Pigs, Profit, Planet:
North Carolina Farmers' Perspectives on Waste Lagoon Conversion

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Abstract

It has been documented that pollution from North Carolina hog waste lagoons contaminates drinking water, lowers air quality, and devastates North Carolina's commercial and recreational fishing and tourist industries. The North Carolina state legislature has offered swine farmers a 90% cost-share grant to convert their lagoons to "Environmentally Superior Technologies (EST)," yet only 11 of 2,200 farms have applied for the cost-share program. This paper sheds light on why hog farmers are not converting their lagoons to EST, finding that the biggest barriers to the adoption of EST are cost and complex operation requirements. Background information, literature, and interviews with North Carolina swine farmers are used to develop a survey that can be applied on a larger scale to gain a deeper understanding of the potential for and pitfalls of retrofitting hog farms in North Carolina.

The NC Hog Industry, Lagoon Legislation, and Environmentally Superior Technologies

North Carolina's economy depends on its 2,200-farm hog industry, yet current swine waste management practices threaten the state's environment, creating externalities that impact human health, quality of life, and North Carolina's fishing and tourist industries. Though the North Carolina state government and corporations have worked to motivate farmers to convert their waste management systems to sustainable technologies, famers have resisted. This project goes directly to the farmers to determine why farmers are not converting their systems, and what incentives could motivate them to do so.

Since the early 1990s, North Carolina's swine production industry has been growing faster than any other state's, moving North Carolina from the sixth largest hog producing state in the US to the second largest. Between 1991 and 1997, although North Carolina placed a two-year moratorium on expansion and new construction of swine farms, North Carolina's swine population grew from 3.7 million to almost 10 million (Ladd 2002). To accommodate this rapid growth, North Carolina's hog industry moved from small, local enterprises to large, industrialized operations: the average size of NC hog farms has grown by a factor of six since 1989, and the number of hog farms plummeted from over 11,400 in 1982 (Ladd 2002) to about 2,200 in 2011 (Oleniacz 2011). Many communities characterized this influx of industrialization as "environmental carpetbagging" because of the widespread negative externalities the pork industry imposed on the state (Ladd 2002). In a series of environmental justice summits, North Carolinians expressed concern that the growing hog industry would push out small, independent farms and economically threaten rural communities, but their resentment was even more strongly tied to the pollution and odor produced by the farms (Ladd 2002).

A hog produces two to five times as much waste as a human; to deal with such enormous quantities of manure, swine farms pump the waste produced by the hogs out of the buildings where the hogs live into football field sized pools called "lagoons" (Osterberg 2004). In the lagoons, hog waste anaerobically decomposes and liquefies, then evaporates, unless it is sprayed onto fields of crops as fertilizer (Ladd 2002). Lagoons produce a diverse range of negative externalities, including polluted water and air, odor, and fish kills that severely damage North Carolina's commercial and recreational fishing and tourist industries. (Stith1995).

As a result, in 1997 the North Carolina state legislature placed a two-year moratorium on the construction of new swine facilities and the expansion of facilities with over 250 pigs through the "Clean Water Responsibility Act." The Act also reestablished zoning authority for counties over hog farms, required "economically feasible" odor control from farmers, mandated nitrogen and phosphorus limits for surface and ground waters, and created a commission with the authority to make storm water runoff rules dealing with hog waste pollution (Basnight 1997). However, the North Carolina public continued to protest the environmental and social impacts of hog farms (Ladd 2002). In 2007, environmental activists threw a birthday party on the lawn of the NC legislature building in Raleigh for all of the children in Eastern North Carolina who cannot have outdoor parties because of the "pervasive and nauseating" stench of the lagoons (Rawlins 2008).

In 1999, Governor Jim Hunt announced a plan to phase out open-air lagoons and sprayfields within ten years. However, his strategy did not provide alternatives to lagoons for farmers, and, to North Carolina citizens' dismay, did not receive support within the state's government (Ladd 2002). Soon after, Hurricane Floyd caused unprecedented and devastating lagoon flooding, providing NC Attorney General Mike Easley with the political support necessary to announce the Smithfield Agreement (Ladd 2002). The agreement between Mike Easley and Smithfield Foods, as well as several other industrial swine producing companies, had four main terms: the companies would 1) immediately enhance environmental protection in waste management operations by providing the NC Attorney General with plans to a) protect NC water quality and b) adopt Environmentally Superior Technologies (EST) for hog waste management and assist contract farmers in doing the same, 2) commit $15 million to the development of EST, 3) install EST, once developed, on company owned farms and help contract farmers install EST, and 4) commit $50 million to environmental enhancement activities (Easley 2000).

The agreement defined EST by five performance criteria: 1) eliminate discharge of animal waste to surface and ground water 2) substantially eliminate atmospheric emissions of ammonia 3) substantially eliminate odor that is detectable beyond the hog farm 4) substantially eliminate disease transmitting vectors and airborne pathogens and 5) substantially eliminate nutrient and heavy metal contamination of soil and groundwater. However, the agreement also mandated that the EST be "technically, operationally, and economically feasible" (Easley 2000). The economic feasibility of an EST depends on the 10-year annualized cost of the EST versus that of the lagoon system, projected revenues from the EST, available cost-share monies or other government financial supports, and the impact of the EST on the competitiveness of the North Carolina pork industry relative to other pork producing states (Williams 2009). Because economic feasibility can include cost-share monies and grants, this term does not accurately reflect the economic competitiveness of EST.

As a result of the Smithfield Agreement, NC State University tested 18 candidate technologies by March 2006, 5 of which meet the criteria for EST. Four of the technologies treated dewatered manure solids with composting, high-solids anaerobic digestion, or gasification processes at centralized facilities. These EST created a variety of marketable outputs, including class A composts, organic fertilizers, and energy (Vanotti 2009).

The fifth EST, called "Super Soils" technology, consisted of an on-farm solids separation/nitrification-denitrification/soluble phosphorus removal system (Vanotti 2009). The super soils technology was favored for new or expanding farms, but, unlike the other four EST, was not considered economically feasible for retrofitting farms (Williams 2009). Therefore, NC State developed a second generation of super soils, which was tested on a full-scale North Carolina farm from 2006-2008. Vanotti et al. found the second generation met all of the environmental EST standards at one third of the cost of the first generation (a 10-year annualized net cost of $132.24 per 1000 lb, or $7.13 per finished pig). Farmers can offset these costs through the sale of greenhouse gas emission reduction credits and water quality credits. These "credits" are a measured amount of pollution reduction sold to organizations that would like to reduce their carbon impact.

Moreover, Vanotti et al. found that animal health and productivity benefited from the EST: mortality decreased by 57% and daily weight gain increased 11% compared to farms run with anaerobic lagoons, allowing the farmer to sell 5.6% more pigs. Furthermore, the second generation of super soils was labor efficient and simple to use: operation only requires two weeks of company training, and the system only needs to be operated during normal working hours (Vanotti 2009).

To encourage agribusinesses and farms to retrofit their waste management systems with EST, the North Carolina General Assembly passed S.L. 2007-523, which offers a significant cost-share program, called the Lagoon Conversation Program (LCP), for lagoon conversion aimed at environmental emissions reductions or energy production (Williams 2009). The grants are allowed cover up to 90% of the cost of conversion for farmers who apply before 2012, 80% for farmers who apply before 2017, and 75% for farmers who apply after 2017. The act also requires that lagoons that pose an "imminent hazard," defined as " a situation that is likely to cause an immediate threat to human life, an immediate threat of serious physical injury, an immediate threat of serious adverse health effects, or a serious risk of irreparable damage to the environment if no immediate action is taken" (G.S. 103A-2), either be converted to EST or closed (Perdue 2007). Farmers avoid their farms being classified as "imminent hazards" by following existing lagoon regulations; this clause has not spurred conversions.

Despite the cost-share program, only 11 swine farms have applied for conversion. In 2007-08, three farms applied, but one farm withdrew its application. Therefore, only two farms entered the program. In 2008-09, two additional farms were added. In 2009-10, due to limited funding, the Division of Soil and Water Conservation decided to prioritize applicants with alternative energy components to their conversion. Yet, none of the applicants included alternative energy plans. Of the six applicants, three were selected for conversion – the project did not have enough funding to accept all six. In fact, the LCP only has $113,892.16 in unencumbered account funds, or enough to convert two farms (*Annual Report* 2010). Therefore, since Lap's beginning in 2007, only seven farms have had the opportunity to participate out of the approximately 2,200 farms in NC (Oleniacz 2011). Of these seven farms, construction has only begun for one. None of the conversions are complete (*Annual Report* 2010). Combined, the seven farms have about 46,152 hogs (Matias 2005, "Terra Blue, Inc." 2010, Chronicle Staff 2010), which is only about 3.1% of the market hog population in NC (Vanderberry 2011). Therefore, relative to the total number of hog farms, the number of farms retrofitting their waste management systems is very small.

Currently, the North Carolina General Assembly is considering a bill to phase out lagoons in NC by September 1, 2016 (Harrison 2011). According to Duke's visiting professor James Johnson, a government and business consultant who worked for the General Assembly until 2005, this bill will not pass. In fact, the bill may not even get a hearing because it is sponsored by two Democrats in a Republican controlled General Assembly. Further, the bill has been sent to the House Rules Committee, where, as Professor Johnson said, "bills go to die." Professor Johnson believes that in order for such a bill to generate support, NC would need another focusing event like the lagoon floods in the 1990's; only another environmental disaster could spur private and public stakeholders to action.

Farmers' decision-making processes, values, and past perspectives

Farmers' decision-making processes are not motivated solely by profit, but also by personal values and tradition. According to a 1999 study, there is a wide range of attitudes that potentially contribute to farmers' decision making processes, including risk aversion, innovation, diversification, off-farm work, environment, production, management, legislation, stress, pessimism, and job satisfaction. These attitudes all have the ability to contribute to or detract from profit, farmers' foremost goal (Willock 1999).

The attitudes are shaped by four core values: economic values, like maximizing income and business expansion, social values, such as tradition and prestige, expressive values, like personal pride, and intrinsic values, like job satisfaction and independence. Though farmers develop rough objectives centered on these four values, few would say that they "plan ahead" or "use objectives in a clear and structured way" (Willock 1999).

An Illinois study further explores farmers' decision-making processes. This study suggests that farms with traditions of environmentalism, on-farm experimentation, and prudent resource usage are more likely to adopt EST (Salamon 1997). Though these findings seem intuitive, they provide valuable information about farmers' priorities; the study shows that farmers choose EST when they value the environment, innovation, and efficiency. While the latter two values can be linked to economics, the former is linked to social or expressive values. This study indicates that economic values do not always trump social and expressive values.

Farmers' perspectives on waste itself can also influence their perspectives on waste management. In Iowa, farmers value the nutrients in hog waste, conserving nutrients to apply to high value products like corn (Hoag 1995). However, farmers in North Carolina view waste as a problem. They water down hog waste, decreasing its nutrient content, and spray the waste on as little land as possible. They use the waste to fertilize low value crops, like grass or hay (Hoag 1995). If farmers' viewed the nutrients as an asset rather than as an obstacle, farmers might be more eager to try EST that produce quality fertilizers as sellable by-products.

RTI International and NC State University collaborated to generate a useful study about NC swine producers' perceptions of alternative waste management systems (Cates 2003). Though this study evaluates older (and therefore more expensive, less effective, and relatively untested) alternatives than are available today, the study provides useful background information on hog

farmers' opinions about EST. The farmers interviewed in this study were generally satisfied with the lagoon system because it is simple, cost-effective, allows production of a large number of animals in one location, and is not labor intensive. The interviewees also did not view the lagoon system as environmentally harmful, and they believed the odor on the farms came from hog houses, not the lagoons. The interviewees felt the limitations of the lagoons were negative public perception, problems associated with excessive rainfall, and onerous regulations, especially water quality regulations (Cates 2003).

The study found that swine producers knew very little about the benefits and limitations of alternative waste management technologies. The interviewees were most concerned with initial investments and operating and maintenance costs of alternative systems. Many believed they would not be able to get loans to finance retrofitting their farms, and suggested the government share this cost. Interviewees emphasized the importance of alternative technologies having proven track records and being "low-tech." They preferred systems compatible with their current lagoons, eliminating need for a significant capital investment (Cates 2003).

The literature suggests several strategies to encourage lagoon conversion. One option is greenhouse gas (GHG) emissions reductions credits. Under this system, each hog farm would be allocated a certain number of GHG emission credits. The credits would be tradable. Because EST can reduce GHG emission by 96.9%, the GHG cap and trade system could push farmers toward retrofitting their farms for economic reasons, potentially justifying the upfront economic cost of installing the systems to farmers (Vanotti 2008). However, given the current policy environment, legislation capping GHG emitted by farms is unlikely to pass. The threat of such regulation is not sufficient to motivate farmers to convert, as explained above (Willock 1999). Moreover, if the legislation were to pass, it could drive small farmers to bankruptcy rather than environmental consciousness because they cannot afford the initial investment of EST (Nene 2009).

Reflexive law solutions, which empower stakeholders rather than directly regulating the producers of externalities, are more feasible in the current policy environment. Information-based regulatory tools, like mandating public disclosure of information, empower consumers, business partners, and shareholders to pressure hog farmers to adopt EST. Such solutions are cheaper and faster to implement than either command-and-control or cap-and-trade regulations (Braunig 2005). However, because only eleven farms in North Carolina are even attempting to retrofit their lagoons, it is unlikely that forcing farmers to publish information about their waste management systems would affect consumers or shareholders. Though there is a market niche for environmentally sustainable pork in the US (Honeyman 2006), it is unlikely that this niche will grow enough to affect CAFOs as well as small, organic farms.

The most non-conventional approach the literature suggests involves promoting the property rights of the recipients of pollution produced by hog farms, rather than focusing on internalizing the costs of pollution in the pork industry (Cutting 2005). However, because lagoons affect so many stakeholders, this approach seems impractical. Some stakeholders, like animals or ecosystems, do not have established or concrete rights, so this approach would overlook them. Further, this approach is more reactive than active; stakeholders could respond to violations of their rights, but not actively prevent the harms associated with lagoons. Because the law is

reactive, it is not likely to motivate farmers to convert their lagoons, especially if they believe they are capable of managing their lagoons well. Finally, because water quality issues are almost impossible to track back to a single violator, such legislation would be practically unenforceable.

There are many potential barriers to retrofitting lagoons; farmers may not know about the environmental harms associated with lagoons, or may know and not care. Even if farmers do care, they might not be aware that alternative technologies are available. Farmers aware of alternatives may not realize the potential benefits of conversion. Risk averse farmer could be excited about EST, but want to wait for later, improved, and thoroughly tested systems before they are wiling to convert. Farmers who know about EST might genuinely prefer the lagoon system or be unwilling to learn how to use a new system.

However, given the high cost of the five EST available to NC hog farmers (Williams 2009, Rice 2008, Miner 1999), I hypothesize that economic issues are the biggest barriers to retrofitting farms with EST. Even so, as better technology is developed, the economic hurdles will become smaller (Vanotti 2009). In fact, some components of EST actually reduce the cost of waste management (Walker 2010). Even if such systems are economically more viable than lagoons once installed, the upfront cost of purchasing, installing, and learning to use the new systems likely deters farmers from retrofitting their farms.

Methods

This project seeks to (1) establish farmers' perceptions of EST now, (2) determine why farmers are or are not applying for the Lagoon Conversion Program, and (3) determine what farmers think will or should happen in terms of waste management technology and regulation in order to further our understanding of what barriers to retrofitting hog lagoons exist. This project does not have the resources to survey all 2,200 North Carolina swine farms; therefore, as a final product, the project will produce a survey that can be more widely applied.

I relied on a round of interviews and a round of trial surveys to inform the final survey. The first round included 30 interviews, and was used to inform the first draft of the longer survey. The longer survey was emailed to six farmers as a trial for the final product survey. The trail surveys were used to ensure that farmers would understand the questions being asked, that the answers would be informative and solicit the information desired from the respondents, and that adequate answer choices were provided in the longer survey.

I found farmers' contact information using Division of Soil and Water quality swine farm permit registration information. I chose a diverse sample of farms based on location, number of hogs, and hog life stage. This information can be found on the map in Appendix A. Farmers' availability and willingness to participate likely influenced the sample; 16.6% of the farmers I contacted declined to be interviewed.

I contacted farmers by phone. In the first round of interviews, I introduced myself as a student from North Carolina working on a research project. I explained that I had heard about companies like Google paying swine farmers to convert their lagoon/sprayfield systems to newer technologies, and that I was interested in hog farmers' perspectives on different waste

management systems. I then asked the farmers five broad questions about the systems that they use and their opinion about all systems available. The interviews were loosely structured. This format allowed farmers to feel comfortable and conversational, while ensuring that I obtained the information I needed. The information from the interviews is recorded in typed notes.

First, I asked farmers about their waste management system and its benefits and drawbacks. Because all of the farmers that I formally interviewed use anaerobic lagoons and sprayfields, these questions allowed me to establish farmers' perspectives on current waste management systems. Then, I asked farmers if they had heard of EST. Through this question, I learned whether information about EST was common knowledge. I also gained insight about where farmers hear about technologies like EST. I asked the farmers what factors are important to them when considering waste management systems, allowing me to determine farmers' priorities. I also asked them about the benefits and drawbacks of these systems. Finally, I asked farmers what incentives could encourage them to convert their lagoons to EST, including grants, cost-share programs, and the potential for regulation. This survey can be found in Appendix B.

At the end of each first round interview, I asked farmers if they would be willing to participate in a longer survey; 83.4% agreed. I gave the survey to six farmers to make sure that all of the questions and answer choices were clear and informative, asked the farmers if there was anything else that I should have asked, and modified the survey based on their responses. The final survey can be found in Appendix C.

Results: Lagoons are cheap and easy to use, EST are expensive and untested

Before beginning the interviews, I spoke with the owner of Lloyd-Ray Farms, who is working with Duke University and Google to convert his lagoon to an energy generating methane capture system. He said that he had never heard of alternatives to traditional lagoons before Duke approached him. He knew that the system being installed on his farm would help reduce his energy costs by burning the gas collected inside his now covered lagoon, but could not explain the technology any further. He said that he was willing to try the new system because Duke assured him that they would cover all of the costs of the system, and because Duke said that if he did not like the system, he could go back to his old lagoon.

However, all of the farmers that I interviewed use traditional anaerobic lagoon/sprayfield technology. I found phone numbers for three farmers who are trying new technologies, but all three were either unavailable or did not want to participate in the project.

The farmers listed a number of benefits of the lagoon system (Table 1), and there is a clear consensus that lagoons' biggest advantage is their low cost. Farmers also appreciate that the lagoons work in conjunction with sprayfield technology to fertilize cash crops or grazing fields, though not all farmers are satisfied with the quality of this fertilizer. One farmer explains, "the crop doesn't get everything it needs using lagoon water. It's not as good as fertilizer . . . It helps, but it's not perfect. Turkey litter is better than half rainwater, half lagoon water, but we're not allowed to use that."

Several farmers consider the convenience of lagoons a major benefit; one farmer explains, "I like that the lagoon is on the farm with my operator so we can use and manage it when it suits us." Another agrees: "[the lagoon/sprayfield system] applies waste timely, when crops need it, at rates that you can control . . . it's easy to manage." This value was further emphasized later in the interviews, when over 35% of farmers mentioned "ease of operation" as an important factor in selecting a waste management system (Table 4).

Table 1: Benefits of Lagoons	Number of Farmers	Percentage
Low Cost	23	76.7%
Fertilizer	16	53.3%
Easy to Operate	6	20%
Reliable/Safe	4	13.3%
Control	3	10%
Proven Track Record	2	6.7%

Farmers struggled to identify drawbacks of the lagoon system (Table 2), though almost a third of the farmers identified "vulnerability to rain" as a flaw. In heavy rain, lagoon levels rise. Farmers usually control lagoon levels by pumping lagoon contents onto their sprayfields. However, regulations require that farmers abstain from pumping in the rain, because the water and waste will not soak into the saturated soil, but rather will spread, potentially contaminating groundwater, rivers, and wells. Farmers also cited potential spills as a drawback for lagoons, but were careful to qualify this flaw by explaining that a correctly engineered, well-managed lagoon will not spill, nor will it overflow in extreme weather. However, the paradox that farmers are most desperate to pump in heavy rains, but cannot, makes a well-managed lagoon nearly impossible.

Occasionally, farmers are forced to out-source their waste management. One farmer explains, "There are guidelines for how much you can pump per acre. If you have more than that you're out of luck. If it rains, you can wait it out and see what happens, but the lagoon could overflow. There are some contractors who can pump it down and haul it to the county waste system. If I were to get in that kind of trouble I don't know what I would do. You just pump and hope for the best."

Though almost all of the farmers reported that they were satisfied with their lagoons, the feeling is not universal. One farmer says of the lagoon/sprayfield system, "I don't particularly like it. There's too much work. You have to worry about the weather. Pumping and equipment make it pretty expensive, but it's still the cheapest thing out there."

Despite the backlash from the media and the environmental community, only one farmer mentioned environmental harms as a drawback of lagoons, and only three mentioned odor.

Overall, the interview responses mirrored the perspectives of 2003 farmers surveyed by RTI international. Farmers are happy with their lagoons because they are simple, cost effective, and not labor intensive. This does not indicate a change in farmers' attitudes toward lagoons in general; rather, it confirms that farmers' views on lagoons have been essentially stagnant for the past eight years.

The biggest difference between the 2003 and 2011 perceptions of lagoons is how farmers view lagoons' drawbacks. Both samples agree that lagoons have problems associated with excessive rainfall and onerous regulation, but none of the 2011 farmers mentioned negative public perception as a problem. This change could be attributed to the weather – since there have been no hurricane-caused lagoon floods in the past eight years, anti-lagoon activists have had fewer focusing events, and the media is paying less attention to the hog industry.

Table 2: Drawbacks of Lagoons	Number of Farmers	Percentage
None	9	30%
Rain	9	30%
Require Maintenance	7	23.3%
Spills	4	13.3%
Odor	3	10%
Over-regulated	2	6.7%
Environmental Harms	1	3.3%

Though the farmers could describe every detail of the lagoon/sprayfield system, they were not as comfortable talking about alternative technologies. All of the farmers were aware that new technologies for waste management exist, but only 56.6% could name any of the technologies, and few could describe technical details of the systems (Table 3).

Table 3: Can Name or Describe an EST?	Number of Farmers	Percentage
Yes	17	56.6%
Solid Separation	*10*	*58.8%*
Covered Lagoon	*9*	*52.9%*
Methane Capture	*3*	*17.6%*
No	13	43.3%

Whether considering a lagoon/sprayfield system or an EST, farmers have one clear priority: cost (Table 4). One farmer explains, "I would have been indifferent between running either [the lagoon/sprayfield or the super soils] system, I just chose the cheapest one. It's a business decision." He qualifies, "we're very environmentally sensitive, and there isn't a lot of difference for the environment either way, for soil, water, or animals, especially if you use the lagoons correctly." This demonstrates that farmers are either uninformed about or ignoring the differences in environmental impact between traditional lagoons and EST.

Statements like these indicate that farmers follow the decision-making patterns described by Willock in the literature; though most farmers demonstrated that profit was ultimately their highest priority, they also felt pressure to be environmentally friendly. When they mentioned spills, overflows, or odor, they mitigated these risks with qualifiers, claiming that well-managed lagoons are environmentally responsible.

After cost, most farmers are concerned about how easy a system is to use. EST that involve solid waste removal systems make a farmer's job easier by cleaning the sludge out of his lagoon for

him, one of the most difficult jobs associated with lagoon maintenance. Some farmers also prioritize systems that do not eliminate water, because their current systems depend on the lagoon/sprayfield system to irrigate and fertilize cash crops or grazing fields. These farmers did not realize that EST also produce fertilizers, which are often higher quality than the lagoon and rainwater combination.

Table 4: Important Factors in Selecting a Waste Management System	Number of Farmers	Percentage
Cost	21	70%
Easy to Operate	11	36.7%
Removes Solids	8	26.7%
Does Not Eliminate Water	5	16.7%
Proven Track Record	3	10%
Covered	2	6.7%

Most farmers would be willing to try a new system, but only if someone else pays for it (Table 5). Some mentioned that before they adopted a new waste management system, they would have to see it working on other farms. Though the state has demonstration farms, skeptical farmers would not adopt EST until the technologies have a longer, more established track record. Others will only try a system backed by the government and a major research institution, like Duke University or North Carolina State University. A few refuse to try a new system entirely; they don't "entertain the idea of new systems because what [they have] is working." Only two farmers would be willing to finance a new system on their own; one said he would be willing to borrow the money and finance the system himself if it enabled him to "cut the work load down so [he] could enjoy pig farming more." Of course, the system would also have to be cost effective and reliable – a standard that neither of the farmers believe current EST have met.

These perspectives support Willock's argument that farmers are risk averse. Their risk aversion is magnified by respect for tradition, an important component of farmers' social values. Moreover, the focus on current costs rather than potential future regulation indicates that the farmers are not financially planning far ahead. This combination of values and decision-making patterns does not bode well for converting lagoons to EST. Farmers might be willing to try EST if they see that their colleagues are using them successfully; the problem is motivating the first farmers to convert their lagoons.

Again, 2011 farmers' opinions on this issue are very similar to 2003 farmers'; interviewees were primarily concerned with the initial cost of the system, though some are more concerned with operating and maintenance costs. Again, many suggest the government cover the cost of retrofitting their lagoons. Very few of the farmers are aware of the governments' role in retrofitting lagoons. One farmer "heard of the Smithfield study," but told me, "that hasn't gone anywhere for anyone because it's cost prohibitive." Another alluded to the LCP, explaining, "to get the other systems, there's government programs, but there's lots of stuff you have to do to be eligible for them. There are a lot of regulations and you have do all of this stuff yourself." If they had to retrofit their lagoons, 2011 farmers, like 2003 farmers, prefer low-tech alternatives with

proven track records. Though the technologies have been on the market for over 6 years, farmers still know very little about the benefits and limitations of alternative waste management technologies.

Table 5: Could incentives motivate conversion to EST?	Number of Farmers	Percentage
Yes	22	73.3%
"I would need enough grant money to make the system cost effective."	*14*	*63.6%*
"I would need 100% of the costs covered."	*4*	*18.2%*
"I would need steady financial support for maintenance and operation, not just installation."	*4*	*18.2%*
"I would need a tax break or subsidy."	*2*	*9.1%*
No	8	26.7%

The potential for future regulation has little effect on farmers' current perspectives on waste management systems. One farmer anticipates a lagoon tax in the future. Others speculate the EPA will regulate lagoons even more strictly than they already do. Still, lagoons are the cheapest waste management system on the market, and they are already in place on almost all of North Carolina's 2,200 swine farms. Farmers seem to agree that current costs are more important than the potential for regulation.

Clearly, the government cannot financially support so many conversions, leading researchers to suggest private solutions, like buying and selling carbon credits. Duke University is paying Lloyd-Ray Farm to convert its lagoons into a methane capture system. Many of the farmers I interviewed said they had heard about opportunities like this at meetings, yet no companies had approached them.

One farmer was an exception; he was approached by TerraBlue, a company that manufactures EST. According to the farmer, TerraBlue encouraged him to apply for government funding to install their super soils system. TerraBlue told him they would sell carbon credits that would pay for his new system's operation and maintenance. However, TerraBlue was unable to convince any companies to purchase their carbon credits. Though the farmer was excited to try the super soils system, he could not financially bear the maintenance and operating costs of the system in the absence of carbon credit funding. While companies have the potential to fund retrofitting hog lagoons, given that TerraBlue could not solicit any carbon credit consumers, carbon credits do not seem popular enough to support the vast amount of lagoon conversions necessary to phase out the lagoon/sprayfield system in North Carolina.

Conclusions

Based on the literature and my interviews with farmers, I found there are three major barriers to retrofitting North Carolina swine waste lagoons with EST: inadequate information provision, lack of funding, and unreliable technology.

The North Carolina state government is not effectively communicating information about EST or the LCP to farmers. Farmers cannot take advantage of programs they have never heard of, and are not likely to invest in technology that they don't understand. Educating farmers about waste management technology is the first step to retrofitting lagoons.

Government programs could significantly improve communication though the Internet. The LCP website has not been updated since 2007, and the page is difficult to find. Farmers are not likely to stumble across the website in the first place, nor are they likely to trust a website that has not been updated in four years. However, EST information is easily accessible on the NC Extension website, indicating the Internet might not be the most effective way to reach swine farmers. Some farmers may not have Internet at home; one farmer asked me to email him using his wife's email address and warned that he would not be able to read the email until she went into work on Monday. Most farmers that I talked to had heard about EST from agricultural fairs and meetings with other farmers. Word of mouth, mailings, and direct communication from livestock agents might be more effective ways to reach farmers.

There is also a chance that farmers know about EST, but do not want to admit that they know about them. One farmer that I spoke with said he had never heard of alternatives to traditional lagoons during his interview. However, after he finished answering my questions, he said, "Young lady, I'm very sorry, but I told you a story. I have heard of those new systems." He then proceeded to tell me very detailed information about the new systems. He said he lied to me initially in case I was trying to sell him something.

Farmers could be hesitant to reveal that they know about EST for several reasons. First, farmers may be afraid of facing criticism for knowing about sustainable systems, yet not retrofitting their lagoons. Second, they do not want to be pressured into adopting systems they feel they cannot afford. By pretending they are ignorant to EST's existence, they escape negative judgment from the media and the public.

However, the information gap is not the only problem. Even if all North Carolina farmers decided to apply for the LCP cost-share grant, the state would not have the funding to support them. For widespread conversion, the state will need to look toward federal and corporate funding. The carbon credit industry does not seem active enough to fund installation, operation, and maintenance for 2,200 hog farms. We likely will have to wait for later, more cost-effective generations of EST to see a large scale push to retrofit lagoons.

Though programs like the LPC can help some farmers adopt EST, their limited funding makes them inaccessible to hog farmers across the state. Efforts to engineer EST have been admirable, but further research is necessary to lower the cost of both installation and operation of the systems before farmers will be willing to adopt them on a larger scale. If NCSU could develop

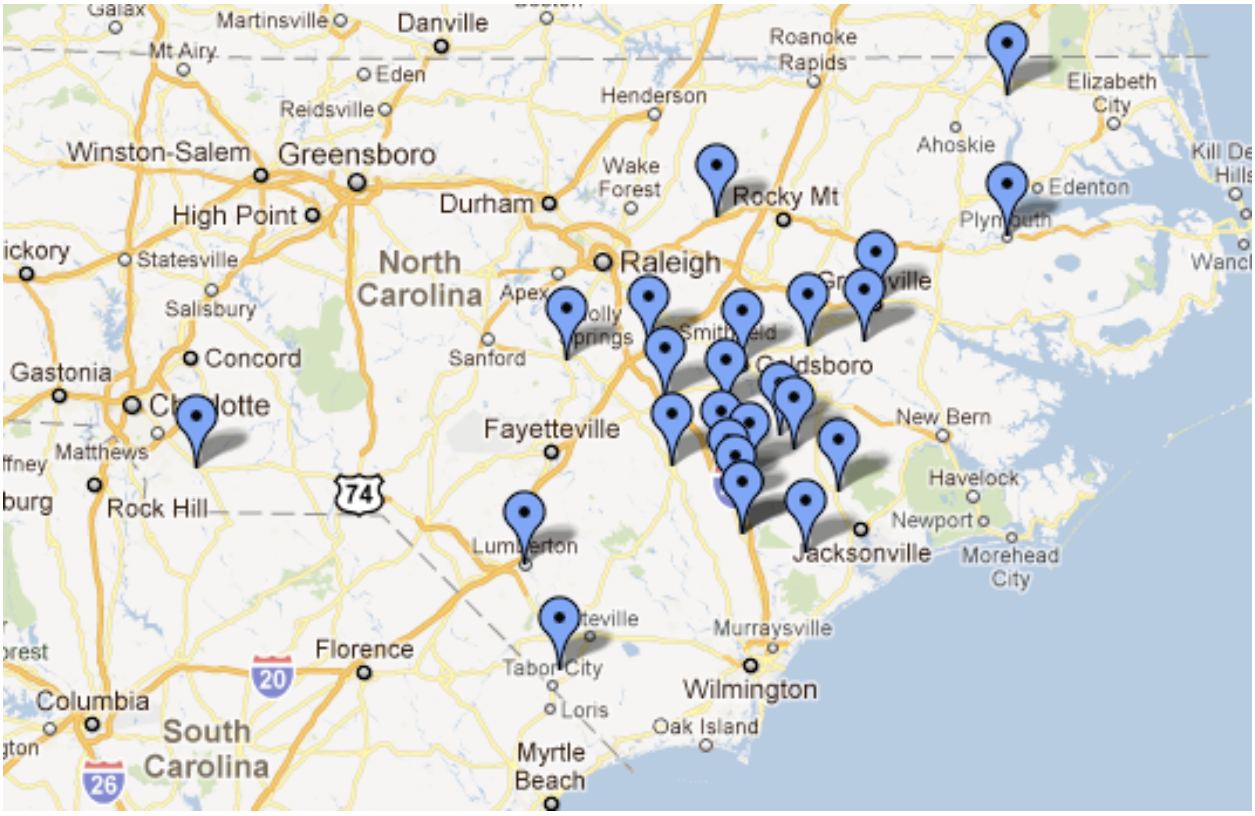
an economical, sustainable alternative to lagoons, some farmers would be willing to invest in the technologies without funding from the government. Designing systems that farmers would be willing to invest in on their own would be an ideal solution to the funding problem, though not necessarily a realistic solution for the near future.

Researchers should not only work toward cost reduction, but also performance improvements. Several farmers reported that they knew farmers who had retrofitted their lagoons, and then returned to traditional systems because EST were too costly, too difficult to operate, or simply didn't work. One farmer mentioned a friend who invested in a methane capture system only to have his brand new generator break almost immediately. Until EST become more reliable, it is unrealistic to ask farmers to invest in these systems.

Given the lack of motivation in the NC legislature, and the economic infeasibility of lagoon conversion, it is unlikely that North Carolina will legislate complete lagoon conversion. Unfortunately, this removes incentives to improve or adopt existing EST. Without focusing events in the future, like the lagoon spills in 1991 and 1995, NCSU's research and the LCP could completely lose funding. Raising public awareness will be necessary to keep pressure on legislators to solve this problem in the absence of focusing events.

Appendix A: Information about Farms Surveyed

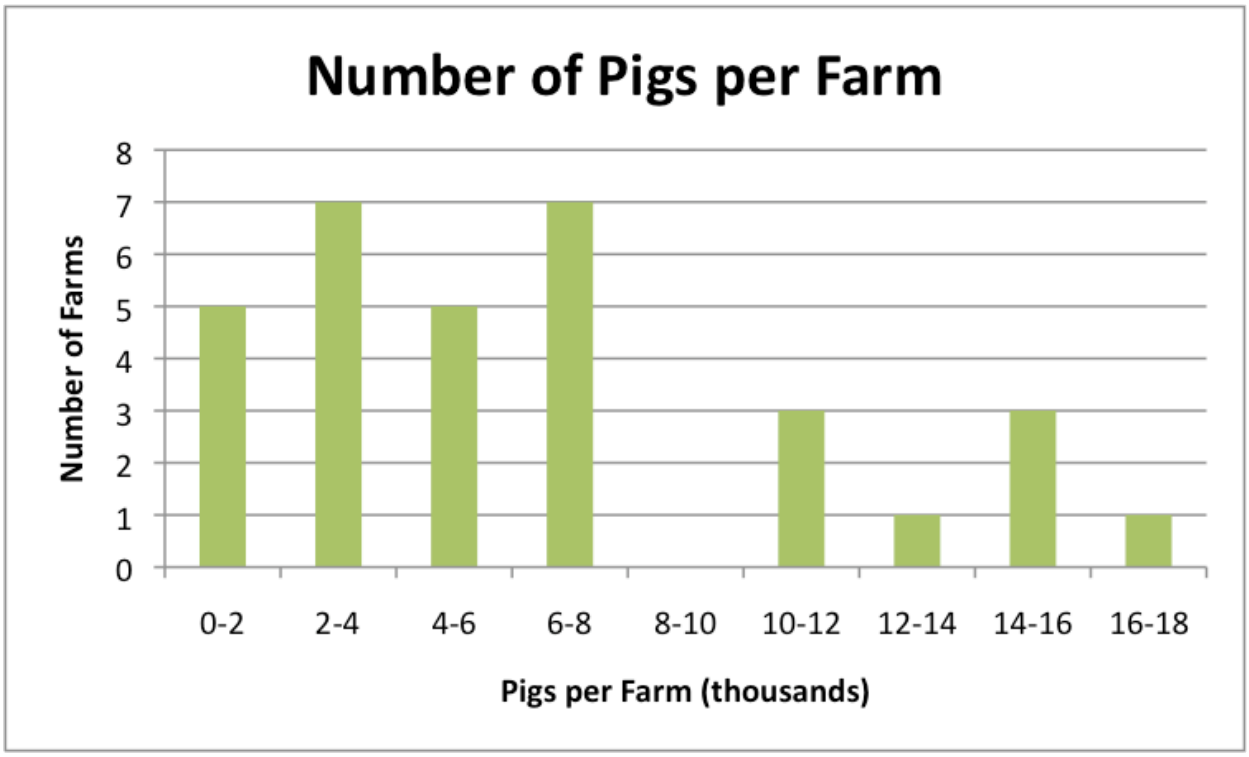
Location of Farms Surveyed:



Types of Farms Surveyed:

Farrow to Wean	5
Farrow to Finish	2
Wean to Feeder	3
Feeder to Finish	20

Number of Pigs per Farm:



Appendix B: Initial Survey

This survey was administered to 30 farmers, and was used to draft the final product survey.

1. What type of waste management system do you use?
2. In your opinion, what are the benefits and drawbacks of that system?
3. Have you heard of any new or alternative technologies to anaerobic lagoons and sprayfields? Can you name or describe any of these technologies?
4. What characteristics are important to you in evaluating waste management systems?
5. Are there any incentives, monetary or legal, that could encourage you to adopt one of the new technologies?

Appendix C: Final Product Survey

Implementation

This survey, for the 2,200 hog farmers in North Carolina, can be administered through the mail, online, or by phone. I recommend that anyone administering this survey use Dillman's Tailored Design Method, as used by the RTI/NCSU 2003 study, "a high performance survey methodology proved to maximize response rates," to increase the amount of returned surveys (Cates 2003). Their suggestions include:

- Conducting data collection over a 6 week period;
- Mailing a reminder card, questionnaire, and business reply envelope a second time (about a month later) to those who have not returned surveys;
- Including a cover letter to explain the goal of the survey and the importance of participating, as well as the confidentiality procedures;
- Having university faculty sign the cover letter to signify importance and legitimacy;
- NOT collecting any identifying information from respondents;
- Using a short (4 page at most) survey;
- Notifying the NC Pork Council and the NC Extension about the survey so that they can attest to the legitimacy of the survey.

Though these suggestions most immediately apply to mail surveys, the advice can be extrapolated to apply to online surveys. The researcher could still collect data over a 6 week period, email a reminder, include a cover letter signed by university faculty, NOT collect identifying information, use a short survey, and notify the Pork Council and the NC Extension.

The phone survey would have to rely on different strategies. The researcher would have fewer options to externally legitimize the survey (no cover letter or signatures). However, the researcher could still be persistent in pursuing survey respondents and could still conduct a short survey. It would be impossible to not collect identifying information, but there would be no need to store or use this information. The Pork Council and the Extension could still be informed about the survey.

Final Survey

1. How many acres are on your farm(s)?

2. What type of swine operation(s) do you have?
    a. Farrow to wean with _____ sows
    b. Farrow to feeder with _____ sows
    c. Wean to feeder with ____ pigs
    d. Feeder to finish with _____ hogs
    e. Farrow to finish with _____ sows and hogs

3. Which of the following describes the ownership of your farm(s)?
    a. Independent
    b. Company-owned. Company: _____
    c. Contract farm. Company: _____

4. How many individuals (including yourself) do you employ for hog production and waste management? Full Time _____ Part Time _____

5. In what county(ies) do you farm? _____

6. What type of swine waste management is used on your farm(s)?
    a. Lagoon/sprayfield
    b. Other: _____

7. What type of manure collection system is used on your farm(s)?
    a. Flush
    b. Pit recharge
    c. Other: _____

8. Suppose you had to replace your existing waste management system with a new Environmentally Superior Technology. When comparing alternatives, what would be the most important cost consideration?
    a. Operating and maintenance cost
    b. Initial/investment cost
    c. By-product revenues

9. When comparing alternative waste management systems, what would be the 3 most important factors in your purchase not including cost? Label 1 (most important), 2, and 3 (least important).
    a. Ease of operation
    b. Amount of maintenance required
    c. Amount of training required for operator
    d. Amount of labor required for operator
    e. Compatibility with existing buildings
    f. Ability to use water for crops or sprayfields
    g. Reliability under rain
    h. Amount of regulation
    i. Level of odor
    j. Environmental impact other than odor
    k. Proven track record
    l. Covered system
    m. Solid separating system
    n. Other: _____

10. On a scale of 1-5 where 1 is “never” and 5 is “very likely,” rate how likely you would be to install a system that has each component. Do not consider cost:
    a. Reduces phosphorus to be land applied
    b. Reduces nitrogen to be land applied
    c. Reduces volume of solid waste to be land applied
    d. Reduces sprayfield size needed
    e. Requires storing solid waste in container and shipping it periodically to a central processing facility
    f. Has a mechanical solids separator
    g. Covers lagoon for digestion
    h. Has an off-site composter
    i. Has a belt system for manure removal
    j. Has aerobic liquid treatment (nitrification pond)
    k. Has a constructed wetland with nitrogen-removing plants
    l. Produces a sellable by-product like energy or fertilizer

11. Which of the following best describes you?
    a. Swine farm owner
    b. Swine farm manager
    c. Other: _____

12. How many years have you been in hog production?

13. Do you have any other comments? Are there any questions you feel should have been included on this survey? If so, what are they and how would you answer them?

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