Assessment of the Estimated Non-Point Source Nitrogen and Phosphorus Loading from Agricultural Sources from Iowa During the 1980-96 Hypoxia Task Force Baseline Period

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Executive Summary

The Iowa Nutrient Reduction Strategy (2013) is a science and technology-based framework to assess and reduce nitrogen and phosphorus flux to Iowa waters and the Gulf of Mexico. It is designed to direct efforts to reduce nutrients in surface water from both point and nonpoint sources. Its development was prompted by the 2008 Gulf Hypoxia Action Plan that calls for Iowa and other states within the Mississippi River watershed to reduce nutrient loadings to the Gulf of Mexico

To develop the strategy, the Iowa Department of Agriculture and Land Stewardship and the College of Agriculture and Life Sciences at Iowa State University partnered in October 2010 to conduct the Iowa Nutrient Reduction Strategy Nonpoint Source Science Assessment (INRS-NSSA). The assessment involved estimating nutrient loads over the 2006-2010 time period, reviewing scientific literature to assess potential performance of practices, estimating potential load reductions of implementing various scenarios involving nutrient reduction practices, and estimating implementation costs.

The initial INRS-NSSA estimated nitrate-N and phosphorus loads using land use and land information from the 2006-2010 time period. This period was used due to the availability of data. However, the 2008 Gulf of Mexico Action Plan states load reductions be "..measured against the average load over the 1980-1996 time period…". Efforts described herein provide estimates of nitrate-N and phosphorus loads from Iowa over this period. As possible, methods consistent with the original INRS-NSSA were employed. Lack of available data over this historic period provided a significant challenge and necessitated interpolation and other estimation for missing years. Assumptions made are detailed within each section. The effort relied heavily on data from the Census of Agriculture in 1982, 1987, 1992, and 1997.

The average nitrate-N load for the 1980-96 time period was estimated to be 292,022 tons, compared to 307,449 tons reported in the INRS-NSSA (Table ES-1). This represents an estimated 5% increase in nitrate-N load from the baseline period specified within the 2008 Gulf Hypoxia Action Plan until the start of the INRS-NSSA. Nitrate-N loads ranged from 273,909 tons in 1992 to 319,714 tons in 1997. Increased nitrate-N loads over this period were due primarily to the steady-to-slightly-increasing corn/soybean and continuous corn acreage and N application rate since the 1980-96 time period.

The average phosphorus load for the 1980-96 time period was estimated to be 21,436 tons, compared to 16,800 tons reported in the INRS-NSSA. This represents an estimated 22% reduction in phosphorus load from the baseline period specified within the 2008 Gulf Hypoxia Action Plan until the start of the INRS-NSSA. Phosphorus loads ranged from a high of 24,797 tons in 1982 to 16,800 tons for the period reported within the INRS-NSSA. Reduced phosphorus loads were primarily due to fewer acres under intensive tillage, and a significant increase in no-till acreage from the 1980-96 time period.

Limitations resulting from data availability and additional research needs are identified within appropriate report sections and summarized within a *Limitations and Future Needs* section. Issues identified include incorporating additional information on the impact of changes in precipitation on water yield and nutrient loads; structural conservation practices; stream bed and bank contribution to phosphorus loads; variable rate nutrient application; and changes in nitrogen content in grain. Load estimates in this assessment account only for changes to loading due to agricultural land management practices and did not consider any point source loading changes.

Table ES-1. Estimates of Nitrate-N and phosphorus load from the 1980-96 time period and the INRS-NSSA (2006-10 time period)

Nutrient	1980-96 Average Load (Tons)	INRS-NSSA Load (Tons)	% Change From 1980-96 to INRS-NSSA
Nitrate-N	292,022	307,449	5% Increase
Phosphorus	21,436	16,800	22% Decrease

Introduction

The Iowa Nutrient Reduction Strategy (2013) is a science and technology-based framework to assess and reduce nitrogen and phosphorus flux to Iowa waters and the Gulf of Mexico. It is designed to direct efforts to reduce nutrients in surface water from both point and nonpoint sources. Its development was prompted by the 2008 Gulf Hypoxia Action Plan that calls for Iowa and other states within the Mississippi River watershed to reduce nutrient loadings to the Gulf of Mexico.

To develop the strategy, the Iowa Department of Agriculture and Land Stewardship and the College of Agriculture and Life Sciences at Iowa State University partnered in October 2010 to conduct the Iowa Nutrient Reduction Strategy Nonpoint Source Science Assessment (INRS-NSSA). The assessment involved estimating nutrient loads over the 2006-2010 time period, reviewing scientific literature to assess potential performance of practices, estimating potential load reductions of implementing various scenarios involving nutrient reduction practices, and estimating implementation costs.

The initial INRS-NSSA estimated nitrate-N and phosphorus loads using information from the 2006-2010 time period. This period was used due to the availability of data. However, the 2008 Gulf of Mexico Action Plan states that reductions “measured against the average load over the 1980-1996 time period, may be necessary.” Efforts described herein provide estimates of nitrate-N and phosphorus loads from Iowa over this period. Loads estimated herein are based on modeled estimates, not measured estimates from monitoring data. Modeling methods were consistent with the original INRS-NSSA. Lack of available data over this historic period provided a significant challenge and necessitated interpolation and other estimation for missing years. Assumptions made are detailed within each section. The effort relied heavily on data from the Census of Agriculture in 1982, 1987, 1992, and 1997. To allow for a direct comparison of the effects of land management on nitrate-N and phosphorus loads, precipitation was held constant throughout this period and water yield was consistent with that used in the INRS-NSSA.

Methods: Land Management

Consistent with the INRS-NSSA, land management information was summarized by USDA Major Land Resource Area (MLRA) (Figure 1). As described, a range of data was used to develop the background information required to estimate nitrate-N and phosphorus loads. Although the years the data were drawn from may not be the same, every effort was made to represent the state as accurately as possible given the available data. County-level data were partitioned based on the percent of the county in each MLRA (INRS-NSSA).

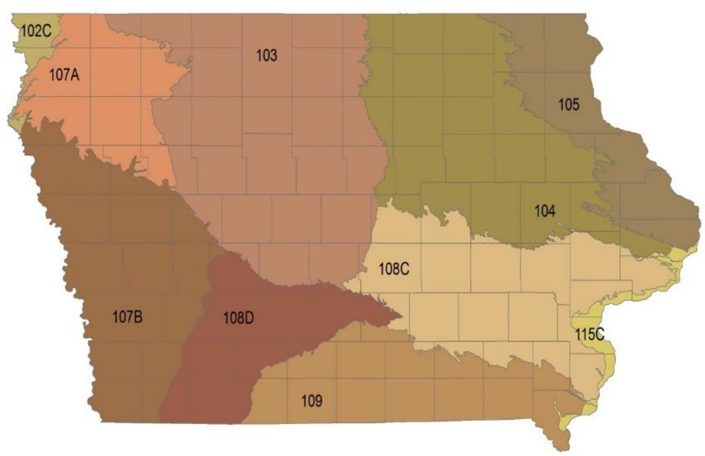

Figure 1. USDA Major Land Resource Areas (MLRAs) in Iowa

Land Use

Land use estimates were obtained from the USDA Census of Agriculture from 1982, 1987, 1992, and 1997. Since the Census of Agriculture included more land use categories than used in the INRS-NSSA, several categories were combined. For agricultural lands, the four land use categories, or “bins” used, were corn-soybean rotation (CB), continuous corn (CC), extended rotations (EXT), and pasture/hay (PH).

Extended Rotation (EXT)

Extended rotation tended to be a “catch-all” for row crop agriculture in the INRS-NSSA and assumed corn in the rotation at least once in five years. However, the INRS-NSSA relied on multiple consecutive years to make determinations on crop rotation, while the Census of Agriculture is simply a snapshot of a given year. As such, adjustments were made to the Census of Agriculture corn and soybean acreages for a given year based on the average ratio of extended rotation/soybeans and extended rotation/corn observed in the INRS-NSSA. These estimates were used to discount the Census of Agriculture CB and CC acres by 1/5 to account for the extended rotation acres.

Corn-Soybean Rotation (CB)

After adjusting for the extended rotation acres, soybean acres from the Census of Agriculture were multiplied by two to represent the CB rotation acreage. Resulting soybean acres then are compared to the Census of Agriculture reported soybean acres. The difference is used to adjust the CB estimated acres. The CB acres are adjusted again, based on the total acres of corn reported in the Census of Agriculture (i.e. if the total acres of corn through estimates is larger than acres reported by the Census of Agriculture, the CB acres are adjusted downward. Finally, due to the forced binning, the acres are adjusted to the relative proportion of rowcrop (CB, CC, and EXT) to Census of Agriculture reported rowcrop (corn, soybeans, oats, and wheat). This step assures over/under estimates are minimized.

Continuous Corn (CC)

To calculate CC, corn portions of CB and EXT were subtracted from the total Census of Agriculture corn acreage. The result was adjusted (up or down) so the CC plus CB (corn) acres add to the Census of Agriculture corn acreage. In the event the CC acreage was negative, the value was set to zero. The acreage for CB was increased to compensate for missing acreage in these cases.

As mentioned for CB, CC and EXT were proportionally adjusted. A sum of all the acreage was used to proportionally weight each land use to the total number of row-crop acres reported by the Census of Agriculture (corn, soybeans, oats, and wheat).

Pasture and Hay (PH)

Pasture and Hay was simply summed from the “Hay-alfalfa, other tame, small grain, wild grass silage, green chop, etc. (acres)”, “Cropland used only for pasture or grazing (acres)”, and “Cropland in cover crops, legumes, and soil improvement grasses, not harvested and not pastured (acres)” land uses in the Census of Agriculture. The resulting tally likely under represents this land use, when compared to satellite derived values used in the INRS-NSSA. However, this does not factor into estimated loads, as this land use ultimately has the same load as other general land uses.

The summary of combined acreage in corn/soybean (CS) and continuous corn (CC) is shown in Figure 2. A breakdown of the four land use categories by MLRA is shown in Appendix A. Total acreage in combined C/S and CC are near or slightly greater than 20 million acres throughout the 1982-1996 period. The low year was in 1987 when USDA farm programs resulted in lower crop production acres. Overall, acreage in CS and CC has been relatively stable since the 1980s.

Though not required for estimating nutrient loads, corn and soybean yields were calculated in order to provide insights into observed patterns. Corn yields were split between CS and CC using a previously defined assumption that CC corn, on average, has a 7.9% lower yield than corn in a CS rotation. Aggregated statewide yields are shown in Figures 3 through 5. Overall, corn and soybean yields have increased during the time period studied.

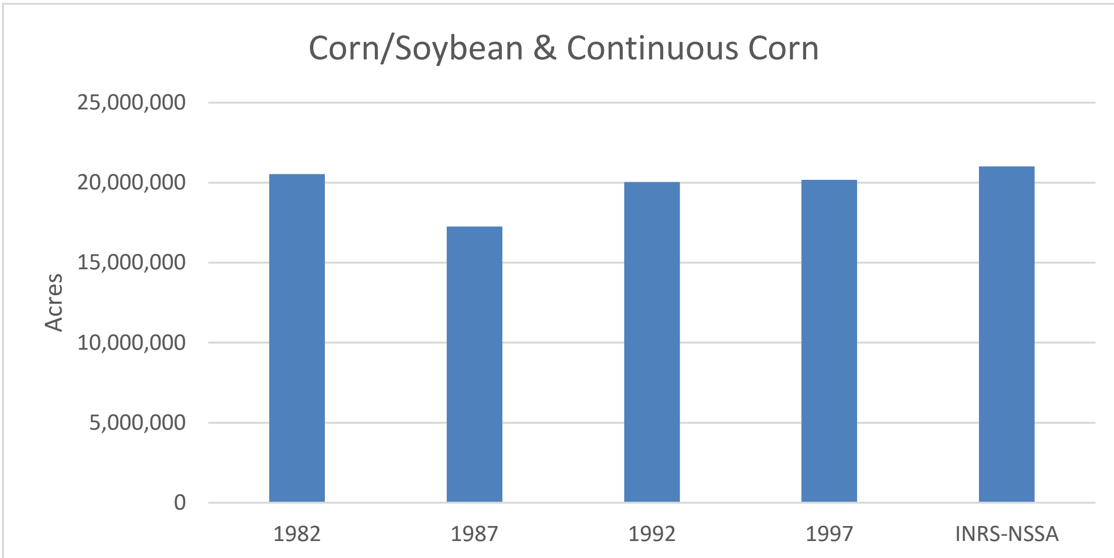

Figure 2. Statewide corn/soybean and continuous corn acres for 1982, 1987, 1992, and 1997 based on Census of Agriculture data. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents an average of 2006-2010.

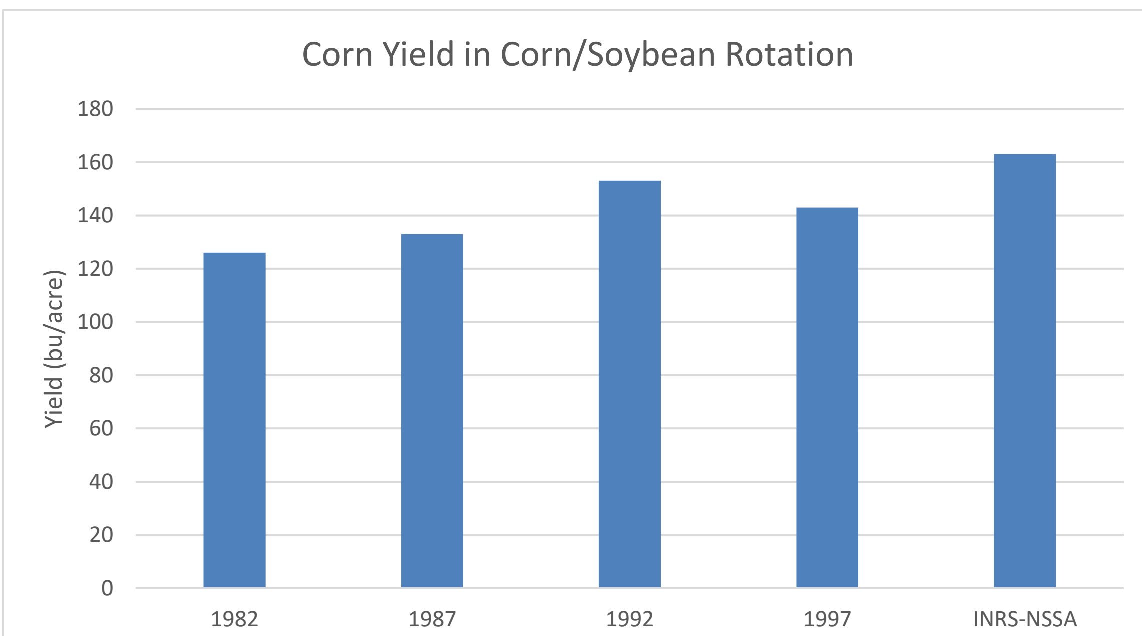

Figure 3. Statewide average corn yield in a corn/soybean rotation for 1982, 1987, 1992, and 1997 based on Census of Agriculture data. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents an average of 2006-2010.

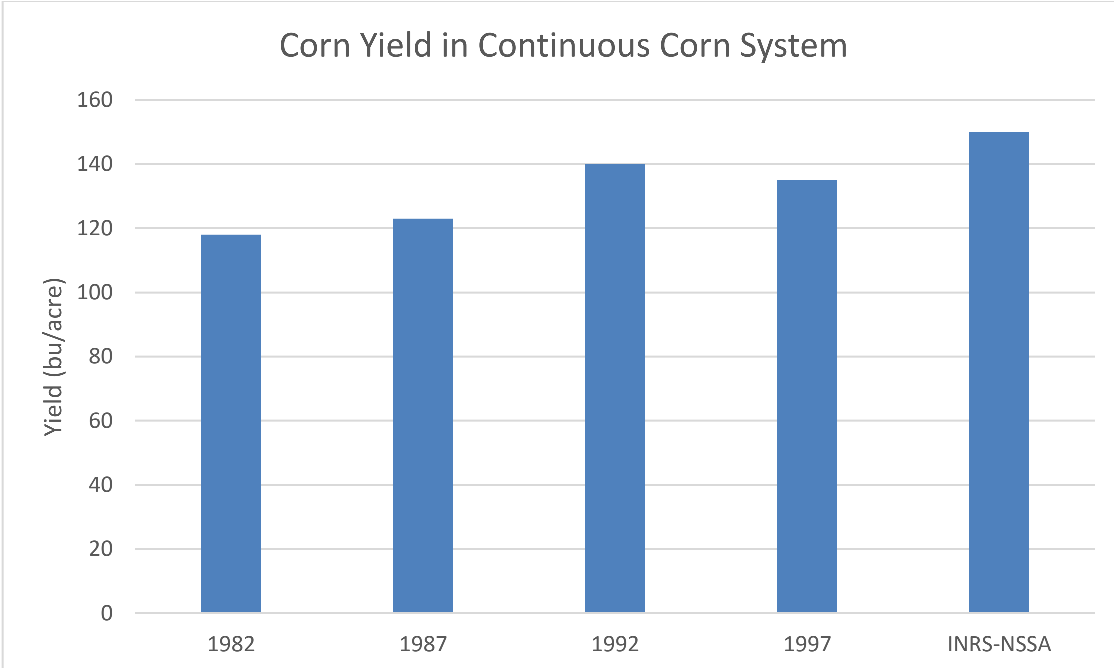

Figure 4. Statewide average corn yield in continuous corn system for 1982, 1987, 1992, and 1997 based on Census of Agriculture data. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents an average of 2006-2010.

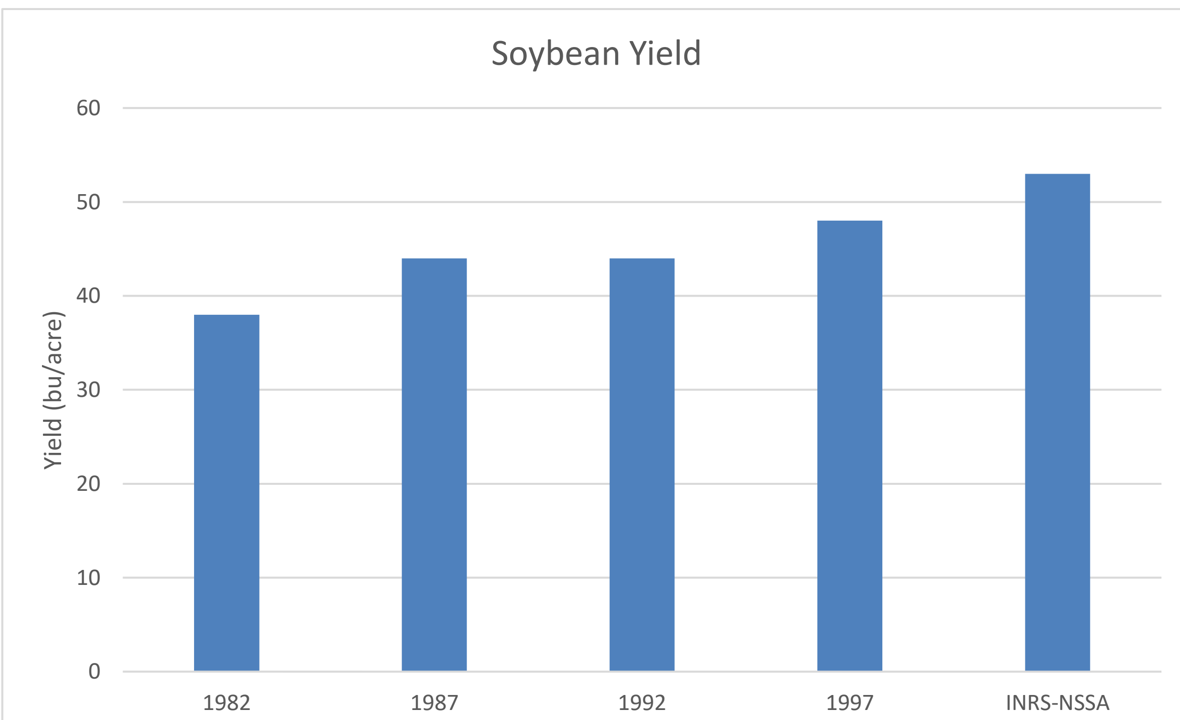

Figure 5. Statewide average soybean yield for 1982, 1987, 1992, and 1997 based on Census of Agriculture data. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents an average of 2006-2010.

Nitrogen and Phosphorus Application

Fertilizer sales data provided on a county-by-county basis from Ruddy et al. (2006) was used to develop proportional county nitrogen and phosphorus distributions. For years where proportional county sales data were not available (i.e. 1982), the relative proportion from each county as developed for 1987 to 2001 was used. These values were quite static over time. However, a trend line was developed for each county to more accurately forecast or back-cast to the years outside of those reported by Ruddy et al. (2006). Statewide fertilizer sales data also were compared with estimates from the Association of American Plant Food Control Officials (AAPFCO). It was assumed all fertilizer was applied to corn (either for grain or silage) from the Agricultural Census.

Values from the "*DSA-Manure and Crop Production-82-97.xlsx*" spreadsheet were used as base data to estimate manure application. This information was developed by Dr. Dan Andersen at Iowa State University using methods described in Andersen (2013) based on animal numbers from USDA Census of Agriculture. Total nitrogen from poultry (NC) and swine (NS) data were used directly from the spreadsheet. A 60% availability coefficient was used with poultry manure for consistency with the original INRS-NSSA. Total nitrogen from beef (NB) and dairy (ND) included cattle on pasture. Since manure from cattle on pasture would not be collected for farm application, this nitrogen value must be removed from the total. As a proxy, total cattle fattened on grain and concentrates was used for manure contributions for years 1982 through 1997. Consistent with the INRS-NSSA, it was assumed cattle produce 0.16 kg of nitrogen per day, and 40% of this is available. Manure numbers were tallied by the fraction of each county in each MLRA, and aggregated to the MLRA scale. All applied and available manure was tallied for use in application to corn acres.

For all nitrogen applied, it was assumed continuous corn receives 50 lbs acre^{-1} more nitrogen than corn in a corn-bean rotation. This assumption is applied to all nitrogen, whether coming from manure or fertilizer. This assumption was consistent with the INRS-NSSA.

The same manure estimation techniques were used for phosphorus, though it was assumed all phosphorus is immediately available. Likewise, the same approach was used for phosphorus sales data as was used for nitrogen sales data.

Nitrogen Application

A comparison of fertilizer nitrogen sales data for Ruddy et al. (2006) and AAPFCO is shown in Figure 6. For reference, there was good agreement between overlapping data years for these two datasets, which was expected as Ruddy et al. (2006) used the AAPFCO data as the basis for their analysis.

Total nitrogen application is a sum of fertilizer and manure applied to corn (Figure 7). More detailed summary of estimated nitrogen application summarized at the MLRA scale is shown in Appendix A. Overall estimated nitrogen application rate to corn in a CS system is shown in Figure 8 with additional MLRA estimates shown in Appendix A. Overall, the nitrogen application rate has been stable to slightly higher when comparing the 1980-96 time period to the INRS-NSSA.

Phosphorus Application

A comparison of fertilizer phosphorus sales data for Ruddy et al. (2006) and AAPFCO is shown in Figure 9. Estimated average total P application (as P_2O_5) to corn, soybeans, and alfalfa is shown in Figure 10. Overall, the phosphorus application rate has been fairly stable when comparing the 1980-96 time period to the INRS-NSSA.

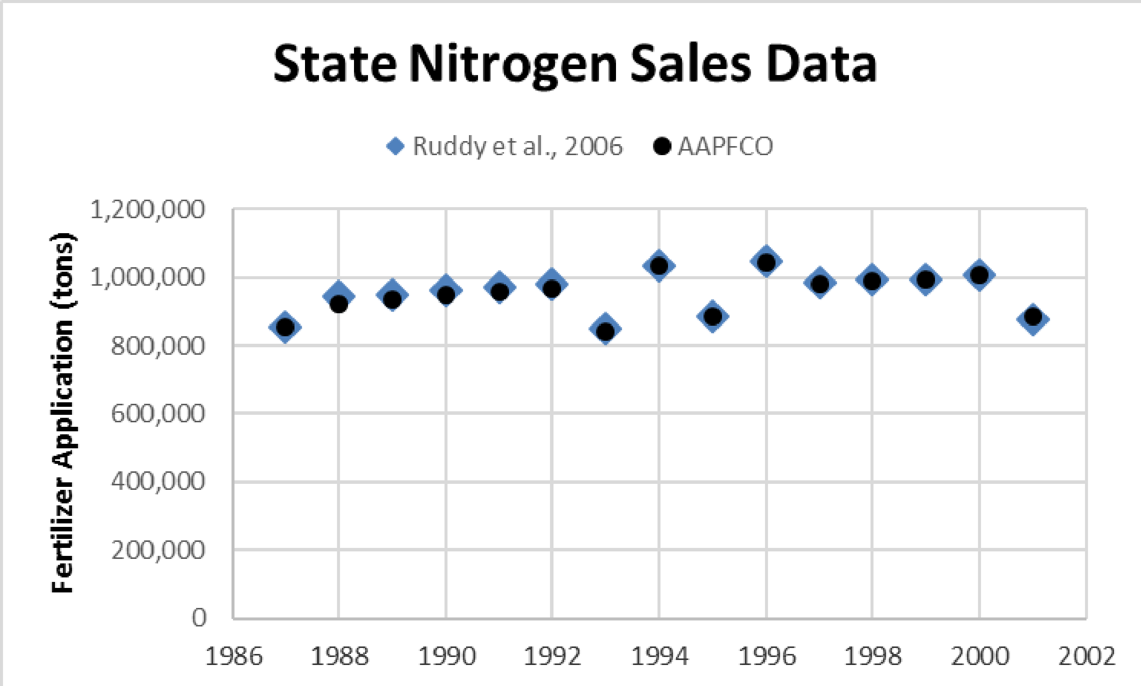

Figure 6. Comparison of nitrogen fertilizer sales data for Iowa from 1986-2002. Data from Ruddy et al. (2006) and the Association of American Plant Food Control Officials.

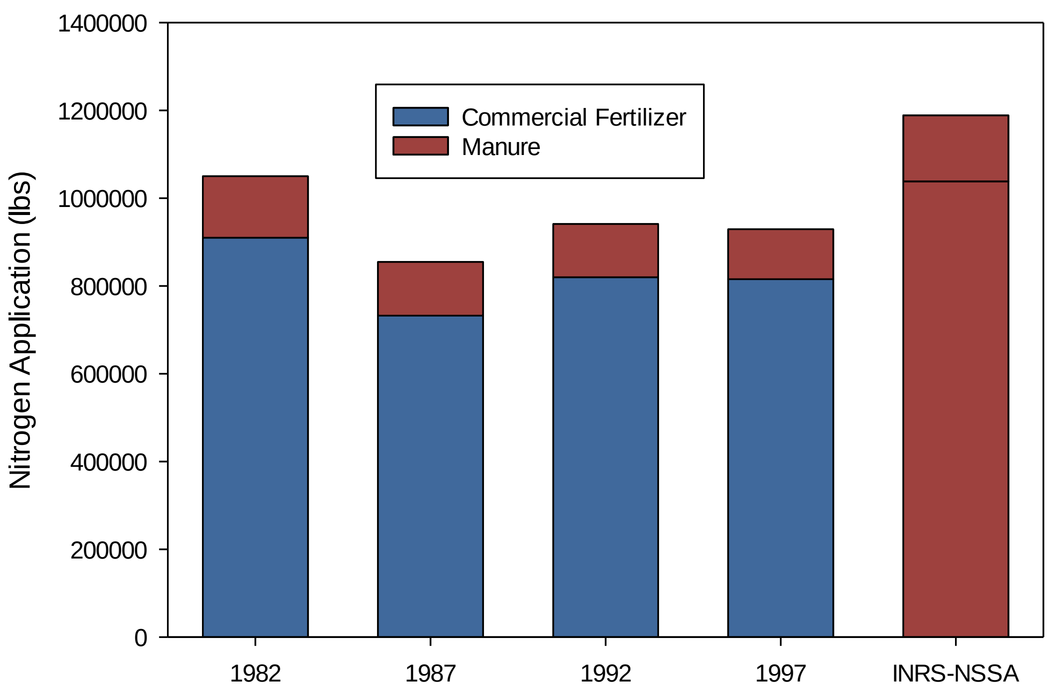

Figure 7. Nitrogen application from commercial fertilizer and manure for 1982, 1987, 1992, and 1997. Data from Ruddy et al. (2006) and the Association of American Plant Food Control Officials. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents an average of 2006-2010.

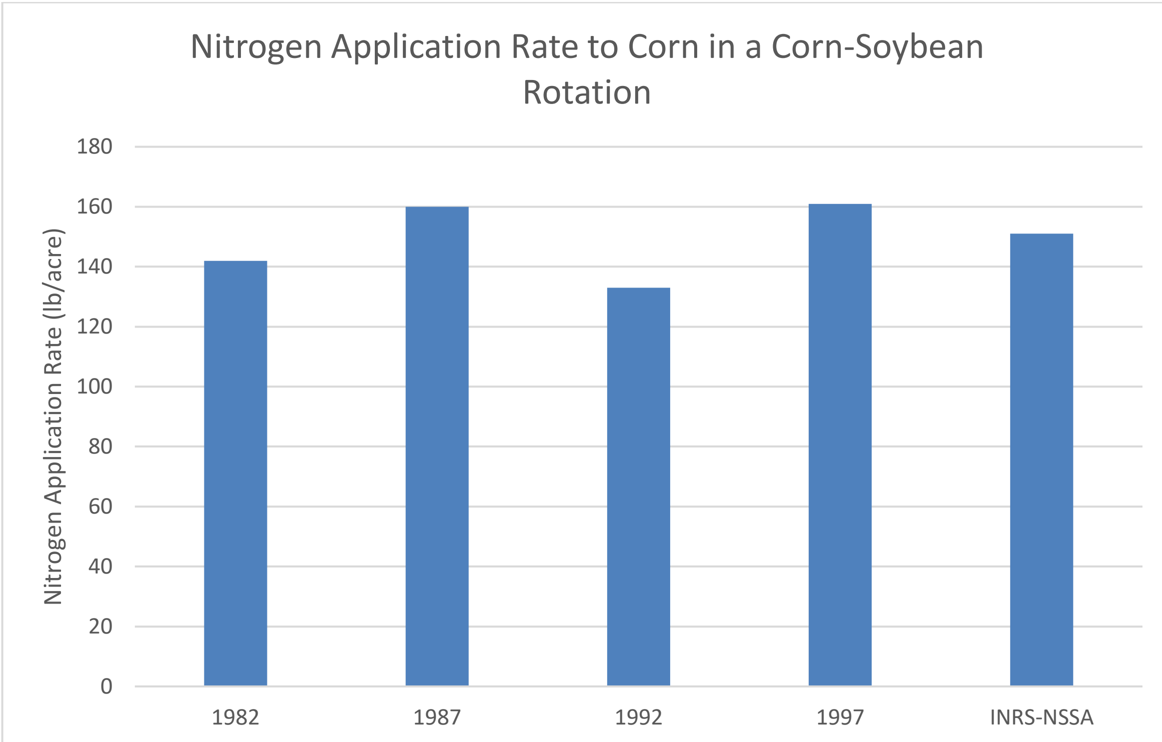

Figure 8. Overall nitrogen application rate per acre to corn in a corn-soybean rotation for 1982, 1987, 1992, and 1997. Data from Ruddy et al. (2006) and the Association of American Plant Food Control Officials. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents an average of 2006-2010.

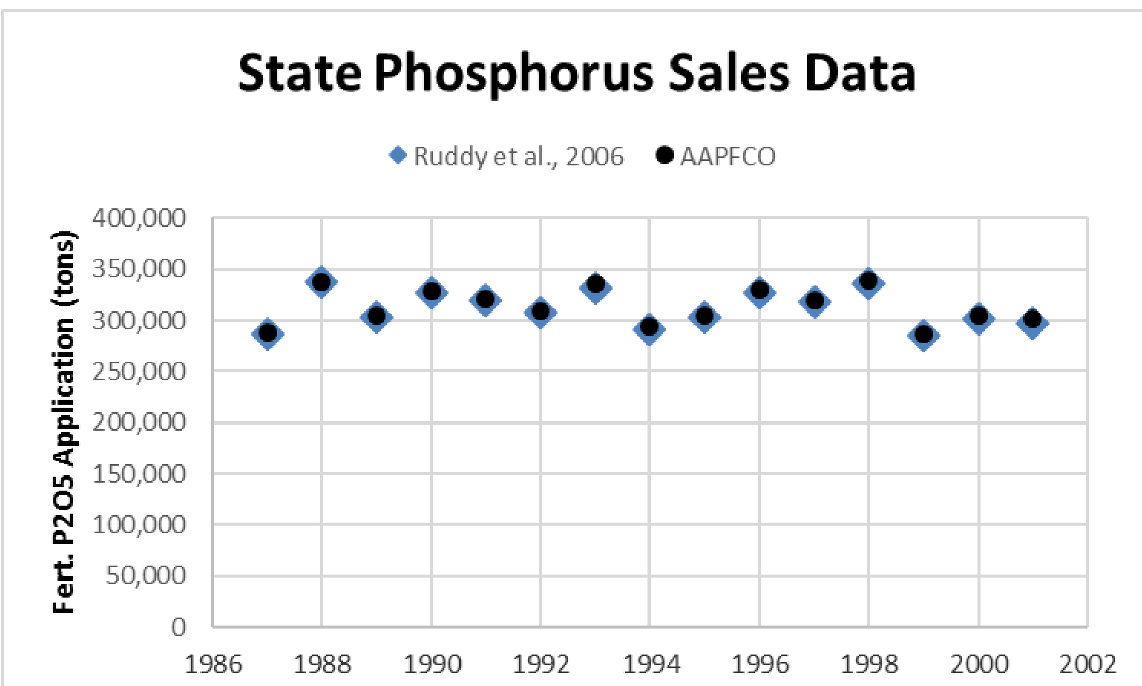

Figure 9. Comparison of phosphorus fertilizer sales data for Iowa from 1986-2002. Data from Ruddy et al. (2006) and the Association of American Plant Food Control Officials.

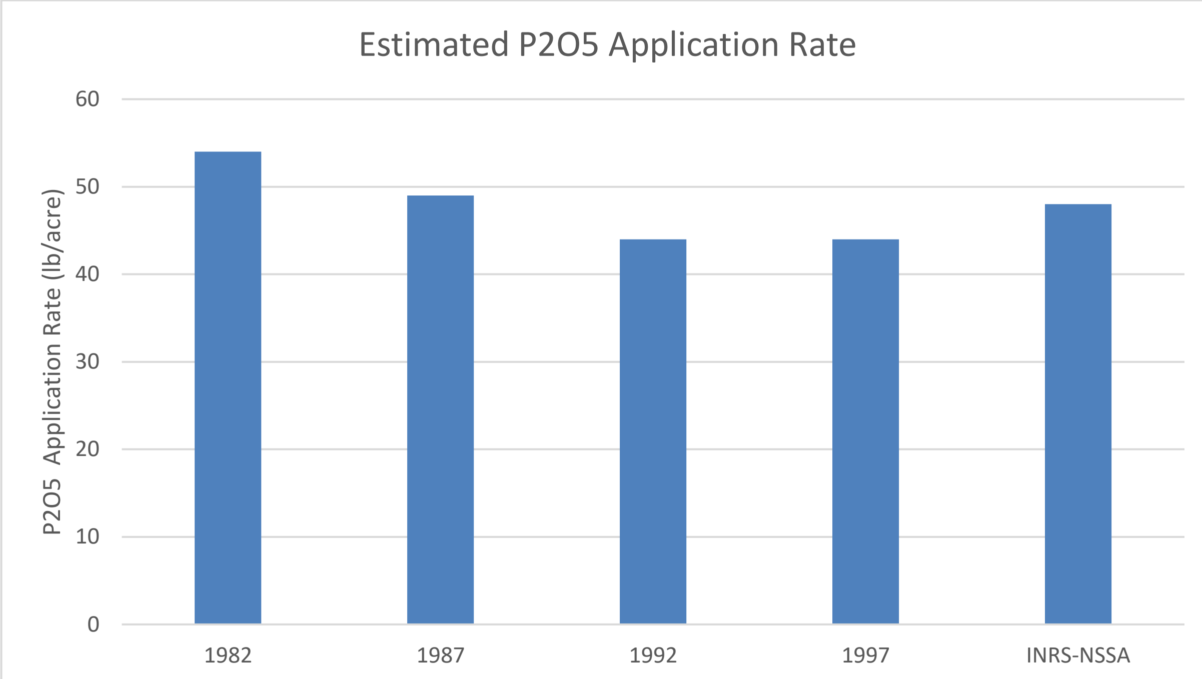

Figure 10. Estimated average P_2O_5 application rates for 1982, 1987, 1992, and 1997. Estimates include rate to corn, rate to beans, and rate to alfalfa. Data from Ruddy et al. (2006) and the Association of American Plant Food Control Officials. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents an average of 2006-2010.

Tillage

Data used to estimate tillage were based on field survey data compiled by the Conservation Technology Information Center (CTIC) for the years 1989-1998, 2000, and 2004. Categories included "conventional" or "intensive" tillage ($\leq$15% residue after planting), "reduced tillage" (15-30% residue after planting), and "conservation" tillage ($\geq$30% residue after planting), which was divided into no-till (NT), mulch till (MT), and ridge till for both corn and soybeans. Ridge till was used in a small percentage of the crop area, and was lumped together with no-till. Methods used to develop tillage estimates for the 1982-1997 period are similar to those used for the INRS-NSSA, though here the assumption is made that the county tillage estimates from CTIC are complete enough to area-weight each county simply based on survey acreages, rather than specific crop acreages. Comparing actual crop acreages to these tillage acreages gives a good linear relationship, which allows the simple use of the total corn and soybean tillage numbers to weight each county for aggregation to the MLRA.

Because CTIC tillage estimates were not available for 1982 and 1987, estimated values are a combination of static values (such as setting no-till to zero in 1982), interpolation (no-till for 1987), and using a trendline (1982 and 1987 for MT). Nuances of final refined numbers were largely professional judgement, though ultimately agreed upon by members of the project team.

Statewide estimates of tillage are shown in Figures 11 through 14, with MLRA estimates shown in Appendix A. Statewide no-till acreage increased significantly in the 1990s. However, adoption of no-till in hillier areas of the state increased rapidly and has since leveled out. Conventional, or intensive tillage, declined between roughly 1% and 2% a year with a slight flattening out since around approximately 1998. Mulch-till and reduced tillage have been relatively constant.

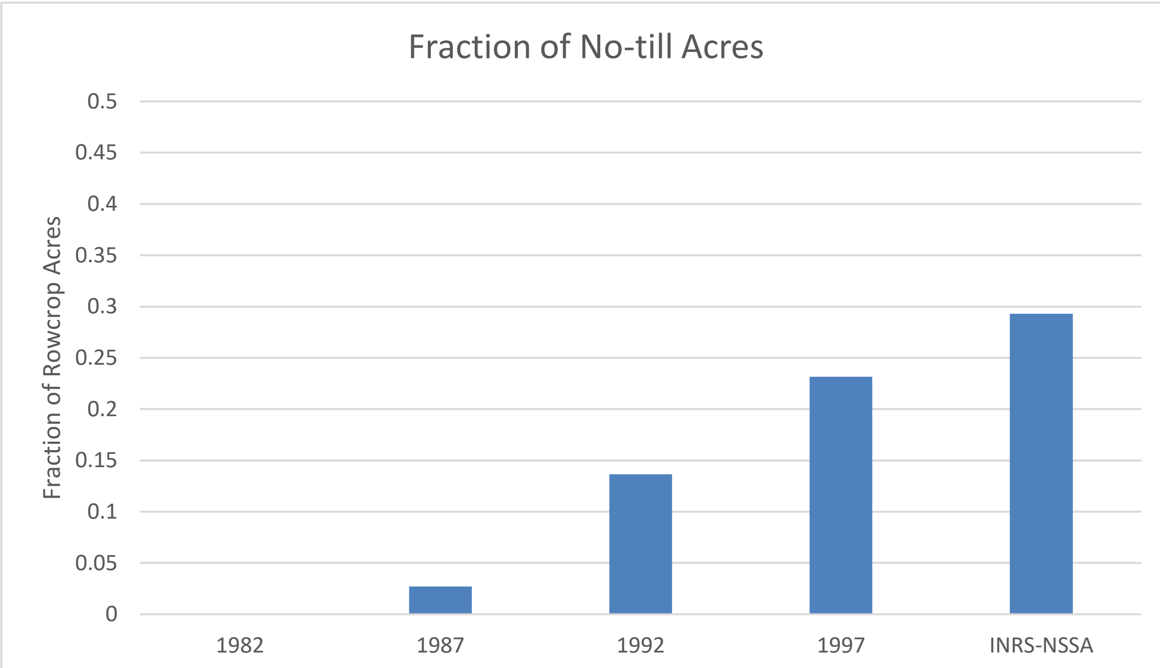

Figure 11. Aggregated statewide no-tillage estimates. Data include estimates from CTIC as well as projected data to align with Census of Agriculture land use. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2008.

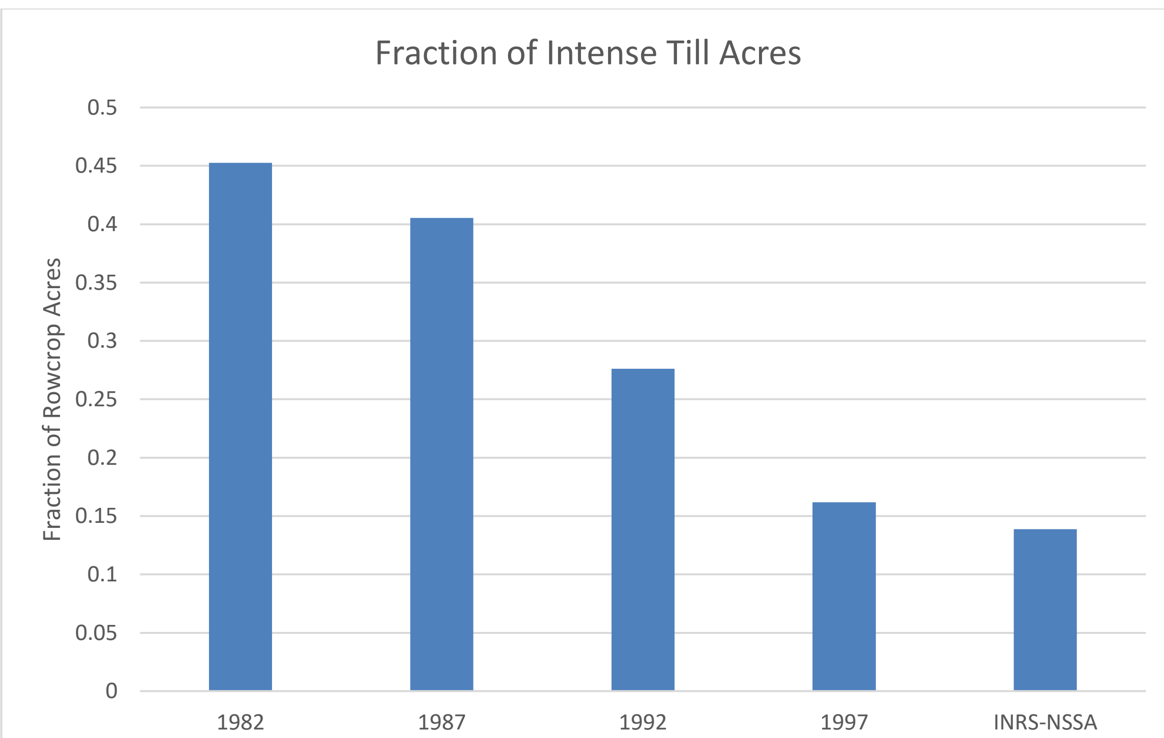

Figure 12. Aggregated statewide intense tillage estimates. These data include estimates from CTIC as well as projected data to align with Census of Agriculture land use. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2008.

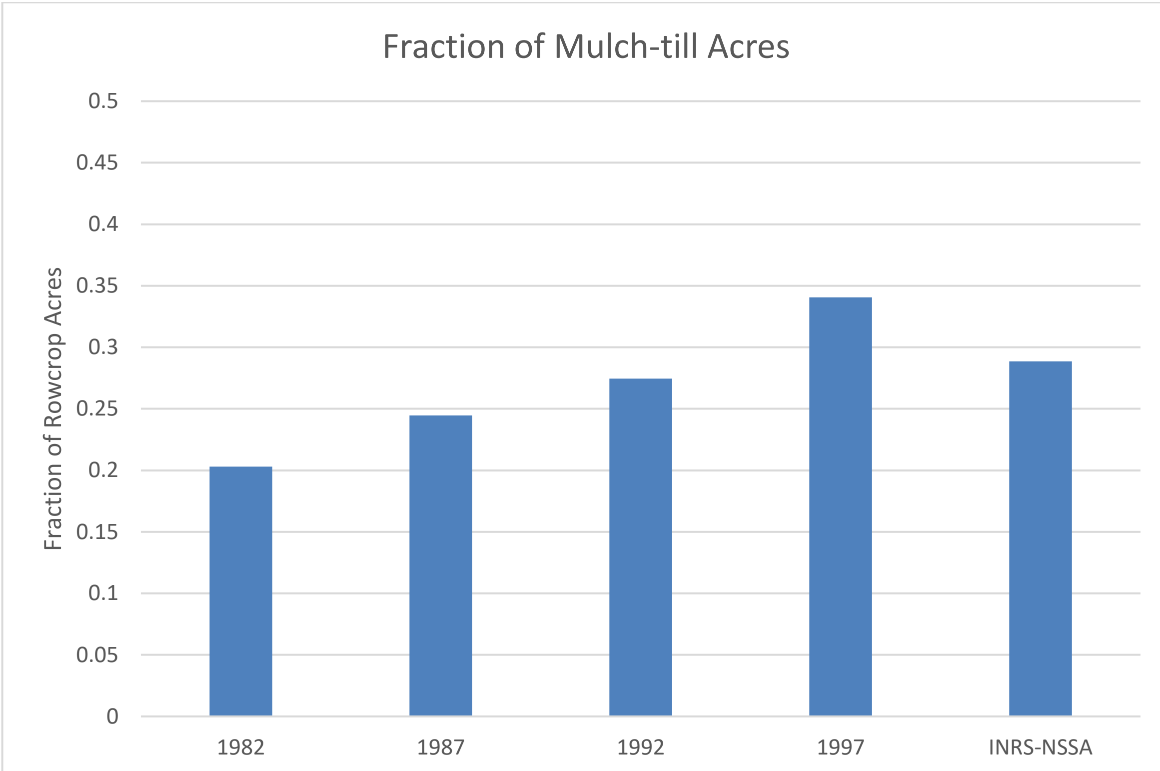

Figure 13. Aggregated statewide mulch-tillage estimates. Data include estimates from CTIC as well as projected data to align with Census of Agriculture land use. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2008.

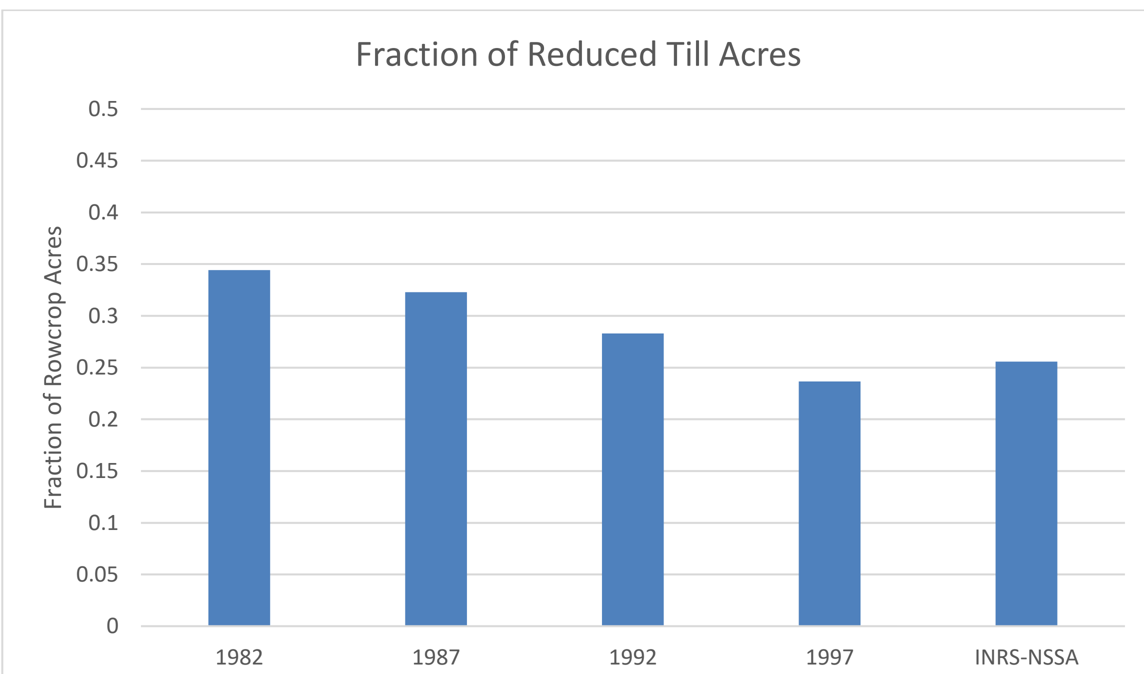

Figure 14. Aggregated statewide reduced tillage estimates. Data include estimates from CTIC as well as projected data to align with Census of Agriculture land use. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2008.

Soil Test Phosphorus

Few estimates for soil test phosphorus (STP) values were available for the 1980-1996 period. As a result, values used in the INRS-NSSA and STP estimates from the Iowa State University Soil Test Laboratory for 1987 were used as the basis for calculating STP estimates for additional years. A linear interpolation was used between 1987 and the INRS-NSSA, while 1982 was estimated using an estimate of phosphorus removed with grain harvest. Area for corn and soybeans (including those crops in an extended rotation) were used along with total crop production to estimate soil phosphorus lost during grain harvest. Additionally, phosphorus application to corn and beans was used as the replaced soil phosphorus. To convert the balance (difference between removal and application) to a STP change value, it was assumed STP represents the top 2.5 feet since this aligns with general soil sampling procedures. Also, a static bulk density of 1.6 g cm^{-3} was assumed, though adjusting this assumption down to 1.4 g cm^{-3} only changes results by 0.1 or 0.2 g kg^{-1}. Finally, since STP was calculated every five years, annual STP change estimates were multiplied by five to make them represent annual changes over time. These annual changes were subtracted from Iowa State University Soil Test Laboratory database results for “current” STP levels, which acted as the accounting basis.

Estimated soil test phosphorus levels at a state level are shown in Figure 15 with MLRA estimates shown in Appendix A. In general, these values are fairly stable to slightly declining for the state for the period of 1982 through the INRS-NSSA.

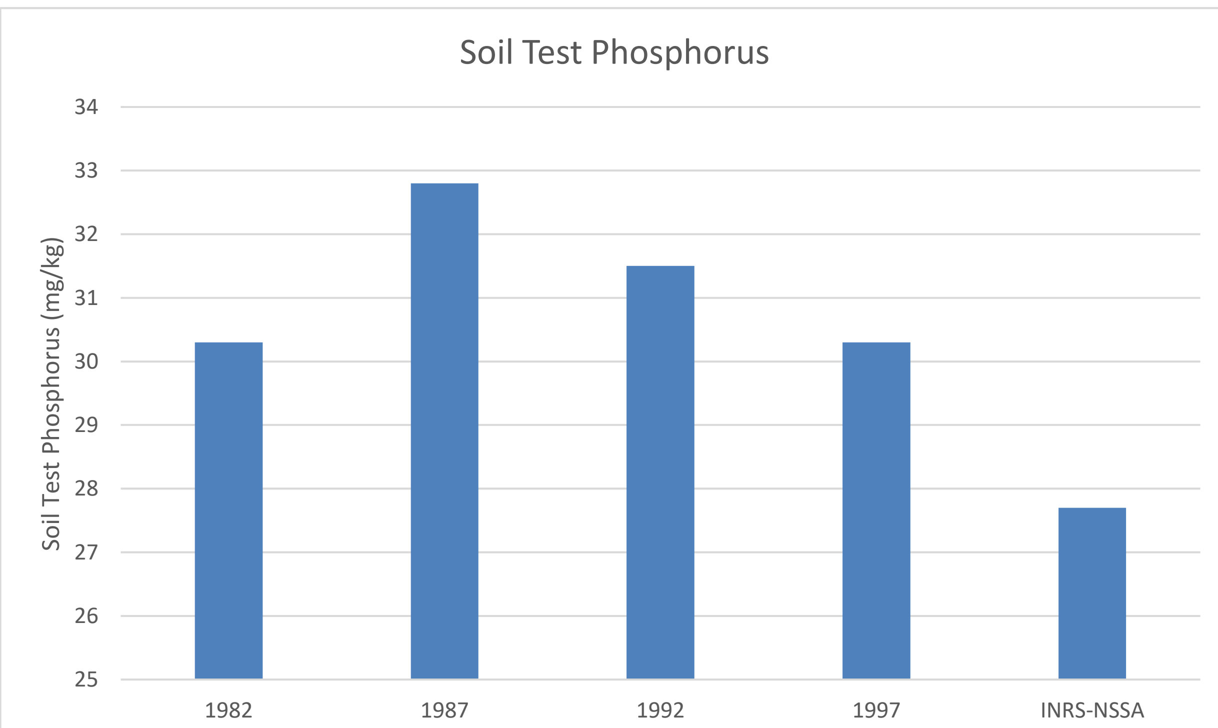

Figure 15. Statewide soil test phosphorus estimates for 1982, 1987, 1992, and 1997. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2006-2010.

Results: Nitrate-N and Total Phosphorus Loads and Loss per Agricultural Acre

Using land management and nutrient management information, the nitrate-N and total phosphorus loads were estimated using methods consistent with the INRS-NSSA. These are not measured loads, but rather estimated loads using the same modeling approach used as part of the INRS-NSSA. For nitrate-N loads, the spreadsheet-based nitrogen load model developed as part of the INRS-NSSA was to estimate nitrate-N delivery to surface waters on a MLRA basis. The primary driving factors for nitrate-N load are land use and nitrogen application rates. To allow for a direct comparison of the effects of land management on nitrate-N loads, precipitation was held constant throughout this period and water yield was consistent with that used in the INRS-NSSA. As a result, across the entire period the water yield was held constant so the only changes in load are a result of land management practices.

Phosphorus loads were estimated for each MLRA using a modification of the Iowa Phosphorus Index as described in the INRS-NSSA. This model estimates phosphorus loss, taking into account location in the state, soil type, soil test phosphorus, phosphorus application rate, tillage practices, source, timing and incorporation practices, runoff, erosion, and distance to the nearest stream or water body (Mallarino et al., 2002). Consistent with the INRS-NSSA, the current amount of land treated by terraces and contour farming was estimated based on best professional judgment of ISU Extension agronomists for areas of the state where these practices would likely be prevalent. Specifically, contour farming was applied to 50% of the land in MLRA 105, and a combination of terraces and contour farming was applied to 50% of the land in MLRA 107b.

To allow for a direct comparison of the effects of land management on nitrate-N and phosphorus loads, precipitation was held constant throughout this period and water yield was consistent with that used in the INRS-NSSA.

It was assumed that nitrification inhibitors were not readily used before INRS-NSSA development, so acres treated with this additive were set to zero for all years. Likewise, no acres were assumed to be treated by cover crops since total areas being planted with cover crops now still is likely below 2%. Finally, all manure was assumed to be applied in the fall. These assumptions are consistent with decisions made by the Science Assessment Team for the INRS-NSSA.

As urban area is a relatively minor component of the Iowa land use, the fraction of urban was held constant for all years. Previous methods for estimating the contribution of urban and forest, which makes up the land use balance, generated the same land use loading rate of 2.54 lbs N acre^{-1} making the constant urban area a moot point, since there is no impact on resulting loads.

The average nitrate-N load for the 1980-96 time period was estimated to be 292,022 tons, compared to 307,449 tons reported in the INRS-NSSA (Figure 16). This represents an estimated 5% increase in nitrate-N load. Nitrate-N loads ranged from 273,909 tons in 1992 to 319,714 tons in 1997. Increased nitrate-N loads over this period were primarily due to the steady-to-slightly-increasing corn/soybean and continuous corn acreage and N application rate since the 1980-96 time period. Estimated nitrate-N loss per ag acre is shown in Figure 17. The loss rate per ag acre for the INRS-NSSA estimate is slightly below the 1982-97 average, but since the overall acreage in agricultural is slightly increased, the overall statewide load is increased. MLRA based load estimates are shown in Appendix B.

The average phosphorus load for the 1980-96 time period was estimated to be 21,436 tons, compared to 16,800 tons reported in the INRS-NSSA (Figure 18). This represents an estimated 22% reduction in phosphorus load. Phosphorus loads ranged from a high of 24,797 tons in 1982 to 16,800 tons for the period reported within the INRS-NSSA. Estimated phosphorus loss per ag acre are shown in Figure 19. Reduced phosphorus loads were primarily due to fewer acres under intensive tillage and a significant increase in no-till acreage from the 1980-96 time period. In addition, a slight decline in soil test phosphorus contributed to a reduction in estimated phosphorus load. MLRA based load estimates are shown in Appendix B.

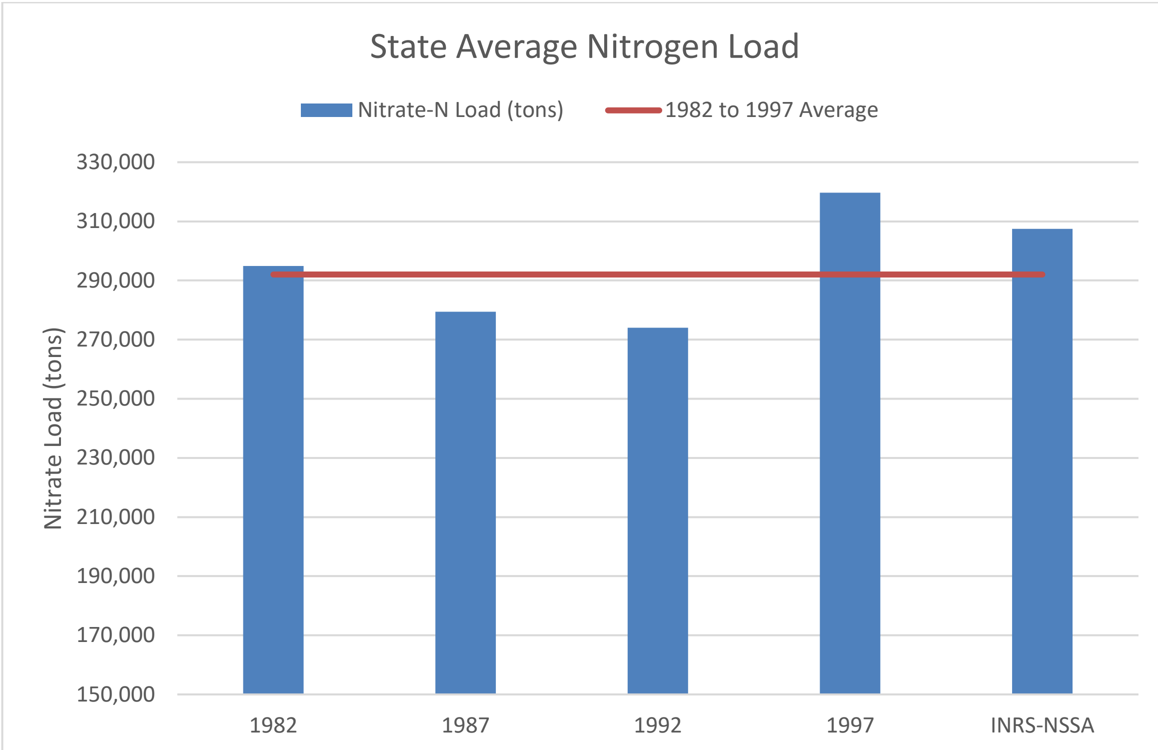

Figure 16. Statewide Nitrate-N load estimates for 1982, 1987, 1992, and 1997. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2006-2010.

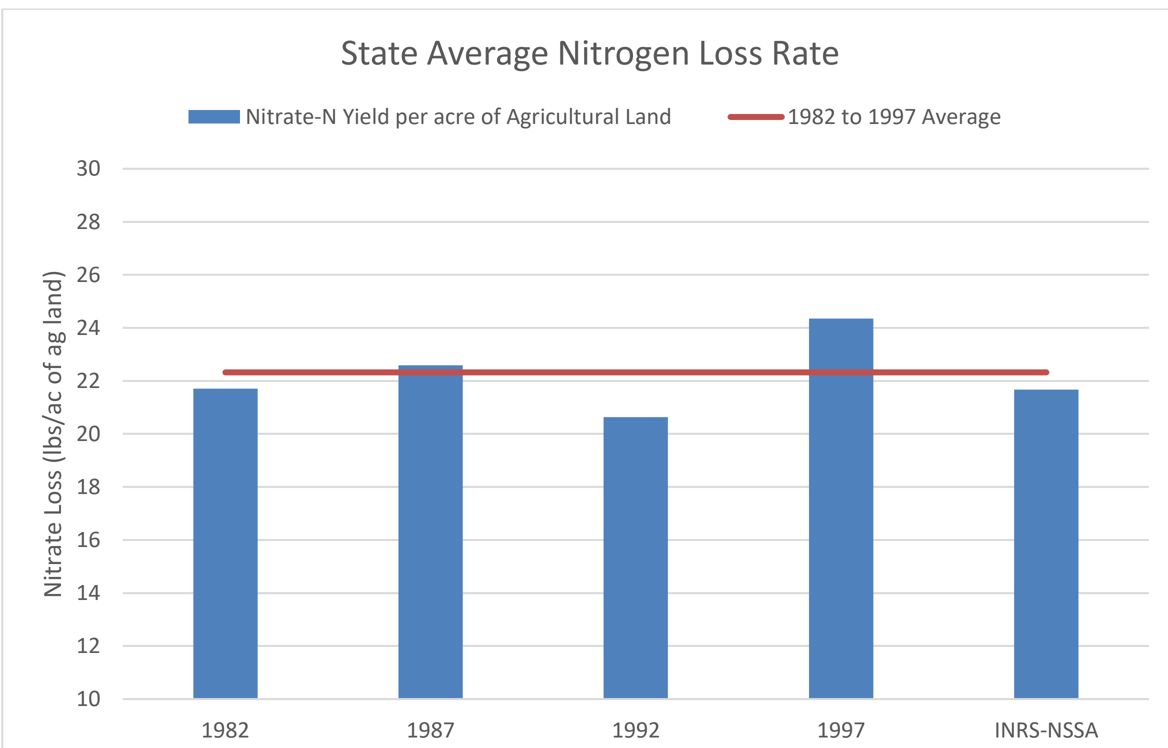

Figure 17. Estimated statewide Nitrate-N loss per agricultural acre for 1982, 1987, 1992, and 1997. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2006-2010.

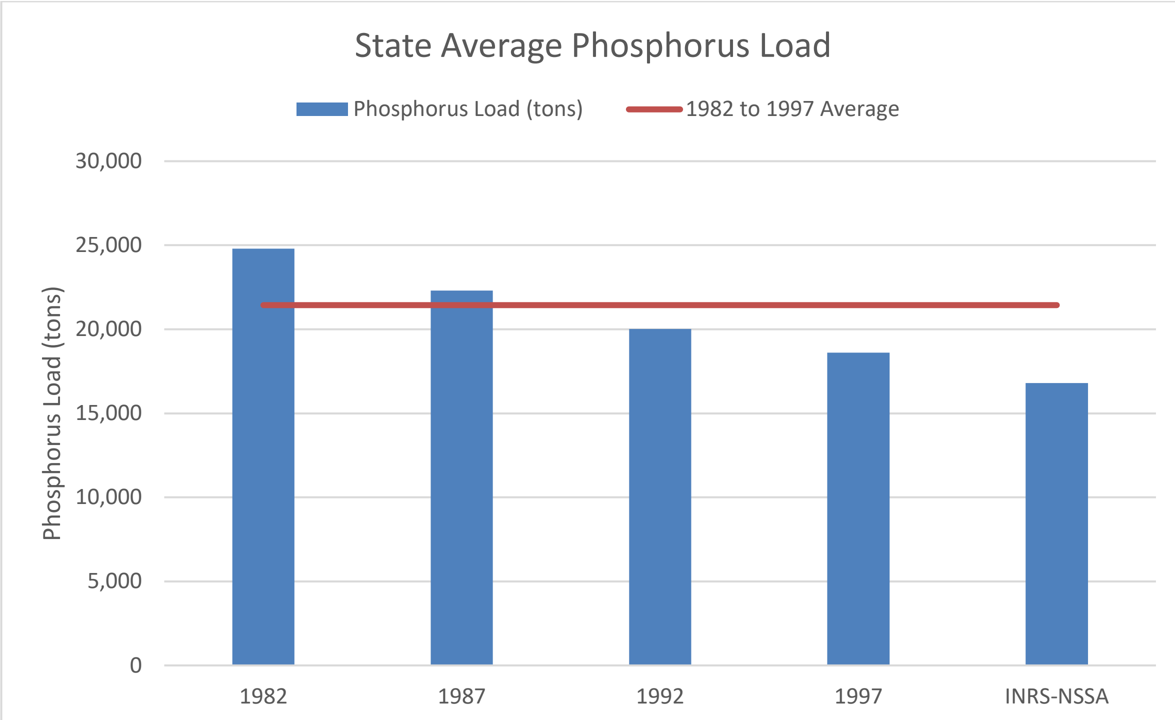

Figure 18. Statewide phosphorus load estimates for 1982, 1987, 1992, and 1997. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2006-2010.

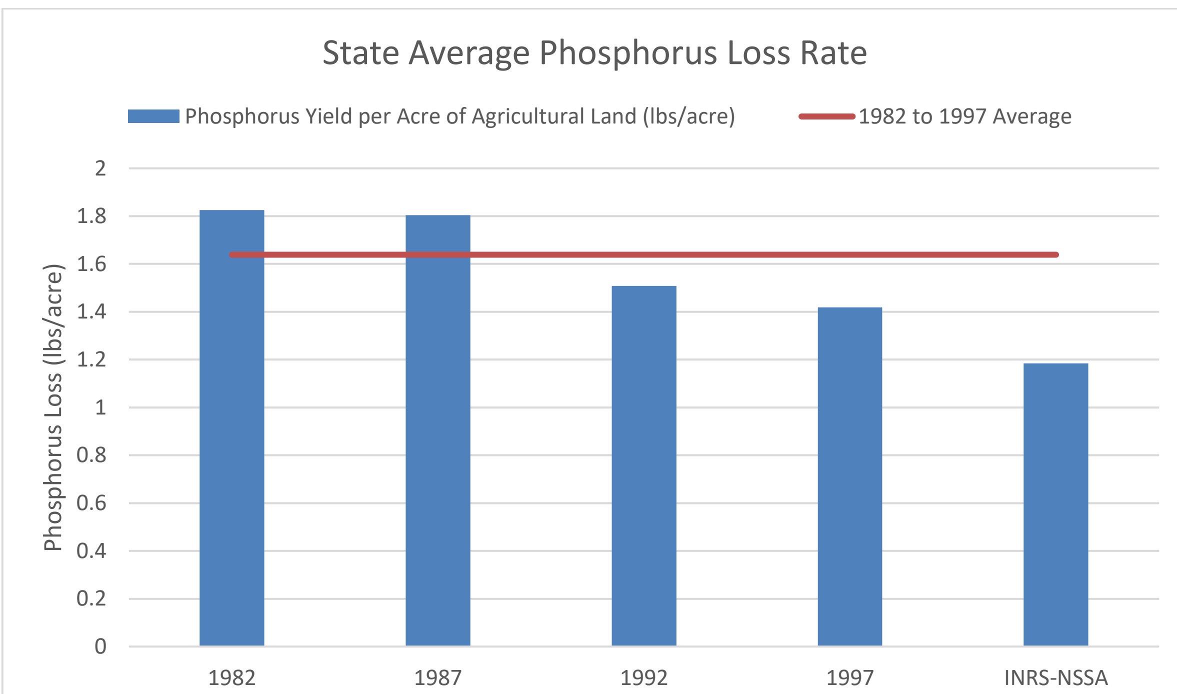

Figure 19. Estimated statewide phosphorus loss per agricultural acre for 1982, 1987, 1992, and 1997. Iowa Nutrient Reduction Strategy – Nonpoint Source Science Assessment (INRS-NSSA) represents data from 2006-2010.

Limitations and Future Needs

Water Yield

This assessment used similar procedures to the INRS-NSSA to estimate nitrate-N and phosphorus loads leaving the state. As noted, this estimate is not measured load from water quality monitoring. In addition, this estimate used the same long-term water yield estimates as used in the INRS-NSSA, which allowed direct comparison to INRS-NSSA values to evaluate the impact of land management. Future work will continue to assess the impact of precipitation on water yield and ultimately nutrient loads. The importance of the work described here is that it allows an assessment of how practice changes since the 1980-96 period are estimated to have impacted nutrient loading from the state without year-to-year variability in weather. The water yield used in this assessment and the INRS-NSSA is long-term water yield from the 1980-2010 period based on estimates from 38 gauge stations throughout Iowa. Additional information on this approach is described in the INRS-NSSA.

Structural Practices

Since the 1980s there have been changes in the implementation of structural practices on the agricultural landscapes. However, without information on the rate of adoption, similar assumptions on the level of implementation were used as in the INRS-NSSA. Since this did not change in between the estimates described within and the INRS-NSSA, this is an area that should continue to be reviewed as new information becomes available on the level of adoption of structural practices over time. Current work in Iowa is mapping structural BMP practices throughout the state. As this information becomes available, the phosphorus load estimates could be reviewed to account for changes from the estimated level of practice implementation.

Stream Bed and Bank Contributions

As with the INRS-NSSA, estimating stream bank contribution to overall phosphorus loading was beyond the scope of this assessment. As methods to better estimate this contribution or to estimate effectiveness of various strategies to minimize these sources become available, this should be considered in future analysis.

Variable Rate Application

As with the INRS-NSSA, available data necessitated that the nitrogen application rate was assumed to be uniform across a MLRA. However, it is acknowledged there is variability in actual application rate around the average. As additional information becomes available on the distribution of nitrogen application, this should be factored into future analysis.

Nitrogen in Grain

Comparing crop yield information from 1980-96 to the INRS-NSSA information indicates an increase in average per acre yield of both corn and soybeans. This might suggest greater nitrogen export with corn crop over this period. However, during this same period there has been some decrease in protein content and nitrogen content in the corn, such that nitrogen export with the grain has likely stayed fairly steady.

Point Sources

Load estimates described here account only for changes to loading due to agricultural land management practices. This assessment did not consider any loading changes due to point source changes.

Comparison of Nitrogen and Phosphorus Loads

While this assessment has similar limitations as the INRS-NSSA, it provides an important comparison of estimated nitrate-N and phosphorus loads exiting the state, accounting for changes in land management practices that have occurred since the 1980-96 time period. Since agricultural programs have long focused on erosion reduction, and a prime transport mechanism for phosphorus is with runoff and soil loss, it is not unexpected that reductions in phosphorus loss are estimated when comparing the INRS-NSSA to the 1980-96 time period. On the other hand, only recently have programs begun focusing on reducing leaching losses of nitrate-N. As a result, since there have been slight increases in acreage of annual row crops and per acre nitrogen application to corn, the reduction estimated with phosphorus was not expected for nitrate-N. So, despite the lack of heavy focus on reducing nitrate-N losses, as has been the case with P, there have been only slight increases in the estimated nitrate-N load over time.

Appendix A – Land use and land management by MLRA

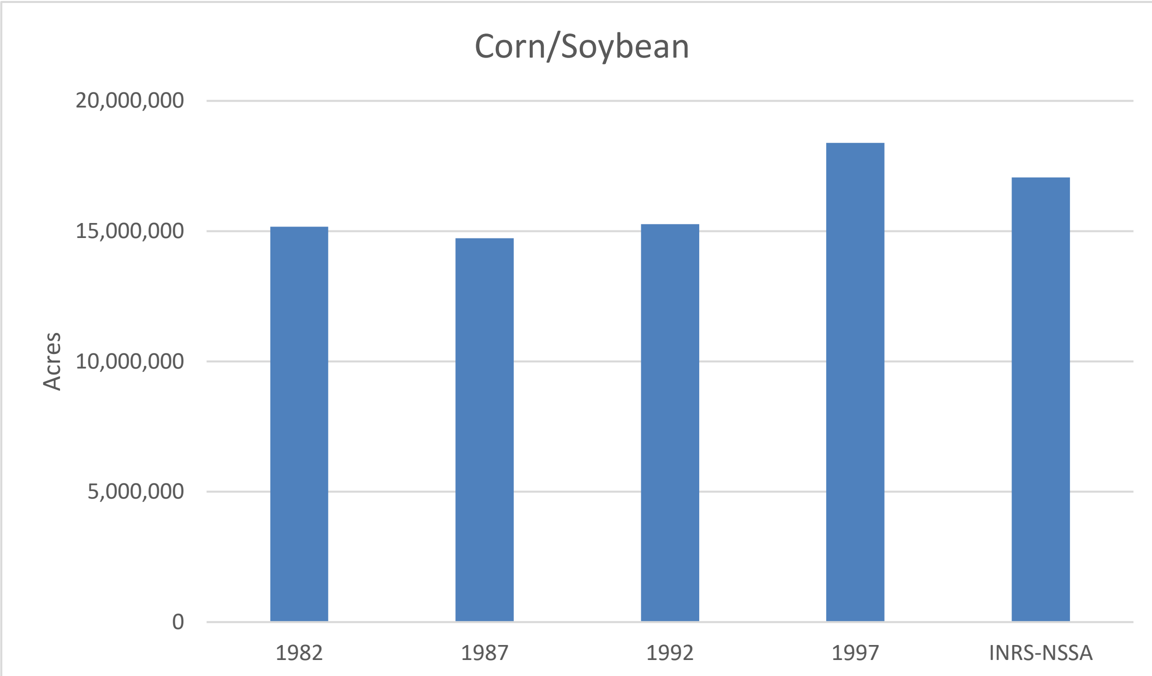

Figure A.1. Corn and Soybean Rotation Areas in Iowa. Areas are based on the Agricultural Census and modified to be consistent with previous assumptions.

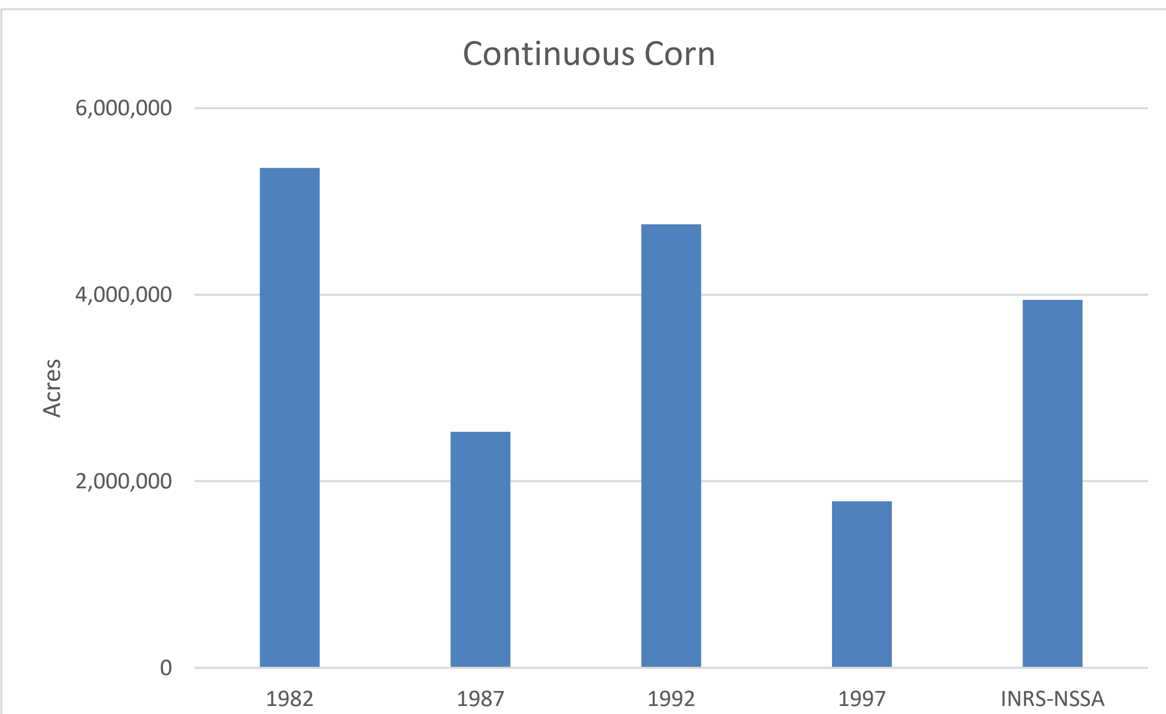

Figure A.2. Continuous Corn Areas in Iowa. Areas are based on the Agricultural Census and modified to be consistent with previous assumptions.

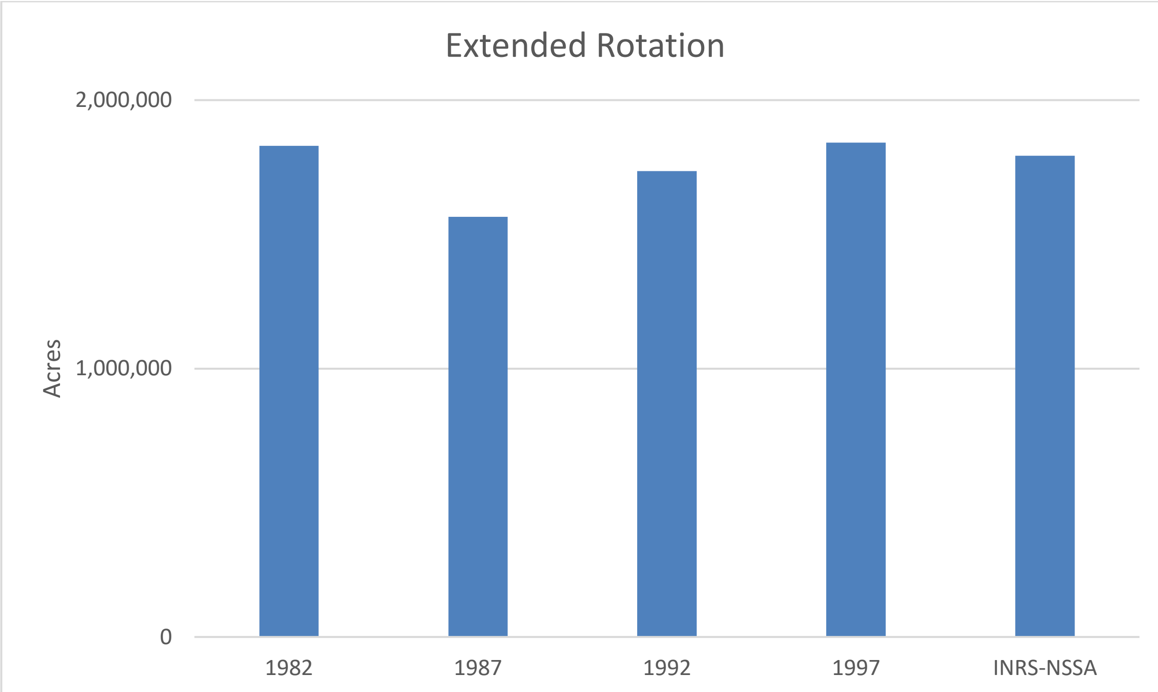

Figure A.3. Extended Rotation estimates based on 2007-2011 Extended Rotation to Soybean ratio.

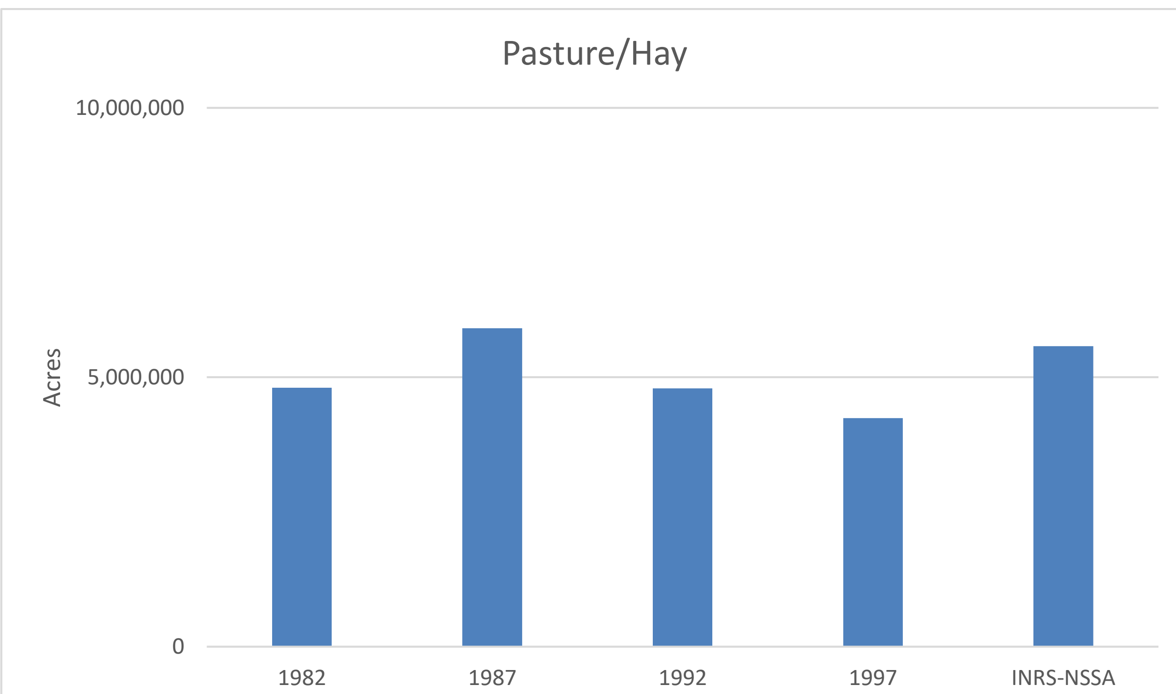

Figure A.4. Pasture/Hay areas based on the Agricultural Census.

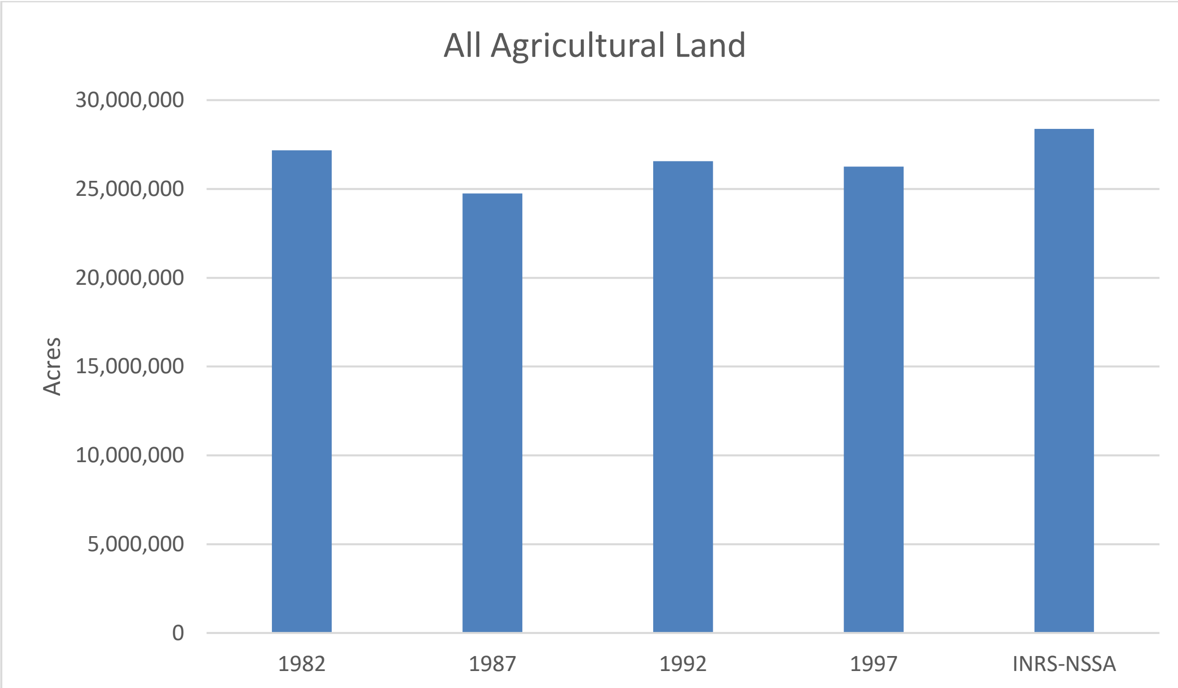

Figure A.5. Total agricultural acres including corn/soybean, continuous corn, extended rotation, and pasture/hay.

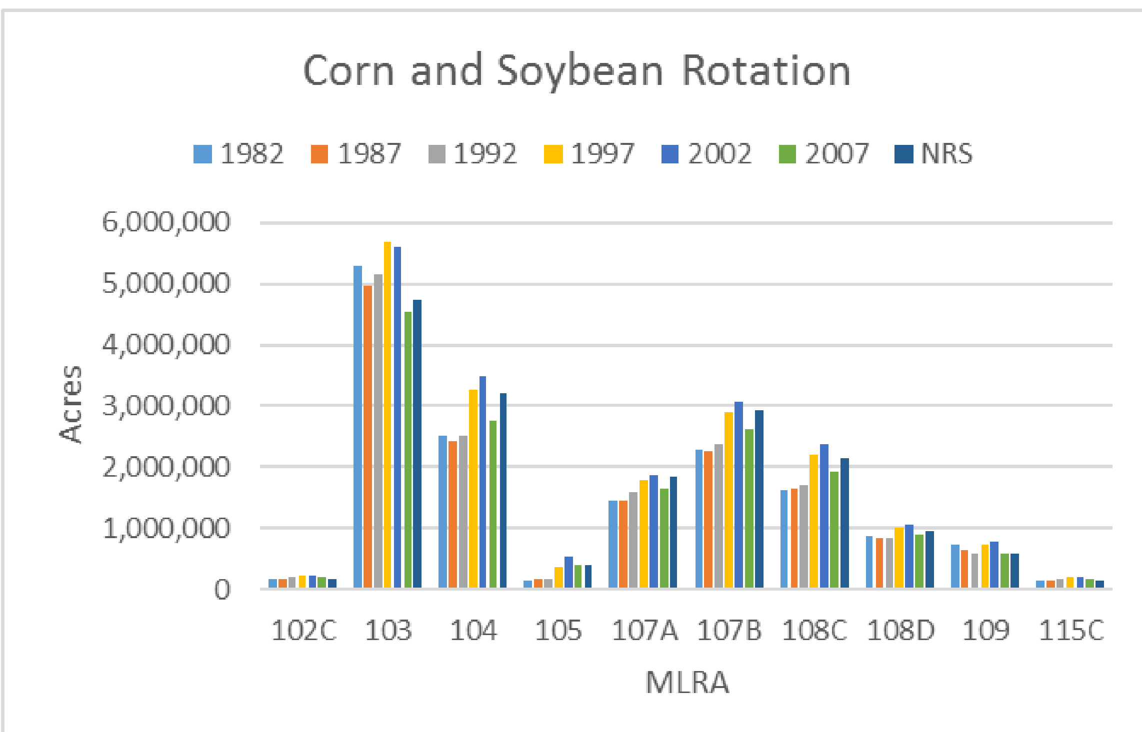

Figure A.6. Corn and Soybean Rotation Areas for each Major Land Resource Area in Iowa. Areas are based on the Agricultural Census and modified to be consistent with previous assumptions.

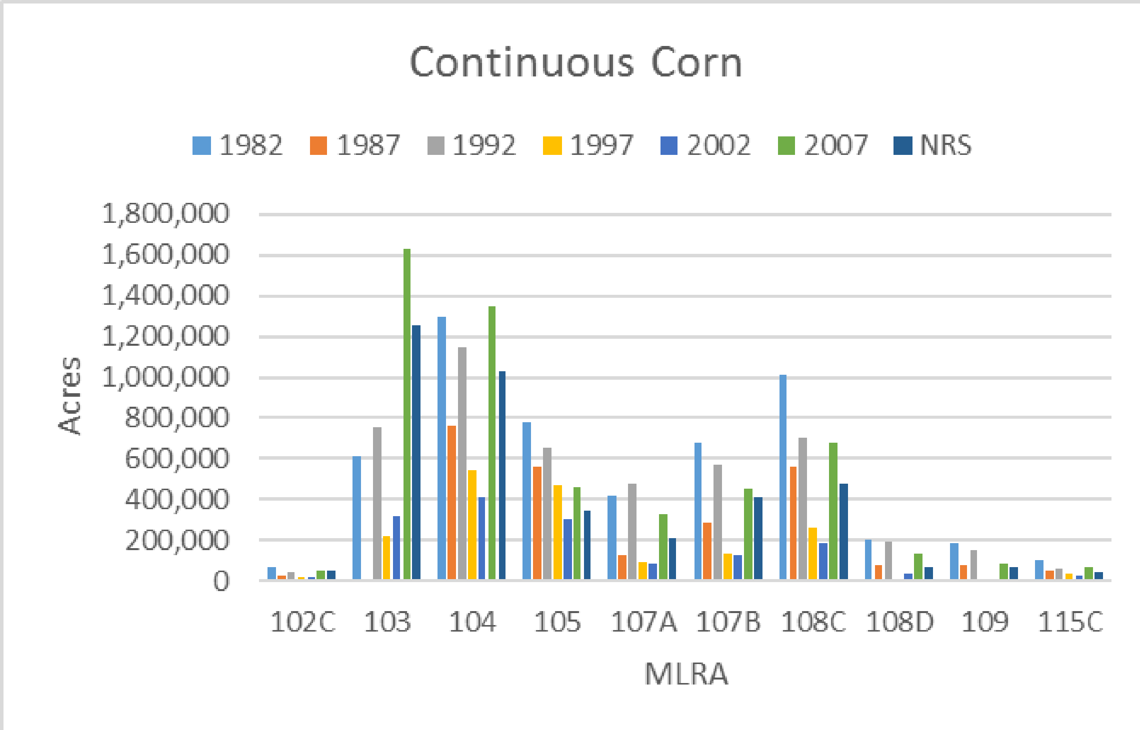

Figure A.7. Continuous Corn Areas for each Major Land Resource Area in Iowa. Areas are based on the Agricultural Census and modified to be consistent with previous assumptions.

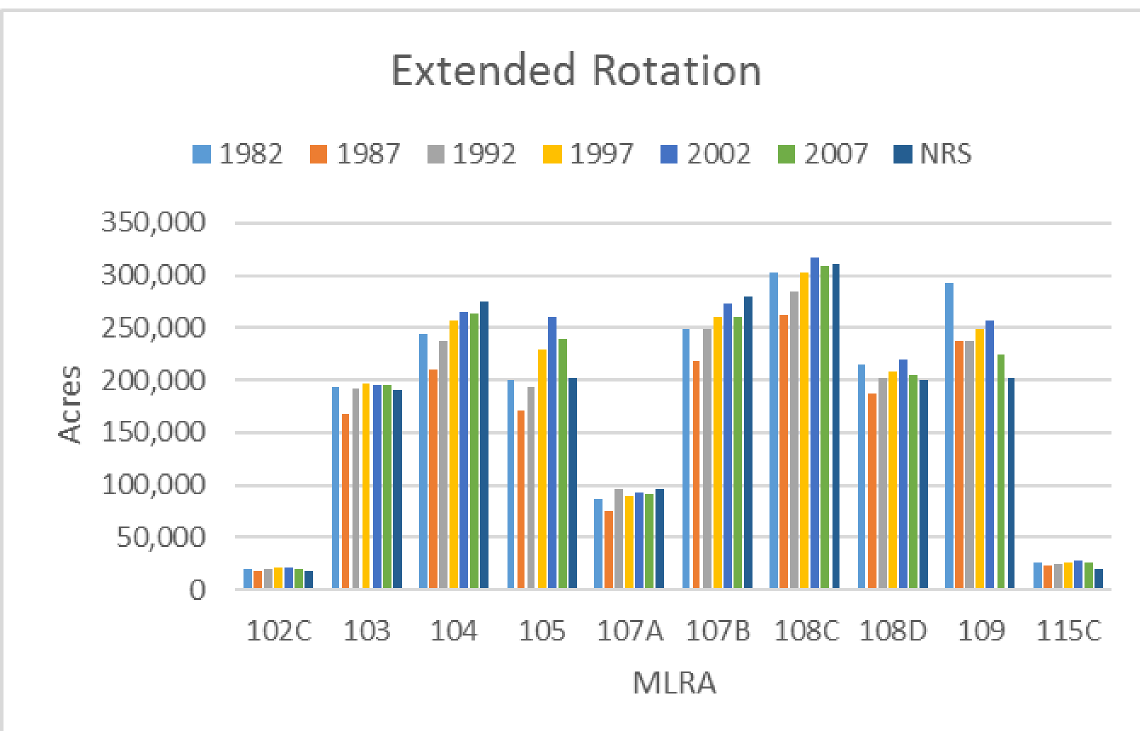

Figure A.8. Extended Rotation estimates based on 2007-2011 Extended Rotation to Soybean ratio.

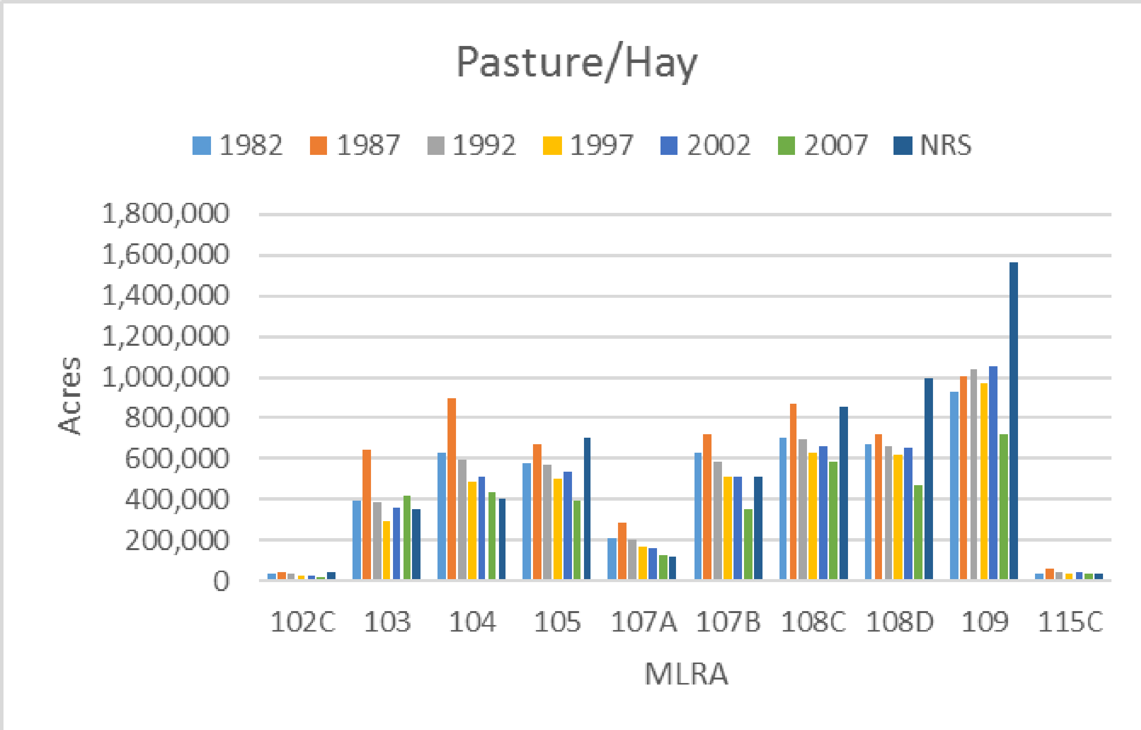

Figure A.9. Pasture/Hay areas based on the Agricultural Census.

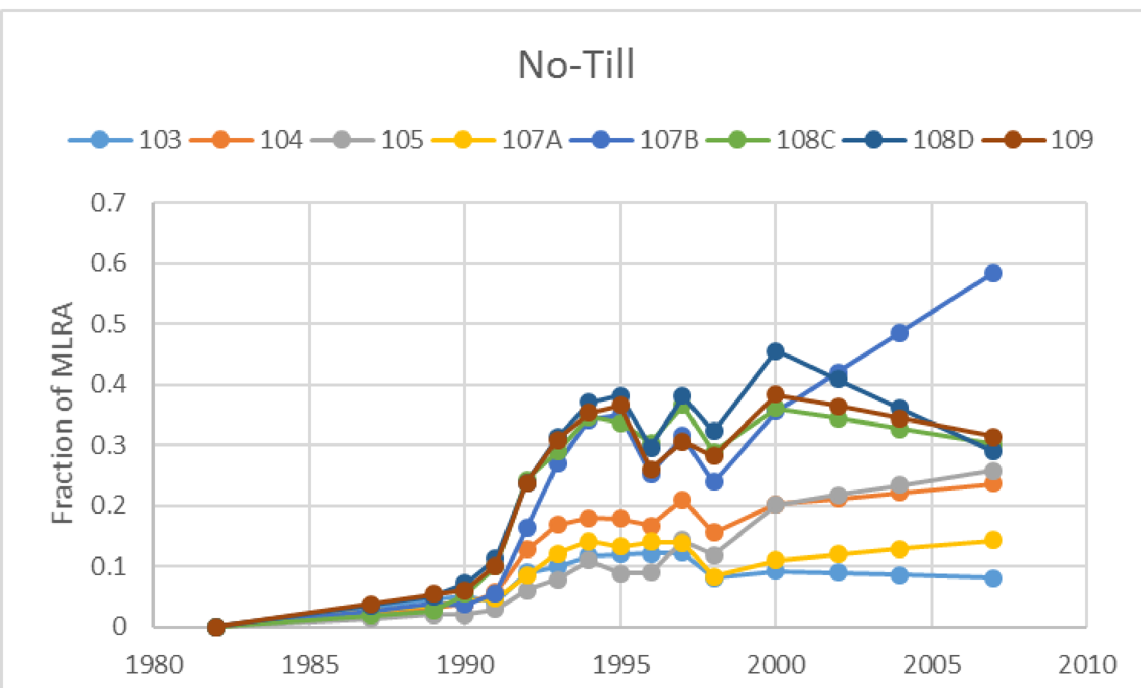

Figure A.10. Aggregated no-tillage estimates for each MLRA. These data include estimates from CTIC as well as projected data to align with Census of Agriculture land use.

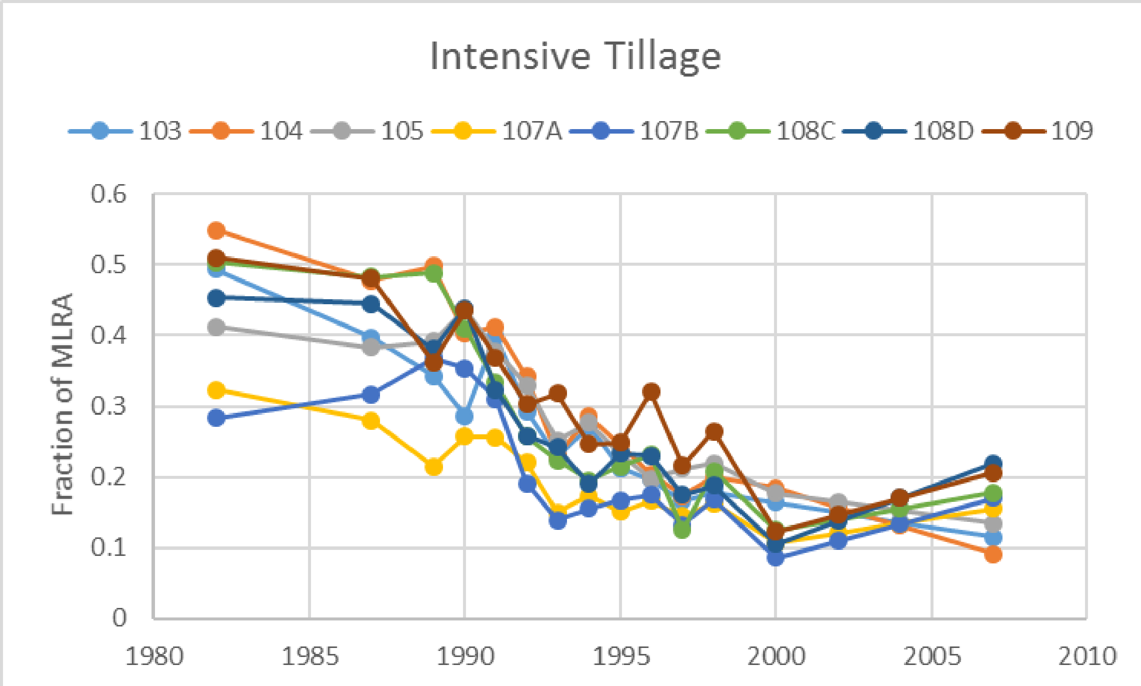

Figure A.11. Aggregated intensive-tillage estimates for each MLRA. These data include estimates from CTIC as well as projected data to align with Census of Agriculture land use.

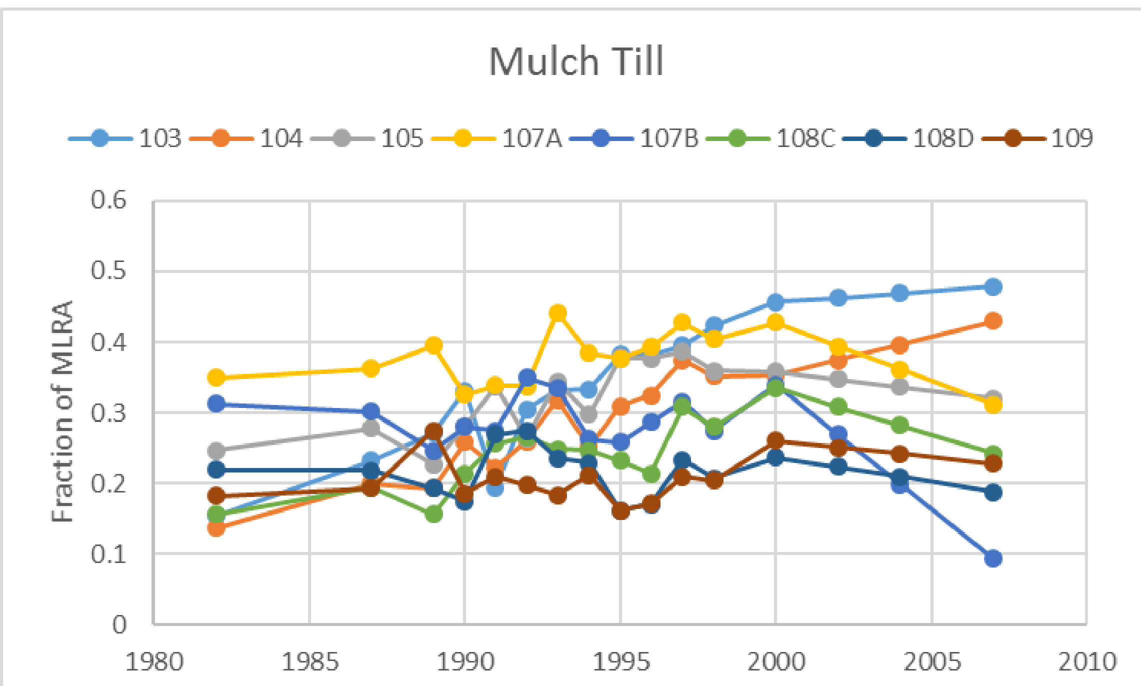

Figure A.12. Aggregated mulch-tillage estimates for each MLRA. These data include estimates from CTIC as well as projected data to align with Census of Agriculture land use.

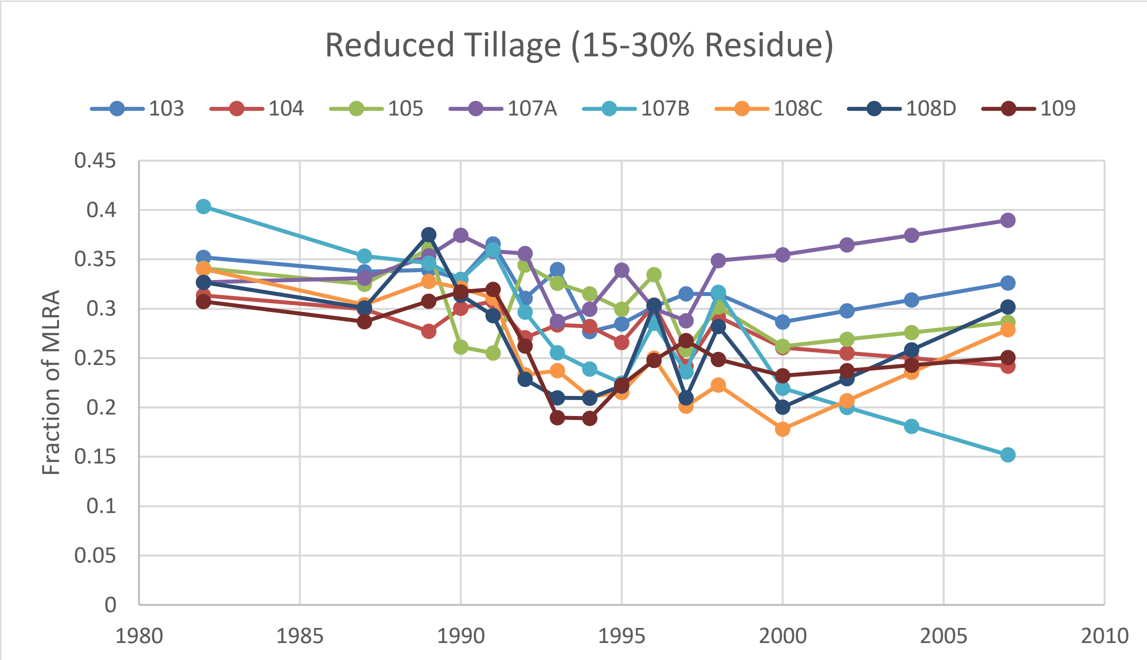

Figure A.13. Aggregated reduced-tillage estimates for each MLRA. These data include estimates from CTIC as well as projected data to align with Census of Agriculture land use.

Table A.1. Fertilizer application to corn in a corn-soybean rotation for each Major Land Resource Area.

MLRA	1982 (Short Ton)	1987 (Short Ton)	1992 (Short Ton)	1997 (Short Ton)	INRS-NSSA (Short Ton)
102C	4,051	5,223	5,079	6,756	7,746
103	161,784	181,061	143,870	187,679	182,482
104	83,163	84,458	76,943	119,164	114,841
105	3,561	4,914	4,893	11,856	12,473
107A	41,794	49,379	36,664	60,289	84,312
107B	72,397	73,655	67,507	101,703	101,757
108C	45,565	54,198	53,989	84,988	86,857
108D	28,146	27,569	23,983	38,000	28,722
109	24,551	26,275	22,938	35,284	20,673
115C	3,471	4,298	4,708	6,640	4,658
State Total	468,483	511,031	440,575	652,358	644,521

Table A.2. Fertilizer Application to Continuous Corn for each Major Land Resource Area.

MLRA	1982 (Short Ton)	1987 (Short Ton)	1992 (Short Ton)	1997 (Short Ton)	INRS-NSSA (Short Ton)
102C	4,788	2,236	3,192	1,408	5,812
103	50,839	0	59,152	19,525	127,816
104	114,779	69,805	95,421	52,094	99,870
105	60,629	45,868	50,006	39,930	30,732
107A	32,504	10,989	31,350	8,022	24,381
107B	57,477	24,414	45,085	12,560	38,499
108C	79,172	48,833	59,763	25,537	50,926
108D	17,603	6,889	15,365	1,108	5,513
109	16,795	8,198	15,439	598	6,133
115C	7,067	4,460	4,972	2,824	4,406
State Total	441,654	221,693	379,744	163,607	394,086

Table A.3. Nitrogen application through manure application to corn in a corn-soybean rotation for each Major Land Resource Area. An approximation of cattle on pasture was made in order to reduce the manure estimates.

MLRA	1982 (Short Ton)	1987 (Short Ton)	1992 (Short Ton)	1997 (Short Ton)	INRS-NSSA (Short Ton)
102C	1,383	1,909	1,843	2,631	2,516
103	22,142	24,219	16,997	25,412	27,296
104	9,886	12,642	10,366	14,092	15,094
105	542	989	935	1,659	1,737
107A	11,483	14,555	9,426	16,349	21,077
107B	11,847	12,606	9,729	11,790	10,139
108C	7,238	8,915	7,915	11,095	10,692
108D	4,220	4,031	2,845	3,713	2,731
109	2,970	3,177	2,485	3,637	2,412
115C	459	557	522	790	452
State Total	72,171	83,600	63,064	91,169	94,146

Table A.4. Nitrogen application through manure to continuous corn for each Major Land Resource Area. An approximation of cattle on pasture was made in order to reduce the manure estimates.

MLRA	1982 (Short Ton)	1987 (Short Ton)	1992 (Short Ton)	1997 (Short Ton)	INRS-NSSA (Short Ton)
102C	1,635	817	1,158	549	1,888
103	6,958	0	6,988	2,644	19,119
104	13,644	10,448	12,855	6,161	13,126
105	9,230	9,227	9,559	5,586	4,281
107A	8,931	3,239	8,060	2,175	6,095
107B	9,406	4,179	6,498	1,456	3,836
108C	12,576	8,032	8,762	3,334	6,269
108D	2,639	1,007	1,823	108	524
109	2,032	991	1,672	62	715
115C	935	578	552	336	428
State Total	67,985	38,519	57,927	22,410	56,281

Table A.5. Overall nitrogen application rate to corn in a corn-soybean rotation for each Major Land Resource Area.

MLRA	1982 (lbs/ac)	1987 (lbs/ac)	1992 (lbs/ac)	1997 (lbs/ac)	INRS-NSSA (lbs/ac)
102C	132	166	148	167	182
103	139	165	125	150	154
104	148	161	138	163	144
105	129	146	132	146	131
107A	148	175	116	171	184
107B	147	152	130	157	139
108C	132	154	145	174	163
108D	148	149	130	164	120
109	153	184	174	212	142
115C	116	140	136	159	146
State Average	142	160	133	161	151

Table A.6. Overall nitrogen application rate to continuous corn for each Major Land Resource Area.

MLRA	1982 (lbs/ac)	1987 (lbs/ac)	1992 (lbs/ac)	1997 (lbs/ac)	INRS-NSSA (lbs/ac)
102C	182	216	198	217	232
103	189	215	175	200	204
104	198	211	188	213	194
105	179	196	182	196	181
107A	198	225	166	221	234
107B	197	202	180	207	189
108C	182	204	195	224	213
108D	198	199	180	214	170
109	203	234	224	262	192
115C	166	190	186	209	196
State Average	192	210	183	211	201

Table A.7. Estimated average P2O5 application rates. Estimates include rate to corn, rate to beans, and rate to alfalfa.

MLRA	1982 (lbs/ac)	1987 (lbs/ac)	1992 (lbs/ac)	1997 (lbs/ac)	INRS-NSSA (lbs/ac)
103	44	40	35	37	48
104	55	51	47	45	47
105	65	62	61	58	56
107A & 102C	69	65	50	55	68
107B	58	50	44	42	40
108C & 115C	56	52	49	46	48
108D	49	41	39	39	36
109	45	44	42	41	42
State Average	54	49	44	44	48

Table A.8. Soil Test Phosphorus estimated (representing 2007 to 2011).

MLRA	1982 (mg/kg)	1987 (mg/kg)	1992 (mg/kg)	1997 (mg/kg)	INRS-NSSA (mg/kg)
103	31.7	32.2	31.6	31.1	30.0
104	34.8	37.2	34.7	32.2	27.1
105	31.6	35.6	34.7	33.7	31.8
107A & 102C	30.8	36.5	35.3	34.1	31.8
107B	28.9	32.6	31.4	30.2	27.8
108C & 115C	31.3	34.0	32.1	30.3	26.7
108D	26.3	29.2	26.7	24.2	19.3
109	22.2	25.0	21.5	18.1	11.3
State Average	30.3	32.8	31.5	30.3	27.7

Appendix B – MLRA based Nitrate-N and Phosphorus Loads

Table B.1. Nitrogen loads for each MLRA in Ag Census years.

MLRA	1982 (Short Ton)	1987 (Short Ton)	1992 (Short Ton)	1997 (Short Ton)	INRS-NSSA (Short Ton)
102C	1,689	1,750	1,784	2,071	2,096
103	78,247	78,266	72,641	82,608	86,745
104	65,618	59,806	60,053	69,894	68,064
105	16,419	14,627	15,350	16,070	13,210
107A	19,154	19,481	17,677	21,896	25,496
107B	34,929	31,101	31,395	36,656	35,702
108C	40,354	38,554	39,724	47,172	46,119
108D	16,333	14,294	14,113	16,821	13,244
109	18,762	18,368	17,822	22,637	13,796
115C	3,413	3,220	3,430	3,888	2,979
State Average	294,917	279,467	273,989	319,714	307,449

Table B.2. Phosphorus loads for each MLRA in Ag Census years.

MLRA	1982 (Short Ton)	1987 (Short Ton)	1992 (Short Ton)	1997 (Short Ton)	INRS-NSSA (Short Ton)
103	2,423	1,989	2,210	2,151	2,045
104	3,322	2,810	2,836	2,591	2,352
105	2,454	2,329	2,117	1,900	1,615
107A & 102C	2,299	2,018	2,144	2,063	1,813
107B	4,436	4,038	3,876	3,545	3,347
108C & 115C	5,403	4,867	3,593	3,441	3,020
108D	2,559	2,422	1,923	1,717	1,501
109	1,902	1,835	1,324	1,210	1,108
State Average	24,797	22,306	20,023	18,618	16,800

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