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Wetland Soils Nutrient Index Development and Evaluation of “Safe” Soil Phosphorus Storage Capacity

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By

Vimala D. Nair
Mark W. Clark
K. Ramesh Reddy
Soil and Water Science Department - IFAS
University of Florida
Gainesville, FL 32611-0510

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EXECUTIVE SUMMARY

To better manage legacy phosphorus (P) in the Lake Okeechobee Watershed, reliable techniques to predict P storage and release from its uplands, ditches, streams and wetlands must be developed. Soil test P (STP) procedures such as Mehlich 1-P fail to precisely indicate whether a given soil is capable of retaining additional P (P “sink”) as opposed to functioning as a P source that would pose an environmental risk. The P saturation ratio (PSR) is the molar ratio of sorbed P (P held by the soil) to the sum of likely sorption components (Fe and Al) in the soil. When related to some measure of releasable P in the soil (i.e. water soluble P), PSR can be used as an indicator of the “change point” at which a soil becomes a P source to the environment. PSR was originally developed for upland soils using oxalate-extractable P, Fe, and Al in a soil PSR_{ox} = [(oxalate extractable-P/31) / (oxalate extractable- Fe/56) + (oxalate extractable-Al/27)]. In recent years, Mehlich 1 (PSR_{M1}) or Mehlich 3 (PSR_{M3}) extractions have been used to predict the threshold PSR above which P release to a water body increases at a greater rate. Phosphorus, Fe, and Al in a soil test solution can be easily obtained in any analytical laboratory in Florida and can be analyzed at a relatively low cost.

Based on preliminary information obtained from an earlier study, this project intended to determine the threshold PSR (or change point) for wetland soils and sediments, ditches and streams using techniques developed for upland soils. In this approach, water soluble P (WSP) is regressed against PSR for soils with a wide range of P, Fe, and Al concentrations, and the change point determined statistically using a non-linear equation. As part of the exploratory process of obtaining a threshold PSR value, compiled archived data were used to evaluate the feasibility of using some of the data for change point determinations, with the objective of using soils with a good range of P, Fe, and Al values which may not easily be obtained if fresh soils were used.

Since the compiled archived soils data did not have all the parameters (P, Fe and Al in the same soil sample) needed to calculate the threshold PSR, a group of soils was selected from a large dataset (> 3200 samples) that ranged widely in total P values. The 164 soils selected were from seven ranches within the Lake Okeechobee Basin. Water soluble P and Mehlich 1-extractable P, Fe, and Al were determined for all the selected soils. A threshold PSR_{M1} value of 0.11 with a 95% confidence interval of 0.06-0.16 was obtained using Mehlich 1-P, Fe, and Al. One of the ranch sites sampled was excluded from the analysis as soils from that site appeared atypical of the other soils in the study. The threshold PSR_{M1} calculated for wetlands in this study is close to that obtained for upland soils in earlier studies (0.10 with a confidence interval of 0.05-0.15). The threshold PSR_{M1} value of 0.1 appears to be applicable for both uplands and wetlands.

Some sandy soils (e.g., Spodosols of the Lake Okeechobee Watershed), even if not previously loaded heavily with P, can have low Mehlich 1 P and PSR $_{M1}$ values at the outset. These soils, however, can quickly reach high-risk concentrations with P loading due to low sorption capacities. Hence, an initially low soil test P or PSR value can quickly increase with additional P applications. Thus, the use of STP or PSR as environmental indicators of P loss from a farm has the shortcoming of failing to indicate the capacity of a soil to retain added P. Soils with very low inherent P retention capacity pose a high P-loss risk even if STP and PSR values are low. Also, some soils with elevated STP can still have some remaining capacity to safely retain P due to relatively high P retention capacity. To address these issues, the use of a PSR-based calculation of the remaining soil P storage capacity (SPSC) that would consider risks arising from previous loading as well as inherently low P sorption capacity was evaluated by researchers at the University of Florida Soil and Water Science Department. The SPSC provides a direct estimate of the amount of P a soil can sorb before exceeding a threshold soil equilibrium concentration, i.e., before the soil becomes an environmental risk.

The SPSC for upland soils can be calculated using P, Fe and Al in a Mehlich 1 solution using the following equation:

$$\text{SPSC} = (\text{Threshold PSR}_{M1} - \text{Soil PSR}_{M1})*\text{Mehlich 1-}[(\text{Fe}/55.8)+(\text{Al}/27)]*31*1.3 \text{ (mg/kg)}$$

When the threshold PSR$_{M1}$ is < 0.1, SPSC is positive (P sink) and becomes negative (P source) when the threshold value is >0.1.

For wetland soils, the same equation as for upland soils was proposed pending modifications to the equation as additional information becomes available. The recommended threshold PSR $_{M1}$ is 0.1 and the "Soil PSR $_{M1}$" was the value obtained for the wetland soil under consideration. The 1.3 factor is the conversion factor for calculation of SPSC using Mehlich 1 parameters for upland soils. The factor was obtained from a simple regression of SPSC calculated using oxalate (assuming that oxalate extractions represent Fe and Al concentrations often used as a surrogate for P retention) and Mehlich 1, and adjusting for the difference in the slope (1.3). At this time, the conversion factor appears reasonable for wetland soils as well since SPSC represents P storage in the mineral fraction of the soil; we have not taken any additional P storage by vegetation in wetlands into consideration.

For validation of the threshold PSR $_{M1}$ of 0.1, additional soil samples from locations within the Lake Okeechobee Basin – Pelaez Ranch (58 samples), Larson Ranch (72 samples), and samples provided by DACS/District (57 samples) were analyzed for WSP and Mehlich 1 - P, Fe, and Al. In addition, 48 samples from outside the Basin were collected and analyzed for the same parameters. For all samples, SPSC was calculated using a threshold PSR of 0.1 and

Mehlich 1-P, Fe and Al in the wetland soil. The relationship of SPSC to WSP for both the archived and newly collected soils was investigated The relationship between WSP (air dry conditions) and SPSC shows that as long as SPSC is positive, WSP is at a minimum, but when SPSC is negative, the release of P from the soil increases. Rate of release of P from the soil (i.e. when $PSR_{M1} > 0.1$ or $SPSC < 0$) is attributed primarily to the solubility of the source of P in the upland or wetland, i.e., a P source which is more soluble (e.g., an inorganic fertilizer) will release P faster compared to P release from a dairy manure-impacted soil when in contact with an identical volume of water. However, P source effects on release rate were not evaluated in this project. The relationship also holds for SPSC and the equilibrium P concentration (EPC_0) on the same wetland soils, i.e., when SPSC is positive EPC_0 is low, but EPC_0 increases once SPSC becomes zero or negative. Note that by definition, EPC_0 is the concentration of P in a soil solution when adsorption equals desorption, and SPSC = 0 is the SPSC at which the soil is neither a P source (will not release P) nor a P sink (will not retain any additional P). Also, the amount of organic matter in a soil does not have an influence on SPSC (some soils with high organic matter had positive SPSC and low WSP), and therefore up to the threshold PSR value (i.e., high sorption sites), P sorption appears related to Fe and Al concentrations only. For the archived soil samples used in this study, organic matter ranged from 0-95% for soils with both positive and negative SPSC.

The following additional analyses on surface soils were conducted (or available) on the 164 archived wetland soils: Mehlich 3 extractable P, Fe and Al and 1*M* HCl extractable P, Fe, and Al. At this time, we recommend P, Fe, and Al in a Mehlich 1 solution (current STP for Florida soils) be used for calculation of PSR and SPSC. The additional data compiled, would be useful for further evaluation of the extractant to be used for SPSC calculations for wetland soils. Mehlich 3 will likely be the new STP for Florida (other states that used Mehlich 1 as the STP have switched to Mehlich 3), and 1*M* HCl extracts comparable amounts of Fe and Al from a soil as oxalate, and could be a valuable replacement for oxalate extractions. SPSC calculations using either Mehlich 3 or 1*M* HCl parameters are not available for upland soils at this time.

The use of SPSC for identifying vertical P movement in wetlands was evaluated by obtaining incremental depths of two Spodosol soil profiles including the spodic (Bh) horizon, one from a wetland and another from a ditch suspected to be heavily loaded with P. In both instances, SPSC was negative (P source) throughout most of the soil profile, and the ditch soil had negative SPSC for the Bh horizon as well, suggesting that P has moved vertically through the soil profile in these two cases. SPSC is additive and therefore the total P storage capacity of a soil to any defined depth can be obtained by summing up SPSC for the various depth increments.

In conclusion, preliminary results support the conceptual use of SPSC as an indicator of soil P storage capacity. The threshold PSR_{M1} of 0.1 is believed to be a reasonable value that can be used at this time to evaluate SPSC for wetland soils. However, further investigations evaluating the larger scale interpretation/application of SPSC to infer edge-of-field / surface water – P concentrations (including more intensive catchment area soil with deeper soil sampling, water sampling, and use of SPSC in models) are recommended.

1 Introduction

Pollution from agricultural and other anthropogenic sources have been identified as the major cause of degradation of water bodies (USEPA, 1996). In 1972, the Federal Water Pollution Control Act (FWPCA) was amended by Congress to include state designation of water bodies by their uses and for states to determine standards by which water bodies would be held to protect designated use. In 1987, the Water Quality Act (WQA), passed by the Federal government, set goals to develop and implement ‘numeric’ criteria for all pollutants based on water, soil or plant parameters. The Clean Water Action Plan (CWAP) designated four categories of water bodies, lakes and reservoirs, rivers and streams, estuaries, and wetlands (USEPA, 1996). Significant progress has been made in open water systems. But in wetlands, only areas in and around the Florida Everglades have had numeric criteria set due to the complexity, heterogeneity, and limited information available for these water bodies.

State environmental resource managers have increasingly become interested in reliable methods to evaluate nutrient enrichment in wetland systems as a means to protect these water bodies as well as connected water bodies downstream. This project is aimed at taking the first step to develop a numeric phosphorus (P) index using soil parameters that would assist in predicting when a wetland soil is no longer able to assimilate additional P and may become a P source. How specifically this numeric index would be integrated into regulatory criteria protective of wetlands or downstream waters is outside the scope of this project, but will be a critical next step in the application of soil indices.

In this effort, a spreadsheet of all relevant data during the past 20 years from wetland nutrient assessment studies conducted at the Soil and Water Science Department, University of Florida was compiled. The objective in compiling this information was to use it as a preliminary dataset to explore various relationships and possible numerical indices typically used in upland soils and see how well they apply to wetland soils. Compiling the data and exploring various soil indices allowed us to identify gaps within the dataset, specifically certain parameters that were not analyzed previously but that are critical to evaluating data for the purpose of a numeric soil P index. These determinations were used to conduct additional analysis on stored samples from the dataset, guide new soils collections and refine methods associated with other parts of this project.

1.1 Theoretical Background

The theoretical basis of this study is described in Section 1.1.2

1.1.2 The Phosphorus Saturation Ratio (PSR) and "Safe" Soil P Storage Capacity (SPSC) Concepts

The PSR and SPSC concepts were originally developed to evaluate behavior of inorganic P in upland soils, where P retention is related largely to iron and aluminum. This concept has not been tested in calcareous soils where calcium and magnesium regulate P solubility and reactivity. In this project, an attempt was made to identify a threshold soil PSR above which P concentrations in the wetland would be an environmental risk (i.e. the wetland soil will no longer retain additional P and will likely begin to release P). Some preliminary data collected on wetland soils (Mukherjee et al., 2009) suggest that the threshold PSR might be a practical indicator to assess nutrient enrichment in wetland soils where P solubility is regulated by iron and aluminum. It should be noted that the Lake Okeechobee wetland soils are dominated by iron and aluminum (Reddy et al., 1998).

1.1.2.1 Phosphorus Saturation Ratio

Soil test P (STP) procedures such as Mehlich 1-P fail to reliably indicate whether a given soil is a P sink or source and hence could pose an environmental risk. A better indicator of P release would be the PSR which can be determined as follows:

$$PSR_{ox} = (\text{oxalate extract.-P}/31) / ((\text{oxalate extract. - Fe}/56) + (\text{oxalate extract.-Al}/27))$$

This molar ratio of sorbed P to the sum of the sorbing components (Fe and Al) in the soil is a useful indicator of the "change point" at which a soil becomes a P source to the environment (Nair et al., 2004) as measured by WSP or any measure of releasable P (Maguire and Sims, 2002; Nair et al., 2004). Note that in the example, PSR is calculated using oxalate extractable-P, Fe and Al; however, PSR can also be calculated using Mehlich 1 or Mehlich 3-P, Fe and Al.

The amount of P released from soils to adjacent porewater will depend on the solubility of the material to which the P is bound and the amount of bound P. This release can best be determined by extraction with water. When soils are extracted with water and plotted against PSR, we get a "change point" (i.e. a point on a WSP vs. PSR graph when P concentrations in the soil solution abruptly increase (Nair et al., 2004). Statistical procedure used in change point determination is given in Section 5.4. This change point PSR has been determined to be 0.1 for upland surface A and E horizons (Figure 1; Nair et al., 2004) calculated using oxalate extractable P, Fe and Al or Mehlich 1- extractable P, Fe and Al. The relationship of WSP to PSR above the change point PSR value is dependent on the procedure used to determine WSP and the solubility of the P source. Chrysostome et al., (2007a) showed that WSP determinations for upland soils using a 5:1 soil:water ratio correlated well with a column leaching experiment for both dairy and poultry-manure amended soils. However when a 1:10 soil:water ratio was used in WSP determination there was a scatter of points after the change point depending on the P source (dairy vs. poultry). This scatter does not affect the change point (threshold PSR) itself, only the distribution of points to the right of the change point threshold. An example of change point determination obtained using a soil test solution such as Mehlich 1 (Nair et al., 2004) instead of WSP in a PSR/WSP relationship for upland soils is shown in Figure 2.

The first indicator of the potential of PSR to be an index of P release from non-upland soils was noted by Sallade and Sims (1997). They found that sediments with similar biologically available P (BAP) and P saturation index values had different PSRs and concluded that the PSR could be used to target ditch sediments with higher potential to release P to overlying waters.

Dunne et al. (2007) found that agricultural ditch soils in the Lake Okeechobee Watershed (LOW) had low to medium TP content (<600 mg kg^{-1}) with organic matter and soil metal content important for predicting soil TP. The degree of P saturation of soils (similar to the PSR concept but expressed as a percentage often includes an empirical factor to account for the fraction of Fe and Al responsible for P sorption for soils of a given region) suggested that dairy and improved pasture soils could impact water quality.

Maguire and Sims (2002) evaluated relationships for various soil tests [both environmental -- FeO-P, WSP, and 0.01 M $CaCl_2$-P (dilute salt solution similar to 0.01*M* KCl used in this report; Section 5) – and agronomical (Mehlich 1, Mehlich 3, and Mehlich 3-PSR)], and dissolved reactive P (DRP) in the leachate. The authors found that “in a relationship between DRP in leachate and all of the soil tests used, a change point was determined, below which leachate DRP increased slowly per unit increase in soil test P, and above which leachate DRP increased rapidly.” Nair et al. (2004) also used a dilute salt solution (0.01M$CaCl_2$) to obtain a threshold DPS value.

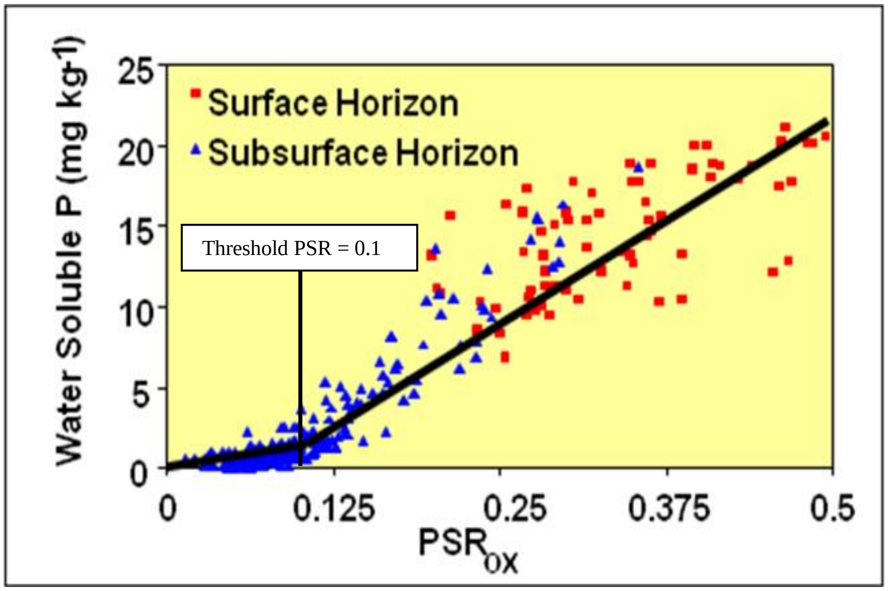


Figure 1. Relationship between the concentration of water-soluble P (WSP) and the P saturation ratio (PSR_{Ox}; calculated using P, Fe and Al in an oxalate solution) for manure-impacted surface and subsurface soils (Source: Nair et al., 2004).

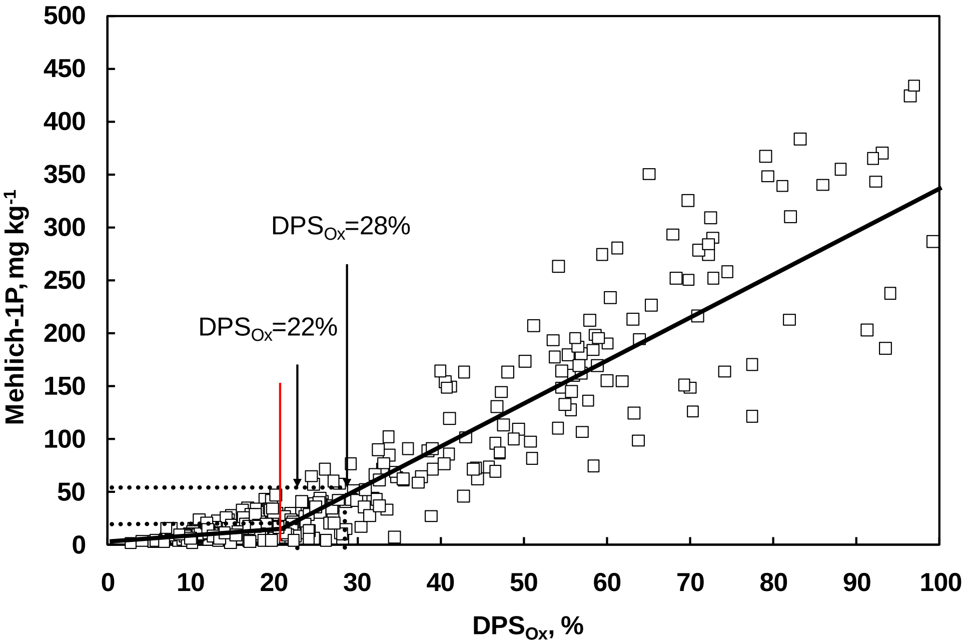


Figure 2. Relationship between the concentration of Mehlich 1-P and the Degree of P saturation (DPS_{Ox}) (PSR_{Ox}; calculated using P, Fe and Al in an oxalate solution) for manure-impacted surface and subsurface soils (Nair et al., 2004). The red line indicated the threshold DPS (DPS=20% or PSR=0.1) as determined using a Mehlich 1/DPS relationship. The DPS values of 22% (PSR= 0.11) and 28% (PSR=0.14) corresponds to high and very high agronomic rates (Kidder et al., 2002).

1.1.2.2 Soil Phosphorus Storage Capacity

The term “soil P storage capacity” has been used previously by several authors (e.g. Reddy et al., 1996). Note that the “safe” soil P storage capacity (SPSC) as used in the current context refers to the amount of P that can be safely stored within a given volume or mass of soil before that soil becomes an environmental risk (Nair and Harris, 2004).

Using the threshold PSR value of 0.1 for upland surface horizon soils, SPSC can be calculated as follows:

$$\text{SPSC} = (0.10 - \text{PSR}_{\text{Ox}}) * \text{Oxalate-extractable } (\text{Fe}/56 + \text{Al}/27) * 31 (\text{mg/kg})$$

Thus, SPSC can be determined on a site-specific basis and will facilitate the necessity and selection of appropriate BMPs for a given site. When SPSC is positive, the soil does not pose an environmental threat, but when the SPSC is negative, the threat of P release increases as SPSC becomes increasingly negative (Figure 3). SPSC can also be used to determine the additional amount of P that can be added to a soil before that soil becomes a P source.

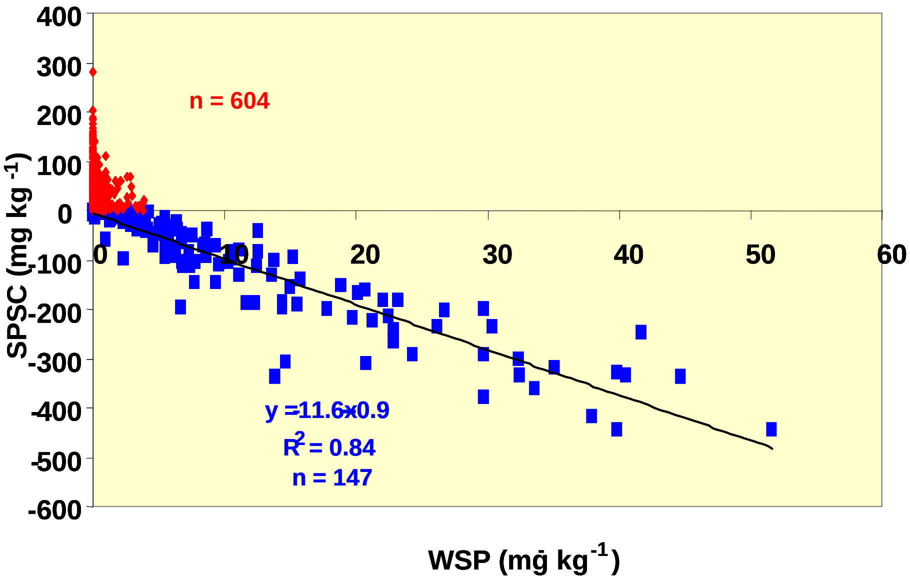


Figure 3. Relationship between soil P storage capacity (SPSC) and water soluble P (WSP) obtained from manure-impacted soils in the Lower Suwannee River Basin (Nair et al., 2007). Red markers are for positive SPSC and blue ones for negative SPSC.

1.2 Relevance of the PSR and SPSC Concepts to Water Quality Issues in the Lake Okeechobee Watershed.

It is likely that the PSR and therefore the SPSC techniques could be used to predict the P storage and release potential of upland soils, ditches, streams and wetlands and thereby predict with reasonable accuracy the influence of soils on the P load that would ultimately reach a water body emanating from anthropogenic activities in the uplands. Preliminary findings from a study in the Okeechobee Basin (Florida Ranchlands Environmental Services Project) comparing eight catchment soil PSR values derived from Mehlich-1 or Mehlich-3 extractions with edge of field water column TP indicate a relatively good fit ($r^2 > 0.650$). The PSR value of a soil indicates whether a soil will release P or has the potential to retain additional P. The PSR of a soil is just a ratio; SPSC of a soil indicates whether a given mass or volume of soil is a P source or P sink. The threshold PSR of a soil could serve as a practical indicator to assess nutrient enrichment in wetland soil systems. The SPSC would likely be used in evaluating appropriate best management practices (BMPs) for soils at a given site. SPSC is additive and can be added across soil horizons.

In wetlands, phosphorus retention is regulated by metals and organic matter accumulation. Reddy et al. (1998a) found that P retention by stream sediments and wetland soils in Florida was strongly correlated with Fe and Al, and that adding total organic C to predictive equations of short term P release improved the variability only slightly, i.e., from 87% to 92%. However, unlike metal phosphorus binding sites that often have a finite amount of storage capacity, vegetative wetlands and aquatic systems that are actively accreting organic matter can continue to retain additional P even after mineral sorption sites are satiated. This illustrates one of the added challenges of predicting water column and downstream phosphorus loads using only soil P indices in aquatic systems.

1.2.1 The Use of a Soil Test Solution for Calculating PSR and SPSC

In designing and evaluating techniques for predicting P release from soils, it is essential to identify a procedure that would be practical. The PSR and SPSC as explained above use P, Fe and Al from oxalate-extraction which is analytically a difficult procedure (McKeague and Day, 1966). Therefore, the use of alternative soil test P extractions to evaluate P release from soils was considered. A soil test solution such as Mehlich 1 or Mehlich 3, analyzed for P, Fe and Al could be an alternate and more practical procedure for identifying an index above which P release from the soil increases rapidly. As mentioned earlier, threshold PSR values calculated on Mehlich 1 soil test solutions have been shown to be as reliable as calculations of PSR values from oxalate extractable P, Fe and Al for upland soils. Note also that we plan to evaluate the potential of calculating PSR in a 1 *M* HCl which is an often used extractant in wetland soil studies (Reddy et al., 1998b).

While it is possible to calculate PSR of a soil using P, Fe and Al in a soil test solution instead of using oxalate parameters, calculation of SPSC from soil test data would require a conversion factor. There can be only one "safe" P storage capacity (SPSC) for a given soil and P and metal extraction capabilities of oxalate, Mehlich 1 and Mehlich 3 solutions are different. These conversions to calculate SPSC have been developed for calculations using Mehlich 1 parameters for upland soils (Nair et al., 2010), but such calculations using Mehlich 3 parameters are currently unavailable.

Objectives

Specific objectives of this project were to:

1. Evaluate various numeric P indices for P release from wetland soils, keeping in mind that the selected index (or indices) should be practical and needed parameters easily determined in Florida laboratories.
2. Develop a protocol (field collection, preservation, analytical methods) for assessing a P index that is indicative of P release from wetland soils.
3. Test the protocol on soil samples from wetlands to determine the extent to which the soil P index (or indices) is predictive of releasable P.

2 Methods Used for Data Collection

As a first step toward achieving our objectives, we compiled data already available from previous soil surveys within the Lake Okeechobee Watershed as well as other locations within the Southeastern Coastal Plain. In this effort, a spreadsheet of all relevant data during the past 20 years available on wetland nutrient assessment studies at Soil and Water Science, University of Florida were compiled. The spreadsheet with pertinent data from the Southeastern US, north of Lake Okeechobee was submitted as part of Deliverable 1.

2.1 Data Sources

The data were compiled from different sources: existing wetland databases in Excel spreadsheets, non-Excel spreadsheets, project reports from hard copies, and stored data extracted from floppy and zip discs. The Excel spreadsheet attached includes all data pertinent to the study: Mehlich 1-P, Fe, Al; oxalate P, Fe, Al; Mehlich 3-P, Fe, Al; HCl-P, Fe, Al [(including the inorganic (Pi) and organic (Po) forms of P)]; total P (TP), water soluble P (WSP) (wet/dry), C, N and pH. The dataset was compiled from several research projects and was submitted as Deliverable 1 of this project. As a result, the dataset collected in each project may not always contain all required information. Gaps in the dataset are left blank in the spreadsheet. Additional challenges in assembling this dataset are identified later in the report.

2.2 Common Analytical Procedures Used for Generating Data in the Spreadsheet

Soil pH: Soil pH was determined using soil: water ratio of 1:1 and glass electrode for most soils (EPA 9045C).

Bulk density (BD): A subsample of wet soil was dried at 70^{o}C to determine dry weight and moisture content. The bulk density was determined by calculating the dry weight of the sample and dividing it by the volume of the corer.

*Loss on ignition (LOI)***:** Loss on ignition was determined by igniting a known amount of ovendried soil (at70º C) in the muffle furnace at 550^{o}C. Loss in weight after ignition corresponds to organic matter content of the soil. Results are expressed as percentage of weight loss on an oven-dry basis.

*Total carbon (TC) and total nitrogen (TN)***:** Total carbon and nitrogen were determined on air-dried, ground samples using Flash EA 1112 Elemental Analyzer (CE Instruments, Saddlebrook, NJ). Results are expressed on an oven-dry basis.

*Total phosphorus (TP)***:** Total P represents the amount of organic and inorganic P in the soil. Total phosphorus was determined by a combination of ignition at 550°C and acid digestion to dissolve and convert organic P into inorganic P, followed by analysis for inorganic P in digests by ascorbic acid techniques using an autoanalyzer (USEPA, 1993; Method 365.1).

Total inorganic phosphorus (TP_i) *determined in 1M HCl***:** Total inorganic P in soil was extracted with 1 *M* HCl (soil to solution ratio = 1:50; 3 hours extraction time). Filtered solutions (0.45 μm filter) were analyzed for P using an autoanalyzer (USEPA, 1993; Method 365.1).

Water soluble phosphorus (WSP): Water-extractable P concentrations provide an estimate of the amount of P that is subject to vertical and/or lateral flow within the soil profile. Water extractable phosphorus in soil was extracted with deionized water using a soil to water ratio of 1:10 or (1:20). Filtered solutions (0.45 μm filter) were analyzed for P using an autoanalyzer (USEPA, 1993; Method 365.1). A 1:20 ratio was often used to ensure sufficient solution for analysis.

*Mehlich 1 extractable phosphorus (Mehlich 1-P)***:** Mehlich 1-P provides an estimate of bioavailable P in the soils (Kuo, 1996). Mehlich 1 extractable P was extracted with double acid mixture (0.025 *M* HCl + 0.0125 *M* H_2SO_4) using soil to solution ratio of 1:10. Filtered solutions (0.45 μm filter) were analyzed for P using an autoanalyzer (USEPA, 1993; Method 365.1).

*Mehlich 1 extractable Ca, Mg, Fe and Al***:** A portion of the Mehlich 1 extract analyzed for P was analyzed for metals (Ca, Mg, Fe and Al) as needed using the ICAP (USEPA, 1993; Method 200.7).

*Mehlich 3 extractable phosphorus (Mehlich-3 P)***:** Mehlich 3 (composition: NH_4F, EDTA, NH_4NO_3, acetic acid, nitric acid) extractions for determination of P (M3-P), Fe (M3-Fe) and Al (M3-Al) were performed as proposed by Mehlich (1984). All metals and P in the Mehlich 3 solutions were determined using Inductively Coupled Argon Plasma Spectroscopy (Thermo Jarrel Ash ICAP 61E, Franklin, MA). The ICAP was used for the determination of P and metals so as to calibrate PSR and SPSC calculations to the analytical procedure available in environmental labs in Florida thus facilitating the use of SPSC by anyone interested in using the tool.

*Oxalate-extractable P and metals***:** Oxalate-extractable Al (Ox-Al), Fe (Ox-Fe), and P (Ox-P) were determined by extraction with 0.1 *M* oxalic acid + 0.175 *M* ammonium oxalate (pH = 3.0) (McKeague and Day, 1966). The suspension was equilibrated for 4 h in the dark with continuous shaking, centrifuged, filtered through a 0.45 μm filter, and analyzed for Al, Fe, and P using an ICAP.

*HCl-extractable metals***:** Extractable metals (Ca, Mg, Fe, and Al) and P in soils were extracted with 1 *M* HCl (soil to solution ratio = 1:50; 3 hours extraction time). Filtered solutions were analyzed for metals using inductively coupled argon plasma spectrometry (ICAP) (USEPA, 1993; Method 200.7). This extractant is used regularly in the Biogeochemistry Lab as a measure of inorganic P in a soil.

3 Gaps in the Dataset Needed for Soil P Index Development

Efforts were made to standardize abbreviations for variables and use consistent units of measurement for all datasets. Metadata were prepared to provide detailed explanations on variable description and methods pertaining to data collection and measurement. Despite these efforts, inconsistency in use of abbreviations for a variable in different projects, lack of detailed information on analytical methods and laboratory procedures for variable measurement and data collection, made data interpretation difficult.

The following are some inconsistencies noted:

1. HCl-P is determined by ICAP; HCl-Pi is determined colorimetrically. These results have been documented correctly, but it is possible for some values reported as HCl-P may actually be HCl-Pi. The accuracy of reporting will be verified while determining the change point for wetland soils should these soils be selected for additional evaluation.
2. The above is applicable to Mehlich 1-P as well (Mehlich 1-Pi or Mehlich 1-Total P).
3. A significant problem noted is the determination of WSP in wetland soils. Most of the soils analyzed at the WBL were performed on wet soils while some of the data reported (e.g. Southeastern US project) were on dry soils.

3.1 Information Needed for Evaluation of "Safe" Soil P Storage Capacity in Wetlands

3.1.1 Threshold PSR for Wetland Soils (as an Index of P Release from the Soil)

To determine a threshold PSR value for wetland soils, it is necessary to relate PSR to WSP of soils across a range of PSR and WSP values. The PSR can be determined using various extractants (see Section 5.3). It was originally thought that the 20 year UF dataset could be used to establish this threshold, but after compiling the database it was found that not only did many soils in the database not have all of the parameters necessary to calculate PSR, but that there were also multiple methods used to measure WSP where in some instances wet soils were used in the extraction and in other datasets dry soils were used in the extraction. Therefore, one unexpected task associated with this project was the need to establish a protocol for the accurate determination of WSP for wetland soils and to either run that protocol on stored samples if possible or acquire new samples so that a threshold PSR value for wetlands using a PSR/WSP relationship could be determined. Alternatively, other procedures need to be evaluated to arrive at the threshold PSR value independent of a WSP determination. New soils were also collected to look into WSP determinations under wet and dry conditions. The relevance of the information of threshold PSR and SPSC assessment will be discussed in Task 4 (Section 6).

3.1.2 SPSC Calculations for Wetland Soils

The general equation for SPSC calculations is:

$$\text{SPSC} = (0.10 - \text{PSR})*\text{Extractable } (\text{Fe}/56 + \text{Al}/27)*31 \text{ mg/kg}$$

where Fe and Al are expressed in moles and P, Fe and Al are in an oxalate extract.

This is the equation developed for upland soils with a threshold PSR of 0.10 (Nair et al., 2004). SPSC for wetland soils can be calculated after obtaining a threshold PSR for wetland soils. The SPSC protocol may need modifications to include addition of organic matter effects on P storage. However, additional storage of P in organic matter may become important only after the high energy Fe+Al sorption sites are exhausted, i.e. after the threshold PSR is reached (see Section 6).

3.2 Results and Discussion

This project is the first attempt at developing a P release indicator for wetland soils utilizing the knowledge on wetland P release indicators based on the earlier work of Mukherjee et al. (2009). Most other work done to date has been on upland soils as discussed earlier. Mukherjee et al. (2009) suggested that it might be possible to develop a threshold PSR for wetland soils using a direct procedure to identify the threshold PSR based on a relationship between WSP and soil PSR modeled as a segmented line with parameters estimated using non-linear least squares (Nair et al., 2004). The authors did, however, by an indirect procedure identify a threshold PSR value of 0.1 using Mehlich 1-P, Fe and Al.

As indicated above (Section 3.1.1) a major problem in developing an index is the lack of a standard protocol for determining WSP in wetland soils, which is the reference against which any soil indices is presently being compared. This problem was noted while compiling the database. Lack of a standard protocol for WSP determinations is not only a problem for this project, but may also affect conclusions that have been made previously in the literature where WSP in wetland soils is related to porewater P concentrations, equilibrium P concentrations, etc. Further, WSP values determined at a given wetland location, cannot be easily compared to values at another location unless methods are determined to be similar.

When this proposal was written, the plan was to use a simple comparison of a “wet” vs “dry” procedure. However, we are now working on developing a protocol for the “wet” procedure. Our preliminary investigations showed that when a soil is extracted under wet conditions, WSP is lower than when extracted under dry conditions. Further, WSP when determined under wet conditions is heavily affected by the antecedent moisture content of the soil. Thus

WSP cannot be used as a reliable P index for wetland soils unless a protocol for standardizing soil moisture content is developed. At this point we have attempted to resolve this issue by evaluating different soils extraction ratios, the use of a dilute soil solution, and wet incubation of dried soils to normalize antecedent moisture conditions. However, we still do not have a consistently reliable method that we can apply to determine a threshold PSR value (see Section 4 of this report for details). In addition to varying moisture contents and high C content, we believe that the P source and its solubility play a major role in non-reproducible WSP values for wetland soils. We collected additional soils and determined WSP under wet and dry conditions, separating the soils by wetland groups as will be explained in Task 4 of this report.

As an initial assessment of PSR and SPSC, we calculated PSR for all available data in the database using P, Fe and Al in Mehlich 1, Mehlich 3 or oxalate solutions (see Deliverable 1 attachment). We looked into the WSP (dry)-PSR (oxalate) relationships for the center and edge of wetlands, drainage ditches and adjacent uplands (4). Wetland community types in the datasets included riverine swamp, non-riverine swamp, riverine marsh, and non-riverine marsh. WSP was determined on air-dried soils, the most uniform procedure we currently have for WSP extractions that is likely applicable to both upland and wetland soils. We used a conservative threshold PSR of 0.1, the same value as for upland soils for determining P sources and sinks and the value suggested by Mukherjee et al. (2009) for wetland soils. Based on the threshold PSR of 0.1 (using a PSR/WSP relationship based on air-dried soils) the number of soils that are P sources and P sinks were:

1. Center of wetlands (123 P sinks; 200 P sources)
2. Edge of wetlands (91 P sinks; 231 P sources)
3. Ditches (51 P sinks; 12 P sources)
4. Uplands (91 P sinks; 169 P sources)

The scatter of points after the threshold PSR (Figure 4) is likely dependent on the P source as well as related to the procedure used in WSP determinations (Chrysostome et al., 2007a). Further discussion on P source effects on WSP determination will be provided in Task 4 when we will have data from analyses of the soils collected during this study (not archived soil samples).

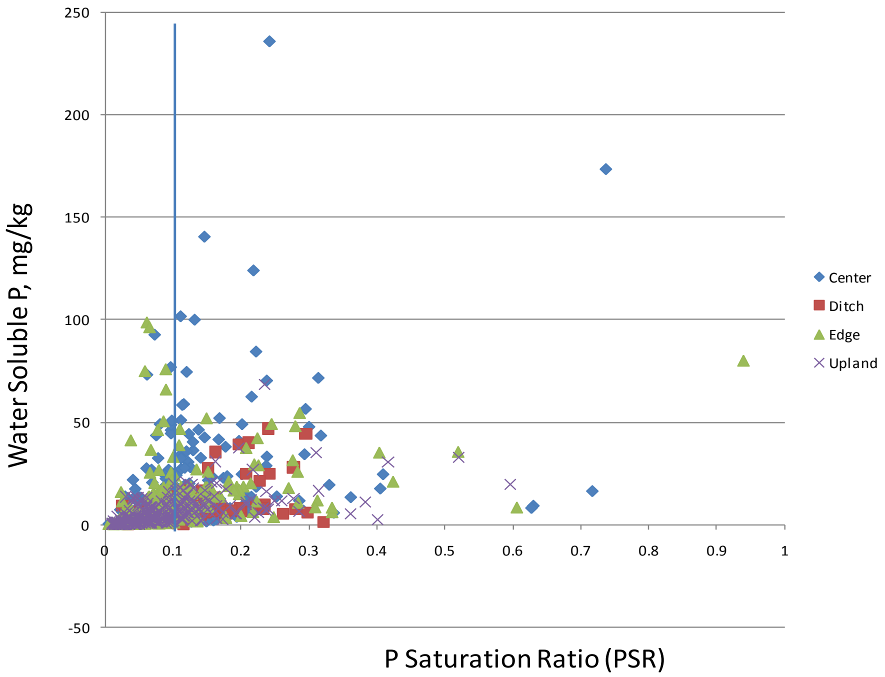


Figure 4. Relationship of water soluble P (WSP) determined on air-dried soils and P saturation ratio (PSR) calculated using P, Fe and Al in an oxalate solution, for soils from the center and edge of wetlands, drainage ditches and adjacent uplands for soils of the Okeechobee watershed and other locations within the southeastern USA. The blue line indicates a change point of 0.1 as suggested by Mukherjee et al. (2009).

Figure 5 was generated to evaluate the influence of organic matter on SPSC and WSP. An evaluation of the relationship of SPSC with WSP (dry) showed that when SPSC becomes zero (i.e. when the threshold PSR is reached), organic matter becomes a strong factor in WSP determinations.

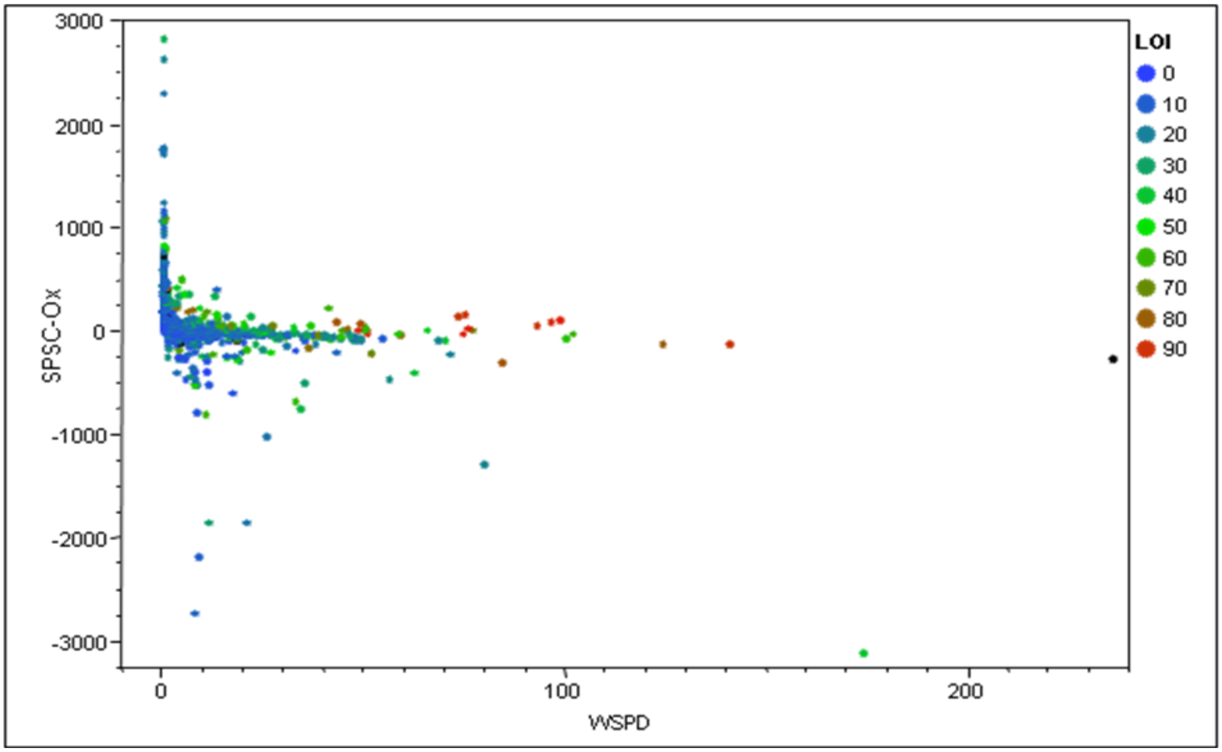


Figure 5. Bivariate Fit of Soil P storage capacity (SPSC-Ox) calculated using P, Fe and Al in an oxalate solution and water soluble P– dry (WSPD) for soils from the center and edge of wetlands, drainage ditches and adjacent uplands of the Okeechobee watershed and other locations within the southeastern USA. LOI = Loss on Ignition.

3.3 Preliminary Implications/Conclusions

- A soil-related index of nutrients may prove beneficial for sampling logistics when compared to water column sampling due to its persistence through wet and dry periods as well as less temporal variable in wetlands.
- It is necessary to refine the protocol for WSP determination for wetland soils before WSP can be used as a measure of releasable P in the soil.
- A threshold PSR for wetland soils could be used to determine a point above which additional P loads cannot be assimilated by mineral components of the soil. This would provide environmental managers the realization that any additional P removal by the wetland would have to be through biological uptake and organic matter accretion.

4 “Wet” vs “Dry” Soil Preparation Method for Water Soluble P Determination

4.1 Water Soluble P Procedure for Wetland Soils

Analyses of data from archived soils from the Okeechobee Isolated Wetlands (OIW) study revealed that the relationship between WSP performed on wet soils vs dry soils (Figure 6) was heavily dependent on the moisture content of the wet soils (Figure7). This observation means that WSP for a wetland soil (1:20 wet soil:solution) at a given location would depend on moisture conditions at the time of soil sampling. Other than that, there is no apparent relationship between the wet and dry procedures.

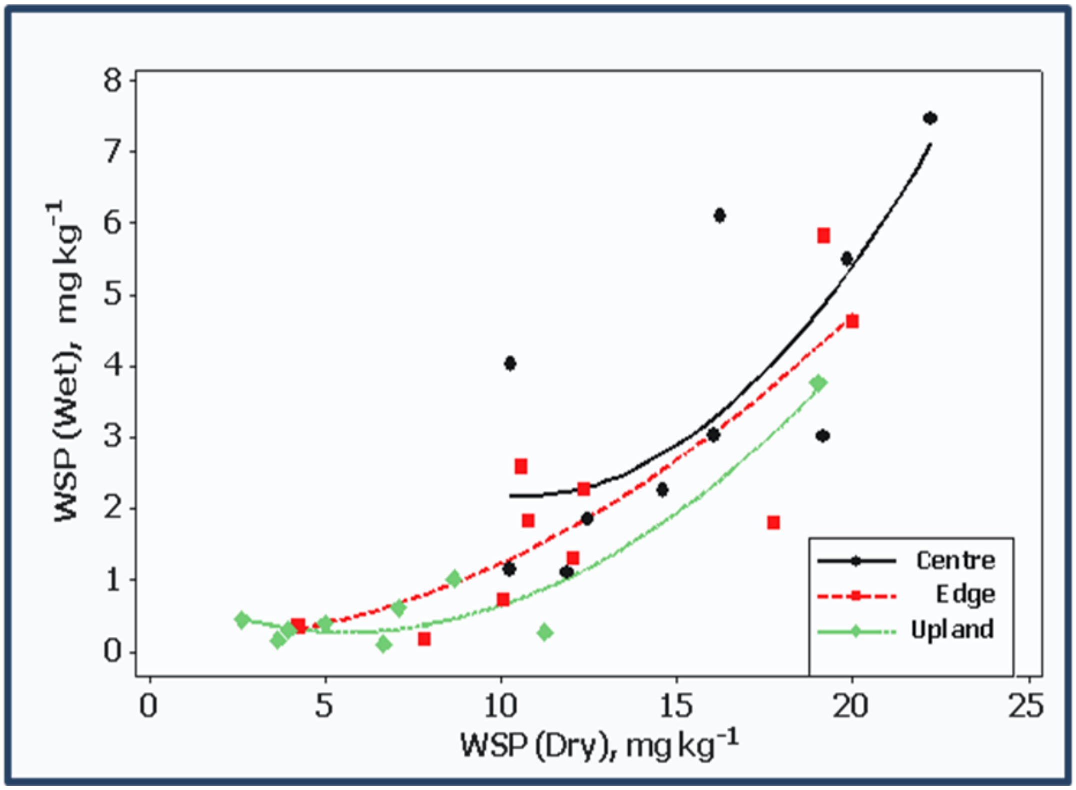


Figure 6. Relationship of WSP (Dry) with WSP (Wet) for soil samples collected from uplands, edge and center of Okeechobee Isolated Wetlands (OIW).

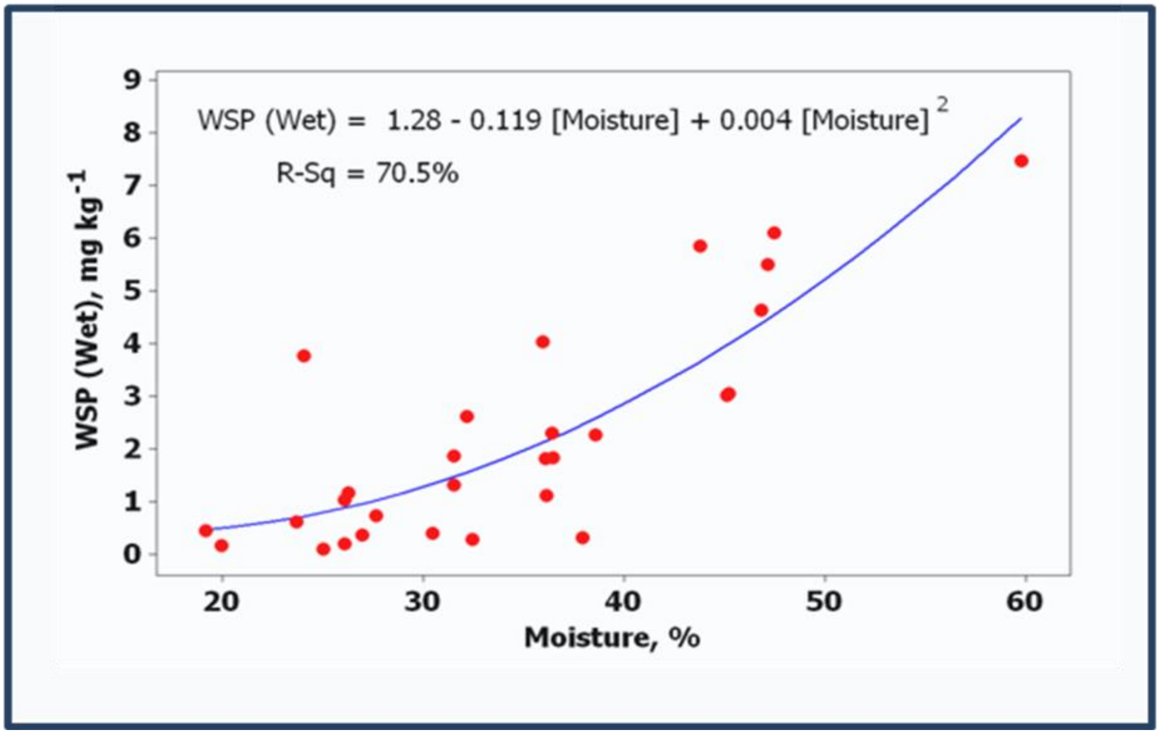


Figure 7. Relationship of WSP (wet) with soil moisture content (n=28).

4.2 Use of Different Ratios for WSP Determination for Wetland Soils

Soils used in this part of the study were collected from the following wetlands:

1. Austin Cary Forest, NE Alachua County, FL – 12 samples (6 profiles; 0-10 and 10-20 cm depths)
2. Tumblin Creek – SW Gainesville, FL12 samples (6 profiles; 0-10 and 10-20 cm depths)
3. Natural Area Teaching Laboratory SW Gainesville, FL – 12 samples (6 profiles; 0-10 and 10-20 cm depths)
4. Santa Fe – NW Alachua County, FL 12 samples (6 profiles; 0-10 and 10-20 cm depths)
5. Larson West Okeechobee County, FL– 36 samples (18 profiles; 0-10 and 10-20 cm depths)
6. Larson East Okeechobee County, FL– 36 samples (18 profiles; 0-10 and 10-20 cm depths)

Total number of samples = 120

The following different ratios were evaluated for WSP determinations for wetland soil samples:

1. **Air-dried soils**: 2 g air-dried soil was extracted with 20 mL of deionized water (DI) after shaking for one hour on an end-to-end shaker. After shaking the solution was filtered through a 0.45 μm filter and the filtrate analyzed for P using an autoanalyzer (USEPA, 1993; Method 365.1). (Procedure A)
2. **Wet soils**:
   - 2.1 Moisture content of wetland soils was determined at 70º C.
   - 2.2 Wet weight equivalent of 2 g of dry soil was weighed and extracted with 20 mL of deionized water (DI) after shaking for one hour on an end-to-end shaker. The solution was filtered through a 0.45 μm filter and the filtrate analyzed for P using an autoanalyzer (USEPA, 1993; Method 365.1). While calculating for WSP concentrations, the solution was taken as 20 mL + water in wet soil, thus each soil had a different soil to solution ratio. (Procedure B).
   - 2.3 Wet weight equivalent of 1 g of dry soil was weighed and extracted with 20 mL of deionized water (DI) after shaking for one hour on an end-to-end shaker. The solution was filtered through a 0.45 μm filter and the filtrate analyzed for P using an autoanalyzer (USEPA, 1993; Method 365.1). While calculating for WSP concentrations, the solution was taken as 20 mL + water in wet soil, thus each soil had a different soil to solution ratio. (Procedure C).
   - 2.4 The above was repeated adding the amount of water needed to maintain an exact 1:20 soil:solution ratio. (Procedure D).

The complete dataset is provided as Table 1 (Austin Cary Forest, Tumblin Creek, Natural Area teaching Laboratory and Santa Fe) and Table 2 (Larson East and Larson West). We tried the relationship of each of the above procedures for water soluble P determined for wetland soils and the WSP for the same soils under dry conditions. There were no relationships (linear or otherwise) for WSP determination for wetland soils (across a range of soils collected from various locations) using any of the three procedures and WSP determined using a 1:10 ratio on air-dried soils. Also, there was no relationship for even wet soils extracted under two different ratios (1:10 and 1:20). Thus, the moisture content at the time of soil collection and likely the organic matter in wetland soils are a source of concern when determining WSP in wetland soils. Based on results obtained in Table 1, we did not use procedure D for soils evaluated in Table 2. We did, however, continue to use procedure C on wet soils that is the regular procedure used in the Wetland Soils Biogeochemistry Lab.

Table 1. Water soluble P determinations using the procedures A, B, C and D for wetland soils from Austin Cary, Tumblin Creek, Natural Area Teaching Lab and Santa Fe locations.

Site	Profile	Depth	Moisture	WSP-Dry (A)	WSP-Wet (B)	WSP-Wet (C)	WSP-wet (D)
		cm	%	mg/kg			
Austin Cary	1	0-10	48.08	4.08	1.18	1.07	0.11
Austin Cary		10-20	15.78	1.86	1.22	1.87	0.18
Austin Cary	2	0-10	21.58	1.96	0.98	1.29	0.07
Austin Cary		10-20	16.34	0.70	0.65	1.11	0.06
Austin Cary	3	0-10	35.29	0.87	1.18	1.02	0.05
Austin Cary		10-20	19.90	0.25	0.87	0.93	0.09
Austin Cary	4	0-10	34.89	4.16	0.96	1.20	0.13
Austin Cary		10-20	13.27	0.87	0.87	1.29	0.13
Austin Cary	5	0-10	25.74	1.37	1.00	1.20	0.14
Austin Cary		10-20	17.61	0.38	0.87	0.93	0.06
Austin Cary	6	0-10	21.34	0.43	1.20	1.02	0.05
Austin Cary		10-20	15.19	0.13	0.60	0.93	0.05
Tumblin Creek	1	0-10	33.54	5.07	2.74	10.88	0.35
Tumblin Creek		10-20	16.08	3.22	3.63	17.35	0.35
Tumblin Creek	2	0-10	21.09	15.44	1.85	20.02	0.67
Tumblin Creek		10-20	23.86	13.22	2.07	11.10	0.32
Tumblin Creek	3	0-10	34.71	12.48	2.99	18.68	0.47
Tumblin Creek		10-20	19.38	11.25	2.88	8.65	0.49
Tumblin Creek	4	0-10	28.75	16.68	8.12	26.49	0.29
Tumblin Creek		10-20	26.63	10.01	6.76	19.80	0.69
Tumblin Creek	5	0-10	31.28	6.43	4.30	11.10	0.53
Tumblin Creek		10-20	33.14	7.91	3.01	6.20	0.34
Tumblin Creek	6	0-10	53.12	9.27	3.01	6.64	0.25
Tumblin Creek		10-20	31.15	12.23	4.08	7.31	0.20
NATL	1	0-10	82.13	N/A	5.39	5.30	0.29
NATL		10-20	31.73	5.81	1.60	2.18	0.11
NATL	2	0-10	81.84	21.62	1.38	2.41	0.18
NATL		10-20	44.18	7.54	2.65	4.64	0.24
NATL	3	0-10	82.45	N/A	1.38	2.18	0.09
NATL		10-20	60.11	8.28	2.94	5.04	0.15
NATL	4	0-10	74.49	29.22	1.09	3.25	0.09
NATL		10-20	37.56	5.32	0.87	1.74	0.15
NATL	5	0-10	79.84	N/A	1.98	4.10	0.11
NATL		10-20	54.50	7.54	1.27	2.18	0.09
NATL	6	0-10	69.55	8.78	0.69	2.63	0.09
NATL		10-20	19.26	2.72	0.65	2.09	0.06

Site	Profile	Depth	Moisture	WSP-Dry (A)	WSP-Wet (B)	WSP-Wet (C)	WSP-wet (D)
		cm	%	mg/kg			
Santa_Fe	1	0-10	63.92	11.49	4.10	5.53	0.40
Santa_Fe		10-20	58.83	8.03	4.48	7.62	0.24
Santa_Fe	2	0-10	42.56	6.06	2.76	10.83	0.45
Santa_Fe		10-20	61.83	11.00	3.86	7.62	0.33
Santa_Fe	3	0-10	74.22	4.08	2.25	5.30	0.15
Santa_Fe		10-20 cm	66.80	5.56	2.65	9.05	0.13
Santa_Fe	4	0-10 cm	43.55	6.80	5.84	12.62	0.51
Santa_Fe		10-20 cm	42.16	5.32	1.83	5.93	0.18
Santa_Fe	5	0-10 cm	63.24	6.06	1.31	10.83	0.29
Santa_Fe		10-20 cm	38.04	4.16	1.09	3.25	0.22
Santa_Fe	6	0-10 cm	75.18	12.97	1.54	3.70	0.11
Santa_Fe		10-20 cm	67.87	5.74	1.60	3.70	0.11

N/A = Not Available

Table 2. Water soluble P determinations using the procedures A, B, and C for wetland soils from Larson West and Larson East in the Lake Okeechobee Basin.

Site	Depth cm	Moisture %	WSP-Dry (A) mg/kg	WSP-Wet (B) mg/kg	WSP-Wet (C) mg/kg
LW-U1-S	0-10	37.2	12.59	1.56	1.17
LW-U1-S	10-20	8.5	2.43	0.84	0.65
LW-U2-S	0-10	25.8	7.73	0.84	0.13
LW-U2-S	10-20	10.0	1.70	0.66	0.13
LW-U3-S	0-10	28.7	13.62	0.62	0.13
LW-U3-S	10-20	9.7	3.91	0.48	2.74
LW-U4-S	0-10	25.2	24.80	5.18	0.65
LW-U4-S	10-20	11.2	5.08	1.20	3.78
LW-U5-S	0-10	32.9	18.62	3.37	1.17
LW-U5-S	10-20	10.1	3.61	1.02	2.48
LW-U6-S	0-10	48.0	21.57	11.33	1.17
LW-U6-S	10-20	10.1	4.49	2.11	10.57
LW-E1-S	0-10	58.5	16.72	4.10	1.17
LW-E1-S	10-20	23.4	18.92	4.10	1.43
LW-E2-S	0-10	59.0	18.64	2.47	3.26
LW-E2-S	10-20	28.1	24.51	3.91	2.21
LW-E3-S	0-10	35.0	20.79	22.90	3.78

Site	**Depth cm**	**Moisture %**	**WSP-Dry (A) mg/kg**	**WSP-Wet (B) mg/kg**	**WSP-Wet (C) mg/kg**
LW-E3-S	10-20	13.0	5.38	2.83	23.89
LW-E4-S	0-10	49.7	20.09	1.56	1.17
LW-E4-S	10-20	25.6	7.14	1.20	0.91
LW-E5-S	0-10	55.6	11.94	8.26	6.39
LW-E5-S	10-20	13.9	3.91	1.93	1.17
LW-E6-S	0-10	44.6	26.57	2.11	1.17
LW-E6-S	10-20	31.2	9.20	1.74	0.91
LW-C1-S	0-10	62.8	16.00	5.00	13.18
LW-C1-S	10-20	46.6	9.79	2.11	2.48
LW-C2-S	0-10	64.9	15.29	2.47	5.35
LW-C2-S	10-20	38.7	10.09	1.38	1.17
LW-C3-S	0-10	50.3	23.04	4.46	3.52
LW-C3-S	10-20	29.4	4.49	2.83	1.43
LW-C4-S	0-10	72.9	24.51	3.91	5.87
LW-C4-S	10-20	44.9	18.03	3.19	2.74
LW-C5-S	0-10	58.4	19.21	3.37	3.78
LW-C5-S	10-20	31.9	12.74	2.65	1.95
LW-C6-S	0-10	69.5	25.69	4.82	4.30
LW-C6-S	10-20	36.8	5.97	2.29	1.95
LE-U1-S	0-10	24.9	10.67	1.20	0.13
LE-U1-S	10-20	9.0	1.84	0.66	0.13
LE-U2-S	0-10	26.0	11.26	1.74	1.43
LE-U2-S	10-20	9.4	1.55	0.84	0.39
LE-U3-S	0-10	32.0	18.92	0.48	0.13
LE-U3-S	10-20	12.6	3.91	0.91	0.13
LE-U4-S	0-10	28.2	7.14	0.48	0.13
LE-U4-S	10-20	8.1	1.55	0.66	0.13
LE-U5-S	0-10	34.7	12.74	0.62	0.13
LE-U5-S	10-20	8.7	1.84	0.48	0.13
LE-U6-S	0-10	31.8	3.91	0.62	0.13
LE-U6-S	10-20	10.6	0.96	2.29	1.17
LE-E1-S	0-10	62.9	21.86	1.93	0.39
LE-E1-S	10-20	36.7	5.38	2.11	1.17
LE-E2-S	0-10	43.0	13.03	2.65	1.17
LE-E2-S	10-20	23.8	5.67	1.93	1.69
LE-E3-S	0-10	43.2	17.92	1.93	0.65
LE-E3-S	10-20	21.1	6.85	1.02	0.91
LE-E4-S	0-10	53.7	22.15	1.74	1.69
LE-E4-S	10-20	35.9	8.32	2.29	2.48

Site	Depth cm	Moisture %	WSP-Dry (A) mg/kg	WSP-Wet (B) mg/kg	WSP-Wet (C) mg/kg
LE-E5-S	0-10	43.5	15.38	2.58	3.00
LE-E5-S	10-20	28.2	11.85	2.03	1.69
LE-E6-S	0-10	58.5	18.62	1.02	0.91
LE-E6-S	10-20	32.3	3.91	0.48	0.39
LE-C1-S	0-10	70.0	26.57	1.20	1.43
LE-C1-S	10-20	34.3	9.20	2.21	1.95
LE-C2-S	0-10	64.2	11.85	1.02	0.65
LE-C2-S	10-20	28.4	8.03	2.29	1.69
LE-C3-S	0-10	60.7	20.39	1.38	0.91
LE-C3-S	10-20	35.2	10.09	1.31	1.17
LE-C4-S	0-10	76.0	27.45	1.56	1.69
LE-C4-S	10-20	35.0	5.38	1.64	0.91
LE-C5-S	0-10	57.2	22.15	1.20	0.91
LE-C5-S	10-20	30.0	8.03	1.93	1.17
LE-C6-S	0-10	51.8	14.80	1.02	0.91
LE-C6-S	10-20	36.8	2.43	0.84	0.91

4.3 Alternate Procedure for WSP Determinations of Wetland Soils

In order to eliminate antecedent moisture content discrepancies during WSP determinations, over 300 air-dried soil samples representative of uplands, edge and center of wetlands were incubated in centrifuge tubes under anaerobic conditions for 15 days to mimic flooded wetland conditions and normalize the antecedent moisture content. The samples were determined from the 0-10 cm depths from the following ranches within the Okeechobee Basin: Buck Island, Alderman, Lightsey, Lykes, Rafter-T, Syfrette and Williamson. The soil samples had organic matter content ranging from <1.0 to 93%. Other properties of these soils are available from the archived soils dataset that was a part of deliverable 1 and can be found under “FRESP” project.

All soils at a 1:10 soil to water ratio (3 grams of soil and 30 mL of deionized water) were purged with nitrogen prior to the incubation. The incubation set-up is shown below (Figure 8). At the end of 15 days of incubation, the soils were shaken for an hour, filtered through a 0.45 µm filter and analyzed for WSP using an autoanalyzer (USEPA, 1993; Method 365.1).

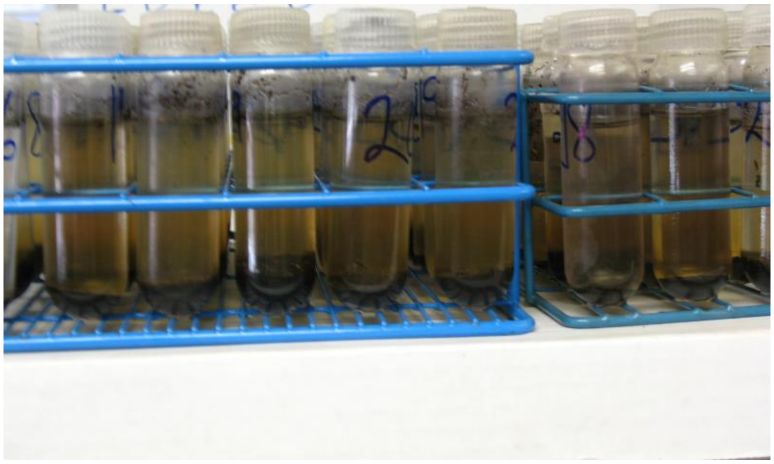


Figure 8. Soil incubation set-up for water soluble P determination for wetland soils.

4.3.1 Relationship of WSP for Wetland Soils under Dry and Incubated Conditions

The relationship between water soluble P as determined using a 1:10 soil to water ratio for dry and incubated soils belonging to the center and edge of wetlands was evaluated. This procedure was conducted to determine if a wet equivalent WSP could be determined on previously dried soils. The relationship is linear (Figure 9) suggesting that the incubation procedure could be suitable for determining WSP wetland soils. However, this is not a practical procedure for determining WSP on a regular basis and it is simpler to determine WSP for wetland soils under dry conditions. Further, a comparison between incubated soils and field collected soils under similar antecedent moisture conditions should be conducted to verify that the incubation WSP results are representative of field conditions.

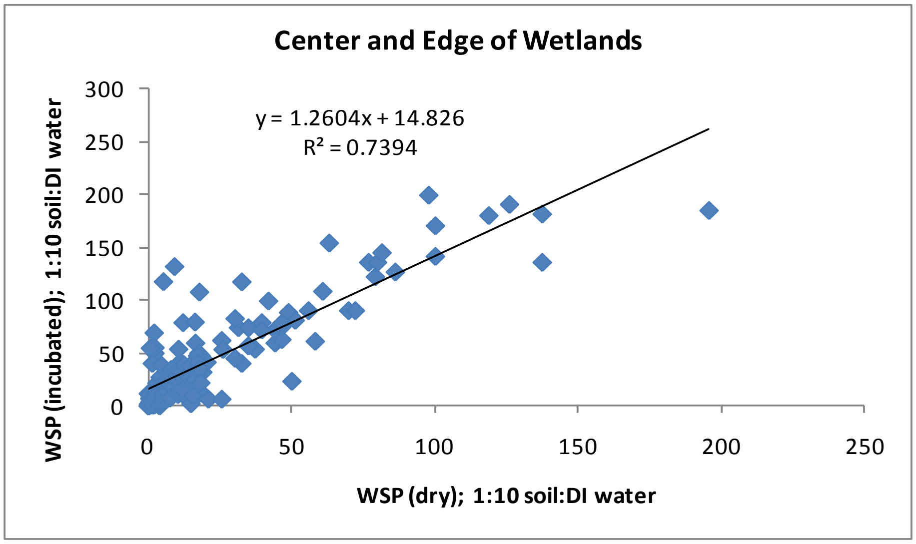


Figure 9. Relationship between water soluble P (WSP) determined on dry wetland soils and under incubated conditions.

4.4 Effect of Soil Preparation on WSP Results

Implications of the Methods used for WSP Determinations for Wetland soils:

1. Comparison of WSP as determined using a 1:10 ratio of air-dried soils to deionized water and various wet soil to DI water extraction ratios used indicated that there were no relationships suggesting that it is difficult to obtain a WSP procedure for wetland soils that is **applicable across all wetland soils.**
2. WSP determined under wet conditions is affected by the moisture content at the time of soil sampling and even wet soils when extracted at different ratios do not give comparable values.
3. Results also suggest that WSP under incubated conditions is slightly higher (1.2 times higher) than values obtained on a 1:10 air dried soil. In order to avoid the moisture effect, it is suggested that WSP for wetland soils be conducted on air-dried soils.
4. WSP determined under air-dry conditions are more likely to give comparable values for a soil at a given location irrespective of the moisture content at the time of soil sampling compared to wet soil extraction.
5. It is also likely that WSP determination on air-dry soils below the change point would be representative of the P release potential of that soil. However, determination of WSP on soils (irrespective of the procedure used) with PSR values above a threshold will be dependent not only on the moisture content, but likely also on the organic matter of the soil (Figure 5) and the solubility of the P source.
6. Water soluble P determination for wetland soils needs a careful re-evaluation before any one procedure can be used that is applicable across all wetland soils.

5 Development of Soil Nutrient Index Criteria

5.1 Field Sampling Protocol

The sampling protocol proposed here is for the purpose of collecting soils to be used in testing the wetland soil indicator index. For this reason, single soil samples (not composite samples) are recommended. If the goal of a soil sampling effort were for the purpose of overall site description or broader water column nutrient interpretation, a soil sampling scheme that would include spatial compositing of soils may be more appropriate to reduce spatial heterogeneity of the soils while also limiting the number and cost of soils being analyzed in the laboratory.

In the sampling location section below we describe the protocol we have used in past sampling efforts where the focus of sampling was to characterize the interaction between surface soils and surface water. However, we also discuss the benefits of sampling deeper in the soil profile which provides an opportunity to evaluate soil/porewater P interactions in the groundwater. Sampling to greater depths in the soil profile is more costly and time consuming but provides a more holistic assessment of the total soil phosphorus storage capacity as well as likely movement of P in the surficial groundwater.

Based on some recent analysis of the SPSC concept for heavily P-impacted wetland soils, we found that sampling to a meter depth or to the spodic horizon (if such a horizon is present) would be needed to assess P leaching through wetland (Figure 10) or ditch soil (Figure 11) profiles. Other characteristics of these soils are given in Table 3.

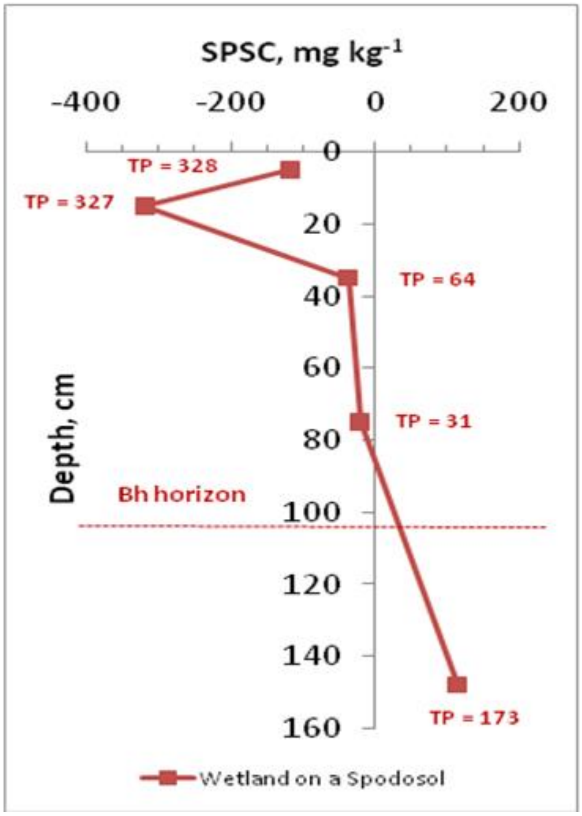


Figure 10. Soil P storage capacity (SPSC) with depth in a soil profile located in a wetland in the Lake Okeechobee Basin. The upper boundary of the spodic horizon is at 105 cm. Total P (TP) values corresponding to each SPSC value is also indicated.

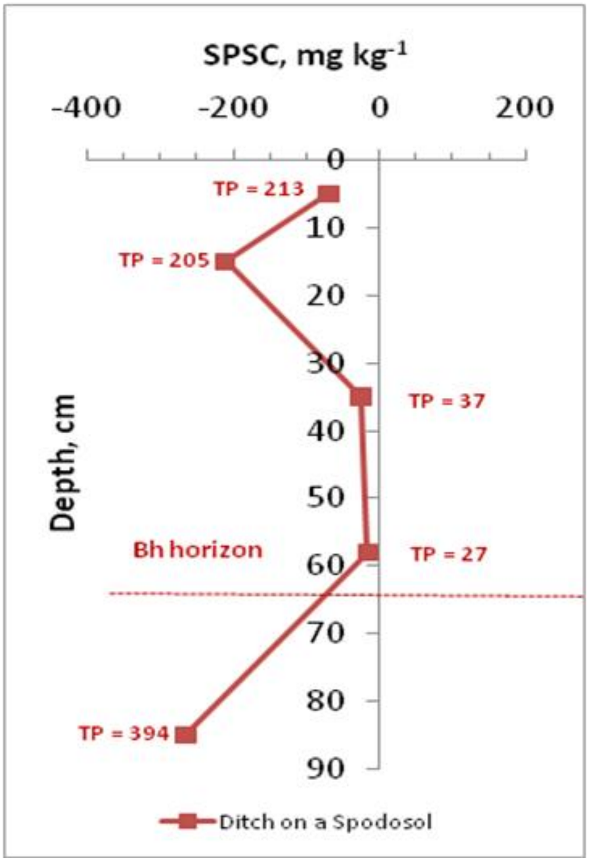


Figure 11. Soil P storage capacity (SPSC) with depth in a ditch located in the Lake Okeechobee Basin. The upper boundary of the spodic horizon is at 65 cm. Total P (TP) values corresponding to each SPSC value is also indicated.

Table 3. Soil characteristics of wetland (Figure 10) and ditch (Figure 11) soil samples collected to a depth of at least 1 m.

Profile #	Depth	LOI	WSP	TP	M1-P	M1-Al	M1-Fe	PSR	SPSC †
	cm	%			mg/kg				mg/kg
Wetland soil	0-10	6.73	45.13	328	124.8	57	6	1.80	-153.2
	10-20	4.41	93.11	327	327.2	70	8	3.86	-414.3
	20-50	1.84	35.53	64	39.3	16	3	1.91	-48.4
	50-125	1.55	9.31	31	21.0	7	2	2.29	-26.1
	125-170	3.11	ND	173	16.7	1142	9	0.01	149.3
Ditch soil	0-10	10.94	59.52	213	73.0	37	2	1.67	-89.3
	10-20	13.36	59.52	205	219.0	68	3	2.73	-274.2
	20-50	0.43	8.11	37	26.6	13	2	1.69	-32.5
	50-65	1.46	12.19	27	16.7	6	2	2.14	-20.7
	65-105	3.49	153.08	394	331.9	582	2	0.50	-344.4

ND = Below the detection limit of the instrument; †Threshold PSR used = 0.1.

5.1.1 Sampling Location

During previous sampling efforts, three zones were sampled within each wetland of interest: a wetland center zone, a wetland edge zone, and an adjacent upland zone (Figure 12). The upland zone was approximately 50-75 meters landward of the “wetland” edge (“wetland” in this sense is not based on a legally delineated wetland boundary, but instead a general indication of the wetland edge based on the distribution of plant species where the influence of flooding is sufficient to shift the vegetative species composition. In most of the improved pastures sampling conducted in the Okeechobee basin, the “wetland” edge was characterized as the point at which bahiagrass was no longer the dominant species present. The edge sampling zone was typically 1/3 the distance between the upland wetland edge and the waterward wetland edge or the center of the wetland if there was no open water. In most of the pasture sampling conducted in the Okeechobee basin the edge zone sample was collected somewhere within the *Juncus effuses* dominated zone of the wetland. The center zone of the wetland was sampled 2/3 of the way between the edge wetland zone and the open water edge or center of the wetland. Vegetation at the center zone sampling location often varied depending on time of year and level of grazing, but was almost always dominated by long hydroperiod wetland species. Typically three or four soil cores were collected within each zone at equidistant points around the wetland or along one side of the wetland depending on size. These cores were then composited by depth (0-10cm and 10-20cm). In addition, soil cores were also often taken from ditches discharging from a wetland or found within a asture.

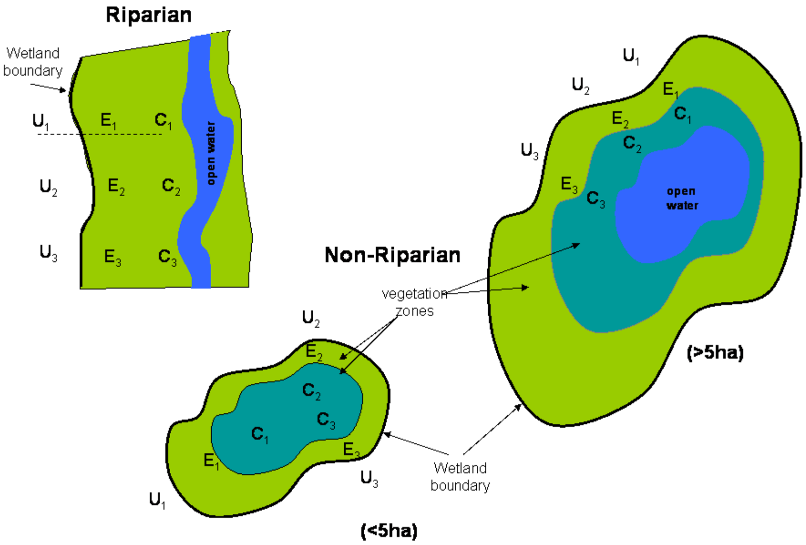


Figure 12. This figure depicts the strategy used in previous studies to sample soils from the center and edge zones within a wetland and from the upland zone adjacent to riparian and non-riparian wetlands.

5.2 Soil Sampling Protocol (depth, preservation, etc)

1. Depth of soil sampling would depend on the purpose the criteria are used for. Our current work concentrated on a maximum depth of 20cm. Typically, soils are collected using a 7-10 cm diameter polycarbonate coring tube, but any volumetric sampling device will work. Analysis for various soil parameters needs a minimum of 500g dry mass of soils. If the soils are mineral soils, one core volume will be sufficient. If however, the soils are high in organic matter content, three cores will be required to achieve the needed soil sample size. If composite cores are necessary, the three cores should be collected within a one square meter area.
2. If deeper soil cores are required then an auger may be used to obtain soil samples above the water table.
3. Soils should be transferred to 1 gallon plastic bags and labeled with the following: Location name (Site ID and zone if applicable); depth of soil sampling, date and time as well as the person who collected sample.
4. Soil samples should then be immediately placed in a cooler on wet ice ($4^{o}C$).
5. Samples should be delivered to the laboratory as soon as possible.

5.3 Phosphorus Saturation Ratio and SPSC Calculations

A generalized calculation for the P saturation ratio (PSR) of a soil is:

$$PSR = (\text{extractable-P}/31) / ((\text{extractable-Fe}/55.8) + (\text{extractable-Al}/27))$$

and for the soil P storage capacity (SPSC) is:

$$SPSC = (\text{Threshold PSR} - PSR_{soil}) * \text{Extractable } (Fe + Al) * 31 (mg/kg)$$

where Fe and Al are expressed in moles.

The extractable P, Fe and Al referred to could be in Mehlich 1 (Nair et al., 2004), Mehlich 3 (Nair et al., 2004) or possibly a 1*M* HCl solutions; the latter as an extractable P form will be evaluated during the course of this project. However, correction factors may be needed when using an extractant other than oxalate which is was the original extractant used for determining PSR of soils (Breeuwsma and Silva, 1992).

5.4 Statistical Determination of the Threshold PSR

The relationship between PSR (calculated using any one of extractants mentioned above) and WSP was modeled as a segmented line (Eq 1), with parameters estimated using non-linear least squares. The change point (d_0) in the fitted segmented-line model was directly estimated. To ensure that the two line segments joined at the change point, the slope of the left-hand line is estimated as a function of the change point and other model parameters (Eq 2). Standard errors were estimated from the Fisher information matrix and confidence intervals are constructed using these standard errors and an appropriate t-distribution critical value. Computations were performed in SAS (© 2001, SAS Institute, Inc., Cary, NC, Version 8.1) using a NLIN procedure.

$$\mathrm{WSP} = \begin{cases} a_0 + b_0\mathrm{PSR} & \mathrm{PSR} \le d_0 \\ a_1 + b_1\mathrm{PSR} & \mathrm{PSR} \ge d_0 \end{cases} \qquad (1)$$

$$b_0 = \frac{(a_1 - a_0) + b_1 d_0}{d_0} \qquad (2)$$

5.4.1 Measure of P Release from a Wetland Soil

The change point is an indicator of the PSR value at which P release from the soil increases exponentially. Water soluble P is probably the simplest and most easily determined parameter for assessing P release. For upland soils, WSP extraction is performed on air-dry soils. We hypothesized that WSP for wetland soils may be better performed on wet soils. However, it appears that WSP determination is affected by both the moisture content and the total C in the soil. We will probably need additional research to resolve this unforeseen fundamental issue of determining which WSP extraction method best represents actual P release characteristics in wetlands and why wetland soil characteristics are causing results to be so variable (Section 4.2). However, until a procedure for determining WSP for wetland soils is finalized, WSP on air-dried soils would likely be the better indicator of P release compared to any other extractant. Other researchers working on wetland soils (Dell'Olio et al., 2008) also determined WSP on air-dried soils using a 1:10 soil to water ratio as we have done. The "change point" is not expected to change whether WSP is performed on wet or dry soils; any changes in rate of release of P based on the procedure for determining WSP (dry vs wet) will impact the slope of the line after the change point. Maguire and Sims (2002) and Hooda et al. (2000) indicated that WSP is a better predictor for P loss in runoff and leaching than Mehlich 3-P (or any other standard soil tests) which supports our choice of WSP determined on air-dried soils as the best predictor of releasable P available at this time.

An additional feature that has not been brought into discussion so far is the effect of the P source in the wetland soil. The P source has been shown to produce great variability in the P release potential (Chrysostome, 2007a), particularly after the change point. Therefore, even if a good relationship could be developed for a WSP/PSR relationship (after the threshold PSR) for a given P source (such as beef pastures in this study), it does not mean that the relationship (regression equation) would be applicable across wetlands impacted with different P sources. Again, the method in determining WSP will have an impact on the P release from the soil. Note, however, that the threshold PSR is not site-specific, but should be applicable across all soils. The SPSC, on the other hand, has the ability to predict if and when a soil becomes a P source. An identical PSR value for two different soils (> threshold PSR of 0.1) does not mean that both soils are at equal risk for P loss. Please refer to the draft Fact Sheets attached for more details on the two concepts. These Fact Sheets are currently being modified based on comments from our Extension personnel and will be uploaded as EDIS publications when changes are complete.

In order to arrive at a change point for wetland soils, we determined WSP, Mehlich 1-P, Fe and Al as well as Mehlich 3-P, Fe and Al on air-dried soils. All determinations for P, Fe and Al in Mehlich 1 and Mehlich 3 solutions were performed on an ICAP as it is an often-used (and easily available) procedure in the US for environmental evaluation of P risk (McDowell and Sharpley, 2001; McGuire and Sims, 2002; Dell'Olio et al., 2007). We analyzed over 300 soil samples from various wetland locations within the LOB (FRESP project) for which data were already available for 1 *M* HCl- P, Fe and Al (see attached). The samples were determined from the 0-10 cm depth from the following ranches within the Okeechobee Basin: Alderman, Buck Island, Lightsey, Lykes, Rafter-T, Syfrette and Williamson. These samples were then sorted by location and only wetland soils (164 samples) were included in the change point determination (Figure 13).

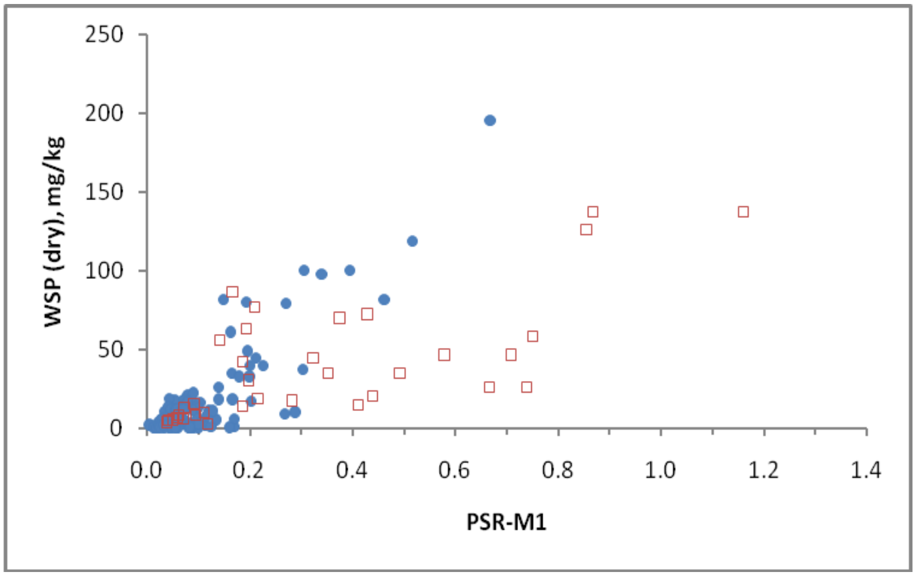


Figure 13. Relationship of water soluble P (WSP) on air-dried soils vs PSR calculated using Mehlich 1-P, Fe and Al (PSR_{M1}) for wetland soils from various locations (Alderman, Buck Island, Lightsey, Lykes, Rafter-T, Syfrette and Williamson) within the Lake Okeechobee Basin (closed circles represent soils from the various locations; open squares represent Buck Island Ranch soils.

A change point could not be statistically detected using all the selected soils. However, when soils of the Buck Island Ranch (open red squares in Figure 13) were removed a discrete change point was obtained at a PSR of 0.11 (Figure 14) with a confidence interval between 0.06 and 0.16.

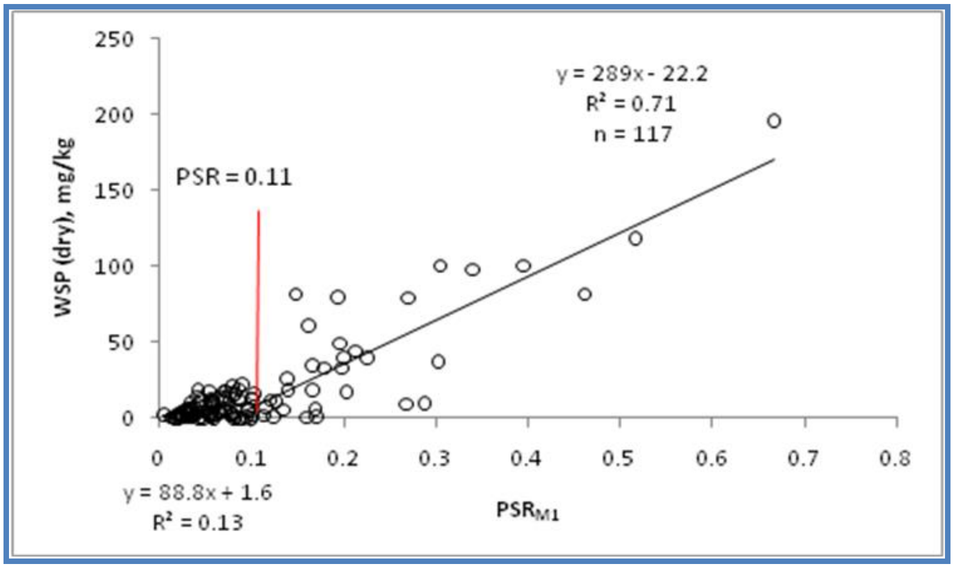


Figure 14. Relationship of water soluble P (WSP) on air-dried soils vs PSR calculated using Mehlich 1-P, Fe and Al (PSR_{M1}) for wetland soils from various locations (Alderman, Lightsey, Lykes, Rafter-T, Syfrette and Williamson) within the Lake Okeechobee Basin. Buck Island Ranch soils were excluded.

Non-detection of a change point for a given group of soils is not uncommon. McDowell and Sharpley (2001) could not detect a change point in a WSP/Mehlich 3-P relationship when WSP was determined on a 1:5 soil:solution ratio after 24 hours of shaking. However, a change point could be detected for the same soils when the shaking time for WSP was reduced to 0.5 hours. Hesketh and Brooks (2000) reported fairly large effects on the concentration of P extracted with varying soil to solution ratio in a 0.01 *M* $CaCl_2$-P/Olsen P relationship. However, the change point was unaffected by the soil:solution ratio. The authors concluded that "the change point could be a constant soil parameter describing the potential for P movement in drainage water." Based on these observations, the change point is expected to remain a constant whether WSP is determined on air-dried soils or on wet soils. Any changes to the P release will occur only after the change point (i.e. when the high energy sorption sites are exhausted). The other confounding factor is the solubility of the P source which would be affected by the soil:solution ratio as well; the change in the linearity of the slope of the line after the change point would be different for soils impacted by different P sources even if they are extracted using the same soil to solution ratio. Again, these confounding factors would not have had an effect on the change point.

5.5 Recommended Value to be used as a Threshold PSR for Wetland Soils

Based on information gathered during the course of this project our present recommendation is to use 0.1 as the threshold PSR for wetland soils, with a 95% confidence interval of 0.06 to 0.16.

6 Validation of the Soil Nutrient Index Criteria

For validation of the threshold PSR of 0.1 for wetland soils by calculating the SPSC and relating SPSC to extractable P (Section 1.1.2), we collected additional soil samples from the following locations:

1. Pelaez Ranch (58 samples)
2. Okeechobee isolated wetlands (OIW) at the Larson Ranch (72 samples)
3. Samples from the Okeechobee Basin collected by Florida Department of Agriculture and Consumer Services (FDACS) / South Florida Water Management District (District) (57 samples)
4. Samples from locations outside the Lake Okeechobee Basin (48 samples)

Total number of samples = 235. The various parameters we evaluated are given in the attached spreadsheets.

6.1 Water Soluble P Determinations

The newly collected soil samples provided the opportunity to evaluate and explain various problems noted during the determination of a WSP procedure that can be used across all wetland soils. The discrepancies observed while comparing WSP under wet and dry conditions also suggested that any “water parameter” currently used as a measure of releasable P from a wetland (such as overlying P in a wetland or porewater P concentrations) would likely not be a good predictor of the P that is likely to be lost from the wetland. An obvious reason for the discrepancy noted would relate to the solubility of the P source (Harris et al., 2007; Nair et al. 2010) since different P sources with the same total P will release P at different rates.

We looked into WSP determinations under wet and dry conditions, separating the data by the four locations of soil samples noted above; the relationships for soils of the Okeechobee Basin are shown in Figures 15 and 16. The relationship between WSP under wet and dry conditions depend on the location of soil sampling and therefore, in addition to the amount of P, very likely related to the P source as well. The differences in the slopes of the lines suggest that P release from a soil is dependent on various site-specific conditions including the source of the P.

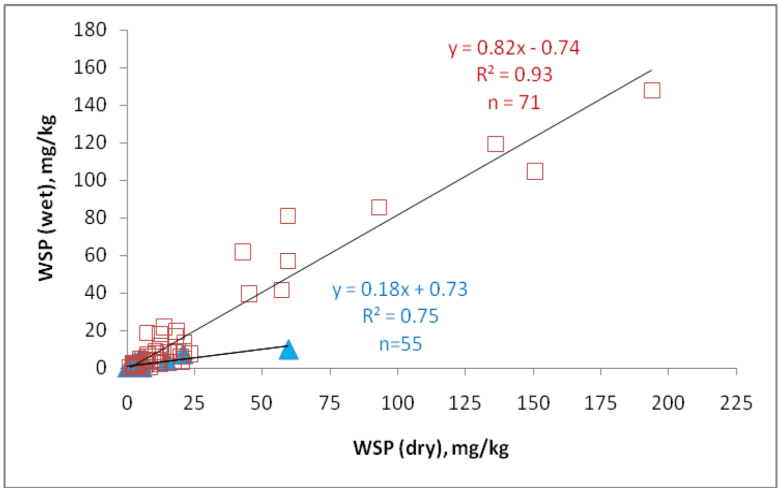


Figure 15. Relationship of WSP determined under wet and dry conditions for 0-10 and 10-20 cm depths at Pelaez Ranch (open red squares) and soils collected by FDACS/District (blue triangles) with one outlier removed.

The slope of the line in the WSP wet vs dry relationship for Pelaez Ranch soils is steeper than that for either the samples collected by FDACS/District (Figure 15) or the samples of the Okeechobee Isolated Wetlands (n=72; Figure 16). Also note the huge variation in P concentrations at the various sites.

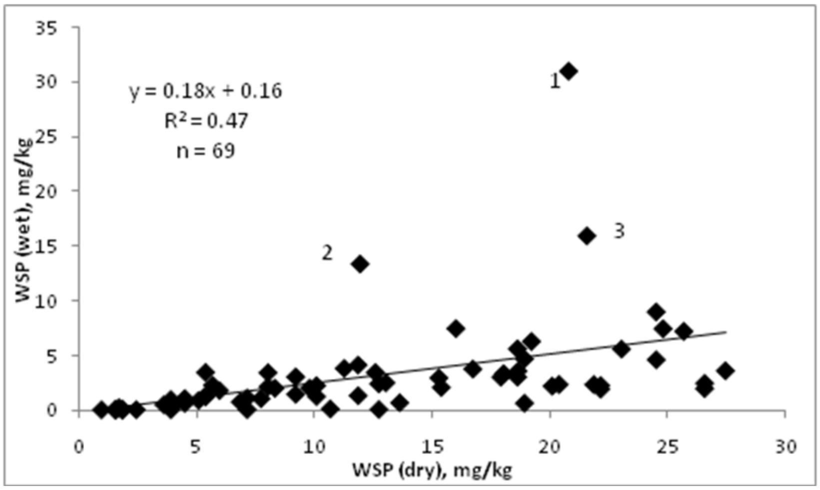


Figure 16. Relationship of WSP determined under wet and dry conditions for 0-10 and 10-20 cm depths for soils of the Okeechobee Isolated Wetlands. Locations marked 1, 2 and 3 are outliers. Note low WSP compared to other sites.

Based on all information we have so far, we believe that WSP conducted on an air-dried soils represent the most reliable value for WSP determination for a wetland soil. The moisture content of a soil sample at the time of its collection would vary substantially and reproducible values from the same location would be difficult if WSP determinations are on wet soils.

6.2 Relationship of SPSC with Water Soluble P

For evaluation of SPSC with releasable P, we considered soils from Pelaez Ranch and those collected by FDACS/District with a wide range of P concentrations and minimal confounding factors based on observations of WSP concentration relationships with wet and dry soils (Figure 15). For calculation of SPSC, the following recommended equation (Nair et al., 2010) was used where P, Fe and Al are all values in a Mehlich 1 solution.

$$\text{SPSC} = (\text{Threshold PSR}_{\text{M1}} - \text{PSR}_{\text{M1}}) * \text{Mehlich 1- (Fe + Al)} * 31 * 1.3 \text{ (mg/kg)}$$

where Fe and Al are expressed in moles.

The relationship of SPSC calculated using a threshold PSR value of 0.1 and WSP as determined on air-dried soils of Pelaez Ranch and the samples collected by FDACS/District is given in Figure 17.

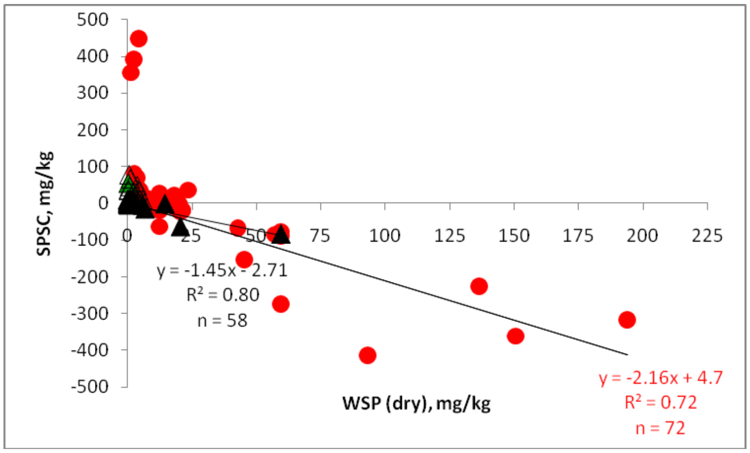


Figure 17. Relationship of SPSC calculated using a threshold PSR value of 0.1 and WSP as determined on air-dried soils for Pelaez Ranch (red circles) and FDACS/District samples (black triangles). Regression equations (red for Pelaez Ranch and black for FDACS/District samples) are for soils with negative SPSC. When SPSC is positive WSP is a minimum.

The relationship shows that when SPSC is positive (>0), the soil is a P sink and P loss from the soil is a minimum. We specify "minimum" rather than "zero" to account for any artifacts of the analytical procedure (instrument detection limits, duplicate differences within acceptable values, etc.) that will not always result in an exact zero value. When SPSC becomes negative (<0), the wetland soil is a P source. The Larson sites (Okeechobee Isolated

Wetlands) have low WSP (Maximum < 30 mg/kg) and therefore would cluster in or near zero SPSC in Figures 17 and 18 with low releasable P. Likewise, all samples collected outside the LOB have very little releasable P as well. However, it is suggested that additional sampling to a greater depth be done at these sites to verify that these soils are not an environmental problem. The P could have moved vertically through the soil profile as illustrated in Figures 10 and 11. Further, we had collected single soil samples (*vs* composited samples) for the purpose of developing and validating the protocol. When used in actual risk assessment, it is recommended that multiple soil samples are taken at any given location to avoid misinterpretation of results due to heterogeneity in the soil sample collected. In spite of thorough mixing of the soils once brought into the lab, it is always possible that the soil sample will not be homogenous, particularly when the moisture content is very high. Depending on the purpose of the soil sampling, compositing samples may be a desirable option. Application of the PSR and SPSC concepts is discussed in a later section.

Since SPSC in the relationship SPSC/WSP relationship in Figure 17 was calculated using a threshold PSR of 0.1, it suggests that the threshold PSR of 0.1 as determined for upland soils (Nair et al., 2004), can be used for wetland soils as well. The confidence interval for the upland soils was 0.05 to 0.15 and for wetland soils 0.06 to 0.16 at the 95% confidence interval. For calculation of SPSC and for all modeling purposes, the threshold PSR value of 0.1 may be used for both upland and wetland soils unless additional research indicates an alternate value be used for wetland soils.

We re-visited the SPSC/WSP (dry) relationship for all soils (including the Buck Island Ranch samples) used in threshold PSR development for wetland soils (Section 5.4.1). While the Buck Island Ranch (BIR) samples were not included in obtaining the change point, they were included in the SPSC/WSP (dry) relationship (Figure 18) with SPSC calculated using a threshold PSR of 0.1 for wetland soils. Section 5.4.1 discusses instances where change points may not be detected for some soils within a group of soils though the change point will still be applicable for those soils. When SPSC is less than zero (i.e. when the soil is a P source), P is released from the soil. The regression equation in Figure 18 is for all soils of the eight beef ranches (including Buck Island Ranch) in this study.

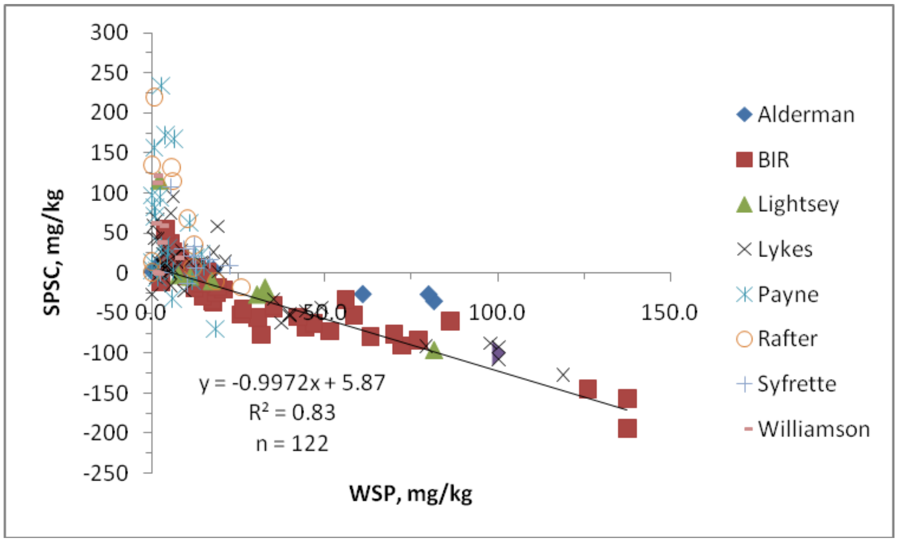


Figure 18. Relationship of SPSC calculated using a threshold PSR value of 0.1 and WSP as determined on air-dried soils for wetland soils of the Lake Okeechobee Basin (Alderman, Buck Island Ranch, Lightsey, Lykes, Payne, Rafter, Syfrette and Williamson) as documented under FRESP project in the attached spreadsheet.

Figure 19 illustrates how the confidence interval limits around the change point affect P release when SPSC is a P source (SPSC<0). This is the same data in Figure 18, i.e., the data of soils from the Lake Okeechobee basin (FRESP project soils). The graph suggests that a threshold PSR between 0.06 and 0.16 may not make a substantial difference in P release patterns of wetlands soils and therefore it is reasonable to use the midpoint PSR value of 0.1 for wetland soils with a confidence interval of 0.06 to 0.16, the same value as suggested for upland soils (Nair et al., 2004).

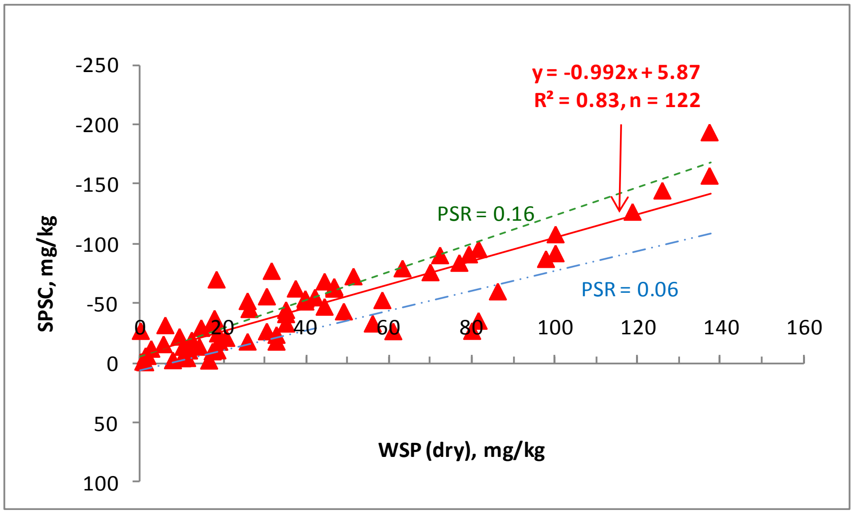


Figure 19. Phosphorus release from wetland soils of beef ranches when SPSC<0. Also indicated are SPSC values calculated using the most restrictive (0.06) and conservative (0.16) confidence intervals for beef ranches in the Lake Okeechobee Basin in this study.

6.3 Relationship of SPSC to the Capacity Factor

The capacity factor (CF) is SPSC when calculated using P, Fe and Al in a soil test solution (Mehlich 1, Mehlich 3 or 1 *M* HCl). Since a soil can have only one true SPSC, the capacity factor needs to be calibrated against an oxalate-derived SPSC and a calibration factor added to the CF equation.

6.3.1 Capacity Factor Calculated using Mehlich 3 and 0.1*M* HCl-P, Fe and Al

6.3.1.1 Capacity Factor from Mehlich 3 parameters

The Capacity Factor using P, Fe and Al in a Mehlich 3 solution (CF_{M3}) can be calculated as follows:
CF_{M3}= (Threshold PSR_{M3} – PSR_{M3}) * Mehlich 3- (Fe/56 + Al/27)* 31 (mg/kg)
where Fe and Al are in moles.

At this time, we do not have an equation for calculating SPSC using Mehlich 3-P, Fe and Al as discussed earlier. We therefore calculated CF_{M3} and evaluated the relationship of SPSC with CF_{M3} (Figure 20) for the newly collected Pelaez Ranch soils which had the best spread of P concentrations among all the soils collected recently. The relationship shows linearity for positive and negative capacities though the slope of the equation is different due to the difference in solution composition and extractability of P and metals by the two solutions particularly when SPSC is very high. This aspect of the study needs additional evaluation after the final equation using Mehlich 3-P, Fe and Al for SPSC calculations is obtained as a part of an ongoing project with FDACS.

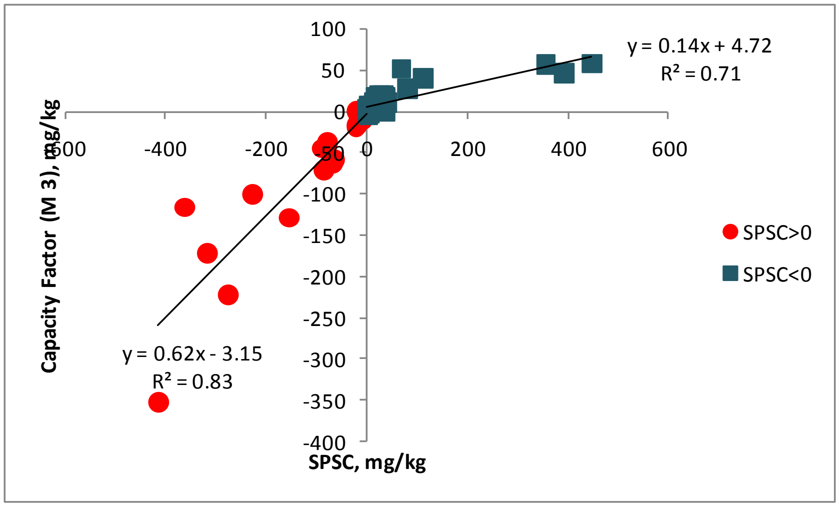


Figure 20. Relationship of the capacity factor calculated using P, Fe and Al in a Mehlich 3 solution and SPSC calculated using Mehlich 1-P, Fe and Al for the newly collected Pelaez Ranch samples (n = 72) which had the best spread of P concentrations among the more recently collected soils from the Lake okeechobee Basin.

The data was superimposed on a relationship of the CF $_{M3}$ vs SPSC of soils used in developing the threshold PSR (FRESP project soils; Figure 21) and Figure 22 verifies that the threshold PSR of 0.1 is applicable for SPSC and CF_{M3} calculations. Note that the CF_{M3} was calculated assuming a threshold PSR of 0.1. This threshold value is tentative and will be modified when the data is further evaluated for upland and wetland soils.

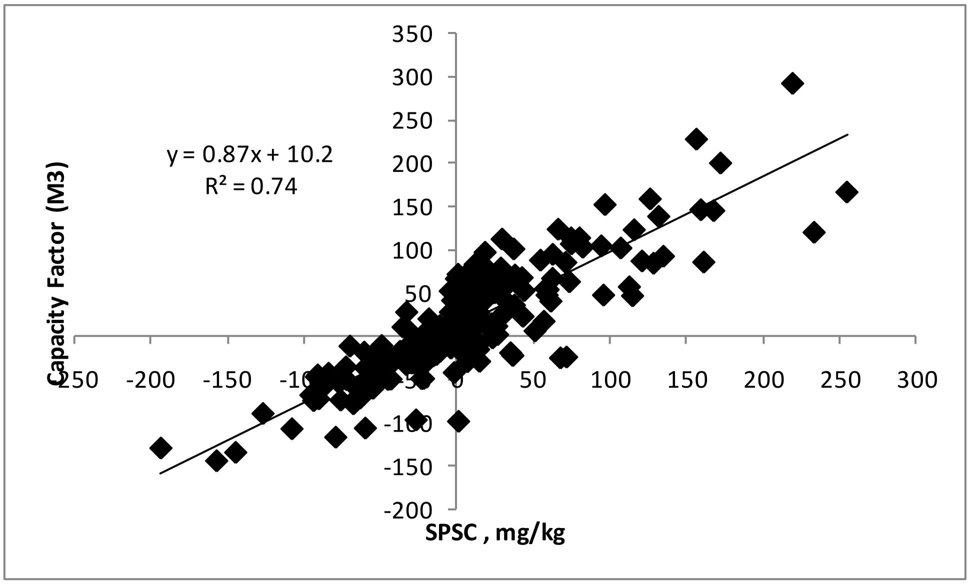


Figure 21. Relationship of the Capacity Factor calculated using Mehlich 3-P, Fe and Al with SPSC for soils representative of various locations in the Lake Okeechobee Basin (n = 156; 4 outliers removed).

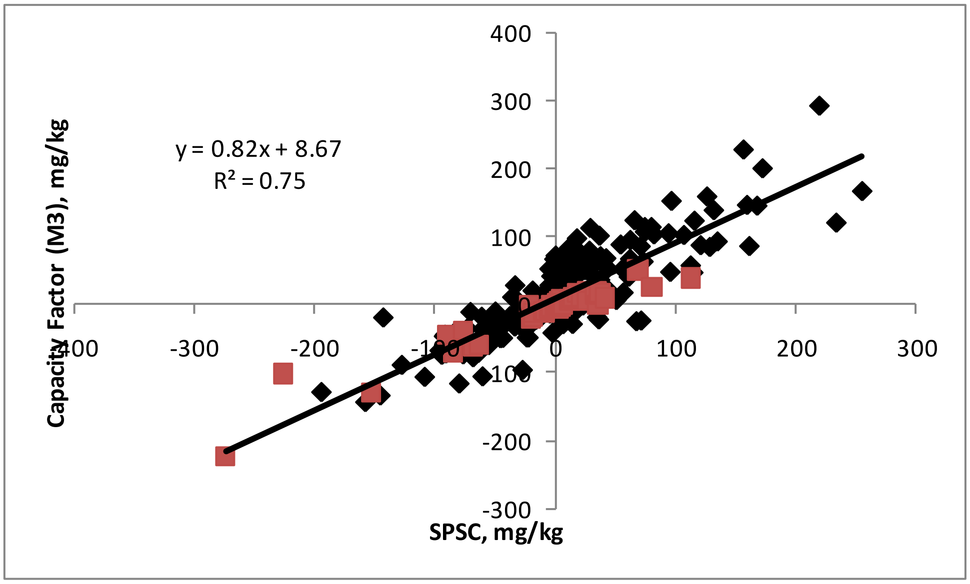


Figure 22. Relationship of the Capacity Factor calculated using Mehlich 3-P, Fe and Al with SPSC for soils representative of various locations in the Lake Okeechobee Basin with data from Pelaez Ranch (red squares) superimposed. Data from the high positive storage capacity (CF > 300 mg/kg, Figure 20) locations within Pelaez Ranch are not included in this graph. Total number of samples, n = 224.

6.3.1.2 Capacity Factor Calculated using 1 *M* HCl -P, Fe and Al

This project also provided an opportunity to evaluate the potential of a 1 *M* HCl solution as a possible extractant for the calculation of SPSC. This solution is used routinely in the Wetlands Biogeochemistry Lab as a single extractant for the determination of inorganic P in soils.

CF_{HCl}= (Threshold PSR_{HCl} – PSR_{HCl}) * HCl- (Fe + Al)* 31 (mg/kg)
where Fe and Al are in moles.

We calculated the CF_{HCl} for all archived wetland soils of the FRESP project for which the data were available. Note that the CF_{HCl} was calculated assuming a threshold PSR of 0.1. This threshold value is tentative and will be modified when as additional information becomes available. The relationship (Figure 23) suggests that it could be possible to use this extractant, but would need additional evaluation to figure out why some soils have unusually high CFs when 1 *M* HCl is used as the extractant.

Dunne et al. (2006) showed a 1:1 relationship between Fe and Al in an oxalate and 1*M* HCl solution and proposed that a 1*M* HCl solution would be a preferential extractant for Fe and Al than oxalate since the oxalate procedure is cumbersome and not an easy extractant to work with.

We do not have a conversion factor for calculating SPSC using 0.1*M* HCl- P, Fe and Al. The relationship between CF_{HCl} and SPSC (Figure 24) shows that HCl appears to overestimate SPSC particularly at the higher SPSC values. On-going research at our laboratories (Chakraborty et al., 2010) suggests that SPSC calculated using oxalate parameters may be underestimating the capacity of a soil to hold P, when the concentrations of Fe and Al are high, i.e. when positive SPSC is high. We tested CF_{HCl} for wetland soils as a function of capacity factor calculated using M1-P, Fe and Al for wetland soils (CF_{M1}) for the same range of SPSC for upland soils (maximum SPSC = 200 mg/kg). The equation SPSC = 1.14 [CF_{HCl} + 49.5] was obtained for 116 wetland soils though the R^2 value was only 0.4. Additional research must be conducted to enable the use of 1 *M* HCl to calculate SPSC if we are referencing PSR and SPSC calculations to oxalate- P, Fe, and Al.

The relationship between SPSC as obtained by oxalate and using Mehlich 1-P, Fe and Al (with a 1.3 correction factor, i.e CF_{M1}*1.3) for Florida wetland soils that were a part of the Mukherjee et al. (2009) paper for the lower range of Fe+Al (below SPSC=100 mg/kg) gave the following relation: SPSC [calculated using M1-P, Fe and Al] = 1.1 [SPSC calculated using Ox-P, Fe and Al] - 20.9; R^2 = 0.87; n = 75. SPSC calculated using oxalate or Mehlich 1- P, Fe and Al gives an almost 1:1 relationship for wetland soils as well, particularly when SPSC is < 100 mg/kg (includes both positive and negative SPSC).

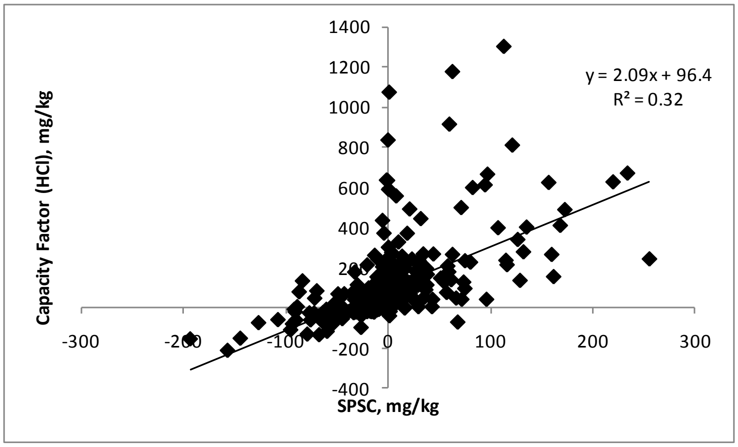


Figure 23. Relationship of the Capacity Factor calculated using 1 *M* HCl-P, Fe and Al with SPSC for wetland soils representative of various locations in the Lake Okeechobee Basin.

A plot of CF_{HCl} for wetland soils and SPSC calculated using oxalate P, Fe and Al for upland soils vs CF calculated using Mehlich 1-P, Fe and Al (i.e. without any correction factor gave the relationship in Figure 24. The conversion factor thus obtained is close to the 1.3 value we are currently using. In plotting this graph we assume that for wetland soils, the relationship between Fe and Al extracted by a 1*M* HCl solution is similar to that extracted by oxalate (Dunne et al., 2006). Though results are promising, additional work needs to be conducted if a 0.1 *M* HCl solution is to be used for SPSC calculations.

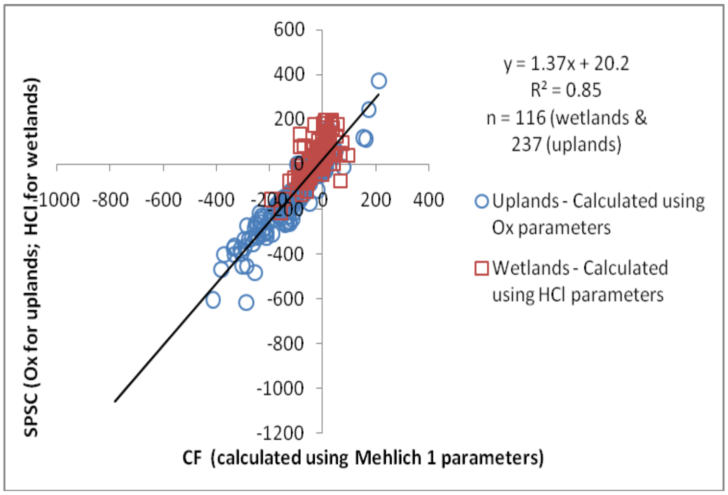


Figure 24. Relationship of the Capacity Factor calculated using 1 *M* HCl-P, Fe and Al for wetland soils or oxalate P, Fe and Al for upland soils with the capacity factor as determined using P, Fe and Al in a Mehlich 1 solution.

6.4 Equilibrium Phosphorus Concentration (EPC_0)

Since EPC_0 is the concentration of P in solution where adsorption equal desorption, EPC_0 is expected to be related to SPSC, and should be minimum when SPSC=0. To test this hypothesis and to evaluate the relationship between SPSC and EPC_0, we selected 40 soil samples from the following ranches within the Lake Okeechobee Basin: Alderman, Buck Island, Lightsey, Lykes, Payne, Rafter-T, and Syfrette. Selected samples had a wide range of organic carbon (LOI: 3 to 90%) and total phosphorus concentrations (44 to 1280 mg/kg; Table 4).

Table 4. Soil samples selected for equilibrium P concentration determinations.

Serial #	**Location**	**Loss on ignition**	**Total P**
		%	**mg/kg**
1	Syfrette	3	44
2	BIR	13	121
3	Rafter-T	4	129
4	BIR	13	141
5	Lightsey	13	155
6	Lykes	18	162
7	BIR	16	186
8	BIR	6	189
9	BIR	19	200
10	BIR	14	258
11	Rafter-T	14	273
12	Rafter-T	11	306
13	Rafter-T	12	324
14	BIR	30	334
15	Syfrette	30	353
16	Lightsey	29	360
17	Rafter-T	23	368
18	BIR	35	371
19	BIR	29	381
20	Rafter-T	17	386
21	BIR	21	389
22	Payne	12	408
23	Lykes	42	410
24	Lykes	40	412
25	Rafter-T	21	419
26	Lykes	40	423
27	Lykes	36	431
28	Lightsey	18	434

Serial #	Location	Loss on ignition	Total P
29	Lykes	62	459
30	Lykes	41	507
31	Lykes	51	590
32	Lykes	73	634
33	Alderman	90	743
34	Lykes	79	769
35	BIR	49	872
36	Rafter-T	42	958
37	Payne	71	981
38	Payne	75	997
39	Payne	66	1091
40	Rafter-T	56	1279

EPC_0 was determined using results from a multipoint isotherm with solution P concentrations of 0.0, 0.1, 0.5, 1, 5 and 10 mg L^{-1}. Phosphate sorption was measured using one gram of an air-dried, homogenized soil treated with 10 mL of 0.01*M* KCl solution containing various levels of P (Gale et al., 1994; Nair et al., 2002) in 50 mL centrifuge tubes. The tubes were placed on a mechanical shaker for a 24-hour equilibration period. At the end of the period, the soil samples were centrifuged at 6000 rpm for 10 min and the supernatant filtered through a 0.45 µm membrane filter and the filtrate analyzed for soluble reactive P (Murphy and Riley, 1962) using a Technicon^{TM} Autoanalyzer (EPA 365.1). All extractions and determinations were at room temperature (298 ±3 K). Final solution P concentrations were plotted against the change in initial solution P concentration and points were fitted with a quadratic equation. The final solution concentration at which the fitted line intercepted the zero Y axis where no solution P was sorbed or desorbed was determined to be the EPC_0 value.

6.4.1 EPC_0 and PSR (and SPSC)

The PSR for the selected samples (same soils as in section 6.4) for EPC_0 determination was calculated using Mehlich 1-P, Fe and Al. A plot of EPC_0 against the PSR suggests that this sudden release of soluble P occurs when the threshold PSR is reached (Figure 25). However, this relationship is preliminary, and has not been evaluated for upland soils either. Due to hysteresis in most soils, the EPC_0 (just like WSP or any other measure of releasable P) will resist increasing until the high-energy sorption sites are exhausted (i.e. threshold PSR or SPSC=0). We also evaluated the relationship of EPC_0 to SPSC (Figure 26). SPSC was calculated using the following equation:

$$\text{SPSC} = (0.1 - \text{Soil PSR}_{M1}) * \text{Mehlich 1-extractable } (\text{Fe}/56 + \text{Al}/27) * 31 * 1.3 \text{ (mg/kg)}$$

The relationship also indicates that as long as SPSC is positive, EPC_0 will be minimum, but will increase once SPSC becomes negative. Therefore "zero" SPSC (or threshold PSR of 0.1) will be a good indicator as to when the equilibrium P concentration would begin to increase in a wetland. Similar to WSP, EPC_0 would likely be affected by the solubility of the P source. Figure 26 was generated from soils representative of several wetlands within the LOB and the wetlands would likely be impacted by various P sources.

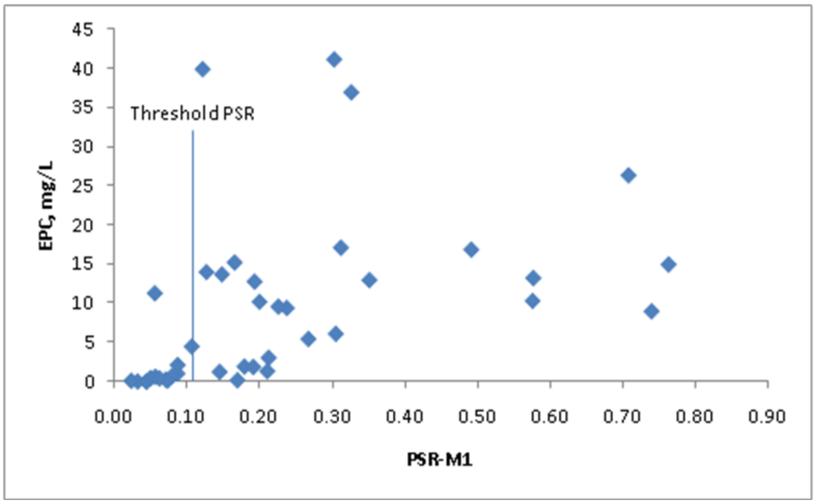


Figure 25. Equilibrium phosphorus concentration (EPC_0) as a function of P saturation ratio (PSR) calculated using P, Fe and Al in a Mehlich 1 solution. The threshold PSR indicated is the value determined for wetland soils.

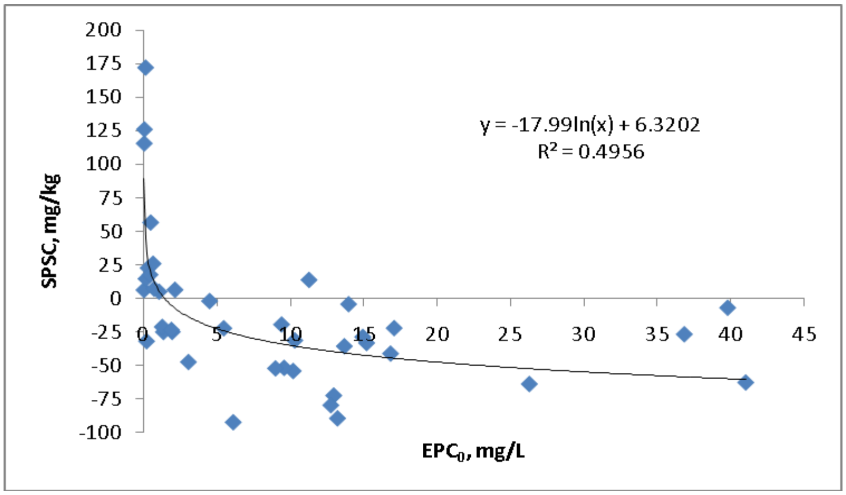


Figure 26. Soil P storage capacity calculated using Mehlich 1-P, Fe and Al as a function of the equilibrium P concentration (EPC_0).

6.5 Evaluating SPSC for Use as Indicator of P Release from Wetland Soils

6.5.1 Samples collected by FDACS/District

We looked into the relationship between dissolved reactive P (DRP) and total P, i.e. P in the filtered and unfiltered water samples collected by FDACS/District. The relationship is linear (Figure 27) with approximately 75% present as DRP in these soils.

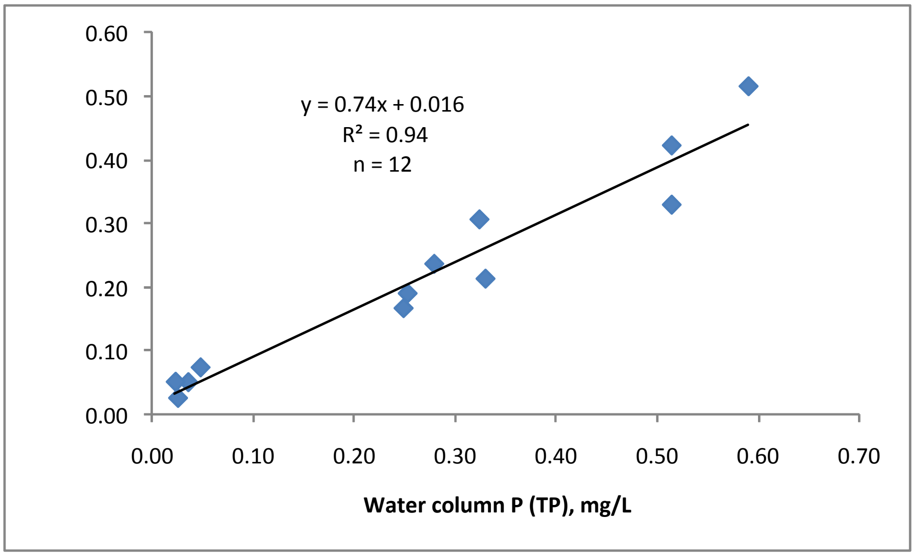


Figure 27. Relationship of dissolved reactive P (DRP and total P) in the water column.

Table 5 shows the total P in the water column along with some parameters on soils at the same location. SPSC was calculated for all soils based on a threshold PSR of 0.1. Most of the soils were not a major environmental problem with SPSC close to zero (Figure 15). Included in the table are selected soils (from NC-STA) provided by FDACS/District where SPSC was found to be negative. Total P, however do not seem to be very different from the rest of the soil samples. Although no “overlying water” was collected above these soils, the WSP concentrations are high at some of these locations. Sample 1067 with positive SPSC had WSP that was not detectable.

Some suggestions for follow up at these locations:

1. It would be useful to collect additional soil samples (a few composited samples) to confirm there are no problems associated with the soils at the various locations.
2. It is also suggested that a one-time deep soil sampling be performed at other locations as well, again to confirm that there no problems. On a routine basis, on minimally-P impacted soils (where SPSC>>0), only occasional surface soil sampling would be needed.

Table 5. Total P in the water column and parameters associated with the underlying soil for samples collected by FDACS/District

Lab ID	Location	Field ID	LOI	WSP-Dry	TP	PSR	SPSC	Water column P
			%	mg/kg	mg/kg		mg/kg	(Total, mg/L)
1013	Micco Landing-W1	U10	4.78	2.59	53	0.06	3.2	0.25
1020	Micco Landing-W2	U10	4.58	1.39	55	0.02	10.9	0.51
1026	Micco Landing-Ditch	U10	4.25	3.07	69	0.03	11.6	0.51
1034	Micco Landing-W3	U1-10	4.58	1.15	71	0.03	6.6	0.33
1044	Micco Landing-W3 C2	C2-10	9.68	2.35	325	0.03	31.4	0.25
1046	Bass	U10	2.16	0.19	51	0.02	11.6	0.04
1052	TC-STA Inflow	0-10	4.57	0.19	166	0.07	4.1	0.28
1054	TC-STA Ditch 1	0-10	3.83	0.43	160	0.34	-5.2	0.59
1056	TC-STA Ditch 2	0-10	8.76	0.43	393	0.12	-3.7	0.32
1058	TC-STA Outflow	0-10	4.27	0.43	155	0.07	3.4	0.05
1060	Lemkin Inflow	0-10	9.95	0.43	250	0.09	0.3	0.02
1062	Lemkin Outflow	0-10	10.05	0.19	190	0.39	-2.8	0.02
1064	NC-STA C1-In	0-10	3.67	0.91	55	0.02	7.4	N/A
1065	NC-STA C1-In	10-20	2.87	1.39	38	0.03	4.5	N/A
1066	NS-STA C1-Out	0-10	0.00	6.91	120	0.13	-15.8	N/A
1067	NS-STA C1-Out	10-20	0.99	ND	167	0.06	51.3	N/A
1068	NS-STA C2-In	0-10	2.56	20.59	159	0.38	-63.3	N/A
1069	NS-STA C2-In	10-20	2.74	59.00	166	0.35	-83.8	N/A
1070	NS-STA C2-Out	0-10	2.59	5.95	83	0.15	-5.2	N/A
1071	NS-STA C2-Out	10-20	4.52	14.59	174	0.11	-1.3	N/A

ND = Below the detection limit

N/A= Not available

6.5.2 Pelaez Ranch Samples

Table 6 shows the total P in the water column along with LOI, WSP, soil TP, PSR and SPSC of soils from Pelaez Ranch.

Table 6. Total P in the water column and parameters associated with the underlying soil for samples collected from Pelaez Ranch.

Lab #	**Profile #**	**Depth cm**	**Location**	**LOI %**	**WSP (dry) mg/kg**	**TP mg/kg**	**PSR**	**SPSC mg/kg**	**Water column P**	
									DRP mg/L	**TP mg/L**
501	1	0-10	Upland	14.6	4.8	479	0.04	36.1		
502		10-20		12.4	3.8	455	0.06	41.2		
503	2	0-10	Edge	14.7	2.6	392	0.01	37.3		
504		10-20		2.6	0.9	49	0.00	14.6		
505	3	0-10	Wetland	13.1	20.3	201	1.08	-21.4		
506		10-20		3.2	1.9	ND	0.00	2.9		
507	4	0-10	Ditch	42.7	12.4	721	0.03	27.5		
508		10-20		33.2	2.6	454	0.00	80.4		
509	5	0-10	Wetland	4.9	11.9	106	0.07	2.7		
510		10-20		3.3	5.7	65	0.07	4.7		
511	6	0-10	Edge	9.0	7.2	121	0.08	1.5		
512		10-20		5.9	2.1	39	0.00	15.8		
513	7	0-10	Upland	12.3	15.3	127	0.11	-0.7		
514		10-20		5.8	3.1	26	0.00	5.3		
515	8	0-10	Upland	18.5	17.2	225	0.07	3.2		
516		10-20		5.8	3.8	51	0.02	11.1		
517	9	0-10	Upland	6.4	10.5	177	0.13	-5.6		
518		10-20		6.4	12.2	202	0.18	-63.2		
519	10	0-10	Upland	12.7	12.2	170	0.03	6.9		
520		10-20		4.6	2.6	22	0.00	5.0		
521	11	0-10	Wetland	27.7	3.1	636	0.00	33.8	ND	0.05
522		10-20		6.1	0.7	43	0.00	26.0		
523	12	0-10	Ditch	8.4	7.6	ND	0.06	87.1	ND	0.47
524		10-20		3.0	1.2	ND	0.00	1.5		
525	13	0-10	Ditch	82.2	23.5	1218	0.04	2.0	ND	0.23
526		10-20		55.3	2.4	415	0.00	392.3		
527	14	0-10	Ditch	26.5	4.3	452	0.00	447.9		
528		10-20		15.8	1.2	151	0.00	356.2		
529	15	0-10	Upland	9.2	7.6	56	0.02	4.9		
530		10-20		5.5	2.1	23	0.00	2.7		

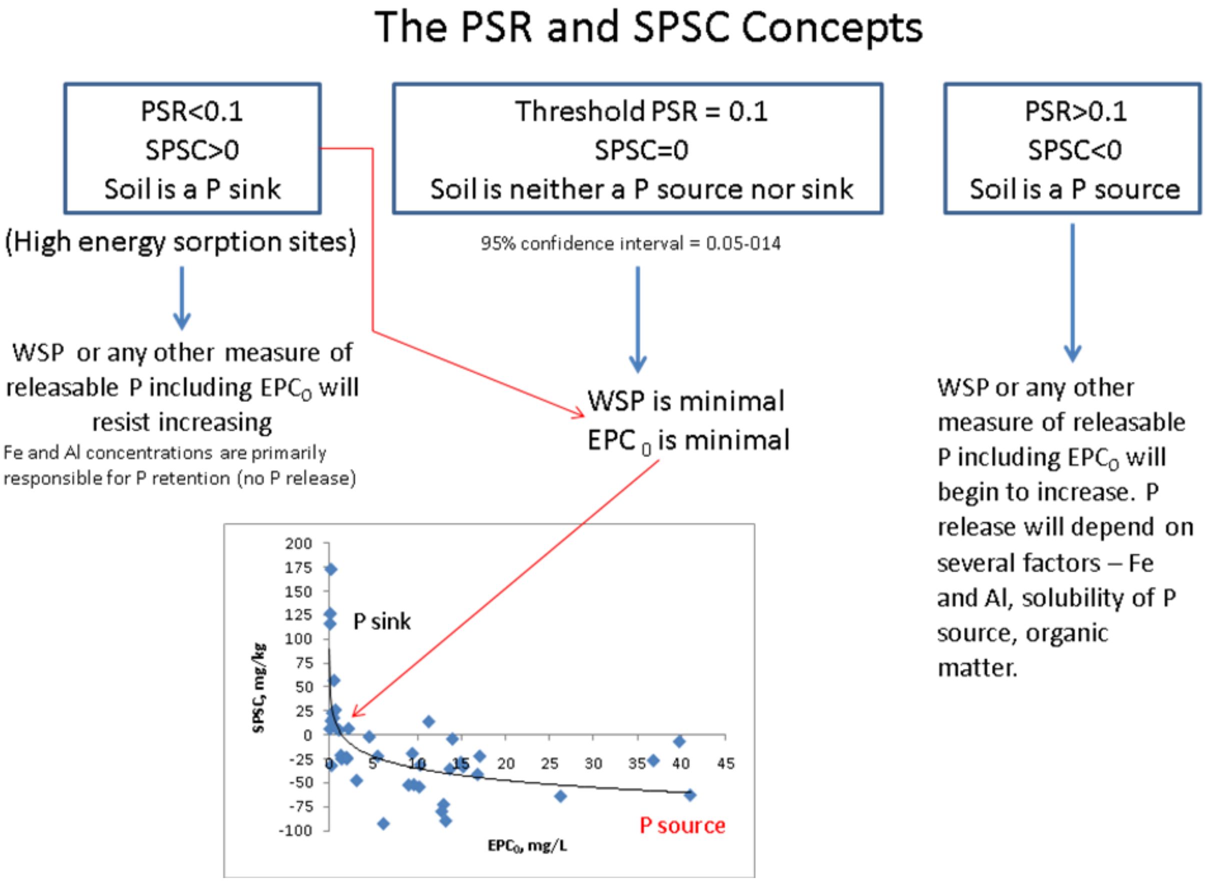
Lab #	Profile #	Depth cm	Location	LOI %	WSP (dry) mg/kg	TP mg/kg	PSR	SPSC mg/kg	Water column P	
									DRP mg/L	TP mg/L
531	16	0-10	Upland	8.9	12.2	120	0.24	-18.6		
532		10-20		9.8	9.6	84	0.07	5.4		
533	17	0-10	Wetland	10.8	10.7	143	0.08	1.7		
534		10-20		0.5	1.6	ND	0.05	2.0		
535	18	0-10	Edge	29.0	18.9	329	0.04	14.5	4.21	6.91
536		10-20		23.1	3.6	68	0.01	68.9		
537	19	0-10	Edge	12.2	18.2	195	0.17	-8.3		
538		10-20		3.1	2.4	34	0.11	-0.6		
539	20	0-10	Upland	9.4	8.6	132	0.10	0.3		
540		10-20		3.7	2.8	ND	0.03	6.1		
541	21	0-10	Upland/Edge	9.2	11.2	95	0.02	4.4		
542		10-20		3.9	1.6	0.02	0.00	3.6		
543	22	0-10	Ditch	13.6	18.2	121	0.05	22.1		
544		10-20		2.7	4.3	ND	0.06	4.6		
545	23	0-10	Upland/Edge	10.6	18.4	156	0.16	-9.4		
546		10-20		7.2	5.5	ND	0.07	2.2		
547	24	0-10	Upland	9.6	9.6	87	0.07	5.6		
548		10-20		N/A	N/A	N/A	0.03	5.3		
549	25	0-10	Upland	20.7	136.3	875	7.03	-226.3		
550		10-20		17.6	59.5	361	1.40	-76.8		
551	26	0-10	Ditch	10.1	13.6	123	0.25	-8.5		
552		10-20		5.6	7.9	34	0.10	-0.1		
553	27	0-10	Wetland	17.0	19.9	231	0.13	-3.2		
554		10-20		4.6	6.4	23	0.06	3.7		
555	28	0-10	Wetland	6.7	45.1	328	1.80	-153.2		
556		10-20		4.4	93.1	327	3.86	-414.3		
557	29	0-10	Ditch	10.9	59.5	213	1.67	-89.3		
558		10-20		13.4	59.5	205	2.73	-274.2		
559	30	0-10	Ditch	5.1	193.9	210	6.87	-316.7		
560		10-20		8.7	57.1	180	0.98	-85.2		
561	31	0-10	Upland	11.6	150.7	608	12.08	-361.2		
562		10-20		4.1	21.1	72	0.32	-20.3		
563	32	0-10	Upland	6.7	42.7	132	0.90	-68.1		
564		10-20		4.3	21.1	43	0.20	-17.9		
565	33	0-10	Wetland	13.1	8.4	183	0.06	5.6		
566		10-20		2.7	1.2	35	0.03	6.8		
567	34	0-10	Wetland	6.4	2.8	118	0.01	26.9	2.12	3.55
568		10-20		2.9	0.9	33	0.00	33.8		

Lab #	Profile #	Depth cm	Location	LOI %	WSP (dry) mg/kg	TP mg/kg	PSR	SPSC mg/kg	Water column P	
									DRP mg/L	TP mg/L
569	35	0-10	Wetland	6.5	3.8	64	0.03	4.8		
570		10-20		1.2	1.2	ND	0.01	3.2		
571	36	0-10	Ditch	18.1	18.9	315	0.07	5.8	2.12	3.60
572		10-20		5.1	7.4	87	0.04	13.5		

ND = Below the detection limit

6.6 The PSR and SPC Concepts and their Practical Implications

Conceptual evidence of the SPSC soil index is based on our understanding of P dynamics in soils and when comparing SPSC to EPC_0 values on the same wetland soils (Figure 28). However, at this time a soil's indices alone should not be expected to provide a standalone predictor or proxy of water column P concentration at the edge of field or within the water column of a wetland across all landscapes. The realities of other physical, chemical and biological factors that affect P concentration once it is released from the soil and enters the overlying water column cannot be anticipated based on a soil index alone. Integration of all factors influencing water column P might best be expressed using a watershed or wetland model that includes an accurate measure of soil P storage characteristics. What the proposed soil index provides is a measure of overall and long-term status of the soils mineral P storage capacity, in other words the point at which the mineral P sorption sites in the soil will no other sorb additional P and therefore the soil environmental P concentration will begin to increase rapidly. If all other physical, chemical and biological factors were equal among watersheds, this index alone could be used to predict water column P. From a management perspective the P storage status of the soil is a critical variable in determining the role soils are/will play in the retention or release of P to groundwater and overlying surface water. Using a change point value of 0.1 with appropriate range of uncertainty until a WSP method for wetland soils can be agreed upon and this number refined seems to us a prudent approach forward at this time. Suggested applications of PSR and SPSC are shown in Figure 29. The SPSC concept has been validated in laboratory experiments (Chrysostome et al., 2007b).



The PSR and SPSC Concepts

PSR<0.1
SPSC>0
Soil is a P sink

(High energy sorption sites)

WSP or any other measure of releasable P including EPC$_0$ will resist increasing

Fe and Al concentrations are primarily responsible for P retention (no P release)

Threshold PSR = 0.1
SPSC=0
Soil is neither a P source nor sink

95% confidence interval = 0.05-014

WSP is minimal
EPC$_0$ is minimal

PSR>0.1
SPSC<0
Soil is a P source

WSP or any other measure of releasable P including EPC$_0$ will begin to increase. P release will depend on several factors – Fe and Al, solubility of P source, organic matter.

Figure 28. Diagram explaining the PSR and SPSC concepts, and their relationships with equilibrium P concentration (EPC$_0$) for wetland soils from the Lake Okeechobee Basin.

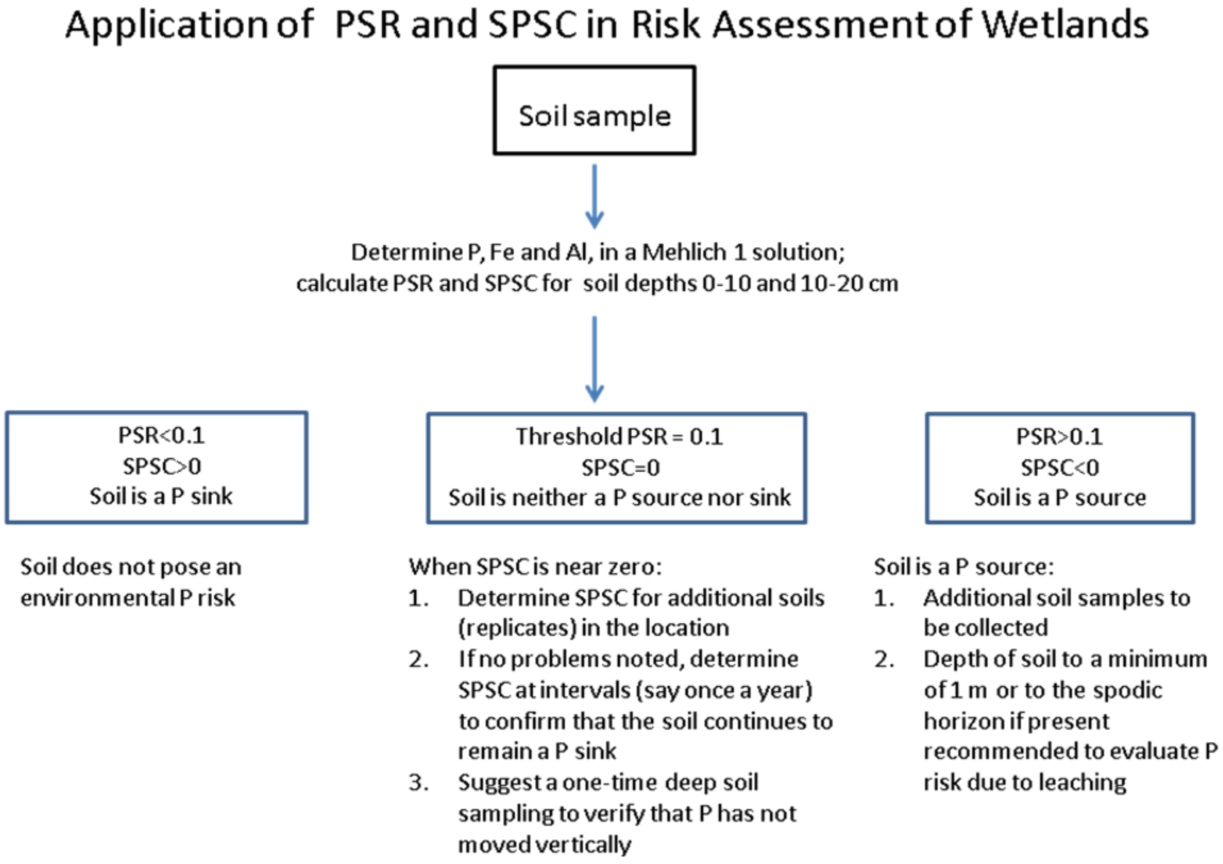


Figure 29. Applications of PSR and SPSC concepts in risk assessment of wetland soils. This conceptual application is based on a threshold PSR of 0.1; the 95% confidence interval is 0.06 to 0.16.

7. Conclusions

A threshold PSR (change point) was developed for wetland soils from a relationship of WSP determined on air-dried soils and PSR calculated using Mehlich 1-P, Fe and Al. Our initial hypothesis was that WSP on wet soils would likely be a better representative of P release from wetland soils. However, evaluation of WSP determination under wet conditions revealed that reproducible values could not be obtained due to high variability of moisture content of wetland soils at the time of sampling. Air-dried soils gave more reproducible values for WSP for wetland soils. Based on a change point of 0.1 (95% confidence interval between 0.0.06 and 0.16), we calculated SPSC for archived soil samples of the FRESP project representing eight beef ranches in the Lake Okeechobee Basin and related negative SPSC to WSP; the relationship was linear with an R^2 of 0.83 supporting the use of a threshold PSR value of 0.1. If a different threshold PSR was used, WSP would not be minimum when SPSC>0. Freshly collected soil samples from the Lake Okeechobee Basin that had a wide range of P levels also showed linearity between negative SPSC and WSP ($R^2 = 0.72$ for Pelaez Ranch samples, and 0.80 for samples provided by FDACS/District).

The threshold PSR for upland soils in other studies is also 0.1 with a confidence interval of 0.05-0.15. Based on all lines of evidence that support the conceptual use of SPSC as an indicator of soil P storage capacity, we believe that the threshold PSR of 0.1 is the best value we have at this time to calculate SPSC for wetland soils. The threshold PSR will be refined if necessary as more data becomes available. We strongly believe that SPSC is the most appropriate and promising soil index available for the purpose of estimating P storage and release potential. There are presently no practical alternative indices available for this purpose. Further investigations evaluating the larger scale interpretation/application of SPSC to infer edge-of-field / surface water – P concentrations (including more intensive catchment soil and water sampling, and use of SPSC in models) are suggested.

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9 Appendices

The list of past projects which have information pertinent to the current study is given in Appendix Table 1 below. The metadata for the dataset is available from the spreadsheet and in Appendix Table 2. The dataset was a part of Deliverable 1.

Appendix Table 1. Wetland soil studies at the Soil and Water Science Department, University of Florida during the period 1987-2009.

PROJECT	LOCATION	FLORIDA COUNTIES	SAMPLING DATE	GPS LOCATION METHOD	NUMBER OF LOCATIONS	DEPTHS, cm
LA-INB	Lake Apopka	LakeOrange	June 1987	LORAN	90	Various depths
OKS	Lake Okeechobee	Martin,Okeechobee,Glades, Hendry, Palm Beach	June 1988	LORAN	171	Various depths
GRIFFIN	Emeralda Marsh	Lake	June 1995	differential beacon GPS	24	0-15
GR_FRAC	Emeralda Marsh	Lake	Dec 1995	differential beacon GPS	4	0-3,3-6,6-9,9-12,12-15
IRL	Indian River Lagoon	Brevard,Indian River, St.Lucie	Mar 1997	differential beacon GPS	24	0-10 or 12
BCM_PHASE_I	Blue Cypress Marsh Conservation Area	Indian River	Sept 2000	differential beacon GPS	87	0-10, and detritus layer
EPA_OIW Project	Lake Okeechobee Interior Wetlands (OIW)	Okeechobee	May, July, Aug and Sept 2003	n/a†	444	0-10
Taylor Creek	Taylor Creek STA	Okeechobee	May 25, 2005	n/a	140	0-10. 10-20, 20-30 and some 2 cm increments
OIW2009	Lake Okeechobee Interior Wetlands 2 (OIW)	Okeechobee	2009	n/a	28	0-10
Report 09-29B ESP	Lake Okeechobee Interior Wetlands (OIW)	Okeechobee	2007, 2008, and 2009	n/a	318	0-10
SFWMD Project C91-2637	Various sites Lake Okeechobee Basin	Okeechobee, Highlands	March, May, and August, 1992	n/a	433	various depths
FRESP	Lake Okeechobee Basin wetlands	Okeechobee, Highlands	November 2007, August 2008	n/a	318	0-10
SWBS	Southeastern USA	Southeastern USA	February to October 2003	n/a	607	0-10

† n/a = not available

Appendix Table 2**.** Metadata for the dataset.

ID	COLUMN NAME	PARAMETER	COLUMN_TYPE	UNITS	DESCRIPTION
1	Unique_ID	Unique ID	Long Integer	none	A unique number for this row (assigned as a row is added to the data table)
2	Project	Project Name	Varchar(50)	none	The name of the project
3	Location	Location(Station)	Varchar(25)	none	A station/location identifier from the original data set
4	Site_ID	Sites(Soil-ID)	Varchar(25)	none	Site/soil identifier from the original data set
5	Sample Zone	Sample zone	Varchar(25)	none	D=Ditch, C=interior(centre) of Wetland, E=Edge of wetland, U= Upland
6	Lab_Number	Lab#	Varchar(25)	none	Laboratory sample identifier
7	Date	Sampling date	Smalldatetime	date	Sampling date
8	Layer_Type	Type of layer	Varchar(50)	none	Type of layer, ie sand, mud , and detritus
9	Vegetation	Vegetation	Varchar(50)	none	Type of vegetation found at the location
10	Mean_Depth	Average depth	Real	cm	The mean depth of the sample
11	Initial_Depth	Top depth	Real	cm	The top depth of the sample
12	Final Depth	Bottom depth	Real	cm	The bottom depth of the sample
13	Moisture	Moisture content	Real	%	Water content of fresh sample MC=[(initial Wt - dry(oven) Wt)/initial Wt]*100
14	pH	pH	Real	pH units	pH of the wet sample
15	BD	Bulk density	Real	g/ cm3	Dry bulk density
16	Ash	Ash content	Real	%	Ash content of dried soil at 550oC
17	LOI	Loss on ignition	Real	%	Percentage of weight loss of soil ignited at 550 degree C for 4 h (LOI=100-ash content)
18	TP	Total phosphorus	Real	mg/kg	Total phosphorus content of dried sample
19	TPI (P-HCl)	Total inorganic phosphorus	Real	mg/kg	1 M HCl extractable P of dried samples
20	HCl-TP	Total phosphorus with HCl	Real	mg/kg	1 M HCl extractable P determined on the ICAP
21	HCl_CA	1 MHCl extractable Ca	Real	mg/kg	1 M HCl extractable calcium of dried sample
22	HCl_Mg	1 MHCl extractable Mg	Real	mg/kg	1 M HCl extractable magnesium of dried sample
23	HCl_Fe	1 MHCl extractable Fe	Real	mg/kg	1 M HCl extractable iron of dried sample
24	HCl_Al	1 MHCl extractable Al	Real	mg/kg	1 M HCl extractable aluminum of dried sample
25	TPO	Total organic phosphorus	Real	mg/kg	TP minus TPi

ID	COLUMN NAME	PARAMETER	COLUMN_TYPE	UNITS	DESCRIPTION
26	WSPD	Water soluble P of dry soil	Real	mg/kg	Water soluble P of dry soil
27	WSPW	Water soluble P of wet soil	Real	mg/kg	Water soluble P of wet soil
28	M1-P	Mehlich 1 P	Real	mg/kg	Dilute solution of hydrochloric and sulfuric acids [0.005 N HCl + 0.025 N H_2SO_4 in 1lt H_2O]
29	M1-TP	Mehlich 1 total P	Real	mg/kg	
30	M1-Ca	Mehlich 1 Ca	Real	mg/kg	Dilute solution of hydrochloric and sulfuric acids [0.005 M HCl + 0.05 M H2SO4 in 1lt H_2O]
31	M1-Mg	Mehlich 1 Mg	Real	mg/kg	Dilute solution of hydrochloric and sulfuric acids [0.005 M HCl + 0.05 M H2SO4 in 1lt H_2O]
32	M1-Fe	Mehlich 1 Fe	Real	mg/kg	Dilute solution of hydrochloric and sulfuric acids [0.005 M HCl + 0.05 M H2SO4 in 1lt H_2O]
33	M1-Al	Mehlich 1 Al	Real	mg/kg	Dilute solution of hydrochloric and sulfuric acids [0.005 M HCl + 0.05 M H2SO4 in 1lt H_2O]
34	M3-P	Mehlich 3 P	Real	mg/kg	Stock M-3 Solution (3.75 M NH4F + 0.25 M EDTA in 1Lt of H2O
35	M3-Ca	Mehlich 3 Ca	Real	mg/kg	Stock M-3 Solution (3.75 M NH4F + 0.25 M EDTA in 1Lt of H2O
36	M3-Mg	Mehlich 3 Mg	Real	mg/kg	Stock M-3 Solution (3.75 M NH4F + 0.25 M EDTA in 1Lt of H2O
37	M3-Fe	Mehlich 3 Fe	Real	mg/kg	Stock M-3 Solution (3.75 M NH4F + 0.25 M EDTA in 1Lt of H2O
38	M3-Al	Mehlich 3 Al	Real	mg/kg	Stock M-3 Solution (3.75 M NH4F + 0.25 M EDTA in 1Lt of H2O
39	P-Oxl	Oxalate extractable P	Real	mg/kg	0.1M oxalic acid + 0.175M Aluminum Oxalate (pH = 3.5)
40	Al-Oxl	Oxalate extractable Al	Real	mg/kg	0.1M oxalic acid + 0.175M Aluminum Oxalate (pH = 3.5)
41	Fe-Oxl	Oxalate extractable Fe	Real	mg/kg	0.1M oxalic acid + 0.175M Aluminum Oxalate (pH = 3.5)
42	MBP	Microbial biomass P	Real	mg/kg	Microbial biomass P=$NaHCO_3$ TP_F minus $NaHCO_3$ TP_NF
43	PMP	Potentially mineralizable Phosphorus	Real	mg/ kg/d	Phosphorus mineralized rate during 10d incubation at 40 degree C
44	TN	Total Nitrogen	Real	g/kg	Total nitrogen content of dried soil
45	MBN	Microbial biomass N(c)	Real	mg/kg	Microbial biomass N=(K_2SO_4 TKN_F minus K_2SO_4 TKN_NF)/0.37
46	PMN	Potentially Mineralizable Nitrogen	Real	mg/ kg/d	Nitrogen mineralized rate during 10d incubation at 40 degree C
47	TC	Total Carbon	Real	g/kg	Total carbon content of dried soil

Appendix Table 3. Mehlich 1 P, Fe and Al as determined using ICAP, soluble reactive phosphorus (SRP) in a 1:10 soil:0.01 M KCl solution, water soluble P (dry soils) and SRP as obtained after incubation of soils for 15 days.

Lab ID	Location	M1-P	M1-Fe mg/kg	M1-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-M1 (TP)
13	BIR	42.24	55.12	214.4	1.79	12.35	79.08	0.15
14	Lykes	111.4	139.8	291.8	0.27	79.38	122.65	0.27
15	Lykes	68.50	73.46	245.4	0.54	44.46	59.72	0.21
18	Lykes	26.96	38.84	69.12	1.47	9.38	132.33	0.27
20	Lykes	82.86	108.0	309.0	1.33	39.81	79.08	0.20
25	Lykes	121.2	95.94	158.0	1.44	118.94	180.73	0.52
26	Lykes	77.70	203.6	94.32	1.69	0.00	243.65	0.35
28	Lykes	105.4	117.2	244.4	0.95	100.32	142.01	0.30
35	Lykes	23.64	228.2	273.6	0.32	17.85	50.04	0.05
36	Lykes	41.72	324.4	301.4	0.05	21.19	6.48	0.08
38	Lykes	18.45	83.96	126.1	0.93	5.03	8.88	0.10
39	Lykes	351.6	534.8	167.8	0.05	18.07	108.13	0.72
40	Lykes	68.04	143.6	233.8	1.21	49.12	88.77	0.20
41	Lykes	13.18	60.84	148.6	1.03	3.19	12.75	0.06
42	Lykes	84.96	76.06	74.12	0.66	195.71	185.57	0.67
43	Lykes	22.06	428.4	486.0	1.12	5.43	17.59	0.03
44	Lykes	37.10	204.8	866.8	0.03	6.17	9.84	0.03
45	Lykes	8.69	81.36	143.2	3.67	125.81	4.04	0.04
46	Lykes	111.4	164.6	166.4	4.47	100.32	171.05	0.39
50	Lykes	7.72	25.40	65.92	4.69	19.22	32.11	0.09
52	BIR	89.92	110.6	242.8	2.12	51.45	81.33	0.26
56	BIR	92.18	99.00	237.4	1.68	31.66	74.31	0.28
59	BIR	42.96	33.36	193.0	0.91	18.67	47.57	0.18
68	BIR	163.2	44.16	101.2	3.62	137.56	182.15	1.16
78	BIR	116.2	186.4	520.0	0.16	86.36	127.16	0.17

Lab ID	Location	M1-P	M1-Fe	M1-Al	SRP (0.1M KCl)	WSP (mg/kg)	SRP(mg/kg) 1:10 incubated	PSR-M1
			mg/kg	mg/kg	mg/L	1:10 dry wt		(TP)
81	BIR	124.0	240.2	400.6	0.65	77.05	136.32	0.21
82	BIR	47.64	14.97	110.3	0.26	35.15	57.06	0.35
85	BIR	25.84	24.36	579.6	0.12	3.88	8.74	0.04
92	BIR	76.16	46.54	183.0	0.53	44.46	72.16	0.32
96	BIR	20.04	16.19	415.6	0.09	5.26	14.78	0.04
97	Syfrette	15.77	29.08	33.64	N/A†	10.29	38.94	0.29
98	BIR	25.36	8.29	98.80	0.81	18.99	39.80	0.21
101	BIR	79.84	17.90	177.0	1.79	70.07	90.49	0.37
103	BIR	91.40	39.64	408.8	0.07	42.14	99.66	0.19
107	Payne	7.96	15.86	200.8	0.13	4.34	27.27	0.03
110	Payne	46.30	80.62	1930	0.09	2.63	8.88	0.02
114	Payne	59.26	99.42	256.6	0.17	5.94	23.88	0.17
115	Syfrette	58.70	300.0	426.4	0.98	22.42	N/A	0.09
131	Syfrette	41.84	261.8	532.6	0.49	50.29	23.42	0.06
153	Syfrette	43.74	132.6	427.4	0.78	16.70	59.72	0.08
159	Lightsey	42.02	736.4	787.4	0.02	2.29	69.40	0.03
160	Lightsey	94.00	121.2	118.8	3.71	81.70	30.68	0.46
169	Lightsey	14.36	35.72	81.36	0.72	11.21	27.75	0.13
171	Lightsey	41.10	42.20	180.4	1.64	32.83	40.34	0.18
211	Rafter-T	43.95	76.75	581.0	0.16	12.05	25.82	0.06
212	Syfrette	6.90	12.16	54.20	0.27	2.54	50.04	0.10
213	Rafter-T	81.85	98.95	672.0	1.05	0.00	50.04	0.10
216	Rafter-T	67.15	101.0	635.0	1.05	0.00	30.68	0.09
225	BIR	58.70	109.0	379.8	0.71	2.54	55.33	0.12
230	Lykes	22.50	161.8	281.4	4.75	3.23	21.68	0.05
231	Lykes	46.55	348.2	132.4	0.41	5.52	117.99	0.13

Lab ID	Location	M1-P	M1-Fe mg/kg	M1-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-M1 (TP)
234	Lykes	71.70	100.4	157.8	1.85	37.48	53.83	0.30
236	Lykes	32.80	199.4	578.0	0.05	18.92	12.19	0.04
237	Rafter-T	24.60	621.0	1386	N/A	0.72	7.01	0.01
246	BIR	126.6	112.6	516.5	3.38	63.31	154.66	0.19
248	BIR	136.8	31.90	122.0	4.20	137.56	136.32	0.87
249	BIR	126.2	36.45	111.0	4.09	126.15	191.32	0.85
250	BIR	20.80	12.16	35.40	0.71	20.68	41.53	0.44
258	Alderman	7.69	21.32	84.60	0.08	17.89	11.80	0.07
261	Alderman	11.61	20.48	115.9	0.12	2.77	8.13	0.08
264	Alderman	46.20	81.90	350.8	0.83	16.53	79.63	0.10
267	Williamson	19.30	11.05	289.6	0.30	6.77	31.05	0.06
270	Williamson	29.80	34.90	642.0	0.05	2.29	0.80	0.04
273	Williamson	44.70	92.20	764.0	0.03	0.16	0.00	0.05
276	Williamson	28.80	129.0	1000	0.02	0.72	9.97	0.02
279	Williamson	0.78	-1.42	8.90	0.00	0.72	0.80	0.08
282	BIR	22.48	37.92	87.24	0.56	14.21	5.84	0.19
287	BIR	14.84	41.28	158.4	0.19	13.06	16.38	0.07
294	Lykes	7.57	19.99	148.8	0.26	14.22	13.63	0.04
297	Lykes	26.80	468.0	296.8	0.47	0.83	1.72	0.04
298	Lykes	34.35	246.8	575.0	0.03	0.27	1.72	0.04
299	Lykes	1.92	3.22	20.24	0.07	2.52	3.55	0.08
300	Lykes	50.40	318.4	570.5	0.03	1.65	9.97	0.06
301	Lykes	30.90	245.0	216.6	0.10	3.05	11.34	0.08
302	Lykes	12.55	190.6	72.20	0.14	4.21	0.00	0.07
303	Lykes	12.48	109.6	499.6	0.11	1.60	1.72	0.02
304	Lykes	10.78	35.08	38.24	0.01	1.19	1.72	0.17

Lab ID	Location	M1-P	M1-Fe mg/kg	M1-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-M1 (TP)
305	Lykes	10.20	89.15	242.2	0.11	3.05	3.00	0.03
306	Lykes	2.82	33.64	103.7	0.45	1.65	0.80	0.02
309	Alderman	42.75	38.40	174.4	2.23	80.14	136.32	0.19
312	Alderman	53.25	68.20	253.4	1.64	61.07	108.83	0.16
315	Alderman	83.60	83.50	451.2	2.10	81.70	145.49	0.15
319	Rafter-T	21.15	620.0	790.0	N/A	0.00	9.05	0.02
4	Lykes	12.04	29.52	167.0	0.72	7.78	7.42	0.06
6	Lykes	8.73	39.20	199.1	2.98	6.40	5.97	0.03
17	Lykes	13.77	48.24	191.4	2.58	10.71	14.20	0.06
19	Lykes	11.54	35.48	125.7	0.15	5.72	14.20	0.07
21	Lykes	11.40	42.56	156.8	0.75	2.97	10.33	0.06
22	Lykes	7.08	33.08	109.0	0.57	4.34	2.10	0.05
27	Lykes	95.30	204.6	145.8	0.78	98.00	200.09	0.34
29	Lykes	64.04	197.4	241.6	1.47	35.15	74.24	0.17
33	Lykes	23.24	15.09	15.80	1.34	0.00	146.85	0.88
37	Lykes	15.16	45.48	302.8	0.21	8.46	17.59	0.04
55	BIR	37.12	35.56	83.84	1.11	17.39	47.57	0.32
58	BIR	37.84	24.80	68.00	1.02	17.85	33.76	0.41
64	BIR	62.76	15.15	110.5	0.22	46.79	75.18	0.46
65	BIR	39.44	12.45	63.92	3.99	35.15	57.06	0.49
67	BIR	42.04	37.36	111.5	0.14	17.62	40.66	0.28
71	BIR	86.64	47.44	358.0	0.54	30.50	82.94	0.20
77	BIR	90.74	56.86	157.0	3.73	72.39	90.49	0.43
86	BIR	22.12	21.52	321.2	0.20	6.86	13.91	0.06
88	BIR	28.08	131.9	155.9	0.27	10.06	29.44	0.11
89	BIR	87.30	203.2	441.2	0.40	56.10	90.49	0.14

Lab ID	Location	M1-P	M1-Fe mg/kg	M1-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-M1 (TP)
102	BIR	29.76	11.60	57.48	0.21	14.64	38.07	0.41
106	Payne	57.34	366.2	1448	0.06	6.40	21.46	0.03
111	Payne	11.50	23.64	212.0	0.43	12.58	39.37	0.04
112	Payne	30.10	77.50	253.6	0.06	0.00	10.33	0.09
113	Syfrette	31.84	160.2	423.4	0.53	12.35	39.37	0.06
130	Syfrette	34.64	146.0	949.4	0.10	5.43	10.33	0.03
137	Payne	21.58	24.50	227.2	0.05	15.09	2.10	0.08
139	Payne	22.64	51.62	1222	0.05	0.72	3.55	0.02
140	Payne	46.28	66.34	302.2	0.89	11.67	16.16	0.12
142	Payne	30.94	78.20	708.4	0.16	0.95	54.88	0.04
146	Payne	135.6	61.28	682.4	0.88	18.34	35.50	0.17
147	Payne	18.14	39.70	787.8	0.05	0.00	12.75	0.02
148	Payne	3.64	10.75	659.4	0.11	2.28	11.30	0.00
151	Rafter-T	55.41	43.46	1346	0.17	5.72	16.14	0.04
152	Syfrette	28.60	137.5	382.8	0.51	9.15	30.66	0.06
161	Lightsey	29.28	28.92	64.24	1.37	30.50	45.18	0.33
162	Lightsey	14.44	28.12	48.44	0.81	17.39	35.98	0.20
164	Syfrette	22.56	32.32	322.4	0.49	11.89	31.63	0.06
166	Lightsey	12.06	72.60	55.92	0.31	7.78	19.53	0.12
168	Lightsey	27.44	33.44	104.2	1.27	32.83	117.81	0.20
173	Payne	45.95	3.35	412.6	0.14	6.22	12.75	0.10
174	Payne	38.60	0.35	298.2	0.06	1.62	40.36	0.11
175	Payne	22.15	55.10	718.0	0.10	0.83	11.32	0.03
176	Payne	40.35	105.4	1456	0.11	3.86	0.65	0.02
177	Payne	46.55	90.95	451.4	1.00	0.00	11.32	0.08
178	Payne	43.15	93.95	542.5	0.35	4.76	38.89	0.06

Lab ID	Location	M1-P	M1-Fe mg/kg	M1-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-M1 (TP)
179	Payne	43.70	20.55	371.0	0.47	13.04	26.30	0.10
200	Rafter-T	28.24	11.22	171.0	0.62	18.53	21.95	0.14
206	Syfrette	11.68	13.76	137.9	0.48	12.62	25.33	0.07
208	Payne	43.40	21.55	522.0	0.25	14.41	26.79	0.07
215	Rafter-T	65.65	82.10	986.0	0.13	10.33	24.85	0.06
219	Payne	42.70	178.0	307.4	0.37	1.39	5.97	0.09
220	Rafter-T	35.90	62.40	328.0	0.48	11.82	16.14	0.09
222	Rafter-T	49.05	74.00	272.4	1.15	25.84	6.48	0.14
223	Payne	32.30	8.20	506.0	0.05	2.74	151.69	0.06
227	BIR	22.76	20.60	308.8	0.17	8.16	34.62	0.06
228	BIR	44.50	79.80	369.8	0.42	8.50	27.72	0.09
232	Lykes	71.10	108.2	222.0	1.55	39.81	72.16	0.23
241	BIR	56.88	12.87	63.80	1.74	46.79	78.63	0.71
251	BIR	40.84	5.38	50.84	0.80	26.29	53.61	0.67
252	BIR	48.64	30.44	583.2	0.27	6.09	20.82	0.07
253	BIR	46.72	12.33	48.32	0.96	58.43	61.37	0.75
254	BIR	57.92	19.24	77.96	1.60	46.79	63.00	0.58
257	BIR	46.12	8.96	50.00	2.14	25.84	62.21	0.74
259	Alderman	4.07	16.66	113.1	0.01	4.31	0.80	0.03
262	Alderman	4.16	16.26	91.12	0.04	1.84	0.80	0.04
265	Alderman	16.56	39.40	155.4	0.18	16.53	25.55	0.08
268	Williamson	8.42	9.46	323.2	0.11	1.84	6.30	0.02
271	Williamson	41.95	47.80	1098	0.01	0.49	0.00	0.03
274	Williamson	1.54	-0.68	11.18	0.02	1.06	N/A	0.12
277	Williamson	1.80	-1.15	10.32	0.03	0.61	N/A	0.16
280	Williamson	0.72	-1.55	12.04	0.00	0.38	11.34	0.06

Lab ID	Location	M1-P	M1-Fe mg/kg	M1-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-M1 (TP)
283	BIR	9.44	29.76	75.84	0.20	15.85	9.97	0.09
288	BIR	10.69	39.40	166.8	0.06	5.38	5.38	0.05
295	Lykes	3.88	24.68	35.24	0.11	4.91	3.55	0.07
308	Payne	60.70	101.6	899.5	0.32	10.80	53.96	0.06
310	Alderman	3.70	25.00	91.80	0.02	2.73	8.00	0.03
313	Alderman	4.80	22.40	113.2	0.03	10.58	10.88	0.03
316	Alderman	1.63	7.26	20.36	0.04	0.24	11.80	0.06
320	Rafter-T	58.45	92.85	1234	N/A	6.08	14.09	0.04

† N/A = Not Available

Appendix Table 4. Mehlich 3 P, Fe and Al as determined using ICAP, soluble reactive phosphorus (SRP) in a 1:10 soil:0.01 M KCl solution, water soluble P (dry soils) and SRP as obtained after incubation of soils for 15 days.

Lab ID	**Location**	**M3-TP** mg/kg	**M3-Fe** mg/kg	**M3-Al** mg/kg	**SRP (0.1M KCl)** mg/L	**WSP (mg/kg)** 1:10 dry wt	**SRP(mg/kg) 1:10** incubated	**M3-PSR** (TP)
13	BIR	99.90	427.6	691.0	1.79	12.35	79.08	0.10
14	Lykes	165.0	435.5	832.0	0.27	79.38	122.65	0.14
15	Lykes	120.8	234.3	766.8	0.54	44.46	59.72	0.12
18	Lykes	168.5	425.5	830.0	1.47	9.38	132.33	0.14
20	Lykes	129.5	282.5	818.5	1.33	39.81	79.08	0.12
25	Lykes	164.8	318.0	496.5	1.44	118.94	180.73	0.22
26	Lykes	81.70	529.0	10.38	1.69	0.00	243.65	0.27
28	Lykes	137.8	306.3	637.8	0.95	100.32	142.01	0.15
35	Lykes	63.60	689.5	234.3	0.32	17.85	50.04	0.10
36	Lykes	80.75	779.8	189.0	0.05	21.19	6.48	0.12
38	Lykes	16.06	261.9	223.9	0.93	5.03	8.88	0.04
39	Lykes	40.70	1035	43.25	0.05	18.07	108.13	0.07
40	Lykes	85.85	482.0	76.18	1.21	49.12	88.77	0.24
41	Lykes	28.45	600.3	444.3	1.03	3.19	12.75	0.03
42	Lykes	109.3	212.3	194.0	0.66	195.71	185.57	0.32
43	Lykes	59.58	880.5	1086	1.12	5.43	17.59	0.03
44	Lykes	22.82	276.2	479.1	0.03	6.17	9.84	0.03
45	Lykes	17.59	351.5	435.1	3.67	125.81	4.04	0.03
46	Lykes	146.0	435.8	120.1	4.47	100.32	171.05	0.38
50	Lykes	55.60	275.5	698.0	4.69	19.22	32.11	0.06
52	BIR	108.3	222.1	523.0	2.12	51.45	81.33	0.15
56	BIR	96.40	237.5	251.9	1.68	31.66	74.31	0.23

Lab ID	Location	M3-TP mg/kg	M3-Fe mg/kg	M3-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	M3-PSR (TP)
59	BIR	99.60	205.2	571.0	0.91	18.67	47.57	0.13
68	BIR	162.0	97.53	229.8	3.62	137.56	182.15	0.51
78	BIR	145.0	142.5	261.5	0.16	86.36	127.16	0.38
81	BIR	112.4	525.5	347.8	0.65	77.05	136.32	0.16
82	BIR	64.70	89.60	296.1	0.26	35.15	57.06	0.17
85	BIR	91.18	312.8	1410	0.12	3.88	8.74	0.05
92	BIR	99.23	161.5	119.2	0.53	44.46	72.16	0.44
96	BIR	85.63	333.0	1465	0.09	5.26	14.78	0.05
97	Syfrette	21.53	161.4	13.35	N/A	10.29	38.94	0.21
98	BIR	30.35	34.73	231.9	0.81	18.99	39.80	0.11
101	BIR	170.3	200.5	737.0	1.79	70.07	90.49	0.18
103	BIR	187.3	219.8	995.0	0.07	42.14	99.66	0.15
107	Payne	31.95	453.8	721.0	0.13	4.34	27.27	0.03
110	Payne	27.80	302.1	1145	0.09	2.63	8.88	0.02
114	Payne	125.8	836.3	2543	0.17	5.94	23.88	0.04
115	Syfrette	97.83	1046	642.8	0.98	22.42	N/A†	0.07
131	Syfrette	62.78	925.3	558.8	0.49	50.29	23.42	0.05
153	Syfrette	60.70	447.9	810.0	0.78	16.70	59.72	0.05
159	Lightsey	56.60	710.0	1224	0.02	2.29	69.40	0.03
160	Lightsey	115.2	270.8	274.0	3.71	81.70	30.68	0.25
169	Lightsey	32.88	232.5	50.50	0.72	11.21	27.75	0.18
171	Lightsey	63.30	132.0	399.9	1.64	32.83	40.34	0.12
211	Rafter-T	187.3	327.5	1303	0.16	12.05	25.82	0.11
212	Syfrette	40.50	551.0	380.1	0.27	2.54	50.04	0.05
213	Rafter-T	299.3	517.0	1493	1.05	0.00	50.04	0.15
216	Rafter-T	226.3	436.0	1503	1.05	0.00	30.68	0.12

Lab ID	Location	M3-TP mg/kg	M3-Fe mg/kg	M3-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	M3-PSR (TP)
225	BIR	107.1	297.4	754.0	0.71	2.54	55.33	0.10
230	Lykes	45.78	456.5	613.8	4.75	3.23	21.68	0.05
231	Lykes	76.33	839.3	56.08	0.41	5.52	117.99	0.14
234	Lykes	82.90	196.9	137.2	1.85	37.48	53.83	0.31
236	Lykes	96.20	322.1	1161	0.05	18.92	12.19	0.06
237	Rafter-T	70.33	1638	2378	N/A	0.72	7.01	0.02
246	BIR	317.0	365.8	1560	3.38	63.31	154.66	0.16
248	BIR	188.0	137.0	308.0	4.20	137.56	136.32	0.44
249	BIR	177.0	128.5	301.3	4.09	126.15	191.32	0.42
250	BIR	40.45	91.20	108.0	0.71	20.68	41.53	0.23
258	Alderman	22.71	92.80	310.1	0.08	17.89	11.80	0.06
261	Alderman	41.51	108.5	438.9	0.12	2.77	8.13	0.07
264	Alderman	103.0	352.8	355.8	0.83	16.53	79.63	0.17
267	Williamson	68.50	256.8	867.0	0.30	6.77	31.05	0.06
270	Williamson	23.94	335.1	516.0	0.05	2.29	0.80	0.03
273	Williamson	33.50	461.4	652.0	0.03	0.16	0.00	0.03
276	Williamson	22.88	509.0	712.0	0.02	0.72	9.97	0.02
279	Williamson	18.51	223.7	415.3	0.00	0.72	0.80	0.03
282	BIR	49.87	139.2	295.8	0.56	14.21	5.84	0.12
287	BIR	54.70	238.5	575.0	0.19	13.06	16.38	0.07
294	Lykes	21.66	169.2	440.6	0.26	14.22	13.63	0.04
297	Lykes	30.69	559.0	195.4	0.47	0.83	1.72	0.06
298	Lykes	60.60	348.3	773.0	0.03	0.27	1.72	0.06
299	Lykes	2.86	12.27	44.23	0.07	2.52	3.55	0.05
300	Lykes	113.1	993.5	1095	0.03	1.65	9.97	0.06
301	Lykes	32.26	352.4	117.9	0.10	3.05	11.34	0.10

Lab ID	Location	M3-TP mg/kg	M3-Fe mg/kg	M3-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	M3-PSR (TP)
302	Lykes	34.88	545.8	229.5	0.14	4.21	0.00	0.06
303	Lykes	83.90	297.0	1667	0.11	1.60	1.72	0.04
304	Lykes	16.62	78.80	111.9	0.01	1.19	1.72	0.10
305	Lykes	29.91	214.3	660.0	0.11	3.05	3.00	0.03
306	Lykes	10.34	168.9	246.6	0.45	1.65	0.80	0.03
309	Alderman	60.25	103.8	407.8	2.23	80.14	136.32	0.11
312	Alderman	88.03	173.3	627.8	1.64	61.07	108.83	0.11
315	Alderman	122.6	208.5	1057	2.10	81.70	145.49	0.09
319	Rafter-T	43.93	1075	670.3	N/A	0.00	9.05	0.03
4	Lykes	30.08	213.9	548.0	0.72	7.78	7.42	0.04
6	Lykes	26.67	277.8	682.0	2.98	6.40	5.97	0.03
17	Lykes	44.50	336.3	841.3	2.58	10.71	14.20	0.04
19	Lykes	19.53	180.4	319.8	0.15	5.72	14.20	0.04
21	Lykes	39.00	233.0	555.3	0.75	2.97	10.33	0.05
22	Lykes	16.48	143.3	375.8	0.57	4.34	2.10	0.03
27	Lykes	112.8	671.5	145.8	0.78	98.00	200.09	0.21
29	Lykes	103.1	533.5	714.8	1.47	35.15	74.24	0.09
33	Lykes	138.3	210.8	252.5	1.34	0.00	146.85	0.34
37	Lykes	48.43	457.8	888.3	0.21	8.46	17.59	0.04
55	BIR	55.30	229.5	79.90	1.11	17.39	47.57	0.25
58	BIR	43.63	115.5	169.1	1.02	17.85	33.76	0.17
64	BIR	121.8	143.5	437.3	0.22	46.79	75.18	0.21
65	BIR	56.20	77.20	205.4	3.99	35.15	57.06	0.20
67	BIR	87.20	245.3	391.0	0.14	17.62	40.66	0.15
71	BIR	165.5	233.5	929.3	0.54	30.50	82.94	0.14
77	BIR	129.8	207.0	393.5	3.73	72.39	90.49	0.23

Lab ID	Location	M3-TP	M3-Fe	M3-Al	SRP (0.1M KCl)	WSP (mg/kg)	SRP(mg/kg) 1:10	M3-PSR
		mg/kg	mg/kg	mg/kg	mg/L	1:10 dry wt	incubated	(TP)
86	BIR	45.18	210.4	733.0	0.20	6.86	13.91	0.05
88	BIR	59.00	516.0	381.1	0.27	10.06	29.44	0.08
89	BIR	94.70	464.8	841.8	0.40	56.10	90.49	0.08
102	BIR	47.33	97.80	177.2	0.21	14.64	38.07	0.18
106	Payne	50.60	445.5	1493	0.06	6.40	21.46	0.03
111	Payne	63.20	401.8	1203	0.43	12.58	39.37	0.04
112	Payne	76.75	834.3	2338	0.06	0.00	10.33	0.02
113	Syfrette	45.23	377.4	758.0	0.53	12.35	39.37	0.04
130	Syfrette	47.47	395.9	1112	0.10	5.43	10.33	0.03
137	Payne	32.33	870.0	285.3	0.05	15.09	2.10	0.04
139	Payne	64.23	798.0	2165	0.05	0.72	3.55	0.02
140	Payne	53.95	815.5	98.43	0.89	11.67	16.16	0.10
142	Payne	39.60	908.0	650.6	0.16	0.95	54.88	0.03
146	Payne	60.10	341.3	255.9	0.88	18.34	35.50	0.12
147	Payne	34.83	827.8	1233	0.05	0.00	12.75	0.02
148	Payne	33.98	859.8	792.5	0.11	2.28	11.30	0.02
151	Rafter-T	142.0	432.5	2238	0.17	5.72	16.14	0.05
152	Syfrette	38.72	320.5	391.8	0.51	9.15	30.66	0.06
161	Lightsey	49.63	104.1	165.9	1.37	30.50	45.18	0.20
162	Lightsey	26.44	142.2	133.7	0.81	17.39	35.98	0.11
164	Syfrette	84.00	366.9	1041	0.49	11.89	31.63	0.06
166	Lightsey	24.10	249.1	147.5	0.31	7.78	19.53	0.08
168	Lightsey	40.29	112.0	263.6	1.27	32.83	117.81	0.11
173	Payne	68.90	547.3	410.3	0.14	6.22	12.75	0.09
174	Payne	54.25	485.8	157.5	0.06	1.62	40.36	0.12
175	Payne	50.55	844.8	930.0	0.10	0.83	11.32	0.03

Lab ID	Location	M3-TP mg/kg	M3-Fe mg/kg	M3-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	M3-PSR (TP)
176	Payne	128.0	711.8	2520	0.11	3.86	0.65	0.04
177	Payne	79.70	838.0	407.8	1.00	0.00	11.32	0.09
178	Payne	66.83	1013	452.8	0.35	4.76	38.89	0.06
179	Payne	58.75	863.0	275.3	0.47	13.04	26.30	0.07
200	Rafter-T	85.50	221.5	663.0	0.62	18.53	21.95	0.10
206	Syfrette	47.26	416.6	835.0	0.48	12.62	25.33	0.04
208	Payne	77.73	645.3	412.5	0.25	14.41	26.79	0.09
215	Rafter-T	207.9	239.5	1473	0.13	10.33	24.85	0.11
219	Payne	55.45	791.8	112.4	0.37	1.39	5.97	0.10
220	Rafter-T	114.7	217.6	633.0	0.48	11.82	16.14	0.14
222	Rafter-T	96.30	269.3	581.0	1.15	25.84	6.48	0.12
223	Payne	57.08	574.5	755.3	0.05	2.74	151.69	0.05
227	BIR	88.60	304.1	982.0	0.17	8.16	34.62	0.07
228	BIR	87.90	221.6	750.0	0.42	8.50	27.72	0.09
232	Lykes	119.7	250.5	601.0	1.55	39.81	72.16	0.14
241	BIR	90.60	95.50	113.2	1.74	46.79	78.63	0.50
251	BIR	59.90	57.20	52.70	0.80	26.29	53.61	0.65
252	BIR	157.4	163.2	1391	0.27	6.09	20.82	0.09
253	BIR	59.60	148.1	26.34	0.96	58.43	61.37	0.53
254	BIR	87.10	146.6	87.20	1.60	46.79	63.00	0.48
257	BIR	63.50	111.2	22.42	2.14	25.84	62.21	0.73
259	Alderman	16.12	65.30	320.8	0.01	4.31	0.80	0.04
262	Alderman	17.15	71.50	268.5	0.04	1.84	0.80	0.05
265	Alderman	52.30	179.9	514.0	0.18	16.53	25.55	0.08
268	Williamson	50.90	258.4	935.0	0.11	1.84	6.30	0.04
271	Williamson	32.29	239.4	663.0	0.01	0.49	0.00	0.04

Lab ID	**Location**	**M3-TP** **mg/kg**	**M3-Fe** **mg/kg**	**M3-Al** **mg/kg**	**SRP (0.1M KCl)** **mg/L**	**WSP (mg/kg)** **1:10 dry wt**	**SRP(mg/kg) 1:10 incubated**	**M3-PSR (TP)**
274	Williamson	32.67	278.0	730.0	0.02	1.06	N/A	0.03
277	Williamson	27.93	196.3	547.0	0.03	0.61	N/A	0.04
280	Williamson	21.62	200.7	716.0	0.00	0.38	11.34	0.02
283	BIR	23.63	134.3	246.4	0.20	15.85	9.97	0.07
288	BIR	33.18	179.4	449.4	0.06	5.38	5.38	0.05
295	Lykes	6.85	97.00	98.70	0.11	4.91	3.55	0.04
308	Payne	144.8	768.5	1715	0.32	10.80	53.96	0.06
310	Alderman	13.59	87.30	275.6	0.02	2.73	8.00	0.04
313	Alderman	13.74	62.70	248.9	0.03	10.58	10.88	0.04
316	Alderman	6.24	20.42	66.50	0.04	0.24	11.80	0.07
320	Rafter-T	61.40	249.0	821.0	N/A	6.08	14.09	0.06

[†] N/A = Not Available

Appendix Table 5. HCl- P, Fe and Al as determined using ICAP, soluble reactive phosphorus (SRP) in a 1:10 soil:0.01 M KCl solution, water soluble P (dry soils) and SRP as obtained after incubation of soils for 15 days.

Lab ID	**Location**	**HCl Pi** mg/kg	**HCl-TP** mg/kg	**HCl-Fe** mg/kg	**HCl-Al** mg/kg	**SRP (0.1M KCl)** mg/L	**WSP (mg/kg)** 1:10 dry wt	**SRP(mg/kg) 1:10** incubated	**PSR-HCl** TP	**PSR-HCl** Pi
13	BIR	91.17	149.62	1545	992	1.79	12.35	79.08	0.07	0.05
14	Lykes	121.45	184.72	1003	929	0.27	79.38	122.65	0.11	0.07
15	Lykes	67.00	114.24	479	861	0.54	44.46	59.72	0.09	0.05
18	Lykes	138.29	213.72	1185	1162	1.47	9.38	132.33	0.11	0.07
20	Lykes	92.51	142.69	657	1040	1.33	39.81	79.08	0.09	0.06
25	Lykes	137.04	202.46	919	647	1.44	118.94	180.73	0.16	0.11
26	Lykes	62.57	111.07	1711	533	1.69	0.00	243.65	0.07	0.04
28	Lykes	114.71	171.26	987	925	0.95	100.32	142.01	0.11	0.07
35	Lykes	45.87	99.84	1434	1147	0.32	17.85	50.04	0.05	0.02
36	Lykes	58.76	150.08	2520	1183	0.05	21.19	6.48	0.05	0.02
38	Lykes	36.66	131.41	3199	1799	0.93	5.03	8.88	0.03	0.01
39	Lykes	17.07	52.43	753	1386	0.05	18.07	108.13	0.03	0.01
40	Lykes	10.95	40.55	704	598	1.21	49.12	88.77	0.04	0.01
41	Lykes	63.01	130.89	1328	940	1.03	3.19	12.75	0.07	0.03
42	Lykes	83.31	140.49	498	258	0.66	195.71	185.57	0.25	0.15
43	Lykes	18.02	42.52	1398	512	1.12	5.43	17.59	0.03	0.01
44	Lykes	5.41	15.41	360	304	0.03	6.17	9.84	0.03	0.01
45	Lykes	88.67	142.53	1465	496	3.67	125.81	4.04	0.10	0.06
46	Lykes	119.82	194.73	1183	584	4.47	100.32	171.05	0.15	0.09
50	Lykes	83.18	136.04	1368	343	4.69	19.22	32.11	0.12	0.07

Lab ID	Location	HCl Pi	HCl-TP	HCl-Fe	HCl-Al	SRP (0.1M KCl)	WSP (mg/kg)	SRP(mg/kg) 1:10	PSR-HCl	PSR-HCl
		mg/kg	mg/kg	mg/kg	mg/kg	mg/L	1:10 dry wt	incubated	TP	Pi
52	BIR	86.70	136.93	677	617	2.12	51.45	81.33	0.13	0.08
56	BIR	69.06	116.55	585	487	1.68	31.66	74.31	0.13	0.08
59	BIR	51.17	97.20	369	545	0.91	18.67	47.57	0.12	0.06
68	BIR	158.55	217.19	376	333	3.62	137.56	182.15	0.37	0.27
78	BIR	116.53	190.09	408	408	0.16	86.36	127.16	0.27	0.17
81	BIR	132.98	211.13	2749	1657	0.65	77.05	136.32	0.06	0.04
82	BIR	43.74	78.28	200	334	0.26	35.15	57.06	0.16	0.09
85	BIR	32.94	89.40	638	1565	0.12	3.88	8.74	0.04	0.02
92	BIR	68.23	127.97	400	542	0.53	44.46	72.16	0.15	0.08
96	BIR	39.98	111.74	896	2229	0.09	5.26	14.78	0.04	0.01
97	Syfrette	60.43	160.41	1521	2919	N/A	10.29	38.94	0.04	0.01
98	BIR	30.11	50.02	114	361	0.81	18.99	39.80	0.10	0.06
101	BIR	88.83	150.79	280	626	1.79	70.07	90.49	0.17	0.10
103	BIR	120.47	286.63	563	1485	0.07	42.14	99.66	0.14	0.06
107	Payne	80.45	200.36	3376	4382	0.13	4.34	27.27	0.03	0.01
110	Payne	76.85	199.49	2019	6590	0.09	2.63	8.88	0.02	0.01
114	Payne	127.00	288.19	3075	5213	0.17	5.94	23.88	0.04	0.02
115	Syfrette	108.44	182.19	2764	1954	0.98	22.42	N/A[†]	0.05	0.03
131	Syfrette	71.90	142.71	2893	2159	0.49	50.29	23.42	0.03	0.02
153	Syfrette	70.65	144.87	1707	2134	0.78	16.70	59.72	0.04	0.02
159	Lightsey	104.16	233.83	3201	2338	0.02	2.29	69.40	0.05	0.02
160	Lightsey	147.15	210.06	819	452	3.71	81.70	30.68	0.22	0.15
169	Lightsey	36.11	77.70	678	568	0.72	11.21	27.75	0.08	0.04
171	Lightsey	57.77	83.31	393	657	1.64	32.83	40.34	0.09	0.06
211	Rafter-T	42.01	171.49	517	1676	0.16	12.05	25.82	0.08	0.02
212	Syfrette	69.34	108.37	2146	1478	0.27	2.54	50.04	0.04	0.02

Lab ID	Location	HCl Pi mg/kg	HCl-TP mg/kg	HCl-Fe mg/kg	HCl-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-HCl TP	PSR-HCl Pi
213	Rafter-T	85.10	331.19	795	2128	1.05	0.00	50.04	0.11	0.03
216	Rafter-T	67.59	238.92	750	2345	1.05	0.00	30.68	0.08	0.02
225	BIR	85.34	176.97	1067	1610	0.71	2.54	55.33	0.07	0.03
230	Lykes	10.45	24.48	575	278	4.75	3.23	21.68	0.04	0.02
231	Lykes	46.50	109.82	1821	1008	0.41	5.52	117.99	0.05	0.02
234	Lykes	106.21	179.35	814	695	1.85	37.48	53.83	0.14	0.08
236	Lykes	64.31	239.94	1468	3174	0.05	18.92	12.19	0.05	0.01
237	Rafter-T	58.42	162.17	5535	4188	N/A	0.72	7.01	0.02	0.01
246	BIR	233.05	463.15	1007	2379	3.38	63.31	154.66	0.14	0.07
248	BIR	197.65	300.90	436	535	4.20	137.56	136.32	0.35	0.23
249	BIR	175.14	231.83	421	468	4.09	126.15	191.32	0.30	0.23
250	BIR	26.01	45.47	160	125	0.71	20.68	41.53	0.20	0.11
258	Alderman	17.61	32.62	367	840	0.08	17.89	11.80	0.03	0.02
261	Alderman	21.17	42.61	379	985	0.12	2.77	8.13	0.03	0.02
264	Alderman	63.95	153.22	992	1789	0.83	16.53	79.63	0.06	0.02
267	Williamson	46.83	132.94	775	1888	0.30	6.77	31.05	0.05	0.02
270	Williamson	103.81	172.39	5311	6892	0.05	2.29	0.80	0.02	0.01
273	Williamson	407.76	498.00	9551	9965	0.03	0.16	0.00	0.03	0.02
276	Williamson	202.16	300.80	4915	7291	0.02	0.72	9.97	0.03	0.02
279	Williamson	117.13	118.49	2329	5030	0.00	0.72	0.80	0.02	0.02
282	BIR	34.38	71.33	330	415	0.56	14.21	5.84	0.11	0.05
287	BIR	24.84	64.28	548	871	0.19	13.06	16.38	0.05	0.02
294	Lykes	15.17	33.92	504	654	0.26	14.22	13.63	0.03	0.01
297	Lykes	81.14	152.85	2525	453	0.47	0.83	1.72	0.08	0.04
298	Lykes	59.23	90.96	2624	1067	0.03	0.27	1.72	0.03	0.02
299	Lykes	99.02	131.14	1944	2273	0.07	2.52	3.55	0.04	0.03

Lab ID	Location	HCl Pi mg/kg	HCl-TP mg/kg	HCl-Fe mg/kg	HCl-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-HCl TP	PSR-HCl Pi
300	Lykes	3.85	4.03	20	48	0.03	1.65	9.97	0.06	0.06
301	Lykes	185.18	245.96	3561	3257	0.10	3.05	11.34	0.04	0.03
302	Lykes	57.69	87.57	2427	1152	0.14	4.21	0.00	0.03	0.02
303	Lykes	33.16	71.02	1420	329	0.11	1.60	1.72	0.06	0.03
304	Lykes	145.36	195.93	2192	4421	0.01	1.19	1.72	0.03	0.02
305	Lykes	21.11	25.57	170	162	0.11	3.05	3.00	0.09	0.08
306	Lykes	63.41	123.51	4152	661	0.45	1.65	0.80	0.04	0.02
309	Alderman	71.89	129.54	347	983	2.23	80.14	136.32	0.10	0.05
312	Alderman	80.55	152.15	481	1181	1.64	61.07	108.83	0.09	0.05
315	Alderman	87.66	168.68	501	1845	2.10	81.70	145.49	0.07	0.04
319	Rafter-T	39.83	81.55	3219	2639	N/A	0.00	9.05	0.02	0.01
4	Lykes	14.17	28.58	357	473	0.72	7.78	7.42	0.04	0.02
6	Lykes	11.04	26.57	471	607	2.98	6.40	5.97	0.03	0.01
17	Lykes	20.18	42.50	549	730	2.58	10.71	14.20	0.04	0.02
19	Lykes	11.23	22.72	305	292	0.15	5.72	14.20	0.04	0.02
21	Lykes	7.36	23.34	333	412	0.75	2.97	10.33	0.04	0.01
22	Lykes	8.52	21.76	238	352	0.57	4.34	2.10	0.04	0.02
27	Lykes	37.72	83.61	813	1006	0.78	98.00	200.09	0.05	0.02
29	Lykes	48.59	100.26	1039	701	1.47	35.15	74.24	0.07	0.04
33	Lykes	118.03	164.67	538	295	1.34	0.00	146.85	0.26	0.19
37	Lykes	23.59	64.44	942	1056	0.21	8.46	17.59	0.04	0.01
55	BIR	35.79	59.89	407	218	1.11	17.39	47.57	0.13	0.08
58	BIR	33.70	51.17	227	188	1.02	17.85	33.76	0.15	0.10
64	BIR	54.83	73.87	203	316	0.22	46.79	75.18	0.16	0.12
65	BIR	42.13	58.60	159	222	3.99	35.15	57.06	0.17	0.12
67	BIR	39.61	69.34	367	292	0.14	17.62	40.66	0.13	0.07

Lab ID	Location	HCl Pi	HCl-TP	HCl-Fe	HCl-Al	SRP (0.1M KCl)	WSP (mg/kg)	SRP(mg/kg) 1:10	PSR-HCl	PSR-HCl
		mg/kg	mg/kg	mg/kg	mg/kg	mg/L	1:10 dry wt	incubated	TP	Pi
71	BIR	104.96	230.56	593	1210	0.54	30.50	82.94	0.13	0.06
77	BIR	96.56	152.35	544	509	3.73	72.39	90.49	0.17	0.11
86	BIR	22.73	57.67	575	1040	0.20	6.86	13.91	0.04	0.02
88	BIR	45.51	105.02	1582	461	0.27	10.06	29.44	0.07	0.03
89	BIR	104.33	174.50	2335	1921	0.40	56.10	90.49	0.05	0.03
102	BIR	26.13	48.24	132	178	0.21	14.64	38.07	0.17	0.09
106	Payne	90.75	326.35	3308	4800	0.06	6.40	21.46	0.04	0.01
111	Payne	86.53	182.21	2395	3643	0.43	12.58	39.37	0.03	0.02
112	Payne	67.45	208.12	3513	5356	0.06	0.00	10.33	0.03	0.01
113	Syfrette	55.59	118.37	1623	1860	0.53	12.35	39.37	0.04	0.02
130	Syfrette	57.25	146.01	1961	3777	0.10	5.43	10.33	0.03	0.01
137	Payne	109.12	187.86	6091	3531	0.05	15.09	2.10	0.03	0.01
139	Payne	67.58	204.05	2863	5815	0.05	0.72	3.55	0.02	0.01
140	Payne	88.48	144.71	3609	1613	0.89	11.67	16.16	0.04	0.02
142	Payne	72.80	147.16	4343	3516	0.16	0.95	54.88	0.02	0.01
146	Payne	60.02	112.00	1305	1059	0.88	18.34	35.50	0.06	0.03
147	Payne	81.61	157.02	3772	5328	0.05	0.00	12.75	0.02	0.01
148	Payne	71.80	151.57	4629	4402	0.11	2.28	11.30	0.02	0.01
151	Rafter-T	57.34	188.14	834	3643	0.17	5.72	16.14	0.04	0.01
152	Syfrette	57.64	119.89	1197	1680	0.51	9.15	30.66	0.05	0.02
161	Lightsey	65.94	80.30	263	219	1.37	30.50	45.18	0.20	0.17
162	Lightsey	35.19	51.39	372	170	0.81	17.39	35.98	0.13	0.09
164	Syfrette	64.87	130.86	1025	1722	0.49	11.89	31.63	0.05	0.03
166	Lightsey	24.76	42.06	408	155	0.31	7.78	19.53	0.10	0.06
168	Lightsey	56.57	82.11	328	378	1.27	32.83	117.81	0.13	0.09
173	Payne	152.40	310.64	1783	3246	0.14	6.22	12.75	0.07	0.03

Lab ID	Location	HCl Pi mg/kg	HCl-TP mg/kg	HCl-Fe mg/kg	HCl-Al mg/kg	SRP (0.1M KCl) mg/L	WSP (mg/kg) 1:10 dry wt	SRP(mg/kg) 1:10 incubated	PSR-HCl TP	PSR-HCl Pi
174	Payne	134.99	245.50	1961	2948	0.06	1.62	40.36	0.05	0.03
175	Payne	72.38	158.80	4299	4508	0.10	0.83	11.32	0.02	0.01
176	Payne	68.44	304.89	2431	5724	0.11	3.86	0.65	0.04	0.01
177	Payne	63.77	148.01	2774	2167	1.00	0.00	11.32	0.04	0.02
178	Payne	86.88	156.98	5114	2749	0.35	4.76	38.89	0.03	0.01
179	Payne	118.57	206.77	3323	2803	0.47	13.04	26.30	0.04	0.02
200	Rafter-T	49.81	108.46	535	1346	0.62	18.53	21.95	0.06	0.03
206	Syfrette	54.70	118.64	1702	1999	0.48	12.62	25.33	0.04	0.02
208	Payne	143.61	301.69	2634	3449	0.25	14.41	26.79	0.06	0.03
215	Rafter-T	51.90	385.50	446	2498	0.13	10.33	24.85	0.12	0.02
219	Payne	113.37	203.53	3263	2580	0.37	1.39	5.97	0.04	0.02
220	Rafter-T	23.73	101.78	334	863	0.48	11.82	16.14	0.09	0.02
222	Rafter-T	36.57	110.58	587	1089	1.15	25.84	6.48	0.07	0.02
223	Payne	166.34	336.98	2135	4220	0.05	2.74	151.69	0.06	0.03
227	BIR	54.25	127.20	977	1736	0.17	8.16	34.62	0.05	0.02
228	BIR	41.11	92.89	553	1092	0.42	8.50	27.72	0.06	0.03
232	Lykes	104.38	202.45	908	1321	1.55	39.81	72.16	0.10	0.05
241	BIR	85.82	128.70	263	336	1.74	46.79	78.63	0.24	0.16
251	BIR	60.17	94.20	138	255	0.80	26.29	53.61	0.25	0.16
252	BIR	169.19	527.45	667	5264	0.27	6.09	20.82	0.08	0.03
253	BIR	62.01	106.15	361	242	0.96	58.43	61.37	0.22	0.13
254	BIR	84.10	128.73	396	343	1.60	46.79	63.00	0.21	0.14
257	BIR	78.58	121.61	326	324	2.14	25.84	62.21	0.22	0.14
259	Alderman	5.53	14.94	129	383	0.01	4.31	0.80	0.03	0.01
262	Alderman	6.74	18.60	163	372	0.04	1.84	0.80	0.04	0.01
265	Alderman	22.94	59.34	472	876	0.18	16.53	25.55	0.05	0.02

Lab ID	Location	HCl Pi	HCl-TP	HCl-Fe	HCl-Al	SRP (0.1M KCl)	WSP (mg/kg)	SRP(mg/kg) 1:10	PSR-HCl	PSR-HCl
		mg/kg	mg/kg	mg/kg	mg/kg	mg/L	1:10 dry wt	incubated	TP	Pi
268	Williamson	29.93	110.00	934	1937	0.11	1.84	6.30	0.04	0.01
271	Williamson	184.71	197.15	4385	10933	0.01	0.49	0.00	0.01	0.01
274	Williamson	165.49	198.53	3241	7430	0.02	1.06	N/A	0.02	0.02
277	Williamson	168.99	212.87	2241	6285	0.03	0.61	N/A	0.03	0.02
280	Williamson	138.54	148.27	2886	9243	0.00	0.38	11.34	0.01	0.01
283	BIR	13.39	27.77	200	256	0.20	15.85	9.97	0.07	0.03
288	BIR	14.58	41.47	382	696	0.06	5.38	5.38	0.04	0.01
295	Lykes	4.45	9.72	181	98	0.11	4.91	3.55	0.05	0.02
308	Payne	107.27	309.76	2933	3576	0.32	10.80	53.96	0.05	0.02
310	Alderman	8.69	20.09	164	322	0.02	2.73	8.00	0.04	0.02
313	Alderman	9.07	21.30	156	349	0.03	10.58	10.88	0.04	0.02
316	Alderman	3.55	8.79	36	70	0.04	0.24	11.80	0.09	0.04
320	Rafter-T	57.09	195.03	1194	3161	N/A	6.08	14.09	0.05	0.01

[†] N/A = Not Available