Ecography

ECOG-05015

Terskaia, A., Dial, R. J. and Sullivan, P. F. 2020. Pathways of tundra encroachment by trees and tall shrubs in the western Brooks Range of Alaska. – Ecoraphy doi: 10.1111/ecog.05015

Supplementary material

Appendix 1

Figure A1. Mean annual air temperature over time (1950-2018) in Kotzebue, Alaska. The dark blue line is a linear fit to the Kotzebue data and the grey shading indicates 1.0 S.E. The years of aerial image analysis (1952, 1979 and 2015) are indicated by dashed vertical red lines.

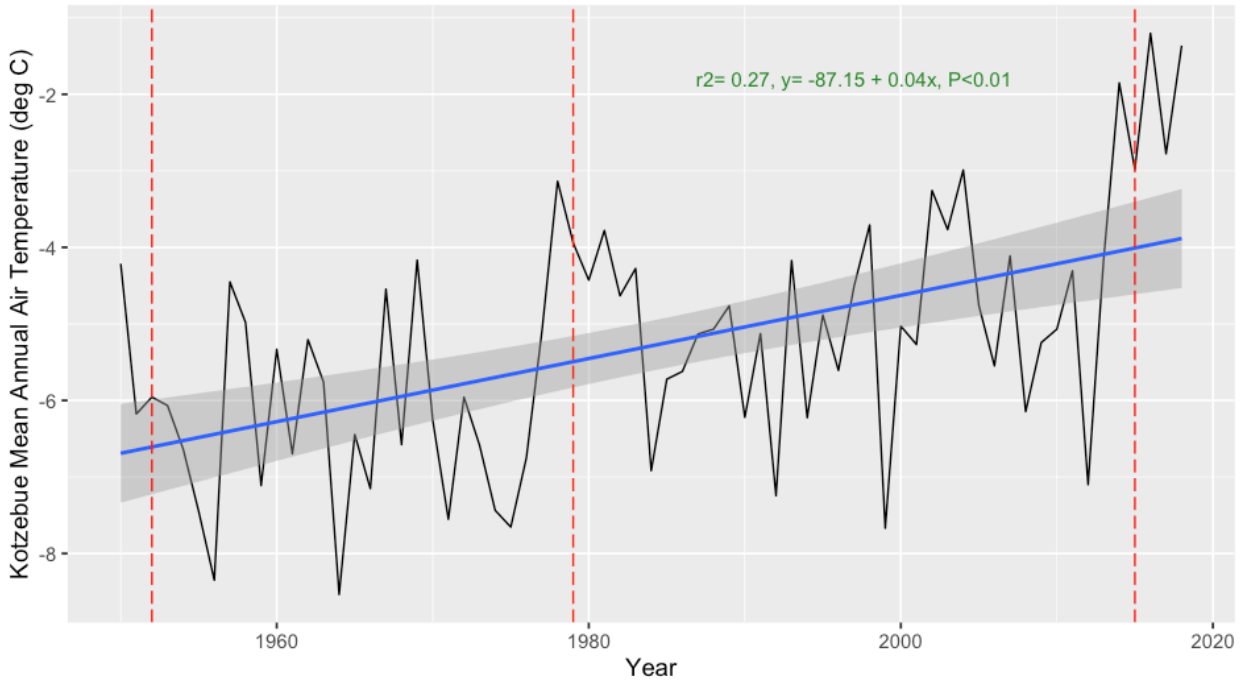

Figure A2. Relationships between mean monthly air temperature (June-September) in Kotzebue and at our floodplain weather station in the Agashashok watershed (2006-2018).

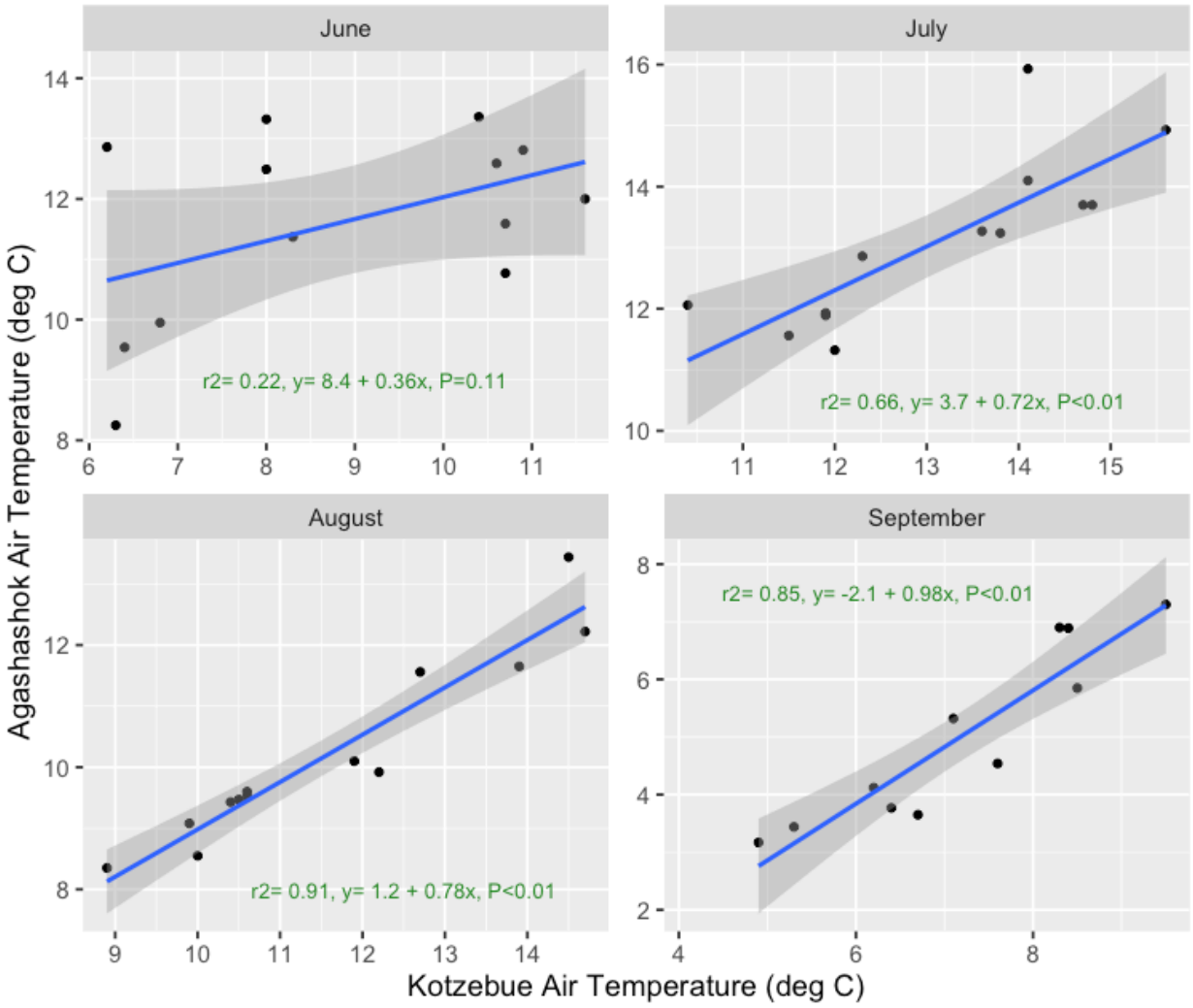

Table A1. Transition matrix for the random point analysis of vegetation change between 1952 and 1979 in the 5457 ha study area within the Agashashok watershed in the western Brooks Range.

1952	**1979**									**Total (1952)**
	Unvegetated	Alpine Tundra	Arctic Tundra	Floodplain Tundra	Shrub	Tree-Shrub	Open Woodland	Closed Canopy	Alluvium	
Unvegetated	**610**	74	4	2	2	0	0	0	0	692
Alpine Tundra	0	**419**	0	0	41	3	62	3	0	528
Arctic Tundra	0	0	**676**	0	75	0	31	0	0	782
Floodplain Tundra	1	0	0	**76**	2	0	13	0	8	100
Shrub	0	0	1	0	**138**	25	4	0	0	168
Tree-Shrub	0	0	0	0	0	**26**	0	0	0	26
Open Woodland	0	0	0	0	0	1	**163**	101	3	268
Closed Canopy	0	0	0	0	0	0	0	**297**	2	299
Alluvium	0	0	0	29	0	0	2	0	**159**	190
Total (1979)	611	493	681	107	258	55	275	401	172	**3053**
Relative Change (%)	**-12**	**-7**	**-13**	**+7**	**+54**	**+112**	**+3**	**+34**	**-9**	

Table A2. Transition matrix for the random point analysis of vegetation change between 1979 and 2015 in the 5457 ha study area within the Agashashok watershed in the western Brooks Range.

1979	2015									Total (1979)
	Unvegetated	Alpine Tundra	Arctic Tundra	Floodplain Tundra	Shrub	Tree-Shrub	Open Woodland	Closed Canopy	Alluvium	
Unvegetated	**562**	45	1	1	2	0	0	0	0	611
Alpine Tundra	1	**400**	0	0	27	3	58	4	0	493
Arctic Tundra	0	0	**539**	0	71	15	51	5	0	681
Floodplain Tundra	1	0	0	**64**	10	1	16	0	15	107
Shrub	0	1	1	0	**200**	47	4	4	1	258
Tree-Shrub	0	0	0	0	0	**54**	0	1	0	55
Open Woodland	0	0	0	0	0	6	**131**	135	3	275
Closed Canopy	0	0	0	0	0	0	2	**399**	0	401
Alluvium	0	1	0	28	2	0	0	1	**140**	172
Total (2015)	564	447	541	93	312	126	262	549	159	**3053**
Relative Change (%)	**-8**	**-9**	**-21**	**-13**	**+21**	**+129**	**-5**	**+37**	**-8**	

Table A3. Transition matrix for the random point analysis of vegetation change between 1952 and 2015 in the 5457 ha study area within the Agashashok watershed in the western Brooks Range.

1952	2015									Total (1952)
	Unvegetated	Alpine Tundra	Arctic Tundra	Floodplain Tundra	Shrub	Tree-Shrub	Open Woodland	Closed Canopy	Alluvium	
Unvegetated	**563**	119	5	1	4	0	0	0	0	692
Alpine Tundra	1	**327**	0	0	61	15	106	18	0	528
Arctic Tundra	0	0	**536**	0	129	31	64	22	0	782
Floodplain Tundra	0	0	0	**50**	6	1	25	2	16	100
Shrub	0	0	0	0	**105**	51	6	6	0	168
Tree-Shrub	0	0	0	0	0	**26**	0	0	0	26
Open Woodland	0	0	0	0	0	2	**59**	204	3	268
Closed Canopy	0	0	0	1	0	0	0	**297**	1	299
Alluvium	0	1	0	41	7	0	2	0	**139**	190
Total (2015)	564	447	541	93	312	126	262	549	159	**3053**
Relative Change (%)	**-18**	**-15**	**-31**	**-7**	**+86**	**+385**	**-2**	**+84**	**-16**	

Table A4. ΔAIC by model and year for multinomial of vegetation class by topographic variables.

elev	$elev^2$	slope	$slope^2$	north	slope:north	north:(elev+$elev^2$)	ΔAIC_{52}	ΔAIC_{79}	ΔAIC_{15}
x	x	x	x	x	x		17	0	0
x	x	x	x	x	x	x	0	2	5
x	x	x	x	x			78	68	55
x	x	x	x				171	143	97
x	x			x		x	715	776	743
x	x			x			738	777	736
x	x						822	845	778
x							1029	1025	942

Table A5. Confusion matrix comparing predictions of the multinomial model with the random point vegetation classifications for the 1952 aerial image. The model was fitted to a random selection of 50% of the data and the predictions were compared with the observed vegetation classes. Overall accuracy is 0.71 (95% CI: 0.69, 0.74).

Prediction	**Reference**		
	Trees	Arctic Tundra	Alpine Tundra
Trees	**138**	47	49
Arctic Tundra	89	**363**	98
Alpine Tundra	62	46	**478**

Table A6. Confusion matrix comparing predictions of the multinomial model with the random point vegetation classifications for the 1979 aerial image. The model was fitted to a random selection of 50% of the data and the predictions were compared with the observed vegetation classes. Overall accuracy is 0.71 (95% CI: 0.68, 0.74).

Prediction	**Reference**		
	Trees	Arctic Tundra	Alpine Tundra
Trees	**203**	67	62
Arctic Tundra	93	**329**	80
Alpine Tundra	63	33	**448**

Table A7. Confusion matrix comparing predictions of the multinomial model with the random point vegetation classifications for the 2015 satellite image. The model was fitted to a random selection of 50% of the data and the predictions were compared with the observed vegetation classes. Overall accuracy is 0.71 (95% CI: 0.68, 0.74).

Prediction	**Reference**		
	Trees	Arctic Tundra	Alpine Tundra
Trees	**310**	91	76
Arctic Tundra	83	**258**	60
Alpine Tundra	66	24	**421**

Figure A3. Spatial distribution of multinomial model predictions of tree presence for 1952 (top layer), 1979 (middle layer) and 2015 (bottom layer).

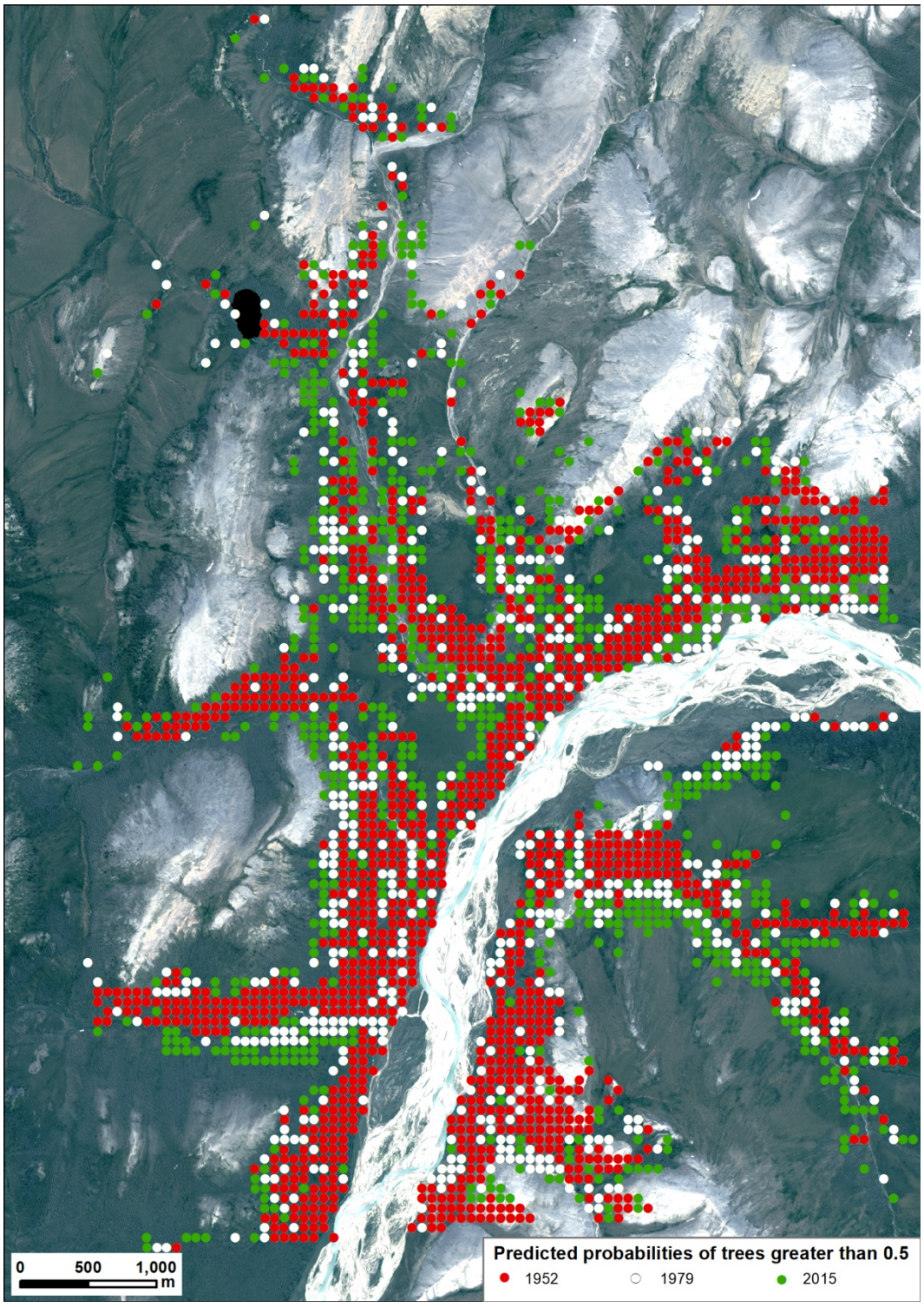

Figure A4. Treeline soil temperature as a function of soil moisture in the Agashashok study area. Measurements were made at 5 cm depth during the 2017 growing season using iButton temperature sensors at three treeline sites that differ strongly in soil moisture and understory vegetation type (n=8 sensors/site). The wet and moist treelines are among those classified as arctic treelines in the present study, while the dry treeline was classified as an alpine treeline. The three sites do not differ strongly in terms of elevation (wet: 160 m, moist: 130 m, dry: 165 m), indicating that a given growing season soil temperature isotherm likely occurs at a higher elevation where soils are dry.