Supplementary Materials for

Improved vegetation ecological quality of the Three-North Shelterbelt project region of China during 2000–2020 evidenced from multiple remotely sensed indicators

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Contents of this file

Text S1. Principal component analysis of each indicator

The results of principal component analysis for only four years are presented in this paper (Table S1). The cumulative contribution of the first (PC1) and second principal components (PC2) to the VEQI of the four-year data exceeded 93%, indicating that most characteristics of the six indicators were integrated by PC1 and PC2. Therefore, PC1 and PC2 were selected to construct the VEQI.

Table S1. Results of PCA of each indicator.

Each index	2000		2007		2014		2020	
	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
LST	–0.269	0.802	–0.272	0.832	–0.264	0.825	–0.241	0.903
WUE	0.061	0.693	0.075	0.851	0.213	0.835	0.170	0.739
NPP	0.869	0.269	0.932	0.252	0.911	0.231	0.9311	0.135
FVC	0.902	0.248	0.902	0.262	0.902	0.252	0.932	0.102
LAI	0.812	0.419	0.830	0.323	0.910	0.283	0.909	0.221
WET	0.442	0.739	0.418	0.732	0.423	0.769	0.413	0.902
Eigenvalues	3.132	1.903	3.113	2.186	3.098	2.312	2.769	2.356
Variance contribution%	54.13	35.62	53.56	34.46	53.21	35.56	50.68	39.31
Cumulative variance contribution%	54.13	89.75	53.56	88.02	53.21	88.77	50.68	89.99

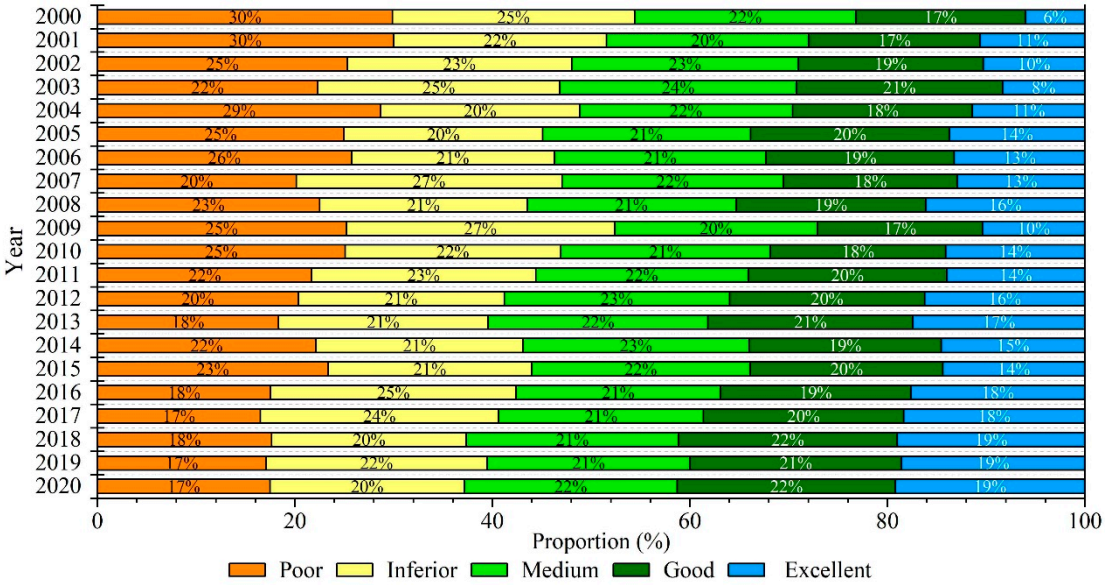

Figure S1. Area proportion statistics of VEQI for each grade over the years.

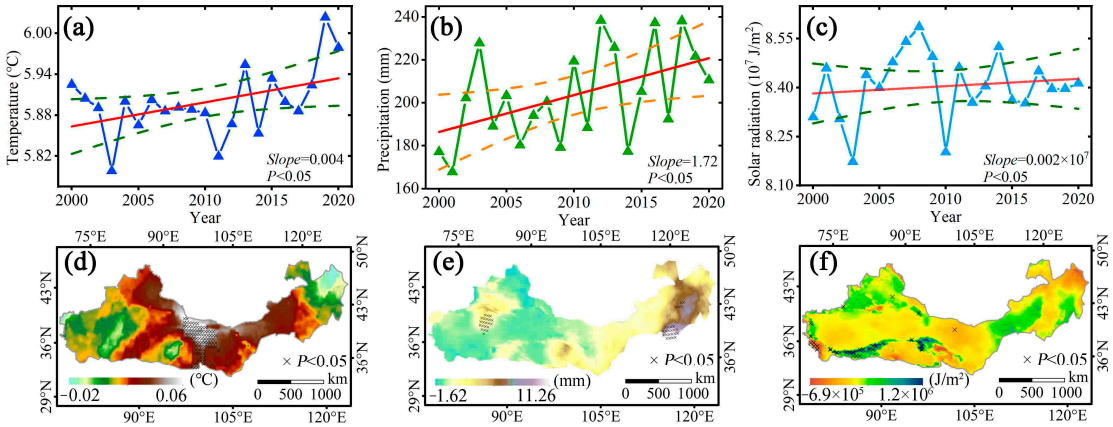

Figure S2. Spatio-temporal change characteristics of TEM (a, d), PRE (b, e), and SNR (c, f) in the TNS from 2000 to 2020.

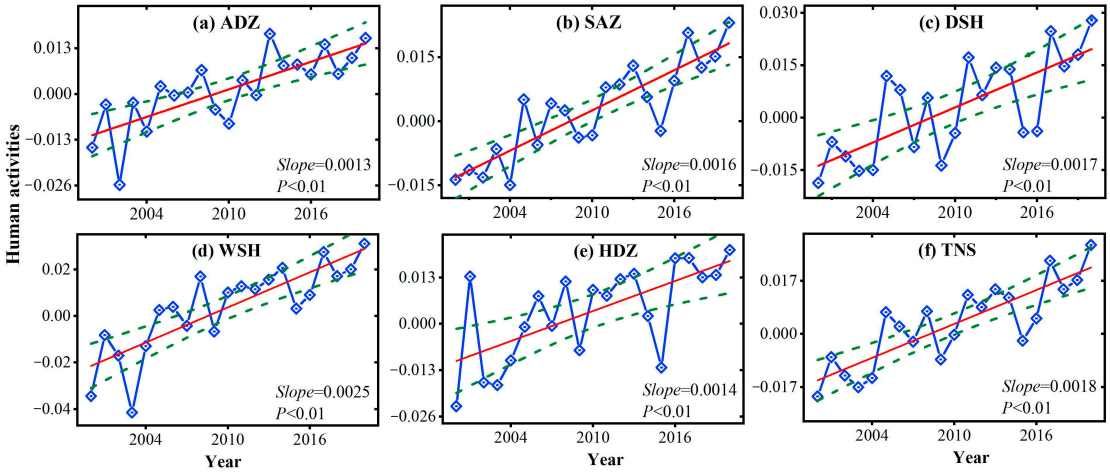

Figure S3. Temporal trends in the residuals of TNS and each climate zone.

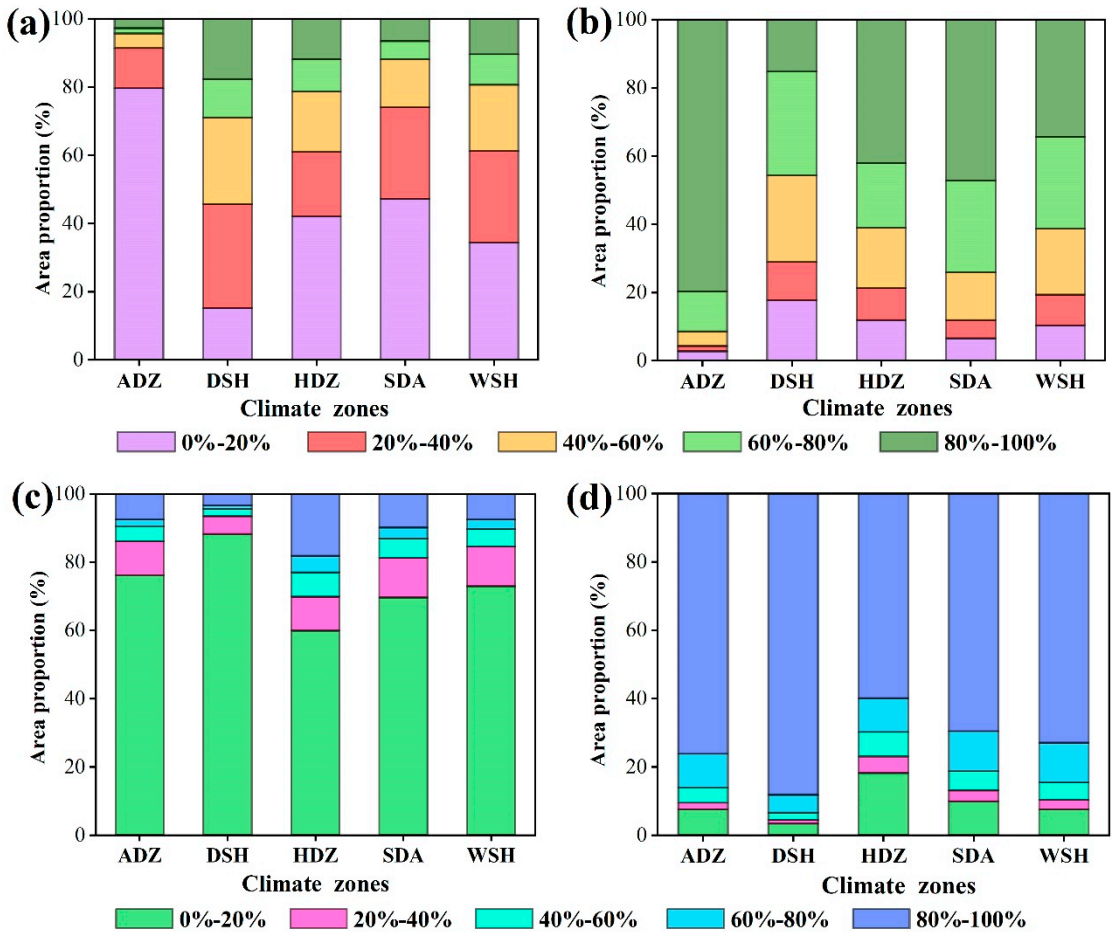

Figure S4. Statistics of the relative contributions of climate variation and human activities to VEQI in each climate zone: (a) and (c) are the relative contributions of climate variation to VEQI in increasing (decreasing) regions, respectively; (b) and (d) are the relative contributions of human activities to VEQI in increasing (decreasing) regions, respectively.

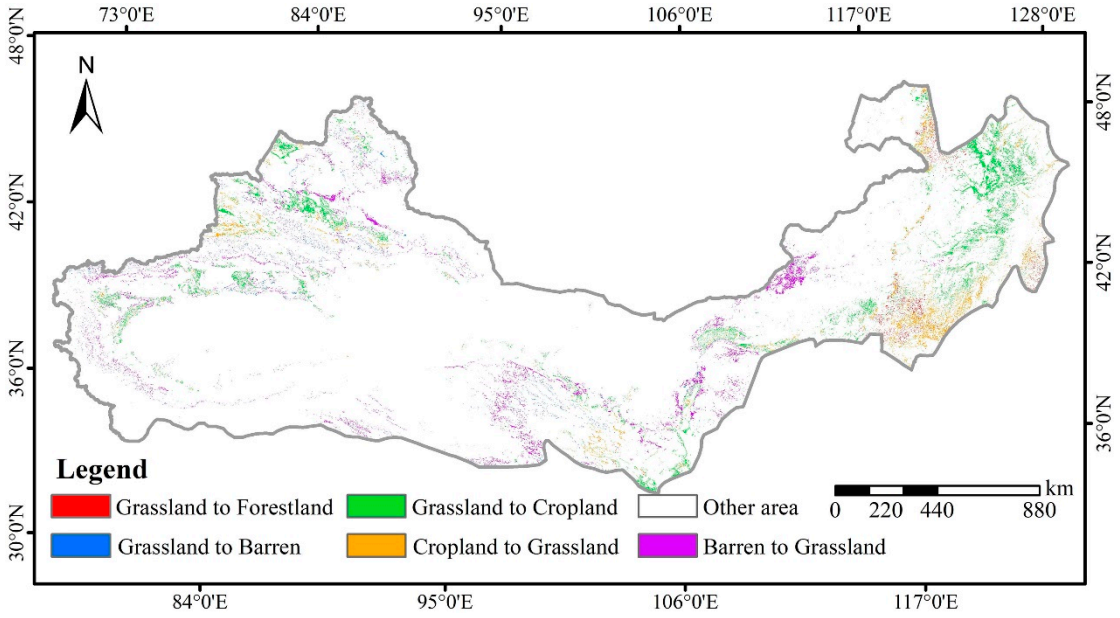

Figure S5. Spatial distribution of the transfer of main land-use types of the TNS from 2000 to 2020.

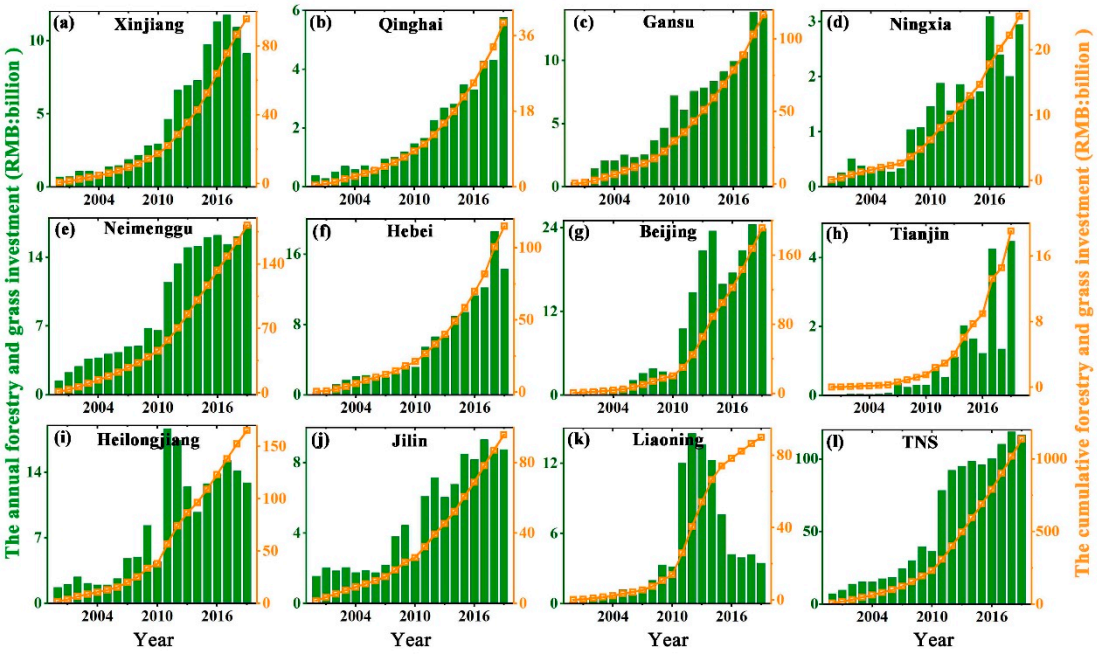

Figure S6. Statistics of annual fixed and cumulative fixed investments in forestry projects in the TNS and each province from 2000 to 2020.

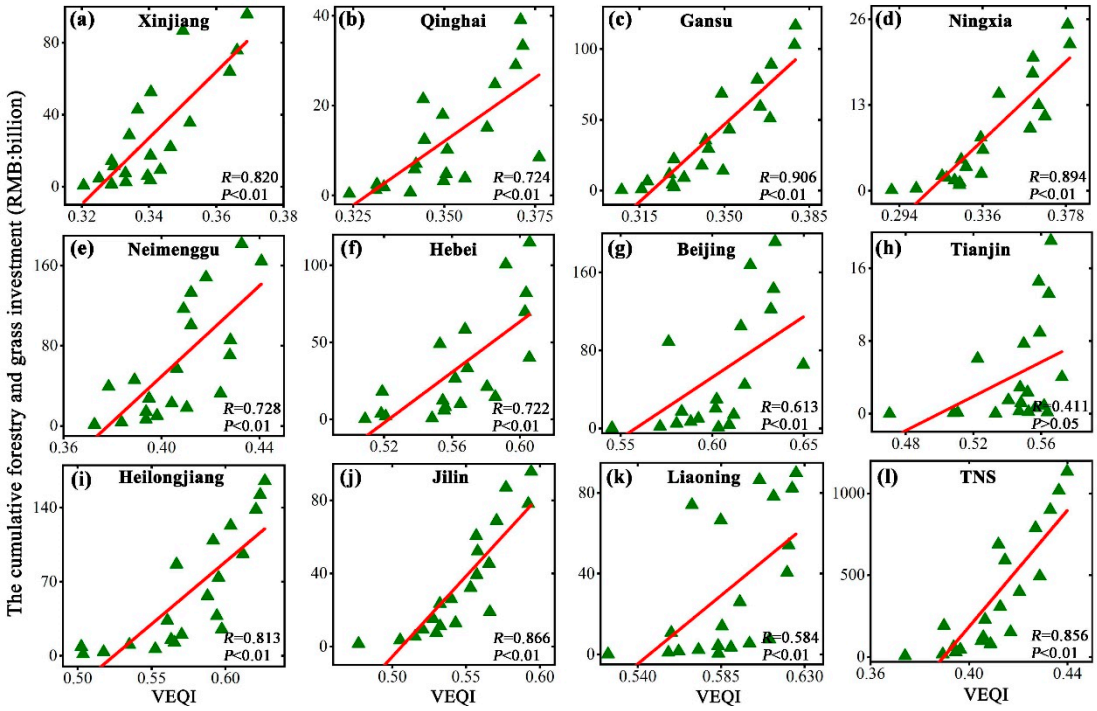

Figure S7. The relationships between cumulative fixed investment and VEQI of forestry projects in the TNS and each province.

Table S2. Future trends of VEQ in the TNS.

Future trends	Variation trends and Persistence		Proportion (%)	
	Slope & MK-Significant & Hurst exponent	Coupling results		
Malignant	Slope<–0.001 &|Z|>1.96 &0.5<Hurst<1	Significant degradation& Persistence	0.55	51.31
	Slope<–0.001 &|Z|≤1.96 &0.5<Hurst<1	Insignificant degradation& Persistence	1.33	
	Slope>0.001 &|Z|>1.96 &0≤Hurst<0.5	Significant improvement & Anti-persistence	31.48	
	Slope>0.001 &|Z|≤1.96 &0≤Hurst<0.5	Insignificant improvement & Anti-persistence	17.95	
Benign	Slope>0.001 &|Z|>1.96 &0.5<Hurst<1	Significant improvement & Persistence	13.79	22.35
	Slope>0.001 &|Z|≤1.96 &0.5<Hurst<1	Insignificant improvement & Persistence	5.72	
	Slope<–0.001 &|Z|>1.96 &0≤Hurst<0.5	Significant degradation & Anti-persistence	0.52	
	Slope<–0.001 &|Z|≤1.96 &0≤Hurst<0.5	Insignificant degradation & Anti-persistence	2.32	
Stability	–0.001 ≤ Slope ≤ 0.001	Stability	26.34	26.34

Table S3. Suitable scopes or types of the factors.

Climate zones	Factors	Suitable scope or type	VEQI	Climate zones	Factors	Suitable scope or type	VEQI
ADZ	TEM/℃	11.21–15.59	0.268	SAZ	TEM/℃	−2.48–0.43	0.308
	PRE/mm	36–53	0.259		PRE/mm	504–738	0.389
	WS/m.s^{-1}	1.50–1.86	0.265		WS/m.s^{-1}	2.41–2.76	0.326
	EVA/mm	1266–1366	0.268		EVA/mm	1172–1313	0.307
	SOI/mm	0–22.49	0.249		SOI/mm	64.99–149	0.346
	SNR/10^{7}J.m^{-2}	8.3–8.9	0.258		SNR/10^{7}J.m^{-2}	9.8–11.3	0.323
	PD/person.km^{-2}	11358–15459	0.241		PD/person.km^{-2}	6281–37690	0.426
	DEM/m	0–661	0.281		DEM/m	0–730	0.328
	SLO/°	0–1.13	0.260		SLO/°	0–1.13	0.294
	ASP	Plane	0.246		ASP	Plane	0.289
	VT	PF	0.461		VT	PF	0.480
	ST	Silty clay	0.267		ST	Silt loam	0.425
DSH	TEM/℃	−2.29–−0.14	0.476	WSH	TEM/℃	6.69–9.61	0.609
	PRE/mm	396–444	0.489		PRE/mm	394–422	0.610
	WS/m.s^{-1}	3.48–3.71	0.479		WS/m.s^{-1}	2.58–2.90	0.609
	EVA/mm	638–737	0.487		EVA/mm	680–765	0.620
	SOI/mm	77.25–129.93	0.514		SOI/mm	128.95–167.83	0.611
	SNR/10^{7}J.m^{-2}	10.3–11.2	0.551		SNR/10^{7}J.m^{-2}	10.9–11.4	0.665
	PD/10^{5} person km^{-2}	8.04–16.80	0.476		PD/person.km^{-2}	248618–111877	0.578
	DEM/m	0–408	0.503		DEM/m	344–710	0.644
	SLO/°	4.43–6.64	0.472		SLO/°	0–0.84	0.597
	ASP	East	0.459		ASP	West	0.580
	VT	PF	0.616		VT	BF	0.682
	ST	Heavy clay	0.564		ST	Silt loam	0.616
HDZ	TEM/℃	4.51–6.44	0.740	TNS	TEM/℃	−3.73–−0.63	0.392
	PRE/mm	604–678	0.784		PRE/mm	524–738	0.651
	WS/m s^{-1}	2.15–2.45	0.784		WS/m.s^{-1}	2.49–2.83	0.382
	EVA/mm	929–1031	0.708		EVA/mm	724–831	0.421
	SOI/mm	189.5–234.1	0.679		SOI/mm	136.49–207.98	0.542
	SNR/10^{7}J.m^{-2}	10.1–10.5	0.721		SNR/10^{7}J.m^{-2}	10.2–11.4	0.567
	PD/person km^{-2}	0–35834	0.595		PD/person.km^{-2}	32952–138402	0.505
	DEM/m	268–631	0.664		DEM/m	0–599	0.506
	SLO/°	0.95–2.31	0.638		SLO/°	3.24–6.20	0.347
	ASP	Northwest	0.622		ASP	Southeast	0.351
	VT	BF	0.778		VT	CF	0.617
	ST	Silt loam	0.656		ST	Silt loam	0.507

Table S4. Statistics of the proportion of land use transfer area in the TNS from 2000 to 2020 (km^2).

Land-use types	Forestland	Shrub	Grassland	Wetland	Cropland	Impervious	Snow/Ice	Barren	Water
Forestland	15606.75	83.5	2693	39.5	69.25	0	0	0	0
Shrub	571.25	681.75	1150	0	4.5	0	3.25	9.5	0
Grassland	5926.75	1380.75	1214686	1532.25	69656	347.5	22.75	7095.5	233.25
Wetland	110	0	226	869.25	13.5	1.75	0	9.25	37.25
Cropland	795.75	77.75	27729.25	309.75	252700.3	1167.5	0.75	57.5	129.25
Impervious	0	0	0	0	0	6001.25	0	0	0
Snow/Ice	0	0.25	15.75	0	0.75	0	248.75	153	0.75
Barren	0	502.25	38410.75	59.5	804.5	9	447.25	70372.25	151
Water	0	0	10.75	7.75	1.25	0	2	17.5	240