Table S1 Summary of the main characteristics of three study sites.

Study sites	Position	MAP (mm)	Sampling elevation (m)		Dominant species		Soil type
			Tree	Shrub	Tree	Shrub	
Balang Mts.	102°52′-103°24′E, 30°45′-31°25′N	846	2860, 3290, and 3670	2840, 3160, and 3590	*Abies faxoniana*	*Quercus aquifolioides*	Umbric Cryic Cambisols
Qilian Mts.	102°58′-103°01′E, 37°14′-37°20′N	435	2540, 2870, and 3250	3020, 3250, and 3540	*Picea crassifolia*	*Salix gilashanica*	Calcaric Ustic Cambisols
Changbai Mt.	126°55′-129°00′E, 41°23′-42′36°N	632-1154	1700, 1860, and 2030	1430, 2000, and 2380	*Betula ermanii*	*Vaccinium uliginosum*	Andic Gelic Cambisols

Table S2 Correlation analyses (*R* values) of soil base cations and available micronutrients with soil physicochemical parameters of treeline or shrubline for each sampling site.

		Treeline						Shrubline					
		Ca	Mg	K	Fe	Mn	Zn	Ca	Mg	K	Fe	Mn	Zn
Balang	pH	**0.47**	0.37	0.54*	0.05	-0.13	-0.35	0.87**	-0.13	-0.56*	-0.60**	**-0.40**	**-0.43**
	SOC	0.31	**0.47**	0.40	0.64**	0.67**	0.78**	**0.43**	0.63**	-0.18	0.15	-0.08	0.36
	TN	0.34	0.49*	0.35	0.57*	0.68**	0.72**	0.55*	0.57*	-0.25	-0.07	-0.19	0.26
	C:N	0.04	0.09	0.27	0.34	0.12	0.27	-0.52*	0.00	0.29	0.72**	0.34	0.23
	NO_3^-	0.52*	0.51*	0.63**	0.38	0.11	0.16	0.62**	-0.16	-0.51*	-0.35	-0.17	0.10
	NH_4^+	0.08	0.08	-0.21	0.02	**0.43**	0.02	0.00	0.07	0.22	0.13	0.37	0.07
	TIN	0.55*	0.54*	0.51*	0.39	0.33	0.16	0.61**	-0.15	-0.48*	-0.34	-0.14	0.10
	Olsen P	**0.40**	**0.67****	0.54*	0.29	0.31	0.49*	-0.21	-0.08	0.37	0.24	-0.09	-0.28
Qilian	pH	-0.85**	-0.79**	0.63**	**-0.43**	-0.12	-0.40	-0.07	0.07	0.38	0.35	0.49*	-0.13
	SOC	0.59*	0.60**	-0.36	0.08	-0.09	0.22	0.64**	**0.45**	-0.37	-0.20	-0.25	0.10
	TN	0.95**	0.94**	-0.72**	0.63**	0.38	**0.46**	0.01	0.09	0.22	-0.03	-0.35	0.01
	C:N	-0.52*	-0.49*	0.53*	-0.70**	-0.57*	-0.32	0.79**	0.48*	-0.63**	-0.21	-0.04	0.07
	NO_3^-	-0.48*	-0.38	0.32	-0.18	-0.12	-0.39	-0.51*	-0.01	0.32	0.26	0.28	-0.05
	NH_4^+	0.19	0.30	-0.19	0.24	0.36	0.32	**0.46**	0.13	0.03	-0.33	-0.30	-0.09
	TIN	**-0.43**	-0.31	0.27	-0.12	-0.04	-0.30	-0.26	0.10	**0.44**	0.04	0.10	-0.14
	Olsen P	0.48*	0.53*	-0.28	0.20	0.12	0.47*	-0.33	-0.25	0.67**	**0.46**	0.39	-0.14
Changbai	pH	0.03	-0.22	0.13	-0.57*	**0.41**	0.15	0.66*	0.49*	**-0.46**	-0.53*	0.65**	**0.41**
	SOC	-0.09	0.15	0.56*	0.91**	-0.57*	0.07	0.67**	0.83**	0.36	0.61**	**0.41**	0.54*
	TN	**0.43**	0.65**	**0.44**	0.71**	-0.32	**0.43**	0.78**	0.88**	0.22	0.47*	0.53*	0.55*
	C:N	-0.70**	-0.58*	**0.42**	0.66**	-0.61**	**-0.42**	-0.48*	-0.50*	0.09	0.06	**-0.40**	-0.24
	NO_3^-	-0.07	-0.20	-0.32	-0.21	0.18	-0.12	-0.25	-0.32	0.02	-0.07	-0.30	-0.16
	NH_4^+	0.09	0.19	0.61**	-0.07	-0.29	0.49*	-0.29	**-0.43**	-0.09	-0.32	-0.22	-0.20
	TIN	-0.03	-0.11	-0.08	-0.23	0.06	0.07	-0.28	-0.37	-0.02	-0.15	-0.29	-0.18
	Olsen P	0.01	0.12	0.49*	0.18	0.04	**0.44**	0.27	0.48*	0.49*	0.17	0.20	0.34

* and ** indicate significant level at $P < 0.05$ and 0.01, respectively. Bold type represents $P < 0.1$.

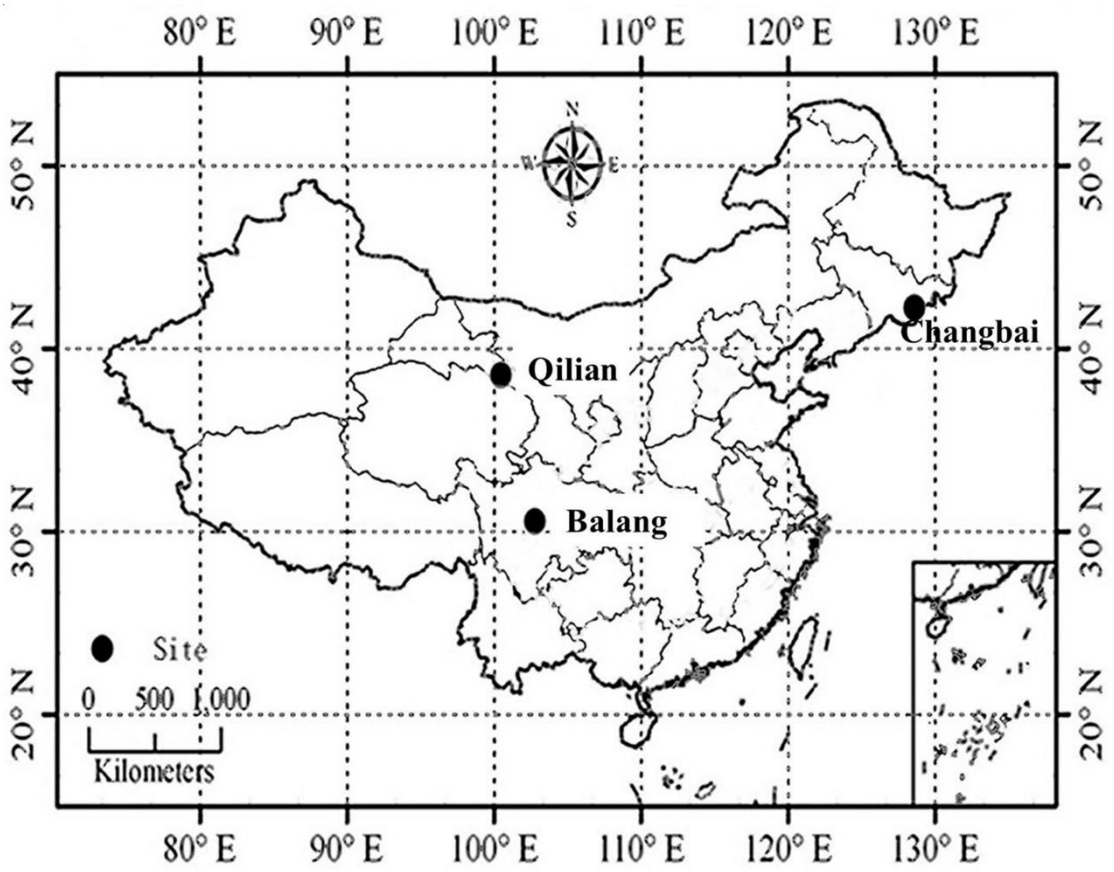
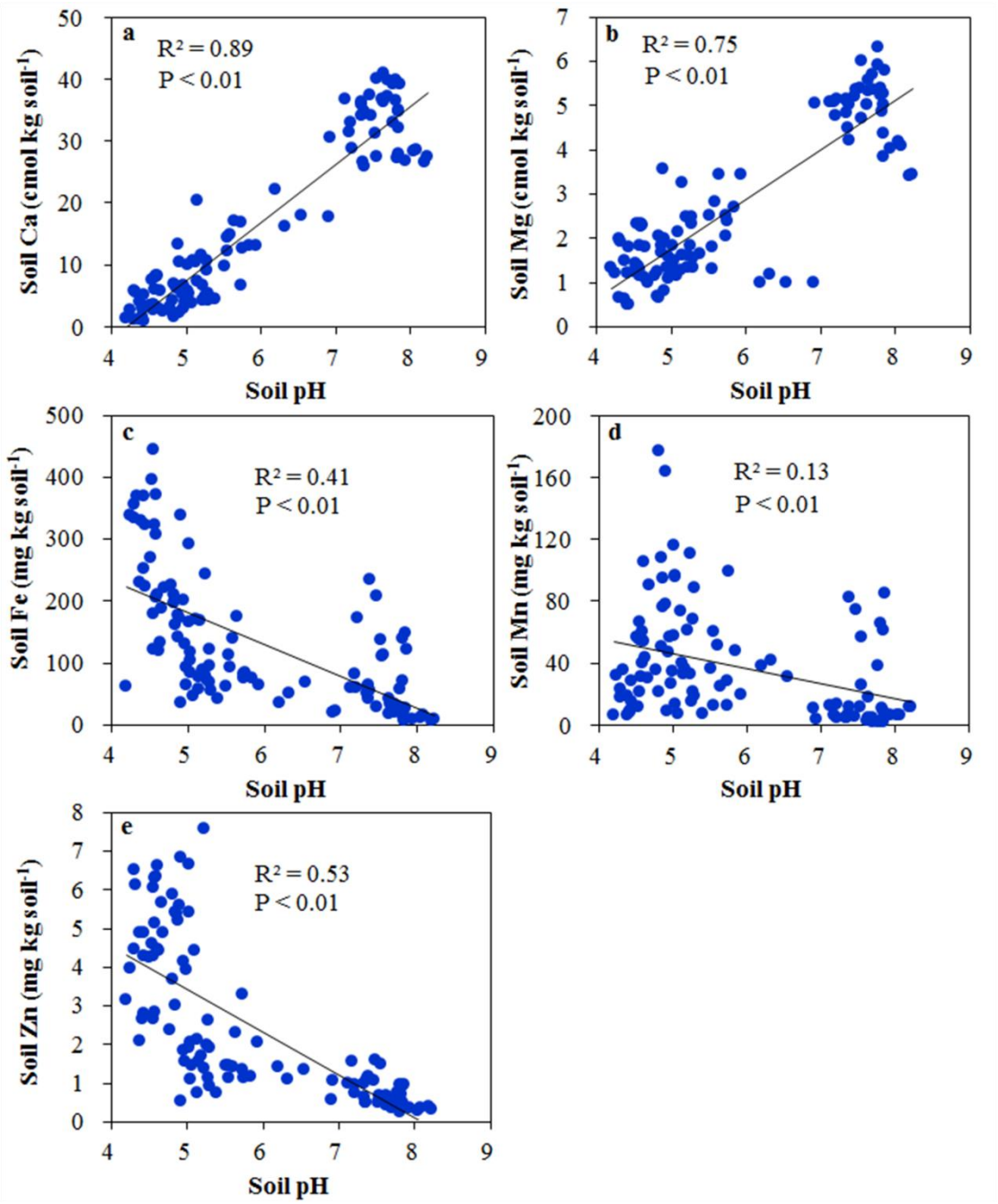
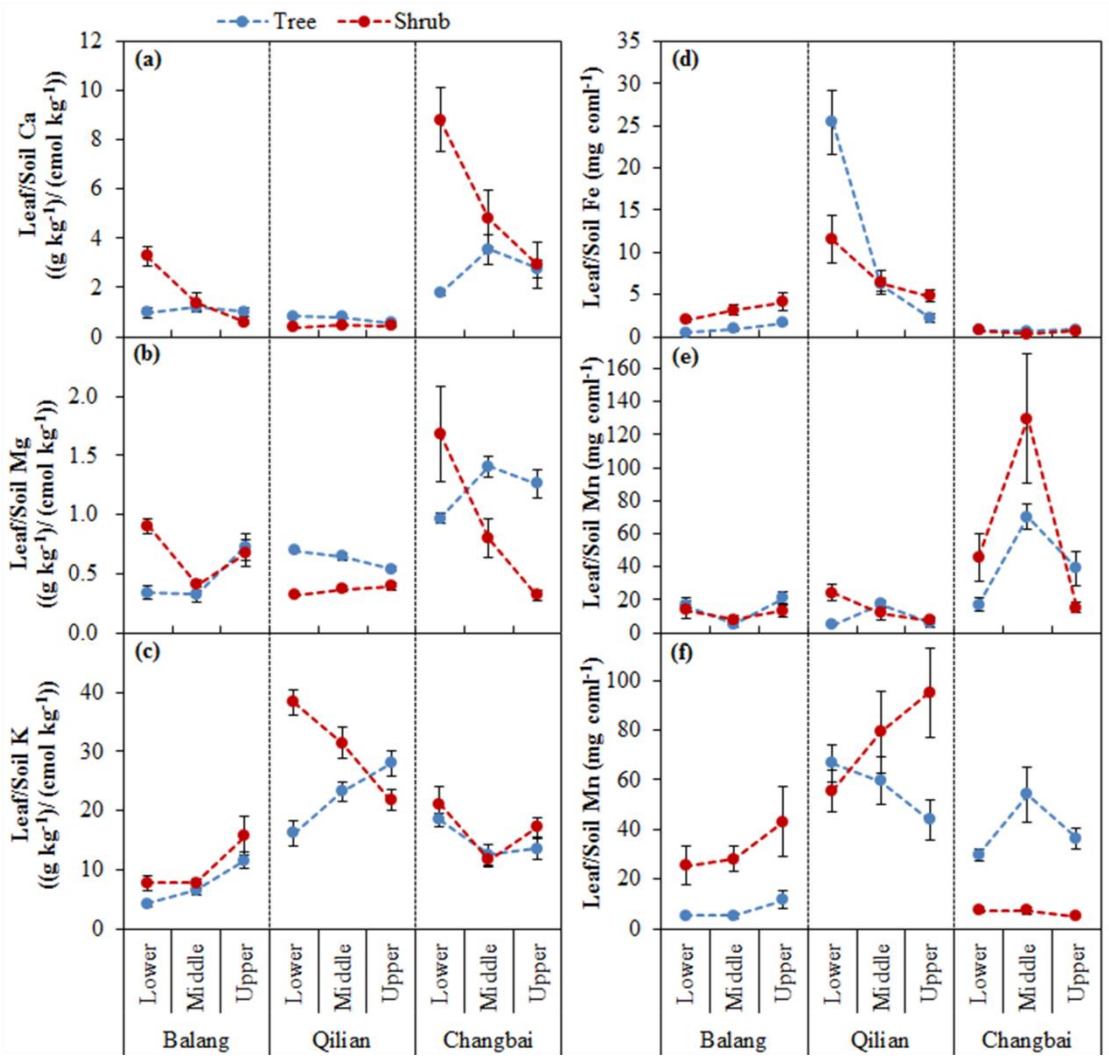


Fig. S1 Location of three sampling sites.



10

Fig. S2 Correlation analyses between soil pH and soil exchangeable base cations of Ca (a) and Mg (b) and available micronutrients of Fe (c), Mn (d) and Zn (e) under trees and shrubs across three sampling sites.



15

Fig. S3 The ratio of nutrient concentrations of Ca (a), Mg (b), K (c), Fe (d), Mn (e) and Zn (f) in plant leaves to their availabilities in soils at lower and middle elevations as well as at the upper limit of trees or shrubs for each of the three sites.

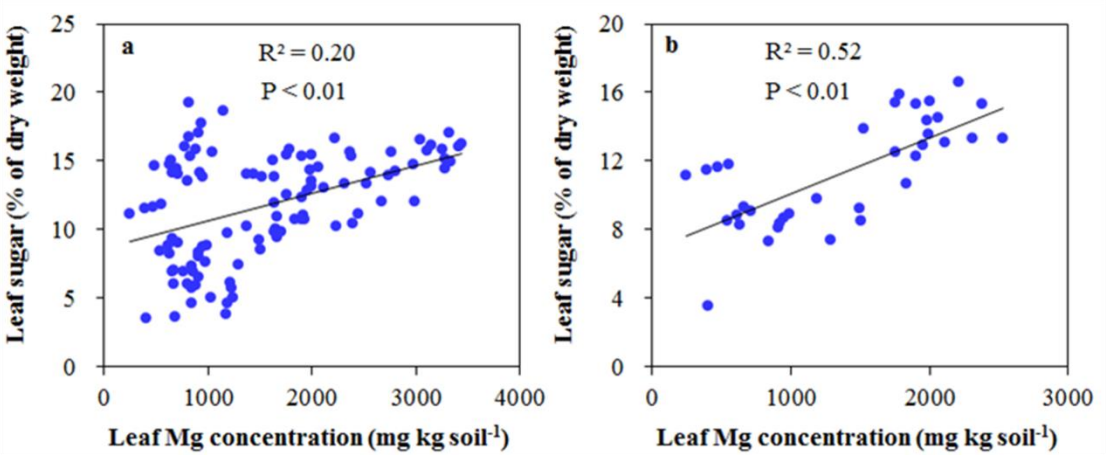


Fig. S4 Correlation analyses between Mg concentration and soluble sugar contents across three sampling sites (a) and at Changbai (b).