Diurnal Variations in Greenhouse Gas Emissions from a Macrophyte-Covered River

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Abstract: One of the other necessities for a life support system is water. It is a valuable natural resource that, through the hydrological cycle, constitutes the center of an ecological system. Water is often viewed as an endless and disposable resource, even though it is finite and thought to be the foundation of all life on Earth. Water has been essential to the evolution, expansion, and advancement of human civilization throughout history. As a result, its evaluation and ongoing attention are essential, particularly in emerging nations like India where it affects both the economy and society. Water shortage has resulted from the continued population growth, urbanization, unchecked pollution, global warming, and decreasing rainfall, which have limited the usage of lakes, ponds, and rivers for industrial, agricultural, and municipal purposes. The industrial revolution has made matters more complicated, and from the start of the industrial age at the beginning of the previous millennium, the earth's atmosphere has changed. Concerns regarding future climate changes are raised by the rising quantities of greenhouse gases, such as CH4, CO2, and N2O, or radiatively important trace gases. The physical characteristics of the environment, including incoming solar energy, air temperature, and precipitation and wind patterns, are impacted by the ongoing rise in trace gases and aerosols.

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I. Introduction

Water contamination has emerged as one of the world's most serious environmental issues in recent years. In a chemical sense, water is rarely pure. It has a variety of contaminants, including suspended and dissolved materials. Toxic compounds dissolve or float in water and are deposited when they enter lakes, streams, rivers, seas, and other bodies of water. Aquatic ecosystems are impacted as a result of the declining water quality. Additionally, pollutants have the ability to seep into and impact groundwater. Waters that are polluted are unsuitable for drinking, bathing, washing, and other uses because they are murky, disagreeable, and smell foul. There are two categories of water pollution sources: point sources and nonpoint sources. When dangerous materials are released straight into a body of water, this is known as a point source of pollution. By altering the ecosystem, a nonpoint source indirectly distributes contaminants. One of the most crucial elements of environmental preservation is the management of water pollution. The natural processes that support the global ecosphere and life on Earth are seriously threatened by factors such as societal instability, resource depletion, environmental deterioration, and an expanding human population. Large-scale changes in land use patterns and an increase in the usage of chemical fertilizers are the results of agriculture and society as a whole struggling to fulfill the needs of the growing global population. The global bio-geochemical cycles have been severely disrupted as a result, increasing the emissions of radiatively significant trace gases. The industrial revolution has made matters more complicated, and from the start of the industrial age at the beginning of the previous millennium, the earth's atmosphere has changed. Concerns regarding future climate changes are raised by the rising quantities of greenhouse gases, such as CH4, CO2, and N2O, or radiatively important trace gases (Chanu et al., 2022). The physical characteristics of the environment, including incoming solar energy, air temperature, and precipitation and wind patterns, are impacted by the ongoing rise in trace gases and aerosols. Large amounts of nutrients and heavy metals are taken up by the macrophytes and stored in their body parts. Aquatic macrophytes can also remediate macronutrients from water through important mechanisms such rhizo-filtration, volatilization, and degradation because of their large biomass output potential and rapid development rate (Peixoto et al., 2016). Therefore, in order to use them in large-scale phytoremediation programs to remove pollutants and heavy metals from lakes, ponds, and other water bodies, it is crucial to evaluate the effectiveness of various promising aquatic plants with regard to nutrient uptake and storage at the spatial and seasonal scale. In addition to providing nutritious fodder for herbivorous and domesticated animals including cattle, horses, buffaloes, and goats, a number of macrophyte species are being used as possible food sources for the local population as edible fruits or leafy vegetables. Dead and decomposed plants generate great farm yard manure, which can be used as compost, mulch, fertilizer, ash, and other materials for growing a variety of crops in home and kitchen gardens as well as agricultural fields. Crucially, these plants serve as the aquatic food chain's primary energy source. Many researchers have tried to assess their potential for use as a cattle feed source in medicine over the past few decades. Given the current focus on using aquatic macrophytes for food, feed, and medicine, it is imperative to fully comprehend their phytoconstituents, proximate composition, anti-nutritional qualities, and any potential harmful effects before implementing them on an industrial scale (Marliden, 2015).

II. Aquatic Macrophytes

The ecological assemblage of taxonomically varied macroscopic plants known as aquatic macrophytes, or hydrophytes, completes their life cycle either permanently or sporadically in water environments (Oliveira-Junior et al., 2018). These plants can thrive in a variety of aquatic settings, including freshwater bodies, wetlands, swamps, marshes, brackish environments, and marine environments, thanks to a variety of adaptation processes. Furthermore, a unique transitional group of aquatic plants known as amphibious plants live the majority of their lives on soil that has been soaked with water, yet they are not always in water. Macrophytes inhabit almost every type of freshwater ecosystem, including waterfalls and thermal springs. Wetlands, swamps, marshes, and jheels are primarily composed of macrophytes, however aquatic macrophytes often inhabit rivers, lakes, lagoons, ponds, and reservoirs (Rabaey & Cotner, 2022).

Figure 1: Submerged Macrophyte

III. Greenhouse Gases and Climatic Change

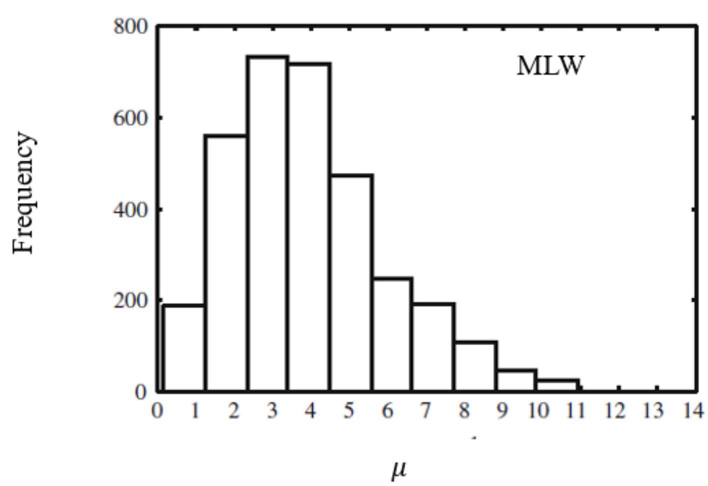
Increased emissions of gases into the atmosphere are caused by industrialization, the growth of agricultural activities through deforestation, the intensification of agricultural activities through frequent and periodic plowing of arable soils, and human interventions by providing plant nutrients through organic or inorganic inputs. Human activity has changed the biogeochemical cycling of several elements. In fact, human disturbance of the corresponding elemental cycle has been a major factor in the rise in atmospheric concentrations of C02, CH4, and N20. CO2 is the most prevalent greenhouse gas in the atmosphere, and in 1995, its pre-industrial concentration of 280 parts per million rose to 360 parts per million. The CO2 concentration in the atmosphere is rising at a pace of 0.5% each year. The concentration of methane, the second most significant trace gas, rose from 0.8 parts per million before industrialization to 1.78 parts per million in 1995, with an annual growth rate of 0.6%. CH4 is more active than CO2 in terms of radiation. Another significant greenhouse gas, in addition to CO2 and CPU, is N2O, whose concentration has grown by 0.25% annually, from 288 ppbv to 312 ppbv. Despite having a far lower atmospheric concentration than CO2, N2O has a net greenhouse effect that is roughly 300 times larger than CO2. Of these trace gases, CH4 traps roughly 32 times more heat per molecule than CO2 and has a comparatively shorter atmospheric life span of 8–10 years. About 25% of the predicted global warming is thought to be caused by methane (Harpenslager et al., 2022). Because it affects the troposphere's content of CO2, hydroxyl radicals, and ozone, methane is also significant to its chemistry. In the stratosphere, it is a source of H2 and water vapor but a sink for Cl'. Because of its comparatively shorter atmospheric life-time, CH4 is a great option for mitigation initiatives.

IV. Methods

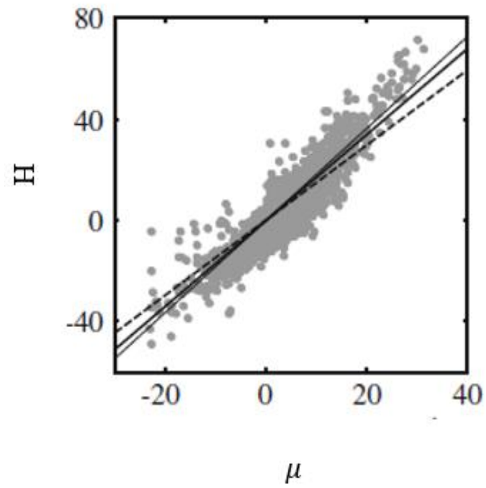
Global warming potential (GWP) provides a metric to compare the relative impacts of different greenhouse gas sources and sinks. For example, the cost-benefit analysis of enhanced carbon storage from residue production (GWP mitigation) versus increased CH4 production from intensively managed flooded rice fields (GWP source) can be assessed by converting all fluxes into common terms. GWP is typically expressed in CO2-equivalents. The conversion from other gases to CO2 is based on each gas's influence on atmospheric radiative forcing compared to CO2. Gases with longer atmospheric lifetimes will have higher GWPs than those that cycle quickly. Agriculture primarily affects three greenhouse gases: CO2, CH4, and N2O. Although the atmospheric concentrations of CH4 and N2O are much smaller than those of CO2, their GWP is significant enough that even small variations can disproportionately impact radiative forcing. The GWP of a production system can be calculated in CO2 equivalents using data on greenhouse gas fluxes during the growing seasons of specific farming or cropping systems.

$$\text{GWP } (CO_2 \text{ equivalents}) = CO_2 + 58(CH_4) + 310(N_2O)$$

The experiment was carried out at a lake in India (figure 1), with varying distances from the shoreline and the impact of submerged macrophytes at each site. The bulk transfer linkages serve as the foundation for the study. The transfer coefficients were calculated using two methods in figure 2. In order to measure how the transfer coefficients changed with wind speed in the first method, we calculated the "effective" transfer coefficients in the second method.



(a)



(b)

Figure 2: (a) Wind-speed Histograms (b) Bulk Transfer Relationship

The seasonally occurring death and decomposition of macrophytes in shallow lakes increases the nutrient load of the water and sediments. Significant amounts of phosphorus, calcium, magnesium, and other minerals are collected on the floor as detritus after the decomposition of aquatic plants, greatly enhancing the water column. The macrophytes compete with algae for nutrients, shade, and harbor grazers, limiting the amount of nutrients available for periphyton and plankton, even if some nutrients are still linked to the sediments. With fluctuating levels of nitrogen imports and macrophyte decomposition, nutrient release is anticipated to occur year-round in tropical lakes (Attermeyer et al., 2016). By releasing dissolved organic matter, the macrophytes contribute significantly to nutrient cycling, as the nitrogen-fixing bacteria require external supplies of organic matter to maintain nitrogen fixation. Detritus in the sediment may have a positive correlation with the dominance of submerged hydrophytes, and as the amount of detritus grows, macrophyte colonization seems to occur more quickly. Due to the increased biomass productivity and effective macrophyte colonization, a remarkably large amount of biomass enters food webs directly through detritus and aquatic herbivorous grazing. Fish, crabs, turtles, and waterfowl all eat a variety of aquatic plant species found in the tropical belt (Junior, 2018).

V. Conclusion

Macrophytes are essential and have a significant impact on wetland environments in a variety of ways. Because shallow water basins provide the perfect conditions for their colonization and quick spread across large areas, their effects are most noticeable there. These hydrophytes alter the physico-chemical properties of the water and underlying sediment, alter the nutrient cycling process, provide food for aquatic organisms in the form of live plants and detritus accumulation, and, most significantly, change the waterscape's spatial structure to a complex aquatic ecosystem dominated by macrophytes. The photic zone of a lake is made up of the littoral zone, which is the shallow, near-shore portion of the water body, and the limnetic zone, which is the open area that receives enough sunshine. Variations in temperature, oxygen saturation, ion concentrations, pH levels, the presence of bottom-rooted plants, and other factors distinguish the two zones from one another. In shallower water bodies, light may reach the bottom and promote the creation of rooted macrophytes, such as in littoral zones, but in limnetic zones, the substratum will not be able to sustain plant growth due to insufficient light and consequently poor photosynthesis.

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