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

Biodiversity and Conservation

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Online Resource 6. Road Potential

We developed a GIS layer of road potential for the Muskwa-Kechika Management Area (hereafter referred to as the Muskwa-Kechika) based on the 1) relative physical feasibility of road development and 2) relative impact distance, which is a measure of proximity to existing man-made features that likely have some potential for encouraging road development in the Muskwa-Kechika. These 2 factors are considered as primary factors of road potential. In addition, we assessed 3) density of wetlands or lakes as a secondary factor that may act as an obstacle to road development where density is too high. These 3 factors were integrated into scores of road potential for planning units (Fig. 1b, main text) across the Muskwa-Kechika.

1. Relative Physical Feasibility

To determine relative physical feasibility of road development across planning units in the Muskwa-Kechika, we used the general principle that flat, low-elevation land with small change in elevation has higher physical feasibility for road development than steep, high-elevation land with a higher change in elevation. We first compiled estimates of elevation (m) and slope (%) from the digital elevation model (DEM) for 50-m cells across the Muskwa-Kechika. We calculated mean elevation and mean slope per cell, elevation range, and standard deviation of elevation for each planning unit across the Muskwa-Kechika. Because these 4 physical variables are highly correlated with one another (Table S6.1), we used principal component analysis to combine them into a single principal component variable that served as a measure of relative physical feasibility of road development.

All variables were transformed with natural logarithms as follows: Ln (mean elevation), Ln (mean slope + 1), Ln (elevation range + 1), Ln (standard deviation of elevation + 1). We tested both untransformed original variables and natural-log transformed variables for normal distribution using normal probability plots and histograms, ran principal component analysis separately for untransformed variables and transformed variables, tested principal component scores from untransformed and transformed variables for normal distribution and linearity, and selected the best performing principal component variable formulated from either untransformed or transformed variables.

Table S6.1 Pearson's correlation matrix of variables used to assess relative physical feasibility of road development in the Muskwa-Kechika Management Area showing moderate to strong correlations between variables ($P < 0.0001$)

	Pearson's Correlation Coefficient (*r*)			
	Mean elevation	Mean slope	Elevation range	Standard deviation of elevation
Mean elevation	--	0.744	0.693	0.643
Mean slope	0.744	--	0.901	0.873
Elevation range	0.693	0.901	--	0.973
Standard deviation of elevation	0.643	0.873	0.973	--

Among the 13,367 planning units in the Muskwa-Kechika; we randomly selected 6,684 planning units (50% of all planning units) to develop the index of physical feasibility of road development and validated the model with the remaining 6,683 planning units. We assessed Pearson's correlations between scores from the principle component of relative physical feasibility and values for each of mean elevation, mean slope, elevation range, and standard deviation of elevation from the validation data set.

The first principle component (PC1) retained the overwhelming majority (87%) of all variability associated with the original 4 physical variables (Table S6.2, PC1), and scores from PC1 areas were highly correlated with the 4 physical variables from the validation data set (Table S6.3). Standardized coefficients indicated that all 4 physical variables equally contributed to the PC1 scores (Table S6.3).

Table S6.2 Proportion of variance among elevation, slope, elevation range, and standard deviation of elevation explained by principal component axes. The first principal component (PC1), explaining the overwhelming majority of variability, was used as an index of relative physical feasibility of road development in the Muskwa-Kechika Management Area, northern British Columbia

	Eigen value	Proportion of Variance Explained (%)	Cumulative Proportion of Variance Explained (%)
PC1	3.491	87.3	87.3
PC2	0.405	10.1	97.4
PC3	0.083	2.1	99.5
PC4	0.021	0.5	100.0

Table S6.3 Relationship between physical variables and the first principal component (PC1), indicating that each of the 4 variables contributed similarly to produce PC1 and showed a strong correlation (r) with PC1 (P<0.0001)

Physical Variable[a]	Component Weight[b]	Standardized Coefficient[b]	Correlation with PC1 (r)[c]
Mean elevation	+0.827	+0.237	+0.831
Mean slope	+0.968	+0.277	+0.970
Elevation range	+0.974	+0.279	+0.975
Std. of elevation	+0.968	+0.275	+0.963

[a] Values in the table are based on natural logarithms of the physical variables

[b] Component weights and standardized coefficients from the principal component analysis were based on 50% random selection (n = 6,684) of all planning units (Fig. 1b, main text) in the Muskwa-Kechika Management Area

[c] Pearson's correlation coefficients were obtained between principal component scores and values of physical variables from the validation data (n = 6,683) not used in the initial principal component analysis

By default, PC1 produced higher scores for physically less feasible planning units. For a practical application, we reversed the original scores of PC1 and adjusted units to percent of the highest reversed score. This process produced scores of relative physical feasibility, in which higher scores indicated higher physical feasibility of road development for planning units up to the highest physical feasibility score of 100 (Fig. S6.1a).

2. Relative Impact Distance

Relative Impact Distance is a measure that combines distance from any location in the Muskwa-Kechika to the nearest human-made features, such as roads or gravel pits, and the potential impact levels that these various features, relative to each other, have on development of new roads. We assumed that new roads are more likely to be developed in locations that are closer to human-made features, and the likelihood of road development is further affected by types of these features.

To determine relative impact distance for 50-m pixels across the Muskwa-Kechika, we used relative impact weights of human-made features developed by Heinemeyer et al. (2004) (Table S6.4). From each 50-m pixel, we measured the distance to the nearest man-made feature (either linear, point, or polygon feature) in each of 7 relative impact weight classes (10, 8, 5, 3, 2, 1, 0.5 – see Table S6.4).

Table S6.4 Relative impact weights of linear, point, and area features, developed by Heinemeyer et al. (2004), for application to the Muskwa-Kechika Management Area

Relative Impact Weight Class	Linear Feature	Point Feature	Area Feature
10	Paved road	Buildings, oil and gas wells[a]	__
8	Gravel road	__	Agriculture field
5	__	Open mine pit, underground mine, pier or dock	__
3	Unimproved road		Logged unit
2	Pipeline	__	__
1	Power line	Rural development sites, abandoned mine, tailing pond, dump, settling basin, electrical/communication substation, tower (transmission, microwave or communication), gravel pit, airstrip	
0.5	Cutline	__	Rangeland

[a] Relative impact weight of oil and gas wells in Heinemeyer et al. (2004) was listed as 5 in their original document; however, we reported 10 based on the value they reported in their archival data for application purposes

We reversed values of the nearest distance to human-made features so that higher distance values were assigned to pixels that are closer to man-made features than those that are 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.

The reversed distance value of each feature from one of the 7 relative impact weight classes was multiplied by the respective relative impact weight of each class, and products were added together to produce a cumulative relative distance impact score for each and all 50-m pixels across the Muskwa-Kechika. We used the following equation to calculate relative impact distance of a pixel:

Relative Impact Distance =
10 x (Reversed nearest distance to feature with impact weight of 10) +
8 x (Reversed nearest distance to feature with impact weight of 8) +
5 x (Reversed nearest distance to feature with impact weight of 5) +
3 x (Reversed nearest distance to feature with impact weight of 3) +
2 x (Reversed nearest distance to feature with impact weight of 2) +
1 x (Reversed nearest distance to feature with impact weight of 1) +
0.5 x (Reversed nearest distance to feature with impact weight of 0.5).

Relative Impact Distance values among 50-m pixels were averaged for each 500-ha planning unit across the Muskwa-Kechika. We adjusted values of Relative Impact Distance at the planning unit scale to percent of the highest value among planning units (highest averaged pixel value), so that higher values indicate planning units that are closer to human-made features up to the highest Relative Impact Distance value of 100 (Fig. S6.1b).

3. Reverse Value of Wetland/Lake Density

We considered lands with large areas of water, especially wetlands and lakes, to be more difficult to develop roads on than dry lands without these bodies of water. We considered wetland/lake density as a secondary factor compared to the conditions of relative physical feasibility and relative impact distance of each planning unit. We created 50-m raster layers of wetlands and lakes from the British Columbia Freshwater Atlas (British Columbia Ministry of Forests, Lands and Natural Resource Operations – GeoBC 2011a, 2011b) and determined the area of wetlands/lakes for each planning unit by counting the number of 50-m pixels with either lake or wetland present. We reversed values so that higher values indicate smaller areas covered by wetlands and/or lakes, and therefore, drier lands with higher suitability for road development. Similar to reversed distance calculations, reverse value was calculated for all planning units by the following equation: reversed value of a planning unit = (minimum value of original values among all planning units – original value of each planning unit) + maximum original value among all planning units. In the final process, values of planning units were replaced by percent of the highest reversed value for number of wetlands/lakes. The highest value of 100 in a planning unit indicated no wetland or lake. Planning units with large areas covered by wetland/lakes received lower values to a minimum value of 0 (Fig. S6.1c).

4. Calculating Road Potential for Planning Units

To determine the road potential of planning units (Fig. 1b, main text) across the Muskwa-Kechika, we combined relative physical feasibility, relative distance impact, and the reverse value of wetland/lake density by multiplying each factor with a weight and then adding them together. We assigned an equal weight of 0.4 to relative physical feasibility and relative distance impact – the 2 primary factors of road potential – and a weight of 0.2 (half the weight of the primary factors) to reverse value of wetland/lake density. Therefore, this equation was:

Road potential of a planning unit = 0.4 x relative physical feasibility score of a planning unit + 0.4 x relative distance impact score of a planning unit + 0.2 x score of reverse value of wetland/lake density of a planning unit.

We calculated road potential for all planning units across the Muskwa-Kechika (Fig. S6.1d).

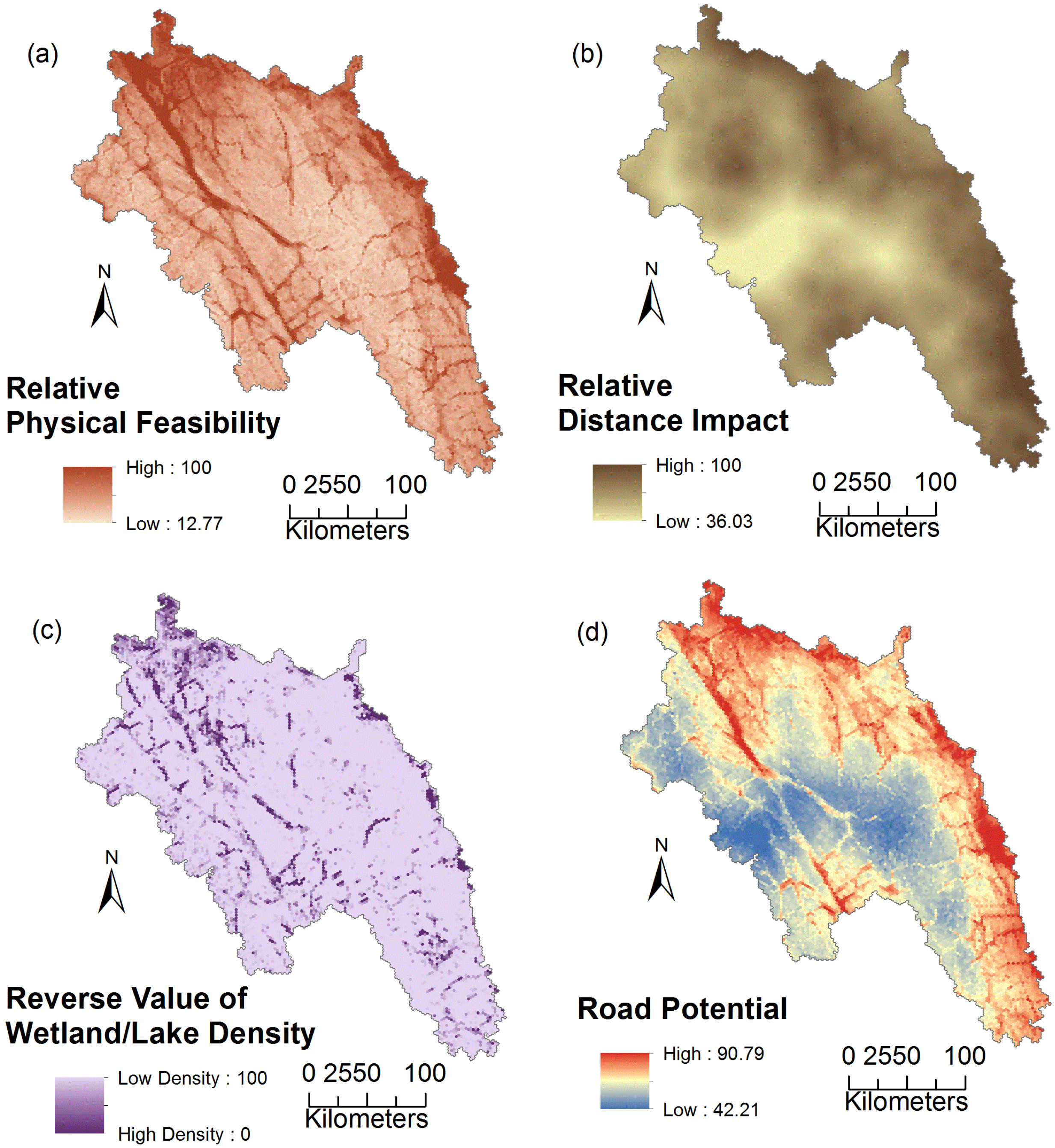

Fig. S6.1 Layers of relative physical feasibility of road development (a), relative distance impact to the nearest human-made features (b), and reverse value of wetland/lake density (c) in the Muskwa-Kechika Management Area, northeast British Columbia. The higher the reverse value of wetland/lake density, the lower the density of wetlands and lakes with higher likelihood of drier lands for road development. These three layers were combined to produce the Road Potential layer (d), which shows likely distribution of road networks in the Muskwa-Kechika Management Area, in the event of expansion of resource development activities

References

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