Best Management Practices in South Florida: A Success Story

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Abstract
A mandatory Best Management Practices (BMP) program was implemented on Everglades Agricultural Area (EAA) farms in 1995 as required by the Everglades Forever Act to reduce phosphorus (P) loads from drainage waters that enter the Everglades ecosystem. All farms in the EAA basin implement mandatory BMPs. Our objective was to determine long-term P load trends of the basin as well as ten individual farms after implementing BMPs for 7 to10 yr. Mann-Kendall trend analysis was used to determine the degree of change in water quality trends. Decreasing trends in P loads were observed in the outflow of the basin and two of its sub basins, the S5A and S8. A decreasing trend in P load was observed on sugarcane farms, while mixed crop farms showed either decreasing or insignificant trends. The insignificant trends are likely related to management practices of mixed crop systems. The EAA Basin P load reductions have consistently exceeded the 25% reduction required by law, indicating the success of the program. Differences in P load reduction exist between farms and sub-basins due to differences in cropping and management systems, and environmental factors.

Key Words
Best Management Practices (BMP), phosphorus (P), Everglades agricultural area (EAA), South Florida, Everglades Forever Act (EFA).

Introduction
The Everglades in south Florida is the largest contiguous body of organic soils in the continental United States (Stephens 1956) originally occupying approximately 778,000 ha (Jones 1942). A portion of the northern Everglades was drained at the beginning of the 20th century for agricultural and urban purposes, becoming what is known today as the Everglades Agricultural Area (EAA). The EAA basin is located south and east of Lake Okeechobee and north and west of Water Conservations Areas (WCA) in Florida, U.S. (Figure 1). The EAA comprises an area of approximately 283,300 ha and is planted predominantly to sugarcane (*Saccharum spp*.) with the remaining arable land planted to winter vegetables, sod and rice (*Oryza sativa* L.). The EAA basin has four sub-basins (S5A, S2/S6, S2/S7, and S3/S8).The soils of the EAA, classified as organic (soil order: Histosol), were formed under anaerobic conditions (Snyder and Davidson 1994). Drainage of organic soils has caused the loss of soil through decomposition leading to soil subsidence and variable soil depths. Soils are deepest in the S5A sub-basin and shallowest in the S3/S8 sub-basin.

To farm successfully, growers in the EAA actively drain their fields via an extensive array of canals, ditches, and large volume pumps. Excess water is pumped off farms into South Florida Water Management District (SFWMD) conveyance canals, from which it is pumped to Stormwater Treatment Areas (STA). After treatment, water is sent southward to the WCAs and the Everglades National Park (ENP). Concerns about the quality of drainage water leaving the basin and entering the ENP prompted the Florida legislature to adopt the Everglades Regulatory program, part of the Everglades Forever Act (EFA). The main objective of the program is to reduce P loads from the EAA basin by 25% or greater compared to a ten-year, pre-Best Management Practices (BMP) baseline period which spans from 1978 to 1988.

Best Management Practices plans are approved through the regulatory program and are implemented by individual permittees. The SFWMD ensures that BMP plans between different permittees are consistent and comparable. To accomplish this task, a system of BMP "equivalents" was developed by assigning points to BMPs. The BMPs are divided into three basic categories consisting of water management, nutrient management, and sediment controls. Farms differ in their water management BMPs, e.g., the amount of rainfall they detain before drainage pumping is initiated. Two BMPs commonly employed by most EAA growers are soil testing and banding of P fertilizer. A second BMP that varies between farm basins is the number and type of sediment control practices. The sediment control BMPs focus on both minimizing the transport of sediments off the farm and removing sediments from canals. The objective of this paper is to determine the long term trends in P concentrations and loads in the EAA after implementing BMPs.

Methods

The EAA Basin Monitoring

The EAA basin-level compliance determination is based on monitoring water volume and P concentrations at various inflow and outflow points defining the boundary of the sub-basins (S5A, S2/S6, S2/S7, and S3/S8) in any given water year (WY) (Figure 1). Conveyance canals serving those sub-basins are shown on map.

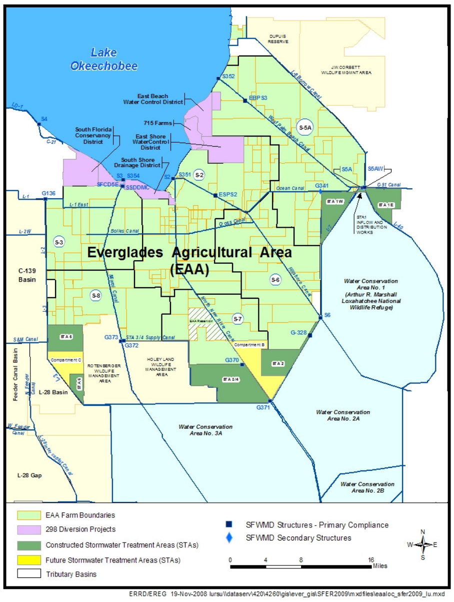

Figure 1. The Everglades Agricultural Area (EAA) basin and primary compliance water control structures used to assess load reduction performance. Water conservation areas (WCA) and storm treatment areas (STA) are also indicated. Map from SFWMD (2009).

On-Farm BMP Research Program

A comprehensive monitoring program to measure the efficacy of BMPs on water quality was initiated on ten farms in 1992 for a period ranging from 7 to 10 yr (Daroub *et al.* 2009). Monitoring was done for farm drainage volumes and P concentrations and other parameters. Six of the farm basins (00A, 02A, 03A, 04A, 08A, and 09A) had sugarcane as the major crop; the remaining four farms had mixed-cropping systems and were planted to sugarcane, sod, vegetables, and rice. For both data sets, trend analysis was conducted to determine trends over time in the basin, sub-basins and ten individual farms using seasonal Mann-Kendall analysis (Gilbert 1987; McBride 2005).

Results

Figure 2 shows the annual total P loads observed from EAA runoff for WY 1980 to WY 2008 in comparison to the target load for that year. Full implementation of BMPs started in WY 1996, and in only one instance, (WY 2007), did the observed annual total P load exceeds the target load resulting in an 18% reduction compared to baseline conditions. Overall, the current BMP program has been successful in achieving an approximate 50% long term average load reduction overall from the EAA basin and exceeding the 25% required by law (Figure 2). For Water year 2008, the total EAA outflow drainage was 76 207 ha-m with a flow weighted P concentration of 0.123 mg L^{-1} yielding a total P load of 94 metric tons. This translated into a 44% P load reduction compared to the pre-BMP period (SFWMD 2009).

Seasonal Kendall trend analysis of aggregated monthly metrics of flow, P concentration, and P load by sub-basin and the EAA basin from 1992-2002 was conducted by Daroub *et al.* (2009) (Table 1). The data, obtained from using the SFWMD DBHYDRO database, was aggregated into hydrological basins: S5A, S6/S7, and S8 sub-basins. The outflow drainage and runoff from the sub-basins and the EAA basin had significant decreasing trends except for the S8 sub-basin (Table 1). This indicated lower drainage volumes from the sub-basins with exception of S8, probably due to shallow soils in the S8 sub-basin with less capacity to hold water. The outflow P concentrations and loads from 1992-2002 had a decreasing trend in all sub-basins except for the S6/7 which had insignificant trends.

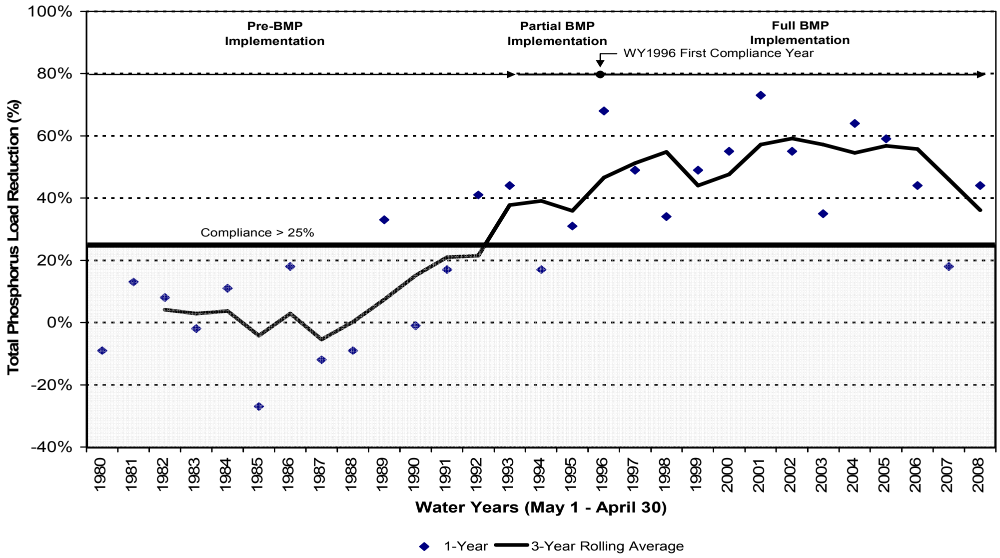

Figure 2. Annual basin-level total phosphorus load percent reduction from the Everglades Agricultural Area (Water Years 1980 – 2008). Figure from SFWMD (2009).

The decreasing trend in the S5A sub-basin is a combination of decreasing trends in P concentrations (highest negative Kendall K and z score) and drainage flow. The pronounced decreasing trends in concentration and loads indicate the success of the BMP program in the EAA. Phosphorus may have been used by the crops, retained in the soil due to adsorption (Porter and Sanchez 1992) and precipitation reactions, or retained in canal sediments (Stuck *et al.* 2001). Farm canals accumulate organic sediments rich in P from biological growth in the canals. Management practices for floating aquatic vegetation growth and dredging canal sediments control the transport of sediments and particulate P and may reduce the loads coming out of EAA farms (Stuck *et al*. 2001).

A decreasing trend was observed in monthly P unit area loads (UAL) for seven of the ten research farms but the trend was not significant for the remaining three farms (01A, 05A, and 08A) (Table 2). The farm with the highest decreasing UAL trend is 09A (highest negative Kendall K and z-score) and reflects a decrease in both drainage volume and P concentration on this farm. None of the ten farms showed increase in UAL trends. Out of the three farms that had insignificant trends in UAL, two had mixed cropping systems (01A and 05A). Farm 05A had low P, but a high volume of drainage water due to seepage problems. Farm 01A was strictly winter vegetable production, had relatively shallow soil depth, and claimed 12.7 mm rainfall detention. Vegetable production requires higher fertilizer rates and lower water tables compared to sugarcane

Table 1. Seasonal Mann-Kendall trend analysis of aggregated monthly metrics by sub-basin in the Everglades Agricultural Area from 1992-2002. Data from the South Florida Water Management District DBHYDRO database.

Basin†	Months	Kendall K	z-Score	z-Prob	Trend
Outflow Flow					
S5A	117	-772	-3.471	0.001	Decreasing
S6/7	117	-545	-2.448	0.014	Decreasing
S8	117	-330	-1.481	0.139	Insignificant
EAA	117	-599	-2.691	0.007	Decreasing
Outflow Concentration					
S5A	115	-1993	-4.815	0	Decreasing
S6/7	115	388	0.935	0.35	Insignificant
S8	117	-541	-2.43	0.015	Decreasing
EAA	103	-745	-2.12	0.034	Decreasing
Outflow Load					
S5A	117	-799	-3.592	0.001	Decreasing
S6/7	117	-340	-1.526	0.127	Insignificant
S8	117	-584	-2.624	0.009	Decreasing
EAA basin	117	-662	-2.975	0.003	Decreasing

Table 2. Trend analysis for monthly unit area P load (UAL) (kg P/ha) by farm location for the ten research farms in the Everglades Agricultural Area.

Site	Crops	Sub-basin	Months	Kendall K	z-Score	z-Prob	Trend
00A	Sugarcane	S5A	118	-587	-2.703	0.007	Decreasing
01A	Mixed	S6	87	-53	-0.192	0.848	Insignificant
02A	Sugarcane	S7	118	-427	-2.339	0.019	Decreasing
03A	Sugarcane	S7	118	-448	-2.001	0.045	Decreasing
04A	Sugarcane	S6	118	-560	-2.629	0.009	Decreasing
05A	Mixed	S8	90	-47	-0.314	0.754	Insignificant
06A/B	Mixed	S5A	118	-447	-1.999	0.046	Decreasing
07A/B	Mixed	S6	118	-453	-2.051	0.040	Decreasing
08A	Sugarcane	S6	110	272	1.439	0.150	Insignificant
09A	Sugarcane	S8	118	-710	-3.174	0.002	Decreasing

production. In addition, farm 01A practised summer flooding of fallow fields, which releases P from soils (Reddy 1983, Newman and Pietro 2001). The third farm that had insignificant farm P loading trend was the small sugarcane farm, 08A, which underwent several farm management changes and incorporated sweet corn as a rotational crop.

Conclusions

The BMP program implemented in the EAA farms basin-wide in 1995, as required by the EFA to reduce P loads in drainage water, is a success story. All farms in the EAA basin implement similar BMPs and basin wide P load reductions have exceeded the 25 percent reduction required by law. Trend analysis on P concentrations and loads out of the EAA basin and sub-basins showed a decreasing trend during the BMP period reflecting the success of BMPs. There are differences between farms in P load reductions probably due to cropping systems and other management and environmental factors.

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