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# Environmental and management factors that influence drainage water P loads from Everglades Agricultural Area farms of South Florida

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ABSTRACT

Environmental impacts from drainage water phosphorus (P) loads from Everglades Agricultural Area (EAA) farms in South Florida led to the adoption of best management practices (BMPs). The BMPs have been very successful at reducing EAA farm drainage water P loads. However, analytical investigation into how environmental and management factors affect farm P loading may allow additional improvements in BMP performance. Sixteen variables that included cropping systems, water management, and farm specific constants were hypothesized to affect farm P loads. Data collected from ten farms between 1992 and 2002 were analyzed using Spearman correlation, Principal Component Analysis, and stepwise multivariate regression. Monthly farm P load on a unit area basis (UAL) showed stronger correlation with drainage unit area volume (UAV) than with flow weighted total P concentration (FWTP). The UAL was negatively correlated with irrigation demand and positively correlated with irrigation P concentration, rainfall, preceding month's rain, drainage pumping to rainfall ratio, and percent fallow plus flooded field acreage (PFFA). A positive correlation between soil depth and FWTP was significant. Stepwise regression analysis identified canal water level management, percent sugarcane acreage, PFFA, and irrigation water P concentration as explanatory variables that impact farm P loads; PCA revealed similar results. The study suggests that lower pumping to rainfall ratio and increased sugarcane acreage lead to lower farm P loads; that irrigation water P concentration impacts farm P loads; and that shallower soils export less P than deeper soils.



## 1. Introduction

The Everglades Agricultural Area (EAA) in south Florida comprises 220,000 ha of cultivated Histosols with about 70% of the land farmed to sugarcane and lesser acreages to vegetables, sod, and rice (Rice et al., 2002b). The EAA is characterized by flat topography, shallow soils, seasonally elevated water tables, and an impermeable marl/limestone bedrock layer underlain by porous shellrock. During the dry season (November through May) and reduced rainfall periods, irrigation water is sourced from Lake Okeechobee to the north. During the wet season (June through October) and during wetter than normal dry seasons, excess precipitation must be pumped off farms to allow crop production. Farm drainage is achieved by pumping water from fields through a system of farm field ditches and farm canals via pump station(s) into conveyance canals that route the water south to Stormwater Treatment Areas (STAs, constructed wetlands) for phosphorus (P) removal via biofiltration and sequestration via sedimentation. Reduced P loads from the EAA to the STAs will enhance their outflow concentrations and increase their longevity (Pietro et al., 2009). Water from the STAs is sent to adjacent Water Conservation Areas (WCAs) where it replenishes groundwater and supplies water to the Everglades National Park to the south. The South Florida Water Management District (SFWMD) manages water quality, flows, and levels in the conveyance canals, STAs, and WCAs.

The EAA is dominated by Histosols (sub order: saprist) which are characterized by high soil organic matter content (>80%) that is highly decomposed (Snyder, 1994; Snyder and Davidson, 1994). The organic soils of the EAA differ mainly in the depth of the O horizon to the limestone bedrock (Rice et al., 2002a). Soils located close to the east and south shores of Lake Okeechobee (S5A and S6 sub-basins) are deeper, with depths greater than 1 m, while soils further south and east of the lake (S7 and S8 sub-basins) are shallower, i.e., less than 1 m (McCollum et al., 1978; Cox et al., 1988; Snyder, 2004). The EAA is located in a sub-tropical environment and has an average rainfall of 1.27 m year$^{-1}$. Distribution of the rainfall is, however, uneven with 66% occurring during the wet season, which lasts from June through October (Ali et al., 2000).

Phosphorus fertilization and soil organic matter oxidation (subsidence) are the two main sources of P exported from the EAA (Sanchez and Porter, 1994). Soil subsidence rates in the EAA have decreased from 3.00 cm year$^{-1}$ in the 1940s and 1950s (Stephens

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and Johnson, 1951) to 2.36 cm year$^{-1}$ in the 1970s (Shih et al., 1978) to less than 1.45 cm year$^{-1}$ in the 1990s (Shih et al., 1998). The decline in subsidence rate is thought to be due to higher water table management and decreases in the amount of readily oxidized organic matter (Shih et al., 1998). Non-point P loading (e.g. P from drainage of agricultural lands) is important because of its ecological impacts on freshwater and marine biota (House et al., 1995; Rabalais et al., 1996; Turner and Rabalais, 2003). Phosphorus is of particular concern because it has been implicated as the limiting nutrient in the eutrophication of lakes and wetlands in south Florida (Davis and Marshall, 1975; Federico et al., 1981). Phosphorus concentrations of more than 0.1 mg L$^{-1}$ are high for freshwater bodies and detrimental to aquatic ecosystems (Correll, 1998; Downing et al., 2001). Phosphorus may be transported through the canal systems into Everglades wetlands, causing deterioration of water quality and alterations to the natural ecosystem (Wright and Reddy, 2001; Childers et al., 2003). Drainage, irrigation, rainfall, cropping systems, and other management factors can increase the potential for P movement into downstream ecosystems (Sharpley et al., 1994). Concerns regarding the impact of elevated P concentration drainage waters from the EAA on the Everglades ecosystem resulted in a regulatory program that requires annual EAA basin P loads to be reduced by at least 25% relative to historic levels (Everglades Forever Act, 1994).

To reduce farm P loads, growers in the EAA are required to adopt BMPs which have assigned points by the SFWMD; each grower's set of BMPs must add up to at least 25 points (Whalen and Whalen, 1996; Sievers et al., 2003; Daroub et al., 2004). Growers in EAA adopt similar sets of BMPs which typically include banding of P fertilizers, application of P fertilizers according to calibrated soil tests, avoiding drainage pumping until a pre-determined amount of rainfall has fallen, and implementing particulate matter control measures to reduce sediment export.

Since basin-wide BMP program implementation in 1995, the EAA basin has achieved an average P load reduction of 50% relative to the baseline period from 1978 to 1988 (Van Horn et al., 2009). The reported variability in sub basin and farm P loads despite 100% participation and implementation of similar BMPs by growers in the EAA since 1995 suggests that there are other factors that may be affecting EAA farm P loads besides those targeted by current BMPs (SFWMD, 2008). Numerous factors have been suggested to affect drainage P loads of EAA farms (Izuno and Rice, 1999). Using Seasonal Mann-Kendall analysis to determine long-term water quality trends in EAA drainage waters, Daroub et al. (2009) reported a decreasing trend in P loads from the outflows of the basin and two of its sub basins between 1992 and 2006. Differences in P load trends were noted within farms and sub-basins and were thought to be due to impact of irrigation water source, cropping systems, and flooding practices. It is not known, however, how these environmental, crop management, and site specific variables impact the individual farm P loads. Our goal was to use multivariate regression analysis to reveal the main factors affecting farm P loads using data collected during a long-term water quality study of ten EAA farms.

We hypothesized that EAA farm drainage water P load is affected by many variables including farm geographical location, irrigation water quality, farm size, soil depth, land use practices, and farm water management. The specific objectives of the study were to (1) evaluate relationships between farm P load and cropping systems, water management, and farm specific variables; and (2) investigate

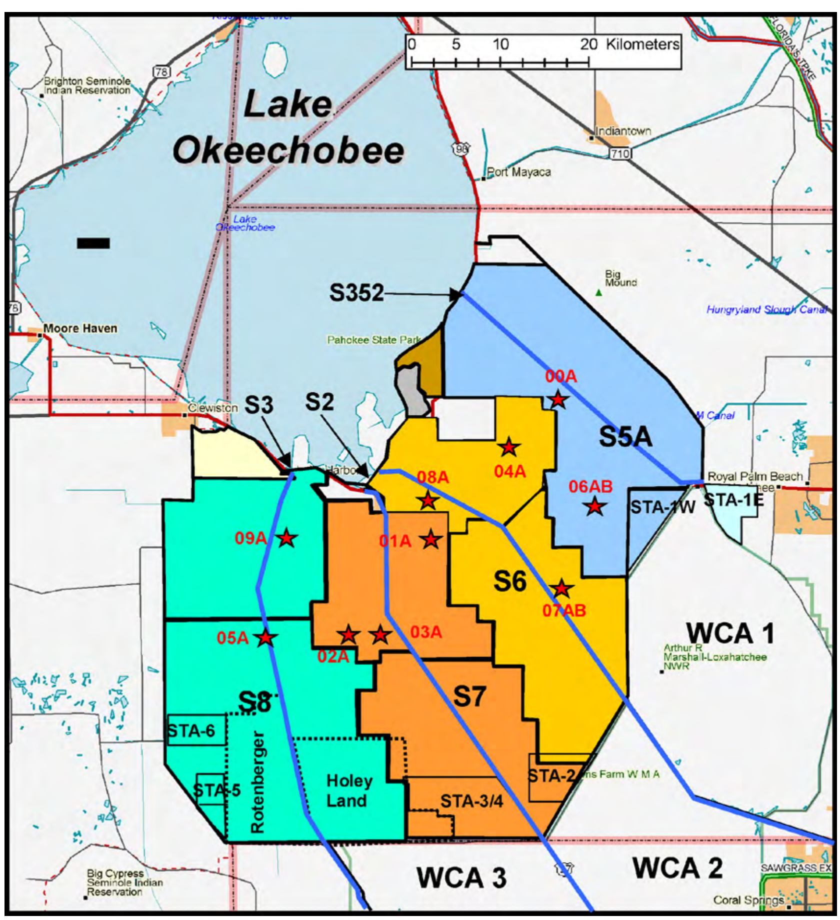


**Fig. 1.** Location of the ten farms (indicated by red stars), sub-basins (S5A, S6, S7, and S8), and irrigation inflow structures from Lake Okeechobee (S352, S2, S3) in the Everglades Agricultural Area in south Florida. Water Conservation Areas (WCAs) and Stormwater Treatment Areas (STAs) are also indicated on the map.