USING ANIMAL DENSITY STANDARDS FOR NUTRIENT MANAGEMENT POLICY ON WISCONSIN DAIRY FARMS

Heather Saam, J. Mark Powell, Douglas Jackson-Smith, William Bland, and Joshua Posner

INTRODUCTION

As demands for more controlled manure management heighten, policy makers seek indicators to assess the environmental impacts of livestock production and to subsequently direct manure management policy. Farm size indicators, based on number of animals per farm, are currently used to target federal manure management policy (USDA-USEPA, 1999). In this way, federal policy is directed toward the nations' largest livestock facilities. However, as it is becoming increasingly evident that all farms, regardless of size, have an important role to play in protecting the environment from nutrient pollution, state and local policy makers have begun to cast the nutrient management policy net more broadly.

In October of 2002, the Wisconsin state legislature passed a set of eight administrative rules and performance standards directed at the control and prevention of polluted runoff (WDNR, 2003). Agricultural-related pollution abatement efforts are directed toward controlling nutrient losses through the implementation of nutrient management plans on all Wisconsin farms by the year 2008. Nutrient management plans will only be mandatory, however, if the state provides at least 70% of the cost of pollution abatement technologies (e.g., buffer strips, manure storage, development of nutrient management plans), with cost-sharing monies initially directed toward designated water quality impairment zones.

While Wisconsin and other states have a long history of using watershed-based indicators to direct pollution abatement efforts, providing blanket cost-sharing coverage or technical assistance to farms within a watershed is likely to reward operators that already are doing a good job of managing nutrients. Public and private sector costs often increase as a result, which are not offset by the benefits of improving the impaired water resource (Shortle, 1999). Because funding is likely to become a limiting factor in implementing Wisconsin's non-point rules (Nowak, 2001), it is important that cost-sharing monies are directed toward operations most likely contributing to non-point pollution problems. An alternative to herd size or location-based indicators for targeting nutrient management policy is animal density, expressed in terms of animals per unit area of cropland.

Animal density is increasingly being used in Europe (Sibbesen and Runge-Metzger, 1995) and in certain parts of the U.S. (Ribaudo et al., 2003). The strength of using animal density as a regulatory standard lies in its ability to provide a straightforward, relatively easy to calculate indicator of a farm's nutrient balancing potential. By characterizing the relationship of animal numbers (and the manure they produce) to the available cropland area for manure utilization, animal density addresses the core movement of nutrients within the farm nutrient cycle (Beegle, 1994). Without adequate cropland on which to recycle manure nutrients, farms of all size have an increased potential for nutrient loss.

While the concept of using animal density as an indicator of nutrient balancing potential is fairly transparent, certain assumptions about feeding practices and the land base available for manure application need to be considered. For example, feeding practice can have a dramatic effect on manure P levels and the amount of land needed to recycle manure P (Powell et al., 2001). Also, it may not be reasonable to assume, given cropping practices and soil and climatic constraints, that all cropland would be available for manure application on an annual basis. In formulating animal density standards, one must consider how to most accurately define the land base potentially available for manure application. The objective of this study was to investigate the implications of using alternative definitions of animal density standards to target nutrient management policy on Wisconsin dairy farms. Different conceptualizations of the land base available for manure application are developed and used to (1) predict the ability of Wisconsin dairy farmers to balance manure production with adequate cropland for recycling manure nutrients, (2) explore the relationship between dairy herd size, herd size expansion, and animal density levels, and (3) contrast cropland area potentially available for manure application with actual reported manure spreading areas.

MATERIALS AND METHODS

In the late-winter and early-spring of 1999, a state-wide random survey of approximately 1,600 representative Wisconsin dairy farmers was conducted (Buttel et al., 1999). Data on dairy herd size, livestock inventories, and crop production were used to calculate animal densities (animal:land ratios). Three categories of cropland available for manure application were considered: total cropland (sum of all cropping acreages), tilled cropland (all cropping acreage BUT only 1/3 of hay acreage and 65% of soybean acreage), and manured cropland (actual acreage reported to receive manure annually). Three different animal:cropland ratios (ALRs) were thus calculated for each farm: (1) animal units:total cropland (ACLR), (2) animal units:tilled cropland (ATLR), and (3) animal units:manured cropland (AMLR).

Low, medium, and high animal density categories (Table 1) were delineated based on the amount of N and P in manure and the average removal of these nutrients by a typical dairy cropping system. Annual manure N production of an AU was adapted from Klausner (1997) and manure P production from Powell et al. (2001) assuming manure from a cow fed a diet containing 0.38% P on dry matter basis. Animal density categories assume that all manure is captured. The amount of manure remaining in pasture, exercise lots, and uneven land spreading of manure are not considered. Also, estimations of nutrient balancing potential do not account for nutrient additions from legume N, commercial fertilizer, and existing soil nutrient levels.

Table 1. Calculated animal:cropland ratio threshold levels for Wisconsin dairy farms

Animal density category	Animal:cropland ratio (AU acre-1)	Implication for nutrient management
Low	< 0.75	Crop P requirements met by manure, N deficit
Medium	0.75 to 1.5	P surplus, crop N requirements met by manure
High	>1.5	P and N surplus

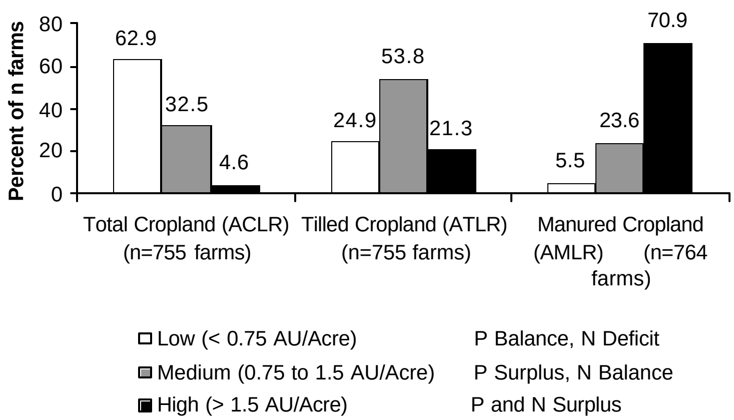
RESULTS

Animal Density by Cropland Category

The degree to which Wisconsin dairy farmers have sufficient cropland for recycling manure nutrients greatly depends on the definition of available cropland used to calculate the animal density ratio (Figure 1). As the definition of available cropland used to calculate the ALR is increasingly restricted from total, to tilled, to actually manured cropland, the percentage of medium and high ALRs increases substantially.

ACLRs indicate that most (95%) Wisconsin dairy farmers have sufficient cropland for meeting N-based manure application standards, and 63% have sufficient cropland for meeting P-based standards. Under ATLR calculations, about 79% of farmers have sufficient cropland for meeting, and not exceeding crop N requirements. However, 75% of farms produce manure in excess of crop P requirements.

Figure 1. Animal density by cropland category for Wisconsin dairy farms



ACLR and ATLR indicators (Figure 1) estimate a dairy farm's ability to recycle manure N and P based on the assumption that manure is applied evenly across each land type. AMLRs, on the other hand, take actual manure spreading behavior into account. Under AMLR calculations, about 71% of Wisconsin dairy farms apparently apply manure in excess of crop N and P requirements. Only 5.5% of farms fall into the low ALR category, which means actual spreading behavior meets P-based application standards. Approximately 24% of farms have medium animal densities and are able to meet N-based manure application standards, but manure applications would exceed crop P requirements.

Impacts of Herd Size and Herd Size Expansion on Animal Density Levels

Herd size. Having sufficient cropland for agronomic manure application rates is a key aspect of nutrient management planning. Without an adequate land base on which to recycle manure nutrients livestock operations of all sizes have an increased risk of over-applying manure and polluting the environment. Our analyses suggest that the distribution of animal density categories is somewhat similar on dairy farms having herd size of less than 200 cows (Table 2). Dairy farms having more than 200 cows, however, have greater percentages of medium and high density farms, and fewer low density farms compared to other herd size categories.

Herd size expansion. Over the past few decades, Wisconsin's dairy industry has followed national trends (USDA, 2000) toward fewer but larger dairy operations. Dairy herd expansions resulting in greater than 1,000 AU are regulated under federal permitting requirements (USEPA, 2000). In Wisconsin, however, most all dairy farms fall below this regulatory herd size level (Jackson-Smith and Barham, 2000). The majority of herd size expansions, therefore, occur outside any regulatory structure. As dairy operations expand, increases in herd size should be accompanied by increases in the land base used for manure application.

A comparison of ALRs by varying degrees of herd expansion, during the period 1993 to 1998, indicates average animal density values increased on operations that increased cow numbers (Table 3). While differences in mean animal density levels are only slight (from 1.63 ACLR for farms that did not expand to 2.54 for farms that increased herd size by more than 100 cows), the positive relationship between herd size expansion and animal density is further established through a comparison of the percentage of expanding versus non-expanding farms that fall into different animal density categories (Table 4). While the majority of low animal density values are found on operations that did not expand herd size, the majority of medium and high animal density values are found on operations that expanded their herds.

Table 2. Nutrient balancing potential by herd size on Wisconsin dairy farms

	Herd Size 1999 (dry and lactating cows)					
	1 to 24 (n=65)	**25 to 49** (n=242)	**50 to 74** (n=235)	**75 to 99** (n=88)	**100 to 199** (n=98)	**200+** (n=27)
Animal Density	% of farms within herdsize class					
ACLR						
Low	55.4	60.7	68.1	60.2	73.5	25.9
Medium	36.9	35.1	29.3	34.1	22.4	55.6
High	7.7	4.2	2.6	5.7	4.1	18.5
Total	*100*	*100*	*100*	*100*	*100*	*100*
ATLR						
Low	23.1	22.7	25.5	26.1	32.7	11.1
Medium	40.0	51.2	61.3	52.3	52.0	55.6
High	36.9	26.1	13.2	21.6	15.3	33.3
Total	*100*	*100*	*100*	*100*	*100*	*100*

Table 3. Average animal:cropland ratios by dairy herd expansion class

		Animal:cropland ratio (AU acre^{-1})	
		ACLR	**ATLR**
Herd expansion class*	*(n farms)*	------*Mean Ratio Value* ------	
Decrease or No Change	367	0.66	1.08
1 to 25 cow increase	261	0.77	1.25
26 to 50 cow increase	61	0.87	1.57
51 to 100 cow increase	27	0.77	1.21
100 or more cow increase	21	1.03	1.49

*Increase in cow numbers during period 1993-1999

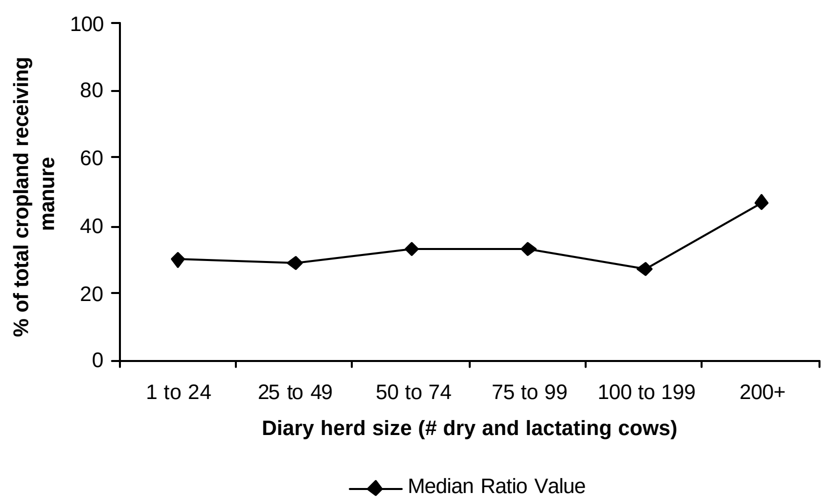
Table 4. Animal:cropland ratio class and herd size expansion

	No Expansion	Expansion
	-------% of farms-------	
ACLR		
Low (< 0.75 AU/Acre)	**54.7**	45.3
Medium (0.75 to 1.5 AU/Acre	42.6	**57.4**
High (> 1.5 AU/Acre)	31.3	**68.7**
ATLR		
Low (< 0.75 AU/Acre)	**63.9**	36.1
Medium (0.75 to 1.5 AU/Acre	47.1	**52.9**
High (> 1.5 AU/Acre)	39.9	**60.1**

The "Manure Gap"

Differences between ALR calculations based on total (ACLR) and manured (AMLR) cropland indicate the "manure gap", i.e. the amount of cropland where manure can be potentially applied but is not (Figure 2). On dairy operations having up to 200 cows, only about 25 to 30% of the total cropland receives manure. Farms having more than 200 cows use almost twice the amount of available cropland to apply manure.

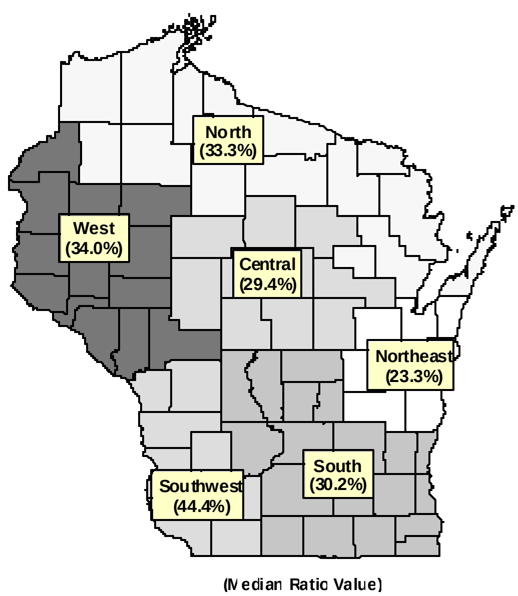
Figure 2. Percent of total cropland receiving manure by dairy herd size category



There are great regional differences in the percentage of total cropland that receives manure (Figure 3). The greatest contrast is between the northeastern and southwestern regions of the state. While dairy farmers in the Northeast have the lowest animal:land ratios based on total cropland (ATCR), they have the highest average animal-land ratios based on actual manure spreading behavior (AMLR). The inverse was true for the southwestern region. This pattern is explained by the fact that an average of 44% of total cropland is utilized for manure application in the Southwest, compared to only about 23% of total cropland in the Northeast. There are several important differences between these two regions that might affect manure spreading behavior. These include differences in soil texture, land tenure, and development pressures.

Soil texture. The southwestern region is characterized by more coarsely textured silt loam soils that have relatively high permeability and drier field conditions in the spring and fall (Hole, 1976). By contrast, the northeast is characterized by more finely textured and less permeable clayey and red loam soils. As a result, farms in the Southwest may have a wider "manure spreading window", or number of days that soil conditions are favorable for manure spreading. Farmers in the Southwest may therefore be able to access a larger proportion of their operated cropland acreage over a greater period of time than farms situated in the Northeast.

Figure 3. Regional differences in percentage of total cropland that receives manure on Wisconsin dairy farms



Land tenure. Differences in land tenure, or the percentage of operated land that is owned, may also explain the regional differences in manure spreading behaviors. Among all farms in our sample, as the percentage of operated land that is rented increases, the proportion of cropland used to spread manure decreases (Figure 4). Meanwhile, farmers in the Southwest tend to rent smaller areas and thus own a greater proportion of their total operated land area than farmers in the Northeast (Table 5). In general, the greater areas of rented land found on farms in the northeastern region may contribute to a decreased percentage of cropland that receives manure. Moreover, the travel distance between where the animals are housed (and where the manure is produced) and the location of rented land parcels can greatly affect whether or not rented land receives manure (Shepard, 2000). Spreading to distant, rented fields may be very time and energy consuming, and hence not an economically viable option.

Figure 4. Percentage of total cropland receiving manure by land tenure class

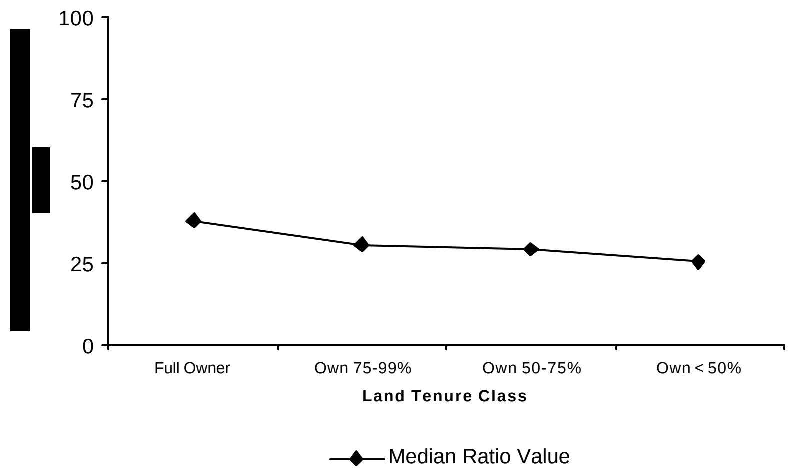


Table 5. Average area of rented land and percent of owned cropland

	Mean Acres Rented Land	Percent Operated Cropland Owned
Region	*(acres)*	*(%)*
South	194	67.6
Southwest	96	76.9
West	137	76.1
Central	117	76.1
Northeast	169	68.7
North	132	61.4

Development pressures. As demographic changes that began with the 1960's movement into suburbia now carry over into traditionally rural landscapes (Norris and Batie, 2000), a dairy farmer's access to close-by or contiguous rented land parcels is becoming increasingly difficult. For example, rather than renting several contiguous fields from a single landowner, farmers are only able to rent fields in several different locations. Because there is a notable higher level of non-farm development pressures in the northeastern region of the state (PATS, 1998) farmers in that area may have greater difficulty finding access to close-by rented land parcels. Evidence from several on-farm follow-up visits suggest that farms in the Northeast are more likely to be renting fields that are more distant from the home farm and more difficult to access without transporting manure on heavily traveled commuter roads. This could create additional disincentives for farmers in this region to spread on their rented cropland, compared to areas with lower development pressure.

DISCUSSION

Definition of Cropland Available for Manure Application is Critical

Animal density standards must consider the percentage of cropland actually available for effective manure application. ATLRs are favorable in the sense that they take into account cropping patterns and tillage practices. On average, tilled cropland accounts for about 64% of the total cropland acreage on dairy farms. From a regulatory point of view, however, the implementation of an ALR standard based on tilled cropland is likely to influence shifts in cropping or tillage practices to maximize the amount of land that is considered tilled and therefore "spreadable." While moving fields out of hay and into more row crops may provide more tilled land for spreading manure, it is also important that ALR standards work in conjunction with farm conservation plans.

While the degree to which Wisconsin dairy farms lack sufficient cropland for recycling manure nutrients depends on how one defines the animal density threshold, only 5 to 20 percent of Wisconsin dairy farms, based on ACLR and ATLR calculations, respectively, lack sufficient cropland for spreading manure according to a N-based manure application standard. The implementation of a more restrictive P-based standard will reduce the amount of manure that can be applied to cropland. A large proportion of Wisconsin dairy farms (37% on total cropland basis, 75% based on tilled cropland) apparently lack sufficient cropland for meeting more restrictive P-based manure application standards. We reiterate that our estimates of nutrient balancing potential based on total or tilled cropland do not account for nutrient additions from legume N, commercial fertilizer, and existing soil nutrient levels.

Results of this study indicate a large gap in knowledge of manure spreading behavior on Wisconsin dairy farms. High animal density levels are prevalent, especially on operations that have experienced herd size expansions. Animal density would provide a useful, and size-neutral indicator for targeting regulatory oversight, and perhaps be an effective way to target limited cost-sharing monies toward high-density operations situated in landscapes that are at greatest risk for nutrient loss. These high-density operations will likely require the greatest assistance in adhering to nutrient management standards. An animal density standard would also provide a much-needed framework for planning dairy herd expansions.

Setting an animal density standard would require some initial consideration of how to define the land base considered available for manure application, and whether a N- or P- based application standard is used. However, the development of an animal density standard based on realistic goals for reducing nutrient losses may have certain carry-over benefits that would help promote the long-term sustainability of Wisconsin's dairy industry. In general, being able to match livestock numbers with an adequate land base for manure application is an important part of good nutrient management. It creates a balance between the number of animals, the amount of forage and grain they need and the amount of manure produced, thereby reducing the need for off-farm feed purchases, manure exportation, and the overall likelihood of nutrient accumulation and loss.

Biophysical and Development Constraints Likely Influence Manure Spreading Areas

ALRs based on “manured” cropland indicate that major adjustments in manure spreading behavior need to be made if dairy farmers are to adhere to N- or P-based manure application standards. In instances where a large manure gap exists (i.e. considerable available cropland not being utilized for manure application), nutrient balance may be achieved through a greater utilization of the available cropland base, especially tilled cropland.

While many Wisconsin dairy farmers apply manure and fertilizer N and P in amounts that exceed crop nutrient requirements (Nowak et al., 1997), the factors that shape this behavior are less well understood. Regional analysis of the manure gap suggest that differences in soil texture, land tenure, and development pressures may be major factors that influence the percentage of operated cropland that receives manure. Additional research needs to be conducted to fully understand these implications.

While there are various approaches to developing manure management policy, an animal density indicator may be particularly appropriate for Wisconsin’s dairy industry. Most farms continue to integrate crop and livestock production and have the potential for on-farm recycling of manure nutrients. From a policy perspective, unlike water quality-based indicators that are difficult to measure and attribute to farm practices, animal density can be accurately assessed on each farm at low costs.

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Author affiliations: Associate Research Specialist and Assistant Professor, Dept. of Soil Science; Assistant Professor, Utah State Univ., Logan, UT; Professor, Dept. of Soil Science; Professor, Dept. of Agronomy, respectively, Univ. of Wisconsin-Madison.