CO2 Crisis – More than Climate Change

From a pre-industrial-revolution level of 280 parts per million in the atmosphere, carbon dioxide (CO_2) has now risen to 400 parts per million. CO_2, as the main greenhouse gas emitted by burning fossil fuels, traps infrared radiation, warms the planet, and melts glaciers and ice sheets. People around the world are struggling to cope with rising seas, floods, heat waves, droughts, massive cyclones, tornadoes, etc.

Weather-related disasters associated with rising CO_2 tend to dominate media attention, but direct impacts of CO_2 on living systems – including photosynthetic organisms such as higher plants and algae, and marine animals with carbonate shells and skeletons – are equally worrisome.

Plants use the sun's energy to combine CO_2 with water during photosynthesis, making glucose and oxygen. To obtain CO_2 from the air, higher plants growing on land typically open pores ("stomata") in their leaves during the day while the sun shines. Plants lose water to the air ("transpire") while their stomata are open. They conserve water at night or during drought conditions by closing their stomata, and photosynthesis shuts down.

Rising CO_2 essentially acts as a fertilizer and directly stimulates plant growth. But as CO_2 levels increase, plants can keep their stomata open for shorter time periods and transpire less while carrying out the same amount of photosynthesis – increasing their water use efficiency.

These two effects of CO_2 act in opposite directions on transpiration. As explained in the article *Active Role of Vegetation in Altering Water Flows under Climate Change* (www.uni-frankfurt.de/54252494/WGIIAR5-CCboxes_FINAL_VW.pdf), the net effect of a CO_2-rich world on the amount of water consumed by plants depends on whether greater total plant growth outweighs increased water use efficiency. Recent evidence suggests that it does.

Overall, plants are growing and transpiring more: sending more water back into the atmosphere. But this leaves less water to run off into river and lakes. A 2009 study in the Journal of Climate (www.globalwarming-sowhat.com/water-/rivers-discharge-48-04--.pdf) concludes that "reduced runoff in low- and mid-latitudes has increased the pressure on limited freshwater resources over the world, especially as the demand increases with world's population growth… This problem is likely to continue or even worsen in the coming decades."

This could mean a greener, leafier world in springtime; but a browner, drier world in late summer and fall, with lower stream flows and lake levels.

Vines do particularly well in a CO_2-rich world. They can grow large quantities of leaves while investing limited amounts of energy in supporting woody tissues. Poison Ivy, for example, is flourishing with rising CO_2, and is producing a more allergenic form of the compound urushiol that causes itchy rashes. Large vines are proliferating in tropical forests, shading out the tree canopy, decreasing overall tree growth and survival, and reducing total forest carbon storage.

Studies indicate that production of allergenic pollen by grasses and Ragweed is increasing with rising CO_2 levels, with potentially significant impacts on human health worldwide.

When it comes to overall food production, the "beneficial" plant-fertilizing effect of a CO_2-rich world should partly offset climate-related risks. But that may be a small consolation to individual farmers who lose their crops to droughts and heat waves.

People are unlikely to enjoy a CO_2-rich world when it comes to aquatic ecosystems.

As on land, CO_2 stimulates growth of photosynthetic organisms that live in water bodies. These organisms include aquatic weeds that interfere with boating, fishing and swimming; and blue-green algal blooms that produce toxins and endanger drinking water supplies. Aquatic plants tend to flourish where there is less wave action and river flow. If runoff is declining owing to higher transpiration by land plants (as appears to be the case), excess aquatic plant growth will be further exacerbated.

Aquatic plants with submerged leaves must rely on CO_2 dissolved in water, rather than CO_2 in air. Dissolved CO_2 in freshwater can be in short supply, particularly in more alkaline water bodies ($pH > 7$) where CO_2 is largely converted to the bicarbonate form (as in sodium bicarbonate, baking soda). Some aquatic plants such as Canadian Waterweed (*Elodea canadensis*) have adapted to alkaline waters by using bicarbonate for photosynthesis.

Water bodies in agricultural regions are generally more alkaline – both because the better agricultural soils tend to have higher pH levels, and because farmers apply lime to raise soil pH. Canadian Waterweed has become a serious invasive aquatic pest, proliferating in lakes and rivers in agricultural regions throughout the world. It is widely used in home aquariums and is spread when their contents are dumped into a local water body.

Our CO_2-rich world is also having negative impacts on saltwater ecosystems. Oceans occupy a large part of the Earth's surface and are absorbing huge amounts (roughly a third) of our CO_2 wastes, far more than land plants and freshwater systems. This waste absorption comes with a price: ocean acidification.

Oceans are naturally mildly alkaline, with a pre-industrial pH of around 8.25. When CO_2 dissolves in alkaline waters it is mostly converted to the bicarbonate form (as noted earlier). This releases hydrogen ions and makes water more acidic. To date, CO_2 pollution has decreased ocean pH to around 8.14, which (because pH is measured on a base-10-log scale) represents about a 25% increase in acidity.

Experimental studies indicate that some marine life is particularly affected by acidification: corals that build reefs made of calcium carbonate, and zooplankton and molluscs (e.g. clams, oysters, snails) with shells made of this same compound. Ocean acidification also affects the sensory organs and behaviour of many fish species, especially their juvenile life stages.

In summary, the human-caused, rapid rise in CO_2 levels from pre-industrial times is having marked effects on terrestrial, freshwater and marine ecosystems. These effects are complex and cannot be as easily grasped by the public as weather disasters, but they are real and worrisome. They add urgency to the need for energy conservation and a transition from fossil fuels to renewable energy sources.