The Effects of Climate Change and Human Interferences to Peatlands

Ezra Spies, Jessica Whitehouse, Tia Blair
Thompson Rivers University, Cmns 2300_01
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Abstract

Peatlands have been discovered to sequester approximately 30% of the world's carbon, despite being only 3-4% of the land cover on Earth. This makes them extremely effective carbon sinks, however, due to humans draining peatlands, they are becoming a carbon source instead. This threatens these ecosystems' stability and the world's climate. This paper reviews the effects of draining and restoring peatlands on factors such as water table, greenhouse gasses (GHG), water quality, and ecosystem functions. It is found that in drained peatlands, the low water table causes mass amounts of carbon dioxide, a major persistent GHG, to be expelled into the atmosphere. Draining peatlands also lowers the quality of water flowing out of the peatland and increases the nutrients in that water, potentially leading to harmful algal blooms downstream. On the other hand, rewetting peatlands slows the amount of carbon dioxide being output, as well as raises plant productivity, which helps reaccumulate peat and draw carbon dioxide out of the atmosphere. Rewetting is also noted to improve water quality over time and reduce overland flow, both of which are known to degrade soil structures and the environment as a whole.

Introduction

Throughout the world, there are nutrient-rich water-logged regions that are essential to native flora and fauna. These lands fall under the broad category of peatlands. Peatlands are defined as "with or without vegetation with a naturally accumulated peat layer at the surface." Peat, the namesake of peatlands, is composed of at least 30% dead organic matter (Joosten, 2003).

Across the Earth, 3-4% of the land surface is composed of peatlands, with the large majority being defined as boreal forests (UNEP, 2022). Boreal forested peatlands are identified by their semi-open canopy coverage and an organic layer deeper than 30 cm (Beaunle, 2021). With Canada as one of the main locations of boreal forested peatlands, it is important to delve into the damages caused to peatlands, along with the restoration processes peatlands require (Joosten, 2003).

The main point of interest in peatlands is their natural ability to sequester carbon, creating a carbon sink. Due to the anaerobic character of peatlands, organic matter from dead plants accumulates faster than it can decay. This gradual build-up of organic carbon residing within the decaying plants creates this carbon sink (Dunn & Freeman, 2014).

Many factors affect a peatland's ability to sequester carbon, including draining the peatland of its water and artificial rewetting of peatlands (Belye and Malmer, 2004). Not all factors create negative change, but they are all connected through peatlands being influenced by humans.

Discussion

The Draining of Peatlands

Primarily, peatlands are drained for economic reasons, specifically agriculture, peat extraction, and land development. This is done by digging artificial ditches and channels, allowing the water to drain from the soil (Haapalehto et al. 2014). As peatlands are full of organic matter and nutrients, they are ideal ecosystems to convert into agricultural land, however, the drainage of these wetlands can have many consequences.

Peat is impressive as it can act as a natural sponge, absorbing rainfall and preventing flooding events in nearby streams and rivers (Prévost et al. 1999). Due to this water-holding capacity, it can be helpful in droughts, as the stored water can be used by plants, and the wildfire risk in peatland ecosystems is heavily reduced. In drained sites, however, the risk of wildfires is higher. Not only is wildfire a concern in dry areas, but the loss of habitat as well. Unique plant species such as mosses and sedges will be driven out and either killed off or forced to find a new habitat that will support them (IUCN, 2024). Additionally, there are insects and other invertebrates that need a specific wetland environment, and if these are affected along with the plants, a severe loss of food sources would occur. Trophic cascades may happen, leading to a detrimental hit on biodiversity and several species.

In a paper by Haapalehto et al. (2014), the authors found that water tables were significantly lower in drained sites than those that were untouched. A lower water table causes faster decomposition, therefore higher (GHG) emissions, and will prevent the soil from being a carbon sink. In the same paper, it was found that the drained sites had higher levels of nitrogen (N) and phosphorus (P) in the water, leading to a decrease in water quality coming out of the site. In studied peatlands, the amount of N and P is generally low, as it is taken up by the organisms in the site (Silvan et al. 2004), so the effects of the increased nutrients are not completely known, but it is likely to cause disturbances within the ecosystem and displace organisms, including those that are at risk.

Water quality is affected not only directly after draining but also many years into the future unless restoration efforts are put in place. It was found by Nieminen et al. (2021), that the release of nitrogen and phosphorus from peatlands that had been drained in the past was two-to-three times higher than that of peatlands that had never been drained, even 10 years after drainage. These repercussions of draining can be mitigated through rewetting peat, which has the potential to prevent or reverse damages done in the past.

The Rewetting of Peatlands

Rewetting a peatland is the process of blocking the drainage ditches and channels, and allowing water to re-accumulate in the peatland. This process is important, not only for habitat restoration and environmental restoration purposes but also for stopping the release of carbon dioxide (CO_2) and reaccumulating carbon from the atmosphere (Wilson et al 2016, Günther et al 2020, Dunn & Freeman 2014) (Fig 1). However, this is not a guarantee and does not happen automatically (Joosten, 2003). How a peatland responds to rewetting is dependent on climate, foliar type, soil temperature, and method of rewetting (Wilson et al, 2016).

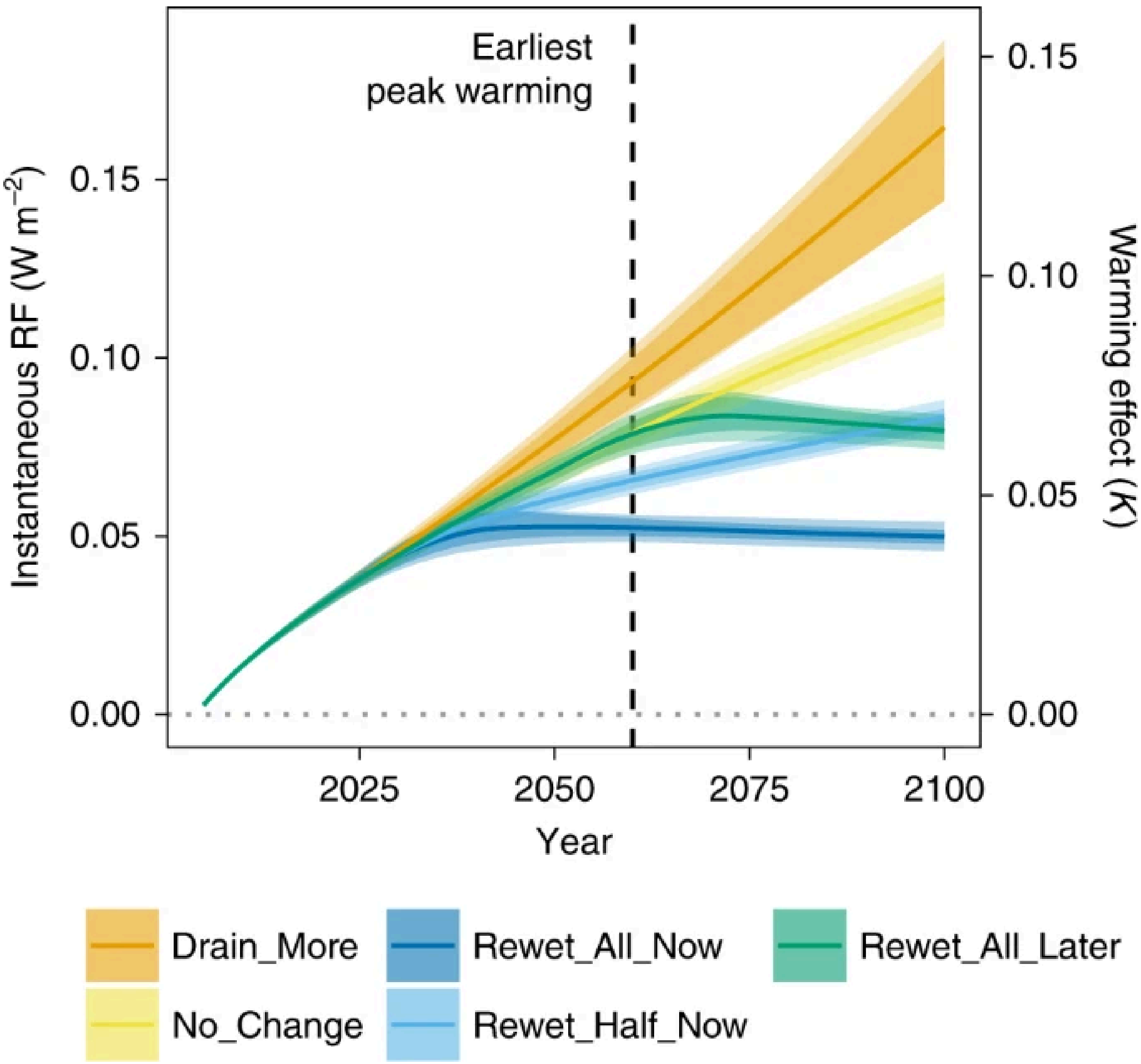

Fig 1. Model of potential emission factor ranges based on five globe-wide peatland management scenarios. Ranges are based on instantaneous radiative forcing from variations of drainage rates (1000-8000 km^2/year) and emission factors (10% and 20% uncertainty, shown by change of opacity) (Günther et al 2020).

Rewetting a peatland has been found to lead to higher amounts of biomass accumulation and higher levels of plant production in these areas (Wilson et al 2016; Schweiger et al 2020). Rewetting also showed higher water saturation for longer periods, as well as higher water tables present than their drained counterparts (Schweiger et al 2020, Haapalehto et al 2014). This is significant, as higher water tables mean that the temperature - a primary factor in decomposition rates in peatlands - is far more regulated and stable (Schweiger et al 2020, Wilson et al 2016, Haapalehto et al 2014, Hu et al 2017, Belyea & Malmer 2004). Not only that, but the high water table in these areas will help plants growing here access water in dry years that are projected using climate data.

In a paper by Wilson et al (2016), it was concluded that draining peatlands creates a carbon source, however rewetting the same peatlands lowers the output of CO2 by 50%. It was also found that in the rewetted peatland low emissions of CH4 were present, and dry peatlands had no detectable CH4 outputs. Similarly, the Haapalehto et al (2014) study found that dissolved organic carbon (DOC) concentration and losses were significantly higher in drained sites and restored peatland DOC levels averaged that of an untouched peatland, however, it was noted that DOC levels change seasonally. This is further supported by the findings of the paper by Günther et al (2020), where the levels of the major GHG that were studied - CO_2, CH_4, and N_2O - plateaued seemingly directly after rewetting occurred, whereas the levels of emissions continued to climb in the peatlands that were left dry.

The Günther et al (2020) paper also considers the radiative effects of CO_2, CH_4, and N_2O. CH_4 may have a more potent warming effect than CO_2, however, it is shorter-lived than CO_2. CO_2 causes more warming in the long term, especially with the added output from leaving drained peatlands dry. This study stresses the importance of mitigating the release of CO_2 into the atmosphere, stating "CH_4 radiative forcing does not undermine the climate change mitigation potential of peatland rewetting. Instead, postponing rewetting increases the long-term warming effect through continued CO_2 emissions." The same is noted in the Dunn & Freeman paper (2014).

Rewetting peatlands was also found to lower overland flow, a major factor in soil - and subsequently ecosystem - degradation, as well as raise water quality of water outflow (Haapalehto et al, 2014). The Haapalehto et al paper notes that rewetted peatlands, due to their healthier and higher functioning plant ecosystems, have overall less overland than dry peatlands because of higher rates of evapotranspiration taking place, as well as the establishment of new surface peat due to raised plant productivity. As stated previously, water quality is higher in rewetted peatlands, and is notably also impacted by the species growing in the peatland, and the effects of seasonal changes (Schweiger et al 2021, Haapalehto et al 2014).

The Long-term Effects and Future of Peatlands

As peatlands are drained and rewet, it is possible to record changes to the peatland along with the surrounding area. This timeline allows researchers to identify patterns and predict how changes in the environment will affect the peatlands in years to come. By comparing drained peatlands, pristine peatlands, and peatlands that were restored 5 and 10 years ago, Haapaletho et al. (2014) found a considerable difference in many factors such as water chemistry. When comparing water chemistry between the four peatlands, the largest difference found was between the pristine peatland and the drained peatland.

Haapaletho et al. (2014) used principal component analysis (PCA), principal components (PC) correlate to pH, calcium, electrical conductivity, sodium, phosphorus, iron, nitrogen, and DOC, to compare and contrast the water quality in the peatlands over the 10 year restoration period. This led to the discovery that while the pristine peatland and the drained peatland were exceedingly different in water chemistry, the restored peatlands were considerably more similar to the pristine peatlands compared to the drained peatlands. As the restored peatland aged, it was found that the water chemistry only improved in health.

While it is imperative to measure the changes that drainage and restoration of peatlands cause over time, it is also pertinent to take a step back and look outside the box. One way to achieve this is by considering peatlands as a tool to fight global warming. As Dunn and Freeman (2011) analyzed, restoring drained peatlands could be the forward-thinking technique humans need to offset carbon emissions. This duo investigated the possible use of peatland restoration to offset GHG emissions for individual countries, specifically countries in the United Kingdom. By restoring and rewetting drained peatlands, Dunn and Freeman found that the carbon sink created by the restored peatlands could reduce the carbon credits countries are allotted in the Kyoto Agreement. These carbon credits are allotted to each country in the agreement, with nations trading the credits to other nations if they do not require their allotted credits (Dunn & Freeman, 2011).

While Dunn and Freeman focused on the effect of restored peatlands on the near future, Belyea and Malmer (2004) analyzed the carbon sequestration of peatlands over 500 years. Using exponential and logarithmic functions, Belyea and Malmer estimated the change in carbon sequestration in the Stone Mosse mire, a peatland in northern Sweden, throughout multiple centuries. While the rate at which carbon was sequestered varied over the years, there was an incline in the amount of carbon being sequestered, as shown in Figure 2. When combining Dunn and Freeman's GHG emission goals with the carbon sequestration increase predicted by Belyea and Malmer, it is clear that by implementing peatland restoration to combat GHG emissions, the effects will improve as the peatlands.

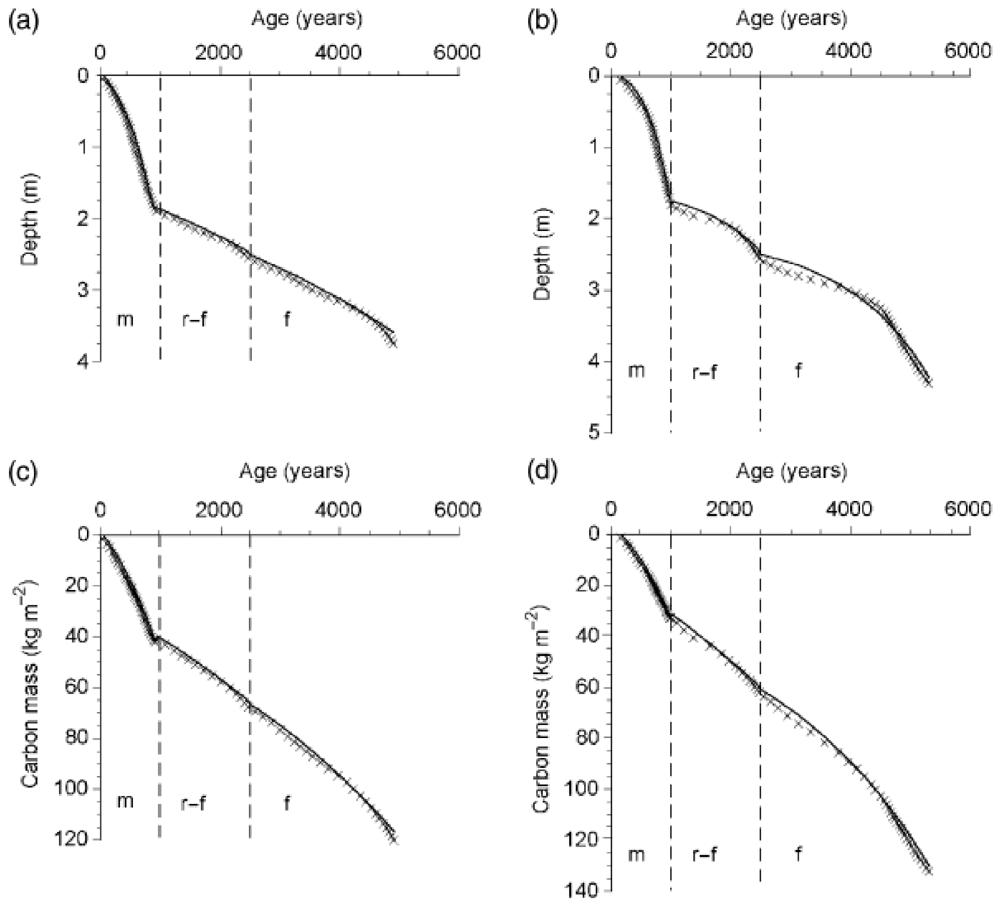

Figure 2. Plots a and b represent the age of the peatland versus the depth of the peat and plots c and d represent the age of the peatlands versus the mass of carbon stored per meter squared. With plots a and c from Core A and plots b and d from Core B (Belye and Malmer, 2004).

The increasing health of rewet peatlands and the decline of GHG emissions were confirmed in the paper by Wilson et al. (2016) as the authors found that the GHG emissions had reduced by 50% annually over a decade. While the paper by Wilson et al. was over a shorter period than Belyea and Malmer (2004), it still reached the same conclusion as the research provided by Belyea and Malmer along with Haapaletho et al. (2014).

Conclusion

Peatlands are unarguably important regarding carbon sequestration, habitat for plants and animals, and biodiversity. As these systems are affected by humans, restoration efforts must be introduced. It was found that the draining of peatlands has adverse side effects such as loss of species, increased wildfire risk, nutrient leaching, and negative impacts on water quality.

Recommendations

Future research could be conducted on flora and fauna interactions with peat, the long-term effects of draining and rewetting, and the effects on ecosystems’ macro and micro-climates to better protect these beneficial environments.

Works Cited

Nieminen, M., Sarkkola, S., Hasselquist, E.M. *et al.* 2021. Long-Term Nitrogen and Phosphorus Dynamics in Waters Discharging from Forestry-Drained and Undrained Boreal Peatlands. Water Air Soil Pollut. 232: 371. https://doi-org.ezproxy.tru.ca/10.1007/s11270-021-05293-y

J. M. Waddington & J. S. Price. 2000. EFFECT OF PEATLAND DRAINAGE, HARVESTING, AND RESTORATION ON ATMOSPHERIC WATER AND CARBON EXCHANGE, Physical Geography. 21(5): 433-451 https://doi.org/10.1080/02723646.2000.10642719

T. Haapalehto, J.S. Kotiaho, R. Matilainen, T. Tahvanainen. 2014. The effects of long-term drainage and subsequent restoration on water table level and pore water chemistry in boreal peatlands, Journal of Hydrology, 519: 1493-1505.
https://doi.org/10.1016/j.jhydrol.2014.09.013.

Marcel Prévost, André P Plamondon, Pierre Belleau. 1999. Effects of drainage of a forested peatland on water quality and quantity. Journal of Hydrology. 214(1–4): 130-143.
https://doi.org/10.1016/S0022-1694(98)00281-9.

IUCN: Peatland Damage. Nottinghamshire: UK Peatland Programme; [accessed 2024, April 1].
https://www.iucn-uk-peatlandprogramme.org/about-peatlands/peatland-damage

N. Silvan, H. Vasander, J. Laine. 2004. Vegetation is the main factor in nutrient retention in a constructed wetland buffer. Plant Soil, 258: 179-187. 10.1023/B:PLSO.0000016549.70555.9d

Dunn, C., Freeman, C. 2011. Peatlands: our greatest source of carbon credits? Carbon Management, 2(3), 289–301. https://doi.org/10.4155/cmt.11.23

Belyea, L. R., Malmer, N. 2004. Carbon sequestration in peatland: patterns and mechanisms of response to climate change. Global Change Biology, 10(7), 1043-1052.
https://doi.org/10.1111/j.1529-8817.2003.00783.x

Beaulne, J., Garneau, M., Magnan, G. *et al.* 2021. Peat deposits store more carbon than trees in forested peatlands of the boreal biome. *Sci Rep* 11, 2657. https://doi.org/10.1038/s41598-021-82004-x

Kopansky, D., Joosten, H. et al. 2022. Global Peatlands Assessment – The State of the World's Peatlands. Knowledge Repository - UNEP, 1-425. https://doi.org/10.59117/20.500.11822/41222

Joosten, H. 2003. Wise use of mires: Background and principles. 1st ed. Totnes, Devon: NHBS Ltd.

Günther A, Barthelmes A, Huth V, Joosten H, Jurasinski G, Koebsch F, Couwenberg J. 2020. Prompt rewetting of drained peatlands reduces climate warming despite methane emissions. Nature Communications. 11(1):1644. doi:https://doi.org/10.1038/s41467-020-15499-z. [accessed 2020 Oct 18]. https://www.nature.com/articles/s41467-020-15499-z.

Schwieger S, Kreyling J, Couwenberg J, Smiljanić M, Weigel R, Wilmking M, Blume-Werry G. 2020. Wetter is Better: Rewetting of Minerotrophic Peatlands Increases Plant Production and Moves Them Towards Carbon Sinks in a Dry Year. Ecosystems. 24. doi:https://doi.org/10.1007/s10021-020-00570-z.

Wilson D, Farrell CA, Fallon D, Moser G, Müller C, Renou-Wilson F. 2016. Multiyear greenhouse gas balances at a rewetted temperate peatland. Global Change Biology. 22(12):4080–4095. doi:https://doi.org/10.1111/gcb.13325.

Hu J, VanZomeren CM, Inglett KS, Wright AL, Clark MW, Reddy KR. 2017. Greenhouse Gas Emissions Under Different Drainage and Flooding Regimes of Cultivated Peatlands. Journal of Geophysical Research: Biogeosciences. 122(11):3047–3062. doi:https://doi.org/10.1002/2017jg004010.