

Supplementary materials

Table S1 Basic information for the alpine treeline sites located in the TP. Codes were used to represent different tree species forming the treeline (Species): S0, *Larix potaninii* var. *macrocarpa* Law; S1, *Abies georgei* Orr. *smithii*; S2, *Abies fabri*; S3, *Abies faxoniana* Rehd.; S4, *Abies georgei* var. *smithii*; S5, *Sabina saltuaria*; S6, *Picea likiangensis* (Franch) Pritz var. *balfouriana*; S7, *Sabina tibetica* Kom; S8, *Juniperus przewalkii* Kom.; S9, *Picea crassifolia* Kom.; S10, *Abies squamata*; S11, *Betul utilis* D. Don; S12, *Abies spectabilis*; S13, *Pinus wallichiana*. Magnitude of treeline advance over last century (Magnitude). Values of 0, 0.5 and 1 represent absence of disturbance, low-intensity disturbance and high-intensity disturbance, respectively. Research methods include field plot survey (FS) and remote sensing (RS). The eight subareas include Hengduan Mountains (HD), Chuangxi region (CX), Linzhi region (LZ), Changdu-Naqu region (CDN), Yushu region (YS), Haixi-Hainan region (HXN), Qilian Mountains (QL), Himalaya Mountains (HM).

Site	subarea	Species	Slope (°)	Elevation (m a.s.l.)	Magnitude (m)	Disturbance	Methods	References
BM1	HD	S0	19	4417	91.2	1 (Fire)	FS	Wang et al.2019
BM2	HD	S0	19	4387	45	1 (Fire)	FS	Wang et al.2019
BM3	HD	S1	15	4247	28.1	0	FS	Wang et al.2019
BM4	HD	S1	22	4397	18.7	0	FS	Liang et al.2016
BM5	HD	S1	26	4398	19.5	0	FS	Liang et al.2016
BM6	HD	S1	25	4428	0	0	FS	Liang et al.2016
BM7	HD	S5	28	4394	0	1 (grazing)	FS	Zhang et al.2007
BM8	HD	S0	19	4359	12	1 (Fire)	FS	Wang et al.2019
GG1	CX	S2	42	3647	16.3	0.5 (grazing)	FS	Ran et al.2014
GG2	CX	S2	40	3622	5.1	0.5 (grazing)	FS	Ran et al.2014
GG3	CX	S2	37	3641	9.2	0.5 (grazing)	FS	Ran et al.2014
GG4	CX	S2	38	3765	0	0.5 (grazing)	FS	Ran et al.2014
GG5	CX	S2	22	3780	2.3	0.5 (grazing)	FS	Ran et al.2014
GG6	CX	S2	31	3802	0.7	0.5 (grazing)	FS	Ran et al.2014
AB1	CX	S0	35	4076	16.9	0	FS	Cui et al.2017
AB2	CX	S3	28	3968	0	0	FS	Cui et al.2017
LZ1	LZ	S4	13	4360	0.3	0	FS	Liang et al. 2011
LZ2	LZ	S4	10	4388	0	0	FS	Liang et al. 2011
LZ3	LZ	S4	15	4378	9.1	0	FS	Liang et al. 2011
LZ4	LZ	S4	15	4370	2	0	FS	Wang et al.2017
LZ5	LZ	S5	12	4520	0	0	FS	Liu et al.2011
RW1	CDN	S4	30	4471.3	3.6	0	FS	Liang et al.2016
RW2	CDN	S4	33	4447.8	5.4	0	FS	Liang et al.2016
RW3	CDN	S6	27	4478.3	68.5	0	FS	Liang et al.2016
BS	CDN	S7	28	4900	0	0	FS	Miche et al.2007
CD1	CDN	S6	36	4299	0	0	FS	Lyu et al. 2016
CD2	CDN	S6	43	4319	0	0	FS	Lyu et al. 2016
CD3	CDN	S6	30	4308	0	0	FS	Lyu et al. 2016
CD4	CDN	S6	38	4472	25	0	FS	Lyu et al. 2016
CD5	CDN	S6	37	4450	0	0	FS	Lyu et al. 2016
CD6	CDN	S6	35	4463	23	0	FS	Lyu et al. 2016
SX	CDN	S7	31	4460	0	0	FS	Zhang et al.2018

YS1	YS	S6	28	4195	64.6	0	FS	Liang et al.,2016
YS2	YS	S7	26	4458	0	1 (grazing)	FS	Unpublished data
HBS	HXN	S8	12	3730	0	0	FS	Fang et al.2009
DLH	HXN	S8	20	4034	0	0	FS	Shao et al.2004
WL1	HXN	S9	20	4034	13.2	0	FS	Liang et al.2016
WL2	HXN	S9	27	3877	53.6	0	FS	Liang et al.2016
DL1	HXN	S8	18	4200	0	0	FS	Wang et al.2017
QL1	QL	S9	33	3385.8	51.5	0	FS	Liang et al.2016
QL2	QL	S9	37	3496	79.9	0	FS	Liang et al.2016
QL3	QL	S9	24	3318	0	0	FS	Wang et al.2017
QL4	QL	S9	31	3680	0	0	FS	Wang et al.2017
QL5	QL	S9	32	3700	0	0	FS	Wang et al.2017
KD1	CX	S2	28	4380	75	0	FS	Zhou et al.2019
KD2	CX	S10	25	4520	40	0	FS	Zhou et al.2019
KCA1	HM	S11	30	4217.2	29.5	0	FS	Sigdel et al.2018
KCA2	HM	S11	33	3931.4	51.7	0	FS	Sigdel et al.2018
EV1	HM	S11	26	4097	14.6	0	FS	Sigdel et al.2018
EV2	HM	S12	39	4133	75.3	0	FS	Sigdel et al.2018
LT1	HM	S11	30	4031.3	16.1	0	FS	Sigdel et al.2018
LT2	HM	S12	35	4067.4	11.4	1	FS	Sigdel et al.2018
MST1	HM	S12	25	3600	31.7	0	FS	Sigdel et al.2018
MST2	HM	S11	20	3950	23.3	0	FS	Sigdel et al.2018
MA	HM	S11	39	4076.3	11.1	0	FS	Sigdel et al.2018
JM	HM	S11	32	3872.6	5.5	0	FS	Sigdel et al.2018
HL1	HM	S11	28	4222.5	16.3	0	FS	Sigdel et al.2018
HL2	HM	S11	43	4050.8	14.8	0	FS	Sigdel et al.2018
SA1	HM	S13	35	3563	124	0	RS & FS	Dubey et al.2003

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Table S2 Location of CRU 0.5° gridded data near the study treeline sites. The climatic variables include: annual/Summer/winter mean minimum temperature changes, annual/summer/winter precipitation changes since 1901. The CRU data was from CRU TS4.01 database. Climatic variables included annual, summer, and winter mean minimum temperature (CAT, CWT, CST) and annual, summer, and winter precipitation (AP, SP, WP) during the last century. Values of CAT, CWT and CST were from the slopes of linear regression of CR temperature data. Note that the same CRU data was used for some nearby treeline sites.

Code	Latitude (°)	Longitude (°)	Nearby treeline site	Time period
Zhangye	38.5	100.5	QL1-5	1901-2017
Delingha	37.5	97.5	DLH	1901-2017
Wulan	37.0	98.5	WL1-2	1901-2017
Nangqian	32.0	96.5	YS1	1901-2017
Yushu	36.5	97.5	YS2	1901-2017
Dulan	36.0	98.0	DL1	1901-2017
Suoxian	31.5	94.5	SX	1901-2017
Maqin	34.5	99.5	MQ	1901-2017
Henan	34.5	100.5	HBS	1901-2017
Changdu	31.5	95.5	CD1-6	1901-2017
Aba	31.5	102.0	AB1-2	1901-2017
Kangding	31.5	102.1	KD1-2	1901-2017
Basu	30	97.0	BS	1901-2017
Ranwu	29.5	96.5	RW1-3	1901-2017
Linzhi	29.5	94.5	LZ1-6	1901-2017
Gongga	30.0	102.0	GG1-6	1901-2017
Deqin	28.5	99.0	BM1-8	1901-2017
MST	28.5	83.5	MST1-2	1901-2017
MA	28.5	84.0	MA	1901-2017
JM	29.5	82.5	JM	1901-2017
Humla	30.0	82.0	HL	1901-2017
Langtang	28.0	86.5	LT1-2, EV1-2	1901-2017
KCA	27.5	88.0	KCA1-2	1901-2017
SA	32.0	77.5	SA1	1901-2017

Table S3 Definitions of the biotic variables and three terminologies used in this study. The explicit hypotheses were shown for biotic variables. The biotic variables included: height growth rate (HGR), tree recruitment (RE), vegetation TI (TI) and expansion potential (EP). To clarify the data analysis, treeline and tree species line was also included in this table.

Variable or terminology	Definition	Hypothesis
Treeline	The uppermost elevation of trees (height >2m)	No
tree species line	The uppermost elevation of tree individuals regardless of their height (e.g. height ≤ 0.50 m)	No
Treeline ecotone	The transition zone between treeline and tree species line	No
EP	The elevational difference between the current treeline and the current tree species line	The value of EP measured in the current time period remained relative constant under climate change
TI	TI is calculated from the mean cover and height of dominant ground vegetation (e.g. shrub, grass) across the treeline ecotone at each treeline site	The value of TI measured in the current time period remained relative constant under climate change
HGR	Annual growth rate for the tree individuals of 2 m	Seedlings took the same amount of time to reach the height of 2 m under past and current climatic conditions
RE	The presence of tree seedlings (height ≤ 0.5 m) and saplings (height >0.5 m and height < 2m) at the treeline	No