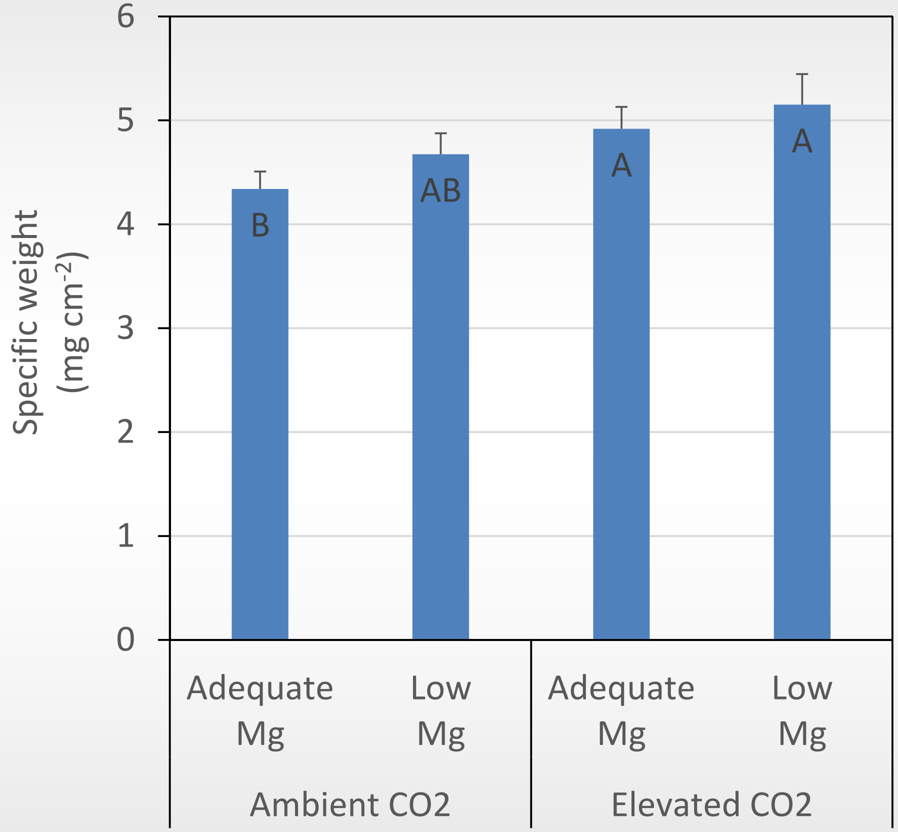


Changes in stomatal conductance and transpiration rate as affect by Mg and CO_2 treatments



Leaf carbohydrate concentration and specific weight as affect by Mg and CO_2 treatments





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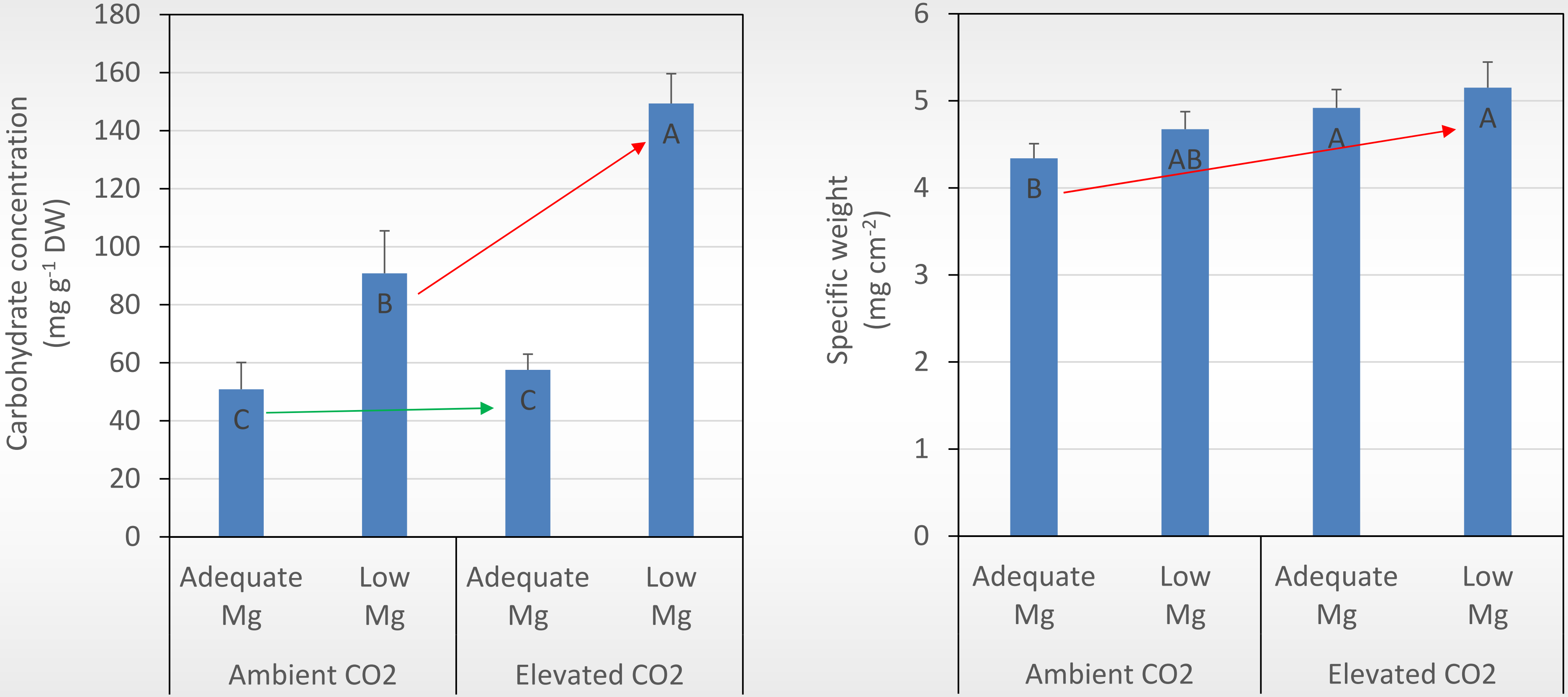
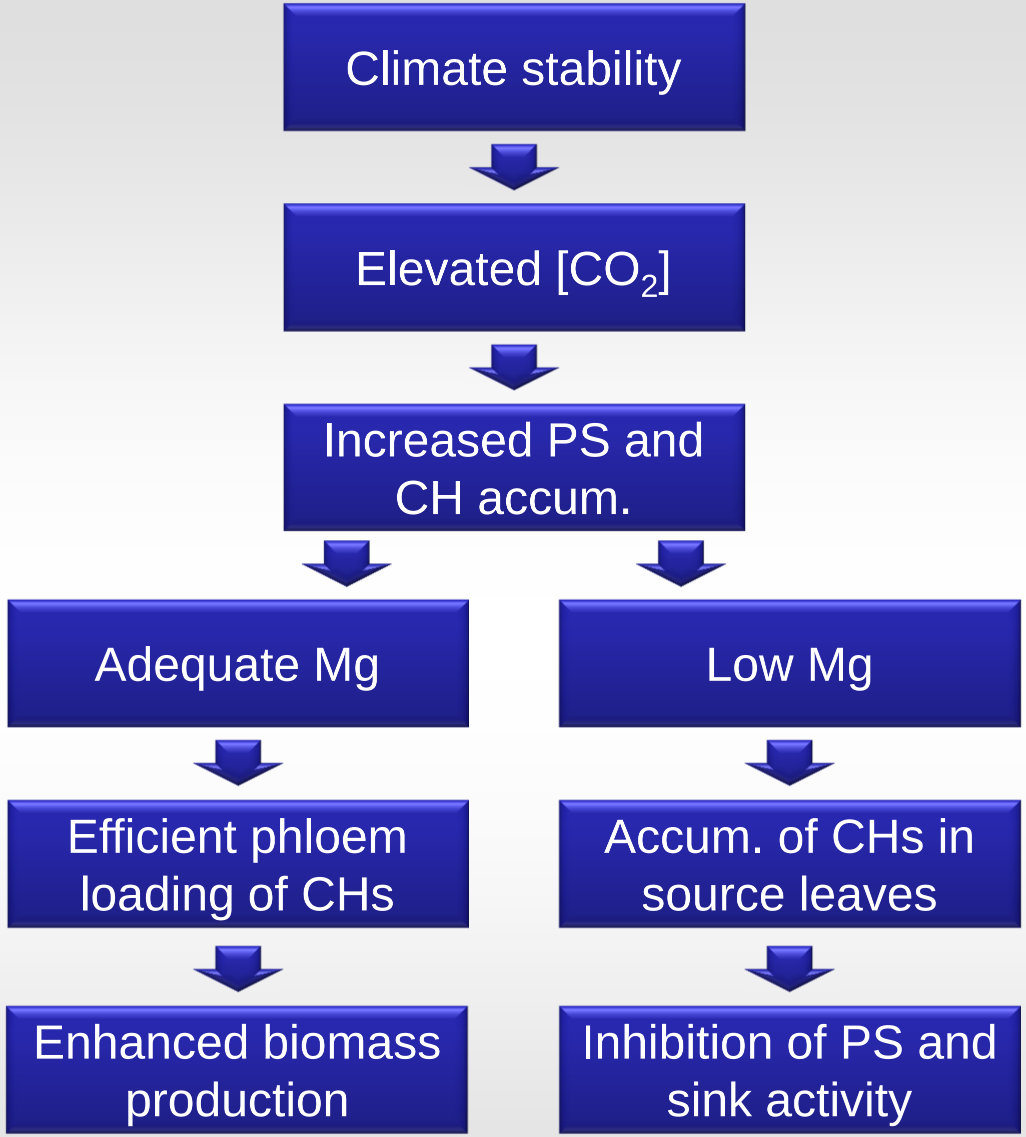


Conclusions:

In plants with low Mg nutrition, an elevated [CO_2] environment…

- does not improve biomass production
- can reduce root dry matter production (root length?)
- does not increase PS rate or chlorophyll concentration
- intensifies CH accumulation and specific wt. of source leaves

Challenge:
Would you invest on Mg to benefit GCC?



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