The rising levels of atmospheric CO_2 impact world vegetation. Is that a bad thing?

Atmospheric CO_2 is on the rise and increasing exponentially. International summits of world leaders try to implement policy to stem the tide of this change, but can enough be done to undo the effects of modern man? The effects of rising atmospheric CO_2 on human life and fauna are constantly discussed, theorised and predicted - indicating a dire future. Shamefully, rarely is the effect on flora ever discussed. Vegetation, covering 25%[1] of the worlds surface, is imperative for the survival and function of the human race - at least in the way it currently operates. Biogeochemical cycles, the global economy, the survival of wildlife and the production of medicines and food are just a few examples of things that depend on vegetation. Therefore, it is certain that, as one of the foundations underpinning our survival, the effect of rising CO_2 on vegetation, and the subsequent ramifications, will be complex and substantial. This essay addresses the potential impact from the perspective of the human race.

The most obvious direct effect of increasing CO_2 on plants is an increase in photosynthetic carbon fixation, leading to enhanced growth.[2] Plants react variably, those with a C3 photosynthetic pathway show higher growth, increasing by 33-40% under elevated CO_2, relative to C4 plants, which increase by 10-15%.[3] Generally however, growth increases with CO_2 elevation. The increased volume of organic food would be considered positive for organisms at higher trophic levels, however there is a negative effect of the fertilisation the increase in CO_2 provides. The positive growth is not selective, so allergens and noxious plants, would also thrive. Consequently, 80% of the population who suffer from allergies will have more severe and frequent symptoms.[4]

The number of plant species included in "world vegetation" is immense and within it there is wide variation in metabolism and physiology. Ultimately, we cannot say with certainty that even plants with the same metabolic pathway will react in the same way, each being unique. Therefore conclusions and evidence drawn from experimental studies may not be easily extrapolated and generically applied, and so when applied may be erroneous. For instance, whilst increased growth would be expected to be a forgone conclusion, preliminary tests on the cassava plant, by Ros Gleadow, showed that growth actually decreased under doubled atmospheric CO_2 concentration.[5]

It should be noted that sustained elevated growth rates would require an increased intake of minerals, such as nitrogen and water. If not present the rate of growth would plateau. Unless artificially supplied, the benefits reaped from increased growth would also plateau.

Another direct effect is that, the elevated concentrations of CO_2 mean plants maintain high photosynthetic rates while their stomatal conductance decreases by 22%. This is as stomata are responsive to atmospheric condition and environmental stress,[6] so an increase in CO_2 concentration decreases the size of stomatal pores, and is inversely proportional to stomatal density.[78] With high concentrations of CO_2, plants can absorb the same amount of CO_2 in a smaller volume of air, so the stomata are open for a shorter period of time. Whilst CO_2 intake would be maintained, plants would lose less water and therefore be able to thrive in more arid habitats.[9] However there are consequences: firstly, precipitation bypasses plant interception, resulting in increased surface runoff and soil moisture levels, which flows into rivers, disrupting the hydrological cycle and increasing potential flood risk.[10] Secondly, evapotranspiration takes place from the stomata into the air, thus cooling the air.[11] The shrinking of the stomata reduces the cooling ability of the plant, intensifying global warming, which would have been attenuated by evapotranspiration.[12] Thirdly, the reduced evapotranspiration leads to less atmospheric water vapour and therefore less rainfall.

The abundance of CO_2, and resultant growth, would make minerals and/or water limiting factors of photosynthesis.[13]. Plants compensate by reallocation of photosynthate to the roots, resulting in

increased root growth. The lengthening of the roots allows greater absorption of water and nutrients from a higher volume of the soil.[14] The increased number and strength of roots, also anchor plants to the ground and bind soil together. This would increase plant stability, making them less susceptible to wind erosion and hydraulic erosion. The soil would also become more consolidated, increasing its stability and reducing the likelihood of mass movement flows. Mass movement flows can cause collapse of houses and infrastructure, as well as the loss of farmland. The knock on negative social and economic effects would be reduced, by the increased soil consolidation.

The chemical composition of plants is also affected. Not only do non-structural carbohydrates increase by 30-40%, but leaf nitrogen concentrations decreases by on average 13%.[15] One reason for this is that the nitrogen is diluted by the increased production of carbohydrates. The other is that decreased stomatal conductance means plants retain more of their water and don't need to take up as much to replace it, thereby reducing the absorption of nitrate ions.[16] This has consequences that affect organisms at higher trophic levels, as in order to satisfy their protein requirement, consumption is increased.[17] For example, the amount of protein in crops such as rice and wheat have decreased by 5-14%, according to FACE experiments.[18] The compensation for decreased food quality may have an effect on human nutrition, and may negate the benefits of increased biomass. Other minerals such as calcium, magnesium and phosphorus may also decrease, again having a negative impact on animals at higher trophic levels.[19]

Increased photosynthesis, from increased atmospheric CO_2, changes plant competitiveness, disease resistance and their ability to protect themselves from animal predators.[20] Sources on how this affects plants however contrast. One study shows that a rise in CO_2 reduces concentrations of compounds in soybeans, that usually make them unappetising to Japanese beetles. This decrease results in an increase of the beetles' consumption.[21] According to Zavala, 50% of the increased plant growth from CO_2 could be consumed by insects exploiting the lower resistance.[22] This would be considered good for insect predators but less so for plants. Additionally, insect predators' increased affinity for certain plants could mean that humans would face reduced crop yield or increased farming costs to pay for protection from pests, adding to the growing insecurity of global food.

A different study states that, the increased rate of photosynthesis means that the plants become "supercharged" so more toxins are produced to protect themselves from consumers.[23] According to Ros Gleadow, and the experiments he has conducted on three different species, cyanide concentration in plants increase under elevated levels of CO_2 - either due to increased cyanide production or decreased protein concentration. This, coupled with the aforementioned increased consumption by animals to fulfil their protein requirement, means animals at higher trophic levels ingest more cyanide.

The consequences of excessive cynanide consumption are often felt in the developing world, where cassava, a plant containing high levels of the substance in its roots and leaves, is a staple for up to a billion people[24]. When improperly produced and frequently consumed it causes a disease called Konza,[25] which causes irreversible paralysis of the legs. The increased concentration in plants could lead to an increased prevalence of disease, especially when manufacturers cut corners. The disability the disease causes would result in an inability to work, decreasing ones affluency, ability to fulfil basic needs, afford education and therefore general quality of life. It would essentially, hinder the sufferers' (and his or her descendants) ability to escape the poverty cycle, it being hard enough to escape without any form of disability.

As well as resistance to predators changing, cold resistance is said to be increased. The previously stated decreased stomatal conductance means less heat is lost through CO_2 procurement. Plants

would be able to thrive in cooler climates, where there are fewer insect predators, and therefore agriculture, in these areas, would also benefit.[26]

Elevated levels of atmospheric CO_2 also causes climate change, despite repudiation from even the current White House administration, and so rising atmospheric CO_2 has indirect, as well as direct, effects on plants.

Climate change leads to a rise in temperature, of 4 degrees Celsius by 2100,[27] causing plants to migrate to more polar regions or to higher altitudes, where the cooler temperatures are found. This can cause extinction when plants aren't able to migrate as fast, or adapt as fast, as temperatures rise.[28] Plants in alpine regions will also face extinction as, already residing in high altitudes, the cooler temperatures they seek are unavailable to them.[29] In fact, according to a 2013 report in the Nature Climate Change journal, 50% of plants will disappear from their current range by 2080.[30]

Climate change creates hotter conditions, in which pests and diseases thrive,[31] resulting in crop pests spreading north and south by 2 miles each year since 1960.[32] The diseases, no longer confined to low latitudes, are spreading - an example being wheat rust, a fungus affecting wheat crops, which has spread 5,000 miles from Africa in a decade.[33] The warmer seasons lasting longer, also due to climate change, means pests are reproducing more frequently. For example, in the Kenai Peninsula of Alaska, the pine bark beetle reproduces three times more often is a single year.[34] The increased range and number of pests and diseases combined with GMO (exacerbating plants vulnerability to disease) and a growing population, as Dan Bebber of the University of Exeter states, "is a serious threat to global food security."[35] Climate change, overall, could cut crop yield by 25% which, considering the world needs 50% more food to feed the 9 billion people residing in it by 2050, could lead to mass human starvation.[36]

The increase in temperature causes thermal expansion - the ocean has stored over 90% of the heat energy produced by climate change - and therefore sea level rise, predicted to rise by 55cm by 2100.[37] A rise of sea level would submerge land underwater leading to the loss of many plants. This would have catastrophic effects for humans. For example, in Bangladesh the loss of rice and vegetables and arable farmland at the coast would lead to malnuturion and mass starvation. Additionally mangroves, a form of vegetation found in the coastal ecosystem of the Sundarbabans, vital in the protection of the Bangladeshi coast, would be lost. Without them the severity of storm surges increases, as do their effects i.e. death toll and land lost. The list is extensive.

Indirectly, rising CO_2 affects vegetation through forest fires. The increase in summer and spring temperatures, and spring weather arriving 10 days earlier in the Northern Hemisphere than in the 1950s,[38] has meant that forest fires have become more frequent and the forest fire season longer.[39] Not only this, but the amount of land the fires travel has become greater due to the increased aridity of the soil – spreading on average an additional 16,000 sq. miles.[40]

How bad the impact of CO_2 on world vegetation is a loaded, multifaceted question. There are numerous reasons behind why this question is incredibly difficult to answer. Firstly, the experiments conducted, fuelling our results and conclusion are uncertain and contrasting. Secondly, the impacts are heavily intertwined - the absorption of CO_2 ameliorating global warming while decreased stomatal conductance exacerbates it - so how severe the impacts are is hard to determine. Additionally, the question itself is problematic, whether something is bad or not is subjective, determined by how one is individually affected. Determining holistically whether something is bad or not is also virtually impossible due to the chaos theory, whereby small changes can lead to drastic consequences. Therefore small changes hold great importance, the consequences of which can only be seen once they occur. As well as this, from a Darwinian perspective, extinction cannot be seen

negatively, as it is from the changes of the earths' environment and extinction of certain species that new ones emerge and thrive.

In conclusion, from the perspective of the human race, we can see that the negatives clearly outweigh the positives. Global food insecurity, leading to malnutrition and starvation, diseases like Konzo, increased allergies, reduced coastal protection, loss of economically valuable ecosystems and the probable extinction of entire species negate the benefits of increased plant growth, cold resistance, and rooting. Consequences of the impacts of rising atmospheric CO_2 on vegetation have such profound and widespread effects that, in light of them, any positives seem trivial.

Bibliography

[1] https://www.nnvl.noaa.gov/green.php [Accessed 20th February 2017]

[2] http://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108 [Accessed 20th February 2017]

[3] https://www.ars.usda.gov/ARSUserFiles/60100500/csr/ResearchPubs/prior/prior_11a.pdf [Accessed 20th February 2017]

[4] http://www.climatehotmap.org/global-warming-effects/plants-and-animals.html [Accessed 20th February 2017]

[5] http://www.abc.net.au/radionational/programs/scienceshow/how-plants-respond-to-increasing-carbon-dioxide/3031138#transcript [Accessed 20th February 2017]

[6] https://staff.concord.org/~btinker/gaiamatters/investigations/stomata.html [Accessed 20th February 2017]

[7] https://staff.concord.org/~btinker/gaiamatters/investigations/stomata.html [Accessed 20th February 2017]

[8] https://www.ars.usda.gov/ARSUserFiles/60100500/csr/ResearchPubs/prior/prior_11a.pdf [Accessed 20th February 2017]

[9] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2267242/ [Accessed 20th February 2017]

[10] https://www.sciencedaily.com/releases/2010/05/100503161435.htm [Accessed 20th February 2017]

[11] http://www.sbse.org/awards/docs/Saxena.pdf [Accessed 21st February 2017]

[12] https://www.sciencedaily.com/releases/2010/05/100503161435.htm [Accessed 21st February 2017]

[13] https://www.ars.usda.gov/ARSUserFiles/60100500/csr/ResearchPubs/prior/prior_11a.pdf [Accessed 21st February 2017]

[14] http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2357&context=usdaarsfacpub [Accessed 21st February 2017]

[15] http://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108 [Accessed 21st February 2017]

[16] http://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108 [Accessed 21st February 2017]

[17] http://www.abc.net.au/radionational/programs/scienceshow/how-plants-respond-to-increasing-carbon-dioxide/3031138#transcript [Accessed 21st February 2017]

[18] http://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108 [Accessed 21st February 2017]

[19] http://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108 [Accessed 21st February 2017]

[20] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2267242/ [Accessed 21st February 2017]

[21] Zavala JA, Casteel CL, Berenbaum MR, De Lucia EH (2007) Elevated CO2 increases susceptibility of soybean to natural herbivores by defeating induction of cysteine proteinase inhibitors. [Accessed 22nd February 2017]

[22] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2267242/ [Accessed 22nd February 2017]

[23] http://www.abc.net.au/radionational/programs/scienceshow/how-plants-respond-to-increasing-carbon-dioxide/3031138#transcript [Accessed 22nd February 2017]

[24] http://aciar.gov.au/files/node/13748/cassava_cyanide_and_konzo_disease__75809.pdf [Accessed 22nd February 2017]

[25] http://www.abc.net.au/catalyst/stories/2891924.htm [Accessed 22nd February 2017]

[26] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2267242/ [Accessed 22nd February 2017]

[27] https://www.theguardian.com/environment/2013/dec/31/planet-will-warm-4c-2100-climate [Accessed 22nd February 2017]

[28] http://www.livescience.com/37057-global-warming-effects.html [Accessed 22nd February 2017]

[29] http://www.climatehotmap.org/global-warming-effects/plants-and-animals.html [Accessed 22nd February 2017]

[30] http://www.livescience.com/37057-global-warming-effects.html [Accessed 22nd February 2017]

[31] http://www.livescience.com/37057-global-warming-effects.html [Accessed 23rd February 2017]

[32] http://science.time.com/2013/09/02/a-warmer-world-will-mean-more-pests-and-pathogens-for-crops/ [Accessed 23rd February 2017]

[33] http://www.economist.com/node/16481593 [Accessed 23rd February 2017]

[34] http://www.climatehotmap.org/global-warming-effects/plants-and-animals.html [Accessed 23rd February 2017]

[35] http://science.time.com/2013/09/02/a-warmer-world-will-mean-more-pests-and-pathogens-for-crops/ [Accessed 23rd February 2017]

[36] http://www.worldbank.org/en/topic/foodsecurity [Accessed 23rd February 2017]

[37] 2014 IPCC AR5 Report by John A. Church (Australia), Peter U. Clark (USA) Chapter 13 [Accessed 23rd February 2017]

[38] http://www.ucsusa.org/global_warming/science_and_impacts/impacts/springs-domino-effect.html#.WLQJWXlviM8 [Accessed 23rd February 2017]

[39] http://www.ucsusa.org/global_warming/science_and_impacts/impacts/global-warming-and-wildfire.html#.WLQHwnlviM8 [Accessed 23rd February 2017]

[40] https://greenfuture.io/climate-change/study-on-forest-fires [Accessed 23rd February 2017]