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Microbial Activity and Phosphorus Availability in A Subtropical Soil under Different Land Uses

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Abstract: Land use changes in the Everglades Agricultural Area (EAA) of south Florida may alter microbial activity and organic matter decomposition and ultimately influence the fate of P in soil. The objectives of this study were to determine effects of long-term cultivation and fertilization on microbial activity and P dynamics for contrasting land uses in the EAA. Soils (0-15 cm) under pasture for 100 yr and sugarcane (*Saccharum* sp.) for 50 yr were amended with P (0, 10, 50, 150 kg P ha^{-1}) and the response of soil and microbial activity measured. Long-term fertilization increased total P for sugarcane (1227 mg P kg^{-1}) relative to pasture (959 mg P kg^{-1}) and changed its distribution, with greater allocation to inorganic pools for sugarcane (53%) than pasture (19%). Farming practices decreased the proportion of applied P recovered in plant-available forms due to greater P retention in inorganic pools. Microbial biomass C was not an adequate indicator of land use change, but biomass N was higher for pasture (71 mg N kg^{-1}) than sugarcane (14 mg N kg^{-1}), while biomass P was higher for sugarcane (3.7 mg P kg^{-1}) than pasture (1.4 mg P kg^{-1}). Carbon mineralization rates were higher for pasture, but organic N and P mineralization were higher for sugarcane. Phosphorus did not appear to be limiting microbial activity for either land use. The microbial community was more efficient at organic N and P mineralization for sugarcane than pasture soil. Long-term fertilization and cultivation increased N and P turnover in soil, but mineralized nutrients did not accumulate in sugarcane due to uptake by crops and retention by soil minerals. Conversion of sugarcane to alternate land uses and subsequent elimination of crop nutrient uptake will increase nutrient accumulation in soil and may pose eutrophication hazards to proximal aquatic systems.

Key words: Everglades agricultural area · Heterotrophic microbial activity · Histosols · Land use · Organic matter decomposition

INTRODUCTION

The histosols in the Everglades ecosystem of south Florida developed under seasonally-flooded conditions as wet pasture or sawgrass prairies, which led to accumulation of organic matter. A major shift in land use occurred in the past century when the prairies south of Lake Okeechobee were drained for conversion to agriculture, mainly for the production of sugarcane and vegetable crops. This region, known as the EAA, is located between Lake Okeechobee and Everglades wetlands and is primarily comprised of organic soils subjected to cropping for approximately 100 years [1, 2]. The conversion of this historic seasonally-flooded prairie system to an annual cropping system altered organic matter and nutrient cycling and led to nutrient export from the EAA into adjacent wetlands [3]. An additional result of this land use change was subsidence, or oxidation of the soil organic matter, at rates currently approximating 1.5 cm yr^{-1} [2].

Soils of the EAA contain approximately 85% organic matter and developed under P-limited conditions [4]. Cropping systems in the EAA require high P inputs, with application rates of 15 to 150 kg P ha^{-1} for sugarcane and vegetable crops [5, 6]. Cultivation practices result in incorporation of bedrock $CaCO_3$ into soil which often increases P retention and decreases availability to crops [7]. A result of long-term fertilization and soil subsidence is the export of P from the EAA through the canal systems into Everglades wetlands, which has

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adversely impacted water quality and altered the natural ecosystem [8, 9]. Therefore, it is important to understand factors influencing P transformations and effects on organic matter decomposition to minimize nutrient export from soil upon onset of changes in land use.

To protect water quality and the unique Everglades ecosystem, considerable attention has been paid to the conversion of cultivated lands in the EAA to their historic use as pastures or seasonally-flooded prairies as part of Everglades restoration projects. However, impacts of long-term cropping on nutrient dynamics in these soils may necessitate extensive management or remediation before conversion to their original state since these pastures developed under nutrient-poor conditions.

Measurement of effects of P enrichment on organic matter decomposition may indicate the potential of these soils for nutrient regeneration, which may differ between current land uses. Soils with a large proportion of P in labile fractions indicate greater availability to plants, but also greater potential loss by leaching or runoff from fields. Microbial biomass and activity can indicate the oxidation potential of histosols [10] and illustrate differences between contrasting land uses so that impacts of future land use change on soil microbial processes and nutrient dynamics can be predicted. Effects of soil disturbance on microbial eco-physiological indicators were determined for wetland soils in the Everglades [11], but relationships between microbial activity and organic matter dynamics for land uses on drained Everglades histosols needs to be assessed. The objectives of this study were to determine effects of long-term fertilization and cultivation on microbial activity, organic matter decomposition and nutrient regeneration of a histosol in the EAA.

MATERIALS AND METHODS

Site Description: The EAA (280,000 ha) is characterized by subsiding histosols underlain by limestone bedrock. These organic soils developed under seasonal flooding and low nutrient status and supported vegetation adapted to these conditions, mainly sawgrass (*Cladium jamaicense* Crantz). Due to conversion of these native pastures to agricultural use by drainage, the dominant vegetation shifted to annual crops of winter vegetables and sugarcane (*Saccharum* sp.) in the early 1900s. In addition to altered vegetation patterns, nutrient inputs into the EAA significantly increased with the introduction of field crops. However, some fields in the EAA were not cropped but instead remained as pasture, although historic water management was altered. These pastures serve as reference sites for investigating effects of cropping systems on soil organic matter and nutrient dynamics.

The study sites are located in the northern EAA near Belle Glade, FL (26°39’ N, 80°38’ W). The long-term average annual temperature is 24°C and precipitation 133 cm at this location. The soils are a Dania muck (euic, hyperthermic, shallow Lithic Medisaprists) with depth to bedrock of 45 cm. Two land uses were utilized for this study; one managed for vegetable production since the early 1900s to the 1950s but predominantly for sugarcane since 1960 and another under perennial pasture and receiving no fertilization or tillage.

Typical annual fertilization for sugarcane is 40 kg P ha^{-1} [6]. Vegetable crops are grown periodically between sugarcane crops and utilize up to 150 kg P ha^{-1}. Nitrogen fertilizers are generally not applied since organic N mineralization supplies the required N. Fertilizers are applied using a one-time application prior to planting. Sugarcane is planted from August through January and harvested after burning from October through April. Sugarcane is vegetatively propagated by placing stalks into furrows 8 to 20 cm deep. Tillage operations include several diskings (to 15 cm depth) after crop harvest and subsoil chiseling (to 30 cm depth) to improve drainage [12]. Frequent in-season time cultivations (to 4 cm depth) are done for weed control [13].

Soil Sampling and Analysis: Triplicate soil (0-15 cm) cores (5 cm diam.) were taken in January 2006 at four sites for each land use and composited to yield four field replicates for each land use. Soil was sampled just prior to sugarcane harvest, air-dried and passed through a 0.5 mm sieve before analysis. Soil (100 g) was amended with P at rates of 0, 10, 50 and 150 kg P ha^{-1}, which encompasses P fertilizer rates typically used for sugarcane and vegetable crops in the EAA. These rates corresponded to 0, 15, 75 and 225 mg P kg^{-1} soil. The P source was a mixture of Na_2HPO_4 and NaH_2PO_4 in a 1 mg mL^{-1} solution adjusted to the pH of the respective soils. Soil samples were then adjusted to 50% of water-holding capacity, thoroughly mixed and incubated under 21% O_2 at 25°C for 21 d. Subsamples were taken at 1, 7, 14 and 21 d for nutrient analysis.

Soils were analyzed for bulk density [14], water-holding capacity [15] and pH using a 1:3 soil:water after equilibration for 30 min. Total organic C was determined by loss-on-ignition at 550°C for 4 hr and conversion to organic C using a factor of 0.51 [16]. Total N was measured by Kjeldahl digestion followed by NH_4 analysis [17]. Extractable NH_4 and NO_3 were determined by extraction (2 *M* KCl) and colorimetric analysis [17,11]. Organic soils of the EAA utilize a water extract for determination of plant-available P [18]. Approximately 1 g of soil was extracted with 25 mL water for 1 hr and analyzed for plant-available P (labile P). Total P was measured by colorimetric analysis (U.S. EPA method 365.4) after Kjeldahl digestion [17]. Total inorganic P was measured after extraction of 1 g soil with 25 mL of 1.0 *M* Hcl for 1 hr. Both total inorganic and water-extractable P were analyzed by the ascorbic acid-molybdenum blue method [19] using an AQ2+ discrete analyzer (Seal Analytical Inc., Mequon, WI).

Microbial biomass C, biomass N (MBN) and biomass P (MBP) were assessed by chloroform fumigation-incubation [11, 20]. Approximately 5 g of soil (at 50% of water-holding capacity) was fumigated for 1 d, evacuated and incubated with 10 mL of 1 *M* KOH at 25°C for 10 d. Carbon dioxide production was quantified after titration of KOH with 1 *M* HCl. Soil MBC was calculated by dividing the mg CO_2-C kg^{-1} of fumigated soil by an efficiency factor of 0.41. Non-fumigated soils (7 g) taken prior to incubation and 7 g of chloroform-fumigated soil were shaken for 1 hr with 25 mL of 2.0 *M* KCl (for MBN) or 25 mL of 0.5 *M* $NaHCO_3$ (for MBP) and filtered. Extracts were analyzed for NH_4-N or P as previously described. Microbial biomass N and P were determined by the difference in NH_4-N and P concentrations between fumigated and non-fumigated samples, divided by an efficiency factor of 0.41 for N, but with no correction for MBP.

For mineralizable C determination, 100 g of soil (at 50% water-holding capacity) were incubated with vials containing 10 mL of 1 *M* KOH at 25°C for 21 d. At 21 d, vials were removed and absorbed CO_2-C quantified by titration as previously described. Mineralizable C was calculated from the quantity of CO_2-C produced during 21 d. For mineralizable N and P, 1 g of incubated and non-incubated soil were extracted with 25 mL of 2 *M* KCl (for mineralized N) and 25 mL of 1.0 *M* HCl (for mineralized P) for 1 hr, filtered and extracts analyzed for NH_4-N and P as previously described. Mineralizable N and P were calculated as the difference between NH_4+NO_3-N or P mineralized during the 21 d incubation and initial concentrations.

A randomized experimental design was utilized with two land uses, four P application rates and four field replications [21]. A two-way ANOVA model was used to determine main effects of land use (sugarcane and pasture soil) and P application rate (0, 10, 50 and 150 kg P ha^{-1}). A one-way ANOVA model was used to determine differences between individual treatments. Significant treatment comparisons were based on Fisher's LSD at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Soil Characterization: Cultivation significantly influenced soil physical and chemical properties, as well as P distribution in organic and inorganic fractions. Soil pH was higher for sugarcane than pasture soils (Table 1) due to inclusion of $CaCO_3$ into soil by tillage and the upward flux of dissolved carbonates followed by deposition on the surface after evaporation [22]. The water-holding capacity decreased with cultivation, likely resulting from destruction of soil structure by tillage. The total C and N content did not differ between land uses, but extractable N was higher for pasture soil. Nitrogen fertilizers are seldom applied for sugarcane production in the EAA, so accumulated inorganic N reflects organic N mineralization. The C:N was similar between land uses, but cultivation decreased the C:P compared to pasture.

Soil Inorganic and Organic P Concentrations: Soil total P was higher for sugarcane (Table 1) as a result of past P fertilization, averaging approximately 40 kg P ha^{-1} yr^{-1} for the past 50 yr. Long-term fertilization significantly increased soil P levels for sugarcane, but P fertilizer inputs were to a large degree offset by P removal in harvested biomass, hence the 268 mg P kg^{-1} difference in total P between pasture and sugarcane after 50 yr of cropping to sugarcane.

Table 1: Physical properties and nutrient concentrations of sugarcane and pasture soils in the Everglades Agricultural Area. Significant differences between land uses were noted by * (P<0.05) and not significant (NS)

Soil property	Units	Sugarcane	Pasture	$P < 0.05$
pH		6.8	5.3	*
Water-holding capacity	%	142.0	196.0	*
Bulk density	g cm^{-3}	0.41	0.44	NS
Total organic C	g kg^{-1}	440.0	435.0	NS
Total N	g kg^{-1}	32.0	30.0	NS
C/N		14.0	15.0	NS
Extractable NH_4-N	mg kg^{-1}	158.0	246.0	*
Extractable NO_3-N	mg kg^{-1}	54.0	162.0	*
Extractable P	mg kg^{-1}	1.3	3.9	*
Total P	mg kg^{-1}	1227.0	959.0	*
Total inorganic P	mg kg^{-1}	650.0	178.0	*
C/P		360.0	460.0	*

The P distribution in soil varied between land uses, with sugarcane having more P in inorganic pools while pasture had more in organic pools. Soils under cultivation had 53% of the total P in inorganic fractions, but pasture soils only 19%, with the differences between land uses attributed to P fertilizer addition to sugarcane [22] as well as potential differences in organic P mineralization between land uses [13]. Total inorganic P was 265% higher for sugarcane than pasture soil, but organic P was higher for pasture (781 mg P kg^{-1}) than sugarcane (577 mg P kg^{-1}). Other studies in histosols have shown that natural areas had a greater proportion of total P in organic forms, while soils that changed land use or were disturbed had more P in inorganic pools [23]. The greater P retention in organic fractions for pasture soils suggests that P cycling was dependent on the decomposition of organic matter, which is primarily affected by water management and soil O_2 status [3]. Future land use changes may include conversion of drained, cultivated soils and pastures to historic seasonally-flooded systems. Flooding of the pasture soils would have the effect of organic matter accretion [12], thereby increasing P retention and stabilizing P held in organic pools. Thus, soils that have a higher proportion of their total P in organic forms, such as pastures, would be less prone to release P and enrich proximal aquatic systems. Flooding has the opposite effect for mineral-associated P [22] since dissolution of P in inorganic pools occurs after flooding [23]. Thus, sugarcane soils would likely be sources of P if converted to seasonally-flooded prairies, which may cause harmful effects to the Everglades ecosystem including eutrophication of surface water and alteration of the structure and function of vegetation and microbial communities [8, 9].

Changes in Plant-available P Concentrations after Fertilizer Application: Plant-available P concentrations in soil were measured 1, 7, 14 and 21 d after P application and levels increased with increasing application rates for all sampling times and both land uses (Table 2). However, concentrations in unamended soil increased proportionally to P-amended soil due to organic P mineralization. At all sampling times, plant-available P levels remained higher for pasture than sugarcane. Lower P levels for sugarcane were related to adsorption and precipitation by mineral components [3]. Cultivated soils have higher Ca levels resulting from incorporation of bedrock limestone into soils by tillage [7], which increased soil pH and fostered sequestration of plant-available P into stable Ca-bound P pools [24]. This greater P retention for sugarcane was reflected in the greater proportion of P in inorganic pools compared to pasture soils (Table 1). The pasture soil had higher total Fe levels [24], which can sequester P as ferric phosphate and decrease its availability. However, most of the P in pasture soil was in the organic fraction (81%), thus its availability in this soil was more dependent on organic P mineralization.

Table 2: Plant-available P concentrations in soil 1, 7, 14 and 21 d after fertilizer application to soil under sugarcane and pasture

Land use	P rate kg P ha^{-1}	Days after application 1	7	14	21	$LSD_{0.05}$
Sugarcane	0	0.3	1.1	1.7	3.6	1.8
	10	0.6	1.5	2.0	4.2	2.1
	50	1.5	2.5	3.1	7.0	2.1
	150	4.8	5.5	10.2	14.0	4.9
Pasture	0	0.7	3.3	7.5	12.2	4.2
	10	1.0	4.2	5.9	5.8	3.4
	50	2.6	5.5	2.9	10.4	3.7
	150	8.5	8.0	8.8	14.3	5.9
$LSD_{0.05}$		3.6	1.6	5.6	5.4	

At the highest application rate, plant-available P was higher for pasture than sugarcane at 1 and 7 d, but from 1 to 21 d for sugarcane (Table 2). Thus, pasture soil exhibited an 11.5 mg kg^{-1} increase in plant-available P from 0 to 21 d. In contrast, plant-available P only increased 3.3 mg kg^{-1} for sugarcane. Lower plant-available P over time reflects greater P retention in soil, thus, organic P mineralized may be rapidly sequestered in unavailable forms for sugarcane. Greater persistence of P in pastures suggested less P retention by precipitation and adsorption reactions.

The percentage of applied P recovered in plant-available pools 1 d after fertilizer application averaged 1.7 and 2.0% for sugarcane and pasture soil. Regression equations showing the quantity of plant-available P produced by 1 d per P application rate were different between pasture than sugarcane (Fig. 1). Farming practices decreased the proportion of applied P recovered in plant-available forms at all application rates. These results have important implications for continuation of cultivation practices, or conversion of pasture to crop production, as cultivation decreased fertilizer P recovery in plant-available forms, necessitating greater fertilizer P requirements with increased farming intensity.

A current land use trend exists in south Florida, as efforts are underway to convert agricultural lands back into their prior use as wetlands and seasonally-flooded pastures. However, long-term effects of fertilization

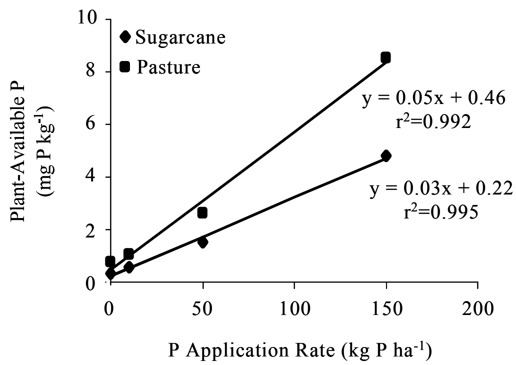

Fig. 1: Regression of the fertilizer application rate to plant-available P concentrations for pasture and cultivated soil cropped to sugarcane

and cropping practices include altered nutrient dynamics which may impede future land use changes. The P enrichment of soils under sugarcane and sequestration of P in inorganic fractions, may lead to regeneration of P from soil after conversion to wetlands and may cause harmful effects to the Everglades ecosystem, such as eutrophication of surface water and alteration of the structure and function of vegetation and microbial communities [8, 9]. The primary mechanism is based on redox reactions and decreases in soil O_2 levels, which cause dissolution of Fe-Al bound P [25] and Ca-bound P [26]. In comparison, pasture soils only have a small proportion of their total P in inorganic form, thus conversion of these soils to wetlands may not increase P regeneration from soil.

Microbial Biomass: Microbial biomass showed variable effects between land uses (Table 3). Whereas biomass N was greater for pasture, biomass P was greater for sugarcane. However, biomass C did not differ between land uses. Microbial biomass C often does not reflect oxidation potential of Everglades histosols [10]. Since these organic soils developed under P-limited conditions [22], long-term fertilization of sugarcane increased the soil P levels and microbial biomass P. In contrast, higher biomass N for pasture resulted from higher inorganic N levels than sugarcane. The removal of the P limitation to microorganisms by fertilization could have induced a N limitation for sugarcane. In fact, histosols of Everglades wetlands have shown N limitation to heterotrophic microorganisms after long-term exposure to P enrichment [10, 27].

The status of microbial biomass pools was reflected by the inorganic nutrient content of soils and land use. Phosphorus enrichment of historically nutrient-poor

Table 3: Microbial biomass and organic P mineralization rates for sugarcane and pasture soil. Significant differences between land uses were noted by * ($P<0.05$) and not significant (NS)

Microbial Activity	Units	Sugarcane	Pasture	$P<0.05$
Microbial biomass C	mg C kg^{-1}	985.0	823.0	NS
Microbial biomass N	mg N kg^{-1}	14.0	71.0	*
Microbial biomass P	mg P kg^{-1}	3.7	1.4	*
Mineralized P @ 21 d	mg P kg^{-1} d^{-1}	5.7	4.1	*

Table 4: Rates of organic C and N mineralization for and pasture soils receiving different P application rates. Values for each parameter followed by the same letter were not significantly different at $P<0.05$

			P Application Rate (kg P ha^{-1})			
Microbial Activity	Unit	Land use	0	10	50	150
Mineralized C @ 21 d	mg CO_2-C kg^{-1} d^{-1}	Sugarcane	65b	66b	64b	67b
		Pasture	84a	85a	83a	83a
Mineralized N @ 21 d	mg N kg^{-1} d^{-1}	Sugarcane	12a	13a	14a	14a
		Pasture	8b	7b	7b	8b

soils enhanced microbial biomass, which increased mineralized P. However, the lack of N fertilization for sugarcane and crop removal of mineralized N via sugarcane harvest resulted in lower MBN than pasture soil. Inorganic N produced from organic N mineralization was likely rapidly taken up by sugarcane, resulting in lower inorganic N accumulation in sugarcane and less opportunity for sequestration by microbial biomass. Thus, microbial biomass may indicate the nutrient status of these land uses and potential for nutrient regeneration from organic matter.

Organic Matter Decomposition and Nutrient Regeneration: Soil C mineralization rates reflected the response of soil microbial communities to nutrient enrichment and gauged the longer-term effects on organic matter decomposition. The P application rate did not increase mineralized C for either land use (Table 4). Mineralized C was significantly higher for pasture soil at all P rates, implying greater potential organic matter turnover rates for pasture than sugarcane. These results were in contrast to an earlier study that showed greater C metabolism for sugarcane than soils under perennial turfgrass [28] or non-tilled soils [10]. However, greater mineralized C for sugarcane may not occur throughout the entire year. The highest rates of C metabolism in these histosols typically occur soon after tillage and soil disruption [10]. A wider seasonal variation in oxidation potential exists after tillage [28] that wanes toward the end of harvest in January [10]. Soils under sugarcane in this study were not tilled or fertilized for 6 months prior to sampling, thus enhancement of organic matter decomposition by cultivation practices was not apparent at the later sampling time of this study, when easily decomposable C would already have been exhausted [28]. In this study, microbial metabolism may have been limited by labile organic C more in sugarcane than pasture soil, thus higher mineralized C for pasture soil. These results were supported by other studies showing that addition of organic C substrates enhanced microbial activity and decomposition for soils cropped to sugarcane [10].

Seasonal fluctuations in organic matter cycling and nutrient dynamics for these histosols [28] may explain contradictory relationships between microbial biomass and C, N and P mineralization rates in this study. The perennial pasture system experienced minimal soil disturbance and the presence of actively-growing vegetation the entire year in this subtropical environment. However, the cultivated soils under sugarcane experienced greater fluctuation in nutrient inputs (fertilization) and exports (harvest), which may change soil chemical and microbial properties relative to pastures. At the sampling date of this study, the actively-growing sugarcane sequestered inorganic N resulting in lower N concentrations relative to pastures. Thus, the higher mineralized N for sugarcane than pastures (Table 4) did not result in greater accumulation of inorganic N in soil because mineralized N was likely rapidly taken up by sugarcane. For sugarcane, the majority of nutrient fertilizer inputs were removed in harvested biomass, thus differences in soil N and P concentrations between land uses represented excess nutrient application (for P), or nutrient deficiencies where nutrient removal exceeded fertilizer input (for N). Conversion of these cultivated soils to alternate land uses and elimination of the sugarcane nutrient uptake component may result in nutrient accumulation in these soils, which may pose eutrophication hazards to proximal aquatic systems upon change in land use.

The mineralized P was 39% higher for sugarcane than pasture soil (Table 3). Similar results observed by Morris *et al*. [10] showed that nutrient regeneration was greatest for sugarcane. Heterotrophic microorganisms were more efficient in sugarcane, as the rate of P mineralization, expressed as a function of the organic P content, was almost twice as high for sugarcane (9.9 mg P g organic P^{-1} d^{-1}) than pasture soil (5.2 mg P g organic P^{-1} d^{-1}). Microorganisms in sugarcane were significantly more efficient at N mineralization (857 mg N g MBN^{-1} d^{-1}) than pasture soil (113 mg N g MBN^{-1} d^{-1}). Likewise, the mineralized P/MBP was significantly higher for sugarcane (2929 mg P g MBP^{-1} d^{-1}) than pasture soil (1540 mg P g MBP^{-1} d^{-1}). However, the mineralized C/MBC did not differ between land uses and averaged 84 mg CO_2-C g MBC^{-1} d^{-1}.

CONCLUSIONS

Microbial biomass and activity measurements reflected differences in nutrient distribution between land uses. Thus, microbial biomass may indicate the nutrient status of these land uses and potential for nutrient regeneration from organic matter. Lower soil N concentrations and MBN of soils under sugarcane may have limited the potential for organic matter decomposition, resulting in lower mineralized C than pasture soils, even though P concentrations and MBP were higher for sugarcane soils. Measurement of organic P mineralization was confounded by P precipitation or adsorption to soil minerals, which influenced the persistence of fertilizer-applied or mineralized P for different land uses. The incorporation of $CaCO_3$ into soils by conventional tillage practices enhanced P sequestration in inorganic pools. Continuation of conventional crop management practices will further increase soil pH and Ca levels, leading to greater retention of P fertilizer in inorganic pools and a decrease in the proportion of P fertilizer in plant-available pools, necessitating higher fertilization rates in the future to maintain plant-available P at concentrations sufficient for crop production. Accumulation of P in inorganic pools of sugarcane may be unstable and ultimately result in dissolution upon onset of flooded conditions that occur during high rainfall events or future land use changes. However, since most of the P in pasture soils was in organic pools, flooding of pasture would decrease organic matter decomposition and increase the stability of organic P. Higher organic N and P turnover in sugarcane, but lack of inorganic N and P accumulation, indicate the importance of sugarcane in sequestering inorganic nutrients in these soils. However, removal of the sugarcane nutrient uptake component and subsequent nutrient regeneration in sugarcane soils upon change in land use may pose potential eutrophication hazards of proximal aquatic systems. Thus, the conversion of current land uses to seasonally-flooded pastures may have a more dramatic effect on P regeneration from sugarcane than pasture soils.

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