Appendix A Proportions (%) of each P fraction to the sum of all P fractions in black soil samples collected in 1990 (initial) and in 2018 under long-term different fertilization treatments. CK, no fertilizer; NK, nitrogen, and potassium fertilizer application; NPK, inorganic nitrogen, phosphorous and potassium fertilizer application; NPKM, NPK plus manure (pig manure from 1990 to 2004, and cattle manure from 2005 to 2018). Pi, inorganic P; Po, organic P.
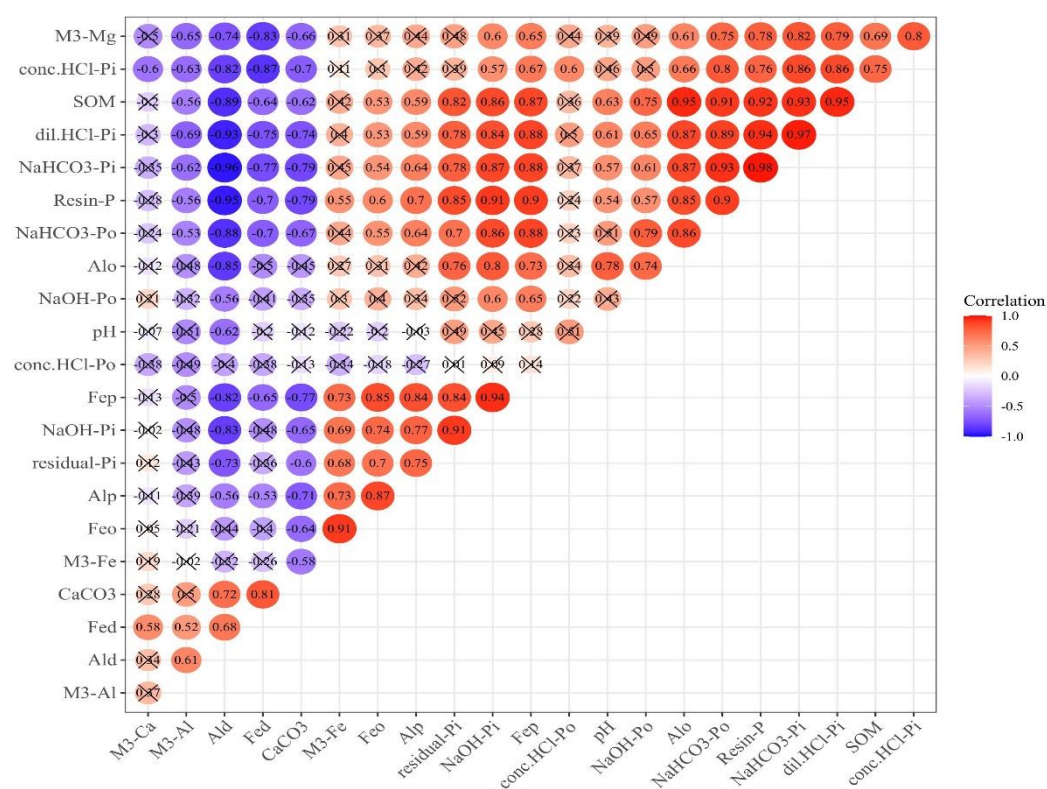
Appendix B (1) Correlation between soil properties and P fraction in 0–20 cm. SOM, soil organic matter; Fe_d and Al_d, free Fe and Al oxide; Fe_o and Al_o, amorphous Fe and Al oxide; Fe_p and Al_p, humus complex Fe and Al oxide; M3-Ca, M3-Mg, M3-Fe and M3-Al were Ca, Mg, Fe and Al extracted by Mehlich-3 extraction. "×" means no significant difference between parameters.
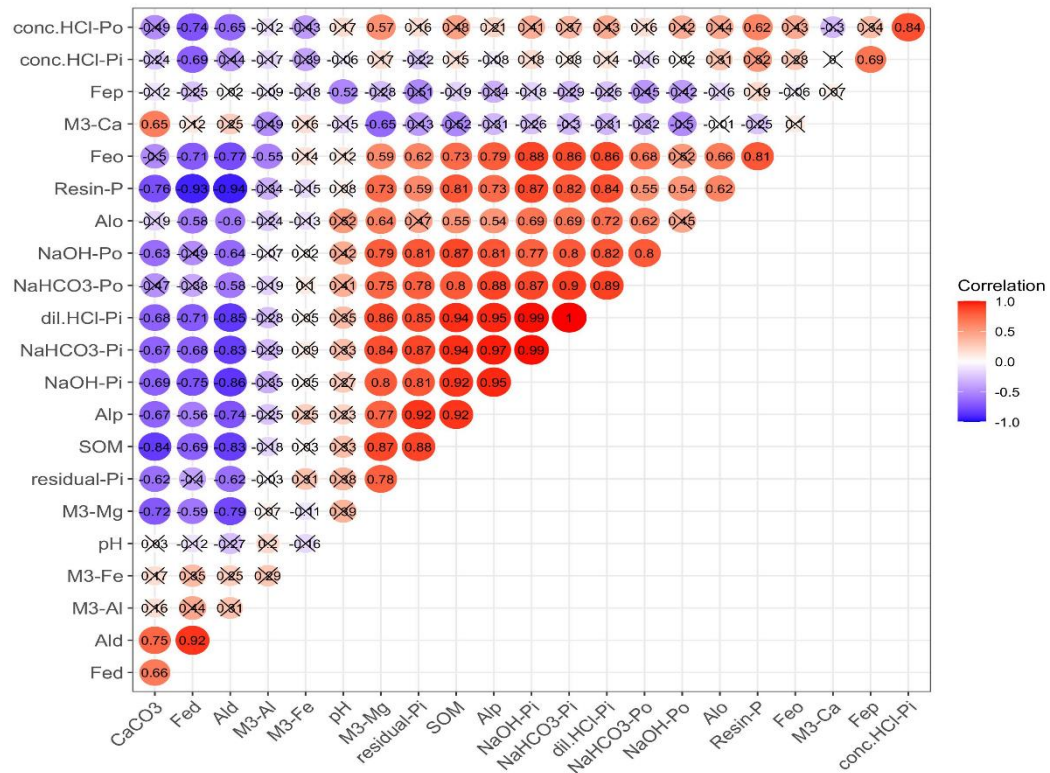
Appendix B (2) Correlation between soil properties and P fraction in 20–40 cm. SOM, soil organic matter; Fe_d and Al_d, free Fe and Al oxide; Fe_o and Al_o, amorphous Fe and Al oxide; Fe_p and Al_p, humus complex Fe and Al oxide; M3-Ca, M3-Mg, M3-Fe and M3-Al were Ca, Mg, Fe and Al extracted by Mehlich-3 extraction. "×" means no significant difference between parameters.
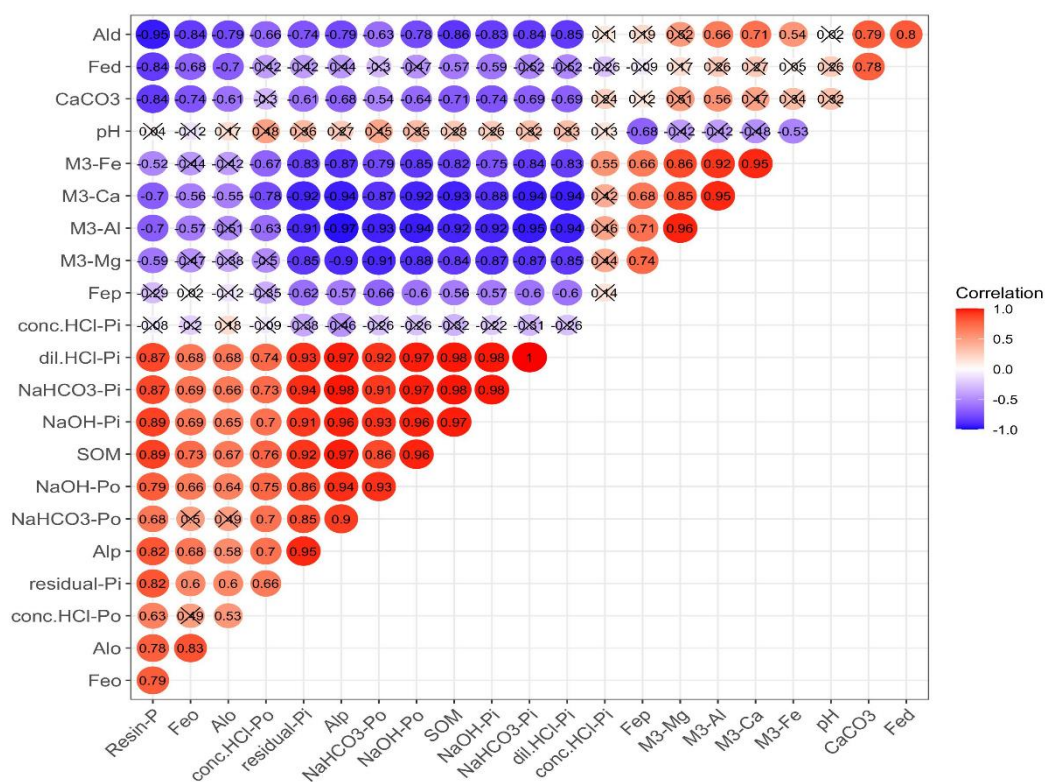
Appendix B (3) Correlation between soil properties and P fraction in 40–60 cm. SOM, soil organic matter; Fe_d and Al_d, free Fe and Al oxide; Fe_o and Al_o, amorphous Fe and Al oxide; Fe_p and Al_p, humus complex Fe and Al oxide; M3-Ca, M3-Mg, M3-Fe and M3-Al were Ca, Mg, Fe and Al extracted by Mehlich-3 extraction. "×" means no significant difference between parameters.

Appendix C Comprehensive interpretation rate of phosphorus fraction by soil properties

Soil depth (cm)	Properties	Explains %	P
0–20	SOM[1]	73.8	0.002
	M3-Fe	16.7	0.002
	Alp	1.8	0.048
20–40	Fed	73.2	0.002
	pH	12.4	0.004
40–60	CaCO$_3$	63.7	0.004
	Ald	10.5	0.024
	M3-Ca	10.1	0.036

[1] SOM, soil organic matter; Fe$_d$, free Fe$_2$O$_3$; Al$_d$, free Al$_2$O$_3$; Al$_p$, humus complex Al oxide; M3-Ca, M3-Mg, M3-Fe and M3-Al were Ca, Mg, Fe and Al extracted by Mehlich-3 extraction.