South Florida Water Management District

Public Workshop for the Everglades Agricultural Area's (EAA) landowners' application to renew the Master Permit to meet requirements to implement a comprehensive program of research, testing and implementation of Best Management Practices

Friday, July 31, 2020, 10:00 AM

AGENDA

1. SFWMD Introduction – Carmela Bedregal
2. EAA Environmental Protection District Master Research Permit – 2020 - 2025 Proposed Scope of Work – Samira Daroub, University of Florida
3. Discussion - Public Questions, Comments & Recommendations
4. Next Steps

For more information, you may contact: Carmela Bedregal, 561-682-2737, cbedrega@sfwmd.gov or go to the ePermitting homepage:

https://my.sfwmd.gov/ePermitting/MainPage.do
Search for Permit No 50-00001-E

Implementation and Verification of BMPs To Reduce Everglades Agricultural Area Farm P Loads: Evaluation of performance differences of EAA farm basins with similar BMPs

Scope of Work 2020-2025

Submitted to the

Everglades Agricultural Area- Environmental Protection District (EAA-EPD)

And The

South Florida Water Management District (SFWMD)

Revision 1: July 8, 2020

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List of Abbreviations:

BMP	=	Best Management Practice
EAA	=	Everglades Agricultural Area
EAA-EPD	=	Everglades Agricultural Area Environmental Protection District
EFA	=	Everglades Forever Act
EREC	=	Everglades Research and Education Center
M3	=	Mehlich III extraction of available P
NELAP	=	National Environmental Laboratory Accreditation Program
SFWMD	=	South Florida Water Management District
SOW	=	Scope of Work
SRP	=	Soluble Reactive phosphorus
TDP	=	Total Dissolved phosphorus
TP	=	Total Phosphorus
TSS	=	Total Suspended Solids
QA/QC	=	Quality Assurance/ Quality Control

Introduction:

The recently finished project on eight farms in the Everglades Agricultural Area (EAA) investigating "*Floating Aquatic Vegetation (FAV) Impact on Farm P Load"* has shown that each farm had site specific properties that influenced phosphorus (P) concentrations and loads. Although the impact of managing FAV was not clear on water quality on all farms in this project, the effect was evident on certain farms. Soil properties, historical land use/cropping patterns and drainage conditions have a variable impact on P loads.

The Everglades Agricultural Area (EAA) basin is located south and east of Lake Okeechobee and north and west of three Water Conservations Areas (WCAs) in south Florida. The EAA comprises an area of approximately 283,300 ha of organic soils (order: Histosols) planted mostly with sugarcane (*Saccharum* spp.), with the remaining arable land planted to winter vegetables, sod and rice (*Oryza sativa* L.). The mandatory Best Management Practices (BMP) program for reducing phosphorus (P) loads from the EAA farms in South Florida is implemented basin-wide since 1995 as required by the Everglades Forever Act (EFA) passed by the Florida State Legislature in 1994 and amended in 2003. The BMP program has been very successful in achieving greater than a 55% long-term average load reduction overall from the EAA basin exceeding the 25% mandated by the EFA (SFWMD, 2019).

Research Justification:

Although all EAA farms implement BMPs in a similar manner, there are differences in farm discharge P concentrations and/or loads. These differences may be related to differences in soil properties and historical land use/cropping patterns. Elucidating factors behind the varied performances of farms, can inform BMP management and implementation. This study aims to focus on factors that are still yet to be considered to elucidate differences between farms and farm basins that use similar BMPs but show significant differences in drainage P concentrations and/or load reductions.

Hypotheses:

1) Phosphorus in drainage water is impacted by the chemistry and properties of organic soils and land management. Phosphorus in drainage water is higher with
    a. Certain prior crops/ land uses,
    b. deeper soils; and
    c. soils with properties that do not promote high P retention (e.g. low Fe, Al or Ca; or high Mg/Ca ratios), due either to native properties or as a result of prior cropping activities.

Objectives:

1) Determine differences in performance in select farms in the EAA basins by evaluating the impact of soil chemistry and historical land use on P concentration and loads on these farms.
2) BMP Education and extension activities: use the information from this research to determine what BMPs work most effectively on farms in the EAA with similar soil, crop, and management conditions.

Review of Literature:

Soils in the EAA:

Soils in the EAA are classified as Histosols, suborder Saprists (Rice et al., 2005). The organic soils, formed from the decay and accumulation of sawgrass (*Cladium jamaicense* Crantz) and other lush vegetation, range from discontinuous shallow patches to accumulations of peat and muck 2.4 to 3 m thick near Lake Okeechobee and less deep farther away from the lake (Davis, 1994). Typically, these soils have an organic matter content ranging from 710 to 910 g kg^{-1} (Porter and Sanchez 1992) and overlie calcareous limestone deposits ranging in depth from about 0.3 to 1 m. In addition, the EAA Histosols have a higher pH compared with other Histosols (Snyder, 2005). Due to drainage and subsequent cropping in the EAA, organic matter decomposition has been exceeding production, resulting in soil subsidence and lowering of the surface elevations in these Histosols (Snyder, 2005; Aich et al., 2013). Subsidence has also produced increases in soil bulk density and ash content in the EAA (Reddy et al., 1998).

There are seven soil series in the EAA. Three of these soil series (Torri, Terra Ceia, and Okeechobee) have soils deeper than 51 inches. The Okeechobee soils have significant amounts of less decomposed organic matter, while the Torri and Terra Ceia soils differ in the amount of mineral content which is higher in the Torri (Rice et al., 2005). The remaining four soil series (Pahokee, Lauderhill, Dania, and Okeelanta) have soil profiles less than 51 inches deep. The Pahokee, Lauderhill, and Dania soils are all underlain by limestone but differ in the depth of the soil profile (Pahokee > Lauderhill > Dania), while the Okeelanta soils are underlaid and have significant amount of sandy materials (Rice et al., 2005).

Phosphorus Chemistry in EAA soils:

The P cycle in Histosols is complex due to high soil organic matter content (OM), organic forms of P, and Fe transformations as a result of a periodic wet and dry cycles (Porter and Sanchez, 1992). Flooded Everglades Histosols have shown that organic P is the primary means of P retention in those soils; however, Ca-phosphates also may play a significant role in P storage (Newman and Pietro, 2001). Phosphorus enrichment in surface soils of the EAA is due to a combination of peat oxidation (soil subsidence) and long-term P fertilizer application (Reddy et al. 2011). These conditions are conducive to having a greater proportion of TP as inorganic P (Reddy et al., 1998). The estimated legacy total P in surface soils of the EAA is 123,000 mt, which constitutes 30% of the estimated TP for the greater Everglades Ecosystem (Reddy et al., 2011).

Best Management Practices for growers in the EAA include soil testing and P application according to soil test. Sugarcane fertilization rate is relatively low ~ 40 kg ha^{-1} / year. This suggests internal P turnover, not P fertilization as the major source of P in the EAA (Reddy et al. 2011). Histosols in the EAA can mineralize 17–39 kg ha^{-1} of plant-available P annually (Diaz et al.,1993). Subsidence may have caused some EAA soils to have a higher mineral content and be composed of less easily degraded OM than earlier (Snyder, 2005). As EAA soils get shallower the underlying limestone rock interacts more with the soil, binding more P with Ca and Mg (Castillo and Wright, 2008; McCray et al., 2012).

Determining phosphorus sorption capacity and factors impacting sorption and desorption of P can give us important indications of the differences between EAA soils. Cogger and Duxbury (1984) found differences in P sorption of soil could be explained by measuring total or extractable Fe and Al contents. The Fe and Al oxide contents of Histosols tends to increase with ash content, which increases with age because of subsidence and mineralization (McCool, 1921). Oxalate-extractable Fe and Al have been shown to be reliable predictors of the P sorption capacity of peat soils in the Everglades (Reddy et al., 1998; Giesler et al., 2005). High levels of Fe, found in some EAA soils can increase P precipitation, especially under fluctuating water tables (Ivanoff et al., 1998).

From a few selected organic soils in the EAA, the Langmuir P sorption maximum (S_{max}) was not increased by a shallower depth of the soil profile (O horizon) or increased $CaCO_3$ content (Janardhanan and Daroub, 2010). The Langmuir S_{max} was significantly correlated with mineral content and negatively correlated with OM. Oxalate-extractable Fe (Fe_{ox})and Al (Al_{ox}) appear to play a role in affecting the P sorption of the selected EAA soils. The S_{max} values were found to correlate with Fe_{ox}, Al_{ox}, and pH but not with $CaCO_3$ content (Janardhanan and Daroub, 2010). The Freundlich sorption coefficient, which indicates P sorption capacity of the soils has been found to be lower in Pahokee soils compared to shallower soils, which indicates lower P sorption capacity in deeper EAA soils (Janardhanan and Daroub, 2010).

Richardson and Vaithiyanathan (1995) suggested that P sorption in Everglades' soils is regulated by $CaCO_3$. In the EAA, P binding with Ca is particularly important in shallow cultivated soils where fragments of the limestone bedrock are incorporated into the soil (Castillo and Wright, 2008). However, Cao et al (2007) found that Mg can inhibit formation of stable Ca-phosphate minerals. Organic P represents a significant pool of P in EAA soils (Reddy et al., 1998), and is higher in uncultivated soils in the EAA (Castillo and Wright, 2008). Organic P in soils can be grouped into easily decomposable (nucleic acids, phospholipids, and sugar phosphates), and slowly decomposable (inositol phosphates) (Reddy et al., 2011). Porter and Sanchez (1992) calculated a P sorption index for EAA soils that was well correlated with pH, total Ca, and free carbonates. Extractable Fe and Al were significant factors if they were a component of linear models that included pH or free carbonates (Porter and Sanchez, 1992).

In summary, examining mineral content of soils (oxides of Al and Fe, and Ca and Mg minerals) as well as P saturation, will inform the sorption and desorption characteristics of the soils and shed light on differences between BMP performance as related to soils differences.

Factors affecting P loads in the EAA:

a) Water Management:

There are several factors that impact discharge water concentration and P loads from EAA farms, and these can be very farm specific. These factors include water management practices, irrigation water quality, soil type and dynamics, and cropping systems (Daroub et al, 2011). Water management, for example drainage to rainfall ratios, canal head difference and drainage velocity in farm canals are all important factors that influence P load (Daroub et al., 2007; Grunwald et al., 2009; Lang et al., 2010; Daroub et al, 2019). Drainage velocity has been found to affect TP and TDP concentrations as well as TP load off fields from EAA farms (Coale et al., 1994, Stuck et al. (2001) Particulate P exported from EAA canals is originated mostly from floating macrophytes growing in EAA canals (Stuck et al., 2001). Drainage water from the EAA is high in Ca, additionally inorganic P has a positive correlation with Ca and Mg in Water Conservation Areas' soils, suggesting the importance of Ca and Mg in P dynamics in the Everglades ecosystem (Reddy et al., 1998). Rainfall affects P discharges from EAA soils. Izuno et al. (1991) found highest total phosphorus (TP) and total dissolved phosphorus (TDP) occurring during the peak rainfall months in the EAA.

Seepage in certain farms increases the necessity for higher drainage volumes and therefore higher loads. In addition, the effects of irrigation water on EAA farm P load have not been investigated fully. It was estimated that approximately one third of the P load discharged from Lake Okeechobee enters the EAA (Reddy et al., 2011). Daroub et al. (2007) reported that irrigation water P concentration and irrigation demand were important in the monthly farm P load multivariate regression prediction equations using data from 10 EAA farms. Irrigation water P concentration was found to have a direct relationship with increased P loads for the sugarcane farms. But no specific on farm research has been conducted to determine exact relationship between irrigation water quality and drainage P concentrations.

b) Cropping systems and nutrient management:

Due to fertilization, water management and soil composition differences, it would be expected that drainage water P concentration would differ by farm and soil type. McCray et al. (2012) evaluated P fractions in five soil locations within the EAA including Terra Ceia, Pahokee, and Dania soils. They found differences in the P fractions within these soils which were partly explained by differences in soil pH. Differences in Fe and Ca concentrations produce different P binding mechanisms in EAA soils. Castillo and Wright (2008) studied P fractions in fertilized EAA soils under pasture and sugarcane cultivation. The authors found that soils used for cultivation retain P by binding it with Ca, while pasture soils retain P by binding it with Fe and Al. Uncultivated EAA soils also present large quantities of P bound to stable organic materials (Ivanoff et al., 1998; Castillo and Wright, 2008). Cultivation reduces the proportion of macroagregates which store P preferentially in the organic P pool, thus cultivation of EAA soils increases P accumulation in inorganic P pools, which decreases the proportion of P fertilizer in plant available form and could increase required P fertilizer rates for sugarcane crops (Wright, 2009).

c) Soils and historical land use

In summary, the BMP program in the EAA has been very successful in the selection and implementation of comprehensive practices including nutrient management, water management, and sediment controls. But there are differences in performance on farms and subbasins that warrant further investigation into factors that have not been investigated in earlier research. This study will investigate the impact of soil properties and historical/current land use on water quality in EAA farms

Methods:

Objective 1: Determine differences in performance in select farms in the EAA basins by evaluating the impact of soil chemistry and historical land use on P concentration and loads on these farms.

Task 1: Selection of Paired Farm Basins:

1) The paired farms must be managed by the same farm operator. This will ensure operator-controlled practices will be consistent among pairs and eliminated as a variable.
2) The paired farms will be within the same SFWMD WOD Basin (S-5A, S-6, S-7 or S-8) to reduce variability in soil composition and characteristics among paired farms. No farms will be selected from Chapter 298 (F.S.) district. In the 298 Water Control District

(WCD), the farm operator and the water management practices are not the same, and some WCDs encompass cities.

3) The paired farms have a BMP plan typical of other farmed lands within the EAA so they will be representative.
4) The paired farms have the same BMP Plan at the start of the research period to reduce variability.
5) The paired farms must have statistically different Adjusted Area Unit P loads (AUAL) and/or concentration distributions when applying the Kolmogorov-Smirnov Test to annual data for the pairs. This test evaluates the differences in mean/median and variance of the distribution as well as the general shape of the distribution (skewed or symmetric).

Three research farm pairs are selected for participation in this research project. The pairs were selected from different SFWMD basins (S-5A, S6, and S-7) to increase the spatial representativeness (e.g. soil properties). The same operator manages the two individual basins in each pair, however, the three selected pairs have three different operators, so they are representative to the extent practicable in that regard. Basin pairs were statistically different when performing the Kolmogorov-Smirnov statistical test on the annual Adjusted Unit Area P Load (AUAL) and/or P concentration data from WY2010-2019 with a resulting p-value less than 0.1.

The following list of pairs meet the above criteria and the operators for each have agreed to participate in the study:

1. 50-018-01 and 50-018-03
2. 50-028-01 and 50-048-01
3. 50-061-07 and 50-061-12

Task 2: Soil properties and historical land use impact on P loads

This research conducted on selected EAA farms will evaluate the impact of soil properties and historical land use on drainage water P concentrations and P load export. The task will include the following steps:

1) Identifying the location of the 40-acre research plots within the research farms: Due to the variable size of the farm basins selected, a minimum of 15% of the total number of 40-acre plots per farm basin, or no less than five (5) 40-acre plots per farm basin, will be sampled to ensure the plots are representative (see Table 2). The 40-acre plots will be randomly selected to minimize potential bias. Selection of the plots will also be coordinated with farm personnel taking into account historical land use.

2) Interviewing the farm operators about past BMP practices, past and current cropping patterns and other relevant factors.
3) Instrumenting the farm (data loggers, canal level sensors, pump RPM sensors, auto-samplers, refrigerators, and tipping bucket rain gauges).
4) Initial soil Sampling from each of the selected farms will be performed at the start of the experiment period for characterization of soils. We will follow UF IFAS sampling recommendation of one composite sample for each 40-acre plot at each depth. We will sample 20-25 soil cores in a zig zag fashion to cover the 40-acre plot and homogenize into one composite sample per depth. The sampling will be done at two depths at 0-6 in and 6-12 in (0-15 and 15-30 cm). A total of 152 samples will be collected (Table 2).

   Soils will be analyzed for the following parameters:

   a. Soil depth
   b. pH, organic C and organic matter content
   c. Total P content, available P content (P extracted with water and with Mehlich3-P)
   d. Mineral content: Fe oxide content, Al oxide content and calcium and magnesium content.
   e. Soil depth will also be measured in a certain number of transects on each of the farms.
   f. We will conduct sorption isotherms to determine sorption maximum of P on selected samples from each farm. The sorption maximum will inform us on the sorption capacity for P of the different soils in these farms and if they vary with soil properties (Janardhanan and Daroub, 2010). Additionally, the Phosphorus Saturation Ratio (PSR) can be calculated for the sampled soils using the following calculation (Dari et al., 2018):

$$PSR = \frac{M3-P\ /\ 31}{(M3-Fe\ /\ 56)+(M3-Al\ /\ 27)} \ldots\ldots\ldots\ldots\ldots [1]$$

5) Annual soil sampling: Additional soil samples will be collected during years 2-4 and analyzed for available P content (P extracted with water and with Mehlich-3). Since selected plots may be planted at different times of the year. We propose to sample annually at one depth (0-6 in) within 6 -8 weeks of sugarcane planting and fertilization for plant cane and after 6-8 weeks of harvesting for the emerging ratoon sugarcane for a total of 76 samples per year. We will not sample fallow fields.
6) Drainage Water: Drainage water samples will be collected over a maximum of 24 hours of drainage pumping. Attempts will be made to collect samples from every drainage event for each of the six farms. The discharge water will be analyzed for total P (TP),

total dissolved P (TDP), particulate P (PP), soluble reactive P (SRP), dissolved organic P (DOP), total suspended solids (TSS), and pH. The TP, TDP, and SRP will be analyzed following the EPA method 365.1 (USEPA, 1993) using the ascorbic acid method (Murphy and Riley, 1962). The PP and TDP will be calculated based on the following equations:

$PP = TP - TDP$ ……………………….. [2]

$DOP = TDP - SRP$…………………….. [3]

Total Suspended Solids (TSS) will be determined gravimetrically on per liter basis (APHA, 1998) based on method 160.2 (USEPA, 2004).

7) Conducting sediment sampling: Canal Sediments will be characterized at the beginning and the end of the experimental period. Sediments will be analyzed for TP, ash content, organic matter, pH, bulk density and mineral content. Wet and dry bulk density and organic matter content by loss on ignition will be determined according to Soil Survey Laboratory Methods Manual (USDA-NRCS,2004). Sediment samples for total P will be ashed at 550ºC for four hours and ground before analysis according to the Andersen (1976) modification of EPA method 365.4 (USEPA, 2003). Sediment depth will be measures at three transects along the length of the canals twice: before start of field monitoring and at the end of field monitoring.
8) Quality Control/ Quality Assurance (QA/QC): The Water Resources Lab at EREC is a NELAP certified laboratory for Soluble Reactive P (SRP) and total P analysis (Lab # E76463)[1]. All the QA/QC is conducted according to EREC quality manual and standard operating procedures.

Statistical Analyses: We will be using multivariate regression analyses to determine variable factors measured that may be impacting P concentrations and loads for each farm basin. These may include drainage variables, soil depth and properties. The statistical analysis for the qualitative data collected on crop rotation/land use will follow categorical data analysis if appropriate. The most appropriate model will be selected based on the number of crops in the rotation and data variability. Further statistical analyses will be determined depending on the frequency of the data and consideration of how it could be meaningfully interpreted.

[1] https://nelac-institute.org/content/NELAP/index.php

Objective 2: BMP Education and Extension Services:

This objective will be met through the BMP workshop and seminar training program and outreach and extension publications. General BMP workshops and seminars will be conducted at least two times a year. These venues emphasize the importance of proper BMP implementation and introduce new and effective implementation techniques as they become available. We will continue our cooperation with UF IFAS extension office, Ft Lauderdale REC faculty as well as cooperating EAA growers assisting with the BMP training workshops offered. In addition, results of this research will be presented in detail in our BMP workshops.

Work Plan:

This work plan will remain in effect for a period of five years. Annual reports and a final report will be provided to EAA-EPD and upon review to the SFWMD according to the schedule listed in Table 2. The annual reports will include an update on research project progress, summary of collected data and initial analysis of data. Other deliverables are listed in Table 3. A final report will be issued after finishing and statistical analysis of field study.

Table 1: Farm Unit BMP Program Information Checklist

1)	**General farm information and description:**
a)	Basin ID
b)	Basin ID size and farm unit size
c)	Drainage and irrigation structures
d)	Structure pumps and capacities
e)	Current crops grown
f)	Historical farm P load parameters and statistics
2)	**BMPs of the farm unit – BMP implementation**
a)	BMPs as reported by Operator(s)
b)	BMPs identified on SFWMD permit
3)	**Canal information**
a)	Main canal sediment depth and type
b)	Cross-sectional area in main canal
c)	Aquatic weed management in main and secondary canals
d)	Canal cleaning program, canal cleaning techniques
4)	**Farming operations – general P supply: fertilizers, soil, irrigation water**
a)	Historical land use data
b)	P fertilization program: soil sampling, soil testing and recommendation
c)	Irrigation practices
d)	Field water table management

Table 2: Number of plots to be sampled for initial characterization.

Farm ID	Area (ac)	Estimated # 40-ac plots	# of plots to be sampled
1801	5857	146	22
1803	9063	227	34
2801	213	5	5
4801	1186	30	5
6107	319	8	5
6112	731	18	5
Total Number of plots to be sampled			76
Number of total samples at two depths = 76*2 = 152			

Table 3: Tentative timeline and Deliverables

Tasks and Activities	**Tentative timeline**
Approval of Scope of Work (SOW)	**Month 0**
Objective 1: On-farm BMP study: Determine factors leading to differences in performance of select farms in the S5 A and S6 basins	
• Purchasing and instrumenting the plots (data loggers, canal level sensors, pump RPM sensors, auto-samplers, refrigerators, and tipping bucket rain gauges.	**Months 1-3** Tentative: Oct – Dec, 2020
• Interviewing the farm operators about past BMP practices. • Collecting historical land use data • Initial soil Sampling and characterization analyses	**Months 1-24** Oct 1, 2020 to Sept. 2022
• Drainage Water sampling and monitoring of farms • Soil sampling once annually for available P testing	**Months 4-54** **(4.5Water Years)** WY2021 (partial): Jan 2021- April 30, 2021 WY2022 = May 1, 2021- April 30, 2022WY2023= May 1, 2022- April 30, 2023 WY2024= May 1, 2023- April 30, 2024 WY2025 = May 1, 2024- April 30, 2025
• Analyze data and issue a Final report (an extension of time for this task may be needed)	**Month 55- 60** May 1, 2025 to Sept 30, 2025
Objective 2: BMP outreach and extension	**Two workshops per year**
DELIVERABLES	**DATE**
Annual Reports An annual report will be submitted to the EAA-EPD with a copy to the SFWMD according to the listed schedule. The report will also include a list of BMPs workshops conducted during the year. A list of attendees will be sent separately annually to the district.	July 2021 – July 2024
Final Report A final report will be submitted to the SFWMD and EAA-EPD.	September 30, 2025

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