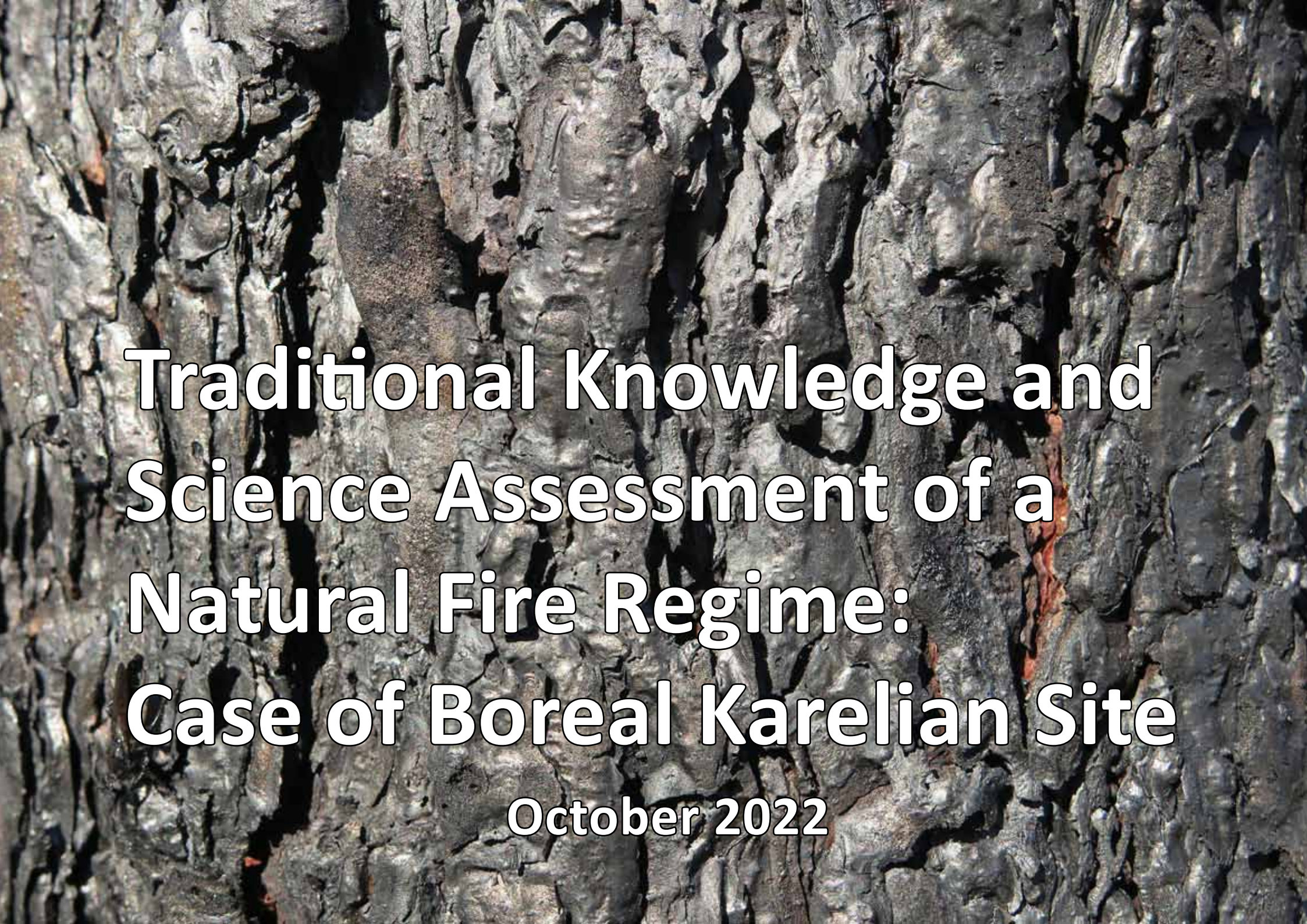

Traditional Knowledge and Science Assessment of a Natural Fire Regime: Case of Boreal Karelian Site

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A view of the burn site in 2021. Photo: Snowchange

Authors:
Docent Kajar Köster, University of Eastern Finland
Ph D Student Antoine Scherer, University of Eastern Finland, Snowchange
Docent Tero Mustonen, Snowchange Cooperative, Finland

Abstract:

This report documents the exact greenhouse gas exchange on a natural boreal forest fire site, reviews the biodiversity impact, and compares the natural fire regime impact to the present boreal forest ecology. Additionally the report discusses the cultural links and reflections of forest fires in the case area of Selkie, North Karelia, Finland.

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MONTPELIER & HAMPSHIRE FOUNDATIONS

Introduction

At the outset of the *"Understanding the New Fire"* (supported by the Montpellier Foundation) the Snowchange research team and associated reseachers wanted to assess and offer a technical report on a recent fire site in the boreal.

We originally focused on Koitajoki river system, a Russian – Finnish borderland catchment, but since the February 2022 war between Russia and Ukraine, this field mission became impossible to achieve.

After consultations with the team in Finland and with the funder the efforts were re-directed to study a recent natural fire site in the boreal forest of Finland, more specifically to Selkie village in North Karelia.

In this report we present the key novel measurements of a forest fire site with a state of the art Trace Gas Analyzer to produce an overview of a pilot site for further understanding of fire.
Additionally we collected a range of links to traditional knowledge and boreal forest fires, which are included to demonstrate that fires have been a part of the life in the boreal – the increased intensity, extent and impacts of these fires are the "new fires" we need to understand around the boreal in order to navigate the future and risks it holds.

Forest Fires in Science: Boreal Regions

Recent studies on forest fires around the world confirm what we have long feared - forest fires are becoming more widespread, and burning twice as much tree cover today, as they did 20 years ago (Tyukavina et al., 2022). The large majority (around 70%) of all fire-related tree cover loss over the past two decades occurred in boreal regions of northern hemisphere (Tyukavina et al., 2022). Increasing fire-related tree cover loss in boreal forests is likely due to the fact that northern high-latitude regions are warming at a faster rate than the rest of the planet (Rantanen et al., 2022).

Forest fires are one of the main natural disturbance types in boreal forests, influencing the ecology, functioning, and biodiversity of these forests. Through combustion, fires release carbon stored in the vegetation and organic matter, and this all can create a positive feedback loop for climate warming (Li et al., 2017). Losses of carbon in fire areas occur both as emissions of main greenhouse gasses (carbon dioxide -CO_2, and methane -CH_4) during the fire and through the post-fire biological processes. Understanding, how changes in fire dynamics influence the carbon dynamics of boreal forests is crucial not only for predicting climate impacts, but also for developing mitigation strategies that support forest resilience.

Generally, boreal forests are carbon sinks, absorbing atmospheric CO_2 through photosynthesis. On the same time boreal upland forest soils are considered as the only major sink for the second most important greenhouse gas, CH_4. From the climate perspective CH_4 is roughly 25 times more powerful at trapping heat in the atmosphere than CO_2, and the atmospheric concentration of CH_4 has been increasing rapidly over recent decades (Ni and Groffman, 2018). Boreal upland forests growing on mineral soils have been considered as one of the major sink for CH_4 (Kuhn et al 2021), but today the scientists have observed big decline in soil CH_4 uptake in the northern hemisphere (Ni and Groffman, 2018).

Forest Fires and Traditional Knowledge: Case of Karelia

The Karelian and Savo-Karelian peoples living in the Eastern Finnish and NW Russian boreal regions are an example of boreal forest culture that has undergone changes and at the same time maintained a cultural continuum with the forest fire regimes. By studying the fires of Karelia we are investigating the cultural links to fire that is rather similar across the boreal through several Indigenous and local communities from the Evenki areas in Eastern Siberia to Finland (Mustonen and Mustonen 2016).

More precisely, after decades, the Selkie fire which is the focus of this report, can be positioned into context. Associated with the record extreme temperatures around the north (CCAG, 2021) a natural forest fire of over 3 hectares happened, around 17th June, 2021. All in all 5,8 hectares burned before the fire was put out by the local emergency services.

Now, compared to the fires in British Columbia (associated with the extreme weather of 49,6 C degrees in Lytton but stretching all the way to Northwest Territories which caused 478,000 hectares of burning as of 30th July 2021, CCAG 2021) or the taiga fires burning in Siberia (1,77 million hectares burning as of 27th July, 2021) the 5,8 hectare fire is very small.

Nevertheless, the context for the June fire in Selkie is the following:

1. It is the first natural lightning-struck fire in the village for decades, due to the industrial forest management, road building and suppression of fires that Finland exercises immediately when the fires happen (avoidance of economic harm to economic forest lots). On the other hand, forest fires are a critical element of natural north boreal forests, where the forest needs to burn occasionally to maintain for example fire beetle species, ecosystem renewal and forest succession in natural forests. It is a natural, and critically important element of northern forests, made now much worse by climate change and extreme temperatures. Backlog of old fires can be witnessed especially on ancient Scot Pine (Pinus sylvestris) stumps and trees in those forests that have them in Finland – acting as ecological and traditional markers of mnemonic memories of what happened and when if a person is immersed in forest reading skills to understand what they see.
2. It was not a stand replacing crown fire, but a surface fire, nevertheless it burned for 4-5 days and was extremely complex to put out by the fire crews.
3. Prior to industrial forestry era (<1940s), fire was respected in the Finnish and Karelian villages, as reflected in the long epic poem “Creation of Fire” (https://fi.wikipedia.org/wiki/Tulen_iskentä) which has been dated back 4000 years. Additional cultural knowledge of fire includes dozens of concepts of fire, the practice of small-scale slash-and-burn lots in the Eastern villages 1000-1920 AD, traditional burns in the forest, and magic and folk lore associated with the lightning strikes and quartz stones that were seen to be the claws of the Kokko thunder bird left behind after a

lightning strike. From here on, I call this the cultural complex of fire for Finnish culture.

4. An Event, as described by Mustonen and Mustonen (2016), is a method of endemic temporal-spatial evaluation in the Indigenous and traditional societies of Eurasia (northern Eurasian continent including tundra and taiga ecosystems) to mark time, significance and belonging with the cosmos. Events are most often non-linear in character, significant in their cultural contexts and open up in rather complex and nuanced ways where the Event and its recounting (such as the long epic poem "Creation of Fire" for Finns) is always considered *special, unique / meaningful, and first and foremost, from a primary source, i.e. natural / cosmic origins.*
5. Within days the industrial forestry apparatus locally had arrived on site to offer the land owner the purchase price of timber that burned, and means and methods of clearing the burn site away as fast as possible, to make way for a "renewed", i.e. plowed forest floor where the marks, memory and sight of the forest fire would be eroded as quick as possible, to make room for an economic forest lot. This process can be seen to have happened from the evaluation viewpoint of what Uitto calls the market assessment.
6. Lastly, the Landscape Rewilding Programme operating in the village, entered into a complex sets of talks with the landowner, driven by values built on an Event and traditional knowledge, to spare and maintain the site by purchasing the fire site into the Programme for study, learning and preservation. These talks are on-going, including an extremely high price for the lot.

What is then this fire, that came to Selkie, as seen from a cultural viewpoint?

It was a primary Event in nature, for the first time in decades. The reason there is a decadal gap is because human systems, built to safeguard the forests-as-wealth, fear the fire. Yet, in the traditional culture, fire is natural, a friend, ally and a power always to be mindful of and to be respected.

This kind of evaluation that would "allow" natural Events, is marginalized, and instead the pathway of assessment-intepretation-action as seen from the economic power position saw the Event as a a) harmful and perhaps threathening / to be feared, b) put out the fire as fast as possible (using also the extensive forest road network built since 1990s into the forests) and ultimately c) offered the land owner the quick economic compensation-out of mind-out of sight actions of clearcutting and clearing the land to make the (ecological) memory disappear.

Selkie fire Event points to a complex reality. Forest fire continues to be a part of a natural boreal forest. Arguments could be made that they should be allowed to burn. Vulnerability in evaluation – how much of that is fear in evolving away from living-within-natural-systems -knowledge?

And yet nobody denies the vulnerable character of the global system today – economy, peoples lives, houses, living areas are subject to forces that in concrete terms threaten them. Perhaps the dual entity of the Selkie Fire Event shows a compass – understanding a fire overall is a nuanced and important process as was reflected in the cultural complex of fire for Finnish culture that is for the most part, replaced with the forests-as-economic-resource -knowledge. This second variant sees the vulnerability (to the primary owner, and to the surrounding forest owners) where the fire is a fear, a threat and ultimately, an enemy, to be put out.

The boreal forest species desperately need the fire. Over 40 insect species need the forest fires (Yle 2020), and from there the food chains all the way to the Eurasian Brown Bear utilize and benefit from the natural burned areas. Names of these insects reflect their interdependence on the forest fires:

- kaskikeiju, (Phryganophilus ruficollis), in Finnish, ”Fairy of the Slash-and-Burn”
- kulokauniainen, (*Melanophila acuminata*), ”Forest Fire Beauty”
- palojahkiainen, (Sphaeriestes stockmanni), ”Burn waiter”
- sysipimikkä, (Upis ceramboide), ”Pitch dark”
- tuhkalatikka, (*Aradus laeviusculus*), ”Lice of the Ash”
- kulokaarnakuoriainen, (*Orthotomicus suturalis*), ”Beetle of the Forest Burn”
- nahkuri, (*Tragosoma depsarium*), ”Leather worker”
- suutari, (*Monochamus sutor*), ”Shoemaker”
- Mustajäärä, (Asemum striatum), ”Black beetle”

(From Yle 2020, draft English translations by the author)

Burned stump on the fire site, 2021. Photo: Snowchange

By investigating the names of these insects, and even if allowing the influences of the modern taxonomy, we can see both the critically endangered role these fire dependent species have and the rich role they may have played in the the cultural complex of fire for Finnish culture.

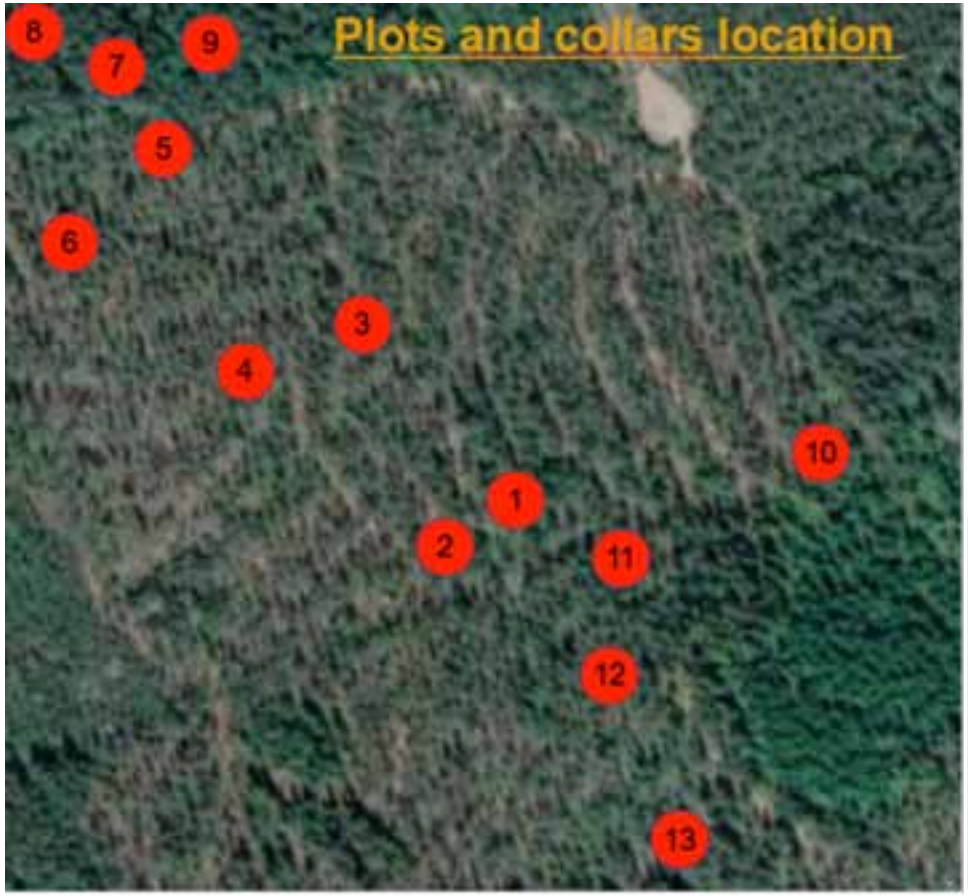
So, by naming, knowing and respecting the fire and its associated species during the cultural complex of fire for Finnish culture, communities may have been in an aware position and in good relations with the fires. Today, based on evaluation of seeing the impact and Event only as a harmful, the natural fire, forest and the species do not have a space or time to cope.

In a fantasy world of uninterrupted cultural complex of fire for Finnish culture, the fire site would be respected, potentially limited if it came too close to critically important village houses for example but in most cases (it was appr. 5 kilometers from a nearest house in modern village) it would have been allowed to burn.

The return of primary and first succession species into the forest site, such as forest strawberries and forest raspberries would have been harvested by the people and also the site would be serving as an important feeding area of boreal ruminants, such as the moose and the forest reindeer (rangifer, now extinct from Selkie due to overhunting). Certain religious objects and wooden materials would be collected from the site, given that this was the site of where Kokko, the Finnish thunder bird, manifested its lightning claws – people would be searching for a quartz stone, one of the splintered pieces of Kokko’s claw. And lastly, people would gather and pass on and sing the “Creation of Fire” song to honor the powers, the weather and the Kokko.

Science Analysis - Study Site, Materials and Methods

- Study sites are located in Selkie, Finland (N 62.66911 E 30.166692), where the fire occurred on approximately 5 hectares in summer of 2021.
- In spring of 2022, we established 13 sample plots (400m^2 circular sample plots) on the burned (B) area and on unburned control areas (U). Sample plots were placed to the top of the hill (Top), to the slope of the hill (Mid) and to the lower part of the hill (Bot) (Figure 1).
- On every sample plot, there was two permanent collars (h=0.09m and Ø=0.31m) installed (placed couple of centimetres into the soil) for total soil CO_2 and CH_4 flux measurements. On some unburned areas also deeper collars (h=0.30 m and Ø=0.31m) were used (marked with "C" in Figure 1) to measure soil heterotrophic fluxes (to exclude the plant and plant root fluxes). On these collars also vegetation was removed.
- Soil CO_2 and CH_4 fluxes were measured with three weeks interval, with portable Trace Gas Analyzer (LI-7810 CH_4/CO_2/H_2O, Li-Cor Biosciences, USA) and with portable dark chambers (h=0.15 m and Ø=0.31m). During the greenhouse gas measurements soil temperature (OMET Multi-Logger temperature probe) and soil moisture (ThetaProbe ML3, Delta-T Devices Ltd., Cambridge, UK) were monitored next to each measurement collar.
- From each sample plot, three soil cores (h=0.5 m and Ø=0.05 m) for soil chemical analyses were taken in June using a soil corer. The soil cores were divided into litter and organic layer (F-horizon) and humus layers (O-horizon) according to the morphology of soil horizons,



Plot	Collar
1 (TopB)	1-2
2 (TopB)	3-4
3 (MidB	5-6
4 (MidB)	7-8
5 (BotB)	9-10
6 (BotB)	11-12
7 (BotU)	13-14-15C
8 (BotU)	16-17-18C
9 (BotU)	19-20-21C
10 (MidU)	22-23C-24
11 (TopU)	25-26C-27
12 (TopU)	28-29
13 (MidU)	30-31

Figure 1. Location of the study areas (Top=Top of the hill, Mid=Slope of the hill, Bot=Bottom/lower part of the hill, B=Burnt areas, U=Unburnt areas), and greenhouse gas measurement collars in different study areas. "C" represents the collar for heterotrophic flux measurements.

and the mineral layers into eluvial (A-horizon) and illuvial (B-horizon) layers. Samples were dried in an oven at 60 °C for 48 hours (till constant mass was achieved), and sieved through a 2-mm sieve and ground with a ball mill (Retsch, Han, Germany). At this point prepared soil samples are waiting soil carbon and nitrogen analysis in Biogeochemistry labs of University of Eastern Finland.

- Basic tree characteristics were measured from each circular sample plot for tree biomass calculations (diameter at breast height, tree height, crown length). Tree ages were determined from increment cores taken from sample trees and analysed with WinDENDRO (Regent Instruments Canada Inc., Quebec, Canada). For tree biomass calculations the specific formulas for pine, spruce and birch were used (Repola 2008, Repola 2009). Also, all dead wood (all material longer than 1.3 m and with a diameter of at least 10 cm) was measured in all sample plots for dead wood biomass calculations.
- In every sample plot there were two 0.5 × 0.5 m ground vegetation squares for species composition and recovery measurements and two 0.2 × 0.2 squares for ground vegetation biomass measurements. Ground vegetation was classified into mosses, lichens and shrubs/grasses and oven dried at 60 °C until constant mass was reached.

Rock in the middle of the burn site. Photo: Snowchange

Summary Science Results

Post fire soil greenhouse gas (CO_2 and CH4) fluxes

- Lowest total CO_2 fluxes were measured on all burned plots (marked as BotB, MidB and TopB in Figure 2). This trend as observed through entire measurement period (summer of 2022, one year after fire).
- Through entire measurement period, highest total CO2 fluxes were measured from unburned control plots soil (marked as BotU_ Unclean, MidU_Unclean and TopU_Unclean in Figure 2). The total CO_2 fluxes on these areas showed increasing trend towards the end of the summer.
- Measurement collars, from where the vegetation was removed to detect soil heterotrophic fluxes, CO_2 fluxes were constantly lower than in unburned control plots with vegetation (Figure 2).

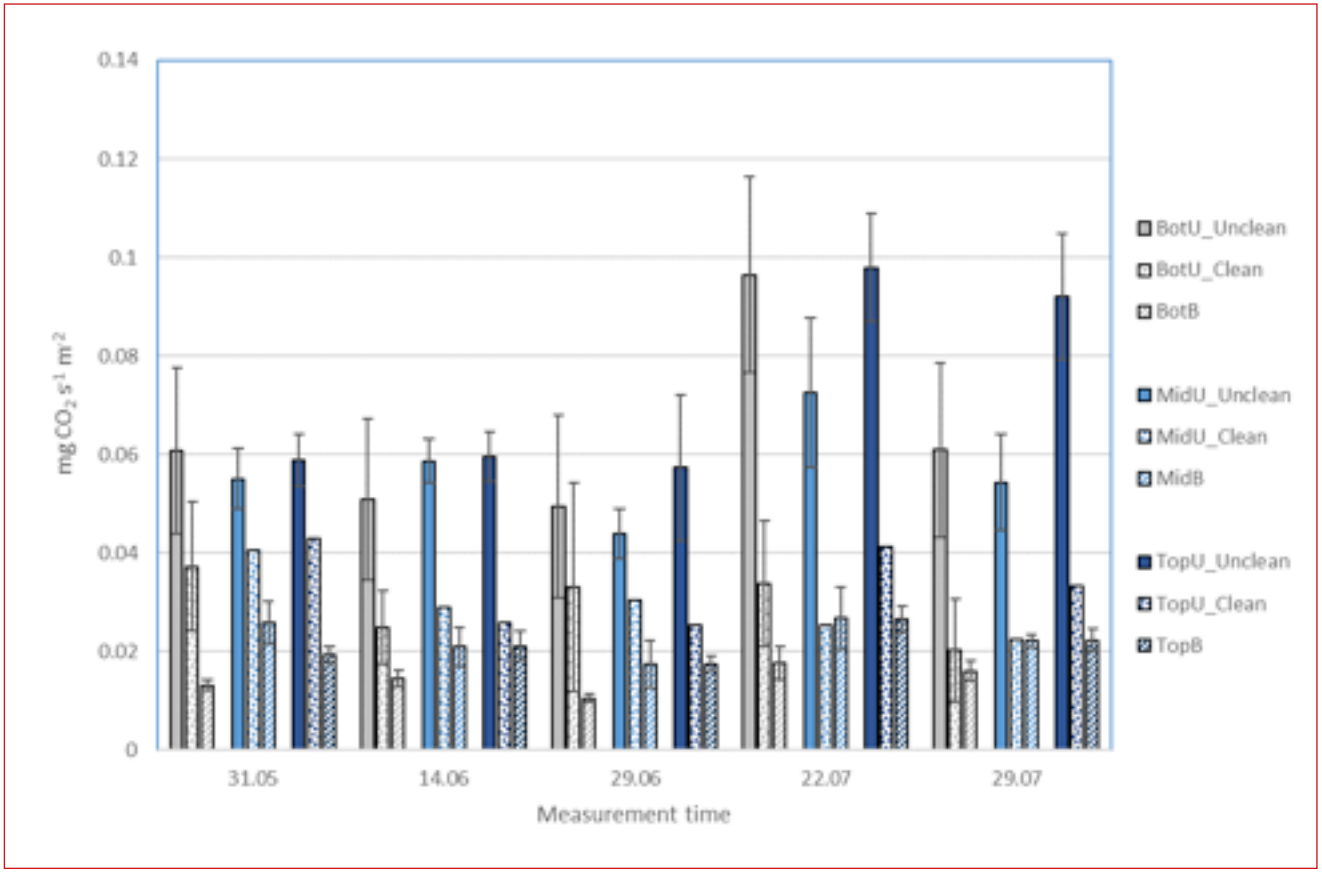


Figure 2. Post-fire CO_2 fluxes from burned (B) and unburned (U) areas from different locations (Top=Top of the hill, Mid=Slope of the hill, Bot=Bottom/ lower part of the hill). "Unclean" represents the collars from unburned control plots where the vegetation remined inside the collar, while "Clean" represents the collars from unburned control plots where vegetation was removed from the collar.

- All the study areas acted as a sink for CH_4, and the soil CH_4 uptake was strongly affected by fire, as the uptake was smallest in burned areas (Figure 3).
- There was no difference in soil CH_4 uptake in sample areas located in bottom/lower part of the hill while unburned control plots with vegetation and unburned control plots without vegetation were compared (Figure 3).
- Sample areas on top of the hill, showed in general bigger soil CH_4 uptake, and on these areas the uptake on unburned plots from where the vegetation was removed was the highest (Figure 3).

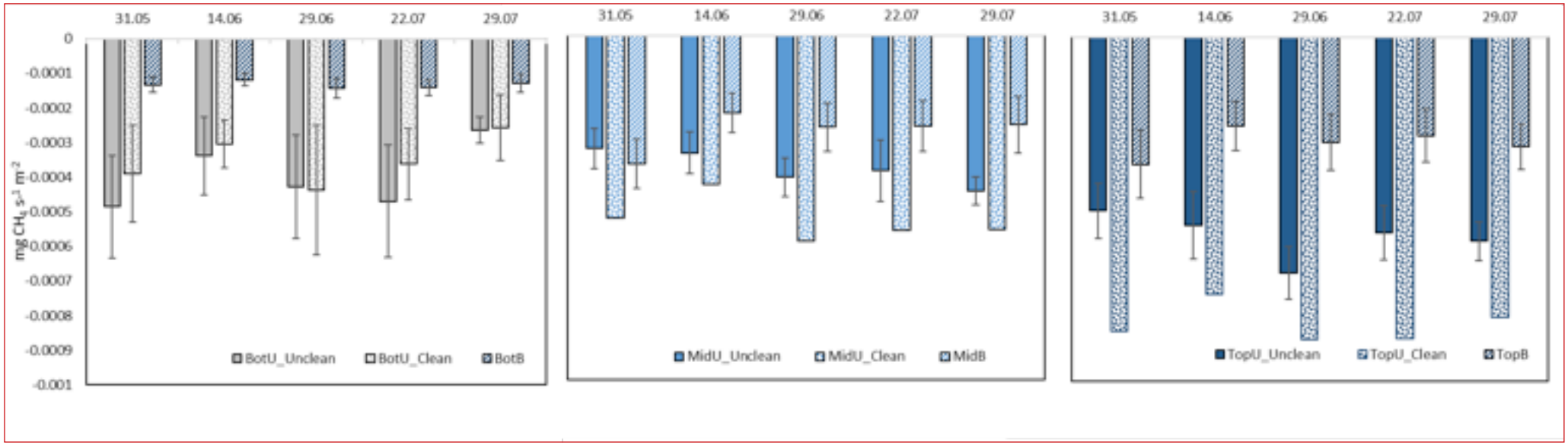


Figure 3. Post-fire CH4 fluxes from burned (B) and unburned (U) areas from different locations (Top=Top of the hill, Mid=Slope of the hill, Bot=Bottom/lower part of the hill). "Unclean" represents the collars from unburned control plots where the vegetation remined inside the collar, while "Clean" represents the collars from unburned control plots where vegetation was removed from the collar.

Biodiversity Impact

- Fourteen months after the fire, the amount (percentage) of standing dead trees really depended on the location of the sample area. On bottom/lower part of the hill the amount of dead trees was 27% from all the trees, while on slope of the hill the amount was 52% and on top of the hill the amount was 68% from all the trees.

Discussion: Role of Natural Fires in the Context of GHG Fluxes and Boreal Ecology

This study focused on non-stand replacing surface fire in boreal Scots pine forests that might affect carbon cycling and storage over large spatial scales and long time periods. More than 70% of the fires in Eurasia are non-stand replacing surface fires (Shorohova et al., 2009), indicating that intermediate-severity fires are dominant in the area. Fire intensity (the released energy, flame length, rate of spread) is considered to be one of the most important fire-related characteristics, and it affects the pattern of the above- and belowground biomass recovery, community dynamics and soil processes (Ruokolainen and Salo 2009).

The post-fire mortality of the trees in this study really depended on the location. Entire study area is located on hill (covering the top of the hill, slope and the low/bottom part of the hill), and this has also effect on soil properties – lower parts are more moist and the soil organic horizon is thicker there. Probably, due to this, also the tree root system is different (compared to more dryer top and slope parts), and the fire has not been damaging the pine trees there so much.

In previous studies from Scots pine forests it has been found that the soil CO_2 efflux is lower in recently burned areas and higher in the areas where more time has elapsed since the last fire (Köster et al., 2015, Köster et al., 2016). Similarly, this study revealed that soil respiration was lowest in burned areas, compared to unburned control plots. This trend can exist for 3–10 years before the soil CO_2 efflux recovers to the pre-fire level (Ribeiro-Kumara 2020), and the main factors affecting it are the vegetation type, vegetation coverage and post-fire biomass recovery, which contribute to the formation of new soil organic matter.

The biggest decline in post-fire soil CO_2 fluxes, is due to the loss of vegetation during the fire. While measuring total CO_2 fluxes (with dark chamber), we are measuring both heterotrophic respiration (CO2 originating from decomposition of litter detritus and soil organic matter by microorganisms) and autotrophic respiration (originated from the respiration of roots) from the soil. The proportions of autotrophic respiration within total respiration can be around to 50%, but during the fire, while the vegetation is killed, we will lose the autotrophic respiration, and it will take some time before the vegetation and their root respiration recovers. Similar trend, decrease in soil CO_2 flux, we can also see while measuring the CO_2 fluxes rom collars located on unburned control plots from where the vegetation was removed and the root system was cut through.

Our results also clearly showed that fire has a significant impact on the CH4 flux between forest soils and the atmosphere, as CH_4 uptake one year after fire was significantly lower compared to unburned control plots. Some earlier studies have observed some slight increase in soil CH_4 uptake within some years after fire (Köster et al., 2015, Ribeiro-Kumara et al., 2020), but this was not clearly the case in Selkie study site.

In forest soils the fluxes of CH_4 result from two microbial processes, methanogenesis and methanotrophy (Megonigal and Guenther 2008). When soils are wet and anaerobic, methanogenic bacteria produce CH_4, while under aerobic soil conditions, methanotrophs (bacteria) oxidize atmospheric and in situ produced CH_4. Some recent studies suggest that increases in fire severity and frequency threaten current boreal forest CH4 sinks (McNamara et al., 2015).

At the same time some other studies have shown that soon after fire disturbance (within a couple of years after fire) the burned areas could be a bigger sink for CH_4 (soils CH_4 uptake increases) (Köster et al., 2015; Köster et al., 2018; Ribeiro-Kumara et al., 2020) compared to unburned/pre-fire conditions. Post-fire differences in CH_4 uptake can be caused by the pyrogenic matter (charred plant material and charcoal)

that is produced during incomplete combustion.

Post-fire darker soil surface is increasing the soil temperature, and decreases soil moisture content, and this might cause higher CH_4 uptake by soils. Also, current study showed that on top of the hill (drier part) the CH_4 uptake rates were slightly bigger compared to the lower part of the hill. On the other hand, there are also evidence that fire affects soil microbiome (fungi, bacteria, microbes) (Köster et al 2021) that can have an effect on soil CH_4 oxidation - fire can damage/kill the soil microbiome, but also to creates habitat for certain fire dependent species. For today we also know that vegetation can be both sink and source for CH_4 and depending on species composition the vegetation can emit/take in CH_4 (Lenhart et al., 2015).

Concluding Reflections on the Fire From A Traditional Viewpoint

As Mustonen (2014) points out, the surviving and highly critically endangered, sustainable traditional knowledge is all but gone, but is often referred to as 'endemic knowledge' of the Forest Finns, as opposed to Indigenous Knowledge of the Sámi. The Fire would be seen as an Event, especially in the context of absence of a natural fire for decades in Selkie.

None of that matters, given the power position of the economic evaluation and the culture that permeates every corner of how forests are looked at in the Finnish culture today. This shift has been amongst the fastest in the world, where the last forest reindeer, a cultural keystone species of Selkie, was killed only in 1928, and the switch from understanding the forests as the cultural complex of fire/forest for Finnish culture has been amongst the fastest in the world.

To position and think using the Selkie Fire Event again, in some ways with proper information and discussion, a general appreciation could emerge, people could even join in celebrating the "past cultural heritage" of fire and some novel, now already forgotten practices, and thoughts could make a speedy splash in media, in society and in the receptive audiences.

Selkie Fire Event, an endemic spatial-temporal event in a small boreal village in North Karelia was an important for many reasons in the village. Many of us read the Selkie Fire Event using the glasses of extreme events of a future to come (CCAG 2021), linking similar fires in other parts of the boreal from Canada to Siberia, into our small community – and witnessing the first fire in decades, back.

But – there is more to the story. The future is not set. The Fire Event has reawakened thoughts, some of which have been discussed in this paper, of the nuanced, good relations we have had as a culture with the natural fire, for thousands of years, prior to the past century of a collapse of the endemic values of Forest Finns.

But even so, an Event has happened in the village. From a primary source, many have forgotten exists, but for a some of us, reminds, that next time thunder comes around, it is the remembering the *Kokko* bird, flying high, and if you know where to go, you'll find a quartz stone piece – a piece of his talon, as a reminder of what was, is and will be…

Landscape view of the burn site. Photo: Snowchange

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Fire brings new life, and keeps old memories.
Photo: Snowchange