Comparison of Land Use Area Estimates from Three Different Data Sources for the Upper Mississippi River Basin

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Abstract

This study presents the results of comparing land use estimates between three different data sets for the Upper Mississippi River Basin (UMRB). The comparisons were performed between the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) National Resource Inventory (NRI), the U.S. Geological Survey (USGS) National Land Cover Data (NLCD) database, and a combined USDA National Agricultural Statistics Service (NASS) Agricultural Census – NLCD dataset created to support applications of the Hydrologic Unit Model for the U.S. (HUMUS). The comparison was performed for 1992 versions of the datasets because that was the only consistent year available among all three data sources. The results show that differences in land use area estimates increased as comparisons shifted from the entire UMRB to smaller 4- and 8-digit watershed regions (as expected). However, the area estimates for the major land use categories remained generally consistent among all three data sets across each level of spatial comparison. Differences in specific crop and grass/forage land use categories were magnified with increasing refinement of the spatial unit of comparison, especially for close-grown crops, pasture, and alfalfa/hayland. The NLCD close-grown crop area estimates appear very weak relative to the NRI and HUMUS, and the lack of specific crop land use estimates limits its viability for UMRB agricultural-based modeling scenarios. However, the NLCD is a key source of non-agricultural land use data for HUMUS and supplemental wetland land use area estimates for the NRI. We conclude that comparisons between more recent versions of the data sets (i.e., 1997 NRI, 1997 or 2002 Agricultural Census, and 2001 NLCD) would not result in significant additional insights and that the 1997 NRI is a viable land use data source for current CARD UMRB water quality modeling studies. However, adoption of other land use data such as USDA-NASS remote sensing data should be investigated.

Keywords: agricultural land, cropland, HUMUS, land use area estimates, NLCD, non-agricultural land, NRI, UMRB, water quality modeling.

COMPARISON OF LAND USE AREA ESTIMATES FROM THREE DIFFERENT DATA SOURCES FOR THE UPPER MISSISSIPPI RIVER BASIN

Introduction

Land use and water resources are directly linked. The type and intensity of land use greatly affects the water quantity and quality of receiving water bodies, whether the land use is natural or has been greatly altered by human activity. Land use activities have direct impacts on water resources, while water quality and quantity greatly influence the siting of land use activities.

Anthropogenic land use influences have greatly affected the water resources of the Upper Mississippi River Basin (UMRB). The Mississippi River and tributary streams have been greatly impacted by excess nitrogen, phosphorus, and sediment loadings from cropland and other sources. The nutrient load discharged from the mouth of the Mississippi River has also been implicated as a key cause of the Gulf of Mexico seasonal oxygen-depleted hypoxic zone (Figure 1), which has covered an extent equal to or greater than 20,000 km^2 in recent years (Rabalais, Turner, and Scavia, 2002). Goolsby et al. (1999) estimated that the UMRB was the source of nearly 39% of the Mississippi nitrate load discharged to the Gulf between 1980 and 1996; 35% of this load was attributed solely to Iowa and Illinois tributary rivers for average discharge years during the same time period (Goolsby et al., 2001). Nutrient inputs via fertilizer and/or livestock manure on cropland and pasture areas are the primary sources of nonpoint source nutrient pollution in the UMRB stream system. Sediment losses to the UMRB stream system are a function of erosion from upland soils, especially from cropland areas, and stream bank erosion. These nonpoint source pollution problems persist throughout the region, despite a wide range of water quality initiatives that have been undertaken at different watershed and regional scales by federal, state, and/or local agencies. This underscores the need for continued assessments of specific subwatersheds and of the entire region, to determine

which management and land use strategies will be the most effective approaches for mitigating nonpoint source pollution problems in the UMRB.

The Center for Agricultural and Rural Development (CARD) has initiated a set of simulation studies to investigate potential water quality pollution mitigation strategies for the UMRB, using the Soil and Water Assessment (SWAT) model (Arnold and Forher, 2005; Neitsch et al., 2005; Gassman et al., 2007). A key input to the modeling system is land use data obtained from the 1997 U.S. Department of Agriculture (USDA) National Resources Inventory (NRI) database (USDA-NRCS, 2007b; Nusser and Goebel, 1997). The land use and other data reported in the NRI is derived from a statistical sampling approach within the UMRB (and for the remainder of the U.S.) and is used in the modeling system at the 8-digit watershed[1] level (Gassman et al., 2006). Other land use data sources are also available that could be used for the UMRB applications, including the U.S. Geological Survey (USGS) National Land Cover Data (NLCD) database (Vogelmann et al., 2001), USDA National Agricultural Statistics Service (NASS) Agricultural Census survey data, and a combined NLCD-Agricultural Census land use data layer that was developed for the Hydrologic Unit Model of the U.S. (HUMUS) modeling system (Arnold et al., 1999).

Land use comparisons have been reported between the NLCD and the Global Land-Cover Characteristics (GLCC) global land use dataset (Brown et al., 1993) across the continental United States (Chen et al., 2005) and for 11 selected U.S. agricultural eco-regions (Chen et al., 2006). However, comparisons between the NRI land use data and the previously described alternative land use data sources have not been reported for the UMRB or for other regions. Thus, the objective of this study is to compare the area estimates of major land use data categories between the NRI, the NLCD, and HUMUS for the entire UMRB (2-digit watershed level), and at the 4- and 8-digit watershed scales (Figure 1). These comparisons will provide valuable insight regarding implications of land use dataset choice for SWAT UMRB simulation assessments and other studies, including the relative strengths and weaknesses of the NRI as compared to the other two land use data sources.

Land Use Data Source Descriptions

The NLCD, NRI, and HUMUS land use layers were compared in this study for 1992, which was the only common year available for all three data sets. The three data sets are described below in further detail, including a description of the Agricultural Census survey data, which are a key component of the HUMUS land use layer.

NLCD Land Use Data

The 1992 NLCD was derived from an analysis of Landsat Thematic Mapper (TM) satellite imagery purchased jointly by the Multi-Resolution Land Characteristics (MRLC) consortium in the early 1990s (Vogelmann et al., 2001). The spatial resolution of the data is 30 meters and it is mapped in the Albers Conic Equal Area projection (North American Datum of 1983 or NAD83). The NLCD data are provided on a state-by-state basis; these state data sets were cut out from larger "regional" data sets that are mosaics of Landsat TM scenes. The USGS National Land Cover Database (NLCD) 2001 (USGS, 2007) data set has also been recently released and features more updated land use data for 2001, which is further described by Homer et al. (2004).

The NLCD classifies land use according to one of 21 categories (Table 1) across the conterminous United States, which were largely derived from the Anderson land use/land cover classification scheme (Anderson et al., 1976; Vogelmann et al., 2001). The significance of a land use/land cover classification scheme is that it provides information not only about the vegetation structure of an area but also about the specific human uses of that area. The Anderson classification scheme is hierarchical in nature, with a progression from more general land use characterizations (Level I) to highly specific ones (Level III). Level III classifications are difficult to discern with satellite data only and thus were not included in the NLCD scheme. Modifications to the Anderson classification scheme include the consolidation of Level II categories into a single NLCD class (i.e., Streams/Canals and Lakes/Ponds to simply Open Water), or their dissection (i.e., Cropland and Pasture: Pasture/Hay, Row Crops, Small Grains and Fallow).

The dominant land use for each of the 30 m^2 units was first estimated using an "unsupervised" clustering algorithm at a sub-regional level for four TM spectral bands. Both summer and spring/fall images were assessed for each scene, to account for the large variations that can occur in vegetation appearance during the course of a year. One hundred

distinct classes were initially generated using this clustering approach, which were then aggregated into one of the final 21 NLCD land use classifications (USGS, 1996).

Classification at this scale results in some error between classes with similar reflectance values. Khorram et al. (1999) attempted to assess the accuracy of a portion of the NLCD and concluded that confusion of deciduous versus mixed forest, evergreen versus mixed, high residential versus low-residential, and high-residential versus commercial/industrial/transportation were common classification errors. Despite these errors, this data set is generally regarded as being among the most accurate available for depicting regional land use patterns.

The USGS and Environmental Protection Agency (EPA) have also conducted accuracy assessments of the NLCD data for selected federal regions using a scientifically rigorous approach. Accuracy assessments follow a revision cycle that incorporates feedback from MRLC Consortium partners and affiliated users. Private sector vendors under contract to the USEPA conducted the accuracy assessments. A protocol has been established by the two agencies that incorporates a two-stage, geographically stratified cluster sampling plan (Zhu et al., 2000) utilizing National Aerial Photography Program (NAPP) photographs as the sampling frame and the basic sampling unit. Results of the accuracy assessment indicate the ability of the NLCD to meet data requirements for applications at the regional to continental scale (Yang et al., 2001).

NRI Land Use Data

The NRI is a scientifically based survey designed to assess conditions and trends of soil, water, and related resources of U.S. non-federal lands at the national, regional, and state levels. NRI datasets were developed for the United States every five years from 1982 to 1997 (Nusser and Goebel, 1997; USDA-NRCS, 2007b). The NRI sample is a stratified two-stage unequal-probability area sample (Nusser and Goebel, 1997). Much of the United States is divided according to the Public Land Survey (PLS) system (USDI, 2007), and the NRI sample selection procedure is developed using the PLS system structure. Counties or analogous units have been used to implement the basic sampling design. The primary sampling units (PSUs) are areas of land called “segments.” The segments vary in size from 16 to 256 hectares (40-640 acres). There are about 300,000 PSUs in the current national sample. Detailed data are collected at a randomized sample

of points within each of these PSUs. Generally, there are three points per PSU, but some PSUs only contain one or two points. There are about 844,000 sample points in the NRI. At each sample point, information is collected on nearly 200 attributes including land use and cover, soil type, cropping history, conservation practices, erosion potential, water and wind erosion area estimates, wetlands, wildlife habitat, vegetative cover conditions, and irrigation method. The NRI data is spatially identified by state, Major Land Resource Area (MLRA), 8-digit watershed, and counties. Nusser and Goebel (1997) provide a more detailed description of the NRI survey design and statistical procedures. Table 2 provides the land use categories of NRI.

NRI data have been collected annually since 2001. In each year, both a Core Panel and Supplement Panel are sampled. The Core Panel is sampled each year while the Supplemental Panel rotates from year to year, consisting of a separate set of NRI sample points each year. The Core Panel and each Supplemental Panel are subsets of the NRI Foundation Sample, which is the full set of NRI sample points. The Core Panel contains about 41,600 PSUs, and the three Supplemental Panels drawn for 2001, 2002, and 2003 each contain about 32,000 PSUs. The density of PSUs collected nationally each year in these annual NRI surveys are roughly 25% of the full national sample, resulting in a greatly reduced resolution of land use characterization as compared to the 1997 NRI and earlier NRI datasets. Thus, these more recent annual NRI survey data cannot be used for the UMRB modeling system because of a lack of sampling points (i.e., these NRI data are statistically valid only at the national level).[2] Therefore, 1997 NRI data are currently used in the UMRB modeling system, with some links to the 1992 NRI data.

Agriculture Census Data

The Census of Agriculture (AgCensus) is the leading source of U.S. agricultural production statistics at the county, state, and national levels (USDA-NASS, 2007a). The AgCensus has been collected on a five-year cycle for years ending in 2 and 7 at the county (or equivalent) level since 1982. The census data within the United States is collected using mailout/mailback data collection procedures. The mailing list for the 1992 census was comprised of individuals, businesses, and organizations that could be readily identified as being associated with agriculture. The list was assembled from the records of the 1987 census, administrative records of the Internal Revenue Service (IRS), and the

statistical records of the USDA. Three different report forms (sample, nonsample, and screener form) were used for data collection in 1992. To assure adequate county- level census coverage and to minimize the reporting burden, a stratified random sample procedure is used to select recipients of the sample form. Operators are selected using strata that reflect product type, value of sales, and total acreage. Responses are collected and a statistical estimation procedure is used to account for non-responders. The AgCensus data is developed using this information. More details on the collection, processing methodology, and reliability of census estimates are given in USDA-NASS (2007b).

AgCensus statistics are used by Congress to develop and change farm programs, study historical trends, assess current conditions, and plan for the future. Many national and state programs use census data to design and allocate funding for extension service projects, agricultural research, soil conservation programs, and land-grant colleges and universities. Private industry uses census statistics to provide a more effective production and distribution system for the agricultural community.

HUMUS Land Use Data (Combined NLCD and AgCensus Data)

The NLCD land use data is widely used for generating inputs for hydrologic/water quality modeling because these data are available in GIS format at a high resolution (30 m). However, as mentioned earlier, these data do not provide area estimates for individual row and close-grown crops (Table 1). In contrast, the AgCensus provides area estimates for agricultural land use including specific crops but does not contain land use data for non-agricultural land categories such as forest, wetland, urban, and water. Thus, the two data sets were merged to provide a more robust land use data layer to support applications of HUMUS, which was initially developed to support USDA analyses of the United States Resources Conservation Act Assessment of 1997 for the conterminous United States. The combined NLCD-AgCensus land use dataset was developed to improve and update the less detailed land use layers that were initially used in HUMUS as described by Arnold et al. (1999).

The HUMUS data set was created by initially setting the broad agricultural and non-agricultural land use areas equal to the corresponding NLCD areas, at the 2-, 4-, and 8-digit levels. The NLCD non-agricultural land use subcategories (e.g., urban, forest) were also incorporated into the HUMUS land use layer. The AgCensus land use subcategories,

including both broad land use designations (e.g., row crop, cover crop) and specific crops (e.g., corn, soybean, hay land) were then imputed within the overall HUMUS agricultural land use category. This process was performed by determining the appropriate areal weights that allowed the AgCensus county-level data to be translated to the 8-digit watershed level for the HUMUS data set. This step provided much more detailed agricultural land use information for HUMUS than could have been obtained using just the NLCD.

Comparison Methodology

The initial phase of the land use comparison process was the grouping of specific land use categories (Tables 1 to 3) into broader land use categories (Tables 4 and 5), which required some subjective decisions as to the most appropriate category into which a specific land use should be placed. This process was carried out in two steps: (1) the grouping of NRI and NLCD land use categories into 12 consistent major land use categories (Table 4), where the NLCD broad non-agricultural land use categories also represented the corresponding categories in HUMUS; and (2) the further partitioning of the HUMUS agricultural land use categories, as reported in the AgCensus, into the four broad agricultural categories (Table 5). For this study, agricultural land included row crops, close-grown crops, pasture, hay, and orchards, while the non-agricultural land included all other categories such as range, urban, fallow, transitional, barren, forest, wetland, and water. The land area estimates for the HUMUS and NLCD broad agricultural and non-agricultural land uses are identical at all levels, and thus are identified as HUMUS/NLCD for the land use area comparisons. There are variations in how some of the land use categories are defined within each source, which precludes direct comparisons for some of the categories. For example, actual land use is not identified for federal land areas in the NRI but is accounted for in the NLCD and HUMUS data sources.

The first step in performing the comparisons between the different land use sources was determining the areas of each land use category at the 2-, 4-, and 8-digit watershed scales (Figures 1). These areas were estimated for the NLCD database by overlaying the land use map on the different hydrologic units. The NRI land use areas were determined using a two-step process in which the total areas for each point were first estimated using the expansion factors associated with each NRI point, and then the point areas were

aggregated to the hydrologic unit levels. The total areas of each land use category were also similarly summed for the HUMUS data within each respective hydrologic unit. The percentage differences in land use area comparisons were performed by comparing the NRI land use areas relative to the NLCD or HUMUS land use area estimates, for each land use category[3] using the following equations:

$$\%\,diff = \left(\frac{NRI - NLCD}{NRI} \right) * 100.0 \quad (1)$$

$$\%\,diff = \left(\frac{NRI - HUMUS}{NRI} \right) * 100.0 \quad (2)$$

where %diff equals the percentage difference, and NRI, NLCD, and HUMUS are the respective land use area estimates for each percentage difference calculation.

Results

Comparison of the Land Use Area Estimates at the 2-Digit Watershed Level

The total UMRB agricultural and non-agricultural land estimates between the NRI and HUMUS/NLCD matched well (Figure 2) with no discernible variation (Table 6). However, comparisons of UMRB-level row crop and close-grown crop areas show definite variations between the three land use sources, especially for the NLCD estimates (Figure 3). The estimated NRI row crop area was 7% less than the respective NLCD estimate (Table 6). On the other hand, the estimated NRI row crop area exceeded the corresponding HUMUS by 7%. The estimated NLCD close-grown crop area for the entire UMRB was considerably less than the corresponding areas for the other two data sources (Figure 3). The NLCD underestimated the NRI close-grown crop area by 74% while the HUMUS estimate was only 10% lower than the corresponding NRI area (Table 6). The combined close-grown crop and row crop areas were much closer for the three land use databases; the overall NLCD and HUMUS areas were 2% higher and 7% lower, respectively, when compared to the NRI. The combined NLCD and HUMUS estimated pasture and hay areas were 4% higher and 15% lower, respectively, than the associated

NRI estimate (Table 6). Overall, these results show that the total URMB cropland and grassland estimates are similar among the three datasets. However, the NLCD appears to underestimate greatly the total UMRB close-grown crop area.

Comparisons of individual crops, alfalfa, and pasture were performed only between the NRI and HUMUS data sets (Figure 3), because the NLCD land use data do not provide individual crop area estimates. The estimated land areas of corn and soybeans, the two dominant UMRB crops, were generally similar. The difference in the estimated soybean areas was just 1% while the NRI corn acreage estimate was 12% higher than the respective HUMUS estimate (Table 6). The estimated areas of oats, winter wheat, and barley (all close-grown crops) and other non-grassland crops were also similar between the two data sets and were much smaller than the corn and soybean areas. The NRI alfalfa/hay area estimate exceeded the associated HUMUS estimate by 11% (Table 6), which was nearly the same as the difference found between the two data sets for the corn area estimates; however, the amount of cropland planted to alfalfa was equal to only about 25% of the planted corn area (Figure 4). In contrast, the NRI pasture area estimate was 29% lower than the estimated HUMUS pasture area (Table 6), which was the largest difference of any of the major land use categories shown in Figure 4

Figure 5 shows comparisons between the NRI and HUMUS for several non-agricultural categories (the HUMUS areas are based directly on the NLCD as previously discussed). The predicted forest areas were relatively close between the two data sources, and are the largest non-cropland areas for both the NRI and HUMUS (except for pasture and hay land). The NRI urban area estimate was roughly double that of the HUMUS urban area, while the HUMUS range area estimate was much larger than the corresponding NRI area and is likely an overestimate. The HUMUS wetland area estimate is over three times greater than the NRI wetland area. The extent of wetland areas in the NRI is known to greatly underestimate the true wetland area as discussed by Gassman et al. (2006). This is due in part to wetlands being located in federal land, which is not broken out into specific land uses in the NRI. This NRI wetland area underestimate has been corrected for the SWAT UMRB simulation by making adjustments to align the wetland areas with those reported in the NLCD, as described by Gassman et al. (2006).

Comparison of the Land Use Area Estimates at the 4-Digit Watershed Level

Land use area comparisons were performed between the NRI and the two other land use data sets for the 14 4-digit watersheds (Figure 1). Percentage differences are reported for all of the comparisons in Table 7. The agricultural land areas estimated for the NRI data sources were within -8% to 11% of the corresponding HUMUS/NLCD area estimates across the 14 UMRB 4-digit watersheds (Figure 6). The NRI estimates for the non-agricultural land areas varied between -32% to 20% as compared to the HUMUS/NLCD area estimates (Figure 7). The NRI row crop area estimates were consistently lower as compared to the NLCD (Figure 8), except for three of the 4-digit watersheds; the percentage differences ranged from -108% to 27% (Table 7). However, the NRI row crop area estimates were always higher (2% to 14%) than the HUMUS area estimates in all 14 4-digit watersheds (Figure 8, Table 7). The NRI close-grown crop area estimates ranged from 47% to 100% higher than the NLCD estimates except for watershed 0701, which was 7% less than the NLCD area estimate (Figure 9, Table 7). The majority of the NRI close-grown crop area estimates were greater than the corresponding HUMUS areas, with percentage differences varying from -61% to 46% (Table 7). The graphical comparisons in Figure 9 further confirm the weakness of the NLCD close-grown crop estimates as compared to the estimates provided by the NRI and HUMUS. The percentage differences determined between the combined row crop and close-grown crop areas (Table 7) for the most intensively cropped 4-digit watersheds (i.e., 0702, 0708, 0709, 0710, and 0713) are relatively small, suggesting that the three datasets provide accurate estimates of total cropland in UMRB cropland-dominated subregions.

Comparisons between the NRI and HUMUS are shown for corn and soybeans in Figure 10, and for hay and pasture in Figure 11. The soybean area estimates between the NRI and HUMUS were within ±10% for 11 out of the 14 4-digit watersheds. The NRI corn area estimates exceeded the corresponding HUMUS corn areas by 3% to 19%. The estimated NRI pasture areas differed from the HUMUS pasture areas by -111% to 17% and were lower in 11 of the 14 4-digit watersheds. The opposite result occurred for the alfalfa/hay area comparisons, which revealed that the estimated NRI areas were higher in 10 of the 4-digit watersheds as compared to the HUMUS area estimates and that the NRI areas ranged from -21% to 32% of the HUMUS areas. The combined NRI estimated

pasture and alfalfa/hay areas ranged from -69% to 5% and -43% to 39% of the corresponding HUMUS and NLCD combined areas. In general, the pasture and alfalfa/hay area estimates at the 4-digit watershed level reflect greater variability between the three datasets as compared to the cropland estimates, which suggests that there is more uncertainty in the grassland use estimates.

Comparison of the Land Use Area Estimates at the 8-Digit Watershed Level

Land use comparisons for the 131 8-digit watersheds (Figure 12) are shown in Figures 13 through 22 between the NRI, HUMUS, and/or NLCD datasets. Percentage differences between the different land use estimates are listed in Table 8, which includes a cross-reference between the 8-digit watershed IDs (Figure 12) and the USGS 8-digit watershed codes.

The NRI agricultural and non-agricultural land use patterns were generally similar to the corresponding HUMUS/NLCD land use estimates at the UMRB 8-digit watershed level (Figures 13 and 14). Slightly more than half of these HUMUS/NLCD land areas were greater than the respective NRI land use areas (Table 9). Differences between the NRI and HUMUS/NLCD agricultural land area estimates were greater than ±30% (-76% to 35%) in only five of the 8-digit watersheds. The percentage differences for the NRI versus HUMUS/NLCD non-agricultural land use comparisons exceeded ±30% (-100% to 57%) for 23 of the 8-digit watersheds. Several of the largest discrepancies were found for 8-digit watersheds with relatively small amounts of agricultural or non-agricultural land; e.g., watershed 5 in Figure 13 and watersheds 70 and 96 in Figure 14.

The extent of estimated row crop area reported in the NRI was also similar to the estimated row crop areas in the HUMUS and NLCD datasets, as shown in Figures 15 and 16. Row crop land area estimate comparisons at the individual 8-digit watershed level reveal essentially opposite results with respect to the NRI (Table 9), with 70% of the NLCD estimates higher and 73% of the HUMUS estimates lower. The greatest percentage differences in the row crop estimates ranged from 88% to -324% between the NRI and HUMUS and from 44% to -893% between the NRI and NLCD. Several of these large differences again occurred for 8-digit watersheds with small row crop areas such as watersheds 3, 5, 9, and 122 in Figure 15 and watersheds 5, 28, 29, and 54 in Figure 16.

Much greater differences resulted in the close-grown crop land area estimate comparisons (Figures 17 and 18). The HUMUS close-grown crop areas followed the general pattern of the corresponding NRI areas across the 8-digit watersheds, and the distribution of the HUMUS close-grown crop area estimates were nearly evenly split between higher and lower values relative to the NRI (Table 9). However, the percentage differences were greater than ±30% (80% to -525%) for 75 of the 8-digit watershed close-grown crop area comparisons between the NRI and HUMUS. The NLCD close-grown crop distributions greatly underestimated the corresponding NRI land areas in virtually all of the 8-digit watersheds (Tables 8 and 9), reflecting the very low NLCD close-grown crop area estimates that were previously discussed for the 2- and 4-digit watershed levels. These 8-digit comparisons further indicate that the NLCD close-grown crop area estimates are likely inaccurate.

Soybean, corn, alfalfa/hay, and pasture 8-digit watershed comparisons between the NRI and HUMUS are shown in Figures 19 to 22, respectively. Similar trends in estimated soybean, corn, and alfalfa/hay land areas can be seen between the two data sets; however, the differences between the NRI and HUMUS pasture areas are noticeably greater. The distributions of HUMUS individual 8-digit watershed land areas relative to the NRI varied considerably (Table 9), with a little over half exceeding corresponding NRI land areas for soybeans while the majority of corn, alfalfa/hay, and pasture areas were less than the associated NRI land areas. Large percentage differences were again found between the NRI and HUMUS estimates for the three crops and pasture, with extreme differences (Table 7) and ranges of 100% to -1112%, 66% to -637%, 72% to -281%, and 48% to -321% for soybeans, corn, alfalfa/hay, and pasture, respectively. Similar to previously discussed comparisons, many of these large percentage differences resulted for 8-digit watersheds with relatively small areas of the respective crop or pasture; e.g., subwatersheds 8 and 9 in Figure 19.

Conclusions

The results of this study show that the NRI is a viable source of land use data for UMRB SWAT simulation studies and other analyses. The NRI land use estimates were in general agreement with the corresponding HUMUS and NLCD estimates for most of the

major land use categories. As expected, the percentage differences increased as the land area comparisons were refined from the larger watersheds (2- and 4-digit) to the smaller 8-digit watersheds. However, the overall consistency in land use estimates indicates that the NRI land use data can be used for UMRB modeling studies with reasonable confidence.

The results of the study also show the clear advantage of the NRI and HUMUS relative to the NLCD for agricultural land use analyses. A key weakness of the NLCD is the lack of specific crop land use data that is available in both the NRI and HUMUS. The NLCD also greatly underestimates the extent of close-grown crops at all levels in the UMRB. However, the NLCD does provide similar overall cropland area estimates relative to the NRI and HUMUS for the most intensely cropped UMRB subregions, indicating that the NLCD is a viable alternative land use data source depending on how the data are applied. It is necessary to incorporate the more complete NLCD wetlands land use into NRI-based UMRB studies, to ensure an accurate accounting of wetland impacts in the region. The NLCD also provides an accurate set of non-agricultural land use data for the HUMUS approach.

The greatest uncertainty between the NRI and HUMUS land use estimates was for close-grown crops, pasture, and alfalfa/hayland, based on the magnitudes of the percentage difference calculations. It is not possible to establish which of the data sources provides the most accurate estimates of these land use categories. Sensitivity analyses of different land use levels for these three agricultural land use categories could provide useful insights regarding the impacts of the differences between the two data sets.

It is likely that comparisons between more recent datasets, such as the 1997 NRI, 1997 or 2002 AgCensus, and 2001 NLCD data would provide only limited additional insights. Cropland is defined as only “cultivated crops” in the 2001 NLCD, which is even less information than the row and cover crop categories provided in the 1992 NLCD. The 1997 NRI also does not show major land use shifts as compared to the 1992 NRI, with the exception of changes in row crop acreage as described by Gassman et al. (1998). Thus, we would not expect that such additional comparisons would result in different conclusions than those found for this study. However, the following future research is recommended for further assessment of the impacts of the different land use datasets on UMRB hydrology and water quality:

- Compare the results of using both the 1997 NRI and HUMUS as land use data sources for SWAT UMRB simulations. This would provide useful insights regarding the impacts of the two approaches on UMRB water resources and potentially reveal additional data gaps that need to be addressed in future UMRB land use data sets.
- Further compare the results of the NRI and HUMUS approaches with the USDA Conservation Effects Assessment Project (CEAP) National Assessment that is described in USDA-NRCS (2007a). The National CEAP assessment is a partial NRI-based approach that incorporates updated data obtained from more recent surveys of agricultural producers.
- Pursue development of a UMRB land use data source based on remote sensing data collected by USDA-NASS (2007c), which can be used to derive crop rotations such as those reported by Secchi et al. (2007) for an Iowa biofuels assessment. The NASS land use data years that will be available for each state in the UMRB after the 2007 remote sensing data are processed as shown in Figure 23. Additional years of NASS remote sensing data beyond 2007 will provide the basis for more accurate crop rotation estimates for some of the states, especially Minnesota and Missouri. Supplemental data may be required in the interim, such as that provided by the 1997 NRI, to develop fully the necessary crop rotations for these states.

Endnotes

1. U.S. Geological Survey (USGS) 8-digit hydrologic unit code (HUC) watersheds as described by Seaber, Kapinos, and Knapp (1987) and in USDA-NRCS (2007c).

2. Combining the annual NRI surveys across years could result in a complete national sample comparable to the 1997 NRI and earlier surveys, which would be suitable for many UMRB SWAT modeling applications. However, it is not clear if this step will be taken in the future.

3. The percentage difference calculations result in negative numbers being reported in Tables 6-8 when the NRI land use area estimates are less than the corresponding NLCD or HUMUS estimates and result in positive numbers for the opposite situation.

TABLE 1. The USGS NLCD land use categories

Code	Land use category
11	Open water
12	Perennial ice/snow
21	Low intensity residential
22	High intensity residential
23	Commercial/industrial/transportation
31	Bare rock/sand/clay
32	Quarries/strip mines/gravel pits
33	Transitional
41	Deciduous forest
42	Evergreen forest
43	Mixed forest
51	Shrubland
61	Orchards/vineyards/other
71	Grasslands/herbaceous
81	Pasture/hay
82	Row crops
83	Small grains
84	Fallow
85	Urban/recreational grasses
91	Woody wetlands

TABLE 2. The USDA NRI land use categories

Code	Land use category
0	Federal land
001	Horticulture fruit
002	Horticulture nut
003	Horticulture vine
004	Horticulture bushfruit
005	Horticulture berries
006	Horticulture other
011	Corn
012	Sorghum
013	Soybeans
014	Cotton
015	Peanuts
016	Tobacco
017	Beets
018	Potatoes
019	Other veg truck
020	Other row
021	Sunflower
111	Wheat
112	Oats
113	Rice
114	Barley
116	Other close
141	Hay grass
142	Hay legume
143	Hay grass legume
170	Summer fallow
171	Aquaculture
180	Other idle
211	Past grass
212	Past legume
213	Past mixed
250	Range
341	Forest grazed
342	Forest not grazed

TABLE 2. Continued

Code	Land use category
400	Farmsteads
401	Other farmland
410	CRP
611	Salt flats
612	Bare exposed rock
613	Strip mines etc
614	Beaches
615	Sand dunes
616	Mixed barren
617	Mud flats
618	River wash
619	Oil wasteland
620	Other barren
630	Permament snow ice
640	Marshland
650	All other land
700	Urban 10a or larger
730	Small built up
800	Public trans
860	Railroad trans
870	Other roads
901	Water 2-40a
902	Water lt 2a
911	Streams per lt 66ft
912	Streams per 66-660ft
913	Streams gt 1/8 mile
920	Water type
921	Lake gt 40a
922	Reservoir gt 40a
923	Bay or gulf gt 40a
924	Estuary gt 40a

TABLE 3. The HUMUS land use categories (combined AgCensus and NLCD)

Code	ID	Land use category
7	FRST	Forest-mixed
8	FRSE	Forest-evergreen
9	FRSD	Forest-deciduous
10	WETF	Wetlands-forested
11	WETN	Wetlands-nonforested
12	PAST	Pasture
15	RNGE	Range-grasses
16	RNGB	Range-brush
18	WATR	Water
19,20	CORN	Corn
23	GRSG	Grain sorghum
28	WWHT	Winter wheat
31	BARL	Spring barley
32	OATS	Oats
52	ALFA	Alfalfa-hay crop
56	SOYB	Soybean
67	COTP	Upland cotton (harvested with picker)
68	TOBC	Tobacco
69	SGBT	Sugarbeet
70	POTA	Potato
74	SUNF	Sunflower
79,59	CABG	Cabbage
93	APPL	Apple-orange
93	ORCD	Orchards
98	BARN	Barren land
111	URBP	Urban-pervious (parks, lawn)
112	URBI	Urban-impervious (buildings, roads)
113	LUMP	Lumped-other crops

TABLE 4. Grouping of the NRI and NLCD land use categories into 12 major land use categories

Category	NRI land use categories	NLCD land use categories
Barren	611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 630	12, 31, 32
Fallow	170	84
Forest	341, 342	41, 42, 43
Non-natural woody	001, 002, 003, 004, 005, 006	61
Pasture/hay	141, 142, 143, 211, 212, 213, 180, 410	81
Rangeland	250	51, 71
Row crops	011, 012, 013, 014, 015, 016, 017, 018, 019, 020, 021	82
Small grains	111, 112, 113, 114, 116	83
Transitional	400, 401, 650	33
Urban	700, 730, 800, 860, 870	21, 22, 23, 85
Water	901, 902, 911, 912, 913, 921, 922, 923, 924, 171	11
Wetlands[a]	640	91, 92

[a]There is a separate wetlands table in the NRI that is the primary source of wetlands land use data.

TABLE 5. Grouping of the NRI, NLCD, and HUMUS land use data sets into agricultural land use categories

Category	NRI land use categories	NLCD land use categories	NLCD HUMUS land use categories[a]
Non-natural woody/orchard	001, 002, 003, 004, 005, 006	61	93
Pasture/hay	141, 142, 143, 211, 212, 213, 180, 410	81	12, 52
Row crops	011, 012, 013, 014, 015, 016, 017, 018, 019, 020, 021	82	19, 23, 56, 59, 23, 67, 68, 69, 70, 74, 79, 113
Small grains / close grown crops	111, 112, 113, 114, 116[b]	83	31, 32, 28

[a]Based on categories reported in the AgCensus.
[b]The NRI close crop category 116 was not included in the comparison due to a lack of a similar category in HUMUS.

TABLE 6. Percentage differences in NRI land use area estimates relative to the respective HUMUS and NLCD estimates at the 2-digit watershed level (entire Upper Mississippi River Basin)

Data Source	HUMUS	NLCD
Agricultural land	0	0
Non-agricultural land	0	0
Row crops	7	-7
Close grown crops	10	74
Row & close grown crops	7	-2
Soybean	1	N/A
Corn	12	N/A
Pasture	-29	N/A
Alfalfa/hay	11	N/A
Pasture & alfalfa/hay	-15	4

Note: A positive percentage difference indicates that the NRI estimate was greater than the HUMUS or NLCD estimate, and a negative percentage difference indicates the opposite relationship.

TABLE 7. Percentage differences in NRI land use area estimates relative to the respective HUMUS and NLCD estimates at the 4-digit watershed level for the Upper Mississippi River Basin

4-digit watershed ID	USGS 4-digit code	HUMUS/ NLCD agric. land	HUMUS/ NLCD non-agric. land	HUMUS close crops	NLCD close crops	HUMUS row crops	NLCD row crops
1	0701	-1	0	-9	-7	10	-17
2	0702	-5	20	-3	84	6	-15
3	0703	-8	4	44	90	12	-108
4	0704	-6	10	25	100	10	-26
5	0705	-8	3	35	100	12	-108
6	0706	7	-20	11	95	7	-2
7	0707	-7	3	22	100	9	-50
8	0708	4	-25	33	83	5	-7
9	0709	-8	27	1	97	9	-6
10	0710	4	-20	46	47	2	-4
11	0711	11	-32	24	55	14	18
12	0712	-7	13	-61	82	4	-8
13	0713	-1	2	-10	81	7	2
14	0714	6	-8	-1	79	8	27

TABLE 7. Extended

4-digit ID	USGS 4-digit code	HUMUS soybean	HUMUS corn	HUMUS pasture	HUMUS alfalfa/ hay	HUMUS row & close grown crops	NLCD row & close grown crops	HUMUS pasture & alfalfa/hay	NLCD pasture & alfalfa/hay
1	0701	1	18	-43	32	8	-16	-9	12
2	0702	0[b]	12	-58	-1	5	-8	-46	6
3	0703	7	17	-54	27	17	-78	-20	21
4	0704	-1	15	-52	4	11	-15	-28	6
5	0705	6	15	-71	23	16	-70	-19	21
6	0706	4	8	17	-15	7	5	5	8
7	0707	-35	9	-39	7	11	-31	-17	6
8	0708	2	7	-9	21	6	-5	-1	39
9	0709	-26	19	-91	-1	9	-2	-49	-21
10	0710	1	3	4	21	3	-3	7	27
11	0711	14	16	11	-21	15	24	5	-7
12	0712	3	8	-111	30	4	-7	-69	-9
13	0713	-4	15	-63	19	6	4	-47	-29
14	0714	6	18	5	3	7	34	4	-43

Note: A positive percentage difference indicates that the NRI estimate was greater than the HUMUS or NLCD value, and a negative percentage difference indicates the opposite relationship.

TABLE 8. Percentage differences in NRI land use area estimates relative to the respective HUMUS and NLCD estimates at the 8-digit watershed level for the Upper Mississippi River Basin

8-digit ID	8-digit watershed	HUMUS/ NLCD agric. land	HUMUS/ NLCD non-agric. land	HUMUS close crops	NLCD close crops	HUMUS row crops	NLCD row crops
1	07010101	-27	0	9	-89	N/A	N/A
2	07010102	-37	1	N/A	N/A	N/A	N/A
3	07010103	13	7	N/A	N/A	-31	-586
4	07010104	11	2	51	-14	52	37
5	07010105	-76	-1	78	-114	-52	-286
6	07010106	-12	1	-138	-494	29	-48
7	07010107	-20	6	-7	33	-31	-126
8	07010108	5	-1	-53	-16	15	-27
9	07010201	-5	-7	10	33	-67	-94
10	07010202	11	-6	31	82	5	-36
11	07010203	-9	7	-74	-102	7	-8
12	07010204	7	-15	-13	32	20	6
13	07010205	-6	-25	-87	97	5	-12
14	07010206	-6	7	-131	9	27	16
15	07010207	9	-12	17	-60	17	7
16	07020001	-28	57	12	89	-13	-69
17	07020002	-10	18	-18	72	5	-46
18	07020003	-7	50	0	95	8	-25
19	07020004	0	17	10	97	10	-10

TABLE 8. Continued

8-digit ID	8-digit watershed	HUMUS/ NLCD agric. land	HUMUS/ NLCD non-agric. land	HUMUS close crops	NLCD close crops	HUMUS row crops	NLCD row crops
20	07020005	-1	4	-58	50	10	-22
21	07020006	-6	-1	-69	77	-2	-24
22	07020007	-1	11	30	96	7	-3
23	07020008	-3	1	34	94	3	-9
24	07020009	-3	28	4	95	3	-6
25	07020010	-3	0	0	81	-2	-15
26	07020011	-1	-1	-33	97	10	-4
27	07020012	1	-6	-47	91	13	0
28	07030001	-18	5	-154	87	-36	-426
29	07030002	-51	-1	51	100	25	-405
30	07030003	22	-6	-39	29	19	-14
31	07030004	24	-10	38	86	38	22
32	07030005	-20	18	53	92	9	-113
33	07040001	-20	26	4	100	-11	-57
34	07040002	-4	18	30	99	10	-7
35	07040003	-11	7	53	100	-17	-76
36	07040004	-6	41	31	100	12	-27
37	07040005	-6	14	42	100	-11	-76
38	07040006	3	5	57	100	13	-4
39	07040007	3	-1	9	100	44	-24
40	07040008	-4	9	-51	100	14	-9

TABLE 8. Continued

8-digit ID	8-digit watershed	HUMUS/ NLCD agric. land	HUMUS/ NLCD non-agric. land	HUMUS close crops	NLCD close crops	HUMUS row crops	NLCD row crops
41	07050001	-21	-2	53	100	66	-95
42	07050002	-34	3	N/A	N/A	N/A	N/A
43	07050003	2	0	N/A	N/A	88	-164
44	07050004	6	-1	-46	100	51	-173
45	07050005	-10	2	46	100	7	-92
46	07050006	-7	13	-21	100	6	-67
47	07050007	-5	15	40	100	1	-119
48	07060001	4	-7	24	100	19	16
49	07060002	13	-41	-61	100	11	1
50	07060003	-4	4	-9	98	-4	9
51	07060004	10	-81	21	97	4	-12
52	07060005	3	-10	-9	90	11	18
53	07060006	9	-23	30	92	5	-14
54	07070001	-20	-1	N/A	N/A	8	-893
55	07070002	-12	6	10	100	-1	-188
56	07070003	-12	7	18	100	27	-44
57	07070004	-4	-5	57	100	-1	23
58	07070005	-2	2	31	99	-8	-9
59	07070006	9	-1	-4	100	-6	-16
60	07080101	2	0	-10	72	3	-6

TABLE 8. Continued

8-digit ID	8-digit watershed	HUMUS/ NLCD agric. land	HUMUS/ NLCD non-agric. land	HUMUS close crops	NLCD close crops	HUMUS row crops	NLCD row crops
61	07080102	7	-21	26	95	5	-9
62	07080103	2	-31	43	87	9	-5
63	07080104	7	-19	9	55	7	-2
64	07080105	2	-37	-44	63	-1	-11
65	07080106	14	-34	-56	70	12	2
66	07080107	4	-29	-18	-16	14	-2
67	07080201	5	-28	57	99	7	-8
68	07080202	-1	-38	50	99	-2	-17
69	07080203	8	-57	-19	79	5	-3
70	07080204	11	-100	64	99	4	-7
71	07080205	3	-17	57	93	6	-4
72	07080206	3	-13	-46	65	7	-4
73	07080207	-2	-39	-18	78	2	-6
74	07080208	8	-38	45	89	0	-14
75	07080209	1	-14	42	83	5	-15
76	07090001	-12	34	21	97	11	-23
77	07090002	-9	38	32	99	19	-25
78	07090003	-6	25	-74	98	13	16
79	07090004	-26	18	35	97	-15	-30
80	07090005	-4	11	22	96	5	-3
81	07090006	-6	28	-387	66	10	-1
82	07090007	-1	11	-146	88	10	1

TABLE 8. Continued

8-digit ID	8-digit watershed	HUMUS/ NLCD agric. land	HUMUS/ NLCD non-agric. land	HUMUS close crops	NLCD close crops	HUMUS row crops	NLCD row crops
83	07100001	-1	18	-3	90	5	-9
84	07100002	0	9	21	-33	-4	-8
85	07100003	2	-24	N/A	N/A	6	2
86	07100004	3	6	47	72	3	0
87	07100005	9	-32	64	86	10	5
88	07100006	-3	-4	65	67	-3	-9
89	07100007	1	-4	73	76	-6	-13
90	07100008	11	-40	40	53	12	-2
91	07100009	13	-39	26	-55	-8	-9
92	07110001	15	-49	29	40	10	8
93	07110002	19	-82	23	-47	21	31
94	07110003	16	-68	34	9	19	28
95	07110004	10	-22	6	80	11	17
96	07110005	18	-98	39	33	31	22
97	07110006	4	-21	38	69	8	0
98	07110007	12	-27	-9	36	23	33
99	07110008	-4	-2	39	77	-7	13
100	07110009	10	-8	-72	49	20	35
101	07120001	-10	20	-83	76	5	-10
102	07120002	-2	26	-63	81	4	-4

TABLE 8. Continued

8-digit ID	8-digit watershed	HUMUS/ NLCD agric. land	HUMUS/ NLCD non-agric. land	HUMUS close crops	NLCD close crops	HUMUS row crops	NLCD row crops
103	07120003	11	10	82	96	7	-10
104	07120004	-9	3	-294	36	10	-13
105	07120005	-1	4	N/A	N/A	5	0
106	07120006	-23	16	-2	92	-13	-44
107	07120007	-4	29	-257	84	7	4
108	07130001	-7	-2	-43	70	4	-1
109	07130002	3	42	49	97	9	3
110	07130003	1	6	-37	61	12	7
111	07130004	-6	26	-7	79	0	-3
112	07130005	0	-5	31	89	5	-2
113	07130006	-4	40	-2	79	6	0
114	07130007	-7	19	-31	84	5	-3
115	07130008	8	-11	49	82	13	10
116	07130009	-9	37	-45	81	-1	-7
117	07130010	9	-18	-3	89	6	3
118	07130011	6	-17	-15	81	15	14
119	07130012	0	-26	-70	74	14	9
120	07140101	-10	1	-58	63	-5	5
121	07140102	24	-10	-525	-70	-46	-28
122	07140103	25	-17	28	80	-324	-183
123	07140104	35	-13	N/A	N/A	N/A	N/A
124	07140105	19	-9	3	78	25	27

TABLE 8. Continued

8-digit ID	8-digit watershed	HUMUS/ NLCD agric. land	HUMUS/ NLCD non-agric. land	HUMUS close crops	NLCD close crops	HUMUS row crops	NLCD row crops
125	07140106	2	-12	2	70	11	41
126	07140107	17	-24	74	91	-52	-30
127	07140108	1	-6	-119	28	30	39
128	07140201	-1	11	-24	88	10	9
129	07140202	-1	-4	0	81	11	44
130	07140203	-4	19	-10	82	1	28
131	07140204	1	9	-10	84	9	37

TABLE 8. Extended

8-digit ID	USGS 8-digit code	HUMUS soybean	HUMUS corn	HUMUS pasture	HUMUS alfalfa/hay	HUMUS row & close grown crops	NLCD row & close grown crops	HUMUS pasture & alfalfa hay	NLCD pasture & alfalfa hay
1	07010101	N/A	N/A	-110	42	-58	-351	-23	11
2	07010102	N/A	N/A	-320	64	N/A	N/A	-22	-9
3	07010103	93	N/A	-38	51	-92	-673	16	32
4	07010104	N/A	57	-40	7	52	29	-20	-2
5	07010105	N/A	-34	-314	8	29	-179	-106	-46
6	07010106	-330	41	-83	43	7	-107	-19	23
7	07010107	N/A	0	-71	37	-23	-70	-18	10
8	07010108	-119	31	-23	40	4	-25	5	24
9	07010201	-1112	-47	4	28	-50	-67	14	21
10	07010202	-88	17	-28	43	11	-9	10	30
11	07010203	-29	22	-62	27	4	-12	-25	-5
12	07010204	30	15	-3	-59	18	8	-14	7
13	07010205	13	9	-59	-1	2	-9	-37	8
14	07010206	39	20	-37	-19	24	16	-34	-27
15	07010207	-54	33	-40	54	17	3	4	12
16	07020001	-1	-25	-114	-35	-4	-13	-94	-68
17	07020002	11	-3	-42	-37	0	-21	-42	22
18	07020003	-3	17	-53	23	7	-8	-38	-5
19	07020004	1	24	-59	-11	10	-4	-53	17
20	07020005	3	15	-14	-13	4	-16	-14	30

TABLE 8. Extended

8-digit ID	USGS 8-digit code	HUMUS soybean	HUMUS corn	HUMUS pasture	HUMUS alfalfa/hay	HUMUS row & close grown crops	NLCD row & close grown crops	HUMUS pasture & alfalfa hay	NLCD pasture & alfalfa hay
21	07020006	-35	18	-24	48	-4	-22	-10	36
22	07020007	16	6	-136	-10	8	1	-98	-18
23	07020008	-11	16	-75	39	5	-6	-44	13
24	07020009	-9	12	-110	32	3	-6	-75	33
25	07020010	-20	11	-9	-16	-2	-14	-9	57
26	07020011	10	7	-141	3	10	-3	-110	27
27	07020012	10	15	-55	-7	11	3	-38	-5
28	07030001	N/A	-10	-52	36	-44	-394	-14	36
29	07030002	N/A	37	-154	17	30	-304	-73	17
30	07030003	N/A	13	8	42	13	-10	24	27
31	07030004	-105	49	17	19	38	28	18	22
32	07030005	21	11	-95	22	17	-78	-44	16
33	07040001	-34	1	-46	-12	-10	-42	-34	1
34	07040002	1	18	-72	2	11	-2	-49	-9
35	07040003	-54	-12	-26	-7	-3	-39	-18	10
36	07040004	2	16	-86	9	13	-19	-50	20
37	07040005	20	-16	2	-33	-3	-47	-9	13
38	07040006	16	14	-21	5	21	13	-8	-3
39	07040007	46	44	-148	29	40	-11	-23	13

TABLE 8. Extended

8-digit ID	USGS 8-digit code	HUMUS soybean	HUMUS corn	HUMUS pasture	HUMUS alfalfa/hay	HUMUS row & close grown crops	NLCD row & close grown crops	HUMUS pasture & alfalfa hay	NLCD pasture & alfalfa hay
40	07040008	1	17	-33	-17	11	-5	-28	-2
41	07050001	86	66	-176	9	64	-65	-75	6
42	07050002	N/A	N/A	-12	-86	N/A	N/A	-25	36
43	07050003	100	N/A	-90	34	77	-164	-27	33
44	07050004	N/A	53	-59	44	41	-143	-1	36
45	07050005	-7	9	-90	19	15	-52	-25	14
46	07050006	-21	10	-50	23	3	-43	-11	6
47	07050007	-32	6	-56	26	8	-80	-11	30
48	07060001	-24	22	6	-32	20	26	-9	-14
49	07060002	32	2	20	14	8	5	18	21
50	07060003	-75	-2	14	-31	-5	20	-3	-22
51	07060004	6	4	36	-17	5	-5	19	39
52	07060005	-45	16	0	-16	10	22	-5	-18
53	07060006	-2	6	22	-5	7	-6	12	35
54	07070001	N/A	N/A	-144	72	-36	-893	-23	41
55	07070002	22	-3	-74	24	2	-111	-17	22
56	07070003	4	27	-108	-4	27	-34	-57	8
57	07070004	-335	15	-21	-4	10	37	-13	-31
58	07070005	-89	-4	3	-8	-3	5	-1	-5

TABLE 8. Extended

8-digit ID	USGS 8-digit code	HUMUS soybean	HUMUS corn	HUMUS pasture	HUMUS alfalfa/hay	HUMUS row & close grown crops	NLCD row & close grown crops	HUMUS pasture & alfalfa hay	NLCD pasture & alfalfa hay
59	07070006	5	-3	25	-7	-5	-2	12	10
60	07080101	-49	16	-7	23	2	-5	1	26
61	07080102	2	7	-6	32	6	-6	10	54
62	07080103	23	1	-74	23	10	-2	-33	22
63	07080104	-19	19	4	20	7	0	7	34
64	07080105	6	-6	10	24	-1	-10	13	47
65	07080106	3	15	20	23	11	3	21	36
66	07080107	16	14	-16	-67	14	-3	-24	23
67	07080201	14	2	-31	13	9	-4	-21	50
68	07080202	-4	0	-6	13	-1	-15	-3	64
69	07080203	0	9	-1	71	5	-3	20	57
70	07080204	2	5	23	58	6	-4	32	71
71	07080205	-1	10	-41	-13	7	-1	-33	31
72	07080206	9	7	-36	26	7	-3	-13	28
73	07080207	-1	4	-55	27	2	-6	-35	41
74	07080208	-8	4	13	39	2	-10	20	43
75	07080209	11	1	-25	18	7	-11	-13	29
76	07090001	4	16	-109	5	12	-16	-50	-6

TABLE 8. Extended

8-digit ID	USGS 8-digit code	HUMUS soybean	HUMUS corn	HUMUS pasture	HUMUS alfalfa/hay	HUMUS row & close grown crops	NLCD row & close grown crops	HUMUS pasture & alfalfa hay	NLCD pasture & alfalfa hay
77	07090002	17	28	-109	-14	20	-15	-62	3
78	07090003	-34	19	-30	-24	10	18	-28	-38
79	07090004	-115	-2	-117	2	-11	-18	-44	-36
80	07090005	-41	17	-105	36	5	-1	-49	-17
81	07090006	-25	23	-164	2	8	-1	-107	-44
82	07090007	-31	24	-143	30	9	1	-87	-20
83	07100001	3	7	-46	37	5	-7	-28	26
84	07100002	-10	1	12	48	-4	-8	18	39
85	07100003	8	5	-40	-132	5	2	-48	9
86	07100004	3	4	-6	-18	4	0	-8	24
87	07100005	23	-3	-43	33	11	6	-27	54
88	07100006	-8	2	-10	-27	-1	-7	-12	30
89	07100007	-7	-6	11	-5	-2	-8	9	25
90	07100008	11	13	2	24	13	0	8	24
91	07100009	-22	0	25	30	-7	-11	26	29
92	07110001	-3	20	25	3	12	11	20	21
93	07110002	34	1	24	-12	21	24	17	15
94	07110003	27	10	19	-27	21	25	11	7
95	07110004	7	18	16	-37	10	25	9	-15

TABLE 8. Extended

8-digit ID	USGS 8-digit code	HUMUS soybean	HUMUS corn	HUMUS pasture	HUMUS alfalfa/hay	HUMUS row & close grown crops	NLCD row & close grown crops	HUMUS pasture & alfalfa hay	NLCD pasture & alfalfa hay
96	07110005	26	36	7	-21	32	24	1	11
97	07110006	9	10	6	-281	16	19	-12	-16
98	07110007	29	29	4	-3	18	33	3	-26
99	07110008	-9	-1	-24	-7	7	32	-21	-62
100	07110009	32	8	-18	45	13	36	1	-64
101	07120001	9	7	-148	9	4	-9	-108	-16
102	07120002	15	-6	-85	22	4	-3	-67	13
103	07120003	-93	38	-4	49	14	0	7	29
104	07120004	1	19	-79	32	8	-13	-52	-1
105	07120005	4	6	-141	52	4	0	-73	-14
106	07120006	-92	13	-86	34	-13	-39	-40	-3
107	07120007	-33	22	-263	49	7	4	-120	-92
108	07130001	-26	19	-197	19	4	-1	-130	-84
109	07130002	10	10	-150	-25	10	4	-127	-7
110	07130003	17	12	-49	-31	11	8	-47	-36
111	07130004	-27	17	-74	-40	0	-3	-69	-42
112	07130005	-46	24	-44	29	6	1	-27	-4
113	07130006	0	10	-245	52	6	0	-164	-74

TABLE 8. Extended

8-digit ID	USGS 8-digit code	HUMUS soybean	HUMUS corn	HUMUS pasture	HUMUS alfalfa/hay	HUMUS row & close grown crops	NLCD row & close grown crops	HUMUS pasture & alfalfa hay	NLCD pasture & alfalfa hay
114	07130007	-7	15	-184	34	4	-1	-133	-74
115	07130008	8	20	-31	19	14	12	-25	-16
116	07130009	-8	4	-183	58	-1	-6	-101	-41
117	07130010	-18	20	15	28	5	7	17	14
118	07130011	9	19	-28	18	13	17	-20	-37
119	07130012	24	6	-37	-123	10	13	-42	-53
120	07140101	-7	7	9	-94	-13	15	-3	-52
121	07140102	-60	-637	37	-56	-74	-31	28	26
122	07140103	-189	-343	33	32	-123	-33	33	28
123	07140104	N/A	N/A	48	4	N/A	N/A	40	42
124	07140105	21	36	17	17	21	35	17	1
125	07140106	-4	30	-18	21	10	45	-10	-72
126	07140107	-44	-27	24	10	10	30	20	10
127	07140108	37	26	-46	-264	26	39	-62	-98
128	07140201	3	15	-153	-109	9	11	-148	-178
129	07140202	13	24	-73	-14	9	50	-57	-283
130	07140203	2	4	-39	23	-1	35	-20	-188
131	07140204	12	16	-36	18	5	46	-18	-215

Notes: A positive percentage difference indicates that the NRI estimate was greater than the HUMUS or NLCD value, and a negative percentage difference indicates the opposite relationship. N/A indicates percentage difference calculations where the NRI area estimate equals zero, resulting in a divide by zero error (see equations 1 and 2); a zero value indicates small percentage differences less than an absolute value of 1.

TABLE 9. Total number of UMRB 8-digit watershed land areas reported in the HUMUS and/or NLCD data sets that are greater or lower than the corresponding NRI 8-digit watershed land areas, by land use category

Land use category	Data set	Number of 8-digit land areas greater than the NRI	Number of 8-digit land areas lower than the NRI
Agricultural land	HUMUS/NLCD[a]	69	62
Non-agricultural land	HUMUS/NLCD[a]	71	60
Row crop	HUMUS	35	96
Row crop	NLCD	92	39
Close grown crop	HUMUS	64	67
Close grown crop	NLCD	20	111
Soybean	HUMUS	69	62
Corn	HUMUS	29	102
Alfalfa hay	HUMUS	48	83
Pasture	HUMUS	97	34

[a]The HUMUS and NLCD agricultural and non-agricultural land area estimates are identical.

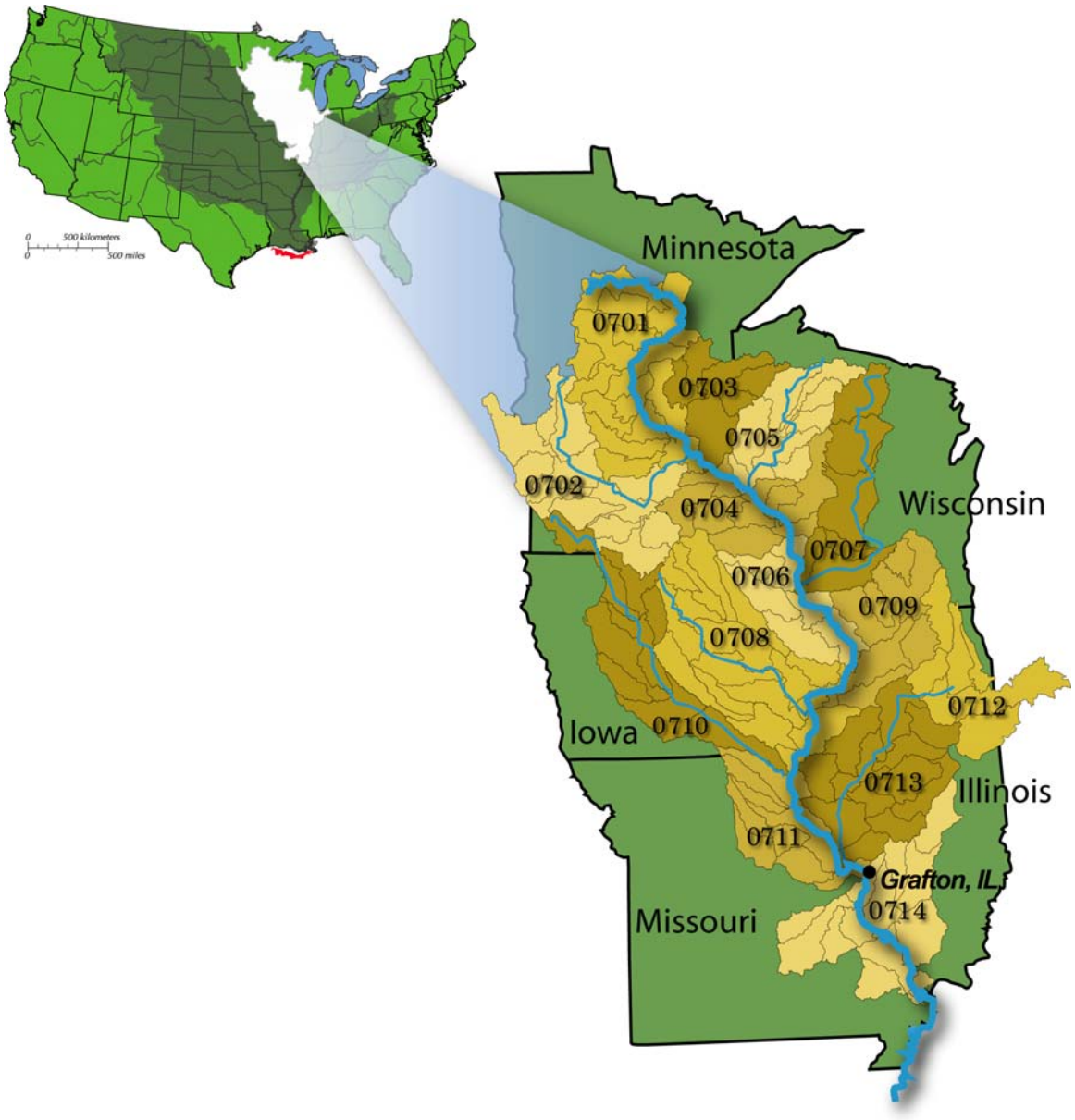

FIGURE 1. The location of the Upper Mississippi River Basin (UMRB) within the Mississippi River Basin, and the delineations of the UMRB 14 major 4-digit subwatersheds and the 131 8-digit subwatersheds (Grafton, Illinois is the assumed outlet for the UMRB SWAT simulations)

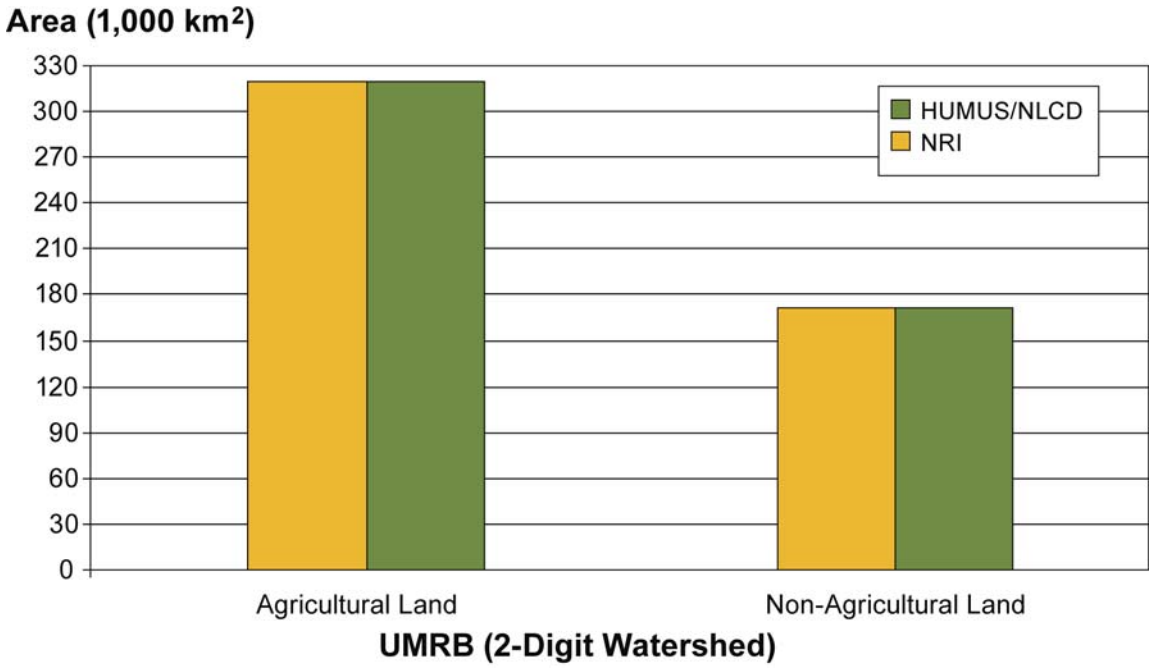

FIGURE 2. NRI versus HUMUS/NLCD agricultural and non-agricultural land area estimates for the Upper Mississippi River Basin (HUMUS and NLCD areas are identical)

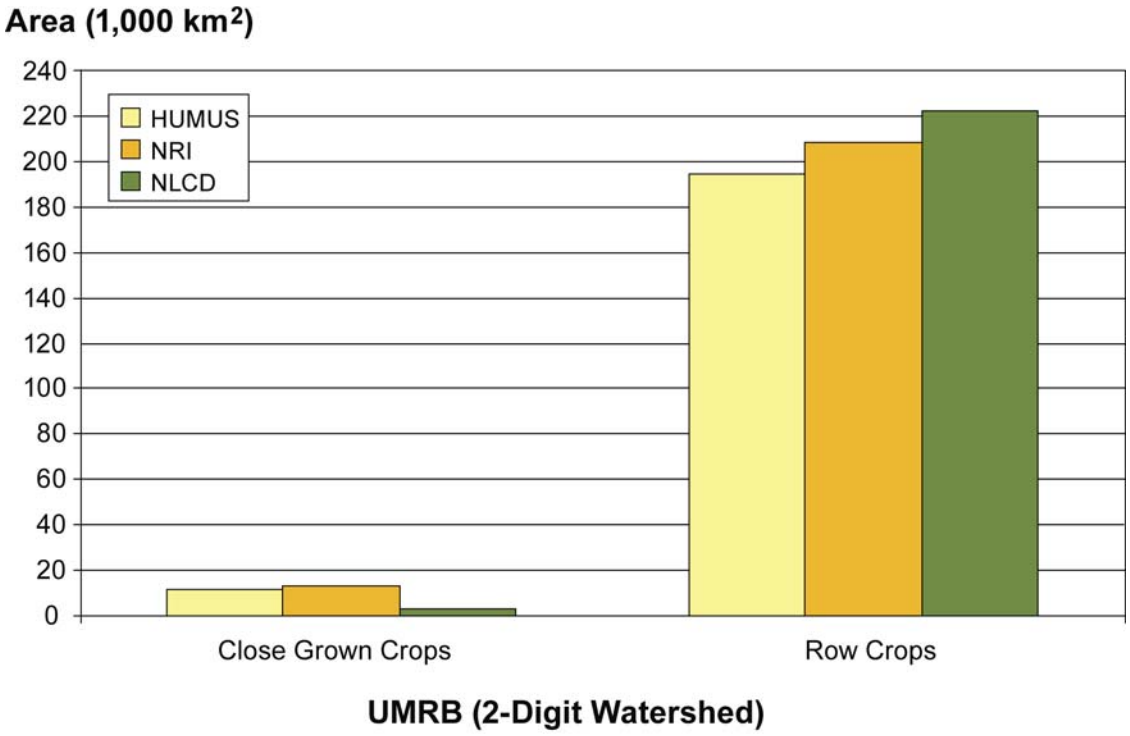

FIGURE 3. NRI versus HUMUS and NLCD close-grown and row crop area estimates for the Upper Mississippi River Basin

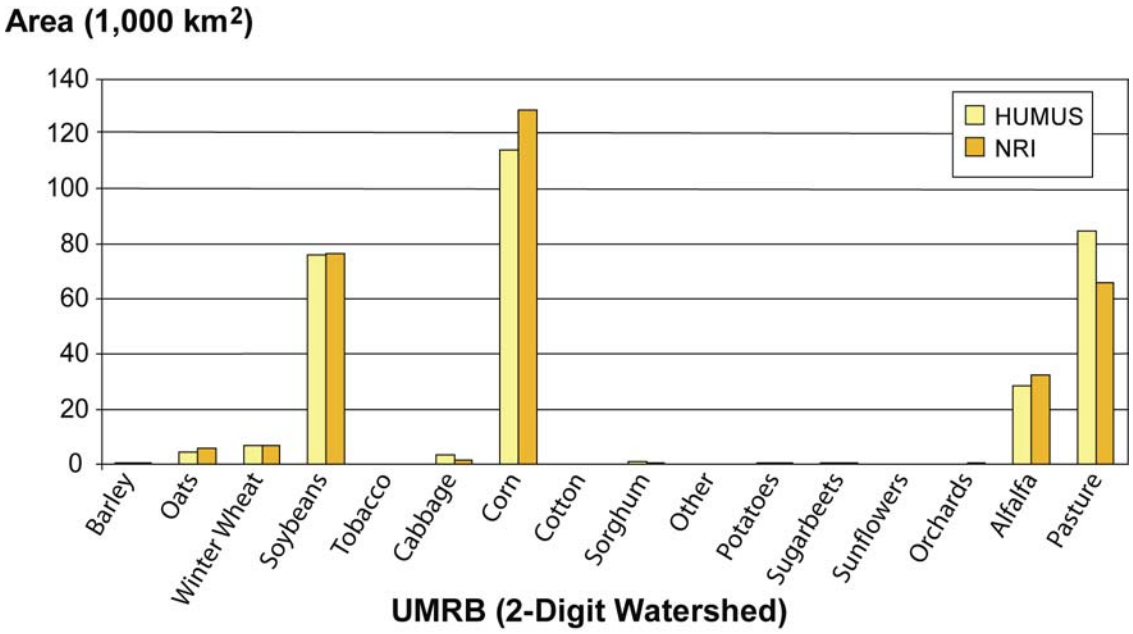

FIGURE 4. NRI versus HUMUS agricultural crop and pasture area estimates for the Upper Mississippi River Basin

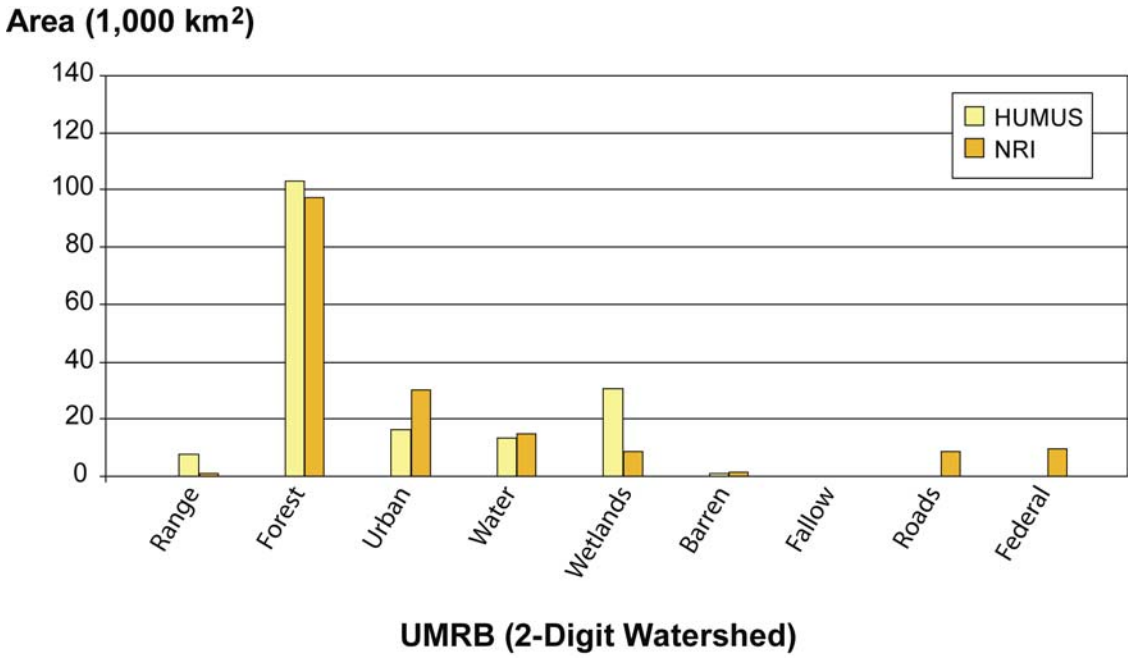

FIGURE 5. NRI versus HUMUS non-agricultural area estimates for the Upper Mississippi River Basin

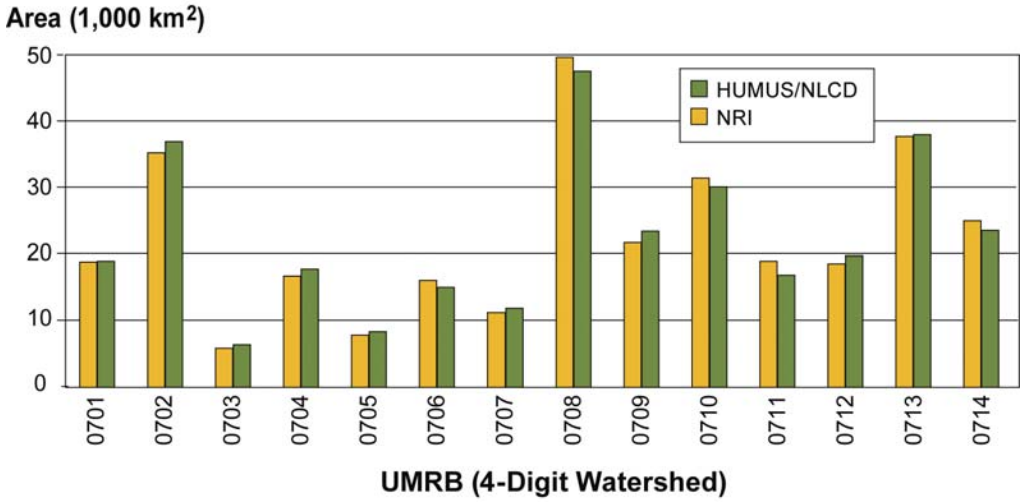

FIGURE 6. NRI versus HUMUS/NLCD agricultural land area estimates at the 4-digit subwatershed level within the Upper Mississippi River Basin (HUMUS and NLCD areas are identical)

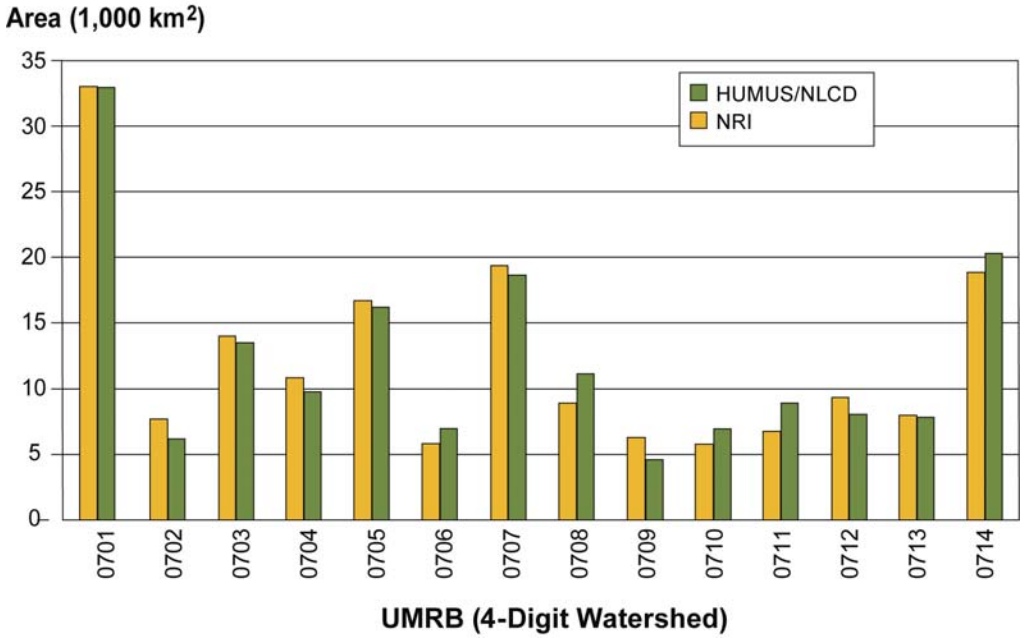

FIGURE 7. NRI versus HUMUS/NLCD non-agricultural land area estimates at the 4-digit subwatershed level within the Upper Mississippi River Basin (HUMUS and NLCD areas are identical)

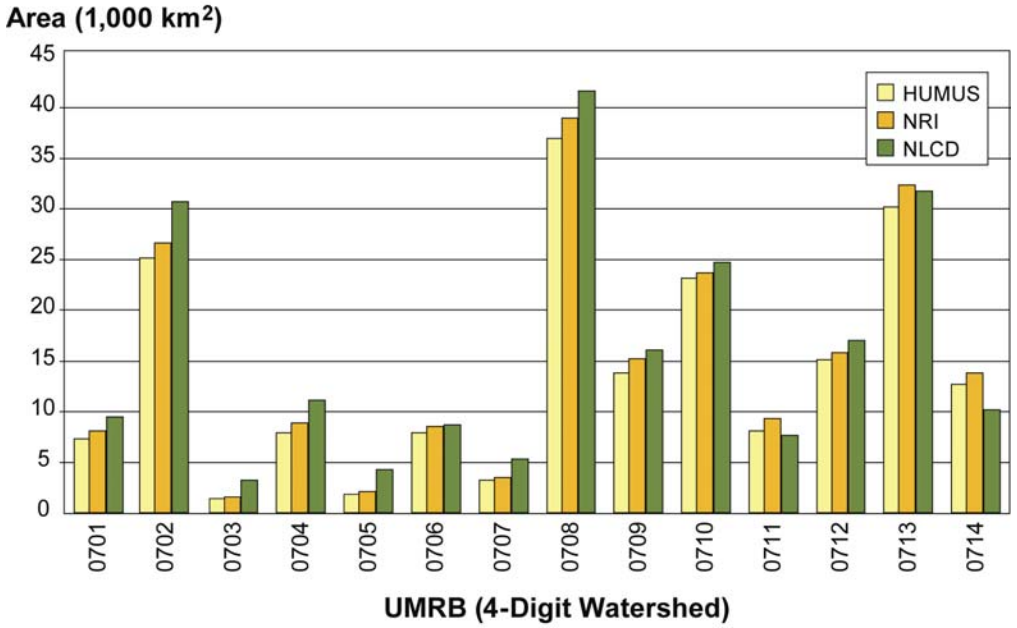

FIGURE 8. NRI versus HUMUS and NLCD row crop area estimates at the 4-digit subwatershed level within the Upper Mississippi River Basin

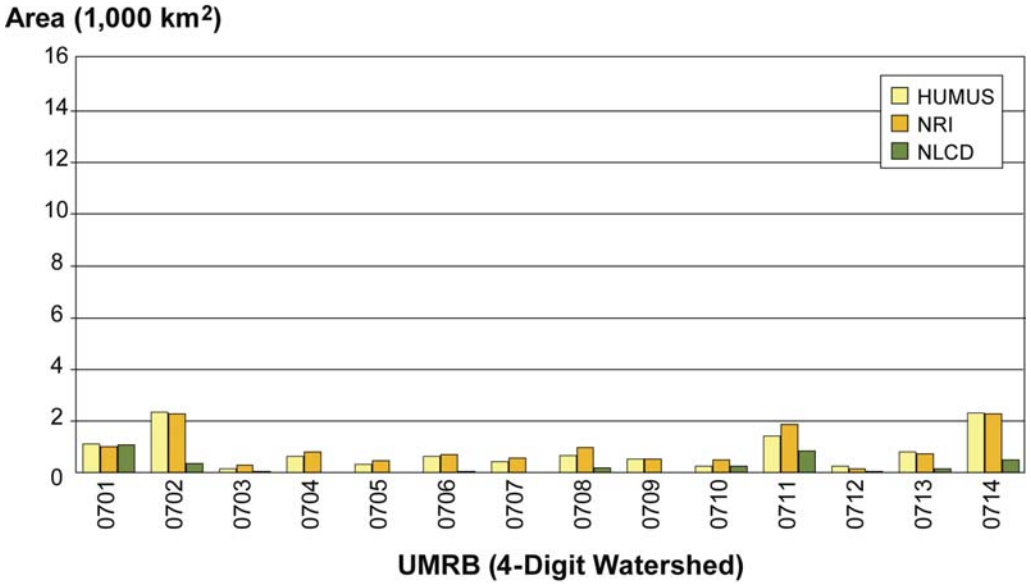

FIGURE 9. NRI versus HUMUS and NLCD close-grown crop area estimates at the 4-digit subwatershed level within the Upper Mississippi River Basin

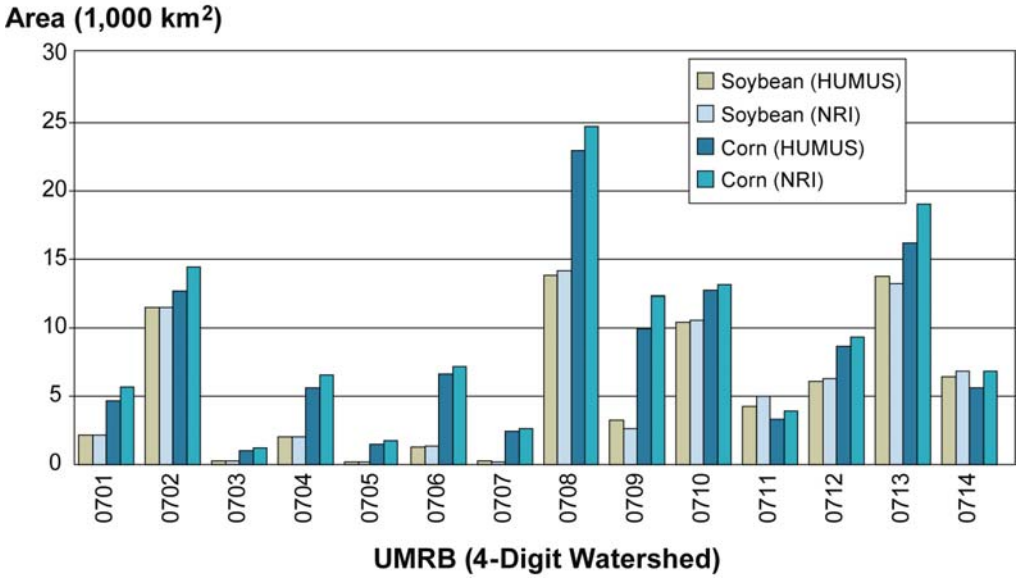

FIGURE 10. NRI versus HUMUS soybean and corn area estimates at the 4-digit watershed level within the Upper Mississippi River Basin

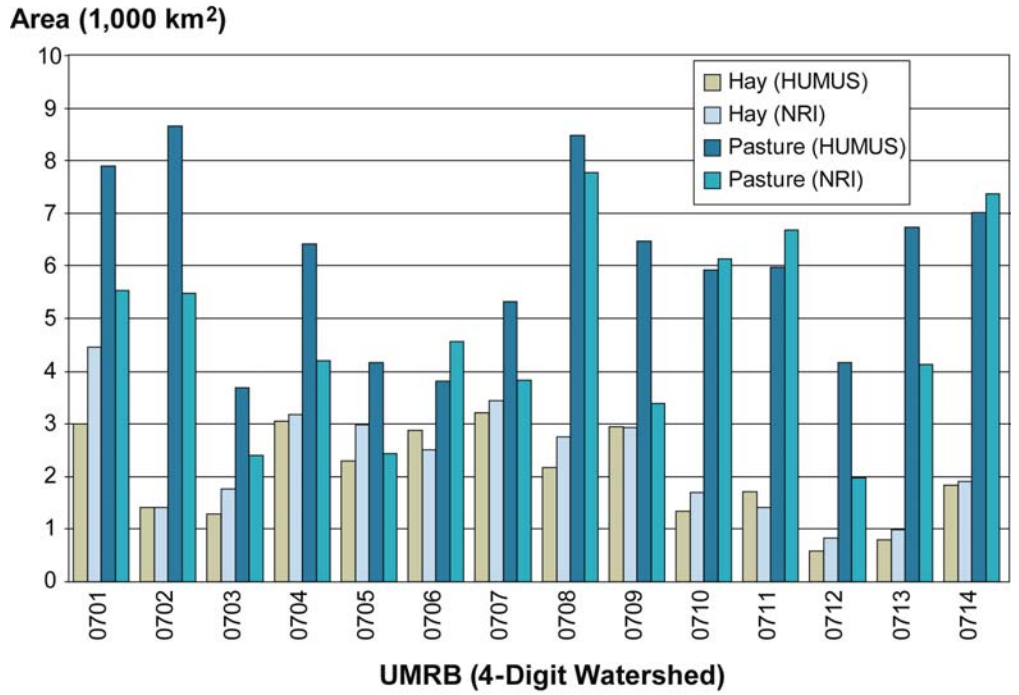

FIGURE 11. NRI versus HUMUS hay and pasture area estimates at the 4-digit watershed level within the Upper Mississippi River Basin

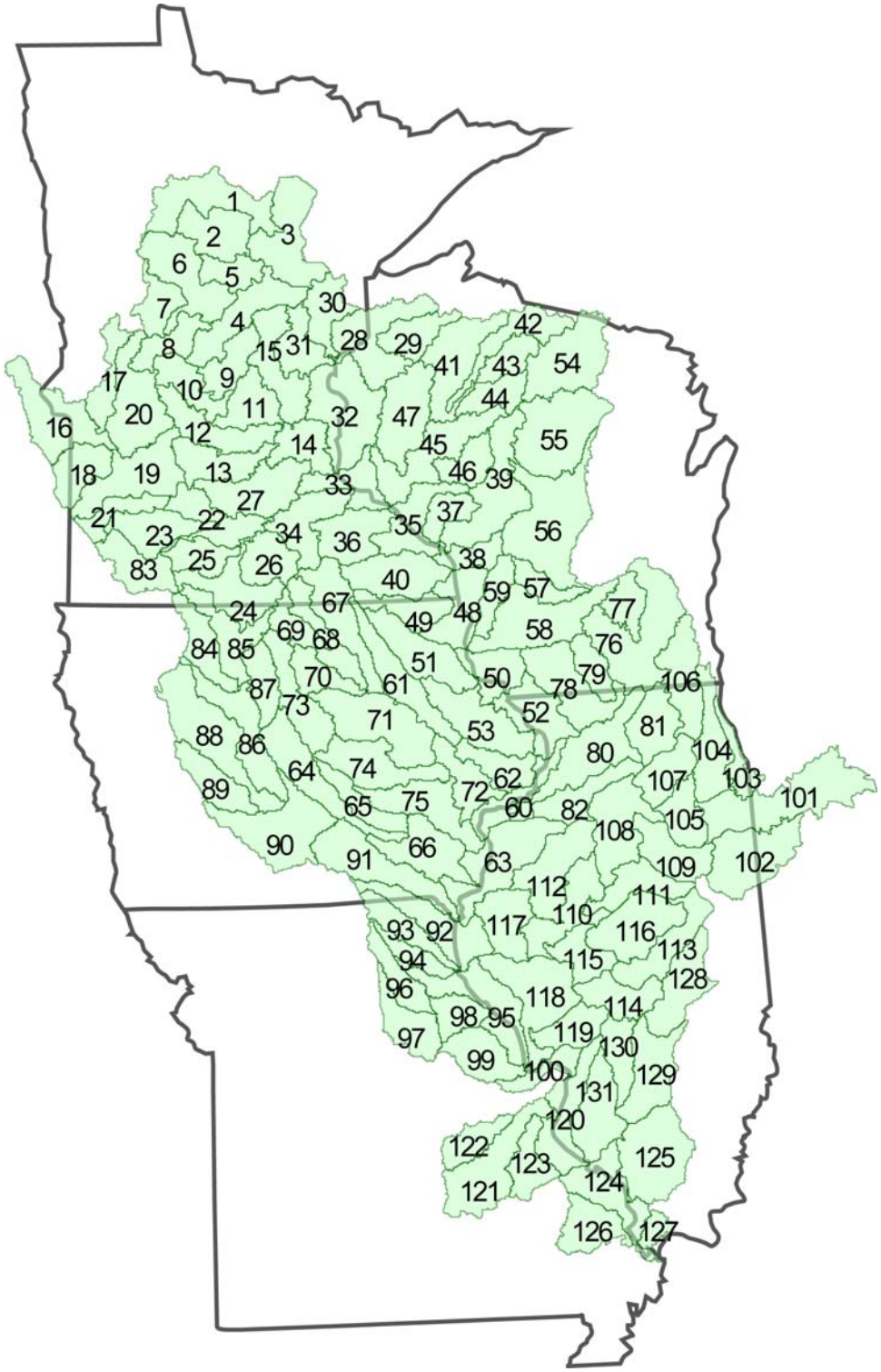

FIGURE 12. Locations of the 131 8-digit watersheds in the Upper Mississippi River Basin (as referenced in Figures 13-22).

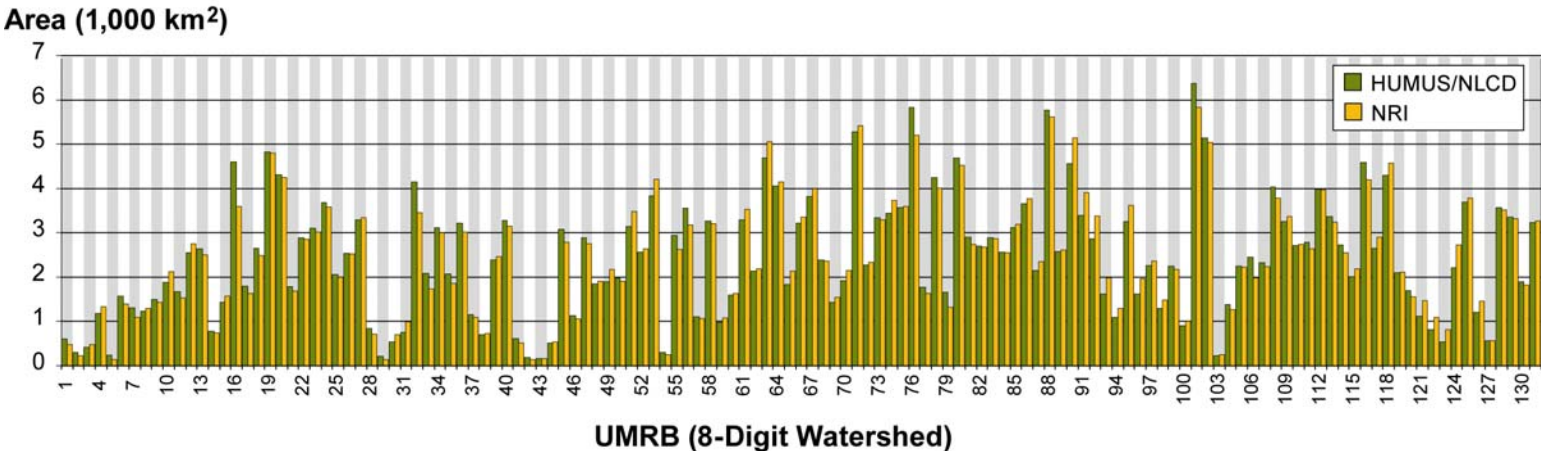

FIGURE 13. NRI versus HUMUS/NLCD agricultural land area estimates at the 8-digit watershed level for the Upper Mississippi River Basin (HUMUS and NLCD areas are identical)

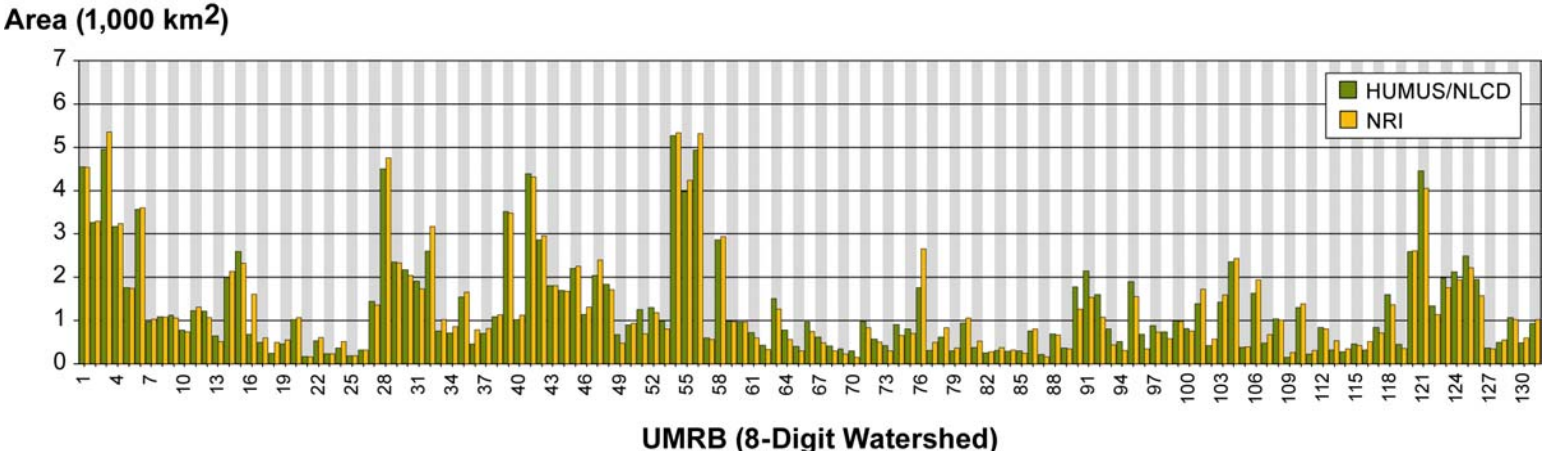

FIGURE 14. NRI versus HUMUS/NLCD non-agricultural land area estimates at the 8-digit watershed level for the Upper Mississippi River Basin (HUMUS and NLCD areas are identical)

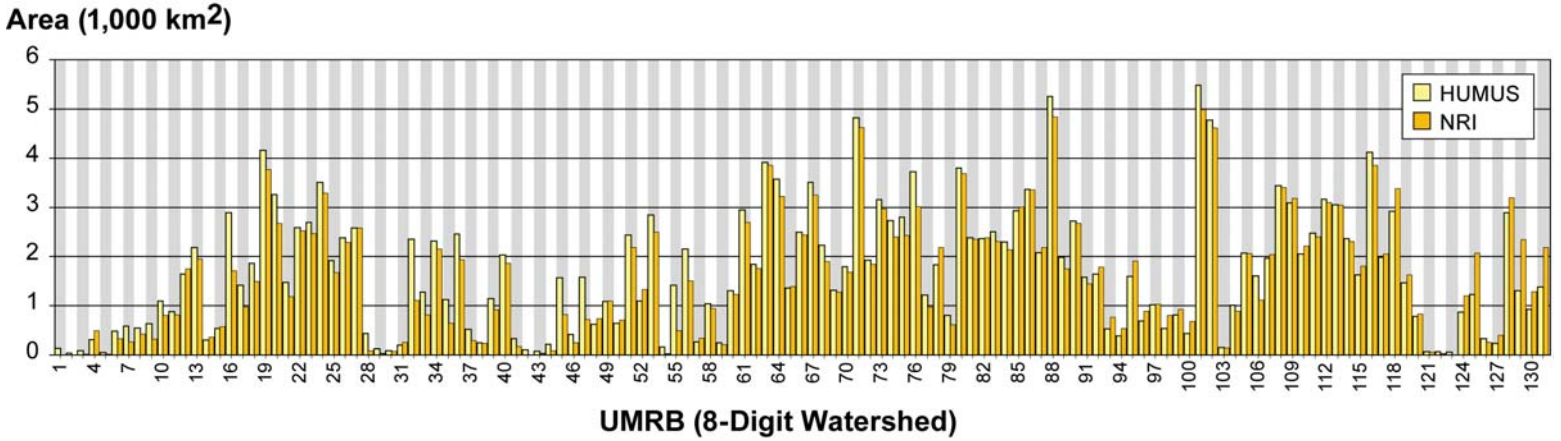

FIGURE 15. NRI versus HUMUS row crop area estimates at the 8-digit watershed level for the Upper Mississippi River Basin

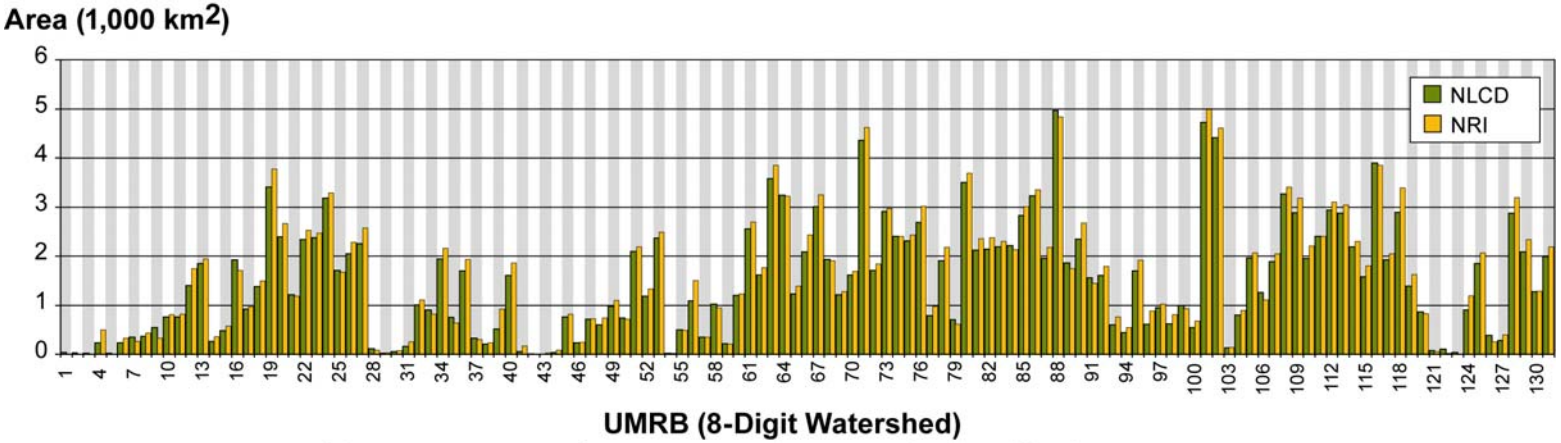

FIGURE 16. NRI versus NLCD row crop area estimates at the 8-digit watershed level for the Upper Mississippi River Basin

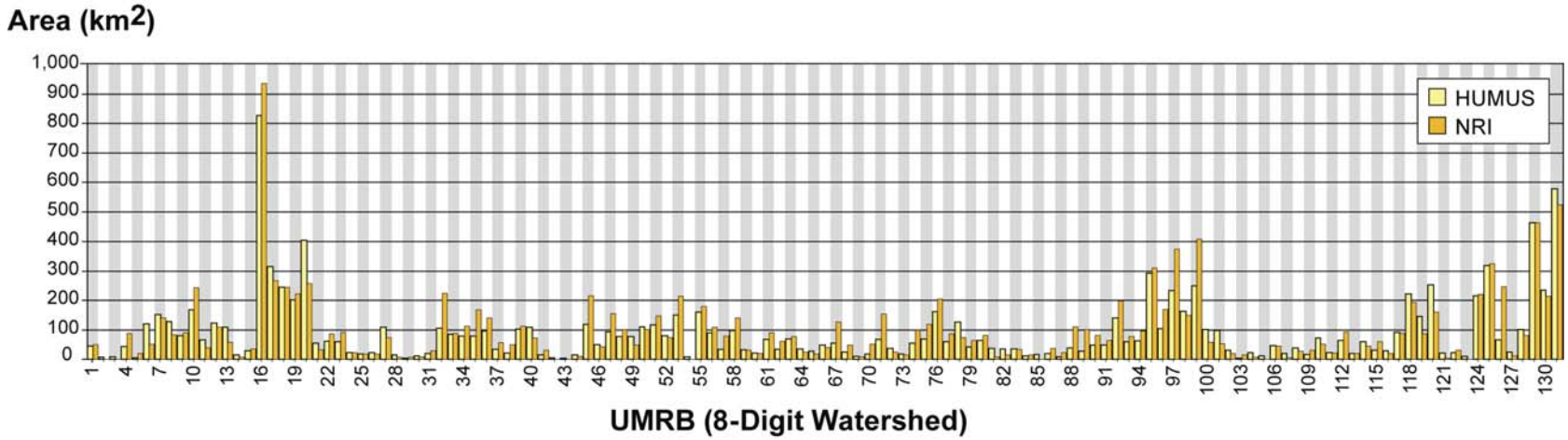

FIGURE 17. NRI versus HUMUS close-grown crop area estimates at the 8-digit watershed level for the Upper Mississippi River Basin

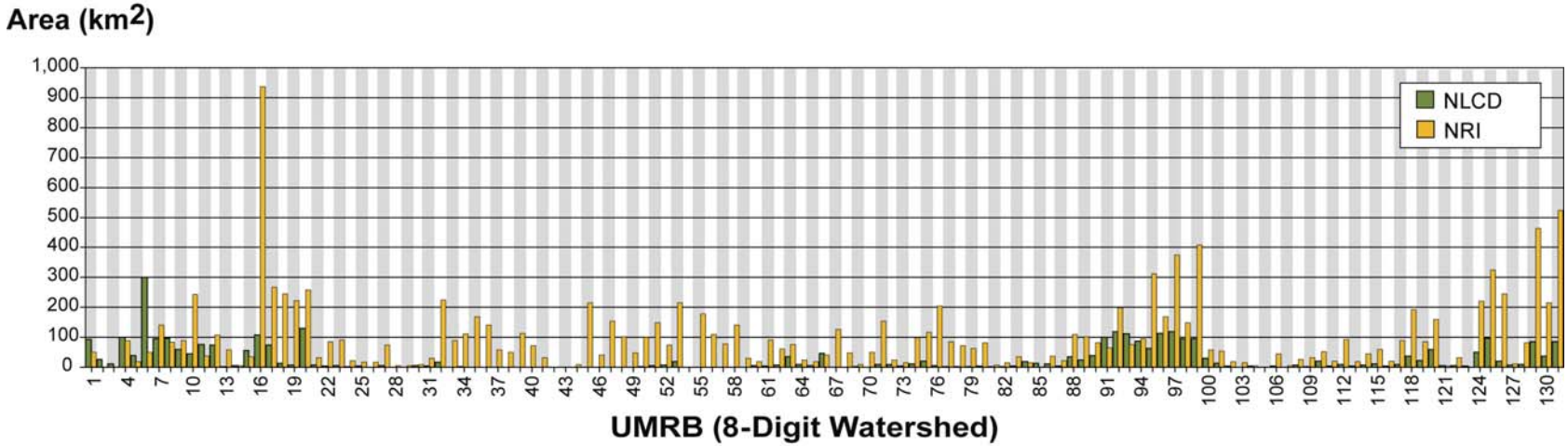

FIGURE 18. NRI versus NLCD close-grown crop area estimates at the 8-digit watershed level for the Upper Mississippi River Basin

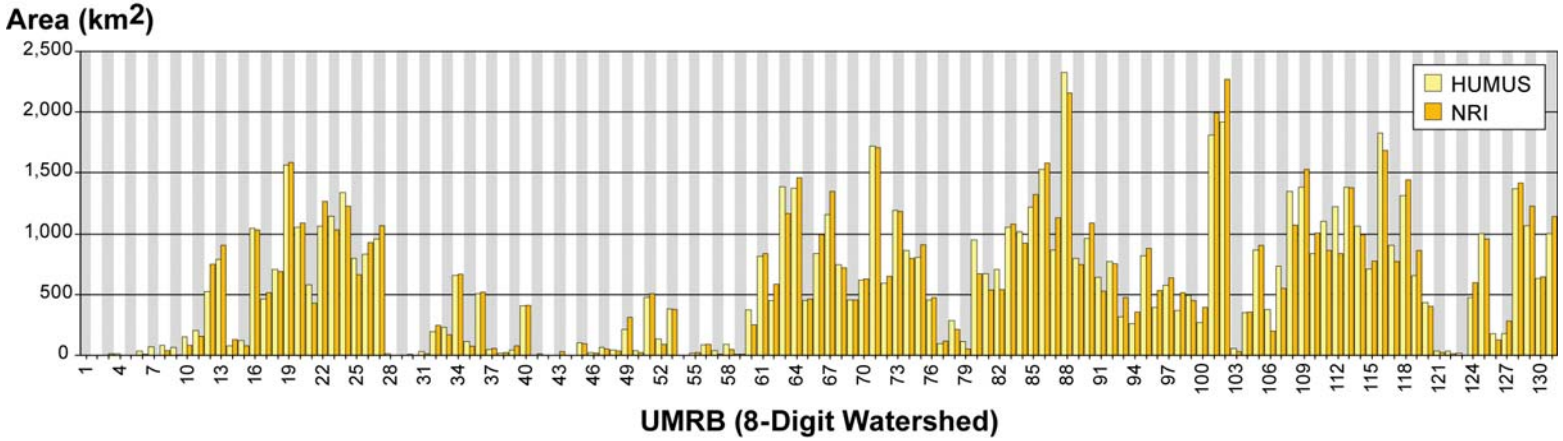

FIGURE 19. NRI versus HUMUS soybean area estimates at the 8-digit watershed level for the Upper Mississippi River Basin

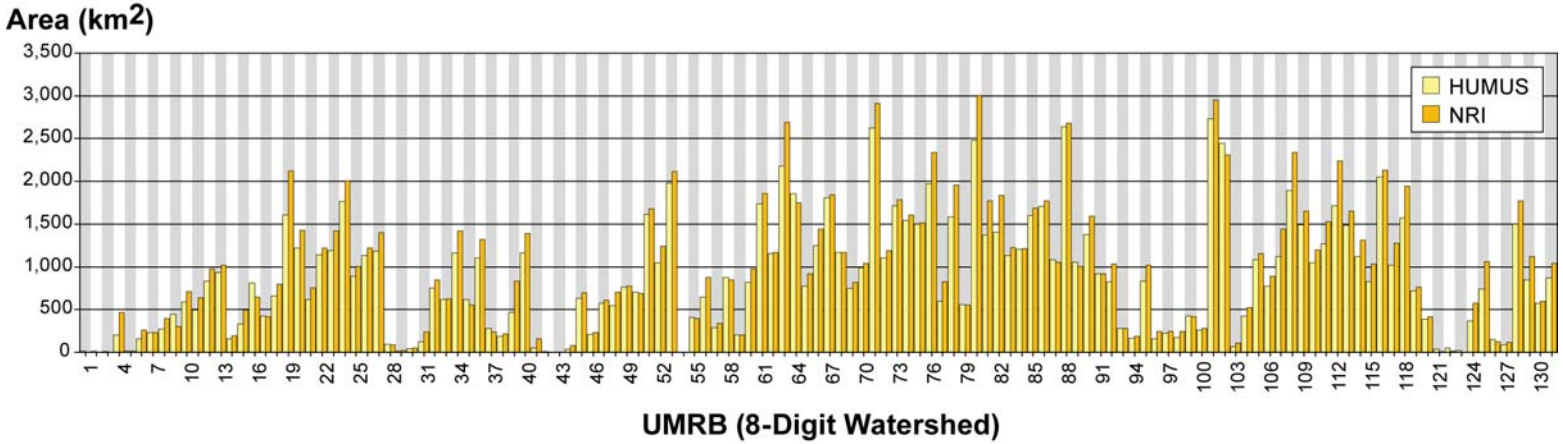

FIGURE 20. NRI versus HUMUS corn area estimates at the 8-digit watershed level for the Upper Mississippi River Basin

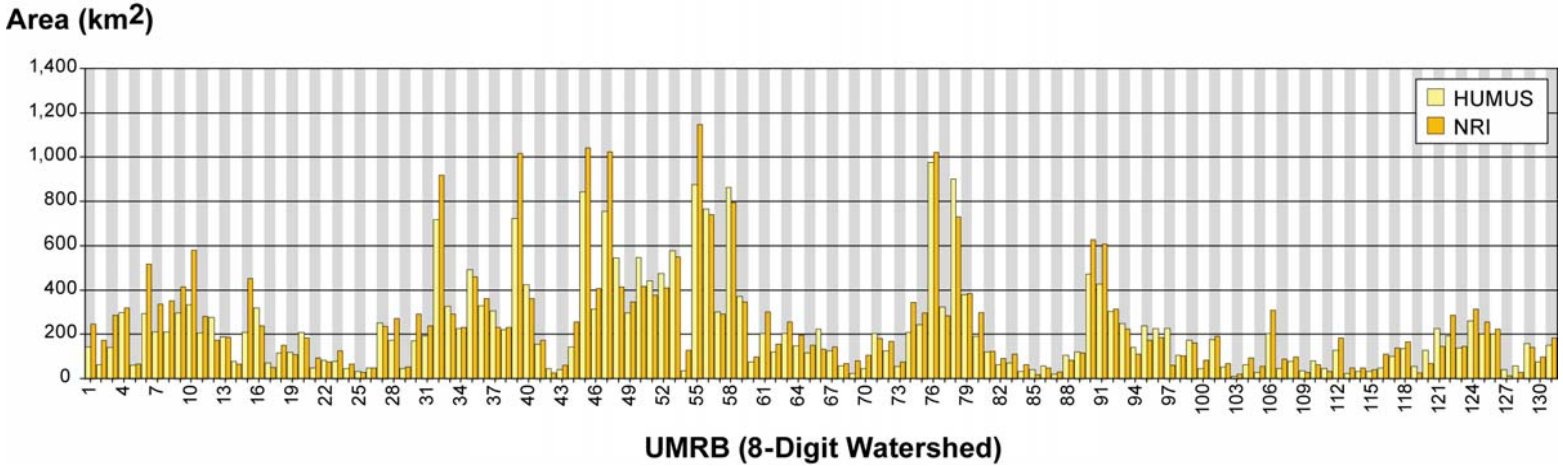

FIGURE 21. NRI versus HUMUS alfalfa/hay area estimates at the 8-digit watershed level for the Upper Mississippi River Basin

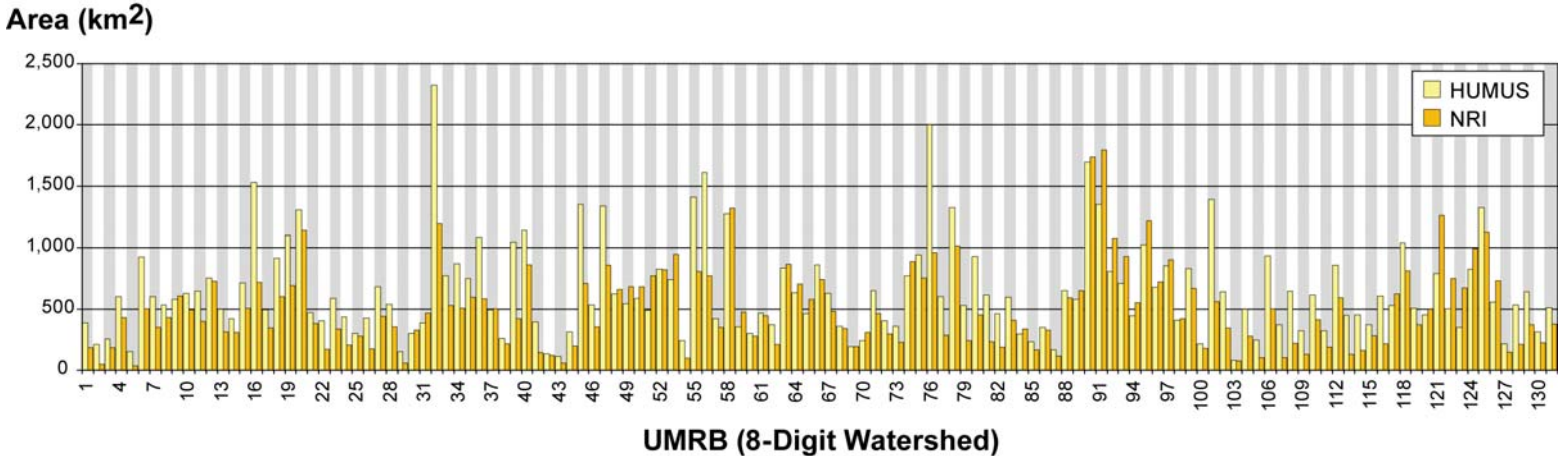

FIGURE 22. NRI versus HUMUS pasture area estimates at the 8-digit watershed level for the Upper Mississippi River Basin

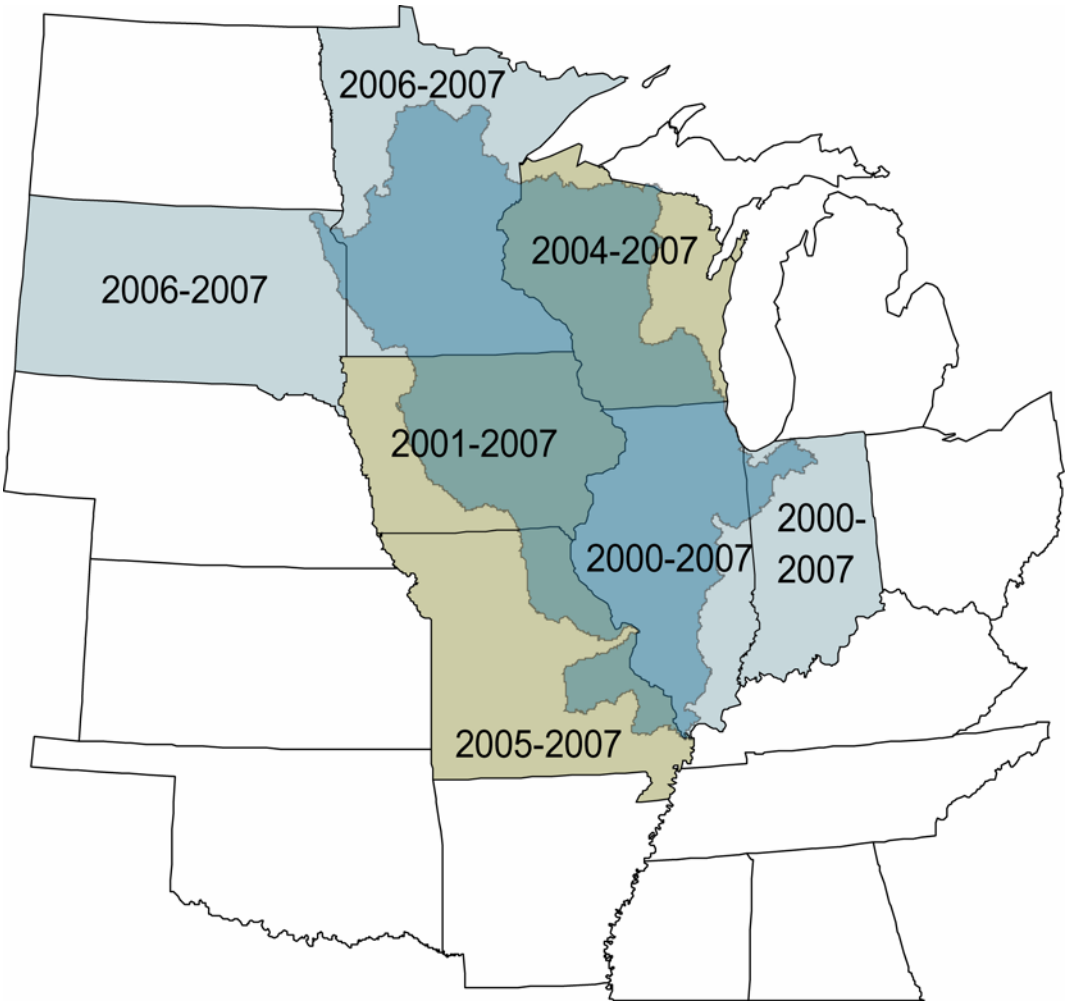

FIGURE 23. Current years of NASS remote sensing data available for the seven primary UMRB states (a very small piece of the UMRB extends into Michigan; collection of NASS data for Michigan will start in 2007).

References

Anderson, J.F., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. "A Land Use and Land Cover Classification System for Use with Remote Sensor Data." Professional Paper 964, U.S. Geological Survey, Reston, VA.

Arnold, J.G., and N. Fohrer. 2005. "SWAT2000: Current Capabilities and Research Opportunities in Applied Watershed Modeling." *Hydrol. Process.* 19(3): 563-572.

Arnold, J.G., R. Srinivasan, R.S. Muttiah, P.M. Allen and C. Walker. 1999. "Continental Scale Simulation of the Hydrologic Balance." *J. Amer. Water Resour. Assoc.* 35(5): 1037-1052.

Brown, J.F., T.R. Loveland, J.W. Merchant, B.C. Reed and D.O. Ohlen. 1993. "Using Multisource Data in Global Land Cover Characteristics: Concepts, Requirements, and Methods." *Photogram. Engin. Rem. Sens.* 59: 977-987.

Chen, P.Y., M. Di Luzio, and J.G. Arnold. 2005. "Spatial Assessment of Two Widely Used Land-Cover Datasets Over the Continental U.S." *IEEE Trans. Geosci. Rem. Sens.* 43(10): 2396-2404.

Chen, P.Y., M. Di Luzio, and J.G. Arnold. 2006. "Spatial Agreement between Two Land-Cover Data Sets Stratified by Agricultural Eco-Regions." *Intern. J. Rem. Sens.* 27(15): 3223-3238.

Gassman, P.W., M. R. Reyes, C.H. Green, and J.G. Arnold. 2007. "The Soil and Water Assessment Tool: Historical Development, Applications, and Future Directions." *Trans. ASABE* 50(4): 1211-1250.

Gassman, P.W., S. Secchi, M. Jha, and L. Kurkalova. 2006. "Upper Mississippi River Basin Modeling System Part 1: SWAT Input Data Requirements and Issues." In *Coastal Hydrology and Processes*, V.P. Singh and Y.J. Xu, eds., pp. 103-115. Highland Ranch, CO: Water Resources Publications.

Gassman, P.W., J. Wu, P.D. Mitchell, B.A. Babcock, T.M. Hurley, and S.W. Chung. 1998. "Impact of U.S. Agricultural Policy on Regional Nitrogen Losses." In *Proceedings of the 3rd International Conference on Diffuse Pollution, Edinburgh, Scotland, 31 Aug. – 4 Sept.* London: International Association of Water Quality.

Goolsby, D.A., W.A. Battaglin, B.T. Aulenbach, and R.P. Hooper. 2001. "Nitrogen Input to the Gulf of Mexico." *J. Environ. Qual.* 30: 329-336.

Goolsby, D.A., W.A. Battaglin, G.B. Lawrence, R.S. Artz, B.T. Aulenbach, R.P. Hooper, D.R. Keeney, and G.J. Stensland. 1999. "Flux and Sources of Nutrients in the Mississippi-Atchafalaya River Basin: Topic 3 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico." NOAA Coastal Ocean Program Decision Analysis Series No. 17. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, Silver Spring, Maryland. Available at: http://www.nos.noaa.gov/products/pubs_hypox.html.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. "Development of a 2001 National Land-Cover Database for the United States." *Photogram. Engin. Rem. Sens.* 70(7): 829-840.

Khorram, S., G. Biging, D. Colby, R. Congalton, J. Dobson, R. Ferguson, M. Goodchild, J. Jensen, and T. Mace. 1999. *Accuracy Assessment of Remote Sensing Derived Change Detection.* Monograph. Bethesda, MD: American Society of Photogrammetry and Remote Sensing.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, and J.R. Williams. 2005. *Soil and Water Assessment Tool Theoretical Documentation*, version 2005. Temple, TX: Grassland, Soil and Water Research Laboratory, Agricultural Research Service. Available at: www.brc.tamus.edu/swat/doc.html.

Nusser, S.M., and J.J. Goebel. 1997. The National Resources Inventory: A long-Term Multi-Resource Monitoring Program." *Environ. Ecol. Stat.* 4: 181-204.

Rabalais, N.N., R.E. Turner, and D. Scavia. 2002. "Beyond Science into Policy: Gulf of Mexico Hypoxia and the Mississippi River." *BioScience* 52(2): 129-141.

Seaber, P.R., F.P. Kapinos, and G.L. Knapp. 1987. "Hydrologic Units Maps." USGS Water Supply Paper No. 2294, U.S. Geological Survey, Reston, VA.

Secchi, S., L. Kurkalova, P.W. Gassman, and C. Hart. 2007. "Land Use Change on the Intensive and Extensive Margin in a Biofuels Hotspot: The Case of Iowa, USA." Working Paper, Iowa State University.

USDA-NASS. 2007a. The Census of Agriculture. United States Department of Agriculture, National Agricultural Statistics Service, Washington, D.C. Available at: http://www.agcensus.usda.gov/.

USDA-NASS. 2007b. Census of Agriculture General Information. United States Department of Agriculture, National Agricultural Statistics Service, Washington, D.C. Available at: http://www.nass.usda.gov/census/census92/ag0100.htm.

USDA-NASS. 2007c. The Cropland Data Layer. United States Department of Agriculture, National Agricultural Statistics Service, Washington, D.C. Available at: http://www.nass.usda.gov/research/Cropland/SARS1a.htm.

USDA-NRCS. 2007a. CEAP National Assessment: Cropland. United States Department of Agriculture, Natural Resources Conservation Service, Washington D.C. Available at: http://www.nrcs.usda.gov/Technical/nri/ceap/cropland.html.

USDA-NRCS. 2007b. National Resources Inventory. United States Department of Agriculture, Natural Resources Conservation Service, Washington D.C. Available at: http://www.nrcs.usda.gov/technical/NRI/.

USDA-NRCS. 2007c. Watershed Boundary Dataset (WBD). United States Department of Agriculture, Natural Resources Conservation Service, Washington D.C. Available at: http://www.ncgc.nrcs.usda.gov/products/datasets/watershed/.

USDI. 2007. The Public Land Survey System (PLSS). National Atlas of the United States. United States Department of the Interior, Washington, D.C. Available at: http://nationalatlas.gov/articles/boundaries/a_plss.html.

USGS. 2007. National Land Cover Database 2001 (NLCD 2001). United States Geological Survey, Reston, VA. Available at: http://www.mrlc.gov/mrlc2k_nlcd.asp.

Vogelmann, J. E., S.M. Howard, L. Yang, C.R. Larson, B.K. Bruce, and N. van Driel. 2001. "Completion of the 1990s National Land Cover Data Set for the Conterminous United States from Landsat Thematic Mapper Data and Ancillary Data Sources." *Photogram. Engin. Rem. Sens.* 67(6): 650-662.

Yang, L., S.V. Stehman, J.H. Smith, and J.D. Wickham. 2001. “Short Communication: Thematic Accuracy of MRLC Land-Cover for the Eastern United States.” *Remote Sens. Environ.* 76: 418-422.

Zhu, Z, L. Yang, S.V. Stehman, and R.L. Czaplewski, 2000. “Accuracy Assessment for the U.S. Geological Survey Regional Land Cover Mapping Program: New York and New Jersey Region.” *Photogram. Engin. Rem. Sens.* 66: 1425-1435.