ENVIRONMENTAL RESEARCH
LETTERS

OPEN ACCESS

RECEIVED
11 December 2025

REVISED
8 April 2026

ACCEPTED FOR PUBLICATION
21 April 2026

PUBLISHED
5 May 2026

LETTER

Determinants of wildfire risk in the low Arctic and northern subarctic of Canada

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Keywords: tundra, climate change, fire, fire risk, taiga, fuel conditions, disturbance regimes

Supplementary material for this article is available online

Abstract

Growing evidence suggests that the frequency and intensity of fire is increasing across the tundra biome. A change to tundra fire regimes is concerning because it will impact carbon emissions, permafrost conditions, vegetation, and habitat. In northern Canada little is known about the relative impact of climate and terrain factors on the risk of fire. In this study we used imagery from the Landsat satellite archive to identify and manually digitise the boundaries of tundra and northern taiga fires that burned in northcentral and northwestern Canada between 1985 and 2023. Our mapping shows that the area burned between 2005 and 2023 is higher than the period from 1985 to 2004, largely because the size of individual fires has increased. A random forests analysis using our fire inventory and spatial data on climate and terrain factors indicates that fuel conditions and mean summer temperature (June–September) are key determinants of fire occurrence. Geospatial modelling also suggests that ongoing climate change will increase the frequency of tundra fire and that future risk will be mediated by landscape characteristics.

1. Introduction

Rapid climate warming at high latitudes is profoundly altering natural disturbance regimes. Across the boreal region of North America, the number of fires and the total area burned have already shown rapid growth in response to climate change (Kasischke and Turetsky 2006, Kelly *et al* 2013, Masrur *et al* 2022). North of the latitudinal treeline, where fires are generally smaller and less frequent, there is also growing evidence that both fire frequency and size are increasing (Kasischke and Turetsky 2006, Masrur *et al* 2022, Vachula *et al* 2022). Shifts in the area impacted by tundra fire are concerning because elevated carbon emissions from the combustion of above- and belowground biomass are a significant feedback to the global climate system (Mack *et al* 2011, Jiang *et al* 2017). More widespread tundra fire will also alter ground temperatures, increase the frequency of thermokarst disturbances in areas of ice-rich permafrost (Mackay 1995, Jones *et al* 2015, Chen *et al* 2021c) and modify habitat quality for many wildlife species (Joly *et al* 2012).

Although many tundra ecosystems can burn, differences in fire frequency among regions evident in recent and paleoecological records indicate that there is significant variability in fire susceptibility across the tundra biome (Chipman *et al* 2015, Hu *et al* 2015, Masrur *et al* 2018, 2022, Vachula *et al* 2022). Spatial differences in fire occurrence are likely a function of temperature and precipitation, which affect fuel condition and the likelihood of ignition (Chipman *et al* 2015, French *et al* 2015, Masrur *et al* 2018, Sae-Lim *et al* 2019, Talucci *et al* 2022). In Alaska, tundra fire is rare at summer temperatures below 11 °C and total summer precipitation more than 150 mm (Hu *et al* 2015). The incidence of tundra fire is also linked with the frequency of lightning, which is itself influenced by both temperature and atmospheric CO_2 concentrations (He *et al* 2022). Past studies also suggest that vegetation type and its effects on fuel conditions are important considerations (Higuera et al 2008, Gaglioti et al 2021, Masrur et al 2022).

Previous analyses show that tundra fire regimes in Alaska and Siberia are changing in response to climate warming (Masrur et al 2022, Talucci et al 2022), but similar investigations have not been conducted in northern Canada and little is known about the relative impact of climate and terrain factors on the risk of fire across this vast portion of the tundra biome. In this study we used imagery from the Landsat satellite archive to identify and manually digitise the boundaries of fires that burned between 1985 and 2023 in northcentral and northwestern Canada. Subsequently, we used these data to examine changes in fire frequency and size, to identify the climate conditions and terrain factors associated fire occurrence, and to evaluate fire risk under future climate.

2. Methods

2.1. Study area

This study focuses on the area extending from the northern taiga transition zone to the mainland Arctic coast. This area covers 1.19 million km^2 of the Northwest Territories and southwestern Nunavut (figure 1). Vegetation cover across the study area is diverse and variation is driven by climate, soils, disturbance history, and suite of other biotic and abiotic factors (Payette et al 2001, Ecosystem Classification Group 2008, 2009, 2012, Fraser et al 2014). Near the southern boundary of our study area, upland tundra and open spruce woodland occur in roughly equal proportions. Moving northward across the study area reductions in summer temperature (June–September) are accompanied by the replacement of woodlands with shrub and graminoid tundra.

Although regional conditions vary across this vast area, long cold winters and short temperate summers are ubiquitous. The annual mean air temperature at stations where climate normals have been calculated (ECCC 2025) ranges from −7 to −14.4 °C. Mean July and January temperatures across the study area range from 6.9 to 14.2 °C, and −23.9 to −33.9 °C, respectively. Annual precipitation across the study area is relatively low, ranging from 209 to 318 mm at stations where climate normals have been calculated (ECCC 2025), with slightly higher precipitation falling in the eastern portion of the study area. The study area is located within the continuous permafrost zone and thermokarst features including thaw slumps, ice wedge polygons, and thermokarst lakes are common landforms (Kokelj et al 2023). Previous analysis of climate data across these regions shows that annual mean air temperature has increased three times faster than the global average (Vincent et al 2015). Summer and winter precipitation have also increased across the study area (Vincent et al 2015, Bush and Lemmen 2019).

2.2. Wildfire mapping

To inventory tundra fires, we took an approach similar to Talucci et al (2022) and used Google Earth Engine to detect wildfires that burned between 1985 and 2023 by calculating the differenced normalized burn ratio (dNBR) using the Landsat satellite archive (supplemental table 1). dNBR is a measure of fire severity that is calculated by subtracting the NBR in the year before a wildfire from the year after a wildfire (Key and Benson 2006). NBR makes use of the strong contrast between near infrared and short-wave infrared reflectance from burned and unburned surfaces, and is calculated as:

$$\mathrm{NBR} = \frac{\mathrm{NIR} - \mathrm{SWIR}}{\mathrm{NIR} + \mathrm{SWIR}}. \tag{1}$$

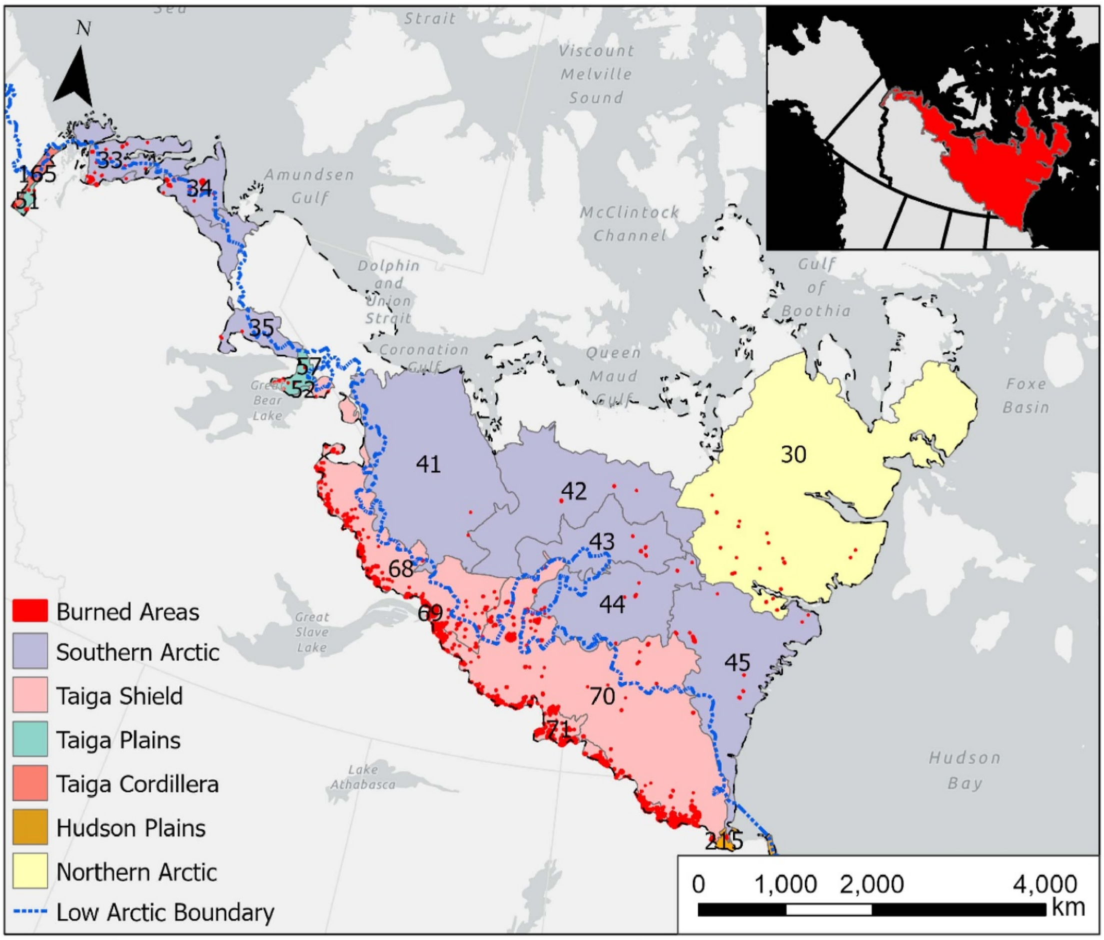
In this study we calculated dNBR for a given year using NBR calculated using imagery one year before and one year after the year of interest:

$$\mathrm{dNBR}_{t1} = \mathrm{NBR}_{t1-1} - \mathrm{NBR}_{t1+1}. \tag{2}$$

Visualizing this index using a rolling window and three burn severity classes (low/unburned: dNBR $<$ 0.2; moderate: dNBR 0.2–0.4; severe: dNBR $>$ 0.4) provided a straightforward and effective way to systematically search for tundra fires, which can be less than 0.02 km^2, using imagery that was sometimes affected by clouds and cloud shadow. After fires were identified using dNBR, their perimeters were manually digitized for analysis. To assess changes in northern fire regimes we focussed on an area that extended from the northern taiga forest to the Arctic Ocean (figure 1). The national burned area composite partly overlaps with this area, but focusses primarily on forested regions, and does not provide comprehensive coverage of tundra ecosystems (Hall et al 2020, Hethcoat et al 2024). Additional details about this workflow are provided in the supplementary materials.

2.3. Data analysis

We used the fire inventory data obtained from manual mapping to explore changes in fire regimes and evaluate spatial patterns of fire occurrence across the study area. These analyses included fire data from 1985 to 2023 (n = 474). To parameterise a random forests (RF) model of fire occurrence, we used a subset of this data including fires from 1985 to 2017 (n = 389). This subset corresponds to climate data available from the Met1km product (Zhang et al 2020). To explore changes in the area burned and the size of individual fires we plotted fire size histograms from: (1) 1985–2004 and (2) 2005–2023. For this analysis we divided the study area into two zones:



30	Wager Bay Plateau	51	Peel River Plateau
33	Tuktoyaktuk Coastal Plain	52	Great Bear Lake Plain
34	Anderson River Plain	57	Grandin Plains
35	Dease Arm Plain	68	Coppermine River Upland
41	Takijuq Lake Upland	69	Tazin Lake Upland
42	Garry Lake Lowland	70	Kazan River Upland
43	Back River Plain	71	Selwyn Lake Upland
44	Dubawnt Lake Plain/Upland	165	British-Richardson Mountains
45	Maguse River Upland	215	Coastal Hudson Bay Lowland

Figure 1. Study area in the Northwest Territories and western Nunavut with the fires inventoried for this study shown in red. The dashed blue line shows the boundary of the low Arctic mapped by Timoney *et al* (1992). See table 1 for details on area burned and fire rotation period in each ecoregion. The red area in the inset at the upper right shows the coloured portion of the main map. Ecoregions within the study area are delineated with grey lines and numbers based on Agriculture and Agri-Food Canada (2013). Sources for the basemap layer include: Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community.

(1) tundra and (2) northern taiga. The tundra zone (924 510 km^2) extended from Timoney *et al's* (1992) low Arctic boundary to the mainland Arctic coast (figure 1). The northern taiga zone (264 348 km^2) extended from the low Arctic boundary south to Timoney's line denoting approximately equal areal coverage of woodland and tundra (figure 1). To test the hypothesis that mean fire size was greater from 2005 to 2023 than 1985–2004 we performed a one-sided t-test in each zone assuming unequal variance (R Core Team 2022). To explore spatial patterns in the area burned across the study area, we calculated the total area burned within a 10 km by 10 km grid. This data was then used to perform a logistic regression (family = binomial; link = logit) that modelled the odds (p/q) of fire occurrence as a function mean summer air temperature (R Core Team 2022). Following (Talucci *et al* 2022), we also estimated the fire rotation period in each ecoregion by dividing the study period (38 years) by the

Table 1. Explanatory variables used in random forests modelling and their spatial resolution. Summer climate averages were calculated using data from June to September. Digital elevation model is abbreviated as DEM.

Variable	Units	Source resolution	Source
Average summer temperature	°C	0.5 arcminutes	(Zhang *et al* 2020)
Average summer precipitation	mm	"	"
Average summer wind speed	m s^{-1}	"	"
Average summer relative humidity	%	"	"
Future climate (see above)	*See above*	"	"
Solar radiation (March and July)	kJ · m^{-2} d^{-1}	"	(Fick and Hijmans 2017)
Frequency of summer lightning	#strikes—mean monthly	5 arcminutes	(Kaplan and Lau 2022)
Ecoregion	Categorical	1:5000 000–1:2000 000	Agriculture and Agri-Food Canada 2013
Surficial geology	Categorical		(Fulton 1989)
Land cover	Categorical	30 m	(Latifovic *et al* 2017)
Elevation (DEM)	Metres	90 m	(Farr *et al* 2007)
Slope	Degrees	"	*Derivative of DEM*
Aspect	Cardinal Direction	"	"
Topographic position	Index	"	"

proportion of the ecoregion burned in that time period.

We trained a RF classification model to investigate the drivers of wildfire occurrence (i.e. presence/absence) using fire data from 1985 to 2017 and reserved fire data from 2018 to 2023 as an independent testing set (supplemental table 4). RF models are ensemble machine-learning models that generate many regression or classification trees by repeatedly subsetting available data to increase predictive capability while reducing overfitting (Breiman 2001, De'ath 2007). We used the RF package (Liaw and Wiener 2002) to analyse our data, growing a forest with 500 trees. Our RF analysis focused on the entire study area, because results were similar when we performed the same analysis separately for tundra and northern taiga zones (supplementary figures 1 and 2). We also used out-of-bag (OOB) predictions to estimate the accuracy of our model. OOB error is a cross-validation metric that evaluates the accuracy of each decision tree against the subset of data that is randomly withheld during training, providing a robust, unbiased estimate of how well the model classifies unseen data, referred to as generalisation error (see: supplemental table 4).

The data used in our analysis consisted of digitized fires that burned from 1987 to 2017 ($n = 381$) and a random sample of unburned locations ($n = 1070$). To ensure that the unburned locations were unlikely to be influenced by factors contributing to observed fires, we created a 1 km buffer around the perimeters of each fire and selected points outside this buffer, not overlapping with water. Climate and terrain variables at each burned and unburned location were characterised by taking the average of each variable inside the burned area and inside a circular buffer around each unburned point equal to the average fire size in the training dataset (8.4 km^2). Categorical variables were treated similarly, where the modal value of the variable within the fire perimeter (or unburned buffer area) was used to characterise the conditions. The variables used in the RF model are summarised in table 1 and described in more detail in the supplementary materials.

We assessed the relative influence of each variable in the model of wildfire occurrence by calculating the mean decrease in model accuracy upon removal of that variable, scaled to the standard error across all permutations (Liaw and Wiener 2002). To assess how individual variables influenced the probability of wildfire occurrence we plotted the partial dependence of the three variables with the greatest influence on model accuracy (ecoregion, land cover, and average summer temperature) using the *pdp* package in *R* (Greenwell 2017) to create partial dependence plots. These plots show the log-odds of an area being burned across the range of a given variable, while keeping other variables constant, with values greater than 0 indicating a higher relative likelihood that an area will experience a burn.

We used the predict function in the RF package (Liaw and Wiener 2002) to estimate a fire favourability index across the entire study area. Spatial predictions were generated across the study area by calculating the proportion of decision trees within the RF model that voted for the 'burned' class.

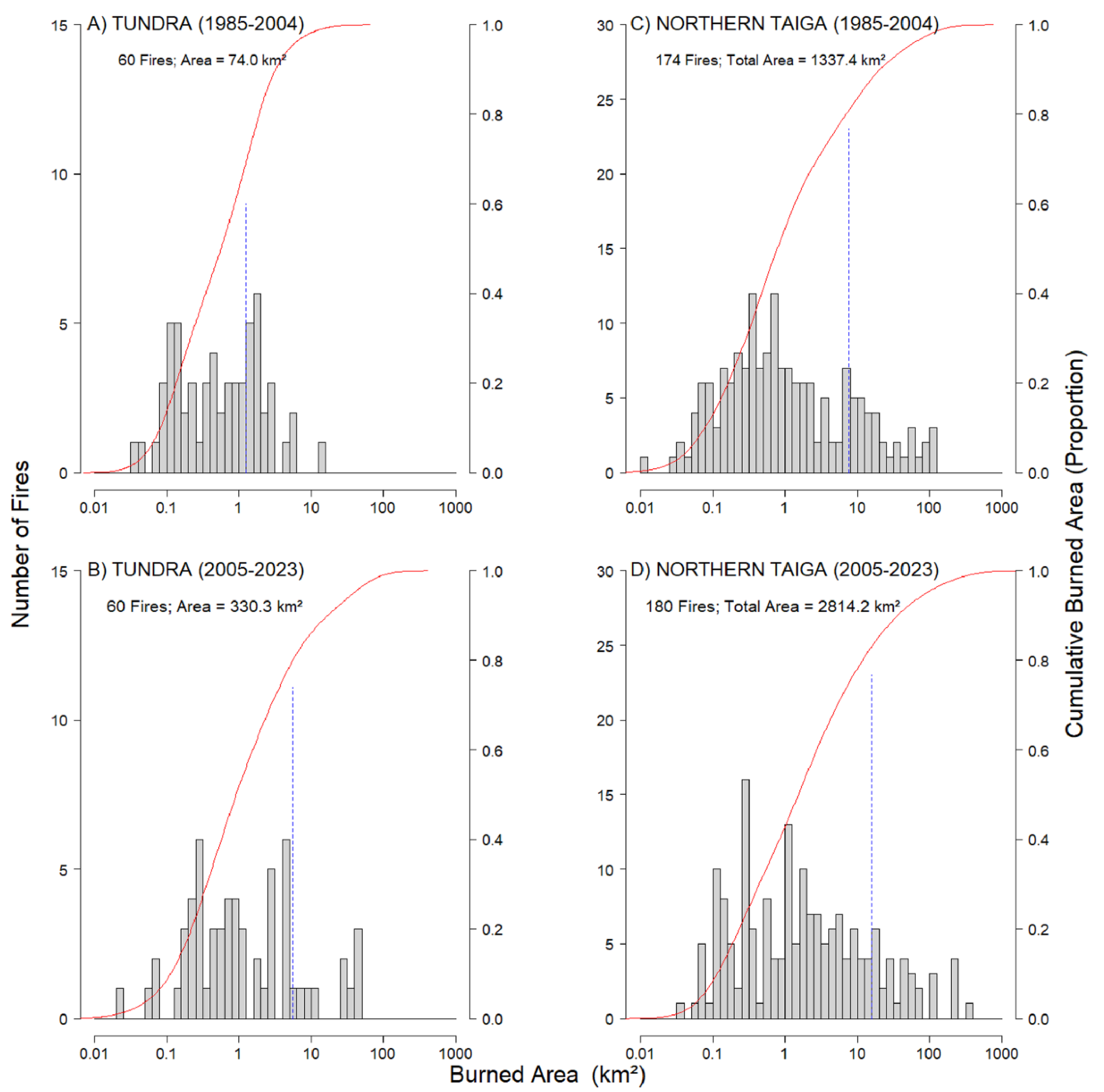


Figure 2. Histograms showing the size distribution of mapped fires from (A) 1985–2004 and (B) 2005–2023 for the tundra zone and (C) 1985–2004 and (D) 2005–2023 for the northern taiga zone. The red line on each figure indicates the cumulative distribution of burned area. The dotted vertical lines indicate the average burned area.

These continuous values, ranging from 0 to 1, reflect the model's confidence in classifying a given cell as burned based on its environmental covariates. We also created fire favourability indices under future climates using the predict function to estimate relative susceptibility of the landscape to burn under projected future climates. Specifically, we used climate data (temperature, precipitation, wind speed and relative humidity) under emission scenarios which capture a range of climate futures (RCP 4.5 and 8.5). These data were obtained from the Canadian regional climate model.

3. Results

Mapping in the tundra portion of our study area documented 120 fires between 1985 and 2023. Although there were the same number of fires in this area from 1985 to 2004 and from 2005 to 2023, the total area burned was four times higher from 2005 to 2023 (figures 2(A) and (B)). This change was associated with an increase in the number of fires greater than 10 km^2 and a significant increase in mean fire size of approximately 4 km^2 between these time periods (figures 2(A) and (B), $t_{62} = 2.8$, $p < 0.01$). The highest density of tundra fires was located in the Tuktoyaktuk Coastal Plain and Anderson River Plain ecoregions, which had fire rotation periods of 1323 and 7308 years, respectively (table 2). Other ecoregions located in the southern Arctic had less than 0.1% of their total area burned and had fire rotation periods greater than 60 000 years (table 2).

In the northern taiga zone, we mapped significantly more fires than in the tundra zone (354 vs 119). Taiga fires were larger and covered more than 10 times the area of fires in the tundra, despite the smaller total area of the northern taiga zone (figure 1). The total area burned in this zone increased from 1337 km^2

Table 2. Fire characteristics organised by ecozone and ecoregion.

Ecozone	Ecoregion	Fire rotation period (years)	Average fire size (km^2)	Cumulative area burned (km^2)
Southern Arctic	Anderson River Plain	7308	40.5	607
	Back River Plain	160 093	10.6	42
	Dease Arm Plain	924 957	1.5	6
	Dubawnt Lake Plain/Upland	64 965	9.7	126
	Garry Lake Lowland	454 045	11.6	35
	Maguse River Upland	61 537	16.0	176
	Takijuq Lake Upland	1193 356	3.0	18
	Tuktoyaktuk Coastal Plain	1323	173.0	3287
Taiga Shield	Coppermine River Upland	1106	59.9	8809
	Selwyn Lake Upland	315	45.7	3474
	Kazan River Upland	2375	47.5	9364
Taiga Plains	Grandin Plains	10 919	9.8	98
	Peel River Plateau	723	55.5	555
	Great Bear Lake Plain	953	35.5	36
Taiga Cordillera	British-Richardson Mountains	45 862	9.1	18
Northern Arctic	Wager Bay Plateau	602 694	3.9	78
Hudson Plains	Coastal Hudson Bay Lowland	10 771	8.3	25

from 1985–2004 to 2814 km^2 from 2005–2023. This change was driven by an increase in the number of fires between 1 and 10 km^2, and a significant increase in mean fire size from 7.7 km^2 to 15.6 km^2 (figures 2(C) and (D), $t_{244} = 2.1$, $p < 0.05$). Many of the fires in the northern taiga zone were clustered in the Taiga Plain and Taiga Shield, including the Selwyn Lake, Peel River Plateau, and Great Bear lake Plain Ecoregions, where the fire rotation periods were 315, 723, and 953 years, respectively. In other subarctic ecoregions, the cumulative area burned made up a smaller portion of the total area, and the fire rotation periods were greater than 1000 years (table 2). The logistic regression of the proportion of each grid cell burned against mean July temperature ($ß = 0.857$, $t = 6.98$, $p < 0.001$) shows that burned area exhibits a non-linear increase when July temperature exceeds 11.5 °C (figure 3(A)).

The RF model we used to assess the influence of climate and terrain factors on the occurrence of northern wildfire performed well with an OOB error of 17%. The RF model correctly classified burned and unburned areas with 83% and 82% accuracy based on OOB and independent testing data, respectively (supplemental table 4). Estimates of omission error for burned and unburned areas ranged from 10% to 28%, and estimates of commission error ranged from 14% to 22% (supplemental table 4). The six variables with the greatest importance were: land cover, ecoregion, summer temperature, wind speed, relative humidity, and lightning frequency (figure 4). The model trained using only fires in tundra zone (or northern taiga zone) shared the same top six (or four) variables as the model trained using data from both zones although the rank of the variables was slightly different (figure 4, supplemental figures 1 and 2).

Partial dependence plots of the top three variables showed that elevated summer temperature and more complex vegetation structure were positively associated with fire occurrence (figure 5). Land cover types with an increased probability of wildfire included shrublands, mixed forest, and grassland (figure 5). Ecoregions included in this analysis that showed the highest probabilities of wildfire occurrence included Anderson River Plain, Tuktoyaktuk Coastal Plain, Coppermine River Upland, Kazan River Upland, and the British Richardson Mountains. Plotting the training data used to build the RF model by mean summer air temperature and total summer precipitation shows that large fires were distributed across the range of precipitation conditions but largely restricted to the domain above 10 °C (figure 3(B)). Fire favourability indices across our study area generated using climate data from RCP 4.5 and 8.5 (figure 6) indicate that future climate change will result in a northward progression of wildfire risk, with predictions in both scenarios of greater than 50% probability across the majority of our study area by 2090.

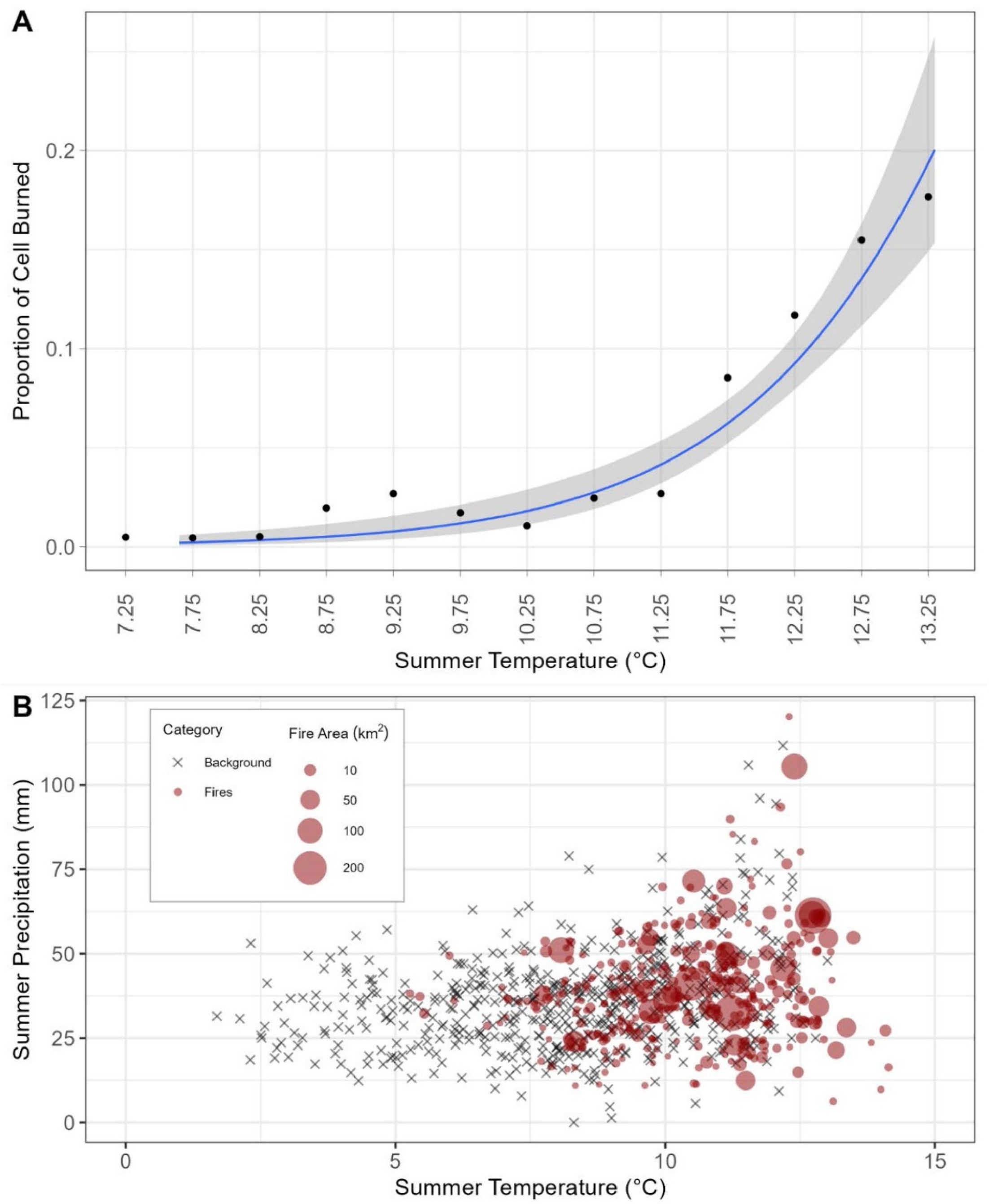


Figure 3. Relationships between climate and the area impacted by fire and fire size. Figure 3(A) shows a generalised linear model of the proportion of each 10 km × 10 km cell burned as a function of the mean summer air temperature (June–August). Data are binned in 0.5 °C increments. Figure 3(B) shows mean summer air temperature (June–August) and mean summer precipitation (June–August) at fires mapped in this study (red circles) compared with the random control locations used in the random forests model (grey xes).

4. Discussion

Our analysis indicates that climate warming will continue to increase the area of tundra and northern taiga affected by wildfire. We document an increase in burned area in both tundra and taiga over the last two decades that coincides with rapid summer warming (Travers-Smith and Lantz 2020, Rantanen *et al* 2022) and a spatial increase in the total area burned with warmer summer temperatures. This conclusion is also supported by our RF model, which shows that elevated summer temperature is strongly associated with fire occurrence. This model had a generalization OOB error of 17%, which is consistent with other RF analyses of wildfire susceptibility (Pourtaghi *et al* 2016) and other regional ecological changes (Chen *et al* 2021a). Our findings are also consistent with research in Alaska and Siberia showing that warmer and drier conditions are important determinants of tundra fire occurrence (Masrur *et al* 2018, Talucci *et al* 2022, Vachula *et al* 2022, Kharuk *et al* 2023).

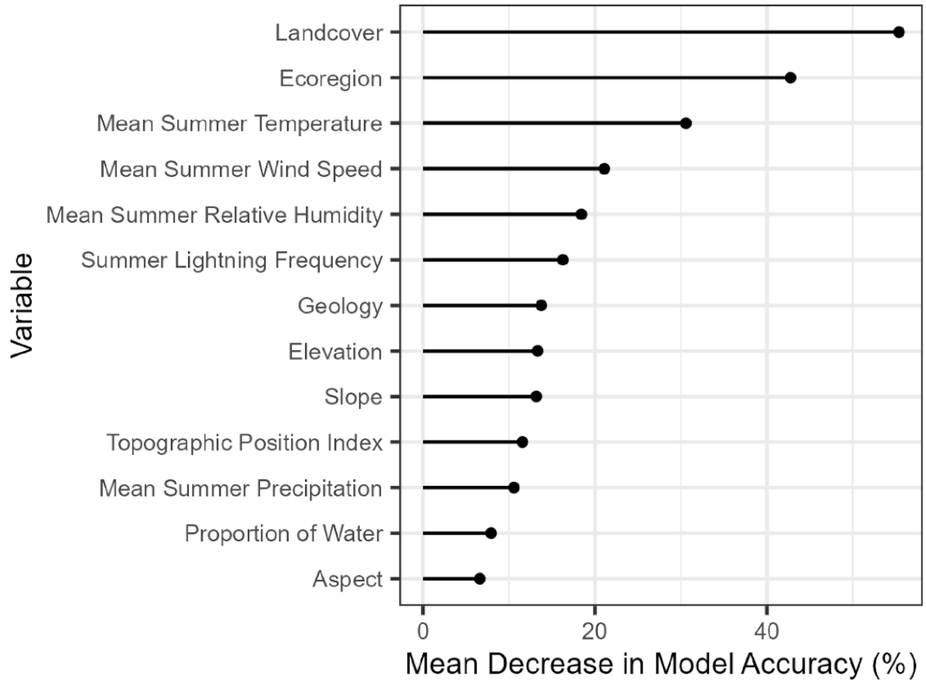


Figure 4. Variable importance plot showing the mean decrease in model accuracy when a given variable is removed from the random forests model. Higher values in mean decrease of model accuracy correspond to variables with greater predictive capabilities to determine presence of wildfire activity.

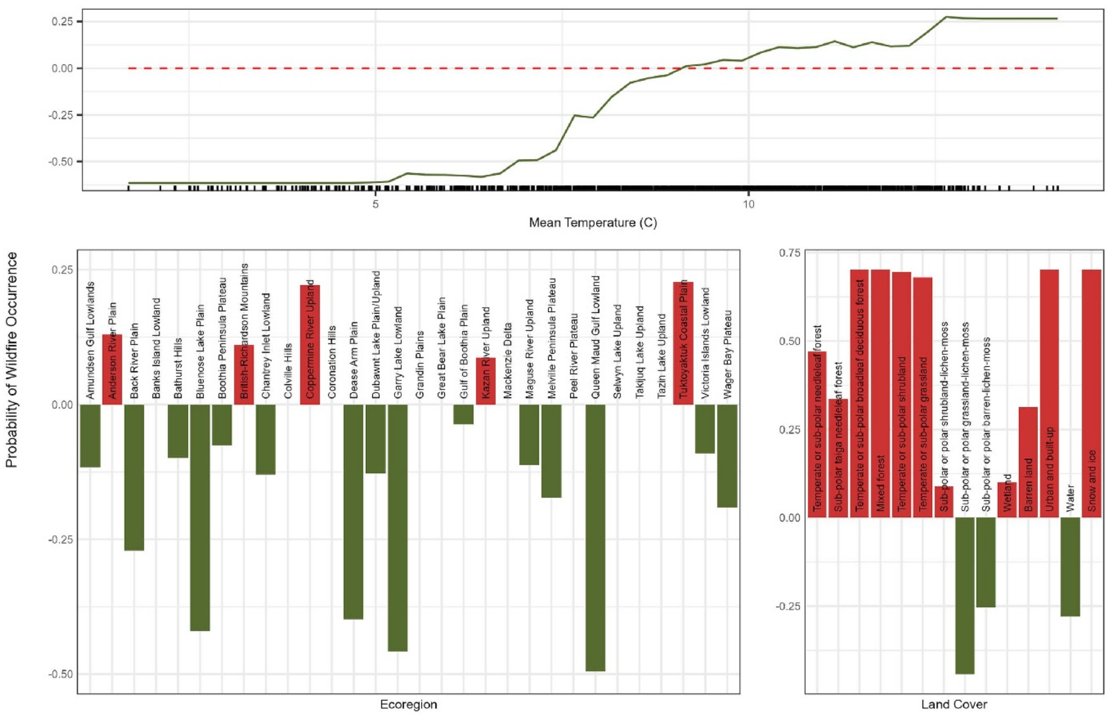


Figure 5. Partial dependence plots of three variables from variable importance analysis. Y-axis represents the probability of occurrence of wildfire for each variable, keeping all others constant.

Our analysis also suggests that fuel conditions are an important determinant of northern fire. Although we did not model fuel condition explicitly, increases in the density and likelihood of fire in the ecoregions with the most abundant woody vegetation indicate that fuels are vital to fire initiation and spread. This conclusion is aligned with research in Alaska showing that tundra landscape positions dominated by shrubs tend to have higher fire occurrence (Masrur *et al* 2022). Fine-scale research on tundra fires in Siberia also shows that more productive tundra vegetation is associated

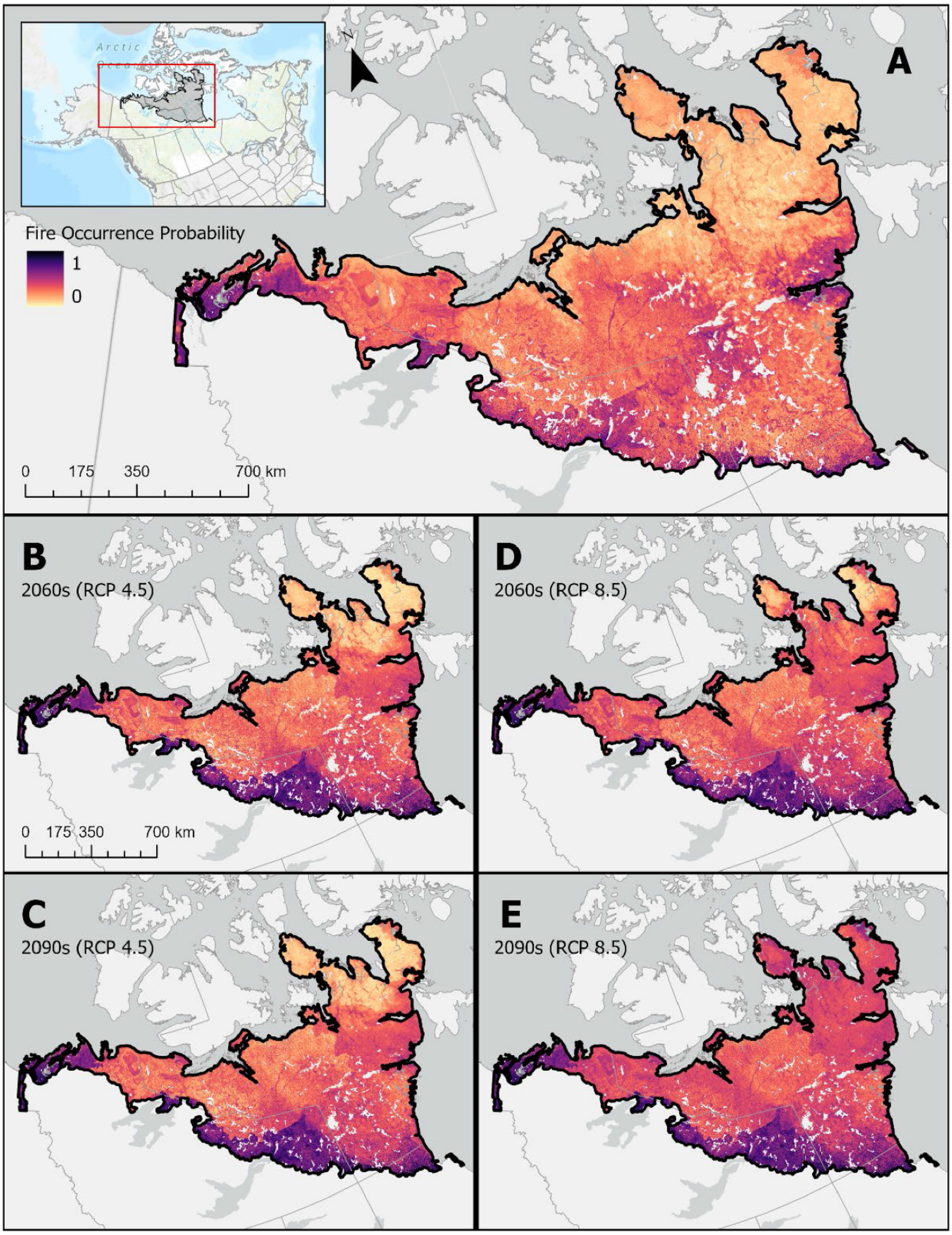


Figure 6. Wildfire favourability across the study area from 1984 to 2017 (A) and future wildfire favourability using climate projections for the 2060s and 2090s (B)–(E). (B) and (C) show fire favourability indices based on RCP 4.5 and (D) and (E) show fire favourability indices based on RCP 8.5.

with increased burned vegetation fraction (Rietze *et al* 2025).

Paleoecological studies show that the strength of the relationship between fuels and historical fire varies with temporal scale. Research focussed on millennial timescales shows a strong relationship between the abundance of upright shrubs and fire frequency (Higuera *et al* 2011). However, on centennial scales, variation in charcoal records is only weakly associated with shrub abundance (Vachula *et al* 2022). Taken together this highlights the importance of fuel, but points to the need for additional research on fuel condition and rates and trajectories of post-fire vegetation recovery (Gaglioti *et al* 2021, Masrur *et al* 2022, Chen and Lantz 2024, Rietze *et al* 2025).

Our finding that topographic position index is comparatively less important than land cover and climate is likely related to the scale of our RF model, which focussed on the presence or absence of fires based on average conditions within burn scars. Previous research at finer scales in tundra (Rietze *et al* 2025) and northern taiga (Talucci *et al* 2022) indicates that variation in topography and its influence on soil moisture are important controls of patterns in burned area and unburned refugia within individual fires scars. Research by He *et al* (2022) also shows that modelled fuel moisture condition is an important predictor of fire occurrence.

Future fire risk across our study area is also likely to be impacted by the effects of fire on permafrost conditions. Wildfire can increase ground temperatures and active layer thickness, and drive terrain subsidence Jones *et al* 2015, Shi *et al* 2019, Chen *et al* 2021c). The magnitude of these changes and their impacts on hydrology and vegetation varies among permafrost terrain types and near-surface ground ice conditions (Jones *et al* 2015, Holloway *et al* 2020, Talucci *et al* 2025). As such, additional research is needed to understand linkages between fire severity, post-fire permafrost recovery and its impact on ecological succession and fuel accumulation (Zhang *et al* 2015, Holloway *et al* 2020).

Our observation that the number of fires remained nearly constant in the periods between 1985–2004 and 2005–2023 in both tundra and northern taiga suggests that increases in total area burned were caused by the impact of warming on fuel conditions rather than a change in the number of ignitions. In Alaska, a strong association between the probability of lightning and fire occurrence (He *et al* 2022) suggests that observed increases in the number of fires (Masrur *et al* 2022) in this area have been driven by increases in lightning strikes (Liu *et al* 2022). In our RF model, the frequency of summer lightning had only moderate importance (figure 4). Trend surfaces presented in Liu *et al* (2022) also show that lightning strike density in the last two decades has decreased across many parts of our study area but shown increases in other areas.

Projections of increased fire favourability based on our RF model are aligned with previous research showing that climate warming will facilitate increased fire activity (Wang *et al* 2017, Young *et al* 2017, Chen *et al* 2021b). However, additional research on the impact of ecological, climatological and terrain conditions on fire ignition and spread is needed to inform planning and decision making. For example, fuel load is not characterised explicitly in our model. Although our RF model suggests that tundra fire will become more common across large areas of the central barrenlands and Baffin island, it is likely that a lack of fuel will constrain the expansion of fire into these, and many other, areas of the tundra biome. Estimates of model accuracy of 82%–83% suggest that the climate and terrain variables included in our model adequately predict broad-scale wildfire favourability. However, lower producer's accuracy (72%–80%) for burned areas suggests that the terrain and climate variables we used are constrained in their ability to predict all fire events, indicating that fine-scale information on fuels, ignitions sources, and other terrain factors could improve prediction. With this in mind, higher values of these favourability indices should not be interpreted as increased likelihood that a given area will burn, but as a shift towards climate conditions that can support fire (Mulverhill *et al* 2024). Future research focussed on modelling tundra fire should integrate more direct indicators of fuels conditions. In the absence of a national-scale field program, this information could be derived from remotely sensed estimates of vegetation structure (Orndahl *et al* 2025, Travers-Smith *et al* 2025).

The large area burned in the southern portion of our study area, where woodlands are relatively common, indicates that shifts in the position of the treeline could have a large influence on future fire regimes. However, given that most studies of latitudinal treeline dynamics show the position of this ecotone has remained largely stable in the face of climate change (Lantz *et al* 2019, LescopSinclair and Payette 1995, MacDonald *et al* 1998, Travers-Smith *et al* 2025), it is unlikely that fire regimes in the tundra will approximate conditions in the northern taiga on decadal timescales. Although the position of the treeline is unlikely to be altered on decadal time scales, wildfires have been shown to increase shrub abundance (Racine *et al* 2004, Higuera *et al* 2008, Jones *et al* 2013, Gaglioti *et al* 2021, Chen *et al* 2021b, Miller *et al* 2023). These studies indicate that post-fire succession in tundra can facilitate increases in fire size and intensity by elevating fuel loads. However, it is likely that this feedback will be limited to the northern range margin of upright shrubs. Beyond this area, it is likely that edaphic factors limiting shrub recruitment (seed availability, soils, etc.) will limit the rate of continental-scale shifts in vegetation structure and fuel conditions (Lantz *et al* 2010, Travers-Smith and Lantz 2020). Studies showing that tundra fire can also lead to the development of grass- or sedge-dominated tundra highlights the importance of additional research on the factors controlling post-fire successional trajectories (Gaglioti *et al* 2021, Chen and Lantz 2024).

The intensification of fire regimes in the tundra and northern taiga has significant implications for the dynamics of northern ecosystems. Studies showing that fire is associated with reduced cover of lichen, which can take decades to recover, indicate altered fire regimes will have significant implications for habitat quality (Jandt *et al* 2008, Joly *et al* 2012, Frost *et al* 2020). The persistence of dense stands of upright shrubs for 50–80 years following fire is also likely to affect the movement of many species (Rickbeil *et al* 2017, 2018).

5. Conclusions

Across the Northwest Territories and western Nunavut, the area of tundra and northern taiga impacted by fire was 4*X* and 2*X* higher, respectively, between 2005 and 2023 than the period from 1985 to 2004. Strong associations between summer temperature and area burned and fire occurrence indicates that increases in burned area are a consequence of climate warming, which is likely to increase the area impacted by fire over the rest of the century. Our analysis also points to the importance of fuel condition, highlighting a need for continued research on post-fire recovery of vegetation structure, and feedbacks among permafrost, hydrological conditions, vegetation succession, and fuel accumulation.

Acknowledgment

This research project was supported by funding from the Natural Sciences and Engineering Research Council of Canada (RGPIN 06210-2018: T.C.L.) and the Polar Continental Shelf Program. The authors thank Erin Grogan, Sasha Plotnikoff, Hana Travers-Smith, Becky Segal, and Ben Milligan for technical and mapping assistance, and two anonymous reviewers whose comments improved this manuscript.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Supplementary methods and results available at https://doi.org/10.1088/1748-9326/ae628d/data1.

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