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Assessment of the phosphorus index for Louisiana

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ASSESSMENT OF THE PHOSPHORUS INDEX FOR LOUISIANA

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Plant, Environmental, and Soil Sciences

By
William Lucas Felicien
BS, Louisiana State University, 2004
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ABSTRACT

A phosphorus index is a semi-quantitative to qualitative model for assessing the potential for loss of soil and fertilizer phosphorus (P) to ground and surface water, therefore, eutrophication risk. The concept of a P Index is recent and popular, with most states having developed a P Index that is either a simplification or extension the original 1993 concept. The Louisiana P Index assigns ratings for P loss potential depending on soil properties, topography and land use. These ratings are intended to guide P fertilizer (including animal waste materials) application so as to preserve water quality. This project has examined measured loss of P in runoff and compared it to P loss ratings calculated using the Louisiana P Index. This was done using small runoff plots and simulated rainfall, consistent with work done elsewhere in the country. Since loss of P from soils enriched in P from years of application of animal waste was the impetus for development of the concept, Louisiana sites included in this study were from the poultry-producing region of the state. Results showed poor correlation between P in runoff and P loss ratings, which was somewhat improved by omitting high P, low P loss ratings data for a grazed pasture. Further insight into P loading into runoff was gained by examining runoff and P concentrations as functions of time. Runoff could often be well-described using the Green-Ampt model for infiltration. For the forest soil plots examined, however, considerably higher P often appeared in runoff than expected based on soil P desorption, and the source of this P may have been the forest litter layer. Continued difficulties in predicting P loss to runoff based on more mechanistic approaches support use the simpler P Index. However, a better understanding of the

mechanisms by which soil P is made subject to runoff loss should lead to improvements in the P Index and better practices for controlling the loss of P to surface water.

INTRODUCTION AND LITERATURE REVIEW

Long-term application of phosphorus-containing fertilizers to crop land tends to build-up the level of soil phosphorus (P). In the Coastal Plain of North Louisiana, poultry litter – an organic matter- and P-rich waste-- has been applied to pastures as a fertilizer for as long as 50 years in some places. These poultry litter amendments have greatly increased P levels far above native levels (Robinson et al., 1994). Although poultry litter is a valuable source of P and other plant nutrients, among the problems that can arise form heavy applications of poultry litter are the leaching and runoff of nutrients which can lead to the degradation of ground and surface waters (Kingery et al., 1993; Parry, 1998). The accumulation of P in soil from the unbalanced use of organic and inorganic P fertilizers has raised concerns over the agricultural contribution to eutrophication of inland waters. Advanced eutrophication, characterized by increased growth of undesirable algae and aquatic vegetation, degrades water quality and impairs its use for fishing, recreation, and consumption. Oxygen is depleted by microbial decomposition and the ecosystem is disrupted (Whithers and Sharpley, 1995).

In North Louisiana, poultry litter is used to re-vitalize the nutrient depleted and highly weathered, Coastal Plain soils. It is also applied to dispose of waste. Where poultry farming is the leading industry, disposal of poultry litter waste poses a problem because there is little open area since most of North Louisiana is forested. Reddy et al. (1980) state that when soils are utilized for disposal purposes, P application rates of animal wastes are considerably higher than crop uptake, resulting in greater accumulation of P in the soil. Accumulation of P in soil increases with poultry litter applications and the potential for nutrient overloading in surface water is aggravated. Although many soils have high capacities to sorb and retain P, when the P sorption capacity of a soil is approached, the potential for off-site transport of P in surface runoff (Sharpley et al., 1994) and through vertical (Heckrath et al., 1995) or lateral (Walthall and Nolfe, 1998) flow all greatly increase. Once soil P levels become excessive, the potential for P loss in runoff and drainage water outweighs benefits from further applications (Whithers and Sharpley, 1995). Research addressing eutrophication threat caused by nutrient overloading with P and nitrogen from poultry litter includes Sharpley (1980), Sharpley et al. (1981), Ahuja et al. (1982), Alberts and Spomers (1985) and Kingery et al. (1994).

Newly adopted regulations for confined animal feeding operations (CAFOs), require development of a nutrient management plan. One component of the plan is assessment of potential losses of P as calculated using a P index. The concept of a P index was first proposed by (Lemunyon and Gilbert, 1993). This archetype has been adapted by most states to meet local conditions and needs (for state-by-state P indices, see Weld, 2003). Table 1 gives the Louisiana P index (adapted from NRCS, 2003).

Although a P index incorporates many of the various conditions that affect P mobility in the soil environment, it is not a predictive model. Attempts to base predictions of P loss on soil P level alone, or relative to P sorption capacity, have generally failed. For example, several studies have examined the use of routine soil P tests to predict P mobilization in runoff water, but results were inconsistent (Sharpley, 1995 and 1997; Pote et al., 1996; Sauer et al., 2000). However, Gaston et al. (2003) recently.

Table 1. The Louisiana Phosphorus Index.

Part A: Phosphorus Loss Potential due to Site Transport Characteristics						
Characteristic	Phosphorus Loss Rating					Value
Erosion	2 x RUSLE in tons ac^{-1} yr^{-1}					
Runoff Class	Value from Table 1A					
Subsurface Drainage	Value from Table 1B					
Buffer Distance to Water	> 30 ft	> 10 ft	> 10 ft	< 10 ft	< 10 ft	
No P Application Zone	> 30 ft	> 30 ft	< 30 ft	< 30 ft		
	0	2	4	8	16	
Priority of Water	VL	L	M	H	VH	
	0	1	2	4	8	
Total Site Value						

A. Runoff class is based on soil permeability class and slope.

Slope %	Soil Permeability Class in h^{-1}				
	> 20.00	2.00 – 20.00	0.20 – 2.00	0.06 – 0.20	< 0.06
concave	0	0	0	0	0
< 1	0	0	0	2	4
1 – 5	0	0	2	3	8
5 – 10	0	2	4	8	16
10 – 20	0	2	4	8	16
> 20	2	4	8	16	16

B. Subsurface drainage potential is based on soil drainage class and depth to seasonally high water table.

Water Table Depth ft	Soil Drainage Class						
	VPD	PD	SPD	MWD	WD	SED	ED
0 – 1	8	16	16	16	16	16	
1 – 3	4	4	4	4	8	8	8
3 – 6	2	2	2	2	4	4	4
> 6		0	2	2	2	2	2
Subsurface Drains	8	8	8	8			

Table 1 continued. The Louisiana Phosphorus Index.

Part B: Phosphorus Loss Potential due to Management Practices						
Characteristic	Phosphorus Loss Rating					Value
Soil Test P	0.10 x Bray 2 P†					
Inorganic P Fertilizer Rate	0.10 x lbs P_2O_5 ac^{-1}					
Surface Applied	No	Yes	Yes	Yes	Yes	
Incorporated	Yes	Yes	Yes	No	No	
When Incorporated / Applied		< 5 d	> 5 d	Warm	Cool	
	2	4	8	8	16	
Organic P Fertilizer Rate	0.10 x lbs P_2O_5 ac^{-1} if manure or compost					
	0.05 x lbs P_2O_5 ac^{-1} if sludge					
Surface Applied	No	Yes	Yes	Yes	Yes	
Incorporated	Yes	Yes	Yes	No	No	
When Incorporated / Applied		< 5 d	> 5 d	Warm	Cool	
	2	4	8	8	16	
Total Management Value						

P Loss Rating = Part A x Part B	Potential for P Loss and Interpretation of Rating
< 600	Low N-based nutrient management OK
600 – 1200	Medium N-based nutrient management OK if practices implemented to reduce P loss in runoff and erosion
1200 – 1800	High Use P-based nutrient management with P application limited to the amount removed in crop harvest
> 1800	Very High No P application and implement P remediation

† Mehlich 3 was recently adopted, replacing Bray 2 (Mehlich 3 P = 0.43 Bray 2 P + 11 for 300 Louisiana soils; Wang et al., 2004).

demonstrated that carefully measured soil P desorption from soil was a much better predictor of P loss in runoff than soil P concentration (as measured by simple extraction procedures) alone. Nevertheless, empirical desorption alone is incomplete in that it does not explicitly account for the known chemistry of soil P. For example, when poultry litter is added to the soil surface and P levels increase, P fixation occurs in acid conditions between phosphate and Fe or Al hydrous oxides and silicate minterals (Iyamuremye, et al. 1996a, 1996b, 1996c; McBride, 1994). The free Fe, Al and sesquioxide clays react rapidly with phosphate to form a series of highly insoluble hydroxyphosphates such as variscite and strengite (Lindsay, 1979). Another type of P fixation is the reaction between phosphates and silicate clays. Phosphate ions attack the broken edge of clay minerals where hydroxyls are exposed. The phosphate ions react with octahedral Al by replacing the hydroxyl groups at the broken edge plane of the clay mineral (McBride, 1994).

Furthermore, soil P occurs in inorganic and organic forms, both with different behaviors in the soil environment. Sharpley et al. (1993) indicated that although poultry litter applications increased both inorganic and organic P concentrations, inorganic P was the larger fraction. Organic P forms include phospholipids, inositol phosphates, and organic acids such as fulvic and humic acids. Most forms of organic P are found to be mobile and, thus, subject to intensive leaching and movement (Harrison, 1987). Walthall and Nolfe (1998) found that inorganic P was far in excess of organic P in poultry-litter amended, pastures in north Louisiana. In contrast they found organic P to be the dominant P fraction in similar but non-amended, forest soils.

Besides the chemistry of soil P affecting its mobility, surface and subsurface hydrology are obviously important. Slope and landscape position are factors affecting the vertical and lateral flow of water. According to Hall (1983), precipitation on the surface can follow three major pathways: overland flow, throughflow and deep percolation. The amount of moisture following these pathways is governed by a complex set of interrelated factors that include amount and duration of rainfall, topography, soil permeability, vegetation and the physical condition of the soil surface.

In contrast to simple regression models based on soil P concentration, highly detailed mechanistic models that attempt to describe infiltration / overland flow and release of dissolved / particle-bound P into runoff water, the physics and chemistry of P mobilization, are sound and can accurately predict P losses from a small uniform area during single event (Wang et al., 1996). However, extension to large areas and over a series of rainfall / runoff events is not practicable. Less detailed models such as EPIC (Sharpley and Williams, 1990) or AnnAGNPS (Young et al., 1989; Darden and Herring, 1999) can account for large-scale spatial and temporal variability but lack the specificity of detailed mechanistic models. Thus, we cannot as yet accurately model P loss at the field- or farm-scale.

Accordingly, the P index is a practical tool. However, the Louisiana P index has not been evaluated as to how well risk ratings correlate with actual P losses. While not intended to be a predictive model, the P index should nevertheless be meaningful. Across the range of index parameters that tally to low potential for P movement, for example, measured P losses should be generally lower than if index parameters state medium potential for P movement.

The main objective of this project, therefore, is to assess performance of the Louisiana P index for distinguishing different sites / management systems as to potential losses of P. Agreement between P index rating and measured P loss would lend confidence to the index and its applicability to nutrient management planning. On the other hand, inconsistencies would be cause to modify and further evaluate it.

Given the superior performance of the P desorption method described in Gaston et al. (2003) compared with soil P extraction data for predicting P mobilization in runoff, it is also of interest to determine whether use of P desorption data leads to better agreement between risk ratings and measured P losses.

MATERIALS AND METHODS

Sites Used

Four sites differing in location and land-use were used to generate runoff for P concentrations. All four were on Ruston series (fine-loamy, siliceous, thermic Typic Paleudults) soils under pasture (either hay production or grazing) or forest (timber or timber / straw production). The hay, timber and timber / straw production sites were on the LSU AgCenter Calhoun Research Station, Calhoun, Louisiana and the grazed pasture was located off-station. The hay field site was part of a long-term study on effects of previous (last applied in 2001) poultry litter fertilization on bermudagrass (*Cynodon dactylon (L.) Pers*.) yield and soil P fate. In this study, poultry litter had been applied at 0, 5, 10 and 20 Mg ha^{-1} annually to plots for six years. The timber production site was part of a parallel long-term study under loblolly pine (*Pinus taeda* L.). The timber / straw production site was part of recently installed study comparing effects of straw raking with or without fertilization with commercial fertilizer or poultry litter to replenish nutrients removed by straw harvest. Each of these studies had three replicates of the three treatments plus control. Runoff data for plots on each of the 36 total plots in these studies was generated. Runoff data for three plots in the grazed pasture was also generated and these data, together, serve as the basis for this evaluation of the Louisiana P-Index.

Runoff Collection

On each of the 36 plots from the three field-plot studies, a stainless steel frame (either 1 m x 1 m, timber / straw production site, or 0.75 m x 1 m, others, with 10 cm height borders) with trough for collecting runoff was installed to a depth of approximately 5 cm in the soil. Three plot frames were similarly installed in the grazed pasture.

Runoff was produced from these plots by applying simulated rainfall (deionized source water) at a target rate of 7 cm h^{-1} for sufficiently long to generate 30 min of runoff (a variation on the protocol of Sauer et al., 2000). The rainfall simulator was a (TLALOC 3000; Joern's, Inc.). Time to initiation of runoff was recorded and six discrete 1 min samples of runoff (1 L Nalgen bottles) were taken periodically over the 30 min of subsequent runoff. All other runoff was collected in bulk (carboys). Runoff from the timber / straw plots and from the grazed pasture plots was drained from the plot trough into a sunken barrel or pit and collected under gravity flow. That from the hay pasture and timber plots was continuously pumped out of troughs using a peristaltic pump. Although the simulator was calibrated to deliver rainfall at 7 cm h^{-1}, application rate was checked following each simulation by collecting a timed volume of rainfall caught by a plastic sheet stretched over a pipe frame of dimensions equal to and centered slightly above the runoff plot frame.

Soil Sampling and Other Field Data

Prior to a rainfall simulation, eight samples of surface 0 – 2 cm and 2 – 15 cm were collected from the outside perimeter of runoff plots using a soil probe. Two additional soil samples to a depth of 15 cm were collected with a 5 cm diameter core. The surface 2 cm samples were used to measure water-soluble and soil-test P and the 2 – 15 cm samples were used to generate phosphate sorption isotherms as described below. The other samples were to determine initial soil water content and soil bulk density. Also, duplicate 30 cm x 30 cm samples of pine straw were collected from outside the forest soil plots. Average slopes of plots were measured with a survey level. Types and density of ground vegetation under pine was noted.

Water Quality Analyses

Following measurement of volume for the six discrete runoff samples per plot, a sub-sample was filtered (0.45 µm syringe filter) into a scintillation vial and acidified to pH 2. The volume of bulk runoff sample was measured (by weight) and the remaining portion of discrete samples was combined with the bulk runoff. This was well-stirred and sub-samples taken for solids (total, dissolved and suspended; TS, DS and SS), COD, total Kjeldahl nitrogen and P (TKN and TP), pH and dissolved N and P (NO_3^-, NH_4^+ and DP). The latter sub-sample was filtered using a 0.45 µm syringe filter. pH was measured in a Station laboratory but other samples were preserved (APHA, 1995) for later analysis (refrigeration at 4^o C and acidification to pH 2 for the TKN + TP and dissolved N + P).

Concentration of molybdate-reactive P in the six discrete samples per runoff plot was measured by the method of Murphy-Riley (1962) as presented by Pote (2000). Other analyses were as per the US EPA (1999) methodologies given in Table 2. Solids and COD were determined in-house and other analyses were conducted by the LSU Agricultural Chemistry Department.

Table 2. Analytical methods for bulk runoff water quality parameters.

Parameter	Analytical Method
DS	EPA 160.1
TS	EPA 160.2
TKN	EPA 351.2
NO_3^- and NO_2^-	EPA 300.0
NH_4^+	EPA 351.2
TP	EPA 365.2, 200.7
DP	EPA 200.7
COD	EPA 410.4

Soil Analyses

Surface 0 – 2 cm and 2 – 15 cm samples were air-dried and ground with mortar and pestle. Bray 2 and water-soluble P in the 0 – 2 cm soil was determined. Phosphate adsorption / desorption was determined using the larger mass of 2 – 15 cm samples. Briefly, 5 g (oven-dry equivalent mass) of soil in centrifuge tubes were mixed with 25 mL of phosphate solution ranging from 0 to 150 mg / L phosphate-P. Suspensions were shaken for 24 h at 25 ^oC, spun down (3,000 rpm), supernatant filtered (0.45 µm), diluted as needed to bring the P concentration into an analytical range up to 1 mg L^{-1}, and analyzed colorimetrically (Pote, 2000). Desorbed and sorbed phosphate-P was calculated by change in solution concentration (with input concentration of P determined by ICP analysis).

Modeling Phosphate Sorption / Desorption, Runoff Rate and Phosphate Loading into Runoff

The distribution of phosphate between solution and sorbed phases was modeled using a modification of the Langmuir equation,

$$\Delta S = -S_o + kS_TC / (1 + kC)$$

where ΔS is the change in sorbed (mg kg^{-1}) phosphate P with respect to the initial sorbed concentration, S_o, C is solution concentration (mg L^{-1}), S_T is the sorption maximum (mg kg^{-1}) and k is the affinity constant (L mg^{-1}). Calculated change in sorbed phosphate-P, ΔS, as a function of equilibrium solution concentration, C, was fit to the Langmuir model by optimizing the parameters, S_o, S_T and k using the PROC NLIN procedure of SAS (1996).

Timed volume of runoff collected in the six discrete samples was expressed as runoff rate (cm h^{-1}) and this, together with measured simulated rainfall intensity was described by the Green-Ampt (1914) model for infiltration. This model may be written as,

$$q = -K_S (\psi_f + z_f - d) / z_f$$

where q is water infiltration rate at the soil surface (cm h^{-1}), K_S is hydraulic conductivity (cm h^{-1}), ψ_f (cm) is potential at the wetting front, located at a depth, z_f (cm), below the soil surface, and d is depth of water ponded (cm) on the soil surface. This form was expressed in implicit finite difference form with the following modifications and solved within a least-squares fitting procedure (van Genuchten, 1981) to give best-fit estimates of K_S, ψ_f and a separate parameter to account for depth of rainfall intercepted and retained (abstracted, A, cm) by grass + thatch in pasture plots or understory + pine straw in forest plots. First, all rainfall was assumed retained by the soil cover, then infiltration to proceed at a rate equal to rainfall intensity so long as the right hand side of the alternative expression of Green Ampt,

$\Delta\theta\ (z_f^{j+1} – z_f^{j}) / \Delta t = -K_S\ (\psi_f + z_f - d) / z_f$

(with q expressed in terms of rate of change in depth to the wetting front, and where $\Delta\theta$ is increase in volumetric water content and z_f is the average depth to the wetting front, $(z_f^{j+1} + z_f^{j}) / 2)$ remained greater than the left hand side for set values of K_S, ψ_f and A. Thereafter, estimated depths to the wetting front, z_f^{j+1}, through a series of time step intervals, Δt, gave calculated infiltration rate, $\Delta\theta(z_f^{j+1} – z_f^{j}) / \Delta t$, less than the measured intensity of rainfall. The rainfall in excess of infiltration was assumed to accumulate on the soil surface (d increasing from 0) and runoff at a rate set by Mannings's formula for overland flow (proportional to depth, d, of ponded water).

During infiltration, phosphate in the surface soil was assumed to be desorbed according to the Langmuir model for soil for a particular plot and be transported deeper into the soil with infiltrating water. Once ponded water developed, phosphate in the surface soil solution was assumed to be released to the ponded water and appear in runoff. During infiltration but before onset of runoff, unsaturated pore space to a depth, d_S (depth of mixing zone assumed release phosphate to runoff water), either filled to saturation with infiltrating water or drained reducing the concentration of phosphate in the soil solution according to,

$d_S\theta\ dC_S / dt + d_S\rho\ (dS / dC_S)\ dC_S / dt = qC_S$

where C_S is concentration of phosphate in the soil solution and dS / dC_S is set by the Langmuir isotherm. Upon appearance of ponded water, exchange of phosphate between the soil solution to the depth d_S and ponded water was described by,

$$d_W \, dC_W / dt + C_W \, d(d_W) / dt = -(q + r + \alpha) \, C_W + \beta C_S$$

where d_W is depth of ponded water, r is runoff rate (cm h^{-1}), and α and β (both cm h^{-1}) are mass transfer coefficients intended to account for diffusion into and from the surface soil solution. Similarly for the surface soil after appearance of ponding,

$$d_S\theta \, dC_S / dt + d_S\rho \, (dS / dC_S) \, dC_S / dt = q(C_W - C_S) + \alpha C_W - \beta C_S$$

Use of a single mass transfer coefficient for exchange between ponded and soil water (i.e., α = β) was not successful in describing phosphate in runoff. This modification is qualitatively consistent with Ahuja (1990) that a variable, rather than constant, dispersion coefficient better described chemical loading into runoff and may be related to the crude (step-function) model for solution phosphate gradient at the soil surface.

The above approach assumes no input of phosphate in rainwater reaching the soil surface. As later discussed, despite use of deionized rainwater source, this was not the case. Since contact with plant material above the soil surface may add chemical species, this model was expanded to allow for variable input of phosphate into the soil before ponding and into ponded water afterwards. In this case,

$$d_W \, dC_W / dt + C_W \, d(d_W) / dt) = -(q + r + \alpha) \, C_W + \beta C_S + (q + r) \, C(t)_{INPUT}$$

Effect of Soil Cover on Composition of Water Reaching the Soil Surface

The effect of addition of P to the water that passed through the straw layer in forest plots was examined in a laboratory leaching study. Briefly, straw from each the timber / straw plots was placed in PVC cups (10 cm diameter, with drain hole in bottom) to surface densities (g / cm^2) equal to those measured from the field. The straw was then misted with a depth of distilled-deionized water approximately equal to the depth of simulated rain used in rainfall simulations and leachate collected in a series of three samples. Leachate was preserved and analyzed for water quality parameters as above.

RESULTS AND DISCUSSION

Applicability of Transport and Source Factors of the Louisiana P-Index

Since the focus of this work was on runoff losses of P without recent surface-applied P fertilizer, only those factors in the P-Index that relate to surface losses of P were examined. These include two transport-related factors, soil erosion and soil runoff class, and one source factor, Bray 2 soil P.

The soil erosion term (see Table 1) is calculated from RUSLE, and includes rainfall, soil erodability, slope gradient and length, crop management and erosion control practice factors. Rainfall factors (here and elsewhere) were approximated from USDA (1995). Erodabilty factors were taken from soil surveys for Bienville, Claiborne, Jackson, Lincoln, Ouachita and Union Parishes (Cooley et al., 2002; Kilpatrick and Henry, Jr., 1989; Stephens, 1999; Kilpatrick et al., 1996; Mathews et al., 1974; and Allen et al., 2000; respectively). Slope gradient and length factors were interpolated from Renard et al. (1997) for sites with low ratios of rill to interrill erosion, and crop management values (pasture and forest with complete soil cover) were taken from Schwab et al. (1996). No erosion control practices were in place (factor = 1).

Soil permeability classes were taken from the above soil surveys and these, together with slope gradients, used to establish the surface runoff class, which, in turn, was converted to a numerical value (Table 1). The summed value, 2 x erosion (tons ac^{-1} yr^{-1}) plus surface runoff class, gave the transport factor for potential P loss, which was then multiplied by 0.1 x measured Bray 2 P to give the P loss potential rating. This rating was then evaluated by comparing it to measured losses of P from runoff plots. While a P-Index is intended to be an assessment tool, not predictive model, it usefulness as an assessment for potential P loss is predicated on a positive relationship between P loss potential and actual P mobilization. Though it stands to reason that the greater is the susceptibility of a site to erosion and runoff, and the greater the level of soil test P, the greater should be the mobilization of P in runoff, whether this is borne out by data was unknown.

Unfortunately, when total P (TP) data (Appendix A) from all 39 plots (including sequential simulations at two of the grazed pasture plots) are compared to P loss ratings, no such positive relationship is seen (Fig. 1). The data for molybdate-reactive and dissolved P are no different in this way (data not shown) than those for total P (Fig. 1). The data in Fig. 1 segregate into groups for the grazed pasture plots and all other data, suggesting that residual excreta should have been taken into consideration as an additional P source term. The effect of this, both with respect to unknown rate per acre and P concentration, and the fact that it is a surface-applied P amendment (Table 1), would substantially increase the source factor of the P loss rating and improve the relationship between it and measured P losses. Nevertheless, excluding the grazed pasture data did not give a significant relationship between measured TP concentration in runoff and site P loss rating.

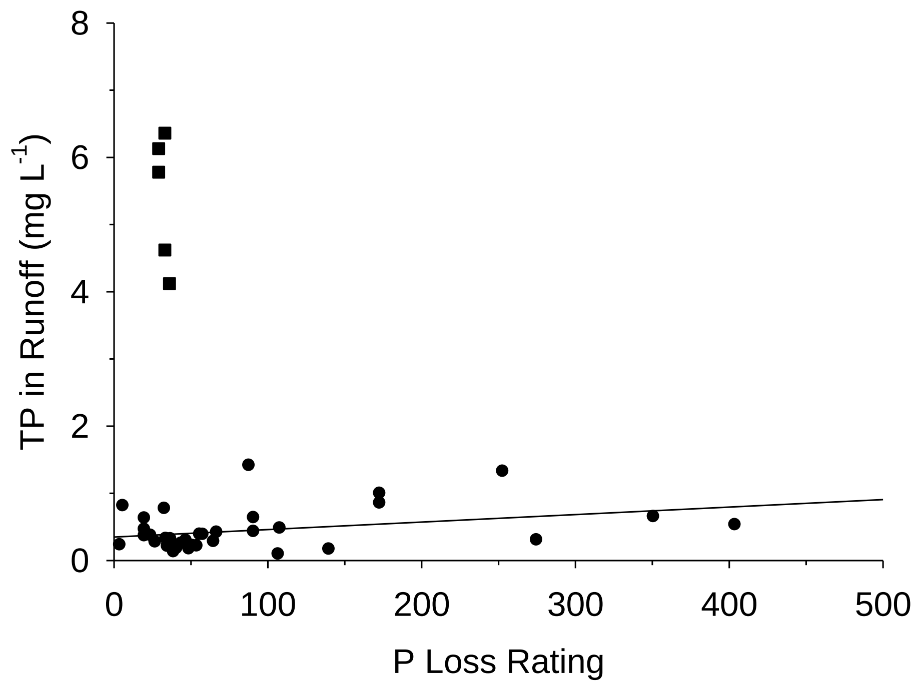


Figure1. Concentration of total P (TP) in runoff from pasture and forest soil plots related to site P loss rating. Data for grazed pasture plots are shown as ■. The linear regression of TP as a function of P loss rating was not significant.

Separating hay pasture from forest plot data led to better relationship between measured TP (or DP and molybdate-reactive P) and P loss rating for the hay pasture plots (Fig. 2) and measured P loss, however, the R^2 (= 0.49) on the relationship, though significant, remained weak. The relationship (Fig. 2) suffers due to data from one plot, which though high in Bray 2 soil P, is assigned 0 for runoff class due to combination of low slope and relatively high permeability of the soil, thereby marginalizing the potential effect of soil P (see Table 1).

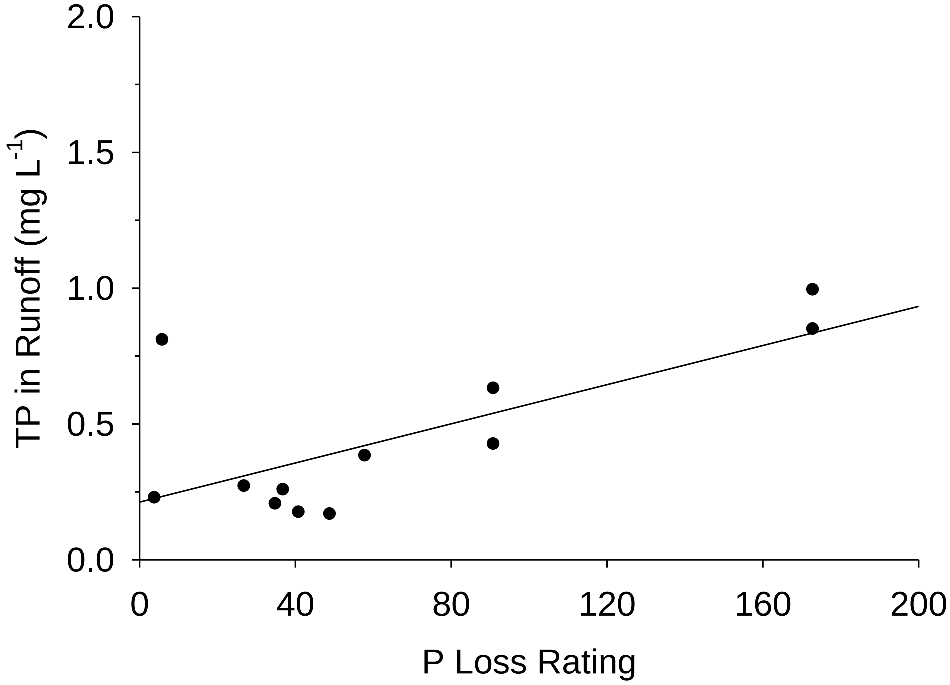


Figure 2. Total P (TP) in runoff from hay pasture plots related to site P loss rating.

Figure 3 shows TP in runoff compared to P loss ratings for the forest soil plots. The relationship between TP in runoff and the P loss rating, though positive (R^2 = 0.10), was not significant. In part, poorer relationship between measured TP in runoff from the forest soil plots and P loss rating may derive from the influence of pine straw on TP in runoff. For example, phosphate concentrations in straw leachate (straw / timber production plots) were typically greater than phosphate concentrations in runoff but not proportionally so. Figure 4 shows phosphate leached from straw collected from plot 4 and phosphate in runoff from this plot, both as a function of time since rainfall began. The effect of phosphate (also DP and TP) release from pine straw is analogous to that of residual excreta in the grazed pasture plots –an additional P source.

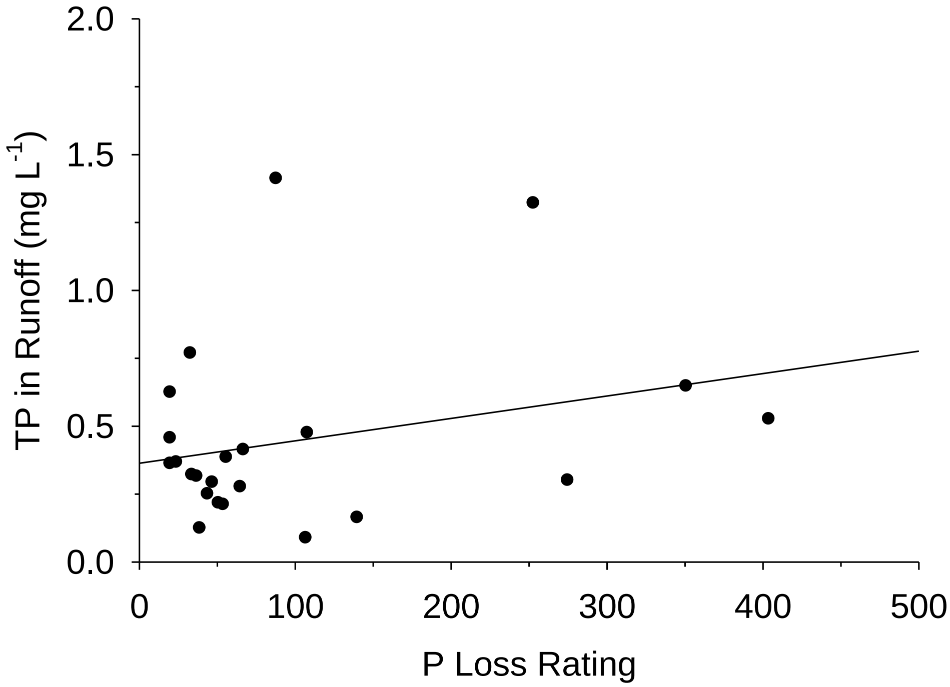


Figure 3. Concentration of total P (TP) in runoff from forest plots related to site P loss rating.

However, when phosphate released from straw on either a per mass basis (mg P per kg straw) or per area basis (mg P per m^2) was compared to soil Bray 2 P, there was no significant relationship (data not shown). Thus, Bray 2 P may not be a measure of this soil-derived P source.

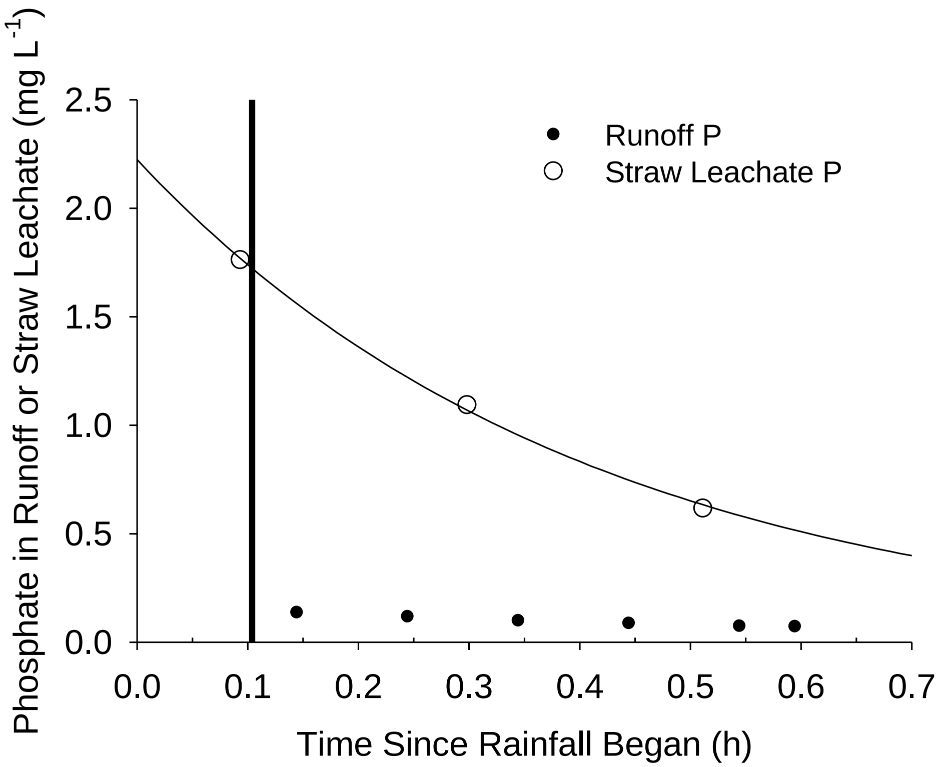
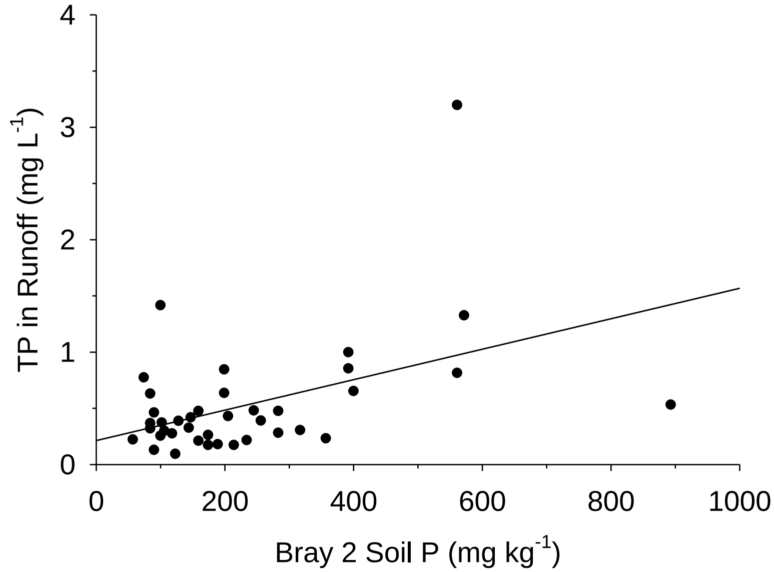


Figure 4. Phosphate in runoff and in pine straw leachate from straw / timber production plot 4. The vertical line marks time at which runoff began.

Gaston et al. (2003) found that Bray 2 soil P was a poorer predictor of TP and DP in runoff than was water-extractable P for three different North Louisiana soils. But in this study, there was limited correlation of runoff TP (DP or molybdate-reactive P) with Bray 2 P (Fig. 5, R^2 = 0.20) or water-extractable P (Fig. 5, R^2 = 0.25).



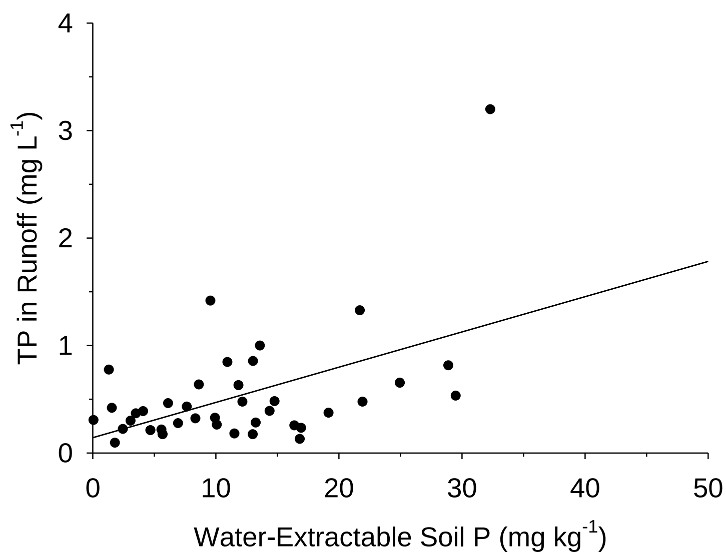


Figure 5. Relationship of TP in runoff to Bray 2 soil P (top) and water-extractable P (bottom).

Preliminary Modeling

Based on some success of Gaston et al. (2003) relating release of DP from surface soil to runoff water that took into consideration decreasing concentration of DP with increasing amount of runoff, this project attempted to first mechanistically describe runoff and couple this with decreasing concentration of P expected for a continuous extraction of soil. A modification of the Green-Ampt (1914) approach was used to describe infiltration and release of phosphate-P was described by a Langmuir isotherm. This approach is inherently limited in that it considers only phosphate-P. It may be argued, however, that although this form is only a part of DP (and TP) in runoff, success in describing loss of phosphate-P is important because it is a bioavailable form. Furthermore, for the sites examined in this study, molybdate-reactive P (often mostly phosphate-P) constituted about 0.76 of DP and 0.69 of TP in runoff. Not surprisingly, DP and TP concentrations were highly correlated to molybdate-reactive P concentrations (Fig. 6). Thus, for the Louisiana sites examined, success in describing phosphate-P implies similar success in describing DP or TP.

Although the basis data (Appendix B) are available for all plots in this study, the preliminary modeling has been conducted using only the 12 straw / timber production plots at this point. The preliminary results were encouraging. In all cases, runoff rate could be described by the model. Figure 7 is typical of results. Best-fit parameters are given in Table 3.

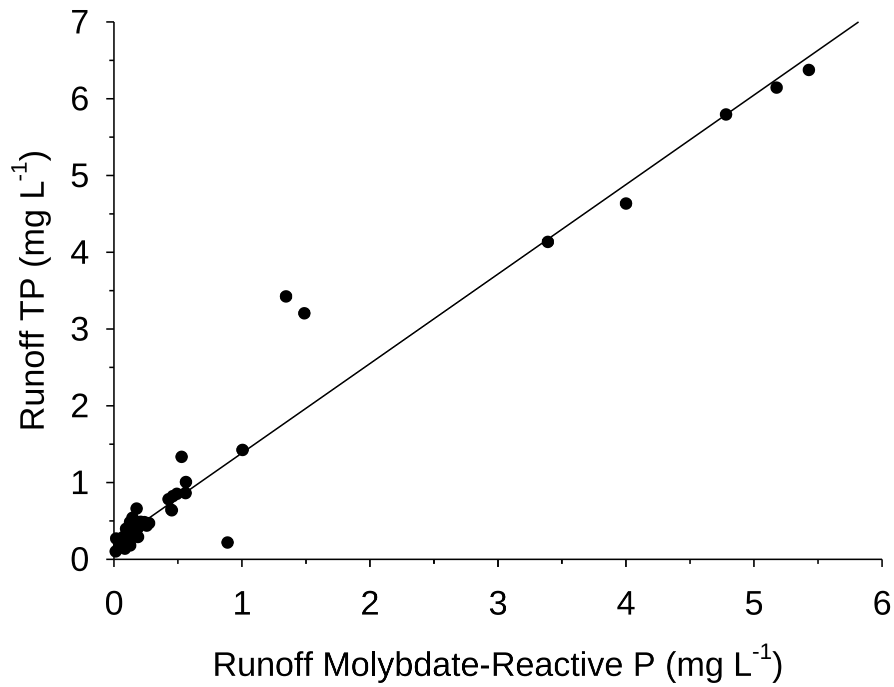


Figure 6. Relationship of TP to dissolved molybdate-reactive P in runoff (R^2 = 0.95).

Table 3. Parameters for the infiltration / runoff model.

Plot	$\Delta\theta\psi_F$ cm	K_S cm h^{-1}	A cm	R^2	Rain cm h^{-1}
1	0.39	0.71	0.99	0.996	6.59
2	3.09	0.35	0.60	0.986	6.21
3	0.16	2.35	0.61	0.998	6.63
4	2.38	0.22	0.57	0.997	6.28
5	0.67	2.49	0.11	0.992	5.98
6	3.34	0.08	0.35	0.994	6.82
7	1.67	0.46	0.35	0.997	6.56
8	0.10	1.05	0.40	0.992	6.17
9	0.34	0.08	0.28	0.995	6.56
10	0.41	1.62	0.10	0.944	6.94
11	1.62	0.42	0.56	0.989	7.37
12	1.10	0.26	0.45	0.994	7.16

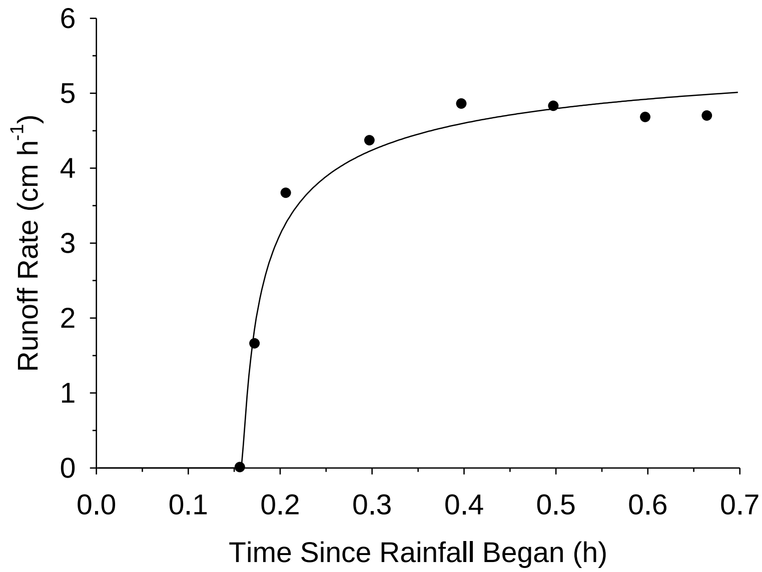


Figure 7. Example fit of runoff rate using the infiltration / runoff model (plot 1).

The sorption / desorption behavior of phosphate was equally well described by the Langmuir model. Table 4 gives parameters and Fig. 8 a typical example fit.

Table 4. Langmuir isotherm parameters for the straw / timber plots.

Plot	S_T	k	S_O	$[P]_O$
1	281.3	0.03943	6.187	0.624
2	218.5	0.02548	16.885	1.676
3	231.5	0.03095	3.133	0.312
4	207.8	0.02138	2.508	0.251
5	258.0	0.02830	11.903	1.182
6	224.8	0.02788	1.374	0.127
7	248.8	0.01920	19.229	1.931
8	271.2	0.02847	3.567	0.358
9	287.8	0.03992	1.616	0.161
10	201.9	0.02123	9.620	0.944
11	288.2	0.02465	16.444	1.648
12	244.8	0.02050	1.862	0.187

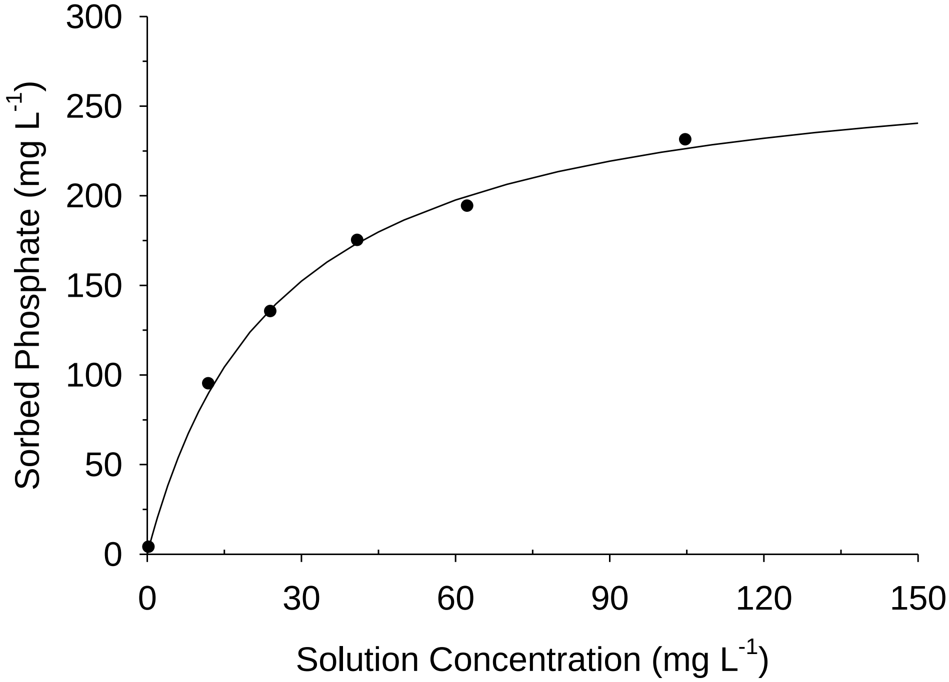


Figure 8. Example phosphate sorption isotherm and Langmuir isotherm (plot 1).

Application of the model without consideration of the phosphate lost from the overlying straw often led to unreasonable estimates of the depth of soil considered to influence runoff concentrations of phosphate. Release of phosphate from a shallow depth of surface soil was inadequate to account for its concentration in runoff simply because there was insufficient phosphate in the soil. Thus, to describe this dual source system, the release of phosphate from pine straw was also modeled so that rainwater reaching the soil surface was enriched with phosphate from the straw. Table 5 gives data for rate of release of phosphate from straw with increasing depth of rain applied. In all cases, the monotonically decreasing concentration of phosphate in straw leachate was well-described by a simple exponential model (see example, Fig. 4).

Table 5. Release of phosphate from pine straw and model parameters.

Plot	[P] mg L^{-1}	R cm	TotVol mL	Coef mg L^{-1}	Exp	R^2
1	7.095	1.272	103.03	8.824	0.3547	0.994
	4.366	2.485	201.28			
	3.094	3.668	297.09			
2	3.112	1.193	96.64	3.757	0.3406	0.978
	1.901	2.391	193.67			
	1.459	3.599	291.52			
3	3.166	1.181	95.68	3.909	0.3726	0.992
	1.893	2.456	198.94			
	1.317	3.687	298.66			
4	1.758	1.185	95.99	2.226	0.3917	0.999
	1.090	2.567	207.89			
	0.613	3.867	313.22			
5	2.498	1.220	98.85	2.226	0.6392	0.985
	0.965	2.593	210.04			
	0.598	3.847	311.62			
6	1.678	1.168	94.60	2.618	0.7750	0.988
	0.566	2.501	202.56			
	0.319	3.774	305.70			
7	2.041	1.427	115.55	2.692	0.3900	1.000
	1.196	2.702	218.83			
	0.729	4.045	327.64			
8	3.612	1.229	99.58	4.051	0.2258	0.942
	2.395	2.638	213.68			
	2.045	4.082	330.68			
9	1.644	1.348	109.21	2.223	0.5247	0.992
	0.743	2.734	221.48			
	0.452	3.991	323.31			
10	2.706	1.201	97.24	4.005	0.6618	0.996
	1.120	2.491	201.75			
	0.579	3.739	302.85			
11	1.168	1.329	107.64	1.750	0.6220	0.989
	0.461	2.652	214.84			
	0.285	3.832	310.36			
12	2.677	1.320	106.96	3.682	0.4983	0.988
	1.228	2.748	222.59			
	0.786	4.038	327.09			

When release of phosphate from straw was included, the rate of loss of phosphate from the straw / timber production plots was generally well-described. Figure 8 is typical of these cases, however, phosphate release from a handful of plots did not decrease monotonically as in Fig. 8 so that in these cases the model did not accurately describe phosphate release into runoff. Model parameters for the nine plots with phosphate loading into runoff that was well-described by this approach are given in Table 6.

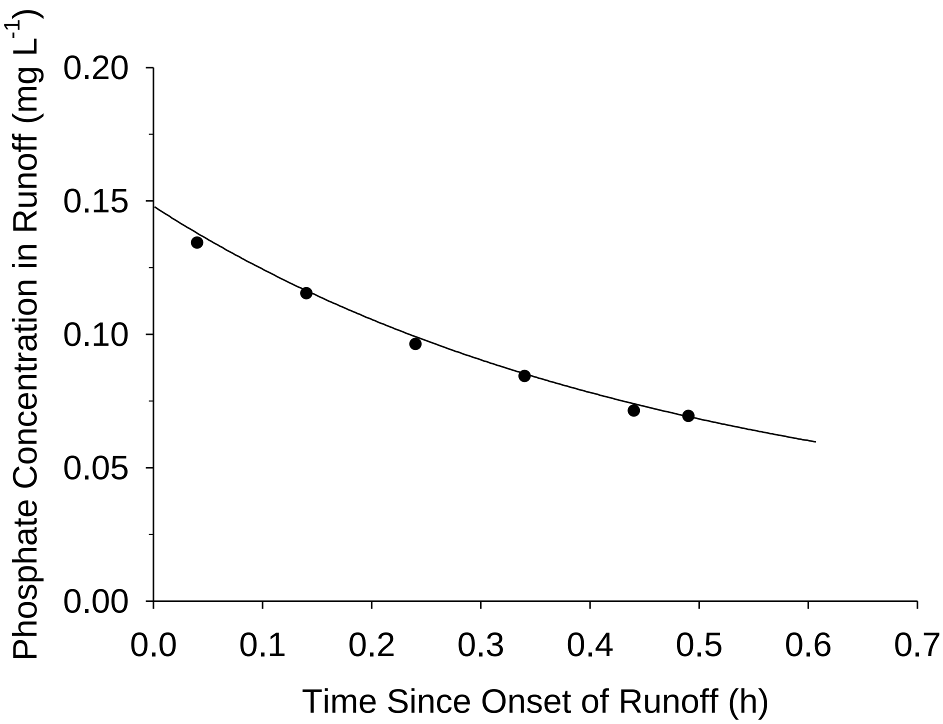


Figure 9. Example description of phosphate loading into runoff (plot 4).

Table 6. Model parameters for phosphate loading into runoff.

Plot	d_S cm	α cm h^{-1}	β cm h^{-1}	R^2
1	0.480	147.1	3.75	0.998
2				
3	0.121	188.7	2.04	0.999
4	0.241	97.6	0.95	1.000
5				
6	0.604	9.4	1.03	0.991
7	0.251	95.4	1.08	0.996
8	0.290	125.4	0.01	0.972
9	0.048	62.8	0.54	0.979
10				
11	0.581	176.5	2.95	0.999
12	0.222	511.4	0.70	0.961

SUMMARY AND CONCLUSIONS

The assessment of the Louisiana P-Index undertaken in this study focused on coastal plain soil that is representative of the poultry producing region of Louisiana. Loss of P from land fertilized with animal waste to surface water is a major concern and the reason why P-Indices have been developed. Yet for the P runoff data collected in this study, there is only a weak positive relationship with P loss rating calculated using the Louisiana P-Index and this only possible by excluding data one of the management systems examined, grazed pasture. Across all management systems –hay pasture, grazed pasture, and forested sites with and without straw removal— there was no relationship. It remains to be seen if better agreement would emerge if other soils and, especially, other agronomic systems were considered. Furthermore, runoff data were small plot-, not field-scale, and only a snapshot in time. Long-term monitoring of runoff from large plots (thereby forcing inclusion of an additional factor, subsurface drainage (Table 1) might give a better positive relationship between P lost in runoff and calculated P loss ratings. Nevertheless, results of this study point to several shortcomings in the Louisiana P-Index. First, surprisingly high concentrations of P from the grazed pasture plots (Fig. 1) were dissimilar to the other data, suggesting that residual excreta constitute a P source similar to amendment with organic fertilizer, increasing the P loss rating (Table 1). Second, although categorization of factors such as the runoff class value is certainly practical within a worksheet format (Table 1), it probably tends to diminish (or exaggerate) the effect of that factor. Third, similar to the suspected effect of residual excreta, other organic materials on the soil surface such as pine straw and perhaps grass thatch, probably act as additional P sources but are ignored by the P-Index.

Besides the primary objective to assess performance of the Louisiana P-Index, the study had a secondary objective of possibly refining it, particularly by considering alternative measures soil P susceptible to loss in runoff. Though earlier work with similar soils (Gaston et al., 2003) found water-extractable soil P a better indicator of P runoff potential than Bray 2 extractable soil P, this was not the case in this study (perhaps in part due to the effect of straw acting as an unaccounted P source). Also, modeling phosphate loading into runoff solely on the basis of its Langmuir desorption from forest soil was inadequate. Only after including phosphate leached from straw did model results compare well with the experimental runoff data.

The side study on phosphate release from pine straw may have implications beyond the immediate problem. To the extent that these results are representative of Louisiana coastal plain forest soils, this natural source of P and other nutrients (including oxygen-consuming substances) should be taken into consideration when proposing water quality standards for P. For example, the USEPA (2000a, b) has recommended TP concentration < 0.1 mg L^{-1} for surface waters in the aggregate ecoregion including North Louisiana, a concentration perhaps comparable to that in runoff from pristine sites. The TMDL simulations for a major water body in the area run for LDEQ by FTN (2002) failed to meet water quality standards without either relaxing standards or reducing loss of oxygen-consuming substances from natural sources. Clearly, there is little tolerance for man-made sources under these scenarios. Yet, if there was a better understanding of natural sources of P and other nutrients lost to surface waters, more realistic standards might be agreed upon such that water quality and economic viability might be preserved.

In closing, it is worthwhile to consider management implications based on the current Louisiana P-Index. The major poultry-producing parishes in north central Louisiana are Bienville, Claiborne, Jackson, Lincoln, Ouachita and Union. The upland soils in these parishes are given in Appendix C, together with acreage and parameters used in the Louisiana P-Index to assess potential surface and subsurface transport loss of P. Table C1 gives runoff parameters, Table C2, erosion parameters, and Table C3, drainage parameters. The area-average runoff, erosion and drainage values for these soils are 4.62, 2.71 and 0.208 tons ac^{-1} yr^{-1}, respectively, giving an average P-Index transport value of 7.75 (runoff value + drainage value + 2 x erosion, Table 1). Across 51 locations on farms of 15 poultry producers in North Louisiana, Waldron et al. (2004) found an average Bray 2 soil P concentration of about 650 mg kg^{-1}. Multiplying this source value (0.1 x Bray 2 P, Table 1) with the above transport value gives a P loss rating of about 500, indicating average low loss potential for P and no need for P-based fertilizer management. For a region-wide P-Index transport value of 8, a Bray 2 soil test P value of 1500 mg kg^{-1} would be the cut-off for switch to P-based management.

Although there was only weak correlation between the runoff P and P loss ratings (hay pasture data only), expected losses (Fig. 2) of P at the threshold for P-based management (P loss rating = 1200, Table 1) would likely be more than an order of magnitude greater than proposed by the USEPA (2000a, b). While the latter may be overly conservative, correlation between runoff losses of P and P loss ratings appears poor, so a middle ground is probably more realistic than either one.

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APPENDIX A –WATER QUALITY DATA, BULK RUNOFF

Table A1. Bulk runoff water quality parameters for hay pasture plots.

Plot	PO_4^{-3}	DP	TP	NH_4^+	NO_3^-	TKN	pH	COD	TS	DS	SS
	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}		mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}
1	0.570	0.837	0.992	< 0.30	< 1.10	< 5.5		26.8	92	52	40
2	0.457	0.594	0.629	< 0.30	< 1.10	< 5.5		31.0	54	48	6
3	0.265	0.385	0.424	< 0.30	< 1.10	< 5.5		25.6	40	36	4
4	0.102	0.268	0.381	< 0.30	< 1.10	< 5.5		37.2	51	37	14
5	0.076	0.225	0.269	< 0.30	< 1.10	< 5.5		27.6	75	31	44
6	0.061	0.266	0.166	< 0.30	< 1.10	< 5.5		19.7	60	50	10
7	0.064	0.100	0.173	< 0.30	< 1.10	< 5.5		18.1	20	15	5
8	0.114	0.190	0.226	< 0.30	< 1.10	< 5.5		21.3	58	9	49
9	1.352	2.100	3.410	0.93	4.13	< 5.5		36.4	96	82	14
10	0.134	0.373	0.204	0.49	< 1.10	< 5.5		31.9	119	103	16
11	0.468	0.785	0.807	0.32	5.06	< 5.5		48.4	161	134	27
12	0.135	0.215	0.256	< 0.30	< 1.10	< 5.5		37.3	78	55	23

Table A2. Bulk runoff water quality parameters for grazed pasture plots.

Plot	PO_4^{-3}	DP	TP	NH_4^+	NO_3^-	TKN	pH	COD	TS	SS	DS
	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}		mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}
1	5.436	6.36	6.36	2.84	0.83	2.95	6.01	46	158	38	120
2	5.185	5.99	6.13	0.66	0.44	3.23	5.58	47	111	22	89
3	3.398	4.20	4.12	< 0.29	< 0.22	1.97	5.82	48	97	28	69
1	4.008	4.62	4.62	0.98	< 0.22	3.02	6.16	32	129	46	83
2	4.790	5.79	5.78	0.42	< 0.22	3.36	6.11	46	100	31	68

Table A3. Bulk runoff water quality parameters for timber production forest plots.

Plot	PO_4^{-3}	DP	TP	NH_4^+	NO_3^-	TKN	pH	COD	TS	DS	SS
	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}		mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}
13	0.191	0.330	0.384	< 0.30	1.03	< 5.5	5.42	43.3	67	34	33
14	0.152	0.253	0.311	< 0.30	1.59	< 5.5	4.84	37.3	74	24	50
15	0.147	0.288	0.371	< 0.30	< 1.10	< 5.5	4.50	19.1	56	5	51
16	0.185	0.288	0.646	< 0.30	1.29	< 5.5	4.78	33.3	207	12	195
17	0.196	0.301	0.275	< 0.30	1.29	< 5.5	5.13	16.4	29	11	18
18	0.537	0.885	1.320	< 0.30	5.38	< 5.5	4.53	43.1	114	38	77
19	0.074	< 0.100	0.210	< 0.30	< 1.10	< 5.5	4.65	18.5	60	12	48
20	0.153	0.244	0.320	< 0.30	1.30	< 5.5	4.50	23.2	56	27	29
21	0.153	0.259	0.525	< 0.30	< 1.10	< 5.5	5.44	17.2	80	15	65
22	0.048	< 0.100	0.162	< 0.30	< 1.10	< 5.5	5.57	15.3	50	33	17
23	0.218	0.356	0.474	< 0.30	< 1.10	< 5.5	4.99	28.0	94	47	47
24	0.108	0.185	0.299	< 0.30	< 1.10	< 5.5	6.03	14.6	60	31	30

Table A4. Bulk runoff water quality parameters for straw / timber production forest plots.

Plot	PO_4^{-3}	DP	TP	NH_4^+	NO_3^-	TKN	pH	COD	TS	DS	SS
	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}		mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}
1	0.283	0.336	0.455	< 0.29	< 0.22	8.68	5.54	25.4	75	49	26
2	0.094	0.082	0.123	< 0.29	< 0.22	4.87		16.4	78	16	62
3	0.103	0.135	0.292	< 0.29	< 0.22	3.65	5.41	24.6	113	6	107
4	0.094	0.074	0.216	< 0.29	< 0.22	3.20	5.43	23.6	76	5	71
5	0.460	0.583	0.623	< 0.29	0.83	3.09	5.55	21.7	29	1	28
6	0.435	0.615	0.767	< 0.29	< 0.22	3.91	5.22	50.1	179	5	174
7	0.139	0.200	0.366	< 0.29	< 0.22	1.93	5.40	26.6	71	8	63
8	0.125	0.152	0.361	< 0.29	< 0.22	2.73	5.37	27.6	82	4	79
9	0.124	0.127	0.412	< 0.29	< 0.22	1.15	5.31	27.0	283	6	277
10	1.012	1.190	1.410	< 0.29	2.07	3.22	5.53	42.0	373	10	363
11	0.080	0.098	0.249	< 0.29	< 0.22	3.04	5.38	15.9	64	1	63
12	0.022	0.033	0.087	< 0.29	< 0.22	1.32	5.18	30.4	52	2	51

APPENDIX B –RUNOFF RATE AND PHOSPHATE RELEASE

Table B1. Hay pasture plot data.

Plot	Rain cm h^{-1}	Time h	Runoff cm h^{-1}	[PO_4^{-3}] mg L^{-1}	Plot	Rain cm h^{-1}	Time h	Runoff cm h^{-1}	[PO_4^{-3}] mg L^{-1}
1	7.09	0.150	0.00		7	7.71	0.183	0.00	
1	7.09	0.167	2.00		7	7.71	0.200	1.57	
1	7.09	0.192	4.03	0.656	7	7.71	0.225	3.63	0.122
1	7.09	0.275	4.07	0.632	7	7.71	0.308	4.33	0.074
1	7.09	0.359	4.12	0.571	7	7.71	0.392	4.37	0.070
1	7.09	0.442	4.14	0.558	7	7.71	0.475	4.40	0.045
1	7.09	0.525	4.08	0.520	7	7.71	0.558	4.47	0.028
1	7.09	0.609	4.04	0.482	7	7.71	0.675	4.34	0.046
2	7.31	0.189	0.00		8	7.69	0.139	0.00	
2	7.31	0.206	1.97		8	7.69	0.155	1.57	
2	7.31	0.231	4.23	0.682	8	7.69	0.180	3.70	0.164
2	7.31	0.314	4.91	0.583	8	7.69	0.264	4.45	0.135
2	7.31	0.398	5.05	0.436	8	7.69	0.347	4.63	0.699
2	7.31	0.481	4.91	0.370	8	7.69	0.430	4.79	0.102
2	7.31	0.564	5.03	0.348	8	7.69	0.514	4.90	0.086
2	7.31	0.648	5.04	0.322	8	7.69	0.630	4.85	0.084
3	7.88	0.236	0.00		9	6.61	0.119	0.00	
3	7.88	0.253	1.33		9	6.61	0.136	0.66	
3	7.88	0.278	3.34	0.351	9	6.61	0.161	1.32	2.398
3	7.88	0.394	5.00	0.280	9	6.61	0.244	1.20	1.731
3	7.88	0.478	6.28	0.248	9	6.61	0.327	0.97	1.374
3	7.88	0.561	6.77	0.239	9	6.61	0.411	0.83	1.054
3	7.88	0.644	6.99	0.238	9	6.61	0.494	0.69	0.831
3	7.88	0.744	7.02	0.231	9	6.61	0.611	0.61	0.724
4	7.50	0.169	0.00		10	6.96	0.101	0.00	
4	7.50	0.186	1.21		10	6.96	0.117	0.53	
4	7.50	0.211	3.19	0.201	10	6.96	0.142	0.97	1.782
4	7.50	0.294	4.55	0.104	10	6.96	0.226	0.82	1.169
4	7.50	0.394	5.46	0.096	10	6.96	0.309	0.76	0.784
4	7.50	0.478	5.86	0.079	10	6.96	0.392	0.72	0.639
4	7.50	0.561	6.17	0.074	10	6.96	0.476	0.70	0.548
4	7.50	0.678	6.41	0.061	10	6.96	0.592	0.72	0.455
5	7.74	0.135	0.00		11	6.79	0.101	0.00	
5	7.74	0.152	1.47		11	6.79	0.118	0.09	
5	7.74	0.177	2.74	0.149	11	6.79	0.143	0.14	2.437
5	7.74	0.260	2.60	0.091	11	6.79	0.226	0.10	2.363
5	7.74	0.343	2.65	0.077	11	6.79	0.309	0.07	1.606
5	7.74	0.427	2.67	0.050	11	6.79	0.393	0.05	1.064
5	7.74	0.510	2.62	0.046	11	6.79	0.476	0.03	0.859
5	7.74	0.627	2.53	0.046	11	6.79	0.593	0.02	0.646
6	7.48	0.122	0.00		12	6.79	0.303	0.00	
6	7.48	0.139	2.64		12	6.79	0.320	0.03	
6	7.48	0.164	5.97	0.124	12	6.79	0.345	0.06	0.057
6	7.48	0.247	6.93	0.058	12	6.79	0.428	0.05	0.034
6	7.48	0.330	7.21	0.055	12	6.79	0.512	0.08	0.029
6	7.48	0.414	7.29	0.052	12	6.79	0.595	0.08	0.014
6	7.48	0.497	7.39	0.042	12	6.79	0.678	0.06	0.011
6	7.48	0.614	7.41	0.034	12	6.79	0.795	0.06	0.008

Table B2. Grazed pasture plot data.

Plot	Rain $cm\ h^{-1}$	Time h	Runoff $cm\ h^{-1}$	$[PO_4^{-3}]$ $mg\ L^{-1}$
1	6.47	0.143	0.00	
1	6.47	0.167	1.76	
1	6.47	0.200	3.67	6.554
1	6.47	0.267	3.38	6.165
1	6.47	0.333	2.74	5.399
1	6.47	0.417	3.32	5.669
1	6.47	0.483	4.45	4.529
1	6.47	0.497	4.80	4.302
2	6.61	0.128	0.00	
2	6.61	0.154	0.33	
2	6.61	0.200	0.94	5.515
2	6.61	0.250	1.37	5.069
2	6.61	0.333	1.97	5.173
2	6.61	0.400	2.56	5.534
2	6.61	0.483	2.79	5.102
2	6.61	0.500	2.89	4.715
3	6.55	0.205	0.00	
3	6.55	0.233	0.19	
3	6.55	0.267	0.40	4.172
3	6.55	0.317	0.60	3.852
3	6.55	0.367	0.83	3.303
3	6.55	0.417	0.87	3.103
3	6.55	0.483	0.86	3.074
3	6.55	0.500	0.87	2.886
1	6.42	0.211	0.00	
1	6.42	0.233	1.34	
1	6.42	0.267	2.65	4.841
1	6.42	0.317	2.65	4.467
1	6.42	0.367	2.73	4.123
1	6.42	0.417	2.79	3.726
1	6.42	0.483	2.92	3.603
1	6.42	0.500	3.03	3.286
2	6.56	0.237	0.00	
2	6.56	0.250	0.10	
2	6.56	0.283	0.51	4.930
2	6.56	0.317	0.82	4.605
2	6.56	0.367	0.98	4.800
2	6.56	0.417	1.16	4.897
2	6.56	0.483	1.12	4.619
2	6.56	0.500	1.06	4.888

Table B3. Timber production plot data.

Plot	Rain cm h^{-1}	Time h	Runoff cm h^{-1}	[PO_4^{-3}] mg L^{-1}	Plot	Rain cm h^{-1}	Time h	Runoff cm h^{-1}	[PO_4^{-3}] mg L^{-1}
13	6.96	0.077	0.00		19	7.54	0.033	0.00	
13	6.96	0.093	0.22		19	7.54	0.050	0.50	
13	6.96	0.118	0.49	0.312	19	7.54	0.075	1.16	0.127
13	6.96	0.202	0.46	0.279	19	7.54	0.158	1.36	0.081
13	6.96	0.285	0.42	0.230	19	7.54	0.242	1.42	0.064
13	6.96	0.368	0.44	0.129	19	7.54	0.325	1.48	0.063
13	6.96	0.452	0.42	0.112	19	7.54	0.408	1.56	0.066
13	6.96	0.568	0.41	0.083	19	7.54	0.492	1.59	0.044
14	5.71	0.078	0.00		20	7.42	0.117	0.00	
14	5.71	0.095	0.26		20	7.42	0.133	0.13	
14	5.71	0.120	0.60	0.173	20	7.42	0.158	0.27	0.198
14	5.71	0.203	0.69	0.206	20	7.42	0.242	0.26	0.180
14	5.71	0.286	0.70	0.166	20	7.42	0.325	0.25	0.164
14	5.71	0.370	0.71	0.138	20	7.42	0.408	0.24	0.141
14	5.71	0.453	0.69	0.121	20	7.42	0.492	0.25	0.124
14	5.71	0.570	0.67	0.107	20	7.42	0.575	0.25	0.111
15	6.84	0.052	0.00		21	7.70	0.067	0.00	
15	6.84	0.061	0.27		21	7.70	0.084	0.17	
15	6.84	0.077	0.54	0.240	21	7.70	0.109	0.34	0.229
15	6.84	0.111	0.55	0.202	21	7.70	0.192	0.33	0.188
15	6.84	0.194	0.55	0.156	21	7.70	0.276	0.35	0.158
15	6.84	0.311	0.56	0.111	21	7.70	0.359	0.35	0.127
15	6.84	0.427	0.59	0.089	21	7.70	0.442	0.33	0.114
15	6.84	0.544	0.60	0.087	21	7.70	0.526	0.34	0.101
16	5.68	0.053	0.00		22	6.97	0.110	0.00	
16	5.68	0.070	0.16		22	6.97	0.127	0.22	
16	5.68	0.095	0.34	0.273	22	6.97	0.152	0.40	0.078
16	5.68	0.178	0.40	0.240	22	6.97	0.235	0.37	0.056
16	5.68	0.262	0.43	0.182	22	6.97	0.318	0.35	0.051
16	5.68	0.345	0.43	0.192	22	6.97	0.402	0.35	0.038
16	5.68	0.428	0.42	0.132	22	6.97	0.485	0.37	0.035
16	5.68	0.545	0.41	0.093	22	6.97	0.568	0.35	0.030
17	7.82	0.159	0.00		23	7.34	0.138	0.00	
17	7.82	0.201	1.31		23	7.34	0.155	0.18	
17	7.82	0.251	2.89	0.150	23	7.34	0.180	0.38	0.203
17	7.82	0.334	3.06	0.224	23	7.34	0.263	0.70	0.144
17	7.82	0.417	3.30	0.193	23	7.34	0.346	1.17	0.136
17	7.82	0.501	3.70	0.194	23	7.34	0.430	1.56	0.219
17	7.82	0.584	3.05	0.201	23	7.34	0.513	1.87	0.285
17	7.82	0.667	2.32	0.213	23	7.34	0.596	1.96	0.319
18	7.49	0.116	0.00		24	7.34	0.141	0.00	
18	7.49	0.157	0.29		24	7.34	0.158	0.17	
18	7.49	0.207	0.55	0.860	24	7.34	0.183	0.38	0.137
18	7.49	0.291	0.46	0.649	24	7.34	0.266	0.42	0.128
18	7.49	0.374	0.40	0.495	24	7.34	0.349	0.44	0.106
18	7.49	0.457	0.43	0.455	24	7.34	0.433	0.46	0.094
18	7.49	0.541	0.45	0.408	24	7.34	0.516	0.47	0.098
18	7.49	0.624	0.44	0.353	24	7.34	0.599	0.49	0.086

Table B4. Straw / timber production plot data.

Plot	Rain cm h^{-1}	Time h	Runoff cm h^{-1}	[PO_4^{-3}] mg L^{-1}	Plot	Rain cm h^{-1}	Time h	Runoff cm h^{-1}	[PO_4^{-3}] mg L^{-1}
1	6.59	0.157	0.00		7	6.56	0.073	0.00	
1	6.59	0.173	1.65		7	6.56	0.089	1.12	
1	6.59	0.198	3.66	0.366	7	6.56	0.114	2.78	0.211
1	6.59	0.298	4.36	0.361	7	6.56	0.214	3.59	0.157
1	6.59	0.398	4.85	0.284	7	6.56	0.314	4.09	0.141
1	6.59	0.498	4.82	0.248	7	6.56	0.414	4.51	0.125
1	6.59	0.598	4.67	0.226	7	6.56	0.514	4.81	0.111
1	6.59	0.665	4.69	0.218	7	6.56	0.564	4.92	0.108
2	6.21	0.127	0.00		8	6.17	0.070	0.00	
2	6.21	0.144	0.39		8	6.17	0.087	1.73	
2	6.21	0.169	1.40	0.099	8	6.17	0.112	3.70	0.219
2	6.21	0.269	2.84	0.066	8	6.17	0.212	3.90	0.147
2	6.21	0.369	4.05	0.088	8	6.17	0.312	4.05	0.113
2	6.21	0.469	4.69	0.093	8	6.17	0.412	4.25	0.098
2	6.21	0.569	4.76	0.104	8	6.17	0.512	4.33	0.092
2	6.21	0.636	4.57	0.112	8	6.17	0.562	4.37	0.079
3	6.63	0.106	0.00		9	6.56	0.010	0.00	
3	6.63	0.123	0.84		9	6.56	0.047	1.49	
3	6.63	0.148	2.07	0.136	9	6.56	0.092	4.16	0.150
3	6.63	0.248	2.86	0.128	9	6.56	0.192	5.73	0.159
3	6.63	0.348	3.31	0.106	9	6.56	0.258	6.01	0.131
3	6.63	0.448	3.47	0.095	9	6.56	0.342	5.84	0.111
3	6.63	0.548	3.52	0.084	9	6.56	0.425	5.94	0.099
3	6.63	0.598	3.47	0.077	9	6.56	0.492	6.09	0.093
4	6.28	0.104	0.00		10	6.94	0.033	0.00	
4	6.28	0.120	1.16		10	6.94	0.050	0.50	
4	6.28	0.145	2.98	0.134	10	6.94	0.075	1.68	0.403
4	6.28	0.245	4.04	0.115	10	6.94	0.158	2.84	0.873
4	6.28	0.345	4.65	0.096	10	6.94	0.242	3.70	1.117
4	6.28	0.445	4.76	0.084	10	6.94	0.325	4.11	1.112
4	6.28	0.545	4.70	0.071	10	6.94	0.408	4.14	1.052
4	6.28	0.595	4.73	0.069	10	6.94	0.492	4.15	1.040
5	5.98	0.107	0.00		11	7.37	0.089	0.00	
5	5.98	0.123	0.26		11	7.37	0.106	1.52	
5	5.98	0.148	0.78	0.599	11	7.37	0.139	3.04	0.107
5	5.98	0.248	1.26	0.295	11	7.37	0.216	5.03	0.096
5	5.98	0.348	1.75	0.398	11	7.37	0.297	5.96	0.082
5	5.98	0.448	2.24	0.477	11	7.37	0.383	4.83	0.073
5	5.98	0.548	2.49	0.517	11	7.37	0.466	5.22	0.069
5	5.98	0.598	2.50	0.534	11	7.37	0.548	5.71	0.065
6	6.82	0.057	0.00		12	7.16	0.069	0.00	
6	6.82	0.074	2.02		12	7.16	0.086	2.02	
6	6.82	0.099	4.41	1.081	12	7.16	0.111	4.55	0.043
6	6.82	0.199	4.97	0.545	12	7.16	0.211	5.31	0.025
6	6.82	0.299	5.30	0.361	12	7.16	0.311	5.60	0.021
6	6.82	0.399	5.64	0.282	12	7.16	0.411	5.60	0.017
6	6.82	0.499	5.95	0.238	12	7.16	0.511	5.59	0.021
6	6.82	0.549	6.08	0.228	12	7.16	0.578	5.61	

APPENDIX C –RUNOFF VALUES

Table C1. P-Index surface runoff values for upland soils in poultry-producing parishes.

Parish	Soil	Area	AvgSlope	Permeability	RunoffClass	RunoffValue	RunoffWeight
		ac	%	in h^{-1}			
Bienville	Beauregard	10500	2	0.6	L	2	21000
	Bellwood	7000	3	0.1	H	8	56000
	Bellwood	6100	10	0.1	VH	16	97600
	Betis	14500	3	20.0	VL	0	0
	Betis	15600	8	20.0	L	2	31200
	Bowie	21100	3	0.6	L	2	42200
	Bowie	22800	6	0.6	M	4	91200
	Boykin	1000	3	2.0	L	2	2000
	Boykin	1000	8	2.0	M	4	4000
	Briley	20100	3	2.0	L	2	40200
	Briley	20800	8	2.0	M	4	83200
	Darden	1200	3	20.0	VL	0	0
	Darley	400	3	0.6	L	2	800
	Darley	500	8	0.6	M	4	2000
	Eastwood	5400	3	0.1	H	8	43200
	Eastwood	5600	8	0.1	VH	16	89600
	Eastwood	4800	16	0.1	VH	16	76800
	Forbing	100	3	0.1	H	8	800
	Forbing	700	8	0.1	VH	16	11200
	Mahan	6300	3	2.0	L	2	12600
	Mahan	2600	8	2.0	M	4	10400
	Malbis	17400	2	2.0	L	2	34800
	Malbis	11500	6	2.0	M	4	46000
	McLaurin	6000	2	2.0	L	2	12000
	McLaurin	2500	6	2.0	M	4	10000
	Metcalf	1400	1	0.6	L	2	2800
	Natchitoches	5000	3	0.1	H	8	40000
	Natchitoches	2600	8	0.1	VH	16	41600
	Oktibbeha	100	3	0.1	H	8	800
	Ruston	7800	3	2.0	L	2	15600
	Ruston	6200	8	2.0	M	4	24800
	Sacul	34600	3	0.2	M	4	138400
	Sacul	76700	8	0.2	H	8	613600
	Sailes	1300	3	2.0	L	2	2600
	Sailes	700	8	2.0	M	4	2800
	Sawyer	18600	3	0.2	M	4	74400
	Shatta	8200	3	0.6	L	2	16400
	Smithdale	200	14	2.0	M	4	800
	Trep	4900	3	2.0	L	2	9800

Table C1, continued. P-Index surface runoff values for upland soils in poultry-producing parishes.

Parish	Soil	Area	AvgSlope	Permeability	RunoffClass	RunoffValue	RunoffWeight
		ac	%	in h^{-1}			
Claiborne	Angie	7900	2	0.2	L	2	15800
	Bowie	19100	3	0.6	L	2	38200
	Darbonne	7300	3	2.0	L	2	14600
	Darley	43700	3	0.6	L	2	87400
	Darley	53600	8	0.6	M	4	214400
	Darley	44700	21	0.2	VH	16	715200
	Eastwood	20100	3	0.1	H	8	160800
	Eastwood	46100	8	0.1	VH	16	737600
	Flo	5400	3	20.0	VL	0	0
	Flo	5200	8	20.0	L	2	10400
	Larue	2600	3	2.0	L	2	5200
	Mahan	12500	3	2.0	L	2	25000
	Mahan	9100	8	2.0	M	4	36400
	McLaurin	2400	3	2.0	L	2	4800
	Ruple	1100	3	2.0	L	2	2200
	Ruple	1400	8	2.0	M	4	5600
	Sacul	18300	3	0.2	M	4	73200
	Sacul	40400	8	0.2	H	8	323200
	Sacul	2900	3	0.2	M	4	11600
	Sacul	13600	8	0.2	H	8	108800
	Smithdale	500	8	2.0	M	4	2000
	Wolfpen	43800	2	2.0	L	2	87600

Table C1, continued. P-Index surface runoff values for upland soils in poultry-producing parishes.

Parish	Soil	Area	AvgSlope	Permeability	RunoffClass	RunoffValue	RunoffWeight
		ac	%	in h^{-1}			
Jackson	Bellwood	5300	3	0.1	H	8	42400
	Bellwood	5000	10	0.1	VH	16	80000
	Betis	1500	3	20.0	VL	0	0
	Betis	1800	8	20.0	VL	0	0
	Bowie	13500	3	0.6	L	2	27000
	Briley	5100	3	2.0	L	2	10200
	Briley	13500	8	2.0	L	2	27000
	Keithville	6900	3	2.0	L	2	13800
	Mahan	3600	3	2.0	L	2	7200
	Mahan	4400	10	2.0	M	4	17600
	McLaurin	17800	3	2.0	L	2	35600
	McLaurin	1600	8	2.0	L	2	3200
	Metcalf	9700	1	0.1	H	8	77600
	Oktibbeha	200	3	0.1	H	8	1600
	Oktibbeha	600	8	0.1	VH	16	9600
	Ruston	6700	3	2.0	L	2	13400
	Sacul	46100	3	0.2	M	4	184400
	Sacul	115500	8	0.2	H	8	924000
	Vaiden	1500	1	0.1	H	8	12000

Table C1, continued. P-Index surface runoff values for upland soils in poultry-producing parishes.

Parish	Soil	Area	AvgSlope	Permeability	RunoffClass	RunoffValue	RunoffWeight
		ac	%	in h^{-1}			
Lincoln	Angie	8700	2	0.2	L	2	17400
	Betis	1500	3	20.0	VL	0	0
	Betis	1200	8	20.0	L	2	2400
	Bowie	11900	3	0.6	L	2	23800
	Bowie	3400	6	0.6	M	4	13600
	Briley	4300	3	2.0	L	2	8600
	Darbonne	2100	3	2.0	L	2	4200
	Darley	29100	3	0.6	L	2	58200
	Darley	42500	8	0.6	M	4	170000
	Darley	32400	21	0.2	VH	16	518400
	Mahan	1700	3	2.0	L	2	3400
	Mahan	12700	8	2.0	M	4	50800
	McLaurin	16800	2	2.0	L	2	33600
	Sacul	12700	3	0.2	M	4	50800
	Sacul	33900	8	0.2	H	8	271200
	Trep	1100	3	2.0	L	2	2200

Table C1, continued. P-Index surface runoff values for upland soils in poultry-producing parishes.

Parish	Soil	Area	AvgSlope	Permeability	RunoffClass	RunoffValue	RunoffWeight
		ac	%	in h^{-1}			
Ouachita	Alaga	800	3	20.0	VL	0	0
	Cadeville	15400	12	0.2	H	8	123200
	Cadeville	900	12	0.2	H	8	7200
	Kirvin	7700	3	0.6	L	2	15400
	Lucy	27900	3	2.0	L	2	55800
	Lucy	55500	12	2.0	M	4	222000
	Ora	1400	6	0.6	M	4	5600
	Ora	3100	10	0.6	M	4	12400
	Ora	14300	8	0.6	M	4	57200
	Ruston	900	2	2.0	L	2	1800
	Ruston	700	6	2.0	M	4	2800
	Ruston	400	10	2.0	M	4	1600
	Savannah	3000	3	0.6	L	2	6000

Table C1, continued. P-Index surface runoff values for upland soils in poultry-producing parishes.

Parish	Soil	Area	AvgSlope	Permeability	RunoffClass	RunoffValue	RunoffWeight
		ac	%	in h^{-1}			
Union	Angie	6000	3	0.2	M	4	24000
	Betis	800	3	20.0	VL	0	0
	Bowie	1300	3	0.6	L	2	2600
	Boykin	1200	3	2.0	L	2	2400
	Briley	1900	3	2.0	L	2	3800
	Darley	6100	3	2.0	L	2	12200
	Darley	54000	8	0.6	M	4	216000
	Darley	33800	21	0.6	H	8	270400
	Eastwood	200	8	0.1	VH	16	3200
	Kirvin	15200	3	0.6	L	2	30400
	Kirvin	20100	8	0.6	M	4	80400
	Mahan	10500	3	2.0	L	2	21000
	Mahan	4800	8	2.0	M	4	19200
	Malbis	21400	3	0.6	L	2	42800
	McLaurin	4100	3	2.0	L	2	8200
	Ora	6500	3	0.6	L	2	13000
	Ora	1900	8	0.6	M	4	7600
	Ruston	60700	3	2.0	L	2	121400
	Sacul	18200	3	0.2	M	4	72800
	Sacul	27400	8	0.2	H	8	219200
	Savannah	13500	3	0.6	L	2	27000
	Savannah	1300	8	0.6	M	4	5200
	Sawyer	10600	3	0.2	M	4	42400
	Sawyer	2800	6	0.2	H	8	22400
	Smithdale	21600	12	2.0	M	4	86400
	Trep	3200	3	2.0	L	2	6400
	Warnock	6300	3	2.0	L	2	12600

Table C2. P-Index erosion values for upland soils in poultry-producing parishes. Average slope length of 200 m, C factor of 0.003 and P factor of 1 are assumed.

Parish	Soil	Area	AvgSlope	LSFactor	Erosion	ErosionWeight
		ac	%		ton ac^{-1} yr^{-1}	
Bienville	Beauregard	10500	2	0.246	0.148	1556
	Bellwood	7000	3	0.335	0.177	1240
	Bellwood	6100	10	1.056	0.558	3406
	Betis	14500	3	0.335	0.070	1015
	Betis	15600	8	0.834	0.174	2719
	Bowie	21100	3	0.335	0.132	2781
	Bowie	22800	6	0.624	0.245	5597
	Boykin	1000	3	0.335	0.082	82
	Boykin	1000	8	0.834	0.205	205
	Briley	20100	3	0.335	0.082	1656
	Briley	20800	8	0.834	0.205	4266
	Darden	1200	3	0.335	0.062	74
	Darley	400	3	0.335	0.070	28
	Darley	500	8	0.834	0.174	87
	Eastwood	5400	3	0.335	0.202	1090
	Eastwood	5600	8	0.834	0.502	2814
	Eastwood	4800	16	1.784	1.075	5162
	Forbing	100	3	0.335	0.202	20
	Forbing	700	8	0.834	0.502	352
	Mahan	6300	3	0.335	0.115	727
	Mahan	2600	8	0.834	0.287	746
	Malbis	17400	2	0.246	0.073	1263
	Malbis	11500	6	0.624	0.184	2117
	McLaurin	6000	2	0.246	0.060	363
	McLaurin	2500	6	0.624	0.153	384
	Metcalf	1400	1	0.159	0.096	134
	Natchitoches	5000	3	0.335	0.132	659
	Natchitoches	2600	8	0.834	0.328	853
	Oktibbeha	100	3	0.335	0.152	15
	Ruston	7800	3	0.335	0.115	900
	Ruston	6200	8	0.834	0.287	1780
	Sacul	34600	3	0.335	0.115	3991
	Sacul	76700	8	0.834	0.287	22021
	Sailes	1300	3	0.335	0.082	107
	Sailes	700	8	0.834	0.205	144
	Sawyer	18600	3	0.335	0.152	2835
	Shatta	8200	3	0.335	0.152	1250
	Smithdale	200	14	1.532	0.528	106
	Trep	4900	3	0.335	0.099	484

Table C2, continued. P-Index erosion values for upland soils in poultry-producing parishes. Average slope length of 200 m, C factor of 0.003 and P factor of 1 are assumed.

Parish	Soil	Area	AvgSlope	LSFactor	Erosion	ErosionWeight
		ac	%		ton ac^{-1} yr^{-1}	
Claiborne	Angie	7900	2	0.246	0.145	1142
	Bowie	19100	3	0.335	0.129	2456
	Darbonne	7300	3	0.335	0.060	440
	Darley	43700	3	0.335	0.060	2634
	Darley	53600	8	0.834	0.170	9115
	Darley	44700	21	2.451	0.941	42068
	Eastwood	20100	3	0.335	0.221	4443
	Eastwood	46100	8	0.834	0.550	25364
	Flo	5400	3	0.335	0.068	369
	Flo	5200	8	0.834	0.170	884
	Larue	2600	3	0.335	0.068	178
	Mahan	12500	3	0.335	0.113	1407
	Mahan	9100	8	0.834	0.280	2549
	McLaurin	2400	3	0.335	0.068	164
	Ruple	1100	3	0.335	0.068	75
	Ruple	1400	8	0.834	0.170	238
	Sacul	18300	3	0.335	0.129	2353
	Sacul	40400	8	0.834	0.320	12933
	Sacul	2900	3	0.335	0.080	233
	Sacul	13600	8	0.834	0.200	2721
	Smithdale	500	8	0.834	0.280	140
	Wolfpen	43800	2	0.246	0.059	2585

Table C2, continued. P-Index erosion values for upland soils in poultry-producing parishes. Average slope length of 200 m, C factor of 0.003 and P factor of 1 are assumed.

Parish	Soil	Area	AvgSlope	LSFactor	Erosion	ErosionWeight
		ac	%		ton ac^{-1} yr^{-1}	
Jackson	Bellwood	5300	3	0.335	0.194	1030
	Bellwood	5000	10	1.056	0.613	3065
	Betis	1500	3	0.335	0.077	115
	Betis	1800	8	0.834	0.191	344
	Bowie	13500	3	0.335	0.145	1953
	Briley	5100	3	0.335	0.090	461
	Briley	13500	8	0.834	0.225	3039
	Keithville	6900	3	0.335	0.127	874
	Mahan	3600	3	0.335	0.127	456
	Mahan	4400	10	1.056	0.399	1756
	McLaurin	17800	3	0.335	0.077	1368
	McLaurin	1600	8	0.834	0.191	306
	Metcalf	9700	1	0.159	0.105	1017
	Oktibbeha	200	3	0.335	0.145	29
	Oktibbeha	600	8	0.834	0.360	216
	Ruston	6700	3	0.335	0.127	848
	Sacul	46100	3	0.335	0.127	5836
	Sacul	115500	8	0.834	0.315	36396
	Vaiden	1500	1	0.159	0.068	103

Table C2, continued. P-Index erosion values for upland soils in poultry-producing parishes. Average slope length of 200 m, C factor of 0.003 and P factor of 1 are assumed.

Parish	Soil	Area	AvgSlope	LSFactor	Erosion	ErosionWeight
		ac	%		ton ac^{-1} yr^{-1}	
Lincoln	Angie	8700	2	0.246	0.148	1289
	Betis	1500	3	0.335	0.070	105
	Betis	1200	8	0.834	0.174	209
	Bowie	11900	3	0.335	0.132	1569
	Bowie	3400	6	0.624	0.245	835
	Briley	4300	3	0.335	0.082	354
	Darbonne	2100	3	0.335	0.062	130
	Darley	29100	3	0.335	0.070	2038
	Darley	42500	8	0.834	0.174	7408
	Darley	32400	21	2.451	0.512	16604
	Mahan	1700	3	0.335	0.115	196
	Mahan	12700	8	0.834	0.287	3646
	McLaurin	16800	2	0.246	0.051	864
	Sacul	12700	3	0.335	0.132	1674
	Sacul	33900	8	0.834	0.328	11123
	Trep	1100	3	0.335	0.070	77

Table C2, continued. P-Index erosion values for upland soils in poultry-producing parishes. Average slope length of 200 m, C factor of 0.003 and P factor of 1 are assumed.

Parish	Soil	Area	AvgSlope	LSFactor	Erosion	ErosionWeight
		ac	%		ton ac^{-1} yr^{-1}	
Ouachita	Alaga	800	3	0.335	0.042	34
	Cadeville	15400	12	1.289	0.520	8004
	Cadeville	900	12	1.289	0.520	468
	Kirvin	7700	3	0.335	0.114	877
	Lucy	27900	3	0.335	0.118	3297
	Lucy	55500	12	1.289	0.455	25239
	Ora	1400	6	0.624	0.220	308
	Ora	3100	10	1.056	0.372	1155
	Ora	14300	8	0.834	0.294	4206
	Ruston	900	2	0.246	0.087	78
	Ruston	700	6	0.624	0.220	154
	Ruston	400	10	1.056	0.372	149
	Savannah	3000	3	0.335	0.101	304

Table C2, continued. P-Index erosion values for upland soils in poultry-producing parishes. Average slope length of 200 m, C factor of 0.003 and P factor of 1 are assumed.

Parish	Soil	Area	AvgSlope	LSFactor	Erosion	ErosionWeight
		ac	%		ton ac^{-1} yr^{-1}	
Union	Angie	6000	3	0.335	0.202	1211
	Betis	800	3	0.335	0.070	56
	Bowie	1300	3	0.335	0.132	171
	Boykin	1200	3	0.335	0.082	99
	Briley	1900	3	0.335	0.082	157
	Darley	6100	3	0.335	0.070	427
	Darley	54000	8	0.834	0.174	9413
	Darley	33800	21	2.451	0.512	17321
	Eastwood	200	8	0.834	0.564	113
	Kirvin	15200	3	0.335	0.152	2317
	Kirvin	20100	8	0.834	0.379	7626
	Mahan	10500	3	0.335	0.115	1211
	Mahan	4800	8	0.834	0.287	1378
	Malbis	21400	3	0.335	0.099	2116
	McLaurin	4100	3	0.335	0.082	338
	Ora	6500	3	0.335	0.115	750
	Ora	1900	8	0.834	0.287	545
	Ruston	60700	3	0.335	0.115	7001
	Sacul	18200	3	0.335	0.132	2399
	Sacul	27400	8	0.834	0.328	8990
	Savannah	13500	3	0.335	0.099	1335
	Savannah	1300	8	0.834	0.246	320
	Sawyer	10600	3	0.335	0.152	1616
	Sawyer	2800	6	0.624	0.284	795
	Smithdale	21600	12	1.289	0.444	9589
	Trep	3200	3	0.335	0.099	316
	Warnock	6300	3	0.335	0.115	727

Table C3. P-Index subsurface drainage values for upland soils in poultry-producing parishes.

Parish	Soil	Area ac	DrainClass	WaterTable	Drainage	DrainWeight
Bienville	Beauregard	10500	MWD	2	4	42000
	Bellwood	7000	SPD	2	4	28000
	Bellwood	6100	SPD	2	4	24400
	Betis	14500	SED	4	2	29000
	Betis	15600	SED	4	2	31200
	Bowie	21100	WD	3	4	84400
	Bowie	22800	WD	3	4	91200
	Boykin	1000	WD	4	2	2000
	Boykin	1000	WD	4	2	2000
	Briley	20100	WD	4	2	40200
	Briley	20800	WD	4	2	41600
	Darden	1200	ED	4	2	2400
	Darley	400	WD	4	2	800
	Darley	500	WD	4	2	1000
	Eastwood	5400	MWD	4	2	10800
	Eastwood	5600	MWD	4	2	11200
	Eastwood	4800	MWD	4	2	9600
	Forbing	100	MWD	4	2	200
	Forbing	700	MWD	4	2	1400
	Mahan	6300	WD	4	2	12600
	Mahan	2600	WD	4	2	5200
	Malbis	17400	MWD	3	2	34800
	Malbis	11500	MWD	3	2	23000
	McLaurin	6000	WD	4	2	12000
	McLaurin	2500	WD	4	2	5000
	Metcalf	1400	SPD	2	4	5600
	Natchitoches	5000	WD	4	2	10000
	Natchitoches	2600	WD	4	2	5200
	Oktibbeha	100	MWD	4	2	200
	Ruston	7800	WD	4	2	15600
	Ruston	6200	WD	4	2	12400
	Sacul	34600	MWD	2	4	138400
	Sacul	76700	MWD	2	4	306800
	Sailes	1300	WD	4	2	2600
	Sailes	700	WD	4	2	1400
	Sawyer	18600	MWD	2	4	74400
	Shatta	8200	MWD	2	4	32800
	Smithdale	200	WD	4	2	400
	Trep	4900	MWD	3	2	9800

Table C3, continued. P-Index subsurface drainage values for upland soils in poultry-producing parishes.

Parish	Soil	Area ac	DrainClass	WaterTable	Drainage	DrainWeight
Claiborne	Angie	7900	MWD	3	2	15800
	Bowie	19100	WD	3	4	76400
	Darbonne	7300	WD	4	2	14600
	Darley	43700	WD	4	2	87400
	Darley	53600	WD	4	2	107200
	Darley	44700	WD	4	2	89400
	Eastwood	20100	MWD	4	2	40200
	Eastwood	46100	MWD	4	2	92200
	Flo	5400	SED	4	2	10800
	Flo	5200	SED	4	2	10400
	Larue	2600	WD	4	2	5200
	Mahan	12500	WD	4	2	25000
	Mahan	9100	WD	4	2	18200
	McLaurin	2400	WD	4	2	4800
	Ruple	1100	WD	4	2	2200
	Ruple	1400	WD	4	2	2800
	Sacul	18300	MWD	4	2	36600
	Sacul	40400	MWD	4	2	80800
	Sacul	2900	MWD	4	2	5800
	Sacul	13600	MWD	4	2	27200
	Smithdale	500	WD	4	2	1000
	Wolfpen	43800	WD	3	4	175200

Table C3, continued. P-Index subsurface drainage values for upland soils in poultry-producing parishes.

Parish	Soil	Area ac	DrainClass	WaterTable	Drainage	DrainWeight
Jackson	Bellwood	5300	SPD	2	4	21200
	Bellwood	5000	SPD	2	4	20000
	Betis	1500	SED	4	2	3000
	Betis	1800	SED	4	2	3600
	Bowie	13500	WD	3	4	54000
	Briley	5100	WD	4	2	10200
	Briley	13500	WD	4	2	27000
	Keithville	6900	MWD	2	4	27600
	Mahan	3600	WD	4	2	7200
	Mahan	4400	WD	4	2	8800
	McLaurin	17800	WD	4	2	35600
	McLaurin	1600	WD	4	2	3200
	Metcalf	9700	SPD	2	4	38800
	Oktibbeha	200	MWD	4	2	400
	Oktibbeha	600	MWD	4	2	1200
	Ruston	6700	WD	4	2	13400
	Sacul	46100	MWD	2	4	184400
	Sacul	115500	MWD	2	4	462000
	Vaiden	1500	SPD	2	4	6000

Table C3, continued. P-Index subsurface drainage values for upland soils in poultry-producing parishes.

Parish	Soil	Area ac	DrainClass	WaterTable	Drainage	DrainWeight
Lincoln	Angie	8700	MWD	3	2	17400
	Betis	1500	SED	4	2	3000
	Betis	1200	SED	4	2	2400
	Bowie	11900	WD	3	4	47600
	Bowie	3400	WD	3	4	13600
	Briley	4300	WD	4	2	8600
	Darbonne	2100	WD	4	2	4200
	Darley	29100	WD	4	2	58200
	Darley	42500	WD	4	2	85000
	Darley	32400	WD	4	2	64800
	Mahan	1700	WD	4	2	3400
	Mahan	12700	WD	4	2	25400
	McLaurin	16800	WD	4	2	33600
	Sacul	12700	MWD	2	4	50800
	Sacul	33900	MWD	2	4	135600
	Trep	1100	MWD	3	2	2200

Table C3, continued. P-Index subsurface drainage values for upland soils in poultry-producing parishes.

Parish	Soil	Area ac	DrainClass	WaterTable	Drainage	DrainWeight
Ouachita	Alaga	800	ED	4	2	1600
	Cadeville	15400	MWD	4	2	30800
	Cadeville	900	MWD	4	2	1800
	Kirvin	7700	WD	4	2	15400
	Lucy	27900	WD	4	2	55800
	Lucy	55500	WD	4	2	111000
	Ora	1400	MWD	2	4	5600
	Ora	3100	MWD	2	4	12400
	Ora	14300	MWD	2	4	57200
	Ruston	900	WD	4	2	1800
	Ruston	700	WD	4	2	1400
	Ruston	400	WD	4	2	800
	Savannah	3000	MWD	2	4	12000

Table C3, continued. P-Index subsurface drainage values for upland soils in poultry-producing parishes.

Parish	Soil	Area ac	DrainClass	WaterTable	Drainage	DrainWeight
Union	Angie	6000	MWD	3	2	12000
	Betis	800	SED	4	2	1600
	Bowie	1300	WD	3	4	5200
	Boykin	1200	WD	4	2	2400
	Briley	1900	WD	4	2	3800
	Darley	6100	WD	4	2	12200
	Darley	54000	WD	4	2	108000
	Darley	33800	WD	4	2	67600
	Eastwood	200	MWD	4	2	400
	Kirvin	15200	WD	4	2	30400
	Kirvin	20100	WD	4	2	40200
	Mahan	10500	WD	4	2	21000
	Mahan	4800	WD	4	2	9600
	Malbis	21400	MWD	3	2	42800
	McLaurin	4100	WD	4	2	8200
	Ora	6500	MWD	2	4	26000
	Ora	1900	MWD	2	4	7600
	Ruston	60700	WD	4	2	121400
	Sacul	18200	MWD	2	4	72800
	Sacul	27400	MWD	2	4	109600
	Savannah	13500	MWD	2	4	54000
	Savannah	1300	MWD	2	4	5200
	Sawyer	10600	MWD	2	4	42400
	Sawyer	2800	MWD	2	4	11200
	Smithdale	21600	WD	4	2	43200
	Trep	3200	MWD	3	2	6400
	Warnock	6300	MWD	3	2	12600

VITA

William Lucas Felicien was born on June 25, 1967, in the Caribbean Island of St. Lucia, He earned a diploma in agriculture in 1988 from Guyana School of Agriculture, South America. He began his career as an Field Assistant for Saint Lucia Model Farms in Roseau, Saint Lucia from 1985 until .1988. After which, he was a Field Research Assistant for the Windward Islands Banana Growers Association Research and Development Division in Roseau, Saint Lucia, 1988 until 1989. Lastly, he was as Agricultural Officer, for the Government of Saint Lucia, Ministry of Agriculture, Agriculture Engineering Services Division in Saint Lucia from 1989 to 2001. As a Minister of Agriculture he maintained Hydrological and Agro-meteorological network. He earned a Bachelor of Science degree in agronomy in 2004 from Louisiana State University, after which he started work on his Master of Science degree in soil science at LSU in 2005.