Carbon Sequestration Techniques: Mitigating Climate Change

Scientific data gathered over the last few decades has indubitably proven the injurious effects that increased carbon emissions to our atmosphere have had on our environment. This exacerbated condition has put a pejorative spin on a previously neutral scientific process known as the greenhouse effect. In short, greenhouse gases, such as carbon dioxide (CO2), trap solar radiation within Earth’s atmosphere to ensure that the climate is regulated and maintains a temperature necessary for life to survive and flourish. However, the problem arises when these greenhouse gases increase in quantity unchecked and allow for less radiation to dissipate, thereby increasing the global temperature in a phenomenon dubbed global warming. The concentration of CO2 in our atmosphere has increased by 31% since 1750 and with rapid global industrialization as the current economic paradigm that number will unequivocally increase sharply over the following centuries (Lal, 2004). It is therefore imperative that we seek out ways to mitigate global climate change by sequestering carbon from the atmosphere and returning it to other carbon pools on Earth where it will be of no harm to the environment or humans and other life forms. Various techniques exist and are being explored to sequester carbon from the atmosphere including the use of forests, soil, and underground storage.

Fixing the problem begins with understanding the differing areas that carbon is stored on our planet. There are five major carbon pools on Earth that house the total amount of existing carbon. In order of increasing storage capacity, the carbon pools are as follows: biotic (560 Gt), atmospheric (760 Gt), soil (2,500 Gt), geologic (5,000 Gt), and oceanic (38,000 Gt) (Lal, 2004). The geologic pool consists of 4,000 Gt of coal and 500 Gt each of oil and gas (Lal, 2004). Similarly, the soil pool is compromised of differing components in the form of soil organic carbon (SOC) and soil inorganic carbon (SIC) (Lal, 2004). SOC is the larger constituent at 1,500 Gt and SIC makes up the remaining 1,000 Gt of carbon found in soil (Baker, Ochsner, Venterea, & Griffis, 2006).

The two biggest culprits responsible for the drastic increase in carbon emissions over the last two and a half centuries have been the combustion of fossil fuels and the changing use of land. The mining and subsequent combustion of fossil fuels has been a greater burden to the Earth’s atmosphere and is responsible for 2/3 of the increasing atmospheric carbon levels, whereas land use changes such as deforestation, biomass burning, the conversion from natural to agricultural ecosystems, the drainage of wetlands, and soil cultivation are responsible for the other 1/3 of change (Lal, 2004). These causes for CO2 emissions are known in the scientific community as sources, which can be both anthropogenic, meaning pollutants caused by human activity, or natural (Lal, 2004). Conversely, anything that serves to remove CO2 from the atmosphere is known as a sink (Lal, 2004). If we are to reverse the deleterious effects our meddling with natural systems has caused we need to learn more about these carbon sinks and how we can utilize them to return carbon to the Earth.

One way of sequestering carbon that has many noted benefits is soil sequestration. The transition from a natural system to an agricultural system has depleted the soil of about 30-50% of its SOC through the commonplace farming practices of plowing and tilling (Baker et. al., 2006). In certain biomes the rates of SOC loss are even higher and are estimated to be as much as 60% in soils of temperate regions and 75% or more in soils of the tropics (Lal, 2004). Because of these losses the current attainable soil carbon sink is only 50-66% of its potential capacity without human interference (Lal, 2004). If we are to utilize soil sequestration as a method of removing carbon emissions from the atmosphere, we need to restore the sinking ability of soil to its fullest potential. This begs the question: how do we return the lost carbon to the soil and begin to increase the soil carbon pool?

There are numerous documented ways of reversing the effects of soil cultivation and thereby increasing the soil carbon pool. These include but are not limited to soil restoration, woodland regeneration, nutrient cycling through composting and manure fertilization, and conservation tillage or no-till farming (Lal, 2004). Conservation tillage, which in its broadest definition includes any tillage method that leaves sufficient crop residue in place to cover at least 30% of soil surface after planting, is estimated by researchers to have the potential to sequester 0.5 t CO2 acre-1 year-1 (Baker et. al., 2006). If farmers practiced conservation tillage globally, projections estimate that 25 Gt C could be sequestered over a period of 50 years (Baker et. al., 2006). The extreme version of conservation tillage, no-till farming, could have even greater and more far-reaching effects. In this case, soil is left undisturbed from planting to harvesting and in addition to sequestering carbon it would protect the soil from erosion and decrease both production costs and fossil fuel consumption (Baker et. al., 2006).

However, findings on the benefits of conservation tillage are limited due to shallow soil sampling, which could be the main cause of these findings. In order to verify the aforementioned findings and further validate the practice, deeper soil sampling must be conducted. The significant losses in SOC could alternatively be explained by the transition of lands from perennial grasses to annual crops (Baker et. al., 2006). The SOC levels measured 2 m below the surface of perennial vegetation proved to be larger than those bellows the annual vegetation (Baker et. al., 2006). Further investigation into the primary causes of SOC depletion and the efficiency of conservation tillage in sequestering carbon must occur before any concrete conclusions are reached. Although this method of soil sequestration requires further research, the benefits of soil sequestration in general are proven and extend beyond reducing the amount of atmospheric CO2. Soil sequestration has also been shown to enhances biomass production, purify surface and ground waters, and restore degraded soil quality (Lal, 2004). These benefits alone give merit to the importance of soil sequestration and should prompt continued exploration.

Plants are an obvious source of carbon sequestration as they depend on the use of CO2 to photosynthesize. The larger the plant the more CO2 they require for conversion into sugar and thus the better they are at sequestering carbon from the atmosphere. Therefore, trees could hold the key to mitigating the climate impact of atmospheric CO2. American urban forests sequester approximately $500 million worth of carbon and purify the air of other toxins that would cost another $4 billion to clean up with alternative ways (Robbins, 2012). Because forests are excellent carbon sinks, afforestation, or the conversion of land into forests, has become a popular method of sequestering carbon. However, there are tradeoffs that occur when lands are transitioned into forests and despite the recognized benefits of forests as carbon sinks these downsides must be considered when the cost-benefit analysis is made.

The conversion of lands into forests has impacts on runoff and groundwater recharge because they are more exacting on the water supplies of the area. Research shows that in various types of environments including grasslands, shrublands, and croplands, afforestation decreased stream flow by an average of 38% (Jackson, Jobbagy, Avissar, et. al., 2005). Additionally, forests increase demands on soil nutrients and cause increases in the salinity, sodicity, and acidity of soil (Jackson et. al., 2005). In 29 of the 36 areas studied by researchers, the exchangeable sodium percentage (ESP) increased, and in four of the cases it crosses the threshold of 15%, at which point the soil begins to degrade (Jackson et. al., 2005). These findings reveal that afforestation can have negative impacts on their immediate environment, despite maximizing carbon sequestration. This does not mean that afforestation is not a sound method of sequestering carbon, but it is indicative that further research and analysis must be done to make sure that the benefits outweigh the costs associated with this transition.

Despite the proven benefits of biomass sequestration, there are researchers that argue that this form of sequestration is of less importance because of their typically low storage time and small capacity. One such scholar is geophysicist and Columbia professor Klaus Lackner who calls biomass sequestration “irrelevant” and “marginal” (2003). Lackner asserts that sequestration storage should be at the minimum centuries long which would give the atmosphere adequate time to restore itself and humans enough time to develop renewable energy solutions before the carbon is reemitted into the atmosphere (2003). His proposed solution is the use of underground injection, which has the capacity for sequestration on a much larger scale. The underground storage of carbon involves its injection through wells into rock reservoirs seated deep in the Earth’s crust where the CO2 would permeate the porous reservoir rock and displace the residual oil or gas, thus forcing it to the surface (Holloway, 2005). The economic gains of this left over oil or gas would offset the costs of sequestration, thus making it an economically sound method of sequestering carbon.

Underground injection is already being practiced around the globe in the form of enhanced oil recovery, or E.O.R. In the process of E.O.R., CO2 is pumped into depleted oil fields to extract the remaining oil trapped in rock pores and crevices (Holloway, 2005). Once the remaining oil has been completely mined, the wells are closed off and the CO2 remains trapped in the areas once filled by the oil (Holloway, 2005). Because CO2 fields are naturally occurring, scientists know that under the right conditions CO2 can be stored underground for long bouts of time (Holloway, 2005). Some of the best places to capture CO2 for transportation to these sites include at power plants, cement plants, and oil and gas refineries. Once these initial reservoirs are filled to capacity, the use of saline aquifers for storage can be used, as long as the sites have been thoroughly investigated and their integrity assured (Lackner, 2003). Carbon storage in saline aquifers has already been tested underneath the North Sea and confirmed as a viable option for geological sequestration (Lackner, 2003).

The dynamic change our climate is undergoing no doubt demands both our attention and immediate action. Our environment provides us with all the necessary resources we need to survive and we must treat it with great reverence and stewardship. This call for action necessitates both a change in the pernicious behavior we have exerted over the last couple centuries and advancements in energy technologies and methods of carbon sequestration. Lackner puts forth three conditions that must form the foundation for our endeavor of sequestering carbon: it must be safe, environmentally acceptable, and stable (2003). Lackner also states that we must first put our efforts into using available technology to sequester carbon from the atmosphere before we make the transition to renewable, sustainable energy sources that are carbon neutral, so that we have sufficient time to develop these technologies (2003). For the Earth’s atmosphere to achieve equilibrium would require emissions to be cut by 60% (Holloway, 2005). Even if we immediately stopped using fossil fuels tomorrow, this would only result in a 30% decrease, so sequestration technology is just as critical as renewable energy research (Holloway, 2005). This highly revealing fact is indicative of the importance and attention that carbon sequestration must be given within the scientific community and society at large. If we are to reverse the harmful effects of our modern society on the environment, we must give precedence to research on carbon sequestration.

References

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