Greenhouse Gas Emissions in the Everglades: The Role of Hydrologic Conditions[1]

Alan L. Wright and K. R. Reddy[2]

Introduction

There is considerable attention being paid worldwide to global warming, and how to better understand factors contributing to greenhouse gas production. Global warming is defined as the rise in global temperatures, which have markedly increased since the industrial revolution in the late 1800s. It is the process by which absorption and emission of infrared radiation by atmospheric gases warm a planet's lower atmosphere and land surface. The mean atmospheric temperature has increased 1.3°F during the last century (Figure 1).

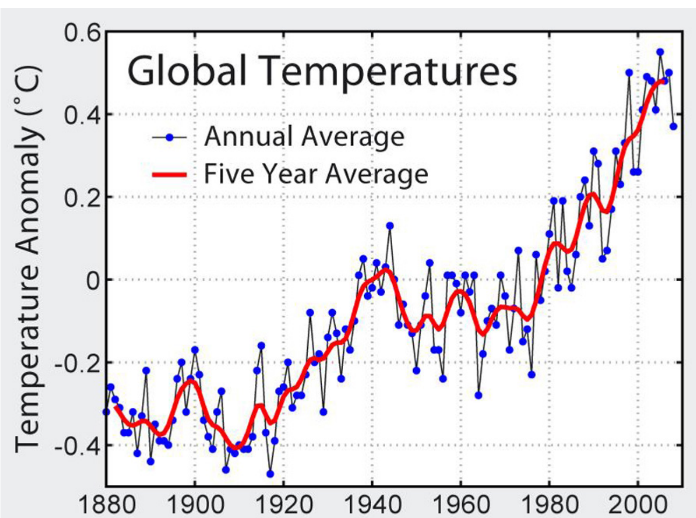

Figure 1. Changes in global temperatures since the industrial revolution.

The objective of this publication is to:

1. describe the relationship between global warming and increases in greenhouse gas emissions,
2. demonstrate the role of Everglades wetlands in the global carbon cycle and their contribution to greenhouse gas production,
3. demonstrate how hydrologic conditions and eutrophication in the Everglades influence the rates and types of greenhouse gases emitted.

Global Warming and Greenhouse Gases

The Intergovernmental Panel on Climate Change (IPCC) concluded that anthropogenic, or man-made, greenhouse gases are responsible for the majority of the temperature increases since industrialization. Climate model projections by the IPCC report conclude that global surface temperatures will likely rise by 2°F during the twenty-first century, indicating a need to alleviate factors contributing to global warming. One such mechanism is to reduce emissions of greenhouse gases to the atmosphere.

Human activities since the industrial revolution have increased concentrations of greenhouse gases in the atmosphere, including carbon dioxide (CO_2), methane

1. This document is SL288, one of a series of the Department of Soil and Water Sciences, UF/IFAS Extension. Original publication date April 2009. Reviewed February 2021. Visit the EDIS website at https://edis.ifas.ufl.edu.

2. Alan L. Wright, assistant professor, Department of Soil and Water Sciences, UF/IFAS Everglades Research and Education Center; and K. R. Reddy, professor, Department of Soil and Water Sciences; UF/IFAS Extension, Gainesville, FL 32611.

(CH_4), ozone, chlorofluorocarbons, and nitrous oxide (N_2O). Figure 2 illustrates the recent trend in global CO_2 concentrations in the atmosphere. The concentrations of the most prevalent greenhouse gases, CO_2 and CH_4, have increased by 36% and 148% since the mid-1700s. These concentrations are considerably higher than at any time during the last 650,000 years, based on data generated from analysis of ice cores from the Antarctic. Consumption of fossil fuels has produced approximately 3/4 of the atmospheric CO_2 increase over the past 20 years. The remainder of the CO_2 increase results from land use changes, such as deforestation and loss of wetlands.

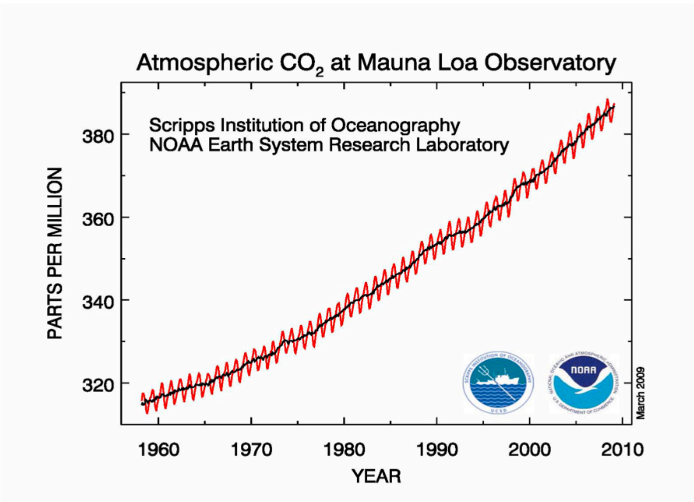

Figure 2. Recent changes in global atmospheric CO_2 concentrations.

Wetlands contribute a significant amount of greenhouse gases to the atmosphere through natural emissions or loss of peat upon land use change or drainage. Wetlands are typified by flooding for long periods of time which results in sequestration of carbon over time as peat consolidates. These soils are commonly referred to as Histosols. On a worldwide basis, wetlands are estimated to contain 33% of the world's soil carbon, even though they only occupy about 4% of the land surface (Gorham 1991; Eswaran et al. 1993). Wetlands are estimated to contain 771 billion tons of greenhouse gases, or 1/5 of all carbon on Earth, which is about the same amount of carbon contained in the atmosphere.

Historical accretion in peatlands typically ranges from 0.1–2 mm/yr, which equates to 6–166 grams $C/m^2/yr$ (Gorham 1991). Many land use changes across the world involve drainage of wetlands for agriculture, development, and other uses. Drainage of organic soils that have accumulated and stored carbon for hundreds or thousands of years can make them sources of greenhouse gases, primarily CO_2, to the atmosphere.

Carbon dioxide, CH_4, and N_2O gases are all emitted by wetlands through natural processes, such as the decomposition of organic matter in soils. Carbon dioxide is produced by both aerobic and anaerobic microbial processes and through root respiration, and it is the most common greenhouse gas emitted from soils. Methane is produced by anaerobic processes in flooded soils and contributes up to 25% of all global CH_4 emissions, including both natural and anthropogenic sources (Reddy and DeLaune 2008). Nitrous oxide is a product of denitrification, which is another mechanism of microbial decomposition of organic matter. Denitrification is the reduction of nitrate to N_2O by microorganisms occurring while they decompose organic matter. For denitrification to occur, and for N_2O to be produced, nitrate must be present in sufficient quantities.

Global Warming Potential

Different greenhouse gases reflect radiation back to the Earth differently, such that 1 unit of N_2O has a greater impact than 1 unit of CO_2. The international standard practice is to express greenhouse gases as CO_2 equivalents or global warming potential (GWP). Emissions of gases other than CO_2 are translated into CO_2 equivalents using global warming potentials. Because CH_4 dissipates more rapidly than CO_2, its lifetime in the atmosphere (12 years) is less than CO_2 and N_2O (100 years). The global warming potentials of the three major greenhouse gases are CO_2=1, CH_4=21, and N_2O=310.

Everglades Wetlands

Some parts of Everglades wetlands are impacted by nutrients (eutrophic), especially in areas near water-inflow points. The interior portions of these wetlands are often nutrient-poor (oligotrophic). Other wetlands in the Everglades are recently constructed, such as the stormwater treatment areas (STAs). Everglades wetlands exist under various hydrologic conditions ranging from seasonal to permanent flooding, and can have variable water coverage depending on weather patterns and surface water withdrawals for agricultural or municipal use.

The Everglades wetlands function to store carbon through accretion of dead biomass as long as organic matter deposition exceeds its decomposition rate. Under flooded conditions where water persists on the soil surface for long periods of time, decomposition of accreted organic matter is slower than its deposition, leading to accumulation of carbon. Even under these flooded conditions, CO_2, CH_4, and N_2O are still released because anaerobic microorganisms are active. During drought or when water is not stored in wetlands, the soils are exposed to the atmosphere, which facilitates high rates of aerobic decomposition which leads to loss of the stored carbon, primarily as CO_2. Burning of soils under drought conditions also leads to major losses of soil carbon as CO_2. Thus, hydrologic conditions have a major influence on the types of greenhouse gases emitted in wetlands.

Various environmental factors other than hydrologic conditions can influence the types and emission rates of greenhouse gasses in wetlands. Nutrient enrichment can have a major influence on gas emissions, and in fact can change the types of gases emitted. Since N_2O is an end product of denitrification, inputs of nitrate into wetlands can stimulate N_2O production at the expense of CH_4. And since N_2O has a much higher GWP than CH_4, eutrophication of the Everglades may result in a more significant GWP than the natural oligotrophic areas.

Carbon Dynamics and Eutrophication of the Everglades

Historic influx of drainage water from the Everglades Agricultural Area (EAA) has resulted in elevated nutrient levels in soils and the water column of the Water Conservation Areas (WCAs) and the Everglades National Park sites proximal to surface water inflow points. This enrichment has caused shifts in ecosystem structure and function, best demonstrated by the replacement of the native sawgrass slough communities with cattails. Subsequently, the role of these wetlands in carbon sequestration and greenhouse gas emissions has been altered as a result of eutrophication.

The carbon content of cattails in the Everglades averages 45% (Chimney and Pietro 2006; Qualls and Richardson 2008). Standing crops in the STAs contain about 1,500 grams of dry matter/m^2, which equates to an aboveground biomass of 600 grams C/m^2. In the oligotrophic Everglades wetlands, cattails are less prevalent and biomass is considerably less, typically about 500 grams dry matter/m^2 or 200 grams C/m^2. These standing biomass stocks represent a significant temporary carbon storage pool, but it is much lower than the carbon stocks of the peat soil. The top 10 cm of nutrient-impacted Everglades wetlands have a density of approximately 0.1 grams/cm^3, and therefore contain 10 kilograms dry matter/m^2 (Qualls and Richardson 2008).

The oligotrophic areas of WCA-2a are dominated by sawgrass having relatively low productivity. Oligotrophic soils accrete 87 grams C/m^2/yr, which is 15% of the 587 grams C/m^2/yr of CO_2 taken up by the wetland (Qualls and Richardson 2008). The impacted cattail zones accrete 212 grams C/m^2/yr, which is 20% of the 1059 grams C/m^2 of CO_2 taken up by the wetland each year (Qualls and Richardson 2008). Each of the wetland types sequesters carbon and has a net CO_2 uptake. But in each case, the production of CH_4 and N_2O, with their much higher GWP, causes Everglades wetlands to be net emitters of greenhouse gases. Those net emissions are estimated to exceed carbon storage by 50-700 grams C equivalents/m^2/yr.

The EAA is probably also a net contributor to greenhouse gas production, although through different mechanisms (Qualls and Richardson 2008). In contrast to wetlands, the primary mechanism for C loss from the EAA is subsidence, which is the loss of soil due to aerobic decomposition with CO_2 as the major greenhouse gas emitted. Approximately 3,300 grams C/m^2 are lost in the EAA to subsidence annually (Qualls and Richardson 2008). In recent years, conversion of agricultural land to wetlands or STAs has occurred for the purpose of treating runoff from agricultural fields. Thus, the use of STAs for water quality improvement of the Everglades is probably a net benefit for mitigation of greenhouse gases because STAs alleviate the subsidence of agricultural lands and convert them to peat-accreting wetlands. Also, implementation of best management practices by sugarcane and vegetable growers in the EAA has slowed the subsidence rate in recent years as a result of maintenance of high water tables, leading to decreased CO_2 emissions.

Greenhouse Gas Flux in the Everglades

Wetlands sequester organic carbon via the accretion of new sediments and soils. It is generally assumed that wetlands serve to store large amounts of carbon, thus land use changes leading to loss of wetland acreage could potentially add significant amounts of CO_2 and other greenhouse gases into the atmosphere. However, they also emit greenhouse gases, CO_2, CH_4 and N_2O. The large CO_2 equivalent multipliers for the radiative effects comparison mean that low emissions of CH_4 and N_2O can counteract the atmospheric CO_2 sequestration function of wetlands. Thus, although wetlands generally act as carbon sinks, they can at the same time enhance the greenhouse effect because they release CH_4 and N_2O, which have greater GWP than CO_2. Most wetlands are net CO_2 sinks, accreting organic matter into soils over time but creating conditions favorable to methanogenesis (the process by which microorganisms convert organic matter to CH_4 in the absence of oxygen), causing wetlands to be net CH_4 sources.

Gorham (1991) reports that the relative emission of CH_4, compared to CO_2 decreases exponentially as the water table recedes below the surface of the soil. Consequently, if the wetland dries out, the mechanism of C loss shifts from CH_4 production to CO_2 production. The median rate of CH_4 loss is 48 grams C/m^2/yr for nutrient-enriched soils compared to 11 grams C/m^2/yr for oligotrophic soils (Qualls and Richardson 2008). However, CH_4 produced in flooded soils is often oxidized before it is emitted to the atmosphere in the root zone of plants and at the oxidized layer at the soil-floodwater interface. Thus, only about 20% of CH_4 produced in wetland soils is released to the atmosphere.

The emission of trace amounts of N_2O can have a larger impact on the total carbon equivalent of wetland emissions than either CO_2 or CH_4, since N_2O has a higher carbon equivalency factor. If Everglades wetlands received large quantities of NO_3 in surface water inputs, then denitrification would become a greater factor in carbon flux. For every gram of nitrate nitrogen reduced, 1.07 grams C are converted to CO_2. Nutrient-enriched Everglades soils can potentially release large amounts of N_2O, ranging up to 0.4 grams N/m^2/yr.

Conclusions

Wetlands play an important role in global warming through the production of greenhouse gases and sequestration of atmospheric carbon. The major greenhouse gases emitted from the Everglades include CO_2, CH_4, and N_2O, and the types of gases emitted are affected by nutrient status as well as hydrologic conditions. Hydrologic conditions influence the rate of greenhouse gas emissions, as drainage of the Everglades increases soil loss and CO_2 emissions. When the Everglades wetlands are drained for agricultural use or during drought, the resulting CO_2 emissions are higher than for flooded wetlands. However, rates of CH_4 and N_2O emissions from flooded wetlands are higher than for drained soils, and due to their higher GWP, the net effect on greenhouse gasses may be similar between both hydrologic conditions. Eutrophication of the Everglades shifts greenhouse gas production through increased emissions of N_2O, which has higher GWP than other gases. Thus, continuation of nutrient loading in wetlands may likely increase their contribution to global warming compared to oligotrophic areas. The creation of wetlands on agricultural lands sequesters carbon in soil and reduces CO_2 emissions, but in turn may increase CH_4 and N_2O emissions.

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