

Protocol Development to Evaluate the Effect of Water Table Management on Phosphorus Release to Drainage Water

Final report

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By

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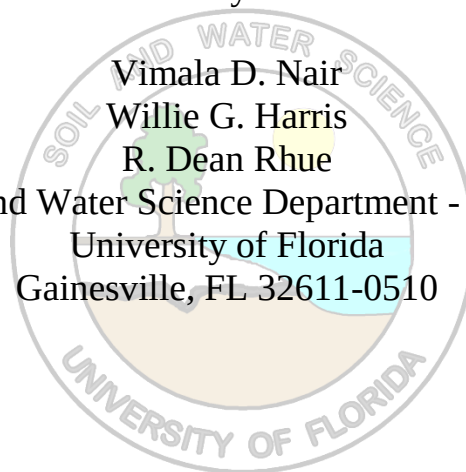


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1 Introduction

The release of phosphorus (P) from surface horizon soils is well documented in several studies on sandy soils in the US (Nair et al., 1995; Pote et al., 1996; Sims et al., 1998; Hooda et al., 2000; Paulter and Sims, 2000; Sharpley and Tunney, 2000; McDowell and Sharpley, 2001). Many of the studies have concentrated on a “change point”, i.e. a P concentration above which there is an elevated risk of P loss to water bodies, via surface and subsurface drainage (McDowell and Sharpley, 2001; Maguire and Sims, 2002; Nair et al., 2004).

Soil test P (STP) values have often been used as an environmental indicator for evaluating potential loss of P from the soil. However, heavy loading of P to sandy soils with very low P sorption capacities such as soils of the Lake Okeechobee Watershed (LOW), can quickly present environmental problems, despite initially low STP values. Environmental risk of P application relates to P sorption capacity up to some threshold where additional P could be detrimental. Phosphorus additions that result in STP concentrations above a change point are likely to be detrimental to water quality.

1.1 Soils of the Lake Okeechobee Watershed (LOW)

Spodosols comprise over 50% of the soils in Okeechobee County, Florida. Typical soil series include Myakka (sandy, siliceous, hyperthermic Aeric Alaquod); Immokalee (sandy, siliceous, hyperthermic Arenic Alaquod); and Pomello (sandy, siliceous, hyperthermic Oxyaquic Alorthods). Spodosols are characterized by the presence of a spodic (Bh) horizon (Figure 1), the depth of which in part determines the soil series. The upper boundary of the Bh horizon occurs at 50-75 cm for Myakka soils, and between 75-125 cm for Immokalee and Pomello soils.

Spodosols of Florida typically have an A horizon extending to about 15-20 cm depth, followed by an eluted E horizon with a thickness generally between 20-140 cm. The Bh underlying the E horizon is a dark colored horizon where C, Al and Fe have accumulated (Soil Survey Staff, 1996). A Bw horizon, commonly present beneath the Bh horizon, has little or no apparent illuvial accumulation of material. Some Florida Spodosols also have Bt horizons, characterized by silicate clay accumulation, beneath the Bw horizon. Florida Spodosols are characterized by a fluctuating watertable that typically reaches a seasonal high at a depth between 15 and 30 cm for the Myakka and Immokalee soils and between 60 and 105 cm for the Pomello series.

The depth to the spodic horizon as it relates to hydrology will be a factor in the usefulness of this horizon to retain and release P for P uptake by grasses and other vegetation, and/or for P release to the environment. Nair et al. (1999) found that the retention capacity of the Bh horizon was in the order Myakka $\geq$ Immokalee $\geq$ Pomello soils and therefore related to the depth of the Bh horizon. The Bh horizons for Myakka and Immokalee soils are closer to the surface than the Bh for Pomello soils, thus increasing the chances for manure-derived P to be retained at the Bh for Myakka and Immokalee soils instead of laterally moving above the Bh horizon.

The amount of P lost from a P-impacted soil (e.g. inorganic fertilizer, biosolids, poultry manure, dairy manure, etc.) will depend on the solubility of the material, which can best be determined by extraction with water. When soils are extracted with water and plotted against the P saturation ratio (PSR), we get a “change point” (i. e. a point in a WSP/PSR graph when P concentrations in the soil solution abruptly increase. The PSR is determined as the molar ratio of P to (Fe+Al); Fe+Al is used as a surrogate for the P retention capacity of the soil (Nair and Harris, 2004; Section 1.3).

High P loading in the uplands would eventually impact ditches, streams and wetlands in the LOW. Thus, these landscape units could function either as a P source or P sink depending on the P load they receive. The sandy surface A and E horizons of Spodosols of the LOW do not have any retention capacity (Yuan and Lucas, 1982; Nair and Graetz, 2002; Nair et al., 1998) and P from the uplands could be lost via surface or subsurface flow (Campbell et al., 1995). Under these circumstances, it is important to understand the P retention and release properties of the more P retentive spodic horizon (Mansell et al., 1991; Villapando and Graetz, 2001; Nair and Graetz, 2002) underlying the sandy surface horizons.

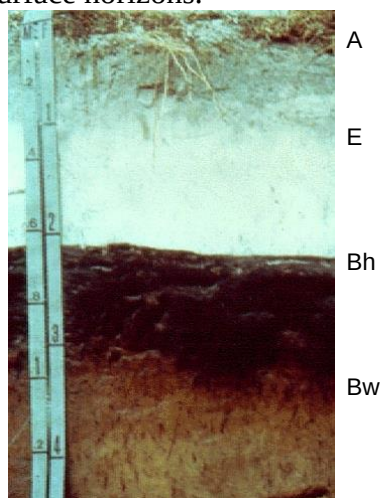


Figure 1 A Spodosol soil profile showing the A, E and Bh and Bw horizons.

1.2 Phosphorus Release Potential from P-impacted Soils

To understand the long-term contribution of P from agricultural lands to South Florida's Lake Okeechobee, it is necessary to evaluate the threshold PSR (PSR at the change point) and the soil P storage capacity (SPSC) of soil profiles within its watershed. P retention and release properties of spodic horizons differ from other Florida soil materials due to the prevalence of organically-associated Al (Harris et al., 1996; Zhou et al., 1997). The organo-Al material has very high surface area and P retention, but releases P more readily than metal oxides typical of other soils. Villapando and Graetz (2001) found that CuCl_2 -extractable Al (organic matter bound Al) was the single most important chemical property contributing to P retention in Bh horizon soils of the LOW. While organic C in the Bh horizon is a re-precipitation of dissolved C with Al, the organic C in surface soils is derived from plant debris decomposition.

Nair et al. (1999) found that the P sorption maximum (S_{max}) as determined by Langmuir isotherms was linearly related to oxalate-extractable Al, and variability in S_{max} was attributed primarily to Al and C. Spodic horizons commonly have vertical gradations in organic C and Al that would affect retention and vertical flux of P. The upper part of the spodic is generally C rich, while Al increases and bulges near the center (Harris and Hollien, 1999). These gradients correspond to morphological changes in the spodic horizon, especially color.

1.3 The Phosphorus Saturation Ratio (PSR)

Using oxalate-extractable P, Fe and Al values, Nair et al. (2004) determined a change point at a PSR of 0.10 for surface and subsurface soils (A and E horizons) of the Suwannee River Basin (Figure 2).

The PSR can be calculated for a soil sample as the molar ratio of oxalate-extractable P to oxalate-extractable [Fe + Al].

$$PSR_{Ox} = \frac{\text{Oxalate - extractable P}}{\text{Oxalate - extractable [Fe + Al]}} \quad \text{or as molar concentration,}$$

$$\frac{\frac{\text{Oxalate P}}{31}}{\left[\frac{\text{Oxalate Fe}}{56} + \frac{\text{Oxalate Al}}{27} \right]}$$

Equation 1

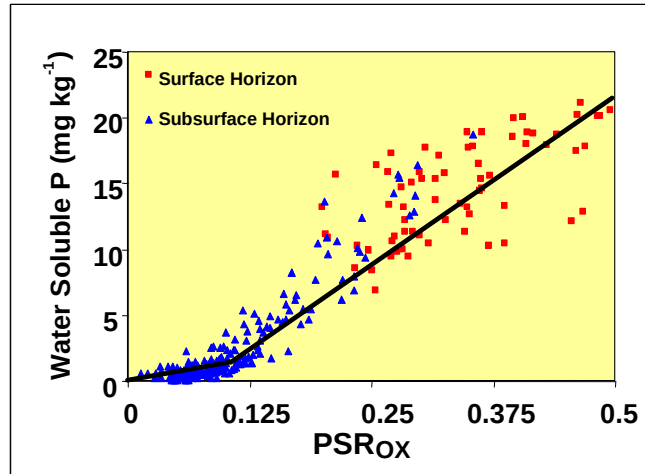


Figure 2 Relationship between the concentration of water-soluble P (WSP) and the P saturation ratio (PSR_{ox}) for manure-impacted surface and subsurface soils from the Middle Suwannee River Basin (Source: Nair et al., 2004).

A threshold PSR value can also be calculated from P, Fe and Al in a Mehlich 1(M1) solution PSR_{M1} as illustrated in Figure 3.

$$PSR_{M1} = \frac{M1 - extractable P}{M1 - extractable[Fe + Al]} \quad \text{or as molar concentration,}$$

$$\frac{\frac{Mehlich1 - P}{31}}{\left[\frac{Mehlich1Fe}{56} + \frac{Mehlich1Al}{27} \right]} \quad \text{Equation 2}$$

Nair et al. (2004) also determined the change point using P, Fe and Al in a Mehlich 1 solutions for surface soils. Mehlich 1 is the current soil test for P (STP) in Florida and P and metals can be easily determined in a Mehlich 1 solution in most analytical labs in the State. The change point (threshold PSR) calculated using P, Fe and Al in a Mehlich 1 solution was 0.1 (Figure 3).

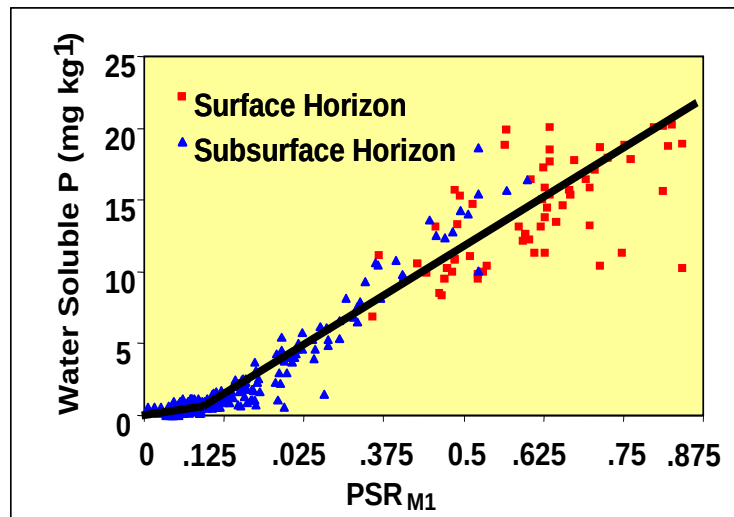


Figure 3 Relationship between the concentration of water-soluble P (WSP) and the P saturation ratio (PSR_{M1}) for manure-impacted surface and subsurface soils from the Middle Suwannee River Basin (Source: Nair et al., 2004).

1.3.1 Advantages of the PSR Compared to a Soil Test (Mehlich 1) P

Soil test P (STP) procedures such as Mehlich 1-P fail to precisely indicate whether a given soil is a P sink or source and hence would pose an environmental risk. A better indicator of P release would be the PSR. By using the same STP extract (such as the Mehlich 1 extract) and analyzing for Fe and Al, a phosphorus saturation ratio (PSR_{M1}) can be calculated.

The following example illustrates why the PSR is a better indicator of mobile P than the STP: Consider two soils with Mehlich 1-P of 1.5 moles (approximately 46 mg kg^{-1}). Soil 1 has a Mehlich (Fe + Al) of 7.5 mmoles and Soil 2 has (Fe + Al) of 15 mmoles. The PSR of Soil 1 would be $(1.5/7.5) = 0.20$ and the PSR of Soil 2 would be $1.5/15 = 0.10$. Therefore Soil 1 would

be a greater environmental risk than Soil 2 though they have the same Mehlich 1-P concentration.

1.4 “Safe” Soil P Storage Capacity (SPSC)

Neither the STP nor the PSR takes into account the capacity of the soil to retain any additional P. Many Florida sandy soils (e.g. Spodosols of the Lake Okeechobee Basin) have minimal P retention capacity in near-surface horizons. These horizons can have low STP but still have elevated risk of P loss because excess applied P would not be retained. Hence, a low STP value is not a valid reason to apply excess P in the nutrient management scheme. To overcome this problem, a new concept, the “safe” soil P storage capacity (SPSC) was proposed by Nair and Harris (2004) using the PSR threshold discussed in Section 1.3.

The SPSC allows a 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. It 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.

$$SPSC = (Threshold\ PSR_{Ox} - Soil\ PSR) * Oxalate\text{-}extractable\ (Fe + Al) \quad \text{Equation 3}$$

(Nair and Harris, 2004)

where

$$PSR_{Ox} = \frac{Oxalate\text{-}extractable\ P}{Oxalate\text{-}extractable[Fe + Al]}$$

and for the surface horizon, the calculation is

$$SPSC = (0.1 - Soil\ PSR_{Ox}) * Oxalate\text{-}extractable\ (Fe + Al) \quad \text{Equation 4}$$

using the threshold value as 0.1 (Section 1.3).

The above equation using oxalate P, Fe and Al was developed for surface A and E horizons. Oxalate extraction is not frequently performed in soil test laboratories in Florida (Nair and Graetz, 2002) or in other parts of the U.S. (Sims et al., 2002) due to practical difficulties in the measurement of parameters in the PSR calculations. More common soil tests include Mehlich 1 and Mehlich 3 extractions. The use of these routine agronomic soil tests to calculate PSR would simplify the measurement of PSR (and therefore SPSC), and provide a more accessible analytical tool for P management. Therefore it is important to assess the use of soil test parameters for SPSC calculations. A soil test solution, such as Mehlich 1 does not exhaustively extract P, Fe and Al unlike an oxalate extracting solution. *However, the relationship between SPSC calculated from oxalate extraction parameters and from soil test parameters is linear and therefore the above equation for SPSC calculations has to be calibrated for its use on a routine basis using easily determined parameters in a soil test solution* (Chrysostome et al., 2007).

When Mehlich 1 is used for calculation of the safe soil P storage of a soil, that factor is referred to as the capacity factor (CF):

$$CF = (Threshold\ PSR_{M1} - Soil\ PSR) * Mehlich\ 1\text{-}extractable\ (Fe + Al) \quad \text{Equation 5}$$

SPSC = CF * X where X is the correction factor that is obtained from a linear relationship between SPSC and CF.

Objectives:

To achieve our overall objective of developing a protocol to evaluate the effect of water table management on P release to drainage water, a threshold PSR for the Bh must be determined. Therefore, the specific objectives of the ongoing study include:

1. Determination of a threshold PSR for the Bh horizon using P, Fe and Al in an oxalate (PSR_{Ox}) and Mehlich 1 (PSR_{M1}) solution.
2. Use the threshold PSR (PSR_{Ox}) to calculate the safe P storage capacity (SPSC) for the Bh horizon
3. Calculate the “Capacity Factor” (CF) using M1-P, Fe and Al
4. Obtain a conversion factor to calculate SPSC from CF
5. Demonstrate the effect of water table management under different soil profile P impact levels.
6. Demonstrate the use of SPSC for phytoremediation.

2. Materials and Methods

2.1. Soil Collection/Sampling

1. Archived spodic (Bh) soil samples that encompass a range in P loading from dairy manure were selected from soils collected by the PIs from the L. Okeechobee Basin (total 115 samples; Figure 4). Sampling locations at the sites representing different soil series and impact levels are shown in Figures 5 – 8.
2. Fresh samples were collected from the following beef ranches
 - a. Hayman’s 711 Ranch (Figure 9): This is a beef ranch that has been in operation since the 1940’s and has locations within the ranch (B, C, D, H and P as designated by the ranch owners) with a range of P concentrations. The variation in P concentrations at this site gave us the opportunity to perform additional soil sampling beyond what was originally planned. A total of 12 soil profiles were sampled at this site.
 - b. The UF Beef Research Unit (BRU; Figure 10): Six soil profiles were sampled at this site.
 - c. UF Range Cattle Research and Education Center at Ona (Ona; Figure 11, Seven soil profiles were sampled at this site.
3. Archived Bh horizon samples that were collected and characterized during the Florida Cooperative Soil Survey Program (FCSSP).

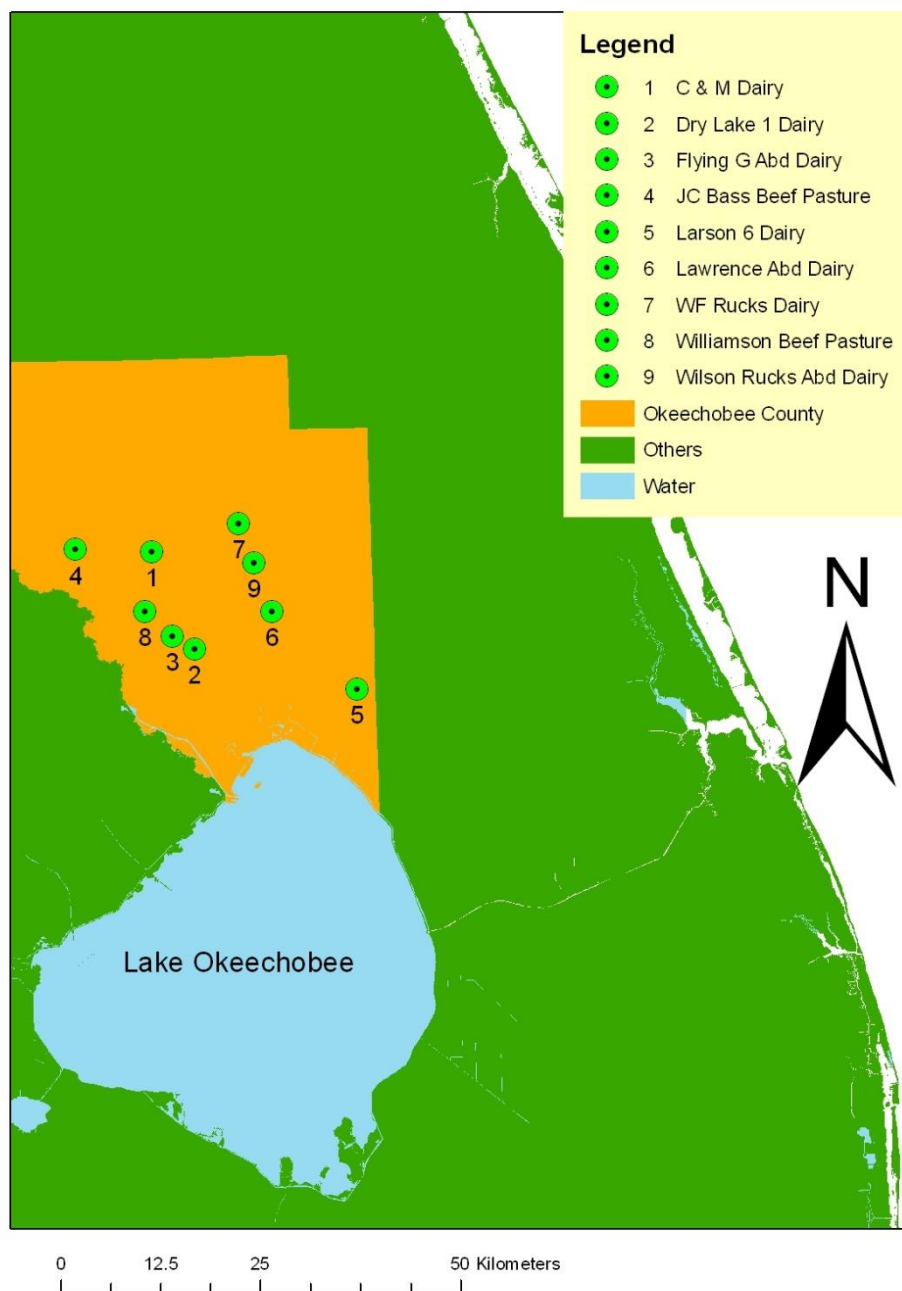


Figure 4 Location of study sites in Okeechobee county, Florida where archived soils impacted by dairy or beef manure were included in this study.



Figure 5 Site and sampling locations, and soil series at the C & M Dairy in the Lake Okeechobee Basin.



Figure 6 Site and sampling locations, and soil series at the W.F. Rucks Dairy in the Lake Okeechobee Basin.



Figure 7 Site and sampling locations, and soil series at the Dry Lake 1 Dairy in the Lake Okeechobee Basin.

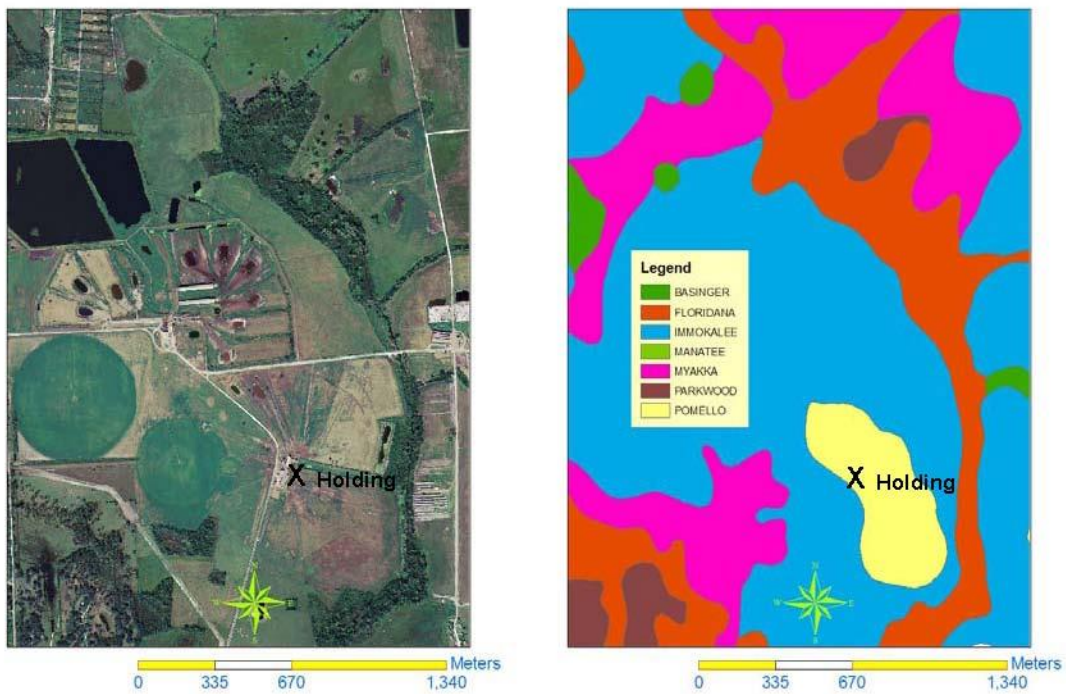


Figure 8 Site and sampling locations, and soil series at the Larson 6 Dairy in the Lake Okeechobee Basin.



Figure 9 Soil sampling points at several locations (B, C, D, H and P) within Hayman's 711 Ranch.

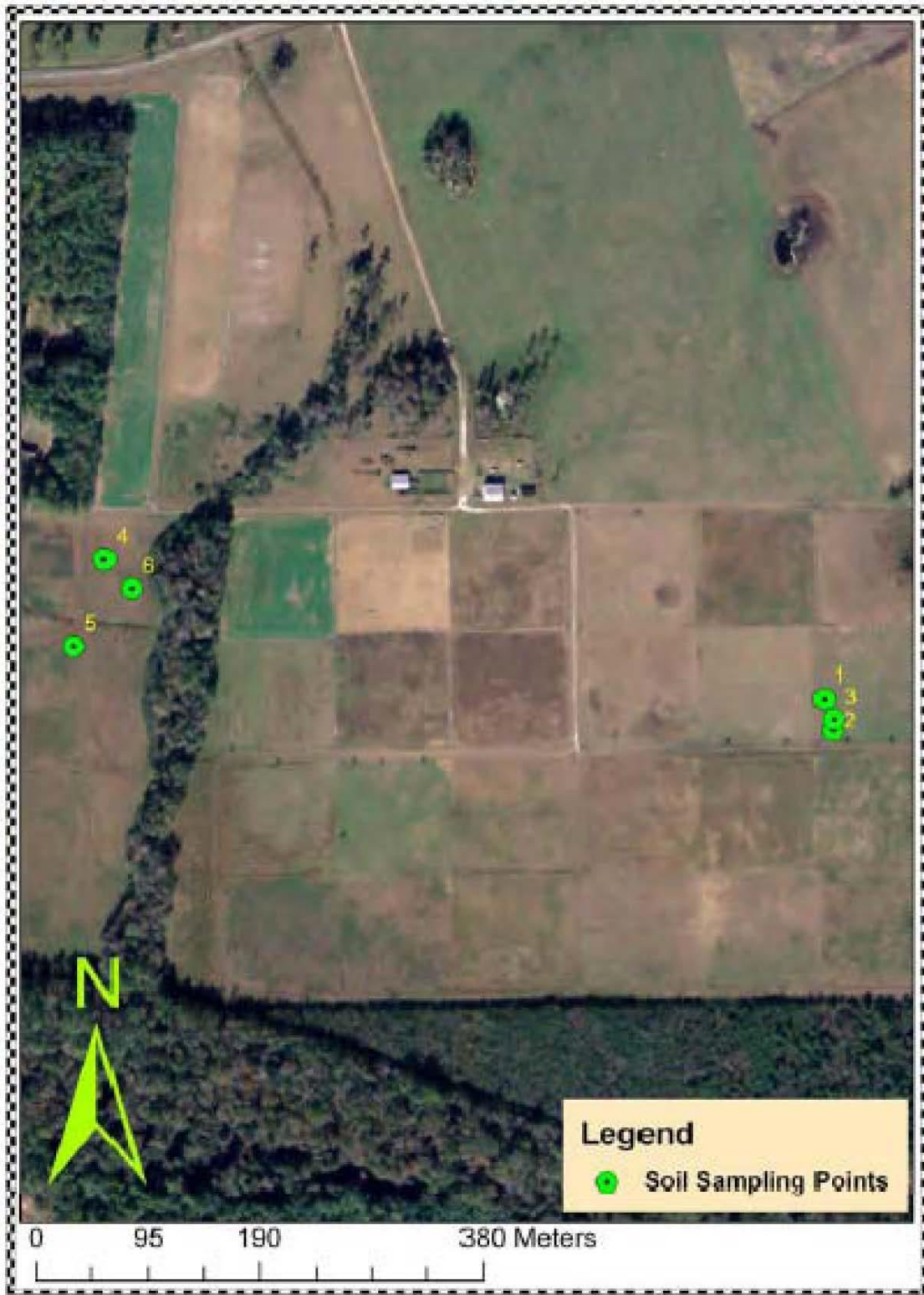


Figure 10 Soil sampling points at the UF Beef Research Unit, Gainesville, FL



Figure 11 Soil sampling points at the Range Cattle Research and Education Center at Ona, FL

2.1.1 Selection of Archived Bh Horizon Soils

The criteria for the selection of soil profiles from archived Okeechobee Basin soils (Section 2.1) included:

- varying P impact levels
- varying depth to the Bh horizon
- dairies that were active at the time of soil sampling and dairies that were not operating as dairies for a period of time (abandoned dairies)

Active dairies were selected to provide a range of years in operation and the abandoned dairies were selected to give a range of years since closing (Table 1). The sites selected included four active dairies, three dairies that had been abandoned for several years, two beef cattle pastures and two areas not significantly affected by human activities (native areas) (Figure 4).

Components of each active dairy sampled included, intensive, holding, pasture and forage areas, providing a range from high- to low cattle manure density. Native areas represent areas largely unimpacted by animals and humans. Intensive areas, where cattle are fed and held prior to milking, are situated closest to the barn and are generally void of vegetation. Holding areas are generally larger than intensive areas and are used for feeding and holding cattle overnight. Bahiagrass (*Paspalum notatum*) pastures are used for grazing, and bermudagrass (*Cynodon dactylon*) forage areas are used for forage production. Only the intensive and holding areas were sampled for the abandoned dairies.

Four sites from those selected (Table 1) were evaluated for P storage within the soil profile. These locations include soil profiles from Myakka (Figures 5 and 6), Immokalee (Figure 7) and Pomello (Figure 8) soil map units and represent varying P-impact levels.

Table 1. Characteristics of the dairies (adapted from Graetz and Nair, 1995)

Dairy	Component	Soil map unit	Dairy age (years)
WF Rucks Dairy	Intensive, Forage, Native†	Myakka sand	9
C & M Dairy	Holding, Pasture	Myakka sand	8
Larson 6 Dairy	Holding	Pomello sand	20
Dry Lake 1	Holding	Immokalee sand	32
Bass	Beef pasture	Myakka sand	NA‡
Williamson	Native	Immokalee sand	
Wilson	Abd Intensive	Immokalee sand	24 (4) §
Lawrence	Abd Intensive	Myakka sand	11 (18)
Flying G	Abd Holding	Immokalee sand	21 (12)

† Age of dairy is not for the “native” component

‡ NA = Not Available

§ Numbers within parenthesis are periods the dairies had been abandoned (abd) at the time of soil sampling.

2.1.2 Collection of Soil Samples from Beef Operation Sites

At each site (Hayman's 711 Ranch, BRU, and Ona), soil profiles were sampled by horizon to include the Bh horizon. If a given horizon was greater than 25 cm deep, the horizon was subdivided so that no soil sample collected was >25 cm deep. Spodic horizons were subdivided based on morphological gradients when present. Otherwise, the upper 5 cm was sampled separately, followed by the remainder of the Bh. We inferred that the upper 5-cm of the Bh horizon may be the more important part of the horizon with respect to P release and loss from the spodic horizon.

A total of 149 soil samples was collected; 69 from the Hayman's 711 Ranch, 38 from the UF Beef Research Unit at Ona, and 42 from the UF Range Cattle Research and Education Center. All soil samples were dried, passed through a 2-mm sieve, and stored for analyses.

2.1.3 Archived Bh Horizon Samples Collected during the FL Cooperative Soil Survey Program

We selected 77 archived spodic (Bh) from soil samples collected and characterized during the FCSSP. The FCSSP was conducted jointly by the University of Florida and the USDA Natural Resources Conservation Service over approximately a 20-year period ending in 1991 to represent a number of soil series with varying depths to the spodic horizon. The selection encompasses Bh, Bh1, Bh2, and Bh3 horizons with upper depth ranging from as shallow as 20 cm to as deep as 178 cm. Soil horizons were delineated and sampled using USDA soil survey conventions and procedures (Soil Survey Division Staff, 1993). A computer-accessible soil data set was established under this program which encompasses a wide array of soil characterization parameters that can serve to provide a context for and complement further research conducted on the samples. These samples represent a particularly valuable resource because (i) they are from whole soil profiles selected to be representative by professional soil surveyors, (ii) they are mostly from minimally disturbed areas (commonly forested), and (iii) their locations are known.

2.2 Soil Analyses

2.2.1 Dairy and Beef Manure-impacted Sites

All Bh soil samples of the archived dairy sites as well as the freshly collected beef manure-impacted sites (section 2.1) were analyzed for pH, water soluble P (WSP; 1:10 soil to water), and oxalate-extractable P, Fe, and Al. (0.1 M oxalic acid + 0.175 M ammonium oxalate solution, equilibrated at a pH of 3.0; McKeague and Day, 1966). Phosphorus, Fe and Al in the oxalate solution were determined using Inductively Coupled Argon Plasma Spectroscopy (Thermo Jarrel Ash ICAP 61E, Franklin, MA).

Soil pH was determined on a 1:2 soil:water suspension. Mehlich 1, or double acid-extractable (0.0125 M H₂SO₄ + 0.05 M HCl) P (M1-P), Fe (M1-Fe) and Al (M1-Al) were obtained using a 1:4 soil:double acid ratio (Mehlich, 1953). Water-soluble P was determined by extracting each soil sample with water at 1:10 soil:water ratio for one hour, and determining P on the filtrate collected after passing through a 0.45 µm filter. Water-soluble P (WSP) and Mehlich 1 P

concentrations were determined by an autoanalyzer (EPA 1983, Method 365-1) by the Murphy and Riley (1962) procedure. Iron and Al in the filtrates were analyzed by atomic absorption spectroscopy. Characteristics of all soils and

2.2.2 Samples Collected during the FL Cooperative Soil Survey Program

Soils from the prevalent Spodosol series sampled during the FCSSP were collected mainly from minimally P-impacted areas. We therefore incubated selected soils with known P concentrations (50, 100, 150, 200, 300 mg P kg⁻¹) for 6 weeks, dried the incubated soils, and performed oxalate and Mehlich 1 analyses on the soils to obtain a range of P-impacted Bh horizons representative of several Spodosol soil series.

The soils were incubated for an additional period (total period of incubation was 10 months) to ensure equilibrium between P and soil components. Oxalate and Mehlich 1-P, Fe and Al analyses were performed after the 10-month incubation. Information on texture analyses, pH total P and organic C on the pre-incubated soils was accessed, and Mehlich 1-Fe and Al were determined. Water soluble P was determined for the 6-week and 10-month incubated soils.

2.2.3 Soil Samples Collected from an Inorganically Fertilized Site

All samples collected from the inorganic fertilized site was analyzed for WSP, oxalate and Mehlich 1- P, Fe and Al using the same procedures adopted for the dairy and beef-manure impacted sites.

2.3 Statistical Analyses

The relationship between PSR and WSP was modeled as a segmented line (Equation 6), 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 (Equation 7). 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.

$$WSP = \begin{cases} a_0 + b_0 PSR & PSR \leq d_0 \\ a_1 + b_1 PSR & PSR \geq d_0 \end{cases} \quad \text{Equation 6}$$

$$b_0 = \frac{(a_1 - a_0) + b_1 d_0}{d_0} \quad \text{Equation 7}$$

3. Results and Implications

3.1 Change Point (Threshold PSR) Determination

3.1.1 Dairy- and Beef Manure-Impacted Soils

Selected characteristics of the Bh horizons of dairy and beef manure-impacted soils (archived samples) are given in Appendix Table 1; Appendix Table 2 contains the information needed for calculation of the PSR and SPSC values for the individual soil samples and includes WSP concentrations for developing the WSP/PSR relationships using oxalate and Mehlich 1-P, Fe and Al data. Similarly, Appendix Tables 3 and 4 contain the needed information for developing the WSP/PSR relationships from beef manure-impacted soils collected and analyzed during the course of this study.

The relationship between WSP and PSR_{Ox} for all manure impacted soils, both from dairy and beef manure-impacted sites is shown below (Figure 12). Details of the procedure used in the statistical analysis are given in Section 2.3. Relationship between WSP and PSR_{M1} for the same manure-impacted soils is shown in Figure 13.

The change point (threshold PSR_{Ox}) has been statistically determined to be **0.05**. We will be using this threshold PSR for all computations of SPSC using oxalate-extractable P, Fe and Al (Section 3.2.1). The threshold PSR_{M1} has been statistically determined to be **0.08**. This value will be used for calculating the capacity factor (Section 3.2.2). Note that the threshold values are determined for the Bh horizon using pooled data from both archived and soils collected during the course of this study. The equations for calculating SPSC using oxalate (Equation 8) or Mehlich 1 (Equation 9) parameters using these threshold PSR values are given in Section 3.2.

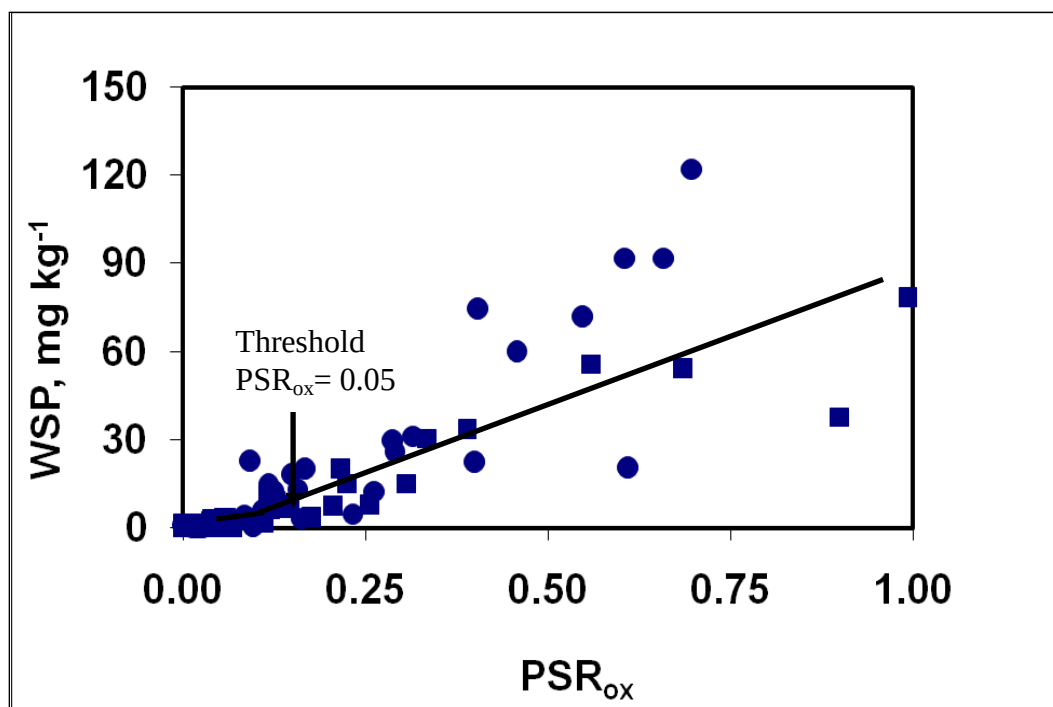


Figure 12 Relationship between water soluble P (WSP) and P saturation ratio calculated for the spodic horizon of manure-impacted soils using P, Fe and Al in an oxalate extract (PSR_{ox}). Threshold PSR value is significant at 0.001 probability level. Closed squares are soils in the current study; closed circles represent data from archived soils.

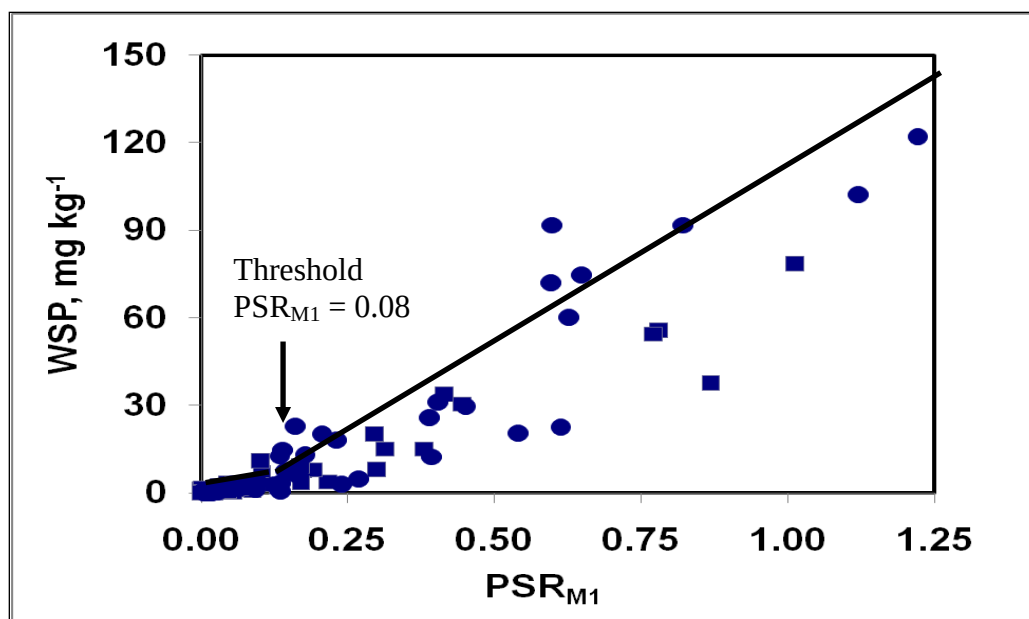


Figure 13 Relationship between water soluble P (WSP) and P saturation ratio calculated for the spodic horizon of manure-impacted soils using P, Fe and Al in Mehlich 1 extract (PSR_{M1}). Threshold PSR value is significant at 0.001 probability level. Closed squares are soils in the current study; closed circles represent data from archived soils.

3.1.2 Inorganically-Fertilized Soils

3.1.2.1 Soils Collected from the Field

Data obtained from the inorganic fertilized soils (Appendix Tables 5 and 6) collected from the field during the course of this study were superimposed on the WSP/PSR_{ox} graph obtained in section 3.1.1 (Figure 12). The WSP values are lower than those obtained for manure-impacted soils (Figure 14). Nevertheless, the threshold PSR_{ox} remains the same so that the threshold value of 0.05 for the Bh horizon can be used for all SPSC determinations independent of the P source. Low WSP values in the Bh horizon of inorganic fertilized sites may, in addition to P-impact levels, relate to the high solubility of inorganic fertilizers which could result in P loss before it reaches the Bh horizon.

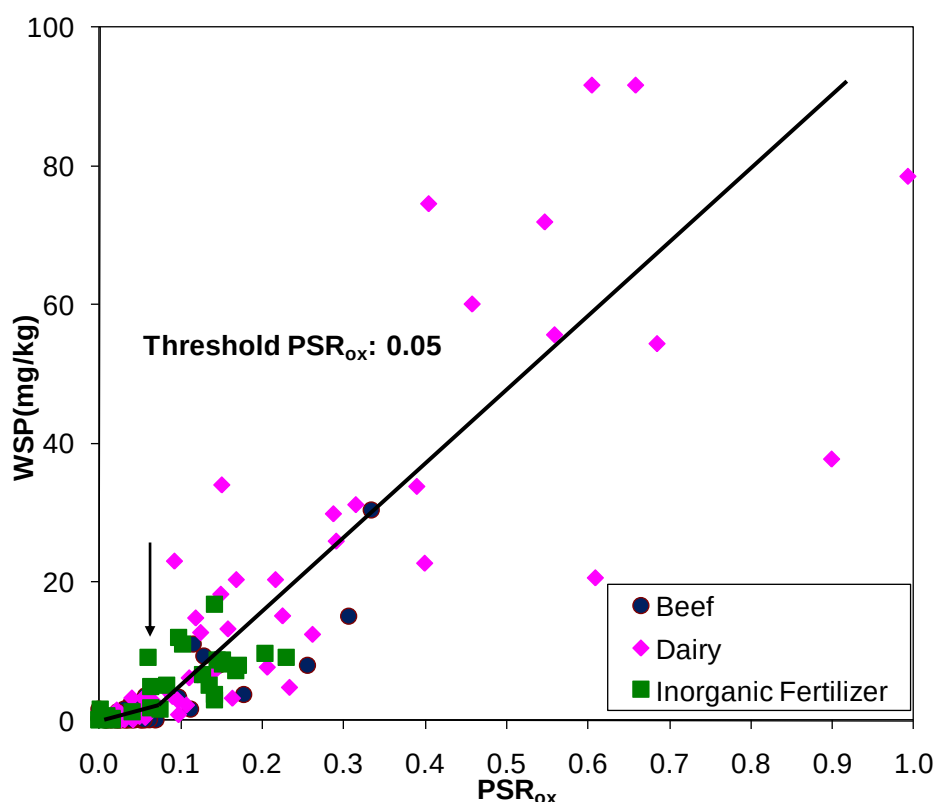


Figure 14 Relationship between water soluble P (WSP) and P saturation ratio calculated for the spodic horizon using P, Fe and Al in an oxalate extract (PSR_{ox}) for manure and inorganic fertilized soils. Threshold PSR_{ox} value is significant at 0.001 probability level. Closed squares are soils in the current study; closed circles represent data from archived soils. Closed circles in green are for inorganic fertilized soils.

3.1.2.2 Archived Bh Horizon Samples Collected during the FL Cooperative Soil Survey Program (Incubation Studies)

Water soluble P values for the incubated soils were compared for the 6-week and 10-month equilibration periods (Figure 15). Linear relationship suggests that after an equilibration of the soils for 10 months, WSP was <65% of the concentration at the 6-week incubation period. There

is a greater scatter of points at the higher P concentrations which may be due to variable entrainment of solution P under the one-time P loading of incubation. In effect, soil variation in factors influencing P sorption (e.g., Al concentration, competition of organic ligands for P, etc.) would manifest themselves most strongly under a high- P-loading since the incubation does not provide cycles of loading and flushing. Despite this scatter and the scatter observed for the WSP versus PSR relation (Figure 16), there is a fairly discrete change point below which WSP is quite low.

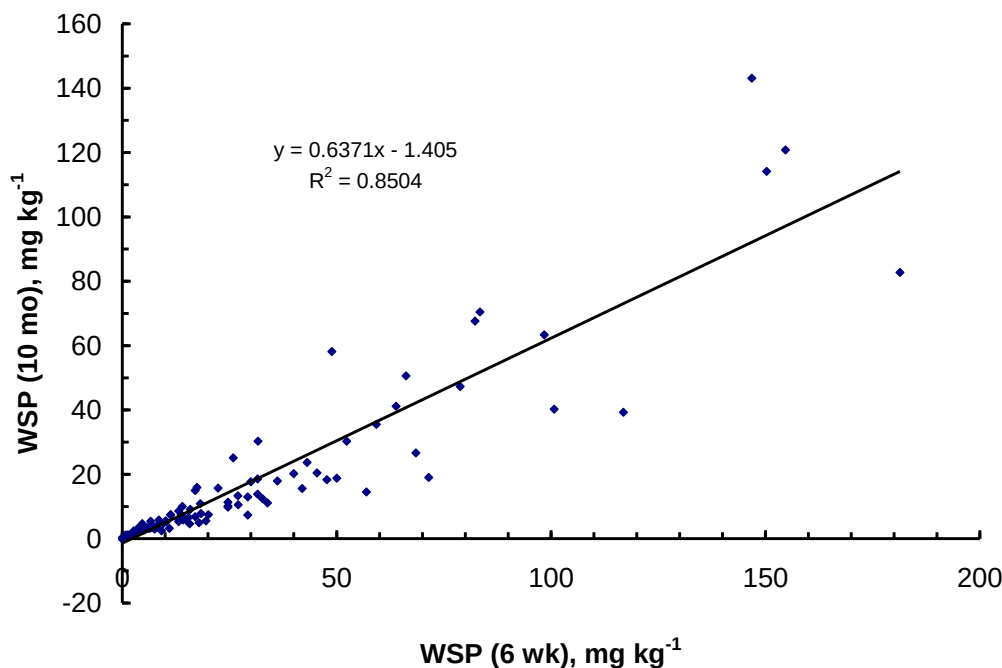


Figure 15 Relationship of water soluble P (WSP) between soils, incubated with varying P concentrations, for 6 weeks and 10 months.

The WSP/PSR_{Ox} relationship for both the 6-week incubated and the 10-month incubated soils are shown in Figure 16. The PSR value ranges up to 8 (only values up to PSR = 1.0 shown in Figure 16), well above values normally encountered in actual field soil sampling, again suggesting that we had incubated the soils with P well above the values normally found in P-impacted soils. The highest PSR level for most of the dairy manure-impacted Bh horizons of Okeechobee Basin soils was < 1.0 (Appendix Table 2). The PSR values for the inorganic site were also below 1.0 (Appendix Table 4). We have therefore used only data from soils collected in the field soil for computation of threshold PSR_{Ox} and threshold PSR_{M1} values. However, even when artificial systems were created, the threshold PSR_{Ox} of 0.05 that was statistically determined appears to be still applicable (Figure 16).

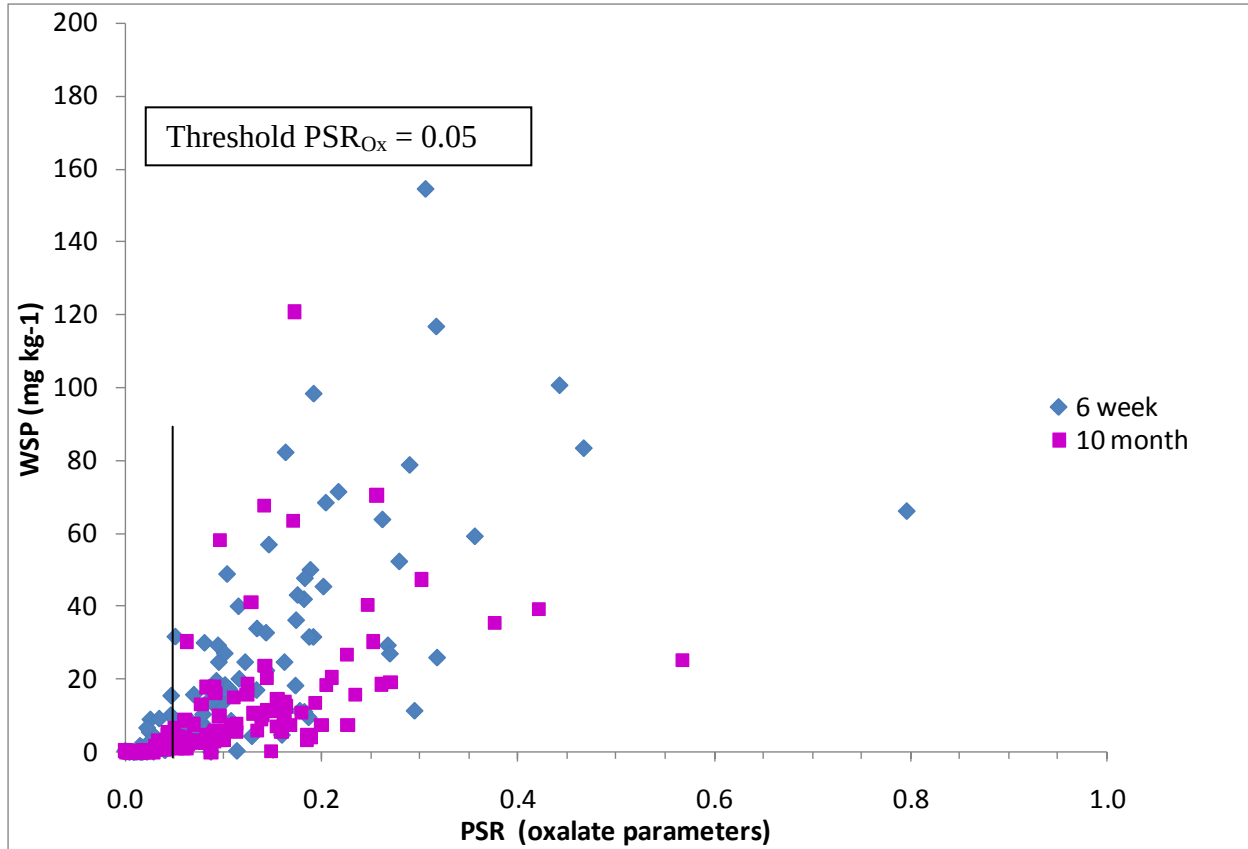


Figure 16 Relationship of water soluble P (WSP) and P saturation ratio (PSR_{Ox}) for soils 6 weeks and 10 months after incubation with known P concentrations. Only data with $PSR_{Ox} < 1.0$ shown in the graph.

3.2 “Safe” Soil P Storage Capacity (SPSC)

3.2.1 SPSC from Oxalate-extractable P, Fe and Al

Using the threshold $PSR_{Ox} = 0.05$, SPSC values were calculated for all archived soils (Appendix Table 2) and beef manure-impacted soils (Appendix Table 4) using Equation 3:

$$SPSC = (Threshold\ PSR_{Ox} - Soil\ PSR_{Ox}) * Oxalate-extractable\ (Fe + Al)\ or$$

$$SPSC = (0.05 - Soil\ PSR_{Ox}) * Oxalate-extractable\ (Fe + Al) \quad \text{Equation 8}$$

3.2.2 SPSC from Mehlich 1-extractable P, Fe and Al

The Capacity Factor (CF) using P, Fe and Al in a Mehlich 1 solution can be calculated using Equation 5

$$CF = (Threshold\ PSR_{M1} - Soil\ PSR_{M1}) * Mehlich\ 1\text{-extractable}\ (Fe + Al)$$

The CF for the soils of the dairy and beef manure-impacted sites and SPSC calculated from Mehlich 1 parameters = $CF * X$ where X is a conversion factor that is obtained from the SPSC/CF relationship (Figure 17). The value of $X = 1.8$.

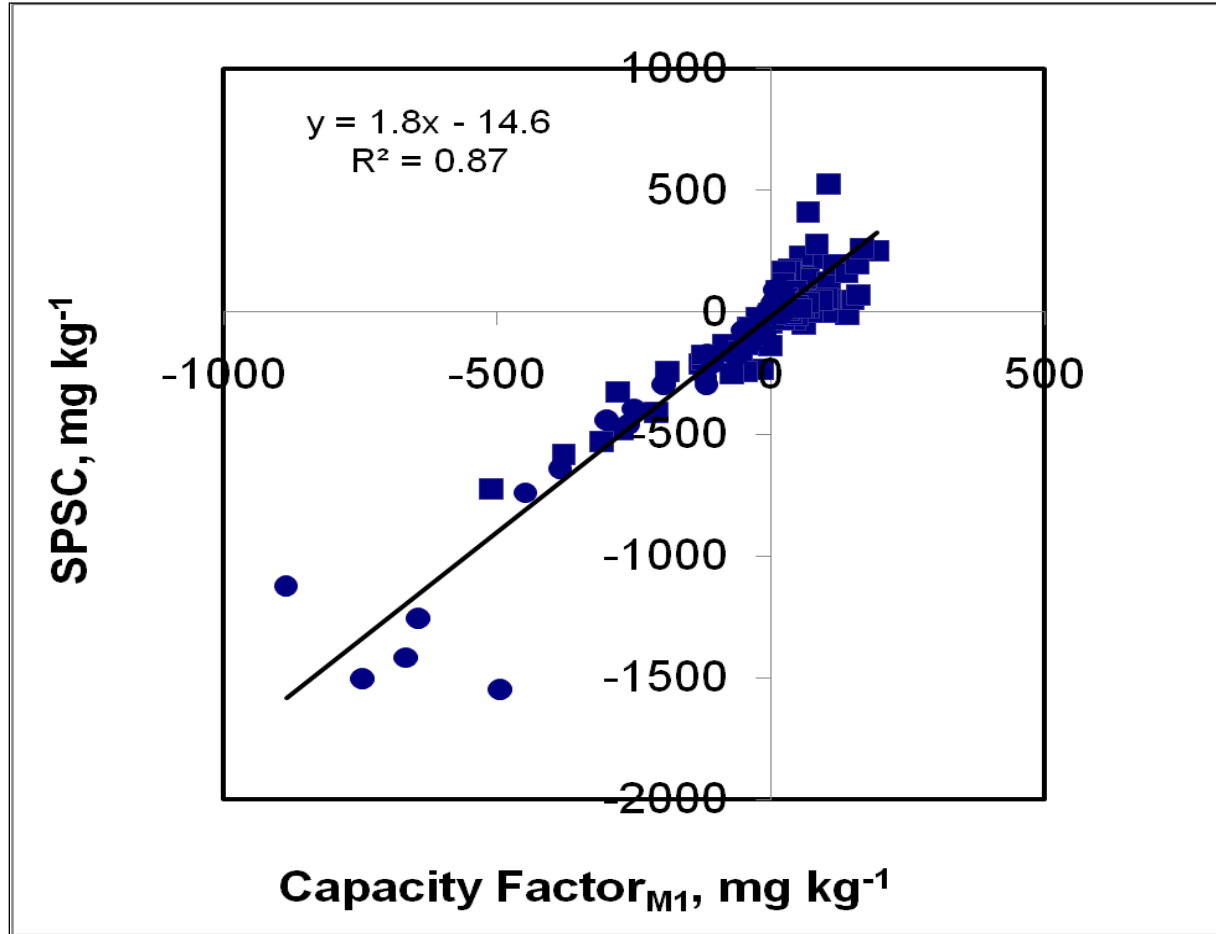


Figure 17 Relationship between soil phosphorus storage capacity (SPSC) and Capacity Factor for spodic horizons calculated using Mehlich 1-extractable P, Al and Fe for beef and dairy manure (organic) impacted soils. Closed squares are soils in the current study; closed circles represent data from archived soils.

Therefore SPSC can be calculated from Mehlich 1 parameters using the following equation:

$$SPSC = (0.08 - Soil\ PSR_{M1}) * Mehlich\ 1\text{-extractable}\ (Fe + Al) * 1.8 \quad \text{Equation 9}$$

3.2.3 Inorganic P and the SPSC/CF relationship

The soils collected at the inorganically-fertilized sites were superimposed on the SPSC/CF relationship (Figure 17) and the values have the same trend (Figure 18) as in the case of beef and

dairy-manure impacted soils confirming that calculating SPSC from CF is possible for both organic and inorganic fertilized soils.

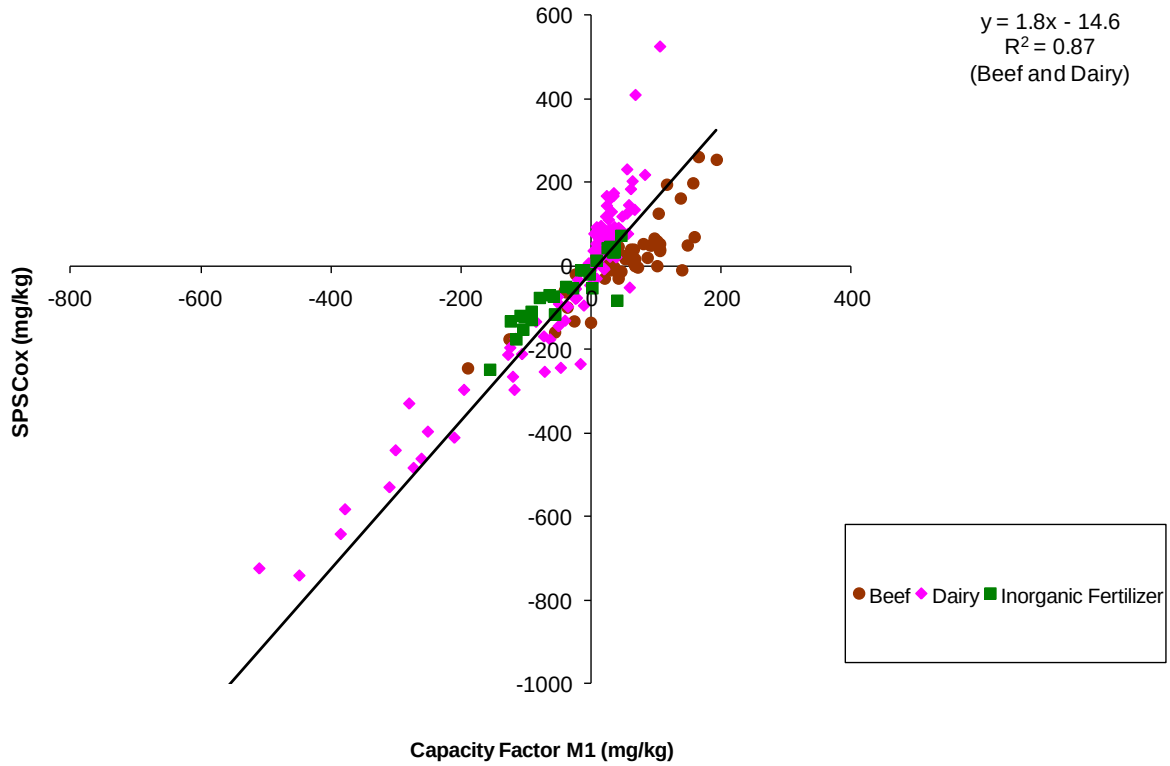


Figure 18 Relationship between soil phosphorus storage capacity (SPSC) and Capacity Factor for spodic horizons calculated using Mehlich 1-extractable P, Al and Fe for organic and inorganically fertilized soils. Closed squares are soils in the current study; closed circles represent data from archived soils.

3.3 SPSC and Water Soluble P

Water soluble P increases linearly when SPSC is negative for the Bh horizon (Figure 19). This observation confirms the relation of SPSC with WSP under field conditions similar to that noted by Chrysostome et al., (2007) in a laboratory study. The remaining storage capacity of the Bh horizons varies considerably but has a maximum of 600 mg kg^{-1} among the soils evaluated in this study. The relationship between SPSC and WSP (Figure 19) shows that as long as SPSC is positive (below the threshold PSR_{Ox} of 0.05), the soil is a P sink; when SPSC becomes negative, the soil becomes a P source.

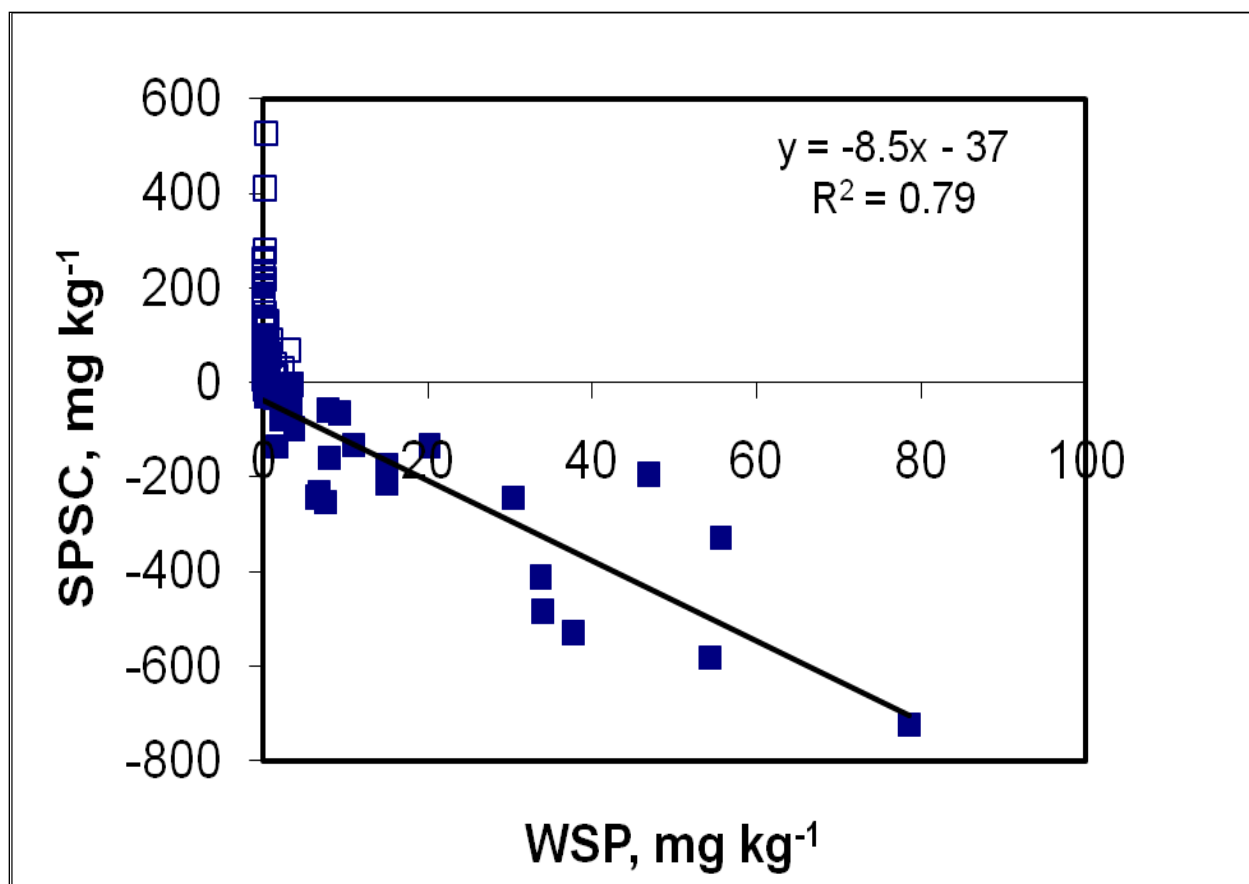


Figure 19 Water soluble P (WSP) versus soil phosphorus storage capacity (SPSC) of spodic horizons (using 0.05 as the change point P saturation ratio for beef and dairy manure-impacted soils, Figure 12). Open and closed markers represent positive and negative SPSC respectively.

The WSP/SPSC relation did not change when inorganic fertilized soils were included in the graphs (Figure 20). This confirms that a threshold PSR of 0.05 can be used for all P-impacted Bh horizons of the Lake Okeechobee Watershed.

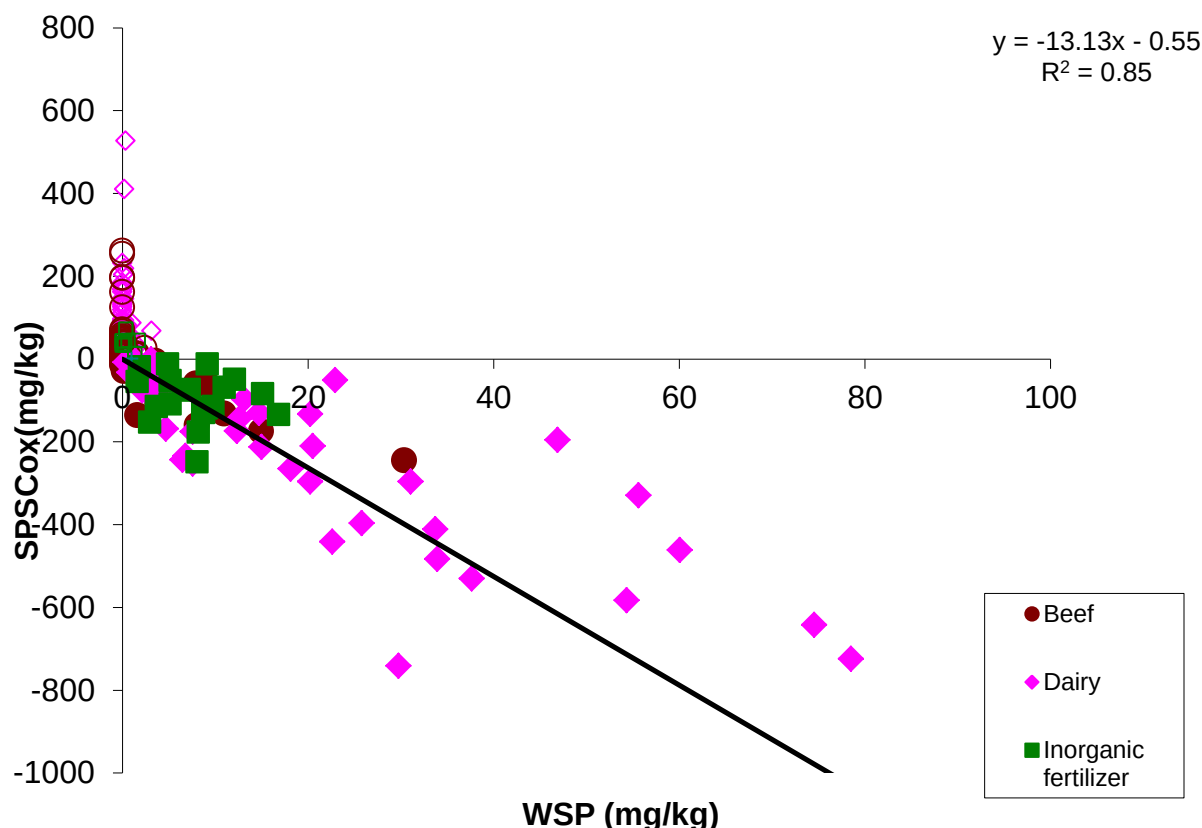


Figure 20 Water soluble P (WSP) versus soil phosphorus storage capacity (SPSC) of spodic horizons impacted by organic and inorganic P (using 0.05 as the threshold PSR_{ox}). Open and closed markers represent positive and negative SPSC respectively. The regression equation is for negative SPSC.

3.4 Range of Bh Soil P Storage Capacities of Prevalent Spodosols Series in Florida.

The Bh horizons of the selected Spodosol samples from the FCSSP archive had a wide range of pH, varying from pH 3.3 to pH 6.8 (Appendix Table 7). Clay content of the Bh horizon varied from 0 to 10%. There is also a wide range in TP, oxalate- P, Fe and Al. Most of these samples were likely collected from minimally P-impacted areas and therefore there is almost no water extractable P except in a few cases. The shallower the upper depth of the Bh, the higher the total C (TC) (Figure 21).

The sorption capacity of the Bh horizon was shown to decrease with depth to the spodic (Bh) (Nair et al., 1999). The higher P retention characteristics were attributed to the higher Al concentrations in soils with a shallower Bh. About 70% of the variability in the sorption capacity in that study was attributed to oxalate-extractable Al, C and pH. Oxalate-extractable Fe did not have any effect on the sorption of the Bh horizon soils probably due to the relatively small concentrations of Fe compared to Al in the soils, similar to the situation in the soils in the current study. An indirect involvement of C (Figure 21) through complex formations of Al and Fe with organic matter would explain higher P retention in the shallower Bh horizon of Spodosols.

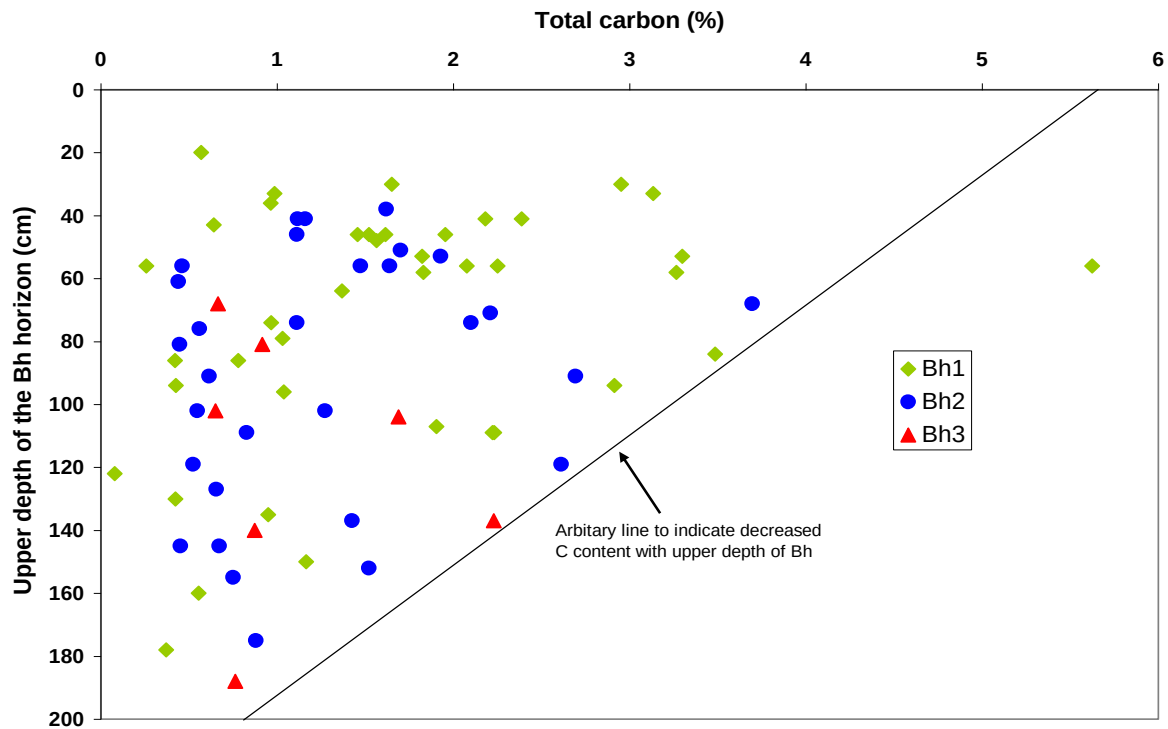


Figure 21 Variation in carbon content with upper depth to the spodic horizon for soils representing various Florida Spodosols.

The SPSC for all Bh horizons of the various soil series calculated using a threshold PSR_{Ox} of 0.05 is given in Appendix Table 8. Most SPSC values for the various soil series indicate that the majority of the soils are minimally impacted since the SPSC values are positive; the soils are P sinks. As indicated earlier, the Bh horizons were collected from minimally P-impacted sites and the remaining storage capacity is expected to be positive.

3.4.1 Incubation Studies

The relationship for SPSC calculated for all incubated soil samples (Figure 22) after 8 weeks and 10 months was linear, with SPSC generally higher for the 6-week equilibrium period compared to the 10 month equilibration. Graphs were generated from data in Appendix Tables 9, 10 and 11. As the incubation time increased, the remaining soil P storage capacity decreased and there was less P available in a water extract (Figure 15). The added P was taken up by the soil just as in a field situation showing a reduction in SPSC over time with increased P additions.

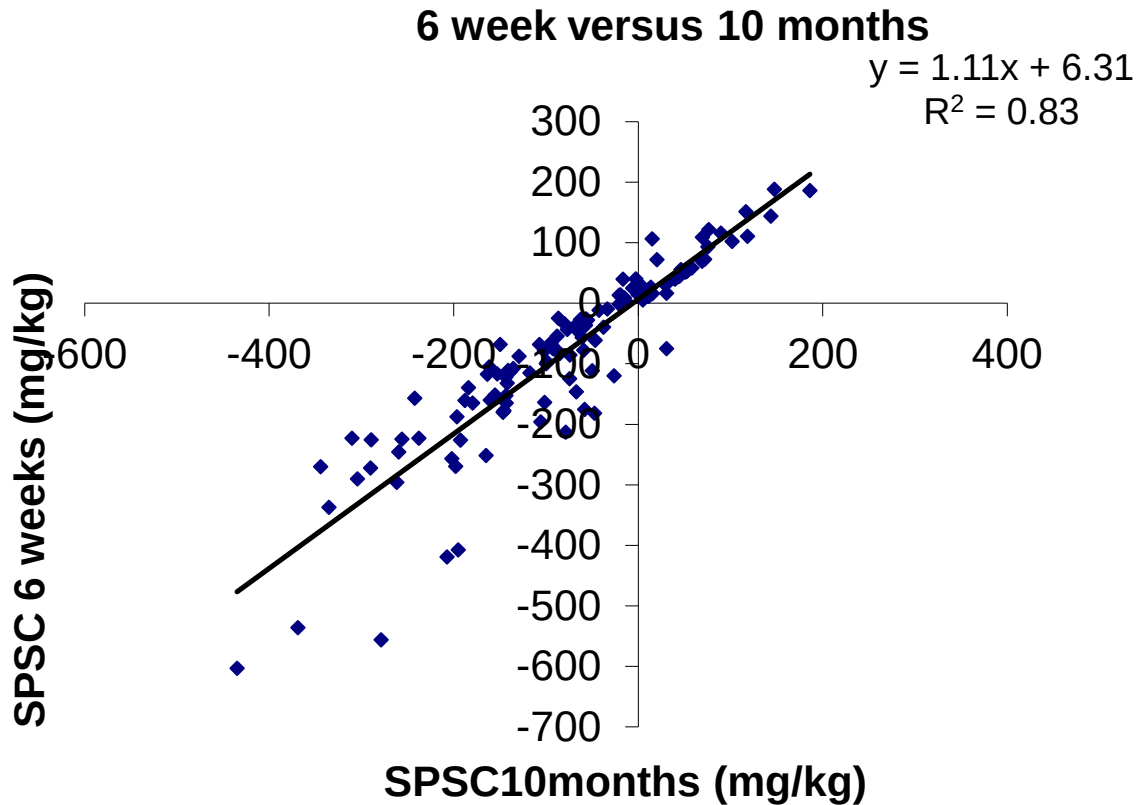


Figure 22 Soil P storage capacity (SPSC) of soils incubated for 6 weeks vs 10 months.

3.5 Phosphorus Releases from Spodosols of the Lake Okeechobee Basin

3.5.1 Some Examples

Figure 23 (below) illustrates the situations that arise when the water table is at different locations with respect to the Bh horizon of a Spodosol soil profile for the case of the surface horizon being a P source (SPSC<0) while the Bh is a P sink (SPSC>0) (Figure 23a) and for the case of both surface and Bh horizons being P sources (Figure 23b). When both surface and Bh horizons are P sinks, the soil should not be of any environmental risk concern, irrespective of the location of the water table. However, even un-impacted A and E horizons of Florida Spodosols have minimal potential to serve as a P sink. Figures 24 -- 29 demonstrate the application of SPSC under different water table scenarios with soil profile depths to 120 cm at locations shown in Figure 4 and specific sites representing varying depths to the spodic horizon and P impact levels within the LOW. The raw data from which the figures were generated are given in Appendix Table 12.

For each horizon, SPSC was calculated in kg ha^{-1} . The depth of the horizon as well as the bulk density should be known to convert mg kg^{-1} to kg ha^{-1} . For bulk density calculations, the following mean values were used: A horizon, 1.31 g cm^{-3} ; E horizon, 1.51 g cm^{-3} , and Bh horizon, 1.48 g cm^{-3} (Graetz and Nair, 1995).

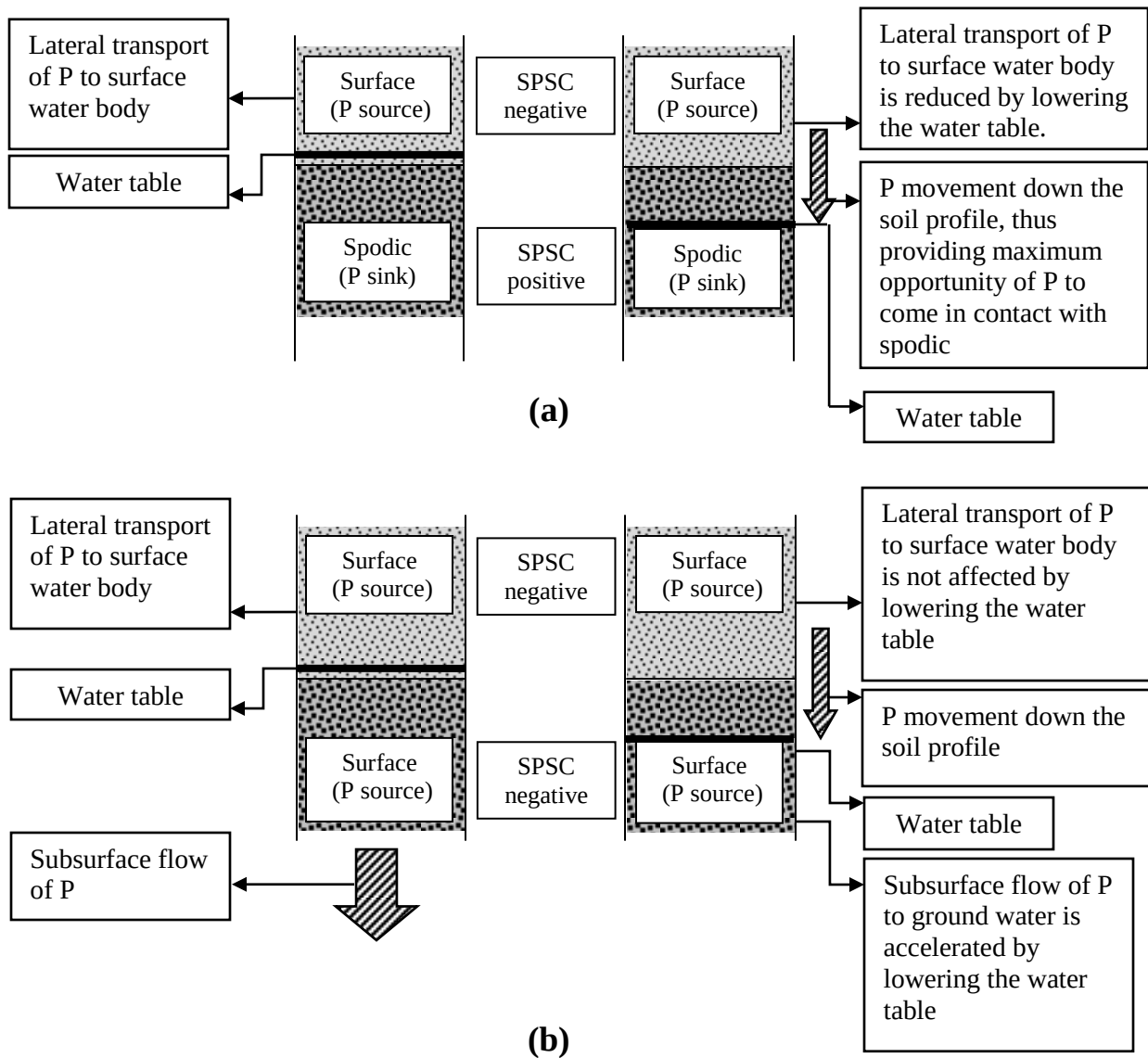


Figure 23 Schematic diagram of a soil profile illustrating the movement of P to surface and subsurface water bodies and its effect with water table when a) spodic is a P sink (SPSC is positive); b) spodic is a P source (SPSC is negative).

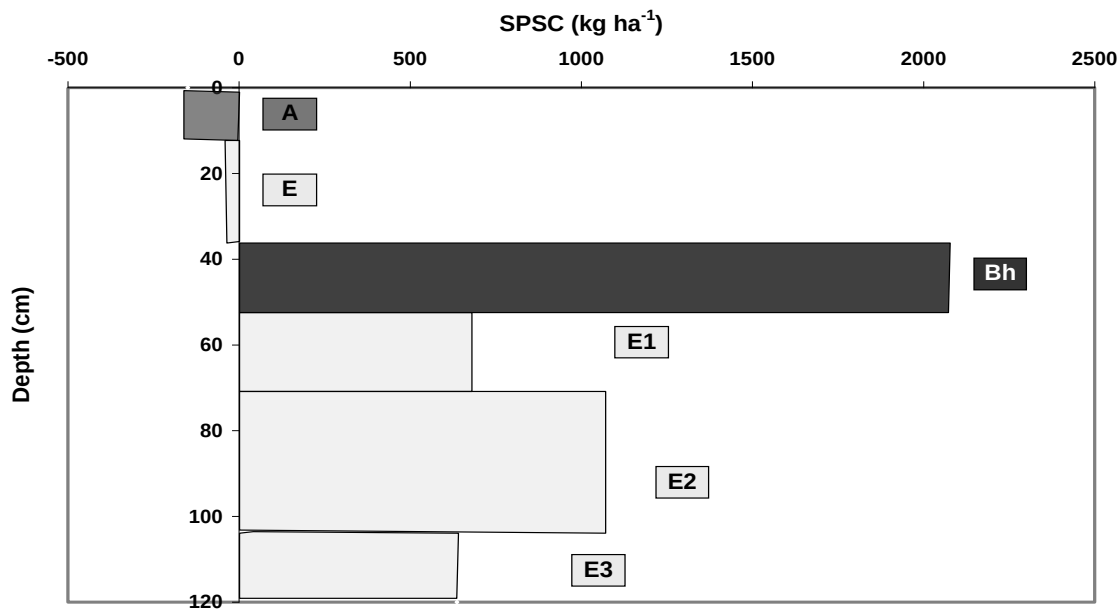


Figure 24 Soil P storage capacity (SPSC) for the C&M Dairy on Myakka soil, under heavy P loading (holding area)

Notes on Figure 24:

- This represents a heavily-manure-impacted Myakka soil (Figure 5) with a relatively shallow spodic horizon. The site was on a dairy that was active at the time of soil collection.
- When the water table is above the Bh horizon, this soil will be a P source (SPSC is negative); when kept below the Bh horizon, P loss from the soil would be a minimum since SPSC is positive.

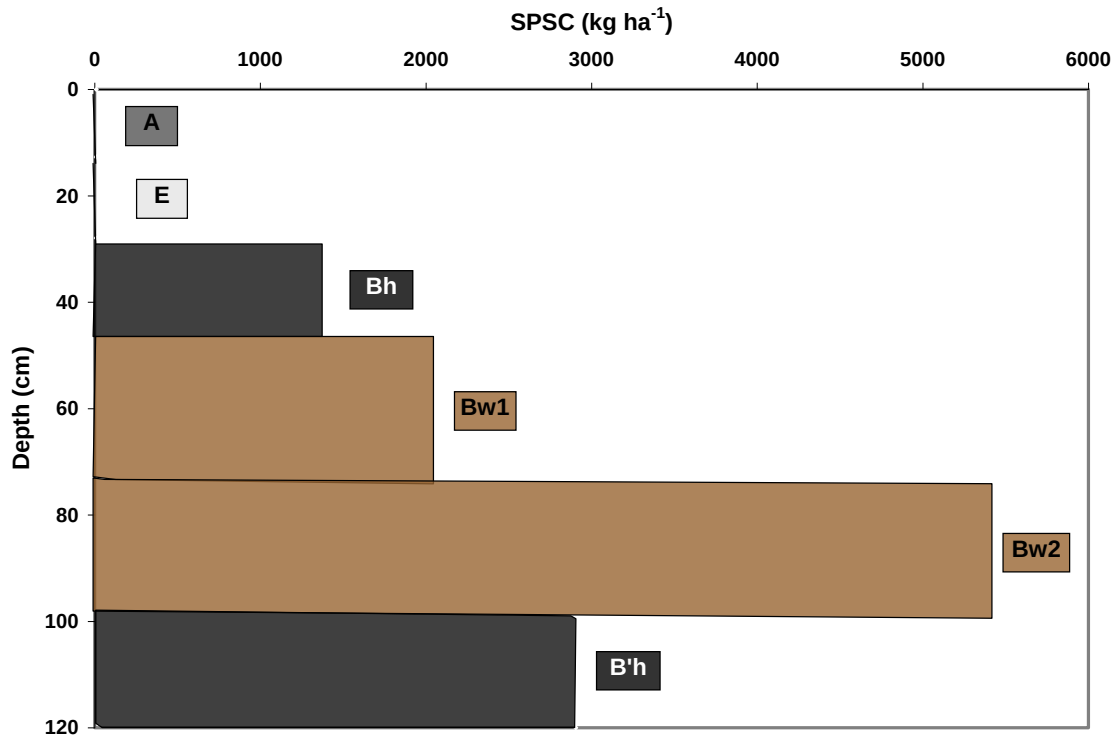


Figure 25 Soil P storage capacity (SPSC) for the C&M Dairy on Myakka soil, under less intensive P loading (pasture).

Notes on Figure 25:

- This represents a relatively low-manure-impacted Myakka soil (Figure 5) with a relatively shallow spodic horizon. This site was on a dairy that was active at the time of soil collection.
- The SPSC of the surface A and E horizons is near zero. While the soils may not pose an environmental risk at this time, they do not have any remaining capacity to safely store additional P.
- The location of the water table in this soil would likely not have a significant effect on P release from the soil unless the soil continues to be loaded with P at which time the surface horizons of this soil would be a P source (SPSC would become negative).

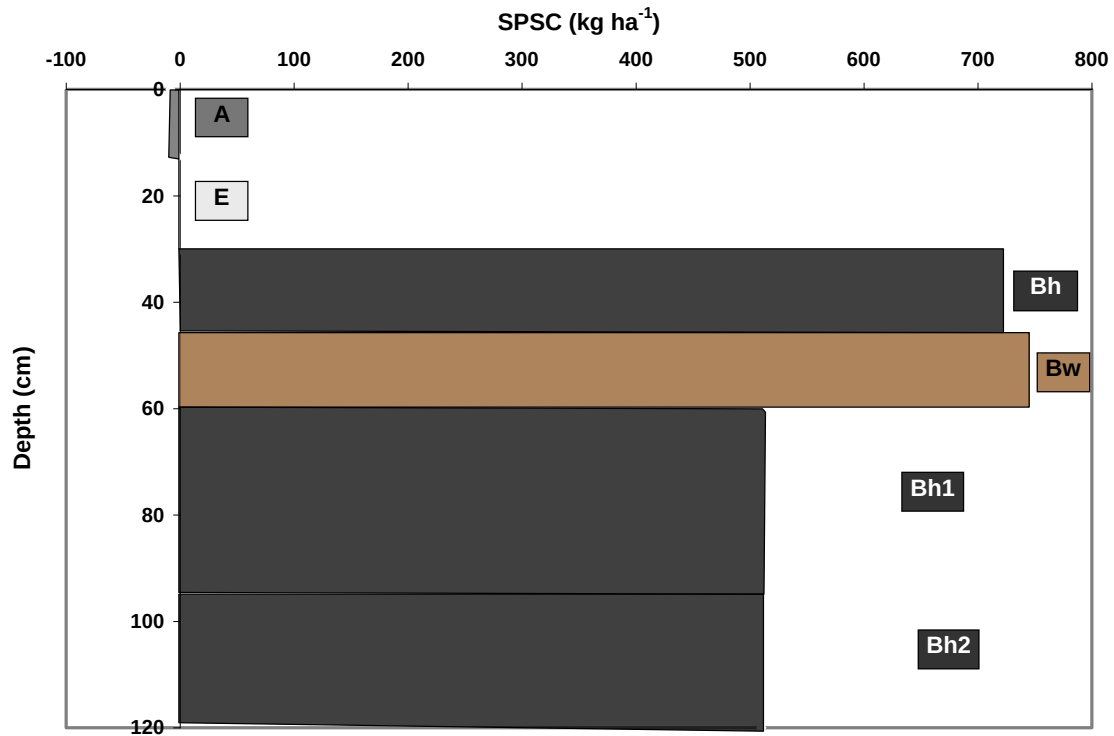


Figure 26 Soil P storage capacity (SPSC) for the WF Rucks Dairy on Myakka soil (Figure 6), under less intensive P loading (forage).

Notes on Figure 26:

- This represents a relatively low-manure-impacted Myakka soil (Figure 5) with a relatively shallow spodic horizon. This site was on a dairy that was active at the time of soil collection.
- The SPSC of the surface A horizon is already negative (soil is a P source). This soil would likely release P when the water table is above the spodic, though the negative impact on adjacent water bodies would likely be minimal compared to the scenario discussed in Figure 24.

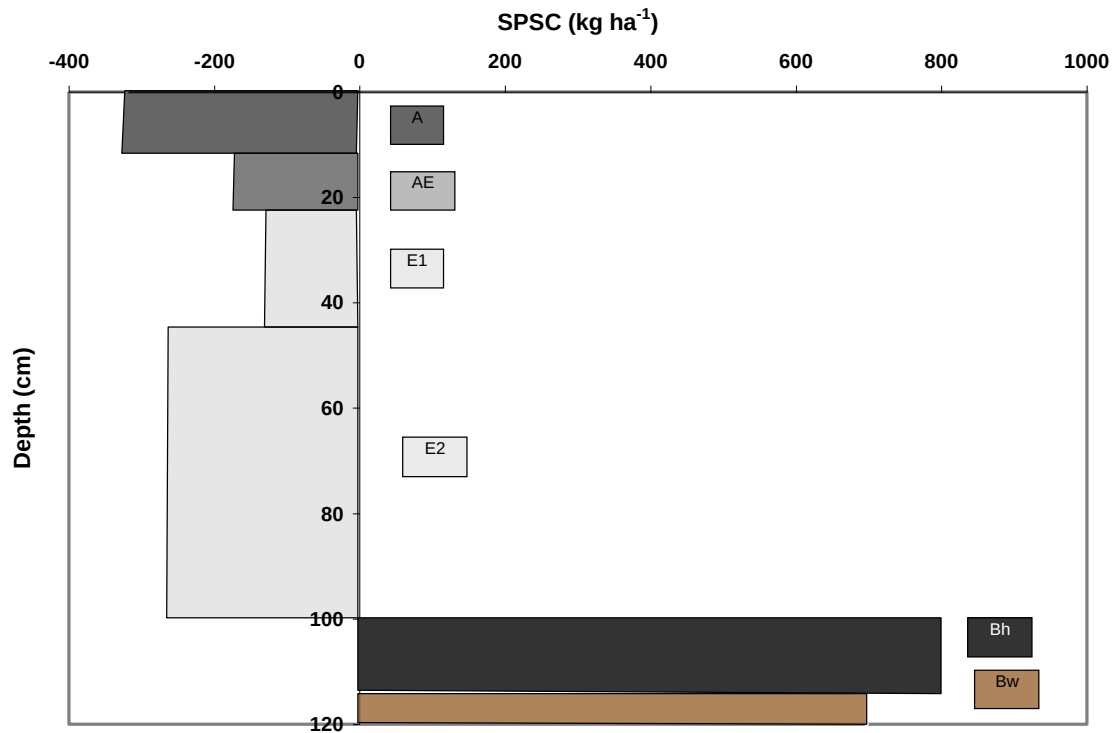


Figure 27 Soil P storage capacity (SPSC) for the Dry Lake Dairy on Immokalee soil, under intensive P loading (holding area).

Notes on Figure 27:

- This represents a heavily-manure-impacted Immokalee soil (Figure 7) with a deeper spodic horizon compared to the Myakka discussed in Figures 24 — 26. This site was on a dairy that was active at the time of soil collection.
- When the water table is above the Bh horizon, this soil will be a P source (SPSC is negative); when kept below the Bh horizon, P loss from the soil would be a minimum since SPSC is positive.
- Since the Bh horizon for this soil is deeper than that for Myakka, the chances of P loss from the Immokalee soil is greater even if P loading at the two sites were similar.

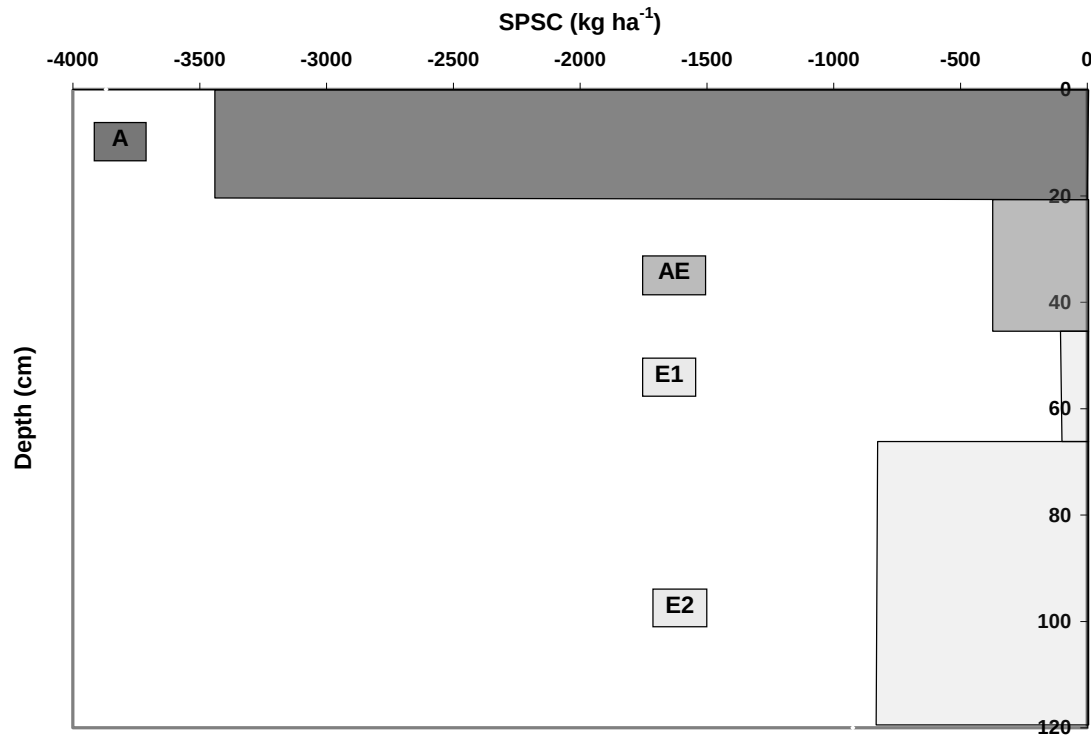


Figure 28 Soil P storage capacity (SPSC) for the Larson Dairy on Pomello soil, under intensive P loading (holding area).

Notes on Figure 28:

- This represents a heavily-manure-impacted Pomello soil (Figure 8) with a deeper spodic horizon compared to the Myakka (Figures 24 — 26) or the Immokalee (Figure 27). This site was on a dairy that was active at the time of soil collection.
- The soil does not have a spodic horizon within the 120 cm depth for which data are available. Therefore the soil will be a P source at all times. up to the 120cm depth
- The deeper the spodic horizon, the greater the chances of P leaving the soil to contaminate adjacent water bodies.

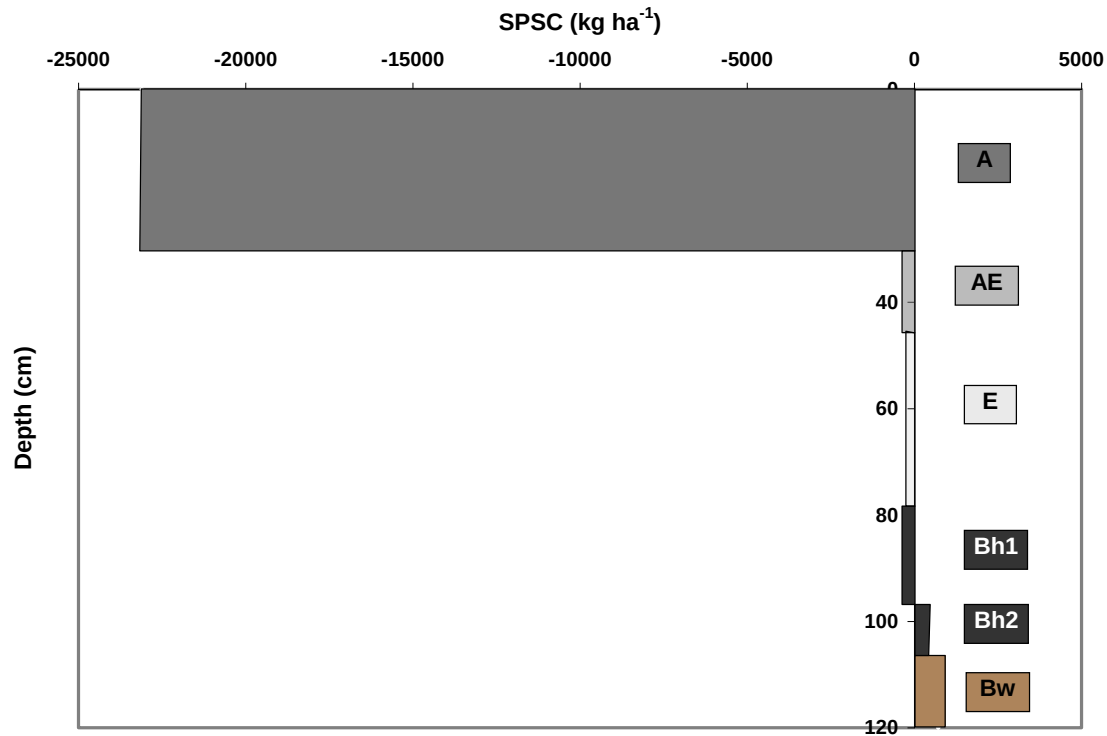


Figure 29 Soil P storage capacity (SPSC) for the Lawrence Dairy (abandoned) on Immokalee soil, under intensive P loading (intensive area).

Notes on Figure 29:

- This represents a heavily-manure-impacted Immokalee soil (Figure 9)
- Though the soil has a spodic horizon within the 120 cm depth for which data are available, the spodic horizon is also becoming a P source (Bh1).
- This site is an abandoned dairy location. Apparently, the P has moved down the soil profile over a period of time and reduced the capacity of the Bh horizon to hold additional P
- P movement down the soil profile will likely continue (see the large negative capacity of the surface horizon)
- This scenario illustrates the situation that may be expected from dairy manure impacted soils over time and therefore the need to address BMP issues as soon as possible

3.5.2 SPSC to 120 cm Depth

Calculation of SPSC for the soil profiles, up to 120 cm depth (Table 2), confirms some of the above observations discussed in Section 3.5.1. SPSC is additive and therefore can be summed up for a soil profile to any depth based on the capacity for individual horizons. However, the capacity of retentive subsurface horizons (Bh, Bw) may not be accessed when they are below the water table; in effect, they may be short-circuited by P being transported laterally above them. Some pertinent findings were:

1. Active dairies in this study located on soils with a shallower spodic had remaining storage capacity to a depth of 120 cm, even when the P loading was high.
2. The dairy located on areas mapped as Pomello had no remaining storage capacity. This soil is a P source up to a depth of 120 cm.
3. All abandoned dairies in this study had negative SPSC to a depth of 120 cm. These dairies are delineated as Myakka and Immokalee map units.

Table 2. Soil phosphorus storage capacity (SPSC) of selected dairy profiles (to 120 cm)

Dairy	Component	Impact level	Depth to Bh (cm)	SPSC (kg ha ⁻¹)
Active				
W. F. Rucks	Native	Very low	51	3560
Williamson	Native	Very low	91	730
W. F. Rucks	Forage	Low	30	2480
Bass	Pasture	Low	81	1710
C&M	Pasture	Low	28	11810
Larson	Holding	High	132	-5320
Dry Lake	Holding	High	99	620
C&M	Holding	High	36	4280
W. F. Rucks	Intensive	High	41	950
Abandoned				
Flying G	Holding	High	117	-36390
Wilson	Intensive	High	56	-9670
Wilson	Intensive	High	58	-2200
Wilson	Intensive	High	84	-24400
Lawrence	Intensive	High	79	-22880

3.5.3 Implications of SPSC for Water Table Management

Soil profiles where the upper depth to the spodic horizon is shallow would have a greater soil P storage capacity to a given depth compared to soils where the spodic is at a lower depth. However, the degree of P access to that capacity is affected by hydrology. Most Spodosols of Florida are poorly-drained (seasonal high saturation about 20-35 cm) under unaltered drainage. The depth of the Bh therefore not only influences the whole-profile P retention capacity, but also the potential for Bh to adsorb P. In effect, the deeper the Bh, the lower that potential. Moreover, the deeper zones of Bh and Bw horizons may be bypassed under natural drainage even when the upper boundaries of these horizons are relatively shallow. Artificial drainage would render the deeper Bh horizons more accessible to P moving through the system, and would likely result in a greater extent of P loading and storage to the profile. The P stored in Bh horizons would be released if the PSR is above the change point (negative SPSC), and in amounts that cumulatively would correspond to the SPSC as calculated for a specific soil volumes. The Spodosol profiles evaluated in this report show a range in the extent to which Bh horizons are loaded beyond their safe capacity (negative SPSC). These data further corroborate that A and E horizons that overly Bh horizons have little or no safe P holding capacity due to minimum concentration of P retaining components.

Accurate prediction of SPSC for Spodosols will require some specific calibration with the horizons that occur in those soils, because compositional distinctions from better-drained soils result in somewhat different P sorption characteristics. This calibration has been performed and tested with SPSC calculations using Mehlich 1-P, Fe and Al as shown below.

Surface soils (A and E horizons):

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

Spodic (Bh) horizon:

$$SPSC = (0.08 - \text{Soil } PSR_{M1}) * \text{Mehlich 1-extractable (Fe + Al)} * 31 * 1.8 \text{ (mg/kg)}$$

Soil profiles where the upper depth to the spodic horizon is shallow would have a greater soil P storage capacity to a given depth compared to soils where the spodic is at a lower depth. Abandoned dairies thus far evaluated in this study have less P storage capacity up to a specified depth than an active dairy under similar high P loading conditions (and soil properties). The P loss from a soil is dependent on the P storage capacity which is highly site-specific. If SPSC of a soil profile is known, it appears possible to predict P release from the soil. If horizons above the spodic horizon have a large negative SPSC, it is likely that raising the water table in such soils would result in minimizing contact with the much more retentive Bh horizon and result in greater P loss from the soil.

3.5.4 P Release from the Spodic Horizon for Plant Uptake

3.5.4.1 The Iron Oxide Strip Procedure

Plant roots absorb P mainly as ionic species such as orthophosphate (Schachtman et al. 1998; White 2003). In many soils, P is present at extremely low concentrations ($< 10 \mu\text{M}$) in the soil solution (Bielecki, 1973; Barber, 1995; Hedley et al. 1995; Marschner, 1995). The P depleted from soil solution by plants is in turn replenished by the soil solid phase. Physicochemical factors such as dissolution-precipitation, diffusion and adsorption-desorption as well as biological factors like mineralization-immobilization, root and rhizosphere activity control the release of ionic P (Achat et al., 2009). The term “labile P” is commonly used to refer to mobile P that is available, or can easily become available, as a nutrient for plant growth. It includes P that is readily desorbed from the surface sites, excluding the P which is deposited by the slow sorption process (McGechan and Lewis, 2002).

There are several methods that have been developed to determine the availability of P to plants. They mainly involve shaking the soil sample either with acid solutions or with dilute salt solutions, and measuring the exchangeable P using ^{32}P . Iron oxide impregnated filter paper has been successfully used as an index of plant P availability, P desorption kinetics and P dynamics in the field (Chardon et al., 1996). This exchange sink is much less intrusive of soil chemistry than acid or base extractants, and thus may provide a better estimate of labile P pool (Menon et al., 1989). The mechanism by which iron oxide paper functions depends on the preferential selectivity of iron oxides for adsorption of P ions over other anions (van der Zee et al., 1987). The iron oxide coatings act as a P sink, and simulate the adsorption mechanisms which take place at the interface of soil and root surface (Myers et al., 1997).

Preparation of iron strips: Whatman 50 filter papers were immersed in 0.65 M FeCl_3 solution overnight. The strips were air-dried and immersed in 2.7 M NH_4OH for 30 seconds, rinsed and kept in deionized water for an hour. The filter papers were then ready for use. These strips were enclosed within a mesh screen and secured with a plastic clamp (Figure 30). In a 30-mL glass bottle, 5g of soil and 30 mL of DI water were added. The mesh screen was inserted with the enclosed filter paper into the bottle so that the filter paper would not move during shaking (Figure 31). The bottle was capped and shaken for 16 hours on an end-to-end shaker. The P was extracted from the filter paper in a 125 mL Erlenmeyer flask by adding 50 mL of 0.2 M sulfuric acid and shaking for 1 hour (Myers et al., 1997).



Figure 30 Iron-strip secured with a plastic clip



Figure 31 Secured iron strip in bottle with soil and deionized water

3.5.4.2 Relationship of Fe-strip P to Water Soluble P

In addition to soils of beef-manure impacted sites (as stated in the contract), we included Bh horizon samples from the inorganic P application site as well as 20 selected samples from dairy-manure impacted sites for this study. Details of the analyses performed for this part of the study are included in Appendix Tables 13 (Dairy manure-impacted sites), 14 (Beef manure-impacted sites) and 15 (Inorganic fertilized sites).

As the Fe-strip P method described above is time-consuming and not an easy-to-determine procedure, we evaluated the relationship of iron-strip P with WSP determined at a 1:10 soil to water ratio. The relationship is linear (Figure 32) which suggests that a simple WSP determination of a spodic horizon should provide sufficient information to allow an evaluation as to whether P can be mined from a soil by plants.

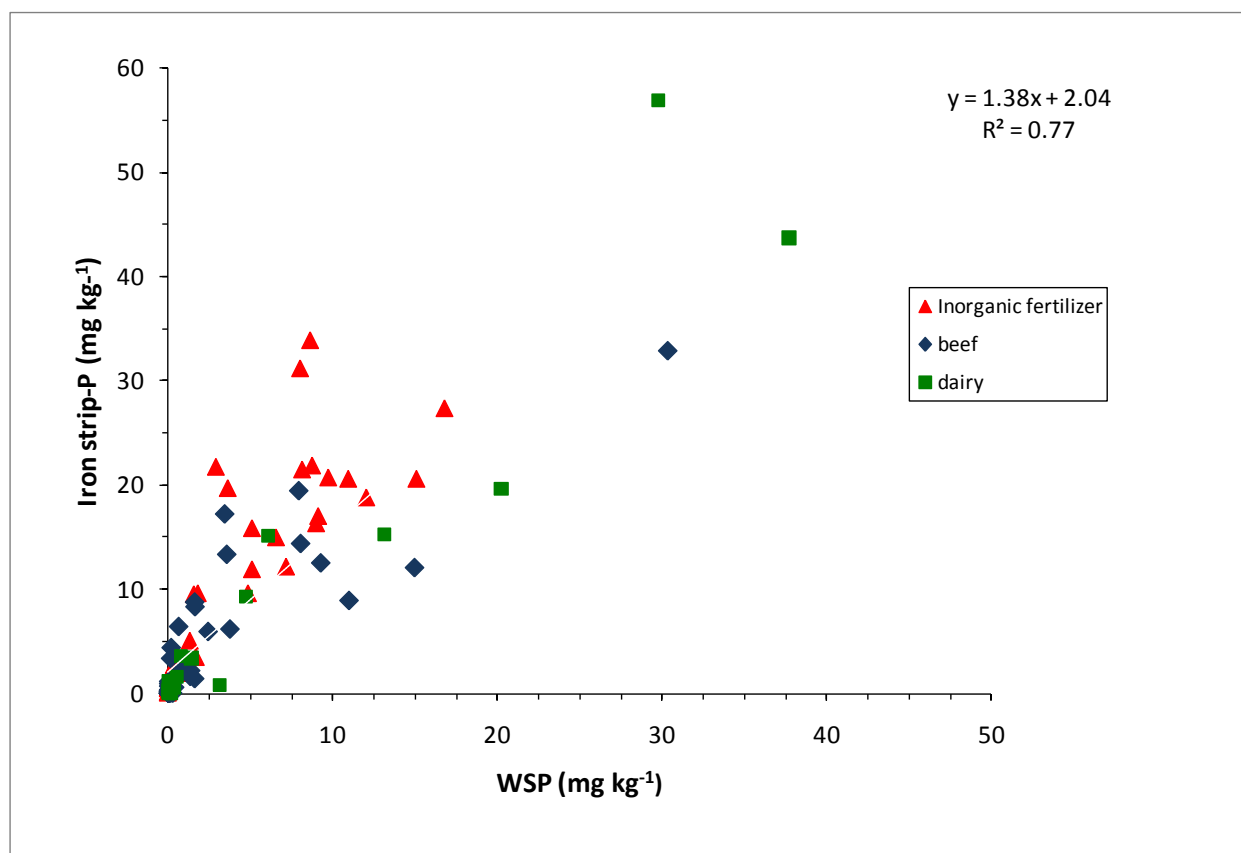


Figure 32 Relationship of iron-strip P to water soluble P (WSP) for Bh horizons of dairy and beef- manure-impacted and inorganic fertilized soils.

3.5.5 Implications of SPSC for Phytoremediation

Information provided in Figure 33 shows that when SPSC is positive, P removed by the iron-strip is minimal. Plant access of P from the spodic horizon is likely very limited when SPSC is positive given the documented relation between plant availability of P and P extracted via the iron oxide strip. Once SPSC is negative, the soil is a P source and phytoremediation techniques could be used for removing excess P from the soil. Therefore, SPSC could be used to evaluate phytoremediation potential of the spodic horizon in addition to its use in water-table management on Okeechobee soils.

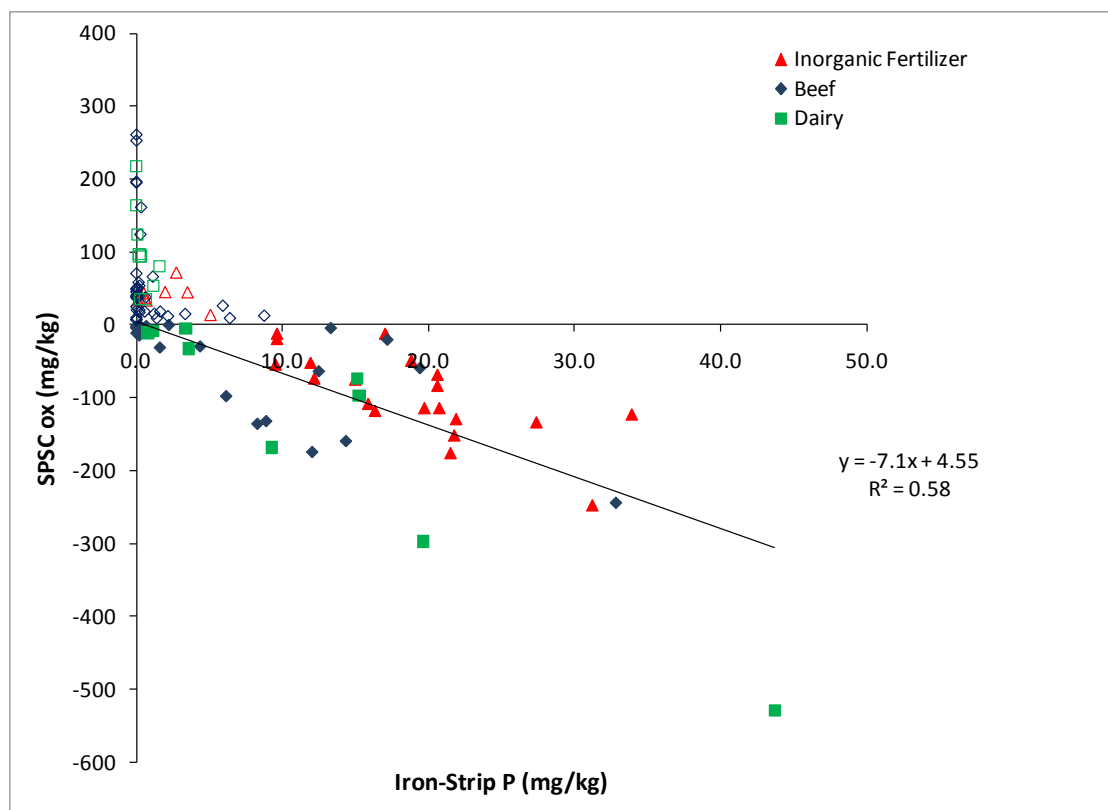


Figure 33 Iron-strip P versus soil phosphorus storage capacity (SPSC) of spodic horizons impacted by organic and inorganic P (using 0.05 as the threshold PSR_{Ox}). Open and closed markers represent positive and negative SPSC respectively. The regression equation is for negative SPSC.

4 References

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5 Appendices

Appendix Table 1. Selected characteristics of Bh horizons of all archived dairy and beef manure-impacted soils (Ox=oxalate; M1 = Mehlich 1).

Lab no	Dairy	Initial depth, cm	Final depth, cm	Comp	pH	C %	TP	Ox-P	Ox-Al	Ox-Fe mg kg ⁻¹	M1-P	M1-Al	M1-Fe
424	WFR	36	46	Pasture	5.40	1.88	71	65	2465	36	5	666	5
429	WFR	71	86	Pasture	5.70	1.34	76	73	1119	57	29	531	6
434	WFR	53	64	Pasture	5.50	1.44	52	54	2545	49	13	523	4
441	WFR	97	132	Pasture	6.00	0.63	30	27	3595	191	2	679	8
444	WFR	41	58	Intensive	6.70	2.60	229	346	5085	98	72	1424	11
448	WFR	41	61	Intensive	4.20	2.36	31	45	2066	26	0	196	2
452	WFR	20	30	Intensive	6.65	1.55	179	248	5245	551	67	1059	29
458	WFR	36	51	Intensive	6.00	1.55	52	100	5095	413	8	758	28
498	WFR	33	43	Holding	7.50	1.29	433	725	4130	188	392	1294	15
508	WFR	122	122	Holding	6.20	0.80	73	34	4345	130	0	894	7
511	WFR	38	46	Holding	6.25	0.75	27	36	1948	51	4	439	6
516	WFR	30	51	Holding	6.20	0.93	49	75	4945	832	5	630	50
523	CM	86	107	Intensive	7.65	0.83	248	361	552	23	312	346	4
529	CM	81	109	Intensive	5.50	1.10	155	273	1046	30	172	477	3
534	CM	79	97	Intensive	7.20	0.78	489	628	786	29	422	476	4
541	CM	127	132	Intensive	5.00	1.23	119	173	669	63	117	341	7
544	CM	41	66	Holding	8.20	2.09	109	417	2985	92	95	524	5
553	CM	112	127	Holding	6.50	0.43	31	31	1735	129	2	267	11
556	CM	41	56	Holding	9.70	2.04	77	88	3600	263	10	699	20
561	CM	36	53	Holding	6.30	1.22	54	64	3245	299	5	385	14
576	CM	48	61	Pasture	5.55	1.15		143	1123	110	57	374	7

Lab no	Dairy	Initial depth, cm	Final depth, cm	Comp	pH	C %	TP	Ox-P	Ox-Al	Ox-Fe mg kg ⁻¹	M1-P	M1-Al	M1-Fe
581	CM	38	53	Pasture	6.20	1.37	59	54	2470	138	3	486	14
587	CM	28	46	Pasture	5.55	2.45	72	58	3345	61	3	750	6
593	CM	46	69	Forage	5.00	1.22	46	43	1894	51	1	140	2
599	CM	25	46	Forage	4.67	1.79	85	53	3660	188	1	333	5
604	CM	28	48	Forage	5.43	1.42	90	75	4000	504	6	425	21
609	CM	25	46	Forage	5.12	1.23	73	44	3615	166	1	259	7
624	WFR	33	56	Pasture	5.30	1.49	157	198	2900	63	34	452	7
629	WFR	36	46	Pasture	6.50	2.65	133	126	3290	56	14	283	4
635	WFR	41	69	Pasture	5.70	1.57	78	79	3880	99	6	690	9
640	WFR	30	46	Forage	5.20	2.41	157	179	2845	71	36	362	4
646	WFR	43	64	Forage	5.39	1.05	60	46	1009	31	9	191	4
651	WFR	28	46	Forage	5.75	1.40	99	102	2895	70	8	313	6
656	WFR	18	36	Forage	6.33	1.07	56	37	2580	276	1	517	27
662	WFR	51	66	Native	4.56	4.50	109	95	3485	231	1	298	4
668	WFR	51	64	Native	4.39	3.86	112	100	3305	28	0	125	2
674	WFR	56	76	Native	4.27	2.81	117	79	1680	10	1	156	2
680	WFR	48	66	Native	4.62	1.93	109	59	1398	21	2	440	4
738	Larson	132	155	Holding	5.62	3.02	82	113	1060	25	51	276	3
756	DryLake	94	114	Pasture	5.75	1.30	141	134	983	176	100	521	10
761	DryLake	94	109	Pasture	5.20	1.56	105	88	1310	104	41	436	9
766	DryLake	58	71	Pasture	6.01	0.55	178	214	688	234	104	315	46
772	DryLake	76	91	Pasture	5.66	1.39	85	72	1272	205	30	275	18
778	DryLake	89	117	Forage	4.97	0.67	48	31	1050	222	8	240	27
783	DryLake	97	109	Forage	5.60	0.54	98	68	590	42	50	320	10
796	DryLake	74	97	Forage	4.79	1.37	63	38	1903	227	1	239	19
805	DryLake	91	109	Intensive	5.97	0.89	32	13	784	103	4	257	10

Lab no	Dairy	Initial depth, cm	Final depth, cm	Comp	pH	C %	TP	Ox-P	Ox-Al	Ox-Fe mg kg ⁻¹	M1-P	M1-Al	M1-Fe
814	DryLake	107	132	Intensive	8.37	1.51	322	352	927	102	244	524	6
818	DryLake	112	127	Holding	7.23	2.63	396	422	2168	58	193	814	4
832	DryLake	99	114	Holding	5.73	2.24	160	141	2845	163	44	762	15
837	DryLake	84	107	Holding	6.83	1.72	151	135	2196	143	72	986	13
842	Larson	122	152	Forage	4.63	0.64	20	12	201	28	1	16	2
847	Larson	122	145	Forage	6.60	1.03	23	14	227	19	7	111	7
858	Larson	76	104	Forage	4.92	3.10	78	69	2570	37	8	297	4
862	Bass	43	58	Beefpast	4.86	0.41	32	13	472	214	1	86	25
868	Bass	46	66	Beefpast	5.27	0.21	21	22	582	618	2	81	48
873	Bass	81	102	Beefpast	4.59	1.41	43	27	1349	138	1	95	6
883	Willianson	53	74	Native	4.35	2.47	76	57	2600	34	1	94	2
885	Willianson	94	107	Native	4.66	1.22	68	76	2980	60	1	174	2
890	Willianson	91	127	Native	4.61	1.04	34	18	948	18	0	38	2
1010	Wilson	56	66	Intensive	8.4	n.a	426	561	540	7	341	341	3
1018	Wilson	66	97	Intensive	7.86	n.a	255	334	1416	0	134	673	2
1023	Wilson	84	132	Intensive	6.54	n.a	404	471	1055	0	261	549	1
1029	Wilson	104	142	Intensive	7.89	n.a	170	202	122	0	134	96	2
1033	Wilson	84	117	Intensive	7.28	n.a	595	762	669	0	554	476	1
1049	Wilson	97	142	Intensive	7.86	n.a	64	63	2540	161	15	644	11
1069	Wilson	132	142	Intensive	7.13	n.a	136	182	12230	241	0	1139	19
1078	Lawrence	56	71	Intensive	6.53	n.a	114	130	455	503	75	240	69
1083	Lawrence	64	86	Holding	8.45	n.a	209	229	238	187	125	175	55
1088	Lawrence	71	97	Holding	8.36	n.a	490	479	1345	189	316	703	9
1094	Lawrence	71	102	Holding	8.67	n.a	254	270	1603	80	142	852	9
1098	Lawrence	61	76	Holding	8.55	n.a	243	241	1567	272	125	809	7
1104	Lawrence	71	97	Intensive	8.42	n.a	163	232	1928	971	77	696	31

Lab no	Dairy	Initial depth, cm	Final depth, cm	Comp	pH	C %	TP	Ox-P	Ox-Al	Ox-Fe mg kg ⁻¹	M1-P	M1-Al	M1-Fe
1111	Lawrence	86	99	Intensive	8.53	n.a	445	504	695	839	346	468	48
1115	Lawrence	51	66	Intensive	8.88	n.a	179	227	1220	949	95	580	38
1123	Lawrence	122	137	Intensive	8.91	n.a	118	142	659	267	66	318	10
1128	Lawrence	112	127	Intensive	8.85	n.a	60	73	1505	352	33	657	25
1132	Lawrence	79	97	Intensive	8.93	n.a	235	215	452	547	146	301	50
1155	Wilson	81	122	Pasture	7.82	n.a	95	114	1023	44	67	462	13
1163	Flying G	97	122	Holding	8.8	n.a	438	518	932	112	299	412	8
1167	Flying G	84	104	Holding	7.05	n.a	2105	2465	3010	156	1420	1007	13
1172	Flying G	76	91	Holding	7.3	n.a	1040	1178	987	12	953	738	9
1183	Flying G	104	117	Holding	6.9	n.a	926	897	2660	136	545	1048	13
1189	Flying G	117	127	Holding	7.9	n.a	618	732	1482	202	439	583	14
1194	Flying G	94	102	Intensive	7.5	n.a	1179	1546	2116	262	741	799	13
1199	Flying G	94	114	Intensive	7.2	n.a	420	399	2275	140	184	695	4
1209	Flying G	71	76	Intensive	7.5	n.a	1488	1674	2173	91	571	830	6
1215	Flying G	69	81	Intensive	7.1	n.a	1297	1639	2311	108	826	873	7
1221	Flying G	99	104	Intensive	7.6	n.a	1300	1382	2115	185	745	1084	9
426	WFR	69	94	Pasture	6.10	0.69	26	26	1083	18	0	373	6
461	WFR	117	120	Intensive	5.25	0.46	20	39	3615	253	0	371	10
504	WFR	124	124	Holding	6.15	1.01	285	367	2062	503	74	592	72
514	WFR	104	120	Holding	5.70	1.65	112	176	2222	110	67	710	10
578	CM	71	132	Pasture	5.25	1.45	n.a	56	1130	57	7	149	6
583	CM	86	107	Pasture	5.10	0.61	68	59	2496	131	1	305	8
590	CM	99	127	Pasture	5.00	0.66	74	91	8605	265	2	755	10
611	CM	107	127	Forage	5.35	0.50	47	38	2665	162	2	259	7
642	WFR	58	94	Forage	5.55	0.17	23	11	618	52	0	96	5
643	WFR	94	120	Forage	5.70	0.16	33	13	821	67	2	164	8

Lab no	Dairy	Initial depth, cm	Final depth, cm	Comp	pH	C %	TP	Ox-P	Ox-Al	Ox-Fe mg kg ⁻¹	M1-P	M1-Al	M1-Fe
682	WFR	76	84	Native	4.49	2.93	62	27	2985	40	0	260	2
864	Bass	84	102	Beefpast	5.38	0.84	56	28	1788	253	2	149	18
675	WFR	76	99	Native	4.32	2.60	74	48	2274	20	3	310	1
879	Bass	91	114	Beefpast	4.46	1.82	28	6	1424	82	0	48	2
1011	Wilson	66	97	Intensive	7.9	n.a	57	62	2092	0	14	458	1
1084	Lawrence	86	97	Holding	8.03	n.a	159	178	1424	652	60	368	45

n.a = not available

Appendix Table 2. Water soluble P (WSP), P saturation ratio using oxalate parameters (PSR_{Ox}), soil P storage capacity (SPSC) using a threshold PSR = 0.05, P saturation ratio using Mehlich 1 parameters (PSR_{M1}), and the Capacity Factor using Mehlich 1 parameters and a threshold PSR of 0.08 for all archived dairy and beef manure-impacted soils.

Lab no	Dairy	Initial depth, cm	Final depth, cm	Component	WSP mg/kg	PSR _{Ox}	SPSC (0.05) mg/kg	PSR _{M1}	Capacity Factor (0.08) mg/kg
424	WFR	36	46	Pasture	0.0	0.02	78	0.01	56.2
429	WFR	71	86	Pasture	0.3	0.06	-7	0.05	19.8
434	WFR	53	64	Pasture	0.0	0.02	94	0.02	35.5
441	WFR	97	132	Pasture	0.0	0.01	185	0.00	60.7
444	WFR	41	58	Intensive	3.4	0.06	-51	0.04	58.9
448	WFR	41	61	Intensive	0.3	0.02	74	0.00	18.1
452	WFR	20	30	Intensive	3.1	0.04	68	0.05	31.2
458	WFR	36	51	Intensive	0.1	0.02	204	0.01	63.3
498	WFR	33	43	Holding	33.9	0.15	-483	0.26	-273.2
508	WFR	122		Holding	0.2	0.01	219	0.00	82.4
511	WFR	38	46	Holding	0.0	0.02	77	0.01	36.4
516	WFR	30	51	Holding	0.0	0.01	232	0.01	54.9
523	CM	86	107	Intensive	55.6	0.56	-329	0.78	-280.0
529	CM	81	109	Intensive	15.0	0.22	-212	0.31	-127.9
534	CM	79	97	Intensive	54.3	0.68	-583	0.77	-378.6
541	CM	127	132	Intensive	20.2	0.22	-133	0.30	-85.1
544	CM	41	66	Holding	6.5	0.12	-243	0.16	-47.0
553	CM	112	127	Holding	0.1	0.02	72	0.01	23.3
556	CM	41	56	Holding	0.0	0.02	126	0.01	54.6
561	CM	36	53	Holding	0.0	0.02	131	0.01	31.3
576	CM	48	61	Pasture	2.1	0.11	-76	0.13	-22.4
581	CM	38	53	Pasture	0.0	0.02	92	0.01	41.8
587	CM	28	46	Pasture	0.0	0.02	135	0.00	66.6

Lab no	Dairy	Initial depth, cm	Final depth, cm	Component	WSP mg/kg	PSR _{Ox}	SPSC (0.05) mg/kg	PSR _{M1}	Capacity Factor (0.08) mg/kg
593	CM	46	69	Forage	0.0	0.02	67	0.01	11.9
599	CM	25	46	Forage	0.0	0.01	163	0.00	29.5
604	CM	28	48	Forage	0.0	0.02	168	0.01	33.9
609	CM	25	46	Forage	0.0	0.01	168	0.00	23.6
624	WFR	33	56	Pasture	1.1	0.06	-30	0.06	8.0
629	WFR	36	46	Pasture	0.5	0.03	64	0.04	12.1
635	WFR	41	69	Pasture	0.0	0.02	147	0.01	57.8
640	WFR	30	46	Forage	0.9	0.05	-14	0.09	-3.0
646	WFR	43	64	Forage	0.2	0.04	13	0.04	9.1
651	WFR	28	46	Forage	0.0	0.03	66	0.02	21.2
656	WFR	18	36	Forage	0.0	0.01	119	0.00	47.6
662	WFR	51	66	Native	0.0	0.02	111	0.00	26.8
668	WFR	51	64	Native	0.0	0.03	91	0.00	11.4
674	WFR	56	76	Native	0.0	0.04	18	0.01	13.3
680	WFR	48	66	Native	n.a	0.04	21	0.00	38.1
738	Larson	132	155	Holding	22.9	0.09	-51	0.16	-25.4
756	DryLake	94	114	Pasture	6.0	0.11	-73	0.17	-51.4
761	DryLake	94	109	Pasture	3.1	0.06	-10	0.08	-0.5
766	DryLake	58	71	Pasture	4.7	0.23	-168	0.27	-72.9
772	DryLake	76	91	Pasture	1.2	0.05	7	0.09	-4.1
778	DryLake	89	117	Forage	0.3	0.02	35	0.03	15.4
783	DryLake	97	109	Forage	0.7	0.10	-33	0.13	-20.5
796	DryLake	74	97	Forage	0.0	0.02	78	0.00	21.5
805	DryLake	91	109	Intensive	0.1	0.01	35	0.01	19.8
814	DryLake	107	132	Intensive	31.1	0.31	-296	0.40	-195.7
818	DryLake	112	127	Holding	20.2	0.17	-296	0.21	-118.2

Lab no	Dairy	Initial depth, cm	Final depth, cm	Component	WSP mg/kg	PSR _{Ox}	SPSC (0.05) mg/kg	PSR _{M1}	Capacity Factor (0.08) mg/kg
832	DryLake	99	114	Holding	1.4	0.04	27	0.05	26.6
837	DryLake	84	107	Holding	1.4	0.05	-5	0.06	19.3
842	Larson	122	152	Forage	0.5	0.05	0	0.03	1.0
847	Larson	122	145	Forage	3.1	0.05	-1	0.05	3.6
858	Larson	76	104	Forage	0.5	0.02	79	0.02	19.6
862	Bass	43	58	Beefpast	0.7	0.02	20	0.01	8.2
868	Bass	46	66	Beefpast	0.0	0.02	29	0.02	7.4
873	Bass	81	102	Beefpast	0.0	0.02	54	0.01	7.6
883	Willianson	53	74	Native	0.2	0.02	94	0.00	8.2
885	Willianson	94	107	Native	0.0	0.02	97	0.01	14.9
890	Willianson	91	127	Native	0.0	0.02	37	0.00	3.3
1010	Wilson	56	66	Intensive	37.7	0.90	-530	0.87	-310.3
1018	Wilson	66	97	Intensive	7.6	0.21	-253	0.17	-71.7
1023	Wilson	84	132	Intensive	33.7	0.39	-411	0.41	-210.6
1029	Wilson	104	142	Intensive	46.9	1.45	-195	1.21	-124.8
1033	Wilson	84	117	Intensive	78.5	0.99	-724	1.01	-510.4
1049	Wilson	97	142	Intensive	1.0	0.02	88	0.02	45.0
1069	Wilson	132	142	Intensive	0.3	0.01	527	0.00	105.5
1078	Lawrence	56	71	Intensive	3.1	0.16	-90	0.24	-49.9
1083	Lawrence	64	86	Holding	20.5	0.61	-211	0.54	-106.6
1088	Lawrence	71	97	Holding	25.8	0.29	-396	0.39	-251.3
1094	Lawrence	71	102	Holding	7.6	0.14	-176	0.14	-63.4
1098	Lawrence	61	76	Holding	12.6	0.12	-144	0.13	-50.5
1104	Lawrence	71	97	Intensive	4.0	0.08	-94	0.09	-11.6
1111	Lawrence	86	99	Intensive	22.6	0.40	-441	0.61	-300.9
1115	Lawrence	51	66	Intensive	14.7	0.12	-130	0.14	-40.4

Lab no	Dairy	Initial depth, cm	Final depth, cm	Component	WSP mg/kg	PSR _{Ox}	SPSC (0.05) mg/kg	PSR _{M1}	Capacity Factor (0.08) mg/kg
1123	Lawrence	122	137	Intensive	13.1	0.16	-97	0.18	-36.0
1128	Lawrence	112	127	Intensive	1.3	0.04	23	0.04	28.6
1132	Lawrence	79	97	Intensive	12.3	0.26	-174	0.39	-116.5
1155	Wilson	81	122	Pasture	2.8	0.10	-54	0.12	-23.9
1163	Flying G	97	122	Holding	60.1	0.46	-461	0.63	-261.1
1167	Flying G	84	104	Holding	122.0	0.70	-2290	1.22	-1328.3
1172	Flying G	76	91	Holding	102.2	1.03	-1122	1.12	-886.0
1183	Flying G	104	117	Holding	29.7	0.29	-741	0.45	-448.8
1189	Flying G	117	127	Holding	74.5	0.40	-642	0.65	-385.3
1194	Flying G	94	102	Intensive	124.6	0.60	-1418	0.80	-667.8
1199	Flying G	94	114	Intensive	18.1	0.15	-265	0.23	-120.6
1209	Flying G	71	76	Intensive	91.7	0.66	-1548	0.60	-495.4
1215	Flying G	69	81	Intensive	91.7	0.60	-1504	0.82	-746.2
1221	Flying G	99	104	Intensive	71.9	0.55	-1257	0.60	-645.4
426	WFR	69	94	Pasture	1.4	0.02	37	0.00	34.5
461	WFR	117		Intensive	0.0	0.01	175	0.00	34.5
504	WFR	124		Holding	6.8	0.14	-235	0.10	-16.6
514	WFR	104		Holding	2.4	0.07	-46	0.08	-1.9
578	CM	71	132	Pasture	1.3	0.04	10	0.04	6.5
583	CM	86	107	Pasture	0.2	0.02	88	0.00	27.8
590	CM	99	127	Pasture	0.2	0.01	411	0.00	67.7
611	CM	107	127	Forage	0.2	0.01	119	0.01	22.5
642	WFR	58	94	Forage	0.2	0.01	26	0.00	8.6
643	WFR	94		Forage	0.2	0.01	36	0.01	13.7
682	WFR	76	84	Native	0.2	0.01	145	0.00	23.8
864	Bass	84	102	Beefpast	0.2	0.01	82	0.01	12.4

Lab no	Dairy	Initial depth, cm	Final depth, cm	Component	WSP mg/kg	PSR_{Ox}	SPSC (0.05) mg/kg	PSR_{M1}	Capacity Factor (0.08) mg/kg
675	WFR	76	99	Native	0.5	0.02	83	0.01	25.6
879	Bass	91	114	Beefpast	0.5	0.00	78	0.00	4.4
1011	Wilson	66	97	Intensive	0.9	0.03	58	0.03	28.4
1084	Lawrence	86	97	Holding	3.4	0.09	-78	0.13	-24.3

Appendix Table 3. Selected characteristics of Bh horizons of all beef manure-impacted soils (TP = total P; EC = Electrical conductivity; Ox = oxalate; M1 = Mehlich 1).

Lab #	Location	H _z	Initial depth, cm	Final depth, cm	pH	EC (dS/m)	TP	Ox-P	Ox Fe	Ox-Al mg/kg	M1- P	M1- Fe	M1-Al
5	H 711	Bh1	59	74	6.49	0.21	74	82	82	2040	13	11	1284
6	H 711	Bh2	74	86	6.63	0.25	132	129	86	2560	19	9	1137
11	H 711	Bh1	56	81	5.68	0.10	168	233	180	1664	132	9	1140
12	H 711	Bh2	81	95	5.03	0.22	84	109	44	2540	27	5	1431
17	H 711	Bh	50	55	6.71	0.12	189	209	117	539	158	16	356
18	H 711	Bh	55	90	6.42	0.19	127	116	58	1445	41	9	896
23	H 711	Bh1	73	78	6.42	0.15	259	288	150	678	231	8	448
24	H 711	Bh1	78	83	5.87	0.25	73	86	81	1927	36	5	1018
25	H 711	Bh2	83	88	5.28	0.31	69	98	40	2840	18	5	1244
28	H 711	Bh1	23	29	5.54	0.12	74	81	987	3095	8	123	1166
29	H 711	Bh2	29	41	5.44	0.08	53	62	1278	3875	1	145	1208
34	H 711	Bh	25	30	5.77	0.03	180	246	491	1687	75	46	792
35	H 711	Bh	30	65	6.05	0.03	92	113	306	1303	46	42	718
38	H 711	Bh	10	15	6.33	0.03	201	198	469	450	75	107	168
39	H 711	Bh	15	23	6.24	0.03	151	137	412	476	59	110	184
45	H 711	Bh1	51	57	4.78	0.05	53	68	122	1122	8	9	448
46	H 711	Bh2	57	62	4.88	0.04	44	52	51	884	1	7	747
47	H 711	Bh2	62	90	4.66	0.06	20	40	38	808	0	7	702
51	H 711	Bh	70	75	5.52	0.02	0	41	81	474	0	18	331
52	H 711	Bh	75 +		5.50	0.02	0	32	50	472	0	13	269
56	H 711	Bh1	48	53	5.03	0.04	153	175	38	2830	4	3	1553
57	H 711	Bh1	53	62	5.00	0.04	145	130	39	2216	9	4	1196
58	H 711	Bh2	62	67	5.09	0.03	87	88	17	1497	3	4	817
59	H 711	Bh2	67	100	5.08	0.03	70	81	21	1147	6	3	559
62	H 711	Bh1	40	48	5.14	0.09	60	63	112	3855	0	8	1494
63	H 711	Bh2	48	53	4.96	0.04	29	50	114	5225	0	6	2097
67	H 711	Bh1	32	40	5.04	0.06	67	85	246	4790	0	18	1700
68	H 711	Bh2	40	45	5.21	0.04	58	64	271	5530	0	12	1800
72	BRU	Bh1	40	45	4.62	0.07	139	101	51	2605	5	7	1064
73	BRU	Bh1	45	51	4.70	0.08	97	85	39	2369	3	7	1184

Lab #	Location	H _z	Initial depth, cm	Final depth, cm	pH	EC (dS/m)	TP	Ox-P	Ox Fe	Ox-Al mg/kg	M1- P	M1- Fe	M1-Al
74	BRU	Bh2	51	75	4.70	0.05	76	63	13	1394	2	4	750
79	BRU	Bh1	58	63	4.30	0.07	53	52	8	878	3	3	354
80	BRU	Bh1	63	72	4.30	0.05	56	50	9	788	3	3	423
81	BRU	Bh2	72	78	4.60	0.05	35	25	0	620	2	2	353
82	BRU	Bh2	78	84	4.76	0.06	56	18	0	675	3	3	345
86	BRU	Bh1	39	44	4.29	0.07	172	109	49	2206	38	7	1040
87	BRU	Bh2	44	49	4.42	0.06	94	38	6	1605	4	5	921
88	BRU	Bh2	49	70	4.60	0.04	76	37	2	1333	3	4	696
92	BRU	Bh1	39	44	3.75	0.20	32	19	5	643	2	4	315
93	BRU	Bh1	44	53	3.58	0.21	14	6	0	841	0	3	425
94	BRU	Bh2	53	59	3.63	0.17	38	9	0	957	0	4	451
95	BRU	Bh2	59	69	3.85	0.15	17	9	0	874	0	4	429
96	BRU	Bh3	69+		3.95	0.10	8	7	2	808	1	5	349
99	BRU	Bh	55	60	4.55	0.02	0	0	62	134	0	16	51
100	BRU	Bh	60	70	4.40	0.01	0	0	38	113	0	12	39
103	BRU	Bh1	24	29	4.72	0.10	96	59	17	2039	4	6	1152
104	BRU	Bh1	29	49	4.55	0.10	84	59	3	1887	3	4	1013
105	BRU	Bh2	49	54	4.34	0.08	59	42	0	1408	1	3	729
106	BRU	Bh2	54	87	4.43	0.06	25	18	0	756	1	3	513
185	Ona	Bh1	34	40	4.32	0.06	111	85	8	2357	1	5	1635
186	Ona	Bh2	40	45	4.79	0.05	82	65	10	2370	0	7	1725
187	Ona	Bh2	45	70	5.00	0.03	52	49	13	1112	20	7	802
192	Ona	Bh1	79	84	5.09	0.01	58	41	62	616	38	8	386
193	Ona	Bh1	84	90	4.90	0.02	29	21	28	575	17	6	293
194	Ona	Bh2	90+		5.06	0.01	29	21	7	533	17	6	331
198	Ona	Bh1	75	80	5.17	0.10	94	90	79	501	71	14	319
199	Ona	Bh2	80+		4.76	0.08	35	42	85	330	45	10	225
204	Ona	Bh1	72	77	5.23	0.04	88	105	336	552	72	48	347
205	Ona	Bh1	77	90	5.05	0.05	11	9	62	344	13	17	197
206	Ona	Bh2	90+		4.95	0.04	0	3	65	288	4	15	155

Appendix Table 4. Water soluble P (WSP), P saturation ratio using oxalate parameters (PSR_{Ox}), soil P storage capacity (SPSC) using a threshold PSR_{Ox} = 0.05, P saturation ratio using Mehlich 1 parameters (PSR_{M1}), and the Capacity Factor using Mehlich 1 parameters and a threshold PSR of 0.08 for beef manure-impacted soils.

Lab #	location	Initial depth, cm	Final depth, cm	WSP mg/kg	PSR _{Ox}	SPSC (0.05) mg/kg	PSR (M1)	Capacity factor (0.08) mg/kg
5	H 711	59	74	0.10	0.035	37.0	0.009	105.7
6	H 711	74	86	0.00	0.043	20.7	0.014	86.3
11	H 711	56	81	10.97	0.116	-132.3	0.100	-26.6
12	H 711	81	95	0.22	0.037	38.1	0.016	104.9
17	H 711	50	55	14.95	0.306	-174.8	0.380	-125.0
18	H 711	55	90	1.31	0.068	-31.1	0.040	41.3
23	H 711	73	78	30.35	0.334	-244.7	0.445	-189.4
24	H 711	78	83	2.40	0.038	26.6	0.031	57.7
25	H 711	83	88	0.00	0.030	66.5	0.013	96.4
28	H 711	23	29	0.00	0.020	124.5	0.006	104.2
29	H 711	29	41	0.00	0.012	195.5	0.000	116.8
34	H 711	25	30	1.60	0.112	-136.0	0.081	-0.6
35	H 711	30	65	0.15	0.068	-29.6	0.055	21.5
38	H 711	10	15	8.02	0.256	-159.8	0.298	-55.2
39	H 711	15	23	3.73	0.176	-98.0	0.217	-37.1
45	H 711	51	57	0.78	0.050	-0.1	0.015	33.7
46	H 711	57	62	0.00	0.050	-0.1	0.001	68.4
47	H 711	62	90	0.00	0.042	7.4	0.000	64.7
51	H 711	70	75	0.10	0.069	-11.1	0.000	31.2
52	H 711	75 +		0.00	0.056	-3.2	0.000	25.3
56	H 711	48	53	0.00	0.053	-11.4	0.002	138.8
57	H 711	53	62	0.00	0.051	-1.5	0.007	100.8
58	H 711	62	67	0.00	0.051	-1.9	0.003	72.7
59	H 711	67	100	0.00	0.061	-14.4	0.009	45.5
62	H 711	40	48	0.00	0.014	161.7	0.000	137.6
63	H 711	48	53	0.00	0.008	253.3	0.000	192.9
67	H 711	32	40	0.00	0.015	196.9	0.000	157.0
68	H 711	40	45	0.00	0.010	261.4	0.000	165.9
72	BRU	40	45	0.00	0.033	50.0	0.004	93.1

Lab #	location	Initial depth, cm	Final depth, cm	WSP mg/kg	PSR _{Ox}	SPSC (0.05) mg/kg	PSR (M1)	Capacity factor (0.08) mg/kg
73	BRU	45	51	0.00	0.031	51.8	0.002	106.1
74	BRU	51	75	0.00	0.039	17.4	0.002	67.1
79	BRU	58	63	0.00	0.051	-1.0	0.007	29.6
80	BRU	63	72	0.00	0.055	-4.3	0.006	36.0
81	BRU	72	78	0.00	0.036	10.1	0.004	31.0
82	BRU	78	84	0.00	0.024	20.5	0.009	28.3
86	BRU	39	44	0.48	0.043	18.6	0.032	57.8
87	BRU	44	49	0.00	0.021	54.0	0.004	80.4
88	BRU	49	70	0.00	0.024	39.2	0.004	60.6
92	BRU	39	44	0.36	0.025	18.5	0.004	27.6
93	BRU	44	53	0.00	0.007	42.0	0.000	39.1
94	BRU	53	59	0.00	0.008	45.7	0.000	41.6
95	BRU	59	69	0.00	0.009	40.7	0.000	39.6
96	BRU	69+		0.00	0.007	39.8	0.001	31.7
99	BRU	55	60	1.58	0.000	9.4	0.001	5.3
100	BRU	60	70	0.24	0.000	7.6	0.000	4.1
103	BRU	24	29	0.00	0.025	58.6	0.003	101.6
104	BRU	29	49	0.00	0.027	49.0	0.002	90.7
105	BRU	49	54	0.00	0.026	38.5	0.001	66.0
106	BRU	54	87	0.00	0.021	25.2	0.002	45.9
185	Ona	34	40	0.00	0.031	50.5	0.001	149.3
186	Ona	40	45	0.00	0.024	70.9	0.000	158.7
187	Ona	45	70	0.12	0.038	15.2	0.022	53.7
192	Ona	79	84	3.53	0.056	-4.3	0.086	-2.5
193	Ona	84	90	1.58	0.031	12.9	0.051	9.9
194	Ona	90+		0.61	0.034	9.6	0.046	13.2
198	Ona	75	80	7.91	0.146	-59.4	0.190	-41.3
199	Ona	80+		3.41	0.098	-20.3	0.170	-23.7
204	Ona	72	77	9.25	0.128	-63.7	0.169	-37.7
205	Ona	77	90	1.34	0.022	12.2	0.054	6.1
206	Ona	90+		0.36	0.008	15.6	0.021	11.1

Appendix Table 5. Selected characteristics of Bh horizons of inorganic fertilized soils at Immokalee (TP = total P; EC = Electrical conductivity; Ox = oxalate; M1 = Mehlich 1).

Lab no	H _z	Initial depth, cm	Final depth, cm	pH	EC (dS/m)	TP	M1-P	M1-Al	M1-Fe mg/kg	OX-P	Ox-Fe	Ox-Al
111	Bh1	70	75	5.6	0.01	123	84	603	7	130	68	1341
112	Bh1	75	100	5.4	0.01	47	28	801	4	30	3	1777
113	Bh1	100	114	5.6	0.01	133	75	796	4	92	0	1282
114	Bh2	114	119	5.7	0.02	181	134	865	4	177	0	1095
115	Bh2	119	135	5.7	0.02	279	170	710	8	235	11	1441
120	Bh1	92	97	5.5	0.01	185	84	270	100	151	580	368
121	Bh1	97	122	5.8	0.02	200	146	565	38	193	468	891
122	Bh1	122	133	5.8	0.02	292	197	889	24	264	228	1411
123	Bh2	133		5.7	0.03	371	241	926	31	352	132	1739
129	Bh1	91	96	5.7	0.01	105	79	226	23	104	345	375
130	Bh1	96	115	5.8	0.02	136		436	8	128	141	713
131	Bh1	115	121	5.9	0.02	218	184	660	4	207	35	1255
132	Bh2	121	126	5.7	0.02	142	119	599	4	134	7	1150
133	Bh2	126	138+	5.5	0.01	50	48	408	4	53	0	732
138	Bh1	81	86	5.7	0.01	88	78	430	3	101	108	858
139	Bh1	86	105	5.6	0.01	53	59	474	3	71	46	1019
140	Bh1	105	118	4.9	0.01	0	6	336	6	1	23	785
141	Bh2	118	123	4.7	0.02	0	0	394	8	8	35	697
142	Bh2	123	130	4.8	0.02	0	0	374	9	0	11	644
147	Bh1	85	90	5.8	0.01	133	120	460	5	124	58	834
148	Bh1	90	108	5.5	0.01	16	17	496	4	10	5	960
149	Bh2	108+		4.9	0.02	27	10	495	3	20	0	1106
154	Bh1	95	100	5.8	0.01	157	136	288	19	151	120	517
155	Bh1	100	115	5.9	0.02	249	157	585	3	187	5	1123
156	Bh2	115+		5.6	0.02	221	75	838	4	167	0	1975
161	Bh1	88	93	5.8	0.01	191	145	579	4	173	40	1105
162	Bh1	93	103	5.9	0.01	77	49	626	3	58	10	1238
163	Bh2	103	118	5.8	0.01	7	4	438	3	0	0	758
164	Bh3	118+		5.5	0.01	19	5	413	4	14	0	826

Appendix Table 6. Water soluble P (WSP), P saturation ratio using oxalate parameters (PSR_{Ox}), soil P storage capacity (SPSC) using a threshold PSR_{Ox} = 0.05, P saturation ratio using Mehlich 1 parameters (PSR_{M1}), and the Capacity Factor using Mehlich 1 parameters and a threshold PSR of 0.08 for inorganic fertilizer -impacted soils.

Lab no	Hz	Initial depth, cm	Final depth, cm	WSP	PSR (Ox)	SPSC (0.05) mg/kg	PSR (M1)	Capacity factor (0.08)
111	Bh1	70	75	5.11	0.083	-51.5	0.121	-29
112	Bh1	75	100	0.36	0.015	71.9	0.030	46
113	Bh1	100	114	1.82	0.063	-18.7	0.082	-2
114	Bh2	114	119	3.64	0.141	-114.3	0.135	-55
115	Bh2	119	135	2.92	0.141	-151.9	0.208	-105
120	Bh1	92	97	9.74	0.204	-114.2	0.230	-55
121	Bh1	97	122	8.76	0.151	-129.4	0.218	-92
122	Bh1	122	133	8.15	0.151	-176.4	0.191	-114
123	Bh2	133		8.03	0.170	-248.4	0.223	-155
129	Bh1	91	96	7.18	0.168	-73.4	0.291	-58
130	Bh1	96	115	15.09	0.143	-83.4	0.000	40
131	Bh1	115	121	16.80	0.142	-133.9	0.242	-123
132	Bh2	121	126	10.95	0.101	-68.1	0.173	-64
133	Bh2	126	138+	4.87	0.063	-11.3	0.102	-11
138	Bh1	81	86	12.05	0.097	-48.6	0.157	-38
139	Bh1	86	105	9.13	0.060	-11.4	0.109	-16
140	Bh1	105	118	1.70	0.001	44.6	0.016	25
141	Bh2	118	123	0.24	0.009	33.2	0.000	36
142	Bh2	123	130	0.00	0.000	37.2	0.000	35
147	Bh1	85	90	6.57	0.126	-74.8	0.227	-78
148	Bh1	90	108	0.61	0.009	44.9	0.029	29
149	Bh2	108+		0.00	0.016	43.2	0.017	36
154	Bh1	95	100	9.01	0.229	-118.0	0.398	-109
155	Bh1	100	115	8.64	0.145	-123.0	0.233	-103
156	Bh2	115+		1.58	0.074	-54.1	0.078	2
161	Bh1	88	93	5.11	0.134	-108.3	0.218	-92
162	Bh1	93	103	1.34	0.041	13.2	0.068	8
163	Bh2	103	118	0.00	0.000	43.5	0.009	36
164	Bh3	118+		0.00	0.015	33.6	0.011	33

Appendix Table 7. Selected characteristics of Bh horizons of the Characterization Soils (TP = total P; Ox = oxalate; M1 = Mehlich 1).

Lab No	Soil Name	Horizon	Initial	Final	pH	TP	Ox-P	Ox-Fe	Ox-Al	M1-P	M1-Fe	M1-Al
			Depth cm	Depth cm					mg kg⁻¹			
5278	IMMOKALEE SAND	Bh1	84	91	4.3	60	50	20	1095	0	1	46
5279	IMMOKALEE SAND	Bh2	91	104	4.1	60	38	6	1560	0	1	115
5280	IMMOKALEE SAND	Bh3	104	119	4.3	40	27	13	1895	1	1	133
5282	IMMOKALEE SAND	Bh	160	183	4.5	40	65	44	3185	3	2	415
5454	PEPPER SAND	Bh1	56	68	4	30	4	633	2665	0	3	13
5455	PEPPER SAND	Bh2	68	81	4	30	19	261	3395	0	2	35
5456	PEPPER SAND	Bh3	81	99	4.8	67	41	162	2322	2	4	227
5532	FARMTON FINE SAND	Bh1	86	91	4.6	30	3	76	610	0	6	109
5533	FARMTON FINE SAND	Bh2	91	102	4.6	15	7	36	610	0	4	109
5534	FARMTON FINE SAND	Bh3	102	122	4.5	40	32	31	853	2	4	92
5563	IMMOKALEE FINE SAND	Bh1	109	119	4	100	44	31	1433	1	2	88
5564	IMMOKALEE FINE SAND	Bh2	119	140	4.2	957	846	0	3730	13	1	120
5565	IMMOKALEE FINE SAND	Bh3	140	165	4.4	857	830	0	3195	167	1	807
5569	WABASSO SAND, LIMESTONE SUBSTRATUM	Bh1	56	61	6.8	15	0	14	85	1	3	30
5570	WABASSO SAND, LIMESTONE SUBSTRATUM	Bh2	61	66	6.5	23	4	52	464	1	6	199
5574	OLDSMAR SAND	Bh1	96	119	5.5	278	180	49	2585	22	6	613
5575	OLDSMAR SAND	Bh2	119	147	5.5	285	217	138	3820	10	11	714
5596	OLDSMAR SAND, LIMESTONE SUBSTRATUM	Bh1	107	127	4.9	15	10	899	440	1	147	221
5597	OLDSMAR SAND, LIMESTONE SUBSTRATUM	Bh2	127	160	5.3	41	13	536	318	5	131	117
5986	SAPELO FINE SAND	Bh	46	58	3.6	52	21	97	1220	1	6	249
6032	IMMOKALEE SAND	Bh1	94	152	3.5	68	68	8	1384	5	1	80
6033	IMMOKALEE SAND	Bh2	152	203	3.3	30	22	5	552	1	1	13
6136	WAUCHULA FINE SAND	Bh1	30	41	4.4	493	591	130	2104	59	5	269
6137	WAUCHULA FINE SAND	Bh2	41	56	4.4	482	492	59	1517	38	3	174
6145	EAUGALLIE FINE SAND	Bh1	74	81	4.5	106	57	690	862	12	75	240
6146	EAUGALLIE FINE SAND	Bh2	81	119	4.8	30	4	213	369	1	50	193
6235	SAPELO MUCK	Bh1	36	41	4.2	45	3	7	413	0	1	55

Lab No	Soil Name	Horizon	Initial Depth cm	Final Depth cm	pH	TP	Ox-P	Ox-Fe	Ox-Al mg kg ⁻¹	M1-P	M1-Fe	M1-Al
6236	SAPELO MUCK	Bh2	41	53	4.3	83	42	0	714	2	1	104
6259	LEON FINE SAND	Bh1	41	51	4.2	76	47	7	1446	2	2	121
6260	LEON FINE SAND	Bh2	51	66	4.4	75	40	0	2810	0	1	275
6301	LEON SAND	Bh	41	61	4.2	45	48	75	3435	1	2	166
6389	SMYRNA FINE SAND	Bh1	94	145	6.2	113	79	183	2298	6	9	324
6390	SMYRNA FINE SAND	Bh2	145	188	6	180	137	83	3905	6	2	272
6391	SMYRNA FINE SAND	Bh3	188	203	5.7	31	289	38	3680	21	3	539
6482	CHAIRES FINE SAND	Bh1	58	74	4.2	68	35	54	1384	1	6	323
6483	CHAIRES FINE SAND	Bh2	74	91	4.5	45	29	14	2189	0	3	336
6558	CHAIRES FINE SAND	Bh1	43	56	4.2	22	7	568	1050	0	44	272
6559	CHAIRES FINE SAND	Bh2	56	68	4.5	22	4	469	981	0	23	199
6560	CHAIRES FINE SAND	Bh3	68	86	4.3	41	20	271	1682	1	22	335
6630	ALLANTON LOAMY SAND	Bh1	150	175	4.7	75	42	231	3860	3	2	507
6631	ALLANTON LOAMY SAND	Bh2	175	203	4.6	68	31	194	4090	1	2	595
6710	CHAIRES FINE SAND	Bh1	46	56	4.1	90	376	155	3680	1	6	255
6711	CHAIRES FINE SAND	Bh2	56	68	4.7	60	36	125	1809	0	2	250
6999	POTTSBURG SAND	Bh1	130	155	4.7	408	21	11	2142	38	9	844
7000	POTTSBURG SAND	Bh2	155	203	4.8	557	557	100	4080	18	5	277
7010	POMONA SANDY BT VARIANT FINE SAND	Bh1	58	74	4	45	20	30	1400	0	1	54
7011	POMONA SANDY BT VARIANT FINE SAND	Bh2	74	104	4.2	52	35	0	1796	1	1	118
7020	FARMTON SANDY BT VARIANT FINE SAND	Bh1	109	137	4.1	15	0	0	1161	0	1	49
7021	FARMTON SANDY BT VARIANT FINE SAND	Bh2	137	152	4.1	30	8	0	1101	0	1	36
7027	WABASSO FINE SAND	Bh	56	76	5.1	8	2	1208	1293	0	90	482
7103	MANDARIN FINE SAND	Bh1	64	76	4.6	53	28	100	2945	1	4	281
7104	MANDARIN FINE SAND	Bh2	76	86	5	40	16	16	1443	1	3	356
7117	LEON SAND	Bh1	56	102	4.1	40	17	0	1234	0	1	32
7118	LEON SAND	Bh2	102	183	4.2	30	12	0	1021	0	1	27
7222	SMYRNA FINE SAND	Bh1	33	46	3.3	60	40	113	6865	0	2	515
7223	SMYRNA FINE SAND	Bh2	46	53	4.1	41	16	114	2605	0	4	423

Lab No	Soil Name	Horizon	Initial Depth cm	Final Depth cm	pH	TP	Ox-P	Ox-Fe	Ox-Al mg kg ⁻¹	M1-P	M1-Fe	M1-Al
7226	SMYRNA FINE SAND	Bh	178	203	4.5	60	15	12	828	6	4	353
7374	POMONA FINE SAND	Bh1	53	71	3.7	21	6	433	1603	0	3	18
7375	POMONA FINE SAND	Bh2	71	127	3.8	53	31	103	2640	0	4	171
7689	OLUSTEE FINE SAND	Bh	20	36	5.1	27	9	316	860	1	23	245
7755	POTTSBURG SAND	Bh1	122	145	5.4	38	14	44	324	3	2	83
7756	POTTSBURG SAND	Bh2	145	202	4.8	38	40	180	2099	2	1	194
	LYNN HAVEN MUCKY											
7882	LOAMY FINE SAND	Bh	48	69	4.3	58	35	0	1039	0	1	69
7915	KINGSFERRY FINE SAND	Bh1	86	109	5	25	15	0	775	2	1	226
7916	KINGSFERRY FINE SAND	Bh2	109	137	4.9	37	13	0	1668	1	1	345
7917	KINGSFERRY FINE SAND	Bh3	137	203	4.9	78	48	0	5000	1	1	369
7927	SAPELO SAND	Bh1	46	53	4.6	59	49	44	1033	2	4	154
7928	SAPELO SAND	Bh2	53	61	4.8	46	29	138	4155	1	4	210
7936	SAPELO FINE SAND	Bh1	46	56	4.6	49	31	14	656	2	3	112
7937	SAPELO FINE SAND	Bh2	56	66	5	35	16	13	2885	0	1	163
7963	POTTSBURG SAND	Bh	135	203	5.2	30	4	0	999	0	1	56
8002	LEON FINE SAND	Bh	53	74	4.7	24	35	0	1872	1	1	232
8076	MANDARIN FINE SAND	Bh	33	43	5.4	69	54	458	2088	4	12	344
8098	SAPELO SAND	Bh1	30	38	5	24	21	110	1073	1	7	185
8099	SAPELO SAND	Bh2	38	43	5.2	24	17	502	3275	0	14	498
8425	IMMOKALEE FINE SAND	Bh1	79	102	3.7	33	1	0	728	0	1	189
8426	IMMOKALEE FINE SAND	Bh2	102	152	3.7	46	6	0	461	1	1	76

Appendix Table 8. Water soluble P (WSP), P saturation ratio using oxalate parameters (PSR_{Ox}), soil P storage capacity (SPSC) using a threshold PSR_{Ox} = 0.05, P saturation ratio using Mehlich 1 parameters (PSR_{M1}), and the Capacity Factor using Mehlich 1 parameters and a threshold PSR of 0.08 for selected characterization soils.

Lab No	Soil Name	Horizon	Initial Depth cm	Final Depth cm	WSP mg kg ⁻¹	PSR _{Ox}	SPSC _{Ox} (0.05) mg kg ⁻¹	PSR _{M1}	Capacity Factor M1(0.08) mg kg ⁻¹
5278	IMMOKALEE SAND	Bh1	84	91	3.14	0.04	13.49	0.00	4.33
5279	IMMOKALEE SAND	Bh2	91	104	0.58	0.02	51.83	0.00	10.58
5280	IMMOKALEE SAND	Bh3	104	119	0.20	0.01	82.00	0.00	11.78
5282	IMMOKALEE SAND	Bh	160	183	0.00	0.02	118.65	0.01	35.46
5454	PEPPER SAND	Bh1	56	68	0.07	0.00	166.74	0.01	1.23
5455	PEPPER SAND	Bh2	68	81	0.00	0.00	183.19	0.00	3.22
5456	PEPPER SAND	Bh3	81	99	0.00	0.01	96.77	0.01	19.40
5532	FARMTON FINE SAND	Bh1	86	91	0.00	0.00	33.77	0.00	10.07
5533	FARMTON FINE SAND	Bh2	91	102	0.00	0.01	29.06	0.00	9.78
5534	FARMTON FINE SAND	Bh3	102	122	0.00	0.03	17.93	0.02	6.86
5563	IMMOKALEE FINE SAND	Bh1	109	119	0.00	0.03	38.78	0.01	7.58
5564	IMMOKALEE FINE SAND	Bh2	119	140	2.50	0.20	-632.69	0.09	-1.77
5565	IMMOKALEE FINE SAND	Bh3	140	165	4.92	0.23	-646.89	0.18	-93.44
5569	WABASSO SAND, LIMESTONE SUBSTRATUM	Bh1	56	61	0.33	0.00	5.30	0.01	2.43
5570	WABASSO SAND, LIMESTONE SUBSTRATUM	Bh2	61	66	0.00	0.01	23.99	0.00	17.69
5574	OLDSMAR SAND	Bh1	96	119	0.07	0.06	-30.02	0.03	35.06
5575	OLDSMAR SAND	Bh2	119	147	0.00	0.05	5.73	0.01	55.79
5596	OLDSMAR SAND, LIMESTONE SUBSTRATUM	Bh1	107	127	0.00	0.01	39.75	0.00	26.15
5597	OLDSMAR SAND, LIMESTONE SUBSTRATUM	Bh2	127	160	0.00	0.02	20.06	0.02	11.84
5986	SAPELO FINE SAND	Bh	46	58	0.00	0.01	51.23	0.00	22.58
6032	IMMOKALEE SAND	Bh1	94	152	4.67	0.04	11.18	0.05	2.35
6033	IMMOKALEE SAND	Bh2	152	203	1.99	0.03	10.11	0.06	0.27
6136	WAUCHULA FINE SAND	Bh1	30	41	18.32	0.24	-467.17	0.19	-34.35
6137	WAUCHULA FINE SAND	Bh2	41	56	14.62	0.28	-403.78	0.19	-21.58

Lab No	Soil Name	Horizon	Initial Depth cm	Final Depth cm	WSP mg kg ⁻¹	PSR _{ox}	SPSC _{ox} (0.05) mg kg ⁻¹	PSR _{M1}	Capacity Factor M1(0.08) mg kg ⁻¹
6145	EAUGALLIE FINE SAND	Bh1	74	81	1.10	0.04	11.48	0.04	13.42
6146	EAUGALLIE FINE SAND	Bh2	81	119	0.07	0.01	23.52	0.00	18.89
6235	SAPELO MUCK	Bh1	36	41	0.07	0.01	21.28	0.01	4.65
6236	SAPELO MUCK	Bh2	41	53	0.33	0.05	-1.05	0.02	7.11
6259	LEON FINE SAND	Bh1	41	51	0.46	0.03	36.50	0.01	9.57
6260	LEON FINE SAND	Bh2	51	66	0.00	0.01	120.88	0.00	24.82
6301	LEON SAND	Bh	41	61	0.00	0.01	151.38	0.00	14.61
6389	SMYRNA FINE SAND	Bh1	94	145	0.00	0.03	58.13	0.02	24.42
6390	SMYRNA FINE SAND	Bh2	145	188	0.00	0.03	89.45	0.02	19.33
6391	SMYRNA FINE SAND	Bh3	188	203	0.00	0.07	-76.97	0.03	28.49
6482	CHAIRES FINE SAND	Bh1	58	74	0.00	0.02	45.54	0.00	29.13
6483	CHAIRES FINE SAND	Bh2	74	91	0.00	0.01	96.61	0.00	30.54
6558	CHAIRES FINE SAND	Bh1	43	56	0.00	0.00	69.27	0.00	26.85
6559	CHAIRES FINE SAND	Bh2	56	68	0.00	0.00	65.22	0.00	19.20
6560	CHAIRES FINE SAND	Bh3	68	86	0.00	0.01	83.68	0.00	31.09
6630	ALLANTON LOAMY SAND	Bh1	150	175	0.00	0.01	186.17	0.00	43.91
6631	ALLANTON LOAMY SAND	Bh2	175	203	0.00	0.01	209.34	0.00	53.29
6710	CHAIRES FINE SAND	Bh1	46	56	0.00	0.09	-160.29	0.00	23.04
6711	CHAIRES FINE SAND	Bh2	56	68	0.00	0.02	71.58	0.00	22.86
6999	POTTSBURG SAND	Bh1	130	155	0.00	0.01	101.92	0.04	39.39
7000	POTTSBURG SAND	Bh2	155	203	0.00	0.12	-320.55	0.06	7.83
7010	POMONA SANDY BT VARIANT FINE SAND	Bh1	58	74	0.07	0.01	60.88	0.00	4.81
7011	POMONA SANDY BT VARIANT FINE SAND	Bh2	74	104	0.00	0.02	67.64	0.00	10.28
7020	FARMTON SANDY BT VARIANT FINE SAND	Bh1	109	137	0.00	0.00	66.65	0.00	4.51
7021	FARMTON SANDY BT VARIANT FINE SAND	Bh2	137	152	0.07	0.01	55.17	0.00	3.29
7027	WABASSO FINE SAND	Bh	56	76	0.00	0.00	105.43	0.00	48.17
7103	MANDARIN FINE SAND	Bh1	64	76	0.00	0.01	143.83	0.00	25.35
7104	MANDARIN FINE SAND	Bh2	76	86	0.00	0.01	67.64	0.00	32.16

Lab No	Soil Name	Horizon	Initial Depth cm	Final Depth cm	WSP mg kg ⁻¹	PSR _{ox}	SPSC _{ox} (0.05) mg kg ⁻¹	PSR _{M1}	Capacity Factor M1(0.08) mg kg ⁻¹
7117	LEON SAND	Bh1	56	102	0.00	0.01	53.67	0.00	2.92
7118	LEON SAND	Bh2	102	183	0.00	0.01	46.33	0.00	2.47
7222	SMYRNA FINE SAND	Bh1	33	46	0.00	0.00	357.59	0.00	47.18
7223	SMYRNA FINE SAND	Bh2	46	53	0.00	0.01	136.58	0.00	38.84
7226	SMYRNA FINE SAND	Bh	178	203	0.00	0.02	32.78	0.01	27.03
7374	POMONA FINE SAND	Bh1	53	71	0.00	0.00	98.02	0.01	1.69
7375	POMONA FINE SAND	Bh2	71	127	0.00	0.01	123.39	0.00	15.43
7689	OLUSTEE FINE SAND	Bh	20	36	0.00	0.01	48.96	0.00	22.55
7755	POTTSBURG SAND	Bh1	122	145	0.00	0.04	5.91	0.04	4.34
7756	POTTSBURG SAND	Bh2	145	202	0.00	0.02	85.74	0.01	16.07
7882	LYNN HAVEN MUCKY LOAMY FINE SAND	Bh	48	69	0.02	0.03	24.23	0.00	6.04
7915	KINGSFERRY FINE SAND	Bh1	86	109	0.00	0.02	29.83	0.01	19.20
7916	KINGSFERRY FINE SAND	Bh2	109	137	0.00	0.01	82.34	0.00	30.39
7917	KINGSFERRY FINE SAND	Bh3	137	203	0.00	0.01	239.34	0.00	32.76
7927	SAPELO SAND	Bh1	46	53	0.46	0.04	11.44	0.01	12.49
7928	SAPELO SAND	Bh2	53	61	0.00	0.01	213.19	0.00	18.92
7936	SAPELO FINE SAND	Bh1	46	56	1.10	0.04	7.16	0.01	8.73
7937	SAPELO FINE SAND	Bh2	56	66	0.00	0.00	150.20	0.00	14.78
7963	POTTSBURG SAND	Bh	135	203	0.00	0.00	52.90	0.00	5.02
8002	LEON FINE SAND	Bh	53	74	0.00	0.02	72.28	0.00	20.87
8076	MANDARIN FINE SAND	Bh	33	43	0.00	0.02	78.06	0.01	28.06
8098	SAPELO SAND	Bh1	30	38	0.07	0.02	44.00	0.01	16.09
8099	SAPELO SAND	Bh2	38	43	0.00	0.00	185.32	0.00	45.88
8425	IMMOKALEE FINE SAND	Bh1	79	102	0.00	0.00	41.01	0.00	17.32
8426	IMMOKALEE FINE SAND	Bh2	102	152	0.00	0.01	20.24	0.01	6.28

Appendix Table 9. Characteristics of Bh horizons of the characterization soils selected for incubation studies (TP = total P; Ox = oxalate; M1 = Mehlich 1).

Lab. No.	Soil	Initial Depth cm	Final Depth cm	Sand	Clay	pH	TP	Ox-Fe	Ox-Al	M1-Fe	M1-Al
				%	%			mg kg ⁻¹			
5282	Immokalee sand	160	183	95.6	1.5	4.50	40	44	3185	2	415
5569	Wabasso sand, limestone substratum	56	61	97.4	1.1	6.80	15	14	85	3	30
5596	Oldsmar sand, limestone substratum	107	127	93.6	0.6	4.90	15	899	440	147	221
5986	Sapelo fine sand	46	58	84.4	4.0	3.60	52	97	1220	6	249
6032	Immokalee sand	94	152	94.3	0.9	3.50	68	8	1384	1	80
6145	Eaugallie fine sand	74	81	91.5	3.7	4.50	106	690	862	75	240
6389	Smryna fine sand	94	145	94.3	1.6	6.20	113	183	2298	9	324
6482	Chaires fine sand	58	74	86.3	5.0	4.20	68	54	1384	6	323
6558	Chaires fine sand	43	56	94.6	2.2	4.20	22	568	1050	44	272
6630	Allanton loamy sand	150	175	90.4	1.6	4.70	75	231	3860	2	507
6710	Chaires fine sand	46	56	89.5	3.9	4.10	90	155	3680	6	255
6999	Pottsburg sand	130	155	88.9	1.9	4.70	408	11	2142	9	844
7103	Mandarin fine sand	64	76	92.5	3.1	4.60	53	100	2945	4	281
7117	Leon sand	56	102	96.8	1.1	4.10	40	0	1234	1	32
7915	Kingsferry fine sand	86	109	92.3	3.8	5.00	25	0	775	1	226
7927	Sapelo sand	46	53	88.1	3.3	4.60	59	44	1033	4	154
7963	Pottsburg sand	135	203	96.3	1.0	5.20	30	0	999	1	56
8002	Leon fine sand	53	74	93.3	2.8	4.70	24	0	1872	1	232
8098	Sapelo Sand	30	38	87.0	5.9	5.00	24	110	1073	7	185
8425	Immokalee Fine Sand	79	102	96.4	1.0	3.70	33	0	728	1	189

Appendix Table 10. Water soluble P (WSP), oxalate P (Ox-P), Mehlich 1-P (M1-P), P saturation ratio calculated using oxalate (PSR_{Ox}) and Mehlich 1 (PSR_{M1}) parameters; soil P storage capacity (SPSC) and capacity factor (CF), calculated using Mehlich 1 parameters after a 6-week incubation period. P levels correspond to 0, 50, 100, 150, 200, 300 mg P kg⁻¹.

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P mg kg ⁻¹	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
5282	Immokalee sand	1	0.0	65	3	0.02	119	0.01	36
		2	0.4	91	34	0.02	93	0.07	4
		3	3.6	159	65	0.04	25	0.14	-27
		4	8.1	224	112	0.06	-40	0.24	-74
		5	13.8	309	140	0.08	-124	0.29	-102
		6	29.3	348	193	0.09	-163	0.40	-155
5569	Wabasso sand, limestone substratum	1	0.3	0	1	0.00	5	0.01	2
		2	25.9	34	40	0.32	-28	1.10	-37
		3	66.2	84	79	0.80	-79	2.16	-76
		4	150.3	117	122	1.10	-111	3.31	-119
		5	181.4	170	204	1.61	-165	5.57	-201
		6	146.8	228	266	2.16	-223	7.25	-263
5596	Oldsmar sand, limestone substratum	1	0.0	10	1	0.01	40	0.00	26
		2	8.9	26	29	0.03	25	0.09	-3
		3	17.0	107	58	0.11	-56	0.17	-31
		4	40.0	116	96	0.12	-66	0.29	-70
		5	63.8	263	124	0.26	-213	0.37	-97
		6	83.4	469	195	0.47	-419	0.58	-168
5986	Sapelo fine sand	1	0.0	21	1	0.01	51	0.00	23
		2	1.7	64	36	0.04	9	0.13	-13
		3	8.0	99	77	0.07	-26	0.27	-54
		4	18.4	148	145	0.10	-75	0.50	-121
		5	33.9	195	177	0.13	-122	0.61	-154

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P mg kg ⁻¹	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
6032	Immokalee sand	6	68.5	297	259	0.20	-224	0.90	-236
		1	4.7	68	5	0.04	11	0.05	2
		2	31.7	81	68	0.05	-1	0.74	-61
		3	48.9	165	135	0.10	-85	1.47	-128
		4	82.3	260	163	0.16	-180	1.76	-156
		5	98.4	306	202	0.19	-226	2.19	-195
6145	Eaugallie fine sand	6	154.7	487	273	0.31	-407	2.96	-266
		1	1.1	57	12	0.04	12	0.04	13
		2	2.7	91	56	0.06	-23	0.18	-31
		3	6.6	104	101	0.07	-36	0.32	-76
		4	19.5	148	158	0.09	-79	0.50	-133
		5	20.1	185	195	0.12	-116	0.61	-170
6389	Smryna fine sand	6	31.6	305	259	0.19	-236	0.82	-234
		1	0.0	79	6	0.03	58	0.02	24
		2	0.7	111	52	0.04	26	0.14	-22
		3	4.1	164	70	0.06	-27	0.19	-40
		4	15.7	191	112	0.07	-54	0.30	-82
		5	13.1	252	140	0.09	-115	0.37	-110
6482	Chaires fine sand	6	22.4	394	190	0.14	-256	0.51	-160
		1	0.0	35	1	0.02	46	0.00	29
		2	1.3	67	34	0.04	14	0.09	-5
		3	7.5	116	75	0.07	-35	0.20	-45
		4	14.9	151	140	0.09	-70	0.37	-110
		5	24.7	198	172	0.12	-117	0.46	-142
6558	Chaires fine sand	6	45.4	327	252	0.20	-246	0.67	-222
		1	0.0	7	0	0.00	69	0.00	27
		2	0.6	60	29	0.04	16	0.09	-2
		3	4.3	196	64	0.13	-120	0.19	-37

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P mg kg ⁻¹	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
6630	Allanton loamy sand	4	7.8	119	108	0.08	-43	0.32	-81
		5	8.5	164	145	0.11	-88	0.43	-118
		6	18.2	264	222	0.17	-187	0.66	-195
		1	0.0	42	3	0.01	186	0.00	44
		2	0.0	40	25	0.01	188	0.04	22
		3	2.7	112	50	0.02	116	0.09	-3
		4	5.0	122	57	0.03	106	0.10	-11
		5	5.1	303	71	0.07	-75	0.12	-25
6710	Chaires fine sand	6	13.1	410	103	0.09	-181	0.18	-57
		1	0.0	376	1	0.09	-160	0.00	23
		2	0.6	65	31	0.01	151	0.11	-8
		3	5.5	107	71	0.02	109	0.24	-47
		4	10.1	199	140	0.05	16	0.47	-116
		5	15.4	201	163	0.05	14	0.55	-139
		6	30.0	348	232	0.08	-132	0.78	-208
6999	Pottsburg sand	1	0.0	21	38	0.01	102	0.04	39
		2	0.3	280	81	0.11	-157	0.08	-3
		3	4.7	393	81	0.16	-270	0.08	-3
		4	9.5	460	145	0.19	-337	0.15	-67
		5	11.3	726	142	0.29	-603	0.15	-64
		6	29.3	659	181	0.27	-536	0.19	-103
7103	Mandarin fine sand	1	0.0	28	1	0.01	144	0.00	25
		2	0.3	50	32	0.01	121	0.10	-6
		3	3.2	116	54	0.03	56	0.17	-28
		4	14.2	325	177	0.09	-153	0.54	-151
		5	6.2	283	110	0.08	-111	0.34	-84
		6	13.1	337	163	0.10	-165	0.50	-137
7117	Leon sand	1	0.0	17	0	0.01	54	0.00	3

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P mg kg ⁻¹	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
7915	Kingsferry fine sand	2	6.6	31	29	0.02	39	0.78	-26
		3	17.4	149	67	0.11	-78	1.78	-64
		4	36.2	246	109	0.17	-176	2.92	-106
		5	50.0	267	158	0.19	-196	4.24	-155
		6	100.7	627	239	0.44	-556	6.39	-236
		1	0.0	15	2	0.02	30	0.01	19
		2	3.2	42	34	0.05	3	0.13	-13
		3	14.0	79	67	0.09	-35	0.26	-47
		4	24.7	144	122	0.16	-100	0.47	-101
		5	42.0	162	154	0.18	-117	0.59	-133
		6	59.2	317	227	0.36	-272	0.87	-206
		1	0.5	49	2	0.04	11	0.01	12
7927	Sapelo sand	2	5.8	97	40	0.08	-36	0.22	-26
		3	15.8	129	77	0.11	-68	0.43	-63
		4	32.7	174	139	0.14	-113	0.78	-125
		5	47.7	221	190	0.18	-161	1.07	-176
		6	78.8	351	241	0.29	-290	1.35	-227
		1	0.0	4	0	0.00	53	0.00	5
7963	Pottsburg sand	2	1.7	17	30	0.01	40	0.46	-25
		3	5.2	119	62	0.10	-61	0.97	-57
		4	11.0	209	96	0.18	-152	1.50	-91
		5	11.3	204	145	0.18	-146	2.25	-139
		6	27.0	309	177	0.27	-252	2.75	-172
		1	0.0	35	1	0.02	72	0.00	21
8002	Leon fine sand	2	1.3	36	31	0.02	72	0.12	-10
		3	7.5	117	70	0.05	-10	0.26	-48
		4	17.9	190	117	0.09	-83	0.44	-96
		5	24.7	205	154	0.10	-97	0.58	-132

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P mg kg ⁻¹	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
8098	Sapelo Sand	6	43.1	377	254	0.18	-270	0.95	-232
		1	0.1	21	1	0.02	44	0.01	16
		2	2.8	33	35	0.03	32	0.16	-18
		3	10.3	102	75	0.08	-38	0.35	-58
		4	17.0	173	134	0.13	-108	0.62	-117
		5	31.6	242	163	0.19	-177	0.75	-146
8425	Immokalee Fine Sand	6	52.3	361	250	0.28	-296	1.16	-233
		1	0.0	1	0	0.00	41	0.00	17
		2	9.2	29	36	0.03	13	0.17	-19
		3	27.1	85	76	0.10	-43	0.35	-58
		4	56.9	122	135	0.15	-80	0.62	-118
		5	71.5	181	181	0.22	-140	0.83	-164
		6	116.9	265	291	0.32	-223	1.34	-274

Appendix Table 11. Water soluble P (WSP), oxalate P (Ox-P), Mehlich 1-P (M1-P), P saturation ratio calculated using oxalate (PSR_{Ox}) and Mehlich 1 (PSR_{M1}) parameters; soil P storage capacity (SPSC) and capacity factor (CF), calculated using Mehlich 1 parameters after a 10-month incubation period. P levels correspond to 0, 50, 100, 150, 200, 300 mg P kg⁻¹.

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
5282	Immokalee sand	1	0.0	65	3	0	119	0	35
		2	0.6	108	1	0	76	0	37
		3	3.2	190	14	0	-6	0	24
		4	3.8	221	35	0	-37	0	4
		5	7.5	258	60	0	-74	0	-22
		6	13.0	285	110	0	-101	0	-72
5569	Wabasso sand, limestone subsrtatum	1	0.3	0	1	0	5	0	2
		2	25.1	60	3	1	-55	0	0
		3	50.6	107	18	1	-102	0	-15
		4	114.2	146	53	1	-141	1	-50
		5	82.7	148	75	1	-143	2	-72
		6	143.1	243	29	2	-238	1	-26
5596	Oldsmar sand, limestone substratum	1	0.0	10	1	0	40	0	26
		2	4.2	54	0	0	-3	0	26
		3	15.0	111	25	0	-61	0	2
		4	20.2	145	64	0	-94	0	-37
		5	41.2	129	64	0	-78	0	-37
		6	70.4	257	68	0	-207	0	-41
5986	Sapelo fine sand	1	0.0	21	1	0	51	0	23
		2	0.8	87	0	0	-15	0	23
		3	3.9	129	148	0	-57	1	-125
		4	7.8	165	37	0	-92	0	-14
		5	11.1	216	20	0	-143	0	3

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
6032	Immokalee sand	6	26.6	329	118	0	-256	0	-95
		1	4.7	68	5	0	11	0	2
		2	30.3	100	11	0	-20	0	-4
		3	58.2	153	36	0	-74	0	-28
		4	67.6	226	40	0	-146	0	-33
		5	63.4	272	95	0	-192	1	-87
6145	Eaugallie fine sand	6	120.8	275	115	0	-195	1	-108
		1	1.1	57	12	0	12	0	13
		2	2.5	111	8	0	-42	0	18
		3	5.5	155	28	0	-86	0	-2
		4	5.6	218	38	0	-149	0	-12
		5	7.5	230	30	0	-161	0	-4
6389	Smryna fine sand	6	18.6	358	151	0	-289	0	-126
		1	0.0	79	6	0	58	0	24
		2	1.1	123	3	0	14	0	27
		3	3.2	199	18	0	-62	0	12
		4	4.6	225	17	0	-88	0	13
		5	5.3	254	109	0	-117	0	-79
6482	Chaires fine sand	6	15.7	339	167	0	-201	0	-137
		1	0.0	35	1	0	46	0	29
		2	1.1	100	0	0	-19	0	30
		3	3.7	147	17	0	-66	0	13
		4	5.9	174	48	0	-93	0	-18
		5	11.4	233	93	0	-152	0	-64
6558	Chaires fine sand	6	20.4	340	81	0	-259	0	-51
		1	0.0	7	0	0	69	0	27
		2	0.8	60	0	0	16	0	27
		3	2.7	102	9	0	-26	0	18

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
6630	Allanton loamy sand	4	3.3	153	17	0	-77	0	10
		5	5.8	205	156	0	-129	0	-129
		6	10.9	272	117	0	-196	0	-90
		1	0.0	42	3	0	186	0	44
		2	0.4	80	1	0	148	0	46
		3	1.6	138	21	0	90	0	26
		4	2.7	213	33	0	15	0	13
6710	Chaires fine sand	5	2.9	197	88	0	31	0	-41
		6	8.6	275	179	0	-47	0	-133
		1	0.0	376	1	0	-160	0	23
		2	0.6	99	0	0	117	0	23
		3	3.1	146	17	0	70	0	7
		4	5.6	185	52	0	31	0	-28
		5	6.6	215	124	0	0	0	-101
6999	Pottsburg sand	6	17.7	357	163	0	-141	1	-140
		1	0.0	21	38	0	102	0	39
		2	0.1	365	8	0	-242	0	70
		3	3.9	467	20	0	-344	0	58
		4	4.6	458	87	0	-335	0	-9
		5	7.3	558	125	0	-434	0	-47
		6	7.3	492	125	0	-368	0	-47
7103	Mandarin fine sand	1	0.0	28	1	0	144	0	25
		2	0.4	95	0	0	77	0	26
		3	2.1	125	156	0	47	0	-130
		4	5.8	315	193	0	-143	1	-167
		5	3.2	221	59	0	-49	0	-33
		6	5.9	351	135	0	-179	0	-109
7117	Leon sand	1	0.0	17	0	0	54	0	3

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
7915	Kingsferry fine sand	2	3.3	87	0	0	-16	0	3
		3	16.0	130	26	0	-59	1	-23
		4	18.0	129	52	0	-58	1	-49
		5	18.8	176	74	0	-105	2	-71
		6	40.2	349	132	0	-278	4	-129
		1	0.0	15	2	0	30	0	19
		2	2.3	57	1	0	-13	0	20
		3	10.1	124	45	0	-79	0	-24
		4	10.2	144	69	0	-99	0	-49
		5	15.6	208	122	0	-163	0	-102
7927	Sapelo sand	6	35.5	334	35	0	-290	0	-15
		1	0.5	49	2	0	11	0	12
		2	3.4	117	2	0	-57	0	12
		3	9.1	167	93	0	-107	1	-79
		4	12.4	199	70	0	-138	0	-56
		5	18.3	248	123	0	-188	1	-109
7963	Pottsburg sand	6	47.3	365	157	0	-304	1	-142
		1	0.0	4	0	0	53	0	5
		2	1.1	60	0	0	-3	0	5
		3	2.7	104	23	0	-46	0	-18
		4	3.2	212	47	0	-155	1	-42
		5	7.5	124	74	0	-67	1	-69
8002	Leon fine sand	6	13.4	222	37	0	-164	1	-32
		1	0.0	35	1	0	72	0	21
		2	1.1	87	0	0	21	0	21
		3	3.0	141	33	0	-33	0	-11
		4	5.0	192	58	0	-84	0	-36
		5	9.8	206	92	0	-98	0	-71

Lab. No.	Soil	P level	WSP mg kg ⁻¹	Ox-P	M1-P mg kg ⁻¹	PSR _{Ox}	SPSC ox 0.05	PSR _{M1}	CF (M1) 0.08
8098	Sapelo Sand	6	23.7	305	100	0	-198	0	-79
		1	0.1	21	1	0	44	0	16
		2	1.8	63	1	0	1	0	16
		3	5.3	129	34	0	-65	0	-16
		4	6.9	200	100	0	-135	0	-83
		5	13.8	210	86	0	-145	0	-69
8425	Immokalee Fine Sand	6	30.3	326	174	0	-261	1	-157
		1	0.0	1	0	0	41	0	17
		2	2.5	62	0	0	-20	0	17
		3	10.5	109	27	0	-67	0	-10
		4	14.5	129	100	0	-87	0	-82
		5	19.0	226	24	0	-184	0	-7
		6	39.3	352	190	0	-310	1	-173

Appendix Table 12 Soil P storage capacity (SPSC) in various soil profiles in the Lake Okeechobee Watershed.

Lab no	Dairy	Hori subdiv	Initial depth cm	Final depth cm	Component	WSP mg kg ⁻¹	Oxalate-P mg kg ⁻¹	Ox-Al mg kg ⁻¹	Ox-Fe mg kg ⁻¹	PSR-ox	SPSC-ox mg kg ⁻¹
442	WFR	A	0	8	Intensive	184.45	349	92	95	2.21	-441
443		E	8	16		30.53	256	47	72	2.71	-242
444		Bh	16	23		17.18	302	4770	84	0.05	531
445		Bw	23	50		27.32	185	1884	77	0.08	148
559	CM	A	0	5	Holding	14.03	86	80	142	0.50	-90
560		E	5	14		2.34	8	2	54	0.26	-7
561		Bh	14	21		0.44	81	4625	429	0.01	786
562		E1	21	28		0.10	21	1377	213	0.01	252
563		E2	28	41		0.08	25	1202	204	0.02	215
564		E3	41	52		0.08	30	1568	158	0.02	266
585	CM	A	0	5	Pasture	0.08	22	89	129	0.13	6
586		E	5	11		0.01	3	28	11	0.07	3
587		Bh	11	18		0.00	58	3345	61	0.02	528
588		Bw1	18	29		0.04	37	2635	309	0.01	468
589		Bw2	29	39		0.00	63	7515	590	0.01	1331
590		B'h	39	50		0.00	54	5605	156	0.01	937
638	WFR	A	0	5	Forage	0.36	17	53	42	0.20	-5
639		E	5	12		0.03	1	1	0	0.72	-1
640		Bh	12	18		0.55	179	2845	71	0.05	321
641		Bw	18	23		0.00	17	2093	132	0.01	366
642		Bh1	23	37		0.00	5	550	44	0.01	97
643		Bh2	37	50		0.00	11	770	68	0.01	132
659	WFR	A	0	6	Native	0.05	17	131	131	0.08	22
660		AE	6	11		0.02	3	24	23	0.08	4
661		E1	11	20		0.00	0	1	0	0.00	0
662		Bh	20	26		0.00	73	3090	45	0.02	466
663		Bw1	26	29		0.00	42	2103	56	0.02	329
664		Bw2	29	42		0.00	32	1489	53	0.02	233
665		Bw3	42	52		0.00	65	2515	115	0.02	386

Lab no	Dairy	Hori subdiv	Initial depth cm	Final depth cm	Component	WSP mg kg ⁻¹	Oxalate-P mg kg ⁻¹	Ox-Al mg kg ⁻¹	Ox-Fe mg kg ⁻¹	PSR-ox	SPSC-ox mg kg ⁻¹
734	L6	A	0	8	Holding	147.40	978	155	380	2.52	-1454
735		AE	8	18		31.60	125	1	0	84.57	-125
736		E1	18	26		17.60	36	1	0	31.73	-36
737		E2	26	52		14.00	59	0	45	2.36	-113
738		Bh	52	61		20.80	83	870	106	0.08	80
739		Bw1	61	70		18.70	54	937	5	0.05	108
740		Bw2	70	85		24.40	86	778	43	0.09	53
828	DL1	A	0	5	Holding	22.70	128	24	74	1.87	-193
829		AE	5	9		17.28	64	0	27	4.30	-128
830		E1	9	18		18.44	37	1	0	32.26	-37
831		E2	18	39		5.66	17	0	15	2.07	-33
832		Bh	39	45		1.89	115	2615	133	0.04	355
833		Bw	45	53		0.57	275	5895	160	0.04	764
871	Bass	A	0	8	Pasture	0.24	15	57	77	0.14	2
872		E	8	32		0.00	0	0	2	0.00	0
873		Bh	32	40		0.70	20	1246	116	0.01	213
874		Bw	40	52		0.02	112	2680	68	0.04	359
887	W	A	0	9	Native	0.00	13	106	125	0.07	22
888		E1	9	14		0.00	0	1	0	0.00	0
889		E2	14	36		0.00	0	0	14	0.00	2
890		Bh	36	50		0.00	12	937	16	0.01	152
891		Bw1	50	60		0.00	81	1502	17	0.05	180
892		Bw2	60	80		0.00	49	972	3	0.04	119
1007	Wilson	A	0	10	Intensive	31.00	2091	153	388	5.35	-3228
1008		E1	10	14		16.00	140	1	0	122.32	-140
1009		E2	14	22		10.10	37	1	0	32.26	-37
1010		Bh1	22	26		22.10	608	580	5	0.91	-510
1011		Bh2	26	38		3.30	65	2036	2	0.03	286
1012		Bw1	38	54		5.40	17	1463	0	0.01	234
1013		Bw2	54	60		5.90	31	629	0	0.04	77
1014	Wilson	A	0	11	Intensive	34.70	129	3	4	21.20	-183

Lab no	Dairy	Hori subdiv	Initial depth cm	Final depth cm	Component	WSP mg kg ⁻¹	Oxalate-P mg kg ⁻¹	Ox-Al mg kg ⁻¹	Ox-Fe mg kg ⁻¹	PSR-ox	SPSC-ox mg kg ⁻¹
1015		E1	11	16		13.80	170	7	15	10.12	-258
1016		E2	16	23		8.20	61	1	0	53.35	-61
1017		Bh1	23	26		81.60	1819	2043	52	0.77	-1484
1018		Bh2	26	38		27.50	420	1767	0	0.21	-116
1019		Bir	38	46		3.00	85	2680	0	0.03	377
1020		Bw	46	54		3.40	56	1500	0	0.03	202
1021	Wilson	A	0	18	Intensive	55.50	2615	343	675	3.41	-3805
1022		E	18	33		8.70	32	1	0	28.20	-32
1023		Bh	33	52		31.50	437	990	0	0.38	-266
1024		Bw1	52	60		17.60	214	604	0	0.31	-110
1025		Bw2	60	64		22.30	170	456	0	0.33	-92
1129	Lawrence	A	0	12	Intensive	33.00	3410	151	702	6.06	-5786
1130		AE	12	18		11.90	141	24	47	2.63	-202
1131		E	18	31		3.70	21	1	0	17.99	-20
1132		Bh1	31	38		4.20	211	453	514	0.26	-125
1133		Bh2	38	42		0.80	25	1158	353	0.02	232
1134		Bw	42	50		9.30	295	3510	198	0.07	335
1185	FlyingG	A	0	7	Holding	10.90	8900	219	912	11.76	-15067
1186		AE	7	15		6.70	159	0	3	96.65	-329
1187		E1	15	24		23.30	32	1	0	27.64	-32
1188		E2	24	46		24.30	17	1	0	14.54	-17
1189		Bh	46	50		12.80	567	1205	139	0.39	-368

Appendix Table 13 Water soluble P (WSP), iron-strip P, oxalate- extractable P, Fe and Al, and soil P storage capacity (SPSC) calculated using a threshold $PSR_{Ox} = 0.05$ for dairy manure-impacted soils.

Lab no	Location	WSP mg/kg	Iron strip P mg/kg	Oxalate P mg/kg	Oxalate Fe mg/kg	Oxalate Al mg/kg	SPSC mg/kg
429	WFR	0.6	76	73	57	1119	66
434	WFR	0.1	52	54	49	2545	147
508	WFR	0.2	73	34	130	4345	253
556	CM	0.7	77	88	263	3600	214
581	CM	0.0	59	54	138	2470	146
599	CM	0.1	85	53	188	3660	215
756	Dry Lake	7.7	141	134	176	983	61
761	Dry Lake	7.8	105	88	104	1310	78
766	Dry Lake	5.5	178	214	234	688	46
778	Dry Lake	0.0	48	31	222	1050	66
783	Dry Lake	1.6	98	68	42	590	35
805	Dry Lake	0.3	32	13	103	784	48
818	Dry Lake	10.2	396	422	58	2168	126
837	Dry Lake	4.6	151	135	143	2196	130
858	Larson	0.7	78	69	37	2570	149
873	Bass	1.4	43	27	138	1349	81
885	Willianson	0.0	68	76	60	2980	173
1010	Wilson	22.1	426	561	7	540	31
1123	Lawrence	13.0	118	142	267	659	45
1183	Flying G	30	926	n.a	n.a	n.a	n.a

n.a = not available

Appendix Table 14 Water soluble P (WSP), iron-strip P, oxalate- extractable P, Fe and Al, and soil P storage capacity (SPSC) calculated using a threshold $PSR_{Ox} = 0.05$ for beef manure-impacted soils.

Lab no	Location	WSP mg/kg	Iron strip P mg/kg	Oxalate P mg/kg	Oxalate Fe mg/kg	Oxalate Al mg/kg	SPSC mg/kg
5	TJ Ranch	0.10	0.03	82	82	2040	37
6	TJ Ranch	0.00	0.03	129	86	2560	21
11	TJ Ranch	10.97	8.88	233	180	1664	-132
12	TJ Ranch	0.22	0.64	109	44	2540	38
17	TJ Ranch	14.95	12.03	209	117	539	-175
18	TJ Ranch	1.31	1.61	116	58	1445	-31
23	TJ Ranch	30.35	32.82	288	150	678	-245
24	TJ Ranch	2.40	5.90	86	81	1927	27
25	TJ Ranch	0.00	1.12	98	40	2840	66
28	TJ Ranch	0.00	0.27	81	987	3095	125
29	TJ Ranch	0.00	0.00	62	1278	3875	195
34	TJ Ranch	1.60	8.28	246	491	1687	-136
35	TJ Ranch	0.15	4.36	113	306	1303	-30
38	TJ Ranch	8.02	14.34	198	469	450	-160
39	TJ Ranch	3.73	6.14	137	412	476	-98
45	TJ Ranch	0.78	2.22	68	122	1122	0
46	TJ Ranch	0.00	0.20	52	51	884	0
47	TJ Ranch	0.00	0.00	40	38	808	7
51	TJ Ranch	0.10	0.00	41	81	474	-11
52	TJ Ranch	0.00	0.00	32	50	472	-3
56	TJ Ranch	0.00	0.91	175	38	2830	-11
57	TJ Ranch	0.00	0.68	130	39	2216	-1
58	TJ Ranch	0.00	0.00	88	17	1497	-2
59	TJ Ranch	0.00	0.20	81	21	1147	-14
62	TJ Ranch	0.00	0.32	63	112	3855	162
63	TJ Ranch	0.00	0.00	50	114	5225	253
67	TJ Ranch	0.00	0.00	85	246	4790	197
68	TJ Ranch	0.00	0.00	64	271	5530	261
72	BRU	0.00	0.00	101	51	2605	50
73	BRU	0.00	0.08	85	39	2369	52

Lab no	Location	WSP mg/kg	Iron strip P mg/kg	Oxalate P mg/kg	Oxalate Fe mg/kg	Oxalate Al mg/kg	SPSC mg/kg
74	BRU	0.00	0.20	63	13	1394	17
79	BRU	0.00	0.20	52	8	878	-1
80	BRU	0.00	0.00	50	9	788	-4
81	BRU	0.00	0.00	25	0	620	10
82	BRU	0.00	0.20	18	0	675	20
86	BRU	0.48	1.63	109	49	2206	19
87	BRU	0.00	0.20	38	6	1605	54
88	BRU	0.00	0.00	37	2	1333	39
92	BRU	0.36	0.56	19	5	643	18
93	BRU	0.00	0.08	6	0	841	42
94	BRU	0.00	0.00	9	0	957	46
95	BRU	0.00	0.00	9	0	874	41
96	BRU	0.00	0.20	7	2	808	40
99	BRU	1.58	1.39	0	62	134	9
100	BRU	0.24	0.00	0	38	113	8
103	BRU	0.00	0.15	59	17	2039	59
104	BRU	0.00	0.00	59	3	1887	49
105	BRU	0.00	0.00	42	0	1408	38
106	BRU	0.00	0.00	18	0	756	25
185	Ona	0.00	0.05	85	8	2357	50
186	Ona	0.00	0.00	65	10	2370	71
187	Ona	0.12	3.33	49	13	1112	15
192	Ona	3.53	13.30	41	62	616	-4
193	Ona	1.58	8.73	21	28	575	13
194	Ona	0.61	6.38	21	7	533	10
198	Ona	7.91	19.40	90	79	501	-59
199	Ona	3.41	17.17	42	85	330	-20
204	Ona	9.25	12.48	105	336	552	-64
205	Ona	1.34	2.16	9	62	344	12
206	Ona	0.36	1.22	3	65	288	16

Appendix Table 15 Water soluble P (WSP), iron-strip P, oxalate- extractable P, Fe and Al, and soil P storage capacity (SPSC) calculated using a threshold $PSR_{Ox} = 0.05$ for inorganic fertilized soils.

Lab no	location	WSP mg/kg	Iron strip P mg/kg	Oxalate P mg/kg	Oxalate Fe mg/kg	Oxalate Al mg/kg	SPSC mg/kg
111	Immokalee	5.11	11.94	130	68	1341	-52
112	Immokalee	0.36	2.75	30	3	1777	72
113	Immokalee	1.82	9.64	92	0	1282	-19
114	Immokalee	3.64	19.73	177	0	1095	-114
115	Immokalee	2.92	21.77	235	11	1441	-152
120	Immokalee	9.74	20.75	151	580	368	-114
121	Immokalee	8.76	21.90	193	468	891	-129
122	Immokalee	8.15	21.52	264	228	1411	-176
123	Immokalee	8.03	31.23	352	132	1739	-248
129	Immokalee	7.18	12.20	104	345	375	-73
130	Immokalee	15.09	20.62	128	141	713	-83
131	Immokalee	16.80	27.40	207	35	1255	-134
132	Immokalee	10.95	20.62	134	7	1150	-68
133	Immokalee	4.87	9.64	53	0	732	-11
138	Immokalee	12.05	18.84	101	108	858	-49
139	Immokalee	9.13	17.05	71	46	1019	-11
140	Immokalee	1.70	3.51	1	23	785	45
141	Immokalee	0.24	0.70	8	35	697	33
142	Immokalee	0.00	0.58	0	11	644	37
147	Immokalee	6.57	15.01	124	58	834	-75
148	Immokalee	0.61	1.98	10	5	960	45
149	Immokalee	0.00	0.52	20	0	1106	43
154	Immokalee	9.01	16.35	151	120	517	-118

155	Immokalee	8.64	33.93	187	5	1123	-123
156	Immokalee	1.58	9.55	167	0	1975	-54
161	Immokalee	5.11	15.88	173	40	1105	-108
162	Immokalee	1.34	5.09	58	10	1238	13
163	Immokalee	0.00	0.16	0	0	758	44
164	Immokalee	0.00	0.09	14	0	826	34
