A Hidden Rabbit Warren: Permafrost and the Challenges of its Thaw

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Abstract

The thaw of vast areas of permafrost is largely being caused by an increase in global temperatures resulting from an increase in greenhouse gas emissions, and this is having countless negative impacts. As permafrost begins to thaw, it has large scale impacts, some of these include the resurgence of bacteria, the release of carbon dioxide, impacts on the foundation of infrastructure and many more. The thaw of permafrost and release of carbon dioxide is of great importance in the current ecological crisis which our world is facing. As carbon dioxide concentration increases, this begins to have irreversible long term global impacts which exceed beyond our imagination, and which serve to amplify the current climate crisis we face. For this reason, it is imperative that we give permafrost thaw more attention and do more to prevent it and mitigate the impacts.

1. Introduction

Permafrost refers to soil which has been frozen below 0°C for two or more years consecutively. Most of the permafrost in the world is located in the Arctic regions, for example, about a quarter of the Northern Hemisphere is permafrost and this includes places such as Alaska, where 'nearly 85% of the state sits on a layer of permafrost' (Denchak, 2018). Due to the increase in global atmospheric temperatures, vast areas of permafrost are beginning to thaw. This essay argues that thawing of permafrost deserves greater attention from geographers than it has been given to date, and that an understanding of this topic is essential to addressing both the climate emergency and the ecological crisis.

Permafrost comes in three forms: continuous, discontinuous, and sporadic. Continuous permafrost is found in the coldest regions, such as Siberia and it extends up to 1500m below the soil surface. In these areas there is very little melting of the upper layers (Skinner *et al.*, 2021). Discontinuous permafrost refers to permafrost found in slightly warmer regions. In these places the permafrost extends around 20-

30m below the soil surface (Skinner *et al.*, 2021). Sporadic permafrost refers to isolated areas of permafrost found in regions which occasionally experience temperatures below freezing but cold enough to prevent summer thaw (Skinner *et al.*, 2021). 17% of global exposed land surface is built upon a layer of permafrost (Biskaborn *et al.*, 2019), so the thaw of this will have long term global impacts on human and natural systems.

Although there are uncertainties about the rate of permafrost degradation, it is clear to me that climatic changes are driving significant permafrost thaw and that this thaw in turn acts as a feedback mechanism which amplifies global warming (Barry and Gan, 2022: 414-416).

2. Impacts of Thawing Permafrost

The impacts of permafrost are varied, and we can be more certain of some of these than others. However, we have clear empirical evidence for some of the effects of this thaw, and thus there can be no doubt that the thaw of permafrost is having large scale environmental and social impacts at a global scale.

2.1 Release of Carbon Dioxide and Methane

One of the most well-known environmental impacts of permafrost has the largest amount of uncertainty surrounding it: the release of carbon dioxide and methane. Permafrost is a vast store of carbon dioxide, holding 'around 60% of the world's soil carbon content in only 15% of the global soil area' (Turetsky *et al.*, 2020). This is significant, because as the permafrost warms and begins to thaw, previously frozen organic matter thaws and begins to decompose. This leads to the release of carbon dioxide and methane. Methane is considered to be 25 times more potent than carbon dioxide in terms of its impact on climatic warming (United States Environmental Protection Agency, 2016). Methodological challenges mean that there is a large amount of uncertainty surrounding estimating how much carbon dioxide and methane the thaw of permafrost will release. Firstly, setting up facilities to measure the carbon dioxide and methane release is difficult due to the extreme conditions in which permafrost exists. Relatively few field stations have been established to collect data on permafrost thaw, even though the 'permafrost zone covers about one-quarter of the Northern Hemisphere's land area.' (Schuur and Abbott, 2011). New technologies, including satellite remote sensing, are improving the study of permafrost change, but this technique remains challenging because physical variables such as ground temperature and thaw depth are not currently measurable using remote sensing (Tedesco, 2015: 307-344).

Perhaps the worst consequence of the thaw of permafrost is the potential to tip over a positive feedback loop as a result of the release of carbon dioxide and methane. Permafrost thaw leads to a positive feedback loop which can be simplified as such: permafrost thaws, this thaw leads to the release of carbon dioxide and methane, these greenhouse gases amplify the enhanced greenhouse effect, causing global temperatures to rise, and therefore there is an increase in the thawing of permafrost. This positive feedback is amplified by the fact that permafrost stores '1400-1600 Gt organic carbon, which is nearly twice the amount in the atmosphere' (IPCC, 2019). The release of this carbon dioxide and methane into the atmosphere is the most severe environmental impact. Once started, this positive feedback loop is one that will self-perpetuate, presenting serious challenges to attempts to mitigate global warming. We do not and will not know the point at which the thaw of permafrost hits the tipping point and begins this positive feedback loop, so it is crucial that people act now to try to reduce global temperatures and reduce the risk of starting this feedback loop.

2.2 Release of Pathogens

Another impact of permafrost thaw, unforeseen to most, is the resurgence of viruses such as anthrax. In 2016 in the Yamal peninsula in the North-West of Siberia, there was an outbreak of anthrax. There had previously been no recent outbreak of the strain of bacteria in this specific area, and scientists concluded that permafrost had preserved this specific strain of the pathogen for over 75 years, and when the permafrost thawed these pathogens were released (Gross, 2019). This demonstrates the potential of permafrost to further store potentially hazardous pathogens, and consequentially, when the permafrost thaws, it releases these pathogens and causes a hazard to human health. The outbreak in Siberia demonstrates how permafrost thaw has the potential to cause locally specific disease outbreaks that could nevertheless have the potential to be transmitted further by natural systems. It demonstrates how permafrost thaw doesn't only affect the climate but can also have profound impacts on human health. Permafrost thaw therefore has social impacts along with environmental impacts.

3. Impacts of Slumping

Another impact that the thaw of permafrost is having is the impact it has on infrastructure. When permafrost thaws, the terrain that lays on top of it can be affected, leading to the development of thermokarsts, defined as 'the process by which characteristic landforms result from the thawing of ice-rich permafrost and/or melting of massive ice' (van Everdingen, 1998). These can vary in scale, with the largest of these being the Batagaika crater in Siberia, measuring one kilometre long (Reuters, 2023), making it the largest permafrost depression in the world. This happens when the ice within the permafrost melts, causing the soil to warm up and become less stable, and leading to it slumping. This slumping has major impacts when infrastructure is built on top of the soil, as this causes the foundations of the infrastructure to become unstable. For example, permafrost slumping caused damage to the Bethel Highway in Alaska, which became unstable and resembled a rollercoaster due to the fact that it was constructed on top of a layer of permafrost. This will have significant social impacts, such as disruption to local transport, and economic impacts within the maintenance costs to the Alaskan state authorities. Although these impacts are geographically specific, they represent what may happen when a wider area of permafrost thaws.

4. Impacts on Local Water (Mercury Release)

A further unforeseen impact of the thaw of permafrost is the release of toxins, such as mercury, into local water supplies. Permafrost stores a large amount of mercury, 'permafrost regions store an estimated twice as much as mercury as other soils, the atmosphere, and the oceans combined.' (Schuster *et al.*, 2018). This mercury is then being released into drinking water supplies, for example there has been a release of mercury into the water relied on by indigenous communities in Alaska for food and water. As mercury accumulates in fish, it also enters the human food chain. Mercury is a toxin, most dangerous is the form of methylmercury, which can lead to mercury poisoning, and in the worst scenario can lead to neurological disease similar to Minamata disease which originated in Minimata, Japan, as a result of eating fish contaminated with mercury in the early 1950's (Ekino *et al.*, 2007). This demonstrates one of the many social injustices caused by the thaw of permafrost. Indigenous communities, who have emitted low levels of greenhouse gases, are nevertheless more vulnerable to these health risks associated with permafrost thaw.

5. Impacts on Nature and Wildlife

The thaw of permafrost can also have large impacts on nature and wildlife. One of these is a positive impact caused by the permafrost converting to a wetland due to permafrost thaw, it has been found that when this happens there is an increase in 'turnover of deep soil organic matter' (Finger *et al*., 2016). This has many positive impacts on the growth of these plants such as feather moss, as it means that nutrients which were once frozen into permafrost are now available to be taken up by plant roots. This therefore leads to an increased rate of growth as the plants are able to use these nutrients to boost processes such as photosynthesis, which is responsible for producing carbohydrates which are critical for a plant's growth. However, this nevertheless only occurs because the permafrost has thawed. Thus, it is difficult to conceive of it as a positive impact since it only happens once permafrost is lost. However, this can still have a small impact on atmospheric carbon dioxide levels, because the aforementioned increase in photosynthesis results in an increase in carbon dioxide sequestration from the atmosphere.

Despite this, overall permafrost thaw still has numerous negative impacts for wildlife. For example, slumping destroys the habitats of many species and makes it difficult for them to breed. On Bylot Island, Canada, permafrost thaw led to 'active layer detachment slides' that caused biodiversity and environmental changes. As a result of this, hawk nesting structure collapsed (Berteaux *et al.*, 2017), leaving these animals without their habitats and without any spaces to use for breeding, therefore leading to a decrease in the number of these hawk species. Countless other animal species rely on permafrost to support their habitat, and therefore the thaw and disappearance of this permafrost leads to the destruction of critical habitats these animals need for survival. This demonstrates how the thaw of permafrost has the ability to critically damage not only human habitats but also the habitats of animals, highlighting how the social impacts of permafrost thaw reach beyond human society and impact animal communities too.

6. Conclusion

In conclusion, it is clear that the thawing of permafrost is a process which deserves more attention in the current ecological crisis. Not only is the thaw of permafrost a major factor leading to the release of increased quantities of greenhouse gases; it also has many local and global impacts which will have profound social and environmental consequences. Strategies to mitigate the impacts of, and adapt to, permafrost thaw need to be given much more consideration in debates about how best to address the climate crisis. Policy makers are beginning to take seriously the importance of permafrost as a store of carbon dioxide and methane (IPCC, 2019), but this needs to be reflected more notably in the subsequent policies they create. Geographers are well placed to address the research gaps and develop new methodologies so that we can better understand the environmental and social impacts of permafrost thaw and thus inform global responses to climate change.

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