DEMONSTRATING SUSTAINABLE INTEGRATION OF VALUE-ADDED MANURE PRODUCTS INTO 21ST CENTURY FARMING

FINAL PROJECT REPORT

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SUBMITTED BY:

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DEMONSTRATING SUSTAINABLE INTEGRATION OF VALUE-ADDED MANURE PRODUCTS INTO 21ST CENTURY FARMING

EXECUTIVE SUMMARY

Agriculture today faces a complex array of challenges that raise concerns about its sustainability in Delaware and other urbanizing regions of the Mid-Atlantic USA. Two important challenges addressed in this project were: (i) the growing environmental pressures facing the state's vitally important poultry industry, and other sectors of animal agriculture, due to continued concerns about the impacts of animal manures on water quality; and (ii) preserving farm land in the face of the land use change that has converted much of Delaware's best crop land into urban and suburban uses; loss of farms is of serious concern because this open space (cropland, forests, wetlands) is important for groundwater recharge, surface water protection, flood prevention, sustaining wildlife habitat and biodiversity and many other ecosystem services.

Our primary objective in this project was to demonstrate, through agronomic and horticultural field studies, the value to agricultural sustainability of producing and exporting value-added manure products, such as pelletized poultry litter (PPL), from farms with animal manure surpluses to farms that have traditionally relied upon inorganic fertilizers and to the horticultural operations that comprise the "Green Industry" Re-distribution of manure nutrients from areas of nutrient excess to areas of nutrient deficit is a recognized national need and should benefit agriculture and the environment Our project was conducted at St. Andrew's School, an educational institution that is ideally suited for demonstration projects focused on sustaining agriculture. St. Andrew's owns one of the largest contiguous pieces of farmland in the state (~2,200 acres with 1,700 acres of cropland), is located in one of the most rapidly developing areas in the region, and is being encroached upon by suburban development Other main objectives were to show that conservation "best management practices" (BMPs), such as riparian buffers on farms and sustainable landscaping practices for suburban areas, could not only protect water quality but also enhance natural ecosystems and habitats; to conduct educational outreach programs on project goals for farmers, the Green Industry, K-12 teachers and students, and the community; and to build, through establishment of the *St. Andrew's Center for 21st Century Farming*, a long-term partnership between St. Andrew's, the University of Delaware, and others interested in sustaining agriculture in the face of rapid land use change

Key findings from this project include: (1) Four years of agronomic studies, conducted in cooperation with St. Andrew's farmers, clearly demonstrated that a value-added manure product (pelletized poultry litter, PPL) could be an effective alternative to inorganic fertilizers for corn grown using conventional or no-tillage production systems. Comparable, or greater, corn yields resulted when PPL was applied at equivalent plant available nitrogen (PAN) rates. Soil and plant N testing in field studies and supplemental laboratory mineralization studies with PPL have provided the data needed to make research-based recommendations of the use of PPL as a N fertilizer for grain production in Delaware. Soil testing for other plant nutrients showed PPL can be a valuable source of many plant nutrients, but that it must be managed carefully to prevent phosphorus (P) buildup to values of environmental concern, which could occur within only a few years if PPL is used as the sole fertilizer source for the crop. However, an alternative approach we evaluated for PPL use (combining near-planting applications of PPL at 30-50% of the plant's total N requirement, followed by soil nitrate testing, and sidedressing with fertilizer N) was found to be an effective means to achieve economically optimum crop yields and minimize the potential for nitrate leaching losses and soil P buildup to excessive levels; (2) Horticultural use of PPL as a turfgrass fertilizer for athetic fields was also assessed in this project. Results from a 2-year study clearly showed, based on data from soil samples, turf clippings, penetrometer readings, and remote sensing, that PPL can be an effective alternative to commercial fertilizer on heavily-used athletic turf fields and other turfgrass areas. Turf grown using PPL and core aeration was of better quality, based on vigor, color, wear-resistance than the standard practice followed at St. Andrew's and most other athletic fields in the region (synthetic fertilizer, core aeration). However, if vibrating aeration was used, PPL and fertilizer resulted in comparable turf quality, suggesting aeration method should be considered when selecting a N source for turf. Soil testing and plant analysis showed that PPL was equally effective as synthetic fertilizer in terms of building soil fertility and maintaining optimum concentrations of nutrients in turf plants; (3) Surface runoff studies conducted at the same field sites as the agronomic studies with PPL found that nutrient (NH_4–N, NO_3–N and PO_4–P) exports from soils amended with PPL were less than those with inorganic fertilizer (urea) or raw litter (RPL). While exports of trace elements from PPL exceeded those from urea, they were much lower than the corresponding exports from RPL. Mass exports of nutrients and trace elements were correlated with event size (rainfall amount) but not correlated with timing of event (days since litter application). Results from this study suggest that the use of PPL in combination with no-tillage may provide an environmentally safe alternative to synthetic fertilizers. A second water quality study evaluated release of natural animal hormones in runoff from agricultural fields receiving land application of PPL. Exports of estrogens were much lower from soils amended with PPL than RPL. No-tillage management practice also resulted in a lower export of estrogens with surface runoff compared with reduced tillage. However, the concentrations and exports of conjugate forms of estrogens were much higher than the free forms for some treatments, indicating that the conjugate forms should be considered for a comprehensive assessment of the threat posed by estrogens in runoff from soils amended with poultry litters; (4) The economic analysis component of this project provided evidence suggesting that sustainable agriculture techniques can lead to profitability in an urbanizing region, but this outcome is most likely if public policy helps producers profit from the full range of benefits they provide to society. In other words, production profitability at the urban fringe is less likely to occur if some services provided by farmer to the public are not brought into the market system. These services are important to society. For instance, agricultural land can provide locally grown produce, water quality, and habitat. Preservation policy, such as conservation easements, helps reward agricultural landowners for these services while ensuring their provision into the future. This research shows that sustainable agriculture, even on unpreserved land, can provide other services that are highly valued by the public. A choice experiment survey of public preferences was conducted, enabling researchers to estimate the benefits of potential land preservation and sustainable agricultural services from the St. Andrew's parcels. The results of the survey suggest substantial benefits for land preservation, the use of broiler litter, and riparian buffers but not for conservation tillage. Within the studied community, the total household benefits of all three sustainable management practices combined ($60.66/year) are estimated to be approximately as large as the benefits from land preservation ($61.37/year) alone. However, the costs are likely to be lower for policies to deliver sustainable practices. One implication is that policy and future research may wish to examine possibilities for subsidizing sustainable management practices in urban-influenced areas as a more cost-effective means of providing benefits similar to those realized through land preservation. A conservative estimate of the statewide net benefits of preservation and sustainable practices is calculated $36,739,320 in net benefits. The results also show that management contracts can increase benefits an estimated 2 to 4 times over preservation alone.

(5) Assessing the ecosystem services value of conservation BMPs installed to protect water quality on farms (e.g., riparian buffers), clearly showed that both the type and amount of plants in our landscapes dictate the quality of the ecosystem services delivered. Today, most of the vegetation on St Andrews property has been removed for farming, recreation and human structures. A relatively thin strip of forest surrounds most of Noxontown Lake and serves as a riparian buffer that filters nutrients from rain water runoff before it reaches the lake and a habitat for local biodiversity. The studies in the project specifically investigated how narrow forest buffers compared with wider buffers in their ability to support breeding bird populations and the caterpillars that birds use to feed their young. At Noxontown Lake it was found that narrow buffers were populated with tree species that supported many species of bird food and thus attracted birds, but at the same time did not provide enough space for many breeding birds. Wider buffers provided more space but contained low quality vegetation in terms of producing bird food. All buffer widths, therefore, appeared to support the same densities and diversity of breeding birds. Therefore, a key conclusion of this study is that the quality of the vegetation in riparian buffers is as important as buffer width in terms of supporting local wildlife. Restoring high quality forest buffers to St Andrews is particularly important because the surrounding suburban developments are nearly devoid of native plants that support local food webs. The results of this project are guiding innovative riparian buffer restoration projects now underway at St. Andrew's. For example, 16 acres of riparian buffer were restored by planting over 1300 native trees and shrubs within the area, which will be monitored in the years ahead by faculty, students, and staff at St. Andrew's for invasion by mutliflora rose, oriental bittersweet, and autumn olive until the plantings become well enough established to slow invasion themselves.

(6) The importance of integrating conservation practices into suburban landscapes, for both water quality protection and ecosystem health, was also assessed, through demonstration of the benefits of sustainable landscaping practices on the campus of St Andrew's School. Completed projects included removal of invasive plant species in forests; enhancing an existing rain garden to increase its aesthetic appeal; reducing the area of mowed turf in a large grassy lawn that required frequent mowing, supports no biodiversity, and fails to reduce or slow storm water runoff so significant sediment and nutrient-rich runoff flows directly into Noxontown Pond. By taking some areas out of mowing, the taller vegetation now slows the flow of runoff, and provides habitat and food for native insects and birds; improving meadow aesthetics – the

"no-mow" zone created a meadow that was enhanced by plantings of perennial wildflowers and native ornamental grasses to increase the aesthetic appeal and help establish native wildflowers; renovating the existing mowed turf to rid the lawn of crabgrass and Bermuda grass. Simply establishing and maintaining a healthy lawn will help reduce runoff and ultimately reduce the amount of nutrients Noxontown Pond, thus slowing the buildup of algae, reduce fish kills, and make that area of the pond healthier; and working with St Andrew's environmental science teachers to develop a protocol for senior independent research projects that could take advantage of sustainable landscaping practices adopted in this project as well as those proposed in a school-wide "Land Use Charette" on the future of land use at St. Andrew's. UD project participants helped develop the plans for the Charette and were also active participants in this day-long event which resulted in land use planning recommendations for the St Andrew's Board of Trustees. (7) Environmental education programs were conducted throughout the project, including a community forum at the start of the project on land use in the St. Andrew's Watershed; four years of "Eco-Quest" environmental science camps for area youth; annual Earth Day programs on ecosystem services;, a half-day community environmental event ("The Watershed In Your Backyard") held for local residents so that they could take home ideas on the various sustainable practices being demonstrated at St. Andrews's in this project The event, which also included a tour of our agronomic field studies and local suburban developments, with opportunities for residents to meet and discuss agricultural and environmental issues with St Andrew's farmers, was co-sponsored by the University of Delaware College of Agriculture and Natural Resources, St. Andrew's School, and the Appoquinimink River Association (ARA), a nonprofit organization, created in 2004, whose mission is to preserve, protect and enhance the rivers and related natural resource areas; and the "Land Use Charette" mentioned above which was the culmination of four years of interaction between project investigators and our partners at St. Andrew's School; (8) Finally, on May 5, 2010, UD President Patrick Harker and Mr. Tad Roach, Headmaster of St. Andrew's School, signed a 5-year memorandum of understanding to "...foster continued collaborations in education, research, and public service in the areas of agriculture and natural resources". A specific objective of this MOU was a commitment to continue our cooperative efforts to establish the *St. Andrew's Center for 21st Century Agriculture*, which has not been accomplished to date, but is still of interest to all partners in this Conservation Innovation Grant.

DEMONSTRATING SUSTAINABLE INTEGRATION OF VALUE-ADDED MANURE PRODUCTS INTO 21ST CENTURY FARMING[1]

INTRODUCTION AND PROJECT GOALS:

Nonpoint nutrient pollution by animal agriculture remains a major, long-standing environmental and economic concern in Delaware and the Chesapeake Bay watershed. Many farms in this watershed have surpluses of manure nutrients, soils that are high in phosphorus (P), and ground waters high in nitrate-nitrogen. The situation in Delaware today is in many ways a microcosm of the problems, and also opportunities, faced by animal agriculture in the rapidly urbanizing Eastern United States. Traditional animal agriculture, particularly poultry and dairy production, is vital to the economy of the state and to sustaining farmland and open spaces by providing a consistent market for grain and forage crops. All these animal industries face a common problem – surpluses of manure because of an inadequate land base on their operations for the environmentally sound use of the manure nutrients they generate. Consequently, there is widespread agreement today that off-farm uses for manures that offer alternatives to continued manure application to the same fields must be developed if we are to sustain animal agriculture.

One strategy being implemented in Delaware has been the re-location of animal manures, or value-added organic products produced from manures, from farms with excess nutrients to farms where the nutrients are needed for crop production. For example, an innovative solution that has been adopted in Delaware, one of the most concentrated poultry producing areas in the U.S., is the transport of excess broiler litter from poultry farms to a regional pelletizing plant (Perdue Agri-Recycle, near Seaford, Delaware) where it is then converted into an organic fertilizer that can be transported by rail and truck to other regions. However, widespread adoption of pelletized poultry litter (PPL) as a fertilizer by farmers and for other land uses (e.g., the "Green Industry" of landscapers, nurseries, and greenhouse) in the Mid-Atlantic region is growing slowly and there is a need for more information on the fertilizer value of PPL that can be used to support recommendations for its agronomic and horticultural use.

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[1] *Project Investigators:* J. T. Sims (project leader), S. Inamdar, D. Tallamy, J. Duke, D. Hansen, S. Barton, J. Bruck, C. Nelson, G. Shriver, J. Gingrich, and J. Sparks; University of Delaware; J McGrath, University of Maryland; and M. Schuller, St. Andrew's School. Contact for more information: Dr. J. T. Sims, College of Agriculture and Natural Resources, University of Delaware, Newark, DE 19716-2103 (jtsims@udel.edu; 302-831-2698)

In general, for an overall state or regional strategy of converting a "waste" product (manure) to a "value-added product" (e.g., PPL) to succeed it must mesh with the needs of the farms and horticultural industries capable of using manures or value-added manure products. It must also reflect the growing reality that land use change, particularly urbanization, is altering the nature and future of farming in the Chesapeake Bay watershed. As is the case nationally, most forms of agriculture in this watershed are faced with the loss of farmland to suburban development and urban expansion. Sustaining agriculture thus requires a new view of the true value of the 21st Century Farm, one that integrates production capacity with the ecological and social contributions farming provides to society. Given the rapid conversion of farmland to urban/suburban uses, it is apparent that animal agriculture needs to demonstrate that it can produce new manure-based products for use by farmers that do not raise animals, for producers of high value crops, and for the Green Industry. Our goal in this project was to demonstrate that animal agriculture can be sustained by producing and exporting value-added manure products from farms with manure surpluses to farms that have traditionally relied upon inorganic fertilizers and to the horticultural operations that comprise the Green Industry. To accomplish this we have worked the past four years with St. Andrew's School, an educational institution that is ideally suited for demonstration projects focused on sustaining agriculture. It is a residential secondary school located in southern New Castle County, Delaware on one of the largest contiguous pieces of farmland in the state (~2,200 acres with 1,700 acres of cropland). There are no animals grown on the farm, manures have not been applied for many years, and the cropland is mainly used for row crops. The School is also located in one of the most rapidly developing areas in the region and is being encroached upon by suburban development on all sides. This situation is representative of much of the surrounding farmland in the region. From 1984 to 1992, southern New Castle County experienced the most rapid localized rate of residential development Delaware, a reported 220% increase in urban uses of land. It is widely believed that much of the farmland in New Castle County may be converted to urban/suburban land uses within the next 20 years. Converting farm land to suburban development results in the loss of open space important for groundwater recharge and protection of surface water bodies, for flood prevention, for sustaining wildlife habitat and biodiversity and for other natural resource functions presumably widely valued by society. Given these concerns, and the need for innovative approaches to sustain farming, St. Andrews School and the University of Delaware's

(UD) College of Agriculture and Natural Resources have cooperated in this Conservation Innovation Grant to address the following objectives:

Objective 1: Establish the St. Andrew's Center for the 21st Century Farm to provide regional leadership in progressive, sustainable approaches to farming in the 21st Century. The Center and the University of Delaware would cooperate to demonstrate how developing a successful strategy for sustainable use of value-added, manure-based, organic products by farms without animals and by the Green Industry can serve as a model approach to the solution of other complex problems facing agriculture in the 21st Century;

Objective 2: Demonstrate and monitor the best management practices (BMPs) required for environmentally sound use of manure-based organic products, specifically pelletized poultry litter, in a wide range of agronomic and horticultural settings;

Objective 3: Demonstrate how innovative conservation BMPs can not only protect water quality but also enhance natural ecosystems and habitats. We do this to show the full range of value of farm-based natural resources to society and our environment;

Objective 4: Conduct educational outreach programs and demonstrations for farmers and the Green Industry on how value-added, manure-based products and ecologically oriented BMPs can be used in their operations. Hold agriculture and natural resource camps for youth, workshops for K-16 teachers and students, and community education workshops designed to show the full value of farming to urban and suburban adults.

This report summarizes the key findings from our USDA Conservation Innovation Grant. More details on project accomplishments and on the continuing cooperative efforts still underway today between the University of Delaware and St. Andrew's School can be obtained from the cooperating investigators or from the numerous publications and presentations made during the project (e.g., scientific publications in refereed journals, three University of Delaware Ph.D. dissertations, Cooperative Extension fact sheets, and numerous presentations at national, regional, and local meetings).

PROJECT OBJECTIVES AND ACCOMPLISHMENTS:

Objective 1: Establish the *St. Andrew's Center for the 21st Century Farm* to provide regional leadership in progressive, sustainable approaches to farming in the 21st Century. The Center and the University of Delaware will cooperate to develop a strategy for sustainable use of value-added, manure-based, organic products by farms without animals and by the Green Industry as a model approach to the solution of other complex problems facing agriculture in the 21st Century.

Accomplishments: The University of Delaware (UD) and leadership at St. Andrew's School have had multiple discussions on the establishment of the *St. Andrew's Center for the 21st Century Farm*. We have met with the Land Use Committee of the St. Andrew's School Board of Directors which led to considerable interest on the part of this committee in establishing a permanent approach to enhance the sustainability of agriculture and natural resources at the school as a model for sustainable development in the region. In 2008, St. Andrew's pursued the establishment of a Land Trust as a means to fund long-term efforts in these areas and asked that we contribute to this process. Unfortunately, financial problems associated with the national economic turndown have delayed establishment of the Land Trust by St. Andrew's and slowed our efforts to establish this Center. While it is now clear that establishing the Center will take more time than originally estimated, we remain optimistic that this will occur in the future.

Two very positive signs that the partnership established between UD and St. Andrew's School in this Conservation Innovation Grant will continue and grow in the future occurred in 2010. First, on April 22, 2010, the leadership of St. Andrew's devoted an entire day to a "Land Use Charette", with the specific goal "... engaging the faculty, staff, and student body in St. Andrew's current land use and planning initiatives. Using insights from area policy makers, involve the School community in active discussions and seek input regarding the future of St. Andrew's land holdings". Cooperating investigators from our Conservation Innovation Grant played a key role in the Charette by summarizing the findings of our project and its relevance to sustaining agriculture and natural resources in the face of continued land use change. Second, on May 5, 2010, UD President Patrick Harker and Mr. Tad Roach, Headmaster of St. Andrew's School, signed a 5-year memorandum of understanding to "... foster continued collaborations in education, research, and public service in the areas of agriculture and natural resources". A specific objective of this MOU was a commitment to continue our cooperative efforts to establish the *St. Andrew's Center for 21st Century Agriculture*.

Objective 2: Demonstrate and monitor the BMPs required for environmentally sound use of manure-based organic products, specifically pelletized poultry litter (PPL) in a wide range of agronomic and horticultural settings

Accomplishments:

Agronomic Studies[2]: Three separate field experiments were conducted from 2007 to 2010 in cooperation with the farmers who manage the 1700 acres of cropland at St. Andrew's School. The overall goal of all studies was to compare PPL and commercial nitrogen fertilizer as nutrient sources for corn production We sought to provide guidance on how to effectively use PPL as a nitrogen (N) fertilizer while simultaneously minimizing the risk of soil phosphorus (P) buildup to values of environmental concern for water quality. The studies were designed to provide information on N availability of PPL under conventional and no-tillage production systems, to evaluate the effects of irrigation on N availability from PPL, and to assess the most effective application strategy for PPL (all PPL broadcast preplant before planting vs. a combination of a reduced rate of PPL applied at planting followed by sidedressing with commercial N fertilizer). Experimental details and key findings for each of the three studies are summarized below; results have been presented at national professional meetings and a research paper is now being prepared for submission in early 2011

Field Study #1: The goal of this study, conducted in 2007 and 2008, was to determine, in small plot studies with corn grown using conventional and no-tillage systems, the fertilizer N equivalency of PPL under field conditions Four farm sites were selected: one used conventional tillage (CT) and three other sites used no-tillage (NT). The experimental design was a 2 x 4 factorial with three replications, arranged in a randomized complete block design Treatments included two N sources (PPL and urea fertilizer) applied at four rates of plant available N (PAN) (0, 84, 168, and 252 kg PAN/ha) Based on past research and laboratory studies designed to quantify the extent and timing of N release from soils amended with PPL compared to normal poultry litters, we hypothesized that 50% of PPL total N would be plant available in the first year after application (Carmona et al., 2008; Sprinkle, 2010). At each location, we collected and analyzed soil and plant samples to determine the effects of N source, tillage, and irrigation on

[2] Project investigators: Dr J Thomas Sims, Dr Alyssa Collins, Dr Joshua McGrath, Cheryl Carmona, and Michael Popovich

parameters such as soil nutrient status via routine soil tests (pH, organic matter, lime requirement, soil test P, K, Ca, Mg, S, B, Cu, Mn, Zn, and soil P saturation), pre-sidedress soil nitrate-N, water soluble P (0-2" soil depth), leaf chlorophyll meter (LCM) readings, corn stalk nitrate contents, and corn grain yields. Corn was harvested in the fall each year, yield measurements were made, and post-harvest soil samples were collected for routine soil test analyses *Key results from Field Study #1 were*: (1) Soil and plant indexes of N availability from PPL showed that our 50% estimate of PAN for PPL was accurate and should be used to guide the use of PPL as a N source for crop production For example, there was no significant difference in soil available N (PSNT) and plant N concentration (LCM) for PPL compared to urea in either 2007 or 2008. Two-year mean values for PSNT averaged across all N rates, were 27 mg/kg for PPL and 31 mg/kg for urea; for LCM, mean values were 50 (PPL) and 51 (urea) SPAD units. However, a slight tendency for reduced PSNT values was noted for PPL when surface applied in no-tillage, suggesting that a 40-45% estimate of PAN should be considered when PPL is not incorporated into the soil. Results also showed PPL was equally effective as urea in terms of achieving realistic corn grain yields, averaging 147 bu/ac for 2007-2008 (over all N rates) vs. 141 bu/ac for urea. In terms of PPL effects on soil fertility, as expected, application of PPL increased soil organic matter content and nutrient levels relative to urea. For example, mean post-harvest soil test values from 2008 (end of the two-year study) at the 168 kg PAN/ha rate (~economically optimum N rate for this site) for pH, OM and Mehlich 3 P, K, Ca, Mg, and S were 6.0, 2.5%, and 85, 267, 601, 112, and 27 mg/kg for PPL; for urea values for these parameters wee 5.6, 2.3%, and 46, 163, 508, 81, and 21, mg/kg The buildup of soil test P with applications of PPL to meet corn N requirements was confirmed to be a significant concern, one that must be monitored and managed to protect water quality. For example, at the highest PAN rate (252 kg PAN/ha), mean M3-P and WSP values for PPL were 145 mg/kg and 19 mg/kg compared to 36 and 1.5 mg/kg with urea, suggesting that continuous application of PPL to meet the full N requirement of corn will quickly build soil test P to excessive levels (> 150 mg/kg).

Field Study #2: The goal of this small plot field study, conducted in 2007 and 2008 at three of the same locations as Field Study #1 (one irrigated site, two dryland sites) was to compare a different approach to the use of PPL for corn production rather than simply to preplant broadcast PPL at a rate that would provide all of the crop's N requirements (as is commonly done by farmers and also as was done in Field Study #1) In Field Study #2, we used a combination of a reduced rate of PPL applied close to planting (60 lbs PAN/acre, a N rate commonly used by farmers who often apply a mixture of UAN solution and pre-emergence herbicides at planting), followed by a sidedress fertilizer N application at a rate based on a soil PSNT test. This approach had several advantages compared to preplant broadcasting PPL to meet all of the crop's N requirement First, multiple applications of N during the growing season are well-known to be more efficient than applying all N at or before planting. Second, by basing the sidedress N rate on a PSNT sample, any seasonal factors (e.g, temperature, drought, heavy rains) affecting the amount and timing of N availability from PPL could be better adjusted for; and third, by applying roughly one-third of corn's N requirement in PPL, we reduced the risk of soil P buildup by applying PPL phosphorus at a rate closer to crop P removal. The experimental design in Field Study #2 was a split plot with three replications. Main plots were preplant N source (PPL vs. urea, both broadcast before planting at a N rate of 60 lbs PAN/acre) and split plots were five rates of sidedress N (30% UAN solution, at N rates of 0, 30, 60, 120, and 180 lbs N/acre). Similar soil and plant data were collected as in Field Study #1. *Key results from Field Study #2 were;* (1) As in Field Study #1, PSNT and LCM values clearly indicated that the approach used to estimate PAN for PPL was accurate. Average PSNT values (3 sites, both years) for PPL and urea were 25 and 27 mg/kg and for LCM were 52 and 51 mg/kg ; (2) PPL applied at 60 lbs PAN/acre in combination with sidedress fertilizer N (30% UAN) resulted in consistently higher yields (~15% greater across all N rates) than urea + sidedress N. The two-year average corn yields for PPL at the economically optimum N rate (60 lbs PAN/acre preplant + 34 lbs N/acre sidedressed) were 152 (PPL) and 130 (urea) bu/acre, respectively; (3) As anticipated, using a lower rate of PPL, combined with sidedress N, reduced the risk of soil test P buildup. In 2007, post-harvest M3-P values (3-site average) for PPL and urea were 80 and 75 mg/kg (not significantly different); in 2008, after the second year of PPL application, M3-P was increased when PPL was used relative to urea (93 vs. 69 mg/kg), but not as dramatically as the increase observed when PPL was preplant broadcast to meet corn needs, as in Field Study #1.

Field Study #3: Demonstrating the use of PPL at the field-scale, using standard farm equipment, in addition to the more detailed studies we conducted at the small plot scale, is critical to farmer acceptance of our findings and the adoption of recommended BMPs for PPL use in corn production. Consequently, in 2009 and 2010, based on the findings of the small plot studies in 2007-2008, we scaled up our field evaluations of PPL and initiated large, field-scale "strip trial" experiments on two of the St. Andrew's farms used in Field Studies #1 and #2. Note that separate locations were used for the strip-trials in 2009 and 2010. These experiments were direct, side-by-side comparisons of (i) our recommended approach for the use of PPL as a N fertilizer for corn (based on small plot findings, we recommended applying PPL immediately prior to planting at a rate of 60 lbs PAN/ac, followed by sidedressing with commercial N fertilizer based on the results of a PSNT sample) and (ii) the normal N management practice used by the farmer at the site (varied slightly between sites and years but typically included only commercial N fertilizer, applied in a starter fertilizer, followed by N applied with an herbicide (60 lbs N/ac), and then sidedressing based on results of a PSNT sample). We conducted similar soil and plant analyses as previously done in the small plot field studies and determined treatment (PPL-based strategy vs. farmer N management practices) effects on corn grain yields. *Key results from Field Study #3 were:* (1) PSNT values were slightly higher where PPL was used, averaging 15 mg/kg compared to 11 mg/kg for the farmer's N management practices, suggesting some differences in early season N availability between the two approaches. However, there were no significant differences between the two treatments in terms of plant N concentrations at mid-silking, as estimated by LCM readings, which averaged 54 and 56 SPAD units for PPL in 2009 and 2010 vs. 55 and 54 SPAD units for the farmers' N management approaches; (2) As in Field Study #2, which used the same treatment approaches at the small plot scale, corn grain yields (2 year averages) were somewhat higher (~10%) for the PPL N management approach (152 bu/ac) than farmers' N management practices using only commercial N fertilizer (140 bu/ac); (3) As expected, application of a modest amount of PPL maintained or slightly increased soil fertility each year. In 2009, pH, OM, and Mehlich 3 P, K, Ca, Mg, and S were, for PPL: 5.6, 1.6%, 106, 126, 441, 89, and 18 mg/kg compared to 5.6, 1.7%, 97, 117, 421, 89, and 18 mg/kg. In 2010 (separate field sites from 2009), pH, OM, and Mehlich 3 P, K, Ca, Mg, and S were, for PPL: 6.1, 2.0%, 56, 154, 576, 98, and 20 mg/kg compared to 5.9, 1.9%, 52, 140, 593, 95, and 17 mg/kg for the farmers' practices. Importantly, using this approach to apply PPL, which moderates the buildup of soil test P, also resulted in only small differences in water soluble P in the top 2" of the soil. In 2009, WSP values were 2.3 mg/kg for PPL vs. 1.0 mg/kg for the farmers' practices; in 2010, WSP values for these same treatments were 0.3 vs. 0.2 mg/kg.

In summary, the four years of research conducted with PPL, at multiple locations, and with different cooperating farmers, has provided the data needed to: (1) make recommendations for PPL rates that will provide adequate PAN for economically optimum crop yields; (2) provide an alternative approach to applying all PPL before planting, one that combines the use of PPL, soil N testing, and sidedress fertilizer N to achieve equal or better yields than fertilizer alone, while minimizing the effects of PPL on soil P and the potential for P loss in runoff

Horticultural Studies[3]: St Andrew's School has large areas of turfgrass maintained for lawns and athletic fields that require regular fertilization and thus provide opportunities to demonstrate the use of PPL in horticultural settings. Further, because turfgrass is often intensively fertilized, it can also potentially be a nonpoint source of nutrient pollution of nearby waters (e.g., Noxontown Pond). Consequently, there has been increased interest in improving the nutrient management and cultural practices used to manage athletic fields in order to sustain turf quality and ensure an attractive and wear-resistant playing surface. Recently, due to concerns about water quality impacts associated with N and P runoff from synthetic turfgrass fertilizers, interest has also grown in using organic turf fertilizers which release nutrients more slowly and thus lessen the potential for nonpoint nutrient pollution. A 3-year field study evaluating the use of PPL as a turf fertilizer, in conjunction with two different types of turf aeration (vibration vs. core), was initiated in the fall 2006 on three athletic fields (football, practice football, soccer) at St. Andrew's School Four treatment combinations were assessed: (i) VS: synthetic fertilizer and vibrating aeration; (ii) CS: synthetic fertilizer and core aeration; (iii) VP: PPL and vibrating aeration; and (iv) CP: PPL and core aeration. The two turf N sources were applied twice per year at equivalent N rates (assuming, based on laboratory mineralization studies conducted with a Matapeake silt loam soil – similar to the dominant soil series at St. Andrew's - that 50% of PPL total N was plant available; note that the N content of PPL is 4%). Synthetic N fertilizer sources used in this study were complete N-P-K fertilizers (6-16-34 in the fall and a 32-3-4 in the spring). Beginning in November of 2006, soil samples, turf clippings, penetrometer readings, and remote sensing measurements (Crop Scan – multispectral readings) were collected for turf areas in these fields Results from this study clearly showed that PPL can be an effective alternative to commercial fertilizer on heavily-used athletic turf fields and other turfgrass areas.

[3] Project investigators: Dr David Hansen, Dr. Susan White-Hansen, and Amy Sprinkle

Some specific findings that support this conclusion are: (1) based on remote sensing data, turfgrass quality (the ratio of turfgrass biomass to depth of green color), was higher in both PPL treatments compared to the standard practice (CS, core aeration, synthetic fertilizer) currently used at St. Andrew's School and at most other athletic fields in this region (CP > VP > CS); however, no differences were noted between CP and VS, suggesting that the turfgrass N source selected should consider the aeration method that will be used; (2) Soil testing and plant analysis showed that PPL was equally effective as synthetic fertilizer in terms of building soil fertility and maintaining optimum concentrations of nutrients in turf plants. Complete results of this study are summarized in "Pelletized Poultry Litter as a Nutrient Source for Turfgrass Sports Fields" which has been accepted for publication in the Journal of Agricultural Science and Technology (2011).

Water Quality[4]: Assessment of the effects of pelletized poultry litter (PPL) and commercial N fertilizer on runoff water quality (nutrients, trace metals, hormones, and dissolved organic carbon) has been completed. These results have been presented in three manuscripts, two of which have been published in refereed scientific journals (Dutta et al., 2010a,b). Eight experimental plots (5 m wide and 12 m long) were established on farm fields at St. Andrew's, with four each in "reduced" and no-tillage treatments. The experimental design was a 4×2 factorial arranged in a randomized block design. Manure applications for each treatment block (reduced tillage or no-tillage) included PPL, raw poultry litter (RPL) at moderate (RPL1) and high levels (RPL2), and a control that received no poultry litter application. Pelletized poultry litter and RPL1 were applied to provide 252 kg ha^{-1} of plant available nitrogen, which resulted in an application rate of 12.6 Mg ha^{-1} for PPL and 23 Mg ha^{-1} (dry weight) for RPL1. The higher rate (RPL2) of raw poultry litter application was set at 35 Mg ha^{-1} (dry weight). Corn (*Zea mays* L.) was planted as a crop in the second week of April 2008, and litter applications on the plots occurred during the third week of April 2008.

The first manuscript investigating the export of nutrients and trace elements was published in the Journal of Water Resource Protection (Dutta et al., 2010a). Sampling was conducted for six natural rainfall events from April through August 2008. Nutrient (NH_4–N, NO_3–N and PO_4–P) exports from plots receiving PPL were less than those with urea or raw litter applications. While exports of trace elements from PPL exceeded those from urea, they were

[4] Project Investigators: Dr. Shreeram Inamdar and Sudarshan Dutta

much lower than the corresponding exports from RPL. Mass exports of nutrients and trace elements were correlated with event size (rainfall amount) but not correlated with timing of event (days since litter application). Results from this study suggest that the use of PPL in combination with no-tillage may provide an environmentally safe alternative to synthetic fertilizers.

The second manuscript exploring the potential for release of natural animal hormones in runoff from agricultural fields receiving land application of PPL was published in the Journal of Environmental Quality (Dutta et al. 2010b). It evaluated the transport and fate of free (estrone, E1; 17b-estradiol, E2b; estriol, E3) and conjugate forms (glucuronides and sulfates) of estrogens, which differ in toxicity. Sampling was performed for 10 natural storm events over a 4-mo period (April –July 2008). Estrogen concentrations were screened using enzyme-linked immunosorbent assay (ELISA), followed by quantification by liquid chromatography with tandem mass spectrometry (LC/MS/MS). Concentrations of estrogens from ELISA were much higher than the LC/MS/MS values, indicating cross-reactivity with organic compounds. Exports of estrogens were much lower from soils amended with PPL than RPL. No-tillage management practice also resulted in a lower export of estrogens with surface runoff compared with reduced tillage. The concentrations and exports of conjugate forms of estrogens were much higher than the free forms for some treatments, indicating that the conjugate forms should be considered for a comprehensive assessment of the threat posed by estrogens.

Finally, the third aspect of the study – exports of dissolved organic carbon in runoff from fields receiving PPL has been developed into a manuscript that will soon be submitted to a refereed journal. It explored the exports of DOC and its relationship with estrogens, and trace elements in surface runoff. The aromatic content of DOC was characterized using specific ultra-violet absorbance (SUVA). Surface runoff samples were collected for 7 natural storm events over the summer (April-June, 2008). Flow-weighted concentrations of DOC and SUVA values in surface runoff from plots receiving poultry litter were significantly ($p \leq 0.10$) greater than control plots. Compared to pelletized litter, reduced-tillage plots with raw litter yielded higher DOC concentrations and aromatic content (higher SUVA values). No significant differences ($p \geq 0.10$) in DOC and SUVA were observed between litter treatments for plots with no-tillage treatment. Concentrations of estrogens and trace elements were positively and significantly ($p \leq 0.10$) correlated with DOC and SUVA, suggesting that DOC played an important role in the exports of these contaminants in surface runoff. Presentations on this research were made at the 2009 and

2010 annual meetings of ASA-CSSA-SSSA. A UD Ph.D. graduate student (Sudarshan Dutta), supported separately by funds from the UD Avian Biosciences Center and Institute of Soil and Environmental Quality, conducted all research in this project with the assistance of an undergraduate intern supported by an internship from the UD Delaware Water Resources Center.

Assessing Farmer and Community Views on PPL[5]: Two separate research projects were conducted and a number of papers, abstracts, and presentations at professional meetings were used to disseminate project findings (Duke et al., 2010; Borchers, 2010; Borchers and Duke, 2010a,b; Borchers and Duke, 2009; Borchers and Duke, 2008; Duke et al , 2007) First, a choice experiment survey was conducted surveying 1,500 households in the area about their willingness to pay for sustainable agricultural practices and preservation of the St. Andrew's parcel. Second, a benefit-cost analysis was conducted for using PPL on agronomic crops and turf grass. The results of the survey suggest substantial benefits for land preservation, the use of PPL, and riparian buffers but not for conservation tillage. Within the studied community, the total household benefits of all three sustainable management practices combined ($60.66/year) are estimated to be approximately as large as the benefits from land preservation ($61.37/year) alone. One implication is that policy and future research may wish to examine possibilities for subsidizing sustainable management practices in urban-influenced areas as a more cost-effective means of providing benefits similar to those realized through land preservation. A conservative estimate of the statewide benefits of preservation and sustainable practices is calculated. When coupled with statewide benefits from preservation of $77,316,330, this benefit-cost scenario thus estimates $94,858,150 in benefits and $58,118,830 in costs, or $36,739,320 in net benefits. The figure below shows a sensitivity analysis for this benefit-cost calculation (where 100% indicates the assumptions leading to the numbers reported above). The results also show that management contracts can increase benefits 2 to 4 times over preservation alone. The benefit-cost analysis for the adoption of PPL shows that a significant subsidy would be needed to encourage farmers and turf grass managers to use the PPL product. Due to the large amount of nitrogen being applied, PPL is an expensive alternative for urea. However, turf fields have proven to be more economically feasible for PPL fertilizer use. Because of the low nitrogen rates typically applied to turf, PPL use is closer to profitability as an alternative fertilizer when purchased in bulk

[5] Project investigators: Dr. Joshua Duke and Allison Borchers

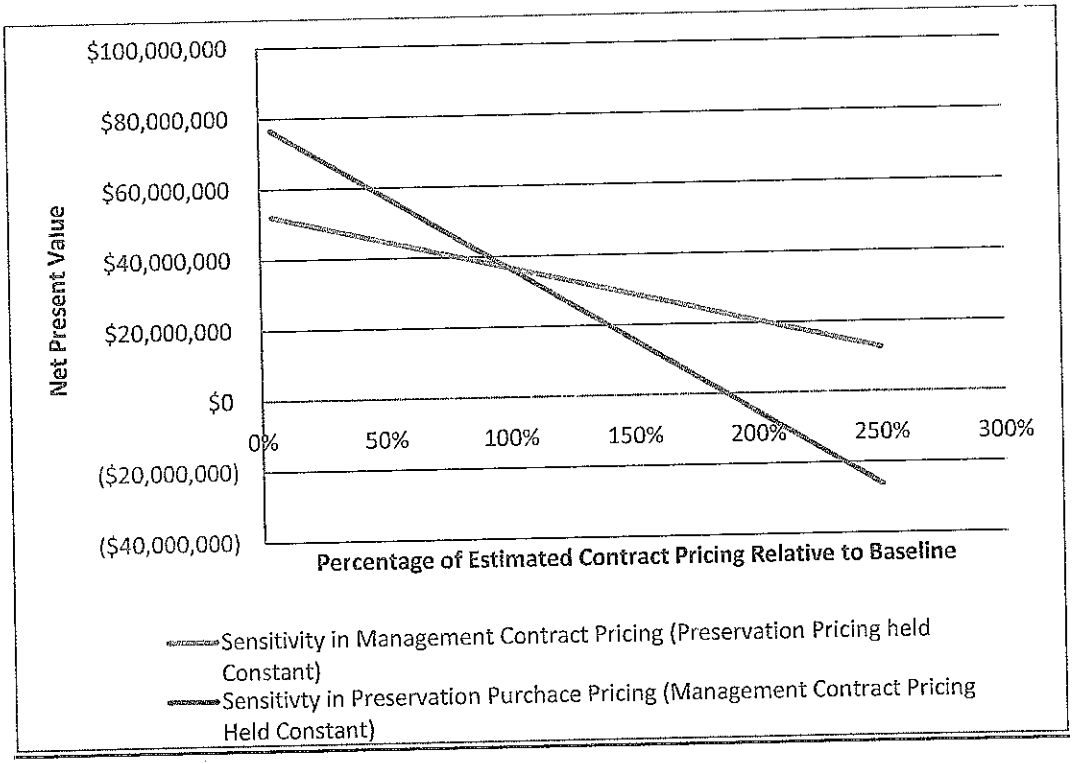

Figure 1 Net Present Value of Benefits from Representative Policy: Sensitivity Analysis for Policy Cost (from Duke et al. 2010)

Objective 3: Demonstrate how innovative conservation BMPs can not only protect water quality but also enhance natural ecosystems and habitats. We do this to show the full range of value of farm-based natural resources to society and our environment.

Accomplishments:

Ecosystem BMPs[6]: Studies completed in this project focus area demonstrated the importance of riparian buffers, not only as water quality BMPs, but also as ecosystems and habitats and how urbanization and suburbanization affects ecological quality in these riparian corridors. Cooperative projects with USDA NRCS, the New Castle County Conservation District, and the State of Delaware Division of Fish & Wildlife included large-scale demonstrations showing how improved management and expansion of riparian buffers separating crop land from Noxontown

[6] Project investigators: Dr. Douglas Tallamy, Dr Greg Shriver, and Brian Cutting.

Pond can enhance water quality and ecological conditions Breeding bird surveys were conducted on 22 transects within the wooded riparian buffer surrounding Noxontown pond. The surveyed buffers were split into two treatments (wide and narrow). The vegetation along each transect was quantified in terms of biomass, species composition, the load of alien plants and the ability of each plant species to support the growth and development of caterpillars, a primary source of protein for birds. Results were used to determine the relationship between these variables and the diversity and abundance of breeding birds. An interesting statistical interaction between buffer width and the quality of plants in the riparian buffers in terms of their ability to support breeding birds was found in this project. Narrow buffers were comprised of large, high quality trees like oaks and black cherries, while wide buffers were characterized by low quality trees like tulip poplar and Ailanthus (Fig 2). At the same time, narrow buffers were not wide enough to support many birds, while wide buffers provided enough space for the territories of breeding birds. Thus, the opposing effects of buffer width (fewer birds in narrow buffers) and buffer quality (more birds associated with the higher quality vegetation of narrow buffers) cancelled each other out, making it appear as if all corridors supported similar bird densities and diversity. It is concluded that the quality of the vegetation in riparian buffers is as important as buffer width in supporting biodiversity, something that should be seriously considered in future efforts to install riparian buffers to protect water quality.

The vegetation characteristics of the suburban developments surrounding the Noxontown Pond watershed were also measured in this project. Understanding the way in which landscapes surrounding St Andrews are currently being managed will guide recommendations on improving the management of such areas for water quality and the sustainability of biodiversity and ecosystem function. In this study, 65 randomly selected suburban landscapes were assessed and it was found that, on average, 92% of the land is in lawn, 74% of the ornamental plant species in these landscapes were non-native, 79% of the actual plants were non-native and 9% were highly invasive (Fig. 3). Thus, the landscapes surrounding St Andrews are nearly barren and the few plants they contain are not contributing to local food webs.

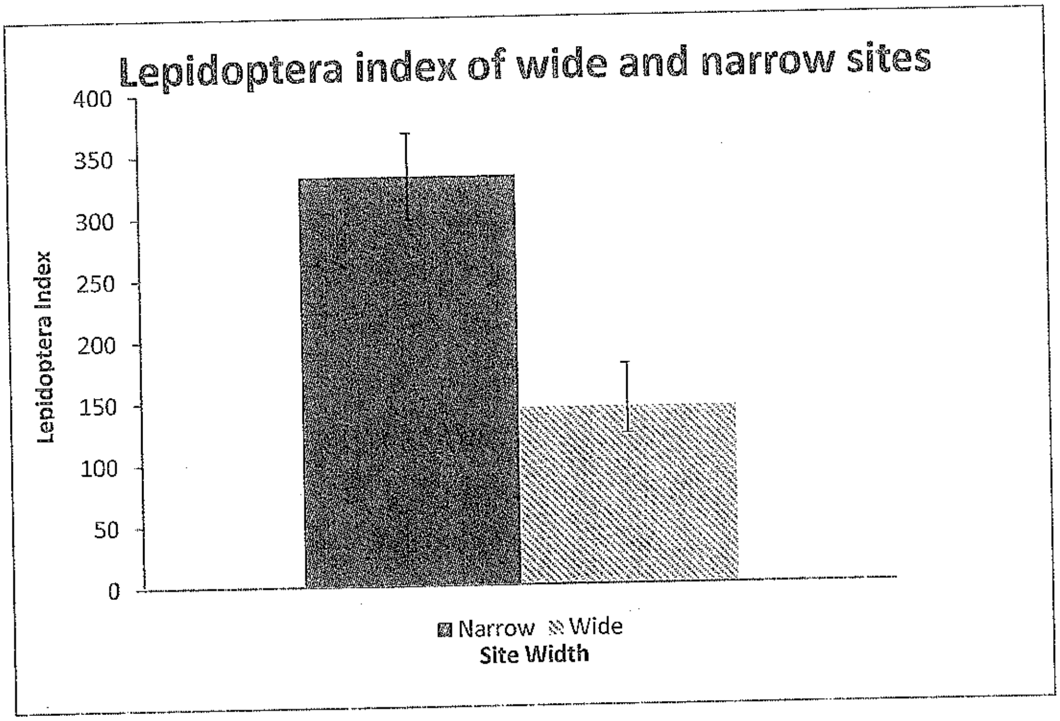

Figure 2: Narrow riparian buffers bordering Noxontown Lake have higher quality vegetation in terms of producing food for breeding birds.

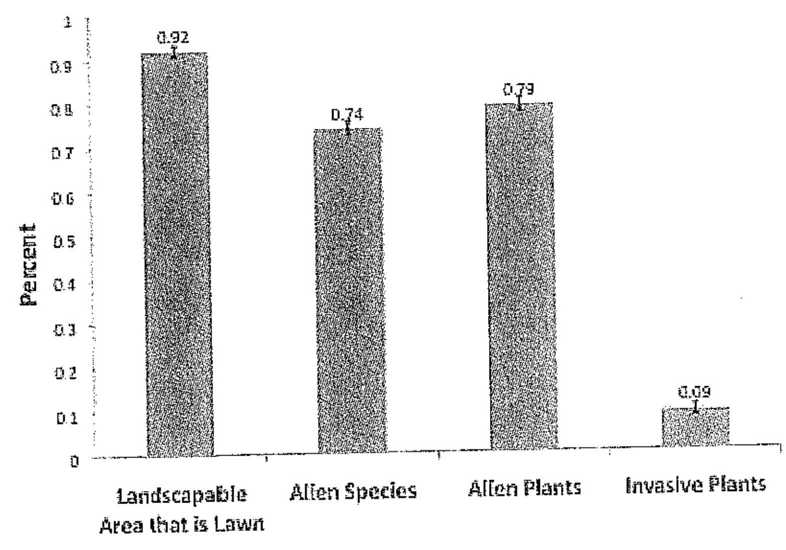

Figure 3: Landscape characteristics of 65 suburban properties in the Noxontown Pond watershed.

Another very significant project accomplishment was the restoration of 16 acres of the sections of riparian buffer around Noxontown Pond that were formerly in grassland. The restoration was accomplished in cooperation with the state Division of Fish and Wildlife by first encircling the area with a deer-exclusion fence and then planting over 1300 native trees and shrubs within the area. The area will be monitored in the years ahead by faculty, students, and staff at St. Andrew's for invasion by mutliflora rose, oriental bittersweet, and autumn olive until the plantings become well enough established to slow invasion themselves.

Finally, avian ecology studies investigated how mercury in atmospheric deposition from urban areas into riparian forests is affecting breeding bird diversity and health. Methylmercury has been shown to have severe effects on bird species in aquatic systems and is the bioactive form of mercury, causing adverse effects at much lower concentrations than un-methylated Hg. During the breeding season of 2007, blood samples were obtained from 16 forest breeding birds at St. Andrews (Northern Cardinals (*Cardinalis cardinalis*), Carolina Wrens (*Thryothorus ludovicianus*), Grey Catbirds (*Dumetella carolinensis*), American Robins (*Turdus migratorius*), and Indigo Bunting (*Passerina cyanea*). In 2008, an additional 10 breeding bird samples were collected. All samples were stored in a cooler in the field, frozen and sent to the Texas A & M Trace Element Research Laboratory, College Station, Texas for analysis. Overall, Carolina Wrens had the highest blood Hg levels and American Robin had the lowest (Fig. 4). These results are similar to other woodlot locations in Delaware and Maryland and provide the baseline information essential for future studies focused on assessing Hg bioaccumulation in the region.

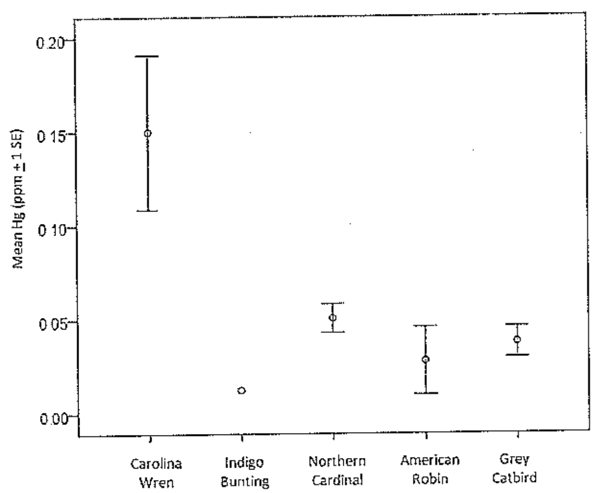

Figure 4. Total Hg levels in forest birds at St. Andrews, Delaware, 2007 – 2008.

Sustainable Landscaping Practices[7]: Studies in this area of the project focused on demonstrating how sustainable landscaping practices can be used in non-agricultural areas to protect water quality and enhance ecosystem health. The campus area at St. Andrew's has lawns, ornamental plantings, and other features similar to the established and newly emerging housing developments in the watershed and provides a good setting to demonstrate these sustainable landscaping practices to the public, community associations, and others. *Specific project accomplishments included education and demonstration projects focused on*: (i) the removal of invasive plant species - students from St. Andrew's school and UD volunteered to help remove invasive plants along the edge of Noxontown Pond and in an adjacent walking trail. In one morning they took out several truck loads of multiflora rose (*Rosa multiflora*), periwinkle (*Vinca minor*), and Japanese honeysuckle (*Lonicera japonica*), among others. The pond edge is now much more open and visibility of the pond from the lake edge walking trail has increased. Two student interns also conducted a summer-long project at St. Andrews to quantify invasive plant removal time along a woodland path at varying levels of plant invasion (Table 1). In cleared areas, they planted native ferns and shrubs;

Table 1. Hours required for invasive plant removal differentiated by density of invasion.

Invasiveness rating (5 – most invaded to 1- least invaded)	**Area of invasive plants removed by volunteers** (sq. ft./hour)
5	181
4	283
3	400
2	605
1	818

(ii) the reduction of mowed turf to reduce nonpoint pollution of Noxontown pond – a cooperative effort with UD project leaders and St Andrew's faculty, staff, and students reduced the area of mowed turf in front of the main campus building where a large grassy lawn serves as a common meeting area for students. The lawn requires frequent mowing, is a monoculture of turf that gives no support for biodiversity, and fails to reduce or slow storm water runoff so significant amounts of sediment and nutrient-rich runoff flow directly into Noxontown Pond. By taking some areas out of mowing, taller vegetation now slows the flow of runoff and provides habitat and food for native insects and birds; (iii) improve meadow aesthetics: a meadow area was established to

[7] Project investigators: Dr. Susan Barton, Dr. Jules Bruck, and Chad Nelson

replace mowed turf by planting perennial wildflowers and native ornamental grasses to increase aesthetic appeal, help bring some native wildflowers to the seed bed, and increase the diversity in wildlife habitat. In the sunny areas smooth aster (*Symphyotrichum laeve* 'Bluebird'), cutleaf coneflower (*Rudbeckia laciniata*), and Northwind switch grass (*Panicum virgatum* 'Northwind') were planted. In the shady areas common blue wood aster (*Symphyotrichum cordifolium*) and white wood aster (*Eurybia divaricata*) were used. Teams of college students, high school students, UD faculty and staff planted the perennials which are now maintained by St. Andrew's staff; (iv) enhance an existing rain garden to increase its aesthetic appeal – rain gardens are growing in popularity as a means to reduce stormwater runoff in urban/suburban developed watersheds. A UD summer intern worked to enhance an existing rain garden on the St. Andrew's campus by selecting two additional species of herbaceous plants (swamp-rose mallow (*Hibiscus moscheutos*) and cardinal flower (*Lobelia cardinalis*)) that would thrive in the cultural conditions of a rain garden and would complement the existing shrubs. The rain garden is now regularly used in education for students and in outreach events held for residents of nearby suburban communities. (v) lawn renovation and management - in 2008, the main lawn was renovated to remove crabgrass and Bermuda grass. Simply establishing and maintaining a healthy lawn reduced runoff and ultimately the amount of nutrients entering Noxontown Pond, slowing the buildup of algae, reducing fish kills, and making the pond healthier. A survey was conducted at the Watershed in Your Backyard workshop (described below) to establish baseline data on people's impressions of mown and unmown turf at St.Andrew's School. The same survey was conducted at the annual UD Botanic Gardens plant sale at the CANR "Ag Day" (community event that attracts >3000 participants). Respondents rated mowed lawn images as less desirable and grassy meadow images as more desirable after reading a one page educational handout about the environmental benefits of meadow (Table 2);

Table 2. Perception of mown turf vs. unmown turf before and after reading fact sheet providing information about lawns and meadows.

Landscape image	**Rating prior to fact sheet** (1-10 Likert scale)	**Rating after fact sheet** (1-10 Likert scale)
Mown turf	6.4	5,5
Unmown turf with path	6.7	7.0

(vi) Environmental curriculum development - during the summer of 2009, an intern (recent UD Agricultural Education graduate) developed an environmental curriculum to be used by St Andrews environmental science classes for their Senior Independent Project (IP). The curriculum that was developed can also be readily adapted and used by environmental science classes in area high schools. In teams, IP students took environmental data on soils, water quality, insects, birds and plants in five different environments (agricultural field, suburban lawn, meadow, forest and pond edge). The intern also worked with St. Andrews students on several Saturdays during the school year By the end of the school year (2009/2010), IP students were able to compare biodiversity in these environments and presented their results at a school-wide Land Use Charette held at St. Andrews in April of 2010. Based on the recommendations coming from the Land Use Charette, two UD faculty working in this project area (Drs Barton and Bruck) subsequently met with St Andrews staff and teachers to make recommendations to further implement sustainable landscape practices. A large area of turf adjacent to Noxontown road from the faculty entrance to the current construction entrance was flagged for reduced (periodic) mowing. The taller grass will act as a groundcover and provide the appearance of a landscape bed around the many trees present in the approximately 3-acre area The reduced mowing will save time and money as well as protect the existing trees from mower damage. Finally, UD faculty worked with St. Andrews environmental stewards in two planting sessions during September and October of 2010 to relocate plants on a steep slope and add *Rhus aromatica* to help stabilize the slope, preventing erosion and sediment contamination of nearby streams, and to provide a more attractive landscape composition, an important consideration in suburban environments.

Objective 4: Conduct educational outreach programs and demonstrations for farmers and the Green Industry on how value-added, manure-based products and ecologically oriented BMPs can be used in their operations. Hold agriculture and natural resource camps for youth, workshops for K-16 teachers and students, and community education workshops designed to show the full value of farming to urban and suburban adults.

Accomplishments:

- Community Outreach: A community workshop open to the public was held in March of 2007 to introduce our Conservation Innovation Grant to communities near to St. Andrew's School At the workshop, titled "Watersheds, Ecosystems, and Community Action", project investigators provided an overview of project goals, outlined specific activities planned for 2007, and invited input from those in attendance on how some project goals could be extended into their communities A spring 2008 community event, the *Watershed in Your Backyard*, was held on St. Andrew's campus on April 14, 2008. The event was co-sponsored by the Appoquinimink River Association and UD Cooperative Extension. It featured educational workshops on how to integrate sustainable practices being adopted at St. Andrew's School (native plants, rain gardens, IPM, soil testing, turf management, riparian plantings) into suburban communities; a watershed bus tour that visited new suburban developments, cropland being managed by one of St Andrew's farmers, and Noxontown pond; and a boat tour of Noxontown pond that included a mini-lecture on land use, water quality, wildlife habitats, and nonpoint pollution We conducted these events to both highlight project goals and accomplishments and provide information on how individuals and neighborhood associations can integrate sustainable management practices that protect water quality and preserve ecosystems into their own communities
- Summer Youth Camps: We conducted, with the cooperation and support of Delaware 4-H, four youth environmental education day camps ("Eco-Quest" camps) at St. Andrew's School in the summers of 2007 to 2010. The camps were two-weeks in duration and hosted ~35 youth campers each. Youth participating in these camps engaged in a wide range of activities related to soil and water quality, ecosystems and wildlife ecology, and the basics of agriculture (almost all campers were from urban/suburban backgrounds) Parents also participated in many activities. The environmental camps received widespread support from

many Delaware agencies and organizations including the Delaware Department of Agriculture, the Department of Natural Resources and Environmental Control, Cooperative Extension's Master Gardeners, numerous departments at the University of Delaware (e.g., Animal Science, Food and Resource Economics, Geography, Plant and Soil Sciences), the Delaware Archaeology Museum, and the UD Botanic Gardens. The camps received extremely favorable comments from campers and their families who learned about many of the ecological and environmental aspects of sustaining agriculture and natural resource areas in an urbanizing landscape.

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Tallamy, D. W. , J. Bruck, K. Pippins, S Walker, S. Shpak, and Ann Lucy. 2010 The abundance, diversity, and nativity of suburban landscape plantings. Cons Biol. *In preparation.*

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Barton, S.S. Sustainable Landscape Design Short Course, New Castle County Cooperative Extension, Newark, DE, March 18, 2010, 4-6 PM.

Barton, S.S. Tour of Sustainable Landscape Projects at St. Andrews, DISC Annual Meeting, Middletown, DE, November 23, 2009

Bruck, J. Harmonizing with Herbaceous Native Plants UDBG Speaker Series, September 7, 2010 University of Delaware, Newark, DE.

Borchers, A M., J.M. Duke 2010a. Valuation of a Quasi-Public Good Using both Revealed and Stated Preference Techniques. Ann. Meeting Northeastern Agric and Res. Econ. Assoc., Atlantic City

Borchers, A.M., J.M. Duke 2010b. Valuation of a Quasi-Public Good Using both Revealed and Stated Preference Techniques. Agric. and Res. Econ. Rev (forthcoming)

Borchers, A M., J.M. Duke. 2009. A hedonic model of agricultural land impacts on residential land values: Evidence from Delaware. Ann. Meeting Northeastern Agric. and Res. Econ. Assoc., Burlington, VT.

Borchers, A.M., J.M. Duke. 2008. Effect of proximity on preferences for land preservation and sustainable management. Ann. Meeting Northeastern Agric. Res. Econ. Assoc., Quebec City.

Borchers, A., J. Duke. 2009. A hedonic model of agricultural land impacts on residential land values: Evidence from Delaware. Agric. and Res. Econ. Rev. 38(2):281

Borchers, A., J. Duke. 2008. Effect of proximity on preferences for land preservation and sustainable management. Agric. and Res. Econ. Rev. 37(2):303.

Carmona, C., Joshua McGrath, Solomon Kariuki, Alyssa Collins and J.T. Sims. 2008. Agri-Environmental Assessment of Pelletized Broiler Litter In Corn Production: Laboratory Studies ASA-CSSA-SSSA International Meetings. Joint Annual meeting, 5 – 9 Oct. 2008. Houston, TX. GSA Boulder, CO and ASA, CSSA, and SSSA, Madison, WI.

Collins, A, J. Thomas Sims, and Joshua McGrath. 2008. Agri-Environmental Assessment of Pelletized Poultry Litter in Corn Production: Field Studies. Joint Annual meeting, 5 – 9 Oct 2008. Houston, TX. GSA Boulder, CO and ASA, CSSA, and SSSA, Madison, WI.

Duke, J.M., A. Borchers, S. Chatterson. 2007. Willingness to pay for sustainable agricultural practices in an urbanizing region. Ann. Conference of the Mid-Atlantic Sections of the American Water Resources Assoc., Newark, DE.

Duke, J.M., A.M. Borchers, S. Chatterson. Public preferences for farmland preservation and sustainable management practices. St. Andrew's School, Middletown, Del., 2009

Dutta, S., S. Inamdar, D. Aga, and J.T. Sims. 2010. Dissolved organic carbon (DOC) in agricultural runoff and its influence on exports of estrogens and trace elements (Oral presentation). *In* Session General Soils and Environmental Quality: I. Annual Meeting, 31 Oct – 4 Nov. 2010. Long Beach, CA. ASA, CSSA, and SSSA, Madison, WI.

Dutta, S , S. Inamdar, D Aga, and J T. Sims. 2009 Exports of hormones in surface runoff from agricultural fields receiving poultry litter (Oral presentation). *In* Symposium – Reactions of Emerging Contaminants at the Water/Mineral Interface: I Annual meeting, 1 – 5 Nov 2010 Pittsburgh, PA ASA, CSSA, and SSSA, Madison, WI.

Dutta, S., S. Inamdar, J.T. Sims, and A. Collins, and N. Kiracofe. 2008. Nutrient and trace metals exports in surface runoff from plots receiving pelletized broiler litter (Poster). *In* Session – Nutrients and Soil Structure: II Joint Annual meeting, 5 – 9 Oct. 2008. Houston, TX. GSA Boulder, CO and ASA, CSSA, and SSSA, Madison, WI.

Kiracofe, N., S Dutta, and S. Inamdar 2008. Comparison of pelletized poultry litter and urea for surface water quality. *In* Annual Poster session, Delaware Water Resources Center, Newark, DE

Sprinkle, A., David Hansen, and Susan White. 2008 Remote Sensing of Turfgrass Quality On Athletic Fields Treated with Pelletized Poultry Litter Joint Annual meeting, 5 – 9 Oct. 2008 Houston, TX. GSA Boulder, CO and ASA, CSSA, and SSSA, Madison, WI

Sprinkle, A., David Hansen, and Susan White. 2008 Nitrogen Availability to Turfgrass from Pelletized Broiler Litter Joint Annual meeting, 5 – 9 Oct. 2008 Houston, TX. GSA Boulder, CO and ASA, CSSA, and SSSA, Madison, WI.

Dr. Doug Tallamy has discussed various aspects of this research in over 150 talks to Audubon societies, Native Plant societies, Master Gardeners, Arboretums, Garden Clubs Watershed associations, Land trusts, and Landscape Architects He also has been a guest on NPR 7 times, including **Science Friday** with Ira Flato.

Tso, J., S Dutta, S. Inamdar, and D. S Aga. 2010 Wrong-way-round ionization enables simultaneous analysis of free and conjugated estrogens, sulfonamides, and tetracyclines by liquid chromatography-mass spectrometry (Oral presentation). *In* Session – Analytical Chemistry for Emerging Contaminants in Environment Northeast Regional Meeting (NERM), 2 – 5 June 2010 Potsdam, NY. Am. Chem Soc. Washington, DC.