CIG NRCS Final Report 2013 Grantee Name: The Pennsylvania State University, College of Agricultural Sciences	
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For our final report, we summarize how we have addressed the deliverables that we identified in our original grant proposal.

1. *Increased farm adoption of innovative conservation cropping systems in the Chesapeake Bay watershed.*

With Cooperative extension educators, we offered to help farmers in four counties conduct on-farm evaluations of a range of innovative conservation cropping system practices (ie. manure injection, cover crop roller crimper, assistance with cover crop adoption, winter canola production). Farmers in all four counties wanted to try manure injection; and in two counties two farmers were interested in trying the cover crop roller crimper to help them terminate and manage large cover crop biomass quantities.

Manure injection

Our team of cooperative extension educators and researchers identified commercial manure haulers and farmers whom were interested in on-farm evaluation of manure injection. The commercial manure haulers agreed to help promote manure injection with additional farmer clientele. We purchased four Yetter shallow disk manure injection rigs in 2010 and one in 2013. In 2010, six preliminary on-farm demonstrations farm compared side-by side, replicated comparisons of manure injection and broadcast manure. Dry weather caused the team to abandon 3 trials, while 3 were taken to yield. In the following three years (2011-13), seventeen trials on the 2010 farms and on ten additional farms in these counties hosted demonstration and research projects .

Summary of number of farms where CIG manure injection data was collected.

County	2010	2011	2012	2013	Total
Berks	1	2	2	0	4
Franklin	1	1	3	0	4
Lancaster	1	3	3	3	9
Total	3	6	8	3	17

Field days on cooperating farms and the Penn State research farms were hosted in two to four counties each year, and educational presentations were presented in numerous counties at educational crop and soil and no-till days, conferences and workshops. A number of on-farm evaluations and educational events were featured in agricultural media publications and local newspapers including Lancaster Farming and the Penn State College of Agriculture Research magazine. Members of our team also participated in educational events such as Pennsylvania State University Southeastern Agricultural Research Center "Farming for Success" field days in multiple years. On a number of occasions, a panel of trained Penn State faculty and staff demonstrated how they quantify the odor reduction associated with manure injection as compared to broadcasting manure. In 2011 in Franklin County, Agricultural Engineer Robin Brandt and his odor assessment panel quantified the reduction in odor when manure was shallow-disk injected versus when similar amounts per acre were broadcasted on the field surface for a field day and for the History Channel's "Modern Marvels" info-drama television show. Video footage of the odor assessment panel, broadcasting manure, and of shallow-disk injecting manure was featured on Modern Marvel's episode entitled "Stink". The segment highlighted manure injection as a technology that can reduce manure odor in a world of good and bad odors.

Cooperative extension personnel also provided one-on-one consultation to numerous farmers whom were considering adopting manure injection and the cooperating manure haulers promoted and injected manure on additional farms each year. In addition, in collaboration with colleagues in a 2010 CIG NRCS awarded grant, and with the use of some funds from the same, we are in the process of completing an educational video of farmers and commercial manure haulers discussing manure injection.

The most active outreach education was conducted in Lancaster County by cooperative extension educator Jeff Graybill and the cooperating manure haulers Josh and Steve Lehman with support from project team members Ron Hoover and Robert Meinen. Ron Hoover, with assistance from Steve Lehman and Robin Brandt, presented and demonstrated manure injection during the annual "Farming for Success" field day in late June 2010. Hoover again participated in the same event during 2011 where he shared the benefits of manure injection. Between 160 and 200 farmers, consultants, legislators, extension educators, and government agency personnel attend this annual event. Jeff Graybill presented an educational presentation about manure injection at two "No-Till Tune-up" workshops (2011, 2013) in Lancaster County and at four different Crop and Soil conferences from 2010 - 2013. All cooperating commercial manure haulers also independently encouraged their clientele to try manure injection and they injected manure on many acres in addition to those fields included in the on-farm studies.

Adoption of manure injection by farmers was highest in southeastern PA, especially Lancaster County where the cooperating commercial manure hauler injected manure into 1300 acres on 12 farms and anticipates the large majority of these farms will continue to inject manure. Due to a strong initial response and continued growth in the practice of injecting manure amongst his customer base, this cooperating manure hauler decided to add manure injection to a

second truck-tanker. He sought assistance with the purchase of a second manure injection rig during fall 2013. In 2013, we requested permission from NRCS to extend the grant for an additional month in order to purchase the manure injection equipment for this cooperator and we purchased the equipment. They anticipate greatly expanding manure injection acreage in 2014. In addition, we have some evidence that additional farmers have adopted manure injection either by working with other commercial manure haulers or purchasing their own equipment. For instance, the manager of Mason Dixon farms in Adams County (southcentral PA) who farms 1700 acres of corn, consulted with Cooperative extension educator Jeff Graybill about manure injection in the early years of this project. The farm purchased a six row Dietrich manure injector system that they used in both fall and spring prior to planting for a total of about 200 acres. They plan to inject manure on 500-600 acres as they constructed numerous manure-holding tanks available at locations far from their dairy barns where soil N is limited.

The manure injection equipment that was purchased for use in Bradford and Sullivan counties was not used in that location because very wet spring weather limited the time available for manure injection. In 2013, we moved that manure injection equipment to Mifflin county in central PA to a new cooperating commercial manure hauler. In 2013, the manure hauler, Matt Synder participated in on-farm evaluations of manure injection with support from our team and Dr. Alex Hristov and Dr. Sjoerd Duiker, whom are funded by the National Fish and Wildlife Federation to reduce the amount of N and P in dairy cow waste in two impaired and targeted watersheds; the Upper Kishcoquillas Creek (Mifflin Co.) and the West Branch Little Conestoga (Lancaster Co.). We anticipate that the on-farm evaluations will continue there in 2014. In Berks and Franklin Counties, cooperating farmers have not continued to inject manure, which is discussed further below.

Cover Crop Roller Crimper

Use of the cover crop roller crimper has continued since 2010 by the Peckman family dairy farm in Franklin County where they have used it to terminate cover mixtures of hairy vetch and cereal rye or crimson clover and triticale. By using the cover crop roller crimper they can allow the green manures to grow longer in spring to increase N fixation and produce more biomass for a high residue mulch. A cover crop roller crimper that was purchased for use in Bradford and Sullivan counties, was not used because wet fall weather and shorter periods of spring growth limited cover crop establishment and development: Seldom was a heavy cover crop produced and rolling/crimping was unnecessary. Therefore in 2013, we transferred the roller crimper to Dauphin County where an organic farmer has been evaluating his ability to use the tool to suppress weeds in a rotational no-till system.

2. *Performance data for innovative conservation cropping systems on farms that represent the range of physiographic regions of the Chesapeake Bay watershed.*

Manure injection

Although the manure injection treatments likely conserved ammonical N in the order of 30-50 lb N/A in our on-farm trials, mixed corn yield response was observed on cooperating dairy

farms. We believe this was due to a number of factors including weather, soil nitrogen reserves, and manure application rates. A wet spring occasionally delayed corn planting and corn yield was further limited by extended hot, dry weather in summer. Corn yields, as well as pre-sidedress soil nitrate test (PSNT) sampling and late-season corn stalk nitrate tests (LSSNT) indicated that soil nitrate levels were sufficient-to-high and those corn crops suffered no nitrogen deficiency. The later planting dates and the summer drought had reduced corn yield potential. This reduced the potential for a crop response to the additional N available to the crop through conservation by manure injection. Further complication seems related to high residual soil N and organic N content due to frequent manure application and legume crops on many fields during previous years. Also, the farmers were understandably reluctant to limit broadcast manure application rates to levels that would leave those plots short of N and result in measurable corn yield reductions when compared with corn grown on similar rates of injected manure. These factors made it unlikely that we would observe a significant increase in corn yield using injected manure treatments, except in years with ideal climate for corn yields. The team worked with cooperators to further lower application rates in 2013. Results from 2013 appear more promising but are still being analyzed.

PSNT protocol research

In a few cases farmers valued manure N conservation to reduce side-dress N applications or because they could apply lower rates of manure to their cropland and sell their remaining manure to other farms. Researchers worked in cooperation with this project to help determine this value.

Mid-season soil testing was conducted at these sites with the goal of establishing a new protocol for PSNT sampling in fields where manure is injected. PSNT protocol includes sampling corn when it is at approximately the six-leaf stage. This test provides a snapshot of N in nitrate form that is available to the corn plant. Guidance is available to determine if additional N is needed for the corn to reach maximum growth by the end of the season. If N is deficient, further guidance allows the producer to determine how much additional N fertilizer is needed at mid-season so that N does not limit corn growth. Current standard testing protocols give questionable results for fields with banded manure because the mid-season soil samples may or may not be collected close to the N-rich manure band. In conjunction with these on-farm PSNT soil testing studies, greater soil profile investigations were conducted at the Penn State Agronomy Research Farm. Testing done with this CIG project will be used to verify protocol recommendations developed with this more precise data collection.

The team is looking forward to analysis of 2013 PSNT results from these cooperating farms. The soil testing was conducted using a protocol developed from previous years. In the suggested protocol, four sets of five soil samples are collected in a line perpendicular to the manure band at spacing of six inches between individual soil sample cores. These 20 soil cores are mixed and submitted for testing as a composite sample. Preliminary work indicates that this protocol would be more reliable than 20 randomly sampled cores in the injected fields. With development of this protocol the impact of this CIG-funded project will continue for many years.

Odor reduction of manure injection

Odor assessment of manure injection at our NESARE Sustainable Dairy Cropping Systems research and education project and at the Franklin County field day revealed that manure injection significantly reduces manure odor, which is important for many Pennsylvania farmers whom farm at the suburban/rural interface. In fact, Josh Lehman, the commercial manure hauler in southeastern PA, reported that odor reduction is the primary goal of some of his customers, particularly when applying manure to rented land, because they want to maintain good relations with the landowner and field neighbors to retain their rental contracts.

Time required and consequent costs of manure injection

The cooperating commercial manure haulers and our observations estimate that manure injection can take up to twice as much time as surface applying manure. This results in higher application fees and limits how many acres manure haulers can apply manure to in spring when optimal weather and soil conditions for manure application is often limited, and farmers are anxious to have their manure storages emptied. Therefore, our cooperating manure haulers for whom we purchased the manure injection equipment charged $5 - 10/A more for manure injection than they did for broadcasting manure. However, the extra time required for manure injection presents additional challenges. Dairy and hog farmers want to empty their manure storage facilities in spring and prepare their fields for planting as soon as possible. Since manure injection takes more time, it can delay timely crop planting, and contribute to a potential yield loss for farmers. For instance, in Berks and Franklin counties, the cooperating manure haulers had contracts with hog farmers and other operators whom valued early and timely manure application and were not interested in the time required or the additional cost of manure injection. Additionally, commercial manure haulers are reluctant to slow their manure application rates during times of year when windows of opportunity to apply manure are small (due to weather and planting times) and demand for their services are high (many clients need to apply manure and plant simultaneously).

Since wet and cool spring weather conditions often limit the optimal times for manure application and corn planting, a manure hauler who injects manure often subsequently won't have time to complete additional manure application contracts when conditions permit. This trade-off creates an opportunity cost associated with manure injection for the commercial manure hauler and possibly the farmer. Due to this 'opportunity cost' associated with the additional time required for manure injection, we expect that significantly more than $10/A is needed to incentivize adoption of manure injection by manure haulers and farmers.

Shallow disk manure injection equipment

The commercial manure haulers reported that the Yetter shallow disk injection units did not withstand heavy usage in stony soils in Pennsylvania. The haulers therefore invested considerable funds (ex. $5,000-6,000) to repair or in some cases to replace injection unit components with stronger parts. Several other manure haulers and farmers reported that Dietrich manure injection equipment was more durable, but since we did not evaluate Dietrich manure injection equipment, we do not have data to verify such reports.

Soil health

Some of our extension educators have occasionally heard reports of or seen fields where manure broadcast on the soil surface was associated with an increase in dead earthworms on the soil surface. By contrast, we neither saw nor heard reports of shallow disk manure injection harming soil biology or health. Interestingly, we often observed that earthworm casts were concentrated over and around manure injection bands. Further, early in the droughty summer periods, corn plants in the broadcast manure treatment plots often exhibited leaf curling, an indication of moisture stress. This contrasted with corn plants in the manure injection treatments that did not show similar signs of moisture stress. It appeared that manure moisture was conserved in the manure injection bands below the soil surface. Injection however requires more field passes than broadcast application, and could lead to greater overall soil compaction.

Cover Crop Roller Crimper

The cover crop roller crimper enables the Peckmans to manage their green manure crops to produce more N and biomass, further they have observed that the high residue mulch helps to reduce soil erosion on their rolling, sloped fields, particularly early in the season when the corn canopy is not sufficient to intercept spring rainfall events. They also report that the mulch helps conserve soil moisture that is important on their droughty slate soils.

3. Identification of information needed to promote adoption, and possible technical assistance that growers may need when adopting the innovations

As discussed above, in some cases, after farmers had the opportunity to try manure injection, they continued to inject manure. However in two of the three major cooperating counties, farmers did not observe a significant crop yield response to manure injection; instead they were deterred by the additional time required and the higher fee associated with manure injection, and they did not voluntarily continue with manure injection. In one year, farmers in Maryland near Franklin County did invest in manure injection to meet that state's new nutrient management law. Later the farmers learned that the law permitted them more time to meet the new manure management regulations, and the following year they returned to surface applying instead of injecting manure. This suggests that on farms where soil N is not limiting crop yields, farmers may not adopt manure injection without significant economic incentives or nutrient management regulations.

By contrast, there were a number of factors or incentives that appear to explain the higher adoption of manure injection in the southeastern PA region around Lancaster County. Farms that valued the opportunity to reduce manure odor and increase their chance of retaining land rental contracts were willing to pay more and take more time for manure injection. Some nearby Maryland farmers adopted manure injection to meet the new nutrient management law requirements for highly erodible land or where there were run-off concerns. We learned that Maryland is supporting manure injection with a significant subsidy of $45/A. In Pennsylvania, there are EQUIP funds that can also be used to subsidize manure injection at $45/A. However,

farms must first have developed a 590 nutrient management plan. Subsequently, the first EQIP funds allocated to a farm are spent to install manure storage facilities to meet 590 nutrient management plan requirements, and not as cost sharing for manure injection. It is likely that farmers would be more likely to adopt manure injection if financial assistance for manure injection were separate or in addition to funding for manure storage.

Educational outreach also likely contributed to increased understanding of the benefits of manure injection and adoption. Lancaster County is the location where the Cooperative Extension educator and the cooperating manure hauler actively promoted manure injection via numerous educational conferences and workshops, and at field days at the Pennsylvania State University Southeastern Agricultural Research Center. Nearly all these events were featured in agricultural media outlets. The cooperating manure hauler, at personal expense, also widely advertised his manure injection services.

Educational programs and incentives are likely be most effective with farms that have low fertility soils, such as grain farms that purchase manure or farms that have low animal units and limited livestock manure to apply to crop acreage. We learned of farms with low fertility soils that were willing to pay for the manure injection to conserve nutrients. Similarly, farms that transport manure longer distances have greater incentive to pay for manure injection for two main reasons: i. Injection conserves N that is costly to transport or supplement in commercial form. ii. As travel distance increases, the additional time required to inject a tanker-load, as a percentage of total round-trip time, when compared to time to broadcast manure, is less. This also means the percentage of cost associated with injection at distant lands is lower because travel time and tanker fill time are the same for either method.

In addition, some cooperating farmers were more willing to inject manure after harvesting ryelage prior to the subsequent corn crop. Manure N in this crop sequence may be more valued and since it was slightly later in spring, demand for manure haulers and time management for the hauler may improve. Farms with fields with high P index may also be willing to adopt manure injection so that they can continue to apply manure to their high P index fields.

In this project, we also learned that there are opportunities to reduce the time required to inject manure. The commercial manure haulers in Lancaster County (Lehmans) used truck mounted injection equipment over tractor pulled tank mounted equipment; this allowed them to travel between manure storages and farm fields at higher speeds and it enhanced their maneuverability both in the field and on the road. Further, to save time, the Lehmans installed a single truck mounted system with a folding toolbar that allowed the machine to have six injection units versus five units, increasing the by 2.5 feet over that of the five unit toolbars.

Further, commercially available injection technology can be improved. Previous experiment station research found that shallow disc manure injection had advantages over other injection methods. However the factory equipment purchased with this grant to advance the earlier research results was not durable enough for the rocky soil conditions present on many cooperators' farms. As a result the second manure injection rig that was purchased for the

Lehmans in 2013, was custom built by a local machine shop in Lancaster County that had rebuilt the original shallow disk injection units purchased for the Lehmans in 2010.

In summary, despite the increased time and cost of manure injection, there were a number of factors and incentives that resulted in adoption and sustained use of manure injection. Extensive educational activities appear to have helped promote adoption, particularly for farms with: i. limited soil fertility, and/or ii. a need to reduce odor to retain land rental contracts. It is likely that farms with high P index my also be willing to incur the cost and time trade-offs associated with manure injection, and possibly farmers planting corn later in spring after ryelage harvest. Dairy and livestock farms that have high fertility soils that are not N limited, are not likely to adopt manure injection without significant financial assistance (ex. $45/A) or nutrient management regulations. Construction of sturdy, durable manure injection units is recommended for rocky soils such as those in parts of Pennsylvania. Truck-mounted manure injection equipment appears to have advantages over tractor drawn tankers and expanding the tool bar from five to six injection units can increase manure application rate during the spring season when rapid manure application and timely field operations have significant economic value to farmers and manure haulers.