UNEP

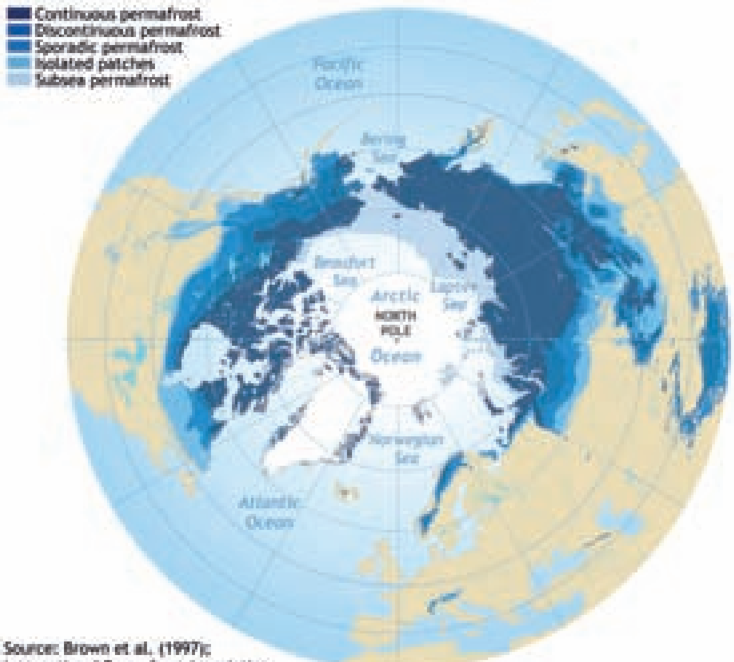
Policy Implications of Warming Permafrost

Policy Implications of Warming Permafrost

UNEP

Executive Summary

Permafrost is perennially frozen ground occurring in about 24% of the exposed land surface in the Northern Hemisphere. The distribution of permafrost is controlled by air temperature and, to a lesser extent, by snow depth, vegetation, orientation to the sun and soil properties. Any location with annual average air temperatures below freezing can potentially form permafrost. Snow is an effective insulator and modulates the effect of air temperature, resulting in permafrost temperatures up to 6°C higher than the local mean annual air temperature. Most of the current permafrost formed during or since the last ice age and can extend down to depths of more than 700 meters in parts of northern Siberia and Canada. Permafrost includes the contents of the ground before it was frozen, such as bedrock, gravel, silt and organic material. Permafrost often contains large lenses, layers and wedges of pure ice that grow over many years as a result of annual freezing and thawing of the surface soil layer.



Source: Brown et al. (1997); International Permafrost Association

About 24% of the northern hemisphere land surface contains permafrost, divided into zones of *continuous, discontinuous, sporadic and isolated patches* of permafrost, depending on how much of the land area contains permafrost.

Two global networks monitor permafrost status: the Thermal State of Permafrost (TSP) network measures permafrost temperature at various depths in 860 boreholes, and the Circumpolar Active Layer Monitoring (CALM) network measures the thickness of the active layer at 260 sites. The active layer thickness is the maximum surface thaw depth in summer. The TSP and CALM networks are the two components of the Global Terrestrial Network for Permafrost (GTN-P), under the auspices of the Global Climate Observing System (GCOS). The International Permafrost Association (IPA) currently coordinates international development and operation of the TSP and CALM networks for the GTN-P. TSP observations indicate that permafrost temperatures have risen over the past few decades. CALM observations are less conclusive due to the melting of ice layers and lenses in near surface permafrost, but show increases in active layer thickness at many sites. Overall, these observations indicate that large-scale thawing of permafrost may have already started.

Arctic and alpine air temperatures are expected to increase at roughly twice the global rate and climate projections indicate substantial loss of permafrost by 2100. A global temperature increase of 3°C means a 6°C increase in the Arctic, resulting in anywhere between 30 to 85% loss of near-surface permafrost. Such widespread permafrost degradation will permanently change local hydrology, increasing the frequency of fire and erosion disturbances. The number of wetlands and lakes will increase in continuous permafrost zones and decrease in discontinuous zones, but will decrease overall as the continuous permafrost zone shrinks, impacting critical habitat, particularly for migratory birds. Risks associated with rock fall and erosion will increase, particularly in cold mountain areas. Damage to critical infrastructure, such as buildings and roads, will incur significant social and economic costs.

Carbon dioxide (CO_2) and methane emissions from thawing permafrost could amplify warming due to anthropogenic greenhouse gas emissions. This amplification is called the permafrost carbon feedback. Permafrost contains ~1700 gigatonnes (Gt) of carbon in the form of frozen organic matter, almost twice as much carbon as currently in the atmosphere. If the permafrost thaws, the organic matter will thaw and decay, potentially releasing large amounts of CO_2 and methane into the atmosphere. This organic material was buried and frozen thousands of years ago and its release into the atmosphere is irreversible on human time scales. Thawing permafrost could emit 43 to 135 Gt of CO_2 equivalent by 2100 and 246 to 415 Gt of CO_2 equivalent by 2200. Uncertainties are large, but emissions from thawing permafrost could start within the next few decades and continue for several centuries, influencing both short-term climate (before 2100) and long-term climate (after 2100).

Below are specific policy recommendations to address the potential economic, social and environmental impacts of permafrost degradation in a warming climate:

1) **Commission a Special Report on Permafrost Emissions:** The Intergovernmental Panel on Climate Change (IPCC) may consider preparing a special assessment report on how CO_2 and methane emissions from thawing permafrost would influence global climate to support climate change policy discussions and treaty negotiations. All climate projections in the IPCC Fifth Assessment Report, due for release in 2013-14, are likely to be biased on the low side relative to global temperature because the models did not include the permafrost carbon feedback. Consequently, targets for anthropogenic greenhouse gas emissions based on these climate projections would be biased high. The treaty in negotiation sets a global target warming of 2°C above pre-industrial temperatures by 2100. If anthropogenic greenhouse gas emissions targets do not account for CO_2 and methane emissions from thawing permafrost, the world may overshoot this target.

2) **Create National Permafrost Monitoring Networks:** To adequately monitor permafrost globally, individual countries may consider taking over operation of TSP and CALM sites within their borders, increasing funding, standardizing the measurements and expanding coverage. This applies to all countries with permafrost, but particularly to countries with the most permafrost: Russia, Canada, China and the United States. The IPA should continue to coordinate development and the national networks should remain part of the GTN-P.

3) **Plan for Adaptation:** Nations with substantial presence of permafrost may consider developing plans evaluating the potential risks, damage and costs of permafrost degradation to critical infrastructure. This applies to all countries with permafrost, but particularly to Russia, Canada, China and the United States. Most nations with permafrost currently do not have such plans, which will help policy-makers, national planners and scientists quantify costs and risks associated with permafrost degradation.

Foreword

Out of the world's entire population, few know what permafrost is and fewer still have ever seen - let alone set foot upon - actual permafrost. Yet permafrost occurs in 24% of exposed land in the Northern Hemisphere. Permafrost is key to the planet's future because it contains large stores of frozen organic matter that, if thawed and released into the atmosphere, would amplify current global warming and propel us to a warmer world.

This report seeks to inform a broad audience about permafrost and communicate to decision-makers and the general public the implications of changing permafrost in a warming climate. It defines basic terminology and describes fundamental physical and biological processes that shape the permafrost landscape using the best scientific information available from published literature. The report discusses the impacts of a changing climate on ecosystems and human infrastructure in regions with significant presence of permafrost, as well as the impacts of thawing permafrost on global climate. Graphics, illustrations and photographs help explain complicated concepts and ideas in a way that is easily understood and visualized by a non-scientific audience.

This report builds upon other reports written in recent years. These reports are very technical in nature and target a limited, scientific audience rather than a broader group of decision-makers and the general public. The 2011 executive summary of the *Snow, Water, Ice and Permafrost in the Arctic* assessment report from the Arctic Monitoring and Assessment Programme focused on how climate change influences the Arctic cryosphere, rather than the other way around, and did not include all areas with permafrost, particularly alpine regions. The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report dealt with the subject of permafrost in a highly scientific fashion under Working Group I in Chapter 4. In 2007, UNEP produced a volume entitled *Global Outlook on Snow and Ice*, where one chapter included an overview of permafrost. Again in 2008, in the *UNEP Yearbook of our Changing Environment*, UNEP devoted a chapter to methane emissions, but did not focus on permafrost. **This current report fills a gap by providing a concise, highly-readable and fully up-to-date description of permafrost and future social, economic and environmental impacts of changing permafrost in a warming climate.**

I would like to thank the team of scientific experts who have prepared this report. We hope their dedication and hard work will be rewarded by wide interest among those who can affect decision-making processes relevant to the state and trends of global permafrost.

United Nations Environment Programme (UNEP)

Achim Steiner,
Executive Director

Table of Contents

1. Introduction 1

2. An Overview of Permafrost 2
   - 2.1. What is Permafrost? 2
   - 2.2. What Controls Permafrost? 6
   - 2.3. Permafrost Monitoring 6
   - 2.4. Current State of Permafrost 7

3. Impacts of Climate Change on Permafrost 9
   - 3.1. Future Climate 9
   - 3.2. Permafrost in the Future 10
   - 3.3. Erosion 11
   - 3.4. Ecosystem Disturbances 13
   - 3.5. Societal and Economic Costs 15

4. Impacts of Thawing Permafrost on Climate Change 17
   - 4.1. Frozen Organic Matter 17
   - 4.2. The Permafrost Carbon Feedback 18

5. Policy Recommendations 21
   - 5.1. Commission a Special Report on Permafrost Emissions 21
   - 5.2. Create National Permafrost Monitoring Networks 22
   - 5.3. Plan for Adaptation 22

6. Conclusions 23

7. Acknowledgements 24
   - 7.1. Lead Author 24
   - 7.2. Authors 24
   - 7.3. Contributing Author 24
   - 7.4. Project Coordinator 24
   - 7.5. Reviewers 24

8. References 25

9. Glossary 30

1. Introduction

Permafrost - perennially frozen ground - covers vast stretches of land at high latitudes and altitudes in both hemispheres. Most regions with permafrost are sparsely populated and remote, and contain vast natural resources in timber, minerals, oil and natural gas. Permafrost also contains almost twice as much carbon in the form of frozen organic matter as is in today's atmosphere, frozen and inert for thousands of years. The remoteness, coldness and sheer scale of permafrost give the impression of stability on geologic time scales. But they are also the regions that will be hit first and hardest by the warming effects of climate change, because the Northern Arctic region is warming at twice the global rate. Should the permafrost thaw, the changes would be swift and irreversible, with global social, economic and climatic consequences.

Few people outside the scientific community understand how climate change impacts the people and ecology in permafrost regions, and fewer still realize that thawing permafrost can influence global climate. This report attempts to bridge the gap between the knowledge of science and the needs of policy, informing international leaders, representatives and science experts, who are negotiating a global climate change treaty or defining national policy on the impacts of a changing climate on permafrost and the impact of thawing permafrost on global climate.

The main objective of this report is to make decision-makers and the public aware of the global consequences of thawing permafrost and offer specific and practical policy recommendations. The report does not describe in detail the complete status of our current knowledge of permafrost or the complex processes that drive permafrost dynamics, nor does it identify science research priorities. There are other documents and reports that serve those functions. Instead, it strives to create a simple reference for the policy-maker to understand the basics of permafrost and why these specific recommendations are made. Consequently, the report is short, with graphics and pictures chosen to illustrate the basic processes. The report places the policy recommendations in a scientific, social and economic context by defining basic terminology and describing the fundamental processes that drive permafrost dynamics.