TESTING A CONNECTIVITY FACTOR FOR THE GEORGIA P INDEX

by

JOHN H. BRYANT

(Under the Direction of David Radcliffe)

ABSTRACT

Nonpoint source pollution in the Etowah River Watershed located in North Georgia is leading to eutrophic conditions in Lake Allatoona and a major source of P has been the poultry industry, specifically the litter generated by the millions of chickens grown annually within the watershed (USEPA, 2009). The Georgia Phosphorus Index (PI) provides a tool to predict bioavailable P loss from agriculturally based land use to surface waters. Gburek et al. (2000b) suggested a connectivity factor to improve the PI based on distance of a field from a stream. According to Osmond et al. (2006), "distance to water resource" is considered a factor in 8 out of 12 states' PIs in the southern United States, but not in Georgia's PI. Romeis (2008) monitored first-order streams on three forested and nine agricultural sites for flow and P concentration. The objective of this study was to compare measured P loads from the agricultural sites to estimates based on the Georgia PI, with and without a modification to include a connectivity factor. Survey data on management practices and soil measurements provided input for the PI and site characteristics. Curve numbers (CN) were calculated from the runoff data of Romeis (2008) and compared to those estimated following standard methods (NRCS, 2001b). Our study showed that the NRCS curve number approach consistently underestimated runoff from the agricultural and forested sites. A method was developed to incorporate a connectivity factor. Results revealed that incorporating the connectivity factor into the PI increased correlations to TP loads compared to the current PI within the watersheds, but the current PI proved very effective as well.

INDEX WORDS: Phosphorus Index, Poultry, Curve Number, Watershed, Etowah, Georgia

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JOHN H. BRYANT

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JOHN H. BRYANT

Major Professor:	David Radcliffe
Committee:	Miguel Cabrera Mark Risse

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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DEDICATION

I am excited to dedicate this thesis to my late grandmother, Big Mama. She was adamant about my continuing education and a source of encouragement in my life. She was the foundation of a family that believes in each other, which has made the difference in my life.

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I thought this would be the easy part of the thesis. However, it brings to mind all of the hard work and effort set forth by someone who passed away just months before the completion of this thesis. Josh Romeis orchestrated this project, but more than that he was a great friend. We had a lot of great and not so great times through the project, but I really want to say thanks for all the help and support along the way.

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I could not go with thanking my amazing wife, Amanda, and my wonderful mom, dad, and sister. I give thanks to the Lord for blessing me beyond belief, and most of all for my salvation.

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CHAPTER I
INTRODUCTION

Lake Allatoona in northwest Georgia (U.S.) receives a large annual load of phosphorus (P), with the Etowah Arm of the lake receiving over 2.1 million kg P yr^{-1} (USEPA, 2009). Researchers concluded during this period that the lake was shifting from mesotrophic toward eutrophic conditions, and suggested that unless P loads were reduced within 10 years, the water could no longer provide drinking and recreational needs. In 2002, this problem led the Georgia Environmental Protection Division (GAEPD) to impose a P load restriction of 4.78 kg ha^{-1} m^{-1} yr^{-1} (1.3 lb ac^{-1} ft^{-1} yr^{-1}). Limiting P inputs in the Lake Allatoona watershed will be a challenge since it encompasses several of the fastest growing counties in the United States.

Point sources, including wastewater treatment plants, are not the problem in the lake; and, in fact, only contribute about 1% of the total P into the Etowah River arm of Lake Allatoona (USEPA, 2009). Much of this nonpoint P is attributed to the poultry industry which produces litter with a high P concentration that is land applied within the watershed. Ultimately, a portion of the land applied P moves into farm streams and is then transported by the Etowah River and other tributaries to Lake Allatoona.

With the P load restriction in place, a solution to the high levels of P must be developed. Ideally, P trading credits could reduce nonpoint sources and alleviate the pressure on point sources.

Georgia’s P Index (PI), a tool to assess the risk of bioavailable P loss from a field, could be an effective means to estimate credits for agricultural trading. Gburek et al. (2000b), proposed adding a connectivity factor to determine the contributing area of runoff for a given size storm event. The connectivity factor essentially allows the PI to incorporate a factor to further assess the risk of bioavailable P loss based on the distance a field is from a stream.

In this study, the accuracy of both the original and modified PI was assessed using data collected from several small agricultural watersheds in the Etowah River basin by Romeis (2008). The modified PI may enable farmers and other stakeholders to decrease nonpoint sources of P from entering Lake Allatoona.

CHAPTER II
LITERATURE REVIEW

Our surface freshwater resources are limited because <1% of all water is available for use (U.S. Geological Survey, 2005). These uses include drinking, recreation, transportation, industry, irrigation, aesthetics, and habitat. However, even with the limited amount of surface water available in the form of lakes, rivers, streams, and wetlands, there is still enough water to fulfill its uses as long as the quality is maintained. One of the threats to water quality is excessive nutrient loading. Excessive nutrients have severe effects on the use of water and may lead to eutrophication.

Eutrophication, caused by Nitrogen (N) and Phosphorus (P), is the third leading cause of impairments in U.S. surface waters. Impaired waters are defined as those that are not suitable for their designated uses, and are required to be listed under the Section 303(d) of the 1972 Clean Water Act (USEPA, 2004). Lake Allatoona in Georgia (U.S.) is one example of an impaired water body because of the excessive P load from its watershed. In 2002, Georgia implemented P load restrictions within the watershed to help alleviate the problem.

Under U. S. Environmental Protection Agency (EPA) water quality criteria, P should not exceed 0.05 mg L^{-1} if streams discharge into lakes or reservoirs, 0.025 mg L^{-1} within a lake or reservoir, and 0.1 mg L^{-1} in streams or flowing waters not discharging into lakes or reservoirs (NC State University, 2005). The recommended criteria are intended to address eutrophication and the associated effects of excessive nutrient input within a watershed. Typically, eutrophic lakes have P concentrations exceeding 0.02 mg L^{-1}. Mesotrophic levels are between 0.01 and 0.02 mg L^{-1}, and oligotrophic are below 0.01 mg L^{-1} (Murphy, 2002). Levels of P in Lake

Allatoona indicate that it is between mesotrophic and eutrophic, and the lake is becoming more eutrophic (Rose, 1999).

Sources of P are widespread within a watershed from both point and nonpoint inputs. The Lake Allatoona watershed contains eight permitted point sources, in combination with numerous nonpoint sources from a high production of broilers and beef cattle on agricultural land and urban development (Rose, 1999). Land use within the Lake Allatoona watershed is predominantly forested (87%), with the greatest anthropogenic impact being land with agricultural practices, predominantly pasture and hay (7.7%) (USEPA, 2003). This use within the watershed suggests that one of the primary nonpoint sources is animal waste. When rainfall occurs, runoff from agricultural land often contains P. P loads increase with increasing precipitation and sediment loss (Udawatta et al., 2004). Kuykendall et al. (1999) found that broiler litter application followed by a large precipitation event resulted in an increase in the DRP loss from the field. Also, the same study states that a percentage of TP in surface runoff as DRP to be 68% following broiler litter application in soils within the Piedmont Ecoregion. Fleming and Cox (2001) showed that over 98% of P is lost in overland flow off grazed pastures, and 45% of the TP is dissolved P for an agricultural watershed in Australia (Fleming and Cox, 2001). The primary point sources include polyphosphates in industrial discharges, mining, and, in Lake Allatoona's case, wastewater treatment plants (Murphy, 2002).

There are many forms of P in water. P can either be in a particulate phase or a dissolved phase. The particulate phase includes P in living and dead plankton, P precipitates, amorphous P, and P adsorbed to particulates. The dissolved phase includes both inorganic and organic P. Phosphates (PO_4^{-3}) are the typical form in natural waters; they can be in an inorganic or organic form (Murphy, 2002).

Inorganic P includes orthophosphates and polyphosphates. Orthophosphate, or reactive P, is one form used by plants and the most stable form. It is found both naturally and from sewage and fertilizers. Polyphosphates are used in detergents and will eventually convert to orthophosphates in water. Organic phosphate is that which is bound to plant, animal tissue, or any organic matter. Decomposition of this organic matter can convert it back to orthophosphate (Murphy, 2002).

Not only does P enter the water in various forms, but it is also able to change as it moves through the watershed. When P is available it is quickly taken up from the water column by the phytoplankton and converted to the organic form. The Redfield Ratio indicates that P averages only 1% of phytoplankton composition. However, Redfield still considered P to be the limiting nutrient (or limiting factor) because of the small amount found in surface waters (Redfield, 1958). As the organisms begin to die, they settle to the surface of the sediment. The organic P will decompose and either be resuspended in the water column or more likely be mineralized by storing the P in the pore water or on adsorption sites on the sediment. Release of P from the sediments will occur according to a chemical equilibrium with adsorbed P. In addition, P bound on iron oxide may be released with iron reduction or in seasonal fluxes. As total P input decreases with the lower flows in the summer and fall, release of P from within the lake tends to increase in eutrophic water bodies. This increase may be the result of microbial activity, which use the settled phytoplankton as a food source and remove the P from the sediment. Another possibility may be that in dimictic systems, the lower oxygen concentrations near the bottom reduce iron oxides and subsequently release P adsorbed in the bottom sediments (Wassmann and Olli, 2004; Parker, 2004). Shallow polymictic lakes tend to release P more frequently (Peterson, 2005).

Dissolved P may be lost by transfer to the sediment, however most P adsorbed to sediment can be attributed to the organic form. This P is available to enter the water column again if the sediment becomes P-saturated. Inorganic P in the sediments may either be Fe, Mn, Al, or Ca bound. Mobile P, in particular iron-bound and organic P, exists on shallow sediment but with depth these are replaced by stable minerals composed of P (Figure 1). Therefore, cycling usually occurs with the shallow sediment interactions (Wassmann and Olli, 2004). The largest percentage of P in lakes (<70%) is often in the particulate phase in sediments. Estimates range from 25% to 50% of P loading bound to lake sediment, and the supply of phosphorus from sources within a lake can be several times the supplies from external sources for periods of time on the order of months (Peterson, 2005).

Iron oxide plays an important role in the P cycle. As Fe(II) is oxidized to Fe(III) it has a high capacity to adsorb P and precipitate. However, if the precipitate is reduced, then P is released. This relationship is altered by the presence of sulfate (SO_4^{2-}) because sulfate bonds to Fe(III) instead of phosphate, therefore mobilizing more P. It also removes dissolved Fe(II) and precipitates as FeS, which leads to permanent burial and much less P buffering capacity by the iron oxides (Figure 2). A certain suggested ratio of dissolved Fe:P must be maintained to allow removal of P by the iron when oxic conditions prevail. The suggested ratio is at least 2:1 (Wassmann and Olli, 2004).

The relationship of Fe and P plays a major role in the Lake Allatoona watershed. Soils within the watershed are Ultisols, which are high in clay and Fe at a low pH. The tendency of soluble P is to react with Fe oxides in a strong adsorption reaction, especially at low pHs. Therefore, as runoff occurs within the watershed, the highly erodible clay particles act as a vehicle transporting P to the water. The suspended sediment continues to provide a buffer for P in the bodies of water throughout the watershed. Resuspension may occur through reduction of the iron oxides (pH), seasonal fluxes, or microbial activity as mentioned before, but most likely from mineralized or stored P.

The state of Georgia is seeking to reduce runoff from various land uses by recommending best management practices (BMPs) that contain specific instructions to reduce soil loss and runoff. Currently, farmers are not required to use BMPs on most farms, but rules are becoming stricter under Phase II of the 1972 Clean Water Act (CWA). In 2002, the EPA amended new concentrated animal feeding operations (CAFO) rules to define CAFOs as any feeding area that a permitting authority determines is a significant contributor of pollutants to the water (USEPA, 2002). Under the new ruling, there are three classifications, small, medium, and large CAFOs. Farmers with more than 1000 head of cattle or 125,000 broilers are considered a large CAFO and must submit a National Pollutant Discharge Elimination System (NPDES) permit along with development of a comprehensive nutrient management plan (CNMP) for their farm. Documentation and annual submittal of CNMP records to the permitting authority will provide valuable data not currently available to the state (AWARE, 2003).

Romeis (2008) monitored streams within the Lake Allatoona watershed, specifically in the Etowah River watershed, which included different characteristics by farms. Some of the sites monitored were farms that had not participated in any conservation programs, were without stack houses for storage of litter, had improper or no use of CNMPs, had high levels of litter application, and had little or no use of buffer zones or fencing cattle from streams. Alternatively some farms monitored had participated in conservation programs, used stack houses, used a proper CNMP, had intermediate levels of litter application, and had riparian buffers and/or fenced cattle from streams. Also included were farms applying less than 4.5 Mg ha^{-1} yr^{-1} or exporting all litter.

Stack houses work well along with a CNMP to produce the best benefits of poultry manure as fertilizer, without negative impacts. These simple buildings allow farmers to store and compost poultry litter until needed based on crop and soil conditions. Reduced cost from replacing inorganic fertilizers with litter provides extra incentive for farmers to implement CNMPs (Cunningham et al., 2003). Storage also increases the amount of plant available P with time, because P release is directly related to decomposition of organic matter (Merka and Ritz, 2004). Litter application and timing also works well with a CNMP. Higher application rates (13 Mg ha^{-1}) produce a higher amount P runoff than lesser rates (2 and 7 Mg ha^{-1}). Timing between litter application and a rainfall producing a runoff event also affect P loss (Schroeder et al., 2004). Poultry litter is not the only source of P from pastures in the Lake Allatoona watershed. Unfenced streams allowing cattle access increases P loading too (Byers, 2005). Buffer zones effectively remove nutrients and filter runoff, in addition to other benefits (GaSWCC, 2000).

A Nutrient Management Plan (NMP) can be defined as "managing the amount, source, placement, form and timing of applications of nutrients and soil amendments", and provides one of the best preventative measures to reducing P runoff (NRCS, 2001a). CNMP's are required if you are a CAFO and are essentially a much more in depth NMP addressing such issues as manure storage and runoff in greater detail for example. However, many of the plans are currently N based, which usually results in an over application of P, since N is often the limiting factor in the soil. Alternatively, P based NMPs reduce P loss and lessen the negative impacts on aquatic systems (Sharpley, 1999). NMPs, especially those that are P based, provide a mechanism to balance nutrients within a farm. When balanced, a farm lessens its dependence on alternate methods focused solely on preventing P runoff. By managing feeding strategies, along with testing for nutrients within the litter and those needed by the crop, litter can be optimized for its benefits while minimizing the negative impacts. Several states, including Georgia, have developed a P Index (PI) that provides a quantitative approach for the establishment of P based NMPs. The PI uses the factors of the soil P and additional P with fertilization (Osmond et al., 2006).

The Georgia PI is a field based tool to assess the risk of bioavailable P loss for an agricultural landuse. Computation of Georgia's PI includes combining the soluble P and particulate P in runoff, in addition to soluble P in leachate. Runoff calculations for P loss consider P in the soil and both organic and inorganic fertilizers applied. Application rates, buffer zones, and soil loss calculated using the Revised Universal Soil Loss Equation (RUSLE) are factors involved in assessing the risk of total P loss. The volume of runoff is generated from the curve number method. The final P Index value calculated gives the farmer an estimate of the potential for movement of P off site and suggestions to reduce P transport (Cabrera et al., 2005). Gaskin et al. (2005) found that the Georgia PI was an effective tool for assessing the risk of high P loss from poultry litter application sites. However, the current PI assesses the risk of P loss from an edge-of-field viewpoint, and not necessarily to an edge-of-stream viewpoint.

Gburek et al. (2000) suggested a modification to the PI that estimates the loss of the P at the edge of a stream and attempts to represent the connectivity of the field to stream. The modification attempts to identify critical source areas that control most of the P export from the field. Using the return period of a particular storm, the PI estimates the contributing area of a small watershed. For example, the larger the storm the larger the contributing area would become. Gburek et al. (2002) further explain the modification as a generalization of the variable-source-area (VSA) hydrologic concept, and implement the modification using data from a small agricultural watershed in east-central Pennsylvania. The result of the study is an applicable and generalized approach that can be implemented in the PI, as an improvement. However, this approach has not been tested in Georgia, but has been implemented in some fashion in other states. According to Osmond et al. (2006), "distance to water resource" is considered a factor in 8 out of 12 states' PIs in the southern United States. The P data from the nine agricultural watersheds in the study by Romeis (2008) provided the opportunity to test the current PI and the PI with a connectivity factor, and determine if the modification is an improvement.

Eutrophication is an imminent problem facing the United State's water quality. When too much of a limiting nutrient, in this case P, is contributed by a watershed negative impacts on the uses occur on the environment and the organisms that use its resources, including humans. The integration of agricultural BMPs to reduce nonpoint source pollution is primarily voluntary in the state of Georgia, and the benefits are unknown. Monitoring can provide a means to quantitatively measure the reduction of P contribution from a specific site. The knowledge gained through monitoring BMP effectiveness and evaluating the current and modified version of the PI could then be implemented to create a valuable part of the credit trading system. Trading of P credits involves a low cost reduction of P input by one source, so that a source with a higher cost of reduction can purchase those credits and subsequently release more P. P credits will be awarded to farmers reducing P contribution to the watershed by implementing BMPs. These credits will encourage reduction of P from the largest nonpoint source. The use and improvement of the PI, the primary tool to evaluate bioavailable P loss, could lead to a decrease in the P loading within Lake Allatoona watershed.

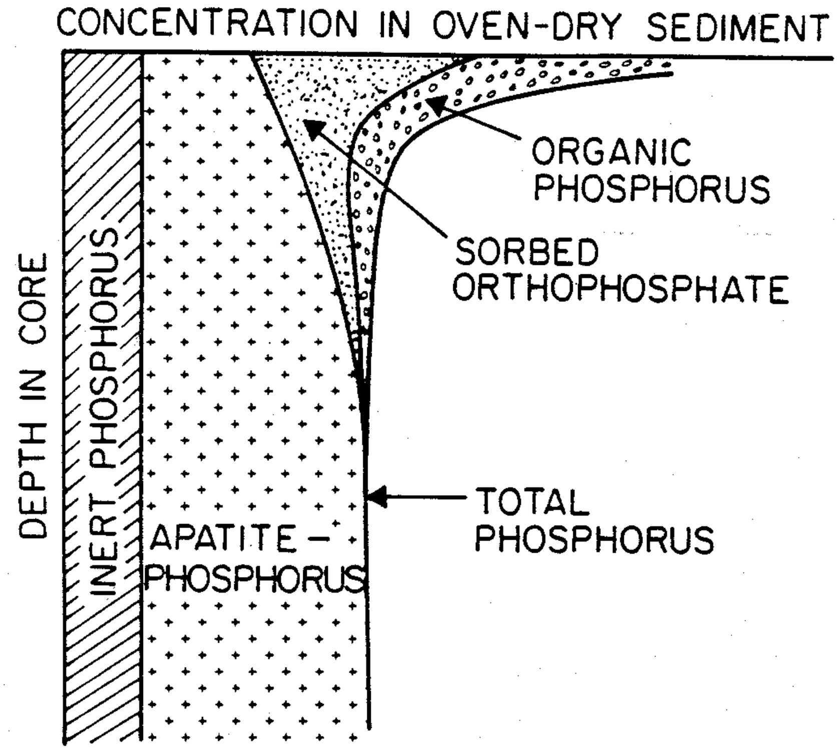

Figure 1. Distribution of P in a sediment profile from Lake Erie with areas indicating percentage (Peterson, 2005).

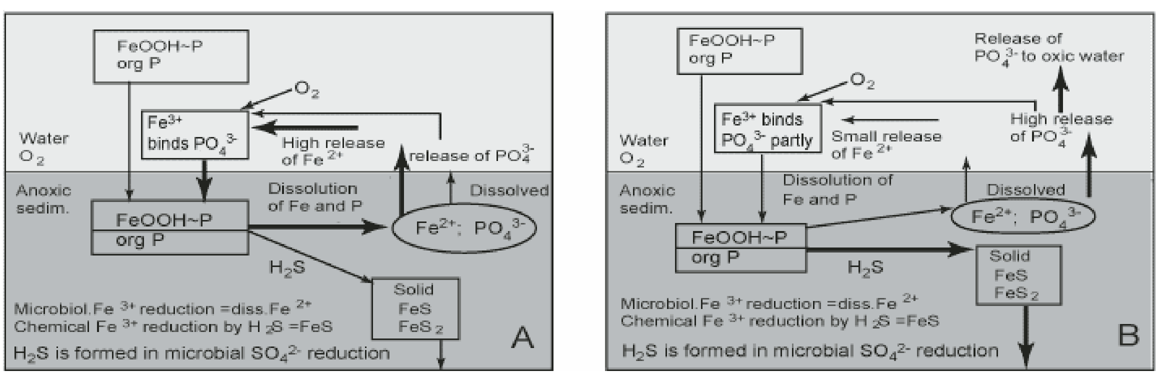

Figure 2. Cycling of iron (Fe), sulphur (S) and phosphorus (P) in a (A) SO_4^{2-} -poor and (B) SO_4^{2-} -rich aquatic environment (Wassmann and Olli, 2004).

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CHAPTER III

TESTING A CONNECTIVITY FACTOR FOR THE GEORGIA P INDEX [1]

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1 Bryant, J.H., D.E. Radcliffe, M. Cabrera, M. Risse, and R. Jackson. To be submitted to Journal of Soil and Water Conservation.

ABSTRACT

Nonpoint source pollution in the Etowah River Watershed located in North Georgia is leading to eutrophic conditions in Lake Allatoona and a major source of P has been the poultry industry, specifically the litter generated by the millions of chickens grown annually within the watershed (USEPA, 2009). The Georgia Phosphorus Index (PI) provides a tool to predict bioavailable P loss from agriculturally based land use to surface waters. Gburek et al. (2000b) suggested a connectivity factor to improve the PI based on distance of a field from a stream. According to Osmond et al. (2006), "distance to water resource" is considered a factor in 8 out of 12 states' PIs in the southern United States, but not in Georgia's PI. Romeis (2008) monitored first-order streams on three forested and nine agricultural sites for flow and P concentration. The objective of this study was to compare measured P loads from the agricultural sites to estimates based on the Georgia PI, with and without a modification to include a connectivity factor. Survey data on management practices and soil measurements provided input for the PI and site characteristics. Curve numbers (CN) were calculated from the runoff data of Romeis (2008) and compared to those estimated following standard methods (NRCS, 2001). Our study showed that the NRCS curve number approach consistently underestimated runoff from the agricultural and forested sites. A method was developed to incorporate a connectivity factor. Results revealed that incorporating the connectivity factor into the PI increased correlations to TP loads compared to the current PI within the watersheds, but the current PI proved very effective as well.

INTRODUCTION

Lake Allatoona in northwest Georgia (U.S.) receives a large annual load of phosphorus (P), with the Etowah Arm receiving over 2.1 million kg P yr^{-1} (USEPA, 2009). Researchers concluded during this period that the lake was shifting from mesotrophic toward eutrophic conditions, and suggested that unless P loads were reduced within 10 years, the water could no longer provide drinking and recreational needs. In 2002, this problem led the Georgia Environmental Protection Division (GAEPD) to impose a P load restriction of 4.78 kg ha^{-1} m^{-1} yr^{-1} (1.3 lb ac^{-1} ft^{-1} yr^{-1}). Limiting P inputs in the Lake Allatoona watershed will be a challenge since it encompasses several of the fastest growing counties in the United States.

Point sources, including wastewater treatment plants, are not the problem in the lake; and, in fact, they only contribute approximately 1% of the total P into the Etowah River arm of Lake Allatoona. Nonpoint sources are the main contributor of the remaining P from the Etowah River arm of the lake. Other than forested land, the largest portion of land use in the Etowah River watershed is agricultural (USEPA, 2009). Much of this nonpoint P is attributed to the poultry industry which produces litter with a high P concentration that is land applied within the watershed. Ultimately, a portion of this land applied P moves into farm streams and is then transported by the Etowah River and other tributaries to Lake Allatoona.

With the P load restriction in place, a solution to the high levels of P must be developed. Ideally, P trading credits could reduce nonpoint sources and alleviate the pressure on point sources. P trading credits would allow a source with a high cost of reduction to receive credits gained by other sources with a lower cost of reduction. Lake Allatoona's primary trading may stem from farmers reducing P inputs at a relatively low cost to allow wastewater treatment plants to increase in size and P discharge. Establishing a credit trading ratio, which accounts for any uncertainty in the net reduction of P, and the trading framework, to connect buyers and sellers, is a complicated process.

Georgia's P Index (PI) could be an effective tool to help establish a trading credit ratio. Its purpose is aimed at assessing the risk of P loss from agricultural systems. Runoff, application rates, and buffers are all input parameters of the current PI. A modification of the original PI, as suggested by Gburek et al. (2000b), could also be implemented. The modification essentially creates a connectivity factor to determine the contributing area of runoff for a given size storm event.

In this study, the accuracy of both the original and modified PI was assessed using data collected from several small agricultural watersheds in the Etowah River basin by Romeis (2008). In Romeis' study, first-order streams draining poultry farms, with and without best management practices (BMPs) were monitored. Streams were monitored for precipitation, P, sediment, and flow. BMPs included consideration of application rates, nutrient management plans, use of stack houses, and riparian buffers or exclusion fencing of streams. In this study, the rainfall and runoff data collected by Romeis (2008) were used to establish curve numbers and the curve numbers were compared to those needed for input to the current and modified versions of the PI. Actual P loads calculated by Romeis (2008) for each site were compared to the potential loss of P predicted by both methods of the PI.

MATERIALS AND METHODS

Study Sites

Romeis (2008) used three criteria in selecting sites: 1) the location was within the upper Etowah River Watershed (hydrologic unit 03150104); 2) it contained a commercial poultry operation, possibly in conjunction with beef cattle; and 3) a headwater stream drained the area and there was little to no impact of landuse that was not associated with agriculture or silviculture. Three streams were in forested watersheds (FORS) and these served as reference streams. The other nine streams were agricultural dominated watersheds (AG) that included poultry and/or cattle production. All three forested sites, FORS-1, FORS-2, FORS-3, were located within the Chattahoochee National Forest, and the agricultural sites (AG-4, AG-5, AG-6, AG-7, AG-8, AG-9, AG-10, AG-11, AG-12) were within Cherokee, Dawson, Forsyth, and Lumpkin Counties (Figure 3). A stream at each site was selected, eleven being perennial first-order streams and one being an ephemeral stream (AG-12). FORS-1, AG-4, AG-9, and AG-11 each contained a pond within its watershed. The Etowah watershed, including the selected sites, is located within the Blue Ridge or Piedmont Level III ecoregions near the foothills of the Southern Appalachian Mountains (Omernik, 1987). The study sites are characterized by a humid, temperate climate. Soils are predominately Ultisols and are described by McIntyre (1972) and Jordan et al. (1973) (Appendix A). Sites ranged in area from 2 to 44 hectares and had varied characteristics including number of livestock raised, management practices, landuse history, and other factors (Table 1).

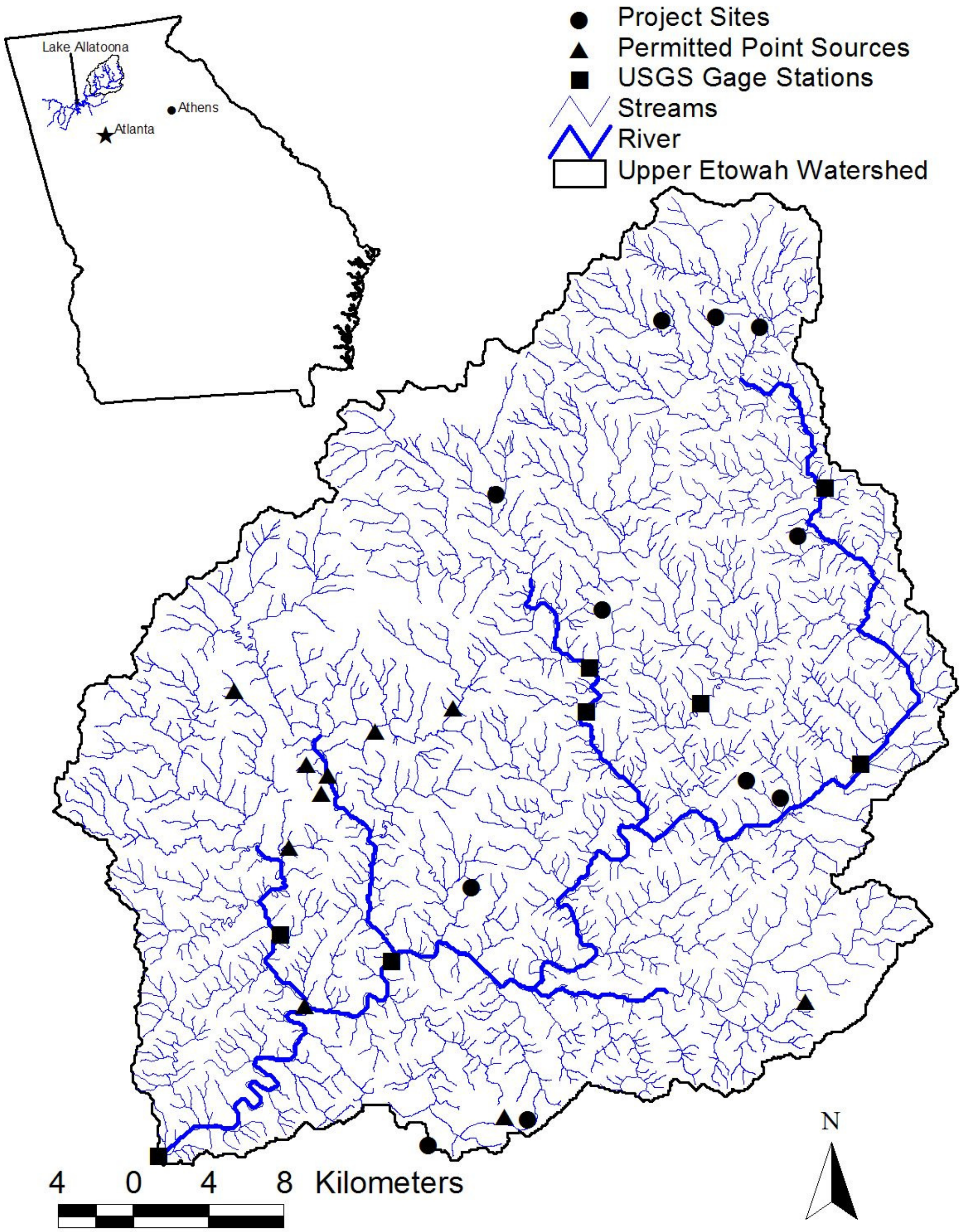


Figure 3. Map of the Etowah River Watershed and site locations.

Table 1. Survey watershed size and general characteristics.

Site	Land Use	Drainage Area (ha)	# of Poultry Houses	Stream Buffer	Livestock Grazing		Pond in Watershed
					Type	Excluded from channel	
1	FORS	44	NA	NA	NA	NA	Yes
2	FORS	28	NA	NA	NA	NA	No
3	FORS	31	NA	NA	NA	NA	No
4	AG	28	3	No	Cattle	No	No
5	AG	2.8	3	No	Cattle	No	No
6	AG	2.4	3	No	Cattle	Yes	No
7	AG	9.7	3	No	Horses	Yes	No
8	AG	7.3	2	Yes	None	NA	No
9	AG	11	9	Partial	Horses, Goats	Yes	Yes
10	AG	19	12	Partial	Cattle	No	No
11	AG	16	2	Partial	Cattle	No	Yes
12	AG	3.2	2	No	Sheep	No	No

Hydrologic and Water Quality Monitoring by Romeis (2008)

In the study by Romeis (2008), monitoring equipment and flumes (for all but one site where a culvert was used) were installed between January and May 2005. ISCO 720 automated samplers measured stage height and collected samples during storms. Stage height was converted to flow using a calibration equation. A tipping bucket rain gage recorded rainfall at each site. Samples were analyzed for total P (TP) following Koroleff (1983) with modifications by Qualls (1989). Samples were also analyzed for dissolved reactive P (DRP) in accordance with Standard Method 4500-P F (APHA, 1998). Monitoring ceased between September and October 2006.

Soil Sampling

In this study, soil samples were collected from each site to measure soil test phosphorus (STP) levels. Individual sites were divided into fields based on land cover characteristics using ArcView GIS 3.2 (ESRI, 1999) in combination with digital ortho quarter quads (DOQQs) taken by satellite in 1999. Seven to ten randomly sampled cores with a 2-cm diameter and up to 10-cm depth were collected to create composite samples from each field. Forested sites were sampled on transects near the stream and mid-slope. Composite samples were then analyzed for Mehlich-1 STP (Mehlich, 1953; Issac and Johnson, 1983). Area-weighted STP concentrations were calculated for each site by multiplying the field concentration by the percentage of area it encompassed within the watershed and then summing the weighted STP levels of all the fields for the watershed STP concentration.

Curve Number

A watershed's CN is based on landuse and soil characteristics and is used to predict runoff for a given storm. CNs are estimated using landuse, hydrologic condition, and hydrologic soil groups (NRCS, 2001) or they can be calculated based on measured runoff and rainfall. Tedala (2009) used the algebraic rearrangement of the standard CN equations to predict the CN for watersheds based on runoff and rainfall data (Equation 1).

$$CN = \frac{1000}{5[P + 2Q - (4Q^2 + 5PQ)^{1/2}] + 10} \qquad (1)$$

where: P – event precipitation (in)
Q – event runoff (in)

Seven sites, FORS-2, FORS-3, AG-5, AG-6, AG-7, AG-8, AG-10, were selected to estimate CNs based on runoff and rainfall recorded ("calibrated CNs"). Sites not included contained ponds that altered runoff. Separation of baseflow from direct runoff was performed using the separation technique described by Hewlett and Hilbert (1967). Separation was done by plotting a line along the hydrograph starting at the initial increase in flow and following a slope equal to 0.0055 liters per second per hectare per hour until an intersection was made in the falling limb of the hydrograph. Once the runoff was totaled along with the associated rainfall, the sums were used in Equation 1 to calculate the CN for a particular storm event. CNs were calculated for each storm over the 15-month recorded period. Antecedent moisture condition (AMC) was an earlier attempt in the National Engineering Handbook Section 4 (now Part 630, Hydrology) to explain variation among CNs focusing mainly on antecedent soil moisture conditions (NRCS, 2001). A five day antecedent precipitation total separated the CN into 3 classes outlined in Table 2. AMC was tested in this study to adjust CN for each storm, as well.

Table 2. AMC parameters adapted from USDA, 1985.

	Total 5-day antecedent rainfall	
AMC Group	Dormant season (cm)	Growing season (cm)
I	Less than 1.27	Less than 3.56
II	1.27 to 2.79	3.56 to 5.33
III	Over 2.79	Over 5.33

Tabulated CNs were calculated using the Engineering Field Handbook tool (EFH2), which is based on USDA, NRCS National Engineering Handbook, Part 650, Engineering Field

Handbook. Essentially, the program simplifies the calculation process and provides area-weighted CNs.

Georgia Phosphorus Index

The Georgia Phosphorus Index (PI) is a tool used to predict edge-of-field bioavailable P loss from agricultural land. It covers all ecoregions in Georgia. Using a Microsoft Excel template called Georgia Phosphorus Index (NRCS, 2009a), PIs were calculated for only the AG sites (including AG-5, AG-6, AG-7, AG-8, and AG-10). An individual PI was calculated for each field within each site and then weighted by area to determine the PI for the watershed (Appendix C). Inputs necessary for the PI calculation included STP (Mehlich 1; lb P acre^{-1}), fertilizer P (lb P_2O_5 acre^{-1}), fertilizer application method and time, manure P (lb P_2O_5 acre^{-1}), type of manure, manure application method and time, hydrologic soil group, CN, yearly erosion (ton acre^{-1} year^{-1}), depth to water table, vegetated buffer width, and STP of buffer (lb P acre^{-1}). STP concentrations were gathered from composite samples by field as described earlier. Fertilizer P, fertilizer application, manure P, type of manure, and manure application information were gathered using a survey generated and distributed to farmers (Appendix B). The survey focused on litter production, land application, application timing, storage, litter export, BMPs, and demographics. The survey was designed to gather more information regarding the individual sites. It was submitted to the University of Georgia Human Subjects Office and approved by the Institutional Review Board (IRB). Surveys were either delivered in person or by mail. Responses were collected either by mail, in person, or participants were allowed to respond via an online survey. Hydrologic soil group was determined by selecting the predominant soil series within a field using ArcView GIS 3.2 (ESRI, 1999) in combination with

SSURGO (Soil survey staff, NRCS, 2009). A tabulated CN was calculated for each field using EFH2. Erosion was calculated using estimated ranges provided by the Georgia CNMP Generator for Poultry (The University of Georgia, 2007). Depths to the water table were based on the predominant soil series descriptions (McIntyre, 1972 and Jordan et al., 1973). Buffer width calculations used a combination of measurements taken in the field along with measurements using ArcView GIS 3.2 and DOQQs taken in 1999. STP concentrations within the buffers were taken from the sampling previously described.

Critical source areas (CSAs) are a major factor in P loss and can be accounted for as a function of the distance from the edge of the field to the receiving stream. Calculating contributing distances from the stream requires an assumption that all runoff from a given storm event occurs from some portion of the watershed adjacent to the stream while the remainder produces no runoff (Figure 4). This assumption is based on a simplification of the variable source area (VSA) concept (Hewlett and Troendle, 1975; Hewlett, 1982). Notice that the contributing area of the watershed is equal to the proportion of the runoff for a given rainfall. It is calculated by dividing the runoff depth by precipitation depth and multiplying the dividend by the total area of the watershed (Equation 2). The resulting contributing area is divided by stream length and then divided by two to calculate the contributing distance from one side of the stream.

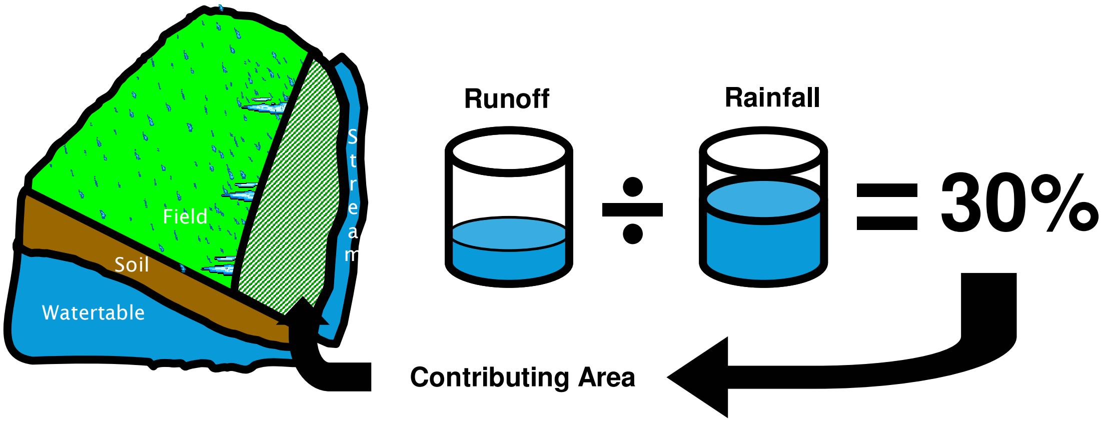


Figure 4. Drawing depicting change in contributing distance from stream based on runoff:rainfall relationship.

$$A_c = (R_d/P_d) \cdot A_w \qquad (2)$$

where: A_c – watershed area contributing surface runoff (m^2)
R_d – runoff depth (m)
P_d – precipitation depth (m)
A_w – total watershed area (m^2)

(corrected from Gburek et al., 2002)

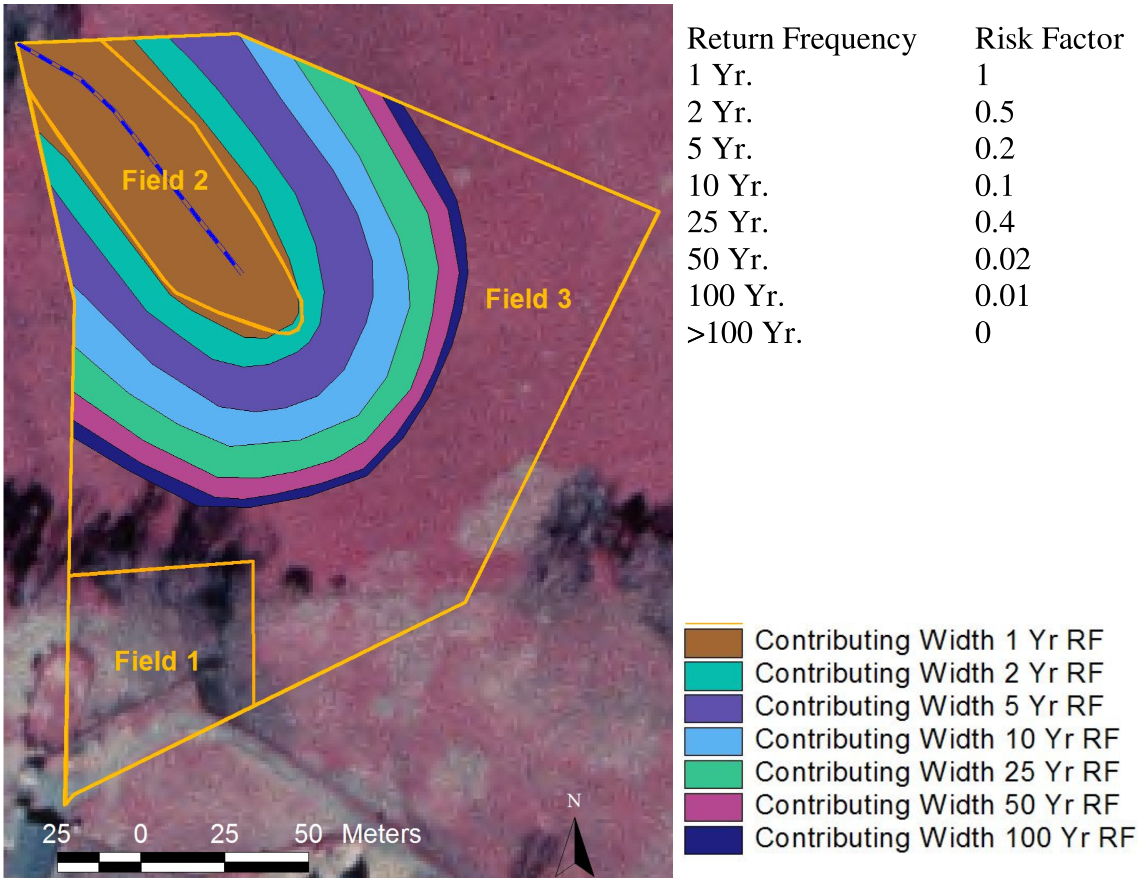
We calculated a connectivity factor in a manner similar to the one described by Gburek et al. (2000a, 2000b) who related distance from a stream to risk of bioavailable P loss. By applying the variable source area concept, the connectivity factor assigns a higher risk of P loss to fields closer to the stream. Equation 3 describes how the connectivity factor was calculated.

$$W = [1/DD \cdot (R_d/P_d)]/2 \qquad (3)$$

where: W = contributing width (one side of stream, m)
DD = drainage density (m^{-1})
P_d = precipitation (mm)
R_d = runoff (mm)
(Gburek et al., 2002)

DD was calculated by dividing the stream length (estimated by ArcView GIS 3.2 in combination with DOQQs taken in 1999 and differentially corrected GIS measurements) by the watershed area which was obtained through manual measurements using ArcMap 9 Version 9.2 (ArcMap) (ESRI 2006) with digital raster graphics of USGS 7.5' topographic maps. An alternative approach available to anyone free of charge is the Web Soil Survey (NRCS, 2009b) which provides the same tools needed for calculation of DD. The first step in this process is to start the web soil survey (WSS) from http://websoilsurvey.nrcs.usda.gov. Second, find the desired location using the "State and County" link under "Quick Navigation". Using the drop down menu, select Georgia and the county that contains the area of interest. Next, click "View" to see that county and use the zoom (+ or -) to navigate to different scales, and the pan function to view different areas of the map. The default base map is aerial photography, but this can be changed to the USGS topographic base map by selecting the "Legend" tab in the upper left corner of the map and scrolling down to check the box next to "Topographic Map". Only one base map can be used at a time. The topographic map is not available at the larger scales while the aerial photography is available. Using the aerial photography enables the user to utilize known landmarks to recognize where a stream channel begins or ends even if it is not a blue line stream on the topographic map. Use the "Define area of interest by polygon" feature to select the watershed and calculate an area in acres. Note that the area of interest (AOI) function can be used and the base map changed with the same AOI. To calculate the area of a watershed, click on the AOI button and then select a point on the watershed boundary to start, and continue to click on the watershed boundary until the last point where you double-click to connect the polygon. The area of the created polygon will be displayed to the left of the map under "AOI Information". The "Measure distance" function allows a stream length to be determined either in English or metric units. To utilize this function, click on the "Measure Distance" button. Point and click on one end of the stream. Continue to click to add points along the stream until the end of the stream. Double-click to end the segment. The length will be displayed below the map. To calculate DD, divide the area in square feet by the total stream length in feet.

Precipitation depth (P_d) for a specific 24-hour return frequency (1, 2, 5, 10, 25, 50, and 100 years) were obtained with Type II rainfall data by county. Runoff depth (R_d) for each of these rainfall totals were calculated using the CN and the EFH2 tool. The contributing width (W) was calculated using Equation 3. Each P_d and R_d had an associated 24-hour rainfall return frequency, so the same return frequency was assigned to the calculated W and contours of W were drawn on watershed maps (Figure 5). Contributing widths were assigned a risk factor equivalent to the probability of the return frequency. Distance from the stream to the closest edge of individual fields was determined using ArcView GIS 3.2 in conjunction with DOQQs (again, this is possible with the WSS). The measured distance from the stream was compared to the calculated contributing widths. If any portion of the field was within an inner contributing width contour, the entire field was assigned to that contributing width. Therefore, a field as a whole might overlap several contributing width contours, but it was assigned to the contributing width associated with the highest potential P loss and its associated risk factor. If a field was outside of the 100-YR return frequency contour then the risk factor was assigned as zero. The assigned risk factor was used to multiply each field PI to create a connectivity weighted PI.



Return Frequency	Risk Factor
1 Yr.	1
2 Yr.	0.5
5 Yr.	0.2
10 Yr.	0.1
25 Yr.	0.4
50 Yr.	0.02
100 Yr.	0.01
>100 Yr.	0

Figure 5. Example of contributing width and associated return frequencies for AG-5.

P load estimations provided by Romeis (2008) allowed for verification of both the current PI and the modified PI. Linear regression was used to develop relationships between the bioavailable P loss predicted and the actual TP loads from the watershed. A comparison was made between the current PIs' ability to predict bioavailable P loss versus the ability of a modified version.

RESULTS

Climatic and Hydrologic Conditions

During the beginning of the monitoring period of the study by Romeis (2008), average to above-average precipitation occurred, while dwindling precipitation toward the later part of the study in 2006 produced well-below average rainfall records. The Etowah River mean annual flow downstream from all of the sites was below average for the duration of the project. Between July and August 2005, tropical storms produced several large rainfall events, including rain bands from Hurricane Dennis that released some of the largest events recorded. Rainfall amounts ranged from 1275 to 1699 mm over a period of time when all sites were monitored (July 1, 2005 to September 30, 2006) (Romeis, 2008). Flow was continuous for all sites except AG-4 (no flow for 36 days between July and September 2006) and AG-12, which is an ephemeral stream and only flowed during or after precipitation events. FORS-1, AG-4, AG-9, and AG-11 all have ponds within the sites' watershed, so for the purposes of many parts of this study were not used.

Poultry Survey

Survey results were collected from the owner/operator from each AG site, except AG-8. The owner/operator at AG-8 was unavailable and discontinued use of the poultry houses on the site during the project. AG-8 input parameters for the PI were estimated based on field observations during the monitoring period, during which there was no evidence of litter being land applied. Appendix B summarizes the results of the survey. Participants answered thoroughly, but all responded by mail and no one responded via the optional online survey. Results were used to apply the PI. Sites varied in both the number of houses, from 2 to 12, and number of birds produced per year, from 156,000 to 1,104,000. Two of the seven sites applied litter/cake to their farm without exporting litter from the site. Of the remaining four sites exporting litter/cake, only two of them exported outside of the 1-2 county area. Generally, litter was applied year round, with most operators applying less in the summer. Only AG-12 utilized a stackhouse to store litter; without storage the litter/cake must be applied, stacked outside, or exported when the houses are cleaned out (time of application is a factor in the Georgia P Index).

STP Results

STP results are shown in Table 3. Area weighted STP (AWSTP) ranged from 3 to 186 mg P kg^{-1} (6 to 371 lbs ac^{-1}). Romeis (2008) found that TP yields and DRP concentrations during baseflow conditions were significantly related to AWSTP concentrations, and therefore had a significant effect on the watershed P load. Figures 6-9 show the DOQQs taken by satellite in 1999, overlain by results from the STP sampling. Distinct differences in AWSTP between land cover, particularly pasture versus forested, were apparent (Figures 6-9 and Table 4). Forested areas contained much lower STP concentrations compared to both agricultural and farmstead (residential, barns, poultry houses, etc.) land use. Among the AG sites, the open pasture areas subject to historic litter application tended to have much higher STP concentrations (Figure 9). AG-7 seemed to be an exception, but this was probably because the pasture with the highest concentration was recently cleared from woods for additional grazing (pre-installation but post-1999 DOQQ) and a small percentage of litter is being applied within the watershed.

Table 3. AWSTP results by site.

Site	Area Weighted STP (mg P kg^{-1})
FORS-1	3
FORS-2	3
FORS-3	3
AG-4	26
AG-5	186
AG-6	133
AG-7	34
AG-8	64
AG-9	52
AG-10	50
AG-11	97
AG-12	151

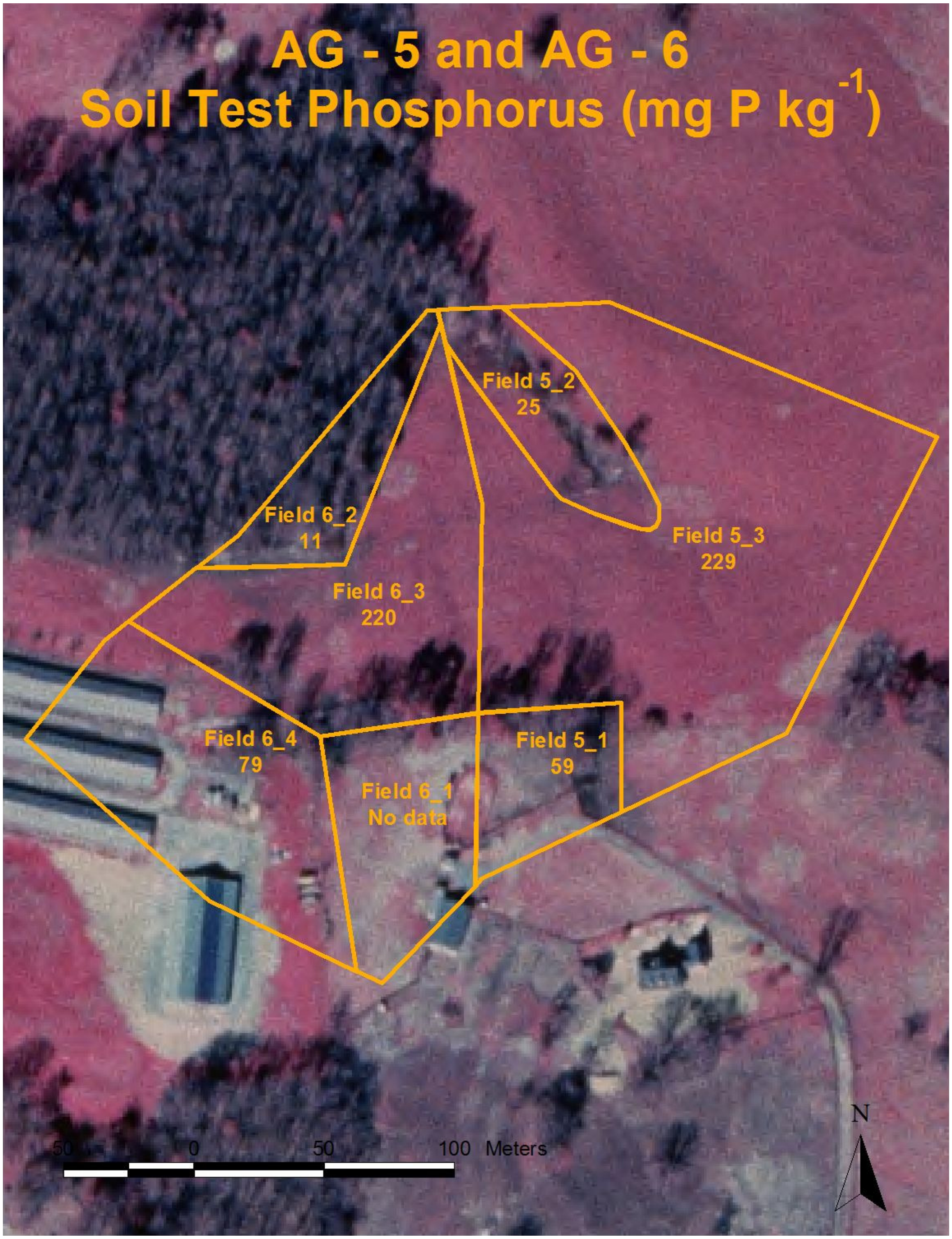


Figure 6. AG-5 and AG-6 STP results by field within the watershed.

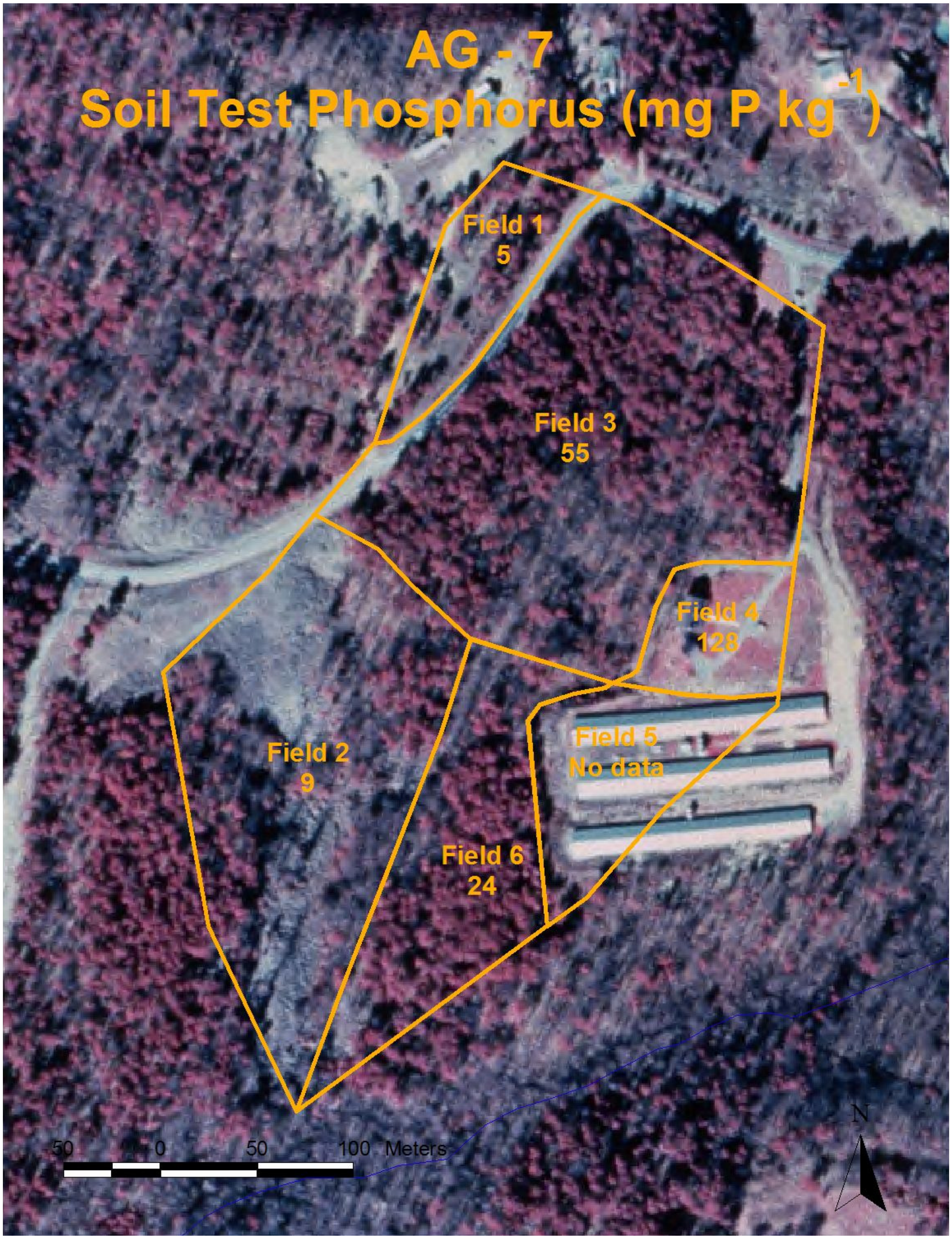


Figure 7. AG-7 STP results by field within the watershed.

Figure 8. AG-8 STP results by field within the watershed.

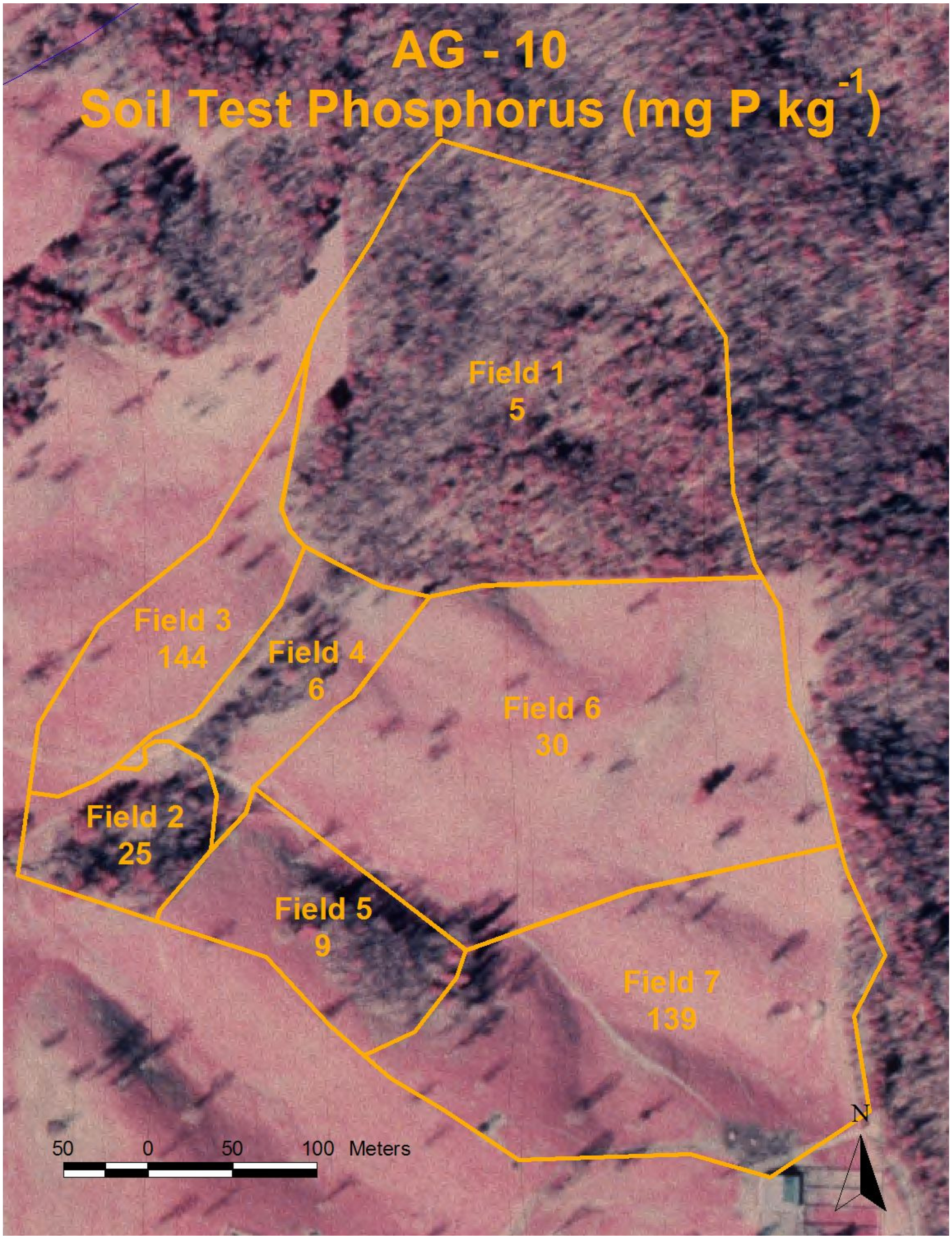


Figure 9. AG-10 STP results by field within the watershed.

Table 4. AWSTP results sorted by landcover.

Statistic	Forest (mg P kg^{-1})	Pasture (mg P kg^{-1})	Farmstead (mg P kg^{-1})
Average	5	113	38
Min	0	9	5
Max	25	275	128
Median	4	103	29

CN Method and Comparisons

The CN method as described by NRCS (2001) was used to estimate average annual runoff within the Georgia PI. Watersheds with a pond (FORS-1, AG-4, AG-9, and AG-11) were not included in CN calculations or in modifying the PI. AG-12 was also excluded because it was an ephemeral stream. An area-weighted CN, called the *tabulated CN* for the purposes of this study, was calculated for each site using the EFH2 tool. A CN, called the *calibrated CN* for the purposes of this study, for each runoff event within each site was also calculated using measured precipitation and runoff data along with Equation 1. A third CN was calculated for each runoff event within the watersheds using the AMC factor (Table 2) (USDA, 1985). The overall trend was that the area-weighted tabulated CN was generally lower than the average calibrated CN, indicating that the tabulated CNs calculated using standard NRCS methods underestimated runoff in both agricultural and forested sites (Table 5). Tedela's (2009) results suggest the same trend of underestimating runoff for forested sites by the tabulated CNs following NRCS procedures. Adjusting the CN for AMC caused a further decrease of the CN and therefore additional underestimation of runoff. No relationship between the tabulated CN and calibrated CN was apparent (Figure 10). The average difference was that the tabulated CN was 16 points below the calibrated CN.

Table 5. Tabulated and calibrated CN by site.

Site	Tabulated CN	Calibrated CN
FORS-2	70	84
FORS-3	70	84
AG-5	61	85
AG-6	79	90
AG-7	76	83
AG-8	69	80
AG-10	59	87

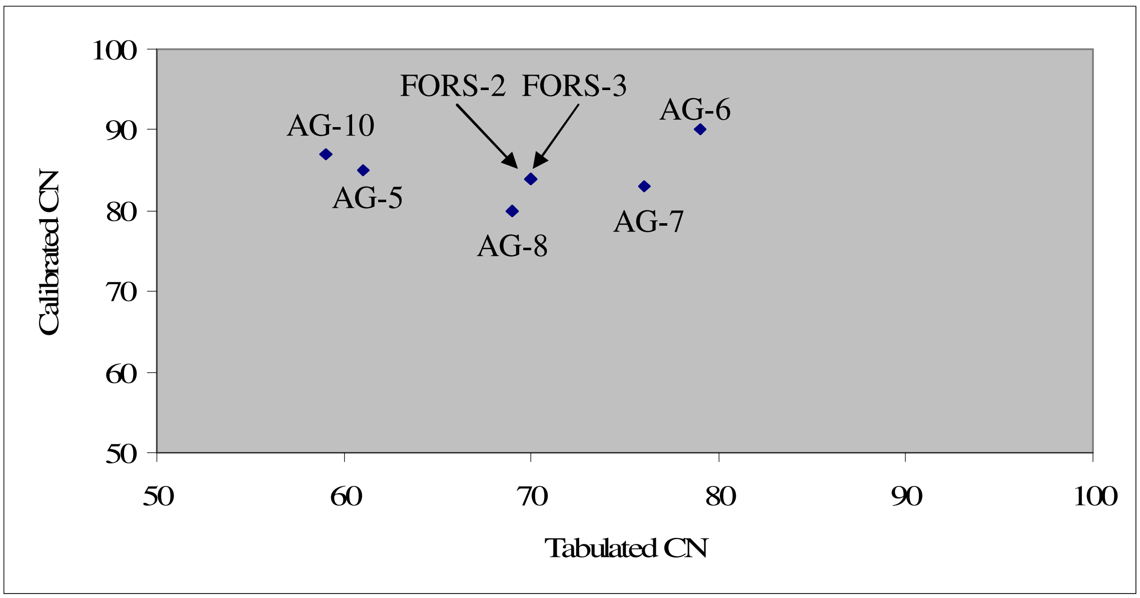


Figure 10. Tabulated CN versus Calibrated CN for FORS-2, FORS-3, AG-5, AG-6, AG-7, AG-8, and AG-10.

Changes to the PI – Incorporating Connectivity

The primary purpose of this study was to calculate a connectivity factor, and analyze its effectiveness. However, before any changes took place, the current PI was calculated and compared to the annual TP loads from Romeis (2008) (Figure 11). Figure 12 shows the relationship between PI modified by the connectivity factor, called PI Connectivity, and the same TP loads from Romeis (2008). The linear relationship and associated R^2-values showed the current PI was highly correlated with the TP loads from these watersheds, but also suggested that a modification to the PI based on a connectivity factor has the potential to improve the Georgia PI. Table 6 reflects the change in PI between the current and modified PI, as well as the associated loads.

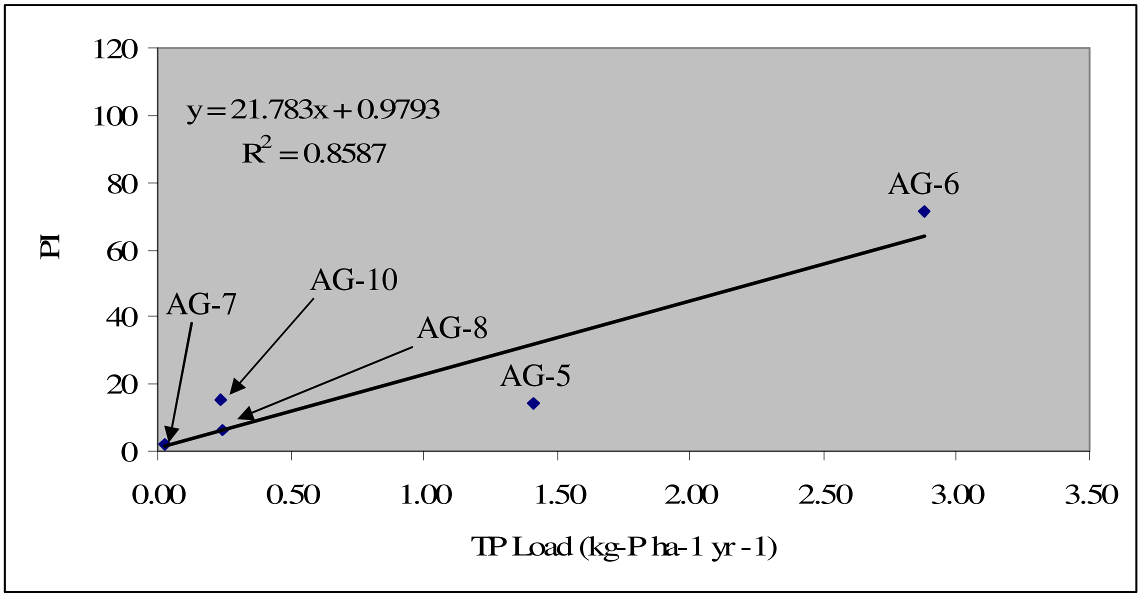


Figure 11. TP loads compared to the current PI calculated with tabulated CN.

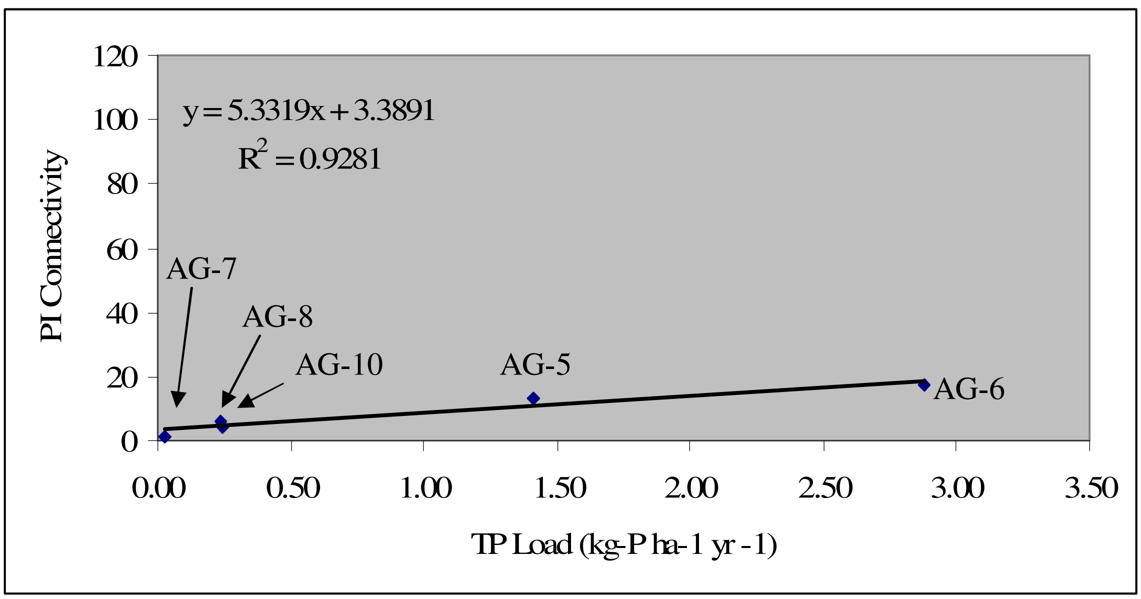


Figure 12. TP loads compared to the modified PI including the connectivity factor calculated with tabulated CN.

Table 6. Current PI results and modified PI results along with TP loads.

Site	PI	PI Connectivity	TP Load (kg-P ha^{-1} yr^{-1})
AG-5	14	13	1.412
AG-6	72	18	2.881
AG-7	2	1	0.031
AG-8	6	4	0.242
AG-10	16	6	0.238

In addition to comparing the PI to TP loads, the PI was also compared to DRP load estimates. Romeis (2008) provided a figure presenting the fraction of TP as DRP in the monitored streams. The figure was used to estimate the fraction and convert the TP loads to DRP loads. The Georgia PI predicts the risk of bioavailable P loss, which is best represented by DRP, and therefore it was important to compare the PI to the DRP. Figures 13 and 14 contain the estimated DRP loads compared to the current PI and the modified PI. Once again, the current PI is highly correlated with bioavailable P loss, but the correlation is slightly improved by adding a connectivity factor.

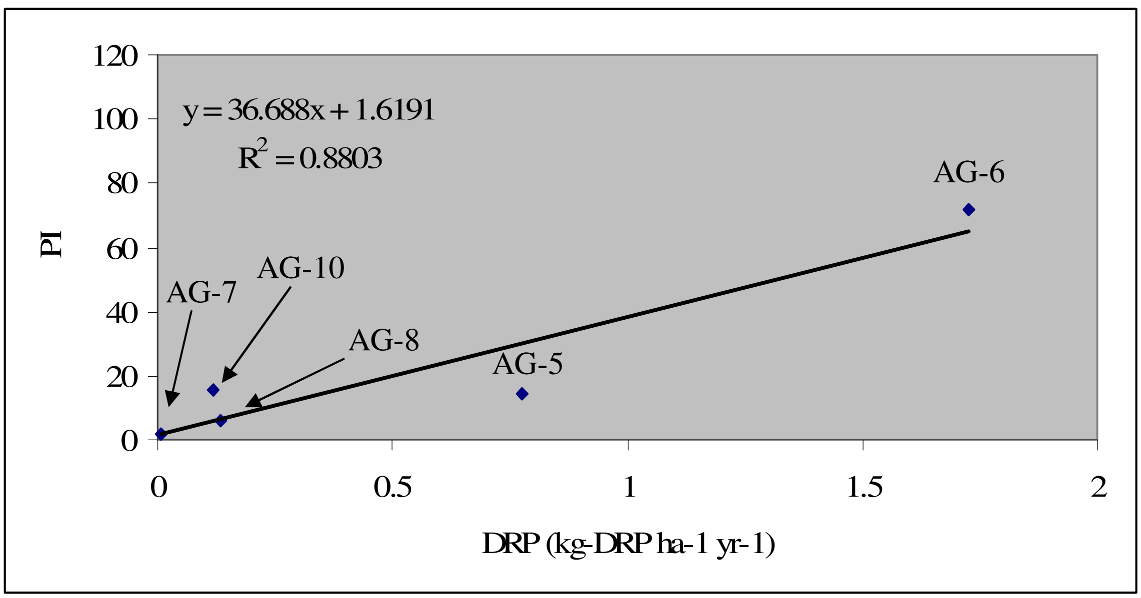


Figure 13. Estimated DRP loads compared to the current PI calculated with tabulated CN.

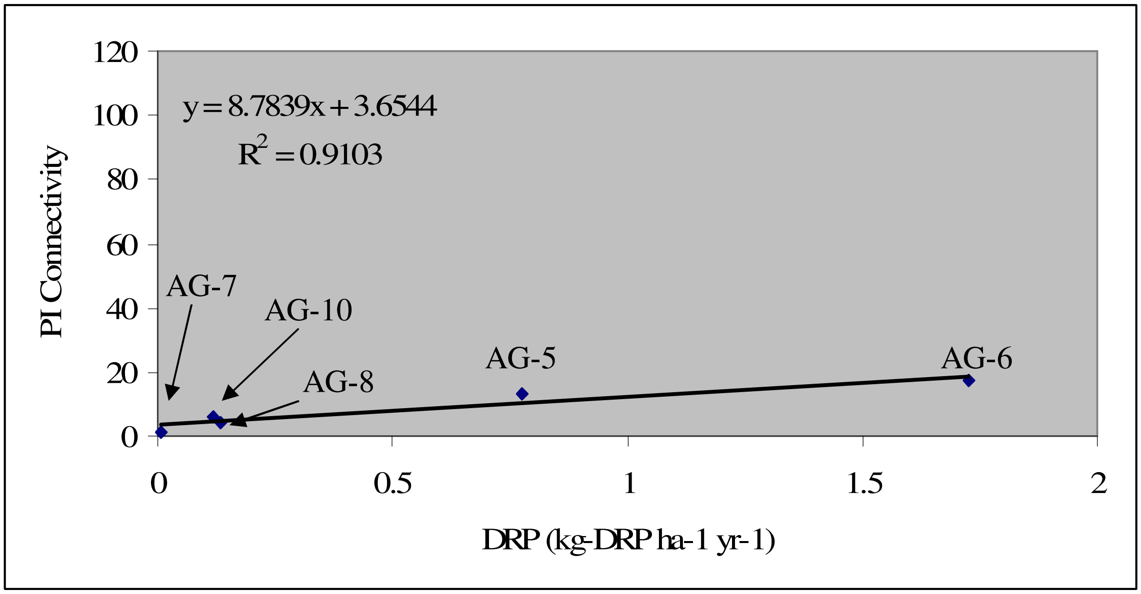
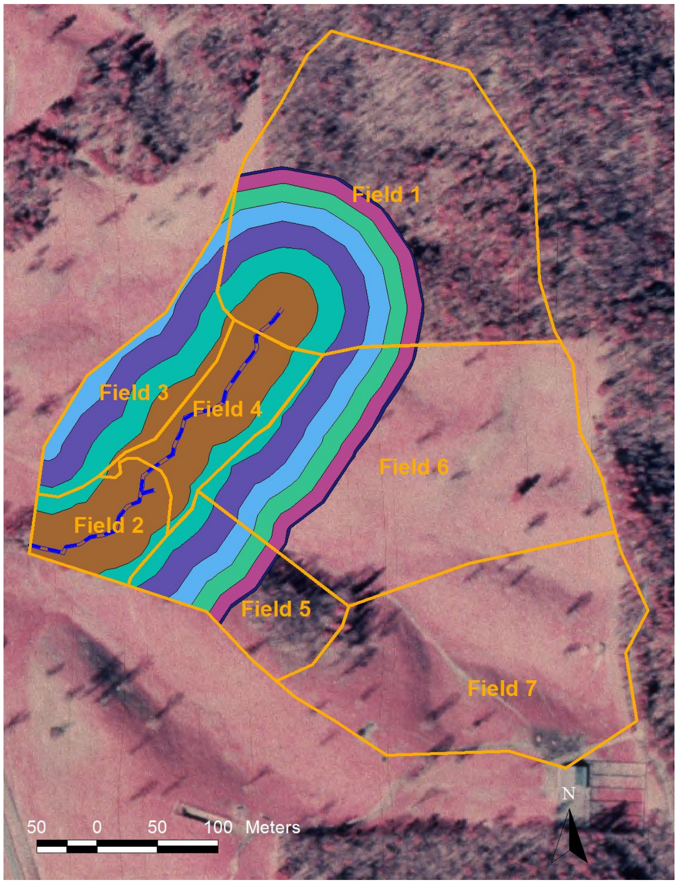


Figure 14. Estimated DRP loads compared to the modified PI including the connectivity factor calculated with tabulated CN.

Applying the connectivity factor not only improves the correlation with measured P loss from the watershed but also changes the decisions that would be made in regard to which fields should receive different management. An example of this is evident at AG-10 (Figure 15). The current PI uses the individual field PI and associated areas to develop an area-weighted PI for the watershed (column 5 of Table 7). The modification essentially changes the field PI based on proximity to the stream (column 8 of Table 7). Fields 1, 2, 3, and 4 of AG-10 result in the same PI using the current and modified PI since these fields are in close proximity to the stream and the associated risk factor is one. However, Fields 5 and 6 essentially have a risk of P loss reduced by half because of the increased distance from the stream under the modified PI. Field 7's distance from the stream is outside of the 100-YR contributing width contour so it was assigned a risk factor of zero reflecting the absence or poor connection to the watershed related to P. The PI is changed in this example from 16 to 6 (Table 7). Depending upon the factors, a PI can be increased, decreased, or remain the same when the connectivity factor is incorporated.

Under the current PI, a farmer might decide reducing manure applications to field 7 was a high priority, but that would not be the case with the modified PI.



Return Frequency	Risk Factor
1 Yr.	1
2 Yr.	0.5
5 Yr.	0.2
10 Yr.	0.1
25 Yr.	0.4
50 Yr.	0.02
100 Yr.	0.01
>100 Yr.	0

Figure 15. Example using AG-10 depicting the connectivity factor contours and changes to the PI based on the assigned risk factors.

Table 7. AG-10 example of the effect of connectivity factor on PI.

Field	PI	Area (ha)	% Area	Area Weighted PI	Dist. from Stream (m)	Risk Factor	Connectivity Weighted PI
1	0	5.6	29	0.0	0	1	0.0
2	2	0.8	4	0.1	0	1	0.1
3	28	1.4	7	2.0	9	1	2.0
4	1	1.0	5	0.1	0	1	0.1
5	18	1.3	7	1.2	35	0.5	0.6
6	24	5.1	27	6.4	36	0.5	3.2
7	28	3.9	21	5.8	182	0	0.0
Total		19		16			6

The Georgia PI was originally developed to estimate the annual bioavailable P loss from a field in kg ha^{-1} yr^{-1}. To make the PI comparable to that of other states, the load loss was converted to a risk index by multiplying by 10 so that the Georgia PI produces values generally between 0 and 100. As such, the expected relationship between the PI and bioavalable P (or DRP) loads is PI = 10 x, where x is the DRP load. The regression equation in Figure 13 shows that in these watersheds, the current PI was estimating about 3 times as high a load as intended: PI = 36.7 x + 1.61. The modified PI did a better job of estimating the bioavailable P loss in that the regression equation in Figure 14 was PI = 8.7 x + 3.6, the coefficient being very close to the desired factor of 10.

Osmond et al. (2006) showed that PIs differ among states largely due to decisions made regarding what value of PI to call medium versus high (and consequently require a change in management practices in most cases). This is a largely arbitrary decision so it is not surprising that states have decided on different "threshold" values for their PIs. In the current Georgia PI, the threshold value for the high category is a PI value of 75, which corresponds to an estimated DRP annual loss of 7.5 kg ha^{-1} yr^{-1}. This study afforded us an opportunity to consider what the threshold value should be in the Etowah River basin, given that a total maximum daily load (TMDL) for P was recently released for Lake Allatoona (USEPA, 2009). In developing the TMDL, the total P load to the Etowah arm of the lake was estimated using a calibrated model. The average annual load to this arm from the beginning of 2001 to the end of 2007 (which was considered to encompass the "critical conditions" associated with drought years) under the TMDL scenario (ie., the load that would not cause a violation of the lake water quality standard) was 50,052 kg yr^{-1} (110,614 lbs yr^{-1}) (Brian Watson, Tetra Tech, Inc., personal communication). The TMDL document specifies the point source waste load allocation (WLA) to the Etowah arm as 5,946 kg yr^{-1} (13,140 lbs yr^{-1}). The load from municipal stormwater systems (WLAsw) is given as 13,048 kg yr^{-1} (28,835 lbs yr^{-1}). If these load allocations are subtracted from the average annual load to the Etowah arm, the total nonpoint source load is 31,058 kg yr^{-1} (68,639 lbs yr^{-1}). The TMDL document estimated the total area of pasture in the Etowah arm that was likely to receive poultry litter (based on distance to poultry houses) as 20,048 acres. Dividing the nonpoint source load by this area produces an estimated loss of 3.8 kg ha^{-1} yr^{-1} (3.4 lbs $acre^{-1}$ yr^{-1}). To comply with the TMDL in the Etowah River basin, this implies that the threshold value for a high PI should be set near 40, instead of the current value of 75.

CONCLUSIONS

The poultry survey results provided much needed information for the Georgia PI. The survey also provided information relating to BMPs used on the farm. The use of stackhouses, exclusion from streams, and litter management may not be a direct factor in the Georgia PI but provide factors that help explain the effectiveness of reducing P loading for a watershed. The fact that litter is being exported from farms indicates that there is a demand for litter elsewhere and may be a viable option for farmers as well as an added source of income.

AWSTP concentrations reflected the difference between forested and agriculturally based sites with agricultural sites having much higher values. Even among the AG sites, AWSTP was related to landcover. Forested areas had much lower concentrations than pasture, probably because of historical litter application indicated by the survey.

Calibrated CNs using measured runoff and rainfall versus those tabulated using the method described in NRCS, 2001 do not seem to be related. However, a trend existed in that the calibrated CNs from the field data were consistently greater than those estimated using the

NRCS method. The average difference between the two calculations was 16. CNs calculated using the AMC agree with the conclusion stated by the NRCS, 2001 and many other sources (Cronshey (1983); Hjelmfelt, et al. (1982); Hjelmfelt (1987, 1991); and Van Mullem (1992)) that no apparent relationship exists between antecedent precipitation and CN. The CN value and its accuracy is a key factor in calculating the PI.

The primary purpose of this study was to investigate the possibility of an improvement to the PI and provide verification of the process. Gburek et al. (2000b) suggested that a connectivity factor would improve the PIs ability to predict P loss. A connectivity factor was not only developed, but verification of the modification occurred by comparing the PI's prediction of P loss to actual P loads from individual agricultural watersheds. It is evident that the current PI is actually performing very well in predicting (R^2 = 0.8587) annual TP loads in agricultural watersheds. Incorporation of the connectivity factor increased the R-value representing the prediction of P loss (R^2 = 0.9281). Estimated DRP loads were also compared to the current PI and the modified PI. Both provided excellent predictions, and again the connectivity factor increased the R-value representing prediction of P loss (Figures 13 and 14).

CHAPTER IV
CONCLUSIONS

The poultry survey results provided much needed information for the Georgia PI. The survey also provided information relating to BMPs used on the farm. The use of stackhouses, exclusion from streams, and litter management may not be a direct factor in the Georgia PI but provide factors that help explain the effectiveness of reducing P loading for a watershed. The fact that litter is being exported from farms indicates that there is a demand for litter elsewhere and may be a viable option for farmers as well as an added source of income.

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The results of this study prove how valuable quality monitoring data is for small watersheds. Future research in Georgia and other states should emphasize the need for similar small scale studies. These studies will lead into better management decisions regarding nonpoint source pollution. Further research to investigate the effectiveness of ponds or other BMPs on P loads and runoff would be a great addition to this study. The PI has proven to be an effective tool to manage P on agricultural lands, and this study should bolster the confidence in the use of the Georgia PI. However, furthering testing of any PI will gain confidence in its effectiveness and possibly lead to additional modifications for improvement. Technology, such as the WSS, is enabling more people and providing better means to manage our resources.

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APPENDIX A.

SOIL DESCRIPTIONS (DOMINANT) AND CHARACTERISTICS BY SITE.

SITE	Field ID	Map Symbol	Mapping Unit	Slope Class	Slope Median	Hydrologic Soil Group
1	1	WgD	Wickham fine sandy loam	10-25	17.5	
	2	WgD	Wickham fine sandy loam	10-25	17.5	
	3	TdG	Tallapoosa soils	25-70	47.5	
	4	TdG	Tallapoosa soils	25-70	47.5	
	5	W				
2	1	WgD	Wickham fine sandy loam	10-25	17.5	
	2	TdG	Tallapoosa soils	25-70	47.5	
	3	WgD	Wickham fine sandy loam	10-25	17.5	
	4	TdG	Tallapoosa soils	25-70	47.5	
3	1	WgD	Wickham fine sandy loam	10-25	17.5	
	2	TdG	Tallapoosa soils	25-70	47.5	
	3	WgD	Wickham fine sandy loam	10-25	17.5	
	4	TdG	Tallapoosa soils	25-70	47.5	
4	1	MCE	Musella cobbly loam	6-25	15.5	B
	2	HLC	Hayesville and Rabun loams	6-10	8	B
	3	TdG	Tallapoosa soils	25-70	50	C
	4	AwB	Augusta fine sandy loam	2-6	4	C
	5	Wed	Wehadkee soils	0-2	1	D
	6	HSD	Hiwassee loam	10-15	12.5	B
	7	HLC	Hayesville and Rabun loams	6-10	8	B
5	1	HJC3	Hayesville sandy clay loam	6-10	8	B
	2	HIE	Hayesville sandy loam	10-25	17.5	B
	3	HJE3	Hayesville sandy clay loam	10-25	17.5	B
6	1	HJC3	Hayesville sandy clay loam	6-10	8	B
	2	HJE3	Hayesville sandy clay loam	10-25	17.5	B
	3	HJE3	Hayesville sandy clay loam	10-25	17.5	B
	4	HIB	Hayesville sandy loam	2-6	4	B
7	1	ThE2	Tallapoosa gravelly sandy clay loam	10-25	17.5	C
	2	ThE2	Tallapoosa gravelly sandy clay loam	10-25	17.5	C
	3	ThE2	Tallapoosa gravelly sandy clay loam	10-25	17.5	C
	4	MiC2	Madison gravelly sandy clay loam	2-10	6	B
	5	ThE2	Tallapoosa gravelly sandy clay loam	10-25	17.5	C
	6	ThE2	Tallapoosa gravelly sandy clay loam	10-25	17.5	C
8	1	HIE	Hayesville sandy loam	10-25	17.5	B
	2	HIE	Hayesville sandy loam	10-25	17.5	B
	3	HIE	Hayesville sandy loam	10-25	17.5	B
	4	HIE	Hayesville sandy loam	10-25	17.5	B
9	1	HIC	Hayesville fine sandy loam	6-10	8	B
	2	HIC	Hayesville fine sandy loam	6-10	8	B
	3	TcE	Tallapoosa fine sandy loam	15-25	20	C
	4	TcE	Tallapoosa fine sandy loam	15-25	20	C
	5	TcE	Tallapoosa fine sandy loam	15-25	20	C
	6	HIC	Hayesville fine sandy loam	6-10	8	B
	7	TcE	Tallapoosa fine sandy loam	15-25	20	C
	8	ThE2	Tallapoosa gravelly sandy clay loam	10-25	17.5	C

	9	ThE2	Tallapoosa gravelly sandy clay loam			C
10	1	HIE	Hayesville sandy loam	10-25	17.5	B
	2	HIE	Hayesville sandy loam	10-25	17.5	B
	3	HIE	Hayesville sandy loam	10-25	17.5	B
	4	HIE	Hayesville sandy loam	10-25	17.5	B
	5	HIE	Hayesville sandy loam	10-25	17.5	B
	6	HIE	Hayesville sandy loam	10-25	17.5	B
	7	HIE	Hayesville sandy loam	10-25	17.5	B
11	1	HIE	Hayesville sandy loam	10-25	17.5	B
	2	Toc	Toccoa soils	0-2	1	B
	3	Toc	Toccoa soils	0-2	1	B
	4	Toc	Toccoa soils	0-2	1	B
	5	HIE	Hayesville sandy loam	10-25	17.5	B
	6	HIE	Hayesville sandy loam	10-25	17.5	B
	7	HJE3	Hayesville sandy clay loam	10-25	17.5	B
	8	HIE	Hayesville sandy loam	10-25	17.5	B
	9	Toc	Toccoa soils	0-2	1	B
12	1	HIE	Hayesville sandy loam	10-25	17.5	B
	2	HIE	Hayesville sandy loam	10-25	17.5	B
	3	HIE	Hayesville sandy loam	10-25	17.5	B
	4	HIE	Hayesville sandy loam	10-25	17.5	B
	5	HIE	Hayesville sandy loam	10-25	17.5	B

APPENDIX B.

POULTRY FARMER BLANK SURVEY AND SURVEY RESULTS.

Litter Production

1. What is the total capacity of your farm? ________________ (# of birds at stocking)
2. How many chicken houses do you have? ________________ (# of houses)
3. On average, how many birds do you raise per year? ________________ (# of birds/year)

Land Application

4. How often do you do a total cleanout? ________________
5. How many tons of litter are produced at cleanout? ________________ (tons of litter)
6. What percentage of litter is land applied on your property? _____ (%)
7. How often do you decake your houses? ________________
8. How many tons of cake are produced? ________________ (tons of cake)
9. What percentage of cake is land applied on your property? _____ (%)
10. What crop(s) is litter/cake applied on (select all that apply)?
    ☐Hay ☐Pasture ☐Crop/Other ________________
11. How many acres do you apply litter/cake on? ________________ (acres)
12. What is your average application rate? ________________ (tons/acre)
13. Do you use any other sources of fertilizer? ☐Yes ☐No
14. If yes, please specify types and amounts applied?

    ____

Timing

15. List the percentage of litter applied in each season:
    _______% in Winter (Dec-Feb) _______% in Spring (Mar-May)
    _______% in Summer (June-Aug) _______% in Fall (Sep-Nov)
16. Do you have a nutrient management plan? ☐Yes ☐No
17. Do you test your soil? ☐Yes ☐No
18. If yes, what are soil test phosphorus levels?
    ☐Low ☐Medium ☐High ☐Very High

Storage

19. Do you have a stackhouse or other litter storage structure?
    ☐Stackhouse ☐Other structure, explain ________ ☐No
20. Do you store your litter/cake? ☐Yes ☐No
21. If yes, how long do you typically store it? ________________ (weeks)

Litter Export

22. Do you export litter off the farm? ☐Yes ☐No (If no, skip to question #29)

23. What percentage is exported? _____ (%)

24. Who provides this service?
☐Broker ☐Yourself ☐Other ________________

25. Are there fees associated with this process?
☐Yes, Approximate amount $_____ ☐No

26. Are you paid for the litter?
☐Yes, Approximate amount $_____ ☐No

27. Is there any further processing of litter/cake (i.e. composting)?
☐Yes, explain briefly ________________ ☐No

28. Do you know where the litter goes?
☐Within 1-2 county area ☐Outside 1-2 county area
☐Do not know

Other Enterprises and Best Management Practices (BMPs)

29. Do you have cattle and/or other livestock?
☐Yes, What do you have? __________ How many of each? _______
☐No

30. Do you use any of these BMPs with cattle/livestock:
☐Exclusion from streams ☐Rotational grazing
☐Alternative watering/shade ☐Buffer/riparian zone
☐On farm pond ☐Other____________

31. How is poultry mortality managed?
☐Burial ☐Incineration
☐Composting ☐Other________________

Demographics

32. What is your age? _____

33. ☐Male ☐Female

34. What was your approximate total household income last year?
☐Less than $15,000 ☐$50,000-74,999
☐$15,000-24,999 ☐$75,000-99,999
☐$25,000-34,999 ☐$100,000 or more
☐$35,000-49,999

35. What percentage of your total household income comes from farming? _____ (%)

36. What was the highest level of formal education you completed?

☐Some High School ☐High School
☐Some College ☐College Graduate

37. What county do you live in? __________________

Site #		5 and 6	7	9	10	11	12
1	What is the total capacity of your farm? (# of birds at stocking)	60000	60500	32000	222800	66500	60000
2	How many chicken houses do you have? (# of houses)	3	3	2	12	5	3
3	On average, how many birds do you raise per year? (# of birds/year)	300000	302500	156000	1104000	332500	300000
4	How often do you do a total cleanout?	0-1 per year	2 years	Once per year	Once yearly	Once in 3 years	Once a year
5	How many tons of litter are produced at cleanout?	250	150	75 (25 loads)	1800	20	114
6	What percentage of litter is land applied on your property?	100	25	0	0	100	0
7	How often do you decake your houses?	4-5 per year	Each flock	Each time	Each growout	Every bunch	After every growout
8	How many tons of cake are produced?	75	60	20 (8 loads)	750 yearly	2	22.5
9	What percentage of cake is land applied on your property?	100	50	80	90-100	100	100
10	What crop(s) is litter/cake applied on (select all that apply)? Hay; Pasture; Crop/Other	Hay and Pasture	Pasture	Hay and Pasture	Pasture	Hay and Pasture	Pasture
11	How many acres do you apply litter/cake on?	250-300	25	400	150	200	20
12	What is your average application rate? (tons/acre)	2	5	1 load per 2.5 acres	5	2	1.12
13	Do you use any other sources of fertilizer?	Yes	No	Yes	No	No	No
14	If yes, please specify types and amounts applied?	19-0-19 400 lbs/ac		13-13-13			

15	List the percentage of litter applied in each season:						
Winter		25	15	30	25	10	30
Spring		25	35	50	25	10	30
Summer		25	15	10	25	5	10
Fall		25	35	20	25	5	30
16	Do you have a nutrient management plan?	Yes		Yes	No	Yes	Yes
17	Do you test your soil?	No	No	Yes		Yes	Yes
18	If yes, what are soil test phosphorus levels?			Medium		Medium	Very High
19	Do you have a stackhouse or other litter storage structure?	No	No	Other structure , explain - if needed	No	No	Stackho use
20	Do you store your litter/cake?	No	No	No	No	No	Yes
21	If yes, how long do you typically store it?			3			8
22	Do you export litter off the farm? Yes; No (skip to #28)	No	Yes	No	Yes	Yes	Yes
23	What percentage is exported?		75		40	100	84
24	Who provides this service?		Broker and Yourself		Other	Broker	Other
25	Are there fees associated with this process? Yes, Approximate amount $_____ ; No		No (sometim es)		Yes	No	No
26	Are you paid for the litter? Yes, Approximate amount $_____ ; No		Yes, $30/load		No	No	No
27	Is there any further processing of litter/cake (i.e.		No		No	No	Yes, compost chickens

	composting)? Yes, explain briefly; No						
28	Do you know where the litter goes? Within 1-2 county area; Outside 1-2 county area; Do not know		Within 1-2 county area		Outside 1-2 County Area	Outside 1-2 County Area	Within 1-2 County Area
29	Do you have cattle and/or other livestock?Yes, What do you have? How many of each?; No	Yes, 200 Cattle	No	NA	Yes, 30-100 cattle	No	Yes, 48 Sheep and 1 Cow
30	Do you use any of these BMPs with cattle/livestock: Exclusion from streams; Rotational grazing; Alternative watering/shade; Buffer/riparian zone; On farm pond; Other				Exclusion from streams		
31	How is poultry mortality managed? Burial; Incineration; Composting; Other	Burial and will start incineration this year	Incineration	Incineration	Incineration	Burial	Composting

APPENDIX C.

GEORGIA PI CALCULATION FOR AG-5, AG-6, AG-7, AG-8, AND AG-10

The Georgia Phosphorus Index
Version 1.7

Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 5_1	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	118.8	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	93.17	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	61	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
10	Low	Low risk	

The Georgia Phosphorus Index
Version 1.7

Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 5_2	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	49.6	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	93.17	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	65	
Erosion	Yearly Erosion (ton/A/year)	1.43	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
14	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 5_3	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	457.65	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	93.17	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	61	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
15	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 6_1	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	118.8	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	93.17	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	79	
Erosion	Yearly Erosion (ton/A/year)	2.55	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
46	Medium	Maintain below 75	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 6_2	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	21.22	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	55	
Erosion	Yearly Erosion (ton/A/year)	0.02	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
0	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 6_3	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	440.9	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	93.17	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	69	
Erosion	Yearly Erosion (ton/A/year)	1.43	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
33	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 6_4	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	157.95	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	93.17	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	98	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
151	Very High	Reduce value below 100	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 7_1	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	9.89	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	TALLAPOOSA C	Phosphorus Transport
Runoff	Curve Number for Runoff	76	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
2	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 7_2	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	18.95	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	373.95	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	TALLAPOOSA C	Phosphorus Transport
Runoff	Curve Number for Runoff	76	
Erosion	Yearly Erosion (ton/A/year)	1.43	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	100	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)	18.95	
P Index	**Category**	**Suggested Management**	
2	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 7_3	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	109.4	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	373.95	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	TALLAPOOSA C	Phosphorus Transport
Runoff	Curve Number for Runoff	72	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	100	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)	109.4	
P Index	**Category**	**Suggested Management**	
1	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 7_4	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	255.4	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	MADISON B	Phosphorus Transport
Runoff	Curve Number for Runoff	74	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
11	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		**Field ID**
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 7_5	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)		**Sources of Phosphorus**
Fertilizer P	Fertilizer P (lb P2O5/A)		
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)		
Manure P Type	Type of Manure P (Table 1)	Manure P Type	
Manure P Method	Manure P Method (Table 2)	Manure P Method	
Hydrologic Group	Hydrologic Soil Group	TALLAPOOSA C	**Phosphorus Transport**
Runoff	Curve Number for Runoff	98	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)		**BMP's**
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
0	0	0	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 7_6	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	48.91	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	Fertilizer P Method	
Manure P	Manure P (lb P2O5/A)	373.95	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	TALLAPOOSA C	Phosphorus Transport
Runoff	Curve Number for Runoff	72	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	100	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)	48.91	
P Index	**Category**	**Suggested Management**	
1	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 8_1	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	125.7	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	61	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
2	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 8_2	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	20.51	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	61	
Erosion	Yearly Erosion (ton/A/year)	0.02	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
1	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 8_3	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	55.41	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	98	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
14	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 8_4	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	353.9	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	61	
Erosion	Yearly Erosion (ton/A/year)	1.43	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
9	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 10_1	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	10.15	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	55	
Erosion	Yearly Erosion (ton/A/year)	0.02	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
0	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 10_2	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	50.64	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	65	
Erosion	Yearly Erosion (ton/A/year)	1.43	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
2	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 10_3	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	287	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	263.15	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	61	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
28	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 10_4	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	11.8	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	0	
Manure P Type	Type of Manure P (Table 1)	None	
Manure P Method	Manure P Method (Table 2)	None	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	65	
Erosion	Yearly Erosion (ton/A/year)	1.43	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
1	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 10_5	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	18.03	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	263.15	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	58	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
18	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 10_6	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	60.17	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	263.15	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	61	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
24	Low	Low risk	

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Press Buttons	Variable	Enter Value in Column	
Below for Help	Today's Date		Field ID
P-Index Info	Operator		
Crop	Crop		
Field ID	Field ID	Site 10_7	
Soil Test P	Soil Test P (Mehlich 1; lb P/A)	277.6	Sources of Phosphorus
Fertilizer P	Fertilizer P (lb P2O5/A)	0	
Fertilizer P Method	Fertilizer P Method (Table 2)	None	
Manure P	Manure P (lb P2O5/A)	263.15	
Manure P Type	Type of Manure P (Table 1)	Poultry Litter w/o alum	
Manure P Method	Manure P Method (Table 2)	Surface applied, not incorporated, Year-round	
Hydrologic Group	Hydrologic Soil Group	HAYESVILLE B	Phosphorus Transport
Runoff	Curve Number for Runoff	61	
Erosion	Yearly Erosion (ton/A/year)	0.31	
Water Table	Depth to Water Table (feet)	8	
Buffer	Vegetated Buffer Width (feet)	0	BMP's
STP of Buffer	Soil Test P of Buffer (lb P/A)		
P Index	**Category**	**Suggested Management**	
28	Low	Low risk	