AN EVALUATION OF DAIRY MANURE MANAGEMENT ECONOMICS

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An Evaluation of Dairy Manure Management Economics[1]

Dairy production in the Cross Timbers region of Texas (Erath, Comanche, Hamilton, Bosque and Mills counties) increased ten-fold from 1969 to 1994. Milk sales in 1991 were $183 million. The dairy sector plays an integral role in the local economy: each $1 million of dairy sales stimulates $520,000 worth of activity in other regional industries, generates in $580,000 in personal income and supports 22 jobs in the region (Jones *et al.*, 1993). The dairy herd in the Cross Timbers region is estimated at 70,000 to 80,000 cows (Texas Institute for Applied Environmental Research, 1992). Each year, an estimated 175,000 tons of manure are produced in Erath County (Gerlin, 1994).

The purpose of this subcontract was to evaluate the economics of on-farm dairy manure handling. The first section of the report provides a brief history and the policy context for dairy producers' selections and management of the manure handling systems currently in place in Erath County. The second section describes typical solid manure management practices for small dairies (the typical size being 150 to 400, and 250 cows being considered representative) and for large dairies (the typical size being 800 to 1200 cows and 1000 cows being considered representative). This description includes cost estimates based on round-table discussions with groups of producers and interviews with individual producers and Extension personnel. These estimates, developed and tailored to current Erath County conditions, draw on empirical studies and cost estimates from other regions, as summarized in an accompanying annotated bibliography. The final section of this report is a discussion of the risks associated with dairy manure

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management in the Cross Timbers region of Texas and a qualitative assessment of the likely responsiveness to selected future dairy manure management options for central Texas producers.

Brief History and Policy Context: Dairy Manure Management Systems in central Texas

The 1980s was the most significant growth decade for the dairy industry in central Texas. Producers whose grandfathers had dairied in central Texas expanded their herds and there was an influx of producers from California and Arizona. This clustering phenomenon put pressure on the institutions and the environment's assimilative capacity in the Cross Timbers region (Pagano and Abdalla, 1994). Some of the new and expanded facilities failed to meet the water protection standards set and enforced by the Texas Water Commission, either in technical design or in management. By 1989, five dairy producers were fined a total of $142,460 (Texas Institute for Applied Environmental Research, 1992). New permit requirements for dairies with over 250 cows were issued by the Texas Water Commission in 1990; these new policies were overviewed and explained in Sweeten, Baird and Manning (1991).

During the winter of 1992, precipitation levels in central Texas were well above average (McFarland, McFarland and Sweeten, 1994). Wastewater storage systems (anaerobic lagoons and adjacent irrigated fields) designed to accommodate a 24-hour, 25-year flood event were unable to handle heavy rainfall even though a 24-hour 25-year event never occurred. Among dairies permitted by the Texas Water Commission (TWC) at that time (that is, all dairies with over 250 cows), 34 dairies experienced emergency discharges into surface water in February and March, 1992. Subsequently, the Texas Sierra Club threatened to file a citizen's lawsuit against 29 of the 34 dairies in June, 1992. A local environmental group -- the Cross Timbers Concerned Citizens -- put pressure on local dairy producers and on state and federal environmental regulatory agencies for changes in water permits and more stringent monitoring and enforcement (Pagano *et al.*, 1994).

In July, 1992, the US EPA's Region VI office in Dallas proposed a draft special permit for confined animal feeding operations (CAFOs), pertaining to dairies with over 700 cows. This permit was required for dairies with over 700 cows, and was compulsory in addition to the TWC-administered water permit and air quality permits for dairies with over 1000 cows administered by the Texas Air Control Board (TACB). The EPA's proposed special permit was described and debated in public hearings. The modified final guidelines for the general permit for CAFOs were published in the *Federal Register* in February, 1993. As of January, 1994, dairies with over 700 cows are required to keep pollution prevention plans which are available for inspection by EPA officials upon request. In addition, dairies with more than 200 cows which may have a discharge from less than the 24-hour 25-year storm event were likewise subject to the general permit.

In 1993, the TWC and the TACB were consolidated to become the Texas Natural Resources Conservation Commission (TNRCC). In June, 1995, the Texas legislature passed a new rule consolidating air and water permits for CAFOs in Texas (Texas Administrative Code, Chapter 321, Subchapter K, 1995).

For the period 1990 to 1995, dairy producers have been motivated to actively seek the least-cost and most economically efficient options for handling their dairy manure in order to comply with federal and state permit requirements. In October, 1992, a group of dairy producers attempted to form the Erath County Fertilizer Products Cooperative to pursue collective approaches to compost handling and marketing. In 1993, the city of Stephenville considered building a centralized composting facility involving both the city's solid waste streams and dairy manure, but in 1994 decided instead to sign a long-term contract with an outside firm to provide the city with waste handling services.

In 1993 the Texas Water Commission conducted a Dairy Outreach Program, visiting every dairy in Erath County and making a baseline assessment of the dairy manure handling system in place (both the physical configuration and its management). In 1994 the TNRCC established an office in Erath County and hired two inspectors to conduct regular visits to evaluate dairy manure handling practices and systems in the Cross Timbers region. During this period dairy producers were feeling significant pressure to satisfy environmental compliance regulations issued and enforced by TNRCC and the US EPA, thus many were actively pursing information on how to best handle their manure on their particular facilities. Many made investments and modifications to bring their dairy manure management systems into compliance.

The next section of this report describes the systems and costs (variable and fixed) of manure handling considered to be representative for a 250 cow (small) dairy and for a 1000-cow (large) dairy in the Cross Timbers region of Texas. Most of these systems were established and finetuned in the period 1990 to 1995.

<u>Typical Dairy Waste Management Practices in the Cross Timbers Region</u>

Solid waste management practices utilized on dairy farms in the Cross Timbers Region of Texas are relatively homogeneous across all dairies in the region due to similarities in production techniques, even across different sized dairies. With very few exceptions, the typical dairy farm in the region is drylot, which means that the cows are kept in uncovered corrals about three-fourths of the time. During the remaining one-fourth of the time, the cows are in alleyways going to or returning from the milking parlor or are inside the parlor. Therefore, most of the manure is deposited in the corrals with only a portion deposited in alleyways.

Solid waste management practices include on-site scraping of corrals and alleyways, stockpiling manure, and transporting stockpiled manure to crop and pasture land. The following are short descriptions of each of the major activities:

- On-site scraping of corrals and alleyways. Scraping is typically done every two weeks using a mechanical scraper and a tractor. The size of tractor used for scraping varies, but generally ranges between 60 and 100 horsepower. There are several types of mechanical scrapers. The majority use either a pull type box scraper or a box scraper that connects to the three point hitch on the tractor. The pull type box scraper drags behind the tractor with the angle of the box adjusted using tractor hydraulics. The process of scraping corrals and alleyways often results in large rocks being dislodged and collected in the stockpiled manure.
- Stockpiling manure. The stockpiles (often referred to as in-pen mounds) are created by continually dumping the box scraper in one location. There is normally a single stockpile in each corral. The tractor operator will pull the box scraper on top of the stockpile to unload. In addition, either an articulated loader or a tractor equipped with a front-end loader is used to stack the manure. The stockpiles are added to every two weeks during the scraping process. After a substantial rainfall event, the stockpiles are restacked.
- Transporting stockpiled manure to farmland. Dairymen in the Cross Timbers region typically remove the stockpiles from the corrals every six months. The timing of manure application on crop and pasture land is generally prior to the growing season for both row crops and pasture based forages. Those producers who spread manure predominantly on coastal pasture spread

more often in the peak forage production season (spring and summer). A tractor, manure spreader and articulated loader or tractor with a front-end loader are used to load stockpiled manure and transport it to crop and pasture land. Cross Timbers dairymen estimated that it required an average of 30 minutes per round trip load (loading, transporting, unloading and returning to the stockpile). The manure spreaders used in the area range in size from 8 to 11 yards. After the manure is spread on the land, the large rocks that would likely cause equipment breakdown are retrieved using manual labor. After the rocks are removed, manure is incorporated into the soil using a tractor and disc as required in manure management permits.

There are very few differences in waste management techniques in use across dairies in this region. The most significant economies of size are in labor; there are also minor differences in the machinery used to collect, stockpile, and distribute the manure and land ownership.

Small Dairies

Dairies in the Cross Timbers Region that range from 150 to 400 cows are categorized as small. Many of these dairies are owned and operated by a single family (parents and children) or multiple families (siblings) without the aid of hired labor. In these instances, family members typically do not receive a salary, rather they draw a family living expense from the business which depends on farm profitability. For purposes of calculating labor costs, the labor costs for the family member who works in manure management are calculated based on the prevailing wage rates for hired labor in the area.

The machinery complement will not be identical on any two dairies but there are typically at least two 60 to 100 horsepower tractors. One of the tractors will be equipped with a front-end loader. Only one tractor is needed for both scraping and stockpiling. Both tractors are needed (one to load and one to pull the manure spreader) to load the stockpiles and transport the manure to its final destination. Most dairies will have a manure spreader. The only alternative is to contract with a private hauler. Contract hauling and spreading ranged in price from $22 to $25 per load. Contract haulers use 18-yard trucks and spreaders; the loading is done by the dairy producers using their own machinery. In contrast, producers who do their own hauling use 10-yard pull-type spreaders. All dairies will have some type of disc plow to incorporate the manure into the soil. The small dairies in the region are more likely to own their crop and pasture land and to own more than enough land to handle all of their dairy waste.

Large Dairies

Dairies in the Cross Timbers region that range from 800 to more than 1000 cows are generally categorized as large. Like small dairies in this region, many of these dairies are owned and operated by a single family (parents and children) or multiple families (siblings). However, in most cases, hired labor is used to supplement family labor. In these instances, it is assumed that hired labor handles manure management activities on the dairy and it is valued at prevailing rates.

The machinery complement on a large dairy is slightly different than that on a small dairy. The large dairy will typically have an articulated loader instead of the tractor that has a front-end loader. The rest of the manure handling equipment is generally the same on small and large farms.

The pattern of land ownership on large farms differs somewhat from the small farms. The dairymen representing large farms in this region indicated that due to more strict waste management regulations, dairymen have been required to demonstrate established leasing agreements or ownership of sufficient land for spreading manure in order to satisfy water permit requirements. In the past three to six years, some large-scale dairy producers have added additional land for manure spreading by either leasing or purchasing land.

Manure Handling Cost Estimates

The following cost estimates were derived from round table discussions with small- and large-scale producers from the Cross Timbers region. Additional information was gathered from many of the secondary sources listed in the annotated bibliography. The technical coefficients required in these calculations were obtained primarily from Livestock Facilities Handbook, Masud et al., and Sweeten et al., 1989 (references listed in the annotated bibliography and additional readings). The cost estimates are for activities and machinery required to handle solid waste on two representative dairy farms in the region, small-scale and large-scale.

Assumptions common in the cost calculations for both the small and large dairies were an assumed 120 pounds of wet manure produced per 1400 pound cow per day. This estimate is for fresh manure with an 87.3 percent moisture content. It was assumed that after scraping, stockpiling, and experiencing rain events, the moisture content would average 30% for the manure transported to farmland. Equipment would have a useful life of 15 years and the percent of annual use of each piece in manure handling would vary. Annual repairs and maintenance would be set at 3.5% of the initial investment cost as in Masud et al.

An annual full-time equivalent salary of $18,500 was used to determine the hourly rate charged each labor activity. Labor costs for loading and transporting were estimated based on the amount of manure to be transported, the size of the manure spreader, and producers' estimates of approximately 30 minutes per round trip load. It was assumed that the manure was spread within a one-mile radius of the dairy. The manure spreader was assumed to have a capacity of 10 cubic yards. Interest rates were assumed to be 10% for machinery. Fuel and lubrication cost estimates were based on two gallons of fuel used per hour and the price of diesel at $1.05 per gallon. Agronomists were consulted regarding the appropriate amounts of commercial fertilizer that was displaced by dairy manure that would maintain forage and crop yields. They indicated that typical rates of fertilizer application in the absence of manure are 200-230 pounds of nitrogen, 70 pounds of phosphorus and 150-200 pounds of potassium. The average prices used for nitrogen, phosphorus and potassium were $240, $243 and $148 per ton.

The basic methodology used to estimate costs was the same for both farm sizes. However, there were differences between the two farm sizes in terms of labor use, machinery used to collect, stockpile, and distribute the manure and land ownership.

Small Dairy Cost Estimates

The estimated manure handling costs for a small (250 cow) Cross Timbers region dairy are shown in Table 1. The major cost items included machinery, labor, and fuel and lubrication. The dairymen indicated that a farm of this size would have two tractors used in manure handling. One of the two would be equipped with a front-end loader. The estimate of 50 percent of annual use for both of these tractors was based on the fact that one of the tractors would be used a significant amount of time for crop production while the tractor with the loader would be used for loading feed in the mixer wagon. The manure handling equipment would be used 100 percent of the time on these activities while the disc plow would only be used about 35 percent of the time. The annual amortized cost of equipment and repairs and maintenance costs were estimated at $7,554. The amortization period for this analysis was 15 years. For small-scale dairies using fully yards. Interest rates were assumed to be 10% for machinery. Fuel and lubrication cost estimates were based on two gallons of fuel used per hour and the price of diesel at $1.05 per gallon. Agronomists were consulted regarding the appropriate amounts of commercial fertilizer that was displaced by dairy manure that would maintain forage and crop yields. They indicated that typical rates of fertilizer application in the absence of manure are 200-230 pounds of nitrogen, 70 pounds of phosphorus and 150-200 pounds of potassium. The average prices used for nitrogen, phosphorus and potassium were $240, $243 and $148 per ton.

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The dairymen indicated that the corrals would be scraped an average of 2 hours every two weeks. Fuel and lubrication costs associated with manure handling were estimated at $199.07 and 413.19 per year for in corral and post corral. The estimated number of loads of manure to be loaded and transported to farmland was 402 with each round trip load taking an estimated 30 minutes. Of this time, it was assumed 5 minutes was the loading time and 25 minutes was required for transporting and unloading. It was indicated that the 30 minutes should include any large rock removal time as well. An estimated 12 hours was assumed to be the time required to incorporate the manure in the soil after spreading. The annual cost for labor was estimated to be $766.49 and $1,590.92 for in corral and post corral. Note that this labor cost estimate is based on an opportunity cost of labor. Since many small-scale dairies rely on family labor, it is not a cash cost.

Total annual costs of manure management activities are estimated at $10,523.74 or $4.47 and $35.08 on a per ton and per acre basis. Total in corral variable costs were estimated to be $965.56 per year, while the post corral variable costs were estimated at $2,004.12 per year. The value of fertilizer that was not needed due to the use of manure was estimated at $13,081.50 per year. The resulting net cost for waste management was -$2,557.76 per year which means that the economic benefit to dairymen of their manure outweighs the economic costs.

Large Dairy Cost Estimates

The estimated manure handling costs for a large (1000 cow) Cross Timbers region dairy are shown in Table 2. The major cost items included machinery, purchased land, labor, and fuel and lubrication. The dairymen indicated that a farm of this size would have one tractor used in manure handling and an articulated loader used to stockpile manure and load the manure spreader. The estimates of 65 percent of annual use for the tractor and 50 percent for the loader were based on the assumption that the tractor would be used a significant amount of time for crop production while the articulated loader would also be used for loading feed in the mixer wagon. The manure handling equipment would be used 100 percent of the time on these activities while the disc plow would only be used about 35 percent of the time. It was also assumed that in order to satisfy more stringent environmental permitting requirements, the dairy is leasing 150 acres of additional coastal pasture at $20 per acre to grow forages and spread dairy manure. Annual amortized cost of equipment, land and repairs and maintenance costs were estimated at $10,929.00.

The variable costs of manure handling involved labor and fuel and lubrication. Fuel and lubrication costs were estimated at $2,718.21 per year for in corral and $1,625.05 per year for post corral. The dairymen indicated that the corrals would be scraped an average of 20 minutes per week. The estimated number of loads of manure to be loaded and transported to farmland was 1,608 with each round trip load taking an estimated 30 minutes. Of this time, it was assumed 5 minutes was the loading time and 25 minutes was required for transporting and unloading. An estimated 36 hours was used for the time required to incorporate the manure in the soil after spreading. The dairymen indicated that twice per year, three hourly workers would normally be hired to remove rocks from the crop and pasture land. The annual cost for labor related to dry manure handling was estimated at $10,465.97 and $7,456.97 for in and post corral work. Normally, a large-scale operation has one laborer who performs mainly outdoor tasks; in dairy producers' parlance, their "outside guy" spends at least half of his time hauling and spreading manure. The remainder of the manure-handling tasks are performed by hired hourly labor.

Total annual costs of manure management activities are estimated at $33,194.76 or $3.52 and $73.77 on a per ton and per acre basis. Total in corral variable costs were estimated to be $13,184.18 per year, while the post corral variable costs were estimated at $9,082.02 per year. The value of fertilizer that was not needed due to the use of manure was estimated at $19,622.25 per year. The resulting net cost for waste management was $13,572.51 per year which means that the economic benefit to dairymen of their manure does not outweigh the economic costs.

A qualitative assessment of attitudes, risk perceptions, risk-minimizing options and future trends:

Cost estimates describing on-farm manure handling for small and large producers indicate that producers could reduce their current costs by considering off-farm manure disposal options rather than stockpiling and land-applying manure on owned and leased cropland. At the same time, when producers consider and weigh trade-offs associated with relegating responsibility for manure disposal to an off-farm entity, some voice reservations.

Perceptions concerning manure-handling options: Some large-scale producers feel "locked in" to their current manure handling practices. Large-scale producers are more likely than small-scale producers to consider allowing an external entity to dispose of their manure. Their open-mindedness to this option, to a large degree, depends on the type and extent of investments they have made in cropland (purchased and/or leased from neighbors) for land applications of solid manure.

In a round table discussion, large-scale producers speculated that they and the other large-scale producers in the county would be likely to consider entering a contract for off-farm disposal of 30% to 50% of their manure if the contractor would pick it up and load it, with the dairy producer still handling the scraping (manure collection and stock-piling). They would have seasonal demand for some share of their manure (before spring and fall crop plantings, normally in February and October). Moreover, they would prefer to keep the high-quality manure (low water content and from corrals with few rocks) and to contract for off-farm disposal of manure with rocks in it. Producers would want to maintain responsibility for scraping corrals because if lots are not properly maintained, then herd health can suffer (in particular, mastitis becomes a problem). Producers agreed that those who are land-locked would benefit the most from the option to contract with an off-farm entity for manure disposal. There was general support for development of any manure-disposal alternatives which would help the dairy industry as a whole, especially those large-scale producers having the greatest difficulty coming into compliance.

On the other hand, some large-scale producers have already made significant investments in land and equipment. Due to these recent fixed investments, they have less flexibility to consider alternative manure handling configurations. One producer remarked that "the idea of providing off-farm manure disposal alternatives is three to six years too late for most of us." Large-scale producers have either purchased cropland adjacent to their dairies or have entered lease agreements with neighbors. They benefit from and value their increasing capacity to produce forages on-farm. This is especially true since the prices of imported alfalfa hay have risen in the Cross Timbers region and its availability is less predictable than a decade ago. For the first time, during the spring planting season of 1995, some non-dairy neighbors were willing to pay dairy producers for manure ($9 for a ten-ton load, delivered and spread). Among large dairy producers, there are a few who see on-farm forage production as integral to their current and future cost-competitiveness. Therefore, they have made or are planning to make investments in equipment for hauling and spreading manure because of the importance of timing of nutrient applications to optimize forage production. Those who depend on contractors to haul and spread their manure are trading off less control of the timing of spring and fall manure nutrient applications to cropland, in favor of fewer headaches and responsibilities with manure-handling equipment maintenance and spreading.

A consideration for producers contracting with off-farm entities to dispose of their manure is the bearer of the liability associated with off-farm spills. A dairy producer is more likely to be willing to enter a contract if the contract specifies that the hauler bears the liability, if a load of manure were to spill on the roadside. Under current contracting arrangements, most manure hauling is limited to within two miles of the dairy facility.

In summary, for a few producers, the value of manure in on-farm forage production has the potential to offset the opportunity cost of management resources employed in manure handling. Future expectations about the costs of purchased feed (and thus about the value of producing forage on-farm) will be a key determinant of the perceived value of manure in the future, especially among large or expanding producers. Furthermore, the current policy environment influencing milk prices and markets is uncertain. Passage of the 1995 farm bill will likely mean less government support and intervention in the dairy industry. Ramifications, for the short term, are lower milk prices and continuing instability. In light of this uncertainty, producers are likely to be resistant to changes in the manure handling practices unless they perceive significant potential for reducing their cash costs in the short run and over the long run.

Risk perceptions concerning water pollution prevention: Dairy producers in the Cross Timbers region of Texas are acutely aware that they bear risks associated with land application of solid manure to cropland. There can be financial consequences from inadequate manure handling: a precedent exists for regulatory activity, threatened lawsuits, and actual lawsuits against dairies in the Cross Timbers region. Furthermore, public hearings and complaints from neighbors can cause costly delays in the issuance of water permits (Pagano *et al.*, 1994). Water pollution prevention has been the focal point of significant concern in the Cross Timbers region. As noted in the introduction, prior to 1990, steep fines were levied against five producers to punish improper manure management in violation of Texas Water Commission permits. Subsequently, all producers with over 250 cows were required to comply with more stringent, revised permit guidelines after 1990. Modifications in systems and management were costly (Leatham *et al., 1991*). In June, 1992, the Texas Sierra Club threatened a lawsuit against 29 dairies whose wastewater storage systems had emergency failures the prior spring, due to unusually heavy rainfall and water-saturated soils which made it impossible to de-water (that is, to irrigate to reduce levels in wastewater storage lagoons). Many dairy producers' borrowing strategies rely on having the option to expand and milk more cows in order to increase cash flows, particularly if milk prices drop (Purvis and Outlaw, 1995). During the period from July, 1992 through February, 1994, while the US EPA's Region 6 special permit was being finetuned, dairy producers were worried about an environmental impact assessment process putting a moratorium on dairy growth in the Cross Timbers region, thus reducing producers' short-run cash-flow flexibility.

In summary, the central Texas dairy industry has been profoundly affected by the modification and enforcement of water protection policies and it has been virtually impossible for any dairy producer, large or small, to escape noticing the potential legal and regulatory ramifications of neglecting proper manure management practices. It may have been possible for some producers, prior to 1992, to place a low priority on manure handling but recent environmental regulatory activities have raised the level of awareness among producers of the potential financial consequences of ignoring permit responsibilities. Cross Timbers dairy producers are beginning to appreciate the potential advantages of maintaining a proactive profile.

News of the possible consequences of water pollution infractions based on the experiences of dairy producers in other regions has a consciousness-raising effect on some dairy producers who read the dairy and farm press. Recently, the dairy media has provided extensive coverage of options and encouragement in favor of "preventative medicine" regarding water pollution prevention, as well as the adverse consequences of failing to satisfactorily comply with permit requirements. In May, 1995, *Dairy Herd Management* magazine suggested a check-list of "eight indicators that you need to improve waste management practices on your farm," with five of the eight indicators being associated with water protection (Franck, 1995). In June, 1995, *Dairy Herd Management* magazine explained and recommended soil testing in order to optimize nutrient management (Roenfeldt, 1995). In August, 1995, *Dairy Herd Management* magazine described nutrient management planning and record-keeping (Roenfeldt, 1995).

Explicitly discussed in *Dairy Herd Management* magazine were provisions under the Clean Water Act whereby producers out of compliance can be fined up to $25,000 per day per violation. The discussion was punctuated by the fact that New York dairy producer Dick Popp has spent $600,000 on legal fees to defend himself in a lawsuit filed by his neighbors under the provisions of the Clean Water Act. Roenfeldt (August, 1995) ventured an estimate of the annual per-cow dollar value of the manure from a dairy cow, at the equivalent of $125 in commercial fertilizer (p. 28), in an attempt to demonstrate positive economic incentives for effective utilization of dairy manure in crop production. An June/July, 1995 article in *Dairy Today* provided further detail on the Dick Popp's lawsuit, *Concerned Area Residents for the Environment v. Southview Farm*, emphasizing that under some circumstances "manure spreading vehicles, including trucks hauling the waste, were themselves 'point sources' of pollution under the Clean Water Act"(Sands, 1995). *Dairy Today* published subsequent articles on nutrient management in August (Mohr, 1995) and on environmental audits ("going on the offensive") in September (Mooney, 1995).

The cumulative effect of this media coverage -- along with experiences in the Cross Timbers region from 1990 to the present -- is likely to make an impression on dairy producers who are alert to financial risks associated with legal and environmental regulatory action. However, no sociological study has been conducted of Cross Timbers dairy producers' responsiveness to media information or their risk perceptions related to manure management.

The physical risks associated with improper dairy manure handling vary according to nutrient management and environmental conditions (in part, soils and precipitation). To minimize the risks of groundwater contamination and surface water runoff, dairy producers apply manure to cropland in accord with the nutrient requirements of growing crops. Soil testing is a prevalent practice in the Cross Timbers region, but manure testing is conducted less regularly and by a smaller proportion of producers. Manure quality and the water content of manure vary by season and according to animal nutrition regimes. Since soil and manure testing is conducted by a mix of private and public entities, no reliable statistics exist on the frequency and the numbers of soil tests run by dairy producers in the Cross Timbers region. Soil testing records are a requirement as part of the EPA pollution prevention plans maintained by CAFOs with over 700 dairy cows.

According to Erath County Extension agent Joe Pope, dairy producers using manure as an organic fertilizer on coastal hay are not likely to supplement with additional inorganic fertilizer. When row crops are planted in the Cross Timbers region, however, some producers supplement manure with inorganic fertilizer (nitrogen only). In round table discussions, producers reported having observed that in the first year when manure is applied as an organic fertilizer, the response is less than in subsequent years, after the organic component of the soil has been improved by manure applications. Though producers have difficulty expressing, quantitatively, their perceptions concerning the economic value of manure, they perceive manure's organic component as ameliorating soil structure. Improved soil structure is perceived as valuable.

Risk perceptions concerning odor: A 1993 lawsuit over dairy odor on a calf ranch (F/R Cattle Company v. the State of Texas) sensitized Cross Timbers dairy producers to the financial costs and risks associated legal and regulatory activity due to inadequate odor management (see Pagano *et al.*, 1994). Neighbors' perceptions and adverse consequences due to odor problems are more salient to some central Texas producers than concerns related to water protection and permits. Similar to the recent media coverage encouraging proactive water pollution prevention and nutrient management, the importance of managing to prevent odor was emphasized in a recent issue of *Hoard's Dairyman*; a national expert on odor, agricultural engineer Ron Miner of Oregon State University, was quoted as saying: "This is REAL! It is not going to go away, no matter how nice you are. ... We're really talking about risk management. Odor complaints and lawsuits are beyond acceptable risk to most producers" (Merrill, 1995). On the other hand, the extent to which a dairy producer has an odor problem -- real or perceived -- depends largely on site-specific circumstances such as buffer zones, precipitation, and wind direction. It is significant that recent changes in Texas regulations pertaining to nuisance odors from CAFOs (Subchapter K, June, 1995) are likely to reduce the likelihood of nuisance odor having legal standing -- either as grounds for neighbors' complaints against dairies or for TNRCC permit infractions.

Manure management practices can reduce the risk of odor problems. Most producers are required to plow under ("disk in") land-applied manure solids to satisfy their TNRCC permits, a practice which also helps to control odor. They can also minimize odor by avoiding handling manure wet and by timing manure applications to avoid periods when soils are saturated. In some cases, however, management practices adopted to minimize potential problems with nutrients leaching into groundwater and/or running off into surface water -- in particular, storage of manure under anaerobic conditions -- can exacerbate odor problems (Purvis and Outlaw, 1995).

Overall implications for dairy producers' likely responsiveness to composting opportunities:

On Tables 1 and 2, question marks are used to represent a risk factor associated with on-farm handling and spreading of manure. Clearly, risk reduction and cost reductions are possible for producers who contract with an off-farm entity to provide manure disposal services rather than spreading it themselves. The producers most likely to be responsive to contracting with an off-farm entity for manure disposal services are those who are land-locked and currently have few good options for manure disposal. Producers who have short-term leasing arrangement for cropland or pasture where they spread manure are more likely to be responsive than are producers who own sufficient cropland to handle their manure. Producers who are building the capacity to produce forage on-farm and who view on-farm forage production as valuable are less likely to be interested in contracting for manure disposal than those who prefer to specialize in milk production. Receptivity among dairy producers is likely to be greatest when producers believe that their current manure handling practices pose an environmental threat and where they feel their current environmental practices are likely to be punished (either through a regulatory enforcement act or through a lawsuit). As long as individual dairy producers and the industry are left alone, they are likely to be satisfied with current dairy manure handling practices.

Suggestions on further economic analysis:

Producers' current costs associated with manure handling provide the basis for estimating their willingness to supply manure to an off-dairy entity willing to dispose of the manure (that is, use dairy manure as an ingredient for a composted mixture at an off-dairy location). The transition from current manure handling practices to a new system is not likely to be automatic. Not all producers are likely to be willing to contract to have their manure hauled off the dairy automatically, as a result of seeing that they can reduce their costs. Similar to Winrock's experience with poultry litter markets in Arkansas, there is likely to be a need for educational efforts with producers as well as market development for composted cow manure. The costs reported here provide the basis for developing "supply side" estimates. Derived demand analysis, similar to the economic approach developed for cattle feedlot manure in west Texas by Glover, is a recommended approach to comprehensively address the economic problem of forecasting supply and demand at various price levels.

Table 1. Summary of Solid Waste Handling Costs for a Representative 250 Cow Cross Timbers Region Dairy Farm.

Avg. No. Cows	No.	250		
Total Land Available for Spreading	Acres	300		
Avg. Cow Weight	lbs	1,400		
Per Cow Manure Production	lbs/day	120	tons/year	22
Total Manure Production 87.3% moisture	lbs/day	30,000	tons/year	5,475
Total Manure Production 30% moisture	lbs/day	12,900	tons/year	2,354

Capital Items	Percent of Annual Use	Investment	Amortized Cost	Repairs and Maintenance	Annual Total	Per Ton	Per Acre
100 h.p. tractor	50	$44,000	$1,898	$770	$2,668		
80 h.p. tractor w/ loader	50	$34,000	$1,467	$595	$2,062		
box blade	100	$2,500	$216	$88	$304		
manure spreader	100	$20,000	$1,725	$700	$2,425		
12 ft. disc	35	$2,250	$68	$28	$96		
Total					$7,554	$3.21	$25.18
Labor Costs							
Avg. Annual Full-time Salary ($)		$18,500					
Avg. Work Week (hours)		40					
Avg. Hourly Wage Rate ($)		$8.89					
In Corral Variable Costs							
Labor Activities:		Hours/year					
Scraping		52			$462.50		
Loading		34			$303.99		
Total		86			$766.49	$0.33	$2.55
Fuel and Lube Costs					$199.07	$0.08	$0.66
Total In Corral Variable Costs					$965.56	$0.41	$3.22
Post Corral Variable Costs							
Labor Activities:		Hours/year					
Transporting		167			$1,484.19		
Incorporating Manure in Soil		12			$106.73		
Total		179			$1,590.92	$0.68	$5.30
Fuel and Lube Costs					$413.19	$0.18	$1.38
Total Post Corral Variable Costs					$2,004.12	$0.85	$6.68
Risk Factor					?	?	?
Total Costs					$10,523.74	$4.47	$35.08
Less Value of Unapplied Fertilizer Pasture land			Acres 300		$13,081.50	$5.56	$43.61
Net Costs					($2,557.76)	($1.09)	($8.53)

1 cu. yd = approx. 1171 lbs at 30% moisture

The number of loads of manure hauled per year was calculated by dividing the number of pounds of manure to be spread by the capacity of the manure spreader (10 cu. yd.).
Loads per year = (2354 tons * 2000)/11710 capacity) = 402.1

Agronomists indicated that typical rates of fertilizer application in the area are 200-230 pounds of nitrogen, 70 pounds of phosphorus and 150-200 pounds of potassium.

Table 2. Summary of Solid Waste Handling Costs for a Representative 1000 Cow Cross Timbers Region Dairy Farm.

Avg. No. Cows	No.	1,000		
Total Land Available for Spreading	Acres	450		
Avg. Cow Weight	lbs	1,400		
Per Cow Manure Production	lbs/day	120	tons/year	22
Total Manure Production 87.3% moisture	lbs/day	120,000	tons/year	21,900
Total Manure Production 30% moisture	lbs/day	51,600	tons/year	9,417

Capital Items	Percent of Annual Use	Investment	Amortized Cost	Repairs and Maintenance	Annual Total	Per Ton	Per Acre
100 h.p. tractor	65	$44,000	$2,467	$1,001	$3,468		
articulated loader	50	$27,000	$1,164	$473	$1,637		
box blade	100	$2,500	$216	$88	$304		
manure spreader	100	$20,000	$1,725	$700	$2,425		
12 ft. disc	35	$2,250	$68	$28	$96		
150 acres of cropland	100		$3,000	$0	$3,000		
Total					$10,929	$1.16	$24.29
Labor Costs							
Avg. Annual Full-time Salary ($)		$18,500					
Avg. Work Week (hours)		40					
Avg. Hourly Wage Rate ($)		$8.89					
In Corral Variable Costs							
Labor Activities:		Hours/year					
Scraping		1,040			$9,250.00		
Loading		137			$1,215.97		
Total		1,177			$10,465.97	$1.11	$23.26
Fuel and Lube Costs					$2,718.21	$0.29	$6.04
Total In Corral Variable Costs					$13,184.18	$1.40	$29.30
Post Corral Variable Costs							
Labor Activities:		Hours/year					
Transporting		667			$5,936.77		
Incorporating Manure in Soil		36			$320.19		
Rock removal ($5/hour)		240			$1,200.00		
Total		943			$7,456.97	$0.79	$16.57
Fuel and Lube Costs					$1,625.05	$0.17	$3.61
Total Post Corral Variable Costs					$9,082.02	$0.96	$20.18
Risk Factor					?	?	?
Total Costs					$33,194.76	$3.52	$73.77
Less Value of Unapplied Fertilizer			Acres				
Pasture land			300		$13,081.50	$1.39	$29.07
Crop land			150		$6,540.75	$0.69	$14.54
Total					$19,622.25	$2.08	$43.61
Net Costs					$13,572.51	$1.44	$30.16

1 cu. yd = approx. 1171 lbs at 30% moisture

The number of loads of manure hauled per year was calculated by dividing the number of pounds of manure to be spread by the capacity of the manure spreader (10 cu. yd.).
Load per year = ((9417 tons * 2000)/11710 capacity) = 1608.4

Agronomists indicated that typical rates of fertilizer application in the area are 200-230 pounds of nitrogen, 70 pounds of phosphorus and 150-200 pounds of potassium.

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