Dendroecological and Dendroclimatic Study in Api-Nampa Conservation Area, Nepal Himalaya

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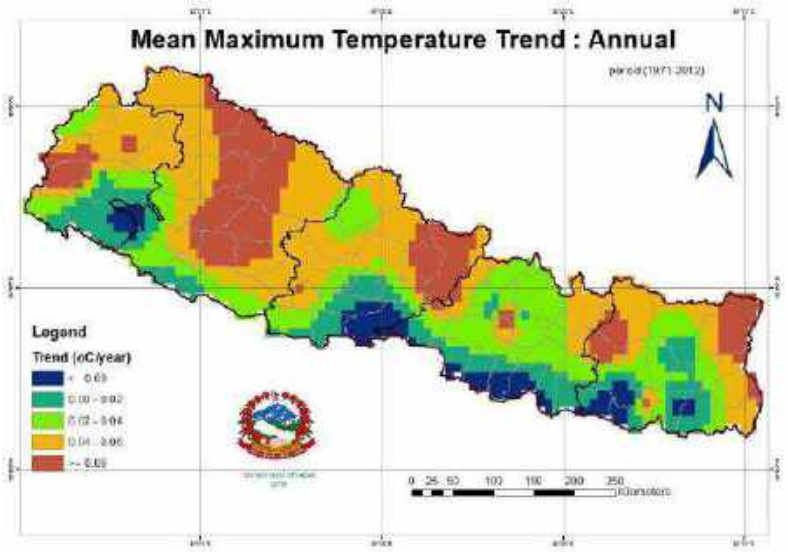
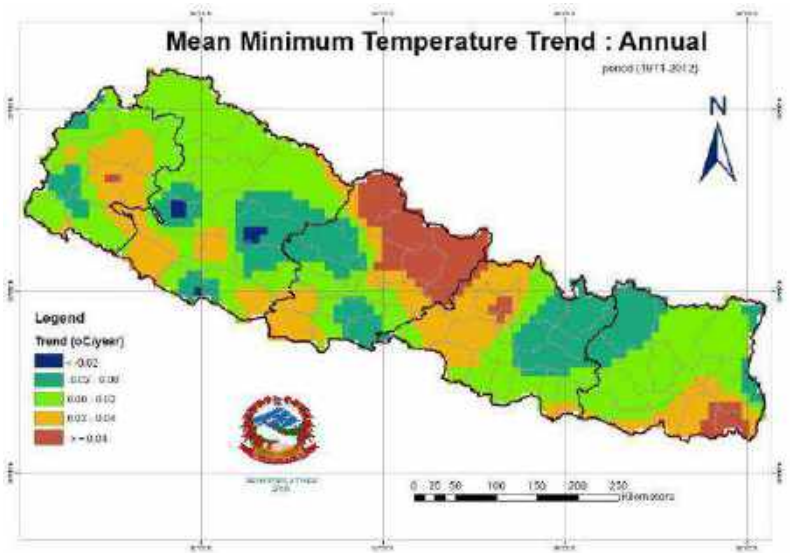
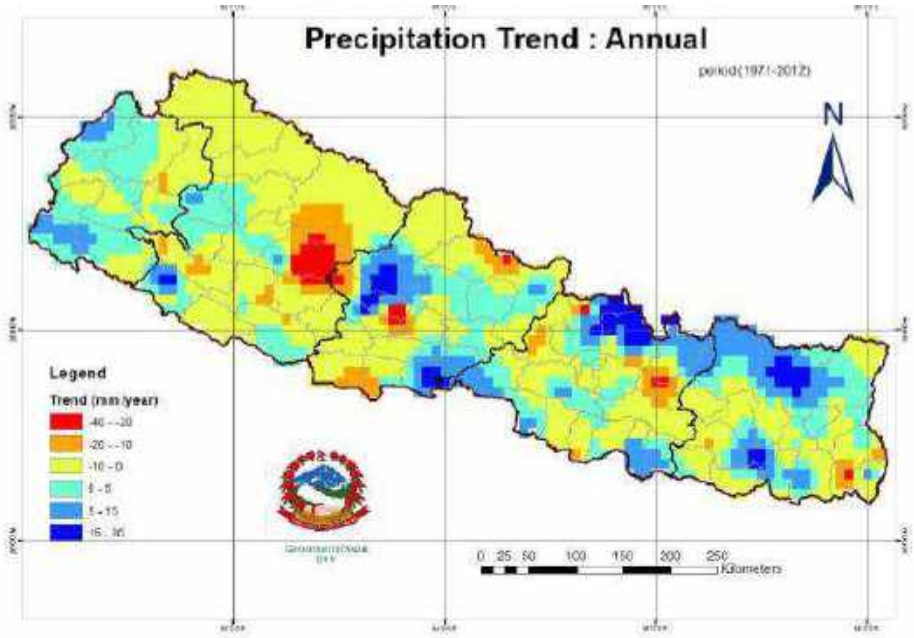
Background

Rapid Climate Change in Nepal Himalaya







DHM 2015 & 2017

Elevation-dependent warming of maximum air temperature in Nepal during 1976–2015

Sudeep Thakuri, Sushama Dahal, Dibas Shrestha, Nicolas Guyennon, Emanuele Romano

RESEARCH ARTICLE

Rising mean and extreme near-surface air temperature across Nepal

Ramchandra Karki | Shabeh ul Hasson | Lars Gerlitz | Rocky Talchabhadel | Udo Schickhoff | Thomas Scholten | Jürgen Böhner

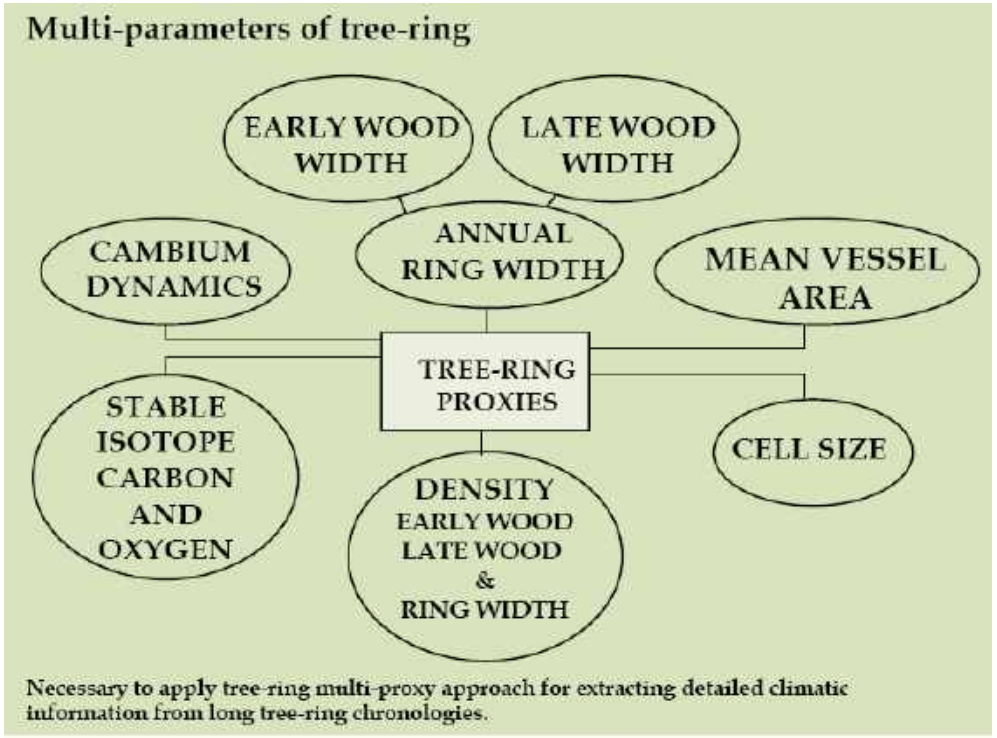
RESEARCH ARTICLE

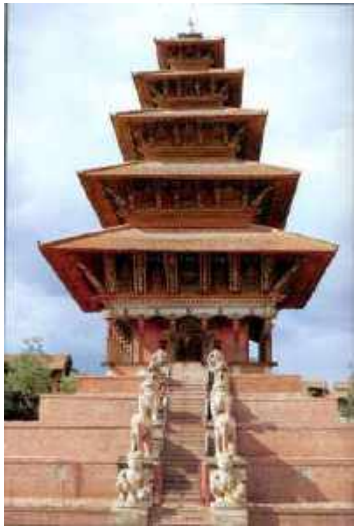
Spatio-temporal variability of extreme precipitation in Nepal

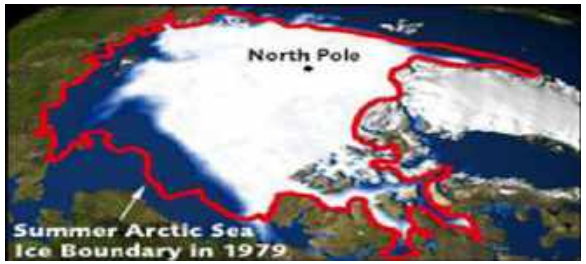
Rocky Talchabhadel | Ramchandra Karki | Bhesh Raj Thapa | Manisha Maharjan | Bimal Paneglai

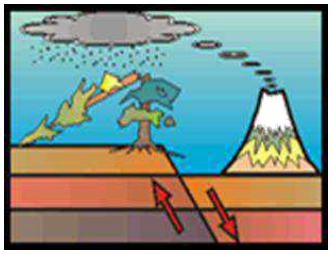
Dendrochronology ?

- Tree is a recorder, a biological databank that records and stores the information from the environment.
- Dendrochronology science uses tree rings dated to their exact year of formation to analyze temporal and spatial patterns of processes in the, biological, physical and cultural sciences.
- Tree-rings are natural proxy climate source









- Architecture
- History of settlements
- Abandonment of societies
- Art history

ARCHAEO-LOGY

- Past temperature
- Past precipitation
- Past droughts or cold period

CLIMATOLOGY

Evidence for and dating of pollution damage to trees

AIR POLLUTION

APPLICATION OF TREE-RING

GEOMORPHOLOGY

- Past earthquakes
- History of stream flow
- Dating of land slides
- Volcanic eruptions
- History of glacier and glacier movement
- History of floods

FOREST MANAGEMENT

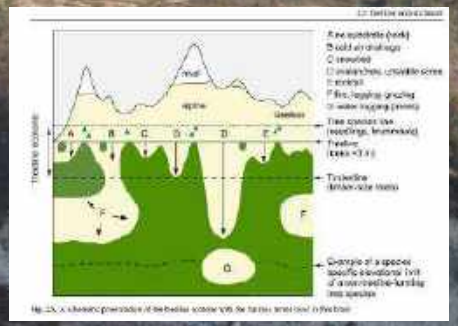
- Forest stand structure
- Past forest fires
- Soil erosion
- Insect spreads

ISOTOPE PHYSICS

- Calibration of c14 decay sequences
- Relationships between stable isotopes in annual rings and climatic factors

What is treeline? Why treeline research?

A life-form boundary that limits regional tree growth, irrespective of species



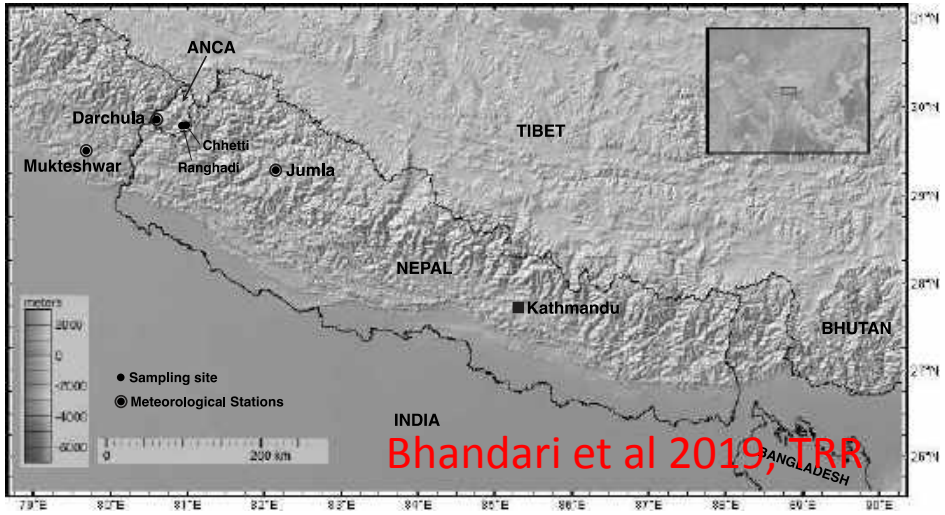
Christian Körner, 2012, Alpine treelines

Treeline at Pangboche, Mt. Everest Region, Nepal

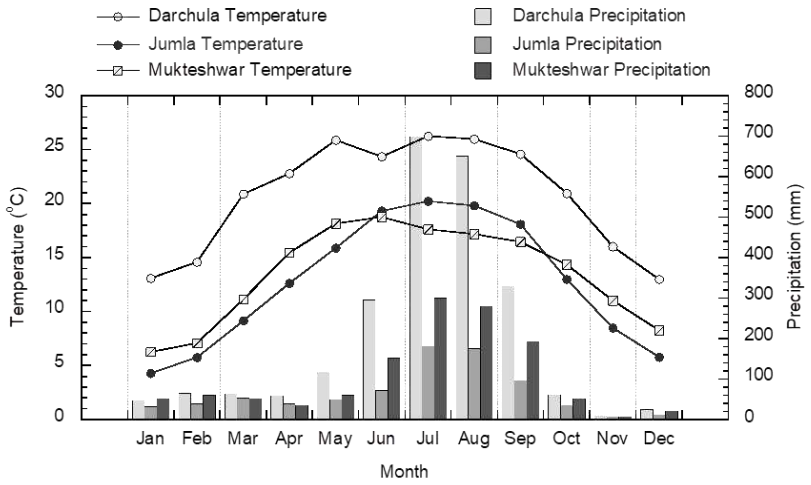
Objectives

- To check the dendrochronological potential of multiple tree species from the ApiNampa Conservation Area (ANCA)
- To check the climatic sensitivity and resilience of different forests in the ANCA to climate change
- To assess treeline dynamics in the region
- To reconstruct climatic history of the region

Study Area and Climate



Bhandari et al 2019, TRR



Bhandari et al 2019, TRR

Field Visits

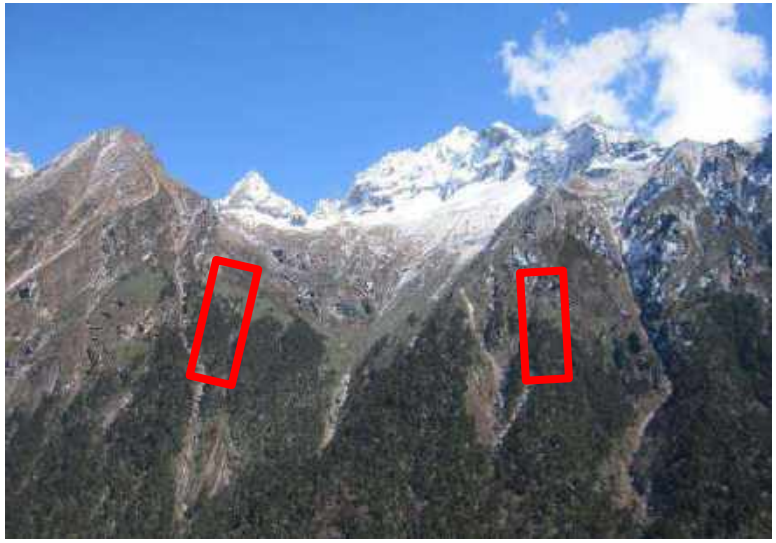
(2014 and 2018)

Site and Species Selection

Field Methods : Treeline Dynamics

Dendroecological survey

Belt transect: 20 m wide and 100 m to 250 m long



Field Methods : Tree Core Sample Collection

(for Dendroclimatology)











Laboratory analysis
(Dendroclimatology)

1. Air drying

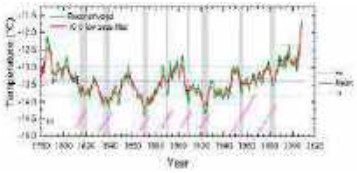
2. Mounting & Air drying

3. Sanding & Polishing

(Machine or hand)

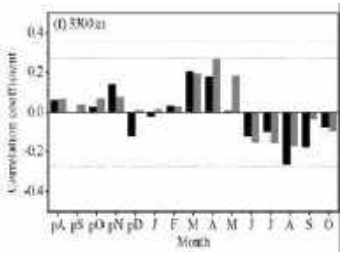
4.Counting and dating

(Streozoom microscope)



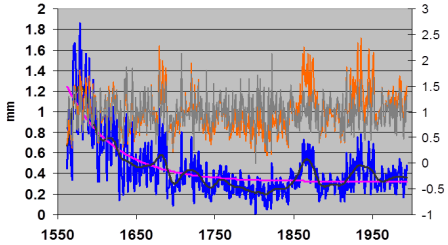
9. Climate Reconstruction

(treeclim or R)



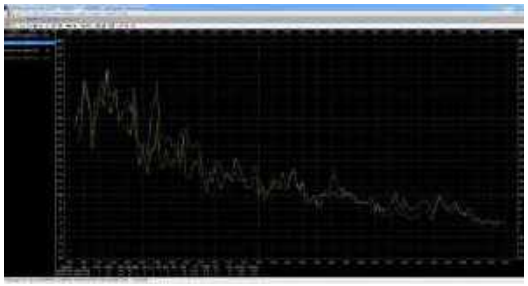
8. Growth-climate Response analysis & Model development

(boorRes and treeclim)



7. Standardization & Chronology dev

(dplR & ARSTAN)



6. Crossdating

(TSAP & COFECHA)

5. Measurement

(LINTAB)

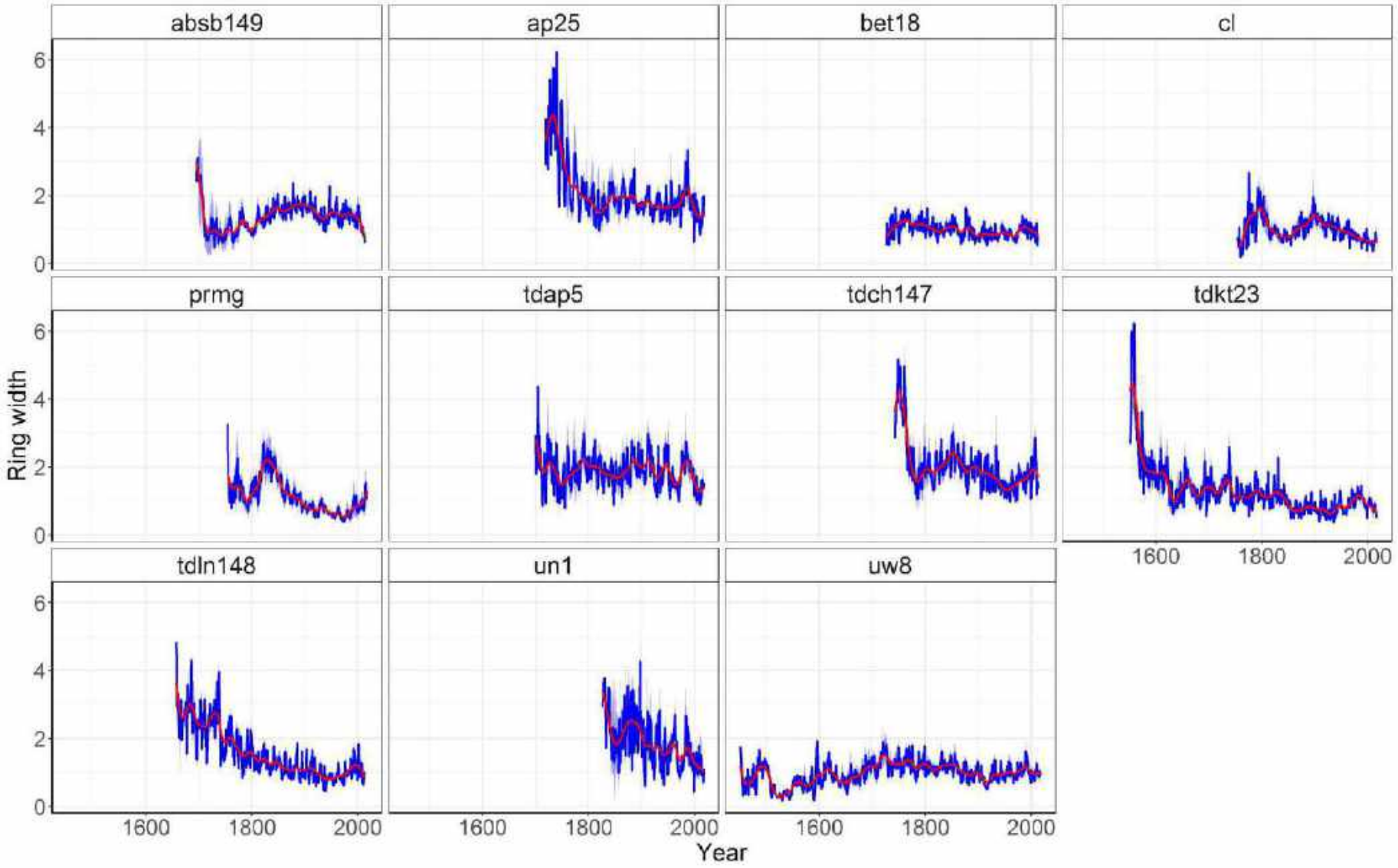
Results and discussion

TRW Chronologies from ANCA

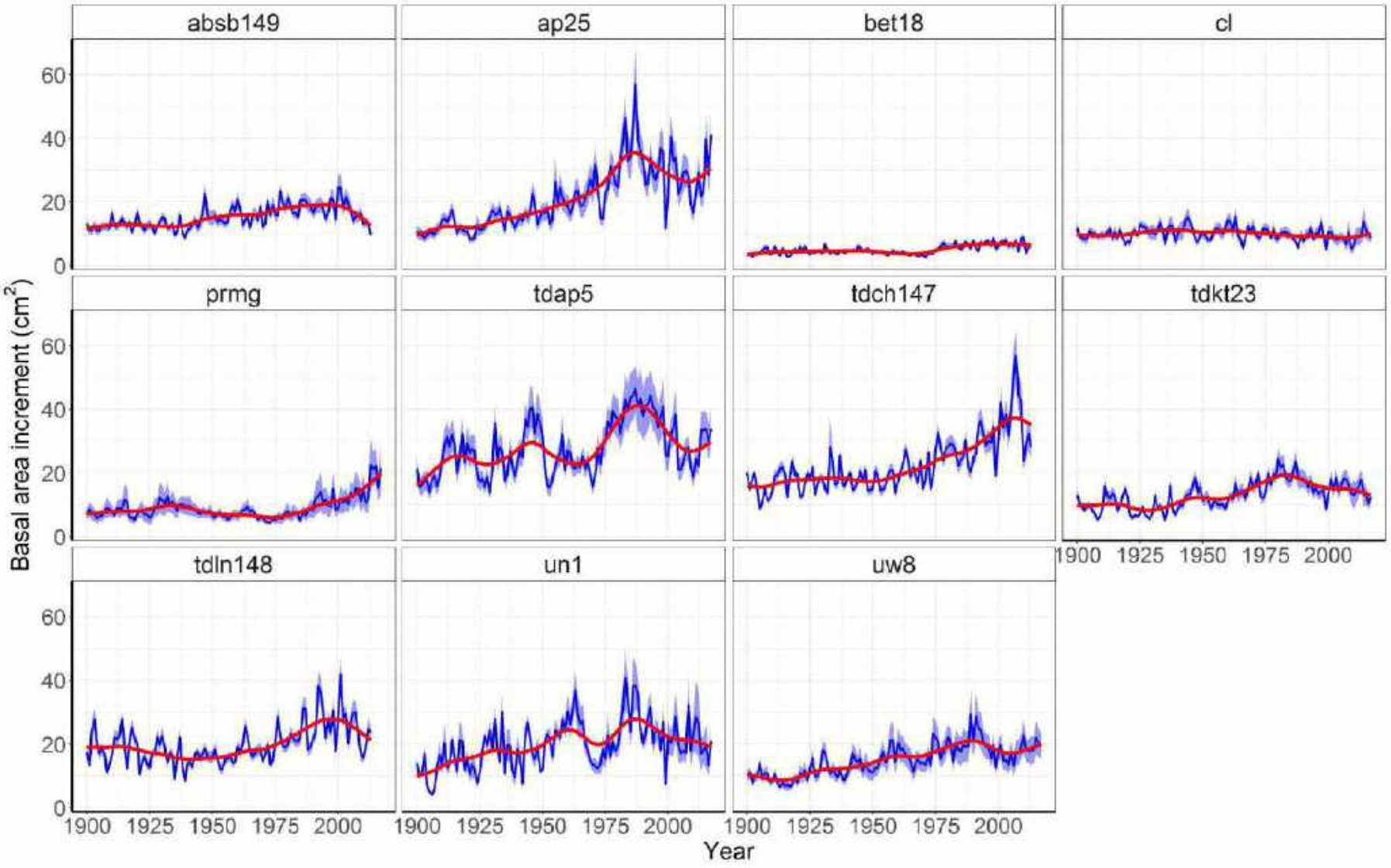
- 11 sampled species
- 13 Chronologies, 10 (or 9) species, 5 conifers, 5 broadleaved (3 diffuse porous, 2 ring porous)
- 1 species (Acer species not measured yet)
- Analysis incomplete (Aesculus, Juniper and Pine)
- Chronology length: 192 to 567 (1451-2017 CE)

Site_Code	Species_name	# trees	# cores	First_yr	Last_yr	Period	Age_min	Age_max	Age_mean	AGR_mean	AGR_median	AGR_min	AGR_max	AGR_std	rho	AR1
absb149	*Abies_spectabilis*	22	41	1696	2013	318	63	318	173.8	1.57	1.40	0.77	2.95	0.79	0.323	0.68
ap25	*Abies_pindrow* ??	22	37	1719	2017	299	81	299	159.1	1.91	1.69	0.52	4.00	1.12	0.376	0.57
bet18	*Betula_utilis*	40	61	1727	2013	287	39	287	136.3	1.06	0.96	0.36	3.20	0.61	0.334	0.55
cl	Unidentified	3	6	1755	2017	263	188	263	227.2	0.99	0.87	0.88	1.15	0.48	0.423	0.71
fl	*Aesculus_indica*	26	26	1729	2017	289	51	289	141.2	2.29	2.11	0.82	4.16	1.23	0.106	0.67
jure153	*Juniperus* sp.	22	46	1565	2017	453	183	453	338.1	0.93	0.78	0.44	1.57	0.60	0.049	0.64
prmg	*Pinus_roxburghii*	5	9	1754	2017	264	77	264	203.7	1.11	0.92	0.77	1.63	0.73	0.438	0.72
tdap5	*Tsuga_dumosa*	17	28	1700	2017	318	70	318	187.0	2.06	1.78	0.61	4.15	1.29	0.327	0.64
tdch147	*Tsuga_dumosa*	21	40	1742	2013	272	92	272	172.0	1.89	1.69	0.45	3.53	0.99	0.439	0.60
tdkt23	*Tsuga_dumosa*	24	39	1550	2017	468	89	468	296.1	1.06	0.87	0.59	1.96	0.74	0.420	0.66
tdln148	*Tsuga_dumosa*	21	34	1657	2013	357	164	354	282.2	1.38	1.12	0.90	2.23	0.86	0.517	0.63
un1	Unidentified	3	4	1826	2017	192	146	192	166.0	1.82	1.63	1.59	2.24	0.92	0.640	0.39
uw8	*Ulmus_wallichiana*	18	26	1451	2017	567	65	567	264.2	1.01	0.85	0.43	2.10	0.62	0.229	0.70

Raw TRW Chronologies



BAI Chronologies



Growth-Climate Relationships

CRU data (1901 to now)

	Tmean																			
	pJun	pJul	pAug	pSep	pOct	pNov	pDec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	DJF	MAM	JJAS
std_ap25	-0.26	-0.20	-0.09	-0.08	-0.10	0.02	-0.12	0.05	-0.02	-0.28	-0.26	-0.35	-0.25	-0.14	0.00	-0.01	-0.02	-0.03	-0.39	-0.20
std_bet18	-0.26	-0.09	0.04	-0.01	-0.02	0.15	0.17	0.11	0.01	-0.16	0.05	0.14	0.35	0.28	0.22	0.11	0.07	0.13	0.00	0.40
std_tdap5	-0.26	-0.23	-0.20	-0.29	-0.27	-0.11	-0.17	0.06	-0.09	-0.27	-0.23	-0.15	-0.12	-0.07	-0.07	-0.20	-0.15	-0.09	-0.30	-0.17
std_tdkt23	-0.28	-0.28	-0.07	-0.14	-0.06	0.07	0.05	0.13	0.04	-0.22	-0.13	-0.20	-0.08	-0.03	0.03	-0.13	0.01	0.11	-0.25	-0.09
std_tdch147	-0.31	-0.11	0.02	-0.13	0.02	0.05	-0.05	0.17	0.16	-0.15	-0.16	-0.31	-0.07	0.19	0.23	-0.02	0.13	0.15	-0.27	0.09
std_tdln148	-0.20	-0.05	0.01	-0.07	0.03	0.08	-0.01	0.15	0.09	-0.20	-0.19	-0.27	-0.08	0.08	0.17	0.10	0.13	0.13	-0.29	0.06
std_uw8	-0.10	-0.05	-0.03	0.10	0.11	0.23	0.24	-0.18	0.06	0.06	0.06	0.05	0.16	0.03	0.05	0.10	0.08	0.05	0.08	0.15
std_cl	0.11	-0.06	-0.19	-0.27	-0.33	-0.44	-0.37	-0.32	-0.37	-0.27	-0.33	-0.11	-0.11	-0.06	-0.07	-0.13	-0.19	-0.52	-0.32	-0.15
std_un1	-0.17	-0.20	-0.04	-0.13	-0.15	-0.03	-0.12	0.01	0.12	-0.09	-0.18	-0.18	-0.07	-0.04	-0.07	-0.03	-0.14	0.04	-0.20	-0.08
std_prmg	0.16	0.32	0.40	0.39	0.30	0.35	0.33	0.14	0.19	0.16	0.18	0.10	0.15	0.24	0.39	0.44	0.42	0.30	0.20	0.41

	Precipitation																			
	pJun	pJul	pAug	pSep	pOct	pNov	pDec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	DJF	MAM	JJAS
std_absb149	0.28	0.16	-0.11	-0.08	-0.02	0.09	0.23	-0.09	-0.10	0.15	-0.01	0.14	-0.03	0.12	-0.06	0.09	0.01	-0.03	0.14	0.06
std_ap25	0.04	0.02	-0.11	-0.01	-0.09	0.21	0.24	-0.12	-0.03	0.31	0.39	0.32	0.05	-0.04	-0.08	0.06	-0.05	0.02	0.53	-0.01
std_bet18	0.07	0.01	-0.12	-0.11	-0.11	0.20	0.10	0.02	0.24	0.20	0.09	-0.02	-0.45	-0.31	-0.12	0.11	-0.01	0.23	0.14	-0.35
std_tdap5	0.18	0.10	-0.04	0.14	-0.05	0.08	0.16	-0.16	0.07	0.22	0.26	0.06	-0.01	-0.01	-0.01	0.18	-0.03	0.03	0.29	0.07
std_tdkt23	0.15	0.02	-0.11	0.05	-0.13	0.17	0.02	-0.20	0.00	0.27	0.18	0.24	-0.07	-0.16	-0.11	0.14	-0.11	-0.10	0.36	-0.09
std_tdch147	0.28	-0.01	-0.20	0.00	-0.04	0.21	0.05	-0.28	-0.08	0.25	0.21	0.28	-0.11	-0.24	-0.20	0.00	-0.14	-0.19	0.38	-0.25
std_tdln148	0.19	-0.05	-0.07	0.01	-0.08	0.23	0.08	-0.23	0.09	0.20	0.26	0.27	-0.02	-0.17	-0.24	-0.04	-0.12	-0.02	0.38	-0.21
std_uw8	0.03	-0.10	-0.11	-0.17	0.01	0.00	0.19	0.19	-0.03	-0.02	-0.07	-0.05	-0.24	0.01	-0.07	-0.09	-0.10	0.16	-0.07	-0.17
std_cl	0.06	0.20	0.23	0.26	0.08	-0.02	0.12	0.16	0.00	0.06	0.09	-0.03	0.21	0.14	0.20	0.09	0.13	0.14	0.07	0.29
std_un1	0.05	0.11	0.01	-0.03	0.06	0.11	0.11	-0.12	-0.16	0.13	0.12	0.06	-0.07	-0.06	0.08	0.00	0.07	-0.13	0.16	-0.02
std_prmg	-0.04	-0.26	-0.28	-0.18	-0.04	0.02	-0.06	-0.10	0.20	0.06	0.07	-0.06	0.01	-0.12	-0.27	-0.21	-0.09	0.06	0.04	-0.27

	Year_scPDSI																			
Year	pJun	pJul	pAug	pSep	pOct	pNov	pDec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	DJF	MAM	JJAS
std_absb149	0.31	0.33	0.19	0.14	0.14	0.14	0.19	0.17	0.05	0.14	0.14	0.19	0.13	0.20	0.11	0.14	0.13	0.15	0.16	0.15
std_ap25	0.15	0.19	0.13	0.09	0.06	0.08	0.19	0.17	0.12	0.24	0.34	0.41	0.33	0.30	0.23	0.21	0.20	0.17	0.35	0.28
std_bet18	0.05	0.09	0.02	-0.03	-0.04	-0.01	0.07	0.11	0.17	0.20	0.18	0.13	-0.03	-0.04	-0.05	0.02	0.02	0.12	0.18	-0.02
std_tdap5	0.27	0.31	0.26	0.27	0.25	0.24	0.30	0.25	0.23	0.27	0.32	0.33	0.29	0.28	0.25	0.26	0.25	0.27	0.32	0.29
std_tdkt23	0.10	0.12	0.07	0.09	0.05	0.06	0.06	-0.01	0.01	0.11	0.16	0.23	0.14	0.09	0.06	0.12	0.08	0.03	0.17	0.11
std_tdch147	0.19	0.13	0.07	0.04	0.01	0.05	0.05	-0.06	-0.05	0.07	0.12	0.20	0.10	-0.02	-0.04	-0.02	-0.05	-0.02	0.14	0.01
std_tdln148	0.19	0.18	0.14	0.08	0.06	0.09	0.13	0.04	0.08	0.18	0.24	0.28	0.20	0.11	0.03	0.01	-0.02	0.09	0.24	0.09
std_uw8	-0.06	-0.10	-0.15	-0.18	-0.17	-0.16	-0.09	0.01	-0.05	-0.05	-0.09	-0.12	-0.18	-0.11	-0.15	-0.17	-0.20	-0.05	-0.09	-0.16
std_cl	0.11	0.15	0.22	0.27	0.26	0.25	0.28	0.31	0.23	0.25	0.27	0.25	0.28	0.28	0.31	0.27	0.30	0.29	0.27	0.30
std_un1	0.07	0.11	0.08	0.07	0.08	0.09	0.13	0.06	-0.03	0.04	0.06	0.03	-0.01	-0.02	0.00	-0.01	0.01	0.06	0.05	-0.01
std_prmg	-0.13	-0.22	-0.25	-0.31	-0.27	-0.27	-0.27	-0.20	-0.10	-0.08	-0.07	-0.08	-0.08	-0.16	-0.20	-0.32	-0.30	-0.20	-0.08	-0.20

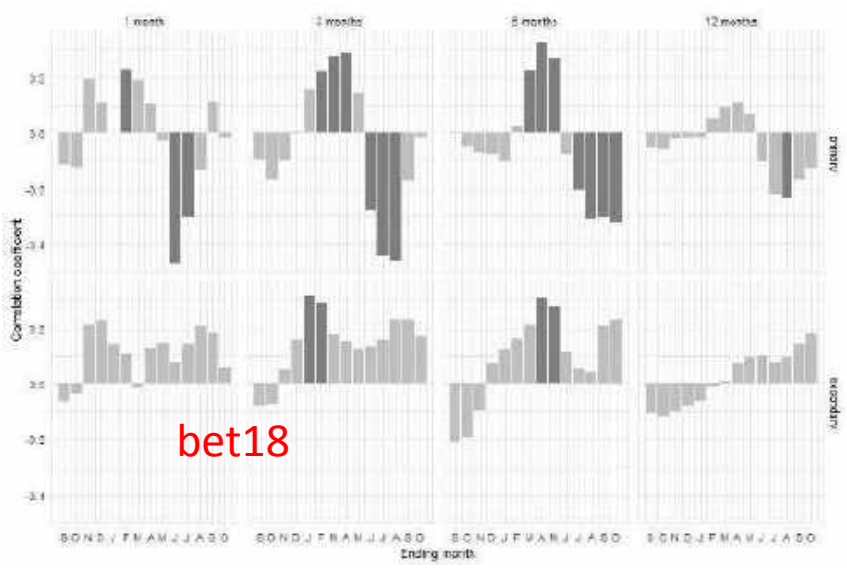
Growth-Climate Relationships

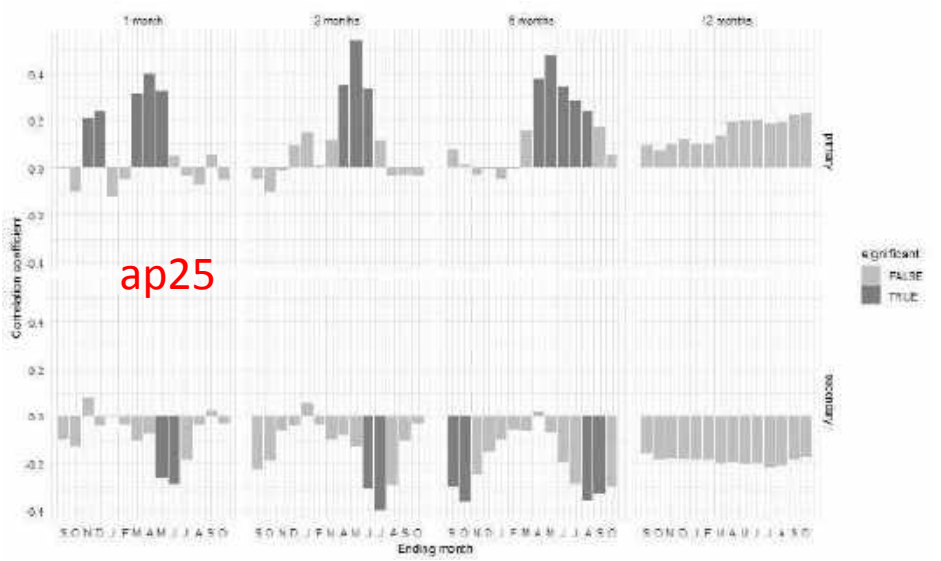
Mukteshwor data (1901 to now)

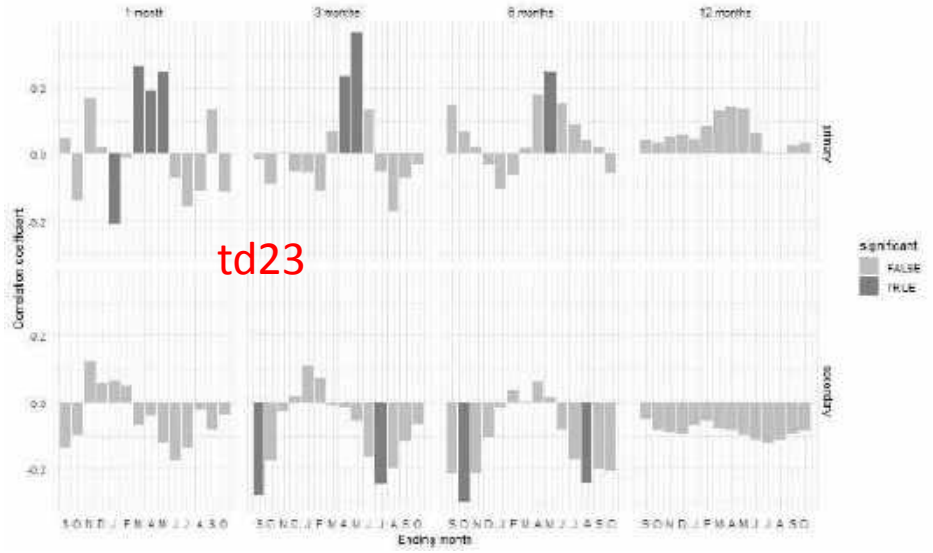
	Mukteswor_tmean													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAM	JJAS
std_absb149	0.050	-0.049	-0.147	-0.038	-0.134	0.031	-0.152	-0.008	-0.036	-0.141	-0.054	0.121	-0.143	-0.042
std_ap25	0.085	-0.041	-0.318	-0.343	-0.327	-0.149	-0.147	-0.074	-0.085	0.008	0.049	0.084	-0.439	-0.178
std_bet18	0.127	-0.164	-0.226	-0.056	0.097	0.395	0.203	0.202	0.045	0.089	0.080	0.078	-0.105	0.356
std_tdap5	0.042	-0.092	-0.271	-0.275	-0.134	-0.077	-0.142	-0.169	-0.238	-0.095	-0.085	-0.016	-0.312	-0.211
std_tdkt23	0.164	0.058	-0.262	-0.232	-0.252	-0.063	-0.086	-0.040	-0.148	0.053	0.022	0.184	-0.333	-0.121
std_tdch147	0.177	0.078	-0.221	-0.260	-0.366	-0.010	0.116	0.087	-0.036	0.169	0.031	-0.006	-0.367	0.041
std_tdln148	0.157	0.003	-0.286	-0.258	-0.357	-0.081	0.039	0.050	0.028	0.114	0.084	0.105	-0.396	-0.012
std_uw8	-0.225	-0.030	-0.027	-0.021	0.048	0.127	0.039	0.014	0.042	0.056	0.133	0.118	-0.005	0.102
std_cl	-0.355	-0.242	-0.187	-0.273	-0.037	-0.120	-0.017	-0.062	0.045	-0.097	-0.333	-0.141	-0.231	-0.075
std_un1	0.079	0.174	-0.068	-0.228	-0.016	0.003	0.023	-0.006	0.072	0.016	0.028	0.052	-0.142	0.031
std_prmg	0.325	0.062	0.151	0.040	-0.081	0.121	0.129	0.251	0.350	0.250	0.396	0.072	0.065	0.292

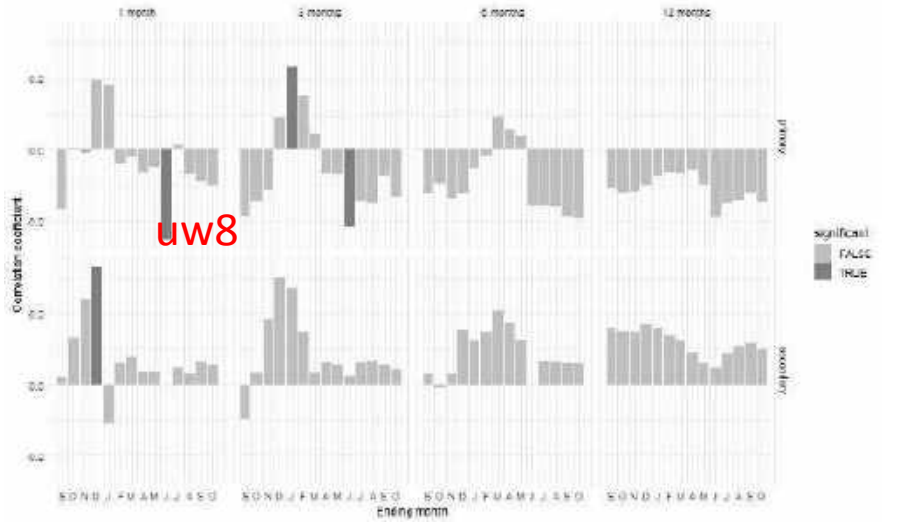
	Mukteswor_ppt													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAM	JJAS
std_absb149	-0.051	-0.026	0.124	0.006	0.107	-0.041	0.169	0.048	0.130	0.101	-0.038	-0.010	0.149	0.147
std_ap25	-0.018	0.048	0.292	0.387	0.332	-0.058	0.067	-0.088	0.127	-0.060	0.081	0.059	0.547	0.038
std_bet18	0.079	0.291	0.212	0.134	-0.135	-0.330	-0.220	-0.087	0.104	-0.114	0.117	-0.089	0.107	-0.197
std_tdap5	-0.071	0.096	0.221	0.294	0.048	-0.053	0.062	0.073	0.201	-0.056	0.042	-0.079	0.288	0.144
std_tdkt23	-0.122	0.054	0.358	0.201	0.157	-0.199	-0.019	-0.060	0.147	-0.128	0.091	-0.209	0.409	-0.029
std_tdch147	-0.195	0.002	0.266	0.235	0.169	-0.215	-0.153	-0.118	0.109	-0.203	0.136	-0.050	0.369	-0.136
std_tdln148	-0.138	0.136	0.210	0.258	0.256	-0.155	-0.118	-0.181	0.068	-0.184	0.098	-0.093	0.396	-0.147
std_uw8	0.204	0.008	-0.007	0.002	-0.145	-0.238	0.007	-0.111	0.042	-0.009	-0.051	0.055	-0.094	-0.109
std_cl	0.215	-0.044	0.006	0.111	0.041	0.185	0.146	0.235	0.067	0.070	0.100	0.075	0.073	0.264
std_un1	-0.088	-0.038	0.131	0.239	0.052	-0.073	0.009	0.028	0.048	0.092	0.053	0.078	0.210	0.014
std_prmg	-0.196	0.129	-0.062	-0.044	-0.051	-0.182	-0.205	-0.221	-0.081	-0.140	-0.033	-0.026	-0.089	-0.290

Seasonal Response

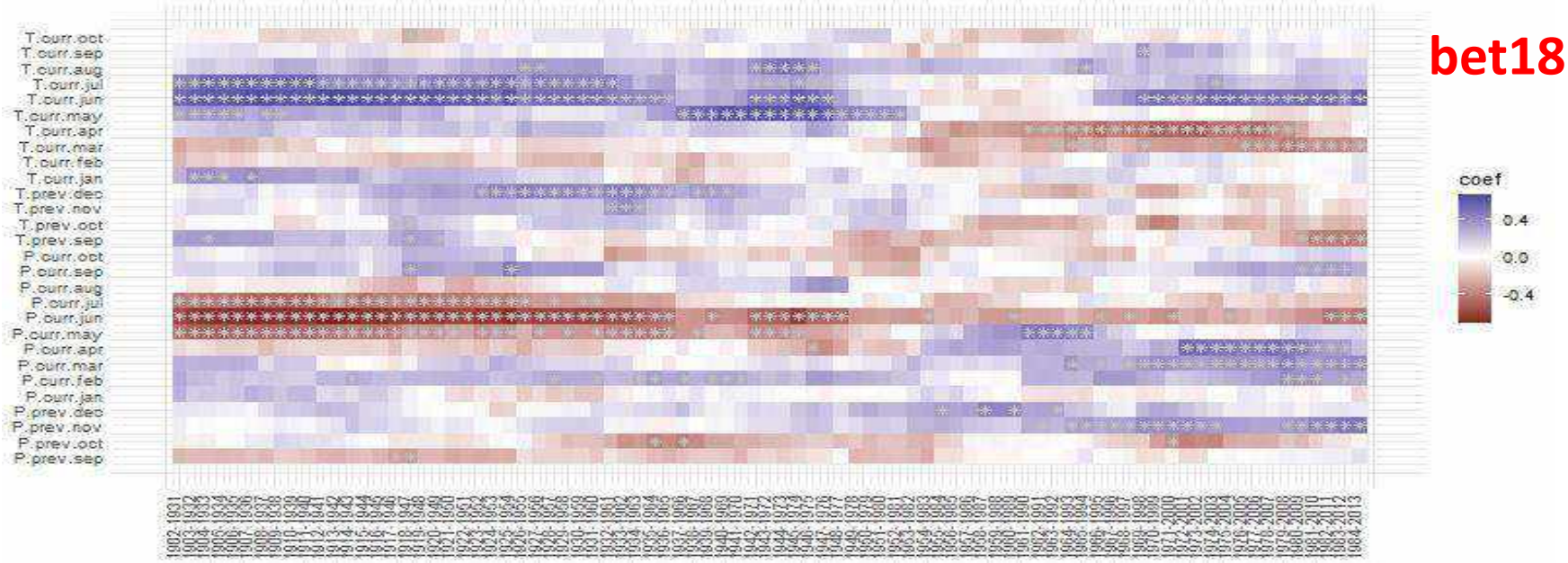




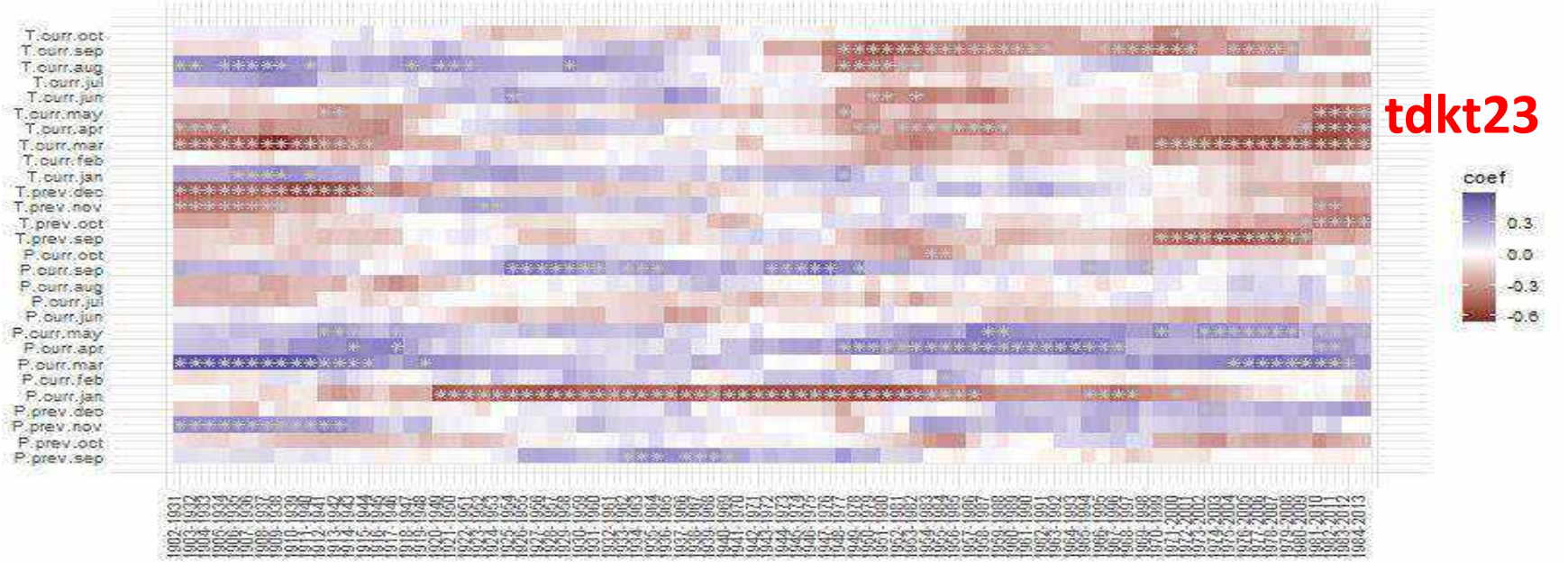




Temporal Stability of Response



bet18



tdkt23

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A 307-YEAR TREE-RING SPEI RECONSTRUCTION INDICATES MODERN DROUGHT IN WESTERN NEPAL HIMALAYAS

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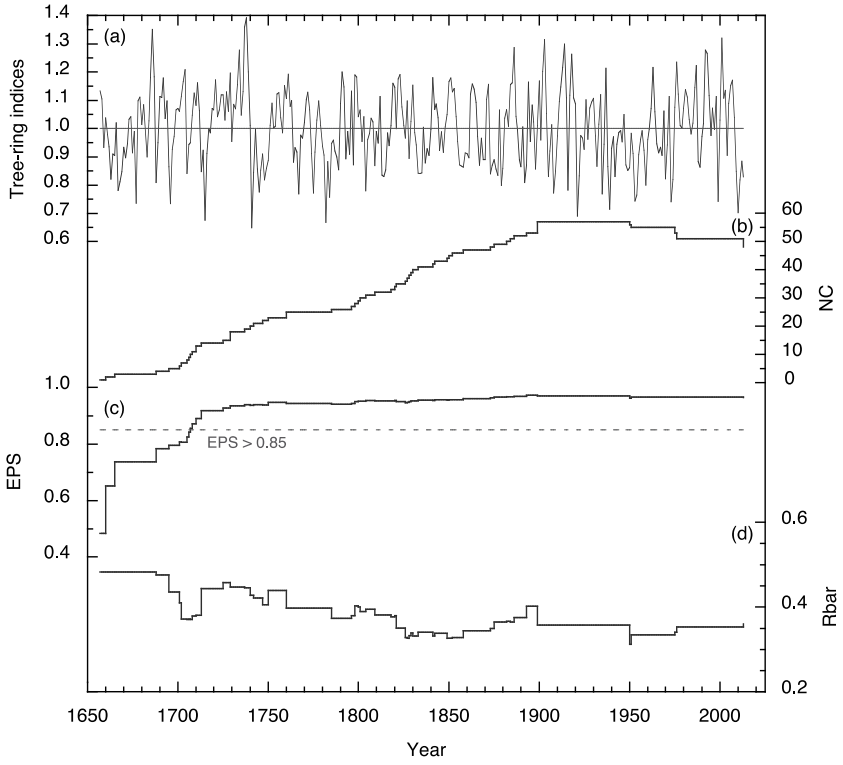

Figure. (a) Ring-width index chronology of *Tsuga dumosa*; (b) Number of cores used to develop this chronology; (c) EPS threshold greater than 0.85 since 1707; (d) Rbar graph from AD 1657 to 2013.

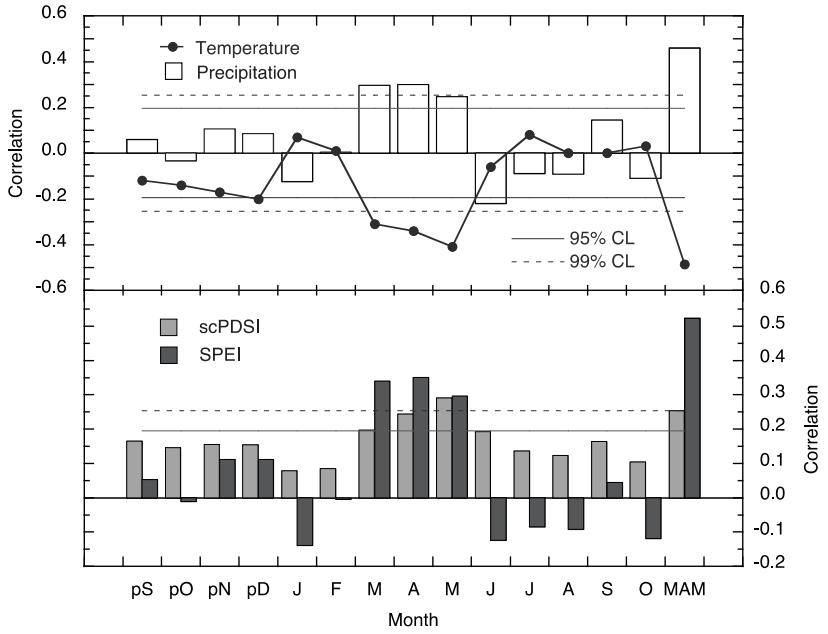

Figure. Top: Histogram showing correlations between the ring-width index chronology of *Tsuga dumosa* and climate data (AD 1897-2013) from Mukteshwar station, India. Bottom: Histogram showing correlation between ring-width index, scPDSI, and SPEI.

Spring (MAM) SPEI01 Reconstruction

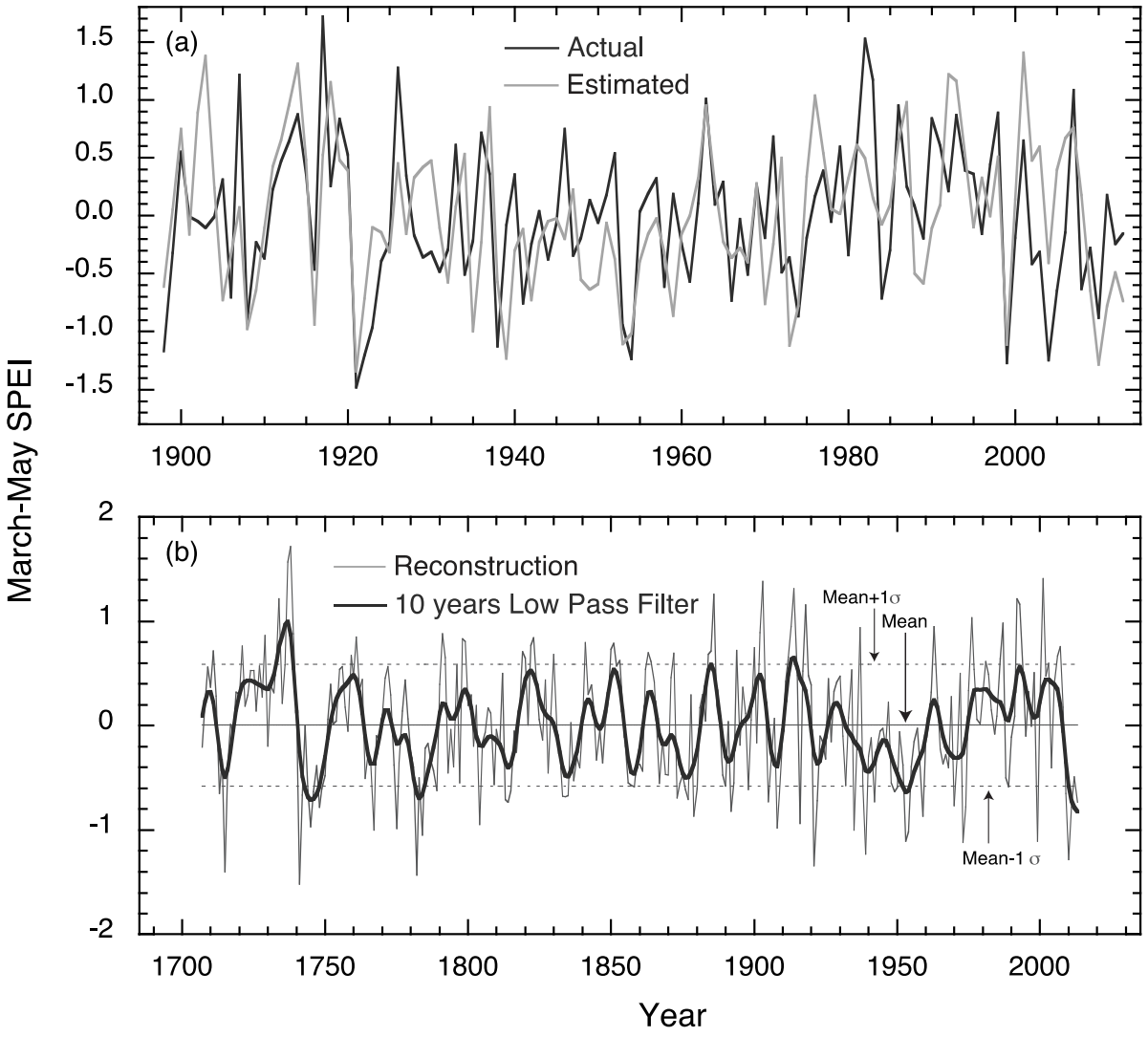

Table 2. Calibration and verification statistics for our March-May SPEI reconstruction. PC = Pearson correlation; RC = Robust correlation; SC = Spearman correlation; RE = Reduction of Error; CE = Coefficient of Efficiency.

Test	Calibration (1956–2013)	Verification (1898–1955)	Calibration (1898–1955)	Verification (1956–2013)
Undifferentiated data				
PC	0.505		0.532	
RC	0.492		0.529	
SC	0.473		0.499	
RE		0.249		0.270
CE		0.280		0.252
1st differentiated data				
PC	0.446		0.434	
RC	0.444		0.380	
SC	0.430		0.357	
RE		0.189		0.199
CE		0.188		0.199

Dry periods : AD 1741–1750, 1781–1789,

1950–1959, and 2009–2013 and

Wet periods: AD 1733–1739, 1819–1823, 1850–1853, and 1912–1914.

A long dry period :1921–1960

Longest wet period :1975–1993.

Driest years: AD 1715, 1741, 1782, and 1921

Wettest years :AD 1737, 1738, 1903, and 2001

Figure. (a)Actual and estimated March-May SPEI01 fromAD1897 to 2013, and (b) Spring reconstructed SPEI along with a 10-year low pass filter for the **period AD 1707-2013.**

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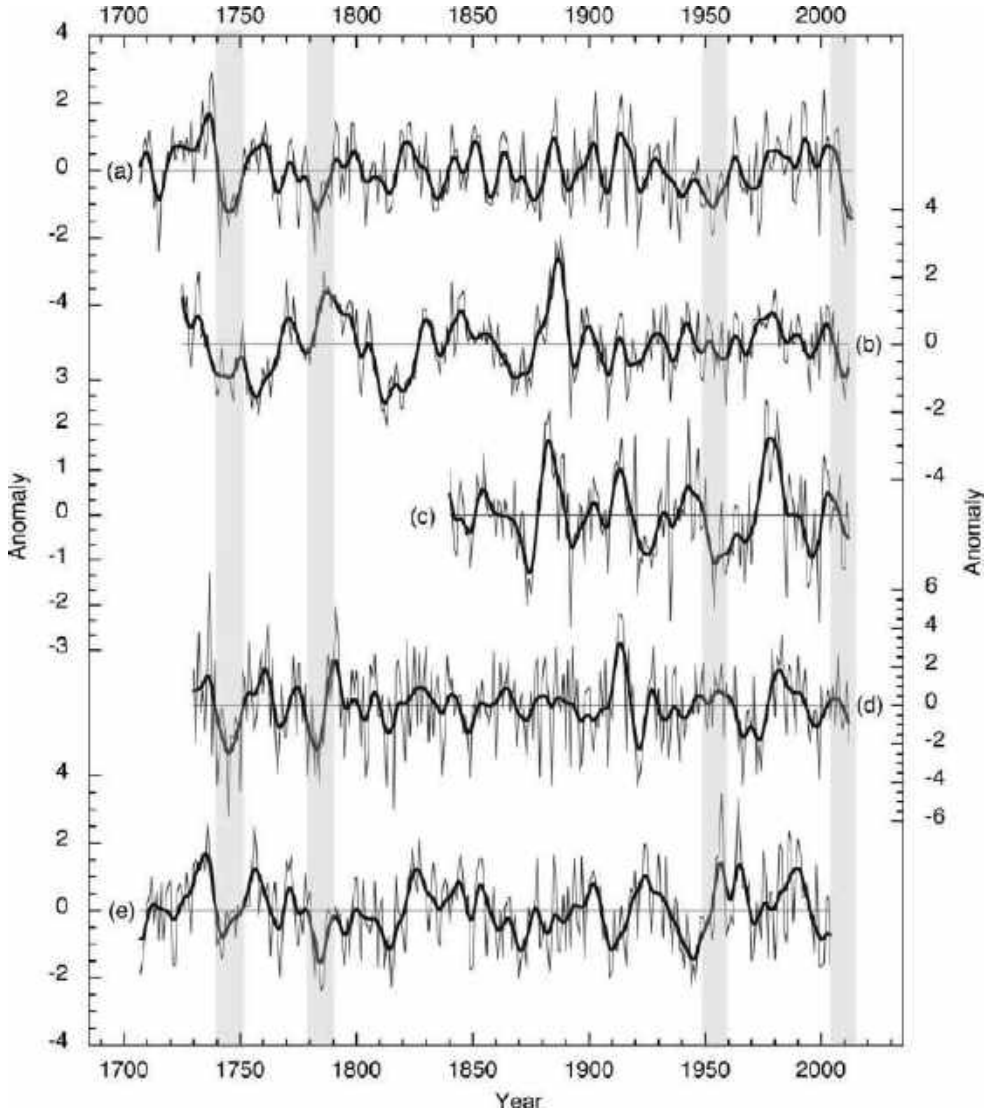
Regional coherencies



(a) Spring SPEI reconstruction from the western Nepal Himalayas (this study),

(b) Spring scPDSI reconstruction from the central Nepal Himalayas (Panthi *et al*. 2017),

(c) Spring precipitation reconstruction from the western Nepal Himalayas (Gaire *et al.* 2017),

(d) February-May precipitation reconstruction from the Kumaon Himalayas, India (Yadav *et al.* 2014),

(e) March-July precipitation reconstruction from Himachal Pradesh, India (Singh *et al.* 2009).

Figure. Comparison of current SPEI01 reconstruction with other regional scPDSI and precipitation reconstructions with grey bars indicating the four most severe droughts in our reconstruction.

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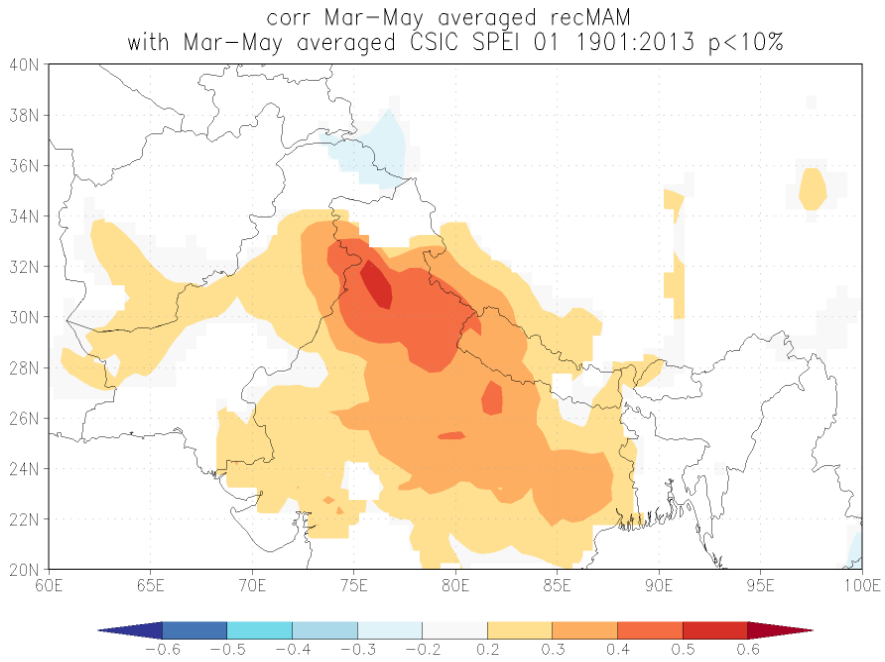
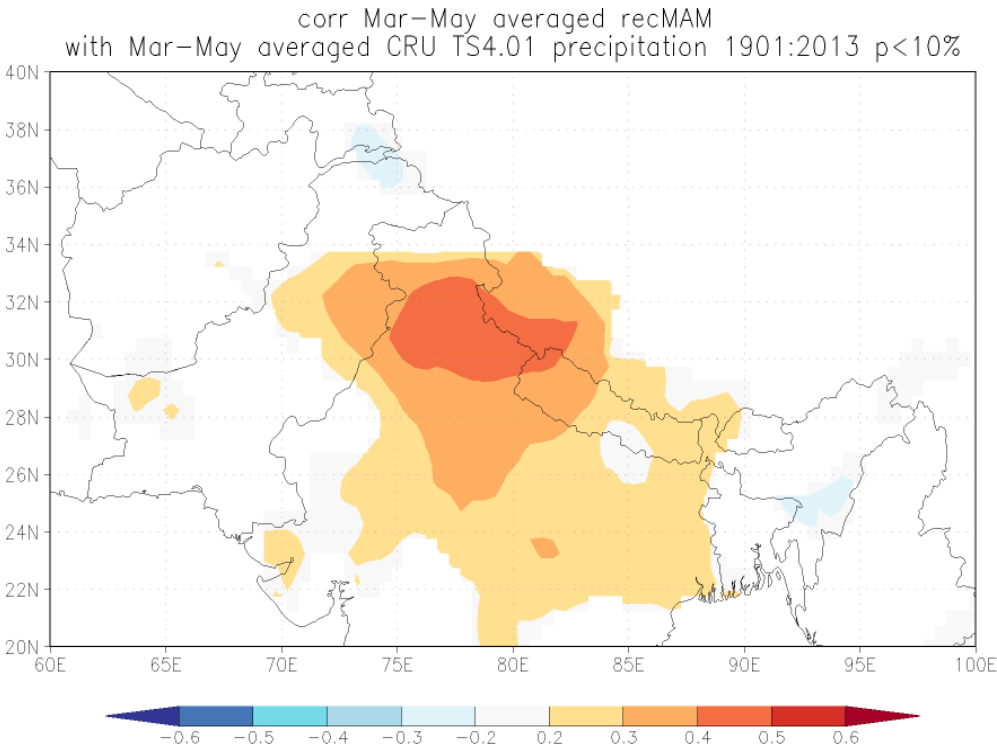
Spatial representation of Rec. SPEI





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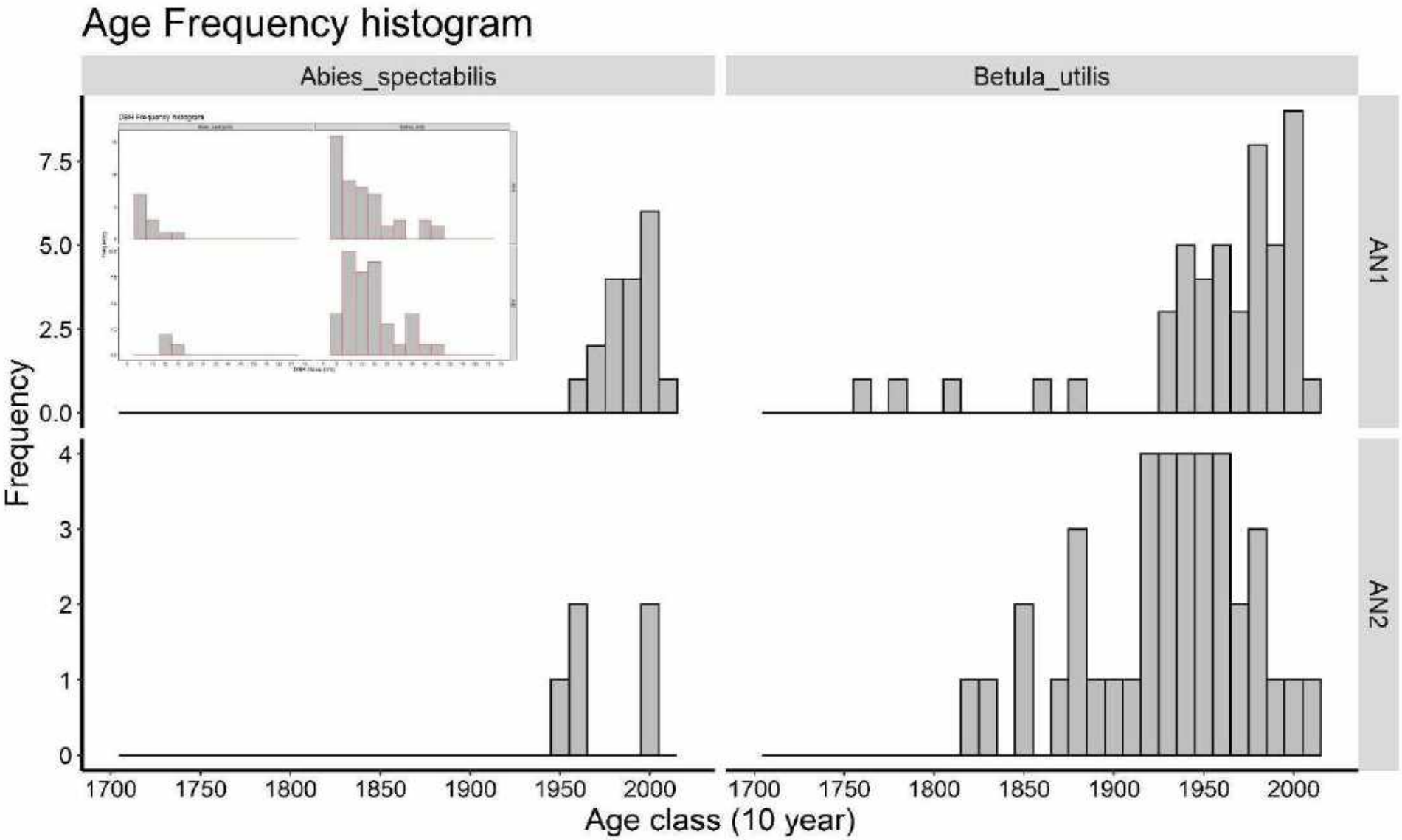
Treeline at ANCA

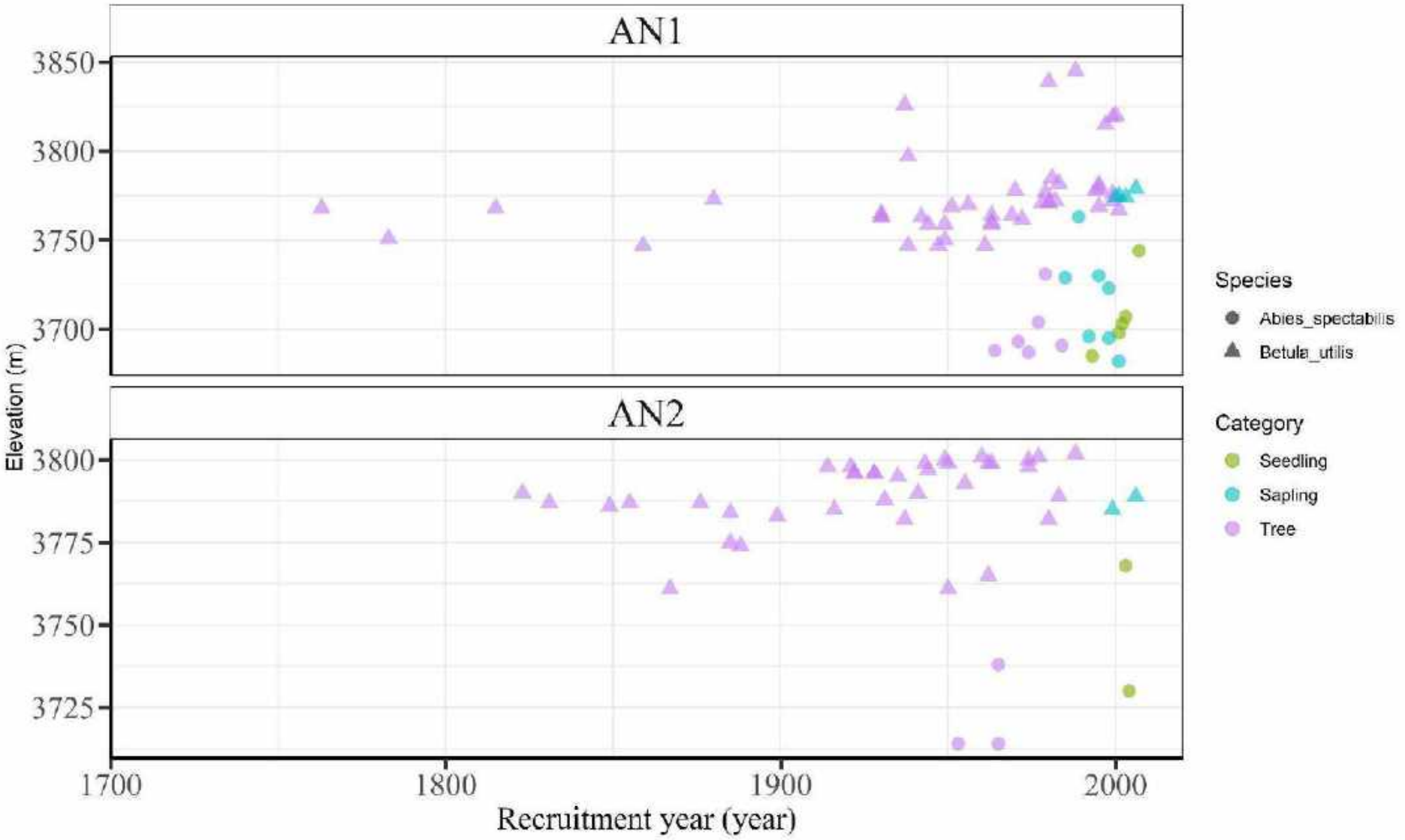
Treeline Elevation: Deuthani (AN1): *Betula* = 3845 m, *Abies* = 3763 m ;
Makarchuli (AN2): *Betula* = 3802 m, *Abies* = 3768 m

Khandeshwori Area

Regeneration and age structure

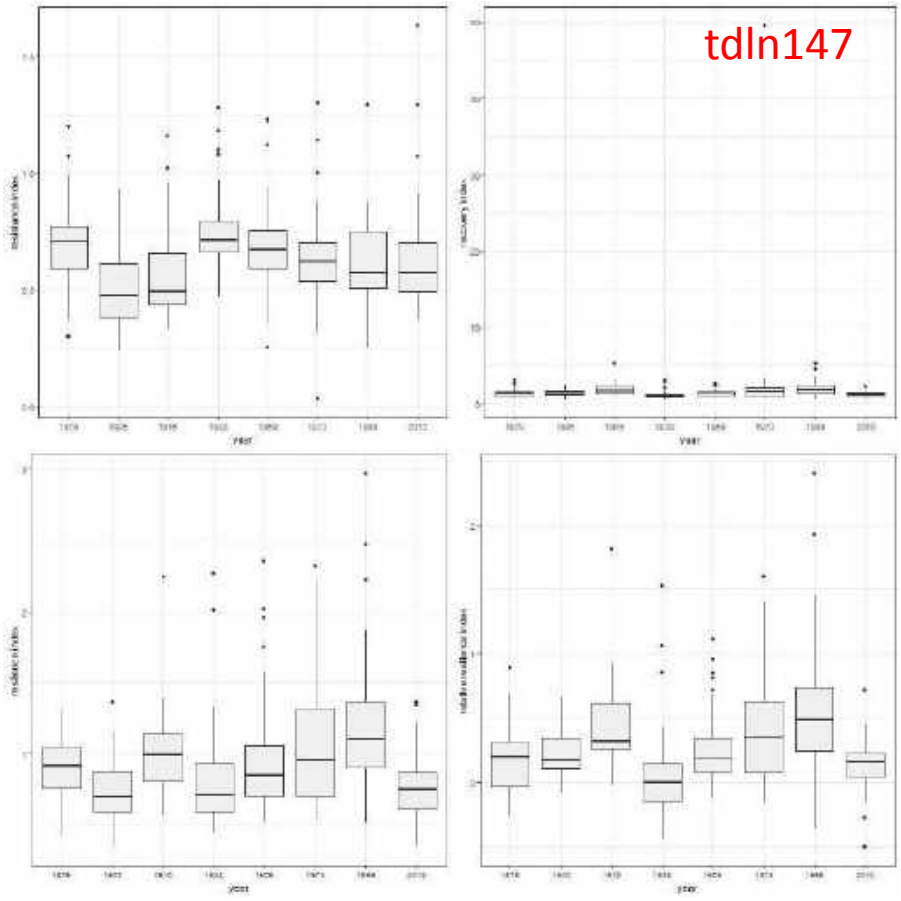


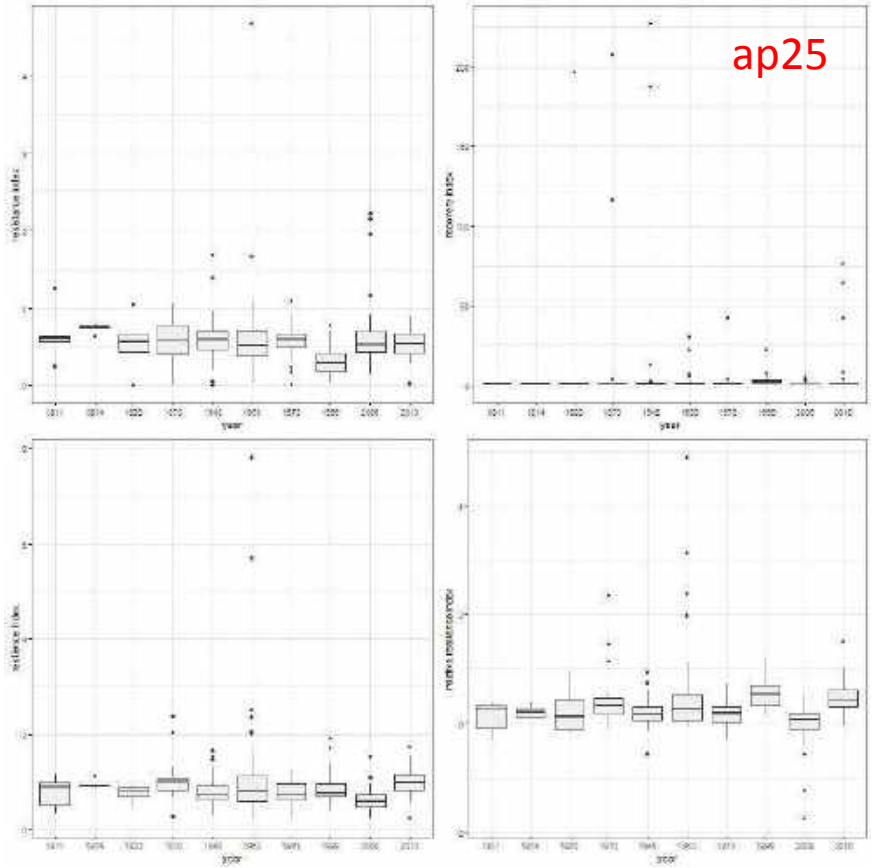
Treeline dynamics



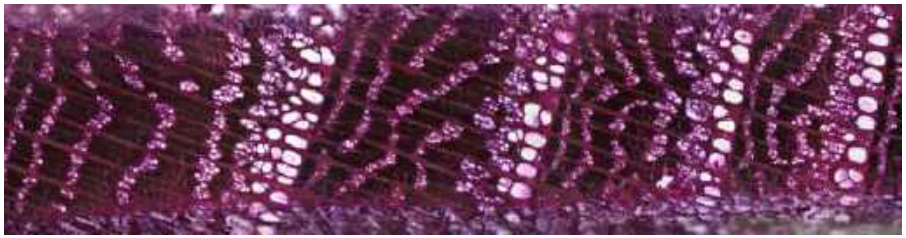
Resilience of Forests to Climate Change

	filename	specie	Pyc_5_75_Narrow	Pyc_5_75_wide
1	nepa147	TSDU	1758, 1767, 1776, 1785, 1789, 1794, 1847, 1893, 1905, 1916, 1999	1753, 1767, 1773, 1784, 1830, 1878, 1907, 1934, 1937, 1972, 2001,
2	nepa148	TSDU	1667, 1677, 1680, 1683, 1688, 1696, 1715, 1730, 1741, 1775, 1782, 1797,	1666, 1686, 1734, 1743, 1812, 1830, 1886, 1894, 1914, 1937, 2001,
3	nepa149	ABSB	1723, 1737, 1768, 1778, 1999	1703, 1713, 1748, 1767, 1862, 1878, 1920, 1937, 1947, 1972,
5	nepa151	TSDU	1577, 1587, 1614, 1640, 1643, 1695, 1741, 1782, 1817, 1821, 1861, 1879,	1573, 1601, 1611, 1616, 1621, 1628, 1629, 1655, 1778, 1812, 1830, 1891, 1894, 1926, 1937,
8	nepa154	ULWA	1619, 1640, 1669, 1685, 1689, 1722, 1802,	1648, 1668, 1688, 1887, 1905, 1926,

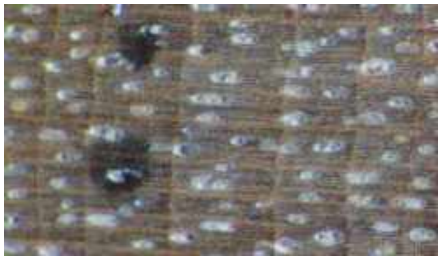




Wood Anatomical Analysis



Ulmus wallichiana



Betula utilis

Aesculus indica

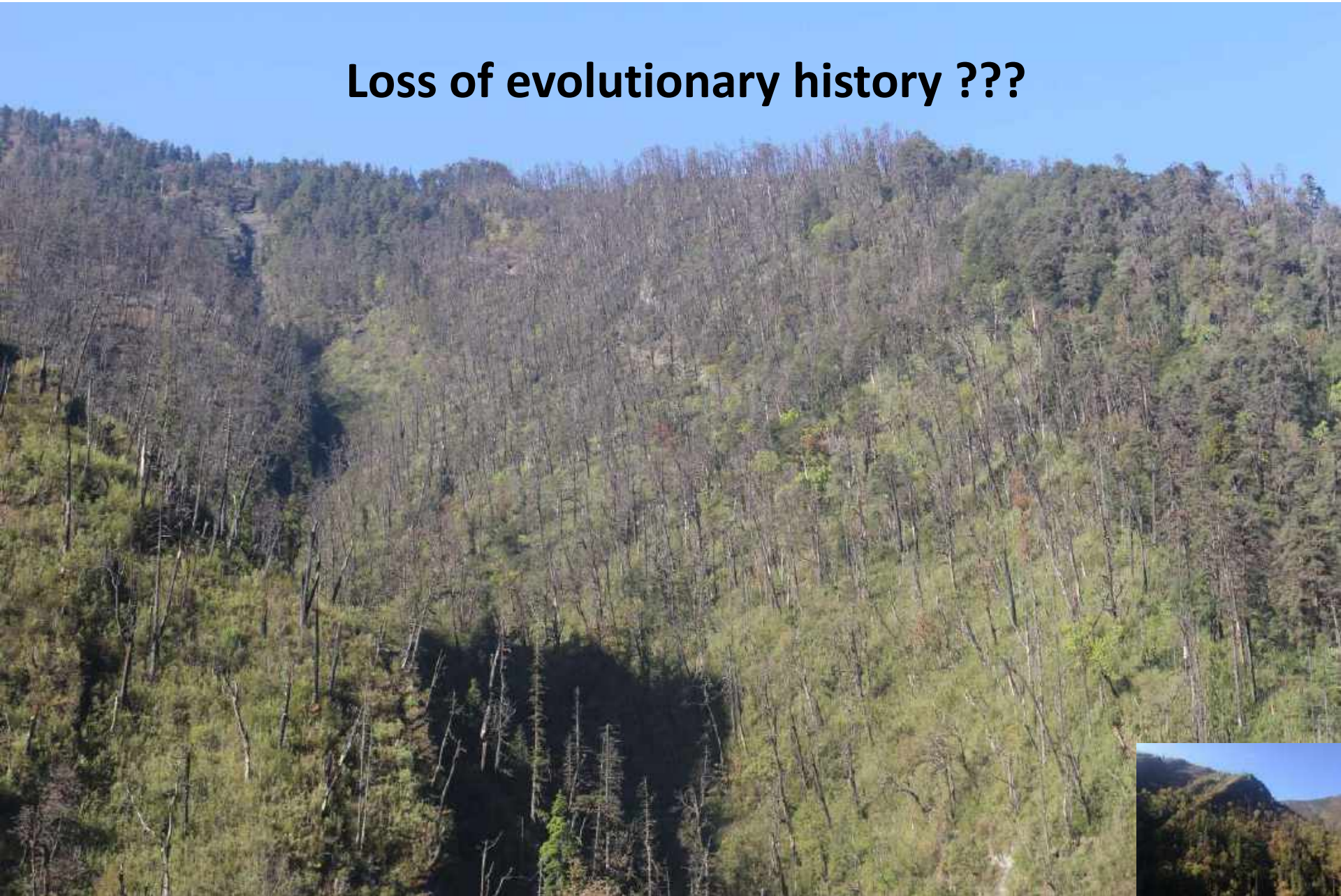
Un-1

Acer species

Un-2

Extreme Forest Fire

Loss of evolutionary history ???



Conclusions and Way-forward

- ANCA holds dendroclimatically promising several tree species
- Spring season climate (especially moisture availability) is the main growth limiting factor
- Treeline research shows differential regeneration pattern along with stand densification as well as possible shifting
- The SPEI reconstruction showed several dry and wet episodes indicating no persistent climate trend within the past three centuries.
- Need integrated and further study using multi-proxy tree-ring parameters for better understanding of the ecosystem level climate sensitivity and vulnerability to climate change

Our study is continue. Need collaborations and support for robust results

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- Field assistants
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