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Carbon Sequestration and Climate Smart Agriculture

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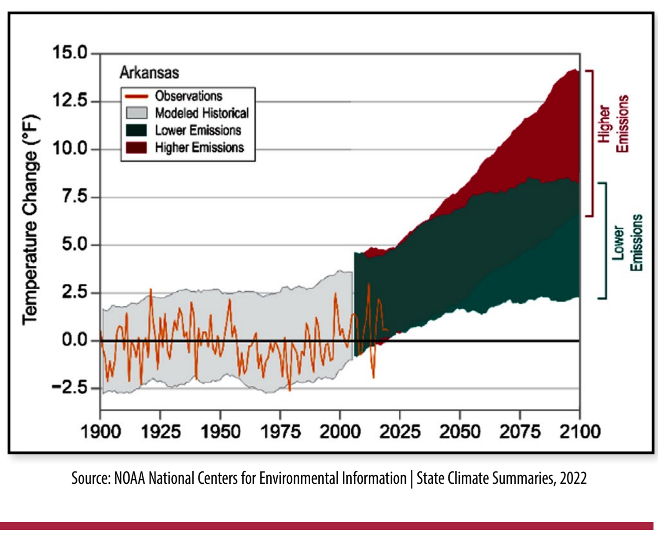
Introduction

For decades events such as the burning of fossil fuels, increased vehicle emissions, reduction in forests, natural emissions (volcanic), and unsustainable farming practices have caused a dramatic increase in the amount of carbon dioxide (CO_2) in the atmosphere. Increases in atmospheric CO_2 cause the planet and atmosphere to become warmer due to the "greenhouse effect". As the atmosphere becomes warmer, the air can hold more water which can lead to more frequent droughts followed by large and intense precipitation events. Overall, increased CO_2 will most likely increase extreme weather events, both drought and intense rainfall.

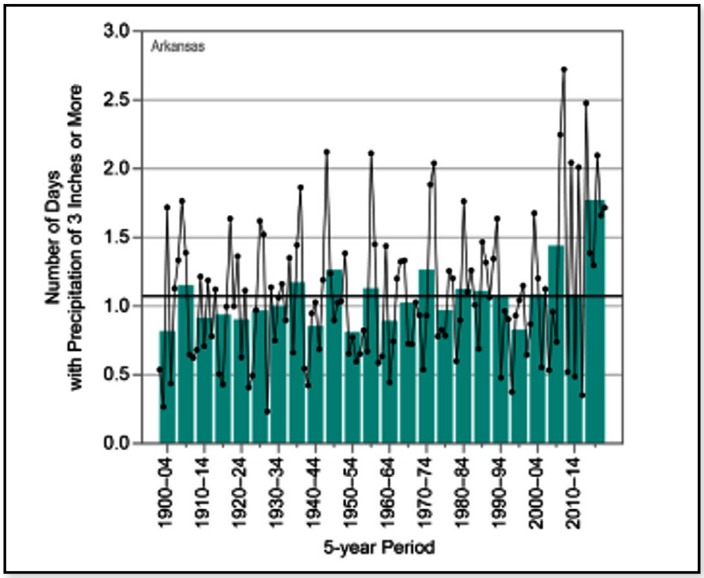
For example, temperatures in Arkansas have risen by 0.5°F since the beginning of the 20th century, with 2015-2019 being the warmest consecutive five-year interval (Figure 1; NOAA 2022). Additionally, the most recent five-year period (2015–2020) had the highest multiyear average precipitation and averaged 1.8 days per year of 3+ inch precipitation compared (Figure 2) to the long-term average of 1.1 days (Figure 3); with 2008, 2009, 2015, and 2018 being the four highest years on record (NOAA 2022). Both annual and summer precipitation patterns can also be highly variable, which is a key characteristic of Arkansas' precipitation climatology. Severe drought episodes during 2005–2007 and 2010–2012 were interrupted by the wettest year on record (2009) and followed by the fifth wettest (2015).

Figure 1. Observed and Projected Temperature Change in Arkansas: Observed and Projected Changes (Compared to the 1901–1960 Average) in Near-surface Air Temperature for Arkansas. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions).



Source: NOAA National Centers for Environmental Information | State Climate Summaries, 2022

Figure 2. Observed Annual Number of 3-inch Extreme Precipitation Events (Days with Precipitation of 3 inches or more) for Arkansas from 1900 to 2020.
Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 1.1 days.



Source: NOAA National Centers for Environmental Information | State Climate Summaries, 2022

The frequency and intensity of extreme heat and extreme precipitation events in Arkansas are projected to increase while the intensity of extreme cold events is projected to decrease (Magugu et al. 2018). For example, there has been a 53% increase in the number of extreme rainfall days (>6 in d^{-1}) and a significant decrease in the number of moderate intensity (0.4 – 1in d^{-1}) and heavy (1 –2.75 in d^{-1}) rainfall days in the Southeastern U.S. from 1985-2014 (Dourte et al. 2015).

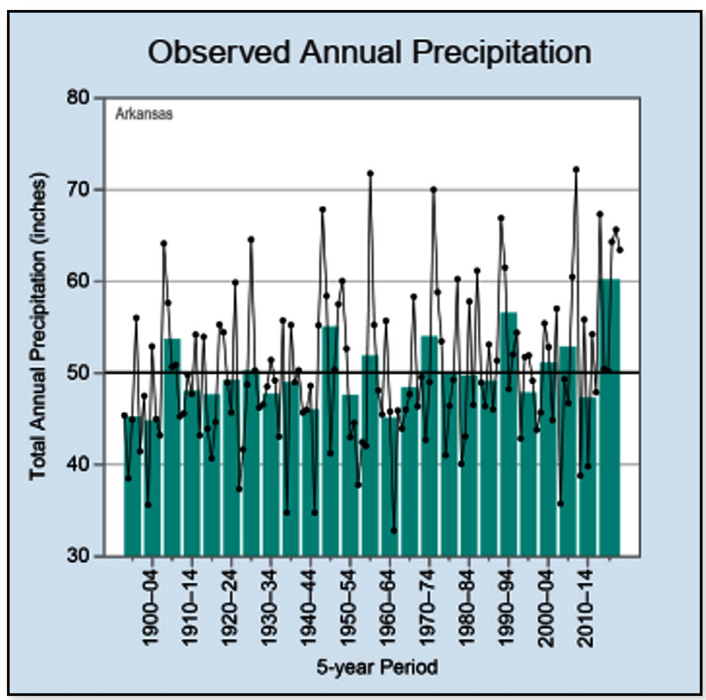
This is of particular concern in Arkansas, as these precipitation extremes can generate large runoff volumes in Arkansas' agricultural landscapes, particularly given the somewhat poorly drained soils of the Mississippi Alluvial Plains in eastern Arkansas. A recent study conducted by the University of Arkansas Division of Agriculture (UADA) found that edge-of-field runoff events >1 inch comprised 25% of the runoff events, although they represented an average of 47% of total annual runoff volume (range = 35-62%), highlighting the disproportionate effect of intense precipitation events.

Implications for Arkansas Farmers

Climate change can impact agriculture in two ways. First, cycles of extreme drought followed by intense high-volume precipitation events that produce flooding can affect planting and harvest windows. These weather patterns can also cause erosion rates to increase, leaving fields susceptible to nutrient and sediment loss through runoff as well as waterway pollution. It can also affect crop production by increasing irrigation demand among other things. Secondly, agriculture can be a solution to climate change as farming practices can be tweaked to increase carbon storage in soils. The practices that increase carbon (C) storage are known as climate smart agriculture and include implementing cover crops, reducing tillage, promoting soil health, reducing runoff, crop rotation, nutrient management, and changes in irrigation water management. The federal government has invested nearly $3 billion through the Partnership for Climate-Smart Commodities (https://www.usda.gov/climate-solutions/climate-smart-commodities) to help farmers implement climate smart practices. Financial incentives will be paid directly to farmers from grants received by private agricultural industries, non-government organizations and Universities. Check the website listed above to find sponsors for financial incentives in your area.

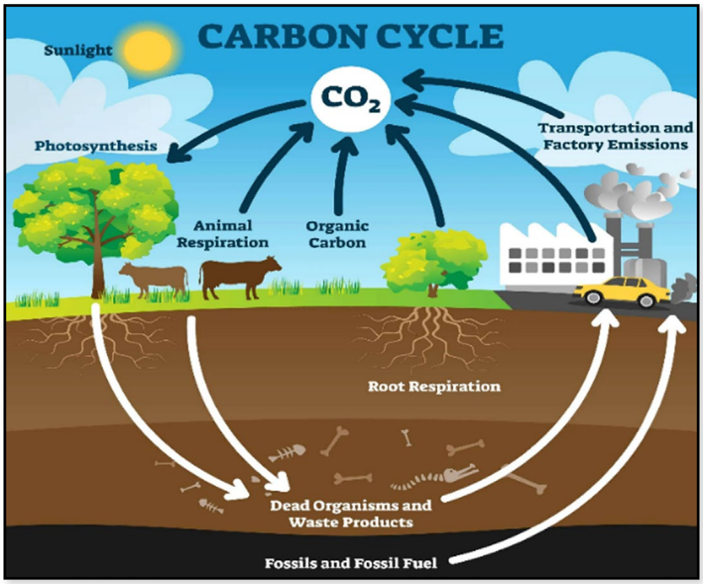
Other market-based incentives are emerging such as carbon markets that could also provide

Figure 3. Total Annual Precipitation, 1895 to 2020.
Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black lines show the long-term (entire period) average of 50.1 inches. Source: NOAA National Centers for Environmental Information | State Climate Summaries, 2022.



Source: NOAA National Centers for Environmental Information | State Climate Summaries, 2022

Figure 4: Illustration of the Carbon Cycle.



Source: GCSE General Certificate of Secondary Education, Shalom Education, 2023

economic incentive for climate smart practices. Before entering a carbon market contract, contact an attorney to review the contract as they may be highly variable and require considerable documentation of implementation.

This fact sheet is intended to provide the science on the relationship of carbon storage in soil (sequestration), agricultural practices and its impact on the climate.

The Carbon Cycle

Carbon is a foundation of all life on Earth. All organic matter contains carbon, and all plant and animal cells consist of carbon compounds. The carbon cycle is a process by which carbon is moved between plants, animals, microbes, minerals, and the atmosphere (Fig.1). Plants remove large quantities of CO_2 from the atmosphere through photosynthesis, thus a substantial fraction of the carbon on Earth is stored in plant material, such as in standing biomass in forests. Decomposing organic matter contributes carbon to the soil, which represents another major pool of carbon on Earth, and releases CO_2 back to the atmosphere through respiration. Oceans also absorb large quantities of CO_2.

Much of the carbon on Earth is stored in rocks, minerals, fossils, and soil. Therefore, when we break up the rocks, minerals, and soil and burn fossil fuels, we are releasing CO_2 into the atmosphere. One significant and often overlooked source of CO_2 in the atmosphere is mineralization of soil organic matter due to soil degradation. Intensive tillage and conversion of prairies and forests into arable farmland results in huge releases of sequestered carbon that contribute to atmospheric CO_2 levels. While it is unavoidable for the atmosphere to contain CO_2, we now understand that certain human activities, such as burning fossil fuels and soil degradation, have accelerated CO_2 release and increased the CO_2 concentration in the atmosphere. The major issue with increasing atmospheric CO_2 concentrations is that CO_2 is one of several greenhouse gases (GHG) that traps and prevents heat from leaving Earth, leading to the greenhouse effect. Carbon dioxide is a vital component of how Earth can have a climate that sustains life. However, too much or too little CO_2 can be disastrous.

How is CO_2 Affecting Us?

The average annual global air temperature has risen over 1° F since the start of global climate records in 1880 (NOAA, 2023). While this change may seem negligible, it is important to keep in mind that this rise in global annual air temperatures matches with many periods throughout the year that are extremely hot, (defined as at least 2 to 3 consecutive days above 90° F). Extreme heat during the growing season leads to weather trends that make it difficult to grow crops, which we have already experienced in the past few decades in many locations.

During seasonal air temperature trends, we experience long periods of drought with extreme heat, which can have negative impacts on crops. Rice is negatively impacted by high nighttime air temperatures that accompany long periods of extreme heat. This impact is seen at the rice mill after harvest where milling yields are determined. Studies have shown that rice processing quality (milling yield) is typically greater in cooler years and lower in warmer years, which has been directly linked to higher nighttime air temperatures (Miller, 2015). When rainfall events occur after several days or weeks of extreme heat, they tend to be excessive and have the potential to drown out crops instead of having a positive impact on their growth, especially if the excessive rainfall occurs early in the growing season. Extreme weather events may deliver several inches of rain onto fields in a short amount of time, leaving more water standing on the field than can infiltrate the soil or drain off the field. Subsequently, when the soil is water-logged, plant roots are not able to absorb enough oxygen, and crops die. Thus, producers are having to irrigate heavily during droughts and get little benefit when rain does come in extreme events. The extreme heat waves also make it unsafe to work outdoors for extended periods of time.

Carbon Sequestration

At this time, the damage that has been done to the atmosphere over decades of human accelerated GHG emissions cannot be undone, and we are now experiencing the consequences of those actions. We can, however, start to reduce what is being emitted now and into the future so that the greenhouse effect and global warming do not get worse. One way to minimize CO_2 emissions is to implement agricultural practices that are known to promote soil carbon sequestration. Soil carbon sequestration refers to the long-term storage of microorganism-processed organic carbon in a relatively stable form in the soil. In general, much of our soil is a natural long-term reservoir for carbon (i.e. a "carbon sink"). In other words, reversing the years of land degradation through effective carbon sequestration in the soil is a measure to help mitigate current CO_2 levels and their impact on climate. However, intensive tillage breaks up the soil, stimulates organic matter decomposition, and causes carbon releases as CO_2 via microbial respiration into the air. In addition, tractors that pull agricultural tillage implements use gasoline and diesel and burn oil which emit even more CO_2 into the atmosphere. As the atmosphere needs some concentration of CO_2 and other GHGs to trap heat and keep the planet habitable, an imbalance in atmospheric CO_2 and what can be taken out of the air through plants and stored in the soil, and/or the oceans is globally disruptive. Presently, atmospheric CO_2 emissions far exceed what is removed from the atmosphere through natural processes.

Climate Smart Practices

Current conventional tillage methods that are commonly used in production systems across Arkansas and the rest of the southeastern United States do little to promote soil carbon sequestration. Implementing practices such as reduced tillage, conservation tillage, or no-tillage and cover cropping, independently or in combination, can improve soil health which can lead to increased soil carbon sequestration.

Reduced tillage decreases the number of passes with a tillage implement and reduces carbon emissions from burning fossil fuels.

Conservation tillage uses less soil-disturbing tillage practices to maintain $\geq 30\%$ residue coverage on the soil surface. When using a no-tillage system, the soil is not disturbed at all, except for potential compaction from the weight of field implements, and maintains soil structure and soil aggregation that protects soil organic matter from microbial decomposition and CO_2 release. Reducing tillage frequency and intensity also decreases the rate of breakdown of plant roots. Cover cropping helps to maintain living plant roots in the soil year-round, which helps sustain resilient microbial communities, atmospheric CO_2 capture through photosynthesis, and provides additional surface residues. Growing high biomass cover crops with high carbon to nitrogen ratios can help increase carbon sequestration in the soil. These high carbon to nitrogen

Figure 5: Cover Crop Emerging Between Harvested Corn Helps Keeping Living Roots in the Ground Between Cash Crop Growing Seasons.

Source: NPR, 2017

ratio residues are more resistant to microbial decomposition and increase soil organic matter, especially when no-tillage or reduced tillage practices are also implemented.

Cover crops are versatile in that different cover crops can be mixed and planted in the same field, allowing several different species to uniquely benefit soil health and contribute to soil carbon storage.

Recommendations

Agriculture is continuously adapting to the climate and changing weather patterns to address profitability and promote sustainable production. While agriculture feeds the world, it is now being asked to help combat climate change by voluntarily implementing climate smart agriculture to better sequester carbon in soils and remove CO_2 from the atmosphere. The implementation of many climate-smart agriculture practices can incur an increased cost to the producer. These practices often cause delayed returns on investments as it takes natural systems substantial time, often years, to provide benefits that increase profitability. These delays in increased efficiency or reductions in inputs often hamper the widespread adoption of climate smart practices. However, the United States via the USDA's Partnership for Climate-Smart Commodities has invested nearly $3 billion dollars to 1) provide financial incentives for adoption of such practices, 2) monitoring reduction of greenhouse gas emissions and 3) developing markets that will pay premium prices for climate smart commodities. To locate a provider of these incentives, please refer to the Partnership for Climate-Smart Commodities website: https://www.usda.gov/climate-solutions/climate-smart-commodities.

For assistance in implementing climate smart farming practices, please contact your local county Extension office.

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