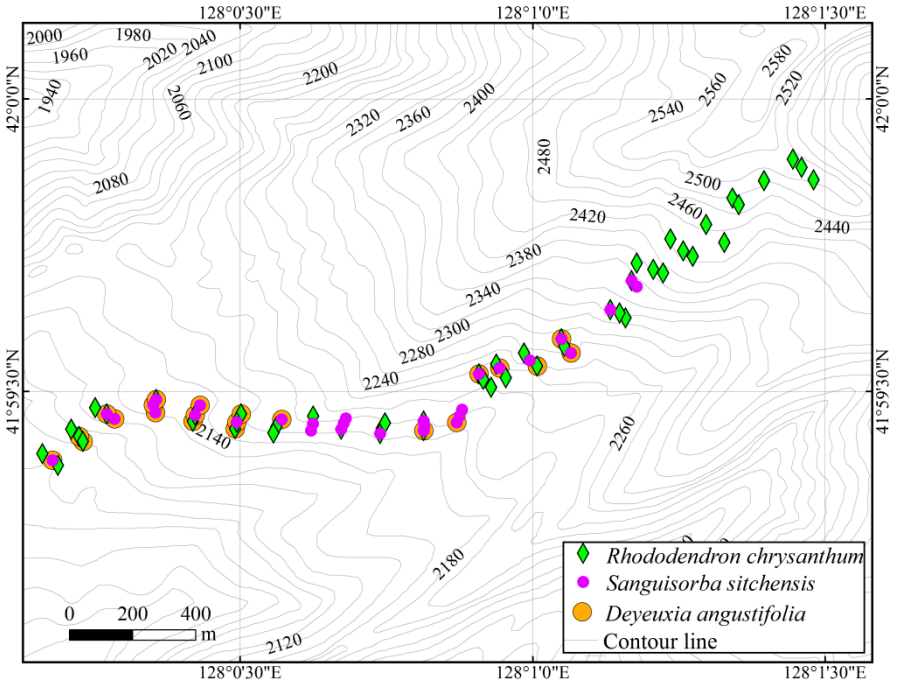
Table S1. Information on six general circulation models from CMIP5 used in this study

Model name	Centre, Country/region	Horizontal Resolution (Lat × Lon)	Leap year
BCC-CSM1.1m	BCC, China	1.112° × 1.125°	No
CCSM4	NCAR, USA	0.942° × 1.25°	No
CNRM-CM5	CNRM-CERFACS, France	1.397° × 1.406°	Yes
MPI-ESM-LR	MPI-M, Germany	1.861° × 1.875°	Yes
MRI-CGCM3	MRI, Japan	1.119° × 1.125°	Yes
MIROC5	MIROC, Japan	1.397° × 1.406°	No

Table S2. The correlations between the environmental variables and plant species are evaluated by canonical correspondence analysis. The significance of the relationships between the environmental variables and plant species were tested using a Monte Carlo permutation test (1000 permutations) for the first two canonical axes.

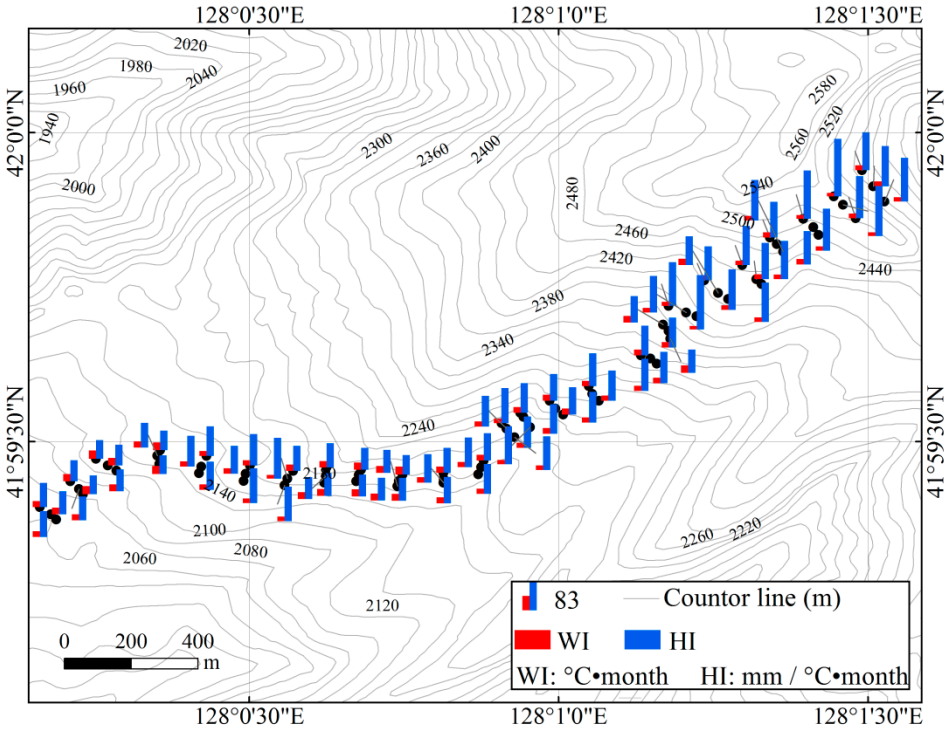
Environmental variables	CCA1	CCA2	R^2	*p*
slope	0.638	–0.770	0.12	0.011
slope direction	0.917	0.399	0.21	<0.001
slope location	0.988	0.151	0.27	<0.001
organic carbon	–0.291	0.957	0.30	<0.001
fulvic acid carbon	–0.594	0.805	0.12	0.015
humic acid carbon	–0.129	0.992	0.15	0.003
soil clay content	0.998	–0.069	0.43	<0.001
soil particle content	0.966	–0.259	0.12	0.008
soil sand content	–0.979	0.206	0.17	0.002
carbon nitrogen ratio	0.587	0.809	0.47	<0.001
soil deep	0.747	0.665	0.27	<0.001
temperature	0.999	–0.205	0.48	<0.001
precipitation	–0.902	–0.432	0.67	<0.001

Figure S1. Current spatial distributions of dominant alpine tundra plant species (*R. chrysanthum*, *D. angustifolia*, and *S. sitchensis*) along western slope transect within the Changbai Mountains.



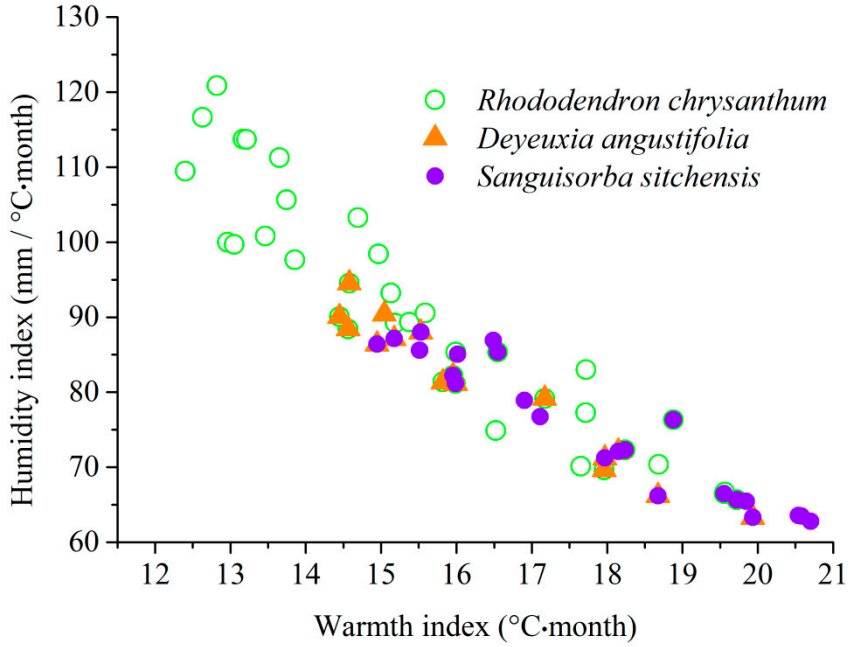
R. chrysanthum exhibits the widest distribution (ranging between 2050 and 2500 m) as well as the broadest temperature and moisture requirements. Data show that although the encroachment of herbaceous species such as *D. angustifolia* occurred at lower tundra elevations, *R. chrysanthum* nevertheless remained the dominant species within vegetation. We were also able to show that *D. angustifolia* and *S. sitchensis* encroached into the tundra from the birch forest zone and were mainly distributed within the low and middle parts of the tundra. The upper elevation limits for *D. angustifolia* and *S. sitchensis* were 2250 m and 2350 m, respectively.

Figure S2. Contemporary distributions of warmth (WI) and humidity (HI) values for each plot across alpine tundra along a western slope transect within the Changbai Mountains



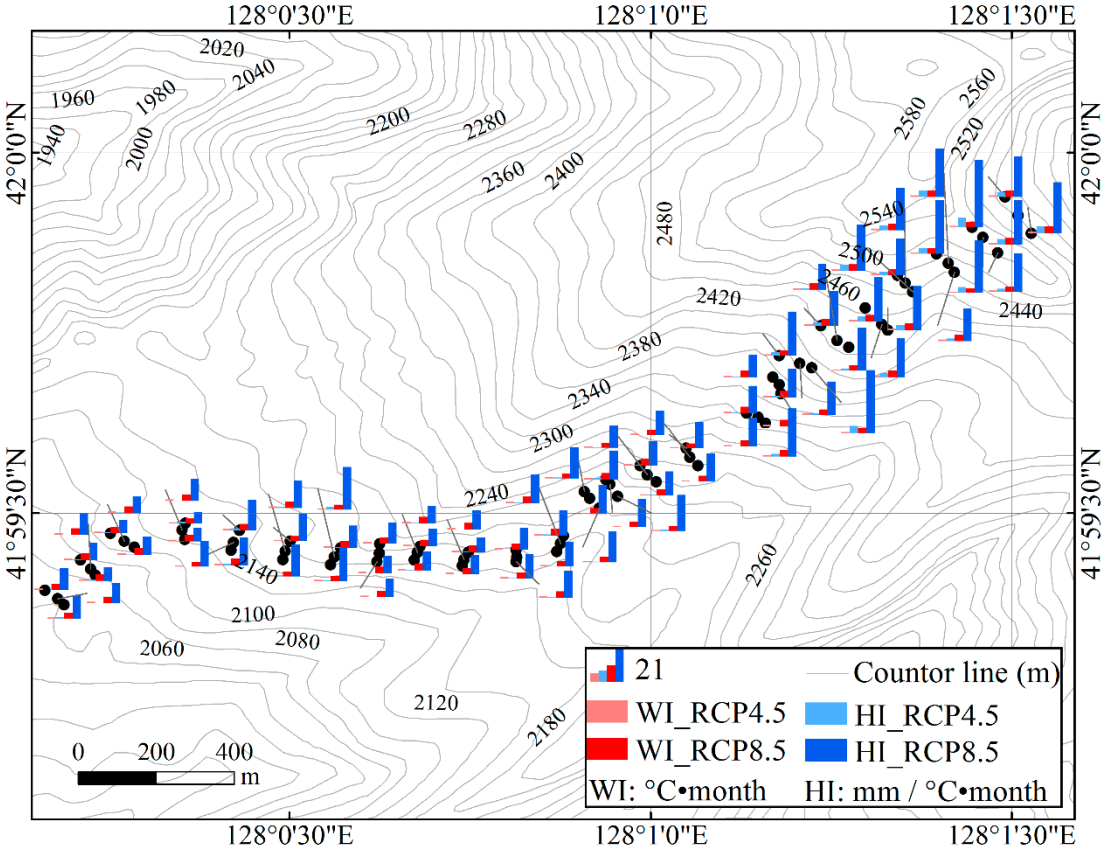
Records show that spatial changes in both WI and HI exhibit differential characteristics depending on both elevation gradient and topography. Indeed, WI values gradually decrease along the elevation gradient considered here and encapsulate fluctuations in the impact of topography in some places. The mean WI was 19.8 °C•month, ranging between 16.5 and 23.2 °C•month at 2050 m. The mean WI value decreased to 10.9 °C•month, ranging between 9.4 to 12.8 °C•month at 2500 m. HI showed gradually increasing along the elevation gradient. The mean HI was 70.4 mm/°C•month (ranged between 66.2 to 74.9 mm/°C•month) at 2050m, and increased to 143.9 mm/°C•month within a range between 120.8 and 166.3 mm/°C•month at 2500m. The combination of temperature and humidity remained relatively warm and dry at low elevations as opposed to relatively cold and wet at higher levels.

Figure S3. Ecological climate niches for the dominant species *R. chrysanthum*, *D. angustifolia*, and *S. sitchensis* were assessed using warmth index and humidity index, respectively.



Data show that WI values for *R. chrysanthum* ranged between 11.6 and 20.1 °C•month while HI values ranged between 61.1 to 122.9 mm/°C•month. As herbaceous species have encroached onto tundra from the birch forest zone, we focused on just their upper elevation limits and calculated minimum WI and maximum HI values in each case. WI values were more than 13.5 °C•month and HI values were less than 95.1 mm/°C•month for *D. angustifolia*, while these values were 14.7 °C•month and 90.4 mm/°C•month, respectively, for *S. sitchensis*. The WI and HI of each species in verification plots (16 plots for *R. chrysanthum*, 12 plots for *D. angustifolia*, and 15 plots for *S. sitchensis*) were all in the ranges of theirs, respectively.

Figure S4. Spatial changes in WI and HI differences during the growing season between 2015 and 2045 under two RCP scenarios (WI values on this graph denote positive values while HI values denote negative values).



WI values for each plot significantly increased under both emission scenarios by 2045 reaching averages of 0.92 °C•month and 3.78 °C•month, respectively. These increases in WI were large at high elevations and smaller at lower levels, while HI values for each plot significantly decreased under both emission scenarios for 2045 reaching averages of 1.13 mm/°C•month and 18.4 mm/°C•month, respectively. Decreasing magnitudes of HI values gradually increased along the alpine tundra transect from low to high elevations.

Figure S5. The AUC values of *R. chrysanthum*, *D. angustifolia*, and *S. sitchensis*.

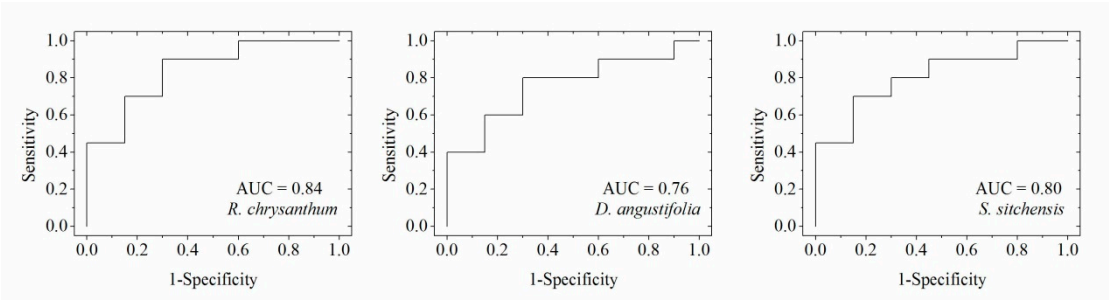


Figure S6. The tourist activities were limited to the wooden walkways, stairs, and observation decks in the Changbai mountains.

Figure S7. The damages of *Sus scrofa* foraging to alpine tundra vegetation within the Changbai Mountains. The areas hogged by *Sus scrofa* are easy to be encroached by the herbaceous plants.