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Agricultural Productivity in The Age of Rising Greenhouse Gas Emissions

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Abstract

Agriculture, which sustains about 58% of India's population, is critically reliant on weather and climate to produce essential food, fiber and other necessities. It contributes 29% to the GDP of developing countries, but climate change poses significant challenges. Variations in rainfall, temperature fluctuations, and extreme weather events impact soil erosion, pest and disease dynamics, and crop quality. Crop yields are closely tied to temperature changes and weather extremes. Variations in rainfall patterns increase water scarcity and drought issues, complicating irrigation planning and reducing rainfall predictability for farmers. Agriculture emits several greenhouse gases (GHGs), such as carbon dioxide, methane, and nitrous oxide, which significantly affect the climate. Carbon dioxide contributes 11%, methane 14%, and nitrous oxide 6% to agricultural emissions. Reducing these emissions can mitigate climate impacts on agriculture. Effective strategies include genetically modifying rice to reduce methane emissions by 50%, applying biochar to improve soil fertility and reduce methane emissions over four years, and using mulching to control water loss, weeds, and nitrous oxide emissions. Biochar, a nutrient-rich charcoal from organic materials, enhances soil's physical, biological, and chemical properties. These mitigation measures can lower GHG emissions and support sustainable agricultural practices, ultimately reducing the adverse effects of climate change on agriculture.

Introduction

Greenhouse gases play a significant role in climate change and global warming. Continuous release of GHGs from various sectors has caused the Earth's surface temperature to rise steadily over the past 50 years. Agriculture contributes significantly to GHG emissions, with key gases being carbon dioxide, methane, and nitrous oxide. These gases respectively account for 11%, 14%, and 6% of agricultural emissions. Global warming refers to the gradual increase in the Earth's average atmospheric temperature. The atmosphere is absorbing more heat energy from the sun and preventing it from radiating back into space. However, it is important to note that without the greenhouse effect, our atmosphere would be much colder, with an average temperature of -18°C.

Causes of Global Warming:

1. **Natural Causes:** Natural causes of global warming include variations in solar radiation, volcanic activity, and changes in the Earth's orbit (Milankovitch cycles). Ocean currents, such as El Niño and La Niña, can redistribute heat, affecting global temperatures. Natural greenhouse gas emissions from sources like wetlands and geological activity also contribute. Changes in the Earth's albedo due to ice ages and interglacial periods influence climate patterns. Lastly, water vapor feedback, where increased temperatures lead to higher atmospheric water vapor levels, amplifies warming through a positive feedback loop.
2. **Anthropogenic Causes**: Anthropogenic causes of global warming include the burning of fossil fuels for energy and transportation, which releases significant amounts of carbon dioxide. Deforestation reduces CO_2 absorption by trees. Industrial processes emit various greenhouse gases. Agriculture contributes methane from livestock and nitrous oxide from fertilizers. Waste management practices, such as landfills, produce methane. Urbanization and land use changes increase surface temperatures and alter local climates through the heat island effect.

Table: 1: Causes of GHG'S (Anthropogenic sources)

Greenhouse gases	How it's produce	Average lifetime in atmosphere	100-year global warming potential
CO_2	Burning of fossil fuels (oil, natural gas, and coal), solid waste, and trees and wood products. Changes in land use also play a role. Deforestation and soil degradation add carbon dioxide	Variable	1

CH_4	Emitted during the production and transport of oil and natural gas as well as coal, Livestock and agricultural practices (rice cultivation)and from the anaerobic decay of organic waste in municipal solid waste landfills	12.4 years	28-36
N2O	Emitted during agricultural (Nitrogenous fertilizer application) and Industrial activities, as well as during combustion of fossil fuels and solid waste	121 years	265-298
Fluorinated gases CFCS	Industrial processes and commercial household uses and do not occur naturally	A few weeks to thousands of years	Varies

Scientific Evidences of Global Warming:

- The concentration of CO2 is now 46% higher than pre-industrial levels.
- In 2020, the global CO2 concentration in the atmosphere was approximately 412.5 ppm.
- By 2021, global CO2 emissions reached 400 MT, increasing the concentration by 1.2% to 417.5 ppm (Global energy-related CO2 emissions, 1990-2021).
- Atmospheric methane levels in 2021 averaged 1,895.7 ppb, about 162% higher than pre-industrial levels (National Oceanic and Atmospheric Administration, April 7, 2022).
- Nitrous oxide concentrations are around 333.2 ppb, which is 123% higher compared to levels in the 1980s. (Greenhouse Gas Bulletin: Another Year Another Record, October 25,2021)

Impact of global warming on Agricultural resources:

1. **Change in mean climate:** The long-term mean climate state significantly influences agriculture and farming practices in any location. The infrastructure and expertise of local farming communities are typically tailored to specific farming methods and crop varieties that thrive under the current climate. Higher temperatures can be particularly harmful in regions already near the physiological limits for crops, such as seasonally arid and tropical areas, increasing heat stress on crops and water loss through evaporation. In mid-latitudes,

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a 2°C local warming might boost wheat production by over 10%, whereas the same level of warming in low latitudes could reduce yields by almost the same percentage. Different crops have varying sensitivity to warming. It's important to note the significant uncertainty in agricultural yield changes for a specific level of warming. By analyzing statistical relationships between growing season temperature, precipitation, and global average yield for six major crops, it has been estimated that warming since 1981 has led to annual combined losses of 40 million tons, with negative impacts observed in wheat, maize, and barley (Lobell and Field, 2007).

2. **Extreme Temperatures:** Short-term temperature variations can be particularly harmful if they occur during critical developmental stages of crops. For example, a few days of extremely high temperatures (over 32°C) during the flowering stage of wheat can significantly reduce yield (Wheeler *et al.*, 2000). Brief warming episodes around anthesis at critical temperatures of 35°C also have a substantial negative impact on yield. However, high temperatures during the vegetative stage do not significantly affect growth and development. Groundnuts grown in semiarid regions regularly face temperatures of 40°C, but exposure to temperatures above 42°C after flowering can drastically reduce yields (Vara Prasad *et al.*, 2003). Maize experiences reduced pollen viability at temperatures above 36°C. Rice grain sterility occurs at temperatures in the mid-30s, and similar temperatures can reverse the vernalizing effects of cold temperatures in wheat. In the United States, temperatures above 29°C for corn, 30°C for soybeans, and 32°C for cotton negatively impact yields.
3. **Heavy Rainfall and water logging:** Heavy rainfall and water logging due to it ultimately result in poor growth of the crop and finally yield loss. Proline is a stress hormone which is formed during the stress conditions affected by plant. Dissociation of the polyribosomes as well as the protein forming amino acid takes place due to increase in duration of waterlogging. Similarly, the chlorophyll content got decrease in the same manner due to poor stomatal conductance as well as poor net photosynthesis. Due to this reduction of all the growth and physiological parameters due to waterlogging, ultimately the numbers of seeds as well as the seed yield get decreased.
4. **Water Availability:** Changes in precipitation patterns can lead to water scarcity or excess, both of which can harm crops. Increased evaporation rates due to higher temperatures

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exacerbate water loss. Regions already prone to drought may face more severe and prolonged dry periods, while areas susceptible to heavy rains may experience more frequent flooding.

5. **Soil Health:** Increased temperatures and changes in precipitation can accelerate soil degradation, reducing soil fertility and structure. High CO_2 levels can affect soil microbial communities and nutrient cycling, potentially altering soil health and crop growth.
6. **Pest and Disease Dynamics:** Warmer temperatures and changing climate conditions can expand the range and life cycles of pests and diseases, posing new threats to crops. Insects and pathogens that thrive in warmer conditions may become more prevalent, increasing the need for pest and disease management.
7. **Crop Quality:** Global warming can affect the nutritional quality of crops. Higher CO2 levels can lead to lower concentrations of essential nutrients such as proteins, vitamins, and minerals in some crops. Changes in growing conditions can also impact the taste, texture, and shelf life of agricultural produce.
8. **Sea Level Rise**: Coastal agricultural areas may face increased salinity and flooding due to rising sea levels, leading to loss of arable land and reduced crop productivity. Saline intrusion into freshwater sources can further compromise water availability for irrigation.
9. **Economic Impacts:** Reduced crop yields and quality can lead to economic losses for farmers and higher food prices for consumers. Adaptation measures, such as investing in irrigation systems, pest control, and resilient crop varieties, may require significant financial resources.

Mitigating these impacts requires combination of adaptation strategies and sustainable agricultural practices to enhance resilience and food security in the face of global warming.

Agro-Techniques to Mitigate Global Greenhouse Gas Emissions

Reducing greenhouse gas (GHG) emissions from agriculture is crucial for mitigating climate change. Here are some effective agro-techniques to achieve this:

1. **Conservation Tillage:** Minimizing soil disturbance through no-till or reduced-till practices helps sequester carbon in the soil and reduce CO2 emissions. Conservation tillage also improves soil structure, water retention, and biodiversity.
2. **Cover Cropping:** Planting cover crops during fallow periods reduces soil erosion, enhances soil organic matter, and sequesters carbon. Cover crops also suppress weeds, improve soil fertility, and reduce the need for chemical inputs.

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3. **Efficient Irrigation Systems:** Implementing drip or sprinkler irrigation systems reduces water use and energy consumption compared to traditional flood irrigation. Efficient irrigation minimizes CH_4 emissions from waterlogged soils, particularly in rice paddies.
4. **Integrated Pest Management (IPM):** IPM combines biological, cultural, and mechanical control methods to reduce the reliance on chemical pesticides. Reducing pesticide use lowers the carbon footprint associated with their production and application.
5. **Agroforestry:** Integrating trees and shrubs into agricultural landscapes sequesters carbon, enhances biodiversity, and improves soil health. Agroforestry systems provide additional benefits such as shade, windbreaks, and diversified income sources for farmers.
6. **Optimized Fertilizer Use:** Using precision agriculture techniques to apply fertilizers more efficiently reduces nitrous oxide emissions from soils. Incorporating organic fertilizers and nitrification inhibitors can also reduce GHG emissions.
7. **Manure Management:** Implementing proper manure storage and handling practices, such as anaerobic digestion, reduces methane emissions. Using manure as a nutrient-rich fertilizer enhances soil health and reduces the need for synthetic fertilizers.
8. **Crop Rotation and Diversification:** Rotating crops and diversifying plant species enhance soil health, reduce pest and disease pressures, and improve carbon sequestration. Crop diversification can also increase resilience to climate variability.
9. **Biochar Application:** Applying biochar to soils sequesters carbon and improves soil fertility and water retention. Biochar production from agricultural residues provides a sustainable way to manage waste.
10. **Genetically Modified Crops:** Developing and using genetically modified crops that are more efficient in nutrient uptake and resistant to pests and diseases can reduce the need for chemical inputs and lower GHG emissions.
11. **Renewable Energy Integration:** Utilizing renewable energy sources, such as solar or wind power, for farm operations reduces reliance on fossil fuels. On-farm renewable energy systems, such as biogas from manure digesters, provide sustainable energy solutions.
12. **Rice Paddy Management:** Adopting alternate wetting and drying (AWD) irrigation techniques in rice paddies reduces methane emissions compared to continuous flooding. Using rice varieties genetically modified to lower methane emissions also contributes to GHG mitigation.

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Implementing these agro-techniques requires a holistic approach and support from policies, research, and extension services to ensure widespread adoption and effectiveness in mitigating GHG emissions from agriculture.

Conclusion:

Mitigating greenhouse gas emissions from agriculture is essential for combating climate change and ensuring sustainable food production. Agro-techniques such as conservation tillage, cover cropping, efficient irrigation, integrated pest management, agroforestry, optimized fertilizer use, and improved livestock management offer practical solutions to reduce emissions while enhancing soil health, biodiversity, and productivity. The integration of renewable energy and innovative practices like biochar application and genetically modified crops further contribute to emission reductions. Adopting these techniques requires a comprehensive approach involving policy support, research, and extension services to encourage widespread implementation. By embracing these strategies, the agricultural sector can play a pivotal role in mitigating climate change and securing a resilient and sustainable future for global food systems.

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