Potential Conflict between Future Development of Natural Resources and High-Value Wildlife Habitats in Boreal Landscapes

Biodiversity and Conservation

Nobuya Suzuki[1], Katherine L. Parker[1]

[1]Natural Resources and Environmental Studies Institute, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9, Canada

Nobuya Suzuki (Corresponding Author)
Email: nobi.suzuki@unbc.ca

Online Resource 5. Wind Power Potential

We created a GIS layer of wind power potential in the Muskwa-Kechika Management Area (hereafter referred to as the Muskwa-Kechika) by assessing and integrating 6 sources of spatial data and records: digital elevation models, Canadian Wind Energy Atlas (Environment Canada 2003), historical wind records from 15 wildfire weather stations (British Columbia Ministry of Forests, Lands, and Natural Resource Operations; Wildfire Management Branch 2014), Freshwater Atlas (British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC 2011), existing power lines, and wind power tenure locations (British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC 2014a, 2014b, 2014c).

We used a 50-m digital elevation model (DEM), which matched pixel size of habitat suitability models of wildlife species, to identify areas in the Muskwa-Kechika that satisfied topographic criteria for wind tower installation. Installation of wind towers requires a gentle landscape; including gentle hills, plateaus, and ridgelines; with feasible slope < 20% or optimum slope < 10% and ≥100 m in width (DNV 2009). We used the following processes to identify 1) gentle hills and plateaus and 2) ridgelines.

Identifying Gentle Hills and Plateaus. To locate gentle hills and plateaus across the Muskwa-Kechika, we used the DEM to first quantify percent slope for each 50-m pixel. Percent slope was assessed for the maximum slope value over an area of 150 m x 150 m around each 50-m pixel across the Muskwa-Kechika and then used to identify low-slope areas. The area of 150 m x 150 m is equivalent to 3x3 50-m pixels or 9 50-m pixels, which comfortably covered a100-m width of land area required for wind tower installation. We used focal statistics in ArcGIS to assign maximum slope value among the 9 50-m pixels to the center pixel. This process is similar to moving average statistics, except we assigned the maximum value of 9 pixels instead of the average value. The outcome of this process was a raster layer with a value in each pixel representing the maximum slope value from the 150 m x 150 m area around that pixel. The maximum slope value was used to ensure that all 9 pixels (150 m x 150 m area) around the center pixel were lower than threshold slope values (10% for optimum and 20% for feasible) for wind tower installation. Using the average value would result in higher values in some pixels and lower values in others; therefore, all 9 pixels might not be suitable for wind tower installation even if the average among pixels was suitable.

Relative Likelihood based on Slope and Elevation. After identifying low-slope areas, we estimated relative likelihood of being a wind power site according to slope and elevation. We assessed topography of 278 wind tenure polygons in northeast BC (Fig. S5.1).

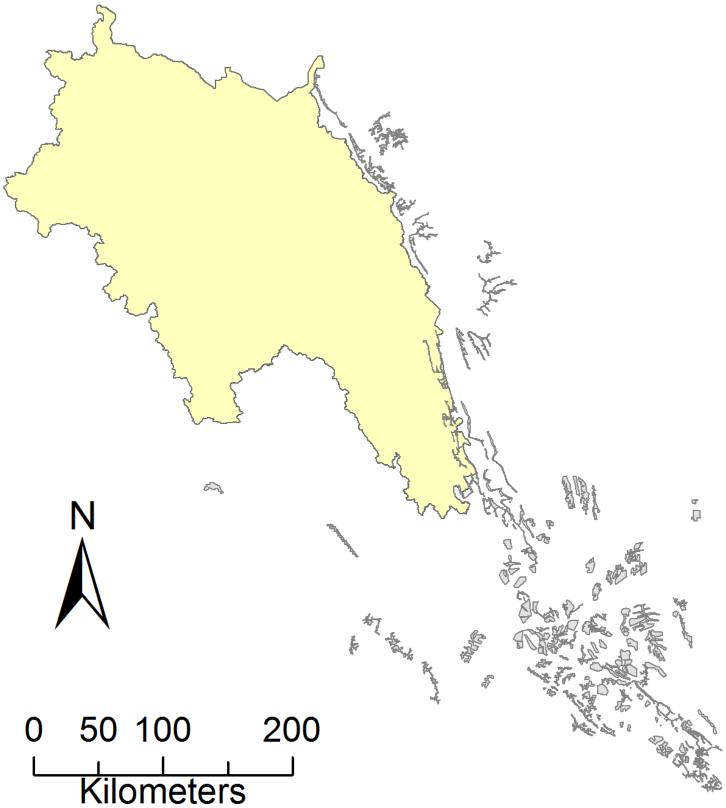

Fig. S5.1 Polygons (n = 278) of wind power tenure sites in northeast British Columbia, mostly located east to southeast of the Muskwa-Kechika Management Area (British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC 2014a, 2014c)

We used a slope raster and a 50-m DEM and counted pixels in 2 slope classes (0–10% and 10–20%) and elevations for these pixels within the boundaries of the wind tenure polygons. Elevations for these pixels ranged from 386 m to 2114 m (Table S5.1, Fig. S5.2). Seventy five percent of pixels from wind tenure sites occurred in elevations between 732 m and 1250 m, and pixel counts dramatically decreased below 732 m or above 1250 m. The highest pixel counts for slope < 10% occurred in elevations between 794–904 m and counts for 10 ≤ slope < 20% occurred in elevations between 904–1077 m.

We divided the range of elevation into 10 classes of equal intervals and also included 2 additional classes of elevations (< 386 m and > 2114 m) where no wind tenure sites occurred. This process created 12 elevation classes for each of the 2 slope classes for a total of 24 combined classes. We assigned the score of 100 to the highest pixel count of 216,220, which was recorded at the combined class of slope < 10% and elevation at 732–904 m, and calculated percent of this highest pixel count for the remaining 23 combined classes. We used these percent-of-the-highest pixel counts as relative likelihood scores of potential wind power sites in the Muskwa-Kechika based on the combined classes of slope and elevation at pixels.

Table S5.1 Relative likelihood of potential wind power sites based on the frequency distribution of 50-m pixel counts within 283 wind tenure polygons in northeast British Columbia, for the 24 combinations of 2 slope classes and 12 elevation classes

	Percent of Highest Pixel Count		Number of Pixels (% of total)	
Elevation (m)	0 ≤ Slope < 10%	10 ≤ Slope < 20%	0 ≤ Slope < 10%	10 ≤ Slope < 20%
<386	0	0	0 (0.00)	0 (0.00)
386–559	0.01	0.02	20 (0.002)	33 (0.003)
559–732	7.34	2.15	15,880 (1.32)	4647 (0.39)
732–904	100.00	46.13	216,220 (17.99)	99,746 (8.30)
904–1077	85.52	58.78	184,908 (15.38)	127,090 (10.57)
1077–1250	69.56	56.03	150,398 (12.51)	121,149 (10.08)
1250–1423	23.66	35.13	50,924 (4.24)	75,959 (6.32)
1423–1596	15.78	28.28	34,125 (2.84)	61,147 (5.09)
1596–1768	6.93	14.21	14,980 (1.25)	30,724 (2.56)
1768–1941	2.15	3.9	4647 (0.39)	8443 (0.70)
1941–2114	0.14	0.32	293 (0.02)	699 (0.06)
>2114	0	0	0 (0.00)	0 (0.00)

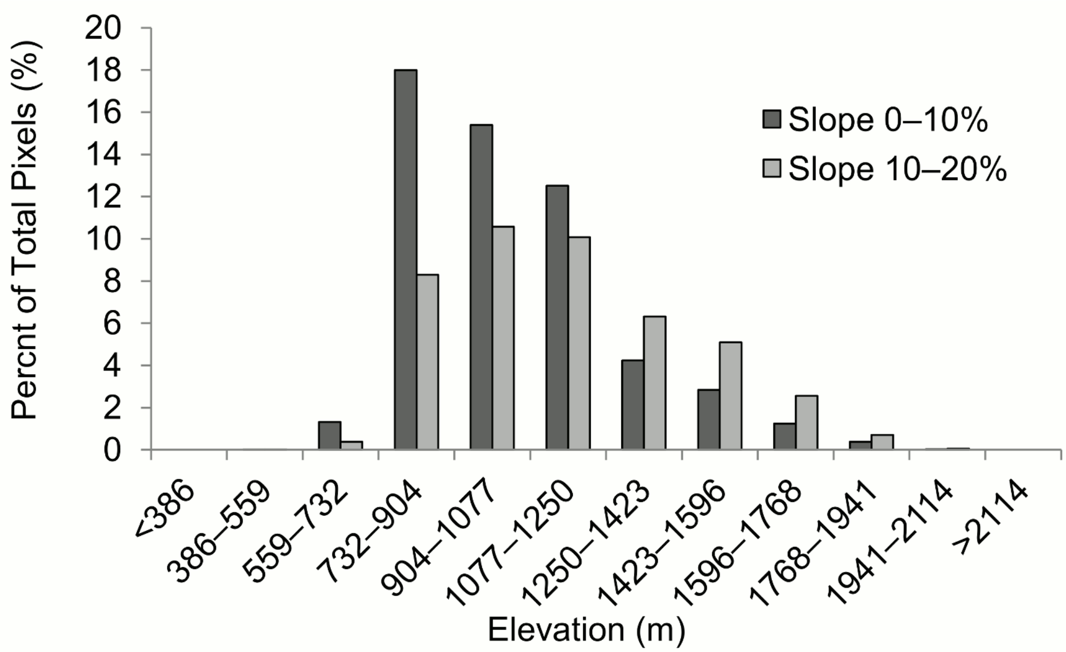

Fig. S5.2 Frequency distribution across 12 elevation classes and 2 slope classes (< 10% and 10 – 20%) for 50-m pixel numbers from 283 wind tenure polygons in northeast British Columbia

Elevation above Nearest Body of Water. The elevation above the nearest body of water is a measure that identifies high plateaus or gentle hills that are located high above floodplains of rivers as well as high above flat or depressed land surfaces associated with lakes and wetlands. We assumed that the higher the area is above water, the higher the potential for wind power generation might be because higher locations, such as high plateaus, are unlikely to be flooded and are well above water tables, yet more likely to intercept winds without too many physical obstructions. Without the measure of elevation above water, the classification based on slope and elevation alone would not be able to distinguish low-slope areas near bodies of water, which are not suitable for installation of wind towers, from low-slope areas of high plateau or gentle hills, which are suitable for wind towers.

To create a raster layer of elevation above the nearest body of water, we used the British Columbia Freshwater Atlas (British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC 2011) and the DEM to quantify differences in elevation between pixels and the nearest river, lake, and wetland from each pixel. Polygon layers of the BC Freshwater Atlas were converted to 50-m raster layers in the analysis. To calculate differences in elevation, we assigned elevations to pixels in raster layers representing bodies of water, used the path distance allocation method (Spatial Analyst in ArcGIS) to assign elevations of the nearest body of water to all pixels across the landscape, and calculated the differences in elevation between elevation of nearest body of water assigned to each pixel and actual elevation of each pixel location. We converted the elevation above water measures of pixels into percent-of-the-highest-pixel value, which created scores between 0 and 100. In our subsequent analysis, we eliminated all pixels < 20 m above the body of water, which is approximately twice the height of peak flood levels of large rivers in BC (Northwest Hydraulic Consultants 2008), to avoid locating potential wind power sites in low-slope areas of river floodplains and on flat or depressed land surfaces of lakes and wetlands. We also eliminated pixels overlapping glaciers in high elevations using a polygon layer of glaciers from British Columbia Freshwater Atlas (British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC 2011).

Ridgelines. We identified ridgelines with gentle slope < 20% and area wide enough (>100 m) to physically allow installation of wind towers. We did not distinguish between slopes < 10% and 20% because ridgelines with slope < 10% were not very common in the Muskwa-Kechika (Snively 2011, Snively and Brumovsky 2011). We used the hydrology tool in ArcGIS to delineate ridgelines (Fig. S5.3) from the DEM (50 m) following the method described by ESRI (2013). We considered a relatively uniform unit of ridgeline to be a "ridgeline segment," which is a segment before a junction or between junctions of ridgelines within a ridgeline network (Fig. S5.4). For each ridgeline segment, we estimated a direction and straight-line distance using the linear directional mean tool in ArcGIS by selecting ridgeline segment as a case field. The directions and straight-line distances of ridgeline segments were later used to determine efficiency of ridgeline segments to intercept wind blowing from specific directions and to determine relative capacity for installing wind towers.

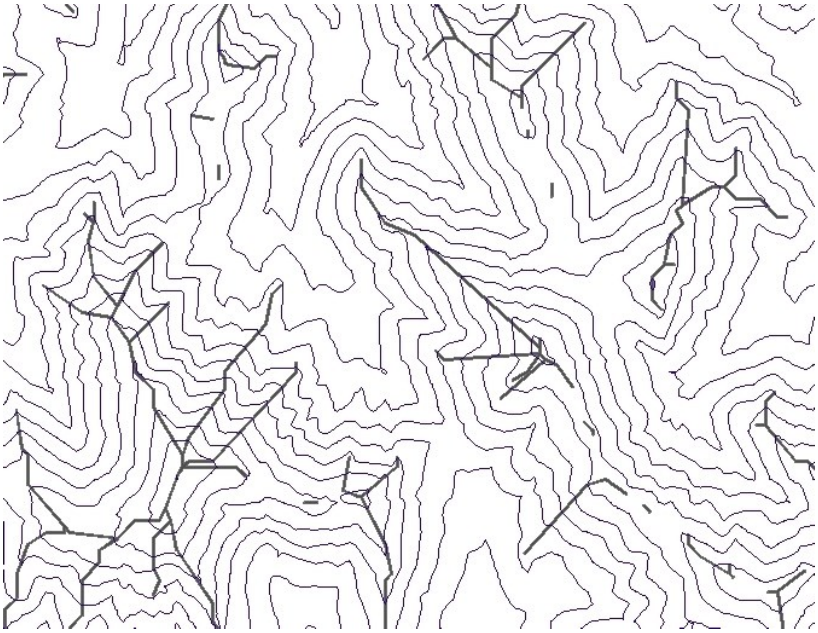

Fig. S5.3 Examples of delineated ridgelines with contour lines in 50-m elevation intervals

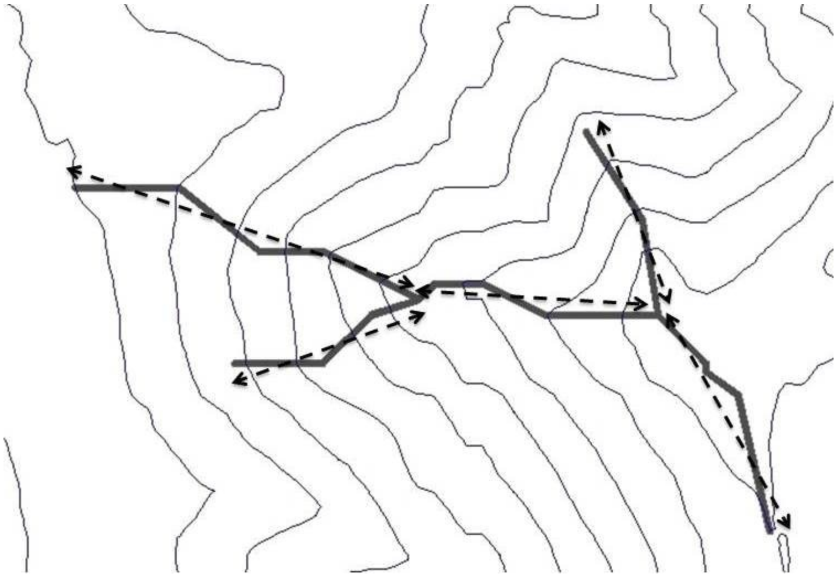

Fig. S5.4 Example of a ridgeline network comprised of 5 ridgeline segments. Straight-line distance and average direction of each ridgeline segment are shown as dotted arrow lines

Effective Ridge Length. We defined effective ridge length as the projected length of a ridgeline segment perpendicular to a given direction of wind (Fig. S5.5). Effective ridge length also is a relative measure of the number of wind power turbines that could be installed for a ridgeline segment to intercept winds blowing from different directions. For every ridgeline segment, we quantified effective ridge length for each of the 4 wind direction pairs: north/south, northeast/southwest, east/west, and northwest/southeast. Effective ridge length is identical for a pair of wind directions. For example, a ridgeline segment in an east-west direction is perpendicular to either north or south winds; therefore, it has the identical effective ridge length for both north and south winds.

Individual ridgeline segments stretch in various directions independent of wind direction. If winds were only blowing from either north or south, a ridgeline segment in the direction of east-west would accommodate a higher number of wind towers that could directly intercept north or south winds when blades line up horizontally to the ridgeline segment, than a ridgeline segment of the same length in the direction of northwest-southeast. In the latter case, turbine heads need to be rotated to align blades horizontally to the east-west direction; however, to avoid blades overlapping each other, tower spacing needs to be wider than that required for an east-west ridgeline. If the ridgeline segment is in the north-south direction when wind is blowing from either north or south, it is possible to install one wind tower that can effectively intercept north or south wind; but turbine blades would end up overlapping if multiple wind towers were installed. Because wind directions are not constant over time, turbine heads need to be rotated without blades overlapping each other to maximize the efficiency of intercepting winds from various directions. Given equal lengths, segments of ridgeline facing perpendicular to the prevailing wind direction would have the capacity for a higher number of wind towers than segments of ridgeline in other directions. Turbine heads can be rotated to intercept seasonally changing winds in other directions.

Even if a ridgeline segment is not facing perpendicular to the prevailing wind direction, a number of wind towers can still be installed with turbine heads facing toward that wind direction or any other direction of wind. The relative number of wind towers that can be installed on a ridge segment that is not perpendicular to wind direction can be determined by projecting a ridge segment on a line perpendicular to a specific wind direction (Fig. S5.5). The length of this projected ridge segment perpendicular to a given wind direction is the maximum length available for tower installation for that wind direction. We refer to this projected length of ridgeline segment as the "effective ridge length" for a specific direction of wind. This effective ridge length is related to how many turbines can be installed for a given ridge segment to intercept winds that are blowing from different directions.

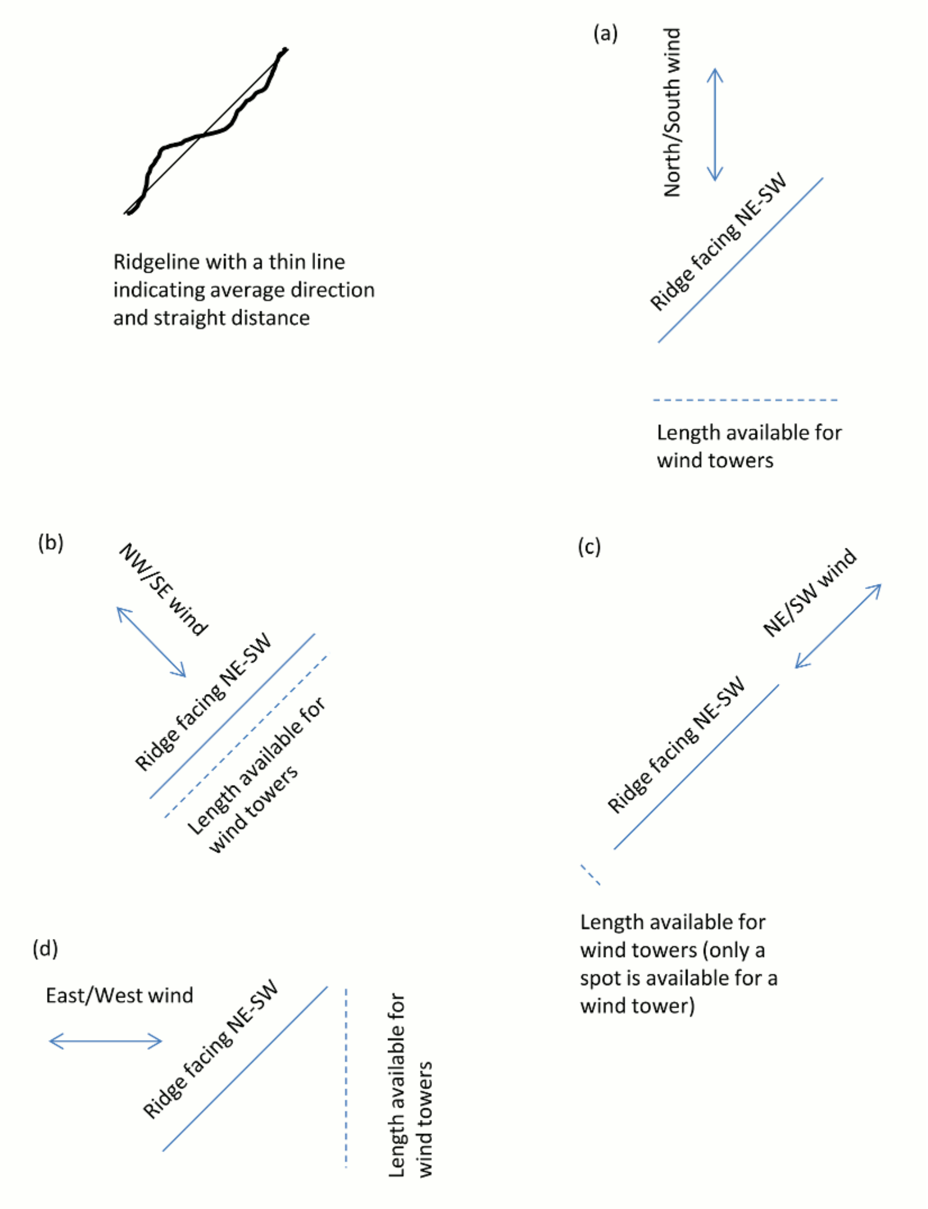

Fig. S5.5 For a given segment of ridgeline, there are 4 effective lengths of ridgeline that are potentially available for wind tower installation in relation to 4 pairs of wind directions

Wind Direction Assessment. We obtained historical weather data from the 15 wildfire weather stations that are located either within or near the boundary of the Muskwa-Kechika Management Area (Fig. S5.6). From these historical weather data, we assessed wind directions across the Muskwa-Kechika and proportions of winds blowing from 8 ordinal directions (N, NE, E, SE, S, SW, W, NW). To apply wind direction statistics across the Muskwa-Kechika, we divided the Muskwa-Kechika into 15 Thiessen polygons created from weather station locations as input points (Fig. S5.6). Each of these Thiessen polygons represents an area within which any location is closer to the assigned weather station than to any other weather station. Statistical results from the wind direction assessment were assigned to Thiessen polygons of corresponding stations.

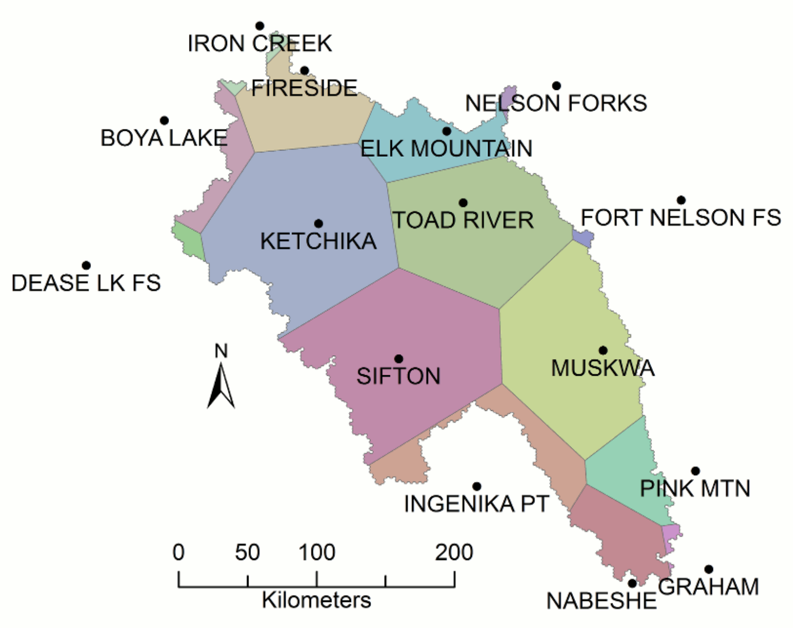

Fig. S5.6 Thiessen polygons were developed to assign lands within the Muskwa-Kechika Management Area, northeast British Columbia, to the nearest wildfire weather stations. Each polygon represents an area, within which any location is the closest to the assigned weather station than to any other weather station

We assessed wind directions and speed between years 2000 and 2013 from the 15 weather stations for the years in which there were 12 months of data. Years without 12 months of data were excluded from the analysis to avoid biases because there is a tendency for stations to lack wind data during the non-fire season in winter months when wind is generally strong. All 15 stations had at least 2 years of weather data that represented 12 months in each year. We did not use data before 2000 because of missing records and also to avoid potential differences in decadal weather patterns. Raw data were comprised of hourly weather records for 24 hours each day. We averaged hourly wind direction data each day and generated daily wind directions. Daily wind directions in the unit of degrees ($0^{\circ} – 360^{\circ}$) were converted to the following 8 ordinal directions: north ($337.5^{\circ} – 22.5^{\circ}$), northeast ($22.5^{\circ} – 67.5^{\circ}$), east ($67.5^{\circ} – 112.5^{\circ}$), southeast ($112.5^{\circ} – 157.5^{\circ}$), south ($157.5^{\circ} – 202.5^{\circ}$), southwest ($202.5^{\circ} – 247.5^{\circ}$), west ($247.5^{\circ} – 292.5^{\circ}$), and northwest ($292.5^{\circ} – 337.5^{\circ}$). For each weather station, the percentage of winds in these 8 ordinal directions was calculated from all daily wind data available for each station relative to the total number of days in each direction (Table S5.2).

Table S5.2 Percentage of wind blowing from 8 ordinal directions with prevailing wind in bold and underlined, based on the analysis of historical records (2000–2013) from 15 wildfire weather stations within or near the border of the Muskwa-Kechika Management Area, northeast British Columbia. Underlined values show most prominent wind directions

	Percent of Wind in 8 Directions							
Station	E	NE	NW	N	SE	SW	S	W
Boya Lake	0.7	0.5	6.5	0.0	11.4	17.9	**57.7**	5.4
Dease Lake	15.3	14.7	0.5	2.5	23.5	8.9	**33.9**	0.7
Elk Mountain	12.7	0.6	2.0	0.8	**29.0**	20.8	23.9	10.2
Fireside	13.4	1.1	0.2	0.2	25.3	24.8	**26.4**	8.6
Fort Nelson	3.2	1.5	5.5	1.8	13.9	26.2	**37.5**	10.4
Graham	4.0	1.6	1.2	0.5	9.1	**48.8**	22.3	12.6
Ingenika Point	3.9	1.2	5.2	0.2	14.5	28.9	**34.8**	11.3
Iron Creek	7.8	1.2	0.2	0.2	25.6	20.0	**38.8**	6.2
Kechika	0.8	0.0	3.4	0.0	**49.1**	13.8	21.8	11.2
Muskwa	13.0	7.6	0.3	0.1	16.4	**32.9**	22.9	6.8
Nabeshe	4.0	0.9	0.9	0.3	13.7	**40.5**	27.6	12.2
Nelson Fork	13.1	16.7	0.3	2.1	13.9	**21.1**	15.9	16.8
Pink Mountain	2.4	0.8	2.6	0.2	8.8	**44.7**	28.0	12.5
Sifton	0.2	0.2	5.2	1.2	8.3	25.3	**49.5**	10.2
Toad River	0.3	0.0	1.1	0.0	16.0	32.9	**37.6**	12.0

Ridgeline Efficiency. We defined ridgeline efficiency as an indirect measure of how effectively a ridgeline segment can potentially generate power based on the directional amount and pattern of wind intercepted by a ridge segment of a given length and direction. To estimate this efficiency, the percentage of wind in each of 8 directions (Table S5.2) first was converted to a proportion, and the proportions for 2 opposite directions were added together to create a coefficient for the pair of opposite wind directions (hereafter referred to as a “direction pair”). We calculated 4 coefficients for 4 direction pairs for the 15 weather stations (Table S5.3), and values from the coefficients were assigned to the Thiessen polygons of corresponding stations. For each ridgeline segment within each Thiessen polygon, the 4 coefficients for the corresponding 4 wind direction pairs were multiplied by the effective ridge length. Each of these 4 products of multiplication represents a measure of how frequently wind from a specific direction would be intercepted by a ridge segment that has a given projected length, which is proportional to the number of wind towers that might be installed, facing perpendicular to the wind. For a given ridgeline segment, we summed values from the 4 products of the multiplication process (NS coefficient x effective ridge length for NS wind; EW coefficient x effective ridge length for EW wind; NE–SW coefficient x effective ridge length for NE–SW wind; NW–SE coefficient x effective ridge length for NW–SE wind). We refer to this sum of the multiplication values as the “value of ridgeline efficiency”. Values of ridgeline efficiency were assigned to a raster layer of ridgeline segments (50-m pixel size). We used percent of the highest pixel values for the final layer of ridgeline efficiency.

Table S5.3 Coefficients based on the proportion of wind occurring in direction pairs (Table S5.2) within Thiessen polygons (Fig. S5.6) created from 15 wildfire weather stations, northeast British Columbia. The products of these coefficients and effective ridge lengths were used to assess ridgeline efficiency to potentially generate wind power

	Coefficient			
Station	N–S	E–W	NE–SW	NW–SE
Boya Lake	0.577	0.060	0.184	0.178
Dease Lake	0.364	0.161	0.236	0.240
Elk Mountain	0.247	0.229	0.214	0.310
Fireside	0.266	0.220	0.259	0.255
Fort Nelson	0.393	0.136	0.277	0.194
Graham	0.228	0.166	0.504	0.103
Ingenika Point	0.350	0.152	0.301	0.197
Iron Creek	0.390	0.139	0.212	0.258
Kechika	0.218	0.120	0.138	0.524
Muskwa	0.230	0.198	0.404	0.167
Nabeshe	0.279	0.162	0.413	0.146
Nelson Fork	0.180	0.299	0.378	0.142
Pink Mountain	0.281	0.149	0.455	0.115
Sifton	0.507	0.103	0.254	0.135
Toad River	0.376	0.123	0.329	0.172

Wind Speed. We initially used wind speed predicted from the Canadian Wind Energy Atlas (Environment Canada 2003), but we found clear discrepancies in the predicted wind speeds in the atlas and those actually recorded at 15 wildfire weather stations. Therefore, we created and used a new wind speed raster layer from daily mean wind speed data from the wildfire weather stations. To create the wind speed raster (cell size = 50 m), we calculated mean wind speed per day for each of the 15 stations (Table S5.4) and interpolated the average wind speed across the Muskwa-Kechika using spline interpolation in ArcGIS (Fig. S5.7).

Table S5.4 Mean daily wind speed estimated from wind data of at least 2 years, in which there were 12 months of data in each year, between 2000–2013 recorded at 15 wildfire weather stations in and in the vicinity of the Muskwa-Kechika Management Area, northeast British Columbia

	Wind Speed (m/s)		95% Confidence Interval		
Station Name	Mean	SD	Lower	Upper	n[a]
Boya Lake	5.67	2.22	5.54	5.8	1065
Dease Lake	7.23	3.67	7.12	7.35	3851
Elk Mountain	3.31	2.29	3.2	3.41	1809
Fireside	6.15	3.35	5.99	6.3	1826
Fort Nelson	6.87	3.07	6.77	6.98	3271
Graham	7.22	4.76	7.02	7.43	2123
Ingenika Point	7.76	6.15	7.47	8.04	1793
Iron Creek	6.14	3.22	6.01	6.27	2477
Kechika	7.7	4.72	7.46	7.94	1461
Muskwa	9.86	6.90	9.43	10.28	1015
Nabeshe	7.42	4.91	7.06	7.79	699
Nelson Forks	8.74	3.61	8.62	8.86	3286
Pink Mountain	6.55	3.59	6.38	6.71	1798
Sifton	5.81	3.08	5.62	5.99	1093
Toad River	4.2	3.46	3.98	4.42	997

[a] Total number of days with wind speed records from which a mean wind speed was estimated

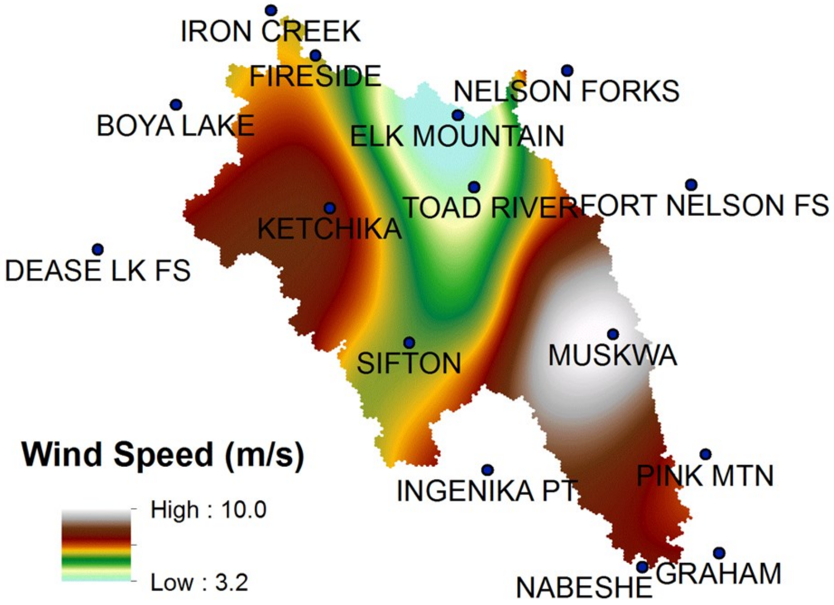

Fig. S5.7 Mean daily wind speed (meters per second) interpolated from the 15 wildfire weather stations in the Muskwa-Kechika Management Area and nearby surrounding area, northeast British Columbia

Reverse Distance to Wind Power Tenure Sites and Power Lines. We assessed distance to either the nearest wind power tenure site or the nearest power line, whichever was the closest, from each pixel and created a raster layer with pixel values as these nearest distances. We used the path distance tool in ArcGIS with a 50-m DEM as a surface raster. We reversed the distance measures so that pixels closer to tenure sites or power lines had higher values than those farther away.

Reversed distance was calculated for all pixels by the following equation:
reversed distance of a pixel = (minimum value of original distance values among all pixels – original distance value of each pixel) + maximum original distance value among all pixels.

Reversed distance measures maintained exactly the same differences in distance relationships among pixels as original distance measures. We then replaced the pixel values with percent of the highest reversed distance measures, which gave the highest score of 100 to pixels closest to wind tenure sites or power lines and the lowest score of 0 to those farthest away (Fig. S5.8).

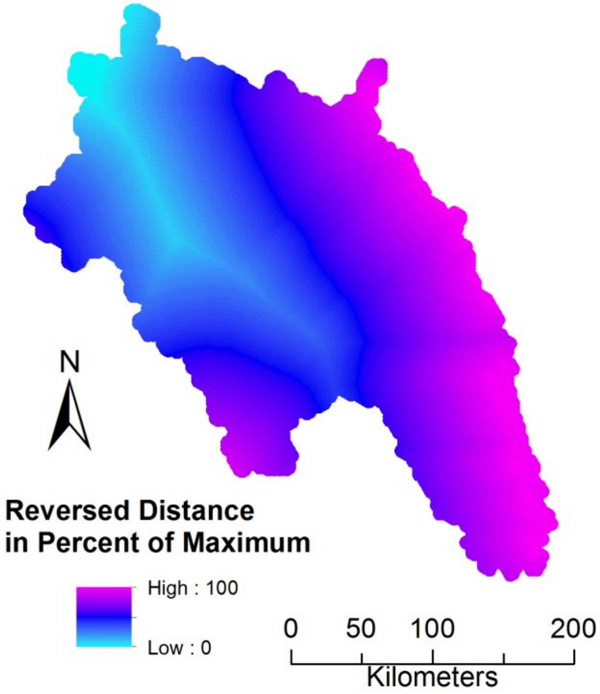

Fig. S5.8 Reversed distance to wind power tenure sites and power lines from each pixel in the Muskwa-Kechika Management Area, northeast British Columbia

Creating Wind Power Potential at the 500-ha Planning Unit Scale. To create the final wind potential layer, we averaged values of the slope-elevation layer (scores 0 – 100) and values of the elevation above water layer (scores 0 – 100) to identify locations where slope and elevations had high likelihood of wind power potential and were also high above bodies of water. We refer to this initial combined layer as the baseline potential layer. To the baseline potential layer we added 50% of scores from each of the ridgeline efficiency, wind speed, and reversed distance to powerline or wind tenure sites. These additions were done where values of the baseline potential layer were > 0 to prevent locations with no baseline wind power potential from getting additional scores. The equation for this process to generate the final wind power potential at the pixel scale (Fig. S5.9a) was: pixel-level wind potential = [(slope-elevation + elevation above bodies of water)/2] + (0.5 x ridgeline efficiency) + (0.5 x wind speed) + (0.5 x reversed distance to power line or wind tenure site).

We calculated a mean pixel score of wind power potential for each 500-ha planning unit (Fig. 1b, main text) to generate wind power potential scores for planning units across the Muskwa-Kechika (Fig. S5.9b).

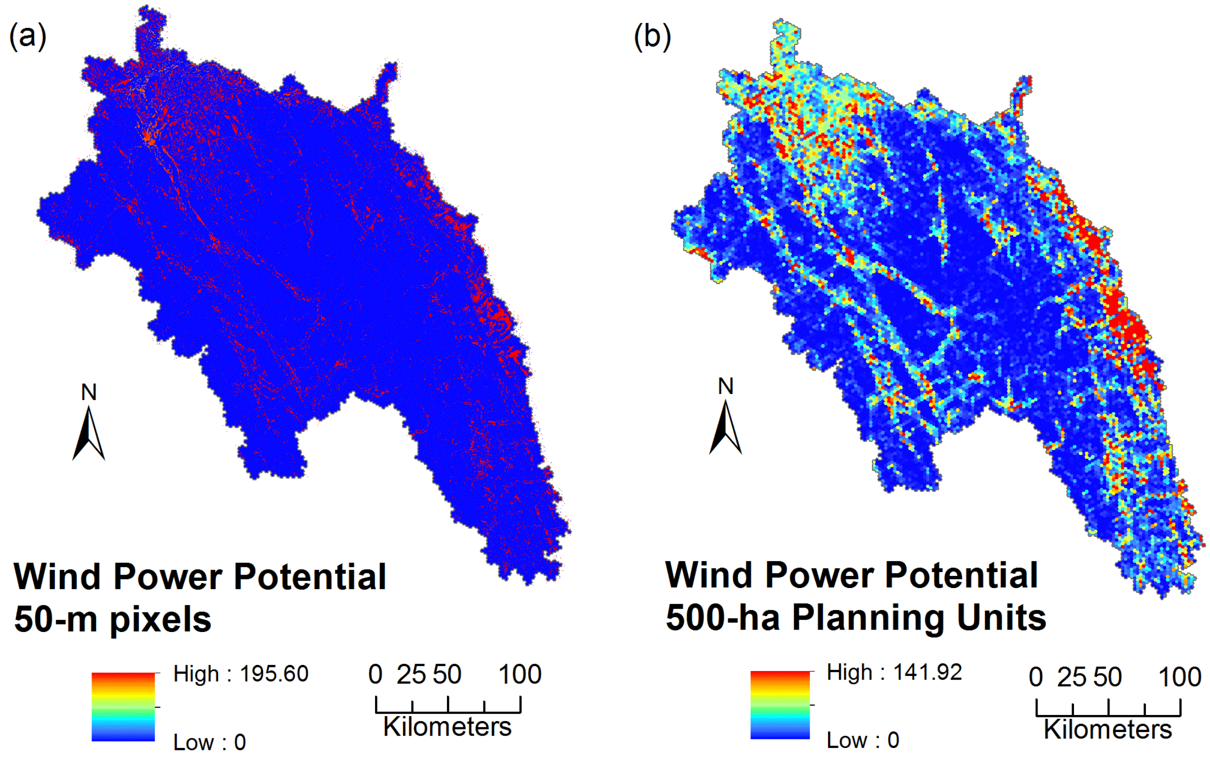

Fig. S5.9 Final wind power potential for the Muskwa-Kechika Management Area, northeast British Columbia, at the scales of 50-m pixels (a) and 500-ha planning units (b)

References

British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC (2011) Freshwater Atlas-Linear Boundaries, Rivers, Lakes, Wetlands, and Glaciers. Data available at http://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-linear-boundaries, http://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-rivers, http://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-lakes, http://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-wetlands, http://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-glaciers. Accessed 18 May 2014

British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC (2014a) TANTALIS-Crown Land Leases. Available at: http://catalogue.data.gov.bc.ca/dataset/tantalis-crown-land-leases. Accessed 19 June 2014

British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC (2014b) TANTALIS- Crown Land Rights-of-Way. Available at: http://catalogue.data.gov.bc.ca/dataset/tantalis-crown-land-rights-of-way. Accessed 19 June 2014

British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC (2014c) TANTALIS-Crown Tenures. Available at: http://catalogue.data.gov.bc.ca/dataset/tantalis-crown-tenures. Accessed 19 June 2014

British Columbia Ministry of Forests, Lands, and Natural Resource Operations – Wildfire Management Branch (2014) http://bcwildfire.ca/weather/stations.htm. Data available upon request

Environment Canada (2003) Canadian Wind Energy Atlas Web. http://www.windatlas.ca. Accessed 12 June 2014

ESRI (2013) How to identify ridgelines from DEM. Knowledge Base Technical Article ID 39093. Document available at http://support.esri.com/fr/knowledgebase/techarticles/detail/39093. Accessed 3 June 2014

DNV (2009) British Columbia hydro wind data study update. DNV Global Energy Concepts Inc. Seattle, Washington, USA. 8 p. plus appendicies. Document available at https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/iep_ltap/2010q3/bc_hydro_wind_data. Accessed 25April2014

Northwest Hydraulic Consultants (2008) Comprehensive review of Fraser River at Hope, flood hydrology and flows – scoping study, final report. British Columbia Ministry of Environment, Victoria, British Columbia. Available at: http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/review_fraser_flood_flows_hope.pdf. Accessed 17 March 2015

Snively M (2011) Investigating impacts of wind power development in the M-KMA –Composite maps for wind speed. Wildlife Infometrics Inc. Report No. 370. Wildlife Infometrics Inc., Mackenzie, British Columbia, Canada

Snively M, Brumovsky VJ (2011) Investigating potential impacts of wind power development in the M-KMA – Physical feasibility model methods and spatial data summary. Wildlife Infometrics Inc. Report No. 367. Wildlife Infometrics Inc., Mackenzie, British Columbia, Canada