Impact of plant invasion and increasing floods on total soil phosphorus and its fractions in the Minjiang River estuarine wetlands, China

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Abstract

Plant invasion and increased flooding intensity projected by climate change models can change the soil capacity of marine wetland to store P. This is a key question to the nutrient balances and eutrophication processes of coastal areas, especially in China coastal area that is receiving the freshwaters of a country in fast economical developing process. We studied the impact of changes in flooding intensity and plant invasion on total soil-P concentrations in the Minjiang River estuarine wetland. Flooding had a weak positive effect on soil P-fractions concentrations, but this effect was largely counteracted by the negative effect of salinity. Soil clay concentration and pH, both of which were related more with species community composition than with flooding intensity, were directly related to the P-fraction concentrations. The replacement of the native mangrove community by the invasive plant *Phragmites australis* was related to a decrease in the soil capacity to store P. A suitable management to maintain this wetland area in optimum conditions to act as a natural eutrophication buffer should tend to favor mangrove communities in the new areas that reach more than 220 days y^{-1} of flooding, and a combination of the three tall-grasses communities below this level of flooding.

Keywords Clay · flooding · invasive plants · *Cyperus malaccensis* · mangrove · *Phragmites australis* · N:P · soil P · soil P fractions · soil pH · soil texture · *Scirpus triqueter*

Introduction

Phosphorus (P) is a crucial element for all living organisms. Next to nitrogen (N), P is the nutrient that most commonly limits plant production in the terrestrial biosphere (Margalef 1997; Aerts and Chapin 2000). Several drivers of global change such as N eutrophication, changes in soil use, species invasion or climate change currently have serious impacts on the P cycle and P imbalances and other important bioelemental cycles, such as that of N (Sardans and Peñuelas 2006; Peñuelas et al. 2012 and 2013). The question now arises whether or not P and its imbalances with other nutrients can alter the capacity of Earth to fix C from anthropogenic emissions of carbon dioxide (Peñuelas et al. 2013).

Global warming is affecting ocean levels through its impacts on the global water cycle (Schewe et al. 2011; Mendelsohn et al. 2012; Piecuch and Ponte 2014), and water stoichiometry (Sardans et al. 2012a; Sardans and Peñuelas 2014). These effects of global warming can further affect the global P cycle and its stoichiometric relationships with other nutrients, which can then affect community structure and function (Sterner and Elser 2002; Sardans at al. 2012b; Peñuelas et al. 2012 and 2013).

The increase in ocean levels could be especially critical for wetland ecosystems (Ramsar 2013). Flooding in these important ecosystems can alter soil contents and the stoichiometric relationships of C, N, P, and sulfur (S) by changing the aerobic/anaerobic biogeochemical equilibrium, nutrient inputs and outputs, and/or the structures of plant communities (Steinman et al. 2012; Recha et al. 2013; Wang et al. 2013), and by altering water flow and fluxes (Zak et al. 2008; McCray et al. 2012). Wetlands are also frequently affected by other drivers of global change such as species invasions that can interact with the increase in flooding duration and intensity to change the capacity of wetlands to store P and/or to change the proportions of different soil-P fractions. Moreover, the expected increase of typhoon events will increase the flood time, water table, soil salinity and anoxic conditions. Furthermore, typhoon events increase litterfall and nutrient cycling in plant-soil system (Wang et al. 2015 submitted).

Estuaries and marshes are sinks for the wastewater from human activities that frequently contain high concentrations of P loaded to rivers (Mustafe and Scholz 2011; Wang et al. 2012). Despite the high priority at a global scale of wetland restoration (Jimenez-Carceles et al. 2008; Mustafe and Scholz 2011; Dunne et al. 2011; Zak et al. 2014), wetlands restored on former agricultural land could potentially release accumulated P and become a source of eutrophication (Kjaergaard et al. 2012; Kinsman-Costello et al. 2014). Under increasing intensities of flooding, we should expect higher levels of anoxic conditions, under which increased Fe^{3+} reduction could increase the release of P from Fe^{3+} phosphates (Jimenez-Carceles et al. 2008; Zak et al. 2008; Kjaergaard et al. 2012).

Invasions of alien plant species are currently increasing and are a serious threat to global plant diversity (Vitousek et al. 1987; Funk and Vitousek 2007). Most studies that have investigated alien success have identified nutrient availability and the competitive capacities of nutrient uptake and of coping with low levels of nutrients as the key factors accounting for the success of the alien species (Sardans and Peñuelas 2012a, b; Drenovsky et al. 2012). Moreover, alien plants frequently alter soil nutrient concentrations and availability, the decomposition of organic matter, nutrient cycling, and soil stoichiometry (Sardans and Peñuelas 2012a,b; Drenovsky et al. 2012). Invasive plant species, such as the common reed, *Phragmites australis*, are spreading in several Chinese wetlands (Tong et al. 2011; Wang et al. 2014). The success of *P. australis* has been associated with its higher nutrient-use efficiency and up-take capacity than native species (Wang et al. 2014). We hypothesized that increased flooding could have an impact on its invasive success and its interactions with plant-soil P-cycle, which in turn could affect the effect of flooding intensity on the status of soil P in wetlands.

China coastal areas receive great amounts of P (Sharpley and Wang 2014; Gao et al., 2015; Li et al., 2015), that have increased by a factor of 2-5 in the period 1970-2000 and threaten to increase additional 30-200% towards 2050 (Strokal et al. 2014). We hypothesized that total P and P-fractions in soil will change in function of flooding intensity and plant community, and therefore the increase or decrease of wetlands capacity to act as a P sink or source in the next decades can be projected in an scenario of flooding enhancement and reduction of wetland surface and enlighten the management possibilities of improving such capacity.

We studied soil-P concentrations under different flooding gradients and under the absence/presence of an invasive species in the Minjiang River estuarine tidal wetland to clarify their effects on P concentrations and fraction variations. We aimed to answer the questions: (i) how do increased flooding and different plant communities, including a successful invasive plant species, affect the concentrations and contents of total soil P and the soil P fractions, and (ii) which physicochemical soil properties are involved in these effects?

Material and Methods

Study areas

This study was conducted in the Minjiang River estuarine wetland in southeastern China, in the transition zone of the mid-subtropical and south subtropical zones (25°50′43″-26°9′42″N, 119°5′36″-119°41′5″E). The estuary has an area of 476 km^{-2} and a relatively warm and wet climate, with a mean annual temperature of 19.7 ºC and a mean annual precipitation of 1346 mm (Zheng et al. 2006). Many wetlands are distributed in the estuary and along the river. We conducted three experiments in this study (Figure 1).

(1) *P. australis* and the native sedges *Scirpus triqueter* L. and *Cyperus malaccensis* var. *brevifolius* Boeckeler are the plant species that dominate the land surface in the Shanyutan wetland and are typically found in the upper (mid to high) portions of mudflats (Liu et al.

2006). These three species can grow in both high-flood and low-flood habitats. We established an experimental setup in this wetland at two flooding intensities and with three species communities. The flooding in the studied areas is based on the tide flood, and therefore depends on the distance to sea. Changes in river flow are also important to control the flood, but the main responsible of the differences of flooding intensity across different wetland areas is sea tidal. The high-flood habitats are flooded by intermediate tides ca. 240 d y^{-1} and are submerged beneath 10-120 cm of water for 0.5-4 h during each tidal inundation. The areas occupied by each species were ca. 8, 9, and 18 hm^2 for *S. triqueter*, *C. malaccensis*, and *P. australis*, respectively. The low-flood habitats are flooded only during spring tides, ca. 80 d y^{-1}, and are submerged beneath 10-50 cm of water for 0.5-2 h during each tidal inundation. The areas occupied by each species were ca. 7, 12, and 6 hm^2 for *S. triqueter*, *C. malaccensis*, and *P. australis*, respectively. The soil surfaces of both the low- and high-flood habitats of the entire estuarine wetland are exposed at low tide, but the soil remains flooded in some low areas. We analyzed two flooding intensities × three communities × six soil layers × three replicates, for a total of 108 samples. With this experiment we analyzed how different flood intensities are related with differences in soil P concentrations and P-fraction in soils under each one of the three tall-grasses depending on flooding intensity.

(2) Communities of the invasive *P. australis* in the Shanyutan, Bianfuzhou, and Youxizhou wetlands were selected as high-flood, intermediate-flood, and low-flood habitats, respectively, from the coast inland to test the effects of flooding intensity on the total soil-P concentration and content and different P fractions. The high-flood habitat (Shanyutan wetland) is flooded by tides ca. 240 d y^{-1} and is submerged beneath 10-120 cm of water for 0.5-4 h during each tidal inundation. The intermediate-flood habitat (Bianfuzhou wetland)

is flooded by tides ca. 220 d y^{-1} and is submerged beneath 10-100 cm of water for 0.5-3 h during each tidal inundation. The low-flood habitat (Youxizhou wetland) is flooded by tides ca. 180 d y^{-1} and is submerged beneath 10-70 cm of water for 0.5-1.5 h during each tidal inundation. We analyzed three flood intensities (the high-flood intensity was the same as that in the first experiment for *P. australis*) × one community × six soil layers × three replicates, for a total of 54 samples (36 were different from those in the first experiment). With this study we analyzed whether or not soils under the invasive species *P. australis* have different P and P-fractions concentrations at different levels of flooding intensity.

(3) *P. australis* in the Shanyutan wetland subjected to high-flood intensity has invaded the wetland over the past 30 years and is now the most prevalent plant species occupying the natural habitat of the native mangroves. *P. australis* has spread occupying sites that previously were covered by mangrove communities. Mangroves had not a high density, and humans tend to reduce its density and to allow *P. australis* spreading. We investigated and compared total soil-P concentration and content and different P fractions in the *P. australis* communities and in the natural mangrove habitat in this high-flood habitat. We analyzed one flooding intensity (high) × two communities (the data for *P. australis* were the same as for the high-flood intensity in the first experiment) × six soil layers × three replicates, for a total of 36 samples (18 were different from those in the first experiment). With this experiment we analyzed the differences in P and P-fractions concentrations between the invasive *P. australis* tall-grass and the native mangrove community in the current wetland areas submitted to the high levels of flooding intensity.

Collection and analysis of soil samples

Soil samples were collected in October 2007 from the *S. triqueter*, *P. australis*, *C. malaccensis*, and mangrove communities in the high- and low-flood habitats. Three replicate plots were randomly established in each community at each flooding intensity. Soil profiles (width, 1 m; length, 1 m; depth, 0.6 m) were excavated, and samples were collected with a small sampler (length, 0.3 m; diameter, 0.1 m) from each of six soil layers (0-10, 10-20, 20-30, 30-40, 40-50, and 50-60 cm) at the centers and both sides of the soil pits. These three samples were bulked to form one sample per layer. A total of 162 soil samples were thus collected (108 for the first experiment plus an additional 36 and 18 samples for the second and third experiments, respectively). In the laboratory, the samples were air-dried, roots and visible plant remains were removed, and the soil was finely ground in a ball mill.

Soil P analyses

Total P (TP) and total inorganic P (Pi) concentrations were determined following the method described by Ruban et al. (1999) (see Appendix 1 in Supplementary Information for details).

Total organic P (Po) concentrations were determined by rinsing the residual soil in the above centrifuge tubes twice with 12 ml of deionized water, freeze-drying, ultrasonicating in a bath for 30 s, ashing for 3 h at 450 °C, transferring to 100-ml centrifuge tubes after cooling, adding 20 ml of 3.5 mol L^{-1} HCl, mixing on the QHZ-98A oscillator at 250 rpm for 16 h at 25 °C, and then centrifuging at 2000*g* for 15 min. The P concentrations of the supernatants were determined colorimetrically as for Pi.

We used the continuous extraction procedure of Lu (1999) to determine the P concentrations in the labile Po, moderately labile Po, moderately resistant Po, and highly resistant Po fractions (see Appendix 1 in Supplementary Information for details). We used the continuous extraction procedure of Ruban et al. (1999) to determine the P concentrations in the exchangeable Pi, Fe+Al Pi, and Ca Pi fractions.

Residual Pi P concentration was determined by:

[residual Pi] = [TP] – [exchangeable Pi] – [Fe+Al Pi] – [Ca Pi] – [total Po].

Determination of other soil parameters

Total S concentrations were determined by method of Lu (1999) (see Appendix 1 in Supplementary Information for details).

Soil bulk density was measured from three 5 × 3 cm cores per soil layer (Wang et al. 2014c), salinity was measured with a DDS-307 conductivity meter (Boqu Scientific Instruments, Shanghai, China), pH was measured with an 868 pH meter (Orion Scientific Instruments, USA), soil particle-size (clay, silt, and sand) contents were determined with a SEDIMAT4-12 particle size analyzer (UGT Scientific Instruments, Müncheberg, Germany), and soil-water content was determined gravimetrically (Lu 1999).

Determination of soil C, N, and P storage

The C, N, and P storages for all soil layers were estimated by following Mishra et al. (2010):

$$C_S = \sum_{j=1}^{n} c_{\mathrm{m}} \times \rho_{\mathrm{b}} \times D$$

where C_S is C, N, or P storage (kg m^{-2}), j is the soil-depth interval (1, 2, … n; 0-10, 10-20, 20-30, 30-40, 40-50, and 50-60 cm) c_m is the C, N, or P concentration (g kg^{-1}), ρ_b is the bulk density (kg m^{-3}), D is the thickness of each soil layer (m), and n is the number of soil layers.

Statistical analyses

The statistical significance of differences in the soil parameters among the flooding intensities and soil layers in the communities was assessed with general linear models and Tukey's post-hoc tests. We determined the Pearson correlation coefficients among all pairwise soil studied parameters. We also determined the effects of water content and species on N and P storage. All univariate statistical analyses were performed using SPSS 13.0 (SPSS Inc., Chicago, USA).

We performed multivariate discriminant function analysis (DFA) to determine the importance of total C, N, P, and S concentrations; DOC, NH_4^+, NO_3^-, and available-S concentrations; exchangeable Pi, Fe+Al Pi, Ca Pi, residual Pi, labile Po, moderately labile Po, moderately resistant Po, and highly resistant Po concentrations; exchangeable Pi:labile Po and total Pi/Po ratios; and total C:N, C:P, N:P, C:S, N:S, and P:S ratios in the separation of the chemical components of the soil in the plots at different flooding intensities for the three species (Raamsdonk et al. 2001). The DFAs were performed using Statistica 6.0 (StatSoft, Inc., Tulsa, USA). All nutrient ratios were calculated in mass basis.

We performed structural equation modelling to determine the best model for explaining the TP concentration, exchangeable Pi concentration, the exchangeable Pi:labile Po ratio, the total Pi:Po ratio, and the recalcitrant P concentration (endogenous variables) as functions of the flooding intensity (as a dummy variable), and the other soil traits such as soil salinity, pH and clay concentrations (exogenous variables). This analysis provided information for the direct, indirect and total effects of the exogenous variables on the endogenous variables and allowed us to determine the direct and indirect relationships of exogenous variables on endogenous variables. For example the direct effect of flooding intensity on total soil P concentrations can be distinguished from the indirect effect of flooding on total soil P due to the effect of flooding intensity on salinity that thereafter has an effect on soil total P concentration. We fitted the models using the sem R package (Fox et al. 2013) and achieved the minimum adequate model using the Akaike information criterion (AIC). Standard errors of the effects were extracted by bootstrapping (1200 repetitions) (Davison et al. 1986; Mitchell-Olds 1986*)*.

Results

Effects of flooding, soil physicochemical traits and species on soil-P pools (Experiment 1)

Flooding increased soil P concentrations of all studied Pi and Po fractions in the *S. triqueter* community but not in soils under the communities dominated by the other two species: the other native species, *C. malaccensis* and the invasive species *P. australis* that did not change P concentrations under higher flooding duration (Figure 2, Table S1).The results of the repeated measures ANOVA (in space) are very similar to those of the GLM analysis of the flooding effect on the variables shown in Figure 2 (Table S1). In the GLM analyses with flooding duration, species and soil depth as independent categorical variables, only the Fe+Al P pools differed, with the Fe+Al Pi pool being higher and the Fe+Al Po (moderately labile) pool lower for *C. malaccensis* than for *P. australis* (Table S2). This asymmetrical effect of increased flooding dependent on species is clearly shown by the PCA with all soil variables, where the PC1 scores for the *S. triqueter* soils subjected to low flooding are very different than those for all other soils (Figure 3). The PCA indicated that bulk density, sand content, and the total Pi:Po ratio were higher in the *S. triqueter* soils subjected to low flooding (Figure 3).

Bulk density was lower (higher silt and lower sand contents) under high flooding intensity, and soil-water content, salinity, and C and N concentrations were higher (Table S2). We observed a significant interaction flooding intensity x species, due to that these effects were particularly observed for *S. triqueter* soils and much less in the other two species. Higher NH_4^+ and lower NO_3^- concentrations were found at high flooding than at lower flooding intensities (Table S2). TP concentration and the concentrations of most P pools were positively correlated with clay and silt contents, total C and N concentrations, DOC concentration, and NO_3^- concentrations and negatively correlated with sand content, bulk density, and S concentration (Table S3). These correlations were stronger in Pi fractions than in Po fractions. Consequently, clay and silt contents and total C, N, and DOC concentrations were negatively correlated with the total Pi/Po ratio, and sand content and bulk density were positively correlated with the total Pi:Po ratio (Figure S1). These effects were mainly due to the large differences between the *S. triqueter* soil under low flooding intensity and all other soils (Figure S1).

The total N:P ratios were higher under flooding in the wetlands of the three species at most soil depths (Table S2, Figure 4). Moreover, this ratio was highest for the invasive *P. australis* soils (Table S2, Figure 4).

The structural models that best explained (lower AIC) the different P fractions and their Pi:Po ratios are shown in Figures 5-7. The best model for TP and exchangeable Pi (Figure 5) concentrations showed that clay content and soil pH had direct positive significant effects on these P variables and that flooding had an indirect negative effect through its positive effect on salinity that subsequently had a negative effect on these P variables (Figures 5-7).

The best structural model for total recalcitrant P (Pi+Po) and total Po concentrations indicated a direct effect of clay content but not of soil pH, while an indirect effect of flooding by increasing salinity was also observed (Figures 6 and 7). This relationship is consistent with the expected according to clay properties. The indirect negative effect of flooding on the exchangeable Pi:labile Po ratio was best explained by the direct effect of flooding on higher total S concentrations that subsequently had a negative effect on the exchangeable Pi:labile Po ratio (Figure 7).

Soil pH and mainly clay content thus had strong positive relationships with P-fraction concentrations, and these effects were stronger in the Po than the Pi fractions, and both consequently decreased the total and exchangeable Pi:labile Po ratios (Figure 5 and 7). Flooding had no significant direct effects on clay content or soil pH. These results were consistent with those of previous univariate analyses where the variability of clay content and soil pH were slightly related with flooding intensity when comparing overall soils. The relationships between clay content and soil pH with flooding intensity were positive in soils under S. triqueter and negative in soils under the other two species (Figure 8).

Effects of flooding on the soil-P pools in the invasive *P. australis* communities (Experiment 2)

The *P. australis* soil in the mid-flood habitat had the highest TP concentrations and stored more P, mainly in the upper 30 cm of the soil, relative to the low- and high-flood habitats (Figure 9a and 9l), due mainly to the high concentrations of the Pi pools (Figure 9 b-e). The exchangeable Pi:total P ratio in the upper 30 cm of soil were higher in the mid- than the low-and high-flood habitats dominated by this invasive species (Figure 9m). The PCA with all soil variables indicated that PC1 (explaining 44.7% of the total variance) significantly ($P<0.05$) separated the scores of the stands of *P. australis* growing under the three flooding intensities. The concentrations of the Po pools increased from soils under low flooding to soils under high flooding intensities, coinciding with a decrease in sand content and bulk density and with an increase in clay and silt contents (Figure 10). Interestingly, the PC2 scores (explaining 27.2% of the total variance) for the soils in the mid-flood habitat differed significantly from the scores for the soils in the low- and high-flood habitats ($P=0.004$ and $P=0.0001$, respectively) (Figure 10). PC2 was significantly loaded by TP concentration, total P stored in the soil, and all Pi pools, with the soil in the mid-flood habitat placed toward the highest values and coinciding with lower C:P ratios (Figure 10). Increased flooding was associated with an increase in total N:P ratios (Figure 11).

Differences in soil P contents between mangrove and communities dominated by the invasive *P. australis* (Experiment 3)

Mangrove soils accumulated more P in the upper 10 cm of the soil than the *P. australis* soil at the same flooding intensity (Figure 12). The mangrove soils had higher bulk densities, sand contents, pHs, salinities, and NO_3^- concentrations and lower water contents, silt contents, total C and N concentrations, and total N:P ratios than the *P. australis* soils (Table S4). The P stored in the upper 60 cm of soil were marginally significantly ($P=0.08$) higher in the mangrove soils than the *P. australis* soils (Table S4).

The PCA with all soil variables indicated that the scores of the mangrove soils were significantly (*P*<0.0001) separated from those of the *P. australis* soils along the PC1 axis (explaining 31.2% of the total variance) (Figure 13). This axis was significantly loaded by sand content, bulk density, pH, salinity, P storage, water content, and NH_4^+ concentration, with the mangrove scores placed toward higher pH, P storage, sand content, bulk density, and salinity and toward lower water content and NH_4^+ concentration (Figure 13).

Discussion

Flooding effects versus species effects on the status of soil P

The relationships of flooding and the P pools were very asymmetrical, depending on the species. Despite we did not can disentangle if differences in soils P concentrations in soils under the different species were the cause or the effect of the presence of these species, the P pools changed most in the soils depending on the flooding intensity in the native *S. triqueter* wetlands than in the sites dominate by the other two studied species. These differences may be related, at least partially, to the very much lower biomass of the *S. triqueter* community than those of the *C. malaccensis* and *P. australis* communities (Wang et al. 2014b).The TP concentrations of ca. 0.7 g kg^{-1} in the first few centimeters of soil in these wetlands were within the range of 0.3-1.3 g kg^{-1} observed in marine and estuarine wetland areas around the world (Carol et al., 2012; Xu et al., 2012; Irick et al. 2013; Gao et al., 2014; Yu et al. 2014).The concentrations of most P fractions abruptly decreased at a depth of 30 cm. Most of the P was stored in the first few centimeters of the soil profiles, as in other wetland areas (Wang et al. 2011; Gao et al. 2014). These areas are thus very vulnerable to P losses from any disturbance that could pose a potential risk of an increase in P in the water column, and consequently its potential export to coastal areas.

Flooding increased TP accumulation, several P fractions, and the exchangeable Pi:labile Po ratio, but these effects were partially counteracted by the indirect effects of flooding on soil salinity and total S concentration, because these variables had negative effects. Clay content and soil pH, however, were mostly associated with the various soil P fractions concentrations that in turn were more related with the dominant species and with the interaction between species and flooding than with flooding intensity alone. Most of the variability of the P concentrations was explained by the variation of the clay contents of the *S. triqueter* communities, which were lowest under lower flooding intensity, along with the lowest concentrations of all P fractions and especially the Po fractions. Higher clay contents were associated with higher sulfur concentrations (under high redox potential of the media) and lower soil pHs, consistent with the higher anoxic conditions expected in soils with high clay contents (Miller et al. 2001; Oxmann et al. 2009). The unique important and general effect of flooding intensity on the P fractions was due to its effect on soil salinity. Pore-water salinity in wetlands has been associated with flooding intensity and thus with species composition and P concentration (Mendoza et al. 2012). These associations may be due to the effects of soil salinity on plant P uptake and thus on the P concentrations and contents in the leaves and litter, together decreasing the capacity of P retention in the ecosystem with increasing salinity (Mendoza et al. 2012).

In our studied sites, settling rates depend partially of the number of hours of flooding. Thus the longer times that water covers the soil as flooding intensity increases should permit higher particle sedimentation, which should be more relevant for clay particles than for the larger sand particles. Moreover, higher clay contents and anoxic conditions should produce lower pHs. But higher flooding intensity was associated with higher clay contents, within the range of flooding intensities of this study only in the wetlands dominated by *S. triqueter*. Our results, thus, suggested that soil clay content could be related with the specific-species cover at some extend. Anyway, the study design was not aimed to disentangle whether the high clay soil concentrations under *S. triqueter* in specially at high flooding intensity is a cause of the occurrence of this species in rich-clay soils or they are the consequence of the existence of this species increasing the capacity to trap clay particle. In another study, exchangeable Pi increased and labile Po decreased under flooding (Newman and Pietro 2001). The clay concentrations were negatively correlated with the total (R^2=0.44, P<0.00001) and exchangeable Pi:labile Po ratios (R^2=0.22, P<0.00001), suggesting that Po mineralization was hindered by high clay contents. Clay content was also negatively correlated with soil pH, but this relationship was not associated with flooding intensity; soil pH was thus not clearly associated with flooding. In contrast to the expected decrease in pH with the more anoxic soil conditions under higher flooding intensity, some studies have observed that soil pH increased with flooding intensity (Saint-Laurent et al. 2014).

Previous studies in wetlands have also reported relationships between clay content and P storage (Chapuis-Lardy et al. 2006; McGrody et al. 2008; Wang et al. 2013), due mostly to high Fe-Al P and Ca P fractions and to the higher adsorption capacity of the soil, because high clay contents provide more solid and large surface per unit weight (Wang et al. 2013). In fact, and consistent with these observations, the Fe+Al Po fraction was the fraction best correlated with clay content (R^2=0.62). Our results thus demonstrate that these effects were mainly related to the species, despite the effects of flooding intensity on the P fractions in the soil profile. Xu et al. (2012) have also suggested that the vegetation could significantly influence P dynamics and availability in the Yellow River delta. However, we can not disentangle whether the different soil texture under the different studied species-communities is the cause or the effect of these species distribution.

The concentrations of TP and in the P fractions mostly did not differ significantly between the *P. australis* and *C. malaccensis* soils. We only observed differences in the Fe+Al P fractions, with higher Fe+Al Pi and lower Fe+Al Po concentrations in the *C. malaccensis* soils, consistent with the slightly higher rates of litter mineralization observed in *C. malaccensis* soils than in *P. australis* soils (Tong et al. 2011). The lack of general differences in the status of soil P between these two species was consistent with the small differences in litter elemental composition in the same wetlands (Tong et al. 2011). But despite the little differences observed in litter composition, we have observed some stoichiometrical differences between these two species in litter C:P (555 ± 1 and 473 ± 1, $P < 0.0001$, respectively) and N:P (12.8 ± 0.04 and 10.3 ± 0.12, $P < 0.0001$, respectively) ratios. These results are consistent with some observed results regarding soil P. For example, the lower soil recalcitrant Po and higher labile Pi/Po ratio in soils under *P. australis* than in soils under *C. malaccensis* suggest higher decomposition rates of organic P consistent of litter with lower N:P ratio related with higher microbial growth rates and activity such as expected in the frame of ecological stoichiometry approach (Mooshammer et al., 2012; Zechmeister-Boltenstern et al., 2015).

Differences among species of flooding effects on P status

Concentrations in the Pi fractions in the upper 30 cm of the *P. australis* soils were higher at the highest flooding intensity than at the lowest and intermediate flooding intensities, whereas concentrations in the Po fractions were lowest at the lowest flooding intensity. The TP stored in soil and the exchangeable Pi:TP ratio in the upper 30 cm of soil were both highest at the intermediate flooding intensity. The intermediate flooding intensity thus produced the highest accumulation of P and the highest proportion of plant-available P in the *P. australis* soils. The biomass of the invasive *P. australis* was thus higher than those of *S. triqueter* and *C. malaccensis* ($P<0.05$) in the high-flood habitat but was only higher than that of *S. triqueter* ($P<0.05$) in the low-flood habitat (Wang et al. 2014b). The higher exchangeable Pi: labile Po ratio in the upper 30 cm of soil at the intermediate flooding intensity in the *P. australis* wetlands suggested that the mineralization rates would be higher at the intermediate flooding intensity, within the range tested in this study.

The N:P ratios in the *P. australis* soils increased with flooding intensity, as also observed when comparing the three species at two flooding intensities. A higher N:P ratio should mitigate the N limitation observed in other studies in this same wetland area (Wang et al. 2014c). N:P ratios of 5.4-5.7 have been considered as indicating that a wetland is a P sink (Jiménez-Cárceles and Álvarez-Rogel 2008). The range of the total N:P ratio (0.5-3) in this wetland area is thus very low, and N is also probably limiting at the highest flooding intensity. Our results thus also suggest that these wetlands are strong P sinks, with consequently low N:P ratios, and that the N:P ratio increases at higher flooding intensities with increases in N accumulation and not by decreases in P content. The capacity to store P at different flooding intensities is a key question in the estuarine wetlands of China, because cropland soils have very high P concentrations (MacDonald et al. 2011; Wang et al. 2014c), consistent with the large amount of P stored in this estuarine area. This capacity to store P is even more crucial in the wetlands of subtropical China, where the high temperatures produce high rates of P mineralization (Rui et al. 2012) and the strong rains cause severe erosion in the river basins, which increase the transport of P from upriver to estuarine areas (Tian et al. 2010).

Our results thus suggest that the best management strategy for maximizing the capacity of this wetland area to act as a P sink should favor the combination of *C. malaccensis* and *P. australis* wetlands in areas of low flooding intensity (<180 d y^{-1} inundation) and the combination of *S. triqueter*, *C. malaccensis*, and *P. australis* wetlands in areas of intermediate-high flooding intensities (>180 d y^{-1} inundation).

Effects of mangrove and *P. australis* wetland on the status of soil P

In contrast with the previous results suggesting a closer positive relationship between clay content and the different P fractions, especially the Po fractions, the sandier soils in the mangrove community stored higher amounts of P in the upper 10 cm of soil than the less dense soil in the *P. australis* wetlands at similar flooding intensities. The higher soil density in the mangrove community allowed a higher total accumulation of P, despite the higher P concentration in the *P. australis* community. This capacity may thus be responsible for the large structural difference between these two communities. Mangrove ecosystems have a large capacity to retain soil nutrients (Tam and Wong 1996; Silva et al. 1998). The slow decomposition of wood in the upper soil layers could play a large role in this capacity (Romero et al. 2005). Nielsen and Andersen (2003) observed that P in the Bangrong mangrove forest in Thailand tended to be concentrated in the leaf litter during decomposition, which was associated with the high P concentrations in the soils. These results suggest that the maintenance of native mangrove communities to act as P sinks is the best management strategy in wetland areas with high flooding intensities (>220 d y^{-1} inundation). Our results strongly suggest that the best management strategy that would both preserve biodiversity and maximize the capacity of the wetland area to act as a P sink for future scenarios o rise in flooding duration, should favor the combination of *C. malaccensis* and *P. australis* wetlands in areas with low flooding intensity (<180 d y^{-1} inundation), the combination of *S. triqueter*, *C. malaccensis*, and *P. australis* wetlands in areas with intermediate flooding intensity (180-220 d y^{-1} inundation), and the maintenance of native mangrove communities in areas with high flooding intensities (>200 d y^{-1} inundation). In fact, this wetland area has been recently declared as National Reserve and some of the current mangrove areas have been planted by China government. This study thus shows the positive results of this policy of repopulation of native mangrove communities in the higher flooded areas to rise the capacity to store P in soil and to avoid eutrophication.

Conclusions

Flooding moderately increased TP accumulation, P concentrations in several P fractions, and the exchangeable Pi:labile Po ratio. Some indirect effects of flooding, such as increases in soil salinity and total S concentrations, contributed to the moderation of the relationship between flooding and the P fractions by counteracting the direct positive relationship with flooding. This moderation occurred because these variables were negatively correlated with total P accumulation, P concentrations in several P fractions, and the exchangeable Pi:labile Po ratio.

We observed an interaction between species and flooding on the total-P and P-fraction concentrations. The relationship between flooding and higher P-fraction concentrations depended on the species community. The principal cause of this relationship was the relationship of each species with the increase in clay content as flooding increased. Clay content was the soil variable most positively correlated with the various P-fraction concentrations and was more dependent on the dominant species than on the flooding intensity alone.

Higher clay contents were correlated with higher S concentrations and lower pHs, consistent with the higher anoxic conditions expected in soils with higher clay contents. Clay content was also correlated with a higher adsorption capacity. All these soil conditions at high clay contents are consistent with lower Po availability to microorganisms and consequently with conditions unsuitable for mineralization and thus with higher Pi concentrations and especially with higher Po concentrations (low Pi:Po ratio).

Thus, taking into account future scenarios of flooding intensity rise and the projected scenarios of the amounts of P received by coastal waters from rivers in China (Strokal et al. 2014), a suitable management to both preserve biodiversity and to maintain this wetland area in optimum conditions to act as a natural eutrophication buffer should tend to favor mangrove communities in the new areas that reach more than 220 days y^{-1} of flooding, and the combination of the three tall-grasses below this level of flooding.

Acknowledgements

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Figure legends.

Figure 1. Location of the the sampling sites.

Figure 2. Distribution of soil P variables (mean ± SE, n = 3) in the soil profiles of the wetlands dominated by *S. triqueter*, *C. malaccensis*, and *P. australis* subjected to low and high flooding intensities.

Figure 3. Distribution of variables and cases in the plot of the first two PCs of the PCA analysis conducted with the P fractions and other soil variables in the wetlands dominated by *S. triqueter*, *C. malaccensis*, and *P. australis* subjected to low and high flooding intensities.

Figure 4. Distribution of total N:P ratio (mean ± SE, n = 3) in the soil profiles of the wetlands dominated by *S. triqueter*, *C. malaccensis*, and *P. australis* subjected to low and high flooding intensities.

Figure 5. Diagrams of the structural models that, by using different physicochemical soil variables and flooding intensity, best explain the variability of total soil P (TP) concentrations and total exchangeable inorganic P (EPi) concentrations in the soil profiles of the wetlands dominated by *S. triqueter*, *C. malaccensis*, and *P. australis* subjected to low and high flooding intensities. The total, direct, and indirect effects of each exogenous variable on the endogenous (TP and TPi) variables are shown in each case with the level of significance (*P* value). Black arrows in the diagram mean positive relationships and red arrows negative relationships. The bar figures show the total direct and indirect relationships of physicochemical soil variables and flooding intensity with total soil P and exchangeable inorganic P (EPi) concentrations.

Figure 6. Diagrams of the structural models that, by using different physicochemical soil variables and flooding intensity, best explain the variability of total soil inorganic P (TPi) concentrations and total organic P (TPo) concentrations in the soil profiles of the wetlands dominated by *S. triqueter*, *C. malaccensis*, and *P. australis* subjected to low and high flooding intensities. The total, direct, and indirect effects of each exogenous variable on the endogenous (TPi and TPo) variables are shown in each case with the level of significance (*P* value). Black arrows in the diagram mean positive relationships and red arrows negative relationships. The bar figures show the total direct and indirect relationships of physicochemical soil variables and flooding intensity with total soil inorganic P (TPi) concentrations and total organic P (TPo) concentrations.

Figure 7. Diagrams of the structural models that, by using different physicochemical soil variables and flooding intensity, best explain the variability of exchangeable-Pi:Labile-Po ratio (EPi:LPo), total Pi:Po ratio (TPi:Po), and soil recalcitrant P (RP) concentrations in the soil profiles of the wetlands dominated by *S. triqueter*, *C. malaccensis*, and *P. australis* subjected to low and high flooding intensities. The total, direct, and indirect effects of each exogenous variable on the endogenous (EPi:LPo, TPi:Po, and RP) variables are shown in each case with the level of significance (*P* value). Black arrows in the diagram mean positive relationships and red arrows negative relationships. The bar figures show the total direct and indirect relationships of physicochemical soil variables and flooding intensity with exchangeable-Pi:Labile-Po ratio (EPi:LPo), total Pi:Po ratio (TPi:Po), and soil recalcitrant P (RP) concentrations.

Figure 8. pH and clay contents (mean ± SE, n = 3) in the soil profiles (0-60 cm) of the wetlands dominated by *S. triqueter*, *C. malaccensis*, and *P. australis* subjected to low and high flooding intensities.

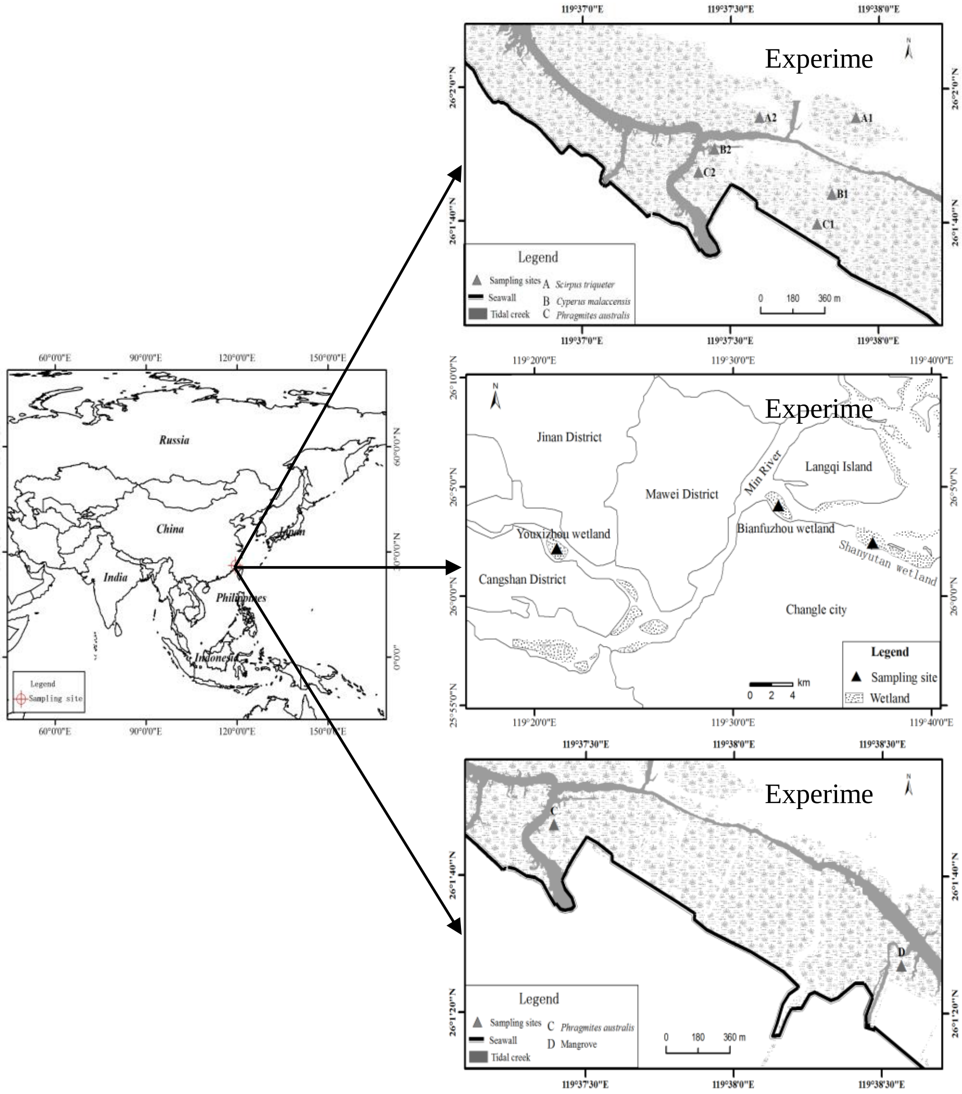
Figure 9. Distribution of soil P variables (mean ± SE, n = 3) in the soil profile of the wetlands dominated by *P. australis* subjected to low, intermediate, and high flooding intensities.

Figure 10. Distribution of variables and cases in the plot of the first two PCs of the PCA analysis conducted with the P-fractions and other variables of the *P. australis* soils subjected to low, intermediate, and high flooding intensities. The arrows indicate the mean of the scores of *P. australis* wetland soils under different duration of flooding and different letters on arrows statistical significant differences ($P<0.05$).

Figure 11. Total N:P ratio (mean ± SE, n = 3) in the soil profiles (0-60 cm) of the wetlands dominated by *P. australis* subjected to low and high flooding intensities.

Figure 12. Distribution of P stored in the soil and total soil P concentrations (mean ± SE, n = 3) in the soil profiles of the wetlands dominated by *P. australis* and the native mangrove community subjected to high flooding intensity.

Figure 13. Principal component analysis of the soil traits as variables and soil samples analyzed in experiment 3 (*P. australis* and mangrove wetland soils in an area of the Shanyutan wetland with high flooding intensity).



Experime
119°37'0"E
119°37'30"E
119°38'0"E
26°2'0"N
26°1'40"N
A1
A2
B1
B2
C1
C2
Legend
Sampling sites
Seawall
Tidal creek
A Scirpus triqueter
B Cyperus malaccensis
C Phragmites australis
0 180 360 m
60°0'0"E
90°0'0"E
120°0'0"E
150°0'0"E
60°0'0"N
30°0'0"N
0°0'0"
Russia
China
India
Japan
Philippines
Indonesia
Legend
Sampling site
119°20'0"E
119°30'0"E
119°40'0"E
26°10'0"N
26°5'0"N
26°0'0"N
25°55'0"N
Experime
Jinan District
Mawei District
Min River
Langqi Island
Youxizhou wetland
Bianfuzhou wetland
Shanyutan wetland
Cangshan District
Changle city
Legend
Sampling site
Wetland
km
0 2 4
119°37'30"E
119°38'0"E
119°38'30"E
26°1'40"N
26°1'20"N
Experime
C
D
Legend
Sampling sites
Seawall
Tidal creek
C Phragmites australis
D Mangrove
0 180 360 m

Figure 1

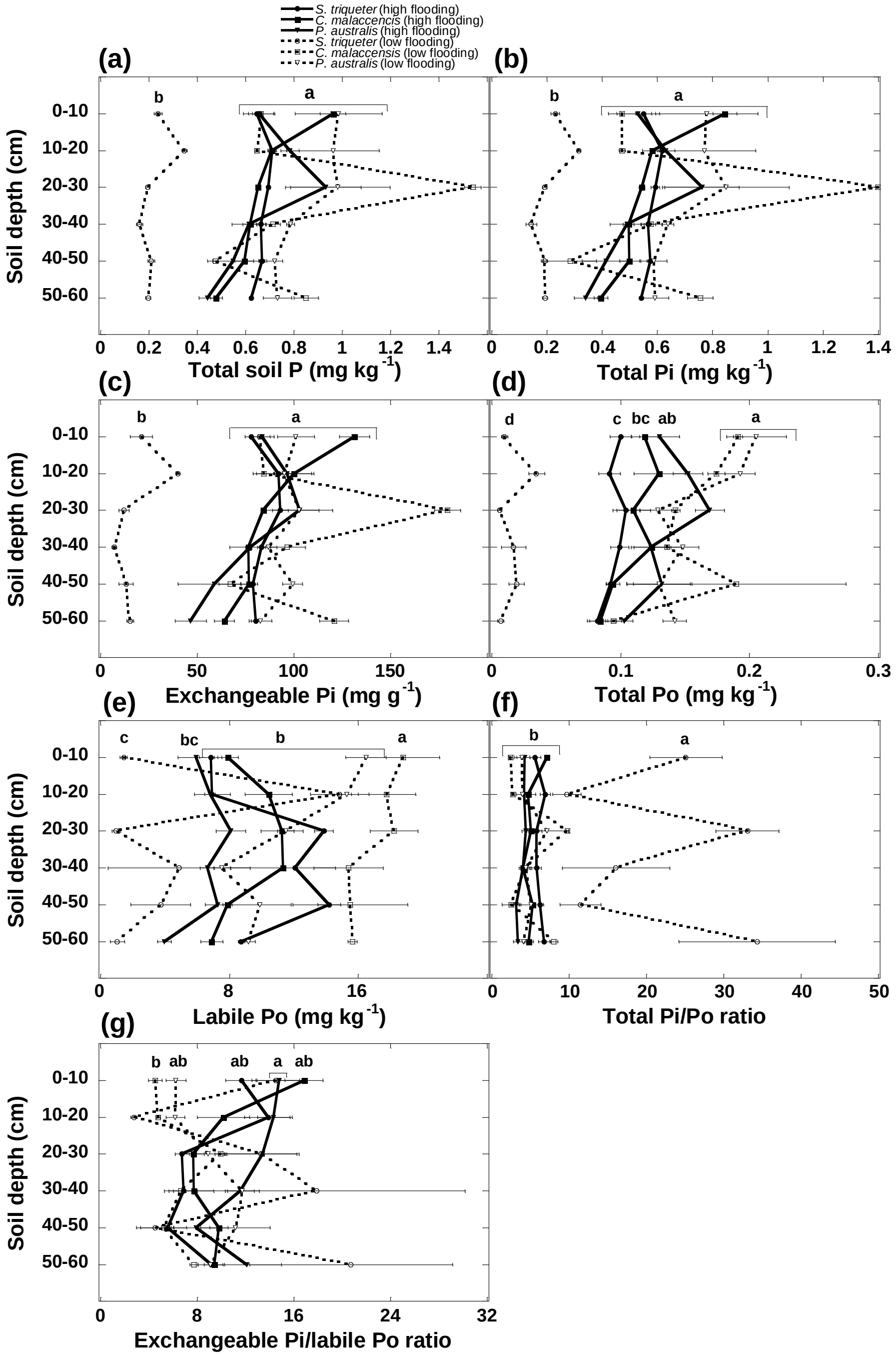

S. triqueter (high flooding)
C. malaccencis (high flooding)
P. australis (high flooding)
S. triqueter (low flooding)
C. malaccensis (low flooding)
P. australis (low flooding)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
Soil depth (cm)
0-10
10-20
20-30
30-40
40-50
50-60
Total soil P (mg kg-1)
0 0.2 0.4 0.6 0.8 1 1.2 1.4
b
a
Total Pi (mg kg-1)
0 0.2 0.4 0.6 0.8 1 1.2 1.4
b
a
Exchangeable Pi (mg g-1)
0 50 100 150
b
a
Total Po (mg kg-1)
0 0.1 0.2 0.3
d
c
bc
ab
a
Labile Po (mg kg-1)
0 8 16
c
bc
b
a
Total Pi/Po ratio
0 10 20 30 40 50
b
a
Exchangeable Pi/labile Po ratio
0 8 16 24 32
b
ab
ab
a
ab

Figure 2

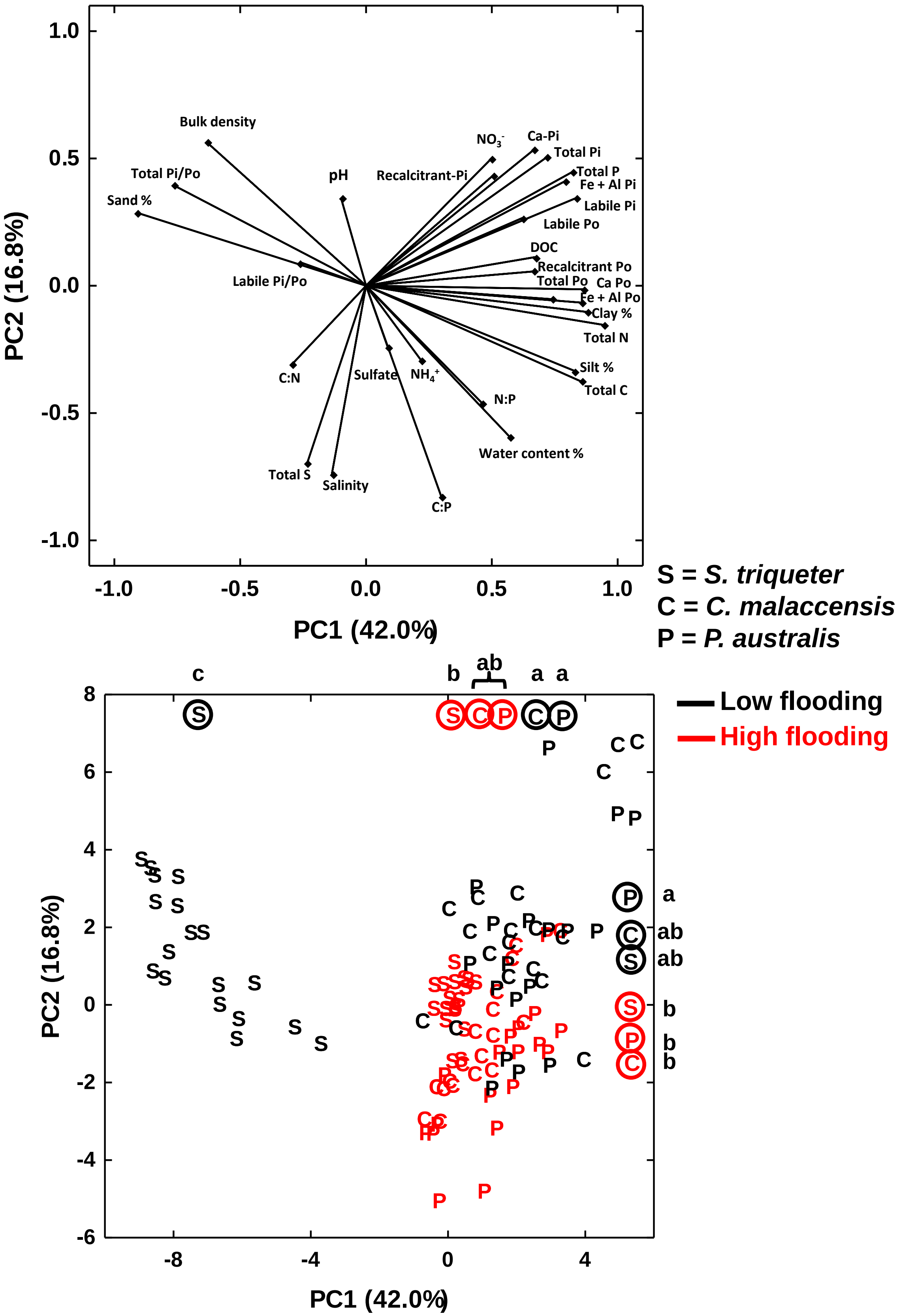

1.0
0.5
0.0
-0.5
-1.0
PC2 (16.8%)
-1.0
-0.5
0.0
0.5
1.0
PC1 (42.0%)
Bulk density
Total Pi/Po
Sand %
pH
Recalcitrant-Pi
NO_3^-
Ca-Pi
Total Pi
Total P
Fe + Al Pi
Labile Pi
Labile Po
DOC
Recalcitrant Po
Total Po
Ca Po
Fe + Al Po
Clay %
Total N
Labile Pi/Po
C:N
Sulfate
NH_4^+
Silt %
Total C
N:P
Water content %
Total S
Salinity
C:P
S = *S. triqueter*
C = *C. malaccensis*
P = *P. australis*
Low flooding
High flooding
c
b
ab
a
a
S
C
P
8
6
4
2
0
-2
-4
-6
PC2 (16.8%)
-8
-4
0
4
PC1 (42.0%)
a
ab
ab
b
b
b

Figure 3

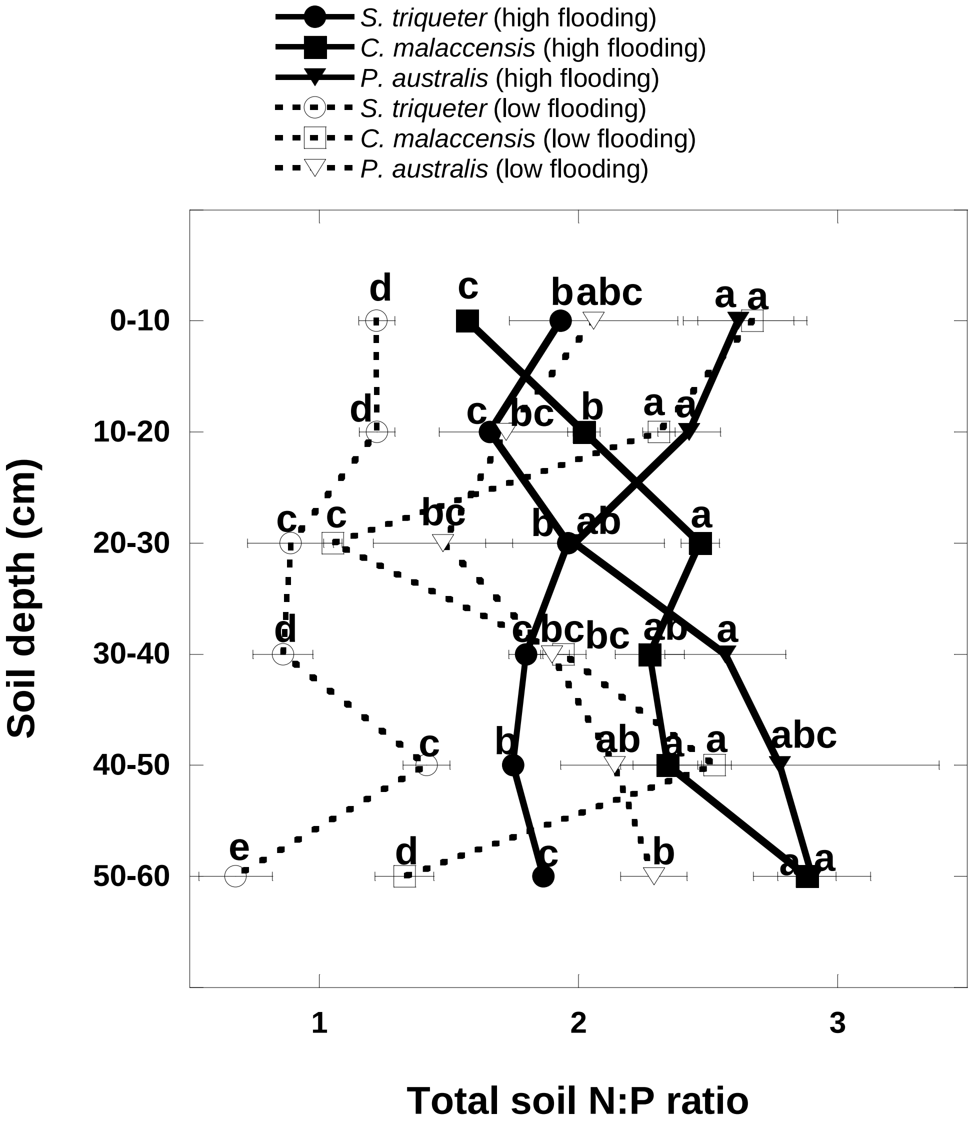
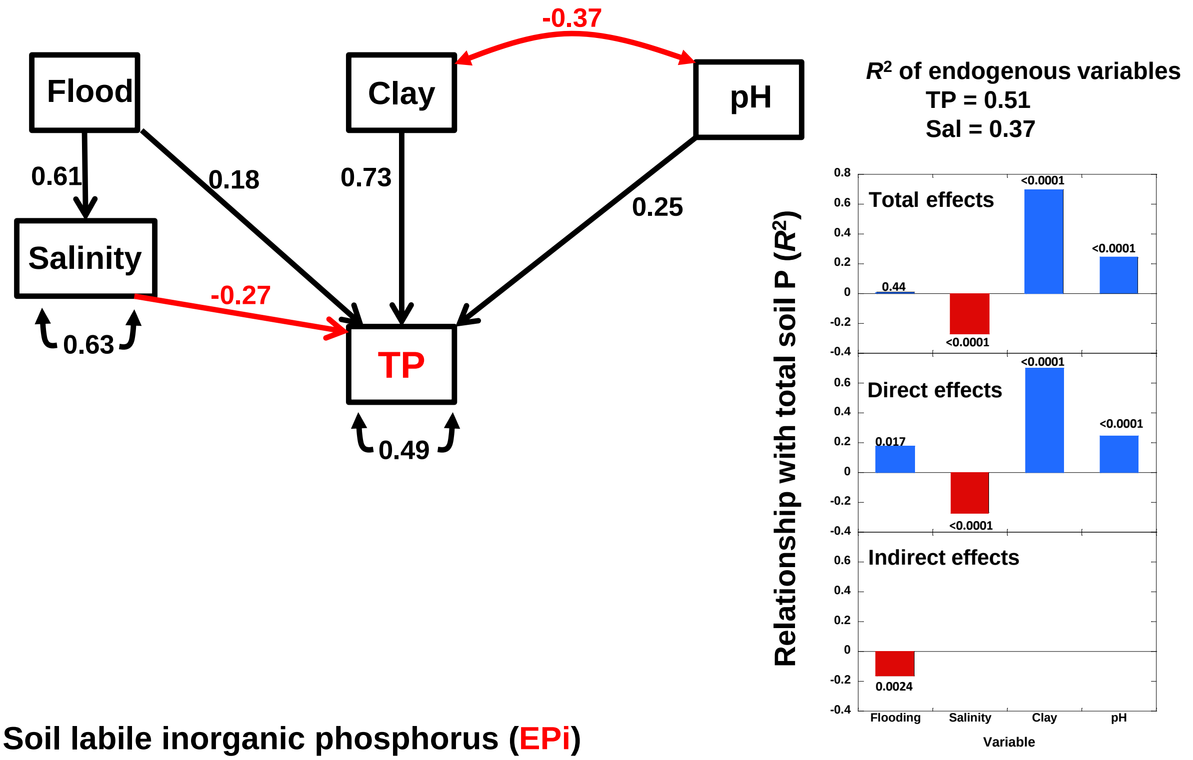

S. triqueter (high flooding)
C. malaccensis (high flooding)
P. australis (high flooding)
S. triqueter (low flooding)
C. malaccensis (low flooding)
P. australis (low flooding)
Soil depth (cm)
0-10
10-20
20-30
30-40
40-50
50-60
Total soil N:P ratio
1
2
3
d
c
b
abc
a
a
d
c
bc
b
a
a
c
c
bc
b
ab
a
d
c
bc
bc
ab
a
c
b
ab
a
a
abc
e
d
c
b
a
a

Figure 4

Total soil phosphorus concentration (TP)



Soil labile inorganic phosphorus (EPi)

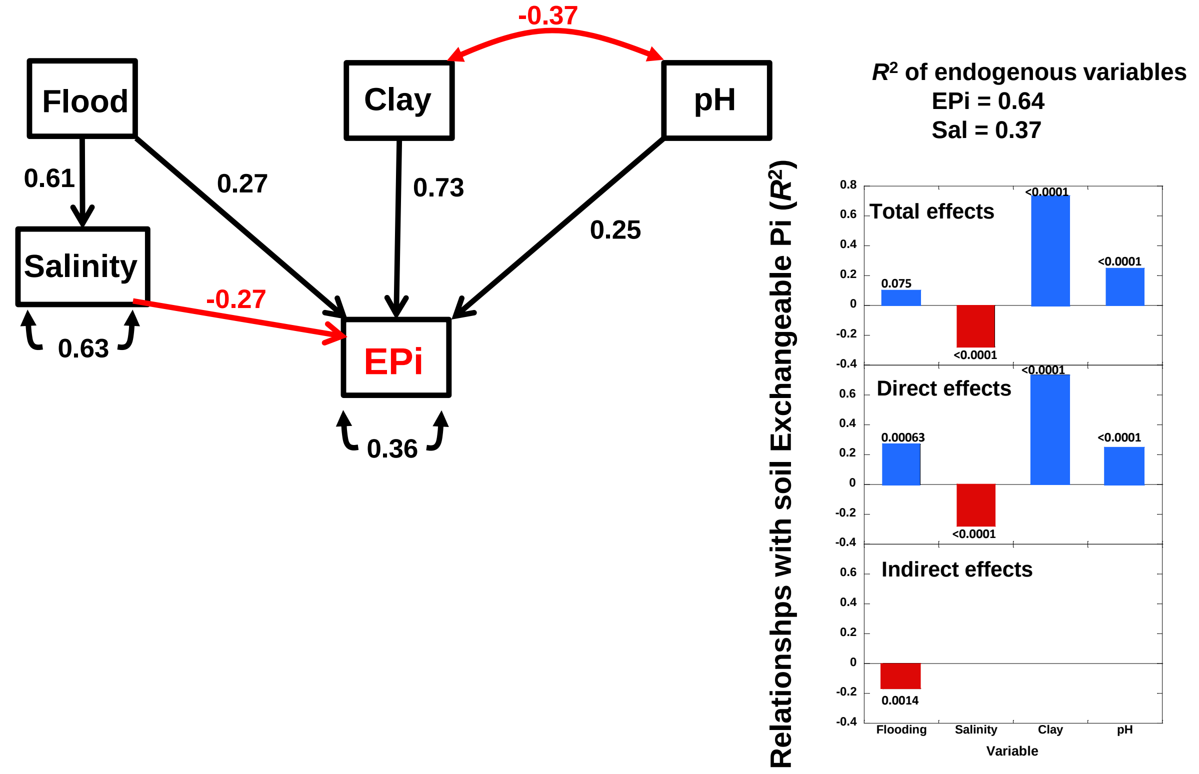
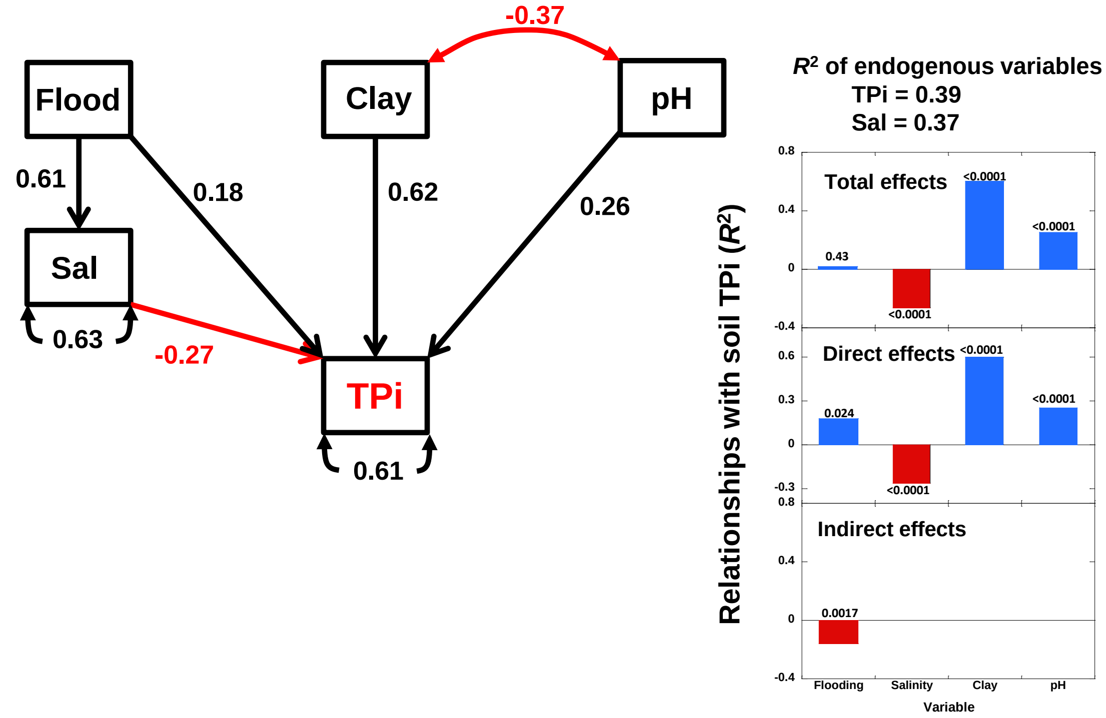


Figure 5

Total soil inorganic phosphorus concentration (TPi)



Total soil organic phosphorus concentration (TPo)

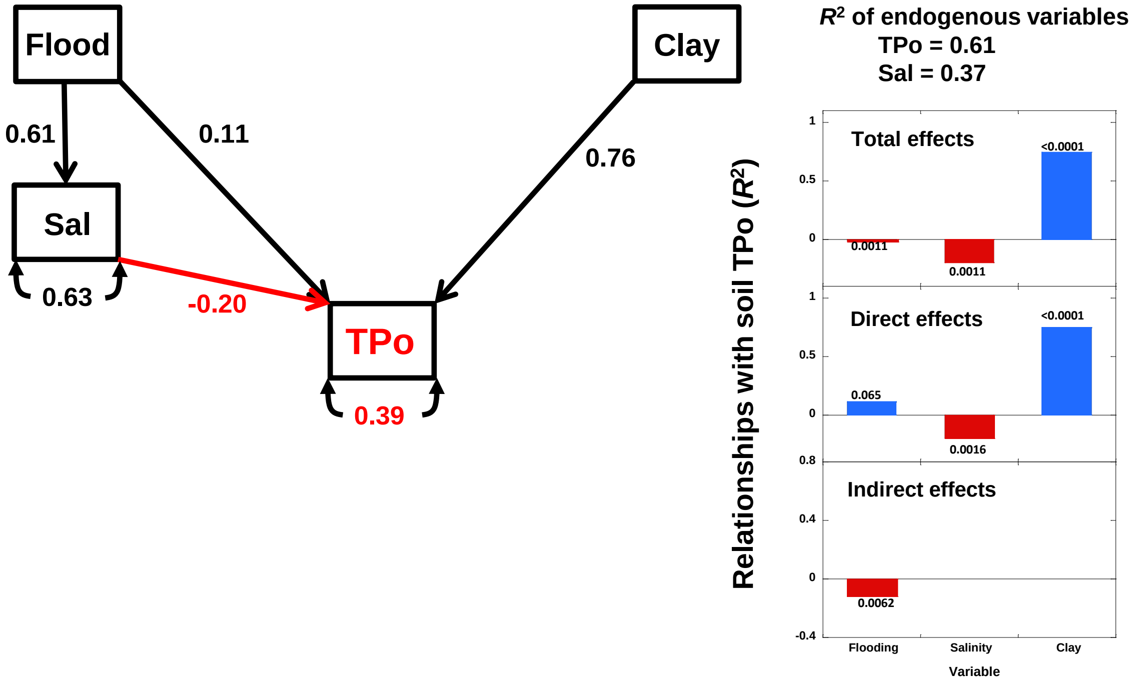


Figure 6

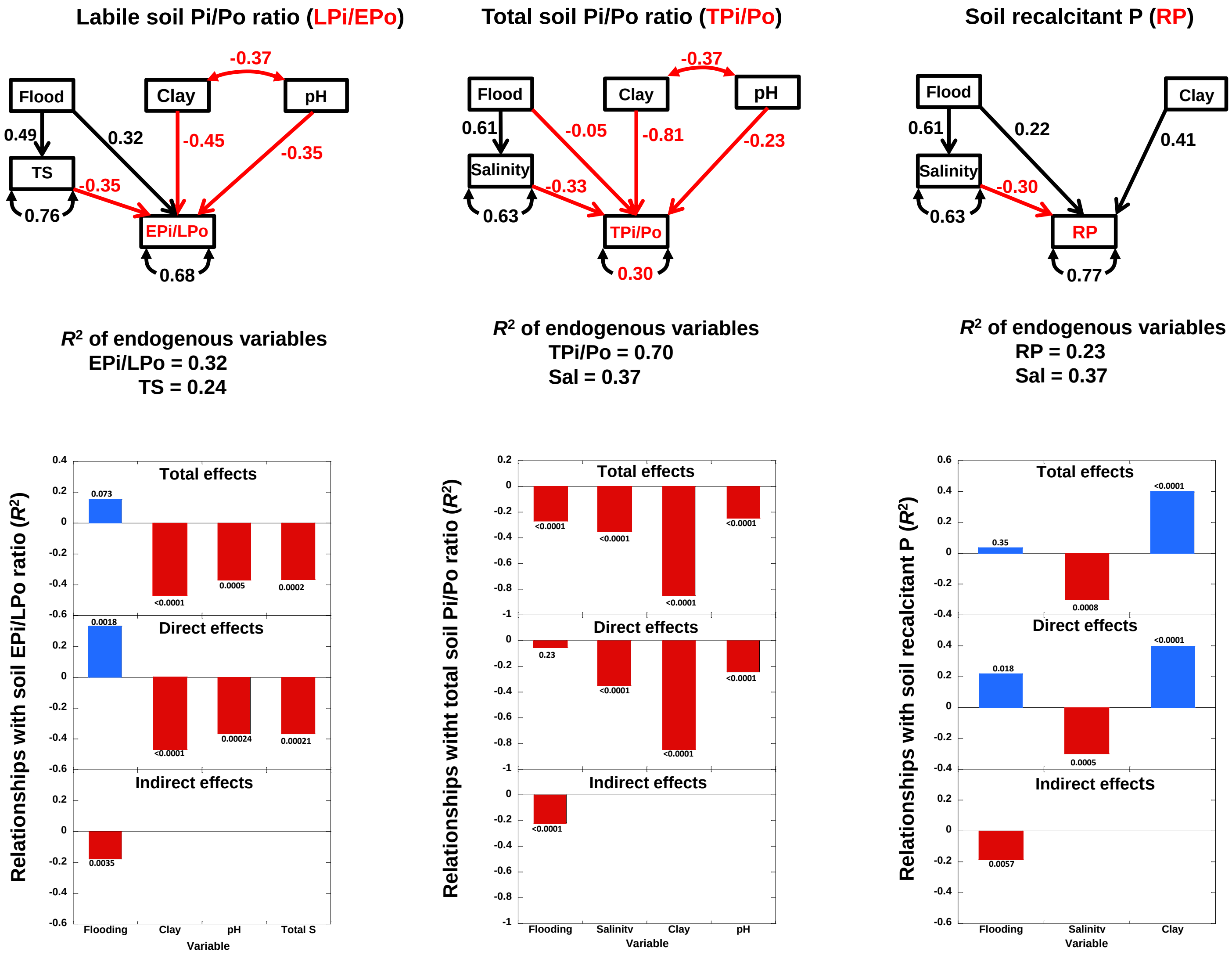

Labile soil Pi/Po ratio (LPi/EPo)
Flood
Clay
pH
-0.37
0.49
0.32
-0.45
-0.35
TS
-0.35
0.76
EPi/LPo
0.68
R² of endogenous variables
EPi/LPo = 0.32
TS = 0.24
Total soil Pi/Po ratio (TPi/Po)
Flood
Clay
pH
-0.37
0.61
-0.05
-0.81
-0.23
Salinity
-0.33
0.63
TPi/Po
0.30
R² of endogenous variables
TPi/Po = 0.70
Sal = 0.37
Soil recalcitant P (RP)
Flood
Clay
0.61
0.22
0.41
Salinity
-0.30
0.63
RP
0.77
R² of endogenous variables
RP = 0.23
Sal = 0.37
Relationships with soil EPi/LPo ratio (R²)
Total effects
0.073
<0.0001
0.0005
0.0002
Direct effects
0.0018
<0.0001
0.00024
0.00021
Indirect effects
0.0035
0.4
0.2
0
-0.2
-0.4
-0.6
Flooding
Clay
pH
Total S
Variable
Relationships witht total soil Pi/Po ratio (R²)
Total effects
<0.0001
<0.0001
<0.0001
<0.0001
Direct effects
0.23
<0.0001
<0.0001
<0.0001
Indirect effects
<0.0001
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Flooding
Salinity
Clay
pH
Variable
Relationships with soil recalcitant P (R²)
Total effects
0.35
0.0008
<0.0001
Direct effects
0.018
0.0005
<0.0001
Indirect effects
0.0057
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Flooding
Salinity
Clay
Variable

Figure 7

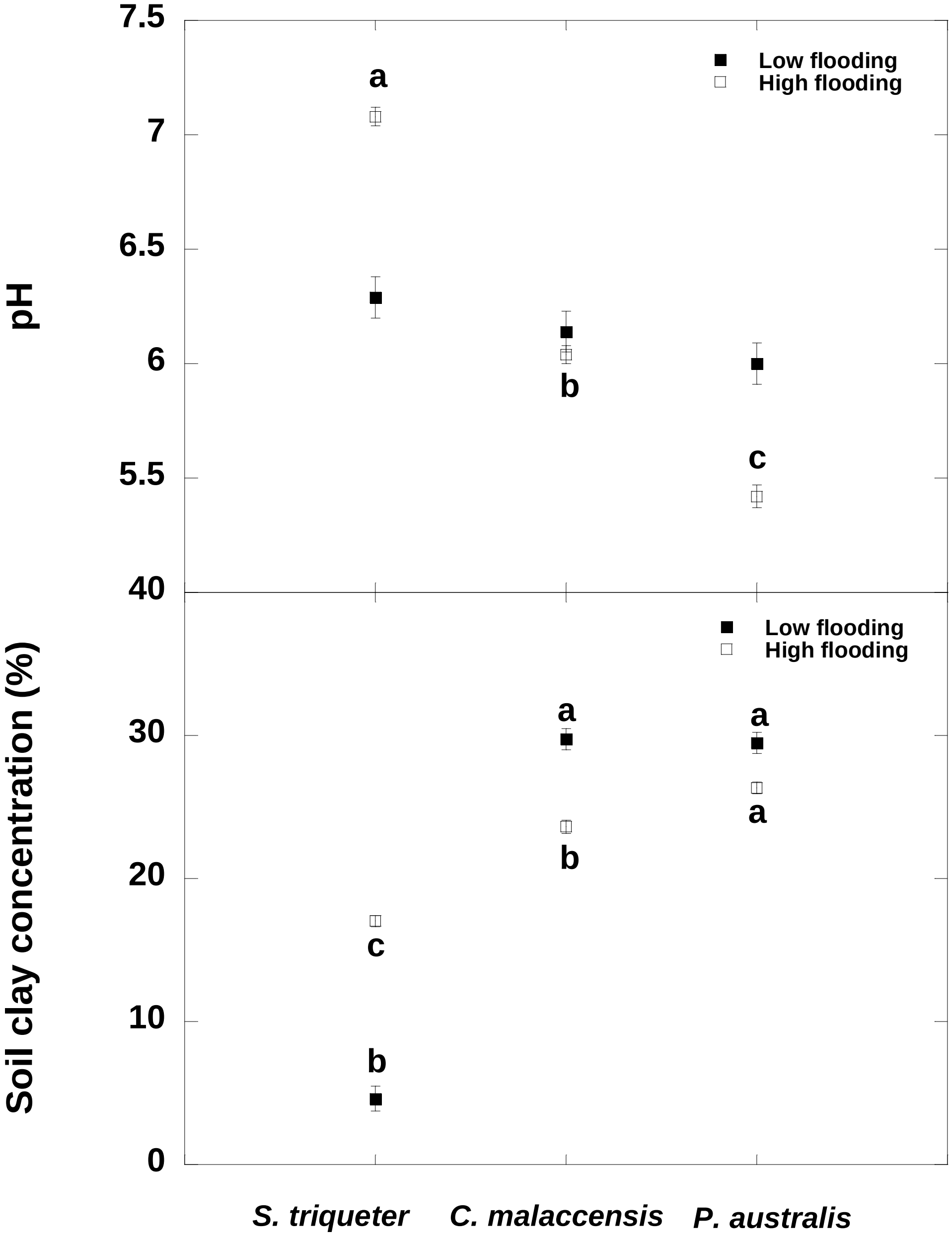

7.5
7
6.5
6
5.5
40
30
20
10
0
pH
Soil clay concentration (%)
■ Low flooding
□ High flooding
■ Low flooding
□ High flooding
a
b
c
a
a
a
b
c
b
S. triqueter
C. malaccensis
P. australis

Figure 8

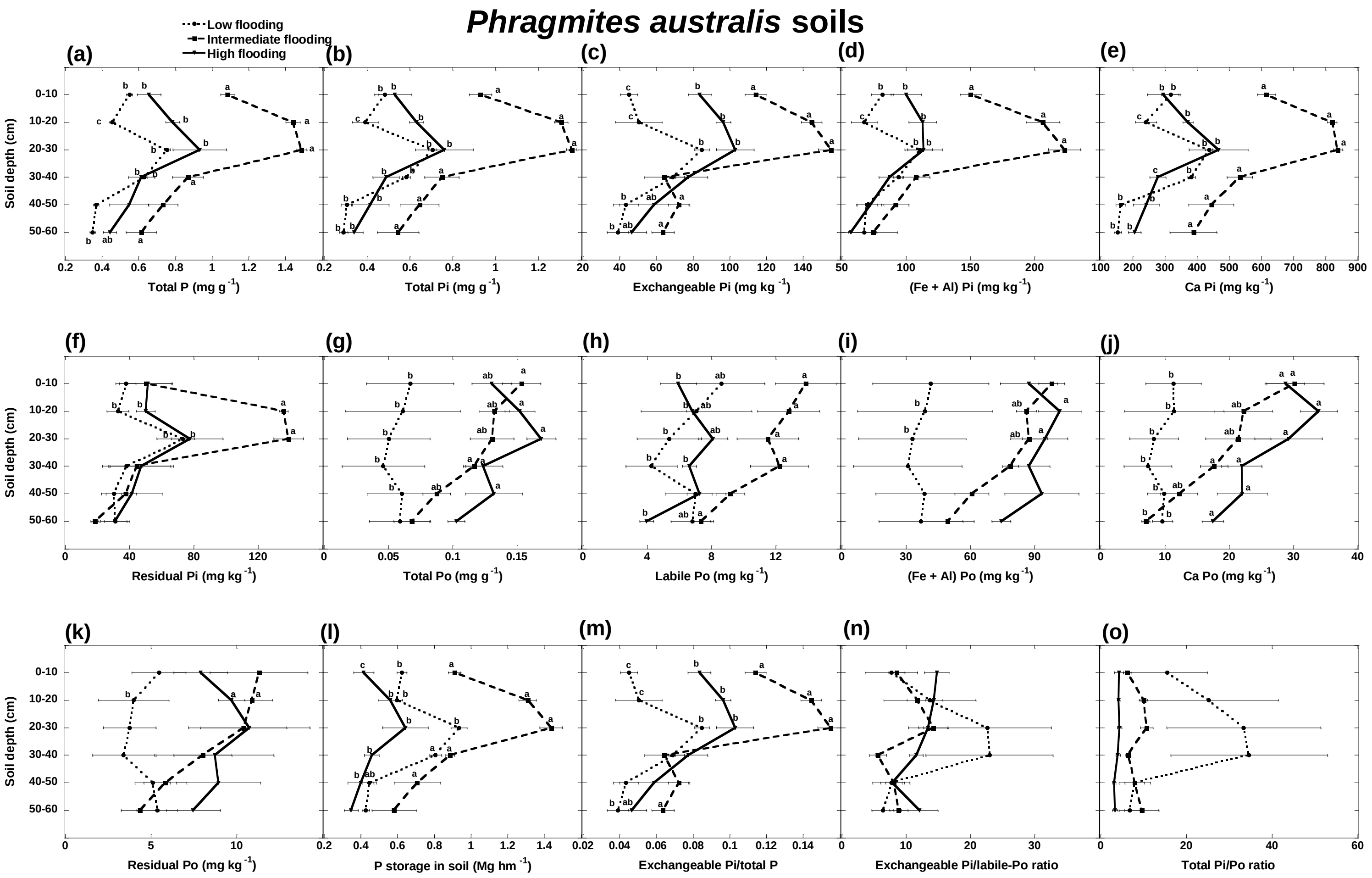

Phragmites australis soils
Low flooding
Intermediate flooding
High flooding
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
(m)
(n)
(o)
Soil depth (cm)
0-10
10-20
20-30
30-40
40-50
50-60
Total P (mg g-1)
Total Pi (mg g-1)
Exchangeable Pi (mg kg-1)
(Fe + Al) Pi (mg kg-1)
Ca Pi (mg kg-1)
Residual Pi (mg kg-1)
Total Po (mg g-1)
Labile Po (mg kg-1)
(Fe + Al) Po (mg kg-1)
Ca Po (mg kg-1)
Residual Po (mg kg-1)
P storage in soil (Mg hm-1)
Exchangeable Pi/total P
Exchangeable Pi/labile-Po ratio
Total Pi/Po ratio

Figure 9

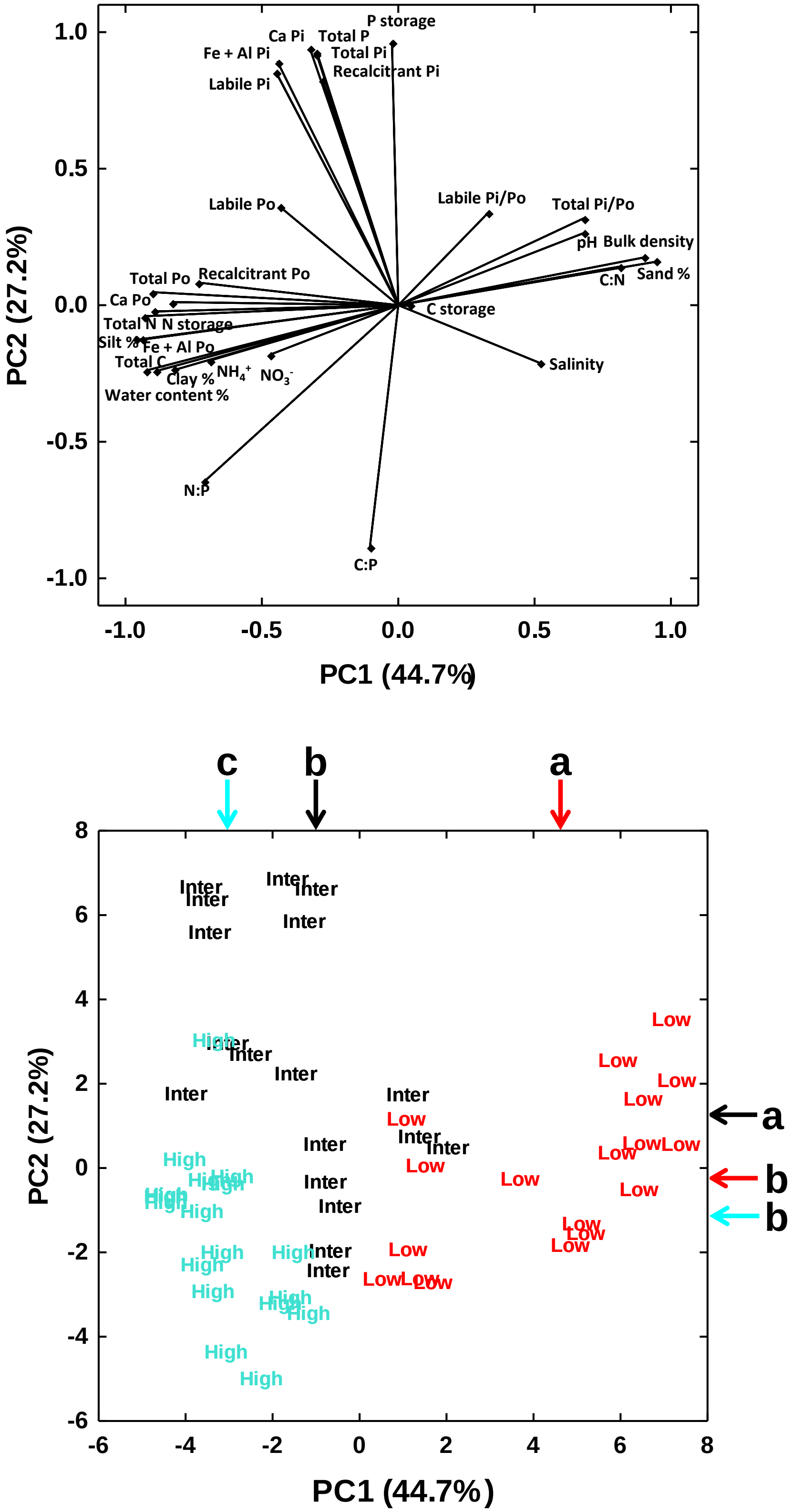

P storage
Ca Pi
Total P
Fe + Al Pi
Total Pi
Recalcitrant Pi
Labile Pi
Labile Po
Labile Pi/Po
Total Pi/Po
pH
Bulk density
C:N
Sand %
Total Po
Recalcitrant Po
Ca Po
Total N
N storage
C storage
Silt %
Fe + Al Po
Total C
Clay %
NH_4^+
NO_3^-
Water content %
Salinity
N:P
C:P
PC2 (27.2%)
PC1 (44.7%)
1.0
0.5
0.0
-0.5
-1.0
c
b
a
Inter
High
Low
a
b
b
PC2 (27.2%)
PC1 (44.7%)
8
6
4
2
0
-2
-4
-6
8

Figure 10

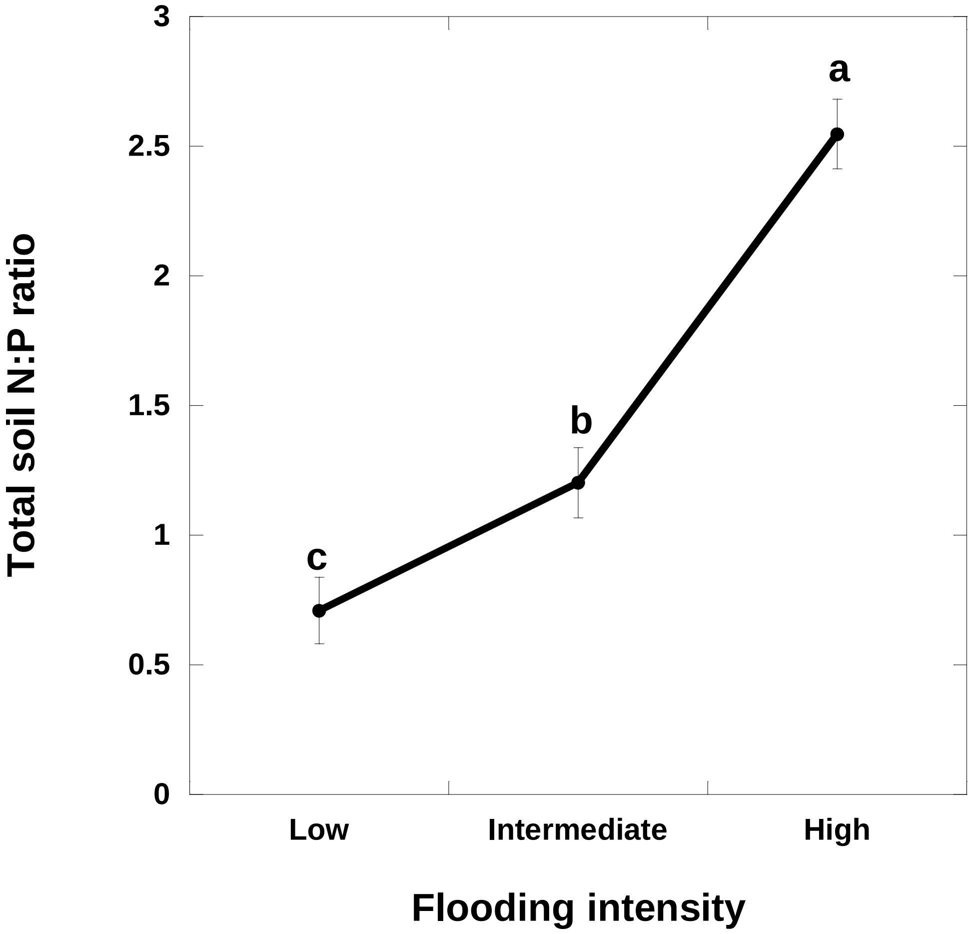

3
2.5
2
1.5
1
0.5
0
Total soil N:P ratio
a
b
c
Low
Intermediate
High
Flooding intensity

Figure 11

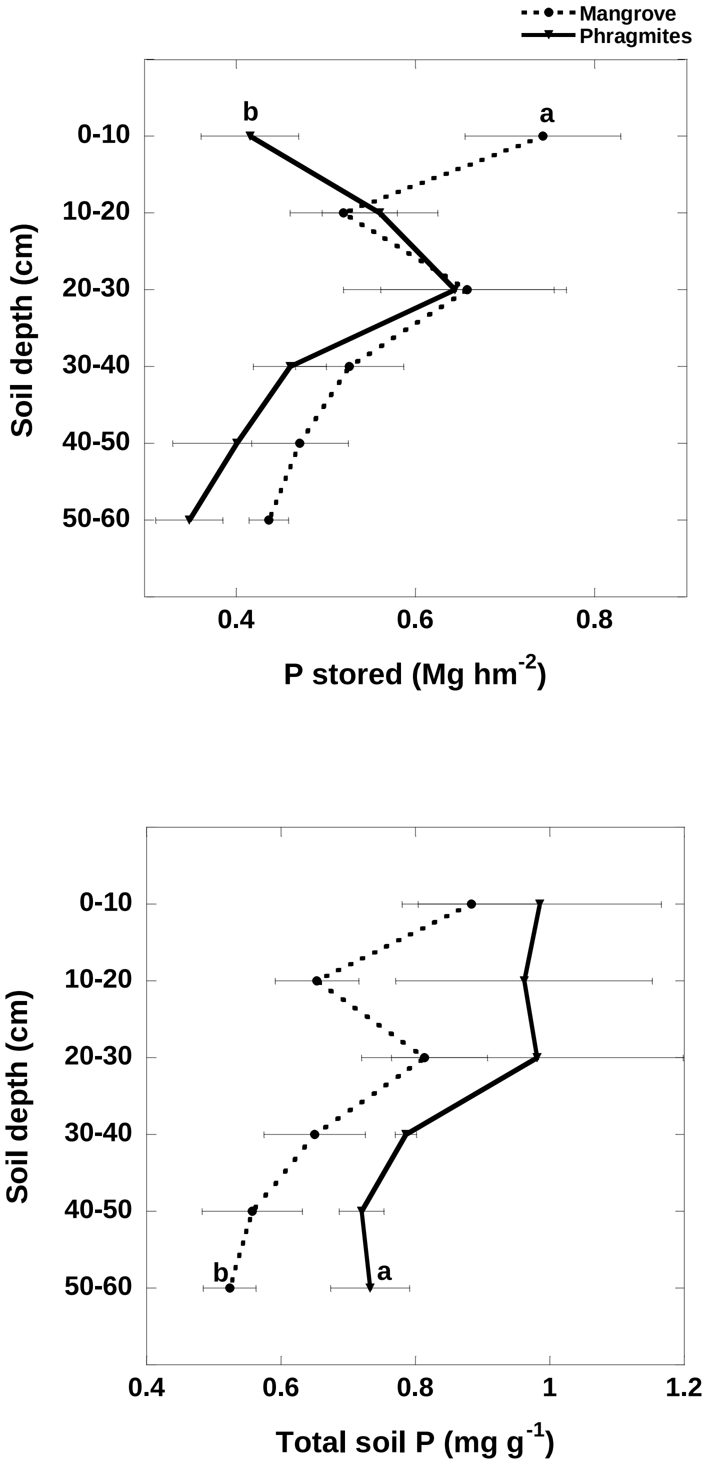

Mangrove
Phragmites
b
a
0-10
10-20
20-30
30-40
40-50
50-60
Soil depth (cm)
0.4
0.6
0.8
P stored (Mg hm^{-2})
0-10
10-20
20-30
30-40
40-50
50-60
b
a
Soil depth (cm)
0.4
0.6
0.8
1
1.2
Total soil P (mg g^{-1})

Figure 12

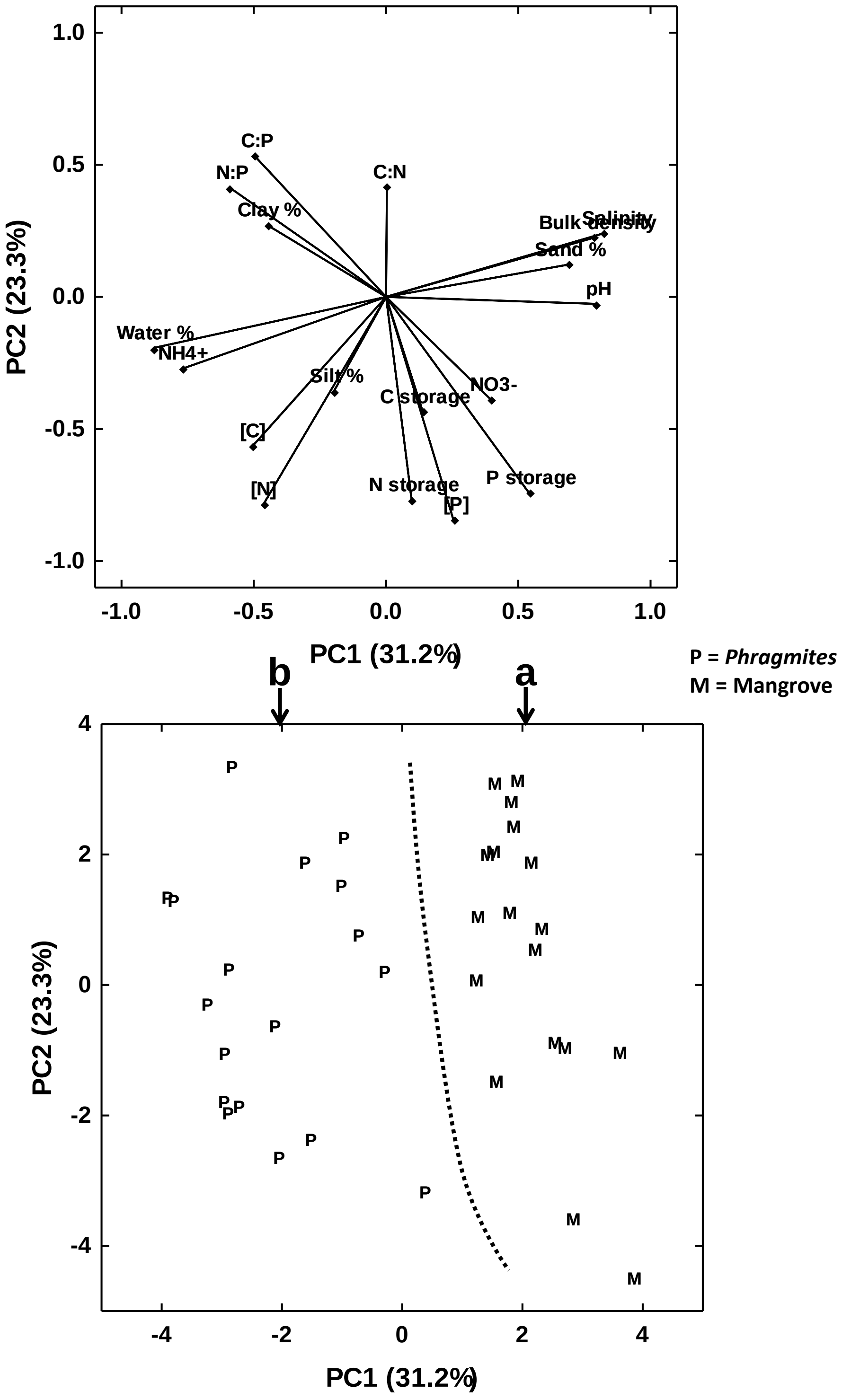

C:P
N:P
C:N
Clay %
Salinity
Bulk density
Sand %
pH
Water %
NH4+
Silt %
NO3-
C storage
[C]
[N]
N storage
P storage
[P]
1.0
0.5
0.0
-0.5
-1.0
-1.0
-0.5
0.0
0.5
1.0
PC2 (23.3%)
PC1 (31.2%)
b
a
P = *Phragmites*
M = Mangrove
4
2
0
-2
-4
-4
-2
0
2
4
PC2 (23.3%)
PC1 (31.2%)
P
M

Figure 13

Supplementary information

Appendix 1.

Analyses of soil P

Total soil P concentration was determined by ashing 200 mg of dry soil for 3 h at 450 °C, transferring to a 100-ml centrifuge tube after cooling, adding 20 ml of 3.5 mol l^{-1} HCl, shaking on a QHZ-98A full-temperature oscillator (Taicang Instruments, Taicang, China) for 16 h at 250 rpm and 25 °C, and then centrifuging at 2000*g* for 15 min. Ten milliliters of the supernatant were transferred to a 50-ml volumetric flask, and the pH was adjusted by adding 4 mol l^{-1} $NaHCO_3$ or 0.5 mol l^{-1} H_2SO_4 until the liquid became yellowish. Five milliliters of molybdenum-antimony anti reagent were added and then deionized water to a volume of 50 ml. The solution stood for 30 min and was then analyzed colorimetrically using a UV-2450 spectrophotometer (Shimadzu Scientific Instruments, Tokyo, Japan) at a wavelength of 700 nm (Ruban et al. 1999). A standard calibration curve was constructed by placing 0, 1, 2, 3, 4, 5, and 6 ml of a 5 mg l^{-1} P standard solution into 50-ml volumetric flasks, adding 5 ml of molybdenum-antimony anti reagent, and then diluting to 50 ml with deionized water, thereby obtaining 0, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6 mg l^{-1} P standard solutions. These solutions were analyzed colorimetrically using the UV-2450 spectrophotometer at a wavelength of 700 nm). Standard calibration curves were constructed by placing 0, 1, 2, 3, 4, 5, and 6 ml of a 5 mg l^{-1} P standard solution into 50-ml volumetric flasks, adding 5 ml of molybdenum-antimony anti-reagent, and then diluting to 50 ml with deionized water, thereby obtaining P standard solutions of 0, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6 mg l^{-1}. The solutions were then analyzed colorimetrically using a UV-2450 spectrophotometer (Shimadzu Scientific Instruments, Toyo, Japan) at a wavelength of 700 nm.

Total soil inorganic P (Pi) concentration was determined by adding 200 mg of dry soil to a 100-ml centrifuge tube, adding 20 ml of 1 mol l^{-1} HCl, shaking on the QHZ-98A full-temperature oscillator for 16 h at 250 rpm and 25 °C, and then centrifuging at 2000*g* for 15 min. The P concentration of the supernatant was determined colorimetrically as described above.

Total soil organic P (Po) concentration was determined by twice rinsing the residual soil in the above centrifuge tube with 12 ml of deionized water, freeze-drying, ultrasonicating in a bath for 30 s, ashing for 3 h at 450 °C, transferring to a 100-ml centrifuge tube after cooling, adding 20 ml of 3.5 mol l^{-1} HCl, shaking on the QHZ-98A full-temperature oscillator for 16 h at 250 rpm and 25 °C, and then centrifuging at 2000*g* for 15 min. The P concentration of the supernatant was determined colorimetrically as described above.

To determine the concentrations in the Po fractions, we used the continuous extraction procedure of Lu (1999). Labile Po was determined by adding 5.0 g of dry soil to a 200-ml flask, adding 0.5 mol l^{-1} $NaHCO_3$ (adjust pH to 8.5) and a spoon of 0.05g phosphate-free activated carbon, shaking for 0.5 h at 25 °C, and then immediately filtering with phosphate-free paper into a 100-ml flask. The P concentration of an aliquot was determined colorimetrically as above. This determination is hereafter called the *first measurement*. A 20-ml aliquot of the filtered liquid was transferred to a 50-ml flask and boiled to dryness in a DK-S28 water bath (Jinghong Instruments, Shanghai, China). Three milliliters of 98% H_2SO_4 and 10 drops of 72% $HClO_4$ were added, and the solution was digested for 0.5 h at 300 °C in a Digiblock EHD36 Digestion System (Zhongzi Instruments, Wuhan, China). The cooled digest was transferred to a 50-ml volumetric flask, deionized water was added to a volume of 50 ml, and the P concentration was determined colorimetrically (hereafter *second* *measurement*) as above. The labile Po was obtained by subtracting the first from the second measurement.

Moderately labile Po concentrations were estimated by summing two determinations. For the first determination, we added 2.0 g of dry soil to a 150-ml flask, added 100-ml 1.0 mol l^{-1} H_2SO_4, extracted for 3 h at 25 ℃, and then immediately filtered the solution with phosphate-free paper into a 100-ml flask. We added 0.05g phosphate-free activated carbon to one of two aliquots. The first determination was obtained by subtracting the first from the second treatment. The second determination was obtained by adding the dry residual soil from the first determination to a 150-ml flask, adding 100 ml of 0.5 mol l^{-1} NaOH, extracting for 6 h at 25 ℃, and then immediately filtering with phosphate-free paper into a 100-ml flask (hereafter called liquid A). Twenty milliliters of liquid A was transferred to a 100-ml flask, decolored with 0.05 g phosphate-free activated carbon, and the P concentration was determined colorimetrically as above.

Moderately resistant Po was analyzed by adding to the soil pellet 20 ml of liquid A to a 150-ml flask, adding HCl to a pH of 1.0-1.8, and standing for 12 h. This solution was filtered. We then prepared two treatments with two aliquots of the filtered solution. A spoon of 0.05 g phosphate-free activated carbon was added to one aliquot, which was shaken for 0.5 h and then immediately filtered with phosphate-free paper into a 100-ml flask. Five milliliters of the filtered solution was transferred to a 25-ml volumetric flask, and the P concentration was determined colorimetrically as above. The second aliquot, 20 ml of the filtered solution, was transferred to a 50-ml flask and boiled to dryness in the DK-S28 water bath. Three milliliters of 98% H_2SO_4 and 10 drops of 72% $HClO_4$ were added, and this solution was digested for 0.5 h at 300 °C in the Digiblock EHD36 Digestion System (first measurement). The cooled digest was then transferred to a 50-ml volumetric flask, deionized water was added to a volume of 50 ml, and the P concentration was determined colorimetrically as above (second measurement). The concentration of the moderately resistant Po was obtained by subtracting the first from the second measurement.

Highly resistant Po was analyzed by the following first treatment, subtracting the second treatment, and then subtracting the moderately resistant Po. The first treatment was conducted by adding 20 ml of filtered liquid A to a 50-ml flask, boiling to dryness in the DK-S28 water bath, adding 3 ml of 98% H_2SO_4 and 10 drops of 72% $HClO_4$, and then digesting for 0.5 h at 300 °C in the Digiblock EHD36 Digestion System. The cooled digest was then transferred to a 50-ml volumetric flask, deionized water was added to a volume of 50 ml, and the P concentration was determined colorimetrically as above. The second treatment was measured by transferring 20 ml of filtered liquid A to a 100-ml flask, decoloring with 0.05 g phosphate-free activated carbon, and the P concentration was determined colorimetrically as above.

To analyze the Pi fractions, we used the continuous extraction procedure of Ruban et al. (1999). Exchangeable Pi was analyzed by adding 200 mg of dry soil to a 100-ml centrifuge tube, adding 20 ml of 1 mol l^{-1} $MgCl_2$, shaking on the QHZ-98A full-temperature oscillator for 16 h at 250 rpm and 25 °C, centrifuging at 2000*g* for 15 min, and immediately filtering the supernatant with phosphate-free paper into a 20-ml flask. The P concentration was determined colorimetrically as above.

Fe+Al Pi was analyzed by adding 200 mg of dry soil to a 100-ml centrifuge tube, adding 20 ml of 1 mol l^{-1} NaOH, then following the same procedure used for total Pi, shaking on the QHZ-98A full-temperature oscillator for 16 h at 250 rpm and 25 °C, centrifuging at 2000*g* for 15 min, transferring the supernatant to a 20-ml flask, adding 4 ml of 3.5 mol l^{-1} HCl, and then standing for 16 h. The supernatant was immediately filtered with phosphate-free paper into a 20-ml flask, and the P concentration was determined colorimetrically as above.

Ca Pi was analyzed by twice rinsing the residual soil in the above centrifuge tube with 12 ml saturated NaCl solution, adding 20 ml of 1 mol l^{-1} HCl, then following the same procedure used for total Pi, shaking on the QHZ-98A full-temperature oscillator for 16 h at 250 rpm and 25 °C, and centrifuging at 2000*g* for 15 min. The supernatant was immediately filtered with phosphate-free paper into a 20-ml flask, and the P concentration was determined colorimetrically as above.

The concentration of the residual Pi was determined by:

[residual Pi] = [total P] – [exchangeable Pi] – [Fe+Al Pi] – [Ca Pi] – [total Po].

Total S concentrations were determined by put 1.0g dry soil into 50 ml flask, add 2 ml 0.27 mol L^{-1} magnesium-nitrate digestion (Lu, 1999) and evaporation to dryness at 70 °C on a hot plate and then drying the residue in an oven at 300 °C overnight (Lu, 1999). The 1.0 g dried residue was digested in 5 ml 3.8 mol L^{-1} nitric acid in a water bath for 2.5 H, oxidizing the S to sulfate. The sulfate concentration was measured by the barium-sulfate turbidity method. The available-S was extracted from 10 g of dry soil. Fifty ml of mixed solution of 8.7 mmol L^{-1}phosphate and 2 mol L^{-1} acetic-acid (Lu, 1999) were added to the extract and measured by the barium-sulfate turbidity method (Lu, 1999). Total organic-C content was determined by $K_2Cr_2O_7$-H_2SO_4 digestion (Sorrell et al. 1997; Bai et al. 2005), dissolved organic-C (DOC) content was determined by extraction with deionized water and measured using a TOC-V CPH Total Organic Carbon Analyzer (Shimadzu Scientific Instruments, Tokyo, Japan), and total N concentration was analyzed by the K 370 Kjeldahl method (Buchi Corporation, New Castle, DE, USA). NH_4^+ and NO_3^- were extracted with 2 mol L^{-1} KCl. The NH_4^+ concentration was determined by the indophenol-blue method (Wang et al. 2014), and the NO_3^- concentration was determined by the zinc-cadmium reduction method (Wang et al. 2014), using the UV-2450 spectrophotometer.

References

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Lu RK (1999): Agricultural Chemical Analysis Methods of Soil. Chinese Agricultural Technology Press, Beijing

Ruban V, López-Sánchez JF, Pardo P, Rauret G, Muntau H, Quevauviller P (1999) Selection and evaluation of sequential extraction procedures for the determination of phosphorus forms in lake sediment. J Environ Monit 1: 51-56

Sorrell B, Brix H, Schierup HH, Lorenzen B (1997) Die-back of *Phragmites australis*: influence on the distribution and rate of sediment methanogenesis. Biogeochemistry 36: 173–188.

Wang WQ, Sardans J, Zeng CS, Zhong C, Li Y, Peñuelas J (2014) Responses of soil nutrient concentrations and stoichiometry to different human land uses in a subtropical tidal wetland. Geoderma 232: 459-470

Table S1. Repeated measures ANOVA (in space = soil depth levels) with flooding duration as dependent categorical variable and different soil P fraction concentrations as dependent continuous variables.

Variable	Independent variables					
	Flooding duration	Species	Repeated factor (soil depth)	Flooding intensity x species	Repeated factor x flooding intensity	Repeated factor x species
Total soil P	F = 0.801 *P* = 0.38	F = 29.8 *P* < 0.0001	F = 21.2 *P* < 0.0001	F = 30.3 *P* < 0.0001	F = 5.76 *P* = 0.0002	F = 6.55 *P* < 0.0001
Total soil Pi	F = 0.611 *P* = 0.45	F = 14.9 *P* = 0.0006	F = 17.9 *P* < 0.0001	F = 19.6 *P* = 0.0002	F = 7.17 *P* < 0.0001	F = 6.3 *P* < 0.0001
Exchangeable Pi	F = 10.8	F = 68.9	F = 17.8	F = 68.7	F = 7.67	F = 5.74

	$P = 0.0066$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
Total soil Po	F = 0.216 $P = 0.65$	F = 44.6 $P < 0.0001$	F = 5.4 $P = 0.0004$	F = 20.2 $P = 0.0001$	F = 2.17 $P = 0.069$	F = 1.10 $P = 0.38$
Labile Po	F = 10.2 $P = 0.0077$	F = 22.1 $P < 0.0001$	F = 7.01 $P < 0.0001$	F = 34.4 $P < 0.0001$	F = 10.84 $P < 0.0001$	F = 3.24 $P < 0.0001$
Total Pi/Po ratio	F = 23.5 $P = 0.0004$	F = 30.8 $P < 0.0001$	F = 6.55 $P < 0.0001$	F = 20.8 $P < 0.0001$	F = 6.43 $P < 0.0001$	F = 2.82 $P = 0.0062$
Exchangeable Pi/Po labile ratio	F = 1.42 $P = 0.26$	F = 1.83 $P = 0.20$	F = 1.94 $P = 0.105$	F = 4.29 $P = 0.039$	F = 4.29 $P = 0.0021$	F = 0.966 $P = 0.48$

Table S2. Results of the factorial univariate general linear model with flooding intensity, dominant species of the community, and soil depth (every 10 cm) as categorical independent variables and with the P fractions and other soil variables as dependent variables. A Duncan post-hoc test was used to determine the significant differences (bold, *P*<0.05) among the dependent variables in each level of the categorical independent variables.

	Flooding duration	Species	Soil depth	Flooding intensity × species	Flooding intensity × soil depth	Species × soil depth	Flooding intensity × species × soil depth
Total P (g kg^{-1} soil DW)	Low = 0.633 ± 0.052 High = 0.667 ± 0.020 *P*=0.16	***S. triqueter* = 0.446 ± 0.038b** ***C. malaccensis* = 0.742 ± 0.047a** ***P. australis* = 0.762 ± 0.040a** ***P*<0.0001**	**0-10 = 0.692 ± 0.067b** **10-20 = 0.693 ± 0.052b** **20-30 = 0.833 ± 0.105a** **30-40 = 0.593 ± 0.051bc** **40-50 = 0.536 ± 0.044c** **50-60 = 0.554 ± 0.053c** ***P*<0.0001**	***P*<0.0001**	***P*=0.0027**	***P*<0.0001**	***P*<0.0001**
Total Pi (g kg^{-1} soil DW)	Low = 0.524 ± 0.046 High = 0.554 ± 0.019 *P*=0.22	***S. triqueter* = 0.392 ± 0.032b** ***C. malaccensis* = 0.610 ± 0.048a** ***P. australis* = 0.615 ± 0.038a** ***P*<0.0001**	**0-10 = 0.567 ± 0.058b** **10-20 = 0.565 ± 0.044b** **20-30 = 0.722 ± 0.096a** **30-40 = 0.485 ± 0.041bc** **40-50 = 0.425 ± 0.041c** **50-60 = 0.470 ± 0.046bc** ***P*<0.0001**	***P*<0.0001**	***P*=0.0005**	***P*<0.0001**	***P*<0.0001**
Exchangeable (labile) Pi (mg kg^{-1} soil DW)	**Low = 72.6 ± 6.3b** **High = 83.5 ± 2.8a** ***P*<0.0001**	***S. triqueter* = 51.2 ± 5.8b** ***C. malaccensis* = 96.9 ± 5.5a** ***P. australis* = 86.1 ± 3.9a** ***P*<0.0001**	**0-10 = 83.0 ± 8.3b** **10-20 = 84.6 ± 5.6ab** **20-30 = 95.7 ± 12.2a** **30-40 = 71.2 ± 7.5c** **40-50 = 65.6 ± 7.1d** **50-60 = 68.3 ± 8.2cd** ***P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**
Fe+Al Pi (mg kg^{-1} soil DW)	**Low = 101 ± 8b** **High = 113 ± 4a** ***P*=0.0004**	***S. triqueter* = 79.2 ± 8.2c** ***C. malaccensis* = 136 ± 7a** ***P. australis* = 106 ± 5.3b** ***P*<0.0001**	**0-10 = 118 ± 11a** **10-20 = 117 ± 7a** **20-30 = 129 ± 17a** **30-40 =98.6 ± 9.5b** **40-50 = 88.7 ± 7.8b** **50-60 = 90.5 ± 10.7b** ***P*<0.0001**	***P*<0.0001**	***P*=0.0001**	***P*<0.0001**	***P*<0.0001**
Ca Pi (mg kg^{-1} soil DW)	Low = 317 ± 28 High = 315 ± 11 *P*=0.91	***S. triqueter* = 234 ± 16b** ***C. malaccensis* = 339 ± 29a** ***P. australis* = 375 ± 25a** ***P*<0.0001**	**0-10 = 318 ± 34b** **10-20 = 326 ± 30b** **20-30 = 438 ± 59a** **30-40 = 285 ± 23b** **40-50 = 254 ± 21b**	***P*<0.0001**	***P*=0.0006**	***P*<0.0001**	***P*<0.0001**

			50-60 = 275 ± 25b **_P_<0.0001**				
Recalcitrant Pi (mg kg^{-1} soil DW)	Low = 37.7 ± 4.9 High = 42.4 ± 3.1 *P*=0.33	***S. triqueter* = 28.0 ± 2.3ab** ***C. malaccensis* = 43.9 ± 5.6b** ***P. australis* = 48.3 ± 5.8a** **_P_=0.0024**	**0-10 = 48.4 ± 7.9ab** **10-20 = 37.3 ± 5.1ab** **20-30 = 59.2 ±11.3a** **30-40 = 30.5 ± 4.1b** **40-50 = 29.1 ± 4.3b** **50-60 = 35.7 ± 4.8b** **_P_=0.0035**	**_P_=0.047**	No significant	No significant	***P***=0.0082
Total Po (g kg^{-1} soil DW)	Low = 0.109 ± 0.011 High = 0.113 ± 0.004 *P*=0.53	***S. triqueter* = 0.055 ± 0.007b** ***C. malaccensis* = 0.132 ± 0.009a** ***P. australis* = 0.146 ± 0.006a** **_P_<0.0001**	**0-10 = 0.126 ± 0.016a** **10-20 = 0.129 ± 0.014a** **20-30 = 0.110 ± 0.013ab** **30-40 = 0.108 ± 0.011ab** **40-50 = 0.110 ± 0.018ab** **50-60 = 0.085 ± 0.010b** **_P_=0.0019**	**_P_<0.0001**	No significant	No significant	No significant
Labile Po (mg kg^{-1} soil DW)	**Low = 11.0 ± 0.9a** **High = 8.72 ± 0.43b** **_P_<0.0001**	***S. triqueter* = 7.46 ± 0.93c** ***C. malaccensis* = 13.1 ± 0.8a** ***P. australis* = 9.04 ± 0.64b** **_P_<0.0001**	**0-10 = 9.56 ± 1.53ab** **10-20 = 12.0 ± 1.1a** **20-30 = 10.7 ± 1.3a** **30-40 = 9.64 ± 1.21ab** **40-50 = 9.74 ± 1.18ab** **50-60 = 7.58 ± 1.12b** **_P_=0.0002**	**_P_<0.0001**	**_P_<0.0001**	**_P_=0.01**	**_P_=0.0007**
Moderately labile Po (mg kg^{-1} soil DW)	Low = 69.7 ± 7.1 High = 73.9 ± 2.6 *P*=0.27	***S. triqueter* = 33.1 ± 4.5c** ***C. malaccensis* = 81.3 ± 4.5a** ***P. australis* = 101 ± 4b** **_P_<0.0001**	**0-10 = 81.8 ± 10.7a** **10-20 = 82.8 ± 9.6a** **20-30 = 68.6 ± 8.1ab** **30-40 = 70.6 ± 8.2ab** **40-50 = 70.5 ± 10.7ab** **50-60 = 56.6 ± 7.3b** **_P_=0.0012**	**_P_<0.0001**	No significant	No significant	No significant
Moderately resistant Po (mg kg^{-1} soil DW)	Low = 17.7 ± 2.2 High = 19.6 ± 1.0 *P*=0.25	***S. triqueter* = 9.53 ± 1.39b** ***C. malaccensis* = 28.9 ± 2.4a** ***P. australis* = 23.7 ± 1.2a** **_P_<0.0001**	**0-10 = 22.4 ± 2.9a** **10-20 = 22.1 ± 2.8ab** **20-30 = 17.5 ± 2.5ab** **30-40 = 17.4 ± 2.1ab** **40-50 = 19.0 ± 4.5ab** **50-60 = 13.6 ± 1.6a** **_P_=0.024**	**_P_<0.0001**	No significant	No significant	No significant
Recalcitrant Po (mg kg^{-1} soil DW)	Low = 10.7 ± 1.4 High = 9.62 ± 0.51 *P*=0.30	***S. triqueter* = 4.89 ± 0.69c** ***C. malaccensis* = 15.1 ± 1.5a** ***P. australis* = 10.6 ± 0.9b** **_P_<0.0001**	0-10 = 12.1 ± 2.0 10-20 = 12.2 ± 1.9 20-30 = 8.96 ± 1.34 30-40 = 9.91 ± 1.46 40-50 = 10.2 ± 2.7 50-60 = 7.62 ± 1.11 *P* = 0.11	**_P_<0.0001**	No significant	No significant	No significant

Labile Pi:Po	Low = 9.21 ± 0.98 High = 10.5 ± 0.5 _P_=0.18	_S. triqueter_ = 10.6 ± 1.40 _C. malaccensis_ = 8.36 ± 0.61 _P. australis_ = 10.6 ± 0.7 _P_=0.10	0-10 = 11.4 ± 1.2 10-20 = 8.68 ± 1.17 20-30 = 9.98 ± 0.90 30-40 = 10.4 ± 2.0 40-50 = 7.36 ± 0.85 50-60 = 11.4 ± 1.65 _P_=0.14	**_P_=0.0059**	**_P_=0.0031**	No significant	No significant
Total Pi:Po	**Low = 10.5 ± 1.5a** **High = 5.10 ± 0.20b** **_P_<0.0001**	**_S. triqueter_ = 13.9 ± 2.0a** **_C. malaccensis_ = 5.09 ± 0.39b** **_P. australis_ = 4.35 ± 0.31b** **_P_<0.0001**	**0-10 = 8.09 ± 2.00abc** **10-20 = 5.38 ± 0.65c** **20-30 = 10.9 ± 2.5a** **30-40 = 6.45 ± 1.44abc** **40-50 = 5.64 ± 0.85bc** **50-60 = 10.2 ± 3.00ab** **_P_=0.0002**	**_P_<0.0001**	**_P_=0.0003**	**_P_=0.017**	**_P_=0.063**
Water content (%)	**Low = 65.1 ± 2.4b** **High = 99.8 ± 1.8a** **_P_<0.0001**	**_S. triqueter_ = 70.6 ± 4.6c** **_C. malaccensis_ = 82.7 ± 2.8b** **_P. australis_ = 94.0 ± 3.2a** **_P_<0.0001**	**0-10 = 88.7 ± 6.7a** **10-20 = 82.5 ± 4.6ab** **20-30 = 78.7 ± 6.2b** **30-40 = 86.3 ± 4.9a** **40-50 = 80.5 ± 5.6b** **50-60 = 77.9 ± 5.3b** **_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**
Bulk density (g cm^{-3} soil DW)	**Low = 1.01 ± 0.02a** **High = 0.748 ± 0.011b** **_P_<0.0001**	**_S. triqueter_ = 0.979 ± 0.038a** **_C. malaccensis_ = 0.871 ± 0.026b** **_P. australis_ = 0.789 ± 0.20c** **_P_<0.0001**	**0-10 = 0.841 ± 0.050b** **10-20 = 0.889 ± 0.038ab** **20-30 = 0.902 ± 0.051ab** **30-40 = 0.854 ± 0.033ab** **40-50 = 0.889 ± 0.046ab** **50-60 = 0.905 ± 0.048a** **_P_=0.015**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**
pH	Low = 6.15 ± 0.06 High = 6.18 ± 0.09 _P_=0.16	**_S. triqueter_ = 6.69 ± 0.08a** **_C. malaccensis_ = 6.09 ± 0.05b** **_P. australis_ = 5.71 ± 0.09c** **_P_<0.0001**	**0-10 = 6.33 ± 0.12a** **10-20 =6.40 ± 0.12a** **20-30 = 6.30 ± 0.11a** **30-40 = 6.12 ± 0.12b** **40-50 = 6.00 ± 0.14bc** **50-60 = 5.85 ± 0.19c** **_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_=0.012**
Salinity (ms cm^{-1})	**Low = 0.895 ± 0.034b** **High = 1.21 ± 0.02a** **_P_<0.0001**	**_S. triqueter_ = 1.11 ± 0.04a** **_C. malaccensis_ = 0.989 ± 0.043b** **_P. australis_ = 1.06 ± 0.04ab** **_P_=0.0061**	**0-10 = 1.03 ± 0.07ab** **10-20 = 1.01 ± 0.06b** **20-30 = 0.946 ± 0.06b1** **30-40 = 1.08 ± 0.06ab** **40-50 = 1.15 ± 0.06a** **50-60 = 1.11 ± 0.05a** **_P_=0.0029**	**_P_<0.0001**	No significant	**_P_=0.0013**	No significant
Clay content (%)	**Low = 21.3 ± 0.2b** **High = 22.3 ± 0.6a**	**_S. triqueter_ = 10.8 ± 1.2b** **_C. malaccensis_ = 26.7 ± 0.7a**	**0-10 = 20.4 ± 1.92b** **10-20 = 22.8 ± 1.8a**	**_P_<0.0001**	No significant	No significant	**_P_=0.021**

	_P_=0.031	**_P. australis_ = 27.9 ± 0.5a** **_P_<0.0001**	**20-30 = 22.0 ± 2.5ab** **30-40 = 22.0 ± 2.4ab** **40-50 = 21.6 ± 2.2ab** **50-60 = 21.9 ± 2.4ab** **_P_=0.11**				
Silt content (%)	**Low = 44.0 ± 3.3b** **High = 71.1 ± 0.6a** **_P_<0.0001**	**_S. triqueter_ = 44.0 ± 5.6b** **_C. malaccensis_ = 64.9 ± 1.0a** **_P. australis_ = 63.8 ± 0.6a** **_P_<0.0001**	**0-10 = 58.9 ± 5.1ab** **10-20 = 60.1 ± 3.8a** **20-30 = 54.7 ± 6.0b** **30-40 = 57.4 ± 5.5ab** **40-50 = 58.6 ± 5.3ab** **50-60 = 55.6 ± 5.8ab** **_P_=0.011**	**_P_<0.0001**	**_P_=0.0035**	No significant	**_P_=0.036**
Sand content (%)	**Low = 34.7 ± 4.9a** **High = 6.56 ± 0.21b** **_P_<0.0001**	**_S. triqueter_ = 45.2 ± 6.8a** **_C. malaccensis_ = 8.37 ± 0.5b** **_P. australis_ = 8.30 ± 0.44b** **_P_<0.0001**	**0-10 = 20.7 ± 6.8ab** **10-20 = 17.0 ± 5.0b** **20-30 = 23.2 ± 8.0a** **30-40 = 20.6 ± 7.3ab** **40-50 = 19.8 ± 6.9ab** **50-60 = 22.5 ± 7.8ab** **_P_=0.034**	**_P_<0.0001**	**_P_=0.017**	**_P_=0.027**	**_P_=0.0062**
Total C (g kg^{-1} soil DW)	**Low = 14.4 ± 1.2b** **High = 19.3 ± 0.4a** **_P_<0.0001**	**_S. triqueter_ = 10.0 ± 1.1c** **_C. malaccensis_ = 18.8 ± 0.4b** **_P. australis_ = 21.7 ± 0.7a** **_P_<0.0001**	**0-10 = 18.6 ± 1.5a** **10-20 = 17.2 ± 0.9ab** **20-30 = 15.1 ± 1.7c** **30-40 = 16.7 ± 1.5c** **40-50 = 16.7 ± 1.8c** **50-60 = 16.8 ± 2.0bc** **_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**
Total N (g kg^{-1} soil DW)	**Low = 1.08 ± 0.09b** **High = 1.42 ± 0.03a** **_P_<0.0001**	**_S. triqueter_ = 0.731 ± 0.084c** **_C. malaccensis_ = 1.44 ± 0.03b** **_P. australis_ = 1.59 ± 0.04a** **_P_<0.0001**	**0-10 = 1.40 ± 0.13a** **10-20 = 1.33 ± 0.11ab** **20-30 = 1.31 ± 0.13ab** **30-40 = 1.19 ± 0.12b** **40-50 = 1.16 ± 0.10b** **50-60 = 1.12 ± 0.12b** **_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**
Total S (g kg^{-1} soil DW)	**Low = 1.19 ± 0.13b** **High = 2.11 ± 0.10a** **_P_<0.0001**	**_S. triqueter_ = 1.98 ± 0.15a** **_C. malaccensis_ = 1.50 ± 0.15b** **_P. australis_ = 1.46 ± 0.16b** **_P_<0.0001**	**0-10 = 1.52 ± 0.22b** **10-20 = 1.48 ± 0.24b** **20-30 = 1.14 ± 0.17c** **30-40 = 1.52 ± 0.18b** **40-50 = 2.06 ± 0.21a** **50-60 = 2.16 ± 0.24a** **_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**	**_P_<0.0001**
DOC (mg kg^{-1} soil DW)	Low = 34.4 ± 2.7 High = 33.1 ± 1.6 _P_=0.38	**_S. triqueter_ = 19.4 ± 0.94c** **_C. malaccensis_ = 37.4 ± 1.8b** **_P. australis_ = 44.3 ± 3.0a** **_P_<0.0001**	**0-10 = 38.0 ± 4.8b** **10-20 = 45.1 ± 5.1a** **20-30 = 34.1 ± 3.0bc** **30-40 = 31.0 ± 3.0bc**	**_P_<0.0001**	**_P_=0.0014**	**_P_=0.0002**	No significant

			40-50 = 28.5 ± 2.7c 50-60 = 25.7 ± 2.1c *P*<0.0001				
NH_4^+ (mg kg^{-1} soil DW)	**Low = 9.09 ± 0.95b High = 22.1 ± 2.2a *P*<0.0001**	***S. triqueter* = 15.1 ± 3.5b *C. malaccensis* = 13.9 ± 1.4c *P. australis* = 17.8 ± 1.6a *P*<0.0001**	**0-10 = 14.0 ± 3.2d 10-20 = 12.2 ± 2.3bc 20-30 = 10.5 ± 1.8bc 30-40 = 13.1 ± 1.0bcd 40-50 = 19.6 ± 4.3b 50-60 = 24.3 ± 5.0a *P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**
NO_3^- (mg kg^{-1} soil DW)	**Low = 2.85 ± 0.41a High = 1.59 ± 0.14b *P*<0.0001**	***S. triqueter* = 1.58 ± 0.20c *C. malaccensis* = 2.30 ± 0.40b *P. australis* = 2.78 ± 0.48a *P*<0.0001**	**0-10 = 3.64 ± 0.78a 10-20 = 3.15 ± 0.70b 20-30 = 2.52 ± 0.50c 30-40 = 1.63 ± 0.25d 40-50 = 1.16 ± 0.27e 50-60 = 1.23 ± 0.24e *P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**
Available S (mg kg^{-1} soil DW)	**Low = 32.5 ± 6.3b High = 59.1 ± 10.8a *P*<0.0001**	***S. triqueter* = 14.5 ± 0.6b *C. malaccensis* = 115 ± 13a *P. australis* = 7.78 ± 0.45b *P*<0.0001**	**0-10 = 27.6 ± 6.2c 10-20 = 28.7 ± 7.9c 20-30 = 29.2 ± 9.1c 30-40 = 49.4 ± 17.0b 40-50 = 64.8 ± 19.7ab 50-60 = 75.2 ± 23.3a *P*<0.0001**	***P*<0.0001**	No significant	***P*<0.0001**	No significant
C:N	Low = 14.2 ± 0.8 High = 13.7 ± 0.2 *P*=0.24	***S. triqueter* = 15.1 ± 1.2a *C. malaccensis* = 13.1 ± 0.3b *P. australis* = 13.7 ± 0.4ab *P*=0.0035**	**0-10 = 14.5 ± 0.92b 10-20 = 14.4 ± 1.1b 20-30 = 11.0 ± 0.5c 30-40 = 16.1 ± 1.5a 40-50 = 13.2 ± 0.8b 50-60 = 14.5 ± 0.6b *P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**
C:P	**Low = 22.7 ± 1.4b High = 30.5 ± 1.3a *P*<0.0001**	***S. triqueter* = 20.5 ± 1.3c *C. malaccensis* = 28.2 ± 1.6b *P. australis* = 31.2 ± 1.9a *P*<0.0001**	**0-10 = 27.8 ± 1.4a 10-20 = 25.6 ± 0.8a 20-30 = 18.6 ± 2.1b 30-40 = 28.0 ± 1.6a 40-50 = 29.7 ± 3.1a 50-60 = 30.0 ± 3.8a *P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*<0.0001**	***P*=0.00014**
N:P	**Low = 1.65 ± 0.09b High = 1.86 ± 0.09a *P*=0.0006**	***S. triqueter* =1.44 ± 0.08b *C. malaccensis* = 1.59 ± 0.10b *P. australis* = 2.24 ± 0.10a *P*<0.0001**	**0-10 = 1.99 ± 0.15a 10-20 = 1.79 ± 0.12a 20-30 = 1.45 ± 0.12b 30-40 = 1.69 ± 0.14ab 40-50 = 1.94 ± 0.17a 50-60 = 1.69 ± 0.19ab**	***P*<0.0001**	***P*=0.0015**	***P*=0.0003**	***P*=0.032**

			***P*<0.0001**				

Table S3. Correlation matrix of the soil P fractions and the main physicochemical soil variables.

	Total Pi	Exch Pi	Fe+Al Pi	Ca Pi	Recal. Pi	Total Po	Labile Po	Moderately labile Po	Moderately resistant Po	Recal. Po	Water cont.	Bulk density	pH	Salinity	Clay content	Silt content	Sand content	Total C	Total N	Total S	DOC	NH_4^+	NO_3^-	Sulfate	C:N	C:P	N:P
Total P	**R=0.98** **P<0.0001**	**R=0.94** **P<0.0001**	**R=0.92** **P<0.0001**	**R=0.96** **P<0.0001**	**R=0.80** **P<0.0001**	**R =0.59** **P <0.0001**	**R =0.51** **P <0.0001**	**R =0.57** **P <0.0001**	**R =0.46** **P <0.0001**	**R =0.43** **P<0.0001**	R=0.32 P =0.001	**R =-0.38** **P <0.0001**	R =0.033 P =0.735	R =-0.30 P =0.002	**R =0.66** **P <0.0001**	**R =0.56** **P <0.0001**	**R =-0.63** **P <0.0001**	**R =0.56** **P <0.0001**	**R =0.70** **P <0.0001**	**R =-0.37** **P <0.0001**	**R =0.50** **P <0.0001**	R =0.10 P =0.303	**R =0.50** **P <0.0001**	R =-0.021 P =0.830	R =-0.31 P =0.001	R =-0.16 P =0.100	R =0.044 P =0.654
Total Pi		**R=0.92** **P<0.0001**	**R=0.91** **P<0.0001**	**R =0.98** **P<0.0001**	**R =0.83** **P<0.0001**	**R =0.43** **P <0.0001**	**R =0.43** **P<0.0001**	**R =0.41** **P <0.0001**	R =0.31 P =0.001	R =0.28 P =0.004	R =0.27 P =0005	**R =-0.33** **P <0.0001**	R =0.078 P =0.42	R =-0.28 P =0.003	**R =0.55** **P <0.0001**	**R =0.47** **P <0.0001**	**R =-0.54** **P <0.0001**	**R =0.45** **P <0.0001**	**R =0.60** **P <0.0001**	**R =-0.34** **P <0.0001**	**R =0.41** **P <0.0001**	R =0.096 P =0.32	**R =0.44** **P <0.0001**	R =-0.026 P =0.79	R =-0.30 P =0.002	R =-0.25 P =0.009	R =-0.072 P =0.457
Exch. Pi			**R =0.96** **P<0.0001**	**R =0.86** **P<0.0001**	**R=0.71** **P <0.0001**	**R =0.58** **P <0.0001**	**R =0.54** **P <0.0001**	**R =0.55** **P <0.0001**	**R =0.47** **P <0.0001**	**R =0.41** **P<0.0001**	**R =0.39** **P <0.0001**	**R =-0.44** **P <0.0001**	R =0.031 P =0.75	R =-0.26 P =0.008	**R =0.70** **P <0.0001**	**R =0.66** **P <0.0001**	**R =-0.72** **P <0.0001**	**R =0.59** **P <0.0001**	**R =0.73** **P<0.0001**	**R =-0.33** **P <0.0001**	**R =0.48** **P <0.0001**	R =0.14 P =0.146	**R =0.41** **P <0.0001**	R =0.11 P =0.270	R =-0.32 P =0.001	R =-0.094 P =0.334	R =0.079 P =0.417
Fe+Al Pi				**R =0.84** **P <0.0001**	**R =0.69** **P <0.0001**	**R =0.52** **P <0.0001**	**R =0.60** **P<0.0001**	**R =0.47** **P<0.0001**	**R =0.43** **P<0.0001**	**R =0.44** **P<0.0001**	R =0.30 P =0.001	**R =-0.37** **P<0.0001**	R =0.19 P=0.049	R =-0.28 P =0.003	**R =0.61** **P<0.0001**	**R =0.63** **P<0.0001**	**R =-0.67** **P<0.0001**	**R =0.51** **P<0.0001**	**R =0.67** **P<0.0001**	R =-0.31 P =0.001	**R =0.43** **P<0.0001**	R =0.072 P =0.461	**R =0.46** **P<0.0001**	R =0.15 P =0.113	R =-0.32 P =0.001	R =-0.14 P =0.151	R =0.0088 P =0.928
Ca Pi					**R =0.81** **P <0.0001**	**R =0.42** **P <0.0001**	**R =0.38** **P <0.0001**	**R =0.40** **P <0.0001**	R=0.30 P =0.001	R=0.26 P =0.006	R=0.22 P =0.025	R =-0.28 P =0.003	R =0.062 P =0.53	R =-0.30 P =0.002	**R =0.52** **P <0.0001**	**R =0.41** **P <0.0001**	**R =-0.47** **P <0.0001**	**R =0.40** **P <0.0001**	**R=0.55** **P <0.0001**	**R=-0.36** **P <0.0001**	**R =0.40** **P <0.0001**	R =0.077 P =0.43	**R =0.43** **P <0.0001**	R =-0.082 P =0.400	R =-0.29 P =0.002	R =-0.30 P =0.002	R =-0.10 P =0.285
Recal. Pi						R=0.28 P =0.004	R=0.26 P =0.007	R=0.23 P =0.016	R=0.23 P =0.017	R=0.17 P =0.075	R=0.18 P =0.056	R =-0.23 P =0.018	R =-0.043 P =0.66	R =-0.16 P=0.094	**R =0.34** **P <0.0001**	R =0.28 P=0.003	R =-0.32 P =0.001	**R =0.33** **P <0.0001**	**R=0.41** **P <0.0001**	R =-0.20 P =0.040	R =0.13 P =0.168	R =0.11 P =0.255	R =0.28 P =0.003	R =-0.09 P =0.351	R =-0.14 P =0.139	R =-0.22 P =0.023	R=-0.11 P =0.272
Total Po							**R =0.61** **P <0.0001**	**R =0.97** **P<0.0001**	**R =0.91** **P<0.0001**	**R =0.82** **P<0.0001**	**R =0.38** **P <0.0001**	**R =-0.42** **P <0.0001**	R =-0.17 P =0.075	R =-0.23 P =0.015	**R =0.78** **P <0.0001**	**R =0.61** **P <0.0001**	**R =-0.71** **P <0.0001**	**R =0.73** **P <0.0001**	**R=0.80** **P <0.0001**	R=**-0.33** **P <0.0001**	**R=0.67** **P <0.0001**	R =0.069 P =0.477	**R =0.52** **P <0.0001**	R =0.012 P =0.904	R =-0.23 P =0.016	R =0.30 P =0.001	**R =0.52** **P <0.0001**
Labile Po								**R =0.53** **P <0.0001**	**R =0.51** **P <0.0001**	**R =0.63** **P<0.0001**	R =-0.016 P =0.87	R =-0.092 P =0.35	R =0.27 P =0.005	**R =-0.35** **P <0.0001**	**R =0.52** **P <0.0001**	**R =0.44** **P <0.0001**	**R =-0.50** **P <0.0001**	**R =0.36** **P <0.0001**	**R=0.45** **P <0.0001**	R =-0.25 P =0.008	**R=0.41** **P <0.0001**	R =-0.057 P =0.56	**R =0.57** **P <0.0001**	R =0.12 P =0.21	R =-0.13 P =0.18	R =0.029 P =0.764	R =0.17 P =0.071
Moderately labile Po									**R =0.83** **P <0.0001**	**R =0.670** **P<0.0001**	**R =0.42** **P <0.0001**	**R =-0.46** **P <0.0001**	R =-0.23 P =0.019	R =-0.20 P =0.037	**R =0.79** **P <0.0001**	**R =0.62** **P<0.0001**	**R =-0.72** **P <0.0001**	**R =0.76** **P <0.0001**	**R =0.82** **P <0.0001**	R =-0.32 P =0.001	**R =0.74** **P <0.0001**	R =0.094 P =0.332	**R =0.51** **P <0.0001**	R =-0.014 P =0.887	R =-0.23 P =0.015	**R =0.34** **P<0.0001**	**R =0.54** **P<0.0001**
Moderately resistant Po										**R =0.86** **P<0.0001**	**R =0.34** **P <0.0001**	**R =-0.36** **P <0.0001**	R =-0.16 P=0.091	R =-0.19 P=0.049	**R =0.65** **P <0.0001**	**R =0.51** **P <0.0001**	**R =-0.59** **P <0.0001**	**R =0.62** **P <0.0001**	**R =0.67** **P <0.0001**	R =-0.30 P=0.002	**R =0.45** **P <0.0001**	R =0.0742 P=0.446	**R =0.34** **P <0.0001**	R =-0.019 P =0.848	R =-0.21 P =0.032	R =0.28 P =0.003	**R =0.54** **P<0.0001**
Recal. Po											R =0.15 P =0.12	R =-0.19 P =0.047	R =-0.015 P =0.88	R =-0.30 P =0.002	**R =0.57** **P <0.0001**	**R =0.43** **P <0.0001**	**R =-0.50** **P <0.0001**	**R =0.53** **P <0.0001**	**R =0.56** **P <0.0001**	R =-0.30 P =0.002	**R =0.43** **P <0.0001**	R =-0.023 P =0.81	**R =0.46** **P <0.0001**	R =0.16 P =0.11	R =-0.16 P =0.092	R =0.25 P =0.009	**R =0.36** **P<0.0001**
Water content												**R =-0.95** **P <0.0001**	R =-0.19 P =0.055	**R =0.51** **P <0.0001**	**R =0.49** **P <0.0001**	**R =0.74** **P <0.0001**	**R =-0.72** **P <0.0001**	**R =0.70** **P <0.0001**	**R =0.66** **P <0.0001**	R =0.31 P =0.001	R =0.25 P =0.010	**R =0.38** **P <0.0001**	R =-0.17 P =0.079	R =0.097 P =0.320	R =-0.029 P =0.77	**R =0.53** **P <0.0001**	**R =0.41** **P <0.0001**

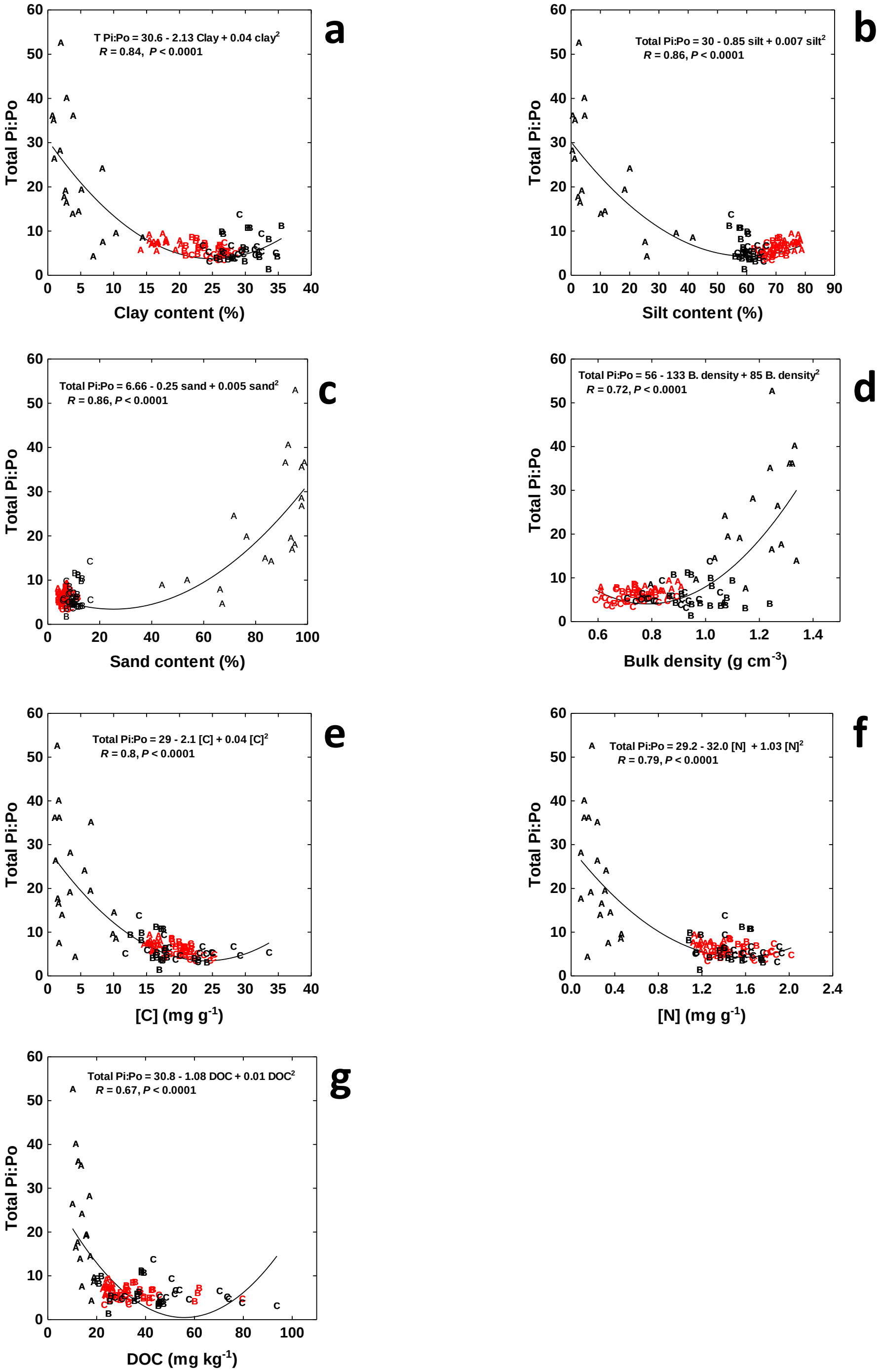
Bulk density	*R* =0.14 *P* =0.14	***R* =-0.49** ***P* <0.0001**	***R* =-0.52** ***P* <0.0001**	***R* =-0.79** ***P*<0.0001**	***R* =0.76** ***P*<0.0001**	***R* =-0.73** ***P*<0.0001**	***R* =-0.69** ***P* <0.0001**	*R* =-0.31 *P* =0.001	*R* =-0.31 *P* =0.001	***R* =-0.45** ***P* <0.0001**	*R* =0.10 *P* =0.30	*R* =-0.13 *P* =0.18	*R* =0.012 *P* =091	***R*=-0.52** ***P* <0.0001**	***R* =-0.37** **P<0.0001**
pH		*R* =-0.16 *P* =0.095	***R* =-0.37** **P<0.0001**	*R* =0.064 *P* =0.51	*R* =0.068 *P* =0.48	*R* =-0.30 *P* =0.001	*R* =-0.21 *P* =0.030	*R* =0.031 *P* =0.75	*R* =-0.073 *P* =0.45	*R* =0.039 *P* =0.67	***R* =0.37** ***P* <0.0001**	*R* =-0.13 *P* =0.19	*R* =-0.027 *P* =0.78	***R* =-0.35** ***P* <0.0001**	*R* =-0.29 *P* =0.002
Salinity			*R* =-0.14 *P* =0.14	*R* =0.22 *P* =0.021	*R* =-0.12 *P* =0.20	*R* =0.11 *P* =0.24	*R* =-0.04 *P* =0.67	***R* =0.75** **P<0.0001**	*R* =-0.31 *P* =0.001	*R* =0.21 *P* =0.032	***R* =-0.55** ***P* <0.0001**	*R* =0.16 *P* =0.103	*R* =0.17 *P* =0.087	***R* =0.40** ***P* <0.0001**	*R* =0.074 *P* =0.448
Clay content				***R*=0.69** **P<0.0001**	***R*=-0.84** ***P*<0.0001**	***R* =0.80** ***P*<0.0001**	***R* =0.86** ***P*<0.0001**	*R* =-0.24 *P* =0.014	***R* =0.62** **P<0.0001**	*R* =0.12 *P* =0.207	*R* =0.31 *P* =0.001	*R* =0.17 *P* =0.076	*R* =-0.25 *P* =0.009	***R* =0.40** ***P* <0.0001**	***R* =0.50** ***P* <0.0001**
Silt content					***R* =-0.97** ***P*<0.0001**	***R* =0.80** ***P*<0.0001**	***R* =0.82** ***P*<0.0001**	R *R* =0.16 *P* =0.109	***R* =0.43** ***P* <0.0001**	***R* =0.38** ***P* <0.0001**	*R* =0.25 *P* =0.009	*R* =0.23 *P* =0.018	*R* =-0.23 *P* =0.018	***R* =0.45** ***P* <0.0001**	***R* =0.45** ***P* <0.0001**
Sand content						***R* =-0.85** ***P*<0.0001**	***R* =-0.89** ***P*<0.0001**	*R* =-0.043 *P* =0.662	***R* =-0.52** ***P* <0.0001**	*R* =-0.33 *P* =0.001	*R* =-0.29 *P* =0.003	*R* =-0.23 *P* =0.019	*R* =0.25 *P* =0.009	***R* =-0.47** ***P* <0.0001**	***R* =-0.50** ***P* <0.0001**
Total C							***R* =0.92** ***P*<0.0001**	*R* =0.058 *P* =0.55	***R* =0.57** ***P* <0.0001**	*R* =0.27 *P* =0.005	*R* =0.26 *P* =0.007	*R* =0.16 *P* =0.11	*R* =-0.044 *P* =0.65	***R* =0.66** ***P* <0.0001**	***R* =0.56** ***P* <0.0001**
Total N								R=-0.18 *P* =0.067	***R* =0.69** ***P* <0.0001**	*R* =0.26 *P* =0.006	***R* =0.40** ***P* <0.0001**	R=0.10 *P* =0.303	R=-0.31 *P* =0.001	***R* =0.42** ***P* <0.0001**	***R* =0.55** ***P* <0.0001**
Total S									***R* =-0.42** ***P* <0.0001**	*R* =0.17 *P* =0.071	***R* =-0.47** ***P* <0.0001**	*R* =0.28 *P* =0.004	***R* =0.39** ***P* <0.0001**	***R* =0.51** ***P* <0.0001**	*R* =0.013 *P* =0.897
DOC										*R* =0.074 *P* =0.45	***R* =0.59** ***P* <0.0001**	*R* =-0.022 *P* =0.82	*R* =-0.22 *P* =0.024	*R* =0.17 *P* =0.079	*R* =0.29 *P* =0.002
NH_4^+											*R* =-0.064 *P* =0.51	*R* =0.031 *P* =0.75	*R* =-0.058 *P* =0.55	*R* =0.16 *P* =0.099	*R* =0.12 *P* =0.210
NO_3^-												*R* =-0.29 *P* =0.002	*R* =-0.23 *P* =0.018	*R* =-0.13 *P* =0.181	*R* =0.21 *P* =0.026
Sulfate													*R* =0.013 *P* =0.89	*R* =0.25 *P* =0.008	*R* =-0.31 *P* =0.001
C:N														***R* =0.38** ***P* <0.0001**	*R* =-0.14 *P*=0.145
C:P															***R* =0.60** ***P* <0.0001**

Table S4. Results of the factorial univariate general linear model with the dominant species of the community and soil depth (every 10 cm) as categorical independent variables and with P fractions and other soil variables as dependent variables. A Duncan post-hoc test was used to determine the significant differences (bold, *P*<0.05) among the values of the dependent variables in each level of the categorical independent variables.

Variable	Community	Soil depth	Community × soil depth
Total P (g kg^{-1} soil DW)	*P. australis* wetland = 0.663 ± 0.049 Mangrove = 0.680 ± 0.041 *P*=0.80	0-10 = 0.770 ± 0.075 10-20 = 0.719 ± 0.044 20-30 = 0.873 ± 0.082 30-40 = 0.632 ± 0.047 40-50 = 0.553 ± 0.058 50-60 = 0.483 ± 0.030 *P*=0.52	
Water content %	***P. australis* wetland = 107 ± 3a** **Mangrove = 83.8 ± 0.7b** ***P*<0.0001**	0-10 = 98.4 ± 8.5 10-20 = 97.8 ± 6.6 20-30 = 98.7 ± 6.6 30-40 = 94.4 ± 6.5 40-50 = 94.3 ± 6.6 50-60 = 90.3 ± 3.6 *P*=0.97	
Bulk density (g cm^{-3} soil DW)	***P. australis* wetland = 0.716 ± 0.020b** **Mangrove = 0.822 ± 0.009a** ***P*<0.0001**	0-10 = 0.735 ± 0.048 10-20 = 0.751 ± 0.032 20-30 = 0.743 ± 0.031 30-40 = 0.783 ± 0.033 40-50 = 0.794 ± 0.038 50-60 = 0.809 ± 0.021 *P*=0.69	
pH	***P. australis* wetland = 5.42 ± 0.05b** **Mangrove = 6.12 ± 0.02a** ***P*<0.0001**	0-10 = 5.90 ± 0.16 10-20 = 5.85 ± 0.15 20-30 = 5.77 ± 0.16 30-40 = 5.72 ± 0.15 40-50 = 5.76 ± 0.16 50-60 = 5.64 ± 0.22 *P*=0.16	
Salinity (ms cm^{-1})	***P. australis* wetland = 1.26 ± 0.03b** **Mangrove = 1.75 ± 0.04a** ***P*<0.0001**	0-10 = 1.48 ± 0.16 10-20 = 1.43 ± 0.13 20-30 = 1.48 ± 0.13 30-40 = 1.53 ± 0.11 40-50 = 1.53 ± 0.10 50-60 = 1.57 ± 0.11 *P*=0.43	
Clay %	*P. australis* wetland = 26.3 ± 0.4 Mangrove = 25.2 ± 0.4 *P*=0.061	0-10 = 24.6 ± 1.2 10-20 = 26.2 ± 0.8 20-30 = 25.4 ± 0.6 30-40 = 26.6 ± 0.4 40-50 = 25.3 ± 0.8 50-60 = 26.3 ± 0.5 *P*=0.86	
Silt %	***P. australis* wetland = 66.8 ± 0.4a** **Mangrove = 65.6 ± 0.5b** ***P*=0.024**	**0-10 = 67.1 ± 0.6a** **10-20 = 66.0 ± 0.7ab** **20-30 = 66.4 ± 0.9ab** **30-40 = 65.5 ± 1.0b** **40-50 = 66.3 ± 1.2ab** **50-60 = 66.0 ± 0.7ab** ***P*=0.026**	***P*=0.026**
Sand %	***P. australis* wetland = 6.83 ± 0.29b** **Mangrove = 9.26 ± 0.33a** ***P*<0.0001**	0-10 = 8.29 ± 0.70 10-20 = 7.78 ± 0.41 20-30 = 8.20 ± 1.00 30-40 = 7.89 ± 1.01 40-50 = 8.41 ± 0.88 50-60 = 7.68 ± 0.45 *P*=0.72	

Total C (g kg^{-1} soil DW)	***P. australis* wetland = 22.0 ± 0.4a** **Mangrove = 18.7 ± 0.7b** ***P*=0.0002**	0-10 = 22.4 ± 0.8 10-20 = 20.5 ± 0.8 20-30 = 20.6 ± 1.2 30-40 = 20.1 ± 1.1 40-50 = 19.6 ± 1.4 50-60 = 18.7 ± 1.3 *P*=0.49	
Total N (g kg^{-1} soil DW)	***P. australis* wetland =1.60 ± 0.06a** **Mangrove = 1.38 ± 0.05b** ***P*=0.0072**	0-10 = 1.67 ± 0.08 10-20 = 1.67 ± 0.10 20-30 = 1.60 ± 0.09 30-40 = 1.43 ± 0.07 40-50 = 1.34 ± 0.08 50-60 = 1.22 ± 0.03 *P*=0.20	
NH$_4^+$(mg kg^{-1} soil DW)	***P. australis* wetland = 20.0 ± 2.4a** **Mangrove = 6.28 ± 0.30b** ***P*=0.00024**	**0-10 = 20.7 ± 7.4a** **10-20 = 16.0 ± 4.4ab** **20-30 = 14.1 ± 3.4ab** **30-40 = 9.8 ± 2.0abc** **40-50 = 7.1 ± 0.6c** **50-60 = 11.2 ± 2.1abc** ***P*=0.019**	***P*=0.019**
NO$_3^-$ (mg kg^{-1} soil DW)	***P. australis* wetland = 1.24 ± 0.12b** **Mangrove = 1.90 ± 0.27a** ***P*=0.020**	**0-10 = 2.52 ± 0.62a** **10-20 = 2.02 ± 0.36ab** **20-30 = 1.46 ± 0.16ab** **30-40 = 1.06 ± 0.11bc** **40-50 = 0.86 ± 0.07c** **50-60 = 1.50 ± 0.30ab** ***P*=0.008**	
C storage (Mg hm^{-2})	*P. australis* wetland =15.7 ± 0.4 Mangrove = 15.3 ± 0.6 *P*=0.63	0-10 = 16.6 ± 1.6 10-20 = 15.4 ± 0.6 20-30 = 15.2 ± 0.3 30-40 = 15.6 ± 0.6 40-50 = 15.4 ± 0.7 50-60 = 15.0 ± 0.9 *P*=0.60	
N storage (Mg hm^{-2})	*P. australis* wetland = 1.13 ± 0.04 Mangrove = 1.13 ± 0.04 *P*=0.99	0-10 = 1.2 ± 0.1 10-20 = 1.2 ± 0.1 20-30 = 1.2 ± 0.1 30-40 = 1.1 ± 0.1 40-50 = 1.1 ± 0.1 50-60 = 1.0 ± 0.1 *P*=0.25	
P storage (Mg hm^{-2})	*P. australis* wetland = 0.471 ± 0.035 Mangrove = 0.559 ± 0.035 *P*=0.086	0-10 = 0.579 ± 0.086 10-20 = 0.540 ± 0.040 20-30 = 0.651 ± 0.071 30-40 = 0.493 ± 0.036 40-50 = 0.436 ± 0.043 50-60 = 0.392 ± 0.028 *P*=0.51	
C:N	*P. australis* wetland = 14.1 ± 0.5 Mangrove = 13.6 ± 0.2 *P*=0.40	0-10 = 13.5 ± 0.7 10-20 = 12.4 ± 0.4 20-30 = 13.0 ± 0.4 30-40 = 14.1 ± 0.4 40-50 = 0.043 ± 14.7 50-60 = 0.028 ± 15.3 *P*=0.49	
C:P	***P. australis* wetland = 36.1 ± 2.6a** **Mangrove = 28.6 ± 1.4b** ***P*=0.017**	0-10 = 30.1 ± 2.1 10-20 = 29.0 ± 1.6 20-30 = 24.5 ± 2.4 30-40 = 32.8 ± 3.3 40-50 = 37.6 ± 4.9 50-60 = 40.0 ± 5.0 *P*=0.60	
N:P	***P. australis* wetland = 2.55 ± 0.13a** **Mangrove = 2.12 ± 0.11b** ***P*=0.017**	0-10 = 2.26 ± 0.21 10-20 = 2.35 ± 0.13 20-30 = 1.90 ± 0.20 30-40 = 2.31 ± 0.19 40-50 = 2.59 ± 0.35	

		50-60 = 2.57 ± 0.19 *P*=0.26	


a
T Pi:Po = 30.6 - 2.13 Clay + 0.04 clay^2
R = 0.84, P < 0.0001
Total Pi:Po
Clay content (%)
0 5 10 15 20 25 30 35 40
0 10 20 30 40 50 60
b
Total Pi:Po = 30 - 0.85 silt + 0.007 silt^2
R = 0.86, P < 0.0001
Total Pi:Po
Silt content (%)
0 10 20 30 40 50 60 70 80 90
c
Total Pi:Po = 6.66 - 0.25 sand + 0.005 sand^2
R = 0.86, P < 0.0001
Total Pi:Po
Sand content (%)
0 20 40 60 80 100
d
Total Pi:Po = 56 - 133 B. density + 85 B. density^2
R = 0.72, P < 0.0001
Total Pi:Po
Bulk density (g cm^{-3})
0.6 0.8 1.0 1.2 1.4
e
Total Pi:Po = 29 - 2.1 [C] + 0.04 [C]^2
R = 0.8, P < 0.0001
Total Pi:Po
[C] (mg g^{-1})
0 5 10 15 20 25 30 35 40
f
Total Pi:Po = 29.2 - 32.0 [N] + 1.03 [N]^2
R = 0.79, P < 0.0001
Total Pi:Po
[N] (mg g^{-1})
0.0 0.4 0.8 1.2 1.6 2.0 2.4
g
Total Pi:Po = 30.8 - 1.08 DOC + 0.01 DOC^2
R = 0.67, P < 0.0001
Total Pi:Po
DOC (mg kg^{-1})
0 20 40 60 80 100

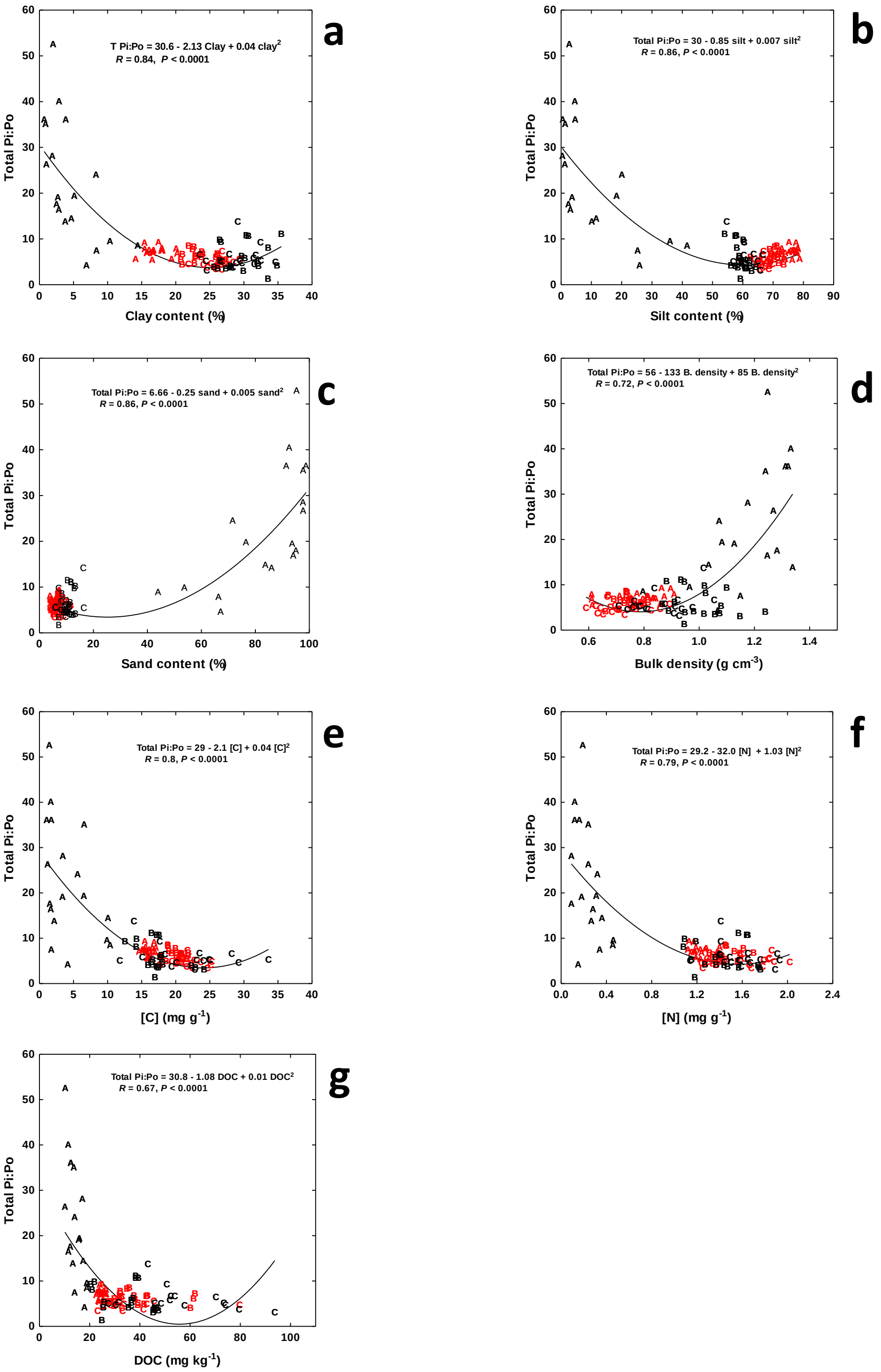


Figure S1. Second-level polynomial regressions between the total soil Pi:Po ratio and clay content (a), silt content (b), sand content (c), bulk density (d), total C concentration (e), total N concentration (f), and total dissolved organic-C (DOC) concentration (g).