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Manure management on a township scale: Using a land evaluation approach in Wisconsin

Trisha Wagner, Peace Corps Ecuador, Trisha.Wagner@gmail.com
Joshua Posner, Professor, University of Wisconsin, JLPosner@wisc.edu
Laura Paine, Dept of Agric. and Consumer Protection Laura.Paine@datcp.state.wi.us

Abstract

In Wisconsin, increased attention to manure management means many farmers will need to look beyond their farm gate in order to correctly manage livestock manure. By integrating easily accessible information at the county level, and with local insight, a series of maps were developed to help land use planners and farmers envision manure management on a landscape rather than single-farm scale. On a township basis, 47% of the area was classified as priority or cautionary for spreading manure, resulting in a stocking rate of approximately 1.07 AU/ha (animal units/manurable hectare). This general discussion about landscape use and nutrient management was very timely as the town and county prepared its 2010 comprehensive "smart growth" development plan.

Introduction

Proper manure management is essential for reducing nutrient buildup on farm fields and for controlling nutrient runoff into surface waters. One way of promoting sound manure management is by linking the number of animals to the area of land and cropping system available for manure assimilation. Over the past few decades in Wisconsin, dairy herd sizes have been growing at an annual rate of 4.6%[1]. Along with increasing size have come increasing stocking rates. While farms with 25 to 100 cows have 0.88 ha of cropland per animal unit (AU=454 kg of animal weight), farms with more than 200 dairy cows have, on average, 30% less cropland per animal unit[2]. Farms with less than 0.3 ha of cropland per animal unit are at the limit of where manure nutrients can be sustainably recycled in typical corn-alfalfa rotations[3]. Clearly, increasing stocking rate threatens the ability of some Wisconsin livestock producers to adequately recycle manure nutrients back onto crop fields and increases the risk of environmental pollution.

A potential solution to this problem is to envision manure management on a landscape, rather than on a single-farm scale. An advantage for Wisconsin and most of the upper Midwest is that the agricultural landscape is a mosaic of livestock and cash-grain farms. From this perspective, livestock farmers could spread manure beyond their farm, facilitating the transfer of nutrients from areas of excess to areas of need. Cabot et al.[4] reported manure transfers between individual farms is currently supported in some capacity in Delaware, Indiana, Iowa, Maryland, Michigan, Ohio, Pennsylvania, South Carolina, and Virginia.

However, as development takes place through the expansion of highway systems, more subdivisions, and increasing traffic, it can prevent linking manure sources and manure sinks--ultimately making it difficult for livestock producers to stay in business. Our concept was that land use planners and community members could, through building a series of maps, examine the geographic proximity of priority manure spreading areas (croplands) to farms where the manure is being produced, and the actual and potential social and physical barriers between the two. With this information, improved land use planning could take place.

A township in Wisconsin is theoretically 9.6 km^2 (6 $miles^2$, or 9,216 hectares). This is an attractive unit for looking at landscape-level manure management as, according to interviews with local nutrient haulers, manure is rarely moved more than 8 kilometers. Addressing this topic is particularly timely due to the recent legislation (1999) requiring all Wisconsin local governments to develop comprehensive land use plans, commonly called the “smart growth” initiative, by 2010[5]. This study describes the application of a mapping model to a township in south central Wisconsin were there is a growing concern among local officials about how to maintain a viable local agricultural industry while accommodating residential growth.

Materials and Methods

The geographical data layers chosen for the land evaluation were based on the recommendations outlined in the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) 590 Nutrient Management Standards[6] for applying manure. The key physical features include slope, identification of soils with high nitrogen leaching potential, proximity to surface water, and land cover. Data layers chosen for additional assessment include the location of livestock farms, size of operations, road system, and location of suburban development. To test the practicality of using this model to build a set of maps linking manure production with spreading areas, a township with livestock farms, grain farms and a growing suburban population was chosen. The Township of West Point (Figure 1a & b) is located along the Wisconsin River in Columbia County, WI. Due to the river truncating the 9.6 km^2 township grid, this town includes approximately 7,540 ha. It has a population of 1,750 people, and has seen a 22 percent growth in residents from 1990 to 2005. This number is expected to increase with the completion of a highway expansion project that improves the link between West Point and the Madison metropolitan area. Census estimates indicate that by 2025 the population will be 2,132[7].

Slope evaluation

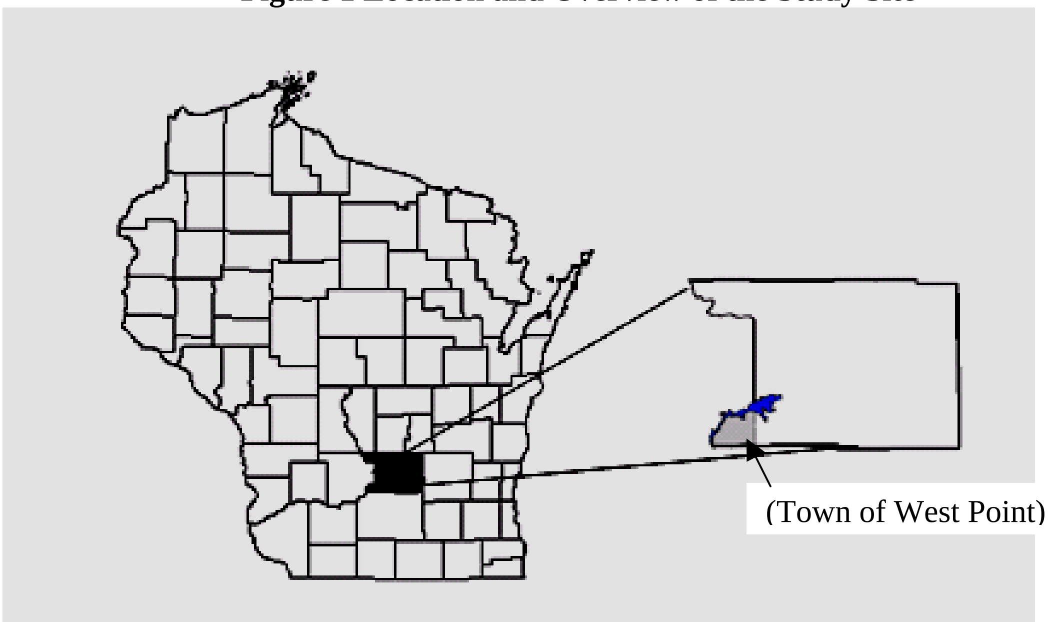
A Digital Elevation Model (DEM) data layer was used to generate landscape slope information. The NRCS 590 nutrient management standard prohibits the application of nutrients on frozen or snow covered soil on slopes greater than 9%, except where conservation practices are implemented, e.g. contour strips and grass water ways[6]. The DEM was downloaded from the US Geologic Survey website at which time 30-m data (1:24,000 scale) was available for the study area[8]. Due to the gradually sloping to rolling landscape, it was felt that this level of precision would still be adequate for identifying the more steeply sloping areas. The slope was calculated using ArcGIS 3D Analyst[9] to represent percent slope of the landscape. After discussions with local NRCS officials, the slope classes were simplified and cropland slopes less than 6% were considered adequate for spreading manure. Cropland slopes between 6 and 12% were cautionary for spreading manure, and the few acres of cropland above 12% were, according to the 590 standard, not available for spreading.

Soil evaluation

Soil survey data were used to evaluate soil constraints such as shallow depth to bedrock (R), perched water table (W), as well as highly permeable soils (A). The NRCS 590 nutrient management standard cautions spreading nutrients on these soils due to the high potential for nitrogen leaching[6]. Tabular information regarding the R, W and A soil properties was obtained from soil scientists at the USDA-NRCS and was attached to Columbia County soils data, downloaded from the NRCS website[10]. Soil survey data is available for the county at 1:12,000 scale. In this study, the soils with R, W or A constraints were considered cautionary for spreading manure, due to a seasonal potential for nitrate leaching. Of equal importance is the potential to lose soil phosphorus (P) to surface waters due to soil erosion and run-off. Unfortunately, it was not possible to include soil test phosphorus (STP) levels in this landscape analysis since the data were not in a georeferenced format. In Wisconsin, when STP levels are above 50 ppm, farmers with nutrient management plans can only add manure to meet rotation P, not nitrogen requirements, and once above 100 ppm, manuring is generally restricted or if absolutely necessary, at rates below estimated rotation removal[6]. During the farmer interviews, soil test values of 100 fields were noted on aerial photos and it was found 25% of the crop fields had STP

>100 ppm. Almost all of these fields were located next to previously active dairy farm installations.

Figure 1 Location and Overview of the Study Site



a. Location of Columbia County, Wisconsin and the Town of West Point

b. 2000 Aerial photograph of the Town of West Point[1]

Land cover evaluation

According to the NRCS 590 standard, manure can only be applied to land where crops are harvested unless an emergency situation occurs. Satellite imagery of the study area's land cover in 2003 was acquired from the National Agriculture Statistics Service[11]. The NASS Cropland Data Layer provides classified yearly imagery of land cover and major crops for Wisconsin, using 30-m resolution imagery from Landsat satellites 5 and 7. Eight of forty-one possible NASS land cover categories used in all states are present in the portion of the Wisconsin image used for the study area. These images were analyzed with ERDAS Image-a satellite imagery processing software[12].

Land evaluation: riparian zones

The NRCS 590 nutrient management standard prohibits the application of nutrients when frozen or snow-covered soils prevent effective incorporation at the time of application, regardless of slope or soil type, in Surface Water Quality Management Areas (SWQMAs)[6]. For purposes of nutrient management planning in this study, SWQMAs are defined as 1.) "…the area within 1,000 feet from the ordinary high-water mark of navigable waters, 2.) ... the area within 300 feet from the ordinary high water mark of a lake or stream….". It was not possible to include the third definition, areas of "concentrated water flow" (e.g. grass waterways in fields) due to the scale of this landscape study. Digital data for the study area's riparian zones were obtained at the county level from the Columbia County Land Information Office at a scale of 1:20,000.

Farm location and animal units

Location of the livestock farms and estimation of animal numbers were determined by consulting town council officials and farmers. Through these discussions, the average number of milk cows on the dairy farms in the study area was obtained. For these operations, the total herd number (including dry cows, heifers, calves) was generated by estimating the herd profile and weight categories[13] (Table 1). The average weight of animals in each age category was then used to estimate animal units (AU) (Table 2).

For beef operations, the average number of head fattened per year was estimated via the same informal survey. The majority of producers bought approximately 230 kg stocker animals in April, fed them on grass for six months until October (340 kg) and then finished the animals to marketing weight (500 kg) over winter. The AU calculation was estimated in two phases, first during the spring/summer grazing months (April-October) when the manure was directly deposited on the pastures, and second during the confinement months (November-March) when the manure needed to be hauled and surface applied.

There was one "feeder" pig operation in the study area. There were 200 sows on the farm throughout the year. An estimation of two and a half pregnancies per sow per year, with an average of eight piglets, results in 4,000 piglets passing through the farm each year. However, there were only about 1600 piglets on this farm at any time because the piglets are only kept from birth to approximately 30 kg (about three months).

Urban development

Through discussions with town officials and the use of aerial photographs and the digitized land parcel data, the areas of urban development were delineated. The digital data layers were acquired through the Columbia County Land Information Office. When the parcel data is overlaid on the photograph, it is possible to identify the growing suburban developments along the Wisconsin River and local lakes.

Table 1 Hypothetical 100 Cow Dairy Herd Profile[1]

Herd Size = 100 mature animals

Mature Animals (100):		**Number of Animals**			**Average weight (kg)**
Milking Cows		**83**			**636**
Dry Cows		**17**			**636**
Young stock (100):	Age range (months)		initial weight (kg)	final weight (kg)	
Calves	birth-6	**25**	57	182	**120**
Yearlings	7-12	**25**	182	329	**256**
Unbred heifers	13-18	**25**	329	455	**392**
Bred heifers	19-24	**25**	455	591	**523**

1. Adapted from Midwest Plan Service [13]

Table 2 Animal Unit (AU) Calculation chart[1]

Animal Unit (AU) Calculation Chart

Animal Type	Average weight (Kgs))	Animal Unit Equivalency Conversion Factor (1)
Dairy Cattle		
milking cow	636	1.4
dry cow	636	1.4
calves	120	.262
Yearlings	256	.562
Unbred heifers	392	.862
Bred heifers	523	1.15
Beef Cattle		
April - October	284	.625
November - March	420	.925
Pigs		
piglets	23	0.05
swine	170	0.375

1. An AU is defined as an average animal body weight equal to 455 kgs[6]

Interviews

Structured interviews (11 with West Point farmers, 19 with farm advisors, two with the Township Board) were crucial to understanding local nutrient management issues. Interviews generally took 1.5 hours with farmers using aerial photos so that we could better understand their farming operation and constraints. Meetings with the farm advisors (extension agents, crop consultants, NRCS soil scientists/agronomists) lasted about one hour and helped place our nutrient and landscape “snapshot” within the context of trends occurring in the agricultural industry. The project’s objectives and results were presented and discussed with the Township Board at the beginning and end of the project.

Results and Discussion

West Point Township consists of predominately rolling hills with about half of the landscape above 6% slope. Steep areas, above 12% slope, are mainly forested bluffs. As can be seen in the NASS cropland cover image in Figure 2, on the flatter ground, cropping acres of corn (*Zea mays*), soybean (*Glycine max*), and alfalfa (*Medicago sativa*) cover approximately forty percent of the town. Another forty percent of the total area is in the broad Pasture/Grassland/ Non-Agriculture (PGNA) category.

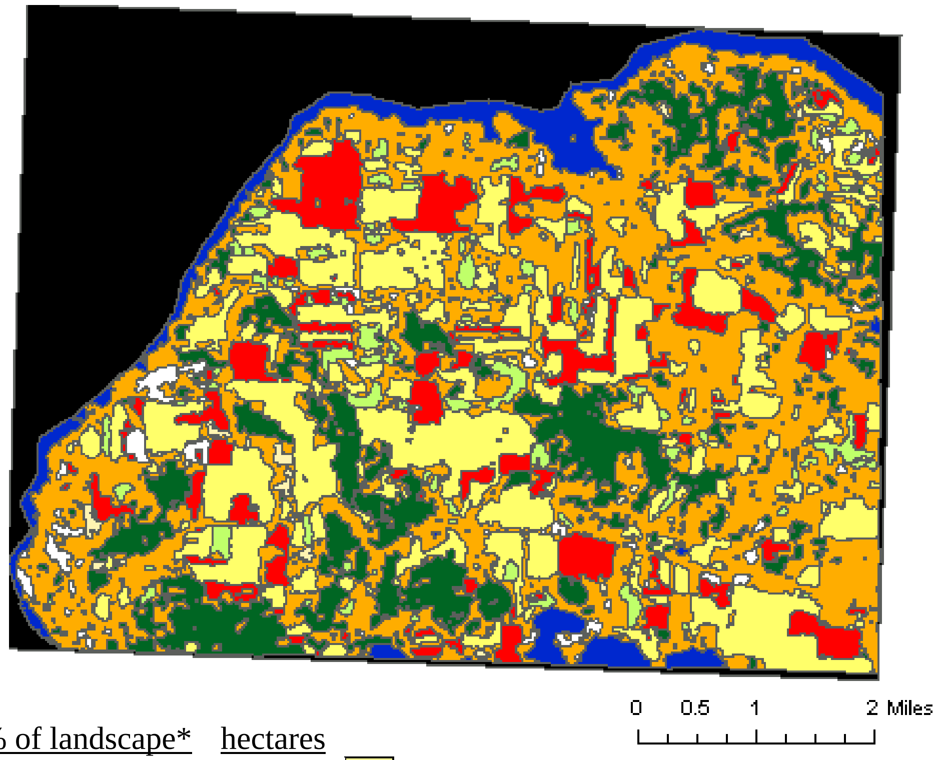
There were twelve dairy farms, nine beef and one hog farm; ranging from 19 to 582 AU, with a total of nearly 4,000 AU in the study area. As can be seen in Figure 3, the livestock farms appear to be evenly distributed throughout the township, and with the exception of one, fairly distant from the development along the Wisconsin River. The town’s four largest livestock farms (>300AU) also appear to be fairly distant from one another. Areas of urban development are not surprisingly near the scenic areas of the town such as the Wisconsin River and Crystal Lake. Here, a new housing development called Paradise Island was replacing older, smaller cabins resulting in increased traffic and land prices. Roads with significant travel (state highways 60 and 113) serve the suburban development areas.

Identifying priority spreading acres

The goal of the land evaluation was to develop four classes relative to manure management: 1) Priority spreading; 2) Cautionary spreading; 3) Grazing zone; and, 4) No spreading permitted. The base data layer for this application is the NASS land cover data layer (Figure 2). Initially, the assumed classes for manure spreading were the cropping area of corn, soybeans and alfalfa for a total of 2,928 ha. However, the large area of PGNA is difficult to classify relative to spreading manure since pasture/grasslands do receive manure, but non-agricultural land does not. Upon closer examination, much of the non-agriculture portion of the class coincides with the suburbanized areas of the town and golf course where the spectral signature is reflecting lawn, similar to grasslands but obviously not available for manure spreading. By consulting the aerial photographs, a 395 m buffer from the Wisconsin River shoreline and a 91 m buffer around Crystal Lake tourist area were created. This 640 ha area is truly non-agricultural and therefore not available for spreading manure.

Further visual analysis showed that much of the remaining Pasture/Grassland was in fact, intermixed with cropland areas. This raised the question of possible spectral signature confusion between cropland that was temporarily in alfalfa/grass mixtures and permanent pasture/grassland. A ground-truth survey was conducted in the study area in the late summer of 2004 to observe the remaining areas classified as Pasture/Grassland. Fifteen Pasture/Grassland sites were randomly selected. Five of the fifteen sites visited were misclassified. Four of these five sites were on flat areas (<6% slope) and in 2004 were in corn or soybeans --indicating they are part of the cropping rotation. These sites were most likely 3rd or 4th year alfalfa stands in 2003 and included enough grass in the vegetation to cause a signature similar to pasture/grassland. Of the ten areas classified correctly, eight were on steeper terrain (> 6% slope) that was either fenced pasture or open grassland.

Figure 2 Town of West Point land cover data layer, 2003[1]



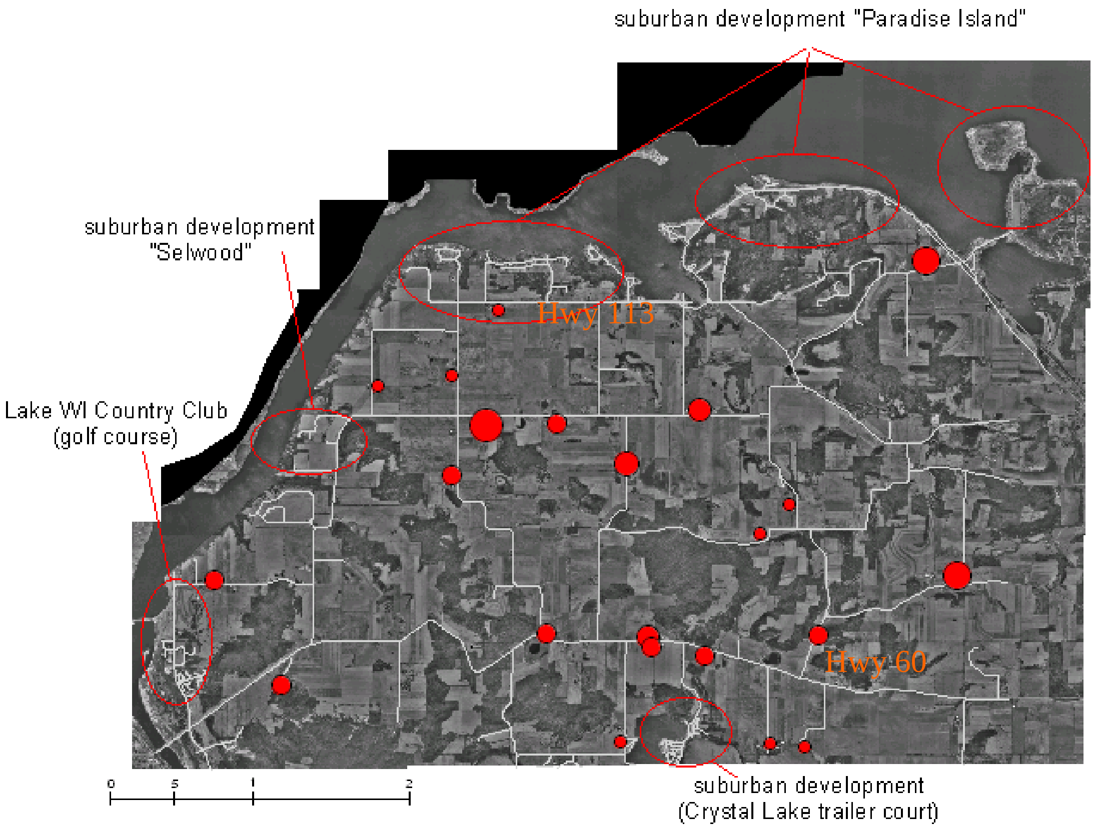
% of landscape*	hectares
25%	1,854
11%	802
4%	273
.5%	41
43%	3,217
16%	1,212
2%	148
	438

* Water not included in tally.

1. National Agriculture Statistics Services, 2004

Figure 3

Livestock Farms of West Point and Suburban Developments



Animal Units (1)	# of Farms
< 100	(8)
101-200	(8)
201–300	(2)
301-400	(1)
>400	(3)

(1) AU=454 kg

Other researchers at the Wisconsin Department of Natural Resources and NASS have also found that the grassland/pasture category included a certain amount of error[14, 15]. As a result, based on the ground truthing and corroborating studies, it was decided to break the Pasture/Grassland category into two categories; 1) areas below 6% slope were considered alfalfa hay fields (796 ha,) and added to the cropping acres; and, 2) areas above 6% slope were kept as pasture/grasslands and considered the grazing zone (1,783 ha).

As is summarized in Figure 4**,** just less than 50% of the township is in cropland (3,554 ha) and the remainder is nearly evenly divided between pasture/grasslands (1,783 ha) and non-agriculture areas (2,209 ha of water, urban, suburban, forest or > 12% slope). Some of this cropland, as explained below, falls into the cautionary spreading category.

Identifying cautionary spreading acres

Areas are identified for "cautionary spreading" because they require additional attention at some time during the year. The schematic diagram in Figure 5 is an outline of how the "possible spreading acres" were divided into priority and cautionary spreading acres. After cautionary acres were identified and removed from "potential" spreading acres due to slope, soil type and water quality management areas (SWQMAs), a total of 2,712 ha remained in the study area as priority spreading areas. According to this interpretation of the 590 regulations, approximately 24% of the annual cropland hectares are under cautionary spreading rules, requiring farmers to take special caution such as incorporating manure within 72 hours of application or only applying manure in mid-summer when the water table is lowered.

Interviews

None of the livestock farmers in the township had a certified nutrient management plan, although about a quarter of those interviewed had a detailed manure management strategy. This finding is not surprising, as only 1.2% of the cropped acres countywide were managed under certified nutrient management plans[16]. Livestock producers were concerned however; that the new USDA-NRCS regulations would affect them and they might need certified nutrient management plans. If they had to transport manure off the home-farm they were concerned about the cost, the danger of spills on the road, and regulations concerning heavy traffic on county roads during the spring thaw period.

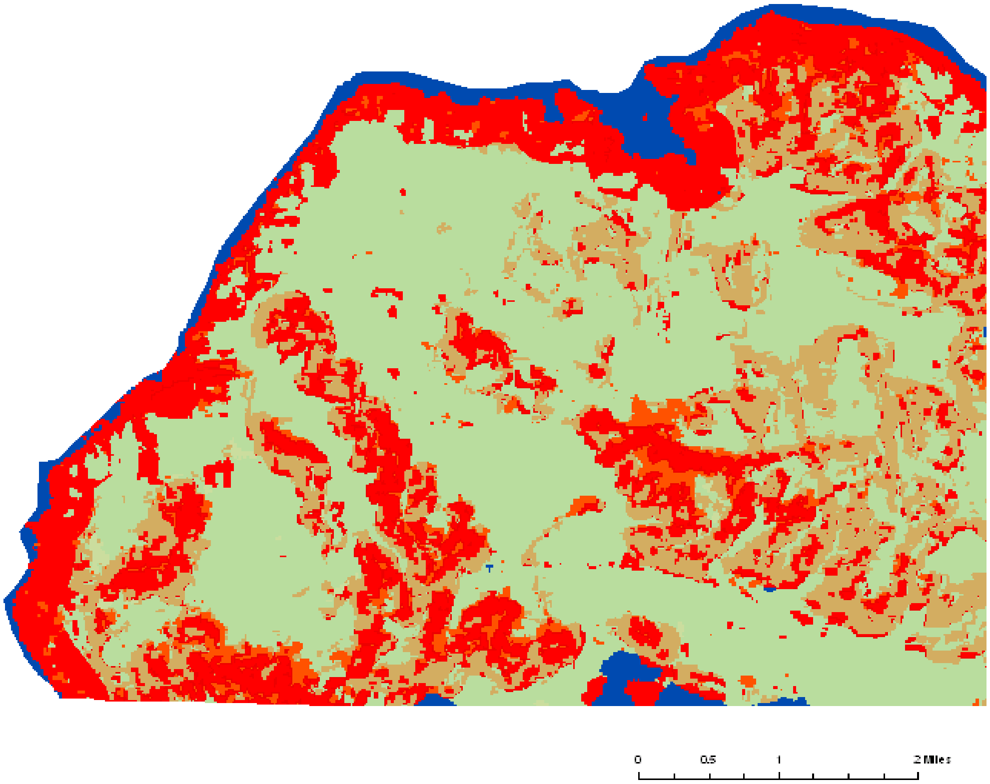
The grain farmers also saw potential constraints in bringing manure into their operations. Often they worked rented land and would have to get permission to include manure in the cropping system, they were concerned with their neighbor's reactions to spreading on fields near their houses, and there was concern about manure being a highly variable source of nutrients. They did, however, appreciate that manure additions would help with maintaining soil quality and reducing fertilizer costs.

Technical Support Providers were split in their opinion about the model presented them. As with the livestock farmers, most were disappointed that the maps resulting from this exercise were not complete enough to be used in developing certified nutrient management plans. On the other hand, they were excited about the role this exercise could play in discussing land development in the township, particularly the development of new sewage districts and sub-divisions that endangered the viability of the farming sector. The Town Board was particularly interested in the pattern shown on the maps and invited the team to present them at two town meetings dealing with agriculture and the smart growth initiative (2/05; 1/06).

Integrated Assessment

Figure 6 displays the farm locations and their relative size (AU) and the four land evaluation categories. In general, farm location appears to coincide with the land that is available for priority spreading. The farms appear to be evenly distributed in terms of AU size and geographic

Figure 4. Spreading, grazing and no-spreading zones, Town of West Point



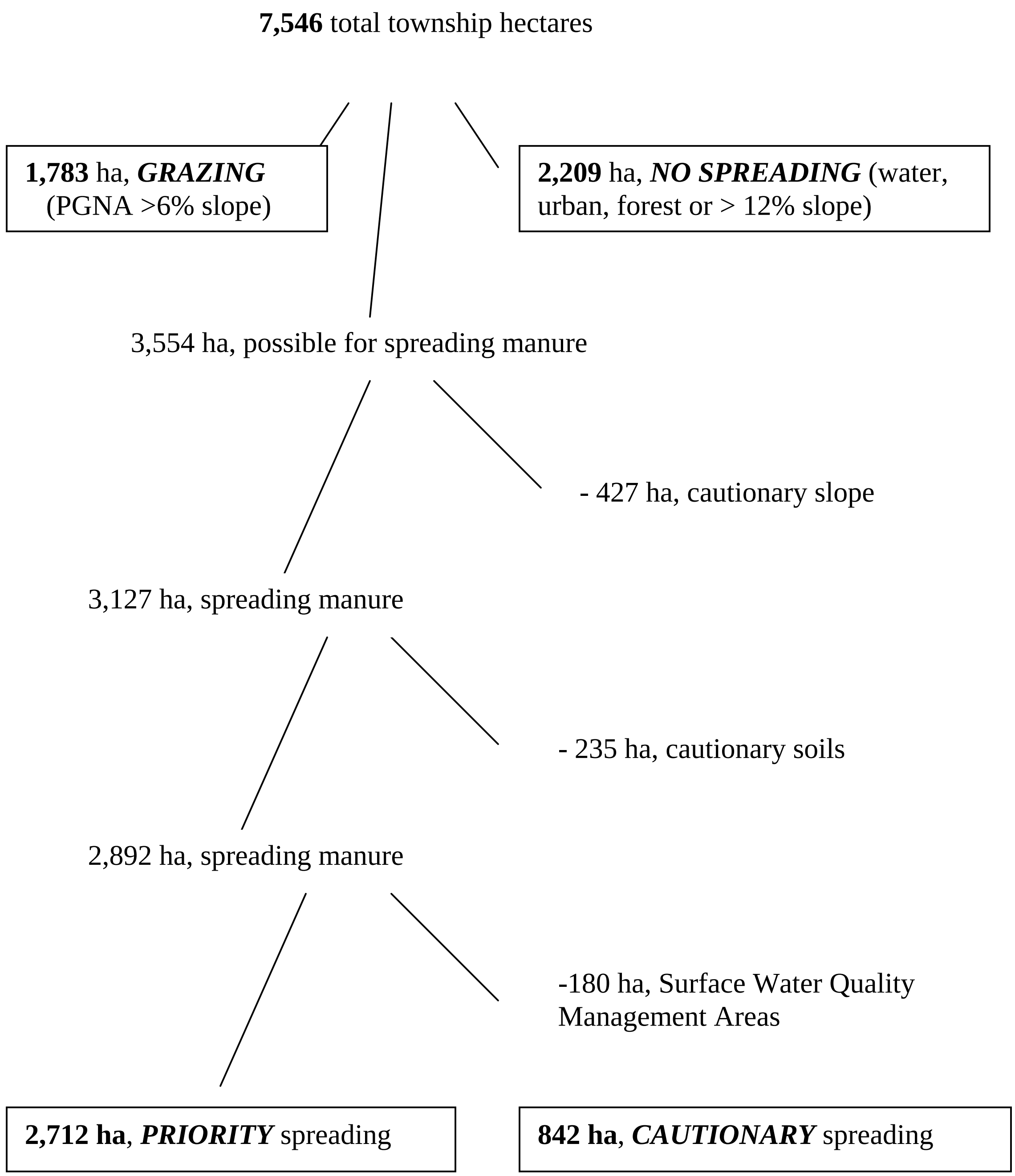
Spreading (corn, soybean, alfalfa) 3,554 ha

Grazing (Pasture/Grassland, > 6% slope) 1,783 ha

No spreading: (> 12% slope, urban, suburban and forest) 2,209 ha

Water

Figure 5 Schematic presentation of land evaluation steps resulting in priority spreading, cautionary spreading, grazing and no spreading areas



location. Suburban developments are along the shorelines of the Wisconsin River and Crystal Lake and the major traffic routes are near the developments. Therefore, for the most part, development is not yet fragmenting the three main valleys used for agriculture. This situation is protected, at least temporarily, as the Town Board has placed a moratorium on division of land and rezoning until its comprehensive plan is complete. In addition, according to the Colombia County Planning and Zoning Department, they are permitting only larger community septic systems rather than numerous small ones in the townships, which promotes suburban clustering[17]. These policies and the general awareness on the town board about the links between livestock farms and cropping acres, will serve to help in locating sites for future suburban developments in the township.

In addition to the spatial representation, calculating stocking rates (animal units/hectare) is a useful way to look at the relationship of livestock to spreading area. There were approximately 3,833 AU in the township on a priority spreading land base of 2,712 ha and cautionary spreading base of an additional 842 ha. When combined, this results in a stocking rate of 1.07 AU/ha. Operations with less than 1.85 AU/ha are considered to have sufficient cropland to assimilate all manure nutrients[3].

The estimated stocking rate of 1.07 AU/ha is actually an overestimation. This is because many of the livestock farmers also graze a portion of their herd for the summer months, thus depositing some of the manure not on crop acres, but directly on the grazing acres. This is particularly the case for the beef operations (18% of the AU in the town) where the summer manure from the young animals is deposited on grazed acres. By grazing the young animals from April through October, beef farmers in the study are estimated to reduce their managed manure stream of P and K by more than 40%.

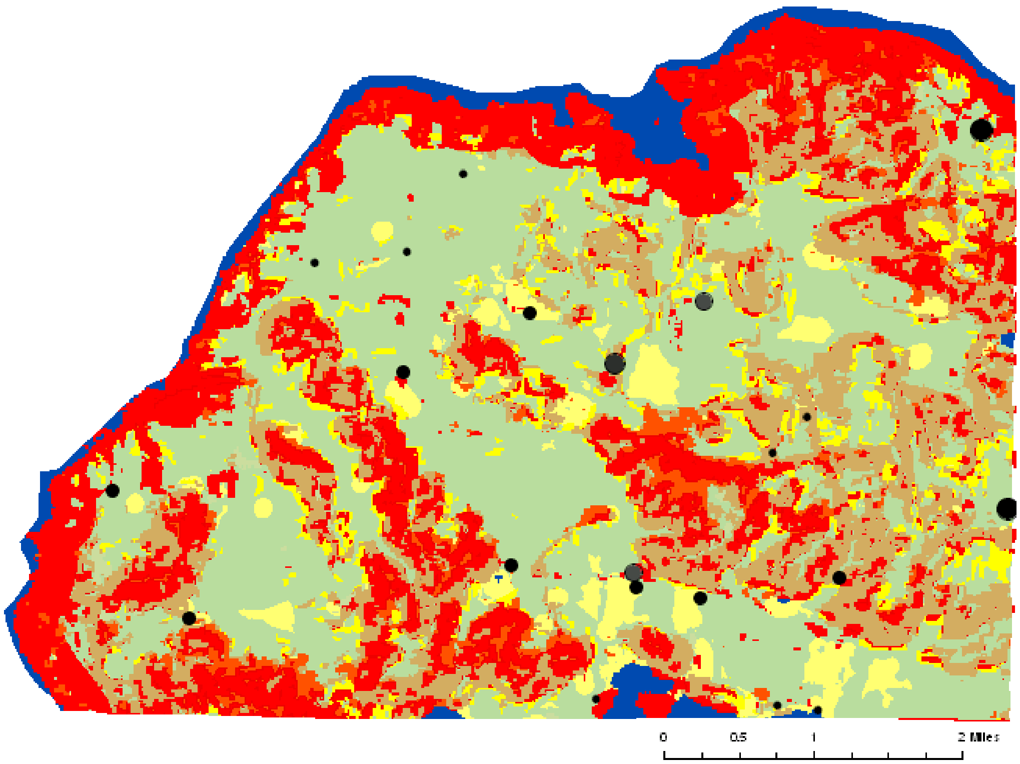
These estimated “global” stocking rates are considered modest, which does afford the growing township the opportunity to plan for both suburban growth and its agricultural sector. This, coupled with the open distribution of the livestock farms and the Town Board’s commitment to maintain a viable agricultural sector, is encouraging.

In reflecting on the process of building this model, it appears that one of its great strengths is that much of the data is readily available (slopes, soils, land cover, hydrology). At no cost, and in collaboration with the Colombia County Land Information Office and National Agriculture Statistics Service, we were able to get our georeferenced base maps. It was much more difficult to get animal numbers and farm locations. In the near future, this part of the process may be greatly facilitated with the implementation of the National Animal Identification System[18]. Once this is in place, it should be possible to query a state database on all the livestock operations. This would make it relatively simple to estimate Animal Units.

Important weaknesses of the data sets is that in the land cover typology, the Pasture/Grassland/Non-Agriculture (PGNA) category is too inclusive and results in underestimating the land available for spreading. Additionally, the lack of georeferenced soil test phosphorus values makes it impossible to highlight areas where no further spreading should take place. Teams using this approach will have to try to address these issues and acknowledge these problems when presenting their findings.

A second strength, however, is that the system is flexible and can be modified to each specific case. For example we were able to simplify the slope classes based on advice from local NRCS officials, differentiate between grass infested alfalfa fields and pasture by slope, and by expanding the border on the Wisconsin River and Crystal Lake, we were able to better define the non-agricultural areas. The flexibility possible with GIS derived maps makes them a potentially powerful tool for land use planning. For example, one could imagine, as part of the township discussion, that priority-spreading land within one-half mile of housing developments would be

Figure 6. Land Evaluation categories and livestock farms in the Town of West Point



Priority spreading (corn, soybean, alfalfa) 2,712 ha

Cautionary spreading 842 ha

Grazing (Pasture/Grassland, > 6% slope) 1,783 ha

No spreading (> 12% slope, urban, suburban, forest) 2,209 ha

Water

Animal Units	# of farms
< 100	(8)
101-200	(8)
201–300	(2)
301-400	(1)
>400	(3)

reclassified as cautionary if producers agreed to only spread on weekdays and inject or incorporate the manure immediately after application. Another example might be an agreement that prohibited heavy manure spreading equipment on highways during rush hour traffic.

Summary and Conclusions

By integrating easily accessible information at the county and state level, and with local insight, a series of maps were developed to help land use planners and farmers envision manure management on a landscape rather than single-farm scale. Such information can inform decision makers of the potential challenges to agriculture in general, and manure management in particular that accompany suburban development. In addition to township and county officials ensuring that agricultural corridors remain viable, producers need to become more proactive about improved nutrient management plans and siting livestock operations so that legitimate complaints of nutrient mismanagement do not offset a still very positive image that farmers enjoy in the township.

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