MANURE MANAGEMENT ON A TOWNSHIP SCALE: USING A LAND EVALUATION AND SITE ASSESSMENT (LESA) APPROACH IN WI

Trisha Wagner[1] and Joshua Posner[2]

INTRODUCTION

Properly managing manure is essential to reducing nutrient buildup on farm fields and 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 (Saam et al, 2005). However, due to the recent upswing in the rate of dairy herd expansion, many farmers now have more manure to spread than can be recycled on their own cropland. Herd sizes grew at a relatively constant rate (2 to 3%) from 1960-1990 in Wisconsin and then increased at a rate of 4.6% from 1995-1999 (PATS 2002a). Along with increasing size have come increasing stocking rates. It appears that farms with 25 to 100 cows have 2.2 acres of cropland per animal unit (AU=1,000 lbs of animal weight), farms with 100 to 200 cows have 1.8 acres per AU, while farms with more than 200 dairy cows have an average of only 1.6 cropland acres per animal unit (PATS, 2002b). This increasing stocking rate threatens the ability of 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 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 in order to facilitate more complete manure nutrient recycling by crops.

A Land Evaluation Site Assessment (LESA) model was developed as a tool to facilitate the discussion, at a community level, of the feasibility of this concept. The major components of the LESA model are two analytic processes: 1) a land evaluation and 2) a site assessment (American Farmland Trust, 2004). The land evaluation begins with the acquisition of digital geographical data layers of a particular landscape's physical characteristics while the site assessment portion analyzes a number of other factors that affect agriculture. Examples include social features such as development pressure, traffic patterns or the presence of scenic areas.

Our vision is that land use planners and community members could build a series of maps to examine the geographic proximity of priority manure spreading areas to farms where the manure is being produced, and the social and physical barriers between the two. Such information would be useful for people who want to accommodate both residential growth while maintaining an agricultural landscape and a viable livestock industry. A township in Wisconsin is hypothetically 6 miles by 6 miles (23,040 acres). This is an attractive unit for looking at landscape level manure management as manure is rarely moved more than 3 to 5 miles, and township governments deal with most land use and local road maintenance issues. In this note we describe the application of the LESA model to West Point township in south central Wisconsin.

[1] Graduate Student, UW-Madison, Land Resources
[2] Professor, UW-Madison, Agronomy Dept.

MATERIALS AND METHODS

The geographical data layers chosen for the land evaluation were based on the regulations outlined in the USDA-Natural Resources Conservation Service (NRCS) 590 Nutrient Management Standards (2004a) for applying manure. The key landscape physical features include slope, identification of soils with high nitrogen leaching potential, proximity to surface water, and land cover. Data layers chosen for the site assessment include the location of livestock farms, size of operations and location of suburban development. To test the complexity 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 Town of West Point (**Figure 1**) was chosen and is located along the Wisconsin River in Columbia County, Wisconsin. Due to the river truncating the 6-mile x 6-mile township grid, this town includes approximately 18,844 acres. It has a population of 1,634 people, and has seen a 22 percent growth in residents from 1990-2003. This number is expected to increase with the completion of the highway expansion project that links the town to the Madison metropolitan area. Census data also reports a 3.4 percent decrease in the land taxed for agricultural purposes (PATS, 2003). There is, not surprisingly, a growing concern among town officials about how to maintain a viable local agricultural industry while accommodating residential growth.

Land evaluation: slope

A Digital Elevation Model (DEM) data layer was used to measure the percent slope of the landscape. 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 (USDA-NRCS, 2004a). The DEM was downloaded from the US Geologic Survey website at which time 30 meter data (1:24,000 scale) was available for the study area (USGS 2003). The slope was calculated using ArcGIS 3D Analyst (ESRI, 2004) to represent percent slope of the landscape. In this study we simplified the slope classes to cropland slopes less than 6% were considered adequate for spreading manure, cropland slopes between 6.1-12% was cautionary for spreading manure, and the few acres of cropland above 12% were, according to the 590 standard, not available for spreading.

Land evaluation: soil

Soil survey data was used to evaluate hydrologic 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 (USDA-NRCS, 2004a). 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 (USDA-NRCS, 2004b). Soil survey data is available for the county at 1:12,000 scale. In this study, the sols with R, W or A constraints were considered cautionary for spreading manure, as they are considered safe against nutrient leaching for only part of the year.

Land evaluation: land cover

According to the NRCS 590 standard, manure can only be applied to land that has a crop taken off of it unless an emergency situation occurs. Satellite imagery of the study area's land cover in 2003 was acquired from the National Agriculture Statistics Service (NASS 2004). The

NASS Cropland Data Layer provides classified yearly imagery of land cover and major crops for Wisconsin, using 30-meter 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 scene used for the study area. Using a satellite imagery processing software, ERDAS Imagine (Leica Geosystems, 2004) the portion of the study was clipped from the Wisconsin scene and a simple nearest neighborhood classifier was utilized to geometrically correct the NASS raster image and resample the raster to avoid frivolous pixilation (ibid).

Land evaluation: hydrology

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, in Surface Water Quality Management Areas (SWQMAs). For purposes of nutrient management planning, SWQMAs are defined as 1.) "…the area within 1,000 feet from the ordinary high-water mark of navigable waters that consist of a lake, pond or flowage, 2.) ... the area within 300 feet from the ordinary high water mark of navigable waters that consist of a river or stream…". Digital data for the study area's hydrologic features were obtained at the county level from the Columbia County Land Information Office at a scale of 1:20,000.

Site assessment: livestock location and number

In Wisconsin, there are not official lists of livestock operations, numbers of animals and addresses. As an alternative, a list of the location of the livestock farms and animal numbers was developed through consulting with town council officials and farmers. Through these discussions, the number of mature cows on the dairy farms in the study area was obtained. Based on this estimate, a total herd number (dry cows, heifers, calves) was generated using a herd profile estimation table (**Table 1**). The average weight of animals in each age category was used to estimate animal units (AU) (**Table 2**).

In the case of beef operations in West Point, the average number of head fattened per year on beef farms was estimated via the informal survey. The majority of producers bought approximately 500 pound animals in April, fed them on grass for six months until October (750 pounds) and then finished the animals to marketing weight (1,100 pounds) over winter. The AU calculation was estimated in two phases, first during the spring/summer grazing months (April-October) and second during the confinement months (November-March).

There is one "feeder" pig operation in the study area. There are 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 are only about 1600 piglets on this farm at any time because the piglets are only kept from birth to approximately 65 pounds (about three months).

Site assessment: urban development

Through discussions with town officials and the use of aerial photographs, digital parcel data and the road network, 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. Other features such as the golf course were also visually identified by this method.

RESULTS AND DISCUSSION

The Town of West Point is predominately rolling hills with about half of the landscape above 6% slope. Steep areas, above 12% slope, are mainly forested bluffs. There is a relatively small area of soils constrained due to hydrologic considerations (725 acres). The majority of these soils are highly permeable soils, which require particular attention to timing of manure applications with expected rapid crop growth and nutrient uptake (figures not shown). As can be seen in the land cover **Figure 2 (**NASS scene from 2003**)**, cropping acres (corn, soybeans, alfalfa) cover approximately forty percent of the town and another forty percent of the area is in the broad Pasture/Grassland/Non-Agriculture category.

There are 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 town, and 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 is replacing older, smaller cabins resulting in increased traffic and land prices. Roads with significant travel (highway 60 and 113) serve the suburban development areas.

Land Evaluation: identifying priority spreading acres

The goal of this 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. These classes are based on the data layers used to interpret the recommended practices of the NRCS 590 nutrient management standard.

The base data layer for this application is the NASS Cropland data layer (**Figure 2**). Initially the assumed classes for manure spreading were the cropping acres of corn, alfalfa and soybeans for a total of 7,321 acres. A large portion of the study area (43%) however, is in a mixed category entitled Pasture/Grassland/Non-Agriculture (PGNA) and therefore difficult to classify relative to spreading manure. 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 photograph, a 1300-foot buffer from the Wisconsin River shoreline and a 300 foot buffer around Crystal Lake tourist area were created. This 1,600 acre area all came from the PGNA category and was identified as non-agriculture and therefore not available for spreading manure.

Further analysis of much of the remaining Pasture/Grassland areas however, appeared to be embedded in cropland, raising 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 to observe the remaining areas classified as Pasture/Grassland. Fifteen Pasture/Grassland sites were selected in the study area. Five of the fifteen sites visited are misclassified. Four of these five sites were on flat areas 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 had included enough grass in the vegetation to cause a signature similar to pasture/grassland. Of the ten areas that were classified correctly, eight were on steeper terrain (> 6% slope) that was either fenced pasture or open grassland.

Other researchers at NASS have also found that the grassland/pasture category included a certain amount of error. The 2003 NASS Cropland data layer scene for the study area is considered highly accurate (Kappa Coefficient of 90%+) for major crops of alfalfa, corn and soybeans but low for grassland and pasture (59% and 57%) (NASS 2003). A high commission error for pasture (44%) suggests that nearly half of the pixels being classified as Pasture/Grassland actually belong in other categories.

This problem is not exclusive to the NASS Cropland data layer. The Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) produced land cover data for the State of Wisconsin in 1993 based on Thematic Mapper (TM) satellite imagery. In this classification substantial confusion exists among forage crops and grassland in both errors of omission and commission (WDNR 1999). Similar to NASS, of all ground-truthed polygons classified as grassland in WISCLAND, only about half were verified as grassland and the others were in fact forage crops (ibid).

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 (1,991 acres) and added to the cropping acres; and, 2) areas above 6% slope were kept as pasture/grasslands to be used for a grazing zone (4,458 acres).

As is summarized in **Figure 4,** there are 5,522 acres unavailable for spreading manure, 4,458 acres in grazing and a total of 8,884 acres in cropland available for spreading. Approximately 50% of the town is in cropland and the remainder is evenly divided between pasture/grasslands and non-agriculture areas (water, urban, suburban, forest or > 12% slope). Some of these crop acres however, according to the 590 standard are cautionary acres.

Land Evaluation: 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 dived into priority and cautionary spreading acres. After cautionary acres are identified and removed from priority spreading for slope, soil and SWQMAs, a total of 6,779 acres remain in the study area as priority spreading acres. According to our interpretation of the 590 regulations, approximately 24% of the crop acres 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.

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 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 fragmenting the three main valleys used for agriculture.

In addition to the spatial representation, calculating stocking rates (animal units/acre) can also be a useful way to look at the relationship of livestock to spreading acres. It is estimated that there are approximately 3,833 AU exist in the town on a priority spreading land base of 6,779 acres (3,833 AU/6,779 ac.), resulting in a stocking rate of .57 AU/acre. With the additional 2,105 acres in cautionary spreading, the stocking rate drops to .43 AU/acre. These

estimated stocking rates are considered low. Livestock operations with less than .74 AU/acre are considered to have sufficient cropland to assimilate all manure P (Saam et al. 2005).

The estimated stocking rate of .43 AU/acre is actually higher than the actual stocking rate. 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 on the grazing acres. This is particularly the case for the beef operations (18% of the town AU) where the summer manure from the young animals is deposited on grazed acres. By grazing the young animals (April-October), it is estimated that beef farmers in the study reduced the managed manure stream of P2O5 by 43% and K2O by 45%.

Considering the low stocking rates and general distance between suburban developments and the farms, manure management is not a crisis situation in West Point.

CONCLUSION

Using primarily secondary data, relatively easily accessible at the county and state level, a land evaluation site assessment tool was developed to help local land use planners and farmers envision manure management on a landscape scale rather than just confined to the farm. Such information can inform decision makers of the social challenges to manure management that can threaten the ability of livestock farmers to implement new nutrient management regulations. Crucial to the site assessment was the involvement of local officials and farmers who supplied valuable information pertaining to social challenges to manure management and commented on the completed maps.

REFERENCES

American Farmland Trust. 2004. Farmland Information Center Factsheet. Land Evaluation and Site Assessment Model. Farmland Information Center. August. www.farmlandinfo.org

Environmental Systems Research Institute. 2004. GIS and Mapping Software. ArcGIS software. http://www.esri.com/index.html

Leica Geosystems. 2004 ERDAS Imagine Software. Available online: http://www.gis.leica-geosystems.com/Products/Imagine/

National Agriculture Statistics Service. 2003. NASS cropland data layer scene for Wisconsin 2003 growing season metadata file. October 2003. http://www.nass.usda.gov/research/Cropland/SARS1a.htm

National Agriculture Statistics Services. 2004. NASS Cropland Data Layer. Available online: http://www.nass.usda.gov/research/Cropland/SARS1a.htm

Powell, J.M., D. Jackson-Smith, L. Satter, L.G. Bundy. 2002. Whole-Farm Phosphorus Management on Dairy Farms. 2002 Wisconsin Fertilizer, Aglime and Pest Management Conference. Madison, WI. Vol. 41, pp 13-24.

Program on Agriculture Technologies (PATS). 2002a. Estimated number of Wisconsin Dairy Farm Entrants and Exiters, and Net Change in Dairy Farm Numbers per

year 1978-1997. University of Wisconsin-Madison. Available online: http://www.pats.wisc.edu/

Program on Agriculture Technologies (PATS). 2002b. Availability of Land for Manure Spreading on Wisconsin Dairy Farms, By Herd Size, 1997. University of Wisconsin-Madison. Available online:http://www.pats.wisc.edu/

Program on Agriculture Technologies (PATS). 2003. Town Land Use Books, ColumbiaCounty, WI. University of Wisconsin-Madison. Available online: http://www.pats.wisc.edu/

Saam, H., J. M. Powell, D. Jackson-Smith, B. Bland and J. Posner. 2005. Use of Animal Density to Estimate Manure Nutrient Recycling ability of Wisconsin Dairy Farms. Agricultural Systems. 84 (2005) 343-357.

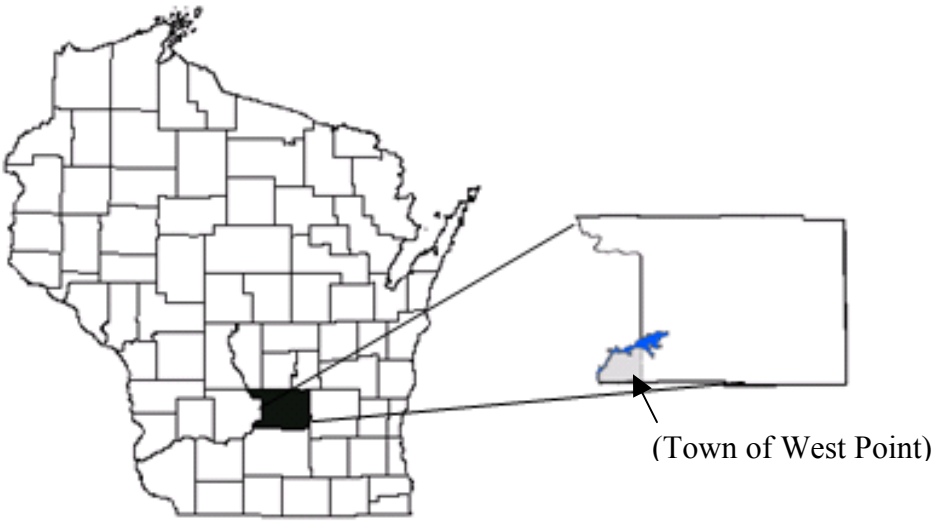
United States Department of Agriculture NRCS, 2004a 590 Nutrient Management Standard. Available online from the Department of Agriculture, Trade and Consumer Protection: http://www.datcp.state.wi.us/index.html

United States Department of Agriculture NRCS. 2004b. Soil Survey Geographic (SSURGO) Database. National Cartography and Geospatial Center. Online: http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/

United States Geological Survey. 2003. EROS Data Center. The National Map Seamless Data Distribution System. Available: http://seamless.usgs.gov/

Wisconsin Department of Natural Resources (DNR). 1999. Land Cover of Wisconsin. A User's Guide to WISCLAND Land Cover Data. Wisconsin Dept of Natural Resources. December 9, 1999. available for download: http://www.dnr.state.wi.us/maps/gis/datalandcover.html#overview

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]

1. Columbia County Land Information Office, 2000

Table 1 Hypothetical 100 Cow Diary Herd Profile[1]

Herd Size = 100 mature animals

Mature Animals (100):	**Number of Animals**	**Average weight (lb)**
Milking Cows	**83**	**1400**
Dry Cows	**17**	**1400**

Young stock (100):	Age range (months)		initial weight (lb)	final weight (lb)	
Calves	birth-6	**25**	125	400	**262**
Yearlings	7-12	**25**	400	725	**562**
Unbred heifers	13-18	**25**	725	1000	**862**
Bred heifers	19-24	**25**	1000	1300	**1150**

1. Adapted from Midwest Plan Service 2000 and David Kammel UW-Madison Biological Systems Engineer 2004.

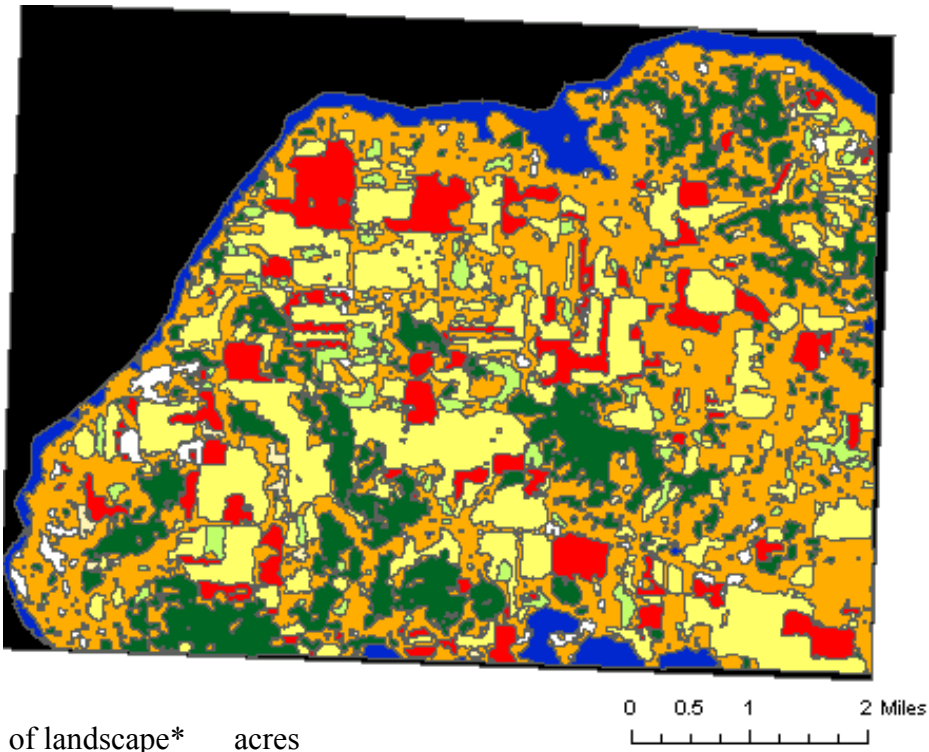
Table 2 Animal Unit (AU) Calculation chart[1]

Animal Unit (AU) Calculation Chart

Animal Type	Average weight (lbs)	Animal Unit Equivalency Conversion Factor
Dairy Cattle		
milking cow	1400	1.4
dry cow	1400	1.4
calves	262	.262
Yearlings	562	.562
Unbred heifers	862	.862
Bred heifers	1150	1.15
Beef Cattle		
April - October	625	.625
November - March	925	.925
Pigs		
piglets	50	0.05
swine	375	0.375

1. An AU is defined by the NRCS as an average animal body weight equal to 1000 lbs, one mature cow of approximately 1000 pounds (USDA-NRCS, 2004).

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



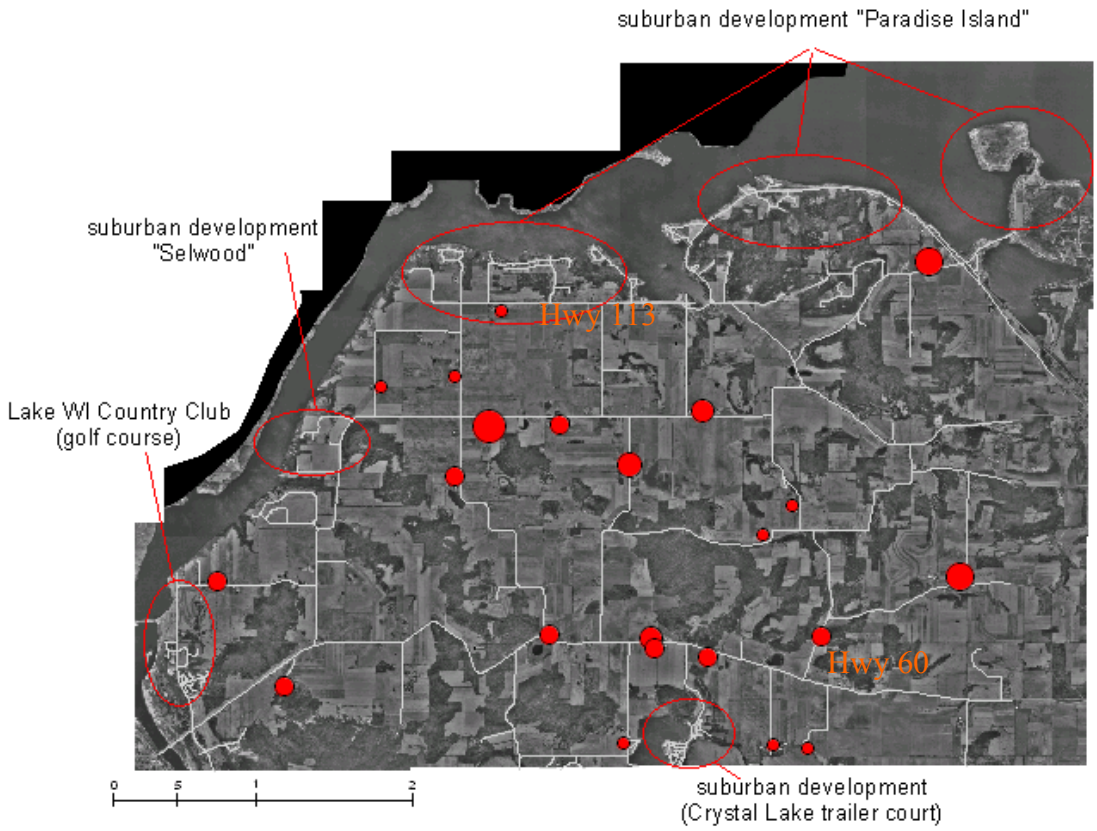
% of landscape*	acres		
25%	4,634		Corn
11%	2,005		Soybean
4%	682		Alfalfa
.5%	103		Fallow/Idle Cropland
43%	8,041		Pasture/Grassland/Non-Agriculture
16%	3,029		Forest
2%	370		Urban
	1,096		Water

* Water not included in tally.

1. National Agriculture Statistics Services, 2004

Figure 3

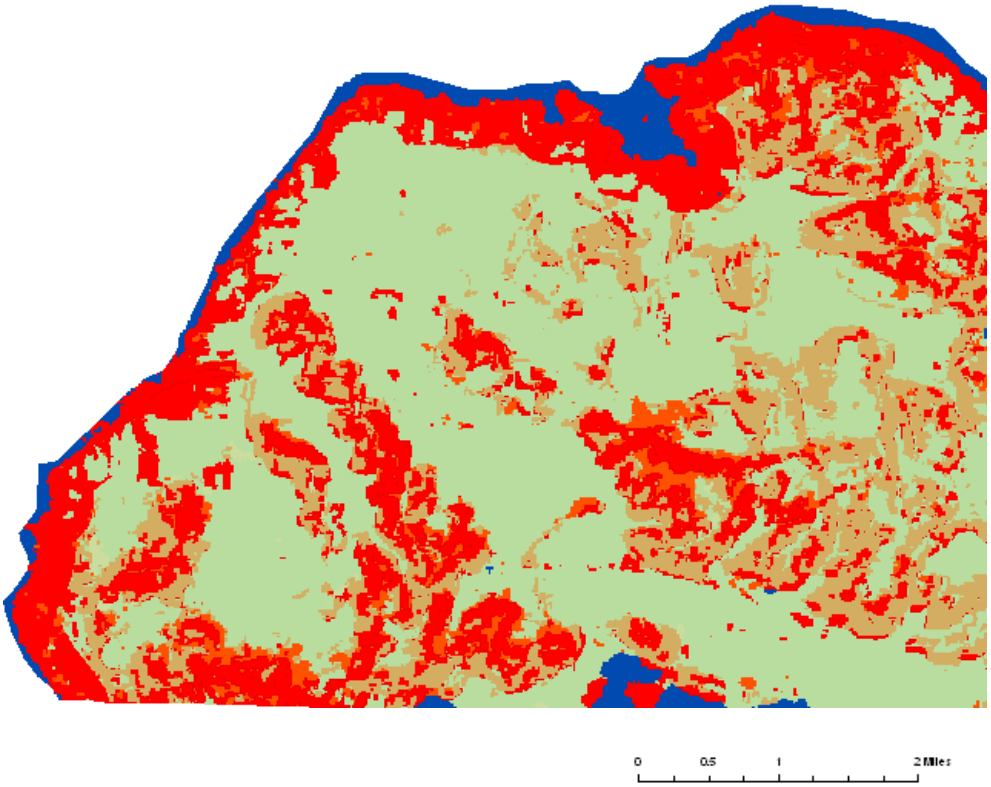
Livestock Farms of West Point and Suburban Developments



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

(1) AU=454 kg or 1000 lbs animal live weight

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



Spreading (corn, soybean, alfalfa) 8,884 acres

Grazing (Pasture/Grassland, > 6% slope) 4,458 acres

No spreading: (> 12% slope, urban, suburban and forest) 5,522 acres

Water

6,137 acres

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

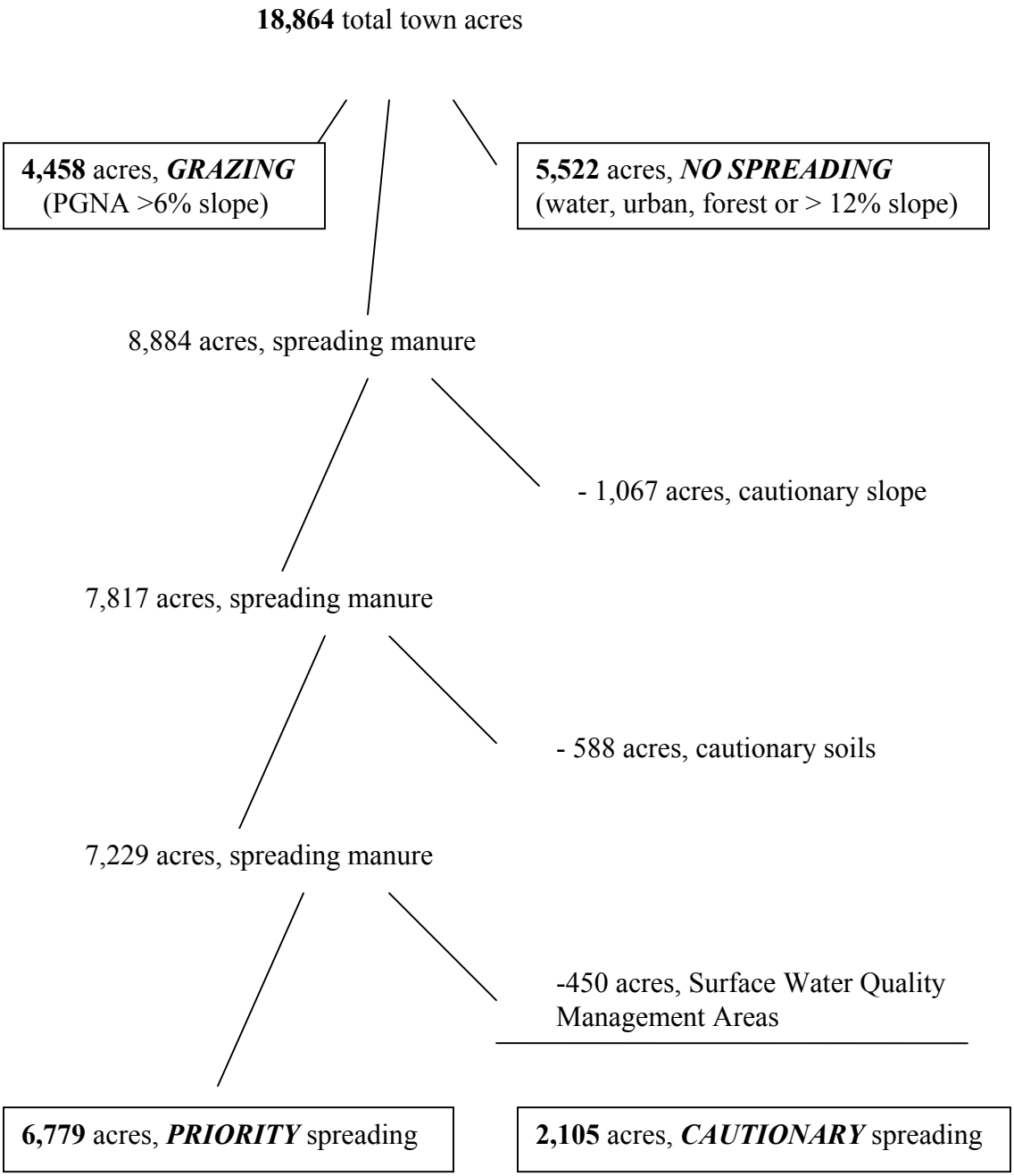
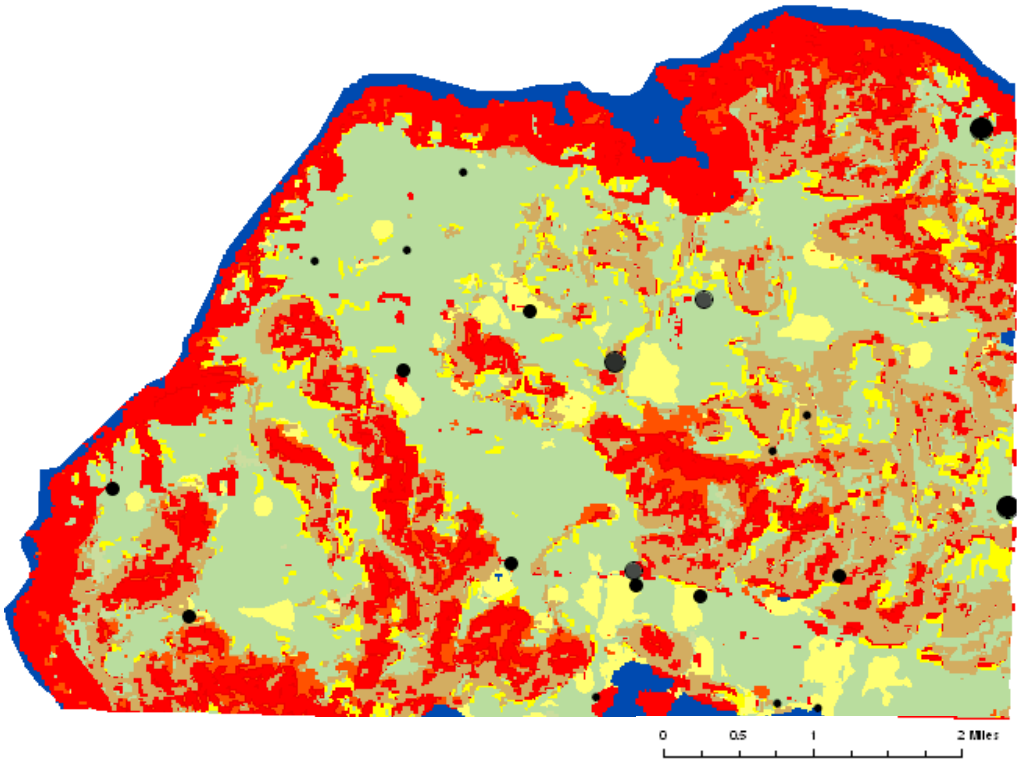


Figure 6. Land Evaluation categories and livestock farms in the Town of West Point



Priority spreading (corn, soybean, alfalfa) 6, 779 acres

Cautionary spreading 2,105 acres

Grazing (Pasture/Grassland, > 6% slope) 4,458 acres

No spreading (> 12% slope, urban, suburban, forest) 5,522 acres

Water

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