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Supplement of

Kilometre-scale simulations over Fennoscandia reveal a large loss of tundra due to climate warming

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Content

S1. Maps of hotspots

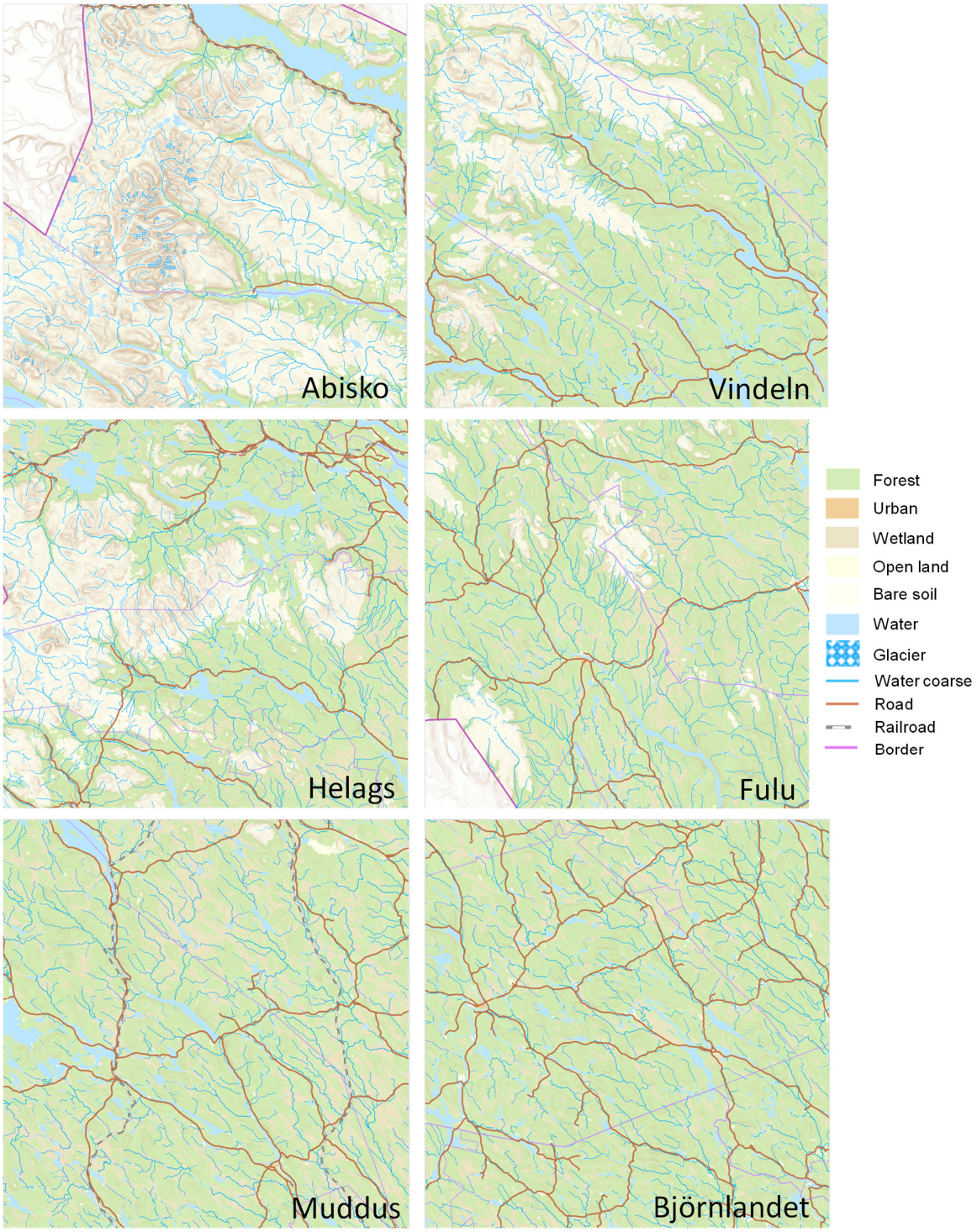

Figure S1. Maps of the six hotspots (90 × 90 km) from Lantmäteriet (The overview map, open data license Creative Commons, (CC0), https://www.lantmateriet.se/en/, accessed 2021-09-09).

S2. LPJ-Guess parameters tuned for the IBS plant functional type

Using the default parameters, test runs with a sub sample of gridcells showed a substantial underestimation of deciduous broad-leafed forest adjacent to the mountains, where it is represented by the Shade-Intolerant Broadleaved Summergreen tree plant functional type (IBS) in the simulations, when compared to the satellite-based products (see section 2.5.1). We therefore tested the IBS parameters from Gustafson et al. (2021), who had adjusted them to more specifically represent the small tree mountain birch (*Betula pubescens* ssp. *tortuosa*) and calibrated it to grow and compete as expected for the Abisko area (Gustafson personal communication). Simulations with these parameters on the other hand resulted in too large an extent of deciduous broad-leafed forest so to reduce the competitiveness of IBS, the original values related to shade tolerance and turnover were used instead. For the same reason, we also adjusted the alphar and turnover_sap parameters.

Table S2. Selected parameters for the shade-Intolerant Broadleaved Summergreen tree plant functional type (IBS), which represents the mountain birch (*Betula pubescens* ssp. *tortuosa*). The columns show the values which differ in the original LPJ-Guess 4.1, the version used by Gustafson et al. (2021) and the version used in the present application.

Parameter	Default 4.1	Gustafson et al. (2021)	Used value	Unit	Explanation
alphar	11	3	5	-	Shape parameter capturing non-linearity in recruitment rate relative to understory growing conditions
turnover_sap	0.1	0.1	0.075	fraction/year	Sapwood turnover
crownarea_max	50	27.3	27.3	m2	Maximum tree crown area
k_latosa	6000	4000	4000	-	Leaf to sapwood area ratio
k_allom1	250	200	200		Allometric parameter (crownarea = k_allom1 × $diam^{1.6}$)
k_allom2	60	30	30		Allometric parameter (height = k_allom2 × $diameter^{0.6}$)
gdd5min_est	350	250	250	°C day	Minimum growing degree days for establishment, with 5 °C limit
phengdd5ramp	200	75	75	°C day	Growing degree days, with 5 °C limit, to attain full leaf cover
gdd0_min	0	450	450	°C day	Minimum growing degree days for establishment, with 0 °C limit
longevity	300	220	220	years	Expected lifetime longevity under non-stressed conditions
greff_min	0.09	0.04	0.09	kg C m^{-2} yr^{-1}	Threshold for growth suppression mortality
parff_min	2500000	2000000	2500000	J m^{-2} day^{-1}	Min forest floor PAR for grass growth/ tree establishment
turnover_root	0.7	0.6	0.7	years	Turnover rate for fine roots
leaflong	0.5	0.3	0.5	years	Leaf life span

Gustafson, A., Miller, P. A., Björk, R., Olin, S., and Smith, B.: Nitrogen restricts future sub-arctic treeline advance in an individual-based dynamic vegetation model, Biogeosciences, 18, 6329–6347, https://doi.org/10.5194/bg-18-6329-2021, 2021.

S3. Description of the reindeer grazing, browsing and trampling implementation

A new function (grazebrowse), which reduces leaf biomass and kills a fraction of the plants, was added to LPJ-Guess code to represent reindeer grazing/browsing and trampling. The reduction of leaf biomass was done for all cohorts at patch level with a specified interval (visit_int, set to three years) after a check that the cohort is below a height that enables reindeer access to its canopy (height_max, set to 2.5 m). Using numbers for Sweden for verification, a three-year visit_int can be motivated from the size of the Swedish land area with reindeer herding (225 000 km^2, www.sametinget.se/rennaring_sverige), the population (225 000 – 280 000 animals in winter, www.sametinget.se/rennaring_sverige), the area represented by a patch (1000 m^2) and assuming that an animal eats one day a year per visited patch, which gives roughly a return time of 2-3 years (225×10^9 m^2 /(250×10^3 animals × 1000 m^2 $patch^{-1}$ × 1 patch day^{-1} $animal^{-1}$ × 365 days $year^{-1}$) = 2.5 years). The fraction of the leaf biomass that is consumed in a year with reindeers visiting the patch (harv_frac, unitless) was calculated as:

harv_frac = visit_int × browse_pref × herbivore_int

where browse_pref (unitless) is a PFT specific parameter that describes how large the fraction of a PFT that is consumed is relative to the availability of the PFT and the total consumption, and where herbivore_int (yr^{-1}) is the relative herbivore intensity (i.e. the fraction of leaf mass on average removed per year, if it is reachable, with a browse_pref of 1). Preference values for reindeer were obtained from extensive observations of Caribou grazing and browsing in Canada (Denryter et al., 2017) (Table 1). Though the species are different in North America compared to Fennoscandia, it was assumed that the North American species were representative at the genus level.

All consumed carbon of the browsed leaves entered the harvest pool, which means that it was removed from the biogeochemical cycling within the ecosystem, but only a fraction of the consumed leaf N was "harvested" (N_browseharvest_scale, set to 0.35). The remaining part of consumed N was maintained in the cohort's leaf N pool, which is a functionality that represents the assumption that N leaving the herbivore as urine is rapidly taken up by the plants (Barthelemy et al., 2018). Ferraro et al. (2022), in their modelling study of caribou population dynamics, used a fraction of 38% of N that is released as egestion the day after consumption and that some of the remaining part is released as excretion based on the range (e.g., varying with age and sex) reported by Mcewan and Whitehead (1970).

A fraction of the biomass (grass PFT types) or number of individuals (tree and shrub PFTs) was killed annually to represent the effect of trampling. The fraction (trampled) was calculated as:

trampled = visit_int × tramp_frac × herbivore_int

where tramp_frac (unitless) is a PFT specific parameter corresponding to the fraction of individuals killed (or biomass killed for grass) per year with a herbivore _int of 1. A maximum value of trampled is currently set to 95%. The "tramp_frac" values (Table 1) are based on the vegetation response in an artificial trampling experiment (Egelkraut et al., 2020).

Table S3. The new PFT-parameters browse_pref and tramp_frac. The browse_pref values are based on the Denryter et al. (2017) study. An average of reported Ivlev's electivity indexes (IEI) was first achieved from reported values for relevant individual species and then "preference" was calculated as (1+ IEI)/(1- IEI).

pft	Species used for calculating the mean of Ivlev's electivity indexes	IEI	browse_pref	tramp_frac
BNE	*Picea mariana, P. glauca, P. Engelmannii*	-0.9	0.053	0
BINE	*Pinus contorta*	-0.94	0.031	0
IBS	*Betula papyrifera* (0.82), *Populus tremuloides* (0.44), *Alnus crispa* (0.66)	0.64	4.6	0
TeBS	No data	0.5	3.0	0
C3G, C3G_wet	Weighted mean of all grasses (weighted by number of observed grazing events for the different species)	-0.176	0.70	0.1
HSE	*Juniperus communis* (-1)	-0.99	0.005	0.01
HSS	*Alnus crispa* (0.66), *Salix* sp (0.72), *Betula glandulosa* (0.4)	0.65	4.7	0.01
LSE, pLSE	*Vaccinium vitis-idea*, *Empetrum* has higher score but that is because its berries are eaten	-0.72	0.16	0.15
LSS, pLSS	*Vaccinium myrtilloides* (0.65), *Vaccinium uliginosum* (0.59), *Salix* sp (0.72)	0.65	4.7	0.15
GRT, WetGRS	Calculated from Table 2&3 for forbes, grasses and graminoid nongrasses	-0.2	0.67	0.1
EPDS	*Vaccinium oxycoccus* (-0.88), *Cassiope mertensiana* (-0.67), *Dryas octopetala* (-0.28), *Saxifraga oppositifolia* (-1)	-0.71	0.17	0.2
SPDS	*Salix reticulata* (-0.82), *Arctostaphylos rubra* (-0.26)	-0.54	0.30	0.2
CLM, pCLM	*Saxifragaceae* (-1), *Caryophyllaceae* (-0.9), lichens *Cladina* and *Cladonia* sp (0.55), mosses (-1)	-0.59	0.26	0.1
pmoss	Various spp.	-1	0.0	0.1

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S4. Climate-change signal in the climate scenario

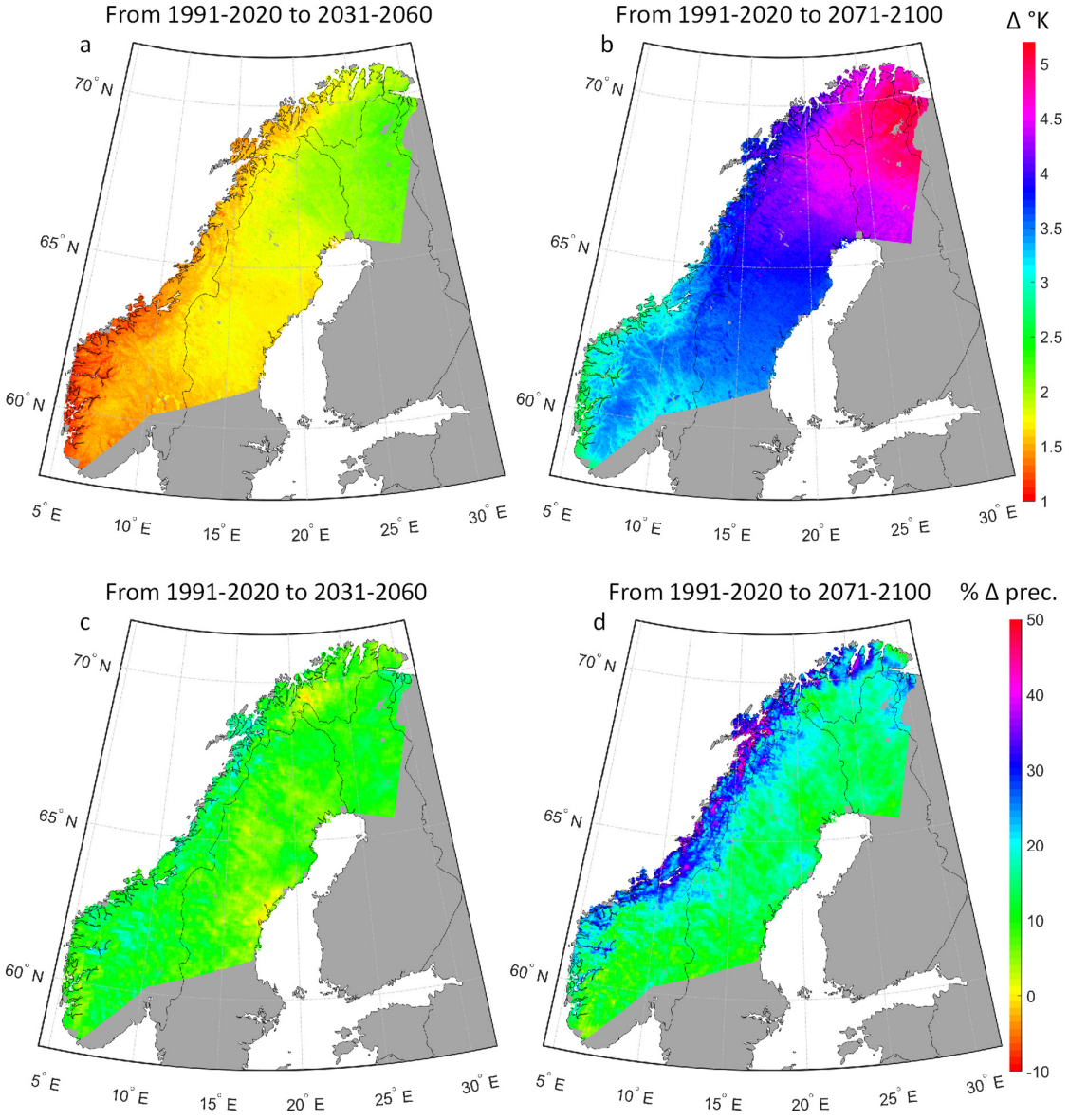

Figure S4. Change in mean annual air temperature (a, b) and relative change in annual precipitation (c, d) from the 1991-2020 to the 2031-2060 30-year periods (a, c) and from 1991-2020 to 2071-2100 (b, d) for the constructed complete 1985-2100 RCP8.5 dataset used in the vegetation model simulations.

S5. Description of conversion of PFT LAI to vegetation classes

First gridcells classified as water according to the 2018 Corine vegetation map were set to water for both GLCE and Corine, and gridcells with a wetland fraction (prescribed and constant over the simulation period based on the PEATMAP product (Xu et al., 2018)) above 0.5 were set to "Peat bogs" and "Bogs and marches" for GLCE and Corine respectively. The rest of the classification was based on simulated LAI of the different PFTs, using these sums and fractions:

totalLAI: sum of all PFTs' LAI

forestLAI: sum of all tree PFTs' LAI (BNE, BINE, IBS, TeBS)

conLAIfrac: sum of conifer tree PFTs' LAI divided by forestLAI

woodLAIfrac: forestLAI + tall shrub PFTs' LAI divided by totalLAI

needleLAIwoodfrac: sum of conifer tree and shrub PFTs' LAI divided by (forestLAI + tall shrub LAI)

shrubLAIfrac: sum of tall and short shrubs LAI divided by totalLAI

grassLAIfrac: sum of grass and forb PFTs' LAI divided by total LAI excluding forestLAI and tall shrub LAI

sedgaLAIfrac: sum of short shrubs, graminoid and forb tundra and flood tolerant grass PFTs LAI divided by totalLAI

CLMgrassLAIfrac: graminoid and forb tundra, cushion forb, lichen and moss tundra and flood tolerant grass PFTs LAI divided by totalLAI

These were then applied according to the FigS5a-b schemes below which are based on the definitions in Bartalev et al. (2003) and Kosztra et al. (2019) for GLCE and Corine, respectively.

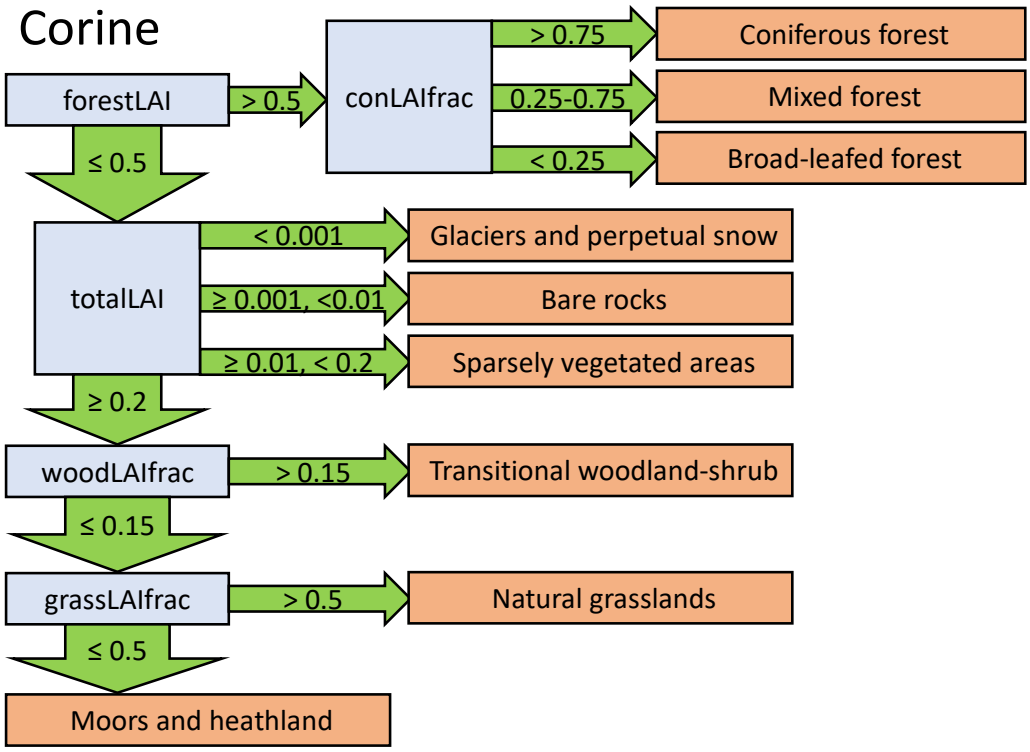

Figure S5a. Scheme for the vegetation classification according to Corine based on simulated LAI.

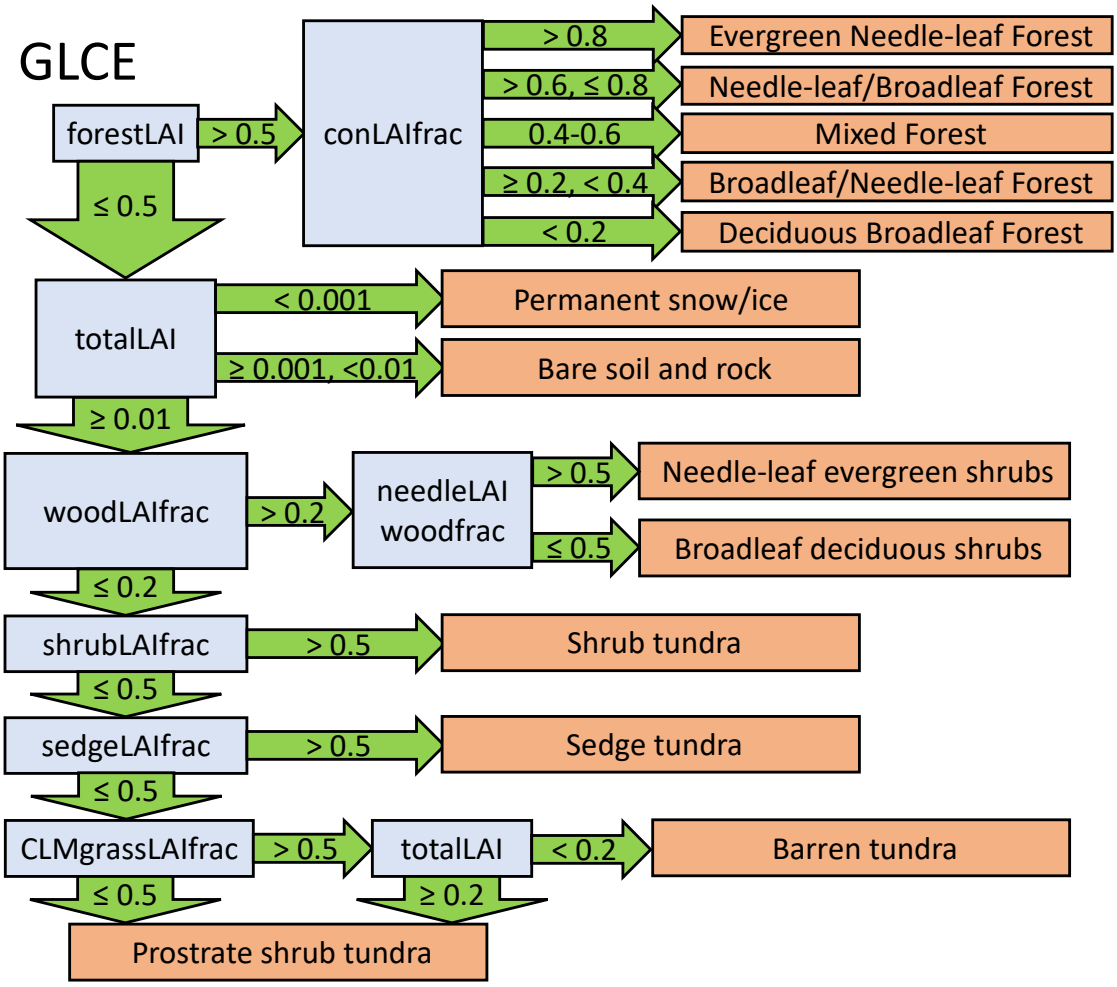

Figure S5b. Scheme for the vegetation classification according to GLCE based on simulated LAI.

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S6. Validation results

Table S6a. Confusion matrix for vegetation classification in 3×3 km gridcells, calculated using simulation output for 1995-2004 compared to the satellite-based GLCE product for 2000. Classes that were not simulated (e.g. cropland and urban) or prescribed (wetlands and water) were not included. The overall accuracy was 32.4%. Merging data to broader classes gave: Forest user accuracy 83.7%, Forest producer accuracy 89.6%, Shrub user accuracy 0.7%, Shrub producer accuracy 17.1%, Tundra user accuracy 82.7%, Tundra producer accuracy 35.8%.

LPJ-Guess classification / Sat. class.	Evergreen Needle-leaf Forest	Deciduous Broadleaf Forest	Needle-leaf/Broadleaf Forest	Mixed Forest	Broadleaf/Needle-leaf Forest	Broadleaf deciduous shrubs	Needle-leaf evergreen shrubs	Prostrate shrub tundra	Sedge tundra	Shrub tundra	Bare soil and rock	Permanent snow/ice	Total	User accuracy
E. NL For.	16129	1320	5454	4357	2270	187	483	110	213	0	0	0	30523	72.9%
D. BL For.	2433	99	351	193	120	24	84	21	72	0	2	0	3399	2.1%
NL/BL For.	607	14	254	158	65	0	4	1	5	0	0	0	1108	3.9%
M. For.	314	19	112	66	26	0	4	0	5	0	0	0	546	1.3%
BL/NL For.	98	3	77	56	15	1	4	0	1	0	0	0	255	0.5%
BL D. shr.	165	16	8	2	5	28	26	9	45	0	0	0	304	0.5%
NL e. shr.	7	2	0	1	1	0	1	0	6	0	0	0	18	0.0%
Prost. shr. tundra	65	62	4	3	0	953	110	411	1922	8	803	67	4408	23.2%
Sedge tundra	362	597	11	10	10	1251	316	301	1445	3	56	2	4364	19.1%
Shrub tundra	1830	2618	181	156	262	2757	1077	796	2844	28	306	27	12882	65.1%
Bare soil and rock	125	10	2	1	4	212	66	124	977	4	1347	425	3297	50.8%
Perm. snow/ice	0	0	0	0	0	1	0	2	27	0	136	66	232	11.2%
Total	22135	4760	6454	5003	2778	5414	2175	1775	7562	43	2650	587	61336	
Prod. Acc.	52.8%	2.9%	22.9%	12.1%	5.9%	9.2%	5.6%	9.3%	33.1%	0.2%	40.9%	28.4%		

Table S6b. Confusion matrix for vegetation classification in 3x3 km gridcells, calculated using simulation output for 2013-2022 compared to the satellite-based Corine product for 2018. Classes that were not simulated (e.g. cropland and urban) or prescribed (wetlands and water) were not included. The overall accuracy was 37.1%. Treating forest as one big class gave a user accuracy of 84.4% and producer accuracy 93.7%.

Satellite class. \ LPJ-Guess classification	Broad-leaved forest	Coniferous forest	Mixed forest	Natural grasslands	Moors and heathland	Transitional woodland-shrub	Bare rocks	Sparsely vegetated areas	Glaciers and perpetual snow	Total	User accuracy
BL forest	2150	2195	647	331	50	1787	2	32	0	7194	38.9%
Con. forest	1542	17434	10848	10	2	212	0	1	0	30049	69.0%
Mixed forest	301	1086	535	3	0	30	0	0	0	1955	4.2%
Natural grassl.	0	0	0	36	3	4	4	43	1	91	0.7%
Moors and heathl.	971	1941	187	1622	377	2834	15	649	5	8601	17.6%
Trans. woodl.-shrub	59	779	337	1	0	2	0	0	0	1178	0.0%
Bare rocks	37	90	14	704	54	267	618	700	270	2754	56.1%
Sparsely veg. areas	465	1731	182	2447	420	2662	321	1966	165	10359	57.4%
Glac. & perp. snow	0	1	0	22	0	9	141	37	80	290	15.4%
Total	5525	25257	12750	5176	906	7807	1101	3428	521	62471	
Producer accuracy	29.9%	58.0%	27.4%	39.6%	4.4%	0.2%	22.4%	19.0%	27.6%		

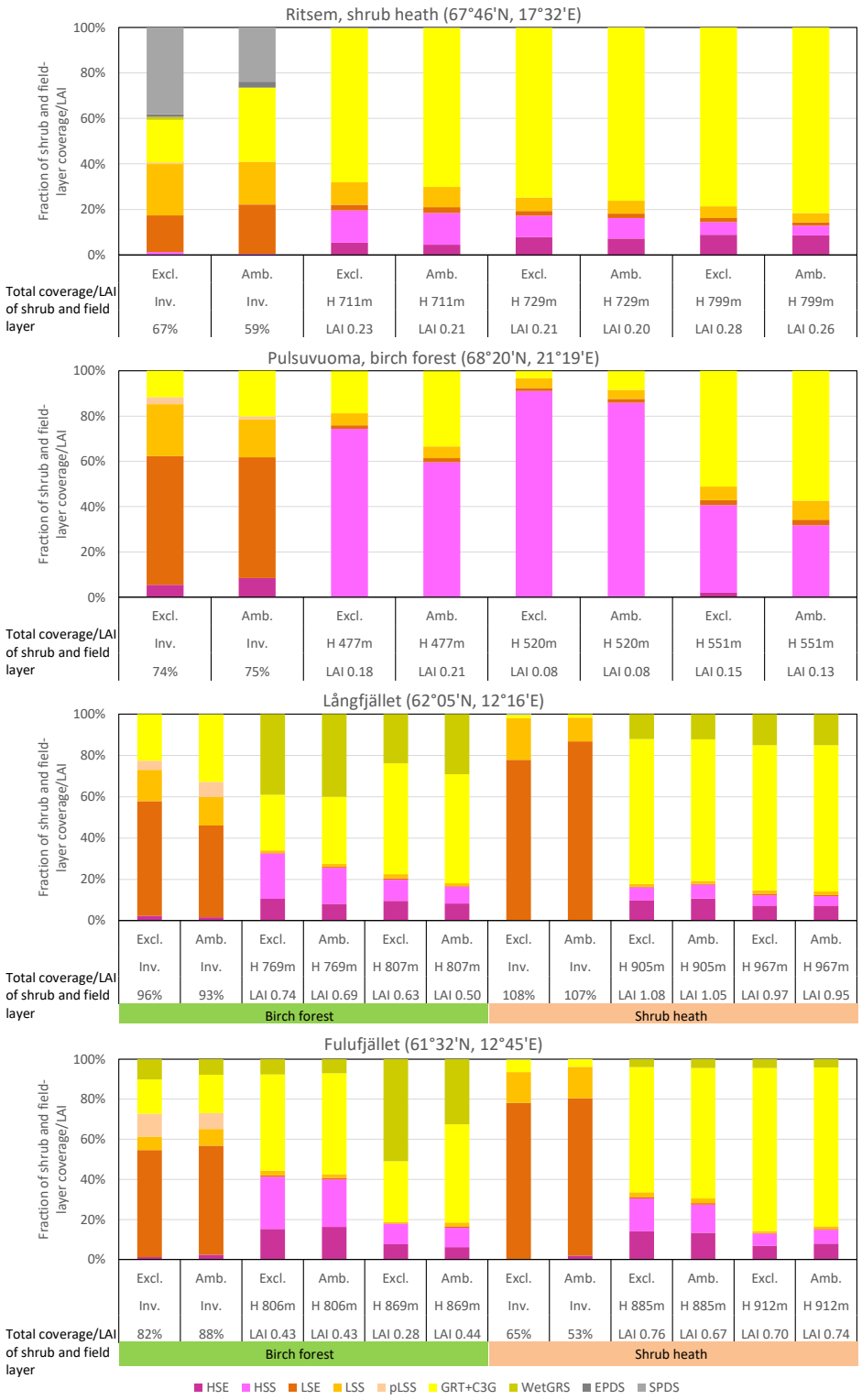

Figure S6. Composition of inventoried (coverage in 2011) and simulated (LAI mean 2009-2013) shrub and field layer vegetation (see Table 1 for explanation of vegetation types) for four locations with exclosure experiments in both/either birch forest and/or shrub heath (Vowles et al., 2017a), shown for plots or simulations with reindeer excluded from 1995 or ambient with reindeer access. Simulations were done for 2-3 gridcells with a representative range in altitude (H).

S7. Confusion matrixes for simulated and satellite-based vegetation classes

Table S7a. Confusion matrix for vegetation classification in 3×3 km gridcells for a 90×90 km area around Abisko, simulations for 1995-2004 compared to the satellite-based GLCE product for 2000 and simulations 2091-2100. Classes that were not simulated (e.g. cropland and urban) or prescribed (wetlands and water) were not included. The total number of comparisons are higher for LPJ-GUESS 1995-2004 against 2091-2100 than for comparison with the satellite-based class, as cells with a satellite-based class that was not simulated (e.g. urban) were filtered out in that comparison.

		LPJ-Guess simulation 1995-2004												
		E. NL For.	D. BL For.	NL/BL For.	M. For.	BL/NL For.	BL D. shr.	NL e. shr.	Prost. shr. tun.	Sedge tun.	Shrub tun.	Bare soil & rock	Perm. snow/ice	Total
Satellite-based class 2000	E. NL For.	0	7	0	0	5	1	0	0	0	0	0	0	13
	D. BL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL/BL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	M. For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	BL/NL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	BL D. shr.	0	3	0	0	0	1	0	0	0	0	0	0	4
	NL e. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Prost. shr. tun.	0	0	0	0	0	19	1	34	76	0	102	5	237
	Sedge tun.	0	1	1	0	0	43	0	30	28	0	1	0	104
	Shrub tun.	0	36	0	0	2	123	7	23	38	0	10	0	239
	Bare soil & rock	0	0	0	0	1	3	0	4	37	0	140	23	208
	Perm. snow/ice	0	0	0	0	0	0	0	0	1	0	0	0	1
	Total	0	47	1	0	8	190	8	91	180	0	253	28	806
LPJ-Guess simulation 2091-2100	E. NL For.	0	0	3	0	0	86	1	5	2	0	0	0	97
	D. BL For.	0	0	0	0	0	0	0	2	7	0	66	22	97
	NL/BL For.	1	7	0	1	3	22	2	1	0	0	0	0	37
	M. For.	0	33	0	0	7	10	0	0	0	0	0	0	50
	BL/NL For.	0	17	0	0	1	2	0	0	4	0	10	0	34
	BL D. shr.	0	0	0	0	0	0	0	0	6	0	37	3	46
	NL e. shr.	0	0	0	0	0	87	5	85	89	0	120	0	386
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	12	2	14
	Sedge tun.	0	0	0	0	0	0	0	1	76	0	9	1	87
	Shrub tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	1	0	1
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	1	57	3	1	11	207	8	94	184	0	255	28	849

Table S7b. Confusion matrix for vegetation classification in 3×3 km gridcells for a 90×90 km area around Vindeln, simulations for 1995-2004 compared to the satellite-based GLCE product for 2000 and simulations 2091-2100. Classes that were not simulated (e.g. cropland and urban) or prescribed (wetlands and water) were not included. The total number of comparisons are higher for LPJ-GUESS 1995-2004 against 2091-2100 than for comparison with the satellite-based class, as cells with a satellite-based class that was not simulated (e.g. urban) were filtered out in that comparison.

		LPJ-Guess simulation 1995-2004												
		E. NL For.	D. BL For.	NL/BL For.	M. For.	BL/NL For.	BL D. shr.	NL e. shr.	Prost. shr. tun.	Sedge tun.	Shrub tun.	Bare soil & rock	Perm. snow/ice	Total
Satellite-based class 2000	E. NL For.	234	3	61	20	4	13	73	7	36	0	0	0	451
	D. BL For.	4	1	0	1	1	5	12	3	19	0	0	0	46
	NL/BL For.	2	0	0	1	0	0	1	0	0	0	0	0	4
	M. For.	3	0	0	0	0	0	1	0	1	0	0	0	5
	BL/NL For.	1	0	0	0	0	0	2	0	1	0	0	0	4
	BL D. shr.	0	0	0	0	0	4	3	0	15	0	0	0	22
	NL e. shr.	0	0	0	0	0	0	0	0	1	0	0	0	1
	Prost. shr. tun.	0	0	0	0	0	4	0	0	13	0	5	0	22
	Sedge tun.	0	0	0	0	0	27	1	3	84	0	0	0	115
	Shrub tun.	0	0	0	0	0	34	9	7	79	0	1	0	130
	Bare soil & rock	0	0	0	0	0	0	0	0	2	0	3	0	5
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	244	4	61	22	5	87	102	20	251	0	9	0	805
LPJ-Guess simulation 2091-2100	E. NL For.	262	0	62	20	3	47	109	19	181	0	0	0	703
	D. BL For.	0	0	0	0	0	0	0	0	1	0	1	0	2
	NL/BL For.	6	3	0	2	3	12	1	0	1	0	0	0	28
	M. For.	0	2	0	0	0	0	0	0	0	0	0	0	2
	BL/NL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	BL D. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL e. shr.	0	0	0	0	0	36	1	3	83	0	8	0	131
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedge tun.	0	0	0	0	0	0	0	0	13	0	0	0	13
	Shrub tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	268	5	62	22	6	95	111	22	279	0	9	0	879

Table S7c. Confusion matrix for vegetation classification in 3×3 km gridcells for a 90×90 km area around Helags, simulations for 1995-2004 compared to the satellite-based GLCE product for 2000 and simulations 2091-2100. Classes that were not simulated (e.g. cropland and urban) or prescribed (wetlands and water) were not included. The total number of comparisons are higher for LPJ-GUESS 1995-2004 against 2091-2100 than for comparison with the satellite-based class, as cells with a satellite-based class that was not simulated (e.g. urban) were filtered out in that comparison.

		LPJ-Guess simulation 1995-2004												
		E. NL For.	D. BL For.	NL/BL For.	M. For.	BL/NL For.	BL D. shr.	NL e. shr.	Prost. shr. tun.	Sedge tun.	Shrub tun.	Bare soil & rock	Perm. snow/ice	Total
Satellite-based class 2000	E. NL For.	349	0	22	3	0	0	9	0	9	0	0	0	392
	D. BL For.	43	0	0	0	0	0	0	0	0	0	0	0	43
	NL/BL For.	16	0	0	0	0	0	0	0	0	0	0	0	16
	M. For.	11	0	0	0	0	0	0	0	0	0	0	0	11
	BL/NL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	BL D. shr.	7	0	0	0	0	0	1	0	0	0	0	0	8
	NL e. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Prost. shr. tun.	0	0	0	0	0	5	0	1	12	0	1	0	19
	Sedge tun.	1	0	0	1	0	18	29	2	82	0	0	0	133
	Shrub tun.	45	0	2	1	0	20	52	4	97	0	2	0	223
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	1	0	1
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	472	0	24	5	0	43	91	7	200	0	4	0	846
LPJ-Guess simulation 2091-2100	E. NL For.	468	0	27	6	0	27	93	5	157	0	0	0	783
	D. BL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL/BL For.	26	0	0	0	0	0	0	0	0	0	0	0	26
	M. For.	15	0	0	0	0	0	0	0	0	0	0	0	15
	BL/NL For.	2	0	0	0	0	0	0	0	0	0	0	0	2
	BL D. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL e. shr.	0	0	0	0	0	16	0	2	46	0	4	0	68
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedge tun.	0	0	0	0	0	0	0	0	3	0	0	0	3
	Shrub tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	511	0	27	6	0	43	93	7	206	0	4	0	897

Table S7d. Confusion matrix for vegetation classification in 3×3 km gridcells for a 90×90 km area around Fulu, simulations for 1995-2004 compared to the satellite-based GLCE product for 2000 and simulations 2091-2100. Classes that were not simulated (e.g. cropland and urban) or prescribed (wetlands and water) were not included. The total number of comparisons are higher for LPJ-GUESS 1995-2004 against 2091-2100 than for comparison with the satellite-based class, as cells with a satellite-based class that was not simulated (e.g. urban) were filtered out in that comparison.

		LPJ-Guess simulation 1995-2004												
		E. NL For.	D. BL For.	NL/BL For.	M. For.	BL/NL For.	BL D. shr.	NL e. shr.	Prost. shr. tun.	Sedge tun.	Shrub tun.	Bare soil & rock	Perm. snow/ice	Total
Satellite-based class 2000	E. NL For.	679	0	41	2	0	0	0	0	0	0	0	0	722
	D. BL For.	7	0	0	0	0	0	0	0	0	0	0	0	7
	NL/BL For.	6	0	0	0	0	0	0	0	0	0	0	0	6
	M. For.	1	0	1	0	0	0	0	0	0	0	0	0	2
	BL/NL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	BL D. shr.	1	0	0	0	0	0	0	0	0	0	0	0	1
	NL e. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedge tun.	9	0	0	0	0	0	3	0	1	0	0	0	13
	Shrub tun.	60	0	3	0	0	0	7	0	3	0	0	0	73
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	763	0	45	2	0	0	10	0	4	0	0	0	824
LPJ-Guess simulation 2091-2100	E. NL For.	545	0	24	0	0	0	10	0	4	0	0	0	583
	D. BL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL/BL For.	217	0	12	1	0	0	0	0	0	0	0	0	230
	M. For.	52	0	11	0	0	0	0	0	0	0	0	0	63
	BL/NL For.	1	0	0	1	0	0	0	0	0	0	0	0	2
	BL D. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL e. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedge tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shrub tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	815	0	47	2	0	0	10	0	4	0	0	0	878

Table S7e. Confusion matrix for vegetation classification in 3×3 km gridcells for a 90×90 km area around Muddus, simulations for 1995-2004 compared to the satellite-based GLCE product for 2000 and simulations 2091-2100. Classes that were not simulated (e.g. cropland and urban) or prescribed (wetlands and water) were not included. The total number of comparisons are higher for LPJ-GUESS 1995-2004 against 2091-2100 than for comparison with the satellite-based class, as cells with a satellite-based class that was not simulated (e.g. urban) were filtered out in that comparison.

		LPJ-Guess simulation 1995-2004												
		E. NL For.	D. BL For.	NL/BL For.	M. For.	BL/NL For.	BL D. shr.	NL e. shr.	Prost. shr. tun.	Sedge tun.	Shrub tun.	Bare soil & rock	Perm. snow/ice	Total
Satellite-based class 2000	E. NL For.	628	4	39	17	8	3	5	0	0	0	0	0	704
	D. BL For.	5	0	0	0	0	0	0	0	0	0	0	0	5
	NL/BL For.	4	0	0	0	0	0	0	0	0	0	0	0	4
	M. For.	1	0	0	0	0	0	0	0	0	0	0	0	1
	BL/NL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	BL D. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL e. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedge tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shrub tun.	3	1	0	0	1	1	0	0	0	0	0	0	6
	Bare soil & rock	1	0	0	0	0	0	0	0	0	0	0	0	1
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	642	5	39	17	9	4	5	0	0	0	0	0	721
LPJ-Guess simulation 2091-2100	E. NL For.	568	0	15	4	1	0	5	0	0	0	0	0	593
	D. BL For.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL/BL For.	91	1	7	5	6	3	0	0	0	0	0	0	113
	M. For.	12	4	18	8	2	1	0	0	0	0	0	0	45
	BL/NL For.	0	0	1	0	0	0	0	0	0	0	0	0	1
	BL D. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL e. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedge tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shrub tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	671	5	41	17	9	4	5	0	0	0	0	0	752

Table S7f. Confusion matrix for vegetation classification in 3×3 km gridcells for a 90×90 km area around Björnlandet, simulations for 1995-2004 compared to the satellite-based GLCE product for 2000 and simulations 2091-2100. Classes that were not simulated (e.g. cropland and urban) or prescribed (wetlands and water) were not included. The total number of comparisons are higher for LPJ-GUESS 1995-2004 against 2091-2100 than for comparison with the satellite-based class, as cells with a satellite-based class that was not simulated (e.g. urban) were filtered out in that comparison.

		LPJ-Guess simulation 1995-2004												
		E. NL For.	D. BL For.	NL/BL For.	M. For.	BL/NL For.	BL D. shr.	NL e. shr.	Prost. shr. tun.	Sedge tun.	Shrub tun.	Bare soil & rock	Perm. snow/ice	Total
Satellite-based class 2000	E. NL For.	189	0	263	153	35	0	0	0	0	0	0	0	640
	D. BL For.	67	0	19	1	0	0	0	0	0	0	0	0	87
	NL/BL For.	21	0	29	5	1	0	0	0	0	0	0	0	56
	M. For.	7	0	6	0	0	0	0	0	0	0	0	0	13
	BL/NL For.	15	0	12	3	0	0	0	0	0	0	0	0	30
	BL D. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL e. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedge tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shrub tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	299	0	329	162	36	0	0	0	0	0	0	0	826
LPJ-Guess simulation 2091-2100	E. NL For.	106	0	13	0	0	0	0	0	0	0	0	0	119
	D. BL For.	0	0	0	3	0	0	0	0	0	0	0	0	3
	NL/BL For.	143	0	108	15	1	0	0	0	0	0	0	0	267
	M. For.	58	0	180	101	14	0	0	0	0	0	0	0	353
	BL/NL For.	11	0	35	49	21	0	0	0	0	0	0	0	116
	BL D. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	NL e. shr.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Prost. shr. tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sedge tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Shrub tun.	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil & rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perm. snow/ice	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	318	0	336	168	36	0	0	0	0	0	0	0	858

S8. Simulated potential reindeer consumption in Sweden by reindeer-herding communities

Table S8. Change in simulated potential reindeer consumption of leaf biomass (g C m^{-2} yr^{-1}) in the 51 reindeer-herding communities in Sweden from the 1995-2004 period, for the different seasonal grazing grounds. The districts are sorted from north to south. Blue cells have a negative absolute change in the range -0.5 to 0 g C m^{-2} yr^{-1} and red cells have a positive change from 0 to 2.11 g C m^{-2} yr^{-1}.

	Spring			Summer			Autumn			Winter		
	2013-2022	2041-2050	2091-2100	2013-2022	2041-2050	2091-2100	2013-2022	2041-2050	2091-2100	2013-2022	2041-2050	2091-2100
Könkämä	0.52	0.78	0.80	0.54	0.90	1.12	0.26	0.46	0.15	-0.15	-0.19	0.11
Lainiovuoma	0.56	0.80	0.58	0.56	0.86	0.70	0.15	0.36	0.14	-0.12	0.08	0.46
Saarivuoma	0.31	0.64	1.16	0.26	0.58	1.44	0.28	0.61	1.05	-0.09	0.11	0.26
Talma	-0.03	0.13	0.22	0.27	0.66	0.93	0.15	0.44	0.64	-0.09	0.00	0.17
Gabna	0.26	0.52	0.67	0.19	0.47	2.07	0.26	0.52	0.67	-0.16	-0.02	0.37
Laevas	0.58	0.88	0.77	0.14	0.33	2.11	0.40	0.66	0.68	-0.09	0.02	0.47
Girjas	0.33	0.56	0.65	0.39	0.65	1.43	0.31	0.53	0.36	-0.10	0.02	0.50
Baste cearru	0.23	0.53	0.46	0.17	0.58	1.75	0.17	0.42	0.43	-0.04	0.11	0.25
Unna Tjerusj	0.37	0.63	1.42	0.35	0.60	1.57	0.24	0.44	0.73	0.07	0.22	0.65
Sirges	0.35	0.52	0.83	0.33	0.55	1.13	0.37	0.53	0.49	0.05	0.12	0.25
Jåhkågaska tjiellde	0.29	0.31	0.77	0.28	0.47	1.67	0.33	0.38	0.86	0.07	0.11	0.27
Tuorpon	0.28	0.40	0.68	0.28	0.46	0.88	0.26	0.36	0.48	0.00	0.05	0.06
Luokta-mávas	0.40	0.43	0.13	0.35	0.48	0.60	0.31	0.32	0.07	-0.15	-0.10	-0.03
Semisjaur-Njarg	0.44	0.54	0.38	0.43	0.61	0.89	0.35	0.43	0.37	-0.05	-0.07	-0.50
Svaipa	0.34	0.31	0.26	0.40	0.63	0.97	0.32	0.28	0.25	-0.16	-0.21	-0.46
Vittangi	-0.13	-0.07	0.25	-0.14	0.03	0.31	-0.06	0.15	0.41	-0.08	-0.06	0.48
Gällivare	-0.03	0.19	0.50	-0.06	0.23	0.77	-0.05	0.19	0.64	-0.08	0.05	-0.08
Serri	0.27	0.65	0.46	0.07	0.33	0.51	0.07	0.33	0.51	0.09	0.26	0.25
Udtja	0.06	0.02	0.26	-0.01	0.08	0.00	0.03	0.12	0.08	0.01	0.05	-0.34
Ståkke	-0.06	-0.10	0.24	-0.06	-0.10	0.24	-0.06	-0.10	0.25	-0.10	-0.10	0.08
Maskaure	-0.05	-0.08	0.82	-0.03	-0.20	0.53	-0.14	-0.25	0.36	-0.13	-0.31	-0.02
Östra kikkejaure	-0.06	0.14	0.57	-0.05	0.13	0.71	-0.06	0.14	0.57	-0.07	0.11	0.18
Västra kikkejaure	-0.13	-0.08	0.57	-0.13	-0.08	0.57	-0.12	-0.06	0.61	-0.22	-0.16	-0.46
Mausjaure	-0.08	0.03	0.83	-0.08	0.03	0.83	-0.16	0.06	0.18	-0.19	-0.18	-0.35
Muonio	-0.09	0.08	0.46	-0.09	0.08	0.46	-0.13	-0.03	0.48	-0.06	-0.03	0.43
Sattajärvi	-0.15	0.11	0.42	-0.12	0.13	0.36	-0.10	0.15	0.46	0.08	0.29	0.66
Tärendö	0.00	0.00	0.00	-0.06	0.13	0.75	0.02	0.20	0.71	-0.02	0.16	0.52
Kalix	-0.04	-0.02	-0.15	-0.04	-0.02	-0.15	-0.04	-0.02	-0.15	-0.13	-0.11	-0.49
Pirttijärvi	-0.02	0.23	0.35	-0.02	0.23	0.35	-0.06	0.09	0.10	-0.09	0.01	-0.18
Liehittäjä	-0.33	0.13	-0.64	-0.10	-0.14	-0.16	-0.09	-0.07	-0.20	-0.27	-0.35	-0.46
Ängeså	-0.13	0.23	0.39	0.07	0.36	0.59	0.01	0.21	0.19	-0.07	0.11	0.14
Korju	0.01	0.07	0.14	0.01	0.07	0.14	0.01	0.07	0.14	-0.13	-0.15	-0.26

Vilhelmina south	0.16	0.17	0.15	0.49	0.58	0.32	0.32	0.33	0.24	-0.17	-0.26	-0.45
Vilhelmina north	0.20	0.15	0.23	0.43	0.59	0.23	0.24	0.23	0.21	-0.17	-0.33	-0.48
Ubmeje tjeälddie	0.31	0.38	0.40	0.43	0.61	0.71	0.40	0.47	0.39	-0.12	-0.11	-0.25
Vapsten	0.28	0.32	0.27	0.28	0.32	0.27	0.27	0.32	0.27	0.04	0.06	0.06
Ran	0.43	0.56	0.48	0.57	0.88	0.67	0.45	0.58	0.45	-0.21	-0.24	-0.47
Gran	0.47	0.58	0.49	0.59	0.80	0.83	0.49	0.67	0.79	-0.10	-0.17	-0.41
Malå	-0.05	0.10	0.11	-0.07	0.09	0.17	-0.07	0.08	0.19	-0.18	-0.23	-0.40
Voernese	0.44	0.50	0.44	0.48	0.55	0.35	0.46	0.48	0.25	-0.11	-0.23	-0.37
Ohredahke	0.38	0.26	0.30	0.38	0.26	0.27	0.38	0.26	0.30	-0.12	-0.17	-0.35
Raedtievaerie	0.11	0.01	0.25	0.42	0.34	-0.09	0.38	0.29	-0.09	-0.22	-0.16	-0.34
Jiingevaerie	0.33	0.49	0.26	0.38	0.74	0.55	0.19	0.11	0.19	-0.14	-0.13	-0.30
Jovnevaerie	-0.15	-0.11	-0.23	0.35	0.35	0.20	0.19	0.16	0.23	-0.21	-0.17	-0.31
Njaarke	0.42	0.24	0.13	0.42	0.24	0.13	0.31	0.09	0.10	-0.06	-0.03	-0.04
Kall	0.23	0.08	0.52	0.23	0.08	0.52	0.20	-0.04	0.47	-0.02	-0.06	0.31
Handölsdalen	0.32	0.61	0.27	0.50	0.85	0.39	0.40	0.68	0.35	0.00	-0.01	-0.03
Tåssåsen	-0.01	0.31	-0.13	-0.04	0.31	-0.12	-0.11	0.26	-0.24	-0.17	-0.09	-0.05
Mittådalen	0.19	0.49	-0.01	0.38	0.82	0.28	-0.25	-0.11	-0.04	-0.15	-0.12	-0.01
Ruvhten sijte	-0.10	0.02	-0.18	0.26	0.60	-0.40	-0.15	-0.08	-0.08	-0.23	-0.40	-0.15
Idre	-0.10	-0.09	-0.14	-0.10	-0.09	-0.13	-0.04	-0.04	-0.30	-0.13	-0.14	0.03