Utilizing Animal Waste as a Source of Nitrogen

Miscellaneous CARD Report

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1. REVIEW OF THE NITROGEN COEFFICIENTS IN THE CARD MODEL

Nitrogen is one of the important inputs for crop production in the CARD linear programming models of U.S. agriculture. Nitrogen is obtained from fertilizer purchasing activities, from carry-over of legume crops, and from the nitrogen content of manure, a by-product of livestock production activities. This paper deals with the nitrogen produced by livestock activities. The coefficients that have been previously used are given in Table 1 together with the units used for each type of livestock. These coefficients were derived in 1971 by Vocke and Nicol and have been documented in [7]. This study is undertaken to revise these coefficients in light of recent technical standards on animal wastes and to identify any regional differences in the coefficients. To relate the current procedure with the previous one, a review of the data and methods used by Vocke and Nicol is presented.

Table 1. Nitrogen fertilizer equivalent wastes available from livestock by livestock class

Livestock Class	Coefficients (lbs. of N equivalent)	Unit of Livestock
Beef Cows	58.0	Head per year
Beef Feeders	0.103	Head per day
Dairy Cattle	142.0	Head per year
Hogs	2.8	Dressed hundredweight
Sheep Feeders	2.17	Dressed hundredweight
Broilers	28.0	Ready to cook 1000 lbs.
Layers	20.5	1000 dozen eggs

Nitrogen Content of Manure by Class of Livestock

Basic data for the nitrogen produced by hogs, beef cows, and dairy cattle are obtained by Vocke and Nicol from Ngoody et al. [6]. Vocke and Nicol obtained nitrogen production data for poultry from Miner [4] and determined nitrogen produced by sheep by taking an average of other classes of livestock. The coefficients they used (Table 2) were given in pounds of nitrogen per day per 1,000 pounds of animal weight.

Table 2. Nitrogen produced (lbs. per day per 1,000 lbs. of animal weight) by livestock class

Livestock Class	Value Reported	Value Used in Calculations[a]
Beef cattle[b]	0.30	0.30
Dairy cattle[b]	0.35-0.44	0.37
Hogs[b]	0.35-0.60	0.35
Poultry[c]	2.00	2.00

[a]Source: Vocke and Nicol [22].

[b]Source: Ngoody et al. [6].

[c]Source: Miner [4].

Adjustment to Animal Production Units

The adjustment of the coefficients in Table 2 for the production units used (Table 1) requires a number of assumptions. These assumptions are given in Table 3.

$$NP = \frac{NC \times AW \times TP}{1000} \quad (1)$$

where:

NP is the nitrogen by-product in animal wastes per unit of livestock activity;

NC is the appropriate nitrogen coefficient;

AW is the average weight of the livestock unit; and

TP is the time period for the livestock unit.

The values for hogs, sheep feeders, and broilers are adjusted using equation 2.

$$NP = \frac{NC \times AW \times TP \times SPUW}{1000 \times DP \times SW} \quad (2)$$

where:

NP is the nitrogen by-product in animal wastes per unit of livestock activity;

NC is the appropriate nitrogen coefficient;

AW is the average weight of the livestock unit;

TP is the time period for livestock;

SPUW is the standard production unit weight (100 lbs. for hogs and sheep feeders, 1000 lbs. for broilers);

DP is the dressing percent; and

SW is the slaughter weight.

The values for layers are adjusted using equation 3.

$$NP = \frac{NC \times AW \times 1000 \text{ dozen} \times 365}{1000 \times RL} \quad (3)$$

where:

NP is the nitrogen by-product in animal wastes per unit of livestock activity;

NC is the appropriate nitrogen coefficient;

AW is the average weight of the livestock unit; and

RL is the rate of lay.

The amount of nitrogen produced per animal unit is given in Table 3.

Table 3. Nitrogen production by livestock class

Livestock Class	Nitrogen Produced (lbs. N)	Unit of Livestock Activity
Beef cows	135.6	Head per year
Beef feeders	0.24	Head per day
Dairy cattle	215.4	Head per year
Hogs	7.2	Dressed hundredweight
Sheep feeders	20.5	Dressed hundredweight
Broilers	90.0	Ready to cook 1000 lbs.
Layers	82.1	1000 dozen eggs

Nitrogen Losses in Waste Handling Systems

Only part of the nitrogen that is produced by livestock reaches the soil because a significant amount is lost through volatilization, runoff, and so on. The major factor Vocke and Nicol use to estimate nitrogen losses is the waste handling system. Percentage nitrogen losses for each livestock activity are weighted averages of the waste handling system losses given by Vanderholm [20]. The percentage nitrogen losses are used to reduce the amount of nitrogen produced (Table 3) to the nitrogen coefficients in Table 1.

2. NITROGEN EXCRETED BY LIVESTOCK

Vocke and Nicol's [22] estimates of the nitrogen produced by class of livestock are revised in this section. The amount of nitrogen produced is calculated using equations 1-3 but with revised estimates of all parameters. Nitrogen production for hogs is also calculated by two different methods to give an indication of the size of the error in the estimates.

American Society of Agricultural Engineers Standards for Animal Wastes Characteristics

Standards for the characteristics of animal wastes were established in June, 1973, by the American Society of Agricultural Engineers (ASAE) [3]. These standards use the same units (lbs. of nitrogen per day per 1,000 lbs. of animal weight) used by Ngoody et al. [6] and give approximately the same coefficients for nitrogen produced. For poultry the ASAE coefficients, however, are significantly lower than those suggested by Miner [4].

Although providing a wider coverage of livestock activities, the ASAE data are more specific than either the Ngoody or Miner sources. For example, the ASAE provides data for feeder hogs but Ngoody et al. [6] refer to hogs in general. Livestock specialists [11, 12, 13] have suggested that coefficients referring to feeder animals would not be correct for breeding stock because the latter are fed a lower protein diet than feeder animals. The coefficients used in subsequent calculations (Table 4) are a combination of those given by Ngoody et al. [6] and by the ASAE

[3]. The coefficient derived from Miner [4] is discarded entirely because the ASAE provides a direct and more recent estimate.

Nitrogen as a By-Product of Hog Production

The following are three approaches used to estimate the amount of nitrogen produced by hogs: 1) based on the difference between the nitrogen content of the feed intake and the hog at slaughter; 2) using equation 1 with average weight and time periods determined from slaughter weight; and 3) using equation 2 with average weight, time period and slaughter weights determined by new assumptions about production relationships. The three calculations give results of 9.89, 6.55, and 6.60 lbs. of nitrogen produced per dressed hundredweight of pork, respectively.

Table 4. Revised coefficients for nitrogen produced (lbs. of nitrogen per day per 1,000 lbs of animal weight) by livestock class

Livestock Class	Nitrogen Coefficient
Beef cows[a]	0.30
Beef feeders[b]	0.34
Dairy cattle[b]	0.41
Hogs	
Breeding unit[a]	0.35
Feeders[b]	0.45
Sheep feeders[b]	1.16
Layers[b]	0.72

[a]Source: Ngoody et al. [6].

[b]Source: ASAE [3].

Approach 1: Calculation based on feed intake

This method is suggested by Stevermer [12]. Iowa State University Animal Science Extension has found that an average of 435 lbs. of feed is required to produce a 100 lb. gain in hogs. The nitrogen in the manure is calculated as the difference between the nitrogen in the feed and the nitrogen in a 100 lb. of hog at slaughter:[1]

Nitrogen in feed (2.2% of 435 lbs.)	9.57 lbs.
Nitrogen in hog (2.6% of 100 lbs.)	– 2.60 lbs.
Nitrogen excreted per 100 lbs. liveweight of gain	6.97 lbs.
Nitrogen excreted per 100 lbs. dressed weight	9.89 lbs.

Approach 2: Calculation based on slaughter weight

The average slaughter weight 1970-74 for all hogs in the U.S. is 240.5 lbs. [15]. The average slaughter weight is a weighted average of the slaughter weights of feeder hogs, sows, and boars:

$$0.93\ AFW + 0.06\ ASW + 0.01\ ABW = 240.5 \qquad (4)$$

where:

AFW is the average feeder weight at slaughter;

ASW is the average sow weight at slaughter;

ABW is the average boar weight at slaughter; and

0.93, 0.06, and 0.01 are the proportions of feeder hogs, sows, and boars, respectively, in the total U.S. slaughter 1970-74 [15].

[1]All figures from Stevermer [12] except for dressing percent. Dressing percent is an average 1970-74 for the U.S. [15] subtracting 7% for the weight of the head.

Based on 1970-74 data [15] it is assumed that the average ratios of feeder weight to sow weight and boar weight to sow weight are 0.54 and 1.2, respectively. The solution to equation 4 when using these ratios gives average weights at slaughter of 226, 419, and 503 lbs. for feeder hogs, sows, and boars, respectively. The nitrogen produced by each type of hog during its life is calculated using equation 1.[1] A weighted average of the nitrogen produced by each type of hog using the weights in equation 4 is 11.1 lbs. per hog slaughtered or equivalently 6.55 lbs. of nitrogen per dressed hundredweight.

Approach 3: Calculation based on production relationships

The nitrogen by-product of hog production is also calculated using equation 2. Assumptions for production parameters are given in Table 5. The result using this calculation is 6.60 lbs. of nitrogen per dressed hundredweight.

Evaluation of results

The estimate of nitrogen produced using Approach 1 (9.89 lbs. per dressed cwt of hog) is approximately one and one-half times the estimates made using approach 2 (6.55 lbs.) or approach 3 (6.60 lbs.). The amount of nitrogen produced estimated with Approach 1 is a measure of all nitrogen that is excreted. The estimates made using the other two approaches use the engineering coefficients from Table 4 and are, therefore, a measure of nitrogen found in manure. Significant amounts of nitrogen excreted may not be found in manure. The estimates

[1] Average weights during life and average age at slaughter are estimated from growth curves [3]. These are estimated to be 89, 267, and 313 lbs., and 166, 730, and 730 days for feeder hogs, sows, and boars, respectively.

made using approach 2 and 3 are more applicable for quantifying nitrogen available from manure.

Currently it is not possible to produce regional estimates with the data available. There is some indication that there may be considerable variation between states. The average number of pigs per litter varies from a high of 8.1 to a low of 5.6 between states in 1974 [15]. This is a production parameter used in approach 3. Approach 2 is the only method easily extended to other states. This approach gives very little variation between states because of the large number of factors used in the calculations that are national averages.

Nitrogen as a By-Product for Other Classes of Livestock

The amount of nitrogen produced by all other classes of livestock are estimated using the same methods as Vocke and Nicol [22]. A single national nitrogen production coefficient is estimated for all classes of livestock except beef cows and layers. Assumed values for the parameters of livestock production used in equations 1-3 are seen in Table 5. The estimates of the amount of nitrogen produced by production units are given in Table 6.

A higher weight is used for layers in the North Atlantic because of the larger proportion of brown eggs sold in that region [9]. Brown eggs are produced by a heavier breed of hen.

Five regional weights are used for beef cows. The different weights are based on cow weight and herd composition reported in a study by

Table 5. Revised values for parameters in livestock production

Livestock Class	Average Weight (lbs.)	Time[a] Period (days)	Slaughter Weight (lbs.)	Dressing Percent (%)	Rate of Lay (eggs/year)
Beef-Cows:[b]					
Corn Belt	1,250	365	-	-	-
Northern Plains	1,160	365	-	-	-
Intermountain	1,280	365	-	-	-
South East	1,230	365	-	-	-
Southern Plains	1,130	365	-	-	-
Beef Feeders[c]	800	1	-	-	-
Dairy Cattle[d]	1,363	365	-	-	-
Hogs:[e]					
Breeding Unit	400	365	200	70.5	-
Feeders	927	162	2,343	70.5	-
Sheep Feeders[f]	90	60	105	49.3	-
Broilers[g]	1.4	60.9	3.7	71.5	
Layers[h]					
North Atlantic	3.03	505	-	-	233
Other U.S.	2.85	505	-	-	226

[a]The time period refers to the length of time the animal is in the production unit during the year.

[b]See Table 7 for determination of average weights. Regions are defined in Appendix A.

[c]Rouse [11].

[d]The animal unit consists of one 1,200 lb. dairy cow and 1/4th of a 650 lb. replacement [5].

[e]Source: The feeders consist of 1.5 litters of 7.1 pigs each which weigh 220 lbs. at slaughter [12]. Average weight and age at slaughter determined from growth curves in [3]. Average weight and slaughter were for the breeding unit estimated by Stevermer [12]. Dressing percent is average dressing percent for the U.S. 1970-74 [15].

[f]Average weight is the median weight for sheep which enter a feedlot at 75 lbs. and are slaughtered in 60 days at 105 lbs. [23]. Dressing percent is an average 1970-74 for the U.S. [15].

[g]Slaughter weight for broilers is U.S. average 1970-74 [13]. Average weight and time period (age at slaughter) are calculated from growth curves for "typical" male and female broilers in Midwest Plan Service [3]. Dressing percent is an average 1970-74 for "young chickens" in the United States [14].

[h]The time period consists of the 20 weeks before hens start laying and a year spent laying. Final weights are 4.0 lbs. for the North Atlantic Region and 4.5 lbs. for the rest of the U.S. [9]. Average weights are assumed. Rate of lay is a weighted average of rates of lay of the states in each region [14]. The area included in the North Atlantic region is shown in Appendix A.

Nix [8]. The estimated weights of other animals in the herd and the weight of the animal unit are shown in Table 7.

3. NITROGEN LOSSES BY LIVESTOCK CLASSES

A significant proportion of the nitrogen produced by livestock never reaches the crops. Some of the nitrogen is lost in the waste handling systems and some is lost by livestock grazing on range lands. Even the nitrogen that reaches the fertilized land can not be completely utilized by the crops. Most of the nitrogen in the manure must be converted by bacteria to a form required by the crops. During that process, some of the nitrogen can be leached or washed away. The nitrogen that is left in the top soil can be substituted for chemically produced nitrogen.

Total nitrogen losses are estimated from the losses in the waste handling systems and in the soil for all classes of livestock except beef cows. It is assumed that nitrogen losses through self-broadcast by grazing livestock and in the waste handling systems are in the same proportion to nitrogen produced. This assumption is important for livestock classes which are frequently unconfined; i.e. dairy cattle and hogs. Total nitrogen losses for beef cows are estimated on the basis of the grazing system, the waste handling system, and losses in the soil.

Table 6. Revised nitrogen production by livestock class

Livestock Class	Nitrogen Produced (lbs. N)	Units of Livestock Activity
Beef Cows:[a,b]		
Corn Belt	137.	Head per year
Northern Plains	127.	Head per year
Intermountain	140.	Head per year
South East	135.	Head per year
Southern Plains	124.	Head per year
Beef Feeders[a]	.272	Head per day
Dairy Cattle[a]	204.	Head per year
Hogs[c]	6.60	Dressed hundredweight
Sheep Feeders[c]	4.70	Dressed hundredweight
Broilers[c]	37.4	Ready to cook 1000 lbs.
Layers:[b,d]		
North Atlantic	55.2	1000 dozen eggs
Other U.S.	56.7	1000 dozen eggs

[a]Calculated using equation 1.

[b]Regions are defined in Appendix A.

[c]Calculated using equation 2.

[d]Calculated using equation 3.

Table 7. Calculation of regional weights for beef cows

Region[a]	Cows weight[b] (lbs.)	Cows prop.[b]	Calves weight (lbs.)	Calves prop.[b]	Replacements weight (lbs.)	Replacements prop.[b]	Bulls weight (lbs.)	Bulls prop.[b]
Corn Belt	1,000	1.0	190	.64	425	.20	1,200	.04
Northern Plains	950	1.0	160	.68	340	.16	1,140	.04
Intermountain	900	1.0	140	.47	550	.46	1,080	.06
Southeast	1,000	1.0	180	.66	425	.16	1,200	.04
Southern Plains	900	1.0	180	.71	325	.15	1,080	.05

[a]Regions are defined in Appendix A.

[b]Source: Nix [8].

Waste Handling System Losses

Nitrogen losses have been estimated by Vanderholm [21] for five representative waste handling systems. These systems and the percent of nitrogen loss are given in Table 8. Some manure is dumped on waste land, incinerated, limed or pitted [17,18,19]. All these methods are included in Table 8 as a sixth system.

Table 8. Estimates of nitrogen loss by physical waste handling system

Physical Handling System	Percent of Nitrogen Loss
I Deep pit storage and liquid spreading	35 to 65
II Anaerobic lagoon and irrigation or liquid spreading	60 to 80
III Oxidation ditch, anerobic lagoon, and irrigation or liquid spreading	70 to 90
IV Bedded confinement and solid spreading	30 to 40
V Open lot, solid spreading, and runoff collected and irrigated	50 to 60
VI Dumped on waste land, incinerated, limed or pitted	100

Source: Vanderholm [21].

The distribution of animal wastes between waste handling systems is needed to apply the data in Table 8. The 1969 Census of Agriculture [17,18,19] provides a distribution of waste handling systems used to dispose of livestock wastes. In the Census, producers were asked which of the following methods they used to dispose of livestock wastes:

1. solid spread on own land;
2. slurry or spray spread on own land;
3. lagoon;
4. sold;
5. dumped on waste land;
6. incinerated, limed or pitted; and
7. other.

Producers were also allowed more than one answer. The number of responses for each method of waste disposal is given by state and by county for beef, dairy cattle, hogs, sheep and goats, and poultry.

Some assumptions are necessary to relate the physical waste handling systems given in the census and those identified in Table 8. No data are available on nitrogen losses from manure that is sold or disposed of by the method "other". Therefore, nitrogen losses for these two methods are assumed to be the same as the weighted average of nitrogen losses of all other handling systems. It is assumed that farmers who reported using lagoons and those who reported spraying a liquid or slurry are mutually exclusive. This assumption is made because a larger number of farmers reported using a lagoon than reported spraying in many states. All these assumptions result in the following four methods of waste handling: 1) solid spreading, 2) deep pit and liquid spreading, 3) lagoon and liquid spreading, 4) and dumped on waste land, incinerated, limed, or pitted. The nitrogen losses assumed for these four methods are given in Table 9.

Table 9. Nitrogen losses in physical waste handling systems by livestock class

Livestock Class	Solid Spreading (% N Loss)	Liquid Spreading[a] (% N Loss)	Lagoon[b] (% N Loss)	Dumped on Waste Land etc.,[c] (% N Loss)
Beef Cows	60.0[d]	-	-	-
Beef Feeders	55.0[e]	47.5	70.0	100.0
Dairy Cows	45.0[f]	47.5	70.0	100.0
Hogs	50.0[g]	47.5	70.0	100.0
Sheep Feeders	60.0[d]	47.5	70.0	100.0
Broilers	35.0[h]	47.5	70.0	100.0
Layers	35.0[h]	47.5	70.0	100.0

[a]Median value for system I in Table 8.

[b]Median value for System II in Table 8.

[c]System VI in Table 8.

[d]System V in Table 8 with high losses.

[e]Median value for system V in Table 8.

[f]Average median value for systems IV and V in Table 8.

[g]System V in Table 8 with low losses.

[h]Median value for System IV in Table 8.

Distribution of Wastes and Waste Handling Systems

The proportion of manure that is disposed by each of these four systems is not the same as the proportion of farms using each system. Lagoon and liquid spray systems are used by relatively large farms. But the system of dumped on waste land, incinerated, limed, or pitted is used by relatively small farms [2]. The distribution of waste handling systems is transformed into a distribution of wastes by handling systems using reported distribution of farms by farm size [16].

Livestock farms are divided into three nonexclusive sizes (small, medium, and large) for each livestock class in each region. Dumped on wasteland, incinerated, limed, or pitted is assumed for small farms; solid spreading is assumed for medium size farms; liquid spreading and lagoons is assumed for large farms. Weights for relative farm size are calculated as follows:

$$w_{ilr} = \frac{AS_{i\ell r}}{AS_{1\ell r}} \qquad (5)$$

$i = 1,2,3,4$ for the waste handling system,

$\ell = 1,\ldots,6$ for the livestock class,

$r = 1,2,\ldots,$ for the region.

where:

$w_{i\ell r}$ is the weight for waste handling system i livestock class ℓ in region r;

$AS_{i\ell r}$ is the average farm size for waste handling system i and livestock class ℓ in region r; and

$AS_{1\ell r}$ is the average farm size of medium farms for solid waste handling system and livestock class ℓ in region r.

The proportion of wastes disposed by each waste handling system is calculated using equation 6:

$$W_{i\ell r} = \frac{w_{i\ell r} WHS_{ier}}{\sum_{i=1}^{4} w_{i\ell r} WHS_{i\ell r}} \qquad (6)$$

$i = 1,2,3,4$ for the waste handling system,

$\ell = 1,\ldots,6$ for the livestock class,

$r = 1,2,\ldots$ for the region.

where:

$W_{i\ell r}$ is the proportion of wastes that are disposed of by waste handling system i and livestock class ℓ in region r;

$w_{i\ell r}$ is the weight for waste handling system i and livestock class ℓ in region r calculated in equation 5; and

$WHS_{i\ell r}$ is the proportion of farmers reporting using waste handling system i for livestock class ℓ in region r.

The proportion of the nitrogen loss by livestock class and region is the weighted sum of the nitrogen loss in all four waste handling systems:

$$NL_{\ell r} = \sum_{i=1}^{4} W_{i\ell r}\, NLS_{i\ell} \qquad (7)$$

$i = 1,2,3,4$ for the waste handling systems,

$\ell = 1,\ldots,6$ for the livestock class

$r = 1,2,\ldots$ for the region.

where:

$NL_{\ell r}$ is the proportion of nitrogen loss for livestock class ℓ in region r;

$W_{i\ell r}$ is the proportion of wastes that are disposed of by waste handling system i and livestock class ℓ in region r; and

$NLS_{i\ell}$ is the nitrogen loss for waste handling system i and livestock class ℓ from Table 9.

The proportion of farms which reported using each waste handling system, weights, and the proportion of wastes disposed by each waste handling system are given in Appendix B. The estimates of the percent of nitrogen loss by livestock class are shown in Table 10.

Table 10. Percent of nitrogen losses in physical waste handling systems by region and livestock class

Regions[a]	Beef Feeders	Dairy Cattle	Hogs	Sheep Feeders	Broilers	Layers
North Central	-	48	50	-	40	40
North Atlantic	-	47	52	-	42	42
South Atlantic	-	54	70	-	43	43
South Central	-	56	66	-	42	42
South West	-	56	68	-	47	42
Great Plains	-	49	53	-	40	47
North West	-	48	60	-	40	40
New England	58	-	-	-	-	-
Middle Atlantic	53	-	-	-	-	-
East North Central	54	-	-	-	-	-
West North Central	55	-	-	-	-	-
East South Central	55	-	-	-	-	-
West South Central	60	-	-	-	-	-
South Atlantic	57	-	-	-	-	-
Mountain	55	-	-	-	-	-
Pacific	55	-	-	-	-	-
United States	-	-	-	60	-	-

[a]Regions are defined in Appendix A.

Nitrogen Losses for Beef Cows

The grazing system is the most important factor determining total nitrogen loss for beef cows. The estimates of nitrogen loss for beef cows are, therefore, based on the grazing system as well as the handling system and losses in the soil.

Within each region identified by Nix [8], an estimate is made of the proportion of the year the beef cows spend in each of the following feeding systems:

1. grazing on rangeland or permanent pasture;
2. grazing on cropland (rotation pasture, aftermath hay, or stubble); and
3. feeding in relatively close confinement requiring the collection and disposal of manure.

These proportions also indicate the proportion of total nitrogen produced that is self-broadcast on rangeland, on cropland, and disposed through a waste handling system. The percent of nitrogen loss is assumed to be 100 percent, 10 percent [2], and 60 percent (System I in Table 8) for the three feeding systems, respectively.

The time spent in each of the above feeding systems for the five regions are given in Table 11. Beef cows spend the entire year on permanent pasture in the Southern Plains region. In the Southeast, beef cows spend the whole year on permanent pasture or stubble. In other regions combinations of all three methods are used.

Table 11. Time spent on each of the three feeding methods by beef cows by region

	Grazing on[a] Range Land (days)	Grazing on[a] Crop (days)	Confinement[a] Time (days)	Nitrogen Loss Percent
Corn Belt	130	175	60	50
Northern Plains	140	150	75	55
Intermountain	245	110	10	72
Southeast	305	60	0	85
Southern Plains	365	0	0	100

[a]Source: Estimates made by Strohbehn [13].

The total nitrogen loss through grazing and in the handling of the manure is the weighted sum of the nitrogen loss in each grazing system:

$$NL_r = \sum_{i=1}^{3} \frac{GSL_i D_{ir}}{365} \qquad (8)$$

$i = 1,2,3$ for the grazing system,

$r = 1,\ldots,5$ for the region.

where:

NL_r is the percent of nitrogen loss in region r;

GSL_i is the percent of nitrogen loss in grazing system i; and

D_{ir} is the number of days per year spent by beef cows in feeding system i in region r.

The estimates of percent of nitrogen loss for beef cows by regions are reported in Table 11.

Nitrogen Losses in the Soil

Pratt et al. [10] have estimated the decay series for various types of manure shown in Table 12. Soil losses reduce the nitrogen available from manure which is applied to crops. The decay series in Table 12 provides a basis for the additional nitrogen losses that are shown in Table 13.

Table 12. Decay series for nitrogen in manures[a]

Manure	Percent of Remaining Manure Available in Year						
	1	2	3	4	5	6	7
Chicken							
Cold Climate	90	10	7.5	5	4	3	-
Warm Climate	90	10	5	-	-	-	-
Fresh Bovine							
Cold Climate	75	15	10	7.5	5	4	3
Warm Climate	75	15	10	5	-	-	-
Dry Corral (2.5% N)							
Cold Climate	40	25	6	3	-	-	-
Warm Climate	40	25	6	-	-	-	-
Dry Corral (1.5% N)							
Cold Climate	35	15	10	7.5	5	4	-
Warm Climate	35	15	10	5	-	-	-
Dry Corral (1.0 N)							
Cold Climate	20	10	7.5	5	4	3	-
Warm Climate	20	10	5	-	-	-	-

[a]Source: Pratt et al. [10] and Azevedo [1].

Table 13. Soil loss of available nitrogen in manures

Livestock Class	Percent Loss
Beef cows (confined)	45
Beef cows (grazing)	20
Beef feeders	35
Dairy cattle	20
Hogs	20
Sheep feeders	40
Broilers	10
Layers	10

Final Results

The chemical fertilizer equivalent of the nitrogen produced by livestock is calculated using equation 9:

$$NE_{\ell r} = NP_{\ell r} (1 - NL_{\ell r}) (1 - SL_{\ell}) \qquad (9)$$

$\ell = 1,\ldots,6$ for the livestock class,

$r = 1,2,\ldots$ for the region.

where:

$NE_{\ell r}$ is the nitrogen fertilizer equivalent wastes available from a unit livestock ℓ in region r;

$NP_{\ell r}$ is the nitrogen produced by livestock class ℓ in region r from Table 6;

$NL_{\ell r}$ is the proportion of nitrogen loss in the waste handling system for livestock ℓ in region r from Tables 10 and 11; and

SL_{ℓ} is the proportion nitrogen loss in the soil for livestock class ℓ from Table 13.

The final results are reported in Table 14.

Regional variation is greatest for beef cows and hogs. The high variation in the results for beef cows is because of very different grazing systems used in different regions. The high variation in the results for hogs is because of the extensive use of lagoons and dumping of hog manure in southern states.

The final coefficients are lower than those estimated by Vocke and Nicol for all classes of livestock except layers. Higher total losses are generally found because soil losses are incorporated into the estimates.

Table 14. Revised values for manure as nitrogen fertilizer equivalent (lbs. per unit) available from livestock by livestock class and region

Regions[a]	Beef cows (head/year)	Beef feeders (head/	Dairy cattle (head/year)	Hogs (dressed cwt.)	Sheep feeders (dressed cwt.)	Broilers (1,000 lbs.) RTC[b]	Layers (1,000 doz.) eggs
North Central	-	-	85.7	2.6	-	20.2	29.4
North Atlantic	-	-	85.7	2.5	-	19.5	30.2
South Atlantic	-	-	75.5	1.5	-	19.2	27.7
South Central	-	-	71.4	1.8	-	19.5	28.3
South West	-	-	71.4	1.7	-	19.5	28.3
Great Plains	-	-	83.6	2.5	-	17.8	26.1
North West	-	-	85.7	2.1	-	20.2	29.4
New England	-	.073	-	-	-	-	-
Middle Atlantic	-	.084	-	-	-	-	-
East North Central	-	.082	-	-	-	-	-
West North Central	-	.079	-	-	-	-	-
East South Central	-	.079	-	-	-	-	-
West South Central	-	.071	-	-	-	-	-
South Atlantic	-	.076	-	-	-	-	-
Mountain	-	.079	-	-	-	-	-
Pacific	-	.079	-	-	-	-	-
Corn Belt	52.2	-	-	-	-	-	-
Northern Plains	43.3	-	-	-	-	-	-
Intermountain	31.3	-	-	-	-	-	-
Southeast	16.2	-	-	-	-	-	-
Southern Plains	0	-	-	-	-	-	-
United States	-	-	-	-	1.1	-	-

[a]Regions are defined in Appendix A.

[b]Ready-to-cook weight.

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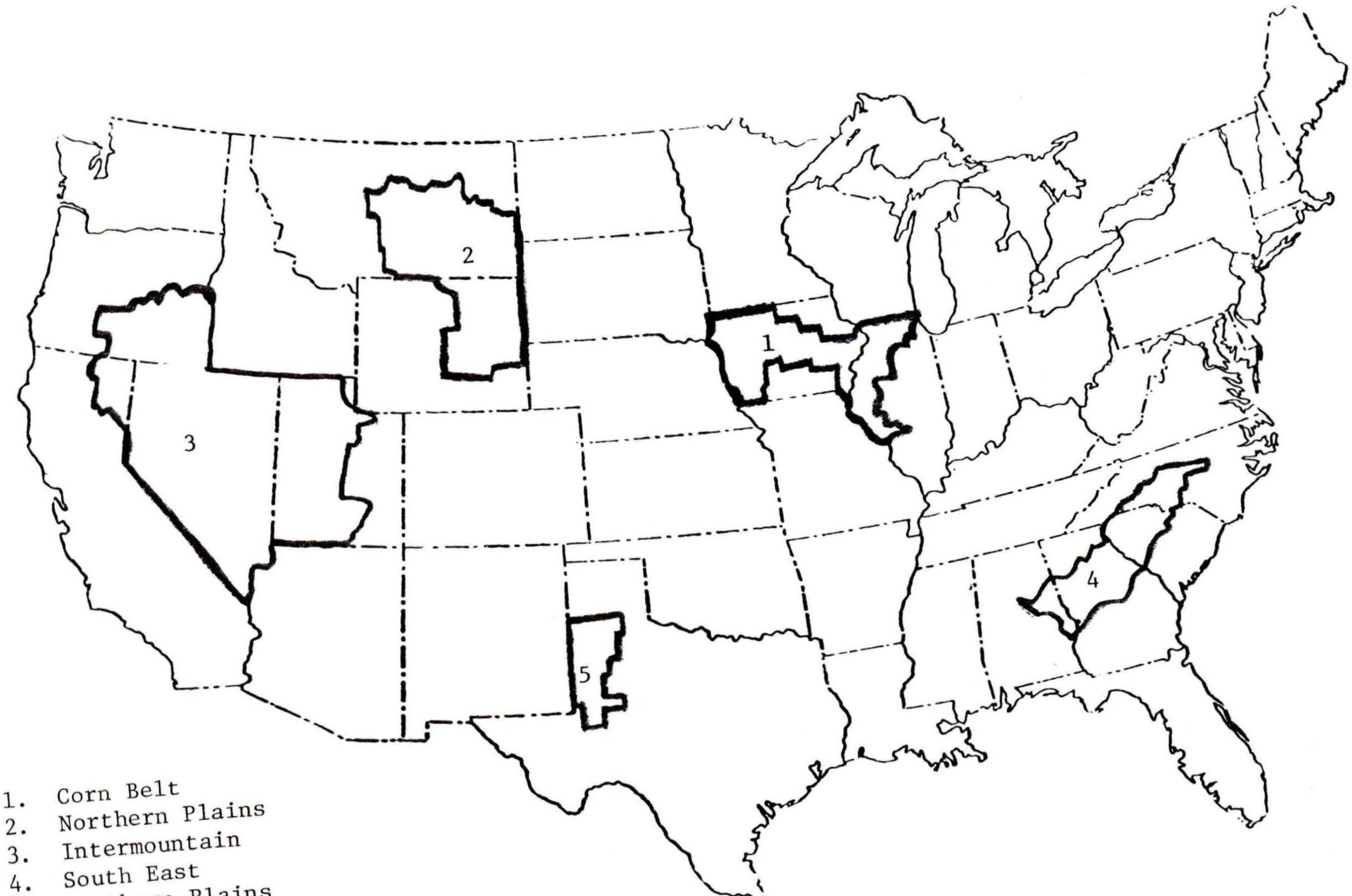
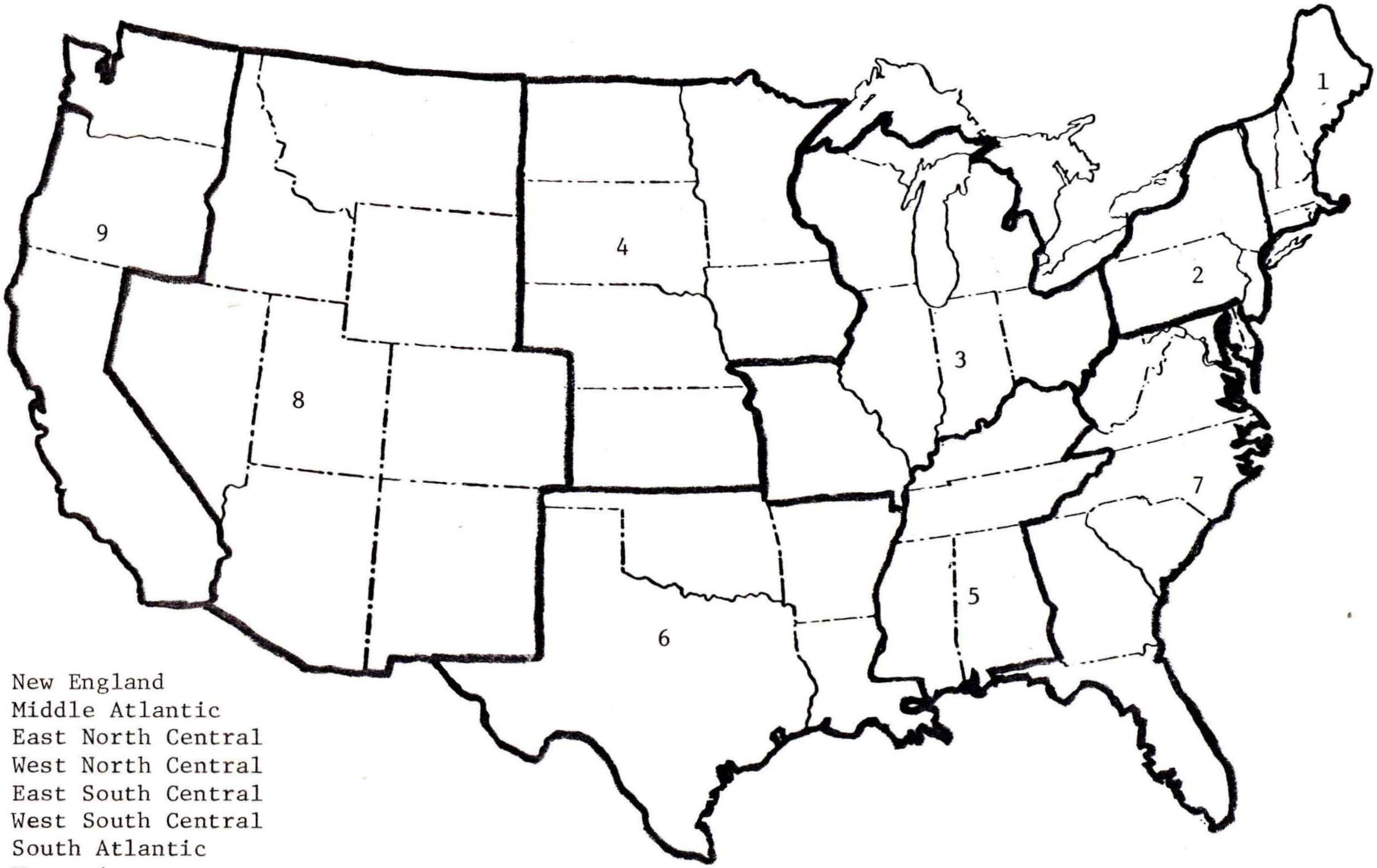
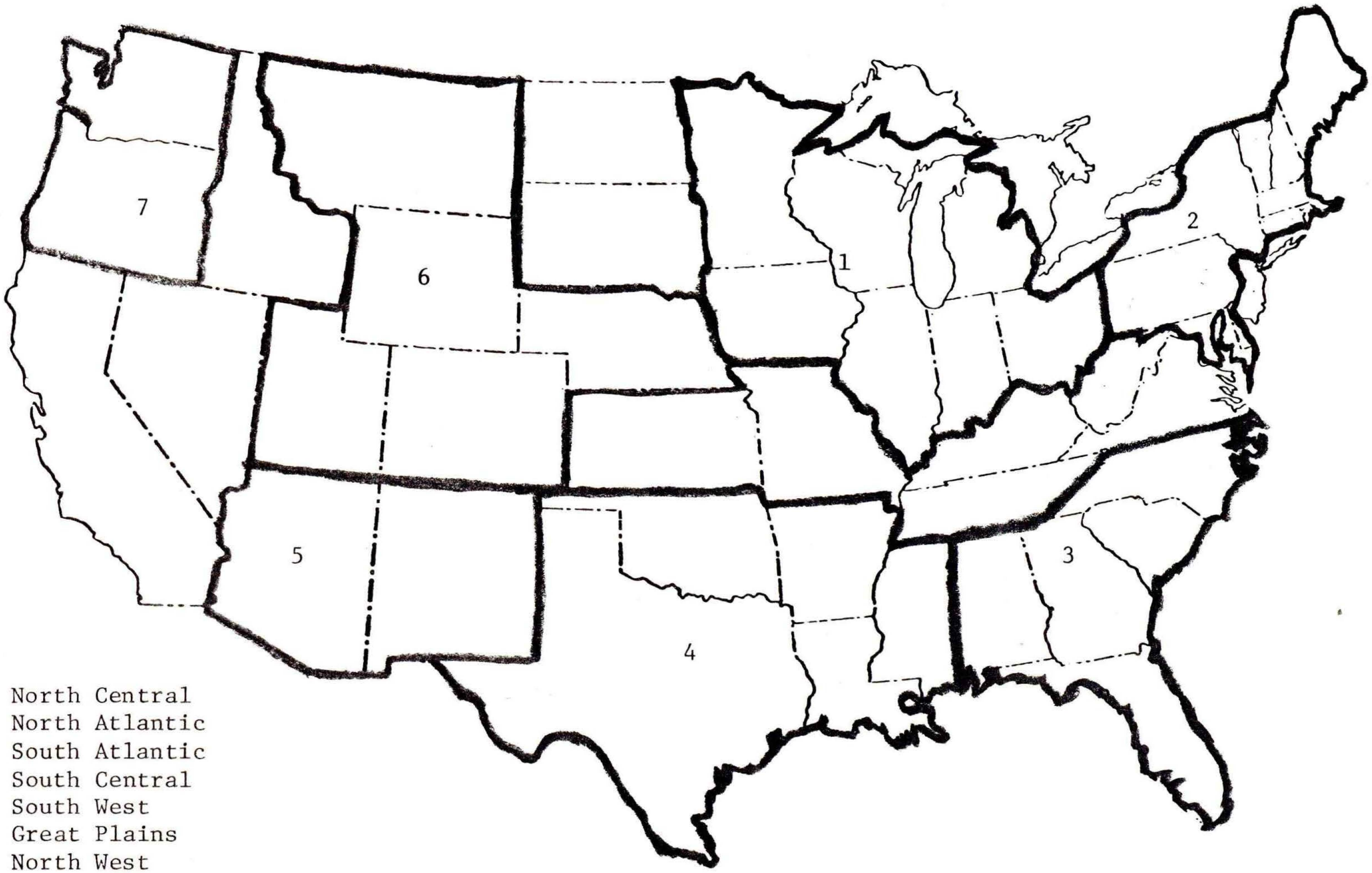


Figure A.1. The beef cow regions



1. New England
2. Middle Atlantic
3. East North Central
4. West North Central
5. East South Central
6. West South Central
7. South Atlantic
8. Mountain
9. Pacific

Figure A.2. The beef feeder regions



1. North Central
2. North Atlantic
3. South Atlantic
4. South Central
5. South West
6. Great Plains
7. North West

Figure A.3. The regions for dairy cattle, hogs, broilers, and layers

APPENDIX B

Distributions of Animal Waste Handling Methods, Weights, and Distributions of Animal Wastes by Waste Handling Methods

Table B.1. Proportion of dairy farms reported using four different waste handling systems

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	.93	.04	.01	.02
North Atlantic	.94	.04	.01	.02
South Atlantic	.72	.08	.07	.13
South Central	.66	.06	.08	.20
South West	.59	.09	.14	.19
North West	.70	.26	.02	.02
Great Plains	.87	.07	.02	.03

Table B.2. Proportion of hog farms reported using four different waste handling systems

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	.90	.08	.01	.01
North Atlantic	.87	.09	.01	.26
South Atlantic	.23	.05	.45	.03
South Central	.39	.07	.29	.25
South West	.32	.03	.34	.32
North West	.62	.11	.13	.14
Great Plains	.89	.06	.02	.04

Table B.3. Proportion of broiler and layer farms reported using four different waste handling systems

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	.83	.09	.01	.07
North Atlantic	.72	.05	.01	.23
South Atlantic	.73	.03	.01	.23
South Central	.77	.04	.01	.18
South West	.77	.04	.01	.18
North West	.69	.03	.04	.25
Great Plains	.80	.06	.02	.12

Table B.4. Proportion of beef farms reported using four different waste handling systems

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
New England	.93	.02	.02	.02
Middle Atlantic	.92	.06	.01	.01
East North Central	.96	.03	-	.02
West North Central	.93	.02	.01	.04
East South Central	.81	.05	.02	.02
South Atlantic	.82	.04	.02	.12
West South Central	.60	.06	.05	.30
Mountain	.85	.03	.01	.11
Pacific	.77	.03	.01	.18

Table B.5. Weights for relative farm size for dairy farms

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	1.0	3.9	3.9	0.9
North Atlantic	1.0	3.3	3.3	0.8
South Atlantic	1.0	3.9	3.9	0.5
South Central	1.0	2.7	2.7	0.6
South West	1.0	2.4	2.4	0.3
North West	1.0	3.0	3.0	0.6
Great Plains	1.0	3.1	3.1	0.6

Table B.6. Weights for relative farm size for hog farms

Regions	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	1.0	2.8	2.8	0.7
North Atlantic	1.0	1.2	1.2	0.8
South Atlantic	1.0	4.9	4.9	0.8
South Central	1.0	2.9	2.9	0.8
South West	1.0	2.2	2.2	0.7
North West	1.0	2.3	2.3	0.7
Great Plains	1.0	3.1	3.1	0.7

Table B.7. Weights for relative farm size for broiler and layer farms

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	1.0	2.7	2.7	0.3
North Atlantic	1.0	1.8	1.8	0.3
South Atlantic	1.0	2.2	2.2	0.5
South Central	1.0	1.8	1.8	0.4
South West	1.0	1.8	1.8	0.4
North West	1.0	1.7	1.7	0.3
Great Plains	1.0	3.3	3.3	0.3

Table B.8. Weights for relative farm size for beef farms

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
New England	1.0	8.9	8.9	0.5
Middle Atlantic	1.0	13.8	13.8	0.4
East North Central	1.0	9.9	9.9	0.4
West North Central	1.0	14.5	14.5	0.4
East South Central	1.0	10.2	10.2	0.5
South Atlantic	1.0	10.0	10.0	0.5
West South Central	1.0	14.6	14.6	0.0
Mountain	1.0	32.4	32.4	0.3
Pacific	1.0	8.4	8.4	0.1

Table B.9. Proportion of manure disposed by handling system for dairy farms

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	.81	.14	.03	.02
North Atlantic	.84	.12	.03	.01
South Atlantic	.53	.23	.20	.05
South Central	.57	.14	.19	.10
South West	.49	.18	.28	.05
North West	.45	.50	.04	.01
Great Plains	.75	.19	.05	.02

Table B.10. Proportion of manure disposed by handling system for hog farms

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	.78	.19	.02	.01
North Atlantic	.22	.06	.52	.20
South Atlantic	.63	.32	.04	.02
South Central	.24	.12	.51	.12
South West	.24	.05	.55	.16
North West	.49	.20	.24	.08
Great Plains	.78	.16	.05	.02

Table B.11. Proportion of manure disposed by handling system for broiler and layer farms

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
North Central	.74	.22	.02	.02
North Atlantic	.79	.10	.02	.07
South Atlantic	.79	.07	.02	.12
South Central	.83	.08	.02	.08
South West	.87	.08	.03	.08
North West	.83	.11	.04	.03
Great Plains	.69	.10	.13	.08

Table B.12. Proportion of manure disposed by handling system for beef feeders

Region	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
New England	.72	.14	.14	.01
Middle Atlantic	.49	.44	.07	-
East North Central	.76	.23	-	.01
West North Central	.37	.10	.08	.01
East South Central	.29	.16	.09	.01
South Atlantic	.55	.27	.14	.04
West South Central	.27	.39	.33	.01
Mountain	.39	.45	.15	.02
Pacific	.69	.22	.07	.02

Table B.13. Handling of sheep manure in the United States

	Solid Spreading	Deep Pit Liquid Spreading	Lagoon Liquid Spreading	Incinerated Land etc.
Proportion of farms using each handling system	.93	.01	-	.06
Weights for relative farm size	1.0	7.0	-	.04
Proportion of manure disposed by handling system	.91	.07	-	.02

APPENDIX C

Suggested Nitrogen from Livestock Coefficients for 28 Market Regions

Table C.1. Nitrogen equivalent animal wastes for CARD livestock market regions

Market Region	Beef Cow[a]	Beef Feeders[b]	Dairy Cows[c]	Hogs[d]	Sheep[e]	Broilers[f]	Layers[g]
Boston	52.2	.073	85.7	2.5	1.1	19.5	30.2
N. York	52.2	.084	85.7	2.5	1.1	19.5	30.2
Baltimore	25.0	.076	80.6	2.1	1.1	19.4	29.0
Charleston	16.2	.076	75.5	1.5	1.1	19.2	27.7
Atlanta	16.2	.076	75.5	1.5	1.1	19.2	27.7
Miami	16.2	.076	75.5	1.5	1.1	19.2	27.7
Pittsburgh	52.2	.081	85.7	2.6	1.1	19.9	29.8
Detroit	52.2	.082	85.7	2.6	1.1	20.2	29.4
Cincinnati	52.2	.081	85.7	2.6	1.1	20.2	29.4
Memphis	25.0	.077	73.5	1.8	1.1	19.5	28.0
N. Orleans	10.0	.075	71.4	1.8	1.1	19.5	28.3
Chicago	52.2	.082	85.7	2.6	1.1	20.2	29.4
St. Louis	52.2	.082	85.7	2.6	1.1	20.2	29.4
Minneapolis	52.2	.081	85.7	2.6	1.1	20.2	29.4
Des Moines	52.2	.081	85.7	2.6	1.1	20.2	29.4
Billings	43.3	.079	83.6	2.5	1.1	17.8	26.1
Kansas City	52.2	.081	80.2	2.3	1.1	19.2	27.9
Okalhoma City	8.0	.074	71.4	1.8	1.1	19.5	28.3
Houston	8.0	.071	71.4	1.8	1.1	19.5	28.3
San Antonio	8.0	.071	71.4	1.8	1.1	19.5	28.3
Denver	43.3	.079	83.6	2.5	1.1	17.8	26.1
Amarillo	0	.071	71.4	1.8	1.1	19.5	28.3
El Paso	0	.075	71.4	1.8	1.1	19.5	28.3
Seattle	31.3	.079	85.7	2.1	1.1	20.2	29.4
Salt Lake City	31.3	.079	83.6	2.5	1.1	17.8	26.1
Phoenix	0	.079	71.4	1.6	1.1	19.5	28.3
San Francisco	31.3	.079	80.2	2.1	1.1	19.2	27.9
Los Angelos	15.0	.079	75.8	1.9	1.1	19.4	28.1

[a]Pounds of nitrogen per beef cow per year.

[b]Pounds of nitrogen per beef feeder per day.

[c]Pounds of nitrogen per dairy cow per year.

[d]Pounds of nitrogen per dressed hundred weight of pork.

[e]Pounds of nitrogen per dressed hundredweight of sheep.

[f]Pounds of nitrogen per 1,000 lbs. ready to cook weight of broilers.

[g]Pounds of nitrogen per 1,000 dozen eggs.

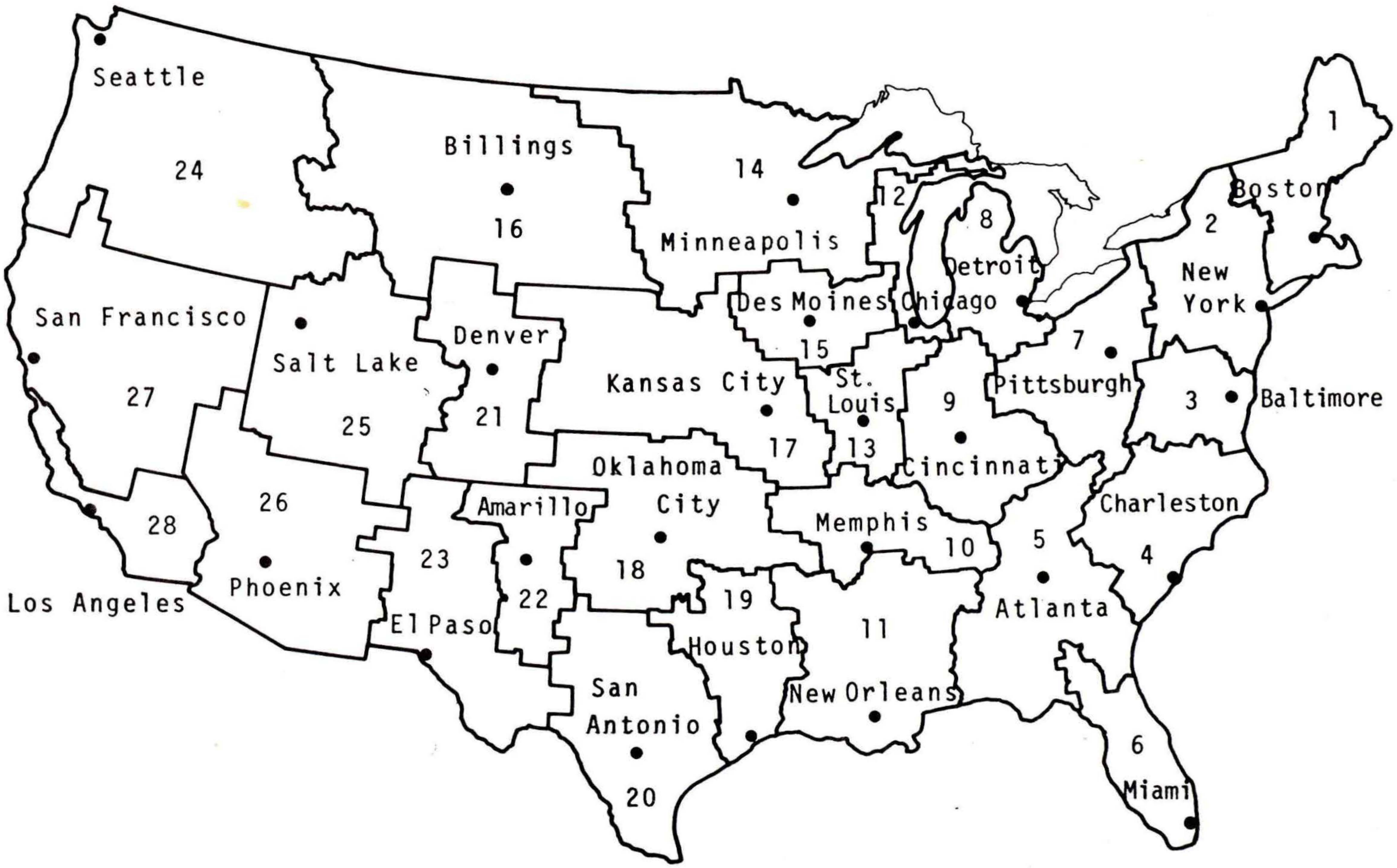


Figure C.1. Twenty-eight market regions

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