The Realities of CO_2: Seeing through the Smog of Rhetoric and Politics

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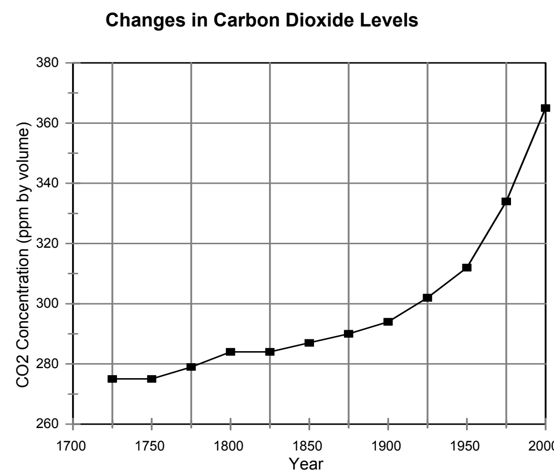
Global atmospheric changes and related climatic impacts are a topic of increasing concern. While no disciplined mind can rationalize that increases in the concentration of atmospheric carbon dioxide (CO_2) are not having an effect on the climate of the earth, just what the specific effects in any given location at any given point in time might be are, as yet, speculative, and probably incalculable. The fact, however, that the exact climatic relationships of the future are incalculable does not obviate the need to consider that there will be consequences for any behaviors, policies, or program approaches that are having measurable impacts on the physics, chemistry, and biology of the earth.

There is a general belief that all things can bear compromise. Yet, few would argue that the pilot of an airplane can compromise airspeed and altitude requirement, as if he could make his own rules. Water that has been mined out of an aquifer really is gone. The soil that washed away in the last thunderstorm, debauching tons of soil into the nearest stream really has lost soil and befouled a stream. Net soil organic carbon loss in a soil really does effect the tilth of the soil. There is a consilience between the physics, chemistry, and biology of the earth that must exist with choices made by all cultures that choose to sustain their inhabitancy. While political compromise can be regarded as a mature approach to solving



certain financial or social issues, if with our behavior we are to challenge the balance of life on this earth, we had better get the facts on natural laws.

As is shown in the graph above (after Neftel, *et al.* 1994), there is no argument that atmospheric carbon dioxide levels have been rising steadily since the industrial revolution, and that the rate of change has risen

[1]This is an essay, not a refereed paper on the subject of carbon cycling. It comes from frustration I feel concerning the happy-talk about "carbon credits" and "carbon sequestration," and "going yellow." It is my hope that it will cause serious citizens to think beyond the rhetoric that is swamping the communications and political landscape and manifesting itself in both government and private information pieces. Our relationship with the earth and obligations to our posterity deserve better than that which is spilling from the pantheon of contemporary thinkers.

exponentially since World War II. Nor is there any question that the average global temperature has risen about 1° Celsius (1.8° Fahrenheit) over the last 250 years. There is a general recognition that this is an untenable trend, but undisciplined thinking has led to spurious responses, policies, and programs to deal with the situation.

There are seven common assertions that deserve to be examined. I believe that glib acceptance of these assertions is leading to massive miscarriages of environmental thinking and policy. They are usually rendered somewhat as follows:

1. Tree planting can offset the use of fossil fuel and mitigate the impact on global warming by storing (sinking) carbon in the wood of the tree.

2. Burning in grasslands causes air pollution and contributes to global warming by giving off carbon dioxide.

3. The principal source of atmospheric carbon dioxide emissions is the internal combustion engine.

4. Growing corn to produce ethanol for internal combustion engines is "the way to go."

5. The burning of natural gas is the best alternative to the use of petroleum-based fuels.

6. Man's activities are too insignificant to induce climate change.

7. No big deal, all these environmental issues, such as global temperature changes, floods, drought, and extinction, are natural and cyclical.

1. "Planting trees can offset the burning of fossil fuel."

Fossil fuels include those that are derived from gaseous CO_2 that was fixed as hydrocarbon[2] some 250 million years ago in the Paleozoic period and, therefore, is surplus CO_2 in the atmosphere when burned (oxidized) in this era. Commonly used fossil fuels include coal, gasoline, diesel fuel, and natural gas.

Figure 1: *Photosynthesis*, a reduction reaction, is the process that "fixes" the carbon to store the food energy all living cells need. In photosynthesis, when 6 molecules of CO_2 + 6 molecules of water (H_20), with chlorophyll activated by light energy (about 675 kcal), are brought together in a special, enzyme-mediated chemical reaction, the result (in one common transformation), is a 6-carbon sugar. The reaction can be expressed essentially as follows.

$$6CO_2 + 6\ H_2O + \text{light} \rightarrow C_6H_{12}O_6 + \uparrow 6O_2$$

Living cells obtain the food energy essentially through an opposite process, *respiration,* where the simple sugar, in the presence of oxygen, oxidizes and yields energy plus carbon dioxide and water.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6\ H_2O + \uparrow \text{energy}$$

Since it is possible to estimate the rates at which trees use (reduce) CO_2 in photosynthesis (Figure 1), and since we know how much CO_2 is released when fossilized, or sequestered, hydrocarbons are burned (oxidized) it is possible to approximate the number of trees it would take to offset the burning of fossil fuel.

[2] A hydrocarbon is a molecule in which carbon atoms are bonded together with other carbon atoms, usually in a single bond, into a carbon-carbon chain in which the other available bonds are prevailingly with hydrogen atoms. The "natural gasses" are relatively short, 1-4-carbon chains: methane, ethane, propane, and butane. Gasoline contains mostly 5-8-carbon chains: pentane, hexane, heptane, and octane. Diesel fuel, jet fuels, kerosene, and the like are multi-carbon alkanes of mostly 15 or more carbon atoms. Coal is mostly bulk organic carbon.

If, for example, young trees are planted for the purpose of sinking (sequestering) CO_2, (removing CO_2 from the atmosphere permanently), certain assumptions must be made. It reasonably can be assumed that young, vigorous, deciduous trees, will have an effective leaf surface of 10,560 ft^2 per tree. One then can estimate that each tree on the average, would "take up" (convert to hydrocarbon through reduction) about 25 pounds of CO_2 net each year in the North Temperate Zone.[3]

In order to calculate how many trees would be necessary to offset emissions, it is necessary to know that approximately 16 pounds of CO_2 are produced for each gallon of gasoline (fossil hydrocarbons) that is oxidized.[4]

So, how many growing trees does it take to offset the burning of fossil fuels? To make the calculations relatively simple, assume locally that there are about 3 million drivers in the Chicago region, each of whom travel 10,000 miles per year in cars that run at an average fuel consumption rate of about 25 miles per gallon. This is probably a conservative assumption, particularly since many motor vehicles languish idly at toll plazas and since the number of tractor trailer trucks seems to burgeon each year. Twenty-five miles per gallon would yield about 0.63 lbs of CO_2[5] per mile, which is equivalent to about 40 miles per tree.

In the aggregate then, in one year, Chicago drivers will generate about 18.9 billion pounds (9.5 million tons) of atmospheric CO_2 gas. If the average tree takes up 25 pounds of CO_2 per year, then 756 million trees would need to be planted in the Chicago area alone to compensate for CO_2 produced from automobiles. In order to allow room for crown growth, one would have to allow 40 trees to the acre,[6] which means that one would need 18.9 million acres of land per year—50% of the size of the state of Illinois. Each of the drivers, or their "carbon credit" agent, would have to plant 260 trees without using any fossil fuel in the process.

Also consider that when trees die and decompose, most of the fixed carbon is liberated as CO_2. Thus the trees must either live and grow forever or be buried deeply enough in into the ground to avoid oxygen and moisture, where the carbon can be stored. Each tree that dies must be replaced without the use of fossil fuel and Illinois would have to comprise more acres of available space for tree planting each year.

[3] It should be noted, that many if not most of the living cells of a tree are non-chlorophyllous, and that all of the cells of the tree must respire during the growing season, a process that uses oxygen (O_2) returns CO_2 back to the atmosphere. Most of the world's net oxygen production is the result of photosynthetic activity of algae in the sea. In terrestrial plants, trees specifically, the remaining carbon is "stored" mostly as cellulose within roots and trunk, which is the non-living wood; it is this creation of wood that we are saying incorporates the 25 lbs of CO_2 per year.

[4] This might seem like a great weight of atmospheric gas, but this is how it works: a gallon of gasoline weighs about 6 lbs and is about 80 percent carbon by weight. Hydrocarbons are made prevailingly of carbon-carbon atom chains with regularly attached hydrogen atoms. When the hydrocarbon is oxidized (burned), the hydrogen atoms are replaced by oxygen atoms so that each carbon atom is separated from all the others and heat is released. Oxygen atoms are quite heavy in relation to hydrogen atoms, so the resulting product is water vapor and about 16 lbs of CO_2. This rapid oxidation, or burning, is essentially the same chemical transformation as respiration (see Figure 1.)

[5] There are also a lot of other compounds, mostly toxic, generated from the oxidation of a gallon of gasoline in an internal combustion engine, such as oxides of nitrogen, carbon monoxide, and various incompletely oxidized hydrocarbons, but the essential point here is not affected.

[6] An acre is 43,560 square feet, or a square about 209 feet on a side. In one commonly used "standard forest planting," the spacing recommendation ranges from 908 to 1210 trees per acre! The same specification specifically recommends using a "machine" to do the planting—which no doubt uses fossil fuel.

Some programs seek to "offset carbon emissions" by setting aside stands of existing forest with the noble motive but spurious idea of protecting the "stored" carbon of this era. There are absolutely crucial reasons for protecting our remnant wooded lands but their appointment as offsets for continued carbon emissions cannot be one of them.

Trees, as all living things, are priceless and important elements of the landscape, but to suggest that planting them results in any practical compensation for the profligate oxidation of fossil fuel does not take into account the fact that, in the Temperate Zone at least, their wood is an integral component of the contemporary carbon cycle. The carbon is not sequestered.[7] The carbon cycle is not a issue that we, however clever we imagine we are, can change.

2. "Grassland fires cause air pollution."

Year by year, most healthy perennial grasslands in the Midwest "fix" more carbon below the ground than is decomposed, particularly on the Wisconsinin Till Plain. Most of that which is fixed above the ground in leaf and stem tissue is returned to the atmosphere during the grassland burn as water vapor, light, and CO_2—CO_2 that was fixed in our current era (post-glacial or Holocene), not the Paleozoic as is largely the case with fossil fuels. Given the fact that more carbon is fixed than burns or is decomposed after a growing season, there is a net removal of CO_2 from the atmosphere every year.[8]

The "smoke" is composed largely of CO_2 and water vapor. Generally, the more opaque the smoke, the greater the proportion of water vapor. The removal of atmospheric CO_2 is optimized in those grasslands that burn after each growing season, because the surface-area development of green leaves (photosynthetic surface) is maximized for the following year.

Each blade of grass is essentially a photovoltaic panel. It deploys sunlight energy to fix CO_2, into a 3 or 4-carbon sugar, a key building block for living tissues. The more square centimeters of photosynthetic leaf surface, the greater the photovoltaic potential.

The burning of the prairies is crucial to their productivity, both above and below ground. When the grassland is burned, each tuft of prairie "bunch grass" produces an optimum array of leaf surfaces, in part because growth starts earlier in the season and the young growth is not inhibited by the duff of the previous year.

The green growth of the season from these tufts or bunches of prairie grass, moves cool water from the below-ground rhizosphere up into the leaves for transpiration, which keeps the leaves relatively cool. At night, water from the humid air condenses on these cool surfaces and moves down the leaves into the ground, which sustains soil moisture—which both waters the system and keeps the oxidation rate lower than otherwise would be the case.

Trees in the Tall-grass Prairie biome are not generally the forms of life in which carbon is tied up in net amounts. Rather, the more abundant source of stored carbon in this biome is soil organic carbon (SOC) that accumulates in the upper soil layers over the course of time. The organic-rich soils of Burnham and Powder

[7] I should point out that the rain forests of the tropical districts of the earth, when healthy and stable, are repositories of carbon.

[8] The limiting factors in the amount of carbon fixed per year include the growing season length, the amount of leaf surface per unit area, humidity, the average daily temperature, and the amount of available atmospheric CO_2 at ground level, which can drop to 0 on a July day at noon in a cornfield. Generally, a regularly burned grassland can fix as much as 3.5 to 4 tons of dry organic carbon above the ground per acre per year—and maybe half that in its fibrous root system.

Horn prairies near the south side of Chicago, for example, date back about 2800 years.[9] Their organic content was calculated to have accumulated at a rate ranging from 266-1225 pounds per acre per year.[10]

This accumulation rate is dependent on several factors, not the least of which is the wetness of the soil and the presence of deep, well developed fine-root systems, such as is typified by grassland vegetation. Generally, the wetter the soil, the greater the rate of soil organic carbon accumulation, since decomposition generally occurs at a lower rate in a shortage of oxygen. This organic carbon consists mostly of the residual, undecomposed material of the dead root systems of fibrous-rooted species such as grasses and sedges, which grow about a third of their living root system every year.[11]

The photosynthetic (reduction)/respiration (oxidation) chemistry is essentially the same as described for the trees, but there is little or no lignified (woody) tissue resident in the grassland system. It is from this post-glacial soil building process that the deep black soils of the Midwest developed. Indeed, these soils are the original reason why our agricultural productivity has been so fecund,[12] albeit temporarily.[13]

Insofar as the long-term health and well-being of our economy and the world's ecological integrity is concerned, there is no sustainable antidote to the continued widespread burning of fossil fuel. For each acre of native grassland, however, particularly where fire is a regular occurrence, there is the possibility of storing up to 2,500 or more pounds of organic carbon per acre each year—equivalent to about 150 gallons of oxidized gasoline.[14]

Currently the default alternative to deep-rooted perennial grassland in many unpaved landscapes is the turf-grass lawn. The usual

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[9] This coincides with the formation of the low sandy lake plains that developed after the last glacial lake stage of Lake Chicago, Lake Algoma, which drained away about 3000 years ago.

[10] The organic-rich soils of these lake plain prairies illuminate the post-glacial history of carbon cycling near Chicago. Cores were analyzed for the carbon content to help reconstruct the vegetational history and carbon budget of wet prairies. A ^{14}C age of 2,805 ± 125 years B.P. from the basal muck of the Burnham Prairie at a depth of 14 cm dates the onset of wet prairie conditions and storage of carbon in the soil. Ash content of the muck ranged from 46.6–86.5%. The carbon content was calculated as 0.06–0.24 g/g of dry sediment, or about 50–230 kg of carbon/ha/year. Charcoal occurrence throughout the muck attests to the fact that the plant communities had been burned regularly, thereby cycling the phytomass to CO_2 and charcoal. Intense recycling of carbon by decomposer fauna is indicated by the dominance of fecal pellets and fungal hyphae in the organic residues and the absence of remnant pollen in the muck soils.

[11] Generally, grassland root systems in the prairie biome turn over about a third of their root system every year, a third growing and a third dying.

[12] In recent decades, of course, we have "improved" corn genetics and developed an ability to, at great cost, bring nutrients and water to worn out land in sufficient amounts to convince ourselves that increasing productivity from 40 bushels of corn per acre to 200 is progress—the presumption being that there will always be a "scientific" miracle available to mitigate the illusory but unsustainable endeavor of commodity food production.

[13] The NRCS has estimated, for example, that across the state of Iowa, the topsoil averaged 18 inches in 1840, right after most of the Indians had been "removed." By 1990, 10 inches had been lost to wind and water erosion, and of the remaining 8 inches, half of the tilth was gone. More ground has been lost since then. Good tilth is largely correlated with organic matter content, which once ranged as high as 25% or more in arable soils. Many farm fields today have less than 2%—if they have any topsoil remaining at all.

[14] The amount and rate of storage is quite variable, dependent upon many factors such as annual average temperature, soil wetness, soil type, slope aspect, *etc.*

management or maintenance in such landscapes is to mow 2-4 times per month, which burns about 1 gallon of gasoline per acre per mowing event in engines that, in most states, are not even equipped with a catalytic converter.[15] In a 36-week growing season that includes 18 to 36 mowings per year, 288 to 576 pounds of CO_2 per acre are emitted into the atmosphere. For every acre of the same landscape converted to native grassland, there could be that much less CO_2 burned; indeed, carbon would be sequestered.

In addition to water vapor, energy, and CO_2, the exhaust emissions of a lawn mower contain many toxic oxidation products, including polycyclic aromatic hydrocarbons and many of the same emissions that are prohibited from the exhausts of today's automobiles. By contrast, the emissions from grasslands, particularly those that burn annually, are negligible. The emissions from raked up piles of leaves, however, present a witch's brew of foul toxicants owing to variations in combustion temperature, oxygen availability, and moisture content. It is far cleaner to let the leaves lie in a thin layer and run a fire through them during the late fall.

Were we to start with the simple truths in looking for solutions, our heads would surprisingly be turned to wholly different solutions that could mean real change, health and well-being for our posterity.

3. "The burning of fossil fuel is primarily responsible for atmospheric increases in carbon dioxide."

While the profligate use of the internal combustion engine generates progressively greater concentrations of atmospheric inorganic carbon, it is not by any means the only source. Another is the practice of commodity-scale row-crop agriculture in soil that, with tillage or cultivation, annually oxidizes more soil organic carbon than is fixed every year. This is because in row-crop tillage the soil is turned over and the natural oxidation or "burning" of SOC by soil microorganisms is stimulated (Reicosky *et al.* 1999).

Reicosky (1998), for example, found that one pass of a moldboard plow caused 5 times as much CO_2 to be lost from the soil in a 19-day period than if plots were left untilled—representing the loss of more organic matter than was fixed all the previous year. In twenty studies in which the moldboard plow was used, the SOC was reduced by an average of 256 pounds per acre per year.

By contrast, in 10 other long-term studies where no-till practices were used, and much of the dry above-ground vegetable matter was allowed to lie, organic matter increased, with an average increase in soil organic carbon of 953 pounds per acre per year.[16]

On the average, oxidation of one pound of SOC forms 3.7 pounds of CO_2. Soil organic carbon is essentially a fossilized form of carbon that is stored in the topsoil. The carbon fixed in stems, leaves, and grain is carbon from the current year and is eventually returned to the atmospheric cycle. If the average row-crop field has a net loss of 250 lbs of SOC/acre/yr, then the surplus CO_2 given off to the atmosphere is 925 lbs/acre. From the earlier discussion we can calculate that a car driven 10,000 miles annually at 25 mpg, produces approximately 6,300 pounds of CO_2. This equates to the weight of carbon produced in one year of row cropping 6.8 acres. Narrowing our

[15] Chronic mowing keeps the leaf surface area unhealthy and at a minimum photosynthetic area for grass survival, severely retarding root system development.

[16] These accumulation figures do not take into account the gallons of fossil fuel burned to plant, fertilize, herbicide, pesticide, and harvest the fields.

views to include only one aspect of our behavior might be politically expedient, but it also can be catastrophic.

4. "Growing corn to produce ethanol for internal combustion engines is "the way to go."

As has already been explained, commodity-scale row crop tillage reduces the tilth of our farmland. When soil loses tilth, it loses its organic matter, and therefore its ability to absorb water. The corollary to lost water absorption is increased erosion, and therefore exaggerated divestment of erodible resources, which then accumulate in somebody else's back yard downstream in amounts too excessive to be useful, if not actually destructive. The long-term consequences on both the local and broader economy are frightening.

As the water in the soil is drained away, the reduction/oxidation relationships change dramatically. Whereas once the prairies held their water, and carbon was fixed beneath the surface in net amounts, annual row crop tillage now causes organic matter to be oxidized more rapidly than it is fixed, a situation exacerbated by the constant drain of water through the tile systems and into the ditches.

Consequently, during each growing season, carbon dioxide that was fixed millennia ago is now released into the atmosphere in amounts greater than it is taken up. Recent studies on the amounts of carbon stored in the Conservation Reserve Program (CRP), in which deep-rooted grasses are planted in some of the less productive or more erodible soils, have shown that nearly ten years of SOC storage can be oxidized within a single growing season after tilling. These amounts can be impressive, since land in CRP, over a broad geographic area, can gain an average of 0.5 tons of organic carbon/acre/year (Gebhart *et al.* 1994).

The loss of tilth in our farmlands, particularly since the 1920's, has led to progressive needs to fertilize, herbicide, and irrigate. The costs of these "inputs" has drastically reduced the profit obtainable on a bushel of product. Under the aegis of the protection of the "family farm,"[17] staggeringly high subsidies are in place to assure that corn and soybean production, specifically in the Midwest, remain a stable enterprise, although by 2002, 80% of the subsidy was going to corporate agriculture. The family farmer is so in debt on the purchases of huge farm equipment designed solely to produce massive quantities of corn and bean, the re-investment in any alternative crops or equipment is an untenable financial possibility.

Inasmuch as alternative crops are not feasible to produce, the huge supply of corn and bean produced keeps the prices down. More land is tilled annually to achieve the subsidy, and more of what is left of our topsoil is lost.

With the recent increases in oil prices the idea has taken hold that converting corn to ethanol to dilute the consumption of oil makes some kind of sense. It is said to be a "win win" program: we can reduce the growth of oil consumption, even as we provide the "family farmer" a new market!

[17] In 2002, the "Farm Bill" budgeted 190 billion dollars to be spent through 2012 on farm subsidies. "This bill is generous and will provide a safety net for farmers, and it will do so without encouraging overproduction and depressing prices," President Bush placated us at a signing ceremony. "It will allow farmers and ranchers to plan and operate based on market realities, not government dictates."

This headlong rush to "go yellow" has increased demand on corn, which has led to higher corn prices, an ostensible positive, albeit only for the short term. This hunger for corn production has stimulated the removal of more land from the Conservation Reserve Program (CRP). According to the USDA, about 2.5 million acres of CRP was tilled in 2008, largely to capitalize on corn production.[18] Not taking into account the fossil fuel inputs to corn and ethanol production, the increased tillage of our land just exaggerates the loss of soil organic carbon.

By failing to question the consequences of commodity-scale corn and bean production, notwithstanding the carbon issues, we have enhanced the phenomenon that the American diet is becoming progressively more corn-based, lacking much of the diversity that was available to the family house hold as late as the 1960's: corn-fed beef, corn syrup fillers, sweeteners, *etc.* Ignoring the natural laws is having direct impacts on the *general welfare*, a constitutional issue: adult and childhood diabetes, obesity, and poor nutrition generally.

5. "Natural gas is the best available alternative as an energy source."

It is often stated that natural gas, a fossil source of fixed carbon, is the long-term solution to our energy need. The assertion is usually stated in combination with the prediction that alternative (non fossil) sources of energy ". . . will never be sufficient to meet our growing needs." Neither is their correlative assertion that the nature of "growing needs" be assessed and considered.[19]

To say that there will never be any replacement for any existing technology is utterly without vision, just as is the assumption the existing ideas with respect to "growing needs" are unquestionable. Similar apocryphal allegations have tried to persuade us in the past:

> "We will never have an economically viable replacement for candles."
>
> "Any vehicle that goes more than 60 miles per hour will suck the wind out of a human being."
>
> "Mother's milk is too sweet and not protein-rich enough. We can produce a formula that works better."
>
> "Why would we want something that can merely fly from one end of the cow pasture to another."
>
> "We will never be able to fly an airplane through the sound barrier."

Little in life is more wrong than the prediction that some particular product of the moment is the end of the line in technology and development. Certainly, natural gas oxidation is much cleaner than the combustion of petroleum-based products and most people agree that, with today's technologies, nuclear energy has shown itself to be an untenable solution. Still, the oxidation of natural gas adds surplus CO_2 to the atmosphere—which, of course, will continue our run toward an unsustainable, unpredictable, environmentally

[18] According to one analysis of USDA figures, by Philip Corzine, "farmers typically don't idle their top-producing land in the CRP program and a great deal of the acres in this program are in fact, much better off never being farmed. So even the "best land" coming out of CRP will likely be at the bottom on typical yields, regardless of what crop is being produced.

[19] Rarely discussed is the beauty and quality of architecture and infrastructure that could arise if we re-energized our economy with creativity and expertise of local craftsmen, artisans, and practitioners who worked together to *reduce significantly energy demands.*

risky and probably economically debilitating future.

We must wean ourselves off of fossil fuel use, not mere rearrange the deck chairs on the Titanic. As Bill McDonough, the architect has tried to point out, one who seeks to go north and is driving south at 90 miles per hour, does not get their merely by slowing down—he must stop and turn the car around.

If we were to apply our creativity to significantly reducing the demand and developing renewable energy sources, our economy would gain new legs and our future would be more secure.

6. Man's activities are too insignificant to induce climate change.

This assertion usually is accompanied by a presumed humility that it is only arrogant people, steeped in self importance, who would accord humanity with that kind of influence. Humble is as humble does. Over a thousand years ago, whoever articulated the admonitions in metophor in Deuteronomy 11:8-17, must have felt that our behaviors could result in climate change.[20] Indeed, the "fertile crescent" as it sits today, scarcely represents the one in which people early formed an agrarian culture.

More recently, Amos Sawyer (1874) tried to explain why the regular afternoon thundershowers had become far and few between, to be replaced by less frequent, more violent rains: *"During the last twenty years our climate [in Illinois] has been slowly but surely changing from wet to dry. . . . But the most important agent [of this change], one that is yet to produce greater mischief, seems to have escaped [our] attention: it is the aqueous. The chemical and mechanical effects of this agency are constantly at work, and the result is plainly visible in the deepening of the channel of all our small streams.*

"[It] is hard at work night and day, summer and winter, overcoming every obstacle placed by nature or man to impede its progress. The work marked out for it to do is no less than the complete drainage of the ponds and lakes of our prairies: and so surely as the world stands, so surely will the task be accomplished. . . . Every little streamlet has its miniature Niagara Falls: but, unlike their giant relation, they are making visible progress every year, and are consequently (strange as the language may seem) more instructive. The 'hard pan,' which only yields after repeated blows from the sturdy laborer's pick, and grinds off its steel at the rate of two inches per day, crumbles and gives way under the combined agency of frost and water: the largest trees in the forest yield to the conquering element. . . . Every little streamlet is bringing its bed down to a level with its parent stream, and the merry rippling of their little

[20] "Therefore shall ye keep all the commandments which I command you this day, that ye may be strong, and go in and possess the land, whither ye go to possess it; And that ye may prolong your days in the land, which the LORD sware unto your fathers to give unto them and to their seed, a land that floweth with milk and honey. For the land, whither thou goest in to possess it, is not as the land of Egypt, from whence ye came out, where thou sowedst thy seed, and wateredst it with thy foot, as a garden of herbs: But the land, whither ye go to possess it, is a land of hills and valleys, and drinketh water of the rain of heaven: A land which the LORD thy God careth for: the eyes of the LORD thy God are always upon it, from the beginning of the year even unto the end of the year. And it shall come to pass, if ye shall hearken diligently unto my commandments which I command you this day, to love the LORD your God, and to serve him with all your heart and with all your soul, That I will give you the rain of your land in his due season, the first rain and the latter rain, that thou mayest gather in thy corn, and thy wine, and thine oil. And I will send grass in thy fields for thy cattle, that thou mayest eat and be full. Take heed to yourselves, that your heart be not deceived, and ye turn aside, and serve other gods, and worship them; And then the LORD's wrath be kindled against you, and he shut up the heaven, that there be no rain, and that the land yield not her fruit; and lest ye perish quickly from off the good land which the LORD giveth you.

cascades greets the ear on every side, and tells you in language not to be misunderstood that they will in time accomplish the work allotted them to perform the thorough drainage of the land through which they pass."

Seeing the impact of our activities on climate was not hard for Amos Sawyer, nor is it hard for field biologists. Floridians more than 50 years old have seen essentially the same phenomenon occur in weather patterns there. Mining water for pools, golf courses, and lawns, along with the stormwater doctrine of development to *collect, convey, and discharge water as rapidly as the law will allow to a neighbor downstream,* has dewatered much of the state. The impact on Florida's climate is not a mystery.

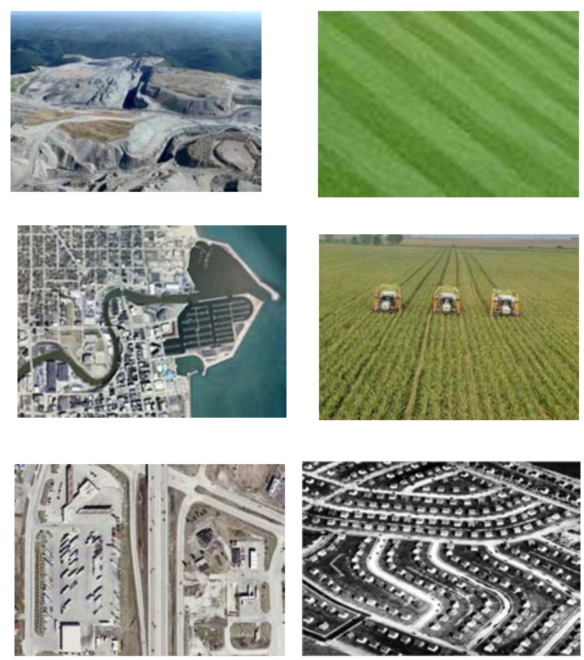
When whole mountains, such as Kayford Mountain, in West Virginia are simply made to disappear to get at the coal, the climate is altered utterly. The"heat-island effect" in great cities is not questioned by those who live in and around them. The "urban drought effect" on the lichen flora is well known to lichenologists.

Skepticism seems to arise when virtually every degrading environmental problem we face is attributable to global climate change. The allegation only one factor is responsible for all environmental ills, namely measured increases in global air temperature that result solely from the emissions of "greenhouse gases," is a red herring.

The plethora of recent wild fires, for example, is blamed on global warming, but the principle reason for their untimely destructive impact is because our culture does not understand what the Indians knew: that the resources in the landscape were best sustained by landscape fire, which they had administered purposely all across the country, nearly annually, from time beyond mind.

Our Holocene-aged ecosystem, having evolved with this relationship with human culture (Wilhelm & Rericha 2007), accumulate dry organic carbon in unburned years to the point where a wayward spark sets off uncontrollable fires, commonly on days when disadvantageously the winds are too high and the humidity too low. The fact that such fires annoy home-owners and damage infrastructure is uninteresting to the natural system. Annual controlled burns, as soon as the first growing season of fuel is combustible, would obviate these concerns, re-hydrate the soil through the growth of native grass root systems, and go along way toward eliminating the threat of flooding and mud slides.

That having been said, it is intellectually perverse not to see the relationship between post-industrial CO_2 levels and global temperature change. What seams less obvious, however, is the contributory roll CO_2 given off during row-crop tillage, mentioned earlier, and



Mans activities that must be having an impact on climate issues, given their impact on temperature, soil organic carbon, soil moisture, and biodiversity.

the dewatering of farmland by ditching and tiling, also as explained earlier (Patchett & Wilhelm 1999).

In addition to tillage agriculture's contribution to atmospheric CO_2, the loss of soil organic carbon (SOC) in the soil has had a tremendous impact on soil temperature, soil moisture, and pH. As SOC diminishes in clayey soils, the clay particles become closer together, which at a point about where SOC drops below 5%, rain water has a more difficult time hydrating the rhizosphere and much of it runs off. In the sandier soils, as SOC drops, rain water tends to bleed through too quickly, leaching nutrients to the ground water or the tile system.

In healthy rhizospheres, living zones, soil moisture levels between 50% and 65%, because of the specific heat of water, provide the critical linkage to the thermal mass of the subtending earth, which is generally stable at the average annual temperature. In our area that is about 55° Fahrenheit. In natural ecosystems, just a centimeter below the surface, soil temperatures rise slowly, steadily, and inexorable to as high as 80° or so, then, well after the hottest time of the year, begin slowly to descend.

When this living zone loses water to runoff or has been lost from this zone, it is no longer so intimately connected to the thermal mass of the earth. The temperature within several centimeters of the surface can vary significantly, even between night and day.

All native plants and most animals are ectothermic, and owe healthy metabolisms to their ability either to thermoregulate or grow in an environment where moisture and temperature levels are essentially stable. Just as endotherms, such as ourselves suffer from even a 1° Celsius (1.8° Fahrenheit) temperature change, so also do ectotherms. All enzyme systems are subject to van't Hoff's rule[21], so temperature changes of that sort can be quite disorienting and unhealthy for organisms.

In our own studies, we see the impact of SOC loss regularly on the diminished diversity and quality of remnant ecosystems. At a sandy prairie remnant in northwest Indiana, for example, where bunch grasses had been removed through mechanical disturbance, the sand was much hotter than the ambient temperature.

The sand in the nearby swards of bunch grass, mostly *Andropogon scoparius*, were quite cool, about 80° Fahrenheit, even in a zone 20 centimeters from the open disturbed sand, where the temperature was 30 degrees hotter on a 72-degree day in September. There were no nests of ants in the open sand, there were three species of native ant in the sward of *Andropogon scoparius: Forelius pruinosus, Aphaenogaster treatae,* and *Formica dolosa.* This area is an Indiana Nature Preserve, known for it native fecundity and diversity, virtually none of which can endure such unmitigated hot summer sand.

The phenomenon is generally the same, though somewhat less dramatic in our loamier soils, particularly those of agricultural character. As soil moisture drops below 50% or so, seasonal and even daily temperature ranges become more extreme, the pH rises (in local soils), and biodiversity is much diminished. Studying it as intimately as we do, we can equate it to the earth's life zones as experiencing fever and chills.

Such conditions are not isolated. Less than 1% of Illinois' landscape is in remnant vegetation, the rest is largely in dewatered

[21] "The velocity of chemical reactions is increased twofold or more for each rise of 10°C in temperature; generally true only when temperatures approximate those normal for the reaction."

agriculture, pavement, lawn, or rooftop. The growing season for native species is about seven months. Soy beans and corn are about the only living thing over more than 80% of the state's surface area, but only for about 3 months. For the other 4, there is no photosynthesis, respiration, transpiration, condensation, reproduction, or any other evidence of life in our soils. They simply lie there, run off water when it rains, and become hot in the day and cold at night.

While we have no way of relating this phenomenon directly to "global warming," there is no question that the Midwestern climate is changing. We might also want to make a distinction between climate as climatologists see it and climate at the scale where most terrestrial organisms live, the boundary where heaven and earth meet—the several feet or so just above and just below the earth's surface. My suspicion is that the two climates are not unlinked.

One can only wonder how much of the obvious must be illustrated to cause some people to quit denying a truth, the substance of which is as obvious as a heart attack.

7. No big deal, all these environmental issues, such as global temperature, floods, drought, and extinction, are natural and cyclical.

Over the last 300 years, for the first time in the history of the world, the human being abrogated an age old relationship with the living earth. Never before have significant masses of land been ditched, tiled, and so wholly dewatered. For the first time in the history of the world, the aquifers have been undergoing dewatering, with large cones of depression spreading across significant portions of continents. Never before has 99% of the biodiversity of the life zones of a continent been replaced by monocultures of commodity products.

A cycle is something that continues to move in a progressive pattern, always to return to a previous circumstance. Cultural value changes seduced from exponential changes in tool production and use, through technological change, along with the widespread tendency to make commodities out of the necessities of life: food, water, and shelter, has resulted in the massive mining of critical resources. When mines run out, their supporting towns are abandoned; the people go elsewhere. The reader can ask himself what happens when nations mine away their water, soil, and biodiversity, replace them with drugs and manufactured items, and divest themselves of an interest in next generations in order to optimize apparent quarterly performance.

A cycle is as fundamental to the natural order of things as one can imagine. How we stop trashing the cycles of nature is the more relevant question.

Summary

Planting trees or setting forests aside cannot offset the oxidation of fossil fuels because fossil carbon represents stored carbon from another era. Such organic carbon is converted to CO_2 in surplus amounts. Trees and vegetation of this era already are cycling carbon into the atmosphere at a rate and concentration to which contemporary life forms are adapted. Relatively sudden changes in atmospheric chemistry, such as we are seeing today, impose global system constraints at a rate to which most life forms have difficulty adjusting during their life spans and physiologic development; most cannot adjust at all. These rapid macrohabitat system changes are not in synchrony with other systems such as day length, genetics, physiology, and chemistry.

Burning grasslands dominated by warm-season native grasses is a relatively clean burn in that the principal oxidant is CO_2 that was fixed in just the last year or so and is, therefore, part of the contemporary cycle. Many such grasslands that grow in loamy soils actually accumulate carbon, by sinking it in the deep black soils that develop under mid-grass to tall-grass prairies.

Those who seek to burn raked up piles of leaves in the Fall should be made aware that they risk diminishing the health and well-being of themselves and their neighbors. The annual, one-time event of grassland combustion, however, is not only a clean burn but one that contributes positively to air quality by facilitating the grassland's removal of net amounts of CO_2 from the atmosphere.

The **burning of fossil fuel** in the internal combustion engine and in coal-fired utilities get the overwhelming attention when policy makers focus on atmospheric CO_2 increases and certainly they comprise a large proportion of the problem. But we cannot blithely ignore the contribution of mechanized row-crop agriculture in which tons of carbon, once fossilized in the deep black soils of the nation's arable land, are "burning" off every year, which means that commodity-scale row-crop agriculture is a major contributor to air pollution.

I do not know what the proportion of the world's "green house gasses" are emitted by row crop agriculture, but I suspect that it is progressively less than in times past, at least in North America. We have been extremely efficient in destroying the tilth of our soils over the last century. Many of North America's original soils had 10-30% organic matter at the beginning of European settlement, and in most areas near all of this has "burned" down to 2% or less—even as more and more quantities of petroleum products are being oxidized.

Growing corn to produce ethanol exaggerates the already un-sustainable practice of row crop commodity agriculture. Not withstanding the lack of energy efficiencies that relate to the fossil fuel burning machines necessary to till, plant, herbicide, harvest, store, and transport corn to a distillery, then process, and transport the ethanol to the filling station, the 2.5 million acres that came out of CRP in 2008, alone, released ten years worth of SOC accrual, or about 125 million tons of organic carbon, oxidized and lost to the atmosphere. Side effects, such as renewed soil loss and downstream flooding do not seem to be on anybody's radar screen. Long-term interest in our nation's economic sustainability and food supply also appear to be a casualty of short-sighted, economic boondoggles.

The **burning of natural gas,** while relatively clean, still converts carbon-hydrogen molecules fixed in another era to CO_2 molecules in excess of those in the contemporary atmosphere. It is a short-term alternative to be considered but its use must not relieve policy makers of the concern over atmospheric CO_2 level increases.

The idea that **man's activities cannot influence world climate** is risible when one takes a look at the breadth, range, and effect of our landscape-level activities.

Convenient as it is to point to **natural cycles**, whatever "cycles" have occurred in the past have not occurred in the context of global mining operations and rapid cultural changes in the time frames and scales the have been visited upon the earth in this era.

No amount of denial, "happy talk," and half-baked science can get around basic physical laws. While the arithmetic values and examples drawn above are necessarily simplified, it is clear that casual attention to the consequences of our behavior does not diminish the realities of the global carbon cycle. The politics, demagoguery, and ignorance that cloud most important subjects in the North American dialectic may be beneficial to a few in the short term, but attempting to flimflam nature is another issue. Adjusting models, rates, and theories does not relieve the need to be attentive to reality and learn to connect the dots.

What all these issues have in common is that practitioners today, more than any time in the history of scholarship, focus on singular aspects of the problem with progressively more narrow training. While it probably is not a serious trend in an of itself, it is one that makes it all the more important to develop genuinely more collaborative approaches to understanding ecological and economic phenomena. I believe René Descartes and Francis Bacon would approve. I dare not speak for Plato; he make think we have gone too far.

To whatever degree we are embarked upon unsustainable approaches to energy, or any other aspect of economy, we should, in an organized but determined way, seek to understand and develop sounder approaches, so that our economy and well-being will prosper for all in the long-term. The alternative to disciplined thinking and attention to the realities is that the earth itself will terminate any unsustainable behaviors in its own way, which is likely to be "insensitive," if not Draconian, to all parties, guilty and innocent. Even the purveyors of spurious solutions have children and grandchildren for whom it is hoped they care more than for their product of the moment.

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