POLLUTION PREVENTION
IN
AGRICULTURAL LIVESTOCK PRODUCTION

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POLLUTION PREVENTION IN AGRICULTURAL LIVESTOCK PRODUCTION

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EXECUTIVE SUMMARY

There is increasing public awareness and concern regarding environmental pollution. Agriculture is one of several industries that face criticism today because of their impact on the environment. Of particular concern is water quality degradation caused by animal waste and agricultural runoff. Pollution prevention technologies can go a long way toward addressing these concerns. They could also be beneficial to producers as pollution prevention represents a move toward efficiency. Anytime waste is reduced, there is opportunity for an increase in efficiency and usually profitability.

This paper describes common agricultural livestock production processes, waste disposal and utilization practices, and then identifies potential pollution prevention measures. The most common disposal practice is direct land application of waste as an organic fertilizer and soil conditioner. This is the foundation of any organic system as ultimately animal waste is returned to the soil, completing an ecological cycle. Opportunities for alternate uses include compost, animal feed, energy production, and alternate biomass production.

Animal manure is a valuable, underutilized resource that is not used to its potential for many reasons. These include: 1) economic feasibility of obtaining maximum utilization; 2) lack of information on the value of manure as a fertilizer; 3) lack of information on alternative uses for animal waste; 4) lack of recognition of its economic value; and 5) producers' unwillingness to try new approaches to waste management. Several federal and state government agencies offer technical and financial assistance to land users to develop and implement conservation, water quality, and waste management plans. These programs have been very successful; however, there is a continuing need for further education and financial assistance.

Improved livestock waste management requires detailed attention to storage and disposal systems, alternate waste utilization practices, and prevention of untreated discharges. The voluntary approach to self regulation, cost sharing plans and state agencies' informational programs are attempting to encourage farmers to try innovative ideas that are economically viable. Pollution prevention and reduction at the source requires the public and the livestock producer to view waste management, not as a disposal problem, but as an opportunity for an alternate utilization of a valuable resource.

The reduction and utilization of animal nutrients in a safe and environmentally sound manner can substantially reduce environmental degradation resulting from agricultural production. This paper identifies pollution prevention opportunities for agricultural wastes that are economically viable to the farmer and environmentally acceptable to the public. It also lists impediments that limit the adaptation of these practices. Finally, it identifies areas where further research is needed to develop pollution prevention techniques that would be economically viable, technically sound, and environmentally sustainable.

INTRODUCTION

The Pollution Prevention Assistance Division (P^2AD), created by the 1993 Senate Bill 200, serves as a source of technical and financial assistance for pollution prevention programs in Georgia. Pollution prevention is the elimination or reduction of wastes at the source of generation or reuse and recycling of wastes in a manner consistent with the protection of human health and the environment. The use of pollution prevention technologies is rapidly growing in many industries. Pollution prevention can increase the profitability of a process while decreasing the stresses that the process exerts on the environment. As one of the largest industries in Georgia, agricultural livestock production is a significant contributor of pollution to the environment. The diversity of agricultural industries presents many obstacles to the adoption of pollution prevention technologies. P^2AD recognized these facts and allocated a budget to establish an agricultural pollution prevention program in cooperation with The University of Georgia Cooperative Extension Service. The primary emphasis of this program is to provide education and technical assistance on pollution prevention to the agricultural community.

This paper and its companion paper on pollution prevention in crop production were created. to provide guidance to the agricultural pollution prevention efforts. The purpose of this paper is to describe common agricultural livestock production processes and waste disposal and utilization practices and to identify potential pollution prevention measures. It results from an in-depth analysis and review of the literature associated with pollution prevention and animal production practices. Information was also gathered from discussions with academicians, extension specialists, and producers to determine current practices and potential waste reduction techniques. By analyzing existing production practices and the concepts behind pollution prevention technologies, many opportunities, impediments, and research needs have been identified. These needs and the potential for new pollution prevention techniques are presented and discussed. The incorporation of pollution prevention principles into livestock production and waste management has the potential to reduce environmental degradation and increase the economic return to the producer. Hopefully, this paper can serve as a catalyst for converting this potential to reality.

Pollution prevention technologies involve the reduction of pollutants at the source rather than control of emissions at the outlet. -This can be accomplished through a reduction in inputs, modification of production processes, reuse or recycling of process outputs, or development of alternative uses for by-products of production. Before discussing the opportunities and impediments for pollution prevention in Georgia's animal production industry, we first need to understand the driving forces behind the move toward pollution prevention. These driving forces can be broken into two categories: economic and environmental. The environmental concerns include a response to regulation and the more common notion of being good stewards of our environment. The economic concerns are based on the fact that animal production is the same as any other industry in Georgia. The more efficient producer will usually survive the longest.

Georgia Livestock Production

Georgia's 1993 total farm income was $4.76 billion. Approximately 40% of this income was generated from the poultry industry and about 16% of it from livestock production. Total livestock production in Georgia generated $756 million in revenue representing 16% of total farm cash

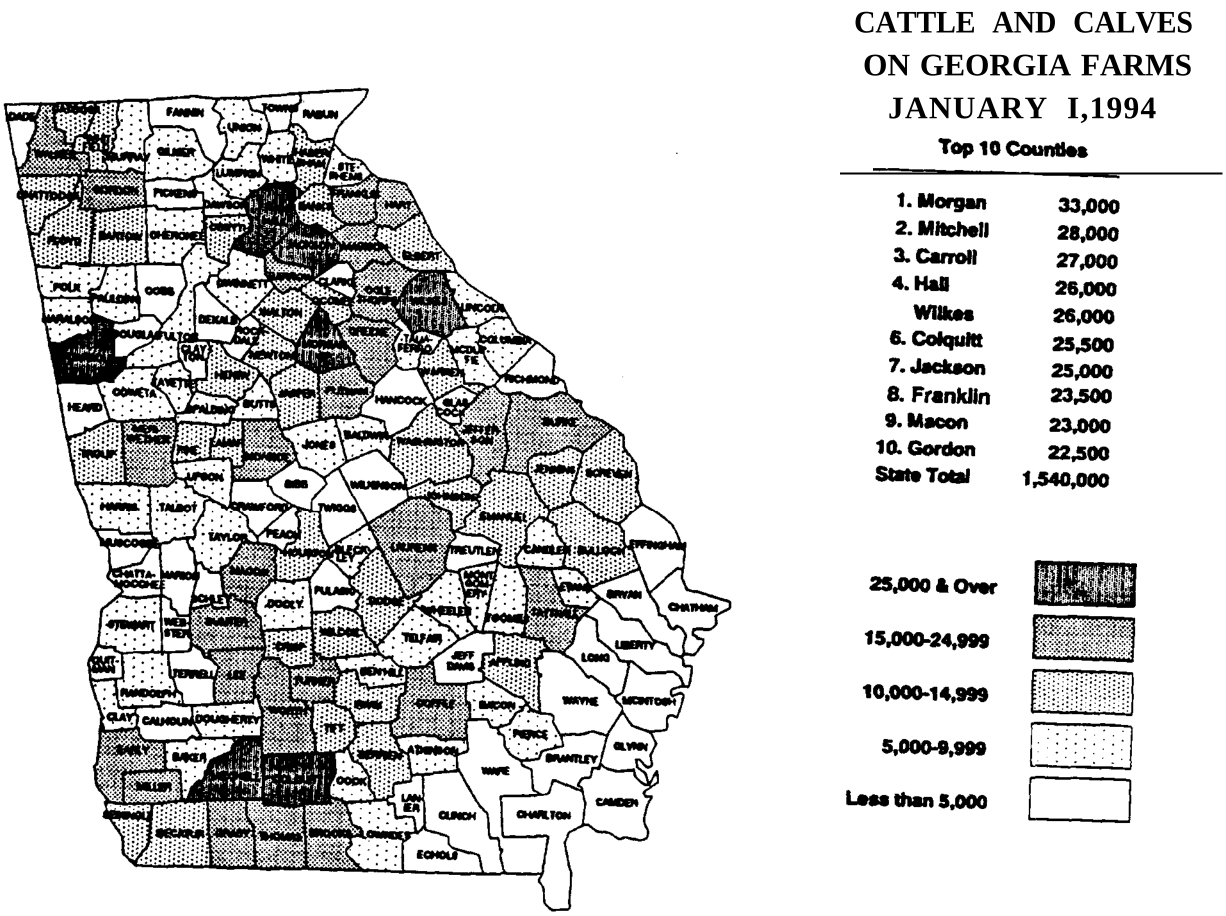

Figure 1 Cattle and Calves on Georgia farms as of January 1, 1994.
Source: Georgia Agricultural Statistics, 1994

receipts (Georgia Agricultural Statistics, 1994). Most of this income was from beef cattle, dairy cattle, and swine with smaller amounts in horses, sheep, goats, and veal calves. Besides this income, farming expenses generated additional business in the agricultural community. In 1993, major expenses for all agricultural industries included feed ($765 million), equipment and repairs ($589 million), interest ($292 million), labor ($213 million), fertilizer ($221 million), pesticides ($117 million), seed ($100 million), fuel and oil ($100 million), and electricity ($42.5 million) (Georgia Agricultural Statistics, 1994). Based on these statistics, animal agriculture in Georgia obviously represents big business.

Georgia ranks second in the United States in production of poultry and poultry products, supplying approximately 12% of U.S. production. Poultry production in Georgia represents 40% of the state's total farm cash receipts generating $1.82 billion in revenue (Georgia Agricultural Statistics, 1994). Due to the economic importance of poultry production in Georgia, pollution prevention for poultry producers will be addressed in a separate paper. However, many concepts discussed in this paper will also pertain to the poultry industry.

Georgia is ranked 21 st nationally in cattle production, generating $312 million in revenue and representing 6.8% of the state's total farm cash receipts for 1993. There were approximately 29 thousand cattle farms in Georgia in 1993 with beef cattle and calves totaling 718,000 head on January 1,1994. Morgan, Mitchell, and Carroll Counties were the top three counties in cattle and calves operations, each maintaining 27,000 or more head. The majority, 72%, of operations maintained less than 49 head and 14.5% had 50-99 head (Georgia Agricultural Statistics, 1994). Figure 1 shows the distribution of all cattle and calves in Georgia's counties. The distribution of Georgia's beef cattle production is relatively uniform and most farms are small enterprises. However, collectively beef cattle production is substantial in Georgia.

Georgia's milk production is ranked 24th nationally, with dairy products representing 5% of the total farm cash receipts. There were approximately 1,200 dairy farms in Georgia in 1993. Milk cows totaled 102,000 head on January 1, 1994. Morgan, Macon and Putnam Counties lead in the number of milk cows, each with over 7,500 head (Figure 2). Dairies in Georgia are not distributed uniformly throughout the state. This creates problems in the utilization of the animal wastes as the small areas with large concentrations of cattle tend to produce more wastes than they can effectively handle. The annual milk production per cow was a record high of 15,198 pounds. Cash receipts from marketing totaled $226.5 million in 1993. Since 1990 the total number of dairy cows in production has annually decreased. However, due to increases in efficiency and genetic gains, total milk production has increased in each of these years.

Swine production in Georgia ranked 14th nationally, and represented 3.9% of total farm cash receipts with revenue at $176.4 million. There were approximately 6,000 swine farms in Georgia in 1993. Hogs and pigs totaled one million on December 1, 1993 with a breeding inventory at 140,000 head. Colquitt, Coffee and Bulloch Counties lead all other counties in the number of hogs and pigs on farms with each maintaining 46,000 or more (Figure 3). Swine production is also non-uniformly distributed; however, the areas of concentrations are different from those for cattle or poultry. A majority, 75%, of operations maintained less than 99 head, 18.3% of operations had 100-499 head and 3% had greater than 1,000 head.

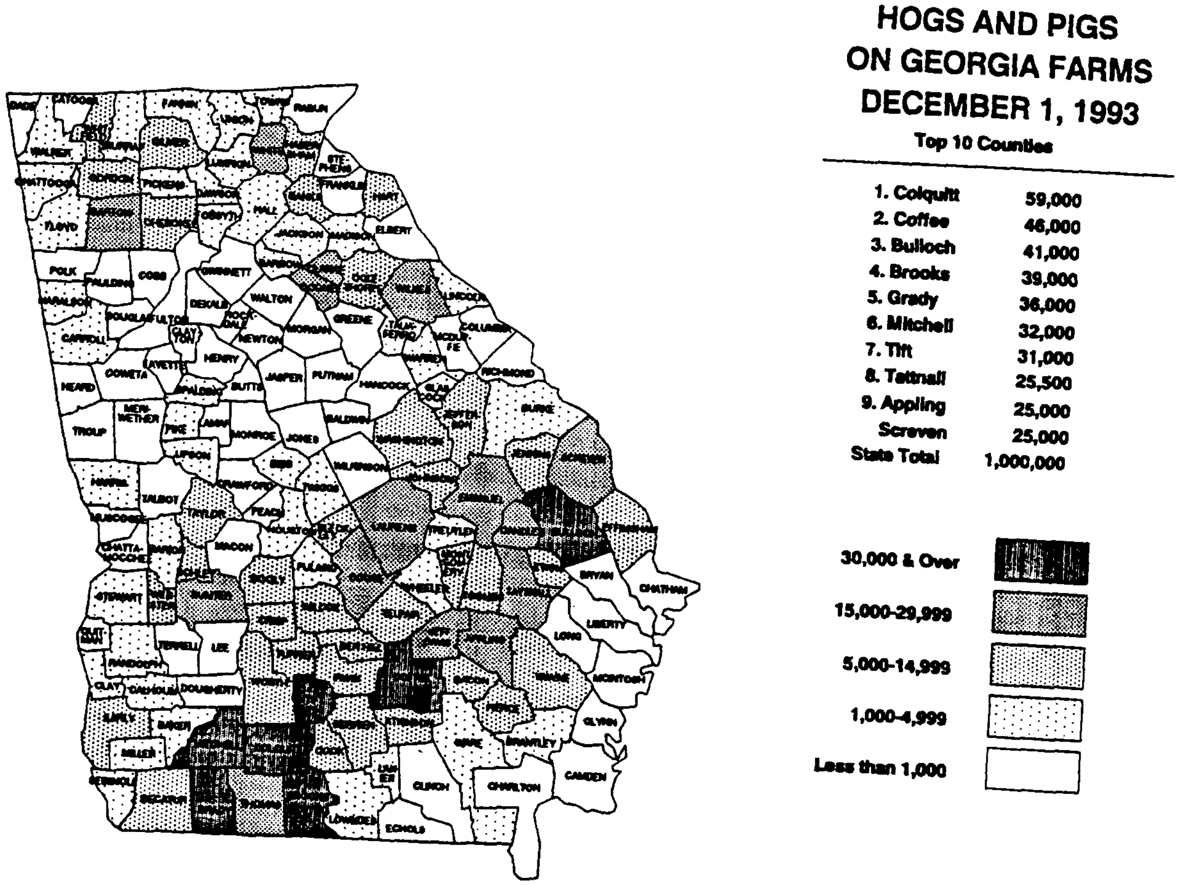

Figure 3 Hogs and Pigs on Georgia farms as of January 1, 1994.
Source: Georgia Agricultural Statistics, 1994

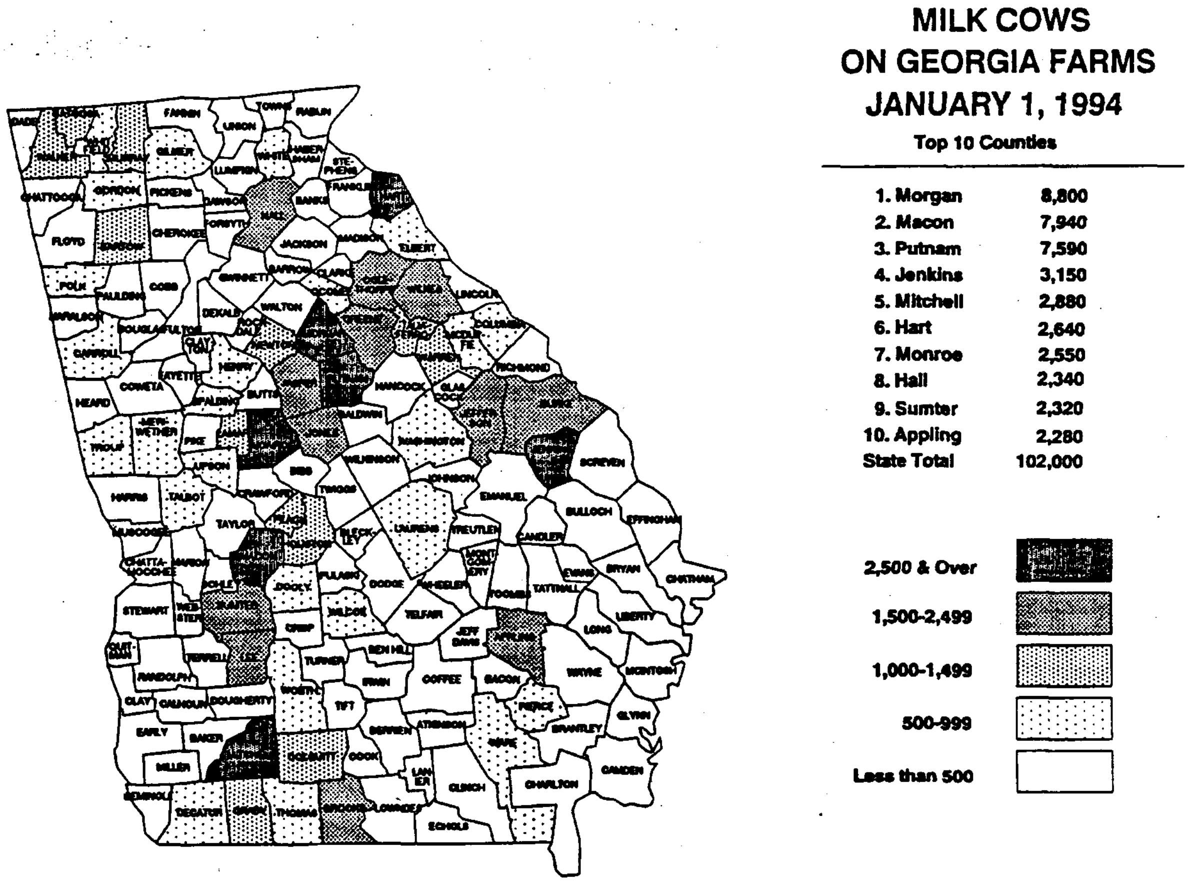

Figure 2 Milk cows on Georgia farms as of January 1, 1994. Source: Georgia Agricultural Statistics, 1994.

Since the passage of the Clean Water Act, more than $540 billion has been spent on water pollution controls. However, nearly 90% of this money was targeted at point sources of pollution (Puckett, 1995). Most of the regulations and allocations of monies did not address groundwater protection, land application of wastes, or control of air contaminants. Section 208 of the 1972 Clean Water Act directed states to develop programs to address NPS, but very little effort was placed on these programs since more substantial water quality improvements could be attained by regulating point sources. Congress took a more direct approach to NPS pollution with the Water Quality Act of 1987. Section 319 of this act requires each state to: 1) identify impaired bodies of water, 2) identify nonpoint sources that add significant amounts of pollutants to these waters and 3) develop NPS management plans to control and reduce NPS pollution. While Congress allocates significant amounts of money to this program, each state is responsible for administering the program as they see fit. This has resulted in mainly educational and technical assistance type programs that promote the voluntary implementation of best management practices (BMPs).

Other federal programs with provisions to address NPS pollution include The Food, Agriculture, Conservation and Trade Act of 1990 (1990 Farm Bill) and the Pollution Prevention Act of 1990. The Agricultural Water Quality Protection Program from the 1990 Farm Bill was designed to provide producers with the financial and technical assistance necessary to develop and implement a comprehensive water quality protection plan. The Integrated Management Systems Program included in the 1990 Farm Bill encourages producers to adopt integrated crop and livestock management practices that minimize agricultural impact. The Conservation Reserve Program and the Agricultural Conservation Program were designed to reduce soil erosion. These programs with the Wetlands Reserve Program will help reduce NPS contamination by reducing runoff and increasing sedimentation and biofiltration. These efforts attempt to "polish" water before entry into streams and lakes.

Over the last decade, the Environmental Protection Agency and other regulatory agencies have shifted their emphasis away from pollution control and toward pollution prevention. This has coincided with a shift toward greater consideration of non-point sources of pollution that may be attributable to agriculture. The Pollution Prevention Act of 1990 states "that pollution should be prevented or reduced at the source whenever feasible." In Georgia, Senate Bill 200 created the Pollution Prevention Assistance Division (P^2AD) within the Department of Natural Resources and authorized it to develop programs of technical and financial support to industries and agricultural producers. Hopefully, through the development and acceptance of pollution prevention technologies that are economically and environmentally sound, the need for future regulation in agriculture industries can be minimized.

Environmental Concerns

The potential contribution of animal agriculture to environmental pollution has been under increasing scrutiny. Contamination from agricultural practices makes up approximately 65% of NPS pollution (Welsch, 1985). A 1989 summary of state water quality assessments conducted under Section 319 of the Clean Water Act (CWA) revealed over one-third of all water impairments attributed to agricultural pollution were caused by livestock waste. This equates to over 7,200 water bodies in thirty-five states that are impaired due to animal wastes (Frarey and Pratt, 1995). Figure 4 shows estimates of relative portions of assessed waters impacted by various categories of NPS

Regulations

Regulation or the threat of legal action are key forces in the acceptance and use of pollution prevention technologies. Historically, most agricultural livestock producers tended relatively small numbers of animals in a pastoral or nomadic setting. Waste produced by these operations was widely dispersed and easily assimilated by the environment. Therefore, almost no regulation was required to insure environmental protection. The trend in livestock production, however, is currently changing. Economics of scale, specialization and regional concentration in all major livestock production areas are fueling a trend toward larger operations. These larger operations are coming under increasing regulatory scrutiny as the waste disposal problems and nuisance concerns associated with these operations attract further attention. This highlights the need for these operations to take voluntary pollution prevention measures before further federal point source regulations are imposed. In this section, an overview of the key regulations that govern the handling and discharge of animal waste on a national and state level are presented.

The Water Pollution Control Acts of 1972 and 1990, better known as the Clean Water Acts, demonstrated some of the earliest federal determination to improve the quality of our water resources. The original goal of the Clean Water Act was to restore the lakes, rivers, and streams of the nation to fishable and swimmable conditions. These acts prohibited the discharge of any pollutant, solid waste or agricultural, by any person to navigable waters of the U.S. from a point source or any discernible, confined or discrete conveyance. However, the Clean Water Act's National Pollutant Discharge Elimination System (NPDES) permit program tempers the blanket prohibition against waste discharge. Confined agricultural feeding operations are the only type of agricultural production operation regulated under the NPDES program. For the purposes of water pollution control, "animal feeding operations" are defined in the USEPA regulations for feedlots (USEPA, 1976) as being areas where animals are stabled or confined for a total of 45 days or more in any 12 month period, and vegetation or forage growth are not sustained over any portion of the facility. A "concentrated animal feeding operation" can be defined by either the number of animals maintained, or any discharge of effluent to surface waters of the U.S. as specified by the USEPA. In 1992, less than 10% of the estimated 10,000 livestock operations in the United States were sufficiently large enough to require NPDES permits (Frarey and Pratt, 1995).

In Georgia, the Environmental Protection Division (EPD) of the Department of Natural Resources is authorized to carry out the Clean Water Acts. The EPD divides all animal operations into large or small operations. Large operations are defined as more than 1,000 beef cattle, 700 mature dairy cattle, 2,500 swine, 10,000 sheep, 55,000 turkeys, 100,000 laying hens or broilers, or 500 horses. Both large and small operations must meet the following requirements: 1) No point source discharges of pollutants into the surface waters of Georgia, 2) The waste storage or handling facilities must be designed to handle a 24-hour, 25 year storm without overflow, and 3) seepage from the waste management or storage facilities is limited to l/8 inch per day. In addition, large operations are required to get land application permits, control runoff, maintain buffer zones, and at times monitor groundwater flow. The EPD has a memorandum of understanding with the USDA Natural Resource Conservation Service (NRCS) that allows the NRCS to supervise the design and installation of all agricultural waste handling facilities.

Most agricultural pollution consists of surface water runoff or groundwater contamination due to infiltration and is considered nonpoint source (NPS) pollution. NPS pollution is any contaminant whose specific point of generation and entry into a water source cannot be defined.

Ground water can be contaminated with excessive nitrates from percolation, seepage, and direct infiltration, resulting in potentially toxic drinking water (Tchobanoglous and Schroeder, 1987).

When organic matter enters waterways, it is degraded by aerobic bacteria. The oxygen used by the microorganisms is measured as biochemical oxygen demand (BOD) or chemical oxygen demand (COD). Most animal manures have BOD in excess of 20,000 mg/l and COD over 50,000 mg/l. This compares with BOD and COD for domestic sewage in the range of 200 mg/l and 500 mg/l respectively. The high oxygen demand associated with runoff from livestock waste can rapidly deplete the water's natural dissolved oxygen supply. This results in fish kills and selectivity of other aquatic life (Tchobanoglous, 1987 and Loehr, 1984). Organic matter also increases the total suspended solids in a stream, thus increasing the turbidity. The decomposition of organic matter contributes to color, taste, and odor problems in public water systems (Tchobanoglous, 1987).

Nutrients are the most common pollutant associated with animal waste. Several studies have documented the fact that watersheds with predominantly animal agriculture tend to have higher nutrient levels in their drainage systems. In fact, an EPA study on 928 watersheds across the nation (Omenik, 1977) found that mean concentrations of N and P in streams draining agricultural lands were nearly nine times higher than streams draining forested areas. Nitrogen and phosphorous compounds are needed for cellular growth; however, excessive amounts in surface waters result in eutrophication, algal blooms, and fish kills due to ammonia toxicity (Loehr, 1984).

Nitrogen compounds are a pollutant in water. They will exert an oxygen demand that reduces the dissolved oxygen content and induces bacterial and algal growth. The chief problem with nitrogen is the formation of nitrates and nitrites. Nitrate nitrogen is highly mobile in the soil, especially in wet, warm, acid soil conditions and weathered clays and sands that exist over much of Georgia. This mobility is the primary reason many nutrient management plans are based on nitrogen rather than more conservative elements.

Loss of nitrate-nitrogen is a concern from both production and environmental perspectives. Farmers incur greater expense if they over apply nitrogen and the excess can often lead to environmental degradation. Volatilization is one way that nitrogen is lost to the environment. Ammonia is volatilized when fertilizers are surface applied to soils under high pH conditions (pH greater than 6.5). Volatilization can be reduced by increasing the buffering capacity of the soil and by increasing the soil's cation exchange capacity. This may be achieved by increasing the soil's organic matter content or through liming. Nitrogen is also lost through lithotrophic (denitrifying) bacteria that convert nitrate to dinitrogen and nitrous oxide gas. Nitrous oxide is thought to contribute to ozone depletion in the atmosphere.

The percolation of nitrates is a special problem. Once nitrates migrate below the soil surface horizon there is little chance of plant uptake or biological conversion under normal field situations. An anion such as nitrate, in most Georgia soils, is prone to ion exclusion in its transport through the soil. This means little if any nitrate is retained by adsorption in the subsoil. Severe nitrogen migration to the subsoil can lead to groundwater contamination. Since most rural residents depend on groundwater for their drinking water supply, nitrates can pose a serious threat to health. The drinking water standard for nitrite and nitrate is 10 ppm. At 40 ppm nitrates can be toxic to warm-blooded animals. Infants are particularly susceptible to nitrate in water as it can result in methemoglobinemia (nitrate cyanosis) that can cause blindness or death. Nitrate in drinking water may also affect fetal development and often cause reproductive problems in many livestock operations. In Georgia, 3.8% of 3,419 shallow wells (having depths less than 100 feet) tested between 1989 and 1993 had nitrate concentrations exceeding 10 ppm. Of the deep wells, 0.9% had pollution. From this graphic, it's obvious that agriculture is a significant contributor to NPS pollution.

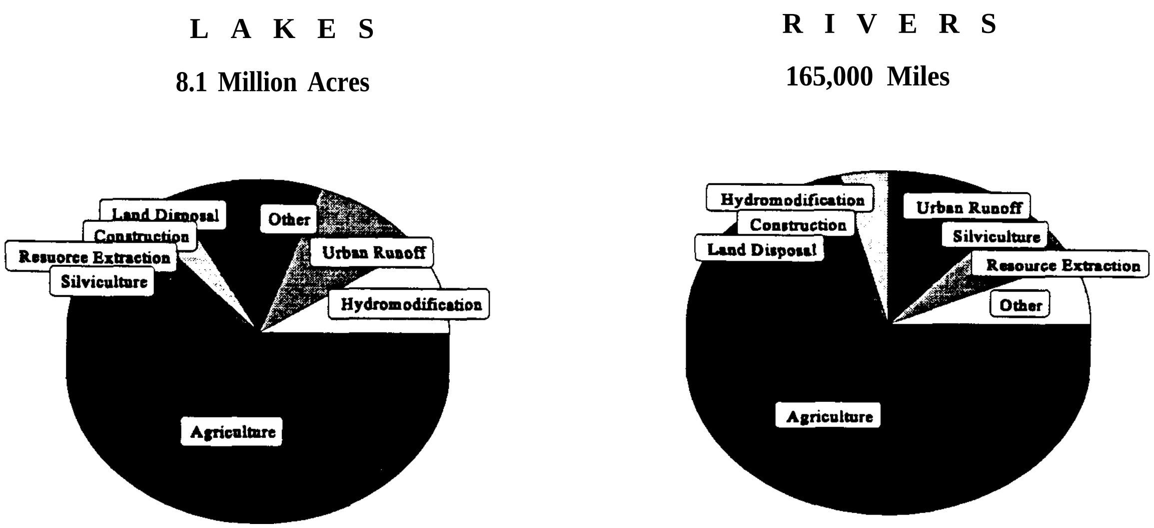

Figure 4 Impact of various sources of NPS pollution. (From Welsch, 1985).

The Georgia Watershed Agricultural Nonpoint Source Pollution Assessment (USDA, 1993) concluded that agriculture was not a major statewide concern, but the assessment showed that many watersheds did have significant agricultural loadings available to potentially impair the water resources designated use. The assessment used models to estimate that of the 84,200 tons of nitrogen (N) and 33,110 tons of phosphorus (P) generated annually from animal waste in Georgia, 29,350 tons of N and 9,670 tons of P could potentially be exported to the State's waterways. The report also stated that some 1,419 miles of streams and 10,700 acres of lakes in Georgia are not meeting their designated uses, primarily due to rural NPS pollution. It also suggests certain areas within the State that have a high potential for NPS pollution from agricultural sources.

Animal agriculture can contribute to pollution in three ways. First, water pollution can be caused by direct runoff from land application fields or feedlots; by leaching caused by excessive nutrient application; or by runoff into poorly sealed wells or leaking waste storage facilities. Second, air pollution can be caused by manure decomposition, microbial agents, or dust. Third, soil pollution can occur from application of nutrients at improper rates that result in nutrient imbalances. Potential pollutants of concern in livestock wastes are organic materials, excessive nutrients, pathogenic microorganisms, odors, and dust (Loehr, 1984). Surface water is primarily affected through soluble contaminants in runoff or insoluble pollutants carried on soil particles during soil erosion events.

LIVESTOCK PRODUCTION PROCESSES

Historically most domestic livestock roamed in open fields, Solid wastes associated with these free range livestock were generally dispersed and easily assimilated into soil without significant surface or ground water contamination. The trend in livestock production, however, is currently changing. Economics of scale, specialization and regional concentration in all major livestock production areas are fueling a trend toward larger operations. As livestock producers expand their production, many have found concentrated feedlots and confinement facilities to be efficient and useful for controlling feeding rates, environmental conditions, diseases, and waste management.

Typically producers maintain livestock such as dairy cows, swine, poultry, and aquaculture in high density areas or concentrated feedlots. Facilities include provisions for providing food and water to the animals as well as means of disposal for manure, wastewater, soiled bedding, spoiled feed, and dead animals. Often inadequate consideration is given to animal waste management as facilities expand from extensive systems to the more efficient intensive systems. Treatment of animal wastes using methods similar to conventional municipal sewage treatment plants is not economically feasible due to the high volume of solid waste and required water for treatment. Since treatment is not a viable option, these larger operations are coming under increasing regulatory scrutiny as the waste disposal problems and associated nuisance concerns attract further attention. This highlights the need for these operations to take voluntary pollution prevention measures before further federal point source regulations are imposed.

This section is intended to present an overview of common animal production practices used in Georgia and the waste streams associated with them. Since animal manure is the primary by-product of animal production, the section begins by defining the important manure characteristics and estimating approximate production for various animals. Animal waste streams in common production sectors are then described. A brief overview of commonly used waste management systems is then presented to form a foundation for assessing the opportunities for incorporating pollution prevention into these waste streams.

Animal Waste Streams

Farm wastes are the unwanted by-products of agricultural production. Often the quantities are small and can be productively recycled but, with increasing farm size- and specialization, excessive amounts of wastes are produced that can cause serious environmental contamination. The most important categories of farm wastes in animal production are manures, slurries, gases from farm livestock, and feed wastes. All contain compounds of potential value to farmers or to society. However, realizing this potential in a manner that is profitable is often difficult. Therefore, in practice, attention is often diverted to either reducing the production of wastes or finding means of ameliorating their impact on the environment (Conway and Pretty, 1991). Rather than viewing manure and other by-products of production as waste, they should be viewed as economically beneficial agricultural by-products.

Manure Characteristics and Production

Animal wastes consist of a variety of components. Livestock manure consists of feces and urine. The feces of livestock primarily consist of undigested food, mostly cellulose fiber and undigested proteins that have escaped bacterial action (Fontenot et al., 1983). Other constituents of concentrations exceeding 10 ppm (Tyson et al., 1995). While these numbers do not suggest a significant problem, it is imperative that wellhead protection measures be used to prevent further contamination.

Phosphorus can be highly destructive as a water pollutant since it is often a limiting nutrient for plant and algae growth. In small concentrations (greater than 10 parts per billion) phosphorus can cause algal blooms in surface water. Algal blooms reduce the aesthetic quality of water bodies, impart undesirable tastes and odors to the water, and can cause severe oxygen deprivation resulting in death to aquatic life. Phosphorus readily combines with other minerals in the soil so phosphorus movement is usually limited to one to two inches in depth even in sandy soils. Runoff that erodes soil particles containing phosphorus is the primary mechanism for phosphorous transport to surface water. The adsorption capacity of the soil can, over time, become depleted if manures are repeatedly applied to the same area. As phosphorous migrates to lower, less weathered soil, it becomes more mobile. While ground water is usually not contaminated by phosphorus, repeated over application could contaminate ground water, especially in shallow aquifers.

Microorganisms naturally occurring in livestock waste can contaminate surface waters making them unfit for human consumption, recreational, and industrial use. Pathogenic organisms in wastes may survive for days in surface waters depending upon environmental conditions. Factors affecting microbial survival include pH, temperature, nutrient supply, competition with other organisms, ability to form spores, and resistance to inhibitors. The ability of pathogenic organisms to cause disease depends upon their concentration, virulence, ingestion and resistance (Loehr, 1984). While most surface water used for drinking purposes is thoroughly treated, with the increases in water-based recreation, limiting the possibility of contamination from pathogens is important.

While most of the environmental concerns discussed thus far have dealt with contamination of the environment external to the farm, it is important to remember that pollution can also have a profound effect on farm productivity. Many concerns that impact human health can also influence livestock productivity and health. For example, nutrients or pathogens in animal drinking water can lead to reproductive problems or death. Producers also have to be aware of contamination in their soils and animal feeds. Nutrient imbalances in the soil can result in decreased feed production or at the other extreme nutrient imbalances in the feed rations. Feed quality must be maintained to insure that natural toxins such as alfatoxins or certain weeds are not fed to the livestock. Preventive measures should also be employed to insure that on-farm products such as pesticides, petroleum products, and medications cannot enter the feed supply. Air quality and environmental control are also essential. Airborne particulate, gases, and dust can all affect both animal and worker productivity.

production. Moisture accounts for a significant amount of the total waste production. For example, the moisture content of cattle manure is 80-88% with urine consisting of 30% of the weight and volatile matter representing 80-85% (Loehr, 1984). Table 2 shows the moisture content of manure for some other classes of animals. The moisture content of the manure or waste is important as it often dictates how farmers handle the waste. Livestock waste can be handled as a solid (<80% moisture), semi-solid (80 to 90% moisture), slurry (91 to 96% moisture) or liquid (>96% moisture). The amount of bedding and dilution water added are often manipulated based on the types of equipment and facilities used for collection, storage and treatment of animal waste. Solid waste systems minimize the volume of manure handled and are commonly used in smaller operations. More liquid forms of waste increase the volume of waste but it can be handled as a fluid and the recovery of nutrients improves. Animal bedding is also important in characterizing animal waste. For example, pine shavings are often used in poultry production and can dramatically decrease the carbon to nitrogen ratios when comparing fresh manure to waste.

Table 2 Moisture Content and Handling Characteristics of Different Types of Manure

Animal Class	Moisture content of Manure	Form	Handling Characteristics
Beef Cattle	88%	Semi-Solid	Left in pasture or Dried and Stacked
Dairy Cattle	88%	Semi-Solid	Add bedding to handle as semi-solid or add liquid for pump or gravity flow
Swine	91%	Slurry	Gravity flow or add liquid to pump
Poultry	75%	Solid	Stackable
Horses	80%	Semi-Solid	Stackable

Today, the industry is moving toward the use of milking parlors where the cattle are routed through the parlor, fed precise amounts of grains, and returned to freestall type barns. These barns are equipped with automated hydraulic flush systems that can collect the manure and other milking center waste for storage in lagoons. In these systems as much as half or two thirds of the total manure produced on the farm is collected. The remaining manure is usually from calves, replacement heifers, and dry cows that are out on pastures. Dairy farms also generate liquid waste from the milking parlor. Liquid wastes consist of milk solids, udder washings, facility washings, and milk unfit for human consumption. These wastes can be treated separately, however, they are often combined with the manure slurry and treated in a similar manner. Figure 5 shows many of the options available for handling the waste streams on dairy farms.

For effective pollution prevention strategies to be implemented on dairy farms the production system must allow for the collection and storage of the animal waste. Therefore, a priority must be getting the older systems up to current standards.

feces include potassium, calcium, magnesium, iron, and phosphorous as well as residues from digestive fluids, bacteria, and foreign matter or dirt consumed along with food (Loehr, 1984). Urine consists of excess nitrogen from digested protein and other liquids and chemicals that pass through the digestive system. The physical, chemical and biological properties of animal manure are affected by the physiology of the animal, the animal size, sex, and breed, the feed ration, digestibility and protein fiber content of the feed, and the surrounding environmental conditions (Hammond, 1993). The quality of the feed influences the quantity consumed, conversion efficiency, and ultimately the quantity and chemical composition of the manure. While considerable variation exists within each animal type, Table 1 presents estimates of manure production and characteristics for several different animal types. Production amounts are important as they ultimately influence the size and type of waste management system employed while the amount of nitrogen, phosphorus, and potassium affect the economic value of the manure.

Table 1 Animal Waste Characteristics. (As excreted per 1,000 pound animal unit, per day).

Type Animal	Weight lb/day	Volume cu ft/day	Dry Wt. lb/day	Nitrogen lb/day	Phosphorus lb/day	Potassium lb/day
Beef (800 lbs/cow)						
Cow	63.0	1.0	7.3	0.33	0.12	0.26
Dairy (1,400 lbs/cow)						
Cow	80.0	1.3	10.0	0.45	0.07	0.26
Heifer	85.0	1.3	9.1	0.31	0.04	0.24
Swine (400 lbs/sow, 40-220 lbs/grower)						
Sow (lactating)	60.0	0.96	6.0	0.47	0.15	0.30
Sow (gestating)	27.2	0.44	2.5	0.19	0.06	0.12
Grower	63.4	1.00	6.3	0.42	0.16	0.22
Boar	20.5	0.33	1.9	0.15	0.05	0.10
Poultry (250 layers, 650 broilers, 440 pullets, 100 turkeys per 1000 lbs.)						
Layers	60.5	0.93	15.1	0.83	0.31	0.34
Pullets	45.6	0.73	11.4	0.62	0.24	0.26
Broilers	80.0	1.26	20.0	1.10	0.34	0.46
Turkeys	43.6	0.69	10.9	074	0.28	0.28
Horses (850 lbs./horse)						
All breeds	50.0	0.80	11.0	0.28	0.05	0.19

Animal waste refers to manure mixed with other ingredients such as bedding, spoiled feed, rain, urine, and other wastewater. The daily waste production of most animals is higher than manure

Beef Production

Beef cattle production falls into two main categories. Operations are either cow/calf operations that produce breeding stock and calves for export to feedlot operations or feedlot operations that buy weaned calves and bring them to market weight for slaughter. Since feedlot operations are highly dependent on large amounts of feed grains, most of them are found in the Midwest where much of this country's corn production is centered. Approximately, 90% of the beef production in Georgia can be classified as cow/calf operations. In these operations the cattle spend most of their time in pastures and the manure is left in field. Since most of this waste is dispersed across wide areas, it does not present many of the problems associated with concentrated livestock production. In fact, it returns nutrients to the soil that promotes future plant growth Nationally, beef cattle in extensive (grazing) production produces about seven-eighths of the total beef cattle manure production while beef cattle in confinement produce the other eighth (Sweeten, 1992). While these confined operations only represent an eighth of the total production, this eighth presents a much larger problem from a pollution prevention point of view as it is concentrated into small areas.

Feedlots in the Midwest often raise several thousand cattle at time. In Georgia, most feedlot operations are much smaller and are designed to produce beef for specific purposes or local consumption. Concentrated feedlots commonly are built either on a continuous Sloped slab concrete floor with frequent manure removal or on open dirt areas with less frequent manure removal. Waste removal from facilities with concrete floors can be accomplished by mechanical or manual scraping, hydraulic flushing, or gravity assisted systems. Onsite detention facilities safely contain waste to prevent contamination of downstream water bodies by deterring runoff. Open feed lots use paved or unpaved surfaces and provide shelter for feed disbursal units. Lots are normally sloped for drainage to assist in waste collection. Manure is generally handled as a solid, periodically scraped and stockpiled. Runoff from open lots is routed to a settling basin or through a grass infiltration area.

Feedlots for beef production are coming under increasing regulatory pressure and are one of the few agricultural operations that can be regulated as point sources. In anticipation of requirements in the proposed 1996 Federal Clean Water Act, Region 6 of the EPA, which encompasses Texas, Oklahoma, Louisiana, and Oklahoma, has recently drafted regulations that require most feedlots to develop Pollution Prevention Plans (Sweeten, 1995). These plans require feedlot operations to document the measures necessary to limit pollution such as Best Management Practices, proper facility design and maintenance, and implementation of employee training and record keeping programs. While the limited number of feedlot operations in Georgia probably negates the utility of requiring such plans in Georgia, these pollution prevention plans should serve as a model for all concentrated animal feeding operations.

Dairy Production

Currently there are close to 600 dairy farms in Georgia with 105 thousand cows that produce about 1.6 billion pounds of milk (Guthrie and Smith, 1994). As with most other animal production industries, the dairy industry in Georgia is moving toward larger farms and more efficient systems. During the last ten years rapid changes have taken place in the rate of adoption of new milking, feeding, and herd housing practices. Before 1985, there were very few operations with milking parlors and freestall housing. Most operations milked in flat stanchion type barns, fed hay outside

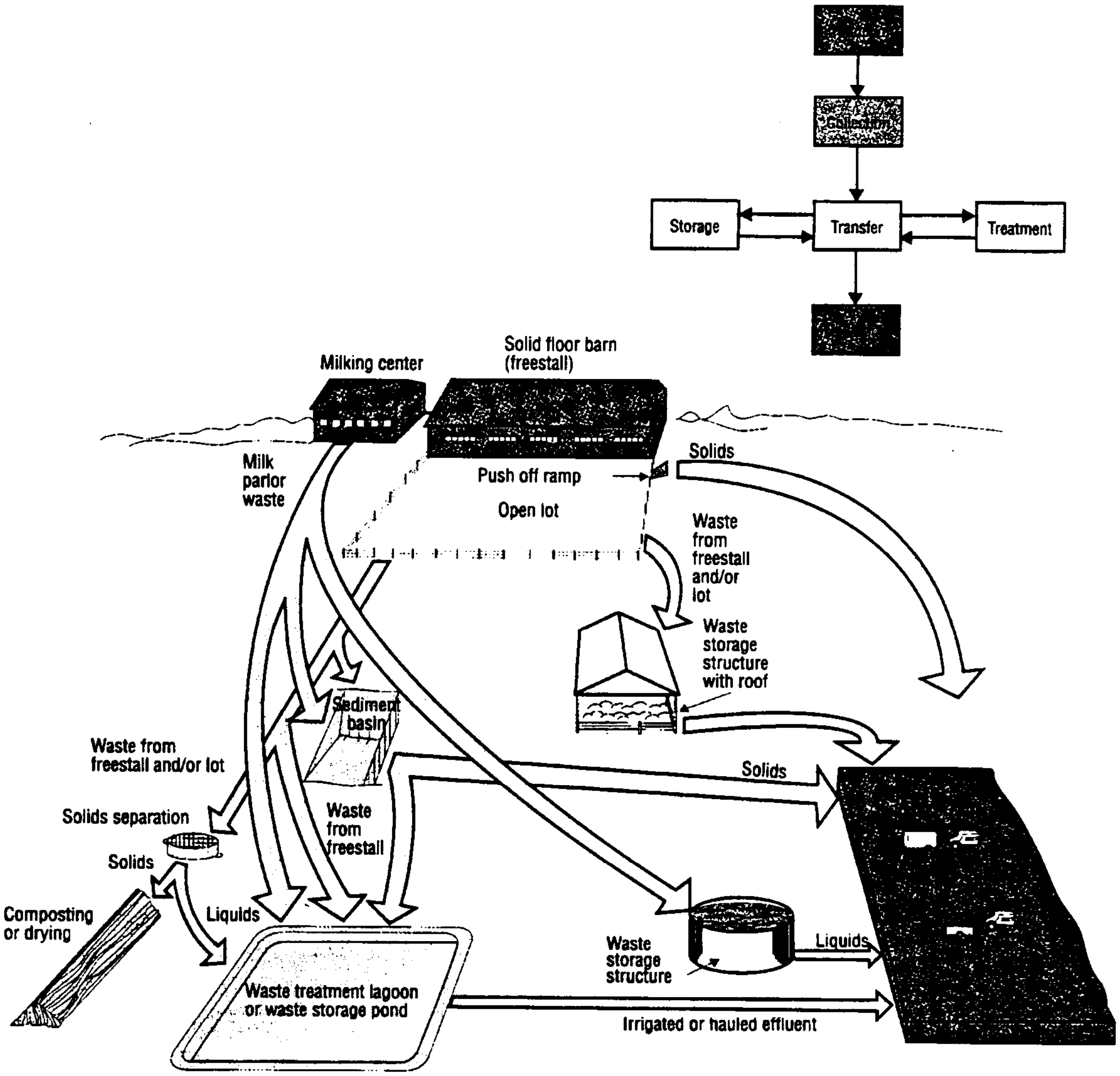

Figure 5 Diagram of waste stream for dairy operations.
Source: Georgia Soil and Water Conservation Commision, 1994.

is usually handled as a solid. Forestry by-products such as wood shavings and sawdust are generally used as bedding. Peanut hulls, rice hulls, and straw can also be used but are usually less absorbent than wood by-products. Recently, the development of methods for using some forms of recycled, processed paper or cardboard as bedding material is also being considered (CAST, 1995). Litter, the poultry manure and bedding, is mechanically removed from the houses either between each batch of chickens or after several batches. This litter is either stored in stackhouse type structures or land applied immediately. Caged systems are usually used for layer production as the collection of eggs often requires mechanization. High rise houses with eight to sixteen feet of manure storage beneath the chickens, shallow pit houses that use flush systems, or belt scraped houses with automated cleaning systems are all frequently used in Georgia. Figure 7 outlines each of these options. While layer manure production in both solid and liquid forms is substantial in Georgia, broiler litter is the single largest animal waste by-product produced in Georgia.

Georgia also produces a considerable number of turkeys. Turkeys are raised in a variety of ways. Most turkey production begins similar to broiler production. Turkey chicks are confined in loose housing and the litter is mechanically removed once the turkeys are removed. However, after four to six weeks many operations convert to external systems where the turkeys are placed in open pastures or lots. Outdoor systems are used because the turkeys no longer require strict environmental control and their size dictates additional space requirements that are not available in confinement, Few studies or published literature sources have documented the environmental impact of outdoor turkey production; however, since the pastures often support very little vegetation one would assume that non-point source nutrient runoff and erosion are very substantial in these systems. In these situations, pollution prevention opportunities include maintaining sustainable stocking rates and incorporating other best management practices to prevent runoff and soil erosion.

in unconfined feedlots, used natural reproduction rather than artificial insemination, and did not provide herd housing. These systems were not only less productive, but they also did not provide any means for collecting and utilizing the animal waste.

Both economics and environmental concern will force many older, less productive, systems to either update or fail. In the newer operations, pollution prevention strategies should target improved utilization of the animal waste and better management and control of waste collection and storage systems. Even in the newer facilities, there are often many areas on the farm where cattle are confined in small open areas. These "loafing" areas are often denuded of vegetation and are external to the waste collection systems. Current research (Radcliffe et al., 1995) shows that these areas may be critical sources of both ground and surface water contamination.

Swine Production

Georgia currently has about 140,000 breeding head of swine; however, this number is expected to grow over the next decade. Swine production facilities usually fall into one of three categories: breeding and farrowing units, nursery units, and feeder/growout units. Historically, most operations had each of these units on one production farm, but the swine industry is currently moving toward more integration and specialization. Large producers, such as Goldkist, are moving into the breeding and nursery operations and contracting the growout phase of production to individual farmers. This allows the farmer to specialize in only one aspect of production while the integrator manages reproduction and genetics.

Open lots systems may be used on paved or unpaved lots. In Georgia, most of the small operations (0-25 head) use open lots on unpaved surfaces. Shelters are often used to provide shade and protection during inclement weather. Manure is generally handled as a solid and mechanically scraped from the lot. Runoff from open lots contains high levels of nutrients and needs to be managed to avoid polluting of surface waters. Often, settling basins, grassed infiltration strips, or riparian zones can be effectively used on these small systems.

Most of the larger operations raise swine in roofed confinement facilities. Here the manure may be managed as a solid, slurry, or liquid. On solid floors bedding can be added and the manure can be handled as a solid. Most often, slotted or partially slotted floors are used with under floor storage pits or gutters. Under floor storage areas can be mechanically scraped but flush systems are commonly employed. In these systems, water is used periodically to flush the waste in the under floor storage area into collection basins or lagoons. In these systems, proper design and management are critical for both odor, insect, and disease control as well as proper utilization of the waste. Figure 6 outlines many of the waste handling options for swine facilities.

Poultry and others

In the poultry industry, nearly all production is in confined, intensive systems. Broilers, small birds raised for six to 10 weeks for meat production, are grown in loose housing and the waste

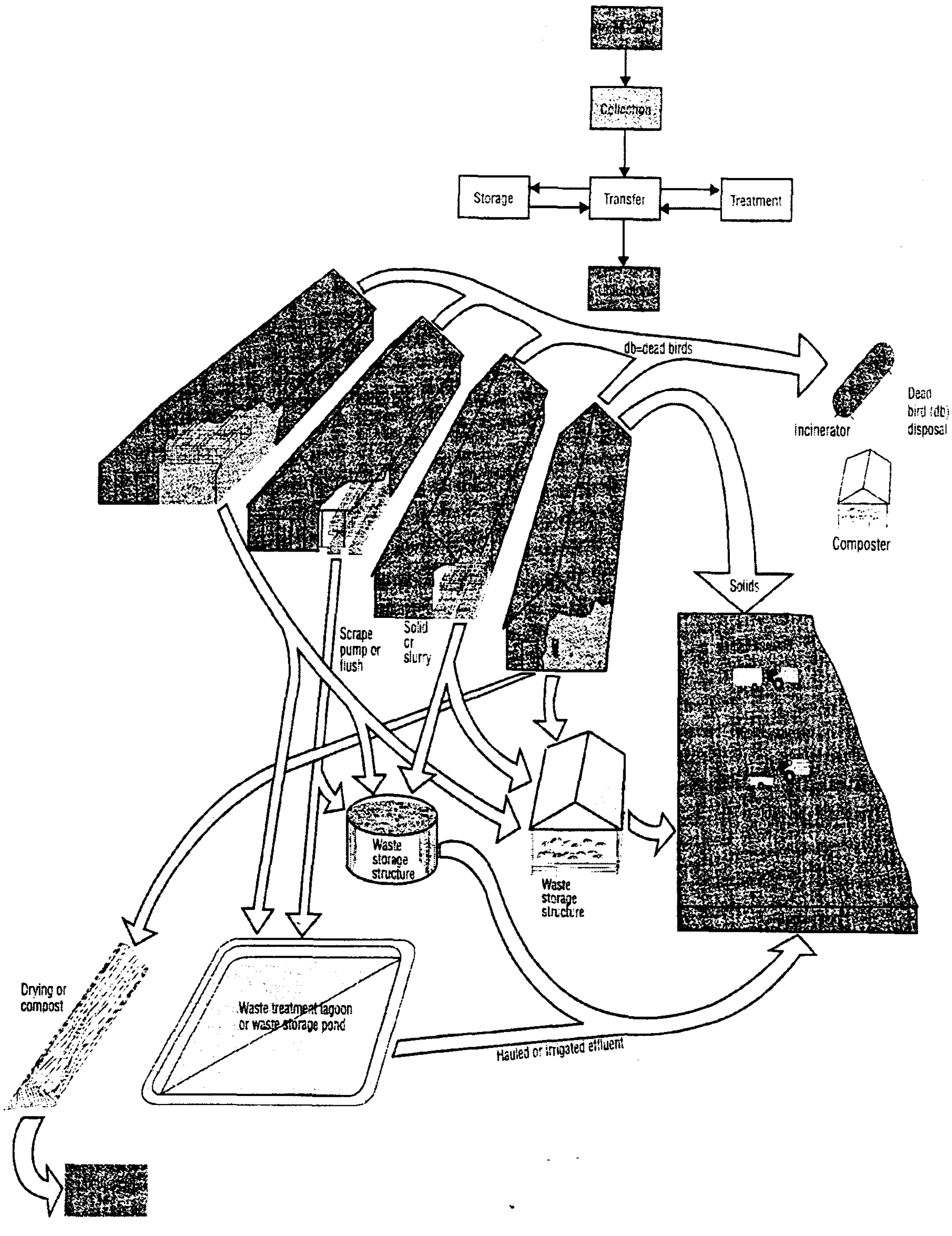

Figure 7 Diagram of waste stream for poultry operations.
Source: Georgia Soil and Water Conservation Commision, 1994.

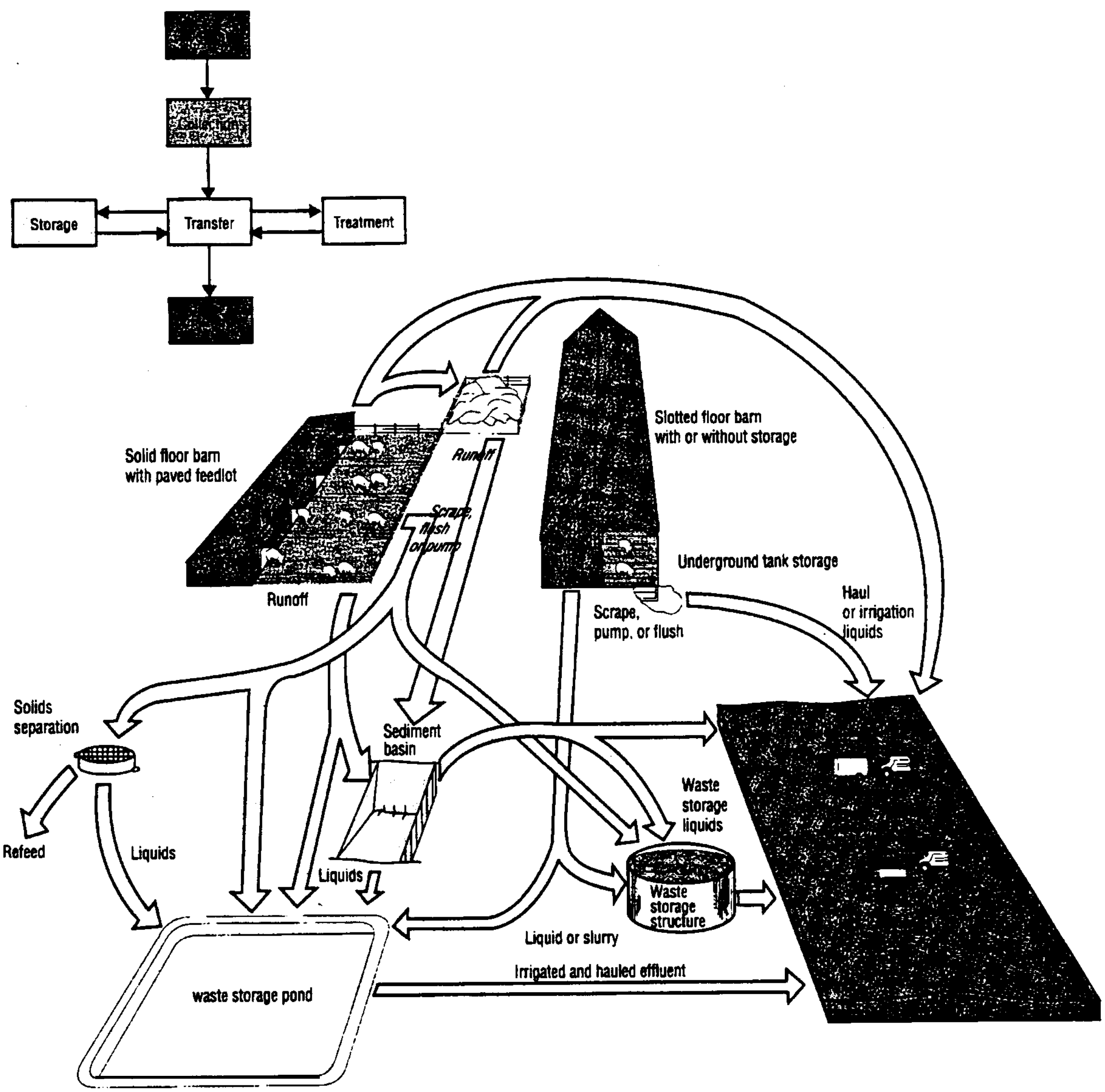

Figure 6 Diagram of waste stream for swine operations.
Source: Georgia Soil and Water Conservation Commision, 1994.

Table 3 Percent of Original Nitrogen Content of Manure by Various Management Systems. Data adopted from USDA-NRCS Agricultural Waste Management Handbook.

Management System	Beef	Dairy	Poultry	Swine
Manure stored in open lot; winter	30-45	15-30		30-45
Manure stored in open lot; summer	40-60	30-45		15-25
Manure liquid and solids stored in covered, watertight structure	15-30	15-30		25-30
Diluted manure liquid and solids held in storage pond or lagoon	25-40	25-35		
Manure and bedding held in roofed structure		20-35	30-45	
Manure and bedding held in unroofed structure; leaching		25-45		
Manure in pits beneath slatted floors	15-30	15-30	10-20	15-30
Manure treated in aerobic lagoon or pond diluted more than 50%	65-80	65-80	70-80	70-80

Systems that handle manure as a solid have the advantage of reducing nitrogen losses; however, they are also labor intensive. Most systems must collect waste daily or weekly unless significant amounts of bedding are used. Common equipment required to handle manure as a solid includes a front-end loader, a scraper, and a manure spreader. To utilize the collected manure, growing crops or pastures should be available during most of the year. An alternative to frequent spreading is to provide a covered storage pad where manure can be stockpiled and used later. Properly designed storage areas are essential to effective pollution prevention as they reduce the possibility of environmental degradation and allow for storage when inclement conditions prevent land application without considerable environmental risk.

Pretreatment is any operation prior to the terminal disposition of the wastes. The primary purpose of pretreatment is to reduce the amount and toxicity of waste to be disposed. Since waste handled in a solid form is often applied directly to the field, most pretreatment measures are used on liquid or slurry wastes. Additional benefits of pretreatment include nutrient, BOD, TSS, and odor reduction. Pretreatment can be accomplished by lagoon storage, runoff retention facilities, or solid separation systems.

Ponds and lagoons are among the simplest forms of storage and pretreatment for liquid and slurry wastes. Lagoon storage systems are often used to hold wastes until they can be incorporated into the soil or another means of disposal. The BOD and nutrient concentration of the wastes collected in lagoons are reduced by biological activity and chemical reactions providing a minimum amount of pretreatment. The major types of ponds can be classified as facultative, aerobic, and anaerobic. Facultative ponds are aerobic near the surface and anaerobic in deeper layers. Also

Horses, goats, and sheep are usually raised in systems that include both open pastures and confinement buildings. The animals spend most of the time grazing open pastures; however, supplemental feed and water are often supplied in some sort of barn. In these systems, a majority of the waste remains in the pasture where it creates few problems. Manure deposited in the barn will be mechanically or physically removed periodically and land applied. Since these operations are usually relatively small, they do not present many pollution concerns in most situations.

Methods of Waste Treatment

While the disposal of animal waste poses one environmental hazard, the storage and handling of waste are also important since most of the severe pollution incidents result from design flaws or accidental spills. Adequate pollution prevention plans should not only reduce the production of waste, but also insure that waste has little opportunity to become pollution. In animal agriculture this can be accomplished by ensuring that the design and operation of waste management systems are adequate and efficient. Designs should ensure that waste storage areas have sufficient capacity to handle large events and prevent the necessity for surface applying in undesirable conditions. Proper siting is an often overlooked design criteria that can result in adverse environmental impacts. Designs should also minimize total volumes by intercepting rainfall and runoff with roofed systems and drainage ditches that keep clean water from entering the waste stream. Secondary containment systems, such as riparian buffer zones, filter strips, wetlands, and farm ponds are also used. Ultimately, the goal of these systems should not be primary treatment, but should be to insure that none of the production by-products leave the production facilities. The purpose of this section is to provide a brief overview of some common animal waste storage and treatment structures and discuss their role in pollution prevention on the farm.

The physical form in which the manure is handled often dictates the types of storage and treatment structures used on the farm. Manure scraped from open lots or confined facilities can vary from 70 to 85% moisture content (Melvin et al., 1981). Solids can be stacked and stored in open or sheltered bins until further treatment. Slurry and liquid waste can be stored in earthen basins, concrete tanks above or below ground, and in lined or unlined metal tanks. Pumps are then used to agitate and move waste into tanks and transport vehicles or through irrigation systems. Transport vehicles can either spread the slurry on the soil or inject the waste into the ground.

Another important consideration in determining how to manage or store waste is the effect the storage system has on the value of the waste. Nitrogen is the nutrient that is most valuable for the production of crops and pastures. Nitrogen value is usually increased by minimizing the handling operations and applying it to the land as rapidly as possible. Conversely, composting operations can decrease nutrient content where waste disposal is a concern. Table 3 shows estimates of nitrogen losses using different management systems. While opportunities for pollution prevention exist with all of the waste management systems, the nutrient losses associated with each system will dictate the ultimate value of the product and therefore affect the opportunities for alternative uses.

action. The most important process for nitrogen removal is denitrification, where nitrogen is converted to nitrogen gas and released into the atmosphere. Studies have shown a 80% nitrogen and phosphorous reduction in runoff and shallow groundwater through a riparian forest (Welsch, 1985). Riparian forests and buffer zones are usually best suited for secondary treatment systems and preventive systems for sensitive areas. Wetlands have the potential to act as primary treatment systems; however, further research is essential for widespread acceptance and use.

Non-Manure Waste Streams

Manure is the number one concern in animal agriculture as it produces the greatest environmental risk, but many other opportunities for pollution prevention on farms that specialize in animal production exist. Surprisingly very little information exists concerning the inputs and by-products in various animal industries, especially at the national level. There is generally very detailed information concerning the products and on-farm inventories in terms of numbers and value. However, this information is of little value when conducting pollution prevention assessments. On the input side, animal feed is the largest concern by far but since many farmers produce their own feed it is difficult to quantify. In addition, most farms use chemicals to control insects and maintain animal health, as well as substantial amounts of water and energy. In most industries, ample opportunities exist to reduce both water and energy inputs so the same is probably true at animal production facilities. Unless these inputs are in high demand, for example during a drought or oil embargo, little emphasis is placed on minimizing their use although it could result in higher profits. Primary on-farm by-products include dead animals, waste feed, insects, and miscellaneous solid wastes. Associated farm machinery including trucks, tractors, and implements and farm structures and maintenance also present opportunities for pollution prevention. To perform detailed pollution prevention assessments, there is a real need to obtain information on each of these parameters for each class of livestock production.

The residuals from feed production and unused feed are substantial by-products from livestock production. Most often, animal feed is either produced off the farm or the residuals are left in the field where they pose little hazard to the environment. The runoff and leachate produced from silage production systems are exceptions that can affect water quality in both surface and ground water. Silage effluent is very acidic-and corrosive to concrete and metal. Seepage from the walls and base of the silage storage area needs to be controlled. This is especially true-as the use of ground storage systems is replacing the use of concrete silos in many areas. The most effective way to reduce silage effluent is to reduce the moisture content by wilting the crop in the field before ensiling. This is not economical because of the costs of adverse weather and extra costs associated with moving the machinery twice. Nevertheless, the benefits of ensiling a drier material are a more complete fermentation and easier transportation. Additional research should focus on determining the effects of ground storage systems on water quality or developing BMP's for dealing with silage effluent. Waste and unused feed is usually mixed with animal manures and disposed of in similar manners. Often these feed substances differ in composition from the manure. By keeping them separated from the manure, alternative uses could be developed and manure characterization would be less variable. While considerable research will be required to investigate and develop the alternative uses for waste feed, it is a plausible alternative that warrants further consideration.

Management of the quality of the internal environment in animal production facilities can enhance animal production performance and minimize animal disease, death loss and behavioral

called oxidation ponds or waste stabilization lagoons, facultative ponds are the most commonly used lagoon type in Georgia. Aerobic ponds require a large surface area to volume ratio and decompose organic matter solely through aerobic oxidation. Aerobic treatment systems are utilized to reduce odor problems, stabilize wastes prior to land application, and to meet regulated effluent standards (Loehr, 1984). Anaerobic lagoons are deep and heavily loaded with organic material to ensure complete depletion of dissolved oxygen. The purpose of anaerobic ponds is the stabilization of wastes by sedimentation and biological activity (Loehr, 1984).

Dual lagoon systems are common practice. Two or more small lagoons in series are more efficient in reducing BOD, TSS, and nutrient concentrations than one large lagoon with the same volume (Loehr, 1984). Usually the first lagoon is anaerobic due to the high loading and produces the greatest reduction in BOD and TSS. The successive lagoons are typically aerobic and "polish" the water and further reduce the BOD and TSS but not with as great of a reduction as the first lagoon. These types of lagoon systems should be promoted as pollution prevention technologies. Additional lagoons in a system not only improve treatment but also extend lagoon life, offer additional volume, and can prevent severe environmental degradation by having successive lagoons to serve as backups for the primary lagoon. Lagoon failures can be costly. In 1995, four different waste lagoons in North Carolina burst over a period of several weeks spilling more than 30 million gallons of animal waste into rivers and streams (Kidwell, 1995). While proper design and management can decrease the chance of lagoon failure, there is a real need to investigate lagoon systems that will prevent off-site contamination if there is a wall failure.

Solid-Liquid Separators segregate solids from a liquid or slurry waste stream. Solids separation can be accomplished by gravity, filters or screens, evaporation, or mechanical separators. Solid separators help make the waste more fluid to improve the handling characteristics and reduce solids buildup in lagoons to increase the lagoon life. While these systems do divide the waste stream into two components, they also make it easier to use each of the components. The separated solids are dried and can be land applied or processed as fertilizer, compost, feed, or used for methane production. The remaining liquids are easier to handle for irrigation or can be recycled for flushing operations. Because they improve utilization and decrease the risk of lagoon overtopping or failure, solid separators are an important pollution prevention technology. Solids separators are currently being installed on many dairies throughout Georgia as a result of educational efforts of the UGA Cooperative Extension Service and the NRCS. Although they do require some management and initial investment, the benefits of increased lagoon life, less pumping costs and maintenance, and better control of waste management make solid separators profitable investments.

Overland flow and grass infiltration systems stabilize and remove organic material and nitrogen by microbial pathways. Organics are initially removed by filtration, sedimentation, and soil sorption. Between applications, the soil microbial zone interface becomes aerobic and material is aerobically stabilized (Overcash and Jumenik, 1976). Advantages of these systems include ease of construction, odor reduction, and nutrient removal. However, they do not have enough capacity to serve as a primary treatment mechanism. From the pollution prevention standpoint, these systems represent excellent opportunities for secondary containment and treatment of overland flow that is not routed through primary treatment systems.

Wetlands, riparian forests, meadows, and other types of natural buffers function as nutrient sinks and remediate contaminated water flow. These buffers facilitate settling of suspended solids and enhance nutrient uptake and transformation by biological activity. Many aquatic plants transport oxygen into saturated sediments, creating aerobic zones in the rhizosphere which increase microbial

POLLUTION PREVENTION OPPORTUNITIES

There are abundant opportunities for the incorporation of pollution prevention concepts in on-farm animal production. This chapter starts by discussing the most obvious method of pollution prevention, source reduction. Since it will be impossible to reduce or eliminate most agricultural pollutants, those that are generated must be reused or recycled in an environmentally safe manner. Therefore, the remainder of this chapter discusses environmentally sound methods of using or recycling farm by-products and best management practices that prevent waste from becoming pollution.

Source Reduction

Pollution prevention tool kits and standard assessment procedures have been developed for many industries. Many principles outlined in these publications will also apply to production farms. General housekeeping and maintenance and detailed inventory control can help farmers reduce non-manure waste generated on the farm. Storage and work areas should be kept clean and well organized to prevent spills and improve efficiency. Very few feed handling systems effectively distribute feed without some loss. By carefully monitoring and maintaining these systems, producers could save money and reduce feed entering the waste stream. Several publications outline opportunities for pollution prevention in petroleum product and farm chemical storage and handling (Hygnstrom et al., 1995 and others). These publications outline a variety of techniques including proper siting and design of storage and mixing facilities, methods for mixing chemicals that minimize spills and allow for recovery, and proper tracking and labeling of containers and rinsates. Most production farms also maintain many farm vehicles and machines. The maintenance facilities could probably benefit from many of the same pollution prevention strategies employed in many commercial garages and service stations.

More specific techniques for waste reduction can be incorporated into facility designs. Diverting rainwater and other runoff from entering waste collection systems reduces the volume of waste to be treated. In areas where animals congregate, concrete surfaces should be used to facilitate manure collection and clear water diversions should be installed to prevent runoff from entering the waste stream. Solid-liquid separators effectively separate waste streams. This allows the liquid waste stream to be reused in hydraulic flushing systems for waste removal or surface applied through irrigation systems. Animal bedding can also enter the waste stream at accelerated rates. Currently, many dairy facilities use fabric or geotexiles to retain freestall bedding which prevents bedding material from being flushed away and cuts down on solid waste generation.

Improvements in animal production efficiency can also be used as a pollution prevention tool. Most gains in animal productivity do not come with a significant increase in the amounts of waste generated by each animal. Advances in reproductive and feeding programs, genetics, feed quality, and environmental control have consistently increased the productivity of American animal agriculture over the last century. These gains will continue and as they do, waste generated per unit of output will probably continue to decrease. Increasing the animals' feed conversion efficiency by using high quality feed also reduces the amount of waste voided. Therefore, improvements in forage and grain quality through plant genetics and biotechnology should result in higher animal efficiencies. Animal scientists, with the aid of indirect calorimetry, can fine tune the digestibility of animal feeds so the animals can exploit more of the energy in the feed (Suszki, 1995). In dairy

problems. While the level of management depends on the type of animal as well as its age, genetic background, and production purpose, most producers need to control several key variables in animal production facilities. These include temperature, humidity, ventilation rates, and air quality. Considerable amounts of energy are spent trying to maintain the optimal conditions for each of these variables. When the conditions fall above or below the optimal zones, it usually results in a stressed and less productive animal. Many research projects have identified the optimal production zones for various animals in different locations and these are generally not in dispute. Pollution prevention needs to be incorporated into this facet of animal production through the promotion of efficient and reliable systems. While an inefficient or poorly designed heating or ventilation system would have little effect on environmental conditions in the immediate vicinity, the increased energy use would have a profound effect on the producer's economic gain and a secondary environmental impact at the energy generation facility many miles away.

Most types of animal production also depend on drugs and chemicals to maintain the health of their animal stock. Little information is available concerning the amounts of waste produced from these products. In the poultry industry, most drugs or vaccines are administered through the drinking water and are therefore purchased as bulk supplies. The swine industry probably uses the largest amounts of medication since these animals are closely confined. A particular problem in this industry is the disposal of needle and razor blades (sharps) used for castration. Since swine are often raised on slotted floors, when sharps are dropped (which often occurs with unrestrained animals) they often fall directly into manure waste streams and end up in manure lagoons and storage facilities. This severely restricts the possibilities for land application and presents disposal problems unless economic separation technology can be developed. The dairy and beef industries do not use as many medications, but the use of any medication on dairy cows does contaminant the milk production, making it unfit for human consumption. Therefore, treated cows are often milked separately and their milk is either fed to younger stock or is added to the manure waste stream.

primary concern in poultry production. Approximately 14 million tons of litter and manure and 300,000 tons of dead birds required disposal on U.S. poultry farms in 1990 (Moore et al., 1995). While this mass alone does not present a problem, the fact that poultry production is often concentrated in regions with small farms and very limited acreage for land disposal often creates localized areas where manure nutrients exceed crop requirements, especially for P. ASAE, 1988, ranked manure production by livestock classes from beef cattle producing the most, followed by dairy cattle, swine, and poultry. Beyond this, Power and Eghball, 1994, estimate that an additional 130,000 tons of N and 28,000 tons of P are produced annually by five minor classes of livestock including sheep, goats, horses, veal calves, and mink.

Historically, many measures have been used for the disposal or reuse of agricultural wastes. Typically, the ultimate objective was not to reduce pollution but find alternate uses for waste by-products. Animal manure is a valuable, underutilized resource. As a biomass resource, manure may be used as a fertilizer and soil conditioner, an energy supplement, a biological growth media, or as a feedstuff. There are many reasons why it is not used to its potential. These include: 1) economic feasibility of obtaining maximum use; 2) lack of information on the value of manure as a fertilizer; 3) lack of information on alternative uses for animal waste; 4) lack of recognition of its economic value; and 5) producers' unwillingness to try new approaches to waste management (Fontenot and Ross, 1981).

Fertilizer and Soil Conditioner

The most common method of effective manure utilization is direct land application as an organic fertilizer and soil conditioner. This is the foundation of any organic system as ultimately animal waste is returned to the soil, completing an ecological cycle. The 134 million ha of cropland and 265 million ha of pasture in the United States provide an ample base for land application of animal manure (Eghball and Power, 1994). The nutrients from livestock wastes are a good source of organic fertilizer. The organic matter deposited enhances soil physical properties such as tilth, structure, water holding capacity, water infiltration rate, and soil microbial activity (Smith and Kemper, 1992). Animal manure supplied 12% of the approximately 17 million tons of total nitrogen applied to U.S. cropland in the recent decade (PPI, 1992). If used to its potential animal wastes could represent a much larger percentage of the total applied nitrogen.

Although land application is the most common waste disposal method, it is not used to its potential. Obstacles include substantial energy and labor costs associated with handling and storage of waste, high transportation costs limiting the potential to transport to off farm areas, problems encountered in collecting representative manure samples for nutrient analysis, and determination of application rates that give the crop sufficient nutrients without having adverse environmental effects. The energy resources required for the production of commercial nitrogen fertilizers are estimated to be about six times higher than the energy requirements for truck and tractor operations for manure application (Smith and Kemper, 1992). Since energy prices are currently low, commercial sources of nitrogen are commonly used. However, with increasing energy prices the potential for greater use of animal waste will increase dramatically. The preference of commercial fertilizers instead of animal manure relates to the ease of application and known concentration of nutrient content. The wide variability of nitrogen in manure requires soil and manure analysis to apply optimum concentrations, whereas commercial fertilizer's nitrogen content is regulated by the state. Land

cows, this can result in substantial cuts in energy lost as methane gas and unabsorbed nutrients in manure. The use of artifical insemination and embryo transfer technology has not only dramatically improved the genetic stock of production animals but has also reduced waste production by eliminating the need for dairy, swine, and beef production facilities to maintain and feed substantial numbers of male breeding stock.

Animal diets can also be manipulated to obtain maximum utilization of nutrients in their feed. Many feed companies in the broiler and swine industries often fortify their feeds with excessive amounts of P and micronutrients to insure that animal productivity is maximized. Manipulation of diets to reduce dietary levels of each nutrient while still maintaining optimal growth is one way of reducing the levels of nutrients in the excreted manure. Bridges et al. (1994) cite several studies where dietary levels of N and P were reduced in swine feeds and productivity was maintained or improved. In the poultry industry, additional opportunities for reducing the amount of zinc, copper, and aluminum added to poultry feeds could improve the quality of broiler litter.

There are also exciting opportunities to decrease the ratio of waste to output production further through feed additives. For example, Lewis and O'Beime, (1994) show that the use of avoparcin, an antibiotic feed additive, improves the efficiency of production resulting in substantial energy savings and reduced nitrogen waste. Sutton et al., (1995) have investigated the use of enzyme additives to improve the digestibility of feeds in swine and cattle. The development of additional feed additives and the use of products from biotechnology such as bovine somatotropin or other growth hormones should continue to increase productivity and serve as source reduction. Purina Mills has developed a program called "Impact" that includes both a feed additive and diet manipulation for the beef industry. This new, innovative feeding technology works by reducing the need for roughage and changing the feeding patterns of cattle. Impact successfully reduces total feed intake, increases the number of meals consumed per day and reduces both the average size and largest meal of the day. In performance comparisons using over 35,000 cows, the Impact program reduced dry matter intake by 6.22%, improved feed conversion by 6.73%, and resulted in a savings of between $1.00 to $1.50 per hundred pounds of gain (Purina Mills, 1995). Not only did this program improve the bottom line, but it also resulted in a 30 to 40% reduction in total manure output. Nutritional programs such as these probably offer the most substantial opportunity for reducing manure output while increasing profitability.

Waste Recycling and Utilization

While source reduction is the best method of preventing pollution from most animal production facilities, farms will never be manure free. Therefore, techniques for effectively using the manure and preventing environmental pollution must be promoted. The average annual amount of manure and nutrients produced by livestock and poultry was estimated based on animal statistics and the American Society of Agricultural Engineers manure production values. The total quantity of dry manure, nitrogen, phosphorus and potassium produced in the United States is approximately 158,6.5,2.0, and 4.1 million tons per year on a dry weight basis (Sweeten, 1992). While many of these nutrients are not recoverable, it still represents a significant resource that should not be overlooked. In fact, Eghball and Power, 1994, place a value of $461 million annually on the manure from beef cattle feedlot facilities alone and estimate that beef cattle feedlot manure could supply enough nitrogen to fertilize more than 4.6 million hectares (ha) of grain crops. Litter associated with broiler production, manure generated from laying operations, and dead birds are the three wastes of

Nutrient loss, specifically N, occurs in storage, during handling, and after application. It is a major problem in effectively using this resource. More than 50% of the N in fresh livestock manure is or can be converted to the ammonium form in a very short time following excretion, so it is subject to volatilization (Eghball and Power, 1994). Biggest nitrogen losses occur when waste is exposed to the atmosphere. Therefore, bottom loading systems that are sealed lose much less than conventional systems. N lost from manure is primarily dependent on temperature, pH, moisture, and carbon/nitrogen ratio. Many practices have been employed, primarily in the poultry industry, to reduce N losses. Besides using management alternatives such as more frequent waste disposal and different types of bedding, several additives have been developed for manure and feeds to reduce denitification and volatilization losses. These include nitrification inhibitors, urease inhibitors, acidifying materials, and precipitants or stabilizers such as alum and gypsum (Eghball and Power, 1994). Moore et al., 1995b, conducted an extensive literature review and analysis of several additives. They found that alum additions to poultry litter resulted in a 99% decrease in ammonia volatilization. While this reduction alone could justify the use of alum, other benefits included reduced atmospheric ammonia levels, reduced ventilation costs in winter months, and a reduction in the P content of runoff from land applied litter. Additives such as these and processes that reduce the losses associated with different waste management systems could present substantial opportunities for pollution prevention and increased waste utilization in the future.

Nutrients applied from waste should match the needs of the crop, but the ratios of N, P, potassium, and the various micronutrients excreted by animals are generally different from those required by crops. Not only does this present problems for the development of application rate recommendations, but it can also produce nutrient imbalances in the soils and crops that receive land applications of animal waste. Animal wastes can improve soil fertility through the addition of potassium, calcium, magnesium, iron, zinc, and other micronutrients. However, excessive accumulations can result in increased salinity and reduced fertility (Overcash and Jumenik, 1976). Ideally, the value of animal manures could be maximized if each individual nutrient could be separated and removed from the waste mixture and crop and soil specific fertilizer mixtures could then be reformulated. Since this solution will not be economical in the future, soil testing and record keeping should be used to prevent nutrient imbalances from occurring.

In the past, nitrogen has been the primary element on which nutrient management plans have been developed due to its importance in optimizing crop yields and its relatively high level of mobility in the environment. Recently, more locations are moving away from the “limiting nutrient” concept and developing nutrient management plans based on other elements such as P, K, and more conservative micronutrients that may accumulate over longer periods. In fact, at the 1991 National Workshop on Livestock, Poultry, and Aquaculture Waste Management (ASAE, 1992) research to decide whether N or P should be used as the limiting factor in developing nutrient management plans was voted as the number one priority by conference participants. Future work with nutrient management planning should focus on the development of sustainable planning methodologies rather than concentrating on individual nutrients. Improved nutrient management planning strategies that limit soil nutrient imbalances rather than maximizing crop productivity (i.e., consideration of elements other than nitrogen) should be developed. By increasing our understanding andknowledge of mineralization rates and their effects on crop growth, we could more accurately account for them in nutrient management plans.

Proper and timely application of animal wastes is important in reducing nutrient losses and pollution potential. Time and method of application depend on climate, cropping system, application is also hindered in areas of urban and suburban populations by concerns for odors and flies. Public perception must be improved for land application to realize its potential.

Since the likelihood of significantly limiting the amounts of waste produced by livestock is not great, efforts should be concentrated on finding the optimal means of reuse. While land disposal of the waste on farmland takes advantage of the nutrient content in the manure, there is increasing concern for nitrate runoff in the surface water, nitrate leaching to the groundwater, and gaseous contamination of the atmosphere. Best management practices are essential for effective use of manure for crop production and pollution prevention. The literature supports that the key components of an animal waste utilization BMP system are proper rate, in conjunction with soil and manure testing, timing, and method of application. Nutrient conservation is the first step toward a best management practice, but management plans and a thorough understanding of the environmental impacts of manure are also essential.

While manure quality under different management systems varies greatly the fact that the primary measure of the quality of the waste is usually its nutritional content is another factor that warrants more attention. The portion of the value of animal waste that can be used as a soil conditioner is often considered intangible. Land applications of animal wastes can have profound effects on soil tilth, infiltration rates, water holding capacity, and fertility, yet little value is associated with these effects. Through improvement in soil physical properties, manure application reduces runoff and erosion. It also reduces the energy required for tillage and the impedance to seedling emergence and root penetration (Eghball and Power, 1994). While many nutrients applied with the manure are not used in the first growing season, the slow mineralization of these nutrients represents a consistent 'source for plant growth. Most soil tests only account for plant available N and P and do not give credit toward the residual effects of manure. Better documentation of and accounting for the economic value of non-nutrient effects associated with organic matter additions will also be essential to more widespread manure use.

Studies have shown that the best method of avoiding groundwater and surface water contamination and possible crop damage is to limit applied manure to the amount required by the crop. This means that the total crop requirement, the nutrient pool in the soil, and the nutrient content of the manure must all be considered. Crop nutrient requirements are generally well known and can be obtained from a variety of sources. To apply the correct amount of manure to meet the nutritional requirements of the crop without applying excessive amounts that could be lost to the environment, producers require some measure of the amount of nutrients in their soil and manure. The nutrient content of the soil can be determined through soil testing. The quantity and characteristics of livestock or poultry waste are highly variable and differ significantly from the initial values for manure excreted by the animal to the time of land application. They depend on the animal type, ration fed, manure management system, climate, storage system, and time and method of land application (Gilbertson et al., 1979). Although estimates of nutritional content can be obtained through published literature, due to the variability in farming practices, animal diets, climate, and waste storage facilities, manure nutrient analysis is usually recommended. Currently, most farmers must sample their manure and soil regularly and often wait extended periods for test results. The development of inexpensive, on-farm nutrient tests would allow for testing at the time of application and more frequent and dependable test results. For producers that do not test their manure, educational and research emphasis should be placed on developing more site specific and detailed estimates of manure nutrient content as well as the economical and environmental effects of over application.

services. Many European governments do provide subsidized transport cost for manure and these programs have generally resulted in greater use of animal waste (Conway and Pretty, 1991). Better integration of farms that produce the crops and livestock and educational programs aimed at showing farmers the economic value of manure as a fertilizer are other methods of reducing the transport costs. Separation, screening, condensing, and dewatering technologies could also be used to produce more transportable products; however, little research is being conducted in these areas.

Due to the expense and labor intensivity of long term field studies required to reliably quantify agricultural nonpoint source pollutants, computer models of nutrient management are needed to evaluate different management scenarios and application conditions (Sharpley and Meyer, 1994). These models should be developed at different levels. Research type models that require extensive inputs should be developed to evaluate manure management alternatives for the development of best management practice recommendations and farm policy (Tim and Jolly, 1994 and Gelata et al., 1994). However, a major limitation to these models is often the lack of detailed parameterization data on soil properties and climate, crop, and tillage information. There is also a need for on-farm type models that require less input data and can be used as educational tools by non-scientific users, Recent developments in geographical information systems (GIS) and advanced interfaces could make many existing models more user friendly and help them to gain broader acceptance and use. GIS systems also have the potential to be used for targeting sensitive areas and for the development of nutrient management plans for smaller areas under site-specific or "precision" conditions.

Composting

Composting is a biochemical decomposition of solid organic waste by thermophilic microorganisms. The product is a stable humus and good soil conditioner with reduced volume, weight, odor, and moisture content. The intense heat generated by the thermophilic microorganisms kills pathogens, inactivates weed seeds, and reduces odors (Kashmanian, 1992). Composted material offers several advantages over raw waste material. Composting converts the nutrients in manure into more stable organic forms that release slowly and are less susceptible to leaching. It also has better handling properties that make it easier to apply, transport, or bag for sale. These improved handling capabilities and the reduced odor offer many opportunities to move large quantities of manure into nontraditional market places. Many argue that composting is not cost-effective with respect to agricultural manure, since it is time consuming, costly, and results in a product that is not any higher in nutrients. However, compost provides non-nutritive agronomic benefits. In addition, many areas of concentrated livestock production have an excess of nutrients and can take advantage of the fact that the composting process produces nutrients in a more stable form. In these areas, composting may ultimately be the primary method of realizing the full value of animal waste.

The typical operation composts material for approximately six months to a year. During this period the material is turned or mixed five to seven times then left to cure for a month or longer. Nitrogen loss during the composting process is dependent on the material as well as the process control and there are considerable research opportunities for determining processes, amendments, or additives that reduce nitrogen loss. Higher quality compost may be produced by closely managing the composting process, maximizing aerobic conditions and controlling the internal temperature of the pile. The management time and labor invested in any compost operation relates

management system, source and form of animal waste, and equipment and labor availability (Gilbertson et al., 1979). Animal waste should only be applied at periods when the nutrients can be used. For crops the best time is immediately prior to planting, while immediately following each hay harvest or grazing cycle usually results in optimal use in forage systems. More frequent applications of smaller amounts can increase plant uptake and use while decreasing the amount lost to the environment. The method of application is dependent on the form of the manure. Whatever form, the keys to successful application are that a known amount is applied at the proper location with minimal losses. All manure application systems should be calibrated regularly. Incorporation is also a recommended practice as it reduces odors, maximizes nutrient availability, and limits nutrient losses (Table 4). Injection systems reduce odors and losses of ammonia and may be the most efficient application method; however, they are not used extensively because of the difficulty in injecting solid materials. Considerable improvements could be made in both the application equipment and methods.

Table 4 Estimated volatilization losses in four days with various application methods. From: Gilbertson et al., 1979

Method of Application	Form of Waste	N volatilization loss (%)
Broadcast	Solid	21
	Liquid	27
Broadcast and incorporated	Solid	5
	Liquid	5
Knifing or injection	Liquid	5
Sprinkler irrigation	Liquid	25

Livestock and poultry production are not distributed uniformly throughout Georgia. Where animal production is concentrated, the land base available for application is usually limited. This limitation mainly arises from restrictions imposed by the economics of manure-transportation. The transport, collection, intermediate storage and general handling of manure to and from the point of processing or use is and will continue to be a problem. Freeze and Sommerfeldt, 1985, found that manure from large feedlots that haul manure in single axle trucks or pull type manure spreaders could only be economically hauled up to 15 km. Often, there is insufficient cropland or pasture within these short distances for environmentally sound land application of all of the manure from large operations. Little research emphasis is being placed on the concepts of materials handling and metering for animal manure, yet the economics of transporting the material to the point of use is often the greatest concern limiting the livestock producers from maximizing the use of this biomass resource (Gilbertson et al., 1984). Bosch and Napit, 1992, found that the export of poultry litter from surplus to deficit areas for use as a fertilizer in Virginia is often economically viable at larger scales, but large scale transfers of poultry litter were not occurring. They suggested that the use of government subsidies to crop producers who purchase litter for use as a fertilizer would encourage more research in transport and increase the incentives for commercial firms to provide litter transfer

Processes for utilizing manure as an energy source include direct combustion or conversion to a gaseous fuel through either biological or thermochemical processes. When direct burning is feasible, it results in approximately twice as much energy as the conversion to methane using anaerobic digestion; however, the residue is of little value compared with the effluent from biogas generation (Gilbertson, 1984). Devices for the thermochemical conversion of manure must take into account its higher ash content, higher moisture content, and greater slagging potential compared with other biomass resources (Badger et al., 1995). The higher volume of ash should not create any problems if properly accounted for in system design; however, it does present problems when conventional systems are modified. Moisture content can present problems as materials over 65% moisture content cannot sustain flame on their own. Therefore, most manure must be mixed with bedding, dried, dewatered, or use flame stabilization. This can often add significant costs to the system. Slagging occurs when the fusion temperature of the ash is lower than the combustion temperature. This causes the ash to melt and build up within the system and creates the largest obstacle for the direct combustion of manure. There are several commercial manure burning projects in place throughout the United States and the United Kingdom. These projects have proved that direct combustion is feasible, but high initial costs and low energy prices will probably prevent more widespread use. The Tennessee Valley Authority currently promotes a direct burning program that does offer substantial pollution prevention opportunity. They have shown that broiler litter can be used as an on-farm heat source cost-effectively (Badger et al., 1995). Although this system also requires relatively high capital costs, preliminary information does suggest that it would be cost effective in the Southern United States.

Biological conversion via anaerobic digestion is typically used and is most cost effective for organic materials with high moisture contents. Anaerobic digestion is a natural process by which bacteria existing in oxygen-free environments decompose organic matter. Anaerobic digesters are designed and managed to facilitate this decomposition and maximize the efficiency of the process. The process produces stabilized organic matter and gaseous by-products consisting primarily of methane and carbon dioxide (biogas). Methane has many potential uses as an energy source on the farm. It can be used as fuel for a generator producing electricity; for fire boilers and space heaters; or for fire chillers and other refrigeration equipment. While the product of the anaerobic digestion is methane, the digestion also produces an effluent with a reduced oxygen demand, volume and weight, organic nitrogen converted to ammonia, few pathogens, and reduced odors and insect population (Roes, 1992). Since little of the waste's nutrients are lost during the digestion process, this is an excellent product for land application or compost. Several successfully operating methane fermentation systems on dairy farms of 200 cows and larger have been reported. Management variables and economics are generally known but could be improved to make these systems more attractive.

While some large scale on-farm methane production operations have been established and are technically feasible, the equipment required to produce large quantities of methane is not simple and requires considerable investment. Thus far this has discouraged most farmers from adopting such systems; however, with improvements in the technology, usage would increase. Digester gas is bulky and is most economic where a continuous need for gas exists, for example in a dairy with a demand for hot water year round (Smith, 1980). Beyond this, it is extremely explosive when mixed with air and must be used as generated since it is not easily compressed to liquid form and therefore expensive to store for transport or later use. Increased emphasis on the use of manure for energy supplements rather than a primary source of power would result in greater usage. Common

problems with biogas reactors include mechanical failures, hydrogen sulfide production, and high initial cost. However, advances in technology are addressing these problems and the biogas value present in manure should increase the viability of these systems.

Lagoons are widely used in the United States to treat animal wastes anaerobically. These systems therefore produce methane and carbon dioxide. While the production occurs at a much slower rate due to the decreased temperature, there are opportunities to collect this methane for alternative uses. Table 5 shows estimates of the amount of biogas that can be reclaimed from animal waste. Safley and Westerman, 1990, used a floating cover to harvest biogas as it escaped from the surface of an earthen lagoon coupled with a collection system to concentrate the gas. This system was highly effective at collecting the biogas rather than releasing it to the environment. Since many facilities already use hydraulic flushing for manure collection and anaerobic lagoons for treatment, effective technology of this type has the potential for rapid acceptance.

Table 5 Biogas production potential from various types of manure.

Animal	Avg. Weight (lbs)	Biogas Production (ft^3/day)	Potential Energy (btu/day)
Horse	850	19.6	13720
Swine	150	4.1	2870
Dairy	1200	22.7	15890
Beef	1000	31.0	21700
Poultry	4	0.21	147

Biogas energy assumes 60% methane with energy content of 700 btu/ft^3.

A voluntary EPA program called AgSTAR encourages the widespread use of energy from waste technologies. As part of this unique partnership, AgSTAR participants--including livestock, energy, and governmental sectors--are coming together to promote the widespread use of profitable manure management systems that reduce pollution. By investing in these technologies, AgSTAR participants realize substantial returns through reduced electrical, gas, and oil bills, revenues from high quality manure by-products, and savings on manure management operational costs. Partners also reduce pollution associated with water resources, odors, and global warming. AgSTAR is a key component of President Clinton's Climate Change Action Plan, which promotes efficiency and U.S. ingenuity as the solution to global warming. AgSTAR regards manures as resources capable of improving profits and the cornerstone of a pollution prevention strategy.

A goal of AgSTAR is to encourage the widespread use of methane recovery systems that reduce the costs of livestock production for producers. AgSTAR is designed to tackle the barriers that impede the widespread use of technologies which capture and utilize the energy value of the gas.

Reliable information on methane recovery systems is difficult to obtain and often incomplete for site specific technical and economic evaluations. AgSTAR charter farms are being installed in key areas across the U.S., demonstrating attractive economic returns with simple operational procedures. Since 1982 a 500-head dairy has been using a conventional methane digester system to help solve its waste water lagoon problems. As a result, the investment reduced annual O&M costs by about $53,000, providing a 21 percent annual rate of return. In 1980 a 1,000 sow far-row-to-finish facility covered a portion of its existing lagoon to collect methane for on-farm energy applications. The collected methane fuels a 75 kilowatt (KW) engine generator, and waste heat is used for space heat and grain drying. As a result, the investment reduced annual O&M costs by about $36,000, providing a 34 percent annual rate of return. Using these charter farms as demonstration sites has encouraged many additional producers to become involved in the AgSTAR program.

Investments in on-farm energy systems require up-front capital. AgSTAR continually identifies and develops financing sources from public and private sources. Low demand for on-farm energy technologies results in a lack of consumer understanding about potential cost savings and farm profitability. Prices remain high due to site-specific engineering and small production runs. AgSTAR promotes on-farm energy technologies and by-products as cost effective and high-quality products to consumers, and informs manufacturers and the agricultural community about benefits of investing in new technologies and markets.

To become an AgSTAR partner, a producer signs a Memorandum of Understanding (MOU) with EPA. In the MOU, AgSTAR partners agree to survey their facilities and install AgSTAR selected technology where it is profitable. Partners also agree to appoint an implementation manager who oversees participation in the program. The MOU also states EPA's commitment to AgSTAR Partners. Through a unique working group, a series of products, information, and services will be available to AgSTAR partners. A state-of-the-art computer software package that enables partners to survey facilities, assess energy options and applications, and select the most profitable installation is also available through the program. AgSTAR will make available a comprehensive methane recovery handbook and reference guide for specific livestock rearing methods and manure management strategies. Sample chapters include technical design, odor control, energy applications, system management, financing availability, and case studies. AgSTAR places public-service advertising in major magazines and newspaper articles, reports on new manure management technologies, and circulates a newsletter and other materials. AgSTAR continually identifies and develops mechanisms that improve economic, technical, and managerial performance, as well as innovative nutrient management strategies.

Animal Feed

Consumption of animal waste is natural for many species. The practice of allowing swine to feed off cattle waste was common for decades. More recently, considerable research emphasis has been placed on using poultry manure as a feedstock for cattle. Animal manure contains essential nutrients that can be used when recycled as feed. Manure contains nitrogen in the protein and nonprotein forms and ash that is a good source of minerals. Ruminants are especially adaptive to incorporated feed due to their ability to digest nonprotein nitrogen and fiber found in waste. Due to the low energy content, feeding manure is not suitable for animals with high energy requirements. In addition, animal manure cannot completely replace protein feeds since crude and digestible protein in waste is lower than typical protein feed. However, about one third of all defecated manure N could be utilized in animal refeeding, depending on the type of manure and animal consuming it

(Eghball and Power, 1994). Currently, about 4.2% of the poultry litter produced in the United States is fed to cattle and much lesser amounts of other wastes are used as feed (Moore et al., 1995). Most of this litter is either deep stacked and fed to wintering cattle or ensiled in combination with other forage or grain feeds. While this does represent some acceptance, manure as an animal feed has the potential for more widespread use.

In research evaluations, processed animal manure incorporated with traditional feed did not alter the quality or taste of meat, milk or eggs. Productivity of animals fed wastes comparing growth rates and production equaled that of livestock fed traditional diets (Loehr, 1984). Several studies have shown that it is imperative that the content of the manure is known and free from foreign materials. Extensive literature concerning the nutritive value of animal wastes recycled as feed reflects the wide variability of the nutrient content of waste. This variability and the fact that most manure cannot supply all of the energy required leads to the general recommendation that manure be used mainly as a feed supplement. Having some knowledge of the constituents of the manure for labeling of the feed is also important. The presence of large concentrations of metals such as copper and zinc or high ash contents from the removal of soil with the manure are also impediments to the feeding of manure. For broiler litter, recommendations have been developed concerning the toxicity levels for feeding many of these substances (Davis, 1993, McCaskey et al., 1991). Often broiler litter will not meet all these specifications. A variety of management practices influence the composition of manure and litter and, therefore, its potential as a feed resource. Further attempts to market animal wastes as feed must address the effects of these management factors and elevated micronutrient compositions so that waste that is “acceptable for feeding” is not restricted.

Evaluation of the potential available to manure as a feedstuff is further hindered by inherent collection, handling and processing problems as well as concerns for human and animal health consequences. Despite public perception, if animal waste could be priced into a ration it would probably be used. Currently, the economics of manure collection, transport, and processing make it an unacceptable option. Energy efficient processing and drying equipment would aid more effective use of wastes for feed. Although disease problems have not been reported from feeding manure to animals under acceptable conditions, there is public concern over the health aspects of feeding animal waste to livestock. Potential transfer of microorganisms can be controlled by dehydration, composting or ensiling prior to use as feedstock. Any process that generates enough heat to kill pathogens will generally be sufficient; however, further research is needed to determine the most effective methods as much of the nutritive value of the waste is lost during this process.

The use of livestock waste as feed for fish has occurred for many centuries. Fish naturally feed off small organisms, plants and animals in the water. Animal manure serves as an indirect food by enhancing the production of natural aquatic food in the fish pond. Bacteria that decompose organic material in manure serve as food for protozoa, zooplankton and higher organisms consumed by fish (Loehr, 1984). Non-manure substances can also be used to effectively prevent pollution in the animal production industry. Feed expenditures accounted for 22% of Georgia’s production expenses (Georgia Agricultural Statistics, 1994). Often commercial and crop by-products can be used as feed supplements. Cows consume residues such as wheat bran, peanut hay, corn stalks, soybeans, cotton seeds, and brewer’s gram. This is a form of pollution prevention as it converts a waste by-product into a useable commodity. Many more opportunities for alternative uses exist and need to be developed.

Other Biological Methods

Biological treatment of waste can be cheaper than physical or chemical methods of containing and treating waste and may yield an additional useable product. It encompasses the use of various forms of aquatic and non-aquatic vegetation as well as the conversion of waste by bacterial or insect action. The use of animal waste as a substrate for protein production from algae, yeasts, fungi, bacteria, fly larvae or earthworms shows promise but further evaluation is necessary. These types of systems are currently underutilized, but additional research could improve these systems by incorporating harvestable products into them.

Constructed wetlands and vegetated filters are probably the most co&on examples of biological systems used to treat animal waste. Aquatic plants can be used to treat animal wastes in a liquid form. Algal production from nutrient laden waste water may be a promising alternative. Microscopic algae and other unicellular organisms grow in high rate oxidation ponds that yield relatively high quality effluent. Oxygen is a by-product of algal photosynthesis that increases the dissolved oxygen in waste waters and supports microorganisms that degrade organic matter. This symbiotic relationship stabilizes organic waste and produces algal biomass. Algae contain 45-65% protein and can produce more protein per landmass than soybeans or corn (Loehr, 1984). The levels of amino acids indicate that algal protein is of high quality. The high ether extract and low crude fiber content suggest a fair energy value. Harvested algae can be used as a feed supplement for fish, poultry and swine or composted for land application. The major problem associated with algae growth for protein recovery is the difficulty with harvesting and processing. For algae production to be efficient, effective harvesting and processing technologies need to be developed to recover and use the algae's protein.

Water hyacinths and other floating plants can remove more than 80 percent of the BOD, ammoniacal nitrogen, oil and grease, and coliform bacteria in anaerobically digested liquor (John, 1985). Once harvested it can be used for compost, mulch, or animal feeds. Systems such as these have been practical in many tropical countries; however, the treated effluent still contains high levels of solids and BOD. In addition, phosphorus removal is limited to the plants' need and usually does not exceed 65% of the waste water content (Oren, 1994). These plants are also prone to decreased nutrient removal in cold weather. Duckweed shows some promise at removing large quantities of nutrients from dairy wastewater and may be the most well suited aquatic plant for waste removal systems (Whitehead et al., 1987). It has growth characteristics that maximize nutrient uptake and is less prone to temperature fluctuations. Duckweed plants have a relatively high nutritional value and a low fiber content that benefits animal digestibility. Besides this, it can be harvested easily with systems that skim the water surface. While duckweed has been used to treat domestic waste water, thus far it has not been well researched for agricultural applications.

The principle of vegetation being used as a filter and absorber of waste in constructed wetlands has been used quite extensively. With proper design and management, constructed wetlands could be used for secondary treatment of wastes or to reduce the nutrient concentration of waste applied to the land. This in turn would reduce the land area needed for land application of animal waste. Many grasses, weeds and other types of vegetation have been tested in these systems with the harvested material being used as an animal feed or composted for land application.

The principle of vegetation being used for waste treatment has been taken a step further in a research project in the Tennessee Valley using municipal sewage and a constructed wetland (New York Times, 1988). Aerated sewage is passed through a cattail and reed marsh where the contaminants are metabolized, absorbed, or just settle in the sediments. In the next open water pond algae feed on the remaining nutrients. In the final stage the liquid is passed across a meadow of grasses to trap the algae and remaining nutrients. Integrated systems such as this may ultimately possess the greatest potential as they offer many opportunities for the production of beneficial products. Although cheaper than municipal facilities, systems such as these require large amounts of land and are yet to be tested with heavy agricultural loads. In addition, more research is required to decide proper design criteria concerning flow conditions and appropriate vegetation for a variety of locations. There is a need for long term studies involving wetlands as the length of time a system will effectively operate without renovation is usually unknown. While there are still many questions concerning the role of these systems in agricultural waste management, they do present an alternative treatment strategy that can produce a valuable output.

The rearing of insects as part of a waste management system is not a new idea; however, effective systems are not being used in most production systems. Decaying organic matter is the natural habitat of the larvae of many insects. The use of waste as larva substrate for either soldier flies or earthworms reduces waste amount and also can provide an additional protein source when harvested and dried. Soldier fly larvae can reduce swine manure bulk by 28% in one six-month fly season (Common Ground, 1995). In systems designed for laying hen operations, Newton et al., 1995, reported that soldier fly larvae converted low value manure into a high quality larvae feedstock, while concurrently reducing manure residue 50% or more and eliminating house fly breeding. Others are attempting to develop systems that use other larvae forms including house flies, earthworms, and beetles. Most systems such as these are in the research stages and much more work will be required before they are widely applicable and accepted. In order for systems such as these to become accepted pollution prevention technologies, the ability to handle and process the insect larvae will need to improve as well as the public perception of these practices.

Best Management Practices (BMPs)

Best Management Practices refers to a combination of practices determined to be effective economical approaches to preventing or reducing pollution generated by nonpoint sources. BMP's can be structural (ie. waste lagoons, terraces, solid separators, and fencing) or they can be managerial (ie. rotational grazing, nutrient management, and conservation tillage). Both types of BMPs require good management to be effective in reducing the generation or delivery of pollutants from agricultural activities. Preventive practices such as these are the most practical approaches to reducing nonpoint source pollution. If the farming community does not participate in voluntary programs using BMPs, then it can be expected that there will be additional calls for mandatory programs to implement BMPs.

Presently, several Rural Clean Water Programs (RCWP), Agricultural Conservation Programs, and Special Water Quality Projects across the United States are designed to demonstrate the effectiveness of various BMPs for the abatement of agricultural pollution. These programs not only promote the use of BMPs to the agricultural community, but also serve as learning tools. A review of 21 different RCWP projects recently summarized many findings nationwide (Osmond et al., 1995). For voluntary BMPs to be effective, they must be implemented as systems rather than individual practices because systems minimize the impact of the pollutant at several points: the source, the transport process, and the delivery. Properly designed BMP systems must also be site specific and placed in the correct locations. Finally, since financial resources are generally limited, BMP implementation should be prioritized and cost-share money should only be used in those locations that will have the most impact. This report also stressed the fact that successful adaptation of on-farm BMPs is highly dependent on education. Producers must understand the impact their practices have on the environment and the mechanism that the BMP uses to reduce this impact.

As part of an effort to promote voluntary adoption of BMPs, the Georgia State Soil and Water Conservation Commission (GSSWCC) has published a booklet called Agricultural Best Management Practices for Protecting Water Quality in Georgia. This publication is intended to serve as a basic guide for anyone implementing agricultural BMPs. In addition, the Conservation Commission is designated as the lead agency for protecting water quality from agricultural nonpoint source pollution. They provide education and technical assistance to insure that the stewardship principles incorporated in agricultural BMPs are understood and employed for maximum benefit to Georgia's land and people. In doing so, they work closely with the Cooperative Extension Service, the NRCS, and the DNR. Table 6 summarizes most of the BMPs promoted by the Conservation Commission. Since this publication adequately covers most BMPs that would be effective in Georgia, it should serve as the reference for BMPs to be used in the agricultural pollution prevention program. The remainder of this section highlights a few of the BMPs that are particularly relevant to Georgia livestock production.

Land Application Management

The literature supports the conclusion that the key components of animal waste utilization BMP systems are proper rate, in conjunction with soil and manure testing, timing, and application method. Many of these considerations were discussed in the previous section on using waste as a fertilizer and soil conditioner. Land application of animal wastes should be managed to ensure immediate runoff is eliminated, odor suppressed, and quantities of limiting materials are not exceeded. Consideration of application rates, timing, and method of manure application should be considered prior to placement. This includes testing the soil and the manure for current concentrations to determine the amount of waste to be applied for optimal plant nutrition. Besides matching nitrogen and phosphorus rates with crop requirement, water infiltration rate, water holding capacity, texture, and total exchange capacity of the soil should be considered to prevent surface and groundwater pollution. Distance to waterways is also an important consideration if animal wastes are surface applied and not immediately incorporated.

Runoff and Erosion Control Measures

Crop runoff protection measures reduce soil erosion and sediment runoff, help protect water quality, conserve water, and can potentially reduce costs and increase production. Essentially, any measure that increases the infiltration rate or water holding capacity of the soil, limits flow velocity, or increases the time that water remains on the soil surface will decrease runoff. Traditional methods used in crop production include conservation tillage, contour farming, and strip cropping. Conservation tillage, planting and culturing crops with a minimum disturbance of the soil, reduces soil loss by 50-95%. Contour farming reduces soil erosion and increases infiltration by providing hundreds of small dams or ridges. Contour strip cropping alternates strips of small grain crops with strips of row crops contoured to the land. The small grain slows runoff, increases infiltration, and traps sediment while the ridges formed by the contoured rows dam water flow and reduce erosion. Measures such as these should always be used when a livestock producer is growing his own feed.

Table 6 Best Management Practice Summary Guide.

BMP	Surface Water				Ground Water	
	Sediment	Soluble Pollutants	Adsorbed Pollutants	Bacteria	N Loss	Pesticide Loss
BMPs primarily used in feed production						
Conservation Tillage	++	?	++	?	?	?
Contours and Terraces	++	+	++	+	-	-
Stripcropping	+	+	+	+	0	0
Cover Crop	+	+	+	0	+	0
Crop Rotation	++	+	++	0	0	+
BMPs for Confined Animal Operations						
Waste Man. System	++	++	++	++	++	0
Diet Manipulation	0	+	+	+	+	0
BMPs for both Confined and Unconfined Operations						
Nutrient Management	0	++	++	+	++	0
Pest Management	0	++	++	0	0	++
Pasture Management	+	0	+	+	0	0
Waterbody Protection	++	+	++	+	0	?
Grassed Waterways	+	0	+	0	0	0
Critical Area Planting	++	+	+	0	0	0
Stream Buffers	++	+	++	++	+	?
Composting	0	++	++	+	++	0

KEY: ++ Medium to high effectiveness
+ Low to Medium effectiveness
0 Almost no effect
- Could have detrimental effect
? Further research is required

Note: BMPs are site specific in nature. These generalizations are not necessarily true under all conditions.

Even with BMPs such as reduced tillage, areas of concentrated overland flow do develop in extreme rainfall events. A grassed waterway is a natural or constructed channel, usually broad and shallow, planted with perennial grasses to protect soils from erosion by concentrated flow. These waterways serve as conduits for transporting excess rainfall and diverted runoff from the fields or pastures without excessive soil erosion. Waterways prevent gully erosion in areas of concentrated flow. The vegetation also acts as a filter to remove suspended sediment and some nutrients, Grassed waterways require careful maintenance and periodic reshaping, especially after large or intense storms. Performing this maintenance regularly is important as the concentrated flow conditions can lead to rapid gully formation if minor washouts are left unchecked.

Pasture Management

Grasslands or pastures are essential to almost any livestock operation, They provide nutrition for cattle or other livestock and food and cover for wildlife. Well-managed grasslands protect valuable soil resources and improve water quality. The fibrous root systems of healthy grasses hold the soil in place so that surface water supplies are not contaminated with sediment. They also provide a nutrient sink for many elements in animal manures. There are several keys to maintaining adequate and sustainable pastures. Plant selection is critical as the plant must be adapted to both the soil and climate to insure adequate cover throughout the year. Determining proper stocking rates that will not damage the vegetative cover and result in increased soil erosion is also essential. Controlling animal traffic can also help to prevent bare spots that could lead to the formation of rills and gullies. Weeds may be a problem in some pastures; however, proper grazing management and fertilization should reduce weed problems. When herbicides are necessary, use only labeled products at recommended rates. When pasture renovation becomes necessary, no-till or other conservation tillage practices that minimize erosion should be used.

Properly designed rotational grazing systems can reduce many water quality problems associated with pastures. A planned grazing system rotates livestock grazing into different pastures. This improves vegetative cover, forage quality, and evenly distributes manure nutrient resources. In this system, fences are used to partition a pasture into many smaller paddocks. Animals graze in a paddock for a short period and then are moved to a fresh paddock. Forage plants in the first paddock are relieved from grazing pressure so that they have time to regrow. Not only does this result in better quality forage, but it can also increase productivity and stocking rates. Timing and paddock design are the key design variables in rotational grazing systems. For timing the goal is to keep pasture plants as palatable and nutritious as possible by keeping them in the vegetative state. Since pasture growth changes throughout the year, the timing and total amount of area required for grazing cannot usually be set. Therefore, these systems are often management intensive and require more time.

Since rotational grazing systems usually result in less animal confinement, there is less manure handling labor and fewer environmental risks associated with manure storage and application. This results in better utilization of the manure nutrients and less soil erosion and pesticide use as a result of healthier pasture. These benefits make rotational grazing a more sustainable practice. Currently many dairy farms throughout the United States are turning to rotational grazing. While an economic comparison of 16 dairy farms in Wisconsin and Minnesota showed that pasture-based herds produced an average of 3,300 pounds less milk per cow than confinement herds, they yielded an average of 46 cents more profit per hundred pounds of milk (SARE, 1995). This increased profit came primarily from reduced feed costs, machinery costs, and building maintenance costs. These dramatic reductions in inputs make rotational and intensive grazing systems a pollution prevention opportunity with substantial potential.

Animal access to surface waters and adjacent areas also represents possible sources of water contamination. Not only does the manure deposited directly in or adjacent to streams pollute the water, but the livestock also reduce stream-side vegetation by foraging or trampling and disturb sediment on the stream bank and bed. This increases erosion and decreases the buffering capacity of the stream-side vegetation. Stream and waterways protection can be accomplished by limiting livestock access and stabilizing stream banks. Access can be controlled by fencing or electronic collars and culverts or low-water stream crossings can be used to join adjacent pastures separated by a stream. Vegetation or riprap installed along the edges of the stream buffer the banks from erosion and also reduce animal traffic.

Natural Vegetative Systems

Filter strips or buffer strips are strips of grass, shrubs, or other close growing vegetation intended to remove sediment or pollutants from runoff. They are normally planted in an area where water will pass over them as sheet flow. The vegetation slows the water, allowing solids to settle out and become trapped in the vegetation. The filtered nutrients and organic matter are biologically decomposed by plants and microorganisms. Filter strips have been found to reduce nitrogen, phosphorus, fecal coliform, and COD in animal waste runoff by 77, 94, 95, and 96%, respectively (Johnson et al. 1982 and Larson, 1994). Natural or constructed wetland systems also act as a biological filter. Oxygenation and microbial degradation by plants and bacteria remove organics while sedimentation and filtering removes suspended solids and adsorbed compounds. As a result, wetland sediments act as a net sink for these constituents. While these systems are not used for primary treatment of waste, they are nevertheless important to animal production. They should be used around feedlots, natural waterways, and land application areas to treat any runoff that may occur and hopefully prevent nutrients from leaving the site.

Water body Protection

All streams, rivers, lakes, ponds, and other water bodies in Georgia are classified according to their use. Since pollutants that enter these water bodies can often travel quickly to other areas or have an increased likelihood of being consumed, these areas are more sensitive to environmental pollutants. By managing the area around these water bodies more intensively, many conditions that may lead to surface or groundwater contamination can be prevented. All potential agricultural pollutants, including pesticides, herbicides, fertilizers, manures, petroleum products, and sediment should be handled with extreme care around any water body. Stream channels and banks should be protected to prevent erosion. Often this can be accomplished using vegetation; however, at times structural measures such as rock riprap may need to be used. Generally, livestock should never have unlimited access to any body of water, but when they do it should be in areas with dense vegetation, smooth stable slopes, and firm surfaces.

Stream side forest buffers or riparian zones are areas of trees, woody shrubs and other vegetation, located adjacent to and up gradient from streams or other water bodies. They usually consist of natural vegetation that provides a filter for sediment and organic material that carry many pollutants. They also provide an area where nutrients may be utilized by vegetation and where chemical decomposition can take place. Riparian zones are not intended to serve as the only water quality practice or to replace erosion control, but they do provide a final opportunity to improve water quality before it enters a stream. While these areas should function naturally, they do require

some maintenance. This is primarily in the form of taking efforts necessary to prevent the formation of concentrated flow paths and gullies. Establishing stream side forest buffers will probably not be cost effective to most animal operations; however, new producers should consider leaving much of the stream side zones out of production.

Facility Design

Pollutant loads from small feedlots can be several times greater than those from land application sites if they are not properly managed. A common source of pollution on open feedlots and dairies are "loafing" areas; outside areas near the barn or feedlot where the livestock gather or any other area of heavy animal traffic. Water runoff from these muddy areas is often contaminated with nutrients and suspended solids. Groundwater contamination can also be caused by nitrate leaching from the excessive manure deposited in the loafing areas. Diversion of upslope rain runoff, channeling of contaminated runoff into an impoundment or natural buffer strip, and locating loafing areas away from wells can reduce surface water and groundwater contamination. Use of geotextiles for erosion control, drainage, and stabilization in loafing areas also restricts ground water contamination, as well as stabilizes the soil and can reduce mastitis in dairy cows. Feed bins and watering sources can also be moved to different locations, allowing the heavily trafficked areas to reestablish vegetation.

Obvious techniques for waste reduction can be incorporated into facility designs. Diverting rainwater and other runoff from entering waste collection systems reduces the volume of waste to be treated. Solid-liquid separators effectively separate waste streams. The liquid waste stream can be reused in hydraulic flushing systems for waste removal or surface applied through irrigation systems. The remaining solids are easily removed for disposal or utilization. Another technique to reduce solid waste is to use fabric or geotexiles to retain freestall bedding and prevent it from being flushed away with other wastes.

Livestock producers should also consider leaving critical areas out of production. Critical areas cannot usually be stabilized by ordinary conservation treatment and if left unmanaged can cause severe erosion problems. Examples of critical areas include dams, dikes, levees, cuts, fills, and denuded or gullied areas where vegetation is difficult to establish. These areas will become reoccurring problem spots if they are put into pasture or cropland. Instead, vegetation should be established and they should be left out of production.

The use of farm ponds is one final method of preventing off-farm pollution. A well-placed pond can collect all of the runoff from a farm and have a positive impact on water quality. It acts as a detention basin by removing sediment and nutrients from the flow and reducing the volumes of flow occurring at peak conditions. It can also filter many nutrients if aquatic vegetation or fish are used. Finally, the pond can act as a buffer between the farm and the external environment. On poorly managed farms, the farm pond can collect and hold any pollutants produced within the farm watershed so that their impact can be reduced. On well managed farms; a healthy pond suggests a farmer that uses environmentally sound practices and causes little environmental degradation.

Mortality Disposal

Disposal of dead animals is important as animal carcasses are probably the largest non-manure by-product of livestock production systems. While fatality rates for larger livestock such as cattle and horses are comparatively low, the poultry industry is faced with the disposal of more than 360 million chickens a year in the United States. The problem is compounded by the fact that

the value of a cow carcass is much greater than that of a few chickens. Rendering operations will often travel to farms to pick up larger carcasses but picking up smaller animals is not economical. Rendering is the best disposal alternative as the carcass does possess some value; however, methods of storing and transporting animal carcasses to rendering facilities must be improved before rendering is commonly accepted in many animal industries. Almost all solid by-products of animal processing plants are converted to animal by-product meals by the U.S. rendering industry. However, most farm mortalities are not rendered and currently are disposed of by methods that are not always environmentally sound and do not retrieve any of the producer's investment (CAST, 1995). Improvements that allow for long term storage of animal carcasses by flash-freezing or acidification could make rendering a more viable option. Another means of promoting rendering would be through centralized collection sites to which growers could bring dead animals. Daily hauling from the central site to a rendering plant could be contracted through a local hauler. While this method does require some capital investment, collection systems can be profitable through the sale of renderable animal carcasses. This has been demonstrated in both the swine and poultry industries of North Carolina (CAST, 1995). A primary concern of these types of systems is biosecurity and the potential for dispersal of pathogens from farm to farm by personnel and vehicles.

Dead animals can also be disposed of by burial, incineration, cornposting, or bacterial digestion; however, none of these methods take full advantage of the economical value of the animal carcass. In Georgia, the most common method of disposal is burial. While this method requires the smallest investment of capital and management, it is coming under increasing regulatory pressure as it poses a threat to the ground water if the burial pit is not properly lined. This is especially true in the southern half of the state where the soils are more permeable. Further research will be required to set the conditions where burial pits do pose a threat to groundwater and to find economical alternatives. Incineration is also a disposal option that produces no return. Incineration would require less labor and management but the economics are highly dependent on the fuel source and the option does present some air quality concerns. A new approach for disposal is by bacterial digestion. Using this method, animal carcasses are placed in sealed pits to be digested. While several of these pits have been installed, further research is needed to determine their effectiveness and how much management will be required after initial installation.

Cornposting and fermentation are alternatives that do provide for some resource recovery. Composting of dead animals produces a product that can be used on the farm but requires time and equipment. Hundreds of facilities for cornposting of chicken and turkey carcasses have been established throughout the Southeastern United States. Dead bird compost is similar to litter in its nutrient composition, except its lower N content that is an expected result of the composting process (Moore et al., 1995). The Extension Service and the NRCS both promote mortality composting and have developed educational and technical assistance programs to assist producers with the composting process. The fact that cornposting does take a little management, time, and initial investment are impediments that must be overcome through educational programs. Fermentation is a method that allows animal carcasses to be preserved in a liquid state until transport to a rendering facility. In fermentation, animal carcasses are usually ground or cut, mixed with various acid or. alkaline solutions, and then inoculated with yeast or carbohydrate cultures. This solution can then be stored in a silo or storage tank and periodically taken to a rendering plant. Research into these types of systems is in the preliminary stages, but it does appear to have some potential for larger operations. Another disposal alternative that should be researched is the use of animal carcasses in integrated systems that produce both herbivores and carnivores. Here, all of the animal carcasses could be used to feed carnivores such as alligators. Systems such as these will require more investigation; however, they appear promising as one system's by-product is the input of another.

Atmospheric Emissions

Livestock production has a significant impact on the atmosphere. Air quality affects the health and well being of both animals and their caretakers. Odor concerns are drawing increasing amounts of attention as the urban/suburban interface expands into traditional agricultural areas. The reduction of methane emissions from livestock could improve animal efficiency and productivity. These methane emissions warrant increasing amounts of attention as more concern is placed on limiting emissions that could contribute to global warming. Pollution prevention can play a vital role in addressing air quality concerns, as production techniques to reduce or prevent emissions to the atmosphere have historically been more successful than technology to control emissions after their production.

The primary sources of most atmospheric emissions are confinement buildings, animal waste storage areas, and land application sites. While odor and gaseous emissions escape from each of these sources, air quality is usually the only concern within confined animal housing. The five primary pollutants that are found in animal facilities include ammonia, hydrogen sulfide, carbon monoxide, methane, and respirable and total airborne dust (Table 7). Government standards have not been established for animal health, but the Occupational Safety and Health Administration (OSHA) has established guidelines for human worker exposure. Animals can generally tolerate higher levels of these pollutants than humans, but the effects on production are not entirely clear. Pollutants such as ammonia, hydrogen sulfide, and methane usually originate from the degradation of animal waste and can be controlled through sound management practices. Carbon monoxide is normally associated with heaters and is usually not a major problem in warmer climates. Airborne dust originates in animal feeds and bedding. Controlling it is important because microbes and pollutant gases attach to the dust. Ways to lower airborne dust concentrations include increasing the relative humidity, adding fat or oil concentrates to the feed, or controlling animal activity and air speeds that stir up dust and keep it suspended longer. Adequate ventilation is also extremely important to preventing the problems associated with air quality pollutants. While significant research has developed management alternatives to control most air quality pollutants, more research is required to refine these alternatives and document the effects of animal environments on production.

Odor problems are the number one complaint against animal growers received by state and federal regulatory agencies (Moore et al., 1995). Odors are a persistent problem compounded by confinement of many animals and especially prevalent near feedlots, loafing areas, and fields receiving land applications of waste. Odors are produced from the animal's skin, urine and manure.

Table 7 Properties and effects of noxious gases generated in livestock facilities.

Gas	Odor	% by volume	Conc. (ppm)	Explosive Level (ppm)	Physiological Effects
Carbon Dioxide (CO_2)	none	na	5,000	300,000	Asphyxiant
Ammonia (NH_3)	sharp	16	50	5,000	Irritant/Asphyxiant
Hydrogen Sulfide (H_2S)	rotten egg	4-46	10	1,000	Poison
Methane (CH_4)	none	5-15	1,000	500,000	Headache
Carbon Monoxide (CO)	none	na	50	4,000	Poison

Noxious gases are generated by microbial degradation of waste and contain methane, carbon dioxide, ammonia and hydrogen sulfide (Loehr, 1984). In the last 15 years, waste researchers have identified more than 75 specific odorous components of animal manure odors (Barth and Melvin, 1984). Since a manure odor is the product of complex interactions of many individual odorous components, it is difficult to characterize it accurately in terms of quality or quantity. Odors from the degradation of fecal residues are deemed to be a nuisance only when their intensity and character are sufficiently objectionable to incur complaints from neighbors. However, there is little agreement on what is an acceptable odor intensity or how long it should be tolerated. To evaluate research on the control or prevention of odors, methods of detecting, defining, measuring, and comparing odors need to be improved.

Odor control methods include treatment of manure, capture and treatment of emissions, and increased odor dispersion (Sweeten 1992). Increased odor dispersion and prevention measures are more economical than capture and treatment. Distance, effective ventilation, and vegetation can aid in odor dispersion but more research effort will be required to find the best methods of effectively incorporating these features into facility designs and layouts. Management measures to treat manure include cleaning facility floors often, maintaining moisture content to control soluble gases, aeration of drainage or bedding, and chemical or biochemical application. Odor control for lagoons consists of floating straw or plastic foam pellets, permeable floating mats, floating tarpaulins, and corrugated material or timber. Gases can be captured in covered tanks, pits, or lagoons, and then subjected to chemical or biofiltration. Soil injection or incorporation of manure into the soil reduces odor problems associated with land application. While research has documented that most of these control strategies can be effective, further efforts will be required to incorporate these ideas into waste management systems. Odor suppressants, counteractants, masking agents and numerous chemicals have also been used in animal production to reduce odors. The results have often been less than satisfactory leading to much confusion concerning these additives. The Animal and Poultry Waste Management Center at North Carolina State University has recently developed a protocol for evaluating the effectiveness of odor control additives; however, further research and evaluation of these additions will be required (Williams, 1995).

Emission of greenhouse gases (carbon dioxide and methane) from livestock is an issue of global concern. The intergovernmental panel on Climate Change estimates that cud-chewing animals account for about one sixth of the world's total emissions of methane (Comis, 1995). Domesticated livestock are the second largest source of methane emissions in the United States while emission from the anaerobic digestion of animal manures are the forth (Hogan, 1993). Together, they account for more than a third of the total methane emissions in the United States annually. The EPA conducted an extensive national study to develop methods of measuring and controlling these emissions (Hogan, 1993). Opportunities and impediments to reducing methane emissions were identified and explored. From this study, two programs were developed to reduce methane emissions from animal agriculture, the AGSTAR program and the Ruminant Livestock Methane Program.

As discussed earlier, the AGSTAR program focuses on the utilization of methane recovered from waste lagoons for energy production. The Ruminant Livestock Methane Program focuses on improving the efficiency of livestock production. This voluntary program is designed to help livestock producers in key regions of the country including Georgia by identifying improved management practices, technologies, and marketing options that will increase productivity while reducing methane emissions. A ruminant can lose from 2 to 12 percent of the energy from its feed to the production of methane. By avoiding this loss, dietary energy is made available for growth or lactation. Although very productive animals produce large amounts of methane, the amount of methane they produce per unit of product compared with less productive animals is very low so selective culling is a major aspect of the program. Poorer nutrition also contributes to higher methane emissions so utilization of better feeding programs is another way to reduce methane emissions, There is also much potential for improving reproductive efficiency in the cow-calf sector. For example, producers aim for about 90 calves for every 100 cows, with the national average about 80. In some regions, however, producers average fewer than 70 calves per 100 cows. Improving the nutrition of breeding heifers and cows will promote faster conception and easier repeat breeding the following year. It will also lead to and sustain higher calving percentages and heavier weaning weights. Keeping these factors as high as possible minimizes both methane emissions and unit costs of production. Outreach activities for this program will include keeping producers informed, integrating results into existing extension programs, developing management tools for producers to survey their operations and assess productivity options, and conducting hands-on demonstrations.

Other research projects have identified further methods of reducing methane emissions. Methanogenic bacteria that produce methane in dairy cattle can be inhibited through antibiotics resulting in better feed conversion; however, the bacteria have displayed evolving resistance to most antibiotics. Losses of ammonia from manure or litter could be decreased by using chemicals to convert the ammonia to non-volatile compounds or by efficiently managing ventilation rates in livestock buildings. Any of the methods that reduce N losses that were discussed earlier in this paper would also have a substantial impact on the amounts of greenhouse gases released to the environment. Since the reduction of ammonia volatilization not only reduces the environmental impact but also adds value to the manure, it should be a priority in most research projects involving animal waste.

RESEARCH NEEDS

While the pollution prevention technologies discussed thus far have proven utility, more improved technologies can and will be developed. Pollution prevention is a relatively new concept. However, the concepts of maximizing productivity, conserving soil and water resources, and minimizing environmental degradation have been investigated by scientists within the agricultural community for many decades. This research has been highly successful. The USDA has estimated the investments in agricultural research return an average of 1.5 to 5 dollars per dollar invested. With returns like this, investing in agricultural pollution prevention research could be the wisest use of limited pollution prevention funds. Throughout this text, the need for additional research has been noted in many areas. This section highlights research needs for new and existing pollution prevention technologies that would most likely produce the greatest impact in terms of producing efficient and beneficial technologies for use in animal agriculture.

Emerging issues related to livestock production include intermedia protection, the transfer of pollution from one media (soil, water, or air) to another; climate change or global warming from emission of greenhouse gases (methane and carbon-dioxide); animal welfare; and water conservation. Future research should be aimed toward these areas to provide answers and solutions to these issues. Accurate assessments of non-manure waste streams and energy and water usage are also essential if more detailed pollution prevention assessments are to be performed. Both odor control and waste management will become more important as traditionally rural areas are faced with an expanding urban and suburban population. As to source reduction for animal waste, most gains will probably come from increasing productivity through genetics, management, and biotechnology or from feed additives to increase digestive efficiency, so research dollars should be invested in these areas. BMPs are the best methods for preventing pollution. Since BMPs are site specific and based on farm management, they will continue to evolve as research produces improved strategies.

In the area of on-farm waste management systems, research should be designed to investigate the following problems:

1. The need to reduce the substantial energy and labor costs associated with handling and storage of the waste.

2. The need to reduce and adequately account for the nutrient losses that occur using different types of storage structures, in different geographic regions, for different types of manure and bedding materials and under different management strategies.

3. For improved nutrient recovery, preservation, and utilization, more basic and applied research on manure, bedding, and feed additives to reduce denitrification and volatilization losses is necessary. These include nitrification inhibitors, urease inhibitors, acidifying materials, and precipitants or stabilizers such as alum and gypsum. The focus of these projects should include both the internal air quality concerns and the effect on the nutritious value of the waste.

4. Design criteria of systems for waste removal, transport, storage, and treatment need to be improved and tailored to specific geographic locations. Natural systems for waste treatment need to be developed and researched for efficiency, economic feasibility, and maximum recovery of desirable by-products.

5. With Guther research on rotational grazing/free range systems and improvements in forage genetics and production, extensive systems could become more economical for small to mid-size producers. Research should involve increasing the productive capacity of open range systems

without exceeding sustainable stocking rates. The impacts of grazing systems on the soil and environmental quality over long periods should also be considered.

Land application of animal waste has been a cornerstone of animal agriculture. However, if used to its potential animal wastes could represent a much larger percentage of the total applied nitrogen without concern for environmental degradation. Further research could lead to this increased use. These projects should focus on the following research needs:

1. The main obstacle this research will need to overcome is the high transportation costs limiting the potential to transport to off farm areas.

2. It also should address problems encountered in collecting representative manure samples for nutrient analysis and determining the nutrient content of manures. Since characteristics and content of livestock or poultry wastes are highly variable, more accurate updated information is needed that reflects the effects of modern rations, breeding, and manure management systems on the value of animal wastes. Finally, development of inexpensive, on-farm nutrient tests would allow for testing at the time of application and more frequent and dependable test results.

3. Determination of application rates that provide the crop with sufficient nutrients without having adverse environmental effects is important for insuring soil and environmental quality. The slow mineralization of the nutrients in manure represents a consistent source for plant growth. By increasing our understanding and knowledge of mineralization rates and their effects on crop growth, we could more accurately account for them in nutrient management plans.

4. More information is needed to adequately account for the losses that occur using different types of storage, transport, and application systems. There also needs to be more projects geared toward, a better understanding of the effectiveness of different methods of manure application on crop nutrient uptake and utilization. There are usually benefits associated with subsurface placement of all fertilizers, yet most are still applied to the surface.

5. The fact that the primary measure of the quality of the waste is usually its nutritional content is another factor that warrants more attention. The portion of the value of organic sources that can be used as a soil conditioner is often considered intangible and should be quantified economically.

6. Research emphasis should be placed on determining the effects of nutrient imbalances on crop growth and environmental conditions. Future work with nutrient management planning should focus on the development of sustainable planning methodologies rather than concentrating on individual nutrients. Improved nutrient management planning strategies that limit soil nutrient imbalances rather than maximizing crop productivity (i.e., consideration of elements other than nitrogen) should be developed. There is also ample opportunity for research on chemical amendments that would make the nutrient content of organic wastes more like that required by the crop.

7. Continuation of research associated with minimiizing the potential for runoff and leaching under various management scenarios is necessary.

8. There is also a need for on-farm decision support systems and environmental models that require little input data and can be used by non-scientific users in planning manure application strategies.

Cornposting can provide a vital link in preventing pollution from all segments of society. As farmers work with off-farm carbon and nutrient sources they will need guidance in developing

and managing the composting process. Anticipated research needs in composting include the following:

1. More research associated with the waste streams of both agricultural and non-agricultural industries to increase the use of off-farm amendments in composting operations. In doing this research, care should be taken to document the effects of these amendments on the value of the compost product and soil and environmental quality.

2. More documentation of the advantages compost can offer over inorganic additions. These should include organic matter build up in the soil, plant disease suppression characteristics, potential for mitigating the effects of some weeds, and the effects microbial and biological stimulants have on plant growth and soil structure. Studies that compare the agronomic qualities of composted manure to those of raw manure should not only highlight the benefits of using compost but also provide additional documentation on the effects of composting on pathogens, weed seeds, odors, nutrients, and soil physical properties.

3. Better equipment for processing and handling composted materials and improved "recipes" are also needed to reduce the time and labor associated with composting operations.

4. Research projects should display increased emphasis on producing consistent composted products in uncontrolled environments and with variable inputs as these are the conditions likely to occur in on-farm cornposting.

In the area of alternate waste utilization, research will likely center on energy production systems, biological recovery systems, and refeeding. Research in these areas needs to address the following issues:

1. Economic studies should be conducted on various systems of alternate waste utilization currently or potentially in use to determine the long term and short term economic benefits as economic data is essential in integrating new technology into traditional practices.

2. Research should concentrate on development of more economical and dependable digesters and reactors for anaerobic energy production systems. Investigations should focus on producing catalysts or process modifications that result in more thorough and faster conversion of the carbon from l&no-cellulose to methane. Finally, there is a need for systems that do not require a liquid form for transport to and from the digester.

3. Better equipment for the handling, storage, and transport of biogas or methane is essential for the acceptance of both anaerobic digestors and biogas recovery systems.

4. Energy efficient processing and drying equipment would aid more effective use of wastes for feed. Research is needed to find the most effective methods for removing all pathogens while retaining as much of the nutritive value as possible.

5. More research data are needed to determine the seasonal effectiveness and long term loading effects on soil and groundwater of biological treatment systems such as wetlands and filter strips.

IMPEDIMENTS AND INCENTIVES

From the preceding discussion, it is apparent that much of the technology for pollution prevention in animal production exists; however, it is of little use if it is not put into practice. Obstacles deterring alternate waste management techniques and pollution prevention programs include economical constraints, lack of information on the value of manure, lack of technical information on alternative uses for animal waste, and unwillingness of farmers to try new approaches to waste management. Much of the problem lies in the farmer's perception of the impact his practices have on the environment. In general, most farmers feel that they are not responsible for the pollution of their environment and that the use of any corrective measure will come at a cost to them (Conway and Pretty, 1991). For a farmer to adopt a pollution prevention technology it must be profitable and have a low initial cost. The solution might be increased environmental education coupled with viable demonstration projects and specific pollution control recommendations that avoid the expected economic losses.

Supalla et al., 1995, conducted a study to assess the factors relating to why farmers choose not to use the recommended best management practices in the Central Platte Valley of Nebraska. He found that environmentally concerned, well educated, well informed, and younger producers who farmed smaller acreage were more likely to apply nitrogen at recommended rates. In Georgia, most of the farmers are not environmentally concerned, well educated, well informed, and younger producers. The USDA Economic Research Service estimates that 91% of the farms in Georgia are owned by a single family. The average farm size is 256 acres; however, 51% of the farms are less than 100 acres and 77% have sales of less than $50,000. The average age of the farm manager is 55 years and most do not have a college education. Since these older and less prosperous farmers are generally not as receptive to change as younger, college educated farmers, the task of informing them and changing traditional practices is often difficult. Educational efforts to change behavior should address the linkages between management practices and environmental quality. Educational programs for nitrogen application should explain how fertilizer recommendations are developed with an emphasis on explanations for recommendations that are lower than traditional amounts. If a fanner understands why he should be concerned and economic alternatives are available, then he will be more likely to use an accepted practice.

The economic background of Georgia farmers also presents an obstacle to pollution prevention. About 54% of Georgia's farmers view farming as a secondary occupation and are therefore less likely to invest resources in improvements. A full time farmer that is dependent on his farming income will be more likely to invest in technologies with a long payback period than would a retired landowner that uses farming to supplement his income. This displays a need for technologies that require little initial investment. In addition, educational programs should always emphasize the economic benefit of preventing pollution as both short term and long term investments, as certain technologies may only be appropriate to certain types of farmers. It is also important that these programs stress that higher productivity does not always equate to more profit, as most pollution prevention technologies could reduce both inputs and total output while increasing the profit margin.

A number of USDA conservation programs share the cost of implementing conservation practices with farmers through direct payment. These include the Agricultural Conservation Program, Water Quality Incentives Projects, the Small Watershed Program, and the Rural Clean Water Program. For fiscal years 1992-1994, these programs provided about $89 million to U.S.

farmers to implement animal waste management practices (GAO, 1995). The main problem with this assistance is that it is often limited in terms of amount ($3,500 per year) and will only cover half of the total cost (75% in some cases). When the cost of various management practices is considered, for example $40 to $80 thousand for a lagoon, $5,000 to $20,000 for filter strips, or $8,000 to $10,000 for a poultry manure storage and composting shed, this often leaves the producer to shoulder a substantial part of the economic burden. Nevertheless, cost sharing is important to the implementation of conservation practices, and agricultural pollution prevention programs need to insure that appropriate pollution prevention technologies are addressed through NRCS cost share programs.

The acceptance and use of state of the art BMPs is also of primary importance as many BMPs can be implemented at little cost to the producer. In the design and implementation of these BMPs, the "whole farm" concept needs to be used to account for a variety of nutrients, conditions, processes, etc. rather than those that are most prevalent. These BMPs need to be carried out on as many farms as possible. Generally, practices that increase net income are compatible with water quality; however, accomplishing this requires a higher level of management (Moore et al., 1995). This management is not only supplied by the owner/grower but also requires significant participation from other sources such as extension agents, NRCS staff, and farm organizations.

Another major obstacle to agricultural pollution prevention is a lack of funding. This comes in several layers. First, there is a real need for more research to investigate suitable agricultural pollution prevention alternatives. While some technologies exist, most require more research and are still considered "experimental". The development of new pollution prevention technologies will require substantial amounts of new research funding or the redirection of existing funding. Second, there is a need for increased funding for education and demonstration. In order for these technologies to be accepted they need to be displayed at a local level and made available to the public through local educational programs. Finally, there is a need for increased economic or regulatory incentives. Regulation will work, but it is not as politically, socially, or economically accepted as voluntary approaches. Incentive-based proposals may provide the needed information and knowledge to improve and expand pollution prevention technologies. This can come as increased cost-sharing or through the development of awards or recognition programs; however, both alternatives will require some funding. One method of indirectly obtaining funding for all these areas is to take advantage of existing programs. Nationally established Water Quality and Sustainable Agriculture initiatives receive substantial amounts of direct federal funding for both research and education. The goals of both programs can be obtained through agricultural pollution prevention. By allying with these programs, the agricultural pollution prevention program could take advantage of both the funding and the irfrastructure already in place.

Since funding is limited, it is also important that it be targeted to the most appropriate areas. While funding could be targeted using several different variables or methods, perhaps the best method is to target it to areas where the problems are the worst. Geographical information systems (GIS) or land informational system could be used to assist in targeting critical areas. GIS is capable of "layering" informational databases over specific land areas. Databases such as watershed boundaries, land cover, animal density, topography, soil surveys, and precipitation can be used. The use of GIS combined with a pollutant generation and transport models can identify and rank critical pollutant source areas as well as target environmentally sensitive areas. This will greatly assist efforts to control and reduce agricultural NPS pollution by concentrating pollution prevention activities in these areas. Other states, such as Virginia, Rhode Island, and Hawaii, are developing

GIS to manage agricultural and urban development (Hamlet et al., 1992). A GIS system that could locate significant land areas within the state that have a nutrient deficit rather than a surplus would be an invaluable tool for a processing company wanting to build a new poultry processing plant. It would also deter the construction of new facilities in areas where environmental concerns are greatest.

The ideas of sustainability and "whole farm planning" need to be incorporated into each of the pollution prevention technologies we implement at the farm level. One method of doing this is to develop sustainable guidelines. For example, if a confined animal feeding facility chooses land application as its method of waste disposal then it should document that it has an adequate land base for the number of animals it intends to feed. This should be accomplished through nutrient management plans that insure that both the soil and water quality will not suffer from the land application. If this cannot be documented, then an alternative disposal or reuse strategy should be developed. The "whole farm planning" concept that Georgia is currently testing is one method of incorporating this sustainability. Whole farm plans look at the entire farm operation rather than individual components to insure that the management decisions made in one area of the farm do not have a negative impact on another area. In addition, these plans give the farmer a tool for exploring all aspects of his operation and could be used to locate appropriate areas for pollution prevention technologies.

CONCLUSIONS

At the core of pollution prevention technologies is the understanding that pollution is a sign of inefficiency and that effective technologies will either reduce inputs or find acceptable uses for the by-products of production. In animal production, manure is the primary by-product and it does have value. Future research needs to center on technologies and practices that increase this value. Whether the research is designed to reduce the loss of nutrients within the manure, increase the ability to transport and use manure, or develop alternative uses for the manure, the goal should ultimately result in a product with greater value.

With increasing numbers of large livestock facilities generating concentrated amounts of animal manure, proper waste management becomes critical in the prevention of pollution. Animal wastes can be managed to minimize environmental impact and used as a valuable resource. Current practices widely use manure as an organic fertilizer and soil conditioner. Alternative uses include energy production, feedstock, and substrate for protein production.

Waste management programs integrate knowledge of nutrient availability, crop nutrient requirements, alternative utilization of waste, and natural treatment. Nutrient management planning for land application of manure and wastewater is necessary to optimize crop production and avoid nutrient imbalance or soil salinity. Land and soil sustainability encompasses beneficial use of manure and compost to improve soil physical properties and increase vegetative cover for control of soil erosion and sedimentation. Using a holistic approach, farm expenses can be reduced and by-products can be marketed, increasing gross profit. Unfortunately water quality and public relations are not tangible assets; however, some value needs to be placed on these parameters.

Public apprehension regarding agricultural producers originates from perceptions or evidence of continuing source and nonpoint source water quality problems. Increasing public awareness and concern about environmental protection place pressures on legislative bodies to construct more stringent environmental regulations. Regulations are necessary to control the minority who have little concern for the environment and who focus on convenience and profit. The voluntary approach coupled with financial and technical assistance encourages producers to adopt a proactive attitude without undue restrictions from regulations. Some financial and technical assistance is available to design and finance facility changes for those who actively seek alternative solutions that improve waste management and water quality. These programs need to be expanded by encouraging communication and teamwork between individual producers, governmental agencies, and the general public. With this teamwork, efforts to minimize negative impacts on the environment have a greater chance for success.

Water quality protection, particularly from nonpoint source pollution or unregulated point sources, is an issue that needs to be addressed by increased research, technology transfer, public policy initiative, and private actions from producers. By actively seeking ways to reduce, reuse, and recycle waste, it is possible to increase the potential profit of individual farms while simultaneously decreasing the negative impact farm wastes have on our environment. Increasing environmental pressures, shifting attitudes toward organic and sustainable agricultural practices, and changes in waste management regulations demonstrate a potential acceptance and encouragement for pollution prevention practices in agricultural livestock waste management.

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